

6th **PIURN** Pacific Islands Universities Regional Network **CONFERENCE**



CONFERENCE PROCEEDINGS

July 1st – July 3rd, 2025

Papua New Guinea University of Technology



Pacific Islands Universities
Regional Network



“Harnessing technologies for the safe and sustainable development of the Pacific”



“Harnessing technologies for the safe and sustainable development of the Pacific”

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Foreword

It is with great pride and deep appreciation that I present the 6th Pacific Islands Universities Regional Network (PIURN) 2025 Conference Proceedings, hosted by the Papua New Guinea University of Technology (PNGUoT).

The theme, Harnessing Technologies for the Safe and Sustainable Development of the Pacific, reflects the critical moment we face as Pacific peoples - caught between immense opportunity, unprecedented challenges and a call to act with wisdom, unity, and foresight.

This compilation represents more than just academic inquiry - it captures the voice, vision, and vitality of over 150 researchers across our region and beyond. Each research paper is a testament to the growing research capacity of our universities, and a symbol of our collective determination to address the pressing issues that define our era. From rising sea levels and climate-induced food insecurity, to renewable energy solutions, and the enduring strength of cultural values and indigenous knowledge - this volume translates the complex landscape of Pacific realities with intellect and purpose.

The high quality of submissions is not merely a measure of scholarly output; it is evidence that the vision behind the establishment of PIURN is bearing fruit. Our regional network was created to foster collaboration, share resources, and translate academic excellence into tangible improvements for our societies. The participation of universities from Australia, New Zealand, and across the Pacific exemplifies the collaborative spirit that will be essential if we are to respond effectively to the shared developmental, environmental, and social challenges of our region.

Indeed, universities must lead - not only in knowledge generation but in shaping the next generation of thinkers, policymakers, and innovators. As custodians of knowledge, our professors, researchers, and postgraduate students have a solemn duty to engage deeply with their disciplines, while also contributing meaningfully to the betterment of our communities. Higher education must no longer sit on the sidelines of development - it must sit at the table of decision-making, providing evidence-based insights to guide sustainable, inclusive growth.

Our Pacific region is blessed with abundant natural resources - land, sea, minerals, energy - and rich cultural heritage. Yet we also face fragility: ecological, economic, and institutional. The UN Sustainable Development Goals remind us that growth must be balanced with responsibility; that innovation must walk hand-in-hand with equity and preservation. The research presented in this book points us in that direction, offering data, analysis, and solutions grounded in the realities of our people.

In closing, I commend the dedication of all contributors, and I challenge all stakeholders - academia, government, industry, and community - to draw from this collective knowledge to shape a Pacific future that is just, resilient, and sustainable.



Professor Ora Renagi, PhD

Vice Chancellor

Papua New Guinea University of Technology (PNGUoT)

1. Brief Background

The Pacific Islands Universities Regional Network (PIURN) held its **6th Conference on 1, 2 and 3 July 2025 at the Papua New Guinea University of Technology (PNGUoT), in Lae, Papua New Guinea**. The 6th PIURN Conference, the first one organized in Papua New Guinea, aligned with the 50-year anniversary of the country's independence. The 8 Universities from Papua New Guinea participated to the Conference, alongside PIURN Member Universities and institutions from the region .

(Australia, New Zealand, Indonesia), The general Theme of the Conference **“Harnessing technologies for the Safe and Sustainable Development of the Pacific”** explored not only the implications of new technologies for our region, but also the integration of traditional knowledge in developing solutions for challenges facing the Pacific. 32 sessions were organized, exploring Climate Change, Digital Strategies for the Pacific, Urban transformation, Quality Education, Environmental Monitoring, Higher Education transformation... The conference also showcased three plenary sessions



2. General Information

Officially established in 2013, under the name of Pacific Islands Universities Research Network, PIURN (Pacific Islands Universities Regional Network) is a consortium of 16 member universities from the Pacific Islands Countries and Territories (Western Pacific University joined the network in August 2025). A PIURN conference has been organized every two years since its inception, bringing together member universities of the network as well as external partners. These conferences not only highlight the academic work of the region but also present collaborative research in the Pacific. PIURN is co-chaired by The University of the South Pacific (USP) and the University of New Caledonia (UNC).

Papua New Guinea University of Technology (PNGUoT) offered to organize the 6th PIURN Conference, 1-3 July 2025, in Lae.

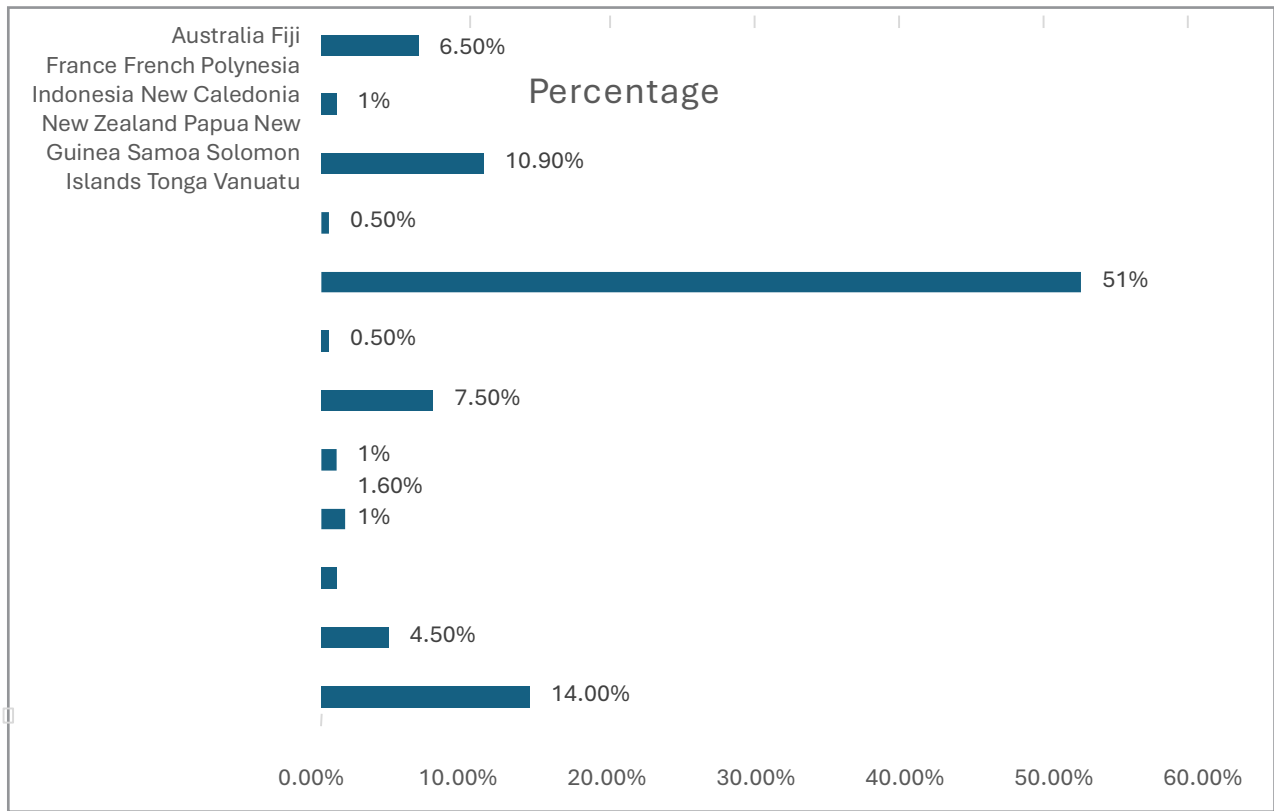
The general theme “Harnessing technologies for the Safe and Sustainable Development of the Pacific” highlighted the commitment of PNGUoT to innovation, resilience and collaboration for the region.

The Call for Papers opened on February 2nd, 2025 until April 30th, 2025. Papers had to be submitted on the following website: <https://piurn2025.sciencesconf.org/>. 181 abstracts were submitted and 157 papers were presented at the Conference. PIURN Member Universities accounted for 158 contributions submitted, therefore 87% of the total of abstracts received.

The 6th PIURN Conference brought together close to 200 delegates from 10 Pacific countries and territories (Australia, Fiji, French Polynesia, New Caledonia, New Zealand, Papua New Guinea, Solomon Islands, Samoa, Tonga, Vanuatu), as well as France and Indonesia.

3. Participation

30 Institutions from across the region were present at the conference. The Pacific region was widely represented in terms of paper presented: 14 PIURN Member Universities, 3 Australian Universities, 1 New Zealand University and a total of 13 universities, research institutes and government bodies from Papua New Guinea. The event was also open to international organizations. The geographical representation of the 5th PIURN Conference is distributed as shown in the table below:



In terms of gender balance, **32.8% of the participants were female and 67.20% were male.**

4. The Conference

The conference was held from Tuesday, July 1st to Thursday, July 3rd, 2025. The programme, made available in English and in French, can be downloaded [here](#).

Participants gathered on July 1st to complete their registration, receiving their programme and conference bags. Guests of honor for the Opening Ceremony were Honourable Minister John Rosso, Deputy Prime Minister and Minister for Lands & Physical Planning, Honourable Minister Kinoka Hotune Feo, Minister for Higher Education, Research, Science & Technology and Sports (video recording) and Mr Sam Koim, Chancellor of the Papua New Guinea University of Technology. Hon. Minister John Rosso stressed the importance of hosting this scientific regional event in the Morobe Province, wished the participants fruitful discussions and encouraged regional collaboration to foster innovation.

The co-chairs of PIURN, Professor Catherine Ris, President of University of New Caledonia, and Professor Pal Ahluwalia, Vice-Chancellor and President of The University of the South Pacific emphasized the success of the network and highlighted the importance for Papua New Guinea to host a PIURN Conference, with 6 PNG Universities being part of the network. The two major sponsors of the Conference, France and Australia, were represented by H.E, the French Ambassador Pierre Fournier and Mr Brenton Kanowski, Australian Consul General.

The opening ceremony concluded with Professor Ora Renagi, Vice-Chancellor of PNGUoT officially welcoming the participants and opening the 6th PIURN Conference. He indicated that “our region stands at a critical cross road. It is through research that is grounded in local knowledge and enabled by global technology, that we can chart a sustainable path forward”.

The conference continued with the plenary session “Island Innovation Unveiled: Transforming Transportation, Health and Resilience”, chaired by Mr Richard Howard, the United Nations Resident Coordinator in Papua New Guinea. This panel discussion showcased the following participants:



The opening ceremony at Duncanson Hall

- Professor David Pieris, The George Institute for Global Health
- Dr. Bobby Porykali, The George Institute for Global Health
- Professor Vinayak Dixit, Director of Global Research and Innovation, University of New South Wales (UNSW)
- Dr. Kipas Binga, The Morobe Provincial Health Authority,
- Dr George Varughese, Director of the The Institute for Global Development

The panel discussion set the tone for the conference by advancing health research and education in Papua New Guinea through strong and evolving partnerships. Grounded in the principles of equity, collaboration, capacity building, and sustainable development, the Healthy Islands Program is specifically designed to support efforts in addressing the country's unique health challenges

Over the three days of the PIURN Conference, 32 sessions were organized, with multidisciplinary topics ranged from "Policy, Higher Education and Institutional Transformation" to "Climate-Smart Agriculture"; "Culture between Tradition and Modernity" to "Natural Resources Exploration"; "Tropical, Communicable Diseases and Health Management" to "Food Security and Nutrition".



Different sessions and presentations

A plenary session on Regional Research Initiatives, on the 2nd day, Wednesday, July 2nd, 2025, reflected on successful regional partnership initiatives while engaging in a talanoa dialogue to explore future pathways for collaboration, chaired by Professor Jito Vanualailai, Deputy Vice Chancellor Education at the University of the South Pacific and co-founder of PIURN. The participants were:

- Professor Jayashree Arcot, Food and Health, UNSW Sydney and Vice Co-ordinator of Oceaniafoods
- Mrs Salote Austin, Oceania Programme Manager, International Science Council Regional Focal Point: Asia-Pacific
- Mrs Emmanuelle Boutier, Director of the AUF Pacific (Francophone University Network)
- Dr Olivier Galy, in charge of the University of New Caledonia Regional Programme “Diversités”

They presented the impact of their programme, aiming to foster equitable and mutually respectful partnerships that deliver meaningful and balanced outcomes for Pacific communities.

The last day of the conference, Thursday, July 3rd, highlighted how strengthening cooperative regional research networks is essential to support informed, context-sensitive responses that address the region’s priorities while ensuring that Pacific voices are empowered. This was the theme of the 3rd Plenary Session “Road to COP 31”.

The session was chaired by Professor Ora Renagi, Vice-Chancellor of PNG Unitech, and the participants were:

- Salā Dr George Carter, Director of the ANU Pacific Institute
- Ahmed El Saeed, Head of Office Asia-Pacific, UN Global Pulse
- Professor Moninya Roughan, Group Leader, Coastal and Regional Oceanography Lab
- Dr Jerry Siota, Solomon Islands National University

The participants emphasized the growing need for more research in the area of mitigating climate change, to better and understand its complex impacts in the region, at an economic, social and environmental level. They insisted on the importance for the Pacific to have a united voice for the COP31, in 2026, which will support the implementation of real-time solutions for local communities.

The three days of the conference concluded with a Closing Ceremony, chaired by Professor Ora Renagi and the two PIURN Co-Chairs, Professor Pal Ahluwalia and Professor Catherine Ris. They congratulated all the participants for their research presentations and informed them about the outcomes of the PIURN Board Meeting:

- The launch of a new research grant, in partnership with the International Science Council
- The 7thPIURN Conference to be hosted in Fiji in 2027
- Western Pacific University (Papua New Guinea) becoming the 16th Member University of PIURN

Two social events were organized. On the 1st of July, a get together at the new Dining Hall of PNGUoT allowed the participants to know each other’s after the 1st day of presentations. The 6th PIURN Conference concluded with the dinner, which showcased a cultural presentation by local dancers.



Participants at the Closing Dinner

5. External partners and sponsors

During the closing ceremony, a special session was held in which Mrs. Ainsley Hemming, Director of International Relations at PNGUoT, and Mrs. Mathilde Souchon, PIURN Coordinator, presented a special trophy to each sponsor in recognition of their support.

The sponsors are listed below:

- Fonds Pacifique (Pacific Funds) from the French Government
- Australian Awards
- Australian Aid Pacific Research Program
- Agence Universitaire de la Francophonie (Francophonie University Agency)
- Konrad Adenauer Stiftung (Australia)
- University of New South Wales
- Vodafone
- Theodist Business Superstore



Pacific Research Program An Initiative of the Australian Aid Program



Australian National University

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Repositioning the PNG University of Technology for National Impact: The Role of Higher Education in Advancing Livelihoods Through Science, Technology, and Policy in Papua New Guinea.

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Abstract: This paper argues that in the 21st century, the relevance and success of the Papua New Guinea University of Technology (PNGUoT) must be measured not only by academic outputs but by its tangible impact on societal well-being. Drawing parallels from global best practices and the Times Higher Education Impact Rankings, the paper positions PNGUoT as central, not only to deliver its programs, benchmarked to international or accredited industry standards but also to ensure that its research is applied in practice through policy formulation achieving Sustainable Development Goals (SDGs) in the country. Grounded in the motto “standards of higher education is synonymous with higher standards of living,” this study explores how PNGUoT can act as a driver for national development. It calls for systemic reforms in PNG’s education and research ecosystem to enable solution-driven engagement with communities and policymakers.

Keywords: PNG University of Technology, Societal well-being, Accredited Industry Standards, Sustainable Development Goals SDG.

1 INTRODUCTION

The vantage point of being a participant at the Papua New Guinea University of Technology (PNGUoT) and being a member of a small Island, Coastal or Highland rural community in a developing country provides a unique perspective on how Technocrats, Lecturers and Administrators of PNGUoT can posit the role of higher education in advancing livelihoods through Science, Technology, and Policy in Papua New Guinea and in deed other similar Technology Universities in similar circumstances in the Small Island Developing States (SIDS).

In this work, the extensive study carried out is focused on the roles that several Technology Universities (in six continents, Figure 1) have played in their various constituencies to impact their societies and assist government policy formulations. The analyses of the findings led to the proposition that in certain cultures and circumstances, the traditional ‘textbook role’ of Technology Universities may need to be adapted, modified and tailored to meet the immediate needs of a targeted society and a group of people that the Universities are set up to serve.



Figure 1. The six continents of interest to this study

The propositions put forward here is not for a complete overhaul of the traditional role of Technology Universities but a modification that would enhance its relevance to its immediate society. This study provides a comprehensive way forward on how PNGUoT as a Technology University in the Pacific Island community of states can actively engage with its *immediate* communities and societies to drive positive change in the social, economic and cultural outlook that would lead to a more comfortable livelihood of the residents of the society. Consequently, PNGUoT will be able to assist the government in proposing policies that will positively influence the standard of living especially in rural and remote islands of PNG.

2. THE TRADITIONAL ROLE OF TECHNOLOGY UNIVERSITIES (TU)

Historically, Technology Universities have always been known traditionally as the global centers of cutting-edge research, innovation, knowledge creation, dissemination, and skill development for the advancement of technology and economic growth. They have played a fundamental role in producing competent industry professionals that would contribute to economic growth and technological advancement in industry, communication and e-commerce. As expected, Technology Universities continue to fuel rapid technological advancements, globalization, and complex socio-economic and information technology infrastructure modernization and wealth creation. As complex as this may seem, the accomplishment of the traditional role is made possible because, through adequate funding by government and industry, Technology Universities possess sufficient intellectual resources, research capabilities, and a diverse pool of talent that can be harnessed to tackle complex challenges simultaneously.

It is very well known that Technology Universities have played a direct role in advancements that have led to new industries, mind boggling products and state-of-the-art infrastructures. The outcome is increased productivity, improved efficiency in existing industries, economic growth, job creation, and higher living standards especially in the developed nations.



Figure 2. <https://digitalfragrant.medium.com/the-role-of-technology-in-a-nations-development-and-its-future-fe120b139272> Courtesy Photo by Denys Nevo Zhai

The photo shown in Figure 2 above is a visual perspective of the pace and complexity of the exponential transformatory role of science and technology universities in the global sphere. This research work appreciates the importance and the need to maintain this role. The proposition is therefore not for a paradigm shift. Rather, this work takes the view that there is also an inherent need to align the goals, the curriculum design and implementation of a Technology University located in a developing country such as PNG with the needs of the global society as well as the needs of the people in the immediate environment of the Universities.

In PNG the people in the immediate environment of PNGUoT (by democracy) are the rural dwellers with basic means, simple aspirations and whose needs are the (taken for granted) essential commodities of life such as

electricity, digital communication and portable water supply... not super highways, fly-overs, globalization and not tunneled-trainlines.

The challenges that would be encountered by universities wishing to address the basic needs of the inhabitants of developing nations such as PNG have been described and summed up in previous work as University Social Responsibility (USR).

This work is an expansion and further development of this framework with a special focus on the Pacific Island State of PNG and its University of Technology PNGUoT as a case study.

3. BEYOND THE TRADITIONAL ROLE OF TECHNOLOGY UNIVERSITIES

This work takes the view that the conventional role of Technology Universities as a frontier center for cutting edge research, scholarship, and drivers of global innovation and economic-development are vital. Therefore, these roles need to be maintained in PNGUoT.

In this work, the betterment of the immediate society of the location of a Technology Universities is argued as an equally important scope that should be in the forefront of the list of aspirations of a university. PNGUoT and other Technology Universities in the Pacific should therefore look beyond the realm of its traditional and global academic functions and set additional ‘indigenous’ goals that will impact the primary society it was inaugurated to serve.

The Pacific Island State of Papua New Guinea is home to about two million city dwellers and about nine million rural and remote island inhabitants. The latter number should therefore be regarded as the immediate society that should benefit significantly from the intellectual, research and infrastructural assets of PNGUoT.

3i. Similar Pioneering work by other Technology Universities

The inspiration for this research work stems from the findings that several other Universities in several continents have attempted similar challenges successfully. A neighboring Australian University exemplified the Triple Helix Model of Innovation by developing different core programs such as ‘knowledge exchange’, ‘UNSW Founders Program’ etc., with a focus on University-Community Collaborations to create a vibrant Entrepreneurship Ecosystem.

PNGUoT is encouraged to emulate and formulate a similar comprehensive structure for technology transfer and science-to-policy translation that can serve as a sustainable model in the quest to enhance the impact of PNGUoT research outcomes in the rural and remote island communities. This can be achieved if dedicated offices, leadership roles, and collaborative programs are established to bridge the gap between academic discovery and practical application, ensuring that scientific advancements contribute meaningfully to societal progress and policy development.

Massachusetts Institute of Technology (USA) ‘Energy Initiative’ is another community-focused program that provides an example of how PNGUoT can lead in energy innovation, policy development, and education in PNG to address its unique energy challenges. It is also proposed that the MIT example be complemented with the experience provided by Columbia University data-driven ‘Center on Global Energy Policy’. The center provides a ‘policy lab’ for academics to engage with policymakers and industry leaders to address energy challenges through appropriate policy formulation. This is at par with the UCLA Center for Health Policy Research focusing mainly on health issues.

The University of the Philippines – Technology Transfer and Business Development Office (TTBDO) is another Government-Academia-Industry Tripple Helix Innovation set up to connect university researchers with SMEs and government agencies for real-world solutions. They have a wide scope of activities ranging such as issuance of licenses to technologies and supporting spin-offs for local application, particularly in agriculture, public health, and disaster response; this includes research on typhoon forecasting and community early warning systems to provide and help shape governments national disaster policies. A similar comprehensive initiative is proposed for PNGUoT to focus on localized scientific innovations—say, in weather or earthquake forecasting, food preservation, or pest control. These can easily be fed into provincial disaster preparedness plans or SME toolkits.

This work also carried out an in-depth study of the activities of Indian Institutes of Technology (IITs) – Rural Technology Action Groups (RuTAGs) which was set up to work with state and local governments to adapt and implement technologies suitable for rural development (e.g., renewable energy, low-cost housing, water purification etc). The success of the program is seen in how the projects directly inform rural development policy and funding priorities. Taking a cue from this, it is proposed that PNGUoT could establish similar rural technology demonstration hubs and advise district development authorities (DDAs) on technology investment aligned with LLG needs.

In Peru, Uganda, Kenya and Cape town, there are several Poverty and Inequality Initiative- (PII). They all provide examples of Community-Based Learning Hubs. Backed by Government-Funded Applied Research for Policy Impact, Makerere University – Outreach Department and Village Demonstration sites (in Uganda) provides an excellent proto type of how PNGUoT can carry out Integrated Research, Training and Extension by running village demonstration farms where new methods are piloted and taught. This can easily be steered by PNGUoT students from rural and Island localities yearning for a worthwhile opportunity for them to live and work in their villages. Such outreach programs could be tailored to be accepted as a part of the Industrial Training or Work Experience aspect of PNGUoT degrees in engineering, agriculture, and environmental science programs. The Land-Grant University Rural Outreach program of Cornell University is another similar example. The program has successfully reached out to all 62 counties in New York State, offering farmers and rural youths’ practical education on crop production, animal husbandry, health, nutrition, and business.

All pioneering work by other Technology Universities reviewed here align well with the proposal and vision of this study in translating science and technology into practical impact through provincial and rural engagement. Hands-on Digital Technology and Digital Communication that can be incorporated into Tertiary and Vocational Education and Training (TVET) is another area that is calling for attention which can be provided by PNGUoT. The pioneering work in this area is not farfetched. The University of the South Pacific (USP) in Fiji Island and the Charles Darwin University (CDU) in Australia have demonstrated how universities can participate actively in Vocation Education Training (VET) alongside its traditional higher education programs. The Pacific Technical and Further Education (Pacific TAFE) run by USP in Fiji delivers technical and life skills training across remote islands via TAFE centers and mobile units. It also Partnered with local government, NGOs, and faith-based groups to deliver programs in community leadership, climate resilience, and fisheries using radio, mobile phones, and printed materials for outreach. The Australian (CDU) program targets indigenous communities and disadvantaged students by offering fee-free TAFE places in certain industries where the chance of employment is high due to skill shortage. A similar strategy should inspire PNGUoT to use digital and hybrid methods to provide modular training in rural energy, sanitation, construction, and SME management. These could be supported by DDA funds or donor programs.

4. THE PNGUOT PROPOSAL AND THE MODUS-OPERANDI

The main proposition of this study is for a PNGUoT Rural Innovation and Extension Service (**RIES**): with the concept note theme; - *"Taking Knowledge to the People: Strengthening Livelihoods through Science, Technology, and Community Partnerships"*.

4i. Proposal Background and Rationale of RIES

Papua New Guinea's rural majority faces persistent challenges in agriculture productivity, small enterprise development, access to appropriate technologies, and sustainable livelihoods. Universities, especially PNGUoT, hold a reservoir of expertise in engineering, science, ICT, and applied technologies that must be harnessed for rural transformation. Drawing on the international models provided earlier, PNGUoT should propose the establishment of RIES as a tool to operationalize its research, teaching, and innovation functions through community-centered engagement.

4ii. Proposal Objectives

The objectives would be to extend PNGUoT's technical expertise to rural communities through training, demonstration projects, and community-based innovations. In addition, final-year students and staff should be engaged in applied rural service-learning activities to ensure knowledge transfer while enriching academic programs. Partnerships with provincial governments, SMEs, and district authorities (DDAs) for inclusive, evidence-based development is another main objective of this proposal. This will support the translation of research into local policy and practice through rural piloting, community validation, and local governance feedback loops.

4iii. Structure of RIES

It is proposed that RIES will operate under the *Directorate of Extension and Community Engagement*, and be implemented through Provincial Technology Centers (PTCs) based in existing PNGUoT satellite campuses or new partner sites. The locations will offer modular short courses (2–4 weeks) in areas such as solar energy and rural electrification, water and sanitation systems, food processing and preservation; low-cost construction methods, SME bookkeeping & digital literacy. The centers will be staffed by full time PNGUoT faculty and trained extension officers. They will be positioned to propose appropriate Village Demonstration Sites and Partner with DDA's and Ward Councilors to pilot the technologies demonstrations on-site. Emphasis would be on local adaptation of tools, practices, and innovations developed by PNGUoT researchers. Final-year students from Agriculture, Engineering, Business, and Environmental Sciences will undertake supervised 6 to 12-weeks rural internships on these sites. The Policy and Practice Feedback Mechanism should be used to provide 'policy briefs' to local and national government.

4iv. RIES Potential Partners

It is proposed that target partners will include Provincial Governments and DDAs, Department of Agriculture and Livestock (DAL), Small and Medium Enterprise Corporation (SMEC), National Planning Department, Faith-based development agencies (e.g., Caritas, Lutheran Development) and international donors organizations (e.g., UNDP, EU, ADB, World Bank, JICA etc)

4v. Proposed Pilot Provinces (2025–2026)

The proposed pilot province is Morobe. This will leverage PNGUoT's proximity and enhance immediate rollout. The Central Province would follow next by targeting areas around Kapari and Rigo, with strong cultural links and development needs. The Eastern Highlands, East Sepik and Southern Highland Provinces would become the follow-up pilot provinces due to the interest, prominence and needs of the provinces in agribusiness, cocoa, fisheries, and rural infrastructure, water, health, post-conflict recovery and market access to the other highlands regions.

4vi. Budget, Resource Mobilization, Outcomes and Impact

An initial K3–5 million seed fund is estimated to actualize this proposition. This is proposed to be sought through Government appropriations (e.g., Higher Education, Agriculture, Provincial cost-sharing agreements, international donor project proposals, private sector sponsorship and other areas such as alumni contributions and university grants.

The envisaged outcome and impact of this study is that it will allow about 100 rural communities to receive regular extension services and over 1,000 villagers per year will receive training in practical technologies that will transform their lifestyle and improve their standard of living.

6. CONCLUSION

In this work, the extensive study and analyses carried out on the roles that several Technology Universities worldwide have played in their various constituencies to impact their immediate society and assist government policy formulation suggests that PNGUoT is endowed with what-it-takes to implement similar programs that are applicable to the needs of its communities; especially in rural education, renewable and sustainable energy access, digital communication, economic growth, poverty alleviation, inequality, climate change mitigation, natural disasters forecasting and prevention, environmental degradation and sustainable use of natural resources.

The RIES strategies that are proposed to achieve these are succinctly summarized in this work and reasons are adduced as to how and why the proposal will enhance robust partnerships with government and donors to achieve interdisciplinary community focused research centers, capacity building and promote knowledge translations from PNGUoT to the PNG rural communities.

We conclude by postulating that the relevance and success of the Papua New Guinea University of Technology (PNGUoT) and indeed other Pacific Island Universities of Science and Technology must be measured not only by the number of graduates produced and absorbed by industry but also by its tangible impact on societal well-being.

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Exploring the role of Traditional Culture in promoting Sustainable Development in Sinsibai, Western Highlands Province, Papua New Guinea

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Abstract: The purpose of this study was to examine cultural changes within the Sinsibai community. A qualitative research approach was employed, using in-depth semi-structured interviews to gather the views of community members. Both focus group and one-on-one interviews were conducted, and purposive and snowball sampling techniques were used. Data were analyzed thematically. The findings revealed that the traditional culture of the people in Sinsibai, located in the Western Highlands Province, has experienced significant changes. While many positive cultural practices have been preserved, some traditions that were no longer beneficial to the community have been discarded. Notably, the introduction of Christianity and education has led to the cessation of tribal fighting in the village, contributing to over 70 years of peace. This has created opportunities for business, education, and agricultural development. A key strength of Sinsibai is its strong community leadership, with most conflicts being resolved by community leaders rather than relying on the police. However, despite the positive cultural changes, challenges remain in the community, particularly with the consumption of marijuana and alcohol by a small number of individuals.

Key words: Culture, Christianity, traditional culture, Sinsibai

1. INTRODUCTION

Culture is a dynamic system of values comprised of learned elements such as assumptions, conventions, beliefs, and rules. These elements enable group members to interact with one another, engage with the world, communicate effectively, and express their creative potential (Brumann, 1999). It encompasses various facets of life, including clothing, child-rearing practices, dietary habits, marriage traditions, political systems, religious beliefs, and death-related rituals (Brumann, 1999). The strength of the Western Highlands Province (WHP) people lies in its land and the rich cultural values that have been passed down through generations. These cultural traditions help strengthen communities and families. Additionally, WHP has fertile land that is highly suitable for agriculture (Kitan, 2013).

Sinsibai village is located within the Mt. Giluwe Rural Local Level Government (LLG) of the Tambul-Nebilyer District in the Western Highlands Province. Situated approximately 30 kilometers southwest of Mt. Hagen, the village is accessible via a 50-minute drive. The community primarily relies on subsistence farming and small-scale commercial agriculture for their livelihood. Crops such as sweet potatoes are cultivated and transported to distant markets, generating modest incomes to meet basic needs like school fees, transportation, healthcare, and other essentials. The village is equipped with essential infrastructure, including a fully operational health center and locally owned trucks that provide transport services to and from Mt. Hagen. Despite this, food security is occasionally threatened by issues such as pests and frost. Educational institutions in the area include Sinsibai Primary School, Sinsibai Elementary School, and the recently established Upper-Nebilyer Secondary School. Most of the residents identify as Catholic, followed by members of the Seventh-day Adventist, Lutheran, and United churches, among others (Gibbs et al., 2022). This paper focuses on identifying the advantages of maintaining traditional culture while embracing post-change developments in the Sinsibai community.

2. LITERATURE REVIEW

2.1 Importance of Traditional Culture

Culture is a dynamic system of learned values, encompassing assumptions, beliefs, and customs that shape the way of life for a specific ethnic group or community (Renteln, 2015). These beliefs and customs are important to maintain for the future generation to know and understand culture (Greaves 1994). For instance, the future generation needs to know and understand the cultural practices, rituals, and languages. This helps communities to stay connected to their roots, fostering a strong sense of identity and contributing to a stable and cohesive societal fabric. This connection also enhances mental well-being and reinforces a sense of belonging (Greaves 1994).

In the Western Highlands Province of Papua New Guinea, traditional culture remains highly significant to the people. They continue to practice traditional customs such as paying bride price, gardening, and resolving conflicts in the Melanesian way. For example, if a conflict arises within the community, local leaders act as mediators to negotiate peace. Once both parties reach an agreement, harmony is restored. Despite the limited police presence, the community successfully maintains peace through these traditional practices (Gibbs et al., 2022; McKenna et al., 2020). In addition, one important aspect of ever day life in WHP is gardening which is practiced by every person in a community. This is not a surprise that WHP is the birth place of Agriculture as Kuk archeological site is found there is more than 9000 years old (Ketan, 2013; Feil, 1987). In the past people lived as hunters and gathers but WHP were the first people to engage in agricultural activities by cultivating food crops and rear pigs for protein and ceremonial activities (Feil, 1987. Pigs were important resources of people of WHP. Pigs were used for bride price, traditional moka, feast and other traditional activities (Feil, 1987; Watson 1977). In the province, pigs are widely raised by most families, though commercial piggeries are relatively rare. The current market rate for an average-sized pig is K1,000, while a fully grown boar can cost up to K3,000. While some pigs are sold annually to cover school fees, the majority are reserved for irregular events such as ceremonial exchanges, bride price payments, compensation settlements, election hospitality, and pig-centered ceremonies (Ketan, 2013).

2.2 Challenges of maintaining the Traditional Culture

There are several influences that change the attitude and behavior of the people in the Western Highlands Province (Kitan, 2023). These changes include education, politics, improved government services such as roads, telecommunication services, electricity and health services and Christianity (Gibbs, et al.2022; Kitan, 2023). For instance, village people have access to mobile phone. Some people use the phone and access internet for good purpose but others use it for accessing illicit materials. Moreover, some developments are positive and changing the life of people (Gibbs, et al.2022). In the Western Highlands Province, there is less or not tribal fight which is a positive change that bring development and help people to live peaceful among themselves (Gibbs, et al.2022). Similar, (Kitan, 2023) most Western Highlanders embrace development and went into business, agriculture and education (Kitan, 2023). Furthermore, Christian is seen as a positive change in the community. In the past, tribal fight was frequent in the Western Highlands Province but not now because of strong community leadership and Christianity (Gibbs, et al.2022).

Furthermore, in most highlands provinces, conflicts predominantly arise from competition over resources such as land, women, and pigs. Conflict is viewed as an unavoidable aspect of life, with no overarching authority to enforce laws across tribes, regions, and cultural groups (Weiner, 2002). In this power vacuum, physical violence is considered an acceptable form of punishment, particularly for repeat offenders. Offending parties may include individuals, clans, or entire tribes (Weiner, 2002). In the Western Highlands Province (WHP), such issues are often resolved amicably by village leaders (Gibbs et al., 2022; McKenna et al., 2020). This was supported by Ketan (2013), in Melanesia, the classic PNG Highlands big-man model encapsulates the essential features of good governance and problem solving. Big-man status was earned through

competitive success in ceremonial exchanges, maintained by carefully cultivating social relationships, and lost if exchange partners and followers were neglected (Ketan, 2013).

Despite strong community leadership and ongoing developments, communities in WHP still face significant challenges. The first challenge is politics, particularly during Local Level Government (LLG) and National General Elections. Elections in WHP are often marked by heightened tribal violence, although tensions typically subside once the elections conclude. The second challenge involves the consumption of marijuana and alcohol. Intoxication frequently disrupts local communities, leading to social disturbances. The third challenge is prostitution, which has been linked to the widespread use of mobile phones. This has resulted in a rise in teenage pregnancies, causing concern among parents and community leaders (Gibbs et al., 2022; McKenna et al., 2020).

3. METHODOLOGY

The study employed a qualitative research approach, using in-depth semi-structured interviews to gather the views of the Sinisbai community in the Western Highlands Province on traditional culture and its associated changes. The study was conducted on March 17, 2022, as part of a group research project titled *Social perspectives of different age and gender groups in selected communities in Western Highlands, Jiwaka, and Madang Provinces, PNG*.

Although the broader project covered topics such as culture, youth, children, widows and orphans, social changes, and development, this paper specifically focused on modernization and cultural changes in the local community. The data used in this paper were derived from the researcher's individual interviews, as some of this information was not captured in the published group research findings. With support and permission from the team leader, the researcher utilized these additional data to write this paper.

The researcher conducted two focus group interviews and six one-on-one in-depth interviews. Prior to data collection, a written request was sent to the Headmaster of Sinisbai Primary School and the community leaders to obtain their permission to conduct the study. Upon receiving approval, participants were approached and invited to participate in the interviews. Only those who expressed interest and provided both written and verbal consent were interviewed.

The study employed purposive and snowball sampling techniques, both of which are widely used in qualitative research (Sekaran & Bougie, 2016). The researcher intentionally selected participants deemed most valuable in answering the research questions. The interview data were recorded on a mobile phone, later downloaded to the researcher's computer, and transcribed.

The interviews were conducted in Pidgin, and the transcription and analysis were also performed in Pidgin. Data were analyzed thematically through the following steps: First, data preparation, audio recordings were downloaded to the researcher's computer and carefully transcribed. Second, preliminary observations were noted. Third, initial coding, detailed examination of the data was conducted to identify codes and develop categories with similar meanings, leading to summarized insights. Fourth, coding scheme development, initial categories were refined into a coding scheme, ensuring consistent feedback from participants was captured. Fifth, dataset application, the coding scheme was applied across the entire dataset to ensure comprehensive analysis. Finally, thematic mapping, a thematic map was created to illustrate the relationships between codes and themes based on shared categories (Roulston, 2001; Boyatzis, 1998). This systematic approach provided a clear framework for understanding the community's perspectives on modernization and cultural change.

3.1 Profile of Participants

No	Participant	Pseudonym	Number of participants	Gender	Age
1	Focus Group	Focus Group#1	10 plus participants	Male	35-60
2	Focus Group	Focus Group#2	8 participants	Male	35-50

3	P1	Participant#1	1	Male	45-55
4	P2	Participant#2	1	Male	45-55
5	P3	Participant#3	1	Male	45-55
6.	P4	Participant#4	1	Male	55-65
7	P5	Participant#5	1	Male	35-50
8	P6	Participant#5	1	Female	35-40

3.2 Coding of themes

No	Initial themes	Findings Coding themes
1	Influence of modernization on culture and traditions	Influence of Christianity on tradition and culture
2	Intergenerational conflict.	Respect leaders and elders
3	Marginalization and exclusion	Collective decision making

4. FINDINGS AND DISCUSSION

4.1 Influence of Christianity on tradition and culture

All participants from both focus groups and individual interviews confirmed that their traditional culture has changed significantly over the years, with some aspects gradually fading away. Major traditional practices that are no longer observed include “tribal fighting, moka ceremonies, traditional feasts, the use of poison to kill enemies, and traditional singing or dances” (Participant #2). Participants highlighted that “Christianity and education” have had a profound influence on their community and personal lives (Participant #3). When asked about the impact of these changes, participants generally viewed them positively. One participant shared:

"We have accepted Christianity and converted ceremonial grounds into church buildings to proclaim the word of God. The tradition of poisoning people, especially enemies, has ceased and is no longer practiced. It was a custom of our grandfathers but has changed due to the influence of Christianity and education" (Focus Group #2).

Participants further emphasized that Christianity has brought peace to their community. They noted the presence of 34 different church denominations in the area, which have collectively formed a Peace Steering Committee. This committee, made up of pastors from various denominations, raises awareness about social issues such as drug use, alcoholism, tribal fighting, and other related concerns.

Additionally, participants acknowledged the role of strong community leadership in maintaining peace. They reported that the seven ward councils in the area have enjoyed over 70 years of peace, with no tribal conflicts. They expressed deep appreciation for Fr. William Ross, a pioneer missionary to the Western Highlands Province, who introduced Christianity to the region. One participant stated:

"We thank Fr. William Ross for bringing three important things to Sinisbai and the Western Highlands as a whole in 1934: The Catholic Church, health, and education. These three contributions have greatly helped our community, allowing us to live in peace" (Focus Group #2).

One of the important cultures of Sinisbai people that is long practiced today is the traditional pig killing ceremony. This was shared by participant 4: “Many of our traditional cultural practices have disappeared as our fathers passed away, taking these customs with them”. For example, they used to raise many pigs and held

special pig-killing ceremonies during specific times, such as when the leaves turned green, and crops like greens grew well in the garden. For such ceremonies, they prepared stones for a mumu (an underground oven for roasting pigs), gathered dry firewood, and readied greens, kaukaus (sweet potatoes), and bananas. The pigs were then slaughtered, and a large feast was organized, bringing together family and friends from far and wide. To distribute the pork, a big wooden table was prepared, and the meat was shared among brothers, sisters, uncles, aunties, and others. Unfortunately, this custom is no longer practiced. "As our fathers passed away, these traditions were lost with them" Participant 4. He further mentioned that during these ceremonies, extended family members would gather, making it an excellent opportunity to strengthen relationships. However, with the decline of such traditions, we have lost this valuable way of maintaining contact with our extended families.

The study findings revealed that most participants attributed the peace and order in their community to the diligent work of churches. Through their preaching of the word of God and consistent promotion of peace and justice, churches have played a pivotal role in fostering harmony. This observation aligns with the literature (Ketan, 2013). The Western Highlands Province (WHP) benefits from strong community leadership, with most issues being resolved internally by the communities themselves. In many villages, there is no police presence, as law enforcement is typically stationed only in district centers or Mt. Hagen town. The peaceful environment in these communities is largely attributed to the influence of churches and their continuous efforts to preach the word of God. However, the disadvantage is that some good cultures are no longer practices today such as the traditional pig kill which unites all the extend family members when they get together for the event.

4.2 Collective decision making

From the two focus groups and six individual participants, all respondents provided consistent answers when asked about how decisions that affect the community are made. It was emphasized that decisions are not made by one individual but are the result of collective agreement within the community. Participants explained that any matter involving the community, such as projects like building a school classroom or a church, is widely discussed, and decisions are made collectively rather than by village leaders or councilors alone. One participant stated: "As a leader and councilor of the people, it's hard for me to make decisions on my own. Yes, I am a councilor, but people in the community have different views and opinions. Hence, I gather input from the community to make a collective decision. It's not a one-man decision but a collective one" (Participant #1). Participants further explained that while individuals may independently make decisions regarding their families, community-wide decisions involve input from everyone. They highlighted that the decision-making process is inclusive, ensuring that no one is excluded. This process takes time—often weeks or even months—to reach a decision that benefits the entire community. A focus group member noted: "We all discuss and come up with one decision because it's not something for one person to decide. It's a community matter, so we all contribute to the discussion and agree on a decision" (Focus Group #2).

Additionally, participants stressed the importance of effective communication in the community. Leaders continuously share messages encouraging positive behavior, such as attending church, working in the garden, and avoiding alcohol consumption, drug use, and prostitution (Participant #4). They also mentioned that raising awareness is an ongoing activity aimed at fostering good habits and preventing social issues.

4.3 Respect Leaders and Elders

The majority of participants expressed that youths in the village generally show respect for their leaders, elders, and parents. However, a small minority tend to disobey their leaders. One individual interview participant shared the following when asked about the relationship between older and younger generations: "As leaders, when we talk to them (young people), they usually cooperate with us. Maybe 90% of the young people listen to the leaders, but about 10% misbehave and do not cooperate" (Participant #1).

Additionally, most participants, both in the focus groups and individual interviews, discussed disciplining children as a way to guide them toward becoming responsible and productive members of the community. They stated that when children are caught engaging in misconduct, such as stealing, fighting, or committing other crimes, they are disciplined by being beaten. Participants emphasized that this is considered a form of discipline, not child abuse. In the village, if an adult is found abusing a child without a valid reason,

they are held accountable and may be required to pay compensation. However, one participant shared a differing perspective, informed by training received from the Catholic Church. This individual advocated for non-violent approaches to discipline, such as talking to children and encouraging them to attend church. As one focus group participant noted: "Some of us attended training provided by the Catholic Church, where we were taught that beating children is not the right way to discipline them. The proper way is to talk to them and correct their behavior" (Focus Group #2).

5. CONCLUSION

The aim of the study was to identify cultural changes in the community that can be viewed as both positive and negative. The study found that there have been changes in the traditional culture of the people of Sinsibai in the Western Highlands Province. While the local people have preserved some positive cultural practices, they have also let go of those that are not beneficial to the community. For example, due to the influence of Christianity and education, tribal fighting no longer occurs in the village. The community has enjoyed over 70 years of peace, which has allowed people to engage in business, education, and agriculture. Most importantly, Sinsibai has strong community leadership, with most issues being resolved by community leaders rather than the police. However, one interesting cultural practice that is dying out is the traditional pig-killing ceremony. This is no longer practiced, as young people are not rearing pigs, and organizing such a ceremony requires considerable time and effort. This ceremony used to bring extended families together. Despite these positive changes, challenges remain, such as the consumption of marijuana and alcohol by a few individuals in the community.

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Perception of Religious Leaders on the Preamble and Section 45(1) of the Papua New Guinea Constitution

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Abstract: This study examines how Christians and non-Christians perceive the Constitution's Preamble and Section 45(1) regarding religious rights. It explores whether the Preamble contradicts or supports Section 45(1). Additionally, it identifies constitutional issues that might conflict with religious practices. The research employed an interpretivist paradigm and a mixed-methods approach to collect and interpret data. The researcher gathers insights from thirty-five religious leaders across three highland provinces of Papua New Guinea (PNG): Jiwaka, Simbu, and Eastern Highlands. The findings indicated that the Preamble, which declares PNG a Christian country, conflicts with Section 45(1) of the PNG Constitution, which guarantees freedom of religion along with rights related to race, color, sex, gender, and place of origin. The study recommends legislative and policy reforms concerning constitutional and religious affairs. Proposed constitutional reforms include revising the Preamble to promote inclusivity by emphasizing shared values such as love, forgiveness, righteousness, and peacemaking; implementing a guided democracy; enforcing accountability among politicians; and reviewing policies related to gender equality. The recommended reforms for religious affairs encompass developing a national policy, organizing inter-denominational forums, registering religious groups, and screening leaders to ensure adherence to moral standards, all aimed at promoting inclusivity and ethical integrity in PNG.

Keywords: Universal Declaration of Human Rights (UDHR), National Goals and Directive Principles (NGDP), noble tradition, cultural context, religious context, religious principles, Christian principles, Judaism, Christianity, Islam.

BIODATA: BEN NINKAMA

Ben Ninkama hails from the remote region of the Gumine district in Simbu Province and received his education there, progressing from elementary to grade 12. He graduated as a primary school teacher from Our Lady of the Sacred Heart Teachers College (OLSH KTC), now known as DWU Rabaul Campus. He taught in Simbu for four years (2013–2016) before joining Melanesia Nazarene Teachers College as a full-time lecturer in the Language Development Strand from 2017 to 2019. During that time, he also served as an adjunct faculty member at Melanesia Nazarene Bible College, teaching English, Educational Psychology, and Research Methods for the Diploma in Ministry and Bachelor of Theology programs. Since 2020, he has been pursuing his doctoral studies at the University of Goroka in Eastern Highlands Province and also earned a Master of Theology from the Christian Leaders Training Center (CLTC) at Banz Campus in Jiwaka Province. Additionally, Ben is passionate about information technology, possessing skills in both front-end and back-end development that he has self-taught to assist churches, institutions, and organizations with their IT challenges. Currently, he is a senior lecturer at Divine Word University, affiliated with the Faculty of Education

1. INTRODUCTION

This study took place in PNG, a diverse Pacific nation with over 800 tribal societies, each possessing unique languages, customs, and governance systems (Waiko, 1997; Kari, 2012). Historically, Great Britain and Germany

colonized PNG, which was later administered by Australia, gaining independence in 1975 (Solon, 1990; Onagi, 1998). It is culturally rich, with traditional education passed down through gender-specific institutions rooted in kinship systems and religion deeply integrated into daily life through over 750 belief systems that emphasize the interconnectedness of the physical and spiritual worlds (Aerts, 1998; Mantovani, 1984; Bazzynu, 2001). Politically, PNG has evolved from a kinship-based governance system to a constitutional democracy, influenced by Melanesian values and the Westminster system, although debates about its legal sovereignty persist (Kari, 2012). The study examines the potential conflict between the constitutional Preamble, which affirms PNG as a Christian nation, and Section 45(1), which guarantees religious freedom, in light of the country's growing religious diversity. It questions whether the Christian declaration conflicts with the right to religious liberty, seeks shared religious principles that align with both sections, and aims to inform policies for national unity and inclusive constitutional interpretation, addressing tensions in PNG's pluralistic society.

2. METHODOLOGY

This study, grounded in an interpretivist approach, examines how individuals construct meaning through symbols, language, and interactions within specific cultural and social contexts, highlighting that reality is intersubjective and context-dependent. It employs a mixed-methods design, combining surveys using Likert scales with semi-structured interviews to collect perception data from thirty-five religious leaders across various Christian and non-Christian faiths in the PNG Highlands (i.e., Jiwaka, Simbu, and Eastern Highlands provinces). Quantitative data were analyzed statistically using Excel, while qualitative insights from interviews and document reviews were content-analyzed for themes and patterns. Ethical standards, including informed consent and confidentiality, were rigorously upheld, with approvals obtained from relevant institutions.

3. RESULTS AND DISCUSSION

This study involved 35 participants—religious leaders from five Christian denominations (Catholic, EBC, Lutheran, Nazarene, SDA) and two non-Christian religions (Islam and Judaism)—across the three provinces of PNG's Highlands region, using both quantitative and qualitative methods. Participants rated statements on a five-point Likert scale (strongly agree, agree, not sure, disagree, and strongly disagree), with responses later grouped into 'agreement' and 'disagreement,' along with individual 'Not Sure' responses. This study organizes its findings into three sections, aligning with the main research questions as shown in Figure 1 below. The first addresses PNG's cultural and religious contexts, the second explores perceptions of the Preamble and Section 45(1), and the third examines shared religious principles across faiths. Each section combines survey data and interview insights to provide a comprehensive understanding of the spiritual landscape, as well as relevant legal and cultural issues.

3.1 Section 1: PNG Cultural & Religious Contexts

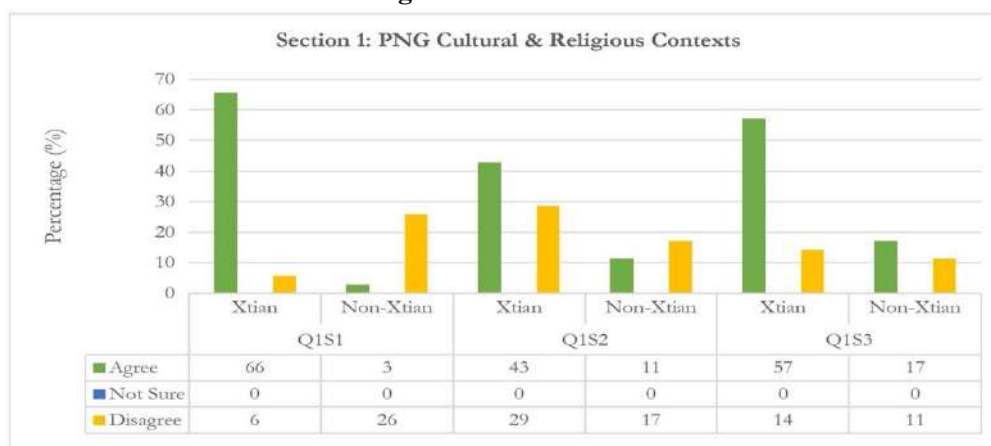


Figure 1: Vector graph illustrating the percentage of responses from section 1, indicating the proportions for three statements in response to Question 1.

3.1.1 Religious Principles that support PNG's Noble Traditions

The study revealed that 69% of both Christian and non-Christian participants believe that religious principles support PNG's noble traditions, such as respecting ancestors, loving neighbors, honoring elders, and making peace, with Christian teachings often reinforcing these values through biblical references. Christians emphasize the importance of respecting ancestors and heritage, promoting the honoring of forefathers while worshiping only God, as seen in Proverbs 13:22 and Fitzpatrick (2001). This respect is crucial for maintaining cultural identity in the face of modern challenges, such as globalization and technological advancements (Knauf, 2016). Christian teachings also emphasize love for neighbors (Mark 12:31) and communal support, which align with PNG's community lifestyle, where acts of service demonstrate divine love (Gibbs, 2005). Respect for elders, grounded in biblical commandments such as Exodus 20:12, strengthens PNG's cultural respect for wisdom. At the same time, peacemaking and reconciliation, as taught by Jesus (Matthew 5:9), mirror traditional conflict resolution methods supported by churches (Narokobi, 1980).

However, 31% disagreed, citing concerns that certain PNG traditions—such as ancestral worship, sacrifices to spirits, or retribution practices—conflict with their religious doctrines, including Judaism's emphasis on holiness, Islam's monotheism, and the focus on justice and fairness. The respondents believe certain spiritual principles, such as those emphasizing holiness (Judaism) or monotheism and rejection of ancestral worship (Islam), may conflict with PNG traditions. Judaism's focus on sacred separation and strict adherence to scriptural laws can limit integration with local customs. Islam's strong emphasis on *Tawhid* (the declaration of faith) rejects practices such as ancestral worship and sacrifices to spirits, which Fuad (2015) views as incompatible with monotheism.

3.1.2 The Right to Cultural Life

The study found that 54% of participants agree that they have the right to cultural life, supported by the PNG Constitution—particularly the Preamble (which declares a commitment to noble traditions), Section 45 (guaranteeing freedom of religious beliefs, including cultural and spiritual expressions), Section 46 (ensuring freedom of cultural, linguistic, and artistic expression), and NGDP Goal 5 (promoting development based on PNG's cultural values, including traditional knowledge and customs)—as well as the UDHR (Articles 22 on social security and 27 on participating in cultural life), these rights promote the preservation of cultural and ethnic diversity, fostering social harmony and unity in PNG's multicultural society (Kari, 2012; United Nations, 2015). Many participants value traditional practices such as land ownership, clan systems, healing rituals, storytelling, funeral customs, community celebrations, and dances, which enhance community cohesion, peace, and mutual support (Cao, 2025). These practices align with central religious teachings in PNG, emphasizing unity and stability.

However, 46% of participants expressed concerns that certain cultural practices—such as sorcery, witchcraft, bride price, polygamy, ancestral worship, and traditional medicine—oppose biblical teachings (Deuteronomy 32:8; Tomlinson, 2012). From a Christian biblical perspective, such practices contradict God's commands and hinder spiritual growth (Romans 12:2; James 5:14-16; Galatians 3:28). Christianity encourages believers to evaluate cultural customs through scripture, rejecting harmful practices that deviate from biblical principles and promotes transformation through the Holy Spirit to uphold love, peace, and holiness (Exodus 20:3-5; Ephesians 5:25-33).

3.1.3 Religious Principles that support Christian Principles

The study shows that 75% of respondents believe various religious principles support Christian values, with three main perspectives. First, many view PNG traditional beliefs as aligning with Christian morals, recognizing that these beliefs honor a creator spirit and attribute spiritual significance to nature, a concept similar to animism (Tylor, 2010). Biblical examples, such as God revealing himself through natural phenomena (Exodus 3:2; Exodus 13:21-22), suggest that animism can reflect divine interaction within PNG (Ninkama, 2023). Traditional practices, such as land ownership and communal rituals, promote morals and social harmony, paralleling biblical values like love

and respect (Trompf, 1989). Second, some respondents acknowledge that core Christian principles, such as faith in one God, the Bible, the Ten Commandments, love, forgiveness, righteousness, and peacemaking (1 Corinthians 13; Matthew 22:37-39; Romans 12:18), are shared across denominations, fostering social cohesion. Third, non-Christians acknowledge shared monotheistic beliefs, including belief in one God, holy scriptures, angels, prophets, judgment, God's law, sin, and forgiveness, which influence their religious practices (Fisher, 2009).

However, 25% of respondents disagreed, emphasizing the differences between Christianity and other religions. Islam and Christianity, for instance, hold distinct views on the nature of God (Tawhid vs. Trinity), prophets, scripture, and salvation, underscoring the unique theological frameworks they each uphold (Mosher & Marshall, 2018). Judaism, though closely related historically to Christianity, emphasizes adherence to Torah laws and the covenant with God, with little overlap in principles that directly support Christian beliefs, as they focus on different central figures and teachings (Revera, 2000). Figure 2 shows the responses to question 2 from section 2.

3.2 Section 2: Preamble & Section 45(1)

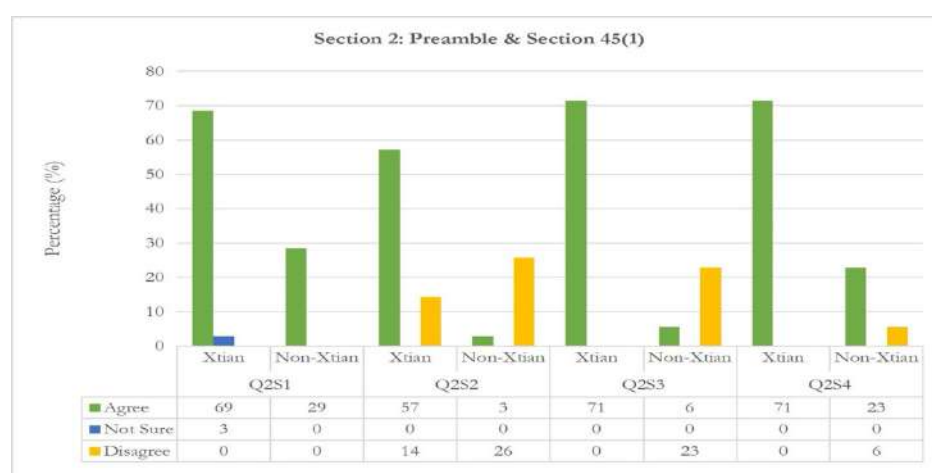


Figure 2: Vector graph illustrating the percentage of responses from section 2, indicating the proportions for three statements in response to Question 2.

3.2.1 The Right to Freedom of Religion

The study's key findings reveal that 97% of participants believe the PNG Preamble conflicts with Section 45(1) of the Constitution, which guarantees religious freedom (Constitution of Papua New Guinea, 2020), with many advocating for constitutional amendments to promote inclusivity based on principles such as love, peace, and righteousness. It also highlights that historical divisions within Christianity, often caused by influential church leaders and differing doctrines (Dowley, 1977), require government regulation of street preaching to promote peace and social order. Traditional spiritual practices, such as healing and protection rooted in a worldview where God communicates through natural symbols, are valued as culturally valid and complementary to Christianity, echoing biblical theophanies (Exodus 3:2; Ninkama, 2023). Ultimately, the study highlights that the primary purpose of religion is moral and social transformation—enlightening individuals' minds and hearts—which is crucial for addressing societal decay in PNG. It urges collective efforts with religious groups to promote values aligned with scripture, such as those found in Romans 12:1-2 (Ninkama, 2023).

However, about 3% of participants emphasized love and respect as central religious duties, summarized by the Ten Commandments, which instruct us to love God and love one's neighbor (Matthew 22:37-40; Mark 12:30-31). The practice of unconditional agape love cultivates virtues such as forgiveness, honesty, and justice, forming the moral foundation essential for societal harmony and spiritual growth (Raffagnino & Puddu, 2018).

3.2.2 The Right to Freedom of Race and Color

The study reveals that 60% of participants view a conflict between their rights to freedom of race and color under Section 45(1) of the PNG Constitution and the Preamble's declaration of PNG as a Christian country, as this

emphasis on Christianity and traditional culture can threaten constitutional and Article 18 rights to thought, conscience, and religion (PNG Constitution, 2020). Foreigners' poor integration into PNG's culturally rooted society contributes to this tension and leads to animosity and discrimination, especially when they disrespect local customs. Factors such as dependency fostered by the education system, church teachings focused on prosperity, reliance on family and clan support, and social problems such as drug and alcohol abuse hinder national progress (Urame, 2007; Ninkama, 2023). Additionally, intermarriage and discrimination against mixed-race children—often stemming from foreigners abandoning PNG spouses—pose social and legal challenges, with enforcement of family laws like the Marriage Act 1963 and Family Protection Act 2013 hampered by geographic, cultural, and financial barriers, thus impeding development and social cohesion (United Nations, 2015).

Conversely, 40% of respondents assert that the Preamble does not conflict with the Constitution. They maintain that the government should uphold human rights outlined in Section 45(1), such as freedom of movement (UDHR Article 13 & Section 52), religion (UDHR Article 18 & Section 45), marriage (UDHR Article 16 & Sections 37, 55), and citizenship (UDHR Article 15 & Sections 46–70). They emphasize the importance of valuing the contributions of foreigners, including skilled workers and researchers, who are vital to economic and social development (Article 13 of the UDHR; United Nations, 2015). Racial discrimination, they argue, hampers national progress and should be discouraged to foster an inclusive and progressive society.

3.2.3 The Right to Political Opinion

The study indicates that 77% of participants view a conflict between their right to political freedom and the Preamble's declaration of PNG as a Christian nation, with both the PNG Constitution (Section 45(1)) and UDHR (Article 21) affirming political rights (PNG Constitution, 2020; United Nations, 2015). These conflicts stem from perceptions that political corruption and leadership issues are rooted in spiritual decay, as biblical teachings suggest (1 Thessalonians 5:23; Hebrews 4:12), with proposals to address this including stricter politician screening and integrating biblical principles like Galatians 5:22–23, Matthew 5:3–12, and Matthew 6:33 into the Constitution to promote integrity. Additionally, some pastors blend prosperity teachings with politics, which weakens the church's moral authority and shifts focus from faith to wealth (Ninkama, 2023). Furthermore, unethical practices such as vote bribery and the influence of wealth undermine democracy, prompting calls for constitutional reforms that emphasize accountability, severe penalties for corruption, and governance rooted in moral righteousness.

Conversely, 23% of participants believe that the Preamble does not contradict Section 45(1), arguing that divine authority guides government systems (Romans 13:1–2) and emphasizing that societal order and peace depend on democratic processes. They underline that voting rights belong to citizens, not spiritual entities, thereby reinforcing accountability through electoral participation.

3.2.4 The Right to Freedom of Sex and Gender roles

The study reveals that 94% of participants believe the PNG Preamble conflicts with Section 45(1) regarding sex and gender roles, citing three main reasons. First, they emphasize that traditional gender roles are vital for societal stability, beginning within the family, with religious teachings across Judaism, Christianity, and Islam highlighting distinct yet complementary roles aligned with divine principles (Deuteronomy 6:6–7; Proverbs 31; Genesis 1:27; Galatians 3:28; Quran 4:34). Judaism assigns men the responsibilities of provision and religious study, Christianity advocates mutual respect with men as leaders and women as nurturers (Ephesians 5:22–25; 1 Timothy 5:8), while Islam recognizes both genders as equal yet assigns men as protectors and providers (Qur'an 4:34). Second, some non-Christians argue that the government's Gender Equality Policy disrupts traditional roles, leading to social issues like domestic violence and divorce, as it challenges cultural and biblical roles that primarily designated men as heads of families. The researcher warns that excessive promotion of gender equality could undermine divine authority, referencing Genesis 3:5 to suggest that surpassing biblical boundaries may lead to societal decline (Ninkama, 2023).

However, about 6% of participants believe that religious teachings in churches can help reduce domestic violence by reinforcing clear roles—an approach more observed in Islamic communities. They advocate for stronger church-based education on gender roles to strengthen families, viewing these as the foundation of societal stability (Genesis 1:27; Ephesians 5:25; Qur'an 4:34). Figure 3 shows the responses to question 3 from section 3.

3.3 Section 3: Common Religious Faiths/Principles

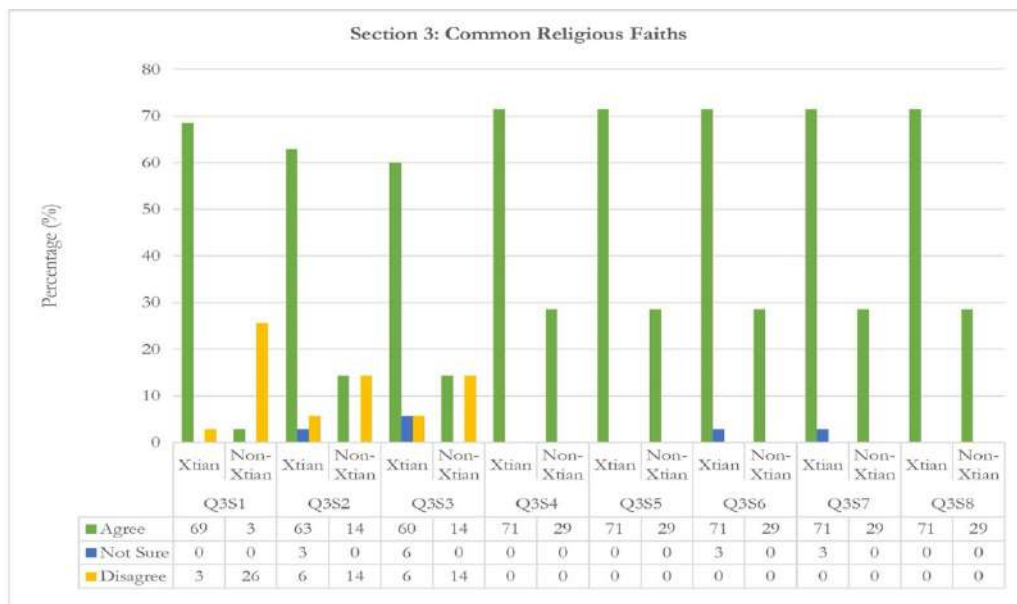


Figure 3: Vector graph illustrating the percentage of responses from section 3, indicating the proportions for three statements in response to Question 3.

3.3.1 Faith in the Triune God

About 71% of participants believe in the concept of the Triune God, supported by biblical references such as Matthew 28:19-20, Genesis 1:26, and Matthew 3:13-17. Christian respondents cite scriptural evidence for the Trinity, while some non-Christians, like Jewish participants, interpret God's presence in different times as a single God working in multiple forms. The study highlights that the deity is central to all three major religions, with a shared belief in one God. Christians predominantly believe in a Triune God—comprising God the Father, Jesus Christ (the Son), and the Holy Spirit—supported by their articles of faith across various denominations, including Catholic, Lutheran, SDA, EBC, and Nazarene. Scriptural evidence for this includes Genesis 1:26 ('Let us create'), Matthew 3:13-17 (Jesus' baptism), and Matthew 28:19-20 (The Great Commission), which articulate the concept of the Trinity (Cunningham, 2009).

Conversely, 29% of non-Christians, including Muslims and Jews, believe in one true God but reject the Trinity. Muslims believe in Allah, a singular God, and regard Jesus as a prophet (Fisher, 2009; Qur'an 50:16). Judaism also emphasizes belief in Yahweh, adhering to the Ten Commandments and the Shema (Deuteronomy 6:14), highlighting the belief in one God and accusing Christianity of polytheism but does not recognize Jesus or the Holy Spirit (Patridge, 2005).

3.3.2 Day of Worship

The study indicates that 77% of participants observe specific days of worship, which vary among religions: Muslims on Friday (Jumu'ah), Jews and Adventists on Saturday (Sabbath), and Catholics, Lutherans, EBC, and Nazarenes on Sunday, reflecting their theological doctrines (Qur'an 62:9; Genesis 2:2-3). Muslims believe Friday is significant because it marks the completion of creation and the day Adam and Eve exited Paradise, serving as a day for spiritual reflection and social unity (Esposito, 2005). Judaism and Seventh-day Adventism (SDA) observe Saturday as the Sabbath, honoring God's rest on the seventh day, as described in the Bible, particularly in Genesis and Exodus (Heschel, 2005). Christian denominations primarily worship on Sunday in celebration of Jesus' Resurrection, considered the first day of new creation.

Conversely, 23% of Christian participants believe in daily worship, citing scriptures like Romans 14:5 and Colossians 2:16-17, which emphasize personal conviction and refraining from judgment regarding Sabbath

observance. These believers focus on daily spiritual discipline rather than a specific day. Participants recommend a national policy on worship days and believe churches or pastors involved in disputes should face legal action to prevent divisions and unrest.

3.3.3 Belief in Baptism

The study shows that 74% of Christian participants believe in both water baptism and Holy Spirit baptism, practices rooted in biblical teachings that symbolize following Jesus and facilitating spiritual transformation and empowerment. Water baptism, typically by immersion or sprinkling (pouring), reflects Jesus' example, while Holy Spirit baptism signifies a profound spiritual transformation and unity among believers. Non-Christian religions like Judaism and Islam also emphasize spiritual immersion—through scripture or faith—as transformative. However, Christianity uniquely teaches that Holy Spirit baptism provides a profound, life-changing experience beyond mere symbolism, establishing a direct relationship with God. About 26% of participants view baptism as a ritual symbolizing commitment rather than a pathway to salvation.

3.3.4 Faith in the Ten Commandments

The findings reveal that all participants (100%) recognize the Ten Commandments as divine revelations from God (Allah or Yahweh) and foundational to their faith, guiding moral, ethical, and community life (Neusner, 2011). Christians regard the commandments as a moral compass, emphasizing love for God and others, with scriptures such as Matthew 22:37-40 and Mark 12:30-31 highlighting these principles. Judaism sees the commandments as central to the covenant, shaping the 613 *mitzvot* and promoting social cohesion (Neusner, 2011). Similarly, Islam emphasizes monotheism and laws against idolatry, theft, adultery, and unjust killing, supported by Qur'anic verses (Qur'an 6:151-153; 4:48). Historically, these commandments have influenced societal morals, laws, and traditional values, although modern education has seen a decline in their moral transmission, contributing to social disorder (Moran, 1983). Overall, they serve as guiding principles promoting love, righteousness, forgiveness, and societal harmony.

3.3.5 Faith in the teaching of love

All participants agree on the importance of love, particularly Christians who distinguish between *philia* [brotherly love], *Eros* [romantic love], and *agape* [selfless love] (Lee, 1988), with the latter epitomized by God's love through Jesus (John 3:16). *Agape*, characterized by unconditional love and forgiveness, is regarded as the universal language essential for societal unity and moral integrity (1 Peter 4:8; Matthew 22:37-40). Non-Christians also emphasize the positive societal impact of love; fostering *agape* is vital for overcoming self-centeredness, promoting reconciliation, and ensuring peace that transcends religious boundaries. Despite the challenges of practicing selfless love, cultivating *agape* is essential for fostering community harmony and moral development across faiths.

3.3.6 Faith in the teaching of forgiveness

The study finds universal consensus (100%) that forgiveness is a vital religious principle, with divine forgiveness rooted in God's mercy through Jesus' sacrifice, symbolized in scriptures like 1 John 1:9 and Psalms 103:12, and accessible through repentance (Hebrews 9:22; Colossians 1:14). Human forgiveness involves releasing resentment, emulating divine mercy, and fostering peace in relationships (Luke 6:37; Matthew 6:15). Many social issues such as conflicts and violence stem from unforgiveness, highlighting its importance for societal stability and individual healing. Christianity views forgiveness as a manifestation of divine mercy, while societal peace hinges on humans' willingness to forgive, thereby preventing retaliation and conflict (Exodus 14:14; Luke 23:34). The study emphasizes that practicing forgiveness is vital for maintaining societal harmony and personal well-being.

3.3.7 Faith in the teaching of righteousness

All participants (100%) affirm righteousness as a core religious principle, representing divine character and moral integrity essential for eternal life (Matthew 5:8; 2 Timothy 3:16). Christians see righteousness as a divine

transformation through the Holy Spirit that restores the believer's relationship with God and unlocks blessings (Matthew 6:33; Psalms 89:14). Non-Christians, including Jews and Muslims, equally associate righteousness with devotion to God, ethical conduct, and social prosperity—linked to love for God and neighbor (Deuteronomy 6:5; Leviticus 19:18; Qur'an 2:177; 92:17-20). Both perspectives emphasize the importance of obedience to divine law for spiritual growth, societal harmony, and material well-being. Righteousness fosters moral integrity, spiritual prosperity, and societal stability, emphasizing divine guidance and ethical living as pathways to a righteous life.

3.3.8 Faith in the teaching of peacemaking

Participants universally (100%) uphold peacemaking as a fundamental religious value, with Christianity and Judaism affirming God as the Prince of Peace and emphasizing faith, prayer, and harmonious relationships (Isaiah 9:6; Matthew 5:9; John 14:27). Islam similarly underscores submission to Allah and justice as essential for peace, encouraging forgiveness and ethical conduct (Surah Al-Anfal 8:61). In PNG, peace is fostered through traditional and Christian conflict resolution methods, emphasizing respect and cooperation, supported by socialization within families and communities under elders' guidance. The UDHR also emphasizes peace, equality, and security as universal rights (Articles 1 and 3). Overall, all faiths and societal frameworks promote peace as integral to spiritual fulfillment, social stability, and justice, advocating divine guidance, mutual respect, and social cohesion.

4. CONCLUSION

The study examines the complex and conflicting perspectives surrounding the PNG Constitution's Preamble, which emphasizes maintaining the nation's 'noble tradition' and 'Christian principles,' affecting diverse groups, including devout citizens, Christian believers, followers of non-Christian traditions, and non-resident non-Christians, highlighting the intricate interplay of religious and cultural identity within the country. It finds that traditional values, such as respect for ancestors and elders, love, sharing, and reconciliation, align with PNG's core principles despite external skepticism towards practices like animism and materialism, highlighting the importance of respecting traditional beliefs alongside Christianity. The research reveals tensions between the Preamble's declaration of PNG as a Christian nation and the constitutional guarantee of religious freedom, which, coupled with societal issues such as race, politics, and gender roles, complicates national cohesion. Despite doctrinal differences, shared principles like love, forgiveness, righteousness, and peacemaking can foster unity. The study's limitations, including restricted funding and a small sample essentially comprising religious leaders from Judaism, Christianity, and Islam, may mean that its findings do not fully represent broader perspectives. Nonetheless, it highlights the importance of constitutional reform, anti-corruption measures, and interfaith dialogue in promoting social harmony. Future research should advocate for policies that align cultural and religious values, regulate religious organizations, and encourage community initiatives to foster greater understanding and cohesion.

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Teachers' content knowledge, teaching methods and their encouragements that influence Grade 10 students' mathematics learning in Port Moresby, Papua New Guinea

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Abstract: Teachers' content knowledge, teaching methods and their encouragement of students are important as they determine the students' mathematics performance at secondary schools in Papua New Guinea (PNG). However, it is evident that significant number of students cannot continue to Grade 11, and simultaneously decline in student enrolment in science related degrees at the university level in PNG. That being the case, this study aims to examine teachers' content knowledge, teaching methods and their encouragement that influence Grade 10 students' mathematics results. A qualitative research approach (interview) is applied in this study. The interview data of nineteen Grade 10 mathematics teachers were analysed through thematic approach to capture rich information. This study highlights that teachers' content knowledge, teaching methods and their encouragement of students have a significant influence on Grade 10 students' mathematics learning. The study concludes that more attention should be given to these three factors at schools, in order to improve Grade 10 students' mathematics learning.

Keywords: Content knowledge, teaching methods, encouragement, mathematics and learning

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1. INTRODUCTION

Mathematics teachers need a solid understanding of mathematics so that they can teach it as a coherent, reasoned activity and communicate its elegance and power. However, research studies indicate that many teachers possess a limited knowledge of mathematics in key content areas such as calculus (Ekawati, Rosyidi, Prawoto, Prahmana & Lin, 2022; Adelabu, & Alex, 2022). This is particularly true in the case that most teachers find it difficult to teach the most complex mathematical problems, the most cognitively challenging, and the most essential to success in higher mathematics and science. Researchers investigating the connections between mathematical content knowledge and teaching methods (e.g., Askew, 2008; Ward & Thomas, 2008) have found clear relationship between these two categories. Ward and Thomas (2008) found that teachers with low levels of mathematical content knowledge also had low levels of teaching methods, but those with high levels of content knowledge had wide range of teaching methods. This evidence supports the claim that a certain threshold of mathematical content knowledge is necessary for good teaching.

In this study, the interview data of teachers are analyzed to identify common themes emerging from the

teacher group. Interviews are only for the teacher-level to obtain perspectives on educators' teaching methods, content knowledge and their encouragement that might affect their students' mathematics achievements. As the literature indicates that students' mathematics achievements are affected by teacherlevel factors, it is important to discuss the issues that are identified in the interviews with teachers. This study will answer the research question "What are the attributes that are deemed important by teachers regarding their mathematics content knowledge, teaching methods and encouragement of students?" In order to answer this question, three main themes are identified and discussed, including content knowledge, outcome of teaching methods, and encouragement towards mathematics. In analysing the interviews, the main themes are first discussed, followed by discussion of participants' responses under each theme. After that, the discussion of the responses are presented, according to the main themes identified.

2. LITERATURE REVIEW

Researchers in mathematics education have proposed different conceptual structures for mathematics knowledge (Ekawati, Rosyidi, Prawoto, Prahmana & Lin, 2022; Adelabu, & Alex, 2022). These conceptual structures often separate pure content knowledge (CK) from the knowledge that facilitates teaching. However, some scholars such as Yang, Schwarz & Leung, (2022) and Maher, Muir, Chick, (2022) doubt whether CK is separable from the knowledge needed for teaching, and empirical work on the distinguishability of these two components provides mixed findings.

Mathematical content knowledge for teachers is important for students learning in mathematics. According to Estrella, Mendez-Reina, Olfos & Aguilera, (2022) subject matter knowledge (SMK) is subdivided into three parts: *Common content knowledge*, *knowledge at the mathematical horizon*, and *specialized content knowledge*. *Common content knowledge* is the body of knowledge and information that teachers teach and the students are expected to learn in mathematics or its content area. For example, mathematics teachers and engineers both use knowledge of how to solve algebraic problems in conducting their day-to-day work. *The knowledge at the mathematical horizon* gives an awareness of how mathematical topics are related over the span of mathematics included in the curriculum (Escudero-Ávila, Montes & Contreras, 2021; Yang, Kaiser, König & Blömeke, 2021).

Moreover, the *specialized content knowledge* is type of mathematical content knowledge specifically needed for teaching (Koyuncuoglu, 2021; Mwinuka, & Tarmo, 2021). These types of knowledge, serve as a critical component for defining mathematics teacher to be effective in their daily preparation and teaching. Literature claims that teachers cannot teach what they do not know themselves (Cavadas, Rézio, Nogueira & Branco, 2022; Getenet, & Callingham, 2021) and, to meet the challenging demands of teaching, teachers must possess sufficient mathematical content knowledge. For instance, according to the Commonwealth of Australia (2008, p. 21), one of the main issues associated with Australia's mathematics and numeracy teaching workforce is that "teachers are not being adequately prepared for teaching numeracy and mathematics". On the other hand, ACDE report also highlights that, "the teaching of mathematics depends on the teachers' mathematical content knowledge and also on their attitudes to teaching mathematics and their understanding of mathematics pedagogy" (2012, p. 14).

Moreover, studies reveal that mathematical knowledge assist teachers to carry out the work of teaching mathematics. Important to note here is the teaching methods employed by teachers (Yang, Hsu, & Cheng, 2022; Rieu, Leuders & Loibl, 2022). It is concerned with the tasks involved in teaching and the mathematical demands of these tasks. Because teaching involves showing students how to solve problems, answering students' questions, and checking students' work, it demands an understanding of the content of the subject matter (Copur-Gencturk & Tolar, 2022; Arnold, Burroughs, Fulton & Álvarez, 2021). Beyond these obvious tasks, we seek to identify other aspects of the work and to analyze what these reveals about the content demands of teaching. To teach all students according to today's standards, teachers need to understand subject matter deeply and flexibly so they can assist students create useful cognitive maps, relate one idea to another, and address misconceptions (Grilo & Cerqueira, 2022; Shongwe, 2021). Teachers need to see how ideas connect across fields and to everyday life since teachers' content knowledge and teaching methods have significant positive effects on student mathematics learning (Rahman, Rosli, Rambely, Siregar, Capraro & Capraro, 2022).

Teaching method is the mechanism that is used by the teacher to organize and implement a number of educational means and activities to achieve certain goals (Bieg et.al, 2017; Ardeleanu, 2019;). Teaching

techniques are the means that reflect the success of the learning process and the competencies of the teacher (Malik & Masri, 2019; Voskoglou, 2019). For instance, from the author's teaching experience, teacher always looks for new ways to deliver knowledge to the learners, and in many occasions, discovered that traditional teaching methods become not effective as it used to be due to the current advancement in technology. Teaching becomes more effective when it is performed in a quicker response to the needs of the learner (Malik & Masri, 2019; Voskoglou, 2019). Studies suggest that design and selection of teaching methods must take into account not only the nature of the subject matter but also how students learn (Ardeleanu, 2019; Asghar, Malik & Masri, 2019). In today's school the trend is that it encourages much creativity. This is due to the fact that human advancement comes through reasoning to enhances creativity. This is evident in mathematics teaching where creativity is encouraged to engage students' interest in learning mathematics.

Encouragement is one of the most powerful tools a teacher can use. Studies highlight that encouragement is the key to unlocking untapped potential in students especially those that have negative approach towards learning mathematics (Khairnar, 2021; Wise, 2022; Osman, Daud & Kumar, 2021) Teachers actions have the ability to lift students up or break them down. Encouraging words and actions are often internalized by students and have the power to motivate them to succeed (Osman, Daud & Kumar, 2021; Khairnar, 2021). A study by Snead, Walker & Loch (2022) found out that encouragement assists students to learn better in mathematics and never giving up on themselves. Literature reveals that it is easy to offer encouragement when a student is succeeding (Lugosi & Uribe, 2022; Aliyu, Osman, Daud & Kumar, 2021). However, encouragement is often the most effective when students receive it while they are struggling to master concepts. Several studies affirm that when a student is failing or struggling, by offering support the teacher can reaffirm their unconditional positive regard for the student to build trust and rapport with the student (Lugosi & Uribe, 2022; Aliyu, Osman, Daud & Kumar, 2021).

There are many steps that teachers can take to encourage children to succeed. Students look to teachers for approval and positive reinforcement (Khairnar, 2021; Wise, 2022), and are more likely to be enthusiastic about learning if they feel their work is recognized and valued. Teachers should encourage open communication and free thinking with their students to make them feel important (Dagdag, Palapuz & Calimag, 2021). Be enthusiastic and praise students often in their learning and recognize them for their contributions. Studies indicate that when classroom is a friendly place where students feel heard and respected, they will be more eager to learn (Astuti, 2021; Khairnar, 2021; Wise, 2022).

3. AIM AND RESEARCH QUESTION

The study aim was to identify the mathematics content knowledge, teaching methods and encouragement from teachers that influence Grade 10 students' mathematics learning.

The guiding research question for this study is: What are the attributes that are deemed important by teachers regarding their mathematics content knowledge, teaching methods and encouragement of students?"

4. RESEARCH METHODOLOGY

This section of the paper discusses the methods and procedures used to collect and analyse the interview data.

4.1 Development and Administration of Interview Questions

The interview questions were developed following basic guidelines (Archibald, 2016; Bamberger, 2012; Creswell, 2008). Each question was constructed with reference to the topic and the purpose of this study. Accordingly, the brevity and clarity of the instrument was prioritised. Biased and negative wordings that may have influenced teachers' responses were avoided. The questions developed were then discussed with three experienced teachers. Feedback from these researchers related to designing the questions on quality of teaching aspects adapted from the teaching quality model in NSW schools, and how the researcher would engage teachers to truthfully express their feelings towards teaching mathematics. Consideration of validity and reliability were paramount for interview questions for the teacher participants (Archibald, 2016; Creswell, 2008). As this study aimed to get Grade 10

mathematics teachers' views about their content knowledge, teaching methods and encouragements to students, they were interviewed. Grade 10 teachers are selected in this study because their students sit for PNG national examination each year. The results of these examinations continues to decline over the years and many students cannot go to universities and colleges, respectively. Prior to the administration of this study, it was necessary to obtain ethical research approval from the University of Adelaide's Human Research and Ethics Committee (UAHREC). The UAHREC granted approval for this study to proceed on 14 July 2017 (Ethics Approval No H-2017-133).

4.2 Participants

Mathematics teachers of Grade 10 students were selected. Teachers were purposefully selected with a mixture of experience, from expert and novice, to ensure that a balance of views and opinions was received (Creswell, 2002; Creswell, 2017). Interviews were scheduled during teachers' non-contact periods. Once the participant appointments were made, interview questions were provided to teachers, in order to obtain as honest and detailed answers as possible. Interviews were then conducted in the 16 schools, with 19 teacher participants. Participants were informed that the whole interview was audio-recorded. Prior to the interview, the researcher explained to participants the purpose, importance, and confidentiality of the interview (Creswell, 2008). After that, the researcher began to ask questions using the interview protocol. Consideration of questioning strategies was sought and observed to elicit the appropriate responses. Questions were rephrased and examples were highlighted relating to scenarios for the participants to more easily understand the questions. At the end of the interview, the researcher thanked the participants, and assurance of the confidentiality of their responses was emphasised.

4.3 Data Analysis

Thematic analysis is the most common analysis approach used in qualitative research. This approach emphasises pinpointing, examining and recording patterns (themes) within data. Themes are patterns across data sets that become the categories for analysis, and are important in describing a phenomenon associated with a specific research question. In this approach, themes are used to capture the essence and spread of meaning; they unite data that might otherwise appear disparate, and correct meanings that occur in multiple and varied contexts. "Thematic analysis can be an essentialist or realist method, which reports experiences, meanings and the reality of participants" (Braun & Clarke, 2006, p. 81). Therefore, thematic analysis works both to reflect reality and to unpack the surface of 'reality'.

In this study, thematic analysis is performed following the six processes of coding phases outlined by Brinkmann and Kvale (2015) and Braun & Clarke, (2006) to create established and meaningful patterns. The first step is familiarisation with the data to sort out ideas through transcribing, reading and re-reading. Second, codes are generated in a systematic approach across the entire data set, in order to collate data that are relevant to each code. Third, themes are identified for coding, and to gather the data for each relevant and potential theme. Fourth, these themes are reviewed to ascertain that they work in relation to the coded extracts and the entire data set, to generate a thematic 'map' of the analysis. After that, the themes are defined and named to tell a clearer story of the data. Finally, a scholarly report of the analysis is produced that relates back to the research question and literature. These six steps to analyse the quantitative data using the thematic approach were organised and expedited through use of the NVivo 12 software.

NVivo 12 is used to analyse the interview data in this paper. NVivo is a data management tool (Hart & Achterman, 2017), that organises and assists in making sense of data during analysis (Hamrouni & Akkari, 2012; Hart & Achterman, 2017). NVivo organises, stores and retrieves data more efficiently than manual methods, saves time, and helps to rigorously back up findings with evidence (Hamrouni & Akkari, 2012). The data were imported from a text file and analysed with NVivo's visualisation tools. The software allows the researcher to classify, sort and arrange information; examine relationships in the data; and combine analysis with linking, shaping, searching and modelling (Hamrouni & Akkari, 2012; Hart & Achterman, 2017). The researcher can test theories, identify trends and cross-examine information in a multitude of ways using the software's search engine and query functions.

There were several steps involved in analysing the interview data with NVivo 12. First, the teachers'

transcribed interviews were loaded into NVivo. After that, themes and sub-themes from the scripts were identified and created. Next, the teacher transcripts were sorted into the appropriate themes and sub-themes and, a mind map was formulated through the NVivo software to create relationships among the themes. This process created a frequency of the number of teachers under each of the themes, making it easier to trace the teachers' responses on the themes. For instance, in this study, four themes were identified, and the software assisted in putting together all the responses of the participants according to their respective themes, with the percentages of responses and the frequency of respondents listed under each theme. This organisational approach of the software requires less time and allows more flexibility than manual methods in comparing interview responses and analysis of data.

4.4 Emerging Themes

This section highlights each of the main themes that were identified in the data by frequency analysis of the teacher-level interview. The three key themes that emerged from the data analysis are: (1) content knowledge, (2) outcome of the teaching methods used in the classroom, and (3) encouragement towards mathematics (practice exercise and students' attitudes/approaches). All of these themes seem to have an influence on the mathematics learning outcomes of students.

4.5 Theme 1: Content Knowledge

Mathematics content knowledge is important for teachers to possess in order to deliver effective lessons to students. Teachers use teaching methods variously to deliver the content of mathematics topics, and it is believed that showing confidence with the content knowledge towards a particular topic is likely to have an impact on students' mathematics results. As mentioned earlier, the content knowledge of the teachers interviewed was used to ascertain its impact on the students' mathematics achievements. Therefore, the results of teacher interviews will instead provide an in-depth exploration of how the content knowledge of mathematics teachers can affect students' mathematics results through their teaching.

The results of the interviews indicate that eight teacher participants have adequate content knowledge and are confident in teaching all topics in the mathematics syllabus. Six other teacher participants are confident in teaching both Geometry and Trigonometry. Two teachers are confident in teaching Series and Sequences, Vectors, Statistics and Money, and only one teacher is confident in teaching Calculus. Algebra is the only topic that all the 19 mathematics teachers are confident in teaching. These findings indicate that some of the teachers are less confident with their content knowledge when teaching some of the mathematics topics. Moreover, the results also reveal that there are six teacher participants who are less confident in teaching Calculus, and four participants who are less confident in teaching Vectors. Furthermore, three other participants are less confident in teaching Probability, with another two participants are lacking confidence in teaching Money. Geometry, Trigonometry, and Statistics are topics that one teacher each has less confidence in teaching. These results indicate that teachers' confidence in teaching mathematics topics can have influence on students' mathematics achievements. Some participants gave their reasons for feeling less confidence in teaching these mathematics topics. One of the participants stated that:

Trigonometry in Grade 12 especially, to do with quadrants and all that yeah and then going on to circular functions, the graphs because there a lot of details to be analysed. Information like the graphs to be analysed for the sine function, cos functions, the features of the graphs, you know what this letter is on the equation, what its meaning and all that, and they have to remember all those. Too many properties and inequalities to remember about certain equations make me you know to forget many things when I am teaching that topic and it makes me feel not confident [Teacher 3].

Two other teachers also shared similar sentiments:

Sometimes when I see that there is no time. May be because the nature of the topic. So many things in there where we need to put together and understand. Find some ways to simplify for the students to understand [Teacher 12]. It takes time and effort for teachers to sit down to read through different books to see the way it's been set up. Where you understand it you can be able to tackle it [Teacher 16].

The above three teachers' views indicate that teachers lack knowledge in the detailed aspects of topics such as Trigonometry, and as a result consume more time and effort attempting to consult different sources in

preparing their lessons. Teachers also struggle to confidently deliver content knowledge that they are less familiar with, even despite extra time and effort put into the preparation of lessons.

These problems arise when teachers are less trained or are recruited directly from non-teacher training universities without the necessary content knowledge. Two teachers emphasised that:

Vectors and small part of calculus. That very area that I am not confident is because I did not pick at my studies at university [Teacher 4].

I am a person I am not a trained teacher but I graduated from university and looking for a job and joined teaching. Because of my background as physics [Teacher 5].

These two participants' views suggest that teacher-training institutions lack the capacity to impart much needed content knowledge to the student teachers in the necessary topics. Further, schools are employing teachers who are not trained to teach mathematics. This results in teachers who lack confidence in teaching some mathematics topics. As a result, students in turn might have different attitudes towards learning mathematics, which can affect their results. One teacher highlighted that:

Sometimes maths is a difficult subject in PNG; there are many students who finds it very hard to understand maths so sometimes in my lesson I try to break the example down to detail to explain for students to understand the concept on how to solve the particular problem [Teacher 7].

This attitude aspect of students is also found in the quantitative studies, showing that students' positive attitudes have a significant effect on their mathematics results. However, the results of the interviews also show that students can have negative attitudes towards mathematics (e.g. that is 'too hard') if their teachers struggle to prepare and deliver lessons.

Teachers' feelings of confidence/lack of confidence to teach mathematics content are compared below in Table 1.1. This comparison is conducted through independent samples t-test analyses.

Table 1.1 Descriptive statistics of the teachers' confidence in teaching mathematics content

Group statistics					
	Confident Level	N	Mean	Std.Deviation	Std.Error Mean
Maths Results	Confident	119	498.91	7.64	0.70
	Not confident	181	495.08	5.72	0.43

The descriptive statistics associated with the confidence level for teachers are reported in Table 1.1. From this table, it can be seen that teachers who are confident with mathematics content are associated with the high mean ($M=498.91, S.D=7.636$) compared to teachers who are not confident with mathematics content ($M=495.08, S.D=5.72$).

Table 1.2 The output of independent sample t-test analysis

		<u>Independent Samples test</u>								
		Levene's Test for Equality of Variances							95% Confidence interval of the Difference	
				t-test Equality of Means						
		F	Sig.	t	df	Sig.(2 tailed)	Mean Difference	Std.Error Difference	Lower	Upper
Maths Results	Equal variances assumed	4.95	0.02	4.95	298	0.00	3.82	0.77	2.30	5.35
	Equal variances not assumed			4.66	203.06	0.00	3.82	0.82	2.21	5.44

Table 1.2 shows the output of the independent sample t-test analysis indicating whether there is a statistically significant difference between teachers with confidence in teaching mathematics content and teachers who are not confident. Both the results of the assumption of homogeneity of variances via Levene's F test, $F(298)=4.94$, $p=0.027$ and the independent t-test $t(298)=4.95$, $p=0.00,95\%$ C.I [2.303-5.345] are associated with statistically significant effects on the teachers' confidence levels. Thus, the teachers who are confident in teaching mathematics are associated with a statistically significant ($p<0.05$) effect with larger means than the teachers without confidence, in determining students' mathematics learning. Furthermore, professional development (PD) is crucial to overcome challenges associated with less confident teachers. PD can help with gaps in teachers' content knowledge, and provide methods to enable them to gain confidence in the effective teaching of mathematics topics. However, 16 out of the 19 teachers interviewed stated that they do not have access to PD for the topics they are less confident in teaching. These teachers stated that PD is not initiated at the department level, nor at their schools as a whole. Six of the teachers said:

No. In that case no. Specially that particular topic ah. Any professional development or in-service there is nothing. But I am interested in taking up any of those [Teacher 1].

I haven't any. The only way is to do is to do research to understand examples and deliver to the students [Teacher 16].

No in-service. We lack teachers so we go in and teach as long as we achieve our objective [Teacher 3].

So far we do not have any in-service. May be because of the head of department have not done a schedule [Teacher 17].

Zero. There is no assistance in that area, no in-service in topics we are not confident to teach [Teacher 3].

No in-service in the school and department [Teacher 7].

These responses indicate that professional development is less prioritised by most of the mathematics departmental heads at schools in Port Moresby. This could have multiple effects on the teaching and learning of teachers and students: teachers may remain less confident in teaching topics, and cannot deliver content knowledge to students effectively or with creativity. This implies that students are likely to get less out of the teachers, and that may consequently affect their mathematics learning.

4.6 Theme 2: Outcomes of the Teaching Methods

Outcomes of the teaching methods in the delivery of content knowledge (topics) by teachers are important to determine and evaluate students' learning processes. This evaluation of teaching methods is observed through the students' positive responses towards lesson participation, approaches towards exercises, results of their assessment tasks (e.g., tests and assignments) in classrooms and the results of their standardised national examination. These elements of the students' learning processes indicate the effectiveness of the particular teaching method employed by their teachers. The effects of these teaching methods determine the outcome of the students' mathematics learning, and are also evident in the teachers' interview responses. Of the teachers interviewed, 12 out of the 19 teachers employing traditional teaching methods (discussed earlier) gave responses on how these methods influence learning outcomes. Two of the participants stated that:

I give students exercises and when they get them correct I know they understand. Sometimes students have to explain correctly in a logical order and that means that they really understand the concept [Teacher 14]. They learn very well I think. Students do more examples and want more practical examples to do the exercises.

The method that I use is very good and I think students are learning more on that [Teacher 10].

These participants' responses indicate that students' understanding of the mathematics concepts are determined by the competence level (number of correct answers) that students display when attempting practical exercises, and teachers' logical explanation of ideas.

The other three participants mentioned that student participation and interaction with teachers shows that students have sufficiently understood the mathematics content. These participants said:

I see the students' response favourable to the method that I use. There seems to be an interaction between a teacher and the student. When I ask questions, students are able to raise their hands and answer the question. In that where I know and realise that, the students are into the lesson that is been presented and are following. I also call the attention of students who do not really participate, who are doing other things. When I am teaching I look around and see that I direct questions to them. In that, way I make them pay attention to what is been discussed [Teacher 7].

The learning is OK. It's not high standard of learning as expected. They need various strategies in order to fully understand the subject [Teacher 13].

Students learning, the most method they are catching up in learning is through chalkboard doing calculation on the board and doing corrections, word problems you know this. The board is a good way of learning that is improvement [Teacher 2].

It is evident in these participants' responses that participation in the lesson indicate that students are learning from the teaching method. However, to facilitate students' participation in lessons, teachers must expend effort to get all students' attention by asking questions. Furthermore, teachers' use of the blackboard for doing calculations, and correcting mathematics problems together with students, effectively improves student learning in mathematics. However, in order to better disseminate mathematics ideas to students, it is still necessary to also utilise other teaching strategies such as student-centred methods. The other six teachers using the student-centred methods also provided responses detailing their methods. Two of these participants highlighted that:

Ok other one when we give in groups, we find that learning is quite effective, because within their own groups, they kind of check on each other. And everyone has part to play in the group and they report to each other so nobody seems to be sleeping [Teacher 3].

One way is they are helping each other during group work. They share ideas in groups esp. those bright ones are assisting the weak ones to understand what was taught in class and doing their presentation to does the same thing [Teacher 12].

These two participants' responses denote that student-centred methods are effective, as students work in groups sharing ideas to assist each other with lessons. This suggests that high-achieving students could assist weaker students when group and peer learning is encouraged, with students checking each other's learning and sharing ideas through presentations. Teachers act to facilitate their students learning processes, and students take ownership of their own learning for desirable learning outcomes.

Another teacher further stated that:

What I find is in certain topics where I demonstrate but the other where I feel that they can be able to help with their peers I give the task to them and they enjoy working with the peers. This is because they understand their peers and friends [Teacher 6].

This response supports the previous two participants' responses emphasis on students of working together in groups to learn from each other, indicating that students work and learn with their peers better than with their teachers.

4.7 Theme 3: Encouragement

Teachers' encouragement of their students is important in improving their mathematics results. Encouragement from teachers can influence students' approaches to learning mathematics. The two important sub-themes that emerged from analysis are practice with more exercises and students' attitudes/approaches towards mathematics. Working consistently on mathematics exercises can give students greater confidence in solving mathematics problems, and deepen their understanding of the subject. For instance, the more they practice and actively solve exercises, the better they will be in mathematics. This view was confirmed by three participants' responses. They highlighted that:

Maths is not something that you can study and memorise, but maths is something you must practically do. I encourage them to do more activities/exercise and do everything so that you can be used to [Teacher 10].

Tell them to do a lot of exercise because they do more practice to understand the concept in mathematics [Teacher 14].

You must do a lot of exercises [Teacher 4].

The responses above clearly indicate that teachers encourage students to do more practice with mathematics exercises to learn and master mathematics knowledge and skills. Similarly, a teacher participant emphasised the importance of relating abstract mathematics knowledge to more practical applications in society. The participant stated that:

One of the things I tell them esp. those who do not show much interest in mathematics is whatever we learn in school we apply outside in real life. Put in practice what we learn in the classroom. Get yourselves involved and learn more to put in practice outside. Money or formula can be applied in real world esp. every way you go in shops or markets there is mathematics. Therefore, you must learn and really understand mathematics [Teacher 7].

Students' attitudes/approaches towards mathematics is another sub-theme identified from the analysis. Of the teacher interviewed, 12 of the 19 encourage students to have positive attitudes or approaches towards mathematics. The sub-theme of students' attitudes towards mathematics was also discussed in the quantitative analysis of this study (Chapter 7). For instance, three of the participants emphasised that:

Cheer them up and tell them you can do it. Mathematics is not that difficult it's fun. I make sure they do questions I give and check their work [Teacher 16].

Maths is interesting because it's all to do with numbers. It interesting in the way I teach mathematics to students [Teacher 19]. I always tell them that it's like you learning $1 + 1$ like you did in Primary school. So you do not learn something very hard. Know your basics well then you can do better and understand because that will be applied and carried on to Grade 9, 10, 11 and 12 [Teacher 12].

I encourage students to be active and be energetic when learning mathematics [Teacher 2].

These responses suggest that the teachers encourage their students to have positive attitudes towards mathematics, for instance, encouraging students by communicating that mathematics is not hard but is interesting and fun. These teachers support their students to understand basic mathematics skills in order to progress to problems at higher-grade levels that require higher skill levels. This encouragement can be prompted through active learning with greater energy. Similarly, some teachers encourage students to approach them (or others they are comfortable with) when they have difficulty understanding mathematics ideas/concepts. Two teacher participants pointed out that:

Encourage Feel free to come and see me when they need help or assist. In addition, I encourage them to help each other. Otherwise, they are not comfortable with me as their maths teacher I encourage them to see their friends, parents or seek assist from other mathematics teachers. My biggest encouragement is to open up, to love the subject and to do what they can be able to do. Any difficulty they can come to see me [Teacher 6].

I always encourage students especially those with problems, those who find work difficult to come and seek help. My own experience in this school for the last five years I give help to anybody because I opened the door. Anyone with problem even they are not from my class I help as the head of department I make my business to do that. I am helping average students and lower achieving students but the bright ones do not come [Teacher 9].

These responses show that teachers are willing to allocate time to assist students that have difficulty understanding mathematics concepts. This approach for students seeking help is important to unpack their uncertainties about mathematics problems, and encourages them to improve in their learning practices thereby subsequently improving their mathematics learning.

5. DISCUSSION

It is clear from the findings and literature review that the impact of teachers' content knowledge of mathematics topics on their students' results can be quite significant. The interview data indicate that the impact seems to be greater when teachers are less confident in teaching some mathematics topics. This could be attributed to the fact that only eight of the teachers interviewed are competent to teach all of the mathematics topics, while 11 are confident in teaching just some of the topics. Besides that, most of the teachers still lack the skills and knowledge in topics such as Vectors and Calculus. The teachers' knowledge gaps in mathematics topics in turn can affect their students' mathematics results (Kelcey, Hill & Chin, 2019), as these topics frequently appear in the Grade 10 national examination. A study by Kelcey, Heather, Hill and Chin (2019) indicates that there are significant correlations between teacher content knowledge, instruction, and student achievements. This argument links well with the ANOVA results of the different teaching methods discussed earlier. This is because using student-centred teaching method and mixing both teaching methods have a high significant influence on students' mathematics learning and these methods can be used to effectively deliver content knowledge to students in the classroom. Teachers using these methods consistently, and who have adequate content knowledge in all mathematics topics can teach and guide students to obtain better mathematics results. This is because teachers having sufficient mathematics knowledge allows them to focus on teaching, readily provide alternative explanations, and incorporate additional resources into lessons (Hallman-Thrasher, Connor & Sturgill, 2019).

However, for teaching to be successful, it is also key that teachers possess content knowledge in multiple ways and have an ability to make this knowledge accessible to students. For this to happen, the evaluation of knowledge in terms of content and pedagogy are important as they are interrelated for teachers' success in their practice. This is because the knowledge needed to make specific content accessible to students which forms a critical component of teacher knowledge, has been shown to have an impact on teaching effectiveness (Hallman-Thrasher et al., 2019). This involves teachers' knowledge of content, students, teaching and curriculum in a holistic approach. This knowledge also includes teacher understanding of the student learning process of a particular topic, for instance, the process of how students might solve a problem, and common conceptions and misconceptions about a topic. Further, the knowledge of how a teacher might teach a particular concept needs sharpening, for instance in areas such as representations, sequencing, pacing, and providing examples that are most appropriate for a given topic (Appova & Taylor, 2019; Hallman-Thrasher et al., 2019). The knowledge of content and curriculum involves knowing what instructional resources are available to teach a given topic and under what conditions they should be used (Appova & Taylor, 2019). It is true that content knowledge that is common to any mathematical profession is needed to teach and learn mathematics, for instance, knowing how to solve an algebraic equation. However, the components mentioned above are fundamental to fully utilise this specific content knowledge in mathematics. In other words, teachers need to develop not just a deeper knowledge of mathematics content but also an understanding of the mathematical process of inquiry and problem solving to enrich their teaching practices and to encourage the development of critical thinking skills in their students (Albert 2012).

Teachers are required to know and understand not only mathematics, but also their students learning processes, teaching strategies, as well as how to challenge and support the classroom-learning environment. In addition, teachers need to know and use mathematics for teaching that combines mathematical and strategical knowledge, as they must continue to learn new or additional mathematics content and study how their students learn mathematics (Zhao & Zhao, 2016). These approaches allow teachers to see their knowledge in teaching mathematics in a wider perspective, and are likely to positively influence students' mathematics results.

However, many participants reported that professional development (PD) is not given priority by school heads to improve on those topics that they are not confident to deliver in the classroom. This reflects the mixed feelings reported in relation to the impact of teachers' relationships with school heads who do not organise PD opportunities, which may be affecting their students' mathematics learning. Though some participants have an interest in PD, they are not given the chance to improve on their weaknesses in content knowledge areas. Studies have shown that PD equips teachers with content knowledge and skills they lack to teach students (Jacob, Hill & Corey, 2017), as it upgrades and updates their teaching processes and allows them to deliver mathematics content on topics more confidently.

Moreover, the interview results show that the three teaching methods (student-centred, teacher-centred and both methods mixed) are employed by teachers of schools in Port Moresby. As shown in the interview analysis, student-centred methods and mix methods have a high significant difference on the students' mathematics results, compared to the solely teacher-centred teaching method. One of the main reasons for this may be because of the shift of teachers' teaching methods from traditional (teacher-centred) methods to the student-centred and mixed teaching methods. Despite that, the traditional method is still prominent in schools in PNG. This suggests that students are generally dependent on teachers for their learning, and are not taking ownership of their own learning. As discussed above, teacher-centred methods treat students as passive learners, and encourage less creativity in learning. Studies have shown that teacher-centred methods have a negative influence on students' academic achievements (Basso, 2019; Olson & Stoehr, 2019). This phenomenon can be evidenced in the mathematics results of students who are taught by teachers using student-centred or mixed methods in Port Moresby, which demonstrate improvement over traditional methods.

Moreover, other studies have argued that student-centred and mixed methods have a positive influence on student academic outcomes (Saadati, Cerda, Giaconi, Reyes & Felmer, 2019; Ulandari, Amry & Saragih, 2019). This is because students are active and are more engaged in their own learning. With these methods, students are also able to construct their own knowledge through research and presentation in groups as mentioned by the participants in this study. Drawing from the researcher's experience as a teacher in Port Moresby, this may be tied to teachers' access to instructional resources, teachers' willingness to adapt, and many other strategies related to student-centred method and mixed methods. Despite this, however, the researcher believes that there remain many issues that are likely to continue to hinder teachers to effectively practice the non-traditional methods in delivering mathematics lessons in the classroom (PNG NDOE, 2006, 2009).

Furthermore, from the interview results, it is evident that the teachers encourage their students in studying mathematics through having positive attitudes and taking efforts to make mathematics more practical. This outcome is consistent with the literature review. Several other studies have also shown a correlation between students' attitudes towards mathematics and their achievements in the subject. Teachers' encouragement contributes to positive student attitudes influencing their decisions and improving their results (KhunInkeeree, Omar-Fauzee & Othman, 2016; Pepin & Roesken-Winter, 2015; Prendergast, Hongning & Block, 2016). Mathematics can be presented as a fun and interesting subject, and when students perform successfully in mathematics, this affects their attitudes towards mathematics in positive ways, and this perception can continue throughout their schooling (Mullis et al., 2012; Stephens, Landeros, Perkins & Tang, 2016). This is because negative attitudes towards mathematics can cause some students to lose self-belief in their abilities (Iqbal, Mirza & Shams, 2017; Kiss, 2018; Soni & Kumari, 2017). In the interviews, the teachers' efforts to eradicate their students' negative feelings towards mathematics is evident, as is the belief that more positive encouragement is likely to influence students.

Practical exercises further motivate students to learn mathematics, by allowing them to understand the concepts and steps involved in solving a problem. It is evident from existing studies that students gain interest and are engaged when concepts discussed in the classroom are practically demonstrated in the real world. In the mathematics context, this is achieved through relating the basic principles of how mathematics concepts apply to the every-day life. For instance, Kiemer, Gröschner, Pehmer, and Seidel (2015) discuss the case of an engineer who went to teach mathematics in India. In their study, Kiemer et al. (2015) demonstrated how the teacher motivated their students by relating what had been learnt in the lesson to what was outside the classroom. This approach was initiated due to the students' interest in applying mathematics theory into practice. Overall, the interview data show that there seems little doubt that teachers can better motivate students to study mathematics by emphasizing the relevance of mathematics in the real world. For instance, Ali (2013) shows how teachers motivate students through solving mathematics problems relating to their everyday lives. This approach can generate excitement among the students to persevere in mathematics because of the practical skills and knowledge that underpin the mathematics lessons. Mathematics in this context promotes reasoning skills that are helpful in students' everyday lives. These kind of encouragements by teachers not only motivate students but also promote positive learning approaches that are likely to have an impact on the students' mathematics learning.

6. CONCLUSION

This study presented the results and discussion from the interviews with the nineteen Grade 10 teachers who participated in this study. The findings were presented in three sections that corresponded to the primary themes that emerged from the results: (1) content knowledge, (2) outcomes of the teaching methods used in the classroom, and (3) encouragement towards learning mathematics.

It is clear from the findings of these interviews that the student-centred method and mixed methods have significant effects, compared to teacher-centred method. As the interview results have shown, the teaching methods adopted by teachers can assist and promote students' learning. Furthermore, the confidence of teachers towards their own mathematics content knowledge has a positive influence on their students' mathematics learning. This means teachers' knowledge of mathematics content, pedagogy, instructional resources and curricula are contributing elements in producing better results. However, as identified in the analysis, teachers also face challenges such as student population increases and a lack of learning resources in classrooms that may affect the practical delivery of lessons to effectively communicate content knowledge. On a positive note, some of the participants involved in this study acknowledged that they encourage students to have positive attitudes towards mathematics learning. They also suggested approaches to help students overcome their struggles towards mathematics when the subject becomes difficult, assisting them to believe in their own mathematical abilities.

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Determination of Rainfall-Runoff Relationship for Wadi Dayqah Catchment

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Abstract. The aim of this study is to investigate the rainfall-runoff relationship for the Wadi Dayqah catchment, Oman. HEC-GeoHMS software was used to delineate catchment boundaries and to determine the sub-catchment areas and their centroids, while HEC-HMS and Excel sheets were used for event modeling and calibration. Three storm events from eight different rain gauge stations, with one Wadi gauge, were used in the study. Phi-index and Green-Ampt infiltration methods were used to model the losses, while the SCS unit hydrograph method, Snyder (Tulsa) unit hydrograph method, and a derived unit hydrograph were used for modeling the transformation process. The inverse-distance method was used for modeling meteorological processes. The developed models using the standard methods did not give reasonable results. Therefore, an empirical relationship between rainfall and runoff volume was developed. The data showed that there is a reasonable exponential relationship between the rainfall depth and the runoff volume of the Wadi Dayqah Catchment. The new relationship was verified by analyzing two storm events and using the observed water level and volume of water in the reservoir, and good agreement was found between the observed and computed runoff volumes. The results of this study will be useful for reservoir management during storm events.

Keywords: Rainfall-runoff relationship, HEC-GeoHMS, Wadi Dayqah, Hydrologic modeling

Presenter or Main Author Biography: Prof. Sana is a hydraulics, hydrology, and coastal engineering specialist with more than 30 years of teaching, research, and consultancy experience. He has published 50 papers in Scopus-listed international journals, 13 in other journals, and 72 papers in international conferences, including 5 keynote lectures. Currently, he is a professor of Hydraulics and Water Resources Engineering at the PNG University of Technology, Lae, Papua New Guinea.

1. INTRODUCTION

1.1 Flash Flooding in Arid Countries

Oman is an arid country with limited natural water resources. Most of the surface runoffs take place as flash floods passing through ephemeral streams (called *Wadi* in Arabic language). To protect from flooding and utilize the runoff, public authorities in Oman have constructed several dams at suitable locations in the streams. Many of these dams serve to recharge groundwater aquifers or to store water for domestic and agricultural usage. Wadi Dayqah Dam located in Quriyat, Oman, is one of these dams meant for flood protection and storage.

According to the Ministry of Regional Municipalities, Oman (2012) Wadi Dayqah Dam has a storage capacity of approximately 100 million m³ and a comprehensive potable water supply system to supply the country's capital, Muscat urban area. The system includes a treatment plant and a pump station with several reservoirs. However, the dam experienced several overflow events where the flood water wasted to the sea, especially during heavy rain events like Phet Cyclone in 2010, in addition to losing 2.5 m depth of stored water annually by evaporation (Ministry of Regional Municipalities and Water Resources, 2012). This amount is about 9 million m³ per year, which is almost equal to 25 percent of the planned supply to Muscat urban area. Figure 1 shows the spillway of Dayqah Dam during Phet Cyclone in 2010.

During the rainfall, especially extreme rainfall events like cyclones, the dam operation team releases the water from the reservoir to provide space for the incoming flood. However, this water release activity is based on the experience of the operation team only and without actual calculations or simulations. Consequently, there is a possibility of wasting precious freshwater during a rainfall event if the amount of water released is overestimated. On the other hand, a risk of flooding is there if the released water is underestimated. Hence, a rainfall-runoff relationship should be established, and based on that, an estimation method should be implemented to determine the amount of water to be released from the reservoir to accommodate the expected flood.

1.2 Study Area

According to the Ministry of Regional Municipalities and Water Resources [1], two dams (main and saddle dams) were constructed on Wadi Dayqah in 2006 and officially opened in 2012. The main dam is built at the main flow stream of the wadi and the saddle dam on the depression to close the gap in the mountains to prevent water from escaping while the water rises in the reservoir. The main characteristics of the dam are shown in Table 1. The levels shown in Table 1 are from the dam foundation, which is at 105 meters above sea level.

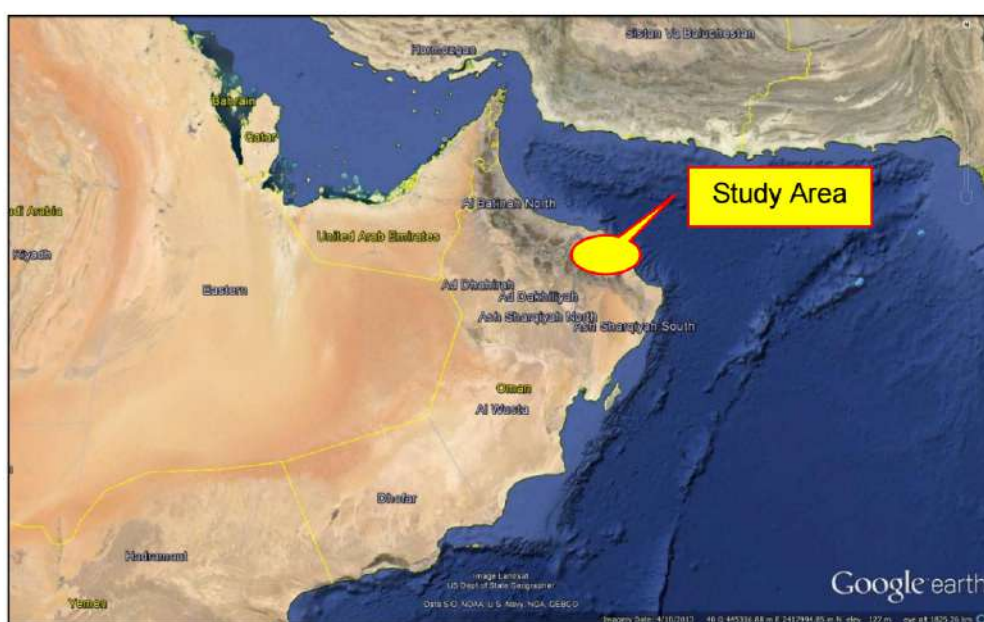


Table 1. Wadi Dayqah Dam Characteristics.

Dam characteristic	Dimension
Length (m)	410
Dam height (m)	75.43
Crest width (m)	5
Base width (m)	55.4
Volume of RCC (m ³)	590,000
Design flood (m ³)	18,398
Spillway crest length (m)	201.74
Spillway height (m)	67.5
Number of outlets (No.)	11
Outlet diameters (m)	1.0 o 1.60

2. RELEVANT LITERATURE

HEC-HMS is one of the popular software for rainfall-runoff modeling globally. Several studies have utilized this model, a few of them are Yener et al. [2], Han [3], Abushandi [4], Choudhari et al. [5] and Jin et al. [6]. Using other models or methods, some studies have been conducted regarding Oman, dealing with the use of tank model to study rainfall-runoff process (Al-Housni et al. [7]), flash floods (Al-Rawas et al. [8]), development of intensity-duration-frequency (IDF) curves (Chitrakar et al. [9]) and analysis of remote sensing data of rainfall in Oman (Al-Quashi et al. [10]). The studies on rainfall-runoff modeling are scarce in the Arabian Peninsula due to the complexity of the inherent processes in arid zones. The present study will help enhance the understanding of the rainfall-runoff process in the Wadi Dayqah watershed.

3. METHODOLOGY

Here HEC-HMS software is used to simulate watersheds using different data sets. The software offers several methods for processing meteorological data. Additionally, it provides flexibility in simulating storm events, infiltration, runoff, and evaporation processes by allowing the selection of multiple methods for each. The software is capable of using GIS to delineate basins and subbasins from terrain data. The geometric characteristics, like basin areas, centroids, longest flow length, stream slope, and average basin slopes, can be estimated. Additional Basin characteristics like curve numbers can be obtained if land use and soil type data are available in GIS format. The level of accuracy of streams and sub-basins delineations depends on the accuracy of the raw DEM data used in terrain processing.

Terrain data of the Wadi Dayqah Catchment of 5×5 meter resolution were obtained from the National Survey Authority (NSA), Oman. These data were used for delineating catchment boundaries and stream flow by the HEC-HMS software. It was found that the total area of Wadi Dayqah Catchment upstream of the wadi gauge is 1873 km² as shown in Figure 2. The catchment was divided into 19 sub-catchments, and the centroid of each was determined using the center of gravity method. Rainfall data from 1977 to 2015 of five five-minute time intervals were obtained from public authorities from different rain gauges that are located within or around Wadi Dayqah Catchment. Also, the daily recorded wadi flow rates of the three main wadis, Wadi Dayqah, Wadi Tayein, and Wadi Khabbah were obtained from 1984 to 2011. However, the records of five-minute intervals from Wadi Dayqah gauge were available for March 1997, only. Three distinct rainfall events were selected for the modeling. One of these events is shown in Fig. 3 and Fig. 4.



Fig. 2. Subcatchments in Wadi Dayqah Watershed developed using HEC-HMS

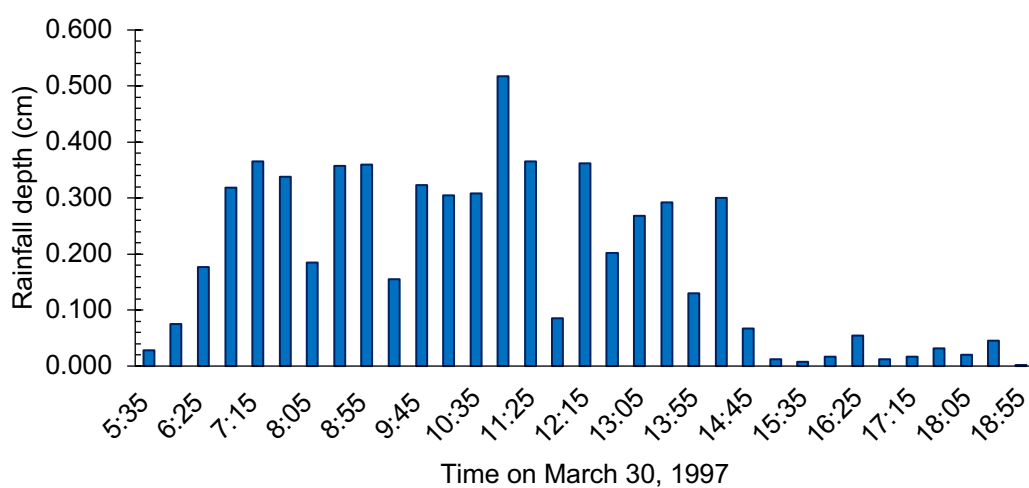


Fig. 3. One of the rainfall events selected for modeling (Event 3).

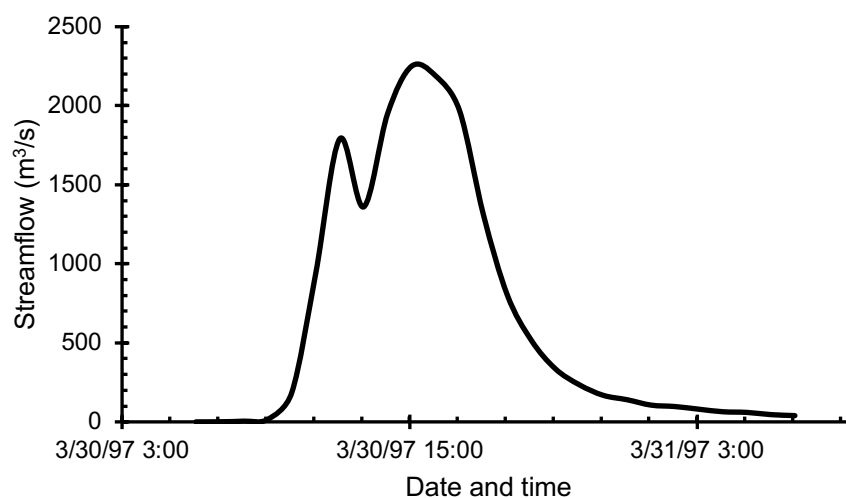


Fig. 4. Streamflow corresponding to Event 3.

In order to establish the rainfall-runoff relationship for Wadi Dayqah Catchment, the following three methods were used: (1) SCS Unit Hydrograph transform method with Green & Ampt loss method (2) Snyder Unit Hydrograph transform method with Green & Ampt loss method, and (3) Unit Hydrograph transform method with a constant (Φ index) loss method. The transform method defines the calculation method of actual surface runoff in each sub-basin, while the loss method defines the calculation method of the actual infiltration process. The evaporation process is ignored in this study, as its impact is minor for a short simulation period. No base flow method was selected as its values were deducted from the wadi observed values before being inserted into the model.

In the UH SCS transform method, the percentage of runoff that occurs before the peak flow is counted by peak rate factor (PRF). For example, the standard SCS UH curve (PRF 484) corresponds to 37.5% of flow occurs before the peak flow. The steeper watersheds typically have higher PRF than flatter watersheds. The peak rate factors for watersheds from flatter to steeper are PRF200 to PRF600, respectively. For Wadi Dayqah Watershed, different PRFs were tried and examined by running the model and comparing the observed and computed runoff hydrographs. It was found that the PRF600 gives the best fit between the hydrographs. Moreover, it was found that the calibrated parameters were affecting the runoff response in the following sequence: percentage imperviousness, lag time, hydraulic conductivity, and then suction head and the saturated content.

4. RESULTS

The summary of the results obtained from the three methods is shown in Table 2. The calibration of the model parameters was done manually in HEC-HMS for Method 1 and Method 2. Whereas, for Method 3 the unit hydrographs were derived from each event. An average UH was then obtained and used to compute the streamflow from the excess rainfall. A reasonable agreement was found between the observed and computed values as depicted by high Nash coefficient values in Table 2.

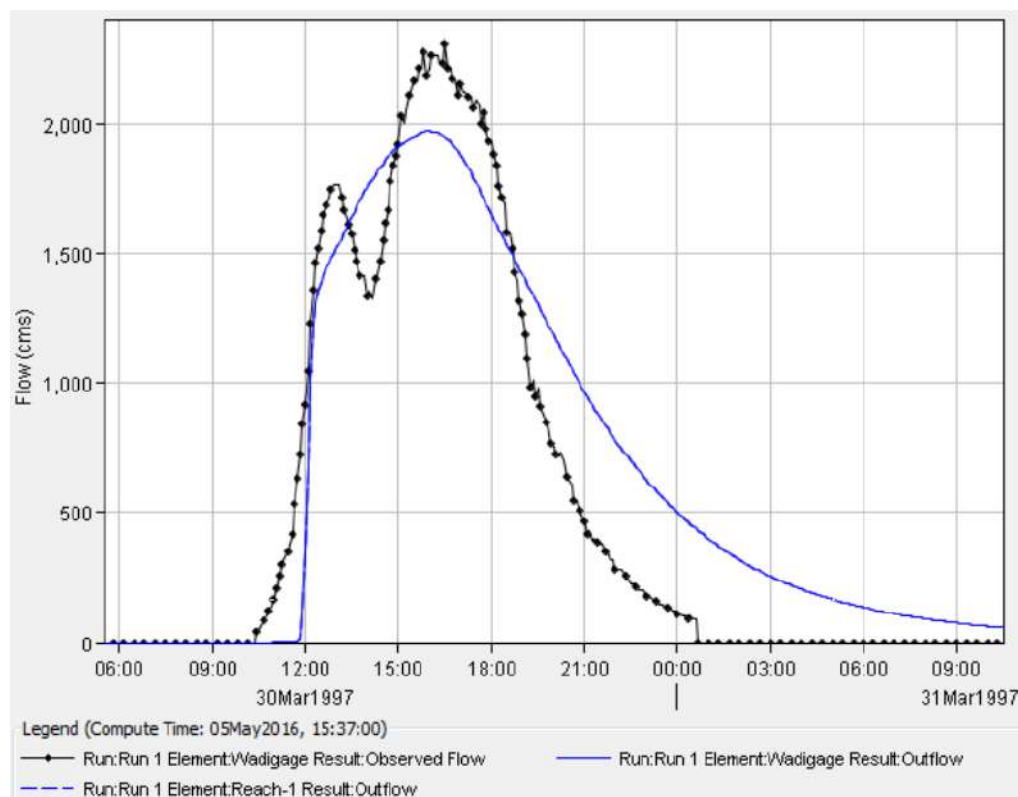


Fig. 5. Streamflow hydrograph from Snyder UH method with Green-Ampt for infiltration (Event 3)

An empirical relationship between the rainfall and runoff volumes was also derived as shown in Eq. (1):

$$\text{Runoff} = 3.4027 \exp(0.0412 \times \text{Rainfall depth}) \quad (1)$$

Where Runoff is in million m³/s and Rainfall depth is in mm.

The relationship between storage volume and water level in the reservoir of Wadi Dayqah Dam was developed using the collected water level and volume data from MRMWR (Eq. 2). The validity of the relationship depends on the accuracy of the field measurements of water level and the contour map of the reservoir area.

$$\Delta = 0.0374h^2 - 9.0958h + 556.02 \quad (2)$$

Where Δ is the water storage volume in million m³ and h is the water level in meters.

Table 2. Calibrated model parameters and summary of results.

Parameter	Event-1	Event-2	Event-3
<i>SCS Unit Hydrograph Transform Method</i>			
Imperviousness (%)	22.4	22.4	22.4
Lag time (min)	315	370	285
Nash	0.44	0.86	0.43
RMSE	0.46	0.33	0.55
<i>Snyder Unit Hydrograph Transform Method</i>			
Imperviousness (%)	20.0	22.4	52.0
Nash	0.23	0.91	0.88
RMSE	0.53	0.27	0.25
Number of outlets (No.)	11		
Outlet diameters (m)	1.00 to 1.60		
<i>Unit Hydrograph Transform Method with Φ index</i>			
Nash	0.87	0.79	0.80

Equation (1) was validated using two rainfall events (Nov. 2 and Nov. 9, 2011) for which the water surface elevation in the Wadi Dayqah reservoir was available. Using the observed water surface elevation the volume of runoff was calculated from Eq. (2). A comparison between Eq. (1) and the data from the rainfall events in 2011 is shown in Fig. 6.

An excellent agreement is found between Eq. (1) and the observed runoff volume, which shows the validity of Eq. (1). However, more observations are required to prove the validity of the equation for a wide range of rainfall depths.

Both Eq. (1) and Eq. (2) were used to develop a simple Excel sheet to determine the amount of water to be released from the reservoir before a storm to ensure the safety of the dam.

5. CONCLUSIONS

For a proper operation of the Wadi Dayqah Dam a hydrologic study is carried out using HEC-HMS model to establish a rainfall-runoff relationship. Three different methods were utilized and varying performance of the estimations was observed. Finally, an empirical relationship between rainfall depth and runoff volume was developed using the available data and validated using another set of data. This relationship along with the existing empirical relationship between the water surface elevation in the reservoir and the volume of water in the reservoir, will be used to release an appropriate amount of water to make room for incoming stormwater. The biggest challenge is the availability of recent data on hydrologic parameters. More data is required to validate the methods proposed in this study.

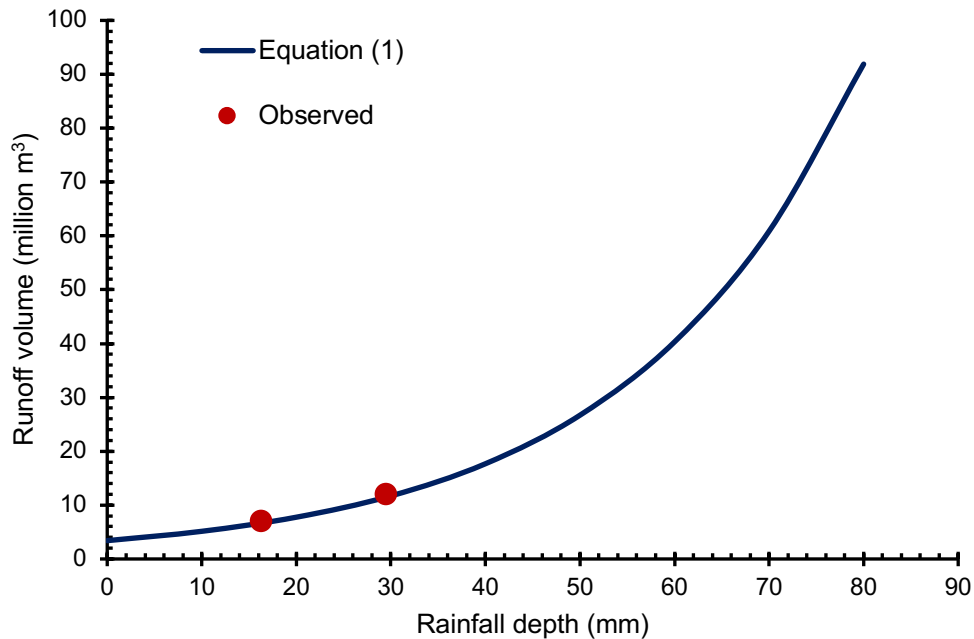


Fig. 6. Empirical Rainfall-Runoff relationship (Eq. 1)

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Wireless Computing in all Area: A Mathematical Approach

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Abstract: Use of wireless interface is one of the milestones of new-generation communication systems, which has an extensive sphere of application in such areas as IoT, mobile devices and for sensors. The research paper under consideration is aimed at investigating wireless computing from the perspective of mathematics and some of the aspects to be discussed are signal propagation, wireless channel characterization, system capacity and error control. We study the basic wireless communication and extrapolate mathematical models/theories and equations for analyzing the nature of the wireless systems, use in networking, and optimization. Wireless computing is one of the most valuable components of the communication in the present world where data transmission can be carried out among various networks without any physical linkages. Wireless computing systems are systems, which involve part of signal processing, part of network optimization and part of information theory; they are the systems that are based on the parameters of ideal systems. In this case, we talk on mathematical models used in the wireless communication channels. propagation models, path loss equations and interference management. Additionally, the paper emphasizes some of the main problems with the usage of graph theory, hints to the queuing theory to structure using adequate algorithm with the overall purpose of improving organizing the network assets as a way of scaling up the wireless networks. This theory goes into detail on most of the advanced concepts like the error correcting codes, modulation schemes and cryptography aspects required in secure communication in wireless computing environment. Therefore, this research aims at establishing a mathematical technique in design, analysis and optimization of wireless systems that we hope that it can be useful in shaping next generation wireless technologies such as 5G and IoT.

Keywords: Wireless Computing, Wireless Communication, Signal Propagation, Network Capacity, Error Correction, Mathematical Modeling

1. INTRODUCTION

Wireless computing refers to the ability to connect devices and exchange information over a wireless medium. the objective of wireless computing is based on the principles of electromagnetic waves communication, channel modeling and network optimization. Key aspects of wireless, such as signal transmission and data packet manipulation, require mathematical models for their prediction. Pertaining to the theoretical foundation of wireless communication in the context of wireless computing and including mathematical supporting forms this paper is also focused. Wireless computing has advanced into a standard element of present-day correspondence structures, merging billions of instruments and empowering an extraordinary trade of data without the demand to link physically. From basic communication through the mobile phones, wireless networks cover smart cities to the IoT making distant devices communicate seamlessly thus changing our everyday life. However, beneath this omnipresent technology is a network of mathematical formula that traditional wireless systems, whose deployment is pivotal to control efficiency, reliability and security in wireless communication [1-4].

This paper, Wireless Computing: Wireless Computing: A Mathematical Approach wants to address the issue of identifying the mathematical structures upon which this field is based upon. Wireless communication is fundamentally the exchange of signals across a medium, which in most cases is the air, a medium that poses definite issues such as signal fade, interference and noise. Such challenges are effectively handled through mathematical models, which assists engineers and scientists deploy better wireless performances. Elements of the physical approach to this mathematical problem include signal processing, network optimization, information

theory, and error correction. Wireless technologies are continuously evolving and with the emergence of 5G and continuous development of IoT that requires more complex and efficient solutions to network, it becomes apparent that new and more advanced mathematical tools are needed. The theory that underlies different areas of networks will be analyzed in this paper including propagation models, queuing theory, graph theory, and optimization algorithms to explain how all these theories can be implemented in order to increase the efficiency, security and scalability of a network. In addition, we will talk about how these mathematical concepts are useful in the modern world problem solving including bandwidth assignment, use of resources in wireless networks, as well as guaranteeing secure communication. By providing a mathematical perspective on wireless computing, this research aims to contribute to the continued advancement of wireless technology, helping pave the way for future innovations in areas like smart grids, autonomous vehicles, and pervasive computing [5].

2. SIGNAL PROPAGATION AND PATH LOSS MODELS

Signal propagation in wireless computing is described by electromagnetic wave propagation over free space. Received signal power is a function of the transmitted power, the distance between the transmitter and receiver, and the physical environment. Most commonly used model to describe signal attenuation is the **Free Space Path Loss (FSPL)** model [6] with program sample shown in Fig. 1 below.

2.1 Free Space Path Loss (FSPL)

The FSPL formula is given by:

$$FSPL(d,f) = \left(\frac{4\pi d f}{c} \right)^2$$

where:

- d = distance between transmitter and receiver (in meters),
- f = signal frequency (in Hz),
- c = speed of light (approximately $3 \times 10^8 \text{ m/s}$).

This formula represents the ratio of transmitted to received signal power in a free space environment. To express the FSPL in decibels (dB), the equation becomes:

$$FSPL_{dB}(d,f) = 20 \log_{10}(d) + 20 \log_{10}(f) - 147.55$$

This relationship is essential for determining how much power will be lost as a wireless signal propagates over distance.

FSPL Formula:

$$FSPL_{dB}(d,f) = 20 \log_{10}(d) + 20 \log_{10}(f) + 20 \log_{10} \left(\frac{4\pi}{c} \right)$$

Where:

- d is the distance (in meters).
- f is the frequency (in Hz).
- c is the speed of light ($3 \times 10^8 \text{ m/s}$).

Python Code:

```

[1]: import math

def fspl(distance, frequency):
    # Speed of light in m/s
    c = 3 * 10**8

    # Calculate FSPL in dB
    fspl_db = 20 * math.log10(distance) + 20 * math.log10(frequency) + 20 * math.log10(4 * math.pi / c)

    return fspl_db

# Example usage: Instead of Input(), set values directly
distance = 100 # Example distance in meters
frequency = 2.4 * 10**9 # Example frequency in Hz (e.g., 2.4 GHz for WiFi)

fspl_value = fspl(distance, frequency)
print(f"Dr. Arun Kumar Singh--Free Space Path Loss: {fspl_value:.2f} dB")

Dr. Arun Kumar Singh--Free Space Path Loss: 80.05 dB

```

Fig. 1 Python Code for Free Space Path Loss (FSPL)

Explanation:

- **Inputs:** The user enters the distance (in meters) and frequency (in Hz).
- **FSPL Calculation:** The program computes FSPL using the formula.
- **Output:** The result is shown in decibels (dB).

This program helps determine the signal loss in wireless communication, which is crucial for network design and optimization [7].

3. CHANNEL MODELING

Communication through wireless is done on a physical medium, known as channel. Some of the factors which have an impact on the behavior of this channel are some noises, interference and fading. One of those commonly used models for wireless channels is Additive White Gaussian Noise (AWGN) channel with sample program shown in Fig. 2 below.

3.1 AWGN Channel

In an AWGN channel, the received signal $y(t)$ is modeled as:

$$y(t) = x(t) + n(t)$$

where:

- $x(t)$ = transmitted signal,
- $n(t)$ = noise, which is modeled as Gaussian noise with a mean of zero and variance N_0 .

The power of the transmitted signal is often compared to the noise power to determine the signal-to-noise ratio (SNR), which is defined as:

$$SNR = \frac{P_s}{N_0}$$

where P_s represents the signal power and N_0 is the noise power spectral density. This relationship governs how much interference or noise affects the quality of wireless communication.

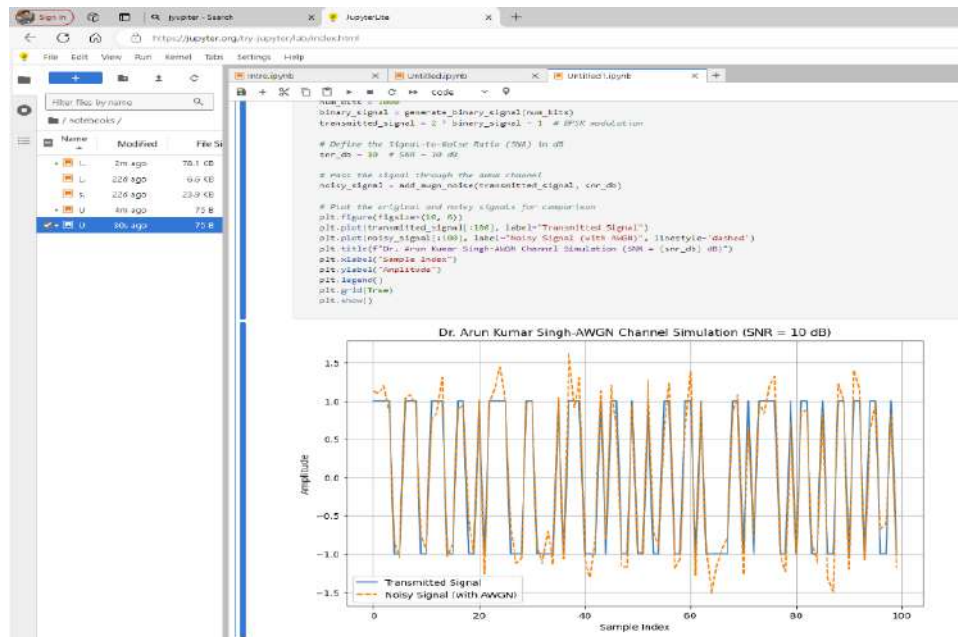


Fig. 2 AWGN Channel

Explanation:

1. **Signal Generation:** We generate a random binary signal of 0s and 1s. This signal is then modulated using Binary Phase Shift Keying (BPSK), where 1 maps to +1 and 0 maps to -1.
2. **AWGN Noise Addition:**
 - o The signal is passed through the `add_awgn_noise()` function, which adds Gaussian noise based on the given Signal-to-Noise Ratio (SNR).
 - o The SNR is defined in dB, and we calculate the noise power relative to the signal power using the given SNR.
3. **Plotting:** We plot the first 100 samples of both the transmitted and noisy signals to visualize the effect of the AWGN.

Parameters:

- **SNR (dB):** Determines the amount of noise added to the signal. Higher SNR means less noise.
- **Signal Length:** You can adjust `num_bits` to simulate longer signals.

This program helps simulate and visualize the effect of an AWGN channel on a simple communication signal. You can experiment by changing the `snr_db` value to see how different noise levels affect the signal quality [8].

3.2 Rayleigh Fading

Rayleigh fading occurs when the wireless signal undergoes multiple reflections before reaching the receiver. The signal is modeled as a random variable with a Rayleigh distribution:

$$p(r)=r\sigma^2e^{-r^2/2\sigma^2}, r \geq 0 \quad p(r) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}}, \quad r \geq 0 \quad p(r) = \sigma^2 r e^{-2\sigma^2 r}, r \geq 0$$

where:

- r = magnitude of the received signal,
- σ^2 = variance.

Rayleigh fading is particularly important in urban environments, where signals encounter many obstacles.

Python Program to Simulate Rayleigh Fading

Below in Fig. 3 is a Python program that simulates Rayleigh fading and visualizes the results using Matplotlib. This program generates a random Rayleigh fading channel and displays the fading envelope over time

Python Code:

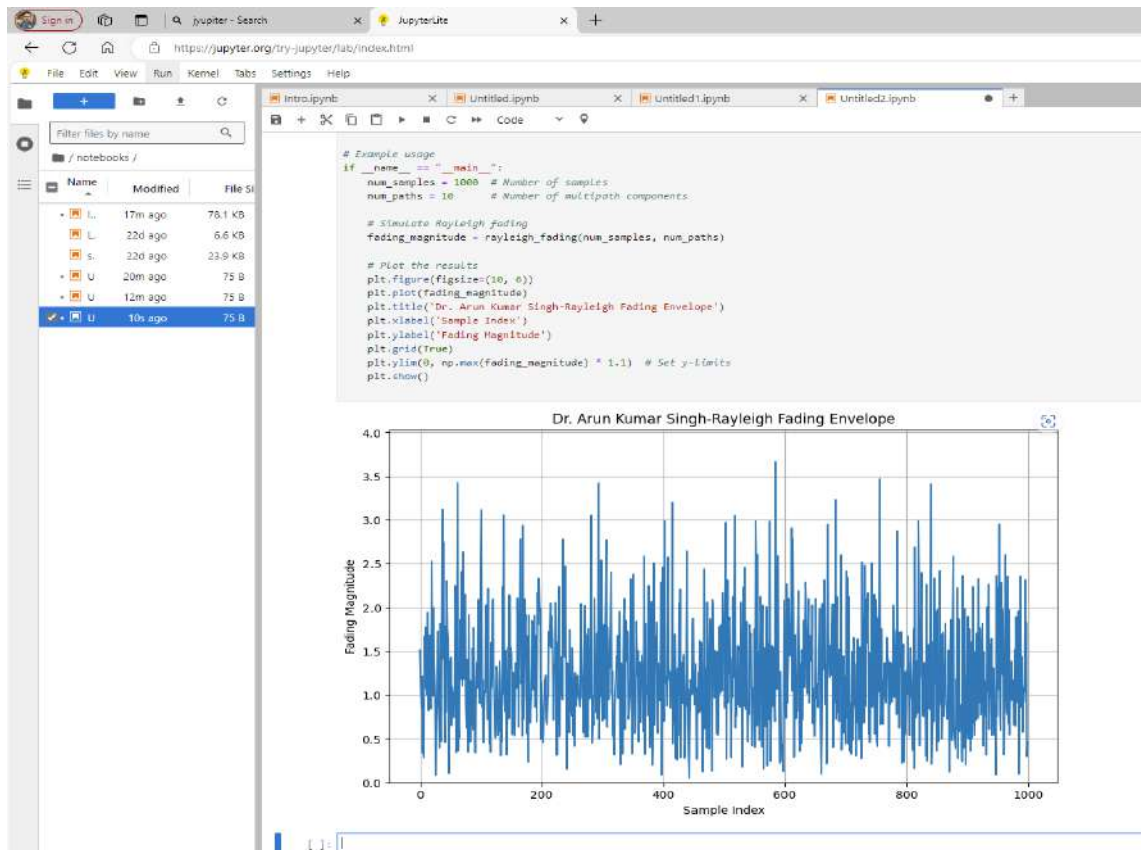


Fig. 3 Python Program to Simulate Rayleigh Fading

Explanation:

1. Function `rayleigh_fading(num_samples, num_paths)`:

○ Input Parameters:

- `num_samples`: Number of samples to generate.
- `num_paths`: Number of multipath components contributing to the fading.

○ Process:

- For each multipath component, the program generates random Gaussian samples representing the contribution of each path.
- A random phase for each path is generated to simulate the time-varying nature of the fading.
- The contributions from all paths are summed to obtain the total fading sample.
- The magnitude (envelope) of the resulting complex signal is calculated and normalized by the square root of the number of paths.

2. Visualization:

- The resulting fading magnitude is plotted using Matplotlib, showing how the signal strength varies over time due to Rayleigh fading.

4. NETWORK CAPACITY AND SHANNON'S THEOREM

The upper bound to the rate at which information can be reliably carried by a wireless channel is then described by Shannon's Capacity Theorem which describes the capacity of the communication channel in consideration of bandwidth and SNR [9].

4.1 Shannon's Capacity Theorem

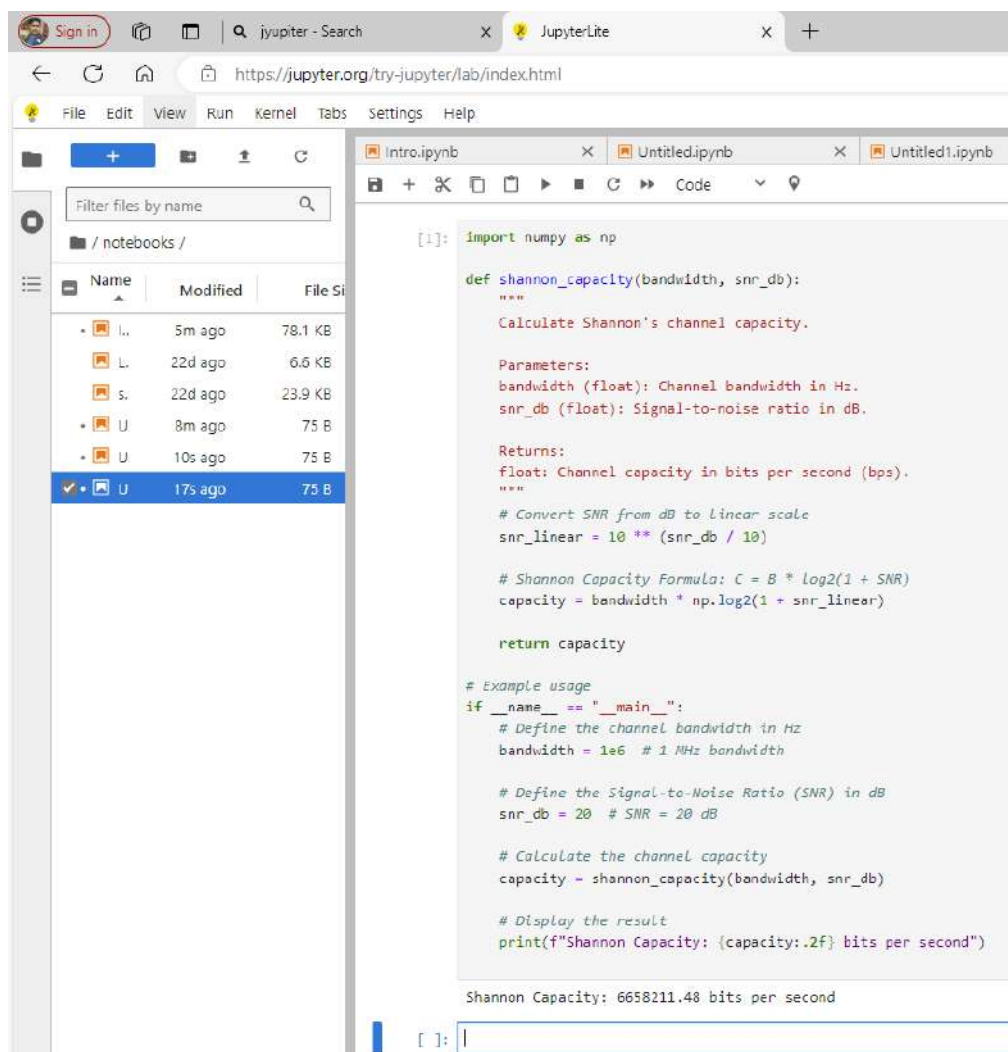
The capacity CCC of a wireless channel is defined as:

$$C = B \log_2(1 + \frac{P}{N_0 B})$$

where:

- CCC = channel capacity (in bits per second),
- BBB = bandwidth (in Hz),
- PPP = signal power (in watts),
- N_0 = noise power spectral density (in watts/Hz).

This equation indicates that the capacity increases with bandwidth and signal power, but is limited by noise and interference. Shannon's theorem is fundamental in wireless computing, as it sets a theoretical limit on data transmission rates. The sample Python Code program for Network Capacity and Shannon's Theorem is shown in Fig. 4 below.



```
[1]: import numpy as np

def shannon_capacity(bandwidth, snr_db):
    """
    Calculate Shannon's channel capacity.

    Parameters:
    bandwidth (float): Channel bandwidth in Hz.
    snr_db (float): Signal-to-noise ratio in dB.

    Returns:
    float: Channel capacity in bits per second (bps).
    """
    # Convert SNR from dB to linear scale
    snr_linear = 10 ** (snr_db / 10)

    # Shannon Capacity Formula: C = B * log2(1 + SNR)
    capacity = bandwidth * np.log2(1 + snr_linear)

    return capacity

# Example usage
if __name__ == "__main__":
    # Define the channel bandwidth in Hz
    bandwidth = 1e6 # 1 MHz bandwidth

    # Define the Signal-to-Noise Ratio (SNR) in dB
    snr_db = 20 # SNR = 20 dB

    # Calculate the channel capacity
    capacity = shannon_capacity(bandwidth, snr_db)

    # Display the result
    print(f"Shannon Capacity: {capacity:.2f} bits per second")

Shannon Capacity: 6658211.48 bits per second
```

Fig. 4 Network Capacity and Shannon's Theorem-Python Code

Explanation:

1. **SNR in dB to Linear Conversion:** Since the SNR is usually given in decibels (dB), the program first converts it to a linear scale using the formula:

$$\text{SNR}_{\text{linear}} = 10(\text{SNR}_{\text{dB}}/10) \quad \text{SNR}_{\text{linear}} = 10^{\left(\frac{\text{SNR}_{\text{dB}}}{10}\right)}$$

2. **Shannon's Capacity Formula:** The capacity is then computed using the formula $C = B \cdot \log_2(1 + \text{SNR}_{\text{linear}})$, where B is the channel bandwidth in Hz, and $\text{SNR}_{\text{linear}}$ is the linear signal-to-noise ratio.

5. ERROR CORRECTION AND CHANNEL CODING

Wireless communication is susceptible to errors due to noise, interference, and fading. Error correction techniques are essential to ensure reliable data transmission. One of the most commonly used error correction schemes is the **Hamming Code**, which detects and corrects bit errors in data transmission [10].

5.1 Hamming Code

The Hamming Code is a type of linear block code used for error detection and correction. The minimum Hamming distance between valid codewords is 3, which allows for the correction of single-bit errors. The codeword length n and the message length k are related by the equation:

$$n = 2^r - 1 \quad k = n - r$$

where r is the number of redundant bits required for error detection and correction.

The Hamming distance between two binary strings a and b of equal length is defined as:

$$d(a, b) = \sum_{i=1}^n (a_i \oplus b_i) \quad d(a, b) = \sum_{i=1}^n \left(a_i \oplus b_i \right)$$

where $\oplus$ represents the XOR operation.

Hamming Code Generation (7,4) Example:

For this example, we'll generate the Hamming code (7,4), where:

- 4 bits of data are encoded into 7 bits by adding 3 parity bits.
- The additional parity bits help in error detection and correction.

Steps:

1. Take 4 data bits as input.
2. Calculate the positions of the 3 parity bits.
3. Encode the data with the calculated parity bits.
4. Simulate an error by flipping one bit and detect and correct the error.

Fig. 5 shown below is a sample Python program for **Hamming Code (7,4)**:

```

return encoded

def detect_and_correct(encoded):
    # Calculate the syndrome bits
    s1 = encoded[0] ^ encoded[2] ^ encoded[4] ^ encoded[6]
    s2 = encoded[1] ^ encoded[2] ^ encoded[5] ^ encoded[6]
    s3 = encoded[3] ^ encoded[4] ^ encoded[5] ^ encoded[6]

    # Combine the syndrome bits to get the error position
    error_position = (s3 << 2) + (s2 << 1) + s1

    if error_position == 0:
        print("No error detected.")
    else:
        print(f"Error detected at position: {error_position}")
        # Correct the error (flip the bit at the error position)
        encoded[error_position - 1] ^= 1
        print("Corrected code:", encoded)

def hamming_code(data):
    # Step 1: Encode the data using Hamming (7,4) code
    encoded = calculate_parity_bits(data)
    print("Encoded data:", encoded)

    # Step 2: Simulate a single-bit error (flipping one bit)
    error_position = 3 # Example: Flip the bit at position 3 (index 2)
    print(f"\nIntroducing error at position {error_position}")
    encoded[error_position - 1] ^= 1
    print("Encoded data with error:", encoded)

    # Step 3: Detect and correct the error
    detect_and_correct(encoded)

# Example usage:
if __name__ == "__main__":
    data = "1011" # 4-bit data
    print(f"Original data: {data}")
    hamming_code(data)

Original data: 1011
Encoded data: [0, 1, 1, 0, 0, 1, 1]

Introducing error at position 3
Encoded data with error: [0, 1, 0, 0, 0, 1, 1]
Error detected at position: 3
Corrected code: [0, 1, 1, 0, 0, 1, 1]

```

Fig. 5 Python Program for Hamming Code

Explanation:

1. Encoding Data:

- The function calculate_parity_bits() takes 4 bits of data as input and calculates the parity bits.
- The positions of the parity bits are calculated as follows:
 - $p1 = d1 \oplus d2 \oplus d4$ $p1 = d1 \oplus d2 \oplus d4$
 - $p2 = d1 \oplus d3 \oplus d4$ $p2 = d1 \oplus d3 \oplus d4$
 - $p3 = d2 \oplus d3 \oplus d4$ $p3 = d2 \oplus d3 \oplus d4$

2. Simulating an Error:

- In the hamming_code() function, we simulate a single-bit error by flipping a bit (position 3, in this example).

6. OPTIMIZATION OF WIRELESS NETWORKS

Network optimization is critical in wireless computing for efficient resource allocation and improved quality of service [11-19]. One mathematical technique widely used for optimization is **Linear Programming (LP)**.

6.1 Linear Programming (LP) for Wireless Network Optimization

In wireless networks, resource allocation problems (such as power distribution, bandwidth allocation) can often be modeled as LP problems. A typical LP problem for power allocation can be formulated as follows:

$$\begin{aligned}
 &\text{Minimize: } f(x) = \sum_{i=1}^n P_i \\
 &\text{Subject to: } C_i = B \log_2(1 + P_i N_0 B_i) \geq R_i \quad \forall i
 \end{aligned}$$

where:

- P_{iP} = power allocated to user i ,
- B_{iB} = bandwidth allocated to user i ,
- R_{iR} = minimum required data rate for user i ,
- N_0 = noise spectral density.

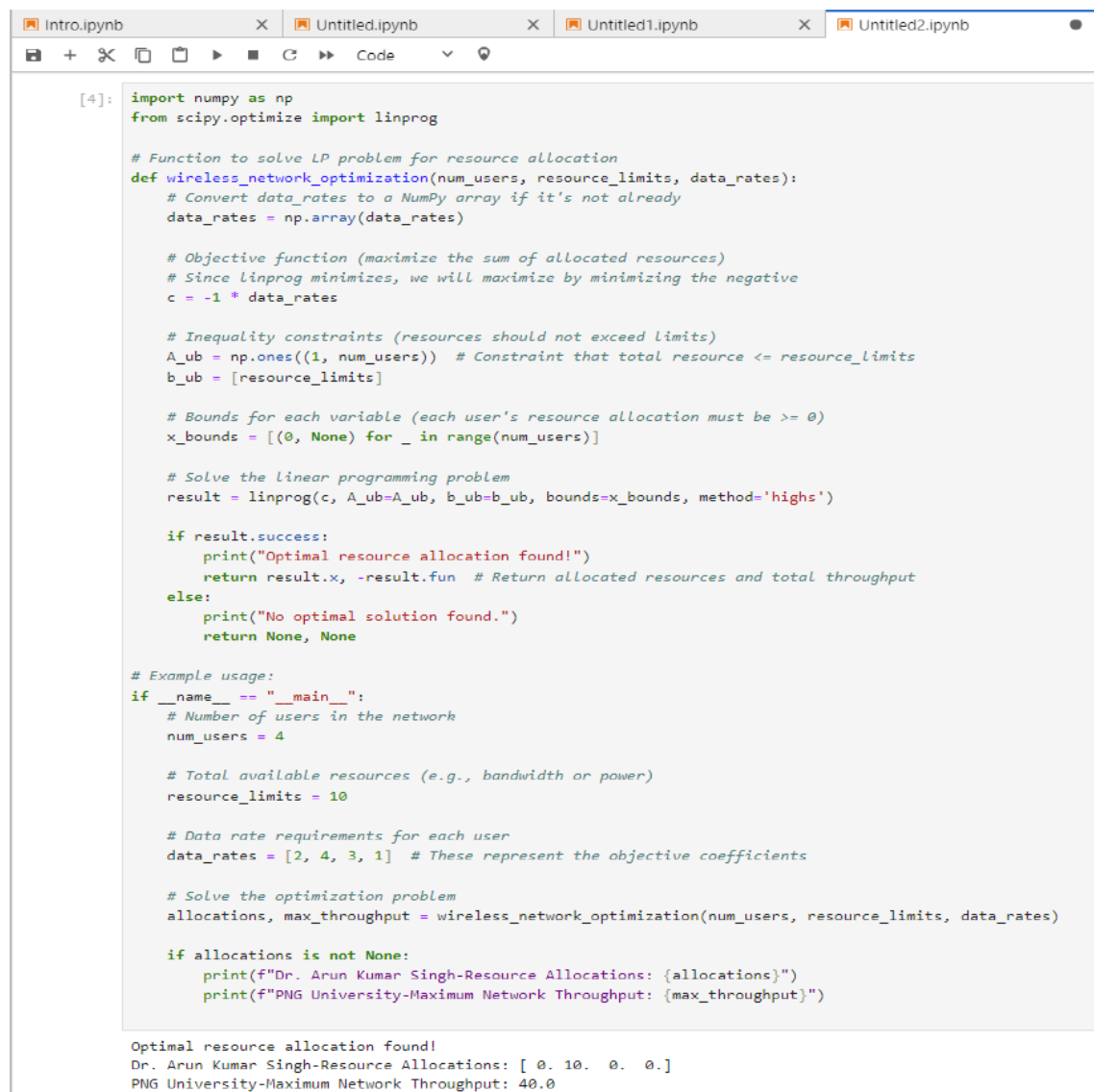
This formulation ensures that power is allocated in such a way as to minimize total power consumption while meeting the users' data rate requirements.

Fig. 6 shown below is a sample Python program that uses LP for **resource allocation in a wireless network**, where the objective is to maximize the total network throughput.

Problem:

- There are multiple wireless users, each with a required data rate.
- The network has a limited number of resources (e.g., bandwidth or power), and the goal is to allocate resources to maximize the total throughput.
- We want to solve the problem using Linear Programming.

Python Program for Linear Programming (using SciPy):



```
[4]: import numpy as np
from scipy.optimize import linprog

# Function to solve LP problem for resource allocation
def wireless_network_optimization(num_users, resource_limits, data_rates):
    # Convert data_rates to a NumPy array if it's not already
    data_rates = np.array(data_rates)

    # Objective function (maximize the sum of allocated resources)
    # Since linprog minimizes, we will maximize by minimizing the negative
    c = -1 * data_rates

    # Inequality constraints (resources should not exceed limits)
    A_ub = np.ones((1, num_users)) # Constraint that total resource <= resource_limits
    b_ub = [resource_limits]

    # Bounds for each variable (each user's resource allocation must be >= 0)
    x_bounds = [(0, None) for _ in range(num_users)]

    # Solve the linear programming problem
    result = linprog(c, A_ub=A_ub, b_ub=b_ub, bounds=x_bounds, method='highs')

    if result.success:
        print("Optimal resource allocation found!")
        return result.x, -result.fun # Return allocated resources and total throughput
    else:
        print("No optimal solution found.")
        return None, None

# Example usage:
if __name__ == "__main__":
    # Number of users in the network
    num_users = 4

    # Total available resources (e.g., bandwidth or power)
    resource_limits = 10

    # Data rate requirements for each user
    data_rates = [2, 4, 3, 1] # These represent the objective coefficients

    # Solve the optimization problem
    allocations, max_throughput = wireless_network_optimization(num_users, resource_limits, data_rates)

    if allocations is not None:
        print(f"Dr. Arun Kumar Singh-Resource Allocations: {allocations}")
        print(f"PNG University-Maximum Network Throughput: {max_throughput}")

Optimal resource allocation found!
Dr. Arun Kumar Singh-Resource Allocations: [ 0. 10.  0.  0.]
PNG University-Maximum Network Throughput: 40.0
```

Fig. 6 Linear Programming (LP) for Wireless Network Optimization

Explanation:

1. **Objective Function:** The objective is to maximize the total network throughput. This is represented by the sum of the allocated resources. Since SciPy's linprog minimizes the objective, we negate the data rates to turn it into a maximization problem.
2. **Inequality Constraints:** The total resources allocated to users cannot exceed the available resource limits. This is enforced through the constraint: $\sum_{i=1}^n x_i \leq \text{resource_limits}$. Here, x_i represents the resource allocated to each user.
3. **Bounds:** The allocation for each user must be non-negative (no negative resources), hence the bounds $0 \leq x_i \leq \text{resource_limits}$.
4. **Linear Programming Solver:** The linprog function from SciPy is used to solve the LP problem. The method 'highs' is a reliable solver for large-scale problems.

7. CONCLUSION

Therefore, wireless computing is a revolution of the kind of communication, computing, and transmission of information in the society. Mathematical model and mathematical approaches are very important for the effective and efficient working of wireless communication system. By applying mathematical models which include linear programming, stochastic process and statistical method, engineers and researchers are in a position to solve a number of problems that arise among wireless networks for example signal processing, resource management, error control and network optimization. The application of the above mathematical models makes it possible to have better insight into some of the issues affective wireless environment including fading, interferences, and capacity limitations. In addition, the proposal helps enforce the design of high-quality algorithms and protocols suitable for dynamic environments to provide quality services to users. As the wireless technologies are being developed further and further, demands for novel mathematical theories and techniques will grow even more, resulting in progress in the 5G network and IoT, to mention just a few domains. Last of all, the combination of mathematics and wireless computing also creates conditions for developing new communication means based on current achievements and stimulating the constant progress of digital integration in the modern world. On extending the notion of wire-less computing, mathematics will continue to form a fundamental base for wireless computing developments, for the solutions to the existing problems as well as the possibilities in future.

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User Perspective of Library Services in the 21st Century in a Tertiary Based Learning Institution

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Abstract. Academic libraries worldwide have supported their parents' institutions to achieve their mission of providing quality education services to students and teaching faculty (Mahmood et al., 2023). These libraries include traditional services such as reading materials, textbooks, study hubs, manual loan systems and reference aids. Today, the digital revolution has introduced technological services such as printing, photocopying, online databases and artificial intelligence (AI) tools as referencing guides. However, while the academic libraries in the 21st century have drastically changed from traditional manual systems to technological driven operations (Momoh & Folorunso, 2019), there are various setbacks encountered by the academic libraries of Papua New Guinea (PNG) that cannot perform likewise. Unfortunately, there is lack of studies conducted in this area of which such evidence is required to enhance the quality of academic library services in PNG. This case study was conducted to examine the user's perception of the academic library services in a developing nation in the 21st century. A qualitative case study has been done with a data collection method of focus group interview and individual semi-interview. A purposive sampling of thirty library users were selected and interviewed in three focus groups and three individual semi-structured interviews. The data collected have been recorded, transcribed and thematically analyzed. The study revealed users were equally satisfied with library facilities and dissatisfied with digital services. Participants perceptions were consistent with satisfaction of conducive library environment such as *'I'm impressed of the set-up of the library, the space is big, very peaceful and quiet', adequate resources, 'easy to locate books..., the library has a lot of computers.* The participants have evenly expressed dissatisfaction in the current trend of technological services stating *'I haven't used the online database like JSTOR..., the problem is the WiFi network, some of the materials we cannot access',* on the databases that were provided by the library. These responses indicate that users needed to be trained and guided with the technological services. The findings of this study recommend a need for more awareness and training to academic students and staff on new technological devices and systems that an academic library provides. Each user is to be trained by librarians to fully utilize technological services to enhance education and research spaces in Papua New Guinea.

Keywords: Academic libraries, service, 21st century

Presenter or Main Author Biography: Geena Iga Kuson, an educational professional and academic librarian of Pacific Adventist University, Papua New Guinea.

1. INTRODUCTION

There are 2.8 million libraries established worldwide, 2.2 million school libraries, 410 000 public libraries and 85 600 academic libraries (International Federation of Library and Association, 2023). Libraries have been established to provide relevant information and quality services to users (Adeniran, 2011).

Among these libraries are academic libraries which are usually acknowledged as significant contributors to a country's human resource development (Okiy, 2010). These specific libraries are attached to their parent institution with the primary role to support the teaching and learning programs of the university (Mahmood, 2023). A recent study done by the International Federation of library and Association (IFLA), which is the largest body

of library organizations worldwide, indicated that these libraries are integral part of the endeavors of academic institutions (INFLA, 2025).

In the recent century (21st), the role of the academic libraries has experienced significant transformations (Anmol et al., 2021). These changes have largely been driven by advancements in technology and has affected the functionality of traditional and modern academic libraries (Olubiyo, 2022). The way information is created, organized and disseminated has taken a different course (Adeniran, 2010). The higher rate of digital tools has not only introduced new tasks for university libraries but have also introduced pressing issues in the field of Library and Information Management Science (Baryshev et al., 2020). For example, storage capabilities are now shifted from flash drives to cloud storage, printed documents can be saved as electronic documents and library resources are accessible through automated cataloguing systems such as Online Public Access Catalogue (OPAC) (Emezie & Nwaohiri, 2013).

These recent practices have been a challenge for all libraries worldwide. In response to these, the Australia Library International Association (ALIA) in its recent conference has acknowledged the sustainable development goals for libraries and have appealed and challenged the libraries in Australia and the international community to push their work forward to continue to bring vibrant and relevant services to library users and their communities (ALIA, 2024). Pacific Adventist University Library has been a recipient of this stand and has embraced the challenge of bringing relevant services to its users and the communities. But the question lies in what would be the best practice to implement going forward.

Studies have been conducted worldwide to identify the best practices, but the focus has been overly emphasized on implementing efficient library services and as a result the libraries have become self-centered rather than user centered (Mamood, 2023). Only a handful of these studies have indicated that these digital services are only useful when the users have utilized these services and think otherwise that they are relevant. This will satisfy the ever-changing needs of its users (Ayiah & Tamakloe, 2023). This indicates that the users perception is considered the best approach to assessing effective library services as they are the only judges.

The lack of information on users' perception of academic library services is rare and unfortunate in the Pacific because it is the sort of evidence required to determine the relevance of services in the 21st Century in any such educational institutions of the Pacific and especially, Papua New Guinea (PNG).

The gross enrolment ratio (GER) for tertiary education in East Asia and the Pacific have approximately reached 51% in the year 2020, this is an increase from 16% in 2000 (UNESCO, 2025). This indicates that there is more engagement in academic activities in the Pacific. However, Hinder (2011) strongly stated that there are more Pacific students participating in tertiary education but there is little research on their information behavior in academic libraries engaged within their capacity.

The library of Pacific Adventist University in PNG has been serving the students, lecturers and staff with academic requirements for the past forty years of establishment. The library users are a composition of the Pacific Island nations and whilst the library has seen growth in its infrastructure, collections and systems over the years, it has equally stived to keep up with the current trend of adopting digital tools to meet user's satisfaction.

This study aims to provide a valuable contribution to the lack of literature in this topic and provide user – centered approaches to academic libraries of PAU, PNG and perhaps the Pacific island nations.

The objectives of these studies are as follows:

- i. To assess the user's perception of library services;
- ii. To identify users' challenges with library services and;
- iii. To provide recommendations to enhance the university library services.

A qualitative case study method was best suited for this research using the phenomenal approach of Braun and Clark (2017) as similar studies have been conducted. This study is grounded on the theoretical framework of LibQual + Model which has been developed by the Association of Research Libraries (Cook et al 2010). A purposive sampling method (Bryman, 2016) was adopted for this study with a group interview of three (3) and three (3) individual interviews. The data was analyzed thematically with inductive coding and theme identification patterns.

This paper will further discuss the following sections: literature review, methodology, findings, discussions and conclusion derived from the findings, and implications and challenges from the study.

2. LITERATURE REVIEW

Academic libraries in the 21st century have changed from traditional manual systems to modern technology-driven operations, integrating digital resources. These libraries now provide a wide range of user-friendly services where information can be accessed remotely (Momoh & Folorunso, 2019).

Many studies have focused on the role of academic libraries and the rapid development encountered while few researchers have considered viewing the relevance of the academic libraries from a user's perspective (Mamood, 2023). The development of digital aids could be a benefit as well a challenge to academic users (Hinder, 2011). Global literature has revealed that users have considered the library as a convenient study hub and have accessed needed information with the aid of a librarian. Few studies have indicated the underutilized of the digital aids (Mushtaq & Arshad, 2022) thus Mamood (2023) strongly argued that seeking users' view and identifying their information behavior will very much benefit a library's course in the 21st century. The academic library of PAU determines to implement the echoed sentiment to identify user's perceptions, challenges and recommendations for improved services.

This study will employ LibQUAL+ model to assess users' perception in university libraries, with a specific focus on the three dimensions. The dimensions provide a structured basis for identifying service strengths and challenges from the user's perspective, that can provide recommendations for library improvement.

2.1 Theoretical Framework: LibQUAL + Model

LibQUAL is a conceptual framework grounded on the theoretical framework of SERVQUAL Model adapted especially for library environments (Cook et al 2010). LibQUAL measures users' perception of library service quality along three dimensions; Effect of service, library as a place and information control. This conceptual framework selected for this study reflects the purpose of this paper – to explore the perception of Pacific users and identify challenges and recommendations. Developed by the Association of Research Libraries in 2000, this theory assists library organizations to assess library services with a focus on the user's point of view. The users can best assess the services from their experience (Mahmood, 2023). This approach is suitable to academic libraries in Papua New Guinea and other developing Pacific nations.

Libraries worldwide have used this framework of LibQUAL tool that has given significant results. A public university in Indonesia (UINSU Medan) has found users to have access to library resources however, the information and communication needs were unmet (Sayekti et al. 2022). A study conducted in Yogyakarta revealed that library staff were polite and have met users' expectations however there was a significant gap of +0.58 and a superior gap of -0.10 (Saufa, 2023). The same study has indicated users to have utilized resources with an adequate gap of +0.53 and a – 0.44 superiority. Under the dimension 'library as a place', the data indicated good and clean space, meeting students' but improvements could be more. Zulfiqar and Khalid (2024) in their study in Southern Punjab University Libraries revealed the service quality of the libraries have met library standards but less gaps existed for information control and library as a place which are highlighted as future improvements. Manjunatha & Shivalingaiah (2004), evaluated customer's perception of service quality in Libraries. A quantitative study was carried out with the collection and analysis of numerical data from a large sample of 1252 respondents. The instrument of SERVQUAL model for data collection through self-administered questionnaires along with statistical analyses such as ANOVA and T- tests were conducted to assess differences in service quality perceptions among various customer groups. The findings showed that customer services provided by the librarians were quality however there is a need for improvement in service delivery.

The literature reviewed has outlined and discussed the perception of users of library services The digital revolution of the libraries has posed challenges for academic libraries while introducing technological advancements and developments. There are present challenges that each academic libraries have identified through research and have worked on to minimise the issues. Most of the literature in this review have conducted a quantitative study to understand the perception of various users in various library organizations. Many of the findings have revealed that library services, inclusive of digital tools and systems provided, however, were underutilized and require consistent awareness and training.

The user centered approach is one that each academic library in these literatures have preferred to identify and measure the quality-of-service delivery and satisfaction of each academic library service. However, it is identified that there is certain inconsistency with the user's perception. Despite the quality service each academic library has used; the users have not fully utilized those services which is unfair feedback to each study. The library spaces are only used for personal preference as the services remain inactive. These literatures have lacked qualitative studies and mixed methods to analyze the perception of each user.

Most of these studies have been conducted worldwide. There is lack of information of similar studies in the Pacific (Hinder, 2011) and Papua New Guinea. It is significant to address these current gaps of library service for any academic and public libraries in the Pacific and the country. In focus of this study there is a need to find strategies to maintain relevant and updated library services for students and teaching staff in spite of technological advancements in PAU. This research will examine the factors that hinders the full use of library services among the users and provide relevant strategies to enhance learning in the university.

3. METHODOLOGY

This chapter outlines the research methodology applied in this study which includes information on the research design, method, data collection, sample, data analysis, study limitations and ethical considerations.

3.1 Research Design

This study has employed a qualitative study collecting primary data from individual interviews and focus group to gather insights into user perspectives on academic library services. The qualitative case study method was selected as it involved the analysis of the phenomena which is possible to derive knowledge of a wider phenomenon from a specific case study (Gorman and Clayton, 2025).

Interview and focus group investigation allows the users to express their views in their own words. The interview and focus group technique (Slovák et al., 2023) is widely used to collect data from the target population. This technique has widely proven effective research techniques to the research platforms. This technique will allow face-to-face discussion, individual perceptions, verbal conversation, group interactions and active listening to acquire important information. In the interview and focus group method, all participants view are respected. (Vogi et al., 2023).

According to Lambert & Loiselle (2008), the integration of focus group and individual interview data makes three main contributions. Firstly, it creates a useful back-and-forth process, where an early model of the phenomenon helps explore individual experiences, and those experiences help improve the understanding of the phenomenon.

Secondly, it identifies the personal and situational factors around the phenomenon, which helps explain how it works. And thirdly, it shows agreement on the key features of the phenomenon. This results in central themes which emerge across the responses which enhanced trustworthiness of findings.

The LibQUAL project for instance, conducted interviews with users of research libraries across North America to gather insights into their perceptions of quality library services. These interviews were part of the initial phase of the LibQUAL initiative, which aimed to develop a standardized tool for assessing library service quality from the user's perspective.

The data collected was through individual interviews and focus groups which allowed users to express their views openly and honestly. This method also encouraged room for personal views to be expressed without fear or favor where views are not dictated by others. An interview guided questions were provided and made available beforehand. Karatsareas, (2022) explains that this method of interview includes predetermined open-ended questions but allows the interviewer to explore new topics that emerge during the conversation. It balances structure with conversational freedom, enabling in-depth exploration of the participant's experiences, opinions, and perspectives. According to Rabiee, (2004), a focus group is a technique that involves the use of in-depth group interviews in which participants are selected through purposive sampling of a specific population to focus on a topic.

3.2 Sample

This recruitment of this study has taken several approaches. Firstly, an invitation was sent to specific student who have met the study criteria. The recruitment and sampling of this study is best known as purposive as the team gathered information from participants who are firsthand users of the library services in Pacific Adventist University.

The Inclusion criteria included participants of more than three years with experience of the PAU Library services or have experienced the PAU Library service environment as a researcher and a current student and or faculty studying abroad. The exclusion criteria included anyone who is not a library user at PAU and who is not a PAU student, faculty, and Alumni with less than three years. A verbal and written consent was sent to each participant and printed. Printed consent was distributed to each participant in a focused group. The participant who wished to withdraw at any time during the study were advised to do so during the study and sign off in the consent form. The research team screened all participants from the initial stage.

The following is the group of participants employed for this study.

- Two Undergraduate focus group (6 individuals)
- One Post graduate focus group students (2 individuals)
- Three faculty individual interview (3 individual interview)

3.3 Data Analysis

Data was analyzed thematically using reflexive inductive coding where patterns of themes have emerged and identified. Participant interviews were conducted at a convenient time at a selected time to the participants availability. A private room of the library was organized and used as a space of interview. The interview for each session lasted 25 – 40 minutes. The participants were emailed consent forms to sign before participation. Other participants were given the consent forms and advised of the ethical standards prior to the interview. The digital audio recorded verbal interactions in focus group and individual interviews which were transcribed by two members of the team. To attain an in- depth information, the interviews were transcribed verbatim. These interviews were analyzed thematically. The interview was facilitated by research personnel which allowed a neutral person presented in front of the participants for the interview sessions. This allowed participants to share their experiences and perception openly to the research topic. This gave the opportunity for every information to be shared and not held back.

3.4 Ethical Procedure

The PAU Research Committee have permitted the study to commence with guided considerations. A written consent was distributed to each participant in a focused group and individual and an audio - record was utilized to collect data. The participant who wished to withdraw was able to do so during the study and sign off in the consent form. This was made known in the participants consent forms and also addressed verbally before interviews. It was also made known that their identity will not be made known. The data was stored securely in a flash drive and the department drive with encoded password. The head librarian has filed the consent form in her office and will be disposed after three years.

4. FINDINGS

4.1 Introduction

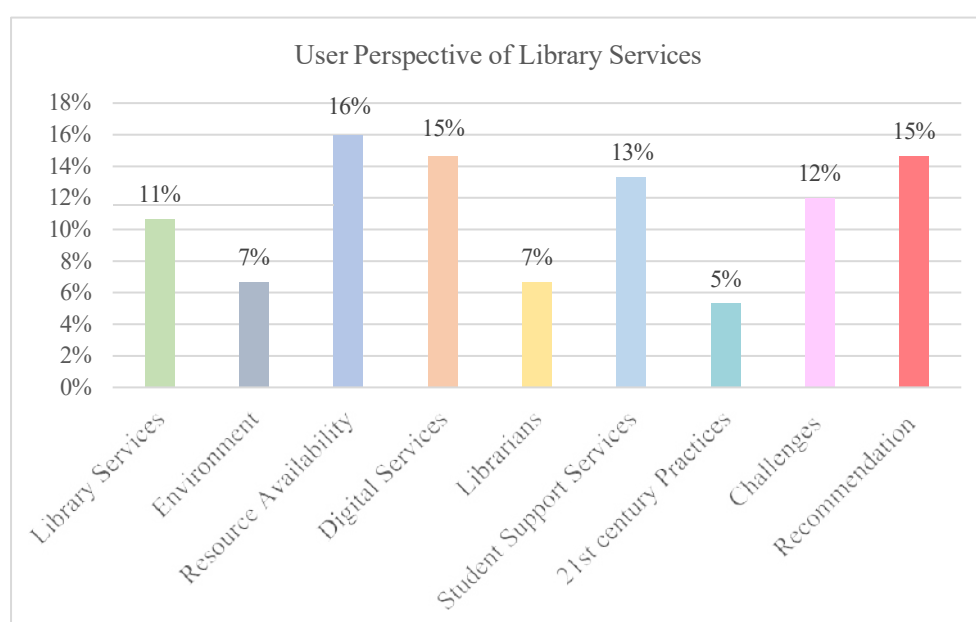
This section presents the findings done in PAU academic library in Papua New Guinea. Using the thematic approach, key themes have emerged from the research which includes library services, conducive environment, resources, digital services, student support, user challenges and recommendations. These themes have been categorized under the LibQUAL dimension and will provide further understanding and experience of user's perception of academic library services.

Table 1 highlights the context of the study which was focused on user's perception and experience of library services. First, this table shows that all users have indicated their experience on various library services for more than three years. This suggests that library users are active participants as lecturers, staff and students during the academic calendar of the university. The research records that the library services are open and accessible to all users in the campus under university credentials indicating that only students and staff members of the university are eligible users. Interestingly, the table reveals an alarming trend where resources are underutilized with the (21st century) practices by the users and the spacious building have recently become limited with study tables and chairs due to higher enrollment.

Many users have indicated the general satisfaction of the library services with space, various learning resources, conducive environment, availability of resources, and student support and have addressed challenges and possible recommendations. Fig. 1 shown below shows the responses on the library services.

Table 1. User Perception of Library Services

Variable (x)	TotalPercentage (y)	
Library Services	8	11%
Environment	5	7%
Resource Availability	12	16%
Digital Access Librarians	11	15%
Student Support Services	5	7%
21 st Century Practice	15	13%
Challenges	7	5%
User Recommendation No response	8	12%
	9	15%
	0	100%



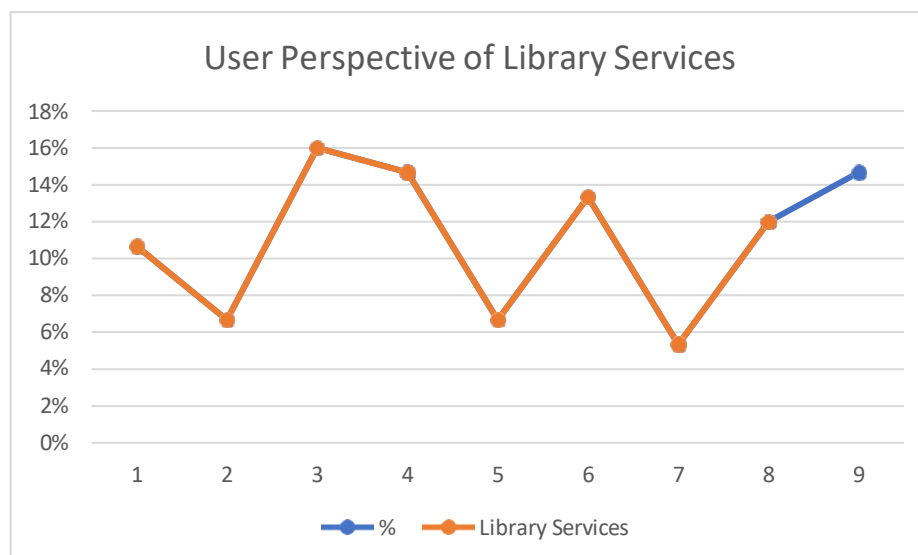


Fig. 1. Responses on the library services

4.2 Library as a Place Library Services

An interesting finding emerged when assessing the services provided by the academic library. All nine participants expressed similar views of the services provided in the library. This response is echoed in the quote from P2: *“The library is providing an excellent service in terms of database. There’s printing available; you have all these computers there, the students can utilize whenever they can, everyone is always present in the library.”* All users have shared the same sentiment which they have witnessed the impact to their academic work. Another response reflected in the quote from P7 which states *“It’s excellent, most of the books I need are here”*. This was a response from a theology student who prefers to use the library books to find answers to his assignment questions.

Students have significantly indicated the importance of the library as a place of learning packed with various resources. As reflected in the response in the quote from P6 which says, *“A library contains everything that you want to learn and get knowledge to abstract from.... For example, you can learn about business or subjects focusing on success, spiritual life, social aspect of life or anything.”* A post graduate student shares his views of an academic library from his firsthand experience with the services he consistently utilizes whilst his studies.

When asked about their views and experience about the general services of the library, few students and faculty who were alumni to the institute had a good comparison of what the service was like in the past and what it is like at present. P1 had this to say *“compared to my time here before, the services have significantly improved. I am very impressed not only with space but with books and now there’s this online data thing for the students to use, I like it, It’s nice”*. The online database has become an introduced practice to the current students where former students have not utilized to search for specific information they needed for research purposes. This was an additional service embraced by a returning student who passed out as an educator when the institution was in its college state. He has experienced the manual service of topic search in the library and have acknowledge a new development.

As a result, their view of the library service found in these institutes are ideal of an academic library in the pacific. This situation underscores the importance of better facilities and technological aid the library could have provided in a developing country in the pacific. Users as P1 have only being exposed to the present academic library and have tried to provide similar services in the school he last taught and was employed.

4.2.1 Conducive Environment

Regarding the physical environment, users have expressed positive views and evenly addressed few challenges they have faced in the library.

P1 said *“The set up is good....A quiet learning environment, you can do your private study. I come almost daily to the library.”* This user claims to be a married student who is accommodated in the campus in the student

village and has a preference to remain at home and study but very much chooses to study in the library. He further states that *“there are tables that student’s book for combine study and discussion. Now I can’t really see whether they are around here....students would want to sit down together because you don’t really have the space outside ...But I like that part in which there’s an allocation of group.”* This student has pointed out that the library atmosphere is suitable for group study as well as apart from his personal studies. Though there is a big landmass in the campus where suitable benches are available outdoors, such an atmosphere of quietness and study setting is not suitable thus the library becomes an ideal place for group study. The user additionally addresses his observation of group study tables that are not available which he reckons must be reintroduced.

Responses from students and faculty have highlighted that the library provides a conducive environment for learning and a place of collaboration between the student and the lecturer as reflected in the interview with a faculty member as stated in the quote from P2, *“I can see that we are given the opportunity to access the information and it’s an excellent way of us to work as a team where lecturers and students get the most.”* The lecturer has indicated that the library not only serves the information needed of students and faculty but also provides a platform for students and lecturers to interact with each other and utilize the opportunity.

A participant claims that the library is not only a conducive study zone but is also a healthy place to study as P6 addressed, *“The library is clean”*. Then P1 additionally said *“The restroom is provided but needs to improve as the que increase”*. The latter user shares his concern for hygiene in the area. Since the building is always clean and has a welcoming atmosphere, there are also clean restrooms provided to ease students’ health needs. Students prefer to use the toilets in the library often because of the condition of cleanliness and health standards. Therefore, this has resulted in long waiting lines.

4.3 Information Control

4.3.1 Resources

The study findings have identified the available resources which users have indicated in the library to enhance their research progress and meet their information needs and have highlighted specific resources that have benefited them. Others (4 out of 9) have addressed the challenges of each resource used which will be covered in the other category under **challenges**.

For example, P1 said *“The library is very good, very impressive not only with space but with books, and the online data... the students use, I like it, it’s nice.”* Books have been one of the main resources provided in the library. Students use a lot of books to find content applicable for academic purposes. A faculty member further states in the quote from P3 *“I don’t think our focus has been on information.... It’s been on books for a long time”*. The user has addressed his hope to provide information on various platforms apart from books that has been the main source of resources. P7 however shares the same sentiment in finding valuable resources in books who said *“Most of my research books I need are here”*.

All participants, however, have also addressed the need to gather information online using computers in the library. P6 stated that *“Computers are connected to the Wifi”*. P7 share the same views *“the computers in the library have fast internet speed so they (students) choose to use these computers”*. P4 further adds *“Most of the students here depend on computers so they rush to occupy a computer in the library.”* The findings suggest that computers provide a notable benefit to students learning. The agreement among students’ participants indicates that computers offer benefits such as research, updates journals, updated e-books and internet preferences. This proposes that the computers have effectively support students in developing necessary research skills and have provided a platform for research.

4.3.2 Digital Services

Given the existing services in the library, participants expressed the benefit of accessing resources through digital platforms. This is affirmed by a faculty member stating:

“I think PAU Library is providing an excellent service in terms of another database. What we (library) are providing is excellent services.... Theres’s printing available, you have all these computers available there, the students can utilize whenever they can...for me those databases are very excellent source of knowledge

where students should access information from like up-to-date information....”

The students have shared the same views indicating that online databases, printing machines and computers are digital services used in this space. P9 specifies which digital service is used commonly *“The most accessed (online database) is JSTORE.”* Another participant said in the quote from P8 *“I use JSTORE and ERIC quite a lot”*. The various online databases provided by the library system have met various research for students and faculty. The digital service available in the form of the library system has eased students with locating resource on the shelves as reflected by P6 *“It’s easy to locate them (books) using the online database.”*

4.4 Effect of Service

4.4.1 Librarians

The librarians play a significant role in enhancing the library services. This have been revealed by the participants as shared by P1 *“I like the way the staff address the students and ensuring that things are done right in here. Even just to bring their bags in, they remind students to take their caps off and the bags to be left there, not bringing them in and ensuring that there is this quietness they walk around. I normally see them walking around and looking at people and that seems to me they are caring. And they are professional in terms of their approach to look after the library”*. Looking beyond immediate roles and challenges, an academic participant (P4) raised a critical point about the library staff *“When I was first year, I wasn’t sure where to locate resources...who would be available to assist me, who is more open so I can ask for assistance ...I would like more library assistance and enough space for more updated resource books.”*. This suggests that the librarians are the key personnels to serve students and be aware of the individual student challenges that they may address their challenges where necessary. Library services are greatly impacted by librarians and the users greatly depend on one.

4.4.2 Student Support Service

The users have made known of the support needed and given to them during their experience of encountering library services. All the participants valued the support given to them provided by the library staff as reflected by P3 stated in the quote *“....and also the student support services, it would be nice if students make a booking with student support.”* The majority (7) of participants reported collaborating with librarians for services needed to support them in their academic progress. These connections provided a valuable support network for the users.

Other support include spiritual emphasize to enable growth in faith as reflected by P1 *“I love the 3pm prayers”*. A theology user reflected in the quote from P7 *“The prayer at 3pm is good.”*. These suggest that extracurricular activities are a means of support and wholesome growth.

Users who are students and parents also utilize the library resources for their children. The reading level of their children is enhanced when parents borrow reading books from the library to educate their children and uplift the literacy level of their children. P8 indicated *“My library card is mostly to borrow books for my children.”*

Looking beyond the challenges of providing student support, participants have also indicated the need to serve student communities such as exhibitions. One participant elaborated in seeing the Adventist community served by the library especially the heritage and archives center becomes the common place to learn of the Adventist history *“I would like to see more historical work done in our archives like not just the history of PAU but the church in PNG, the work of the church in PNG and maybe history about the Pacific. It could be a place where we bring people to learn about the history of our church”* indicated P8.

4.4.3 21st Century Learning Practices

The study findings suggest that the academic library provides technology learning aids and the agreement among students suggests that the current trend practices are available for users to utilize during their interaction with the library. P6 had this to say, *“When I was in first year, the library link was installed in my phone to search for books on the*

shelves, I use it and when I don't I ask the librarians who assist me". Records indicate that phone applications were installed in users' phones to search for items in the library. This application was user friendly and was used to ease the need to use a computer or seek support from a librarian. A user, P8 indicated the use of a reference management tool known as Zotero recommended by the library team. P8 stated in the quote " *...I use Zotero, maybe six weeks ago, the Zotero on my laptop kind of crash and I could not use it anymore. But you know things like that be updated with software like Zotero or Mandalay that can help us, and them stay on top of things so when students need help, we can give them the help they need"*. Two post graduate participants utilize the software's provided and strongly urged the librarians to stay abreast of the current trends.

4.4.4 Challenges faced by users

All parties involved – students and academics expressed concern about each library services and performance. The faculties have indicated the need to address challenges. A faculty member acknowledged this gap, stating *"I don't think we are open to change because we are doing things the same way for a long time. Maybe we want to change but we do not know how to, like I go downstairs, and I look at some of the book's downstairs, I've seen encyclopedias.... You go to a modern library; the encyclopedias are no longer published because the information is outdated. So, I see us continuing with what we know and not quite sure how to progress toward the modern academic library should be like."*

Student users echoed the same concern acknowledging the existing challenges. P6 indicated *"Most of the books for Nursing is not updated. The online library, we are aware of it, but they (librarians) need to come to each school and explain to us more about it."* P5 also addressed *"During my first year, I also faced some difficulties but then now I began to realize that the librarians need to be updated with the latest information like the textbook and reference, news and all things. They need to be updated daily so they can feed us with new information"*. Students have acknowledged notable benefits from the library services and anticipate better services.

4.4.5 Recommendation by Users

Looking beyond the immediate challenges, all users expressed views of improvement and developments. An academic participant raised a critical point: *"If I were to talk about the building, it should probably be open a bit longer late at night"*. This suggests that users value the learning atmosphere to spend longer periods into late night studying. This is supported by another academic participants who states, *"The library needs expanding"*. A student lamented, *"with the increase with enrollment, the space is limited. It is ok at night but during the day the library seems crowded so some sit on the floor"*. P5 shares, *".... Resources are available and relevant to the 21st century but because of the limited space and textbooks. P4 recommends "...extend Wifi services, customer service and be presentable (librarians) to students"*.

All users recommended valid aspects to improve library services, indicating, updated physical resources and digital services, consistent support system, controlled users, training and networking.

5. DISCUSSION

The discussion of this section is focused on library services, conducive environment, resources, digital services, librarians, student support services, 21st century learning practices, user challenges and recommendation.

5.1 Library Services

The findings from the interviewees on library services revealed an interesting perspective. First, the distribution of responses highlighted that a significant portion of respondents, totaling five, addressed their views of an academic library as a learning center. This suggests that all participants have similar views about the role of an academic library based on their current experience of their library. This is in consistent with the findings of Abubakar, (2022) who highlighted that academic libraries provide access to relevant and up-to-date research

information and provide training and support for students' learning needs through a variety of mechanisms. The findings further highlight that libraries help individuals battle poverty, deprivation, and illiteracy by providing information. Furthermore, academic libraries are often acknowledged as vital contributors to a country's human resource development. Academic libraries provide relevant information to educate a country's citizens to be informed and to stay abreast of all academic activities and provide a general worldview of the world around the users. This not only supports an academic but also an ordinary citizen who interacts with a student user.

5.2 Conducive Environment

The physical environment of the library plays a significant role in promoting very good research practices and conducive study habits. As it frequently emerged as a theme during data collection. This aligns with the findings from Monu et al., (2020) the study done in a developing country, Nigeria which highlighted the importance of libraries to provide ideal environment and vital information resources for students to develop and sustain good study habits that are necessary for outstanding academic performance. This stands consistent with the findings from Adeniran (2011) which states that a conducive environment is created for teaching and research activities; readers will be encouraged to visit and use the library resources frequently.

5.3 Resources

Resources are the main component of a library service that a user seeks to utilize. The findings highlight the main resources used by the participants which are books. Three of the users have indicated the books were outdated while the majority of users have specified the availability of online journals which are updated and useful. It is unfortunate that these online journals resources have been underutilized because students have leaned towards the internet options which give them alternate information freely and on time. However, online journals have provided academic credential content and are very appropriate to use for academic purposes. According to Upadhyay & Chakraborty (2008), the use of online journals provides a vast array of research material and publication and up to date materials.

Resources such as computers are also applicable in a library where it is used to provide information such as online journals and other relevant internet explorers. This is suitable for a developing nation where the economy is a challenge to provide various mechanisms of content delivery. Resources available in printed and non-print materials are required in a library to deliver research and educational content in different forms that can be user friendly. (Thompson, 2012) indicated that students who use computers in the library are more likely to use other library services and physical collections. This holds true to the use of computers to access databases, printing and accessing other research avenues.

5.4 Digital Services

The digital services have been an integrated practice since the revolution of technology. Despite the various mediums provided and utilized by users, the online database stands significant in this study. The libraries' consistent providence of updated materials through online databases, journals, encyclopedia and peer research reviews are significant to the user's academic work. The use of online journals provided updated work and ease the task of searching and filtering specific information (De Groote & Dorsch, 2001).

5.5 Librarians

The librarians play a vital role in the services provided. They drive the services forward and implement developments in the field of information. They are recommended to stay abreast of all information and be able to direct a user to the right content where and when necessary (Shank et al., 2011). Librarians can also be educators whilst directing users to search for specific information online or either locating a resource on bookshelves or training a user to use software's such as Zotero reference management guide.

5.6 Student Support

The intellectual well-being of a user is considered vital while utilizing the library services. The user is considered paramount and is given priority to make their experience one that is important to enhance positive mental health and wellbeing. The data collected from 6 out of 9 participants indicated most users as students. This promotes the need for student support model where various activities are conducted by the academic library to provide a wholesome learning experience (Bladek, 2021). The data collected indicated various student support service recommended; this includes spiritual emphasis, children's learning platforms, conducive environment, hygienic restrooms and community exhibitions. However, the student support model requires appropriate documentation, research and review for effective practice in developing nations.

5.7 21st Learning Practices

Since the introduction of technological developments, libraries have adapted the trend of using 21st century devices to enhance user experience (Solomon, 2024). This is revealed also in these studies where users have opted to use digital tools to enhance research and academic work.

All participants have indicated the use of digital tools including the use of Artificial Intelligence assistance. These tools include devices and systems. All student participants have had their mobile phones installed during their first year of enrollment with the library (liberty) link applications to access library collections while their laptops were installed programs by the Information communication and technology (ICT) department to access the library page via internet explorers such as chrome.

The availability of reference management software, known as Zotero, was also introduced and trained by librarians to all users. This software has been updated incorporating the latest version integrated with AI. The data reveals that only a (1 out of 9) user had this installed in the laptop which was used, however, had experienced technological problems while doing so. The challenge is for librarians to stay abreast of information and developments in the field of information so challenges encountered by users can easily be solved. (Shank et al., 2011).

5.8 Limitations of the Study

These study findings could be difficult to generalize to universities in PNG and the pacific island nations due to its focus on a single university. The study may not have captured the diverse experience of all library users and the long-term impact of the university support system on users' outcome.

6. CONCLUSION

Resources were a recurring theme throughout the study. Despite recognizing the role of academic library services from users' perception, users have highlighted the need for challenges to be addressed and have provided recommendations for each category.

While library services offer opportunities to be educated and grow with digital experiences, five out of nine have struggled to utilize the services. Nevertheless, future developments such as the 21st century practices, student support model, source of various academic resources, and informed library staff remain evident.

The university library research project is moving in the right direction by conducting relevant research studies of concerned areas and to bring about developments from the solutions recommended. Reviewing policies and procedures, training and overcoming challenges could be beneficial.

The academic library anticipates to provide a platform for a 21st century academic learning center, educational benefits, wellness center and community literacy hub for the university but a robust support model is crucial to benchmark and evaluate its performance consistently.

6.1 Implications of the Findings

The study revealed that practical research skills are necessary to be utilized during academic work at Pacific Adventist University. Additional factors like training individual students, access to resources and student support are crucial. The findings highlight the limitations of Pacific literature. The case study conducted in a developing country has economic constraints that can have significant effect on the role of users and libraries going forward.

For researchers and universities, the study provides valuable insights for designing effective library service assessment which can utilise the LibQUAL + Model to serve specific users whose second language is English. These could include business houses, financial aids, extension designs, mentorship programs, community support and infrastructure. The study emphasizes the need for collaboration and networking with universities in the Pacific and calls for consistent planning and flexibility.

While academic libraries evolve to suit the needs of the users in the 21st century, it calls for consistent assessment and support from the parents' institutions and founders. This is important for a wider impact on universities.

6.2 Potential areas for further research

It is important to conduct more research involving other universities in PNG to assess the visibility of the findings. Exploring factors like cultural context, political environment and economic development can impact the role of digital libraries. It is important to track users' performance and challenges encountered and overcome during their experience and to see if this experience were applicable in their academic progress.

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Dynamics of Socio-Religious Transformation in Lifou (New Caledonia): From the Traditional Drehu Order to Missionary and Post-Missionary Hegemony

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Abstract: This research offers an ethnographic and historical analysis of social and religious transformations on the island of Lifou, in New Caledonia, following the introduction of Christianity by the London Missionary Society (LMS) in the mid-19th century. The first part of the study reconstructs the foundations of pre-Christian Drehu society, which was centered around *haze* (spiritual forces), chiefly systems, rituals, and clan structures. These elements formed a coherent politico-religious system, interweaving power, territory, and the sacred. The arrival of missionaries marked a radical rupture. The establishment of the LMS led to the replacement of traditional spiritual and social references with a Christian order, characterized by the centrality of the church, the erasure of *haze*, the reform of rituals, and the institution of a new moral authority. These transformations are explored through the lenses of syncretism, acculturation, and identity recomposition. From a diachronic perspective, the dissertation also examines the contemporary impact of Pentecostalism, which rekindles tensions between Christian faith and cultural heritage. Through various life stories, it sheds light on internal conflicts, identity reconfigurations, and social fractures within clans. The research combines ethnographic observation, analysis of missionary archives, and the reflexive position of the author, a native anthropologist from Lifou. This situated perspective provides a nuanced understanding of issues related to transmission, memory, and resistance in a postcolonial context.

Keywords: Christianization, Syncretism, Postcolonial anthropology, Identity reconfiguration, Clan structure, New Caledonia.

Biographical Note: Zénon WEJIEME is a doctoral candidate in social and cultural anthropology at the University of New Caledonia. A native of the Lösi chieftaincy on the island of Lifou, he also teaches the Melanesian language *Drehu* and English at Dick Ukeiwe High School. His research explores contemporary religious dynamics in Oceania, the interplay between customary practices and Christianity, and the impact of spiritual globalization on Drehu society.

1. INTRODUCTION

The island of Lifou, situated in the Loyalty Islands archipelago of New Caledonia, provides a privileged field for analyzing interactions between local traditions and Christian missions. This study is rooted in a historical anthropology of religious transformations, blending ethnographic materials, missionary archives, and a reflexive stance anchored in the author's native background. The aim is to understand how the introduction of Christianity not only redefined relationships with the sacred, power, and territory but continues to fuel tensions in the contemporary postcolonial context.

2. THE TRADITIONAL DREHU ORDER: FOUNDATIONS OF A POLITICAL-RELIGIOUS SYSTEM

Before the arrival of Christianity, Drehu society was organized around a holistic system in which the political, religious, and social dimensions were inseparable [1]. This system relied on a hierarchical and territorially-based structure of clans (*lapa*), articulated with a worldview in which invisible forces—the *haze*—played a central role. These spiritual entities were not merely feared or revered; they structured relationships with the living, time, space, and power.

Political authority, embodied by customary chiefdoms (*hnanyijoxu*), derived its legitimacy from its capacity to mediate relations between the living and the *haze*. Being a chief was not simply about leadership—it implied sacred authority closely tied to ritual knowledge, symbolic places, and speech. Customary speech, transmitted according to precise protocols, was performative: it could “make be”—a relationship, peace, or alliance [2].

Agrarian rituals—especially those connected to yam planting—regulated social time and manifested interclan, intergenerational, and spiritual relationships. Every ritual action was embedded within a web of reciprocal obligations and taboos (sacred prohibitions), ensuring group cohesion and balance between the living and ancestors. Violations of these rules could lead to societal disorder, interpreted as disruptions in human–spirit relations.

Clanic alliances reinforced the stability of this order. They were not based solely on kinship, but on ritual exchanges, mutual services, and shared founding narratives often tied to sacred place names (*toponyms*). Each clan thus possessed a symbolic heritage—places, stories, ceremonial roles—linking it to space, ancestors, and a shared history.

The Drehu cosmology also included a circular concept of time and a strong interconnection between the visible and invisible worlds. Although physically dead, ancestors remained active in the living world, and their memory was sustained through rituals, names, songs, and daily gestures. This constant presence of the past within the present shaped both individual and collective identity.

In sum, the traditional Drehu order constituted a coherent political-religious system where power, the sacred, kinship, and territory were deeply interwoven. Any attempt at rupture—whether internal or external—inevitably triggered a global reorganization. This is precisely what occurred with the arrival of missionaries in the 19th century, who dismantled this system by introducing a new cosmology, moral frameworks, and an unprecedented hierarchy of knowledge.

3. MISSIONARY DISRUPTION: THE LMS AND THE IMPOSITION OF A CHRISTIAN ORDER

From 1842 onward, the installation of the London Missionary Society (LMS) on Lifou constituted a major epistemological and ontological rupture for Drehu society [3]. More than a simple religious conversion, the missionary process symbolically re-founded the society, redefining relationships with the sacred, authority, and collective memory. This transformative project was methodical, structured around religious, moral, and social pedagogy aimed at replacing one universe of meanings with another [3].

The missionary strategy relied on three main components:

1. Systematic denigration of the local spiritual system,
2. Centralization of worship around the temple and school,
3. Formation of a Christian indigenous elite to relay the new moral order.

3.1 Deconstructing Traditional References

From the first contacts, missionaries sought to discredit the *haze*, labeling them as “evil spirits” associated with superstition or demonry. Traditional rituals were dismissed as forms of idolatry, and sacred objects were destroyed or desacralized. Drehu spiritual vocabulary was either prohibited or reinterpreted within a biblical framework.

This process delegitimized the sacred Drehu order and severed the essential link between the living, their ancestors, and territory.

3.2 Reshaping Social Space: The Temple and the School

The LMS also reorganized social space around two centers: the temple, site of weekly worship and collective discipline; and the school, tool for normalizing behavior, values, and language. The mission school taught reading and writing in Drehu, but according to biblical grammar. It became a vector for internalizing Christian moral values: order, work, modesty, and submission to God. This spatial conversion of the sacred—centered on mission buildings—marginalized traditional ritual sites (caves, springs, promontories), depriving them of symbolic function. Thus, spatial conversion was also a political conquest.

4. ACCULTURATION, SYNCRETISM, AND IDENTITY RECONFIGURATIONS

The encounter between missionary Christianity and Drehu culture did not result in a wholesale replacement of one model by another. Instead, it involved complex processes of acculturation, negotiation, and cultural resilience, whereby individuals and communities negotiated between competing symbolic worlds. What emerged was neither intact continuity with the past nor uniform assimilation into Western Christianity, but rather a space of religious hybridity rich in tension and creative identity [4].

4.1 Selective and Differential Acculturation

Christian adoption was neither homogeneous nor instantaneous; it depended on clan positioning relative to the missions, internal rivalries, integration into missionary networks, and relations with colonial power. Some groups—especially those in conflict with established chiefdoms—saw the LMS as an opportunity to assert new legitimacy by aligning with an external spiritual authority.

This differential acculturation generated internal fractures—between staunch traditionalists and those adopting Christian norms. Adoption was selective: some elements of the past deemed “pagan” were rejected, while Christian elements were assimilated into continuities of ritual practice (e.g., funerals, reinterpreted clan chants).

4.2 Syncretism and Cultural Reinterpretation

Local populations actively reinterpreted Christian messages through Drehu symbolic frameworks. For example, Christian baptism echoed Drehu initiation rites marking the transition to adulthood and community life. Syncretic traits appeared in liturgy, funeral practices, and the differentiated use of sacred space. Christian ceremonies (marriages, burials) were often framed by customary discourse, and the temple could function with both Christian and clan dimensions.

This hybridization reveals ritual creativity and cultural adaptability, enabling traditional forms to survive in modified ways and conferring local legitimacy on Christianity.

4.3 Identity Reconfigurations and Loyalty Conflicts

However, this hybridity was often fraught. Identity reconfigurations sparked loyalty conflicts as individuals were torn between custom and Christian faith. Tensions surfaced during significant social junctures: mourning, customary appointments, religious festivals, partner choice, burial sites.

Some practices—such as refusing to attend a customary ritual deemed incompatible with faith—could provoke symbolic ruptures within clans or even familial schisms. Conversely, others sought reconciliation, arguing for full Drehu and Christian identities through contextual reinterpretation.

These tensions highlight broader issues of postcolonial identity construction, where the Kanak subject negotiates multiple, sometimes contradictory, allegiances as integral to their identity. Identity reconfiguration occurs not through imposition, but through dynamic cultural negotiation.

5. PENTECOSTALISM AND THE POST-MISSIONARY ERA: NEW RELIGIOUS TENSIONS

Since the 1990s, Lifou has witnessed a religious reconfiguration driven by the rise of Pentecostalism, part of a wider diversification of the religious field across insular Pacific. Pentecostalism, stemming from global evangelical and charismatic movements, emphasizes a break with ancient traditions—including institutional Protestantism from the LMS—an emotional, direct relationship with God, and individual conversion. It signifies not just doctrinal change but a reversal of traditional religious mediation in favor of immediate, spectacular spirituality.

5.1 Pentecostalism as a Challenge to the Established Order

Pentecostalism often presents itself as a form of “spiritual awakening,” denouncing the lukewarmness of historic churches (Protestant and Catholic) and their complicity with social structures, especially custom. It embodies a radical critique of the post-missionary order, where both pastors and traditional chiefs may be seen as complicit in a rigid social system.

Through fiery sermons, passionate singing, and miraculous healings, Pentecostalism champions rupture with the past: “The old things are passed away; behold, all things are become new” (2 Cor 5:17) [5][6]. This verse encapsulates its theology of break, rejecting both *haze* and clan symbolism, accused of keeping individuals under the sway of spirits or human tradition.

5.2 Social Reconfigurations and Intra-community Conflicts

Pentecostal communities—often emerging from family or tribal divisions—introduce new lines of fracture in tribes. Conversions involve social repositioning, spatial separation (new worship spaces outside the main temple), and loyalty conflicts within clans. Field reports show families where members ceasing customary ceremonies, refusing collective offerings, or challenging customary chief authority in the name of faith. These ruptures can be viewed as spiritual liberation or disintegration of traditional solidarity structures.

Paradoxically, Pentecostalism may recreate strong moral authority in the figure of the pastor-prophet, who serves as a direct mediator with God. Thus, despite its anti-hierarchy rhetoric, the movement can reinforce formal moral leadership outside clan structures.

5.3 Ambivalent Movement: Between Global Modernity and Quest for Rootedness

Pentecostalism’s success lies in its ability to combine modernity and spirituality: its spread is facilitated by media (radio, religious YouTube channels, social networks); its rituals are intense and accessible; its message promises personal deliverance from physical, psychological, or social suffering. It addresses postcolonial uncertainties in a world where traditional anchors erode and missionary institutions appear outdated.

Yet, this engagement with global modernity is often accompanied by local rejection: vernacular languages may be marginalized in favor of French or biblical English; clan founding narratives may be forgotten or reinterpreted as spiritual burdens. This tension reflects a deeper struggle between universal salvation and cultural anchoring.

Some newer Pentecostal churches try to reconcile faith and Kanak culture by revitalizing traditional music, Drehu proverbs, or welcoming ceremonies. This trend remains marginal, but it reflects a desire to invent a middle way between Christian fidelity and cultural rootedness.

In sum, Pentecostalism on Lifou is not just another religious phenomenon: it functions as a laboratory for identity reconfiguration, reflecting post-missionary and postcolonial tensions. It revives old fractures, creates new ones, but also opens unprecedented spaces for spiritual expression, contestation, and creativity.

6. REFLEXIVITY AND SITUATED STANCE: THE INDIGENOUS ANTHROPOLOGIST IN THE FIELD

A key pillar of this research is the adoption of a reflexive and situated stance [7], inseparable from the author's identity as a native Lifou anthropologist. This positioning grants the inquiry deep access to cultural meanings and sensitivity to internal dynamics rarely accessible to outside researchers. It also demands constant methodological and ethical vigilance: the task is not merely to "observe" a society, but to write from within, at the intersection of scientific, familial, customary, and religious loyalties.

6.1 Embodied Knowledge and Privileged Access

Belonging to Drehu society enables profound immersion in linguistic codes, ritual logics, latent tensions, and unspoken norms. This embodied knowledge is not "objective" but a lived understanding of social stakes. It provides access to intimate narratives, silent memories, and local interpretations not readily shared with outsiders. Use of Drehu language in interviews, participation in customary ceremonies, and knowledge of clan genealogies create dense and layered field access. However, this proximity is ambivalent: it aids research but imposes implicit constraints, particularly in sharing sensitive information or critiquing local institutions.

6.2 Self-Analysis as a Tool of Decentering

Being an indigenous researcher also implies constant self-analysis. It is not self-display but acknowledging the lenses through which knowledge is produced. Conceptual choices, interpretive frameworks, and analytical priorities are shaped by personal experience, loyalty conflicts, and sometimes inherited wounds from colonial history. Reflexivity enables decentering from dominant epistemologies: speaking from within Kanak societies, with their symbolic references, internal tensions, and unique historicity. This does not imply abandoning critical analysis, but conducting it from a plural, situated standpoint at the crossroads of scientific knowledge and collective memory.

6.3 Ethics of Speech and Politics of Transmission

Finally, this stance raises fundamental questions about the use of speech and the transmission of knowledge. Writing about one's own society involves deciding what to reveal, conceal, or transform into objects of analysis. In the Kanak context, where speech carries performative and binding value, publishing anthropological analysis means taking a public position, sometimes exposing intra-community tensions. This requires an ethic of responsibility: being faithful without betraying, analyzing without freezing, transmitting without appropriating. It is not about idealizing an "indigenous" posture, but acknowledging that all knowledge production is situated and that this situation entails political and symbolic commitment.

This reflection on the researcher's stance situates this study within decolonial anthropology, committed to centering indigenous voices not as research objects but as sense-making subjects. It also offers methodological perspectives for rethinking anthropological writing as dialogue between forms of knowledge, at the crossroads of lived experience, memory, and theory.

7. GENERAL CONCLUSION

The study of religious and social dynamics on Lifou—from pre-Christian times to the contemporary period—reveals a history marked by deep ruptures, yet also by subterranean continuities and cultural resilience. The introduction of Christianity by the London Missionary Society in the 19th century disrupted the political-religious foundations of Drehu society, substituting traditional spiritual mediations with a new moral and ecclesial order structured around the temple, school, and biblical text.

This ontological shock did not annihilate traditional logics: it displaced, recomposed, and sometimes concealed them in transformed forms. Processes of acculturation, syncretism, and reinterpretation enabled local

actors to appropriate, adapt, or negotiate Christian categories within their own cognitive frameworks. Thus, rather than simple assimilation, the religious encounter generated a symbolic creativity within which cultural identities were reconfigured.

The more recent emergence of Pentecostalism continues this trajectory, introducing a new religious grammar—individualistic, emotional, often conflictual. By radically segmenting from both custom and missionary orders, Pentecostalism heightens intra-community tensions and revives debates over the compatibility of Christian faith and Kanak custom. It paradoxically offers a local response to global dynamics: social uncertainty, political disenchantment, and quests for personal salvation.

Finally, this research—conducted through a situated, committed, and critical stance—underscores the importance of decentering anthropological gaze in a postcolonial context. To think *from Lifou*, using its words, silences, and memories, is to account for the complexity of religious trajectories and to valorize indigenous knowledge as heuristic resources capable of generating their own social intelligence.

In this sense, Lifou is not merely a site of inquiry: it is a place of thought, where tensions between tradition, modernity, faith, and memory open fertile avenues for rethinking the very categories of religion, identity, and transmission.

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A comparative assessment of marita (*Pandanus conoideus*) production challenges and opportunities for further research and development in Papua New Guinea – A Review

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Abstract: Despite being a high-value native crop, marita (*P. conoideus*) has received little research and development attention in Papua New Guinea (PNG). Studies in Indonesia have confirmed that marita oil contains natural antioxidants, including carotenoids, tocopherol, omega-3 and omega-6 fatty acids, and anti-inflammatory properties beneficial to human health. In PNG, the marita holds cultural significance and economic value as it is used in traditional rituals, bride price payments, and barter systems as a special gift, and it serves as a source of income for many families. The literature further shows that most information is on background, especially distribution, cultural significance, and food sources like oil and sauce. Unpublished reports in PNG show twenty-four varieties were found in Lumi, West Sepik Province, eighteen different accessions in Jiwaka Province, and four in the Nipa- Kutubu area in the Southern Highlands Province (SHP). This shows that a diversity of marita exists in PNG, and studies need to be conducted on agronomic practices, nutritional and chemical compositions, molecular diversity analysis, and pest and disease management. This study aims to establish that marita is an underutilized crop in PNG, and there is a need to study diversity nationwide, its socio-economic, cultural, and nutritional importance, and wider cultivation as an alternative crop under climate change.

Key words: Marita, research, cultivars, morphology, nutritional properties.

Main author biography: I, Mr. Jonah Anton, who graduated from PNG University of Technology (Unitech) with a Bachelor of Science in Agriculture in 2013. I joined the National Agriculture Research Institute in 2014 and worked as a crop agronomist until I left for my postgraduate at Unitech this year, 2025. I'm currently studying Master of Philosophy in Agriculture at PNG Unitech.

1. INTRODUCTION

Marita (*Pandanus conoideus*) is a tropical plant and is one of the *Pandanus* species (Stone, 1997). *Pandanus* is a complex genus with 600–700 species identified across the Pacific islands, Malaysia, and Australia (Wagner *et al.*, 1990; Jong and Chau, 1998). Rhoman *et al.* (2011) and Sarungallo *et al.* (2019) asserted that *P. conoideus* is an indigenous crop originating from Papua New Guinea (PNG) and Indonesia. Bourke (2009) stated that marita is grown and consumed by around 1.5 million people in PNG, mainly in the Highlands and Momase Regions, along with Manus, Central and West New Britain provinces.

The marita fruit is utilized as a food supplement with its rich oil content as well as a natural dye, and as a natural remedy for various diseases by the people of the Highlands provinces of PNG (National Newspaper, 22/02/2025). Bourke (2005) stated that the sauce or oil derived from marita is utilized to enhance the flavour of other foods, such as sweet potato, banana, and green vegetables. The crop is able to withstand drought conditions,

making it a valuable food source, flavouring indigenous bush vegetables like Kumu Musong (*Ficus kopiosa*), Fern (*Cyathea spp.*), and highlands Kapiak (*Ficus dammaropsis*) for consumption during adverse periods (Anton *et al.*, 2018). The marita fruit has also been employed in traditional rituals, bride price payments, barter systems, and is regarded as a special gift. Recently, some entrepreneurs have utilized marita to produce herbal medicine for treating diseases, and soap is made from its oil and sold in informal street markets in Goroka and Mt. Hagen (Post Courier-news, 22/02/2025). Figure 1 below shows some of the marita-based products such as soap, oil, and animals' feeds that were displayed during the Jimi Marita Festival show at Karap in Jiwaka Province and processed oil sold at Goroka in the Eastern Highlands Province. Several studies conducted in Indonesia confirmed that marita is a highly nutritious crop containing chemical compounds that provide significant health benefits (Mun'im *et al.*, 2006).

Despite its benefits and significance in society, research on this native crop has been overlooked in PNG. In contrast, Indonesia has conducted extensive research, focusing on characterization, agronomy, nutrition, and molecular studies, which led to product development and export to other countries. This literature is focused on reviewing marita's research in PNG to consolidate and validate information to identify opportunities for further research and development. The review focuses on marita's origin, distribution, production constraints, and physical, chemical, and molecular characterizations.



Figure 1: The oil, cream, soap, and animal feed derived from marita sold locally in the Highlands of PNG.

2. ORIGIN AND DOMESTICATION

According to Jong and Chau (1998), marita is endemic to New Guinea inland in the Pacific region. Rhoman *et al.* (2011) and Sarungallo *et al.* (2019) reported that marita is an indigenous crop that originated from the Highlands and Momase regions of PNG as well as the Papua and West Papua provinces of Indonesia. In Indonesia, marita is limited to all the mainland districts of Papua and West Papua territories at altitude ranging from 50 to 2000 meters above sea level (masl) (Lim, 2012; Murtiningrum *et al.*, 2012). The regions of West Papua and Papua are home to about thirty-nine different types of red fruit, four of which are highly valuable economically: (1) red long fruit, (2) red short fruit, (3) red-brown fruit, and (4) yellow fruit (Xia *et al.*, 2018). According to Bourke (2005), marita is present in all mainland provinces of PNG, but especially in the Momase and Highlands Regions, as well as in Manus, West New Britain, and Central Provinces (Figure 3). Marita is cultivated for consumption, traditional rituals, and sales for income generation.

3. BOTANY, VEGETATIVE GROWTH, AND REPRODUCTIVE DEVELOPMENT

Marita is a tree plant species scientifically known as *Pandanus conoideus* in the Pandanaceae family. In PNG, *P. conoideus* is commonly referred to as "Marita" in Tok Pisin, whereas in Indonesia, it is known as "Buah merah," which literally means "red fruit" (Stone 1997). The stem height of the marita plant can reach heights of 2 to 12 m,

with trunk diameters ranging from 30 to 70 cm (Kerepea *et al.*, 2025). The trunk is typically dark brown with white patches and grows vertically with 2 to 6 branches, featuring spiny surfaces (Figure 2). The plant begins to produce fruit between 1.5 and 3 years-of-age, with each fruiting period lasting approximately 3 to 4 months. The tree is considered old at 20 to 30 years of age (Martiningrum *et al.*, 2012). Marita has a taproot system, with the main root length ranging from 0.2 to 3.5 m and a root circumference of 6 to 20 cm (Kerepea *et al.*, 2025). Leaves are formed at the tips of branches in opposite arrangements, measuring between 100 and 250 cm in length and 10 to 20 cm in width (Thomson *et al.*, 2006). They are flexible, dark green, lined with thorns along the edges and lack petioles (Hyndman, 1984).

The fruit is a drupa, formed from the fusion of multiple flowers into a compound fruit. The length of the drupa ranged from 1.2 to 1.8 cm and shape varies from triangular to cylindrical (Table 1) with a rounded tip and a heart-shaped base, measuring length ranges from 30 to 110 cm and diameter from 10 to 15 cm (Kerepea *et al.*, 2025; Murtiningrum *et al.*, 2012). Kerepea *et al.* (2025) further reported that the fruit color of marita changes from pale red to brick red as it matures. However, this varies with cultivar; for example, *Kukang* from Jiwaka turns from green to orange, while *Pengie Yol* and *Wurum* transition from pale red to brick red at maturity. Marita is a seasonal crop, with its main harvesting season running from October to April, although individual trees may bear fruit year-round (Bourke and Harwood, 2009).

In PNG, marita is commonly propagated using vegetative buds or suckers, as the seeds exhibit low vigor and poor germination rate (Sadsoeitoeben, 1999; Makaruku, 2008; Sianipar, 2016) stated that seed germination is inhibited by a surrounding tissue that acts as a barrier to embryo growth. Vegetative suckers are selected from desirable varieties and planted in a prepared field.



Figure 2: Images of the *P. conoideus* plant (sourced from google website).

4. DISTRIBUTION AND PRODUCTION

4.1. Marita distribution and production in Papua New Guinea

Marita is widely distributed across provinces in the Highlands and Momase regions, and other parts of PNG (Kambuou, 1996; Rhoman *et al.*, 2011; Bourke, 2009). Based on personal observations and discussions with local farmers, Marita is domesticated in several districts of the highlands region, including Tari-Pori, Koroba-Kopiago, and Komo-Magarima in Hela province; all districts of the Southern Highlands Province (SHP) except Upper-Mendi and parts of the Imbongu district; and throughout the Western Highlands Province (WHP) except for Tambul and Tomba in the Tambul- Nebilyer district. In Enga Province, marita is cultivated in Kompam-Ambum, Wapenamanda, and parts of Wabag district, while it is also present across Jiwaka, Simbu, and Eastern Highlands Provinces (EHP). Marita has also been identified in high-altitude areas of West and East Sepik Provinces, part of Madang province, as well as Kabwum, Finschhafen, Bulolo, Menyamya, and Wau-Waria districts of Morobe

Province. Additionally, it is cultivated in some parts of Manus, East and West New Britain, Central, Milne Bay, Oro, Gulf, and Western Provinces (Bourke 2009: Figure 3).

In personal communication with Pandau, a NARI Plant Genetic Resource Technical Officer, on 23rd of December 2024, he identified approximately 24 distinct cultivars from Lumi in West Sepik Province. Furthermore, around 18 distinct cultivars were displayed during the Jimi Marita Festival at Karap in Jiwaka Province (National Newspaper, 23/01/2025), and four were previously identified by Sillitoe (1983) in Nipa, SHP. This suggests that numerous provinces across the Highlands and Momase regions possess unique marita accessions. Marita is typically cultivated along mountain slopes, riverbanks, land boundaries, and marginal areas within garden fields (Bourke and Harwood, 2009). Farmers also noted the absence of structured agronomic practices, such as fertilizer application, pruning, weeding, and pest and disease management practices. These observations are based solely on verbal accounts, as no formal studies have been published in the PNG context.

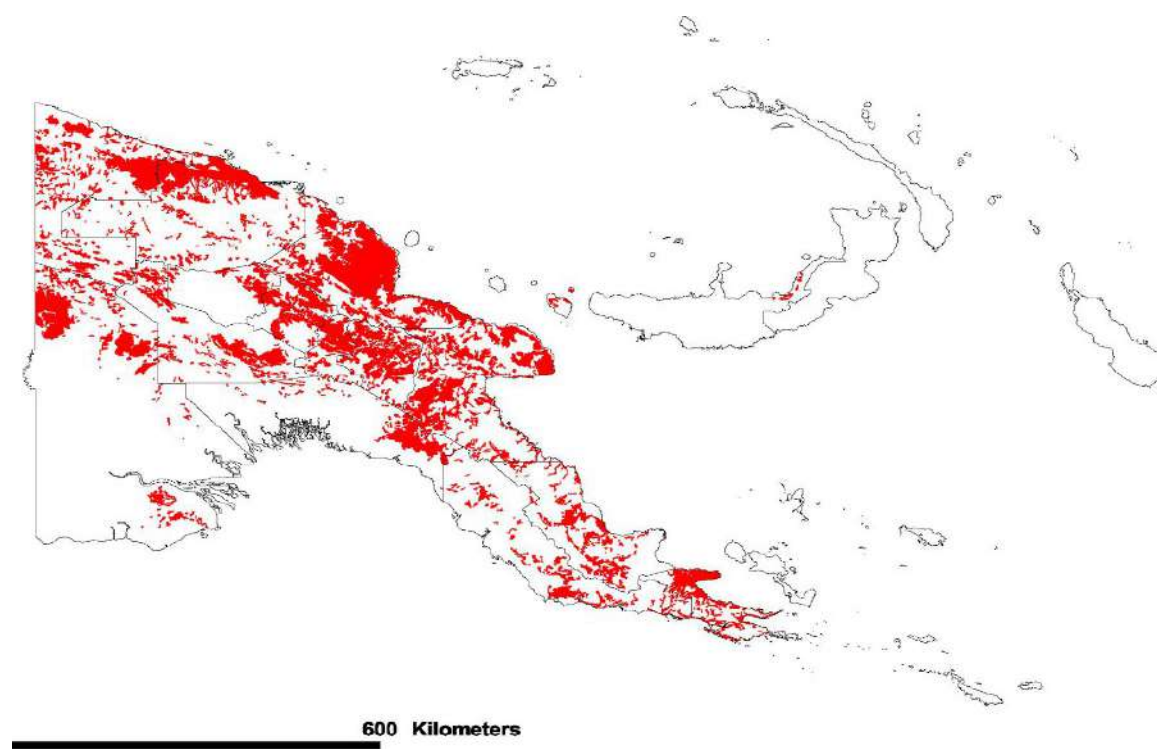


Figure 3: Distribution of *marita* in PNG. Source: Bourke (2009) and MASP database.

4.2. Other places

According to Murtiningrum *et al.* (2012) and Rhoman *et al.* (2011), marita is geographically restricted to the West Papua and Papua Provinces of Indonesia. These regions and PNG are all located on the island of New Guinea, which is the only known natural habitat of marita. It is a native crop, traditionally cultivated and passed down through generations. It thrives particularly on gentle to steep slopes, along the hillsides, riverbanks, and roadsides, despite the absence of proper agronomic management. Farming practices are largely traditional, inherited through generations, and are often carried out without support from agricultural extension services.

5. PRODUCTION CONSTRAINTS

5.1 Ecology (environment and climate)

Several research studies have indicated that marita is a unique fruit crop well adapted to a wide range of ecological conditions in PNG, particularly between 50 to 2,000 masl (Stone, 1997; Bourke, 2009). It thrives in moist

environments, often under shade with a pH ranging from 4.5 to 6 and distributed in areas with moderate to high rainfall (Bourke, 2005). However, marita is restricted in its adaptability to certain soil types and climates. It does not perform well in swampy environments, heavily waterlogged, clay, dry, sandy soils (Makaruku *et al.*, 2021). Similarly, the crop is sensitive to high temperatures (27- 30 °C), altitudes below 20 masl (typically coastal areas), and elevations above 2,000 masl (Bourke, 2009). For instance, Tomba/Tambul in WHP, Upper Mendi in SHP, and Gembogl in Simbu Provinces are located above 2,000 masl and are not conducive for marita cultivation.

5.2. Pests and Insects

Insects and birds are commonly reported as pests affecting marita crop. Ripe marita fruits attract birds, including birds of paradise, which feed on the juice and pulp, causing significant damage (personal comm.). Makaruku *et al.* (2021) documented several insect pests affecting marita in West Papua, including the longhorn grasshopper (*Tettigoniidae*), banana scab moth (*Nacoleia octasema*), and stem borers (*Chilo partellus*). In PNG, the specific pests and insects affecting marita remain largely undocumented. However, Highland farmers during the Jimi Marita Festival reported the damage caused by birds, bark beetles (*Scolytinae*), borer tunnels, and longhorn grasshoppers. This highlighted the urgent need for formal investigations and documentation of pest species associated with marita cultivation in PNG.

5.3. Diseases

Bourke (2010), in his review of fruits and nuts in PNG, highlighted several studies on pests and diseases but found limited information specifically relating to marita. One documented disease affecting marita in Morobe Province is caused by *Erwinia carotovora subsp.* which leads to fruit rot and leaf necrosis (Tomlinson, 1988). Biochemical, physiological, and pathogenic tests confirmed *E. carotovora* as the causative agent affecting the leaves. Tomlinson (1988) also identified black leaf mold fungus and leaf spot as common problems, sometimes resulting in fruit becoming soft, squashy, and malodorous when immature. Infected fruits are often shed prematurely and left to decay due to yellow mottle symptoms. Despite these findings, overall knowledge of marita's diseases remains limited. Tomlinson remains the only researcher to have studied marita's pest and disease problems in detail in Indonesia and PNG.

6. SYNTHESIS OF PAST RESEARCH

6.1 Morphological Characterization

Zebua *et al.* (2019) stated that Indonesia possesses nearly 39 diverse marita accessions that have been identified and documented. These accessions were characterized based on both morphological and chemical traits (Kerepea *et al.*, 2025; Murtiningrum *et al.*, 2012). The morphological characterization included the origin and local name of the accession, core structure, fruit flesh color, fruit length, and length of dupra. Murtiningrum *et al.* (2012) characterized 16 cultivars from Papua in Indonesia and the results is presented in Table 1 below. The 16 cultivars have a triangular core shape, red color except for two cultivars with a dark-red color, fruit length ranges from 21 to 76 cm, and drupa length ranges from 1.2 to 1.8 cm. Kerepea *et al.* (2025), in a separate study, reported that the marita fruit's length ranges from 30 to 110 cm and 10 to 15 cm in diameter and the fruit shape may be cylindrical or triangular with a blunt tip and a heart-shaped base. In some studies, additional plant features were assessed, such as plant height, leaf color, leaf size, fruit size, fruit weight, and branch characteristics (Sianipar and Santosa, 2016). Hyndman (1984) noted that the plant can reach heights of up to 11 meters with a trunk diameter of 20 to 50 cm. The leaf's length ranges from 100 to 250 cm and 10 to 20 cm in width (Kerepea *et al.*, 2025).

The physiological character differences in fruits, leaves and stems are influenced by environmental factors and the genetic make-up (Murtiningrum *et al.*, 2012). Environmental factors such as altitude, soil type, and micro-climate significantly influence morphological expression (Thomson *et al.*, 2006). For instance, cultivars from highland areas may produce larger or more pigmented fruits due to lower temperatures and increased Ultraviolet (UV) exposure, which can enhance pigment biosynthesis.

Table 1: Physical characteristics of accessions from Papua (Indonesia (Murtiningrum *et al.*, 2012).

No:	Origin of accession (district)	Red-fruit accession	Core	Fruit flesh color	Fruit length (cm)	Drupa length (cm)
1	Manokwari/Masni	MID-M	Triangular	Red	62	1.3
2	Manokwari/Minyambow	MHY-M	Triangular	Dark red	76	1.8
3	Manokwari/Minyambow	MHB-M	Triangular	Red	71	1.8
4	Manokwari/Minyambow	MHG-M	Triangular	Red	42	1.7
5	Teluk Bintuni/Merdey	MMS-M	Triangular	Red	68	1.2
6	Teluk Bintuni/Merdey	MMY-M	Triangular	Red	70	1.3
7	Teluk Bintuni/Merdey	MMW-M	Triangular	Red	21	1.7
8	South Sorong/Aifat	MUSM-S	Triangular	Red	66	1.6
9	South Sorong/Aifat	MUSW-S	Triangular	Red	61	1.4
10	South Sorong/Aifat	MUA-S	Triangular	Red	59	1.6
11	Nabire/Nabire	MTB-S	Triangular	Red	52	1.5
12	Nabire/Nabire	MTM-N	Triangular	Red	53	1.8
13	Nabire/Nabire	MTK-N	Triangular	Dark red	54	1.6
14	Jayawijaya/Kelila	MTU-W	Triangular	Red	75	1.6
15	Jayawijaya/Kelila	MTM-W	Triangular	Red	60	1.6
16	Jayawijaya/Kelila	MTK-W	Triangular	Red	60	1.5

6.2 Nutritional Compositions

Extensive nutritional laboratory research conducted in Indonesia has revealed that marita oil contains a wide range of nutritional components. Murtiningrum *et al.* (2012) conducted physio-chemical analysis of 16 cultivars, and the results are presented in Table 2. The moisture content ranges from 40 to 52%, protein from 3.1 to 6.4%, carbohydrates from 61.4 to 79.6%, fat from 11.2 to 30.7%, calcium from 0.53 to 0.9%, iron from 8.32 to 39.37 ppm, and phosphorus from 0.01 to 0.33%. Sarungallo *et al.* (2016) also reported in a separate study on the same nutrition that marita contained 50.8 to 55.6% fat, 36.8 to 46.3% carbohydrate, 654 to 792 ppm phosphorus, and 4919 to 5176 ppm calcium. Bourke (2009) reported on the dietary contributions of marita in the Mt. Bosavi area in SHP, where marita accounted for 44% of fat intake, 15% of energy intake, and 11% of protein in local village diets. However, this study did not specify the particular varieties used for the nutritional assessments. NARI food scientist Miriam Simin did a preliminary analysis of two cultivars (*Pengine Yol* and *Kulang*) from Jiwaka Province at the Professor Kola Chemistry Laboratory, and the results are summarized in Table 2. Despite these efforts, comprehensive nutritional analyses of Marita cultivars across PNG remain incomplete, leaving a significant gap in understanding the full nutritional potential and variation among marita cultivars.

Table 2: Physio-chemical analysis results for *Pengine Yol* and *Kulang* from Jiwaka Province.

Red-fruit accession	Moisture (%)	Crude protein (%)	Iron (mg/Kg)	Calcium (mg/Kg)	Phosphorus (mg/Kg)	Zinc (mg/Kg)
Pengine Yol	77.2	7.2	109.3	2067	1433	21.6
Kulang	72.6	3.2	97.0	2115	1665	28.8

Table 3: Physio-chemical nutritional value of 16 accessions from Papua in Indonesia. Sourced: Murtiningrum *et al.*, 2012.

Red-fruit accession	Water (%)	Protein (%)	Carbohydrates (%)	Fat (%)	Calcium (%)	Iron (ppm)	Phosphorus (%)
MID-M	40.82±0.08	4.01±0.04	71.15±0.19	22.23±0.20	0.60±0.00	23.03±2.09	0.11±0.00
MHY-M	52.70±1.04	5.53±0.31	71.19±0.78	20.50±0.56	0.77±0.02	20.86±0.12	0.01±0.00
MHB-M	51.18±0.06	5.78±0.02	74.67±0.36	16.55±0.34	0.83±0.01	14.65±1.73	0.01±0.00
MHG-M	46.95±0.72	6.48±0.09	78.81±0.59	11.21±0.22	0.74±0.00	16.27±0.86	0.02±0.00
MMS-M	40.26±0.40	5.54±0.26	61.64±0.14	30.72±0.19	0.68±0.00	22.52±0.91	0.32±0.00
MMY-M	43.96±0.01	5.30±0.15	71.43±0.44	21.18±0.36	0.54±0.00	11.83±1.58	0.25±0.00
MMW-M	51.93±0.91	4.33±0.15	68.33±0.65	24.70±0.39	0.58±0.00	17.18±1.20	0.31±0.00
MUSM-S	51.53±0.29	4.77±0.35	77.77±0.17	15.00±0.13	0.90±0.05	39.37±0.36	0.29±0.00
MUSW-S	47.10±0.13	5.37±0.65	64.96±0.41	26.88±0.18	1.11±0.05	21.88±1.01	0.31±0.00
MUA-S	45.18±0.39	5.20±0.18	71.66±1.11	21.10±0.92	0.59±0.01	22.29±0.51	0.33±0.02
MTB-S	41.57±1.29	6.22±0.07	79.66±0.45	11.81±0.32	0.55±0.00	29.07±0.90	0.08±0.00
MTM-N	44.07±2.61	5.69±0.25	68.01±1.82	23.15±1.86	0.79±0.04	26.69±3.72	0.07±0.00
MTK-N	41.42±1.01	5.45±0.37	79.33±0.52	12.27±0.15	0.71±0.01	26.6±4.76	0.07±0.00
MTU-W	51.26±0.38	5.50±0.18	75.66±0.36	16.07±0.37	0.57±0.04	8.32±0.99	0.02±0.00
MTM-W	42.99±0.03	3.12±0.10	66.46±0.21	27.39±0.09	0.90±0.04	24.54±0.02	0.01±0.00
MTK-W	49.02±0.64	5.15±0.02	74.24±0.26	17.96±0.36	0.53±0.02	12.34±0.79	0.01±0.00

6.2. Chemical Compositions

Marita oil is rich in natural antioxidant chemicals or compounds such as α -carotenoids, β -carotenoids, β -cryptoxanthin, α -tocopherol, and unsaturated fatty acids omega 3 and 6 (Sarungallo *et al.*, 2015). Murtiningrum *et al.* (2012) analyzed 16 cultivars in Indonesia, and the results are presented in Table 4 below. Total carotenoids range from 388.75 to 3330.51 ppm, and total tocopherol ranges from 964.52 to 6778.49 ppm. Sarungallo *et al.* (2016) further stated that the main Fatty Acids of oleic ranges from 49.36 to 64.47g per 100g, linoleic from 4.13 to 16.06g per 100g, and palmitic from 14.11 to 19.21g per 100g. These antioxidant chemicals positively contributed to human health. The in-vivo studies reported its positive effects on health, including tumor inhibition and anti-cancer properties, anti-diabetic effects, anti-inflammatory activity, and immune system enhancement (Mun'im *et al.*, 2006; Suroño *et al.*, 2008). Astirin *et al.* (2009) specifically noted the potential of yellow marita fruit oil as an effective agent against breast cancer cells, suggesting it may outperform other conventional treatments. It is important to note that these studies were all from Indonesia. In comparison, the chemical composition of marita cultivars distributed throughout PNG remains unexplored and undocumented.

Table 4: Vitamins, total carotene and tocopherol composition of accessions from Papua in Indonesia. Sourced: Murtiningrum *et al.*, 2012.

No:	Red-fruit accession	Vitamin C (mg/100g)	Vitamin B1 (mg/100g)	Total carotenoids (ppm)	Total tocopherol (ppm)
1	MID-M	20.61±0.93	1.88±0.02	2584.82±224.78	11917.81±72.32
2	MHY-M	16.18±0.59	2.60±0.12	748.86±18.39	5927.11±512.26
3	MHB-M	8.02±0.16	2.30±0.04	332.58±92.36	2988.76±26.57
4	MHG-M	9.97±1.20	2.39±0.15	704.04±37.72	6778.49±293.79
5	MMS-M	12.53±0.11	0.97±0.03	1264.28±38.96	2294.12±211.48
6	MMY-M	18.90±0.00	1.09±0.01	1137.98±37.24	1180.54±46.37
7	MMW-M	21.88±1.27	2.47±0.00	593.89±27.94	2424.49±101.38
8	MUSM-S	9.42±0.61	2.11±0.00	547.96±51.29	2853.23±7.15
9	MUSW-S	8.45±0.28	3.13±0.02	857.90±15.62	1043.04±49.21
10	MUA-S	10.30±0.13	2.22±0.00	603.16±4.63	964.52±39.39
11	MTB-S	3.78±0.08	2.00±0.10	759.12±16.72	4529.84±1178.36
12	MTM-N	5.64±0.82	2.97±0.13	330.51±902.91	6736.36±1625.27
13	MTK-N	7.33±1.25	3.09±0.16	1185.80±198.52	6419.41±723.01
14	MTU-W	4.39±2.30	2.54±0.11	388.75±11.95	1848.96±150.63
15	MTM-W	7.40±1.07	2.21±0.11	545.80±63.46	2599.00±297.95
16	MTK-W	15.41±1.57	2.04±0.06	730.63±106.65	3665.85±521.64

6.3. Phylogenetic and molecular characterization

Prior to the discovery of plant molecular characterization, it is prudent to identify their morphological traits. The development of methods for species identification started with the morphological identification process, which was further consolidated by molecular identification techniques based on short DNA sequences (Zebua *et al.*, 2019). For example, molecular characterization of DNA by Zebua *et al.* (2019), showed that six of the 39 cultivars are 90% similar, although they have various morphological features. Dissimilarities among the sequences indicate genetic divergence as a result of molecular evolution during the course of time. This often involves techniques like DNA sequencing, amplification, or using molecular markers to identify and understand genetic characteristics.

Zebua *et al.* (2019) recommended a standard DNA barcode for plant identification is the maturase gene K (matK). The matK is often used in the study of plant phylogenetic or plant molecular identification. Rachma *et al.* (2017) highlighted the advantages of plant molecular identification using barcoding DNA technique as follows: (1) the molecular identification can be done by anyone; (2) the DNA sequences is not influenced by the environment; (3) molecular identification is easy and fast if DNA sequence target species is provided.

7. FUTURE RESEARCH DIRECTIONS

The majority of the research on marita, including agronomic practices, pest and disease management, varietal characterization, and molecular studies has been conducted in Indonesia. In contrast, PNG's cultivars remain significantly understudied, particularly in terms of morphological, physio-chemical, molecular characterization and agronomic practices. According to email correspondence with Bourke, most of his work focused on providing general background information about marita and emphasized the need for further, in-depth research on this indigenous crop. Similarly, Kambuou (1996), in the FAO publication on PNG's plant genetic resources, also underscored the need for more detailed investigations to support the conservation and utilization of marita in PNG.

A key research priority moving forward is the identification and classification of cultivar diversity across different agro- ecological zones in PNG. This should be accomplished through comprehensive morphological, physio- chemical, and molecular analyses. Once high-value cultivars are identified, further research should focus on optimizing production systems, developing value-added products, and exploring the potential for commercialization and export, particularly of marita oil, which holds significant promise in both domestic and international markets.

8. CONCLUSION

This literature review aimed to evaluate existing research on marita and to identify key knowledge gaps to guide future research priorities. The review revealed that most Marita-related studies had been conducted in Indonesia, primarily focusing on domestic cultivars. These studies cover a range of areas, including cultivar diversity, agronomic practices, pest and disease management, and laboratory-based nutritional, chemical, and molecular analyses. In contrast, PNG has yet to undertake comprehensive, formal research on its own marita cultivars. The limited information available, such as that provided by Bourke (2009), offers only a general background on the crop. No in-depth characterization or molecular studies specific to PNG cultivars have been published. Given marita's cultural, nutritional, and economic significance, further PNG research is necessary and worthwhile.

Priority areas include morphological, physio-chemical, and molecular characterization for cultivar identification, agronomic practices, pest and disease management, harvesting, and processing techniques. Future research should focus on identifying and cataloguing the diverse marita cultivars across PNG. From this, high-value cultivars can be selected for targeted research, value addition, and potential product development and commercialization.

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Science Technology Engineering and Mathematics (STEM) Education: A report on how students at the primary school engage in STEM education lessons

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Abstract: STEM stands for Science Technology Engineering and Mathematics. It is a method of education where in the subjects are taught in coherence instead of in isolation. This research report investigates the strategies used in teaching STEM education lessons and the impacts it has on students. STEM education is a subject which focuses on actions that lifts foundational skills in STEM learning areas, and develops mathematical, scientific and technological literacy for students involved. It also promotes the development of the 21st century skills of problem solving, critical analysis and creative thinking. This case study is inspired by reasons that STEM is being studied as separate subjects in Papua New Guinean (PNG) schools. Also, it is yet to be formally incorporated to PNG's education system and curriculum. This case study used Arts Based Research (ABR) during data collection because ABR is a creative research approach which enables researchers to gather data through observation, interviews and/or questionnaires and analysis of first-hand information from participants. The findings indicate that students' critical thinking and problem-solving skills are enhanced through STEM education because of the hands-on approach and the practical pedagogy involved in facilitating STEM lessons using Lego sets from suppliers like the young engineers in Australia.

Key words: Science technology engineering mathematics, critical thinking, technological literacy, creative thinking, Lego, pedagogy, arts-based research, inquiry-based learning

Author's Biography: Ms. Annette Tsibois Sinnou is a Lecturer at Divine Word University (DWU) Our Lady of Sacred Heart (OLSH) Kabaleo Rabaul Campus. She is from Buka and is married to Christopher with two daughters Margaret and Lynette, a son Gerard (deceased) and a granddaughter Christal. In 2017, she was awarded an Australia Awards Scholarship and thus gained her Masters in Educational Studies at Monash University in Melbourne Australia. She is currently engaged in Primary Teacher Training and has a passion to research further on how Science Technology, Engineering and Mathematics Education (STEM Education) impacts students learning at an early stage. She first presented her research on STEM Education at the Faculty of Education Symposium in Madang (DWU) in 2023 and her paper was approved for publication at the Divine Word University Journal.

Annette is a certified Secondary School Teacher and has 13 years of teaching experience at the secondary school level. She has been lecturing under the Education Strand and also tutoring Basic Computing to year one student teachers. Her teaching experience is accompanied by vast experiences in administrative duties like being the practicum coordinator for DWU OLSH Kabaleo Rabaul Campus. Apart from work experiences under the education faculty, she has also done voluntary office work with Red Cross in Buka. She also lectured/tutored early childhood student teachers at Target Training and Consultancy Services (now known as Dianna Ope Training Institute), which is a private learning institution managed by Dr. Dianna Ope in Bougainville. Currently she is part of the lecturers send by DWU to take part in the sponsored Partnerships for Improving Education (PIE) program that upgrades Elementary Teachers in Bougainville, to gain a Diploma in Teaching Primary.

At the Pacific Islands Universities Regional Network (PIURN) conference, Annette will present on the title; Science Technology Engineering and Mathematics (STEM) Education: Her paper is a report on how students at the primary school engage in STEM education lessons. It is a research report that investigates the strategies used in teaching STEM education lessons and the impacts it has on students. In her research, Annette focuses on STEM as a subject which drives actions that lifts foundational skills in STEM learning areas, and develops mathematical,

scientific, technological literacy, critical analysis and creative thinking for students involved. email: asinnou@dwu.ac.pg.

1. BACKGROUND

In Papua New Guinea, subjects like science, engineering and mathematics, are taught as separate subjects in schools. With the introduction of Science Technology Engineering Mathematics (STEM) Education as a subject on its own in countries like Australia, its significance in children's learning has motivated educationists to explore the impacts it has on students involved.

In Australia, according to the learning areas, STEM develops mathematical, scientific and technological literacy, and promotes the development of the 21st century skills of problem solving, critical analysis and creative thinking. This development goals are challenged by Thomas and Watters' (2015, as cited in Kelley & Knowles, 2016) findings which indicate that students' interest and motivation to STEM learning have declined especially in Western countries and more prosperous Asian nations. This has raised concerns on how effective current STEM education pedagogies are in fulfilling such set goals.

Understanding the mentioned goals and the research that questions the effectiveness of STEM education pedagogies has led to this case study through arts-based research. The following questions form the core of this research report:

- In what ways does STEM education have impacts on how students acquire knowledge?
- How do students use designed STEM pedagogies to engage in critical analysis and problem solving?
- In what ways does STEM Education help motivate students to learn or get engaged in the learning process?

To investigate on the mentioned questions, Stem Primary School was chosen as the research site. The research location is important because my daughters who are also participants, have recently joined schooling in Australia without any introduction to STEM education back in Papua New Guinea (PNG). As a researcher and a mother in this case study, I have seen great learning opportunities while observing how STEM education has had an impact on their learning. Also, it has helped those students in the same class who have been exposed to inquiry-based learning which is used in STEM education lessons in Australia. The use of Lego in STEM education, has increased their interest in attending lessons.

2. RATIONALE

As an educator, this small-scale case study is valued as a starting point to major researches that can be done later. The significance of this research is based on reasons that STEM education has not been introduced as yet in PNG's Education system. Upon completion of this arts-based research at Stem Primary School; it was anticipated that there would be more understanding on how STEM education can be approached in terms of knowledge acquisition and active engagement.

As assumed, 3/4GW and 5/6Q classes that were chosen to be participants formed a very significant combination as they were a mixture of students who have had some exposure and my daughters who have never heard of STEM education. In maintaining the agreement on privacy and not exposing the identity of students, the staff and the school, all photography, interviews and voice recordings done, has not been labelled or directly named. Apart from that, direct views of students' faces have been avoided in shots.

It is such researches by Tharayil, Borrego, Prince, Nguyen, Shekhar, Finelli, and Waters (2018), claiming active learning as promoting student learning and increasing retention rates of STEM undergraduates that has given purpose to investigate further on what actually happens in STEM education at the primary level of schooling years. It has been intriguing to investigate on how STEM education has had an impact in the participants, especially when considering their differing exposure to STEM education backgrounds. This is noted as important because different setting of learning does have an impact on how one might view the success of an implemented program.

As stated by Valsiner (2006, p.601, as cited in Vasilachis de Gialdino, 2009):

“The social representation system of society at some historical period may selectively guide the researcher to seek general knowledge, or through denying the possibility of general knowledge, let the researcher be satisfied by description of local knowledge”.

The benefits anticipated from this research, though small scale, can be highly regarded and appreciated if considered from the following perspective. Firstly, it will help STEM educators at Stem primary school revisit, add or adjust on methods if need be and acknowledge the hard work that they put into each STEM lesson daily. Secondly, that participants will consider the positive outcomes of the research as a praise and the opposite as a reminder to refocus on relevant teaching strategies. Finally, that the researcher gains an insight into a highly regarded program so as to be better equipped for future work or help to my country’s possible implementation of STEM education.

The aim in this creative approach is to investigate through arts-based research by being involved in STEM education at Stem primary school. Furthermore, to investigate on how effective students acquire knowledge and how STEM education pedagogies motivate their interest to engage in learning. The research aimed at incorporating Renold’s (2018) method of giving participants a chance to express themselves. It would have been unrealistic to simply analyse information already researched by others in different countries. As Law (2009) emphasises, ‘it is the job of inquiry to discover and describe the realities as best may be’. Thus, in the course of this research, the practical inquiry that was done during STEM lessons has made it possible to unpack the concept of STEM Education.

3. METHODOLOGICAL REVIEW

While Arts-Based Education Research (ABER) seems as old as its’ first introduction in 1975 by Eisner (1998, as cited in Pentassuglia, 2017), the amended terminology of the research approach to Arts-Based Research (ABR) by McNiff (2011, as cited in Pentassuglia, 2017), has given it its’ new acronym ABR as known today. In this case study, ABR is used because of reasons connected to the definition of ABR as a creative research approach. One of the arguments in favour of ABR that is fitting to the context of this case study is given by Greenwood (2012, as cited in Pentassuglia, 2017), that ‘practices based on the ABR approach respond to the need to both bring out and share understandings and phenomena that are difficult to read properly through traditional approach’.

With reference to his argument, this case study specifically relates to the approach of using ABR as a means of better understanding how STEM education has had an impact on students as young as those in grades 3, 4, 5 and 6 who have been the focus of this study. It is significant because researching about it the traditional way as in using others’ literature to unpack the concept of STEM education would have been very different from the findings that will be discussed in the latter paragraphs. This view on ABR as a qualitative approach, is reinforced by St. Pierre (2013a, as cited in Wolfe, 2017), who makes us notice that ‘what is affectively felt in fluxing relation by the researcher (and participants and virtual audience) makes the data, rather than simply what is deciphered through a hierarchical organisation that is static qualitative coding and thematic analyses based on words as “quasi-numbers”’.

As a creative approach, ABR enables the researcher to actively participate in data collection. It also gives the power to analyse findings and make personal critical review of the findings which would have only been reviewed through the lances of others, through the traditional approach. Such research methods give researchers a voice in contributing to help shape systems where need be. Others in support of this approach have noted that the arts-based method as an indirect form of communication has proven to be effective in changing stands of power holders and experts, enabling a dialogue that creates culturally sustainable aid (Huss, Kaufman, Avgar & Shouker, 2015). This statement supports the fact that ABR can give a person that power to make a difference through finding out or showing something from primary sources collected.

4. METHODOLOGY

Arts Based Research (ABR) has been used in conducting this case study. It is a creative approach because the focus was not on gathering already researched data, but on actually getting involved in the research with

participating students in order to source valuable information to enlighten the issue. This argument is further understood when viewed from Law's (2009) perspective of methods as techniques for describing reality and treating knowledge practices as more or less performative. By getting involved with the participants of grade 3/4GW and 5/6Q, better understanding of their stories about STEM education and especially how it affects their learning has surfaced. The idea of being an active participant in the research is valued more when considering Davies' (2018) argument that 'we don't obtain knowledge by standing outside the world; we know because we are of the world and that we are part of the world in its differential becoming'.

This research used photography, interview, and observation plus active participation by the researcher, to source information from the participating students and from the classes that attended in general. The research method preference is influenced by Taylor (2017) who claims that 'the anthropocentric assumptions of qualitative inquiry posit the role of the researcher as the one whose job is to capture and understand perspectives, usually via dialogue and try to give them voice'. Using photography is a method that was aimed to capture active and fun moments of the participants as they were 'caught in the act' especially when unaware of the researcher taking a picture. This was done without exposing the identity of the participants.

With reference to photography, interview, observation and active participation, there were processes followed before attending the two classes. I had to apply for a Working with Children Check (WWCC) as a volunteer in Australia. After successfully obtaining a WWC card, I was able to be part of the class as an active participant during their scheduled STEM lessons. All these happened after a negotiation over emails to and from the school's secretary and the principal.

The other process that was also done before actually taking photos, doing interviews and recording students was the sending of a consent form with an explanatory statement from the researcher. The school principal helped in distributing the consent forms which were signed by the parents. Though there may be other detailed findings on how STEM education has an impact on students learning and engagement, this research is basically done with the understanding that research done at different settings are not always the same and thus are unique in their own rights. This is supported by Law and Mol (2001, as cited in Law, 2009) that truths are not universal.

5. PARTICIPANTS / MATERIALS / PROCEDURES

After negotiations and confirmation, participants of 3/4GW and 5/6Q classes were confirmed to undertake research on STEM education. It should be noted that the total number of 3/4GW class is 24 students and 5/6Q class is 26 students, and that despite all being part of the lessons, only 12 3/4GW students and 9 5/6Q students were actively involved in interviews, photography, questionnaire and videos recorded for analysis purposes.

A detailed overview of participants that took part in the voice recorded interviews, the questionnaire, photography, video and the recordings that were done without the students and the teacher's knowledge, has formed part of the supporting documents to this research. A transcript from an interview between the researcher and 3/4GW girls also proved to be raw evidence to results that will be discussed in this research report. Moreover, only one teacher is specialised in teaching STEM education lessons at Stem primary school.

The collection of data through interviews, recording, shots and videos was done using an iPad tablet. Despite the challenge encountered in using appropriate devices, all data collected, is of standard.

Before the lessons were attended, a scheduled time was given by the secretary to attend STEM lessons for 3/4GW and 5/6Q. Since Lego lessons were newly implemented at the school, 40 to 80 minutes was devoted to doing STEM through Lego lessons at the STEM lab. I was able to see 5/6Q class on Mondays from 9:40am to 10:20am and the 3/4GW class on Wednesdays from 11:45am to 1:05pm. From observation, the 3/4GW had more time of 1 hour 20 minutes a week, while 5/6Q only had 40 minutes of STEM lessons in a week. Because of this, data collected from 3/4GW seems more detailed than data collected from 5/6Q.

The first visit to each class was for observations to familiarise myself with the students and the teacher's teaching style. Since only three weeks was scheduled for active participation in attending classes, interviews and recordings were commenced earlier than scheduled. Timing to gather detailed data was a challenge. Despite that, interviews were conducted for 5/6Q male and female participants during their first contact of Lego lesson. The 3/4GW class however were interviewed, recorded and taken photos of during their second contact Lego lesson.

Each interview was done in another room within the STEM lab, especially away from the other students

and their teacher. The focus of the interview was on investigating whether there was active learning taking place. This methodology leans towards an epistemological assumption concerned with how knowledge can be created, acquired and communicated (Cohen et al., 2007, p.7 as cited in Scotland, 2012). Also, recordings of students conversing with their teacher was taken while they were unaware. This was purposely done to capture the innocence of the teacher to/from student interaction, without the researcher interfering.

Due to the ethics surrounding the explanatory statement in the consent form, the names of the transcripts of the recorded lessons, interview with their teacher and other students, have been purposely faked. It will however be used as an input to clarifying certain aspects in the findings and discussion sections. Furthermore, the shots were taken at an angle that would not directly expose the identity of the student. Nutbrown (2011 as cited in Allen, 2015) correctly argues that as a researcher, photography in art-based education research is used to help with interpreting what has happened during the research event, focusing on children's learning experiences.

Procedures were followed to collect data during and after Lego lessons, and time was arranged with the teacher, for participating students to complete the questionnaire in a sitting. All anticipated activities and data collection were completed as planned by the third week of observation.

6. RESULTS AND DISCUSSION

STEM education through Lego lessons has impacted how students acquire knowledge and how it motivates them to learn. With reference to the questionnaire, the table (*Table 1*) reveals the results in percentage. The results analysed in the table indicate the following logical conclusions; that in 3/4GW class, the majority of the students indicated that they are always excited to go for all STEM lessons, in contrast to the 5/6Q students who preferred to go only sometimes.

Firstly, their reasons for attending STEM in question 6, shows that the majority of 3/4GW students attend because practical activities done, help them better understand how things work. The 5/6Q students had a balanced response of going to class for practical work, for fun with friends and for the love of learning outside of the usual classroom setting.

Table 1. Results of questionnaire responses in percentage

Questions/Purpose of Question	Class	Explanation in Percentage	Combination of two classes result
Q1. Identifying students' motivation level during a Lego lesson	3/4GW	50% voted yes 30% sometimes 20% most times 0% not at all	34% voted yes 45% put sometimes 20% said most times 0% voted not at all
	5/6Q	10% voted yes 60% sometimes 30% most times 0% not at all	

Q2. Checks on students' Understanding /speed in completing a set of instructions in a Lego lesson	3/4GW 5/6Q	60% voted all the time 35% said sometimes 5% voted most times 0% said never 0% said all the time 70% voted sometimes 30% said most times 0% voted never	35% voted all the time 45% said sometimes 20% said most times 0% said never
Q3. Checks on factors hindering progress in accomplishing lesson objectives.	3/4GW 5/6Q	6% blamed timing 4% said it's too difficult 10% blamed it on disturbances from friends 40% said it's due to mistakes that they must fix before continuing 40% said they always complete tasks on time 45% blamed timing 10% said it's too difficult 10% blamed it on disturbances from friends 45% said it's due to mistakes that they must fix before continuing 0% said they always complete tasks on time	20% blamed timing 8% said it's too difficult 12% blamed it on disturbances from friends 45% said it's due to mistakes that they must fix before continuing 15% said they always complete tasks on time
Q4. Checks on students' knowledge acquisition. Especially concepts learned in class	3/4GW 5/6Q	30% said they remember the word all the time. 60% voted sometimes 10% said not remembering at all 0% said they remember the word all the time. 70% voted sometimes 30% said not remembering at all	25% said they remember the word all the time. 70% voted sometimes 5% said not remembering at all

Q5. Measures the child's level of understanding the processes Followed / knowledge acquired.	3/4GW	65% remembered fixing a problem 5% couldn't remember 25% remembered fixing some problems 5% said they don't face problems	35% remembered fixing a problem 5% couldn't remember 45% remembered fixing some problems 5% said they don't face problems
	5/6Q	10% remembered fixing a problem 10% couldn't remember 80% remembered fixing some problems 0% said they don't face problems	
Q6. Identifies factors that motivate students to attend STEM Lessons.	3/4GW	60% said practical activities help them understand how things work 30% said love learning outside of the usual classroom 10% said they just want to play with friends 0% said they're not always excited 32% said practical activities help them understand how things work	45% said practical activities help them understand how things work 30% said love learning outside of the usual classroom 20% said they just want to play with friends 5% said they're not always excited
	5/6Q	32% said love learning outside of the usual classroom 32% said they just want to play with friends 4% said they're not always excited	

Q7. Checks on students approach to revisiting forgotten concepts learned in class	3/4GW	5% said to take note when the teacher explains it 70% said to ask the teacher to give them the concepts learned. 25% said it does not matter, as long as they can solve a problem.	10% said to take note when the teacher explains it 70% said to ask the teacher to give them the concepts learned. 20% said it does not matter, as long as they can solve a problem.
	5/6Q	15% said to take note when the teacher explains it 70% said they just want to play with friends 15% said it does not matter, as long as they can solve a problem.	
Q8. Checks on students view on the significance of Lego lessons/STEM education in the real world	3/4GW	90% voted yes to the importance of STEM lessons 10% said they're not sure 0% said no	80% voted yes to the importance of STEM lessons 15% said they're not sure 5% said no
	5/6Q	80% voted yes to the importance of STEM lessons 5% said they're not sure 15% said no	

Despite the more time allocated for STEM lessons, results indicate that timing is a major factor when trying to complete a set of Lego instructions. Significantly, both classes agreed that making mistakes during class and redoing the same process causes many delays. Also outstanding in the responses is that both classes opted to ask the teacher to give them words not understood or remembered during class time.

Very few said to take note during class time. These results indicate that the interests of students depend mostly on doing practical activities rather than the theory part of the lesson. Through observations, it is obvious that students enjoyed the practical part of problem solving more than the theory part of note taking on new words introduced during STEM lesson. From the findings shown through questionnaire, the majority of the participants indicated that STEM education can help them to understand how to solve problems in the real world.

Secondly the following photographs shown below (Photo 1, Photo 2, Photo 3, and Photo 4), portray teamwork by the students in solving problems together. It also shows students testing their completed boats, and being assisted by the teacher or other students, when they need help.



Photo 1: A team of 3/4GW girls working together to build a sailing boat. *Photo by Annette*



Photo 2: A 5/6Q Student discussing instruction paper with the other student
Photo by Annette



Photo 3: Year 3/4GW students testing their completed sailing boat. *Photo by Annette*



Photo 4: Teacher assisting a 5/6Q student with instructions. *Photo by Annette*

Moreover, the interview conducted with the 3/4GW girls, shows the team work that exists in working together to resolve problems that arise during the course of the Lego lesson. Despite the results showing students not remembering words introduced in class, it is evident through their participation and interest, that they do learn better when placed in a practical setting. Such results would not have been possible without the ABR approach which regards truth as not universal and in which methods only work to make reality in particular places (Law. 2009).

Finally, but not the least, results from the interviews done shows a trend that locals (Australians) were more interested in the practical STEM lessons while my two daughters favoured learning the traditional way. Both

can be understood from the perspective that they have not been exposed earlier in inquiry-based learning, which is mostly used and encouraged in Lego lessons.

Interview with participating students (2nd May 2018)

Anne (researcher): *Okay, Hi girls.*

All: *Hi*

Anne: *So what did you learn from today's STEM lesson?*

Hidi: *Um....*

Sow: *That I thought because my boat would sink but since we've even up the back part of the boat, it actually was even.*

Jess: *Um...I learned that um...um...if you put more weight on the back, it wouldn't nose dive. It would stay upright like, so instead of having heaps of weight at the front, and sink nose diving. It would actually keep it flat, so that's what I learned.*

Tilda: *I learned today was um...when you put um...a couple more tires on, you balance it out. At the end I was gonna put a tire at the front, another tire at the front, another tire at the back and then four then two at the back as well and then two at the front like...but I didn't get to test that out. But I learned that um... the more tires you have, the more float it is.*

Anne: *Thank you.*

Oliv: *Um...I learned that um...that if you put wheels on it, it will float more than if you don't have them.*

Anne: *Okay and....*

Hidi: *Yeh I also learned that the wheels made it float more than if you didn't have them.*

Anne: *Lyn...*

(Background noise from other students)

Lyn: *Um...I learned that.... if you...if you put um...if you put like a lot of like Lego on it won't really float. Yeh...*

Anne: *Okay, did you come across any problems while building the boat?*

All: *Yeh.*

Jess: *Ah...I didn't really...All of us...is...when we put all that SpongeBob, people and family, it would, it would like break but like if we'd made it more like steadier, it would, it would work.*

Anne: *ah...ah...*

Scow: *Um... I didn't have no problems.*

Jess: *But we had a problem with nose diving.*

Tilda: *Yeh we had problem.*

Hidi: *Cos the um...the points of the weight won't spread around evenly which means it would sink at one point.*

Anne: *How did you solve the problem when you..... you know faced a problem.*

Hidi: *We um...added..... so we had like two tires at the back and one tire at the front, we added to make two tires at the front..... spread the wait evenly.*

Anne: *Was it easy for you to follow the instructions?*

All: *Yesss/Nooo*

Hidi: *The placing of the blocks, trying to count which holes they were going in... and...that was tricky cos you can't see properly.*

Jess: *When we tryna make the bench part where the sail sticks out..Maco did that part..but like he like..it was done wrong so we had to redo it..cos um he was copying the picture and the picture wasn't really that clear..*

Hidi: *...it was really hard.. Jess: ..but um...*

Anne: *But you managed to solve the problem... Jess:...ye ye..*

Anne: *Did you all finish your boat?*

All: *Yeh...haha..that's yes yes yes yes yes yes yes ...haha*

Anne: *Okay, so what often inspires you or makes you feel excited about STEM lessons?*

Jess: *Umm..this is a tough one...*

Hidi: *...I know...I like modifying the things Jess: Yeh yeh.. modifying*

Hidi: *I don't know but cos we did a race car and you could race them*

Oliv: *What excites me to do is that...I get to learn all these new things that I haven't learned before.*

Jess: *I like that because..we have a big bag of Lego at home that like ...there's instructions, but we don't know where the pictures are...and like now at STEM we have Lego and then actually see the actual pieces that we...*

Hidi: *...know where they are...*

Jess: *...yeh..cos at home we just have different Lego pieces in one place*

All: *haha*

Anne: *Um you also have Maths lessons, right?*

All: *Yeh*

Anne: *In the classrooms?*

All: *Yeh*

Anne: *Um so would you say you love maths lessons more or STEM lessons?*

All: *Yeh/Ummm/Maths/Both (all shouting at the same time)* Jess: *Depends...times tables and divisions...haha*

Scow: *Nope ...nobody likes times tables...if it's times tables and divisions, no* All: *haha*

Anne: *Okay um..what would you tell your other friends about STEM lessons...if you were to say something about STEM?*

Tilda: *Um..that it's quite exciting and enjoying because you get to make stuff and you get to test them out with mottos*

Hidi: *I would probably say that um it's fun and you get to um..not many schools get experience this so um ..I mean it's a great experience.*

Jess: *Um it's a great experience because like...you might not have Lego at home so you might think... "oh Lego might be fun...I might enjoy this" because you don't have a lot of fun at home so you don't know if it's gonna be fun or not so..but yeh..I really like Lego so..*

Anne: *Okay thank you and you go back to your class*

All: *Thank you, bye...*

7. PERSONAL REFLECTION

To sum up, below are my personal views on creative/qualitative research. Identified are the phases approached in this creative research and the critical reflections on decisions in each phase of the research. ABR is a methodological approach that I saw fit in conducting this research on STEM education. Personally, I think using a creative research approach to conduct this case study was significance because it allowed for direct involvement in sourcing information and it was more creative and qualitative. As Tracy (2013) states, qualitative research is about immersing oneself in a scene and trying to make sense of it.

Apart from direct involvement, ABR has further enhanced my research and analytical skills as I used my own perspectives to create specific research questions that were aimed at trying to further understand the participants in relation to my topic. Creative researches in its true sense, has given a researcher like me, an opportunity to create something out from nothing. This is because, when drafting questions to investigate more on inspiring topics, it gave me an opportunity to grow and mature as a researcher and to understand the culture in which STEM education is taught. As Tracy (2013) claims, apart from qualitative research being an excellent approach to studying contexts that interest you, it provides insight into cultural activities that might otherwise be missed in a structured survey or experiment.

In identifying the different phases to this case study, I mostly reflected on education-based issues that are challenging to implement back in PNG. It is because of this, that I chose STEM education as my research topic.

The second phase of this case study mostly involved formalities. I had to make contacts and wait for responses before I proceeded with the actual research. This however, was not really challenging because parents, the principal, secretary and others involved were prompt in responding.

The third phase involved the actual conducting of the research. I saw this phase as very important as it helped me uncover unknown knowledge, analyse them, and thus turn it into research findings. This can be better understood when referring to Tracy's (2013) concept of 'thick description' that explains such research as a period of investigating circumstances present in that scene, and moving forward towards grander statements and theories.

I learned a lot from this phase of the research since it opened my mind to understand the difference between ‘traditional’ approaches to teaching as compared to creative approaches to teaching.

The final phase of this research, has been both intriguing and challenging. The different data collection techniques that are used, called for more analysis from a specific approach. This was a challenge because of the time frame to complete the research.

It is interesting to note that even though there is an emphasis on problem solving as a core of any STEM lesson in Stem primary school, there is still a need to research further on how students can be made to understand concepts. Especially understanding concepts that seem so difficult for them to understand at such an early age and in the context of a STEM Education methodological approach.

8. CONCLUSION / LIMITATIONS

In conclusion, everything explained, reasoned, argued and stated about creative research that was conducted, succeeded with each phase and was completed accordingly as scheduled. Despite the anticipated challenges in the course of the research, every stage of the research was finally accomplished. The principal and the secretary were very helpful and prompt in responding to emails and specially making sure those classes were held on time as scheduled.

The limitations of this research arise within the context of timing and the number of participants involved. Due to a short period of time in conducting the research and the limited number of participants, results shown may not truly portray the true essence of the impacts of STEM Education on students. Because of this, there are still greater gaps to fill, especially in understanding how STEM education can effectively help students in acquiring knowledge while at the same time being motivated in a STEM learning environment.

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Pacific short stories on Traditional Agriculture to the Sustainable Development in the Pacific

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Abstract: The Pacific Islands face growing challenges related to food security, climate change, and modernization, threatening traditional agricultural knowledge and practices. While scientific and technological solutions are crucial, the role of literature - particularly short stories - in preserving and transmitting indigenous knowledge remains largely unexplored. This research examines how Pacific short stories depict traditional food crops, farming techniques, and the cultural significance of agriculture, providing valuable insights into sustainability and resilience within island societies. Drawing on narratives from both Anglophone and Francophone Pacific authors such as Wendt, A. (1976), Hau'ofa, E. (1993), Kurtovitch, N. (2000), Gorodé, D. (2005), and Kurtovitch, N. (2011), Tavo, P. (2015), this study highlights how literature preserves oral traditions, documents indigenous farming practices, and reflects the evolving relationship between Pacific communities and their environment. These stories emphasize the importance of food sovereignty, seasonal cycles, and the spiritual and communal dimensions of agriculture. They also reveal tensions between modernization and the preservation of traditional agricultural systems, Nabobo-Baba, U. (2006) and Campbell, J.R. (2015). Through a literary and ethnographic analysis, this study argues that storytelling serves not only as a means of cultural preservation but also as a potential tool for education and policymaking. Integrating literary narratives into discussions on sustainable agricultural development helps bridge the gap between traditional knowledge and technological innovations, ensuring a more holistic approach to food security in the Pacific. This study aligns with the PIURN 2025 theme by emphasizing how cultural narratives can complement and enrich technological advancements for sustainable development tailored to the realities of the Pacific Islands.

Keywords: Pacific literature, short stories, traditional agriculture, food security, indigenous knowledge, sustainability, cultural preservation.

Biography: Lina VUTIALA is a lecturer and researcher at the School of Education of the National University of Vanuatu in Port Vila, Vanuatu, specializing in literature and educational sciences. With 27 years of experience in teaching French as a Second Language, she trains future teachers in didactics and literatures. She holds two Master's degrees and is currently pursuing a PhD focused on Francophone short stories in the Pacific as a vehicle for indigenous knowledge and cultural resistance. Her research intersects orality, ecopoetic, and postcolonial pedagogy. She actively advocates for the integration of traditional narratives into sustainable educational and cultural policies across the Pacific Islands.

1. INTRODUCTION: CONTEXT, STAKES, AND OBJECTIVES

The island Pacific, rich in cultural and ecological diversity, is currently facing increasing tensions between ancestral traditions and contemporary upheavals. Oceanian societies are undergoing the tangible effects of climate change - rising sea levels, soil erosion, and seasonal disruptions - that undermine their long-standing relationship with the natural environment. Compounding these environmental challenges is a growing dependence on imported goods, which threatens local agricultural practices and deeply alters dietary habits, village economies, and traditional ways of life. Simultaneously, the erosion of languages, narratives, and inherited knowledge systems

compromises the transmission of endogenous cultures—despite their capacity to offer context-specific responses to current challenges.

In this context, literature - and more specifically the short story - emerges as a space of mediation and resistance. Often overlooked in literary studies, the short story, through its concise and potent form, provides a privileged medium to address contemporary crises and to envision alternative futures. This article aims to examine how contemporary Francophone Oceanian short fiction engages with the issues of traditional agriculture and sustainable development.

Two main lines of inquiry structure this analysis: first, the valorization of ancestral agricultural practices through narratives rooted in natural rhythms and collective memory; second, the critical stance these texts adopt in relation to exogenous development models. By intersecting literary analysis with ecocritical perspectives, this study explores the role of fiction in current symbolic and political struggles, particularly in relation to local aspirations for food sovereignty, ecological justice, and the preservation of cultural identities.

1.1 Theoretical Framework: Agriculture, Culture, and Transformation

The analysis developed in this article is situated at the intersection of several complementary critical frameworks: environmental humanities, postcolonial criticism, and the *ecopoetic* of the Global South. Together, these approaches shed light on how contemporary Oceanian short fiction articulates a discourse on agriculture that extends far beyond productivity or purely utilitarian frameworks. Agriculture is thus examined not only as a means of subsistence, but also as a cultural, symbolic, and narrative system - deeply intertwined with the history, identity, and political struggles of Pacific Island societies.

1.2 Environmental Humanities: An Ecosystemic Reading of Narratives

Environmental humanities reposition literature within its interactions with ecosystems and global crises. The concept of *ecopoetic* refers to a mode of writing about nature that engages ethics, culture, and politics. In the Pacific context, this approach highlights narratives as mediators between orality, agriculture, and local cosmologies. Short stories thus become “ecologies of speech” (Abram, 1996), in which cultivated landscapes are traversed by memory, ritual, and transmission, forming a mode of resistance against dominant development logics.

1.2. Postcolonial Criticism and Agricultural Sovereignty

Postcolonial criticism sheds light on the legacy of land dispossession and the erasure of traditional agricultural practices imposed by colonial rule. Oceanian short stories revalorize agricultural gestures as acts of cultural and political sovereignty. They challenge productivism models in favor of sustainable, endogenous knowledge systems, positioning fiction within the broader struggles for food autonomy, land rights, and social justice. This narrative reversal constitutes both a literary and political response to dominant development discourses and to the marginalization of island societies.

1.3. Ecopoetic of the Global South: Narrating the Environment from the Periphery

The *ecopoetic* of the Global South analyzes ecological representations emerging from marginalized contexts shaped by extractivism and climate change. In contrast to mainstream ecological discourse, it values inhabited, cultivated, and vulnerable ecologies. In Oceanian short fiction, gardens and subsistence systems become spaces of resistance and hope. Writing performs a symbolic reterritorialization, linking ancestral knowledge to contemporary concerns with ecological justice and autonomy. These narratives form a counter-literary archive that redefines development according to the needs and values of Pacific peoples.

1.4. Synthesis: Culture at the Heart of Resilience

By intersecting these three approaches, agriculture emerges as a central pillar of cultural identity and social resilience in the Pacific. These short stories do more than depict rural life—they offer a critical rethinking of the

links between ecology, culture, and development. They demonstrate that the integration of cultural dimensions into sustainability policies is essential to the emergence of more autonomous, equitable island societies in tune with the rhythms of life.

2. LITERATURE REVIEW: THE SHORT STORY AS A CRITICAL SPACE FOR THE INTERSECTIONS BETWEEN ECOLOGY, CULTURE, AND DEVELOPMENT

Recent literary studies on Oceania highlight the capacity of the short story to articulate the entanglements of ecology, identity, and politics. As a concise narrative form, the short story enables a sharp expression of the social, environmental, and cultural tensions experienced by island societies, making it a privileged medium for rethinking development dynamics and valorizing indigenous knowledge systems.

In her cycle *Les Furtives* (2020), Émilie Notéris demonstrates how the short story captures moments of rupture between extractivist modernity and sustainable ways of life. She frames it as a tool of narrative resistance and ecological alliance, capable of forging connections among humans, non-humans, and living environments.

Déwé Gorodé, a foundational figure of Kanak literature, illustrates in *Sous les cendres des conquies* (1985) the spiritual and cultural embeddedness of agriculture. Her poetic short stories re-inscribe agrarian practices within a network of rituals, inherited knowledge, and sacred spaces, while denouncing their gradual erasure under the pressure of modernity, urbanization, and wage labor. She thereby asserts that the transmission of agricultural knowledge is inseparable from the struggle for cultural sovereignty.

Similarly, Marcel Melthérorong, in *Tôghàn* (2007), explores the role of agriculture in the identity quest of young ni-Vanuatu. Through narrative fragments resembling short stories, he portrays cultivation of the land as an act of cultural reappropriation in the face of globalization.

These works collectively demonstrate that the short story serves as a genuine literary and political laboratory. It offers a space to question the relationships between ecology and identity, and to articulate, through fiction, critical propositions for imagining sustainable ways of inhabiting Pacific Island territories.

3. LITERATURE AS ARCHIVE: ORAL AND WRITTEN TRADITIONS

In a context marked by globalization and cultural erasure, the Oceanian short story plays a central role in the transmission and re-creation of endogenous knowledge systems. Through its brief and concentrated form, it reconfigures oral narratives into a vibrant, contemporary written mode. It functions as a dynamic archive in which agricultural practices, local cosmologies, and ancestral gestures are reactivated. This literary process embodies both cultural resistance and future projection, embedding the land and its associated knowledge within a shared symbolic, political, and spiritual horizon.

3.1. The Short Story as a Vehicle for the Transmission of endogenous Knowledge

The short story ensures the continuity of endangered agricultural knowledge by adapting it into an accessible, affective, and contextually grounded literary form. In *Quand le cannibale ricane* (2015), Paul Tavo illustrates this dynamic through the story of William, who rediscovers his customary garden. Fiction connects agricultural gestures to collective memory, transforming the garden into an embodied text. This return to the land represents a dual movement: the preservation of a fragile local heritage and the rehabilitation of ecological knowledge devalued by dominant systems. As a counter-discourse, the short story challenges the exclusion of peasant knowledge from educational and agricultural policies. It mobilizes the imagination and emotions, serving as an effective cultural mediator. Through narrative, it becomes a tool of resistance, popular education, and identity transformation.

3.2. The Short Story as Cultural and Political Advocacy for Sustainable Agricultural Practices

The short story also functions as a literary manifesto advocating for sustainable agriculture rooted in local traditions. In *L'Agenda* (1996) by Déwé Gorodé, a woman's return to taro cultivation symbolizes a rejection of food dependency and a reappropriation of identity. Taro farming becomes a metaphor for a self-sufficient, rooted model of living. The text implicitly critiques urbanization and externally imposed development policies, instead valorizing slowness, regeneration, and intergenerational transmission. Through poetic language, Gorodé elevates subsistence farming as an act of cultural and political resistance, redirecting the imagination toward ecological and communal sovereignty.

3.3. The Short Story as a Medium of Agricultural Memory

The short story enables the reactivation of agricultural memory, embodied in gestures, narratives, and myths connected to the land. In *Nouvelles calédoniennes* (2012), Waej Génin-Juni's short story *Hula* emphasizes the link between agrarian culture and clan memory, portraying land as an ancestral gift and sacred space. Similarly, in *Tôghân* (2007) by Marcel Melthérorong, a young man rediscovers agricultural knowledge through dialogue with elders. These stories highlight the resilience of ecological practices amid cultural ruptures. The short story isolates symbolic scenes—planting, transmission, ritual—that serve as markers of a memory both affective and political. This memory is not nostalgic but dynamic, revitalized through fiction as a living archive and a tool for cultural regeneration.

3.4. The Short Story as a Critical Tool against Development Models Detached from Local Realities

The short story serves as a vehicle for social critique, confronting development projects that are exogenous and disconnected from local realities. In *Les champs de la terre* (2015) by Pierre Gope, a village community faces the threat of a foreign agro-industrial project. Behind economic promises lie land dispossession and ecological collapse. The fiction reveals the incompatibility of such models with communal logic. The short story thus produces a counter-narrative that deconstructs technocratic discourses and reaffirms local knowledge as fundamental to any sustainable transformation. Rooted in local contexts, it becomes a space of discursive resistance and cultural affirmation.

3.5. The Short Story as a Reflective Medium on the Interrelations between Culture, Ecology, and Development

The short story provides a reflective space for exploring tensions between modernity and tradition, development and ecological integrity. In Oceanian tales and legends, a young female farmer hesitates between inherited techniques and intensive agriculture. The narrative gives voice to elders, dreams, and even personified plants to construct an ethic of reciprocity and care. Here, the short story becomes a laboratory of thought, interrogating the conditions of sustainable development. It offers narratives in which the land is a subject, traditions are living resources, and agricultural choices are existential stakes. The short story embodies a committed cultural ecology based on transmission, environmental justice, and the sovereignty of island peoples.

4. CASE STUDIES: IN-DEPTH ANALYSIS OF THREE OCEANIAN SHORT STORIES

4.1. Paul Tavo, *Quand le cannibale ricane* (2015)

In one of the narratives included in this hybrid collection, Paul Tavo depicts the return of a young man, William, to Lamap, where he reconnects with the customary garden of his childhood. This garden, as a site of transmission for ancestral agricultural knowledge, becomes a space of memory and identity reappropriation. Tavo portrays agriculture as a symbolic and political system, in direct opposition to colonial narratives of progress that devalue

traditional practices. Through poetic prose, the short story transforms the land into a vector of cultural sovereignty and autonomy. It affirms literature's role as a vehicle for ecological knowledge transmission and community resilience within a postcolonial context.

4.2. Déwé Gorodé, *L'Agenda* (1996)

In one of the short stories from *L'Agenda*, a Kanak woman leaves the city to return to taro cultivation in her clan's valley. This return to ancestral practices embodies both an act of identity reclamation and a critique of colonizing development models. Gorodé draws a powerful parallel between agricultural fertility, feminine memory, and land sovereignty. Agriculture becomes an act of resistance grounded in a relational ethic of reciprocity and sustainability. The story mobilizes a postcolonial ecocriticism by interweaving social justice, customary memory, and the ecology of living systems—positioning literature as a space for political agency and spiritual regeneration.

4.3. Chantal Spitz, *L'Île des rêves écrasés* (1991)

Within this fragmentary novel, Chantal Spitz includes a striking episode: a former farmer sees his land expropriated to build a luxury hotel. This conflict crystallizes the opposition between an extractivist model of development and a cosmology deeply rooted in the land. The text denounces the marginalization of agricultural, linguistic, and cultural knowledge. Through poetic language interspersed with *reo mā'ohi*, Spitz constructs an aesthetics of loss and resistance. The short story becomes a multilingual space of ecological memory, interweaving oral transmission, political critique, and disillusionment with the excesses of neocolonial tourism.

Together, these three case studies demonstrate how short fiction can articulate ecological critique, agrarian memory, and cultural transmission, while also serving as a catalyst for endogenous sustainable development.

5. LITERATURE AND POLITICS: LINKING NARRATIVES TO DEVELOPMENT PRACTICES

Contemporary Oceanian short fiction extends beyond the aesthetic or symbolic register; it can be mobilized in educational and political contexts as a lever for transformation. When integrated into school curricula, it promotes ecological awareness, intergenerational transmission, and the valorization of local knowledge—as demonstrated by the textual studies of Déwé Gorodé and Paul Tavo implemented in schools in Vanuatu and New Caledonia.

Beyond the sphere of education, institutions such as the Pacific Community (SPC) and UNESCO Pacific have recognized the cultural value of literary narratives in their sustainable development initiatives. Educational brochures and awareness campaigns have incorporated literary excerpts to resonate more effectively with island imaginaries and to anchor ecological concerns within culturally meaningful frameworks. Literature thus becomes a channel for the appropriation of sustainable practices grounded in strong cultural and symbolic foundations.

Furthermore, fiction plays a key role in social and political mediation: it brings to light the tensions surrounding land, knowledge transmission, and cultural erosion. Its narrative power creates spaces for dialogue between local communities and policymakers. In this sense, fiction functions as a form of narrative diplomacy, capable of influencing agricultural and environmental policy agendas.

Ultimately, Oceanian authors, by connecting storytelling with action, reinvent the role of literature—not merely as a witness to social change, but as a strategic tool for development, bearing memory, commitment, and social transformation.

6. CONCLUSION: IMPLICATIONS AND FUTURE DIRECTIONS

The study of Francophone Oceanian short fiction reveals the extent to which literature can serve as a strategic vector for sustainable development in Pacific Island contexts. By weaving together oral memory, ecological

awareness, and cultural rootedness, these literary narratives reaffirm the centrality of traditional agriculture not only as intangible heritage, but also as an identity- and politics-bearing matrix. They remind us that land is not merely a source of subsistence, but a site of memory, transmission, and social regeneration.

Through the narration of agroecological practices, endogenous knowledge systems, ancestral gestures, and resistance to exogenous development models, the short story fulfills a powerful mediating function—bridging past and future, orality and writing, culture and politics. Whether it is the revalorization of taro cultivation in Déwé Gorodé’s work, the garden as a space of reconciliation in Paul Tavo’s fiction, or the agricultural gesture as a bearer of memory in Marcel Melthérong’s narratives, each text offers a situated vision of development—one that respects local balances and cultural inheritances.

Thanks to its brief and accessible form, the short story emerges as a tool for ecological awareness, intercultural education, and social critique. It constitutes a space of resistance against cultural homogenization, as well as a laboratory for rooted narrative solutions. In this light, literature contributes to a mobilizing “narrative ecology,” in which stories become forces for action, tools for governance, and instruments for reshaping development imaginaries.

This research therefore advocates for increased institutional recognition of Oceanian literature in educational, cultural, and environmental policies. There is a pressing need to support regional literary creation, to encourage the circulation of works in local languages and in translation, and to harness digital tools to expand access to these narratives. By linking fiction and action, memory and innovation, these short stories offer an alternative vision of the future: a future that is grounded, solidaristic, and sustainable—conceived from within the realities of the Pacific.

In this perspective, it is essential that public policies integrate cultural and literary dimensions more thoroughly into sustainable development strategies, particularly within the educational sector. School curricula in Pacific countries and territories should include works from contemporary Oceanian literature—especially short stories centered on traditional agriculture—to promote local knowledge and strengthen young people’s sense of cultural belonging. Such integration would help build a more contextual, multilingual, and ecosystemic education—one that connects academic disciplines to the lived realities of island communities. It would also be valuable to support rural writing residencies, intergenerational storytelling workshops focused on agricultural heritage, and digital platforms for the dissemination of literary texts in both local languages and French. In this way, literature—far from being confined to the symbolic domain—can become a strategic lever for empowerment, transmission, and the co-construction of sustainable development rooted in Oceanian realities.

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Leveraging Data Integration using APIs for Enhanced Data Analytics in Papua New Guinea

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Abstract: Data is the “New Oil”. In a fast-evolving technological world where the survival of organizations mostly depends upon technology, data is the catalyst that is driving business optimization, growth and success. Most successful organizations are data driven. They capitalize on the magical spell of data analytics. Data analytics plays a pivotal role in enforcing well informed decisions in strategic marketing and planning, new product development and other shifts that drive business growth and development across various sectors. Unfortunately, in Papua New Guinea (PNG), due to the splintered nature of diverse data systems and the incapability of interoperability poses significant barriers to effectively capitalize on the strengths of data analytics. Due to the involvement of traditional manual processes and the existence of data and systems in silos, the integration of data and advance data analytics remains a major challenge. This research explores the integration capability of Application Programming Interfaces (APIs) and the potential of leveraging it to address these challenges. It involves a mixed methods approach, consolidating qualitative interviews with data science and analytics professionals and quantitative analysis of case studies from both local and international organizations. It assesses the current state of data integration and analytics in PNG, taking into consideration the limitations of traditional and manual processes of data exchange methods. Significant findings have shown that API-driven data integration presents advantages for growth and efficiency. The study does not only reveal and promotes the rich advantages of API, instead it acknowledges and uncover the challenges that are to be attended for a successful implementation. It proposes a practical framework that is workable in PNG context for API adoption in data integration, which includes a customize architectural design for API Integration. The significance of securing APIs and the transmission of data safely between different systems is echoed in the proposed architectural design. The research exposes the transformative potential of APIs in the space of data integration and analytics in PNG. By embracing API-based data integration, diverse organizations can unlock more reliable and timely insights, ultimately supporting data-driven development and policy-making in the country that are based upon reliable data.

Keywords: Data, Analytics, API, Integration, Interoperability, Silos

Presenter or Main Author Biography: Steward Kalan is currently a Master’s of Philosophy student in School of Mathematics and Computer Science, PNG University of Technology. He is Data Analyst by profession. He has been working in the industry as Data Analyst for four (4) years. For the four (4) years of industry experience, he has been working with National Superannuation Fund (NASFUND) and Bank South Pacific (BSP) or BSP Financial Group. He is currently serving as a Data Analyst with BSP, attached with the Central Data Analytics Business Unit. Mr. Kalan holds a Bachelor’s Degree in Computer Science from the Papua New Guinea University of Technology. His main research work focuses on Leveraging Data Integration using APIs for Enhanced Data Analytics in Papua New Guinea.

1. INTRODUCTION

In today’s data-driven world, the ability to access, analyze, and interpret data in real time has become vital for informed decision-making and strategic planning. Across the globe, organizations are increasingly adopting

modern data integration techniques to streamline operations and uncover valuable insights. One such method is through the use of Application Programming Interfaces (APIs), which allow seamless communication and data exchange between different systems, databases, and applications. This research focuses on how leveraging of data integration through APIs can significantly enhance data analytics capabilities in Papua New Guinea (PNG) - a nation that is gradually embracing digital transformation.

Data analytics in Papua New Guinea is often challenged by data silos, inconsistent data formats, and manual data handling processes, just like any other developing countries and some developed countries as well. Many government departments, businesses, and institutions still rely on legacy systems that lack interoperability. As a result, decision-makers face delays and limitations in accessing real-time, accurate data or most times, decisions are made or passed without data to justify their resolutions to a certain problem (decisions are not data driven). APIs provide a viable solution to these issues by enabling various systems to connect and share data in a standardized and automated manner (Stylos, J., 2009). When effectively implemented, APIs can bridge the gap between isolated datasets and enable integrated platforms for better data visibility, consistency, and reliability.

Globally, industries such as finance, healthcare, education, and logistics have already adopted API-driven integrations to optimize their operations and provide better services. These integrations support functions such as real-time data syncing, automated reporting, predictive analytics, and cross-platform access to key information. Papua New Guinea stands to benefit greatly from adopting similar technologies, particularly in areas like public service delivery, health information systems, financial reporting, and national monitoring and planning. The growing use of cloud-based services and mobile technologies in PNG further underscores the importance of API-enabled platforms for scalable and sustainable data integration solutions.

However, the adoption of APIs in PNG is still in its infancy, hindered by several factors including limited technical expertise, inadequate infrastructure, lack of data governance frameworks, and concerns over cybersecurity. These challenges necessitate a strategic approach to building capacity, enhancing infrastructure, and developing policies that support secure and scalable API deployment (Zibran, M., 2008). Additionally, collaboration between the public and private sectors can play a pivotal role in advancing data integration efforts and promoting data sharing across key sectors.

This paper presents the potential of API driven data integration as a transformative tool for enhancing data analytics in Papua New Guinea. By examining case studies, current practices, and technical frameworks, the study aims to highlight both the opportunities and challenges associated with API adoption. It will also provide actionable recommendations for stakeholders including policymakers, ICT professionals, and business leaders on how to implement and manage API ecosystems effectively to foster data-driven decision-making and national development.

In conclusion, as Papua New Guinea continues its journey towards digital transformation, embracing modern data integration techniques such as APIs is essential. Doing so will not only enhance analytics capabilities but also empower institutions with timely, accurate, and comprehensive data to address the nation's unique development challenges and opportunities.

2. DATA

In a fast-evolving technological world, data is the new oil. It is raw, unprocessed facts and figures that are collected from various sources for analysis, storage and processing. Have you ever wondered how your phone knows which ads to show you at lunch time? Or how the supermarket emails you with specials on your favorite products? It is not a coincidence. It is the work of data being put to use, encouraging you to buy more. Data is a sleeping giant, the maximization of its capabilities is like stepping into a portal of business improvement, success and growth in both private and governmental entities.

Data comes in different forms. Some of these forms include: numbers, texts, images and sensory readings but are not limited to these. Data is pivotal in this age rapid technology involvement in daily operations and strategy development as it drives decision making, supports innovation and enables insights through processes like:

- Data Mining
- Machine Learning

- Data Analytics

By nature, data can be classified into two (2) main categories, data can be either quantitative (numerical) or qualitative (descriptive). From these categories, data can be presented in two (2) types:

1. Structured
Structured Data is organized in predefined formats, often stored in databases or spreadsheets, making it easily searchable and analyzable.
2. Unstructured
Unstructured Data are such data as emails, social media posts and videos, does not have a specific format. This type of data requires sophisticated tools and techniques to analyze and derive insights for decision making. The proper collection, management and analysis of data can lead to powerful insights, helping organizations to optimize operations, predict trends and improve decision making. This paper discusses about both qualitative and quantitative data category that of structured data type.

3. DATA INTEGRATION

Data Integration is the process of combining or harmonizing data from different sources into a unified and coherent format that can be easily accessible for various analytical, operational and decision-making purposes.

In a growing digital landscape where data and the analytics capability are being prioritized by organizations for various business requirements, organizations typically cannot function without gathering data from different sources like databases, apps, spreadsheets, cloud services and others. Furthermore, the storage of data in different locations and formats contributes to the variation in the levels of data quality, which leads to data silos and inconsistencies.

The data integration process aims to overcome these challenges by bringing together data from disparate sources, transforming it into a consistent structure and making it accessible for analysis and decision making. There are different types of data integration in existence. The type of data integration chosen to be used differs as it is based on the needs and requirements of the stake holder. Here are some types of data integration:

1. Data Consolidation
This includes the ETL (Extract, Transform, Load) Process, where data is extracted, transformed and loaded or merged into a single centralized database or data warehouse from various sources.
2. Data Federation
Instead of physically moving data, this approach is done by the creation of virtual database that enables users to access or query multiple data sources as one. This approach works in databases when real time access is needed.
3. Data Propagation
This approach involves the replication or migration of data between databases in real-time or near real-time to ensure all the system in a distributed system have the latest data available.
4. Master Data Management
It gives priority in ensuring consistency in key data across an entity. This approach is all about maintaining single source of truth for essential business data to avoid discrepancies.
5. API Based Data Integration

This approach is common on cloud-based services or applications where APIs are used to allow different systems or applications to communicate and exchange data seamlessly with a secured connection.

6. **Big Data Integration**
For large scale data integration that handles vast amount of unstructured or semi structured data.

Listed above are just few of the many approaches that are used for data integration. This paper will discuss about the API Based Data Integration and its benefits in the space of integration.

3.1 Benefits of Data Integration

Data Integration is not just a concept just for discussion, instead it is a concept that have a lot of benefits in the data world. Here are some of the most pivotal and key benefits of data integration:

1. Improved Data Quality
2. Enhanced Decision Making
3. Streamlined Operations

4. APPLICATION PROGRAMMING INTERFACE (API)

An Application Programming Interface (API) is a set of protocols, tools and definitions that allow different software application to communicate with each other. APIs define method and data structure that developers use to interact with the software component, be it an operating system, library or a web service.

- Application: The Software that uses or provides the API
- Programming: The use of code to interact with the API
- Interface: Point of interaction where the software can request services or data

4.1 Types of API

Different types of APIs are used for different functionalities. Listed here are four (4) basic types of APIs:

1. **Web APIs**
The most common, allowing web applications to interact via HTTP Requests (e.g. REST and SOAP) further elaborate these two.
2. **Operating System APIs**
Allow interaction with system level operations (e.g. Windows API, POSIX)
3. **Library APIs**
Provide functionality from libraries (e.g. graphics, machine learning)
4. **Database APIs**
Enable interactions with databases (e.g. SQL queries through drivers)

4.2 How APIs Work

APIs expose specific functionality of an application via endpoints (URLs) or functions. When a developer sends a request, the API processes it, performs the requested operation (e.g. retrieving data) and then returns a response in a structured format (often JSON or XML). APIs are essential in modern web development as they allow

developers to connect different services or applications. For example, using an API, a frontend application can communicate with a backend server to fetch or send data without directly accessing the database.

4.3 Key Benefits of API

What makes APIs the best approach or concept to be used in different functionalities? Here are some of the key benefits of using APIs:

- **Modularity**
Different parts of an application can evolve independently. APIs allow developers to reuse existing services and functionality rather than building everything from scratch
- **Interoperability**
APIs enable communication between different technologies and platforms.
- **Scalability**
APIs can be reused, making it easier to extend or modify software. APIs allow applications to grow by adding or modifying features without disturbing the existing code.
- **Third Party Integrations**
APIs enable integration with third-party services like payment gateways, social media platforms and cloud services.
- **Data Sharing**
APIs allow different applications to share data seamlessly (e.g. fetching data from a weather API)

This paper writes about WEB APIs by maximizing on the benefits that APIs possess. In a technology and data driven society where different institutions use different systems with data kept in silos, the benefits of using APIs does stand out. The benefits of using APIs provides efficiency and that is why the usage of APIs in Data Integration is instrumental in PNG's data ecosystem.

5. API BASED DATA INTEGRATION

APIs are widely used for Data Integration across different systems, applications and platforms. Data integration involves combining data from various sources into a unified view and APIs play a crucial role in facilitating this process. Here's how APIs are typically used in data integration.

5.1 Common API Types for Data Integration

Here are some common types of APIs are typically used in data integration:

1. **RESTFUL APIs**
Representational State Transfer (REST) is the type of API that is most commonly used for Data Integration. RESTFUL APIs uses HTTP Methods (GET, POST, PUT, DELETE) to perform CRUD (CREATE, READ, UPDATE, DELETE) functionalities. It is popular in Cloud Services, Web Applications and Micro Services and data is exchanged in JSON or XML format.
2. **SOAP APIs**
Using XML Messaging, Simple Object Access Protocol (SOAP) APIs are well structured and are secured and robust than REST APIs.

3. GraphQL APIs
A query language for APIs that uses a more specific approach which require clients to specify the exact data they need.
4. Database APIs
Ensures access to database through standard queries. It allows CRUD Operations directly with tables in a database.
5. Streaming APIs
Handle continuous data flow, such as real time integration from IoT devices, social media streams of financial markets.
6. File-Based APIs
Allows transferring of files between systems (e.g. FTP APIs, SFTP APIs) and is mostly used for base data integration tasks where large datasets are uploaded and downloading periodically.
7. Platform-Specific APIs
This is a Cloud API (Google Cloud, AWS, AZURE) that is often used for integrating cloud resources and services.

This paper presents RESTFUL APIs as a most suitable API for integration of data in PNG's data ecosystem (Costa, P. 2014).

5.2 Key Roles of APIs in Data Integration

Here are some roles that APIs play in Data Integration:

- Data Synchronization – ensuring data consistency
- Data Aggregation – Pull data from different sources and unify them
- Data Migration – moving of data from one system to another
- Automation and Orchestration – automations of data workflows
- Real-Time Integration – enables real-time data transfer and integration

6. DATA ANALYTICS

Data analytics is essential for businesses and organizations in today's data-driven world (Sarker, I. H., 2021). It helps derive actionable insights from vast amounts of data and provides a competitive edge through better decision-making, efficiency, and customer insights. Depending on the type of analysis used, descriptive, diagnostic, predictive, or prescriptive, organizations can understand past trends, investigate causes, forecast future events, and prescribe the best actions. As businesses continue to generate more data, the role of data analytics will only grow in importance, enabling more intelligent, data-driven strategies across industries.

Data Analytics refers to systematic computational analysis of data. It involves transforming raw data into useful information that supports decision making. Data analytics enables businesses to uncover trends, measure performance and identify actionable insights that leads to improve outcomes (Sarker, I. H., 2021). It encompasses various techniques and methodologies from statistical analysis to machine learning.

Data Analytics involves examining raw data to extract meaningful insights, patterns and trends. The process technically includes the following key steps:

- a. Data Collection
- b. Data Cleaning

- c. Data Exploration
- d. Data Modelling
- e. Data Visualization
- f. Interpretation and Reporting

6.1 Different Types of Data Analytics

There are different types of analytics. Depending on the business requirements, specific type of analytics is used to attain the specific results to meet business demands. Here are the four (4) main types of data analytics:

- a. Descriptive Analytics
- b. Diagnostic Analytics
- c. Predictive Analytics
- d. Prescriptive Analytics

6.2 Key Benefits of Data Analytics

Given the nature of how institutions are operating these days, data analytics is a demanding and growing field. Most successful organizations are data drive or data centric as they prioritize the analyzation of data. Here are few key benefits of data analytics:

- 1. Improve Decision Making
- 2. Increase Efficiency
- 3. Enhance Customer Insights
- 4. Risk Management
- 5. Innovation and Product Development
- 6. Cost Reduction
- 7. Competitive Advantage
- 8. Personalization
- 9. Enabling business to offer personalized products, services and experiences.

7. DATABASES

In this approach, the API will be used to transfer structured data in a database from one system to another. Hence, there will two (2) databases:

- 1. Source Database
- 2. Destination Database

The conceptual and logical design of the two (2) databases will be identical. There will be two RESTFUL APIs in each of the databases for enabling communication and data transfer or integration.

8. RESTFUL API DATA INTEGRATION PROCESS

Firstly, the integration of data in this paper involves two (2) databases (databases of two different systems) as mentioned above, source database and destination database. The RESTFUL APIs in this paper are developed using Python Programming for simulation purposes. The security measures in this RESTFUL APIs approach using Python Programming as following:

- AES-256 Encryption protects the data during the process of transferring [9].

- JWT Authentication make sures that only the authorized requests are the processed in the APIs and nothing foreign.
- Initialization Vector (IV) ensures encryption remains secure even if the same data is sent multiple times.
- Base64 encoding ensures data is safely transmitted over HTTP.
- Token Expiration within an hour prevents long term unauthorized access.

This part of the paper provides a step-by-step explanation of how data is transferred from one system to another or integrated.

8.1 Destination System - Requesting Authentication Token

According to the automation schedule that is set on the destination system or database, the process kicks from that side. The Destination System requests for an Authentication Token. It is a request from Destination System that is sent to the Source System.

```
# Function to get JWT token
def get_jwt_token():
    try:
        response = requests.get(TOKEN_URL, verify=False) # verify=False for self-signed certs in local dev
        if response.status_code == 200:
            return response.json().get("token")
        else:
            log_transfer("FAILED", "Token retrieval failed.")
            return None
    except requests.exceptions.RequestException as e:
        log_transfer("FAILED", f"Token request error: {e}")
        return None

# Dummy JWT token endpoint (placeholder for real auth)
@app.route("/token", methods=["GET"])
def get_token():
    return jsonify({"token": "dummy-token"})
```

Fig. 1 Destination and Source System Requesting and Generating JWT Token

Explanation:

- Destination System sends a request to System A.
- Source System generates JWT Token that is valid for an hour.
- Source System returns the token to Destination System

Example:

An example of a response from the Source System sending the generated JWT Token

```
{
  "token": "eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXLTJ5In0:"
}
```

8.2 Destination System – Requests Encrypted Data from Source Database

Through the JWT Token that was generated, the two systems can now communicate and exchange data or integrate it.

```
# Function to request data with retries
def fetch_encrypted_data_with_retry():
    token = get_jwt_token()
    if not token:
        return None
    headers = {"Authorization": f"Bearer {token}"}
    for attempt in range(5):
        try:
            response = requests.get(API_URL, headers=headers, timeout=10, verify=False) # verify=False for local dev
            if response.status_code == 200:
                return response.json().get("encrypted_data")
            else:
                log_transfer("FAILED", f"Error {response.status_code}, Retrying...")
        except requests.exceptions.RequestException as e:
            log_transfer("FAILED", f"Request error: {e}, retrying in {2 ** attempt} seconds...")
            time.sleep(2 ** attempt)
    return None
```

Fig. 2 Destination System requests Encrypted Data from Source System

Explanation:

- Destination System uses the JWT token in the request header to access the data.
- Destination System sends a data request to Source System via the APIs
- Source System verifies the JWT Token and fetches data from the database

8.3 Source System Encrypts Data with AES-256

Data is a very crucial asset that needs to be protect and secured from theft and data bridges. Hence, encryption and decryption are very important as part of data integration.

```
AES_KEY = os.getenv("AES_KEY").encode() # 32 bytes for AES-256
AES_IV = os.getenv("AES_IV").encode() # 16 bytes IV
```

Fig. 3 Source System Data Encryption

Explanation:

- Fetches the data from its database
- Convert it to JSON format.
- Encrypts the data using AES-256 in CBC mode.
- Encodes the encrypted data in Base64 for safe transmission.
- Sends the encrypted data back to Destination System.

Example:

Encrypted response from Source System

```
{
  "encrypted_data": "7gFgL8D3... (Base64-encoded AES data)"
}
```

8.4 Destination System decrypts Data

The Source System sends the encrypted data to the Destination System. The Destination System will decrypt the data and inserts the data into the database.

```
# Function to decrypt AES-256 data
def decrypt_data(encrypted_data):
    encrypted_bytes = base64.b64decode(encrypted_data)
    cipher = AES.new(AES_KEY, AES.MODE_CBC, AES_IV)
    decrypted_bytes = unpad(cipher.decrypt(encrypted_bytes), AES.block_size)
    return json.loads(decrypted_bytes.decode("utf-8"))
```

Fig. 4 Destination System Data Decryption Python Code

Explanation:

Destination System:

- Extracts the encrypted data from the API response
- Decodes the Base64 string to get the raw encrypted bytes
- Extracts the Initialization Vector from the first 16 bytes
- Decrypt the data using the same AES-256 Secret Key
- Removes padding to restore the original JSON Data
- The JSON Data is parsed and inserted into the database

Example:

Here is an example showing decrypted data after processing.

```
[
  {"id": 1, "name": "Steve", "email": "steve@decrypt.com"},
  {"id": 2, "name": "Nathan", "email": "nathan@decrypt.com"}
]
```

9. CONCLUSION

Therefore, leveraging API driven data integration ensures a sustainable and secure pathway to drive and enhance analytics capabilities, increase institutional efficiency and supporting evidence-based policy and decision making across PNG's public and private sectors. The simulation using Python Programming as presented above demonstrated how secure, automated data integration can be achieved through RESTful APIs. Even the secure structure that is used in the API assures that API has the reliable and safe approach to transfer data between two systems or integrate data. To conclude, the usage of API in data integration seem to be an ideal approach to integrate data for enhanced data analytics in PNG.

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Vibration Mode Analysis of a 100m Simply-supported Steel Beam Bridge via POD of FEM

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Abstract: Bridge vibrations pose significant challenges to structural safety and longevity. This study employs the Finite Element Method (FEM) with Euler-Bernoulli beam elements and Proper Orthogonal Decomposition (POD) to analyze the dynamic response of a one-dimensional beam bridge model under sinusoidal external loading. The governing partial differential equation (PDE) describes the behavior of the lines with terms for inertial forces, damping, and flexural rigidity, discretized into a system of algebraic equations using finite elements of a 1D beam. This numerical approach simulates the bridge's linear displacement field over time and space, providing detailed understanding of its vibrational behavior through POD mode extraction. This study highlights the importance of integrating advanced computational tools, such as FEM and POD, into structural engineering practices. Furthermore, this research promotes the safe and sustainable development of infrastructure, particularly in the Pacific region, where rising sea levels and extreme weather events pose significant challenges.

Keywords: finite-element-method, Euler-Bernoulli, POD, bridge-infrastructure, Pacific-weather.

Presenter or Main Author Biography: Japath Tikil is a Master of Philosophy in Mathematics candidate at Papua New Guinea University of Technology, presenting for the first time at the PIURN Conference. His research applies computational methods (FEM and POD analysis) to study vibration patterns in 100-meter steel bridges, identifying dangerous movements caused by wind and traffic. By mapping a bridge's dominant swaying motions and weak points, his work helps engineers precisely place supports and dampers to prevent structural failures - offering practical safety solutions for Pacific Island infrastructure. Under the guidance of Professors Yaip Telue and Samuel Dunstan, Japath's research advances predictive maintenance for bridges through innovative vibration analysis

1. INTRODUCTION

Excessive bridge vibrations from periodic loads pose significant risks, as demonstrated by the 1940 collapse of the Tacoma Narrows Bridge, where wind-generated harmonic forces triggered a destructive resonance (Lin, Y 2022). Although that failure involved aerodynamic flutter, similar dynamics arise under distributed sinusoidal loading, the focus of this study. Here, we analyze a beam bridge subjected to the forcing function;

$$F(x, t) = \sin\left(\frac{\pi x}{L}\right) \sin(2\pi f t) \quad (f = 1\text{Hz})$$

The forcing function mimics rhythmic excitations (e.g., wind, machinery, or pedestrian loads).

The Proper Orthogonal Decomposition (POD), which is essentially the Singular Value Decomposition (SVD) algorithm applied to solutions of partial differential equations [Brunton, S. 2021], is employed here to extract dominant modes from the displacement field. By applying Finite Element Analysis (FEA) and the Finite

Element Method (FEM) to generate data and performing POD on the results, we quantify the displacement field $u(x, t)$ governed by the damped Euler-Bernoulli equation (Fryba, L., 1972; Wang, S., 2019) to assess resonance risks.

Advanced numerical methods, for which finite element methods are the most efficient frequently used, are extremely important for complicated engineering structures (Mackerle, J. 1999). The understanding and mitigation of these vibrations through FEA is critical to ensuring structural safety (Islam, A. 2014). This study combines these approaches to simulate bridge dynamics under sinusoidal loading and identify critical vibrational modes.

The problem is modeled using a partial differential equation (PDE) that describes the displacement of the bridge over time and space. The PDE accounts for inertial forces, damping, internal stiffness, and external forces. By discretizing the bridge into finite elements, the PDE is transformed into a system of algebraic equations, which are solved numerically. The results are further analyzed using POD to extract dominant vibrational patterns, providing a deeper understanding of the dynamic behavior of the bridge. The results are also compared with the spectral method for accuracy.

2. METHODOLOGY

The methodology involves discretizing the bridge, defining initial conditions, constructing mass and stiffness matrices, applying external forces, and solving the system using a time-stepping scheme. The results are then analyzed using POD to identify dominant vibrational modes.

3. GOVERNING PDE AND DISCRETIZATION

The vibrations of the bridge are governed by the equation of a damped one-dimensional beam with external forcing [3; 4]:

$$\rho \frac{\partial^2 u(x, t)}{\partial t^2} + c \frac{\partial u(x, t)}{\partial t} + EI \frac{\partial^4 u(x, t)}{\partial x^4} = F(x, t) \quad (1)$$

where:

- $u(x, t)$ is the displacement (meters)
- $\rho = 1.0 \text{ kg/m}$ is the mass per unit length
- $c = 0.01 \text{ N}\cdot\text{s/m}$ is the damping coefficient
- $EI = 1.0 \text{ N}\cdot\text{m}^2$ is the flexural rigidity
- $F(x, t) = \sin\left(\frac{\pi x}{L}\right) \sin(2\pi f t)$ where $f = 1 \text{ Hz}$ is the external force (N/m)

The bridge of length $L = 100 \text{ m}$ is discretized using:

- FEM: $n_{\text{fem}} = 128$ points (equally spaced points distributed along the beam length from 0 to L with $n_{\text{fem}} + 1$ total grid points)
- Spectral: $n_{\text{spec}} = 64$ (Chebyshev-Gauss-Lobatto points distributed nonuniformly along the beam length $[0, L]$, with higher point density near the boundaries, using $n_{\text{spec}} + 1$ discretization points)

4. INITIAL CONDITIONS

The initial conditions are:

$$u_0(x) = \sin\left(\frac{\pi x}{L}\right) \quad (\text{Initial Displacement})$$

$$v_0(x) = 0 \quad (\text{Initial velocity})$$

5. STEP-BY-STEP DERIVATION OF THE EXACT SOLUTION (UNDAMPED, UNFORCED CASE)

For the undamped, unforced Euler-Bernoulli beam equation:

$$\rho \frac{\partial^2 u(x, t)}{\partial t^2} + EI \frac{\partial^4 u(x, t)}{\partial x^4} = 0$$

The clamped boundary conditions:

$$u(0, t) = u(L, t) = 0, \quad \frac{\partial u}{\partial x}(0, t) = \frac{\partial u}{\partial x}(L, t) = 0$$

5.1 Step 1: Separation of Variables

Assume $u(x, t) = X(x)T(t)$ Substituting into the PDE:

$$\rho X(x)T^{(2)}(t) + EI X^{(4)}(x)T(t) = 0$$

Divide by $X(x)T(t)$ yields two ODEs:

- Temporal ODE: $T^{(2)} + \omega^2 T(t) = 0$
- Spatial ODE: $X^{(4)}(x) - \frac{\rho\omega^2}{EI} X(x) = 0$

5.2 Step 2: Solve the Spatial ODE

Let $\beta^4 = \frac{\rho\omega^2}{EI}$. The spatial ODE becomes:

$$X^{(4)}(x) - \beta^4 X(x) = 0$$

General solution:

$$X(x) = A\cos(\beta x) + B\sin(\beta x) + C\cosh(\beta x) + D\sinh(\beta x)$$

Apply clamped boundary conditions at $x = 0$ and $x = L$ to determine β and mode shapes.

For the fundamental mode: Assume $X(x) = \sin\left(\frac{\pi x}{L}\right)$. Substituting into the ODE:

$$\left(\frac{\pi}{L}\right)^4 \sin\left(\frac{\pi x}{L}\right) - \beta^4 \sin\left(\frac{\pi x}{L}\right) = 0 \text{ Implies that } \beta = \frac{\pi}{L}$$

Natural frequency; $\omega = \sqrt{\frac{EI}{\rho}} \left(\frac{\pi}{L}\right)^2$

5.3 Step 3: Solve the Temporal ODE

Solution: $T(t) = E\cos(\omega t) + F\sin(\omega t)$

$$T(t) = E\cos(\omega t) + F\sin(\omega t)$$

For simplicity, assume $F = 0$

$$T(t) = \cos(\omega t)$$

5.4 Step 4: Combine Solutions

Exact solution:

$$u(x, t) = \sin\left(\frac{\pi x}{L}\right) \cos\left(\sqrt{\frac{EI}{\rho}}\left(\frac{\pi}{L}\right)^2 t\right).$$

5.5 Step 5: Verify Initial Conditions

At $t = 0$:

$$u(x, 0) = \sin\left(\frac{\pi x}{L}\right).$$

6. ANALYTICAL SOLUTION OF ODE MODEL FOR TEMPORAL DYNAMICS

To complement the full beam solution and provide additional physical insight, we analyze a simplified damped harmonic oscillator model that captures the essential temporal dynamics:

$$\frac{d^2 u}{dt^2} + 0.01 \frac{du}{dt} + u = \sin(2\pi t)$$

where:

- $\frac{d^2 u}{dt^2}$ is the acceleration
- $0.01 \frac{du}{dt}$ represents viscous damping
- u is the displacement (spring restoring force)
- $\sin(2\pi t)$ is the harmonic driving force at 1 Hz

6.1 Solution Components

The complete solution consists of:

1. **Transient solution:** Natural response that decays exponentially
2. **Steady-state solution:** Persistent forced oscillation

6.2 Transient Solution

The homogeneous equation describes the system's natural behavior:

$$\frac{d^2 u_h}{dt^2} + 0.01 \frac{du_h}{dt} + u_h = 0$$

6.2.1 Characteristic Equation

Assuming solutions of form $u_h(t) = e^{rt}$ yields:

$$r^2 + 0.01r + 1 = 0$$

with roots: $r = -0.005 \pm \sqrt{1 - 2.5 \times 10^{-5}} \approx -0.005 \pm i$

6.2.2 General Form

The underdamped solution oscillates at the natural frequency while decaying:

$$u_h(t) = e^{-0.005t}(A\cos t + B\sin t)$$

6.3 Steady-State Solution

For the particular solution with forcing $\sin(2\pi t)$

6.3.1 Assumed Form

$$u_p(t) = C \sin(2\pi t) + D \cos(2\pi t)$$

6.3.2 Coefficients

Substitution into the ODE gives:

$$(1 - 4\pi^2)C - 0.02\pi D = 1$$

$$0.02\pi C + (1 - 4\pi^2)D = 0$$

Yielding:

$$C \approx -0.0253, D \approx 1.69 \times 10^{-4} \approx -0.0253, \quad D \approx 1.69 \times 10^{-4}$$

6.3.3 Amplitude-Phase Representation

The solution can be expressed as:

$$u_p(t) = \frac{\sin(2\pi t - \phi)}{\sqrt{(1 - 4\pi^2)^2 + (0.02\pi)^2}} \approx 0.0253 \sin(2\pi t + 0.0067)$$

where the phase shift $\phi \approx 0.0067$ radians $\phi \approx -0.0067$ radians.

6.4 Complete Solution

Combining components with zero initial conditions:

$$u(t) \approx 0.0253 \sin(2\pi t + 0.0067)$$

This simplified model helps validate the temporal behavior observed in the full FEM solution, particularly the steady-state amplitude and phase characteristics.

7. FINITE ELEMENT METHOD FOR FORCED, DAMPED EULER-BERNOULLI BEAM

7.1 Shape Functions Definition

For a 2-node beam element of length h , the linear shape functions are:

$$N_1(x) = 1 - \frac{x}{h}, \quad N_2(x) = \frac{x}{h}$$

Node evaluations:

$$\text{At } x = 0: N_1(0) = 1, N_2(0) = 0$$

$$\text{At } x = h: N_1(h) = 0, N_2(h) = 1$$

7.2 Mass Matrix Formulation

Consistent mass matrix formulation

$$M_{local} = \rho \int_0^h \begin{bmatrix} N_1^2(x) & N_1(x)N_2(x) \\ N_1(x)N_2(x) & N_2^2(x) \end{bmatrix} dx$$

7.2.1 Term-by-Term Integration:

a) M_{11} term:

$$M_{11} = \rho \int_0^h \left(1 - \frac{x}{h}\right)^2 dx = \rho \int_0^h \left(1 - \frac{2x}{h} + \frac{x^2}{h^2}\right) dx = \rho \left[x - \frac{x^2}{h} + \frac{x^3}{3h^2} \right]_0^h = \rho \left(h - h + \frac{h}{3} \right) = \rho \frac{h}{3}$$

b) M_{12} term:

$$\text{c) } M_{12} = \rho \int_0^h \left(1 - \frac{x}{h}\right) \left(\frac{x}{h}\right) dx = \rho \int_0^h \left(\frac{x}{h} - \frac{x^2}{h^2}\right) dx = \rho \left[\frac{x^2}{2h} - \frac{x^3}{3h^2} \right]_0^h = \rho \left(\frac{h}{2} - \frac{h}{3} \right) = \rho \frac{h}{6}$$

d) M_{22} term:

$$M_{22} = \rho \int_0^h \left(\frac{x}{h}\right)^2 dx = \rho \left[\frac{x^3}{3h^2} \right]_0^h = \rho \frac{h}{3}$$

$$\text{7.3 Final Assembly: } M_{local} = \frac{\rho h}{6} \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}$$

Numerical example ($\rho = 1.0 \text{ kg/m}$, $h = 0.78125 \text{ m}$):

$$M_{local} = \frac{1 \frac{\text{kg}}{\text{m}} \times 0.78125 \text{ m}}{6} \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} = \begin{bmatrix} 0.2604 & 0.1302 \\ 0.1302 & 0.204 \end{bmatrix} \text{ kg}$$

7.4 Beam Bending Formulation

7.4.1 Weak Form $\int_0^h EI$

$$\int_0^h EI \frac{d^2}{dx^2} \frac{d^2 v}{dx^2} dx = \int_0^h q(x) v(x) dx$$

7.4.2 Cubic Hermite Shape Functions:

$$H_1(x) = 1 - 3\left(\frac{x}{h}\right)^2 + 23\left(\frac{x}{h}\right)^3$$

$$H_2(x) = x\left(1 - \frac{x}{h}\right)^2$$

$$H_3(x) = 3\left(\frac{x}{h}\right)^2 - 2\left(\frac{x}{h}\right)^3$$

$$H_4(x) = \frac{x^2}{h}\left(\frac{x}{h} - 1\right)$$

7.4.3 Full Stiffness Matrix:

$$K_{full} = \frac{EI}{h^3} \begin{bmatrix} 12 & 6h & -12 & 6h \\ 6h & 4h^2 & -6h & 2h^2 \\ -12 & -6h & 12 & -6h \\ 6h & 2h^2 & -6h & 4h^2 \end{bmatrix}$$

7.5 Static Condensation

7.5.1 Step 1: Partitioning

$$K_{full} = \begin{bmatrix} K_{\omega\omega} & K_{\omega\theta} \\ K_{\theta\omega} & K_{\theta\theta} \end{bmatrix}$$

Where:

$$K_{\omega\omega} = \frac{EI}{h^3} \begin{bmatrix} 12 & -12 \\ -12 & 12 \end{bmatrix}, K_{\omega\theta} = \frac{EI}{h^3} \begin{bmatrix} 6h & 6h \\ -6h & -6h \end{bmatrix}, K_{\theta\theta} = \frac{EI}{h^3} \begin{bmatrix} 4h^2 & 2h^2 \\ 2h^2 & 4h^2 \end{bmatrix}$$

7.5.2 Step 2: Inversion

$$K_{\theta\theta}^{-1} = \frac{1}{12h^4} \begin{bmatrix} 4h^2 & -2h^2 \\ -2h^2 & 4h^2 \end{bmatrix} = \frac{1}{3h^2} \begin{bmatrix} 1 & -\frac{1}{2} \\ -\frac{1}{2} & 1 \end{bmatrix}$$

7.5.3 Step 3: Multiplication

$$K_{\omega\theta} K_{\theta\theta}^{-1} = \frac{EI}{h^4} \begin{bmatrix} 1 & -1 \\ 1 & -1 \end{bmatrix} \mathbf{A}$$

$$\mathbf{A} K_{\theta\omega} = \frac{EI}{h^3} \begin{bmatrix} 12 & -12 \\ -12 & 12 \end{bmatrix}$$

$$K_{\theta\omega} = \frac{EI}{h^3} \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix} \mathbf{A} \mathbf{K}$$

7.5.4 Step 4: Condensation $K_{condensed} = K_{\omega\omega} - \mathbf{A} \mathbf{K}$

7.6 System Matrices

7.6.1 Stiffness Matrix Assembly:

$$K_{fem} = [i-1:i+2, i-1:i+2] + \frac{EI}{h^3} \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$$

7.6.2 Damping Matrix:

$$C_{fem} = \alpha M_{fem} + \beta K_{fem} \text{ or } c M_{fem}$$

7.7 Boundary Conditions

7.7.1 Clamped ends implementation:

Left End:

$$\begin{aligned} M_{fem}[0,:] &= \mathbf{0}, & M_{fem}[0,0] &= 1 \\ K_{fem}[0,:] &= \mathbf{0}, & K_{fem}[0,0] &= 1 \\ C_{fem}[0,:] &= \mathbf{0}, & C_{fem}[0,0] &= 1 \end{aligned}$$

Right End:

$$\begin{aligned} M_{fem}[-1,:] &= \mathbf{0}, & M_{fem}[-1,-1] &= 1 \\ K_{fem}[-1,:] &= \mathbf{0}, & K_{fem}[-1,-1] &= 1 & C_{fem}[-1,:] &= \mathbf{0}, & C_{fem}[-1,-1] &= 1 \end{aligned}$$

7.8 Time Integration (Crank-Nicolson) A

$$A = M + \frac{\Delta t}{2} \left(C + \frac{\Delta t}{2} K \right)$$

$$b = \left(M - \frac{\Delta t}{2} \left(C + \frac{\Delta t}{2} K \right) \right) V_{prev} + \Delta t F(t)$$

Solve for v_{next} ; $V_{next} = A^{-1}b$

Update the displacement: $u_{next} = u_{prev} + \Delta t v_{next}$

8. THE SPECTRAL METHOD IS APPLIED AS A NUMERICAL METHOD TO FIND SOLUTION OF THE FORCED, DAMPED EULER-BERNOULLI EQUATION (F(X, T) AND C ARE NOT EQUAL TO ZERO) TO VERIFY THE RESULTS OBTAINED IN FEM

8.1 Discretization Using Chebyshev Points

The first step in the spectral method is selecting an appropriate grid (discretization points). Unlike uniform grids (used in finite differences), spectral methods often use Chebyshev-Gauss-Lobatto (CGL) points, which are clustered near the boundaries (ends of the domain). This clustering helps in resolving boundary layers and improves accuracy. For a beam of length $L = 100$ m, we define $N = 64$ Chebyshev points as:

$$x_j = \frac{L}{2} \left(1 - \cos\left(\frac{j\pi}{N}\right) \right), j = 0, 1, \dots, N$$

These points are non-uniform, with higher density near $x = 0$ and $x = L$. The clustering helps in accurately capturing boundary effects (since beam vibrations are strongly influenced by clamped/fixed ends).

8.2 Chebyshev Differentiation Matrices

Since the beam equation involves a fourth derivative $\frac{\partial^4 u}{\partial x^4}$, we need a way to compute derivatives numerically at the Chebyshev points. This is done using Chebyshev differentiation matrices.

8.2.1 First Derivative Matrix ($\mathbf{D}_1$)

The first derivative of a function $u(x)$ at the Chebyshev points can be approximated as:

$$\frac{du}{dx} \approx \mathbf{D}_1 \mathbf{u}$$

where $\mathbf{D}_1$ is an $(N+1) \times (N+1)$ matrix with entries:

$$(D_1)_{ij} = \begin{cases} \frac{c_i(-1)^{i+j}}{c_j(x_i - x_j)}, & \text{if } i \neq j \\ -\sum_{k \neq i} (D_1)_{ik}, & \text{if } i = j \end{cases}$$

where:

- $c_i = 2$ if $i = 0$ or $i = N$ (endpoints)
- $c_i = 1$ otherwise

8.2.2 Higher-Order Derivatives ($\mathbf{D}_2$, $\mathbf{D}_3$, $\mathbf{D}_4$)

The second, third, and fourth derivative matrices are obtained by matrix powers:

$$\mathbf{D}_2 = (\mathbf{D}_1)^2, \quad \mathbf{D}_3 = (\mathbf{D}_1)^3, \quad \mathbf{D}_4 = (\mathbf{D}_1)^4$$

This means that the fourth derivative $\frac{\partial^4 u}{\partial x^4}$ is approximated as $\mathbf{D}_4 \cdot \mathbf{u}$.

8.3 Applying Boundary Conditions (Clamped Beam)

The beam has clamped boundary conditions at both ends:

$$u(0, t) = u(L, t) \quad (\text{Zero displacements})$$

$$\frac{\partial u}{\partial x}(0, t) = \frac{\partial u}{\partial x}(L, t) = 0 \quad (\text{zero slope})$$

8.3.1 Modifying the Differentiation Matrix

To enforce these conditions:

1. We remove the first and last two rows and columns of $\mathbf{D}_4$ (since they correspond to the boundary points)
2. The modified matrix $\mathbf{K}_{\text{spec}} = EI \cdot \mathbf{D}_4[2:-2, 2:-2]$ now represents the stiffness operator for the interior points

8.4 Solving the Dynamic Beam Equation

The full PDE for the beam is:

$$\rho \frac{\partial^2 u(x, t)}{\partial t^2} + c \frac{\partial u(x, t)}{\partial t} + EI \frac{\partial^4 u(x, t)}{\partial x^4} = F(x, t)$$

8.4.1 Time Discretization (Using Finite Differences)

We use the Crank-Nicolson method (an implicit time-stepping scheme) for stability:

1. Discretize time as $t_n = n\Delta t$
2. Approximate derivatives as:

$$\frac{\partial^2 u}{\partial t^2} \approx \frac{u^{n+1} - 2u^n + u^{n-1}}{\Delta t^2}$$

$$\frac{\partial u}{\partial t} \approx \frac{u^{n+1} - u^{n-1}}{2\Delta t}$$

3. The resulting system is: $I \left(\frac{\rho}{\Delta t^2} + c \frac{\rho}{2\Delta t} + EI K_{spec} \right) u^{(n+1)} = F^{(n+1)} + \left(2\rho \frac{I}{\Delta t^2} - c \frac{I}{2\Delta t} \right) u^{(n-1)}$

This is a linear system solved at each time step

9 SUMMARIES OF FINITE ELEMENT METHOD AND SPECTRAL METHOD FOR DYNAMIC BEAM RESPONSE

9.1 Finite Element Method (FEM)

The dynamic response of the beam is governed by the partial differential equation:

$$\rho \frac{\partial^2 u(x, t)}{\partial t^2} + c \frac{\partial u(x, t)}{\partial t} + EI \frac{\partial^4 u(x, t)}{\partial x^4} = F(x, t) \quad (2)$$

where:

- $u(x, t)$ is the transverse displacement
- ρ is the mass per unit length (kg/m)
- c is the viscous damping coefficient (N·s/m)
- EI is the flexural rigidity (N·m²)
- $F(x, t)$ is the distributed external force (N/m)

The finite element solution is obtained by solving the discrete system:

$$\mathbf{M}\mathbf{u}''(t) + \mathbf{C}\mathbf{u}'(t) + \mathbf{K}\mathbf{u}(t) = \mathbf{F}(t) \quad (3)$$

where:

- $\mathbf{M}$ is the global mass matrix
- $\mathbf{C}$ is the global damping matrix ($\mathbf{C} = \alpha\mathbf{M} + \beta\mathbf{K}$ for Rayleigh damping)
- $\mathbf{K}$ is the global stiffness matrix
- $\mathbf{F}(t)$ is the nodal force vector
- $\mathbf{u}(t)$, $\mathbf{u}'(t)$, and $\mathbf{u}''(t)$ are the displacement, velocity, and acceleration vectors respectively

9.1.1 FEM Implementation Steps

1. Matrix Construction:

- Derive element mass matrix using shape functions:

$$\mathbf{M}_e = \rho \int_0^h \mathbf{N}^T \mathbf{N} dx \mathbf{M}$$

- Derive element stiffness matrix:

$$\mathbf{K}_e = \mathbf{EI} \int_0^h \mathbf{B}^T \mathbf{B} dx \mathbf{K}$$

where $\mathbf{B} = d^2 \mathbf{N} / dx^2$

2. Time Integration:

- Apply Crank-Nicolson scheme:

$$\left(M + \frac{\Delta t}{2} C + \frac{\Delta t^2}{4} K \right) u_{n+1} = \left(M - \frac{\Delta t}{2} C - \frac{(\Delta t)^2}{4} K \right) u_n + \frac{\Delta t}{2} (F_n + F_{n+1})$$

3. Boundary Conditions:

- For clamped ends ($x = 0, L$):

$$u = 0 \text{ and } \frac{\partial u}{\partial x} = 0$$

implemented by modifying system matrices:

$$\mathbf{K}_{ii} = 1, \quad \mathbf{K}_{ij} = \mathbf{K}_{ji} = 0 \quad \text{for constrained DOFs}$$

9.1.2 Connection between Continuous and Discrete Forms

The discrete system (2) exactly corresponds to the continuous PDE (1) through:

- $\mathbf{M}\ddot{\mathbf{u}}$ discretizes $\rho \frac{\partial^2 u}{\partial t^2}$
- $\mathbf{C}\dot{\mathbf{u}}$ discretizes $\rho \frac{\partial u}{\partial t}$
- $\mathbf{K}\mathbf{u}$ discretizes $\mathbf{EI} \frac{\partial^4 u}{\partial x^4}$
- $\mathbf{F}(t)$ represents the projection of $F(x, t)$ onto nodal forces

9.2 Spectral Method Validation

The spectral method is used to validate the results obtained from the Finite Element Method by providing a high-accuracy solution for the beam's displacement. The spectral method involves solving the beam equation using Chebyshev differentiation for the fourth derivative of the displacement function. The steps in the Spectral Method are as follows:

- Discretization: The beam is discretized into a grid of points, and the fourth derivative operator $\mathbf{D}_4$ is approximated using Chebyshev differentiation.
- Boundary Conditions: Clamped boundary conditions are incorporated by modifying the stiffness matrix and removing the first and last points in the grid.
- Solution: The displacement $\mathbf{u}(x, t)$ is computed by solving the system of equations derived from the spectral method using the time-dependent forcing function.

The displacement $\mathbf{u}(x, t)$ from the spectral method is obtained by solving the matrix equation:

$$\mathbf{K}_{\text{spec}} \mathbf{u}(x, t) = \mathbf{F}(x, t)$$

where $\mathbf{K}_{\text{spec}}$ is the stiffness matrix obtained from the spectral method, and $\mathbf{F}(x, t)$ is the external force. The results from the spectral method are then compared with the results from the FEM to validate the accuracy of the numerical solution.

9.3 Validation and Comparison

The displacement $\mathbf{u}(x, t)$ obtained from the FEM is validated by comparing it with the displacement obtained from the spectral method. The agreement between the two methods serves as a verification of the FEM implementation. If the results from both methods show close agreement, it confirms that the FEM is correctly capturing the dynamic behavior of the beam.

The spectral method provides a more accurate solution for comparison due to its high-order accuracy, and thus, serves as a benchmark for validating the FEM results.

10 PROPER ORTHOGONAL DECOMPOSITION

Performed on centered FEM data:

10.1 Mean Displacement

The mean displacement is calculated as:

$$\bar{u}(x) = \frac{1}{N} \sum_{i=1}^N u(x, t_i)$$

where N is the total number of time steps, and $u(x, t_i)$ is the displacement at position x and time t_i .

10.2 Snapshot Matrix

The snapshot matrix $\mathbf{U}$ is constructed with the displacement values at each spatial location x and time step t_i , as follows:

$$U = \begin{bmatrix} u(x_1, t_1) & \dots & u(x_1, t_N) \\ \vdots & \ddots & \vdots \\ u(x_m, t_1) & \dots & u(x_m, t_N) \end{bmatrix}$$

where:

- m is the number of spatial points.
- N is the number of time steps.
- $u(x_i, t_j)$ represents the displacement at the spatial point x_i and time step t_j .

Proper Orthogonal Decomposition is performed on centered FEM data:

$$\text{mean displacement} = \frac{1}{N} \sum_{i=1}^N u(x_i, t_j)$$

Centered data = $\mathbf{u}(x_i, t_j) - \text{mean}$

SVD: $\mathbf{U}\Sigma\mathbf{V}^T = \text{centered data}$ [2]

11 THE VALIDATION RESULTS TO VALIDATE THE FINITE ELEMENT METHOD

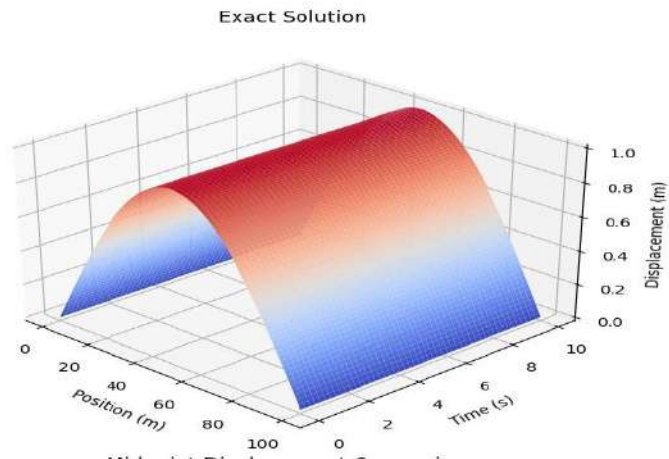


Figure 1: The exact solution for $c=0$ and $F(x,t)=0$

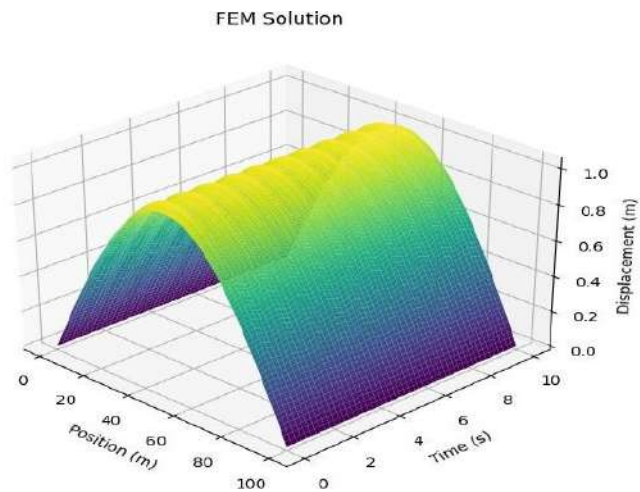


Figure 2: FEM solution with $c = 0$ and $F(x,t) = 0$

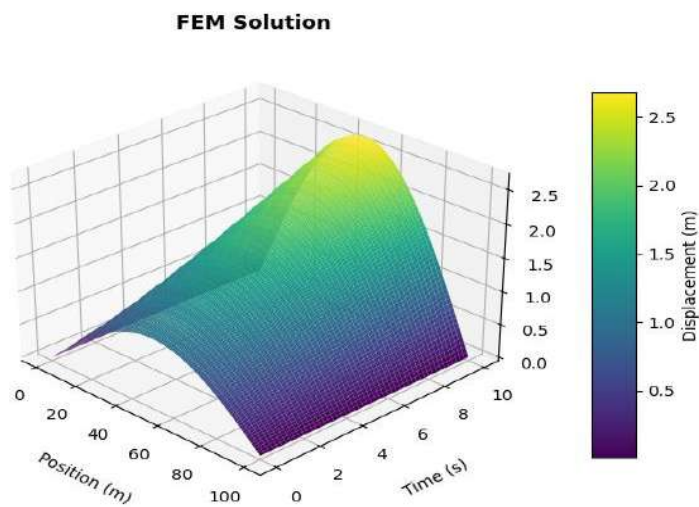


Figure 3: The full FEM solution with both c and $F(x,t)$ not equal to zero

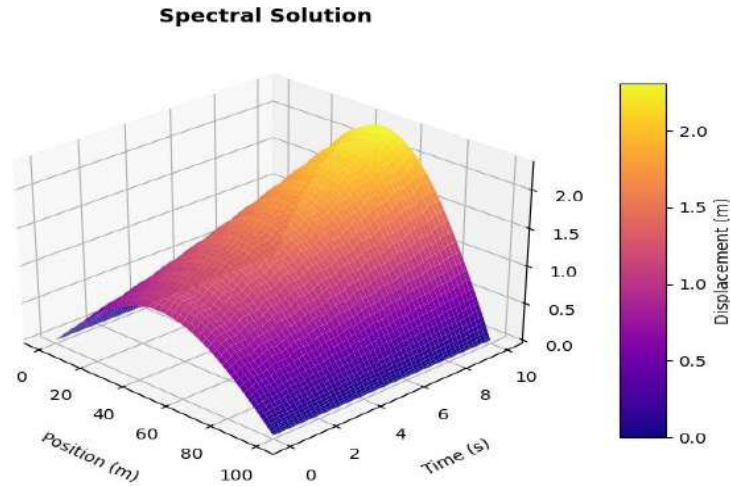


Figure 4: The full spectral solution with both c and $F(x,t)$ not equal to zero

11.1 The discussion of the validation results to validate the Finite Element Method

The PDE:

$$\rho \frac{\partial^2 u(x,t)}{\partial t^2} + c \frac{\partial u(x,t)}{\partial t} + EI \frac{\partial^4 u(x,t)}{\partial x^4} = F(x,t)$$

does not have an exact solution when $F(x,t)$ is not equal to zero and c is not equal to zero, so the spectral solution as shown in Figure 4 is compared to the Finite Element Method solution as shown in Figure 5 and the results are identical which validates the FEM.

More validation of the Finite Element Method is done by equating $F(x,t)$ and the damping coefficient c to zero and the results shown in Figure 2 and Figure 1 are identical, which then validates the FEM.

12 RESULTS

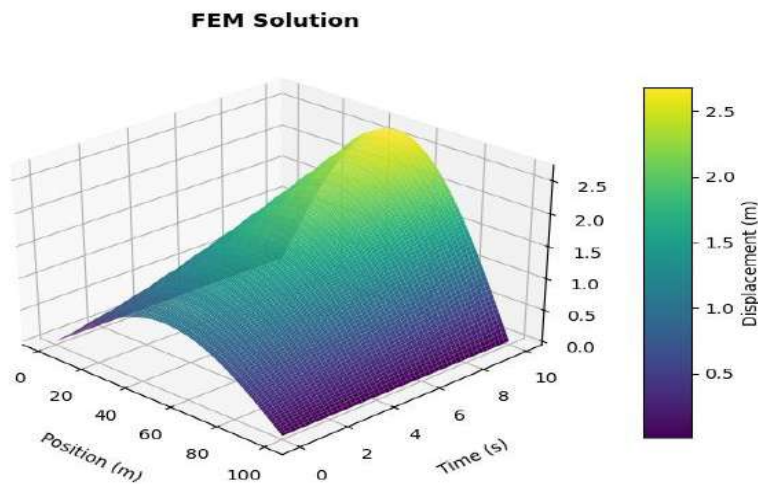


Figure 5: The full FEM solution with both c and $F(x,t)$ not equal to zero

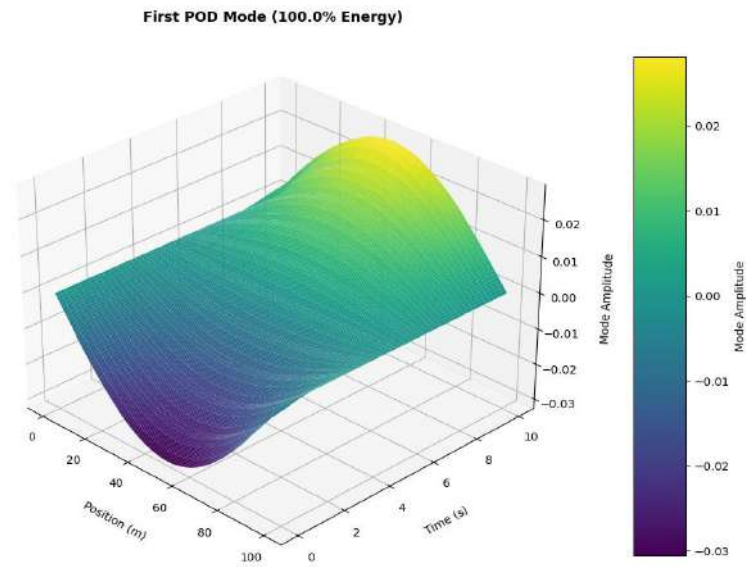


Figure 6: First dominant POD mode from the FEM data capturing the foundational vibrational mode of the bridge with lowest frequency and peak displacements

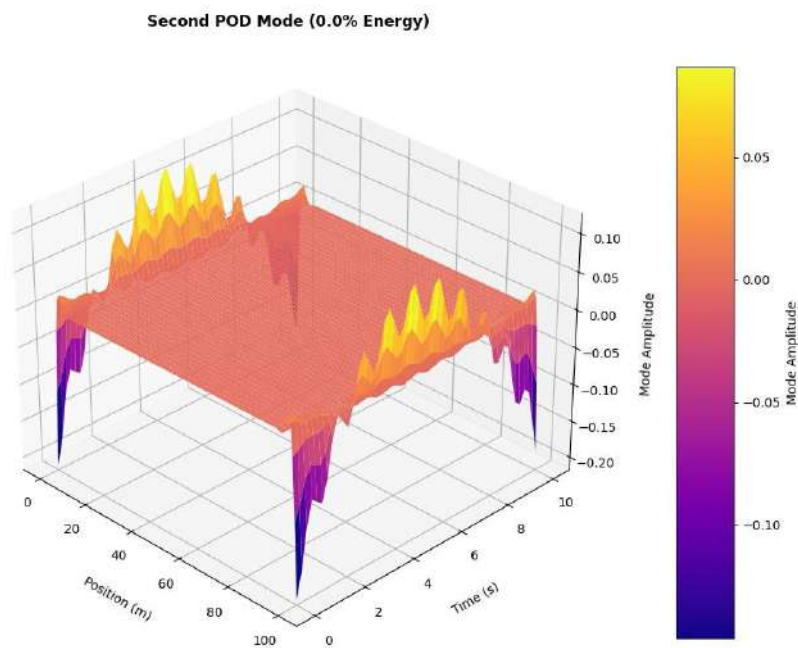


Figure 7: Second dominant POD mode from the FEM data capturing the next significant vibrational pattern with higher natural frequencies and larger local displacements.

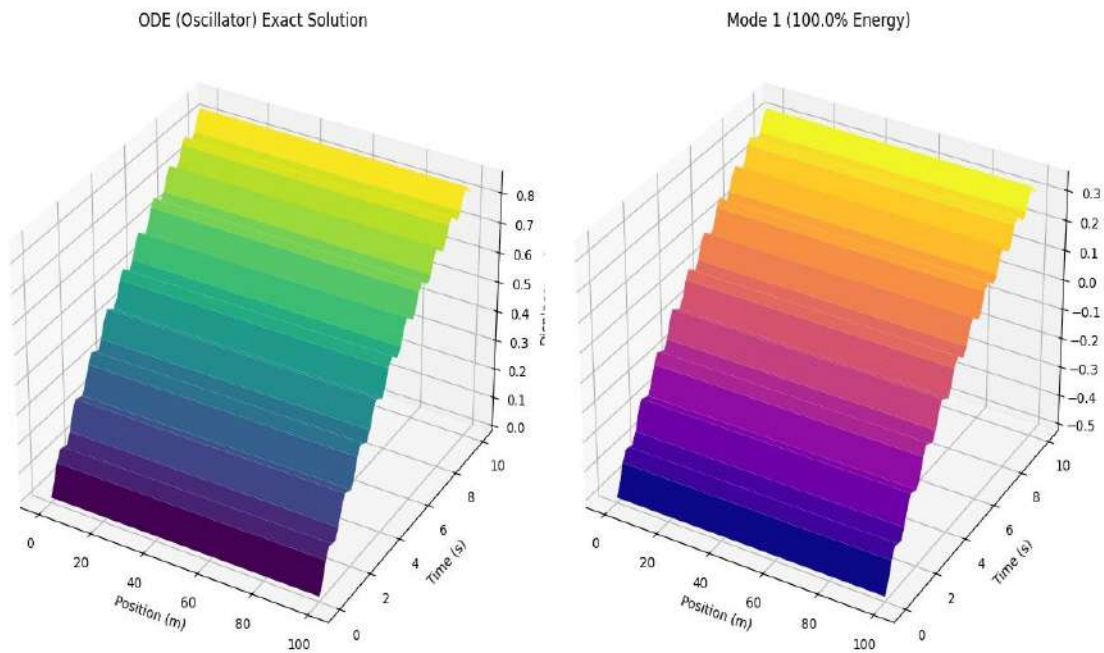


Figure 8: The 3D graph on the left shows the plot of the exact solution of the ODE: $u(t) \approx 0.0253 \sin(2\pi t + 0.0067)$ and the graph on the right shows the Single dominant POD mode

13 DISCUSSIONS

13.1 FEM Full Solution Result

The full solution of the system obtained using the Finite Element Method (FEM) provides a comprehensive understanding of the vibrational behavior of the bridge over time. As shown in Figure 5, the three-dimensional plot illustrates the evolution of displacement along the length of the bridge. The peaks in the plot correspond to areas of maximum displacement, which are critical for identifying regions susceptible to structural stress. The sinusoidal nature of the external force is reflected in the periodic oscillations observed in the solution. This result confirms that the bridge experiences significant vibrations, particularly at specific points along its length, which could lead to fatigue or failure if not properly addressed.

13.2 First POD Mode Result

The first Proper Orthogonal Decomposition (POD) mode, as depicted in Figure 6, represents the most dominant vibrational pattern of the bridge. This mode captures the long-wavelength oscillation, which is characterized by a smooth sinusoidal deformation throughout the length of the bridge. The first mode accounts for the largest portion of the system's energy, as indicated by the corresponding singular value. This result is particularly useful for engineers because it highlights the primary mode of vibration that contributes most significantly to the dynamic response of the bridge.

13.3 Second POD Mode Result

The second POD mode, shown in Figure 7, represents a higher frequency vibrational pattern with more localized oscillations. Unlike the first mode, which spans the entire bridge, the second mode exhibits shorter wavelengths and more concentrated areas of displacement. This mode is crucial for identifying secondary vibrational behaviors that may not be as immediately apparent in the full FEM solution. The significance of the second mode lies in its ability to reveal potential stress concentrations or localized weaknesses in the structure of the bridge. Engineers can use this information to implement localized reinforcements or to design specific damping strategies that address these higher frequency vibrations, further improving the bridge's resilience to dynamic loads.

13.4 Engineering Insight and Practical Applications

The combination of the FEM full solution and the POD modes provide a powerful framework for analyzing and addressing bridge vibrations. The FEM solution offers a detailed, time-dependent view of the bridge's response to external forces, while the POD modes distill this information into dominant patterns that are easier to interpret and act upon. By understanding the first and second POD modes, engineers can prioritize design modifications that target the most critical vibrational behaviors.

13.5 Ordinary Differential Equation vs. Partial Differential Equation Comparison

The 3D graph in Figure 8 (left) shows the plot of the exact solution; $u \approx 0.0253 \sin(2\pi t + 0.007)$ of the ODE $\frac{\partial^2 u}{\partial t^2} + 0.01 \frac{du}{dt} + u = \sin(2\pi t)$ solution governed by:

$$\frac{\partial^2 u}{\partial t^2} + 0.01 \frac{du}{dt} + u = \sin(2\pi t) \text{ where } u \approx 0.0253 \sin(2\pi t + 0.007)$$

The equation represents a **damped harmonic oscillator** where $\frac{d^2 u}{dt^2}$ is the **inertia term** (acceleration) $0.01 \frac{du}{dt}$ is the **damping term** (friction), u is the **restoring force** (spring-like force), and $\sin(2\pi t)$ is the **driving term** (external periodic forcing).

The 3D graph in Figure 8 (right) shows the single dominant POD Mode 1 which captures 100% energy. The ODE exhibits one temporal mode that is identical to the exact solution, with no Mode 2 or Mode 3 contributing any energy at all. When comparing it with the POD modes of the Euler-Bernoulli PDE:

$$\rho \frac{\partial^2 u(x, t)}{\partial t^2} + c \frac{\partial u(x, t)}{\partial t} + EI \frac{\partial^4 u(x, t)}{\partial x^4} = F(x, t)$$

where $\rho = 1.0 \text{ kg/m}$, $c = 0.01 \text{ N}\cdot\text{s/m}$ is the damping coefficient, $EI = 1.0 \text{ N}\cdot\text{m}^2$ is the flexural rigidity and $F(x, t) = \sin\left(\frac{\pi x}{L}\right) \sin(2\pi f t)$ is the external force (N/m), it shows multiple spatial modes, where Mode 1 is not equal to Mode 2, and neither mode matches the exact FEM solution, resulting in energy being distributed across the modes.

14 CONCLUSION

This study presents an integrated FEM-POD methodology for vibration analysis of a 100m steel beam bridge under harmonic loading. The computational approach successfully identified two dominant vibration modes: a global bending pattern governing the overall structural response and localized oscillations revealing critical stress concentrations. The results demonstrate that harmonic excitation induces characteristic vibration patterns that can be systematically analyzed using this framework. The

developed methodology offers an effective tool for vibration assessment in bridge engineering, with applications extending to similar slender structures subjected to periodic dynamic loads.

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Albacore tuna (*Thunnus alalunga*) habitat and variability in French Polynesia

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Abstract. Albacore tuna is important for the economy and food industry of French Polynesia. Nowadays, it represents 55% of the offshore fishery. With its lower resilience to climate change, relative to other tuna species, albacore requires focused study. This study investigates albacore's spatial distribution and relative abundance within the FP Exclusive Economic Zone (FP-EEZ) by analysing monthly fishery data from 2000 to 2022. Environmental parameters influencing Catch Per Unit Effort (CPUE) are assessed using a Generalized Additive Model (GAM) to define preferred habitat of albacore tuna. The parameters include sea surface temperature (SST), dissolved oxygen (DO) at 100m, chlorophyll concentration (Chl), sea surface salinity (SSS), and zonal and meridional currents. GAMs have the possibility to analyses past data in order to create a model that can predict on short and long-term time scale. Our results reveal a clear seasonal variability with a peak between May and December, and a pronounced interannual variation linked to El Niño Southern Oscillation. Our data show that part of the FP-EEZ is a spawning ground for albacore tuna, providing critical insights for sustainable fisheries management. GAM is a powerful tool to help making decisions as for a proper management of fishery resource in French Polynesia EEZ.

Keywords: Albacore tuna; Fisheries management; Generalized additive model; Spatial distribution; French Polynesia EEZ.

Presenter or Main Author Biography: M. Guinard is a PhD student at the University of French Polynesia, where she focuses on tuna stock modelling to support sustainable resource management in marine ecosystems.

1. INTRODUCTION

Seven million tons of tuna are landed annually, accounting for about 8% of total global marine capture fisheries (FAO, 2024a). The catch includes skipjack tuna (*Katsuwonus pelamis*, 57%), yellowfin (*Thunnus albacares*, 30%), bigeye (*Thunnus obesus*, 8%), and albacore tuna (*Thunnus alalunga*, 4%) (FAO, 2024b; ISSF, 2024).

The primary tuna fisheries are located in the South Pacific and are managed by two commissions: the Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission-Conservation Area (IATTC-CA). The Western and Central Pacific Ocean (WCPO), under the jurisdiction of the WCPFC, contributes up to 51% of global tuna production (ISSF, 2024). In the southern WCPO, fishing activities are divided among distant-water longline fleets from Taiwan and China, and domestic longline fleets operated by Pacific Island Countries and Territories (PICTs), including French Polynesia (FP) (Chang *et al.*, 2021).

Located within the WCPO, French Polynesia is directly reliant on the WCPFC. In 2021, FP's tuna production represented only 0.3% of total fishing effort within the WCPFC, despite its large Exclusive Economic Zone (EEZ). Since 1990, FP has developed its own fleet of longliners which yield annually an average of 5,000 tons of pelagic fishes, reaching a peak of 7,528 tons in 2022. Tuna species account for 85% of this catch, with bigeye, yellowfin, and albacore tuna (Fig. 1). Tuna plays a central role in the local economy and represents a vital source of protein in the local food system

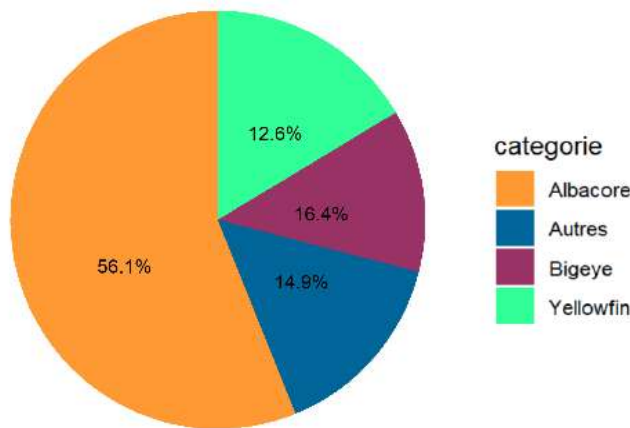


Fig. 1. Production Repartition of FP offshore fishery average from 2000 to 2022.

Offshore fishing in FP is particularly dependent on tuna, especially albacore, which constitutes over half of tuna landed. Although it benefits from consistent access to albacore stocks, the yield highly fluctuates on seasonal and interannual timescales. These fluctuations stem from the migratory behavior of albacore between spawning and feeding grounds.

To better understand and characterize the spatio-temporal variability of albacore tuna, we use a Generalized Additive Model (GAM) where part of the predictors are expressed as a sum of smooth functions (Hastie and Tibshirani, 1986). GAMs have been used to model albacore migration across different ocean basins with diverse spatial and temporal resolutions.

This study aims at improving our understanding of albacore habitat preferences by using a more complete and spatially detailed CPUE (Catch Per Unit Effort) dataset. We apply a GAM to link albacore abundance with environmental variables specific to FP waters.

2. MATERIAL AND METHOD

2.1 Fishery Data

The French Polynesian tuna fishery consists exclusively of longline fishing vessels. Established in 1988, the fishery has since expanded to include a fleet of approximately 80 longliners ranging from 13 to 24 meters in length. Only longline fishing is allowed in the FP EEZ and more than 70% of the hooks are deployed between depth of 50 and 250 m (Labelle, 2006).

Fishery data were provided by the Department of Marine Resources (DMR) of FP. Albacore tuna fishery data cover the period from 2000 to 2022 with a monthly resolution. The data were collected between 5°S and 30°S and between 160°W and 130°W (Fig. 2). The logbook includes data on number of individuals caught, number of hooks used and wet weight of fish for a given date and location. Averages have been carried out to form a 1° grid data set with a monthly resolution. Time series of albacore data are obtained at 391 locations (Fig. 2).

The index used to quantify the relative abundance of fish is the Catch Per Unit Effort (CPUE). CPUE is calculated using the following formula:

$$CPUE_{ymij} = \frac{Catch_{ymij} \text{ (Tons of albacore caught)}}{Fishery\ Effort_{ymij} \text{ (No. of hooks used)}}$$

where $CPUE_{ymij}$ represents the nominal CPUE within the 1° x 1° fishing grid for a given year y , month m , longitude i and latitude j .

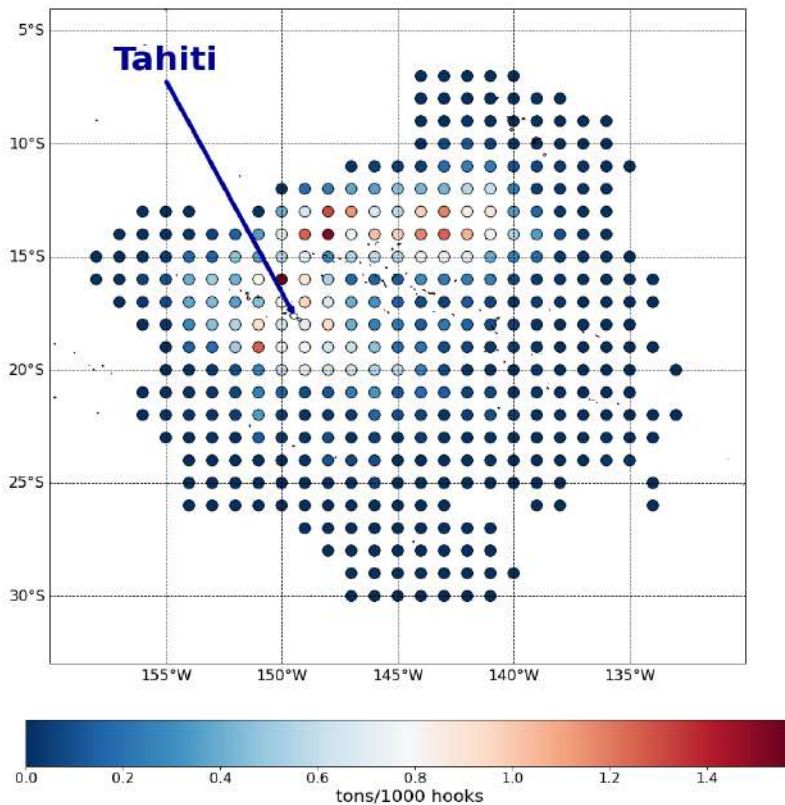


Fig. 2. Yield distribution across the Polynesian EEZ at 391 locations.

2.2 Environmental Data

The environmental parameters used in this study are obtained from the Global Ocean Biogeochemistry Hindcast model provided by the Copernicus Marine Service (https://data.marine.copernicus.eu/product/GLOBAL_MULTIYEAR_BGC_001_029/description).

The monthly data with a spatial resolution of $0.25^\circ \times 0.25^\circ$ have been spatially averaged onto a 1° grid to match the CPUE data. The parameters chosen for our GAM are: seawater temperature, chlorophyll-a, salinity, dissolved oxygen at 100m, zonal and meridional currents. This choice is guided by what is commonly used in the literature to define the tuna habitats.

In order to study the effect of the El Niño Southern Oscillation (ENSO) on albacore distribution, the Multivariate ENSO Index (MEI) was used to identify 7-month periods within each year corresponding to strong El Niño, strong La Niña, and neutral phases. Based on this method, six La Niña events were selected: 2000, 2008, 2010, 2011, 2021, and 2022; two neutral phases: 2003 and 2004; and two El Niño events: 2015 and 2016. During these periods, the average albacore production was calculated using both observed and modelled catch per unit effort (CPUE), in order to assess the impact of ENSO events on albacore production within the FP-EEZ.

2.3 Generalized Additive Model

Environmental factors are known to significantly influence species distributions across ecosystems (Guisan and Zimmermann, 2000). The GAM is extensively used in fishery science. It allows to define the predictors as a sum of smooth functions of the explanatory variables (Hastie and Tibshirani, 1986), making it particularly well-suited for capturing complex and non-linear relationships between CPUE and environmental parameters (Mondal *et al.*, 2022).

In this study, albacore tuna CPUE is modelled as a function of 10 explanatory variables: latitude (lat), longitude (lon), chlorophyll-a concentration (Chl), surface sea salinity (SSS), surface sea temperature (SST),

dissolved oxygen at 100 m depth (DO), zonal speed (u), meridional speed (v) and dates (month and year). The mathematical formulation of between CPUE and environmental parameters is as follow:

$$\log(CPUE + h) \sim \beta + s_1(lat) + s_2(lon) + s_3(Chl) + s_4(SSS) + s_5(SST) + s_6(DO) + s_7(u) + s_8(v) + te(month, year) + \varepsilon$$

Where h is a small constant, set at 10% of the total CPUE average, added to address issues related to log transformation (Chang *et al.*, 2021), s_i are the spline smooth functions, te is the tensor smooth function, β is the intercept term and ε is the residual term. The model is based on statistics and we assume that the response variable follows a Gaussian distribution.

After several runs, the best model is selected based on statistical criterion: lowest Akaike Information Criterion (AIC) and highest adjusted correlation (R^2). In our case, the best GAM gives an AIC of 71,000 and a R^2 of 0.16.

3. RESULTS AND DISCUSSION

3.1 Temporal variation

The time variability is analysed through climate indicators like the annual variability (season), the interannual variability associated to ENSO, and the decadal variability like the Interdecadal Pacific Oscillation.

Fig.3 shows the time series of the spatially averages of albacore CPUE and the predicted CPUE by the GAM. As expected, the predicted CPUE are underestimated but its time variability is similar to the observed CPUE. The time series shows that there is a seasonal signal, an interannual signal and also a decadal oscillation even though the time series is short. Indeed, a climatological monthly analysis confirm the seasonal signal with low CPUE values from January to April and high CPUE values from May to December. The interannual signal, with periods between 2 and 8 years, is also clear on Fig. 3. As an example, the difference between the 130 tons in 2016 and the 90 tons in 2017 is due to ENSO.

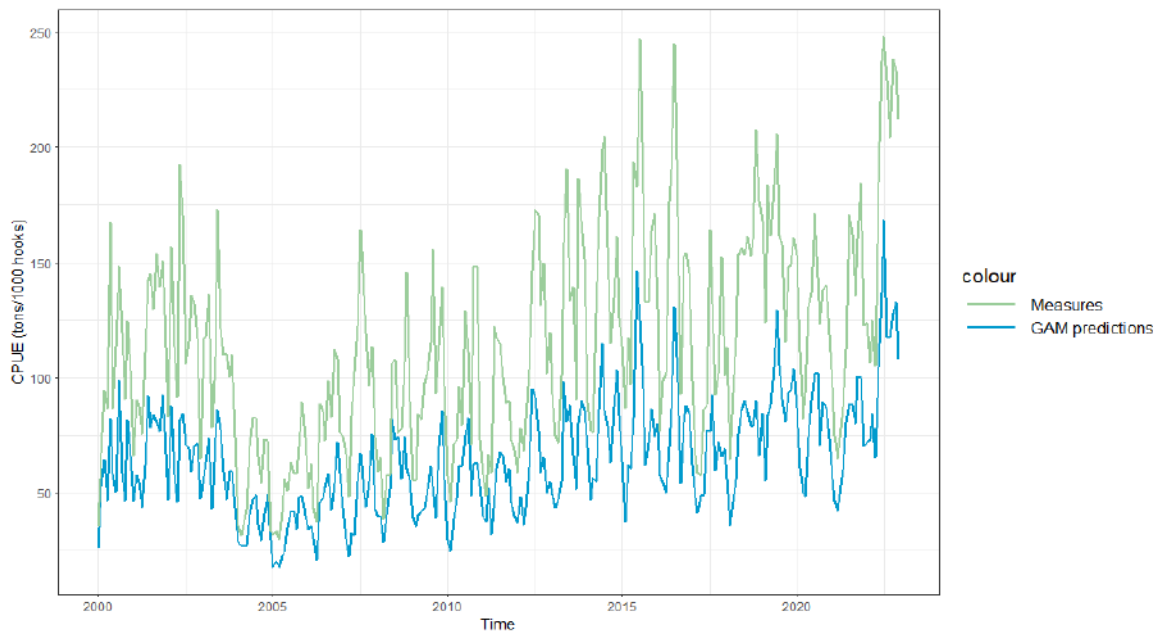


Fig. 3. Spatially averages of Albacore CPUE (in green) and GAM predicted CPUE (in blue) from 2000 to 2022.

3.2 Seasonal Spatio-temporal Distribution

Fig. 4 shows the spatial and temporal distribution of monthly CPUE (both observed and predicted values). For readability reason, only February (low production month) and November (high production month) are selected to illustrate the spatial distribution of albacore tuna. Fig. 4 shows that our model determine fairly well the locations where the catches are low or high. As previously reported, from January to April, CPUE remains low and start to rise around May, particularly between 10° and 23°S and 155° to 137°W. June and July mark the peak abundance, as indicated by the dominance of red patches. Tuna is mainly located in the same region as in May; however, in June, a particularly high abundance (>1 ton/1000 hooks) is observed between 9–16°S and 141–151°W. By July, this high-density zone expands with an additional hotspot emerging between 17–22°S, may be ling to a tuna migration. In August, abundance declines but remains concentrated around 9–16°S and 141–151°W, as seen in June and July. The decline continues into September, followed by a secondary peak in November, before decreasing again in December.

Albacore tuna is known to spawn in equatorial waters, between 10 and 25°S, where temperatures exceed 24°C during the austral summer, between September and January (Ramon and Bailey, 1996; Senina *et al.*, 2020; Williams *et al.*, 2012). In addition, albacore tuna is mature and only reproduce if they exceed 14 kg weight (Farley *et al.*, 2012, 2013). Our data show that the albacore tuna caught between 10 and 25°S weight more than 14kg. Mature albacore tuna is found in the FP-EEZ around November when optimal conditions are met.

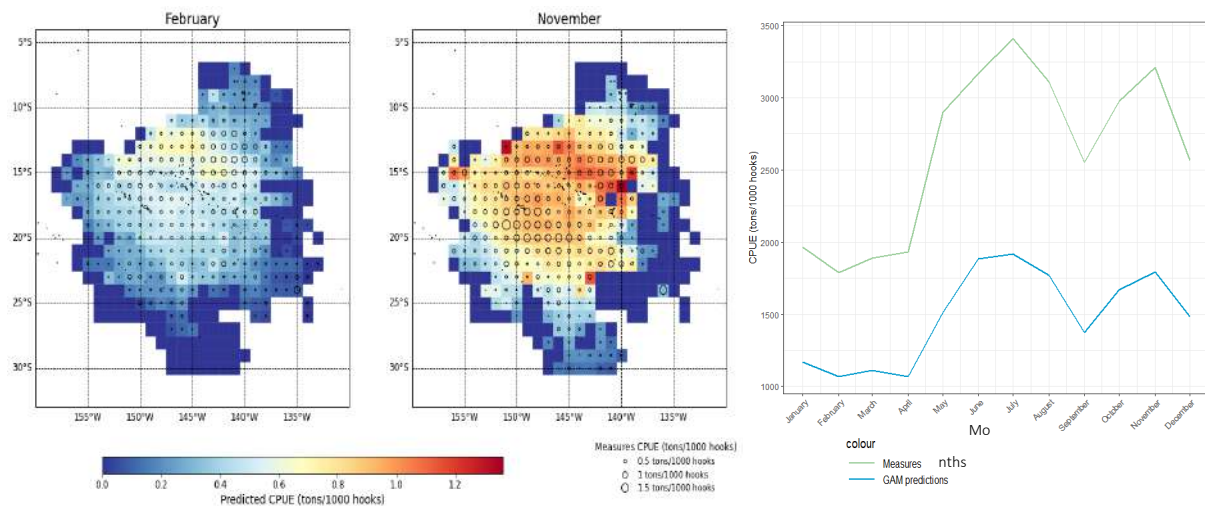


Fig. 4. (Left and Middle) Monthly spatial distribution of true CPUE (circles) and predicted CPUE (color gradient). (Right) Spatially averages of Albacore CPUE (in green) and GAM predicted CPUE (in blue) from January to December.

3.3 Interannual Spatio-temporal Distribution

The South Pacific Ocean conditions changes with ENSO which includes a warm phase (El Niño), a cold phase (La Niña), and a neutral phase. The change of oceanographic conditions would affect the spatial distribution of albacore tuna (Fig. 5).

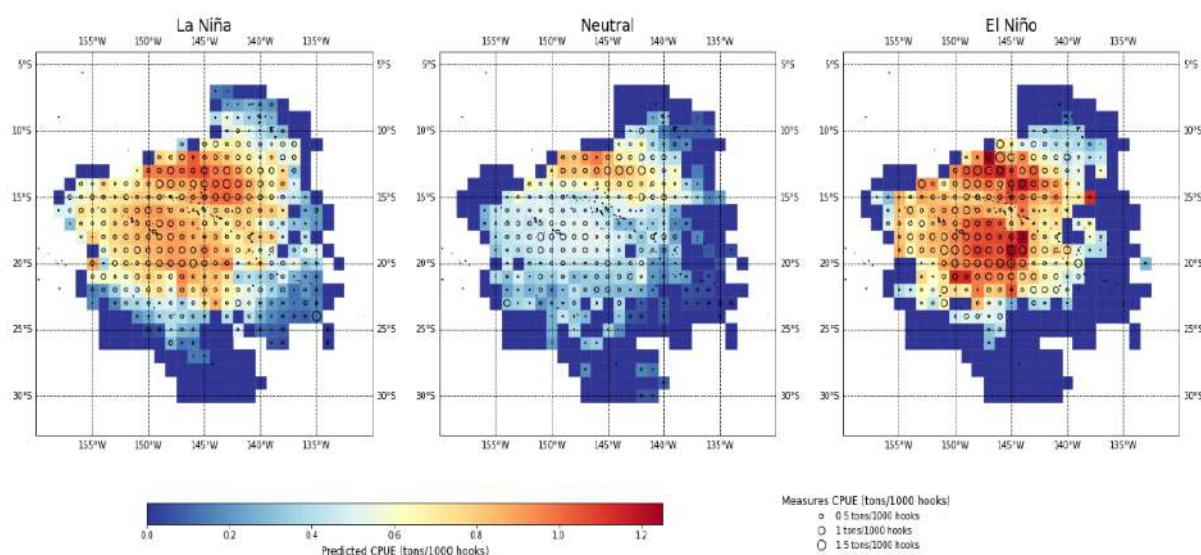


Fig. 5. True CPUE (circle) and predicted CPUE (color gradient) for La Niña (left), for neutral phase (center), and for El Niño (right).

The highest CPUE values are observed during El Niño years, with values exceeding 0.8 tons/1000 hooks between 11–24°S and 154–141°W. Two high CPUE zones (>1 ton/1000 hooks) are noticeable: one between 11–14°S and 155–141°W, and another between 17–22°S and 151–144°W. During La Niña, high CPUE values are found in similar areas as for El Niño but with lower values. During a neutral phase, CPUE values are the lowest.

4. CONCLUSION

This study, based on GAM, is the first done in the FP-EEZ in order to investigate the spatial and temporal variabilities of albacore tuna distribution within the French Polynesia EEZ. Our analysis shows a high-productivity period between May and December, and that during El Niño there is an increase in albacore tuna catch. We also show that the conditions are met to consider the FP-EEZ as a major spawning ground for albacore tuna. In a future work, the GAM will be used to predict albacore tuna abundance under several climate change scenarios.

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Python for Network Automation: A Comparative Study of Tools, Architectures, and Industry Use Cases

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Abstract: Managing large-scale networks has become increasingly complex in today's technology-driven environment. Traditional manual configurations no longer meet the speed, consistency, or scalability that modern organizations demand. Network automation is no longer optional, but it is essential. Python is a programming language valued for its readability and rich ecosystem, has proven to be a pivotal tool in network management. It enables engineers to automate manual routine network tasks, reduce the risk of human error, and integrate seamlessly with a wide range of devices and protocols. This paper evaluates Python's role in network automation through a comparative study of tools (Netmiko, NAPALM, Ansible), real-world use cases, and emerging trends like intent-based networking. We also highlight current academic perspectives, outline implementation challenges, and provide best practices based on real-world scenarios. The goal is to present a balanced, human-written overview that can help engineers, IT managers, and researchers understand how Python is reshaping the way networks are designed and managed.

Keywords: Network Automation, Python, Netmiko, NAPALM, Paramiko, Ansible, Nornir.

Author Biography: Wera Dawa currently a Master of Philosophy (MPhil) Student Under the School of Mathematics and Computer Science at the Papua New Guinea University of Technology, Lae Morobe Province, Papua New Guinea. He recently Graduated from his Bachelor's Degree on April 11th (2025). He is a junior researcher and this is his first paper. His main research work focus on Artificial Intelligent, Computer Networking, Deep Learning and Data Science.

1. INTRODUCTION

Imagine needing to update configurations on hundreds or even thousands of network devices. Traditionally, this would involve manual entry, device by device, with a high chance of human error during configurations. In today's fast-paced, cloud-integrated IT environments, that method simply does not cut it. Network automation has emerged as the natural evolution of infrastructure management. It allows systems to be configured, managed, and updated through code rather than a command line typed in by hand. Python has taken center stage in this transformation. Its ease of use and flexible syntax make it accessible even to those with limited programming experience. Its compatibility with a broad range of vendors and networking technologies only strengthens its position as the go-to language for network automation. In this paper, we explore why Python is well-suited for automating networks, what tools and libraries are most effective, how professionals are using it in the field, and what challenges remain. We also connect this discussion to insights from existing literature to ground our approach in both theory and practice.

2. LITERATURE REVIEW

Research into network automation has grown significantly in recent years, paralleling the rise in complexity of network systems and the demand for scalable, secure operations. While early studies focused on the use of proprietary systems or vendor-specific platforms, more recent work points to Python as a universal enabler of

automation due to its vendor-neutral architecture.

Chuppala, Fu, and Ratnasamy (2023) introduced DBNet, a framework that treats network state like database records. Using Python, the system automates configuration through transactional logic, improving consistency and rollback capability. Their approach shows how Python can simplify operations by applying proven database techniques to network control.

Similarly, El Rajab, Yang, and Shami (2023) explored zero-touch networking, a growing area in 5G and beyond, where systems self-configure without manual input. They found that Python is often used in these systems to run AutoML models that can predict faults, optimize resources, and even generate configuration scripts in real time.

Building on this, Yang et al. (2024) proposed a complete AutoML framework for zero-touch security, where Python was used to coordinate detection models and response scripts. Their study proved Python's versatility in high-stakes environments where security and uptime are critical.

Wang, Singh, and Rahman (2023) focused on hybrid networks those combining cloud and on- premise infrastructure. Their study concluded that Python-based automation platforms offer smoother cross-platform compatibility than vendor-specific tools. In particular, Python's REST API handling and modularity made it easier to orchestrate workflows across diverse environments.

Jorepalli and Bairy (2024) added another layer of insight by integrating Terraform, Ansible, and Python. They demonstrated that when used together, these tools significantly reduced misconfiguration risks and helped teams scale their operations more reliably. This finding is especially relevant as many organizations now manage thousands of devices and services across multiple locations.

Earlier work remains foundational. Clemm and Medhi (2021) noted the move from reactive to predictive management and highlighted Python's ability to support real-time monitoring and adaptation. Barroso (2016) introduced NAPALM, a Python library that unifies communication across different network vendors. Lindholm (2021) showed how companies save time and reduce errors with Python scripts embedded in DevOps workflows.

Lastly, Red Hat's Ansible documentation (2022) and Ylonen and Lonvick's (2006) SSH protocol paper continue to support the use of Python tools like Ansible, Paramiko, and Netmiko in both legacy and modern environments.

Together, this body of work shows a clear trend: Python is not just a helpful tool for network engineers instead, it is becoming the standard language for building scalable, intelligent, and flexible network automation systems.

3. METHODOLOGY

3.1 Research Approach

This study synthesizes findings from peer-reviewed literature, industry reports, and community forums to evaluate Python tools. We prioritized sources published post-2020 to reflect modern hybrid networks, excluding proprietary tools without open documentation. While lab experiments could validate performance, our goal was to assess real-world adoption and scalability. Rather than relying on lab-based simulations or experimental setups, the research focused on an interpretative assessment of the capabilities, limitations, and strategic fit of various Python-based network automation tools.

3.2. Tool Selection Criteria

The tools Netmiko, Paramiko, NAPALM, Ansible, and Nornir were selected based on the following criteria:

- Popularity and Community Support: Frequency of mention in industry forums and GitHub repositories.
- Vendor Support and Compatibility: Breadth of hardware/software environments the tool can interface with.
- Functionality: Capabilities to handle common automation tasks such as device configuration, auditing,

compliance, and orchestration.

- Use Case Documentation: Availability of case studies or user reports that validate their operational effectiveness.

3.3. Data Collection and Analysis

Data was collected through:

- Literature Review: Extensive review of recent journal articles, whitepapers, and documentation (e.g., Chuppala et al., 2023; Wang et al., 2023).
- Comparative Tables: Tools were compared using feature matrices derived from official documentation and expert usage summaries.
- Case Studies: Use cases were synthesized from community-shared projects, open-source contributions, and enterprise reports.

3.4. Evaluation Criteria

Each tool was assessed based on:

- Ease of Use
- Declarative vs. Imperative Paradigm
- Support for CLI, SSH, and APIs
- Scalability and Error Handling Mechanisms
- Best Fit Use Case

These dimensions enabled a nuanced understanding of where and how each tool adds the most value in real-world network environments.

4. PYTHON'S ADVANTAGES FOR NETWORK AUTOMATION

One of Python's defining strengths is that it does not try to be everything for everyone, but it turns out to be enough for most people. For network engineers, this means they can write a useful script after just a few hours of learning basic syntax. That is a low barrier to entry with high potential payoff.

Python works especially well in environments where the network includes a mix of older hardware running CLI-only operating systems and newer devices that expose programmable APIs. In such setups, a language that can handle both SSH-based interactions (for traditional gear) and RESTful API calls (for modern systems) becomes indispensable. Python does both with ease.

Moreover, Python's open-source nature means there is a community behind every tool. If you run into trouble, chances are someone else has already solved it or at least discussed it on platforms like GitHub, Stack Overflow, or community forums. This support network becomes a hidden accelerator for learning and implementation.

It's also worth noting that Python is versatile beyond automation. Engineers who use Python for scripting often go on to use it for data analysis, visualization, or even AI integration tying in monitoring tools, log analysis, or anomaly detection engines. As such, Python becomes not just a tool, but a long-term investment in skill development.

5. CORE PYTHON TOOLS AND THEIR ROLES

When we talk about Python and network automation, it is not just the language that matters but the tools that come

with it. These tools are what make automation scalable, flexible, and resilient. Below are some of the most commonly used libraries and frameworks for network automation.

5.1 Netmiko

Created by Kirk Byers, Netmiko is a wrapper around Paramiko (the underlying SSH library) that simplifies sending CLI commands to network devices. It is ideal for quick wins: pushing configurations, grabbing command output, or making bulk changes across many routers or switches. Its strength is simplicity, it handles login prompts, delays, and session management automatically.

Example Code:

```
from netmiko import ConnectHandler

device = {
    "device_type": "cisco_ios", "ip":
    "192.168.1.1",
    "username": "admin",
    "password": "admin123",
}
net_connect = ConnectHandler(**device)
output = net_connect.send_command("show version") print(output)
```

5.2 Paramiko

This is a lower-level SSH library that gives you more control but requires more code. It's best used when you need to do something very specific that Netmiko does not support out of the box. For example, automating a proprietary or obscure device that is unable to respond well to standard patterns.

Example Codes

```
import paramiko

ssh = paramiko.SSHClient() ssh.set_missing_host_key_policy(paramiko.AutoAddPolicy())
ssh.connect("192.168.1.1", username="admin", password="admin123")

stdin, stdout, stderr = ssh.exec_command("show ip int brief") print(stdout.read().decode())

ssh.close()
```

5.3 NAPALM

NAPALM is designed for consistency. It does not just send commands but rather abstracts the entire process of device interaction. Instead of sending a show command and parsing the result, NAPALM gives you structured data in Python dictionaries. This makes it ideal for audits, backups, and state comparisons.

Example Code:

```
from napalm import get_network_driver

driver = get_network_driver("ios")
device = driver ("192.168.1.1", "admin", "admin123") device.open()
facts = device.get_facts() print(facts)

device.close()
```

5.4 Ansible

Ansible is unique because it uses YAML files called playbooks to describe automation tasks. But under the hood, is all Python. Ansible is agentless and works over SSH or APIs. It is great for orchestrating larger workflows and ensuring repeatability. If you want to make the same change across 200 switches without writing loops in code, Ansible is your friend.

5.5 Nornir

Nornir is newer but growing fast. It offers the flexibility of Python with a structured approach to task execution. Unlike Ansible, which is declarative, Nornir is fully scriptable. This makes it better suited for situations where logic and conditionals are central to the automation process.

Each of these tools has its sweet spot. Together, they create a toolkit that covers nearly every network automation scenario imaginable.

6. BEST PRACTICES & FRAMEWORK DESIGN

Using Python tools effectively requires more than just writing scripts. Here are several best practices drawn from industry leaders and real-world implementations:

- Start Small: Begin by automating simple tasks like backing up configurations or checking interface statuses.
- Use External Files: Store device inventories in YAML or JSON, not in your script.
- Template Your Configs: Use Jinja2 templates for configuration generation.
- Log Everything: Automation should produce logs that can be audited.
- Secure Credentials: Never hardcode passwords. Use environment variables or secret management tools.
- Test Before You Push: Run scripts in a virtual environment like GNS3 or EVE-NG first. Lara and Kolb (2020) emphasize that validating scripts in controlled environments before production deployment is essential to prevent downtime and ensure reproducibility.

Adopting these practices reduces the risk of unintended consequences and makes automation more maintainable over time (Clemm & Medhi, 2021).

7. USE CASE MAPPING OF PYTHON AUTOMATION TOOLS

Rather than recommending a one-size-fits-all solution, we believe it is more useful to map tools to real-world scenarios. Table 1 is a matrix that outlines which tools are best suited to common tasks:

Table 1. Table 1 displays a matrix of common python automation tools and their best suitable tasks

<i>USE CASE</i>	<i>NETMIKO</i>	<i>PARAMIKO</i>	<i>NAPALM</i>	<i>ANSIBLE</i>
DEVICE CONFIGURATION PUSH	Fully supported	Fully supported	Fully supported	Fully supported
CONFIGURATION AUDITING	Not supported	Not supported	Fully supported	Fully supported

COMPLIANCE VERIFICATION	Not supported	Not supported	Fully supported	Fully supported
MULTI-DEVICE DEPLOYMENT	Limited support	Not supported	Fully supported	Fully supported
ZERO TOUCH PROVISIONING	Fully supported	Partial supported	Fully supported	Fully supported
ENCRYPTED SESSION SCRIPTING	Not supported	Fully supported	Not supported	Not supported
CI/CD PIPELINE INTEGRATION	Limited support	Not supported	Fully supported	Fully supported

This chart is not exhaustive, but it illustrates that no tool is perfect for every scenario. Netmiko and Paramiko are better for custom scripting and prototyping, while NAPALM and Ansible are more aligned with modern DevOps workflows.

8. DISCUSSION (TOOL COMPARISON AND STRATEGIC FIT) AND EVALUATION (COMPARATIVE ANALYSIS)

To better understand how each tool fits into network operations, let's look at a side-by-side comparison:

Table 2. Table 2 represents a side-by-side comparison of the automation tools

<i>Tool</i>	<i>Supported Vendors</i>	<i>Ease of Use</i>	<i>Use Case Fit</i>	<i>Declarative?</i>	<i>CLI/SSH/API Support</i>	<i>Best For</i>
<i>Netmiko</i>	Over 60 Vendors	Medium	High	No	SSH	Direct CLI Automation
<i>Paramiko</i>	Generic SSH compatible	Low	Medium	No	SSH	Custom or Legacy SSH Script
<i>NAPALM</i>	10+ major platforms	High	High	No	SSH and API	Multivendor state/ config management
<i>Ansible</i>	Broad (via modules)	High	High	Yes	SSH and API	Scalable, repeatable deployment

From this, we see that Ansible is ideal for large-scale environments where repeatability is critical. NAPALM, on the other hand, excels in multi-vendor settings that require uniform state retrieval. Netmiko is excellent for quick wins and small deployments, while Paramiko is better suited for fine-tuned, lower-level scripting.

Rather than performing physical lab testing, this paper uses published documentation, user reports, and comparative studies to evaluate each tool. Here are some qualitative findings:

- Ansible is the most widely adopted in enterprise settings due to its YAML-based syntax and declarative nature (Red Hat, 2022).
- Netmiko remains a go-to for engineers looking for simple SSH automation with less overhead (Byers, 2019).
- NAPALM is a favorite among teams dealing with vendor diversity and configuration consistency

(Barroso, 2016).

- Paramiko is often embedded into custom tools or scripts requiring detailed SSH session control.

Most organizations benefit from combining two or more tools. For instance, using Netmiko for quick tasks, Ansible for orchestrated deployments, and NAPALM for auditing ensures full coverage.

9. REAL-WORLD APPLICATIONS: CASE STUDIES AND USE CASES

Theory is useful, but how does Python automation work in actual organizations? Below are a few anonymized examples derived from industry reports, community discussions, and personal observations from engineers in the field.

Case 1: An Internet Service Provider (ISP) Standardizing Device Configurations

An ISP in Southeast Asia faced the challenge of managing over 2,000 edge routers from multiple vendors. Their manual provisioning process took an average of 1.5 hours per router and was prone to configuration drift. By integrating Python scripts using NAPALM and Netmiko, the provider developed a reusable template system. Device onboarding time dropped to under 15 minutes, and errors were virtually eliminated.

Case 2: Financial Institution Enforcing Compliance

A European bank needed to ensure that its network devices met strict audit policies. Engineers wrote a Python tool using Nornir and YAML-based inventory files to periodically check configurations and alert the team if any drift occurred. This eliminated the need for quarterly manual audits and reduced compliance-related incidents by 40% in a single fiscal year.

Case 3: University Campus Automating VLAN Management

In a mid-sized North American university, the IT department used Netmiko scripts to manage VLAN provisioning across dozens of buildings. Previously, changes required physical visits and manual CLI entries. With Python scripts tied to a central database of devices, updates could be deployed campus-wide in under an hour. Network downtime during semester changes dropped by 70%. These use cases are reconstructed from anonymized industry reports and technical forums, inspired by trends reported in the literature (Lindholm, 2021; Jorepalli & Bairy, 2024).

10. CHALLENGES AND LIMITATIONS OF PYTHON-BASED AUTOMATION

No tool is without its drawbacks, and Python is no exception. While its strengths are well- documented, there are several limitations to consider.

10.1 Vendor Inconsistencies

One of the biggest hurdles in network automation is dealing with different vendor ecosystems. A command that works on a Cisco switch might be completely different or even unsupported on a Juniper device. While tools like NAPALM aim to smooth these differences, they can't abstract everything. Engineers still need a solid understanding of vendor-specific syntax and quirks.

10.2 Error Handling and Debugging

Python scripts can fail in unpredictable ways if not written carefully. For instance, if a device returns an unexpected prompt, the script might hang or crash. Engineers must account for numerous exceptions, from timeouts to malformed input, which increases the complexity of robust script development.

10.3 Skill Gaps

Many network engineers are highly experienced with CLI-based management but have limited programming experience. While Python is beginner-friendly, the learning curve still exists. Organizations must invest in training and skill-building to fully leverage automation.

10.4 Security Concerns

Automation tools often require credentials to access network devices. Hardcoding these in scripts is risky. Secure practices like using encrypted credential vaults or environment variables are essential, but not always straightforward to implement.

10.5 Scaling Limitations

Python scripts can perform exceptionally well on small to mid-sized tasks but may encounter performance bottlenecks when managing thousands of devices concurrently. Asynchronous programming can help, but orchestration tools (e.g., Ansible Tower) might be better suited for very large deployments.

11. TRENDS AND THE FUTURE OF PYTHON IN NETWORK AUTOMATION

As we look ahead, several trends suggest that Python's role in network automation will only deepen.

11.1 Shift Toward Intent-Based Networking (IBN)

IBN allows engineers to define a desired network state, and automation tools take care of enforcing it. Python is already being used to prototype and implement IBN workflows, especially in SDN (Software-Defined Networking) environments.

11.2 AI and Machine Learning Integration

Python is the dominant language for AI/ML development, and this opens up exciting possibilities. For example, using machine learning to predict network congestion or detect anomalies becomes much easier when your automation layer is already built in Python.

11.3 Cloud-Native Networking and IaC

Infrastructure as Code (IaC) is extending beyond servers and storage into network infrastructure. Python works well with tools like Terraform, AWS SDKs, and Azure CLI, making it an excellent bridge for hybrid cloud automation strategies.

11.4 Open Standards and Telemetry

New telemetry protocols such as gNMI and streaming analytics are becoming standard. Python libraries that support real-time data collection and visualization (e.g., Prometheus clients, InfluxDB) are helping engineers create smarter networks that monitor and heal themselves.

12. CONCLUSION

Python has emerged as more than a scripting language for network engineers it has become a foundational tool

in the automation of complex, dynamic infrastructure. With its combination of accessibility, flexibility, and power, Python allows teams to improve efficiency, reduce errors, and create repeatable workflows.

This paper has examined the tools, libraries, and practices that are reshaping modern network management. We have highlighted both success stories and common obstacles, and offered a forward-looking view on how Python will continue to evolve alongside the networks it helps to automate. In short, Python is not just part of the future of networking, it helps defining it.

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The Transition of Secondary Students into Higher Tertiary Education: The Perspective of Divine Word University, Madang Province, Papua New Guinea

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Abstract: This paper provides an overview of students transitioning from secondary school to higher education institutions and their experiences with contemporary learning. This study explored the challenges and barriers students encounter when transitioning into tertiary education at Divine Word University (DWU) and identified available support services to aid in student development. This study employed an interpretivist philosophy thus; qualitative methodology was used. Data was collected using one-on-one interview with semi-structured questions. Data was analyzed using thematic analysis. The results indicated that students faced multiple challenges, particularly when moving from secondary education. Key challenges expressed by DWU students are, getting nervous and anxious, leaving parents behind and becoming independent, mismanagement of time, excessive social media use, limited digital literacy, and difficulty in adapting to the online system at DWU. Additionally, adapting to the environment is a significant challenge, which leads to students losing government scholarships, being distracted from studies, and experiencing peer pressures. However, there are support services offered by DWU Student Services, such as counselling, psychoeducation and peer mentoring programs, weekend sports, and Information, Communication and Technology services that help students adapt to the tertiary education system. Hence, it is significant for students to utilize the services available to overcome the challenges expressed. The findings underscore the importance of early engagement with students and the proactive use of available support services to facilitate their transition into higher education. Thus, enhancing orientation programs, increasing digital literacy support, and promoting greater awareness of the offered support services are vital areas for improvement to empower students in their learning.

Keywords: Students, Transition, DWU

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1. INTRODUCTION

Transitioning from secondary school to higher tertiary education is a critical phase in a student's academic journey. This period is often marked by significant milestones in academia, social, and personal adjustments as students navigate a new learning environment, thus increasing independence and higher expectations.

Understanding the challenges and experiences of students during this transition is essential for improving support systems and ensuring academic success. The low retention rate among students in higher education is a concern globally. A study conducted in South Africa reported the “annual drop rates of students from a secondary school to higher institutions to be 35%”. This rate indicates that students entering university were not counselled or prepared well before their higher education studies. Preparation of students for higher institutions is vital to prepare them physically and mentally to adapt to the new environment.

This study focuses on the perspectives of students at Divine Word University (DWU) in Madang Province, Papua New Guinea. It aims to explore the factors that influence students’ transition, including academic preparedness, socio-economic challenges, cultural influences, and institutional support. By examining the experiences of DWU students, this research seeks to identify key barriers and facilitators in their adjustment to tertiary education. The findings will contribute to developing targeted strategies to enhance student support services and improve retention and success rates.

This study will employ a qualitative approach. The insights gained will be valuable for educators, policymakers, and university administrators in creating a more effective and supportive learning environment for incoming students.

2. AIM

The study aims to explore the challenges and barriers experienced when transitioning into higher tertiary education and to suggest ways to address these challenges and barriers identified.

3. OBJECTIVES

- To explore the challenges and barriers experienced by first- year students at DWU when transitioning into higher tertiary education
- To investigate the effectiveness of the support services offered at DWU for student formation into higher tertiary education
- To suggest solutions in addressing the challenges that students experience in their transition period

4. KEY RESEARCH QUESTIONS

What are the challenges and barriers experienced when transitioning from secondary education into higher tertiary education?

4.1 Specific questions

1. What are your experiences from a secondary education level transitioning into tertiary education?
2. What are the challenges that students experienced in their transition period?
3. What are the services or programs provided to assist students in their transition period?
4. What are the expectations that students have when coming into a tertiary institution?
5. What are some ways that can be done to overcome the challenges experienced?

5. RESEARCH PROBLEM

Transitioning into university for the first time presents a significant challenge for students, particularly those coming directly from secondary school. The academic and social environments of universities differ greatly from

the structured and closely guided context of secondary education. At the secondary level, teachers provide continuous support, whereas in university, lecturers and tutors are generally available only during scheduled class sessions. Adapting to this new academic culture and environment is often overwhelming. Students face not only institutional expectations but also pressures from their families to succeed. As noted by Guzman et al., the transition into higher education can be a distressing experience, with financial constraints often compounding the challenges and shaping students' experiences and expectations. Therefore, this study aims to explore the perceptions of first-year students at Divine Word University regarding their transition into university life.

6. RATIONALE

The transition to university is a significant milestone in a student's educational journey, presenting both challenges and opportunities. Common challenges include adapting to a new academic environment, developing independent study habits, and managing increased responsibilities. On the other hand, opportunities may include gaining personal freedom, becoming more independent, and making autonomous decisions. This study aims to explore the perspectives of Divine Word University (DWU) students on their transition experience, identifying key factors that influence their adjustment, academic success, and challenges. Understanding these factors will assist educators, policymakers, and institutions in designing targeted support systems to improve students' academic performance and overall university experience. The findings will contribute to enhancing orientation programs, academic support services, and student welfare initiatives to ensure a smoother transition into higher education.

7. METHODOLOGY

7.1 Research Design

This study employed a qualitative research design to explore the transition experiences of secondary school students entering tertiary education, with a focus on Divine Word University (DWU) in Madang Province. Qualitative research is appropriate for examining participants' perspectives and lived experiences in depth. A phenomenological approach was adopted to capture the essence of the transition experience from the viewpoints of both students and academic staff.

7.2 Research Setting

The research was conducted at Divine Word University, a nationally recognized tertiary institution in Madang Province, Papua New Guinea. DWU was selected as the research site due to its diverse student population, which includes individuals from various secondary schools across the country. This diversity provided a rich context to examine the challenges and facilitators of the secondary-to-tertiary transition.

7.3 Participants

Participants were selected using purposive sampling, targeting individuals who had directly experienced the transition process. The sample included:

- 15 continuing (second-year, third-year & fourth-year) university students from different secondary school backgrounds.

This sample size is considered adequate for phenomenological studies, which priorities depth over breadth.

7.4 Data Collection

Data were collected through semi-structured interviews. This method allowed for flexibility in exploring individual experiences while maintaining consistency in the topics discussed. Each interview lasted approximately 30-45 minutes and was conducted in person at the DWU campus, in a private and comfortable setting. Interviews were audio-recorded with participants' consent and later transcribed into words.

7.5 Data Analysis

Transcribed data were analysed using thematic analysis, following Braun and Clarke's six-phase framework: familiarization, coding, generating themes, reviewing themes, defining and naming themes, and producing the report. Qualitative Data Analysis (QDA) Miner Lite was used to assist with data management and coding. Emerging themes were compared across student and staff narratives to identify commonalities and differences in perceptions of the transition experience.

7.6 Ethical Considerations

Ethical approval for the study was obtained from the Divine Word University Research Ethics Committee. Participants were informed about the purpose of the study and their right to withdraw at any time without any negative consequences. Written informed consent was obtained from all participants. Confidentiality was maintained by anonymizing participant data and securely storing all research materials.

8. LITERATURE REVIEW

The transition from secondary school to tertiary education is a critical period in a student's academic and personal development. This process often involves not only adapting to a new learning environment but also dealing with academic, social, and emotional challenges. For students in Papua New Guinea, particularly those entering universities like Divine Word University in Madang Province, this transition is shaped by factors such as educational preparedness, socio-economic background, cultural expectations, and institutional support.

The Concept of Educational Transition

Educational transition refers to the shift from one level of education to another, typically involving increased academic demands and independence. At the secondary-to-tertiary level, students often experience a significant change in curriculum style, expectations, and support systems. According to Kift, a successful transition depends not only on individual resilience but also on how well the institution scaffolds the learning experience in the first year.

The PNG Context

In Papua New Guinea, the transition from secondary school to university is complicated by geographical disparities, limited access to quality secondary education, and a lack of preparation for university-style learning. Many students from rural and under-resourced schools enter tertiary institutions like DWU with insufficient academic foundations, especially in English, mathematics, and information technology. Additionally, cultural and linguistic diversity in PNG adds another layer of complexity. Students often face challenges adjusting to English as the primary medium of instruction in universities, given that many come from vernacular-speaking regions.

Institutional Perspectives: Divine Word University

Divine Word University (DWU) has recognized the unique challenges faced by first-year students and has implemented programs to ease this transition, such as orientation weeks, foundation courses, and peer mentoring initiatives. However, there remains a gap in the literature documenting the effectiveness of these interventions from the perspectives of the students themselves. Studies conducted within DWU have highlighted issues such as

homesickness, academic pressure, limited ICT skills, and difficulty in self-directed learning. These findings align with broader research on tertiary transitions, which emphasize that emotional and academic adjustment are closely intertwined.

The Role of Support Systems

Research shows that family support, peer networks, and institutional mentorship programs play vital roles in helping students adjust to tertiary education. In the PNG context, extended family obligations can either support or burden students, depending on socio-economic circumstances. For DWU students, access to mental health services, academic counselling, and faith-based support groups has been cited as a key factor in coping with university life.

Gaps in the Literature

While much has been written about tertiary education challenges in PNG, there is limited qualitative research specifically addressing student perspectives on their transition into Divine Word University. Most studies focus on administrative or policy-level issues without delving into the lived experiences of first-year students. This study aims to fill that gap by exploring students' insights into the transition process at DWU.

9. RESULTS

9.1 Theme: Challenges Experienced When Transitioning into Higher Tertiary Education

One-to-one interviews conducted with continuing students at Divine Word University revealed that the transition from secondary school into tertiary education was marked by a range of academic, technological, emotional, and socio-cultural challenges. Participants - ranging from second-year to fourth-year students—shared retrospective accounts of their first-year experiences, offering insights into the long-term impact of these transitional difficulties.

9.2 Academic Transition Difficulties

All participants described their first year as academically overwhelming. The sudden shift from teacher-led instruction in secondary school to self-directed learning in university was a major adjustment. Many recalled being unfamiliar with university-level expectations, such as academic writing, referencing, and independent research.

“At first it was not easy, everything I saw was not easy. I had to find my way around to learn. There is more free time, but when I came in it was different from what I expected. I have to adjust myself and get on with my studies, I should not wait for the lecturers to tell me what to do, and I want to do well and complete my studies.” (Participant 6, 3rd Year)

9.3 Technological and Digital Challenges

Many continuing students recalled struggling with digital tools and online learning platforms during their first year. Some had never used a computer before entering DWU and were unfamiliar with basic programs such as Microsoft Word, PowerPoint, and Moodle.

“The online system of doing the test was new because nothing like this was taught in the secondary schools. I was hit hard to really understand aah, the online learning and computer use was all new to me.” (Participant 9, 4th Year). Internet access and affordability were also cited as major issues, particularly among students from rural backgrounds.

“Back then, I had to buy my own data to access Moodle. It was expensive, and sometimes I had to skip meals just to buy credit.” (Participant 5, 3rd Year)

9.4 Emotional and Social Adjustment

The emotional impact of the transition was strongly felt. Students shared experiences of homesickness, loneliness, and culture shock during their initial months at DWU. Being away from family and living in a new environment with unfamiliar people contributed to feelings of isolation and anxiety. *“The first semester was the hardest. I cried a lot at night because I missed my family, and I didn’t feel comfortable talking to new people.”* (Participant 1, 2nd Year)

Some students found it difficult to make friends initially, especially if they came from remote provinces or spoke a different language. *“I stayed quiet most of the time because everyone spoke differently. I felt like an outsider.”* (Participant 4, 3rd Year)

These accounts indicate that transitioning into higher tertiary education at DWU presents multi-dimensional challenges, many of which continue to influence students’ academic performance and emotional well-being in later years. The interviews underscore the importance of early interventions in first year such as digital literacy training, academic mentoring, and orientation programs to support student retention and success.

10. DISCUSSION

10.1 Theme: Challenges Experienced When Transitioning into Higher Tertiary Education

The findings from one-to-one interviews with continuing students at DWU revealed that the transition from secondary to tertiary education is characterized by significant academic, technological, and emotional challenges. These reflections provide critical insights into the initial struggles faced by students and how those experiences shaped their adjustment and ongoing academic journey.

10.2 Academic Adjustment

Consistent with prior studies, students described a marked shift from teacher-guided learning in secondary school to the expectation of independent, self-regulated learning at the university level. This abrupt change was challenging for many, especially those from rural or under-resourced schools where rote learning was more common. Difficulties with academic writing, time management, and understanding lecture content in English support existing findings that first-year students in the Pacific often lack the academic literacy required for higher education. This suggests that bridging programs or extended foundation years could be beneficial, especially for students with limited academic exposure prior to entry.

10.3 Technological and Digital Barriers

Participants' accounts of struggling with digital tools mirror the findings of Azila-Gbette et al., who reported that students with limited ICT experience often feel alienated in blended and online learning environments. At DWU, although the provision of laptops has improved digital access, many students still reported difficulties with basic computer use and navigating platforms (e.g., Moodle, Microsoft Word). These findings reinforce Cheong et al.’s assessment of the digital divide in Papua New Guinea, where poor infrastructure and high data costs limit meaningful participation in digital education. It is evident that access alone is insufficient—training and ongoing digital support are necessary to close the digital competency gap.

10.4 Emotional and Social Adjustment

The emotional challenges described—homesickness, loneliness, and cultural dislocation align with literature emphasizing the psychological toll of academic transitions. Students who moved from rural or remote areas reported feelings of exclusion due to language differences or social discomfort, echoing Bourdieu’s concept of “cultural capital,” where students from underprivileged backgrounds may lack the social tools needed to integrate into university life. These emotional struggles, particularly during the first semester, could hinder academic

engagement and retention unless addressed through early socialization programs, peer mentoring, and culturally responsive support structures.

10.5 Integrating Student Voices into Institutional Planning

A significant contribution of this study lies in its focus on continuing students' reflections. Their retrospective insights provide a deeper understanding of the long-term effects of early transitional challenges. Unlike first-year students still navigating the adjustment, continuing students are able to articulate what specific supports they lacked and what interventions would have made a difference. This perspective is crucial for informing policy and practice at DWU, particularly in areas such as first-year experience programming, mental health services, digital literacy training, and inclusive pedagogy.

RECOMMENDATIONS

The study suggests several actionable strategies for DWU and similar institutions:

- **Strengthen First-Year Orientation** to include academic literacy workshops and digital skills training.
- **Provide Peer Mentoring** through upper-year students to reduce feelings of isolation.
- **Expand Financial Aid** to include living expenses, not just tuition.
- **Enhance Pastoral Support** with culturally sensitive counselling and peer-led wellness groups.
- **Implement Early Warning Systems** to detect and support at-risk students in their first semester.

CONCLUSION

The experiences of continuing DWU students highlight that the transition into tertiary education remains a multi-dimensional challenge that goes beyond academic performance. Addressing these barriers requires an integrated, student-centred approach that combines academic support, technological empowerment, emotional well-being, and financial aid. By listening to and learning from students who have already navigated this transition, DWU can design more effective, equitable, and sustainable support systems.

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On the Impact of Exotic Naturalized Trees in the Landscapes of Papua New Guinea - the situation in Bulolo and Wau

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Abstract: Exotic tree species are tree species that have been introduced into an area outside their normal distribution. Over the years, exotic plants have been introduced in Papua New Guinea (PNG) for aesthetic, agricultural, landscaping, and many other uses. Today, some of these plant species are noticeably dominating the natural ecosystems, particularly the disturbed landscapes, where they are suppressing regeneration of native plant species. This is the trend of species composition expected under the disturbance following from climate change and anthropogenic and natural disasters. Little is known about their rate and extent of their distribution, potential benefits and negative impacts on the environment and the ecosystem as a whole. The natural forests often are not able to rebound from alteration of forests by anthropogenic activities through agricultural farming practices, logging, mining, infrastructural development and settlements, and also natural disasters. The rate and extent of the exotic tree species dominating the vicinity in and around the township of Wau and Bulolo, namely, *Albizia chinensis* (Fabaceae), *Leucaena leucocephala* (Fabaceae), *Pinus caribaea* (Pinaceae), and *Piper aduncum* (Piperaceae), *Samanea saman* (Fabaceae) and *Spathodea campanulata* (Bignoniaceae) were assessed using aerial images to demonstrate the actual formation of forest communities by exotic tree species in a PNG landscape. The survey data demonstrated a positive impact that exotic tree species can naturalize well into the landscape ecosystem they thrive in, forming new forest communities. Their spread has had both beneficial and negative impacts on natural landscapes, and community livelihoods.

Keywords: Bulolo, exotic trees, Papua New Guinea

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1. INTRODUCTION

Papua New Guinea (PNG) has 12 major natural forest types and 10973 described plant species. This includes 2854 (26%) species of trees native to this country of which 1284 are endemic to PNG. Despite PNG being rich with native trees, in recent years, exotic plant species have been noticeably dominating the natural ecosystems, particularly the disturbed landscapes, where they are suppressing regeneration of native plant species. This is the trend of species composition expected under the disturbance following from climate change and anthropogenic and natural disasters. Little is known about their rate and extent of their distribution, potential benefits and negative impacts on the environment and the ecosystem as a whole.

This paper presents the rate and extent of the spread of dominant exotic tree species, namely, *Albizia chinensis* (Osbeck) Merr. (Fabaceae), *Leucaena leucocephala* (Lam.) de Wit (Fabaceae), *Pinus caribaea* Morelet

(Pinaceae), *Piper aduncum* L. (Piperaceae) *Samanea saman* ((Jacq.) Merr (Fabaceae) and *Spathodea campanulata* P. Beauv. (Bignoniaceae) in and around the vicinity of the townships of Bulolo (Coordinates: 7.2011° S, 146.6447° E) and Wau (Coordinates: 7.3371° S, 146.7159° E) were assessed using aerial imagery to demonstrate the actual formation of forest communities by exotic tree species in a PNG landscape. The drone images and the ground photographs were taken on selected sites between Bundun (6.8495° S, 146.6172° E) and Kaisinik (Coordinates: 7°22'0" S and 146°46'1" E) are shown in Figure 1.

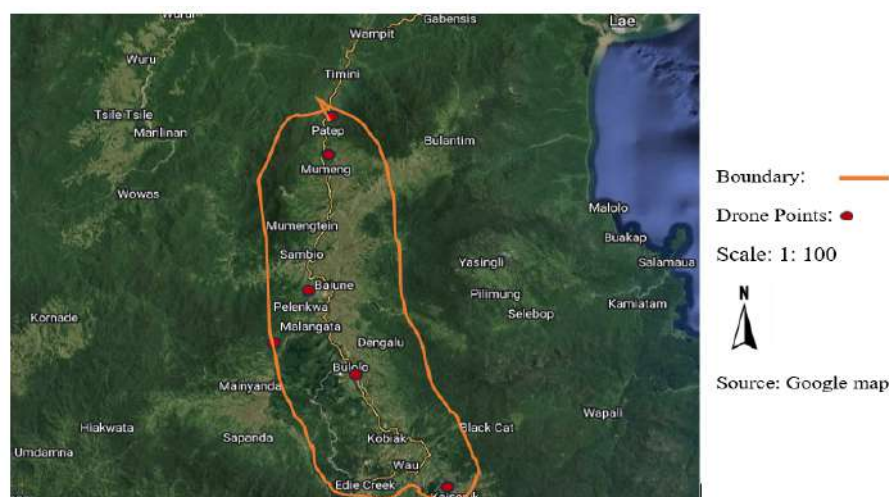


Figure 1: Location of the study area

2. AERIAL IMAGES AND THE FIELD PHOTOGRAPHS OF COMMON FOREIGN TREE SPECIES IN BULOLO AND WAU

2.1 *Albizia Chinensis* (Osbeck) Merr.

Albizia chinensis is a native to China, Southeast Asia, Bangladesh and Myanmar. It is also found in India, Sri Lanka, Thailand and in Java, Bali and Nusa Tenggara. It is cultivated in many tropical countries, including PNG as well. In PNG it was planted for shade and for providing nitrogen in coffee.

In the Bulolo area, the species was initially planted in coffee gardens. However, currently, the tree species is scattered all across the landscape. There are certain such as Guragko and Patep, this species has formed patches of pure stands.



Drone image at Bundun

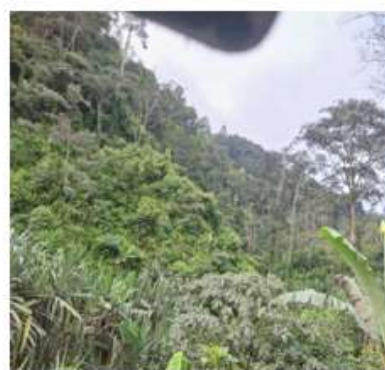


Photo taken on the site

Figure 2: Stands of *Albizia chinensis* at Bundun

2.2 *Leucaena leucocephala* (Lam.) de Wit

Leucaena leucocephala, commonly known as Leucaena, occurs naturally in Mexico and Central America, but has been widely introduced to various parts of the world, particularly in tropical and subtropical regions, including Papua New Guinea. This species was brought into this country for shade and improvement of soil fertility in coffee plantations and as a forage crop, particularly for cattle.

In Kumalu (Coordinates: 6°58'45"S 146°37'08"E), *Leucaena* has dominated the floodplain succession, which is apparent dominance over other plant species in areas previously filled with debris and rocks from mud flows. Niche partition was observed along waterlogged patches at the riparian zones of the floodplains, the coexistence of *Leucaena* and *Phragmites kharka* Retz.) Trin. Ex Steud which is also native l Africa, the Middle East, and southwestern Asia and *Piper aduncum*, another exotic species. In other sites, the species is sparsely distributed.



Drone image at Kumalu



● Photo taken on the site

Figure 3: (a) Drone image and (b) Photograph showing the spread of *Leucaena leucocephala* along the Kumalu river system, and closed-up of them growing alongside *Phragmites kharka* respectively.

2.3 *Pinus caribaea* Morelet

Pinus caribaea is native to Bahamas, Colombia, Cuba, Guatemala, Honduras, Mexico, Nicaragua, Panama. However, it is exotic to many countries in tropical and subtropical regions within the altitudinal limits of sea level of 10-1500 m. It is also grown in PNG, mainly in grassland areas.

In Bulolo and Wau areas, *P. caribaea* was planted mainly in grasslands for commercial plantation and to improve grassland sites for later plantings of Araucarias. However, currently, this species is not only growing in its original planting sites but it has grown into new sites naturally. It has been observed in Bulolo-Wau areas, that this species can withstand fires.



Drone image at Kaisinik



● Photo taken



Figure 4: *Pinus caribaea* stands

Drone images and the photographs are showing the spread of *P. caribaea* and its associates with other exotic naturalized trees such as *Piper aduncum* and *Albizia chinensis*, forming forest communities as observed in Zenag (Coordinates: 9.4520° S, 147.1900°E) and Kaisnik (coordinates are 7°22'0" S and 146°46'1" E).

2.4 *Piper aduncum* L.

Piper aduncum, commonly known as Spiked Pepper or Daka Diwai in PNG, is native to tropical America, from Mexico to northern Argentina, and the West Indies. It's also naturalized in various areas outside its native range, including South East Asia, Indonesia, Malaysia, the Pacific Islands and Papua New Guinea.

This species has also become widely introduced outside its native range in southern Florida, Puerto Rico, and in the Asia-Pacific region including Malaysia, Indonesia, Philippines, Papua New Guinea, Solomon Islands, Vanuatu, Fiji, Hawaii, Micronesia, American Samoa, Niue, the Marianas, Tonga, Samoa, the Cook Islands and Palau. It was introduced in PNG unintentionally as only one tree was seen in Heldsbach, Finschhafen (Coordinates: 6.4946° S, 147.8304° E) in 1935, but it is now grown naturally extensively across the landscapes of the country.

In the Bulolo and Wau areas, this species is found in almost all ecosystems in the landscape. Also, in any small openings this species occupies the sites rapidly, causing hindrance for the native tree species to establish. Field observations in Zenag and Kaisnik revealed that this species associates well beneath other species such as *Albizia chinensis* and *Pinus caribaea*. Even in Kumalu, *P. aduncum* was dwelling well under the *Leucaena leucocephala*.



Figure 5: *Piper aduncum* stands

2.5 *Samanea saman* ((Jacq.) Merr

The tree species, *Samanea saman* is synonym of *Albizia saman*, which is commonly known as Rain Tree is from the family of Fabaceae. The species is easily recognized by its umbrella-shaped canopy Rain Tree is believed to be native in northern South America (Colombia, the Caribbean slope and the Orinoco drainage of Venezuela), and in Central America as far north as El Salvador. It is reported that the species is now widespread from Mexico south to Peru, Bolivia, and Brazil. In these areas, it occurs in low-elevation dry forests and grassland/savannah habitats.



Drone image at Bulolo



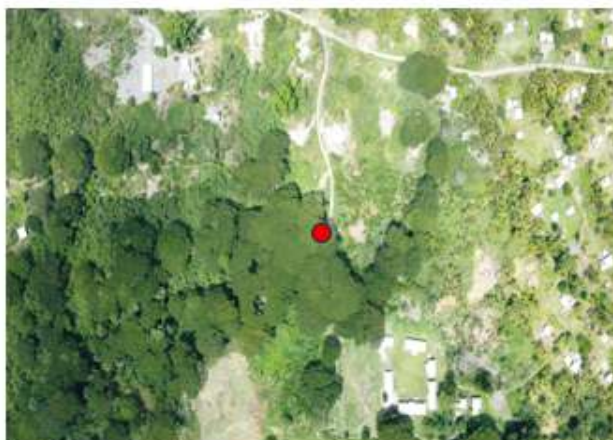
● Photo taken



Drone image at Baiune



● Photo taken on the site



Drone imager at Patep



● Photo taken on the site

Figure 6: Stands of *Samanea saman*

It is one of the important species in the Pacific as a shade tree on small farms, along roads, in parks and pastures [18] is widely found in the tropics. In PNG, it is found in certain places, like Rigo (Coordinates: 9.7922° S, 147.8254° E) [10], Markham (Coordinates: 6.4159° S, 146.2929° E) and Erap (Coordinates: 6° 31' 59" S, 146° 41' 59" E).

In Bulolo, *Samanea saman* has dominance in Bulolo valley. It is found mainly in old gold dredging sites in Bulolo township, Baiune (Coordinates: 7.0883° S, 146.6243° E) and Latep (Coordinates: 7.1522° S, 146.5851° E). In these sites, the species occurs in patches of pure stands, facilitating survival of both terrestrial and arboreal plants. Also, the species associates well with *Spathodea campanulata*, forming forest communities. In Patep, it was observed that Cocoa (*Theobroma cacao*) was grown under this tree. In other sites, food crops were grown beneath this tree, and local people were keeping it for shade.

2.6 *Spathodea campanulata* P. Beauv

Spathodea campanulata, also known as the African Tulip tree, is native to tropical Africa, particularly in Guinea, Angola, Sudan, Ghana and Zambia. It is now widely cultivated and even naturalized in many tropical and subtropical regions outside of Africa, including areas in Mexico and the Pacific Islands, including PNG, where it is considered invasive.



Drone image at Bulolo



● Photo taken on the site



Drone image at Baiune



● Photo taken on the site

Figure 7: Stands of *Spathodea campanulata*

In Bulolo *Spathodea campanulata* is mainly found in Bulolo and Baiune areas. In some sites, the species forms a pure stand in patches, while in other sites, the species grows together with *Samanea saman*.

3. CHARACTERISTICS OF VULNERABILITY OF NATIVE TREES VERSUS DOMINANCE OF EXOTIC TREES

Exotic tree species are often successful in new environments due to a combination of factors. Characteristics of vulnerability of native trees versus dominance of exotic trees described here are based on the tree species' initial growth and survival on the sites which are normally on open spaces.

Table 1: Characteristics of vulnerability of native trees versus dominance of exotic trees

Vulnerability of native trees	Dominance of exotic trees
Adaptability to local environmental conditions	Adaptability to a broader environmental condition
Moderate seed production	Mass seed production
More shade tolerant species	More shade intolerant species
Short lived in open spaces	Long lived in open spaces
Less tree species with nitrogen fixing abilities	Many tree species with nitrogen fixing abilities
Less tree species is propagated from vegetative parts	Many tree species are propagated from vegetative parts are
Weak resilience to disturbance	Robust resilience to disturbance:
Less vigorous dispersal systems	Robust dispersal systems
More predators	Less or predators
Mixed stand	Pure or dominant stands

Source: (i) Native trees (ii) Exotic trees.

CONCLUSION

The survey data demonstrated a positive impact that exotic tree species can naturalize well into the landscape ecosystem that they thrive in, forming new forest communities. Their spread has had both beneficial and negative impacts on natural landscapes, and community livelihoods. The situations in Bulolo suggest that similar trends are happening in the landscape of PNG, and in the future, it is most likely that the exotic tree species are expected to dominate the landscapes of PNG. This is expected in the mid-altitude where *Albizia chinensis* and *Leucaena leucocephala* have already migrated out of their initial planting site in the natural ecosystems. Also, *Piper aduncum* which migrated swiftly into the high-altitude areas is expected to dominate the highland landscapes as well.

The literature search revealed that little is known about the rate and extent of distribution, potential benefits and negative impacts of these exotic species on the environment and the ecosystem at large. Due to disturbances caused by anthropogenic activities, natural disasters and climate change, it is expected that the exotic plant species are likely to have dominance on PNG 's landscape as [23] stated that all of the species in this paper are invasive. Further studies are highly necessary to understand the rate and extent of distribution, potential benefits and negative impacts of these exotic species on the environment and the ecosystem at large in PNG.

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Preliminary Results on Development of Sustainable and Biodegradable Food Packaging Films Using the Peels of Indigenous Banana Plant *Musa ingens* from Enga Province of Papua New Guinea

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Abstract: “Sustainability” and “Plastic/polymer pollution” are probably the two challenging phrases that the world is currently facing and the scientific investigations are focusing on. While mitigating plastic pollution has become a humongous task, sustainability has always come in handy with vastly spread biodiversity. Papua New Guinea (PNG) is one such blessed country with a hugely diversified bioresources. Food industry is one massive area that contributes to pollution, mostly through food packaging and single-use plastics. Of many known banana varieties in PNG, *Musa ingens* is special as it holds the record of being the world’s largest banana tree, and they are widely found at elevation limits between 1000-2100 m. Based on recent research published, this study was undertaken, however, with raw banana peels instead of ripened ones, to check if the fruit-ripening factor plays a significant role in preparing biofilms, and further if raw peels result in films with superior properties. The study indicated that raw peels were also able to produce biodegradable films. Preliminary results are encouraging and the films were able to be prepared, stretched as well as biodegraded within a definite timescale. The study indicated that some vital factors for putting these films into food packaging applications like water solubility (~21-47%, lower the better), moisture content (~16-35%, lower the better) and stretchability/elongation (~3-12%, higher the better) are still challenges to overcome. A discussion on subtle modifications done to the laboratory procedures and various results obtained will be presented. Further, a comparison of properties of films obtained from the present study with those of ripened peels reported in the literature will also be presented in the paper.

Keywords: Banana peels; *Musa ingens*; packaging films; biodegradable films; plastic pollution; sustainability.

1. INTRODUCTION

1.1 Plastics and Pollution

Plastics play an integrated role amongst the human community. Many different types of polymers are used in almost all areas of applications. They are widely being used due to their strength, manufacturability and workability, properties like unusual conductance, excellent biocompatibility, good insulation, to name a few. It is very unfortunate that most of the plastics and plastic additive chemicals do not effectively biodegrade, but rather decompose and transform, thus persisting in the environment and entering into atmosphere, hydrosphere, lithosphere and finally biosphere, where a high level of bioaccumulation and biomagnification result. In spite of the development of biodegradable and recyclable plastics, either that the littered plastics do not get biodegraded and decomposed within a short period of time, or do they reach proper recycling facilities to put them into reuse. Littered plastics, in the open environment, are constantly exposed to heat and light (sunlight), warmth (seawater and ground), microbes (land and water) and oxygen (atmosphere). Natural weathering of plastics results in embrittlement and breakdown to microplastics, and become very efficient in adsorbing metals and other persistent organic pollutants. Plastics degrade to micro- (<5 mm dia) and nano- (<1 µm dia) plastics and they get transported with the help of land and air and finally reach marine waterbodies wherein they stay for decades together.

1.2 Sustainable Solutions

Of all uses that plastics have been put into, packaging in food and beverage industries is one area where a wholesome of them are currently being used. Several sustainable solutions like use of lignocellulosic biomass are ventured into, but with a wide gap of essential functional properties like (i) resistance to degradation, moisture, puncture, temperature, gas and impact, (ii) impermeability to moisture, gas, oil and aromas, (iii) re-sealability and (iv) breathability. Vital characteristics like mechanical properties, shelf life, water vapour barrier and food decolouration and vitamin degradation are assessed using properties like (a) tensile strength, tear strength, elongation, (b) changes in moisture content and oxidative and microbial changes, (c) moisture loss and gain and (d) oxygen transmission rate and light transmission respectively. An estimate shows that 113 billion MT of carbon equivalent is generated in the earth by biomass, every year. Many cellulosic materials were used to prepare biopolymer films.

Papua New Guinea is a developing Pacific country belonging to Oceania continent. Based on the available statistics (10.73 million population, 65% falls between 15-64 years, ~45% of banana mass is peels, banana consumption rate in PNG 109 kg/capita/y, ~267 million kg of banana peels are produced annually in PNG which are littered and most of them undergo anaerobic degradation to produce methane gas, a strong greenhouse gas. By converting into biofilms, buildup of greenhouse gas is drastically reduced, simultaneously promoting sustainability and circular economy. In this short study, biofilms were prepared from unripe banana peels in order to evaluate their properties against those prepared from ripe bananas. Raw bananas from *Musa ingens* were used, which is the world's tallest banana tree, indigenous to PNG and grow in the highlands at an altitude of 1,000 to 2,100 m from the sea level. Table 1 shows the comparison of various parameters between ripe (RBP) and unripe banana peels (UBP). Peels from UBPs are found to be rich in cellulose, and hence chosen for the present study.

Table 1. Comparison of properties of RBP and UBPs.

#	Parameters	UBP (typical)	RBP (typical)
1	Moisture (%)	4.6 – 17.3	15.5 – 17.8
2	Protein (%)	1.94 – 2.41	2.18 – 2.73
3	Fat (%)	2.63 – 3.05	1.76 – 3.25
4	Ash (%)	11.9 – 13.5	11.3 – 14.7
5	Carbohydrates (%)	51.3 – 52.3	48.4 – 51.9
6	Energy (kJ/100g)	1015 - 1026	990 – 1012
7	Cellulose (%)	18 – 59	7 – 21
8	Hemicellulose (%)	17 – 20	6 – 20
9	Lignin (%)	7 - 16	6 – 12

2. EXPERIMENTAL

Banana peels were obtained from wild and unripe banana *Musa ingens* at lower Lai region of Wapenamanda district of Enga province, Papua New Guinea, with GPS coordinates of -5°40'0.012" N and 143°55'0.012" E. Laboratory grade reagents and deionized water were used throughout the study. Equipment like drying oven with natural convection (Binder, ED56 model), grinder (Brook Crompton, Series 2000 model), mechanical rotary shaker (Labec, TS-520D model), UV-visible spectrophotometer (Varian, Cary 50 Bio model) and centrifuging machine (Kokusan, H-103n model) were used. Subtle modifications to the reported procedure were followed for preparing biofilms (Fig.1, modifications shown in boxes above arrows). Formulae for calculating various parameters are shown in Equations (1)-(5), and the procedures followed were those reported in except for elongation test that was manually carried out.

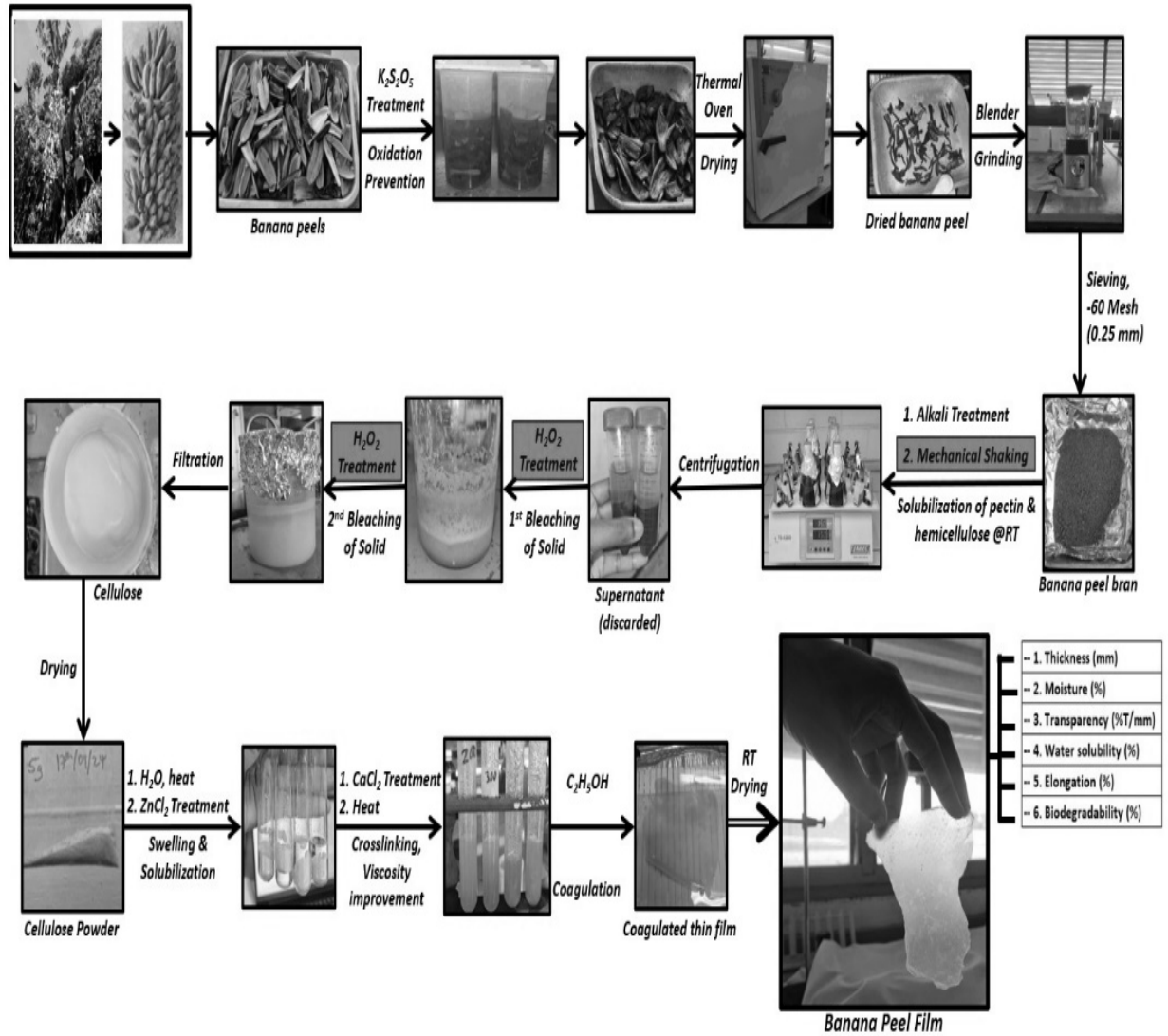


Fig. 1. Process flow chart for preparation of cellulose-based biofilms.

$$\text{Moisture content (\%)} = \left(\frac{\text{Initial Wt.} - \text{Final Wt.}}{\text{Initial Wt.}} \right) \times 100 \quad (1)$$

$$\text{Transparency (\%T/mm)} = \frac{\% \text{Transmittance @600 nm}}{\text{Film thickness (mm)}} \quad (2)$$

$$\text{Water solubility (\%)} = \left(\frac{\text{Initial Wt. of dry film} - \text{Wt. of insoluble portion after the test}}{\text{Initial Wt. of dry film}} \right) \times 100 \quad (3)$$

$$\text{Elongation (\%)} = \left(\frac{\text{Elongation at break (mm)} - \text{Initial length (mm)}}{\text{Elongation at break (mm)}} \right) \times 100 \quad (4)$$

$$\text{Biodegradability (\%area)} = \left(\frac{\text{Initial area of film (cm}^2\text{)} - \text{Area after 6 d of soil burial (cm}^2\text{)}}{\text{Initial area of film (cm}^2\text{)}} \right) \times 100 \quad (5)$$

3. RESULTS

Measured properties of Raw/unripe banana peel films (UBPF) and comparison with reported values for those of RBP (RBPf) are shown in Table 2.

Table 2. Comparison of properties of UBPF, RBPf *V/s* polyethylene.

Description	[CaCl ₂], mM			
	200	300	400	500
<u>Film thickness (mm)</u>				
UBPF (this study)	0.03-0.08	0.04-0.05	0.03-0.04	##
RBPf	0.045-0.069	0.057-0.069	0.071-0.095	0.08-0.1
Polyethylene	----			
<u>Moisture content (%) ↓</u>				
UBPF (this study)	35.00	27.77	16.94 @	##
RBPf	22.30	19.57	18.12	13.73
Polyethylene	0.05-0.07			
<u>Transparency (%T/mm)</u>				
↑				
UBPF (this study)	26.23	34.30 \$	28.33 @	##
RBPf	45.10	38.35	34.82	31.97
Polyethylene	15-20			
<u>Water solubility (%) ↓</u>				
UBPF (this study)	46.66	37.00	21.00 @	##
RBPf	65.71	48.85	38.98	24.45
Polyethylene	0			
<u>Elongation (%) ↑</u>				
UBPF (this study)	12.0 @	8.2	3.8	##
RBPf	12.97	8.61	5.97	4.85
Polyethylene	69.33			
<u>Biodegradability (%) ↑</u>				
UBPF (this study), 6 days	100.00 @	84.12 \$	91.83	##
RBPf, 30 days	92.40	86.20	83.10	75.70
Polyethylene	0			

\$ - Probable error in measurements; @ - Preferable values for chosen parameters; ## - Not completed (study in progress); ↓↑ - Preferable trend for chosen parameters

Banana peel films prepared from varying Ca²⁺ concentrations (200, 300, 400 and 500 mM) are shown in Fig. 2.

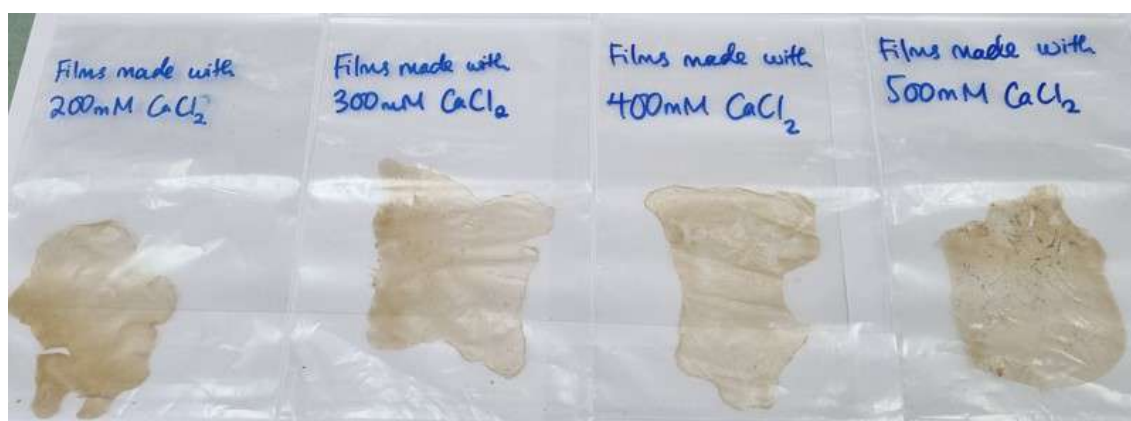


Fig. 2. BPF prepared using 200-500 mM CaCl₂ solutions.

4. DISCUSSION

4.1 Experimental Procedure

During the film preparation, alkali treatment was done in order to transform cellulose-I to its another polymorph (cellulose-II) which is proven to be thermodynamically more stable. Cellulose-II contains antiparallel chains of linked glucose units and intermolecular hydrogen bonds. A slight modification to the reported procedure was done by: (i) using relatively milder bleaching agent H_2O_2 to the insoluble residue instead of a stronger agent, NaClO_2 , (ii) reducing the speed of mechanical rotary shaker from 350 rpm for 14 h to 200 rpm for 24 h, and (iii) reducing the speed of centrifuging machine from 10,000 rpm for 5 min. to 2,500 rpm for 20 min. Films were produced using differing CaCl_2 concentrations and 400 mM film was found to be clear and possessing easy film-forming tendency.

4.2 Properties of Banana Peel Films (BPF)

The measured thickness was found to have huge variations between various spots of the same film. This is due to the lack of thin layer chromatography applicator and hence the coagulated solid residue was manually spread on a flat surface. With higher concentrations of Ca^{2+} , properties like moisture content, water solubility, elongation% and biodegradability decrease. Polyethylene is a hydrophobic polymer with a very low moisture content compared to BPF prepared in the present study. This is due to the non-polar covalent bonds in polyethylene and higher degree of polar covalent bonds in the cellulosic structure. The lower transparency observed could be due to the use of milder bleaching agent compared to those published for RBPF. However, the trend with UBPF is found to be opposite when compared to RBPF, which warrants further investigation. Also, higher transparency observed in the present study compared to conventional polyethylene films is encouraging. Presence of other species due to ineffective bleaching has also probably influenced in reducing the water solubility. The films prepared in the present study are raw films with no addition of functional additives like plasticizers. Presence of higher $\text{H}_2\text{O}\%$ has significantly helped in imparting plasticizing effect, when plasticizers themselves are not present. This effect has necessarily helped the observed higher elongation. The decrease in biodegradability with increasing $[\text{Ca}^{2+}]$ could understandably be due to effective crosslinking of a number of Ca^{2+} ions between vertical chains providing certain matrix rigidity.

4.3 Mechanistic Aspects

The type of polymorph present in bio-resources is cellulose-I, that got converted to cellulose-II during the biofilm preparation. The original cellulose strands are hold together by weak van der Waals forces and H-bonds between hydroxyl groups (Fig. 3). When cellulose was treated with ZnCl_2 , it solubilizes by breaking those weak bonds and coordinating with Zn^{2+} ions. The size of Zn^{2+} ions (88 pm) is insufficient to bridge two strands and hence single Zn^{2+} ion coordinates to a single strand. Later, when CaCl_2 was added, the relatively larger Ca^{2+} ions (114 pm) fill the gap and bridge two strands thus holding them together, allowing to improve the viscosity and enabling to coagulate from the solution. In order to enhance properties like elongation, flexibility, tear strength, etc. in bio-based films, a suitable MCl_x solution is required that improvises the current scenario with Ca^{2+} ions, which remains highly challenging. While strong covalent interactions persist in conventional polyethylene films (Fig. 4) that leads to properties like flexibility and stretchability, bio-based cellulosic films possess discrete ionic interactions between strands, that leads to limited flexibility.

Chemical guiding principles for further development process. (i) *Biocompatibility* – human bodies shall show no negative impact, for example, use of sodium salts might result in absorption of Na^+ ions from the film to the packed food, thus increasing human blood pressure levels; (ii) *nontoxic* – toxic heavy metal salts (CdCl_2 , etc.) shall not be used as they are known to have biochemical toxic impacts after absorption; (iii) *ionic size* – shall best fit between strands such that a good stability is provided to impart strength, water vapour permeability, moisture absorption, etc.; (iv) *complex stability* – oxygen of -OH moieties interact with metal ions to form bonds; according to Pearson's hard soft acid base theory [18], O^- is a hard base and only suitable hard acid metal ions can interact

strongly to form stable interactions and hence stable films; and (v) *ionic charge* – plays a vital role in further stabilizing the coordination complex formed, in order to achieve desired properties.

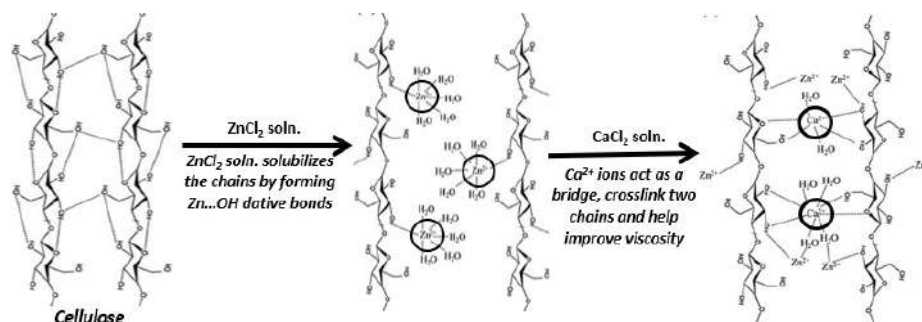


Fig. 3. Solubilizing and crosslinking in cellulose (strand structures adopted from [16]).

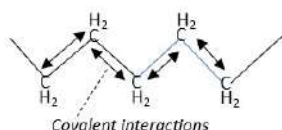


Fig. 4. Covalent interactions in conventional PE films.

Chemistry around calcium ions. The role of calcium ions in welan, an exopolysaccharide, was reported to bridge the two double helices through oxygens and water molecules, with metal's coordination number expanding to as high as 7-9 which are not so common, and further the $\text{Ca}^{2+} \dots \text{O}$ bond lengths varying from 2.61-3.42 Å. On a similar note, in this study, the role of calcium ions is also predicted to bridge cellulose strands which make the films strong enough, simultaneously imparting a limited flexibility. In the literature, positive charges of calcium ions were reported to be counterbalanced by two carboxylate units of the welan structure. However, in this study, since the previous experimental steps were not involved in alkali addition, the weakly acidic hydroxyl hydrogens (i.e., $\text{org-OH} \rightarrow \text{org-O}^- + \text{H}^+$) cannot be removed to counterbalance positive charges of Ca^{2+} ions.

4.4 Open Challenges

Several challenges persist in switching over from unsustainable to sustainable pathways. Some of them are: (a) meeting current demand *Vs* supply, (b) scaling up issues arise when switching over from a lab-scale preparation to massive industrial production, (c) structures of cellulose slightly vary from one to the other depending on origin (number of functional groups present, molecular weight, etc.), (d) matching of properties with current PE packaging films, and (e) many number of hydroxyl groups are present that affects properties like moisture content, water solubility, permeability to water vapour, etc., thus insisting on chemical modifications to cellulose structures by replacing hydrogens on -OH moieties with alkyl groups.

5. CONCLUSIONS AND FUTURE SCOPE

The study indicated that the properties of films derived from UBP match very well with RBP. However, extensive study on properties is required to proceed further. Biobased food packaging films are indeed a promising green alternative to polyethylene packaging films. Suitable physical, chemical or physicochemical modifications to the existing functionalities in banana peels need to be focused on to improve properties and hence their application potentials in industries, especially for food packaging. Some of the modifications like (i) surface coating to achieve suitable properties like water permeability, elongation and tensile strength, (ii) blending with suitable conventional plastics (in low percentages) or other bioplastic materials (like polylactic acid), or with other common plasticizers (like sorbitol, glycerol, etc.) can bring in essential characteristics like vapour-water barrier properties and stability, and (iii) chemical modifications on cellulosic part of banana peels can improve resistance to moisture uptake, tolerance to higher percentages of moisture, compatibility, etc. could perhaps maintain the freshness and tastes of

perishable foods (fruits, vegetables, seafoods, etc.). Thus, the reactivity / hydrophilicity / polarity of hydroxyl groups of cellulose can be modified using typical esterification and etherification reactions by converting hydroxyls to esters and alkoxy. While considering such modifications, it is worthy to focus on making the entire process “sustainable” and “renewable”. For example, property-enhancers like corn starch, carboxymethylcellulose, etc. could be derived from bio-sources which ultimately reduce waste and promote circular economy.

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CONTAMINATION OF DUMP SOILS BY TOXIC HEAVY METALS: AN EMERGING RISK TO GROUNDWATER QUALITY

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Abstract: Heavy metals such as lead (Pb), cadmium (Cd), and mercury (Hg) pose significant concerns due to their persistence in the environment and their potential risks to human health and ecosystems. Contamination of soil can jeopardize groundwater quality, as precipitation may facilitate the leaching of these metals into the water supply. Given that groundwater serves as a crucial source of drinking water, such contamination can adversely affect aquifer geochemistry, resulting in severe health and environmental consequences. This study corroborates earlier research that identified the presence of Cd, Pb, and Hg in borewell samples by assessing heavy metal concentrations in the soil surrounding the Papua New Guinea University of Technology's dump site. Utilizing Inductively Coupled Plasma Mass Spectroscopy (ICP-MS), the investigation revealed concentrations of Cd, Pb, and Hg ranging from 0.0031 to 0.0062 mg/L, 0.04 to 0.63 mg/L, and 0.0008 to 0.0018 mg/L, respectively. The findings indicate a significant increase in heavy metal concentrations in proximity to the dump site over the years.

Key Words: Ground water, Open dump site (ODS), Heavy metal contaminants, Inverse distance weight (IDW) interpolation.

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1. INTRODUCTION

The management of municipal solid waste (MSW) in Lae City is through open dumping and burning. This study assessed its impacts on groundwater quality, given that heavy metal contamination in soils can result in leaching of metals into the groundwater aquifer. Solid waste such as scrap metals, metallic devices, batteries, and electronic waste found in open dumps are some of the sources of heavy metals. Heavy metals such as Cd, Pb, and Hg are highly toxic, even at very low concentrations. As such this study evaluated Cd, Pb, and Hg in dump soil to confirm previous studies on bore wells near the dump site. Surface water and groundwater aquifer are venerable and susceptible to heavy metals contaminations as confirmed by studies over the decade.

Leachate, a waste fluid, is created when rainwater flows through a waste disposal plant and according to studies it has a high propensity to seep through soil and contaminate the water table below. These leachates containing heavy metals and or inorganic or organic substance reaching groundwater persist and degrade groundwater quality and provide a serious health risk to the consumer.

The open dump site in which this study centered is located inside the perimeter of PNG University Technology and beside it is the pump house where raw water is harvested and treated at Traka Treatment Facility by Water PNG Limited and distributed through Lae City and surrounding communities for consumption and domestic uses. Potable water is one of the basic necessities for human survival. A vital component of successful health protection measures, access to drinking water can be a fundamental right and a necessity for good health. Since improved access to clean drinking water has measurable health advantages, it is crucial. Therefore, access to clean drinking water is essential to human survival. According to The United Nations General Assembly (UNGA) has listed access to clean water and sanitation for all as one of the sustainable development goals to be attained by 2030.

To determine and validate the level of heavy metal (Cd, Pb, and Hg) contamination in the dump soil close to the borewell, this self-funded investigation was carried out.

2. THE STUDY AREA AND SITE MAP

This study was recently carried out in the industrial metropolis of Lae, Morobe Province, Papua New Guinea (PNG), located near the PNG University of Technology, illustrated on the map.

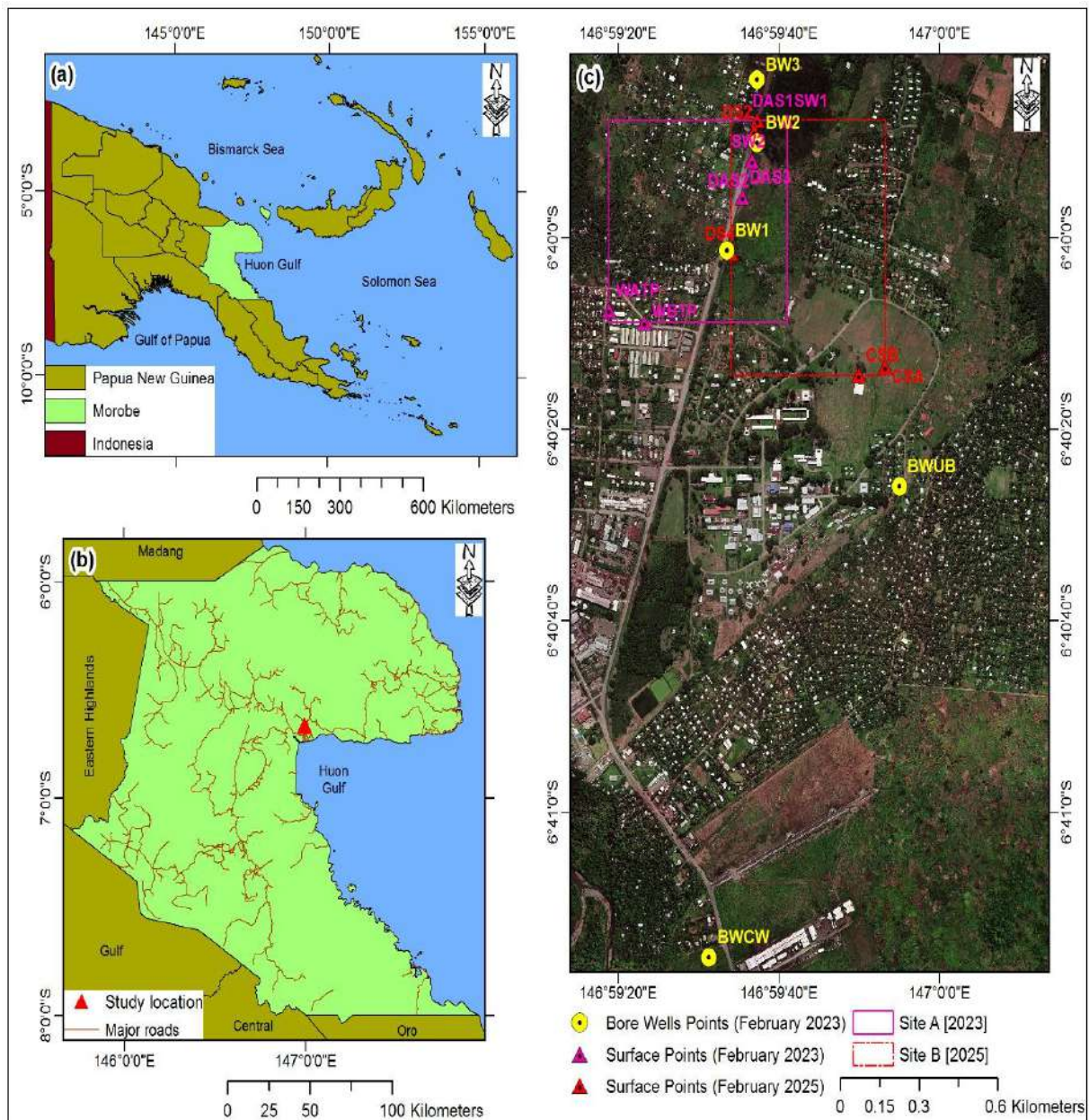


Figure 1 Map Depicting the Study Area

Six (6) soil samples were taken in total, two (2) control soils away from the dump and four (4) near the waste disposal site as tabulated below.

Table 1 Sampling Coordinates

Sl. No.	Station Type	Sampling Point	Longitude	Latitude
1	Bore well 2023	Borewell 1 (BW1)	146.9926	-6.66704
2		Borewell 2 (BW2)	146.99369	-6.66390
3		Borewell 3 (BW3)	146.99369	-6.66207
4		Borewell Igam Market (BWIM)	146.98597	-6.64910
5		Borewell Carwash (BWCW)	146.99202	-6.68756
6		Borewell Uni Block (BWUB)	146.99862	-6.67388
7		Water Before Treatment Plant (WBTP)	146.98980	-6.66913
8	Surface Point 2023	Water After Treatment Plant (WATP)	146.98857	-6.66876
9		Dump Area Soil 1 (DAS1)	146.99474	-6.66326
10		Dump Area Soil 2 (DAS2)	146.99352	-6.66443
11		Dump Area Soil 3 DAS3)	146.99320	-6.66548
12		Surface Water 1 (SW1)	146.99474	-6.66326
13	Surface Points 2025	Surface Water 2 (SW2)	146.99352	-6.66443
1		Control Soil A (CS A)	146.998145	-6.67045
2		Control Soil B (CS B)	146.997232	-6.67062
3		Dump Soil 1 (DS1)	146.993721	-6.66329
4		Dump Soil 2 (DS2)	146.993635	-6.66358
5		Dump Soil 3 (DS3)	146.993569	-6.66445
6		Dump Soil 4 (DS4)	146.992823	-6.66716

3. ANALYTICAL TECHNIQUES

Sampling and Sample Preparation: For heavy metal testing, soil samples were collected from the control and dump sites at a depth of 5 to 10 cm, and they were then taken to the National Analytical and Testing Services Laboratory. The samples were processed according to Soil Chemical Methods- Australasia by air-drying at room temperature for 4 weeks. The soils were homogenized using mortar and pestle, sieved through 0.45 μ .

Sample Treatment: For each of the homogenized soil samples, 1.0000g of soil was weighed into a 150 ml beaker that had been washed and rinsed with distilled water. The samples were acid digested overnight with aqua regia solution and processed by heating the mixture at 80°C to boiling until the mixture volume reduced to less than 15 ml in volume. The digested solutions were removed from the hot plate, cooled, and transferred into a 100 ml polyethylene container previously washed in an acid bath and rinsed with distilled water and diluted to 50

ml with distilled water.

Sample analysis: The digested aliquots were analysed for Cd, Pb, and Hg using Inductive Couple Plasma Mass Spectroscopy (ICP-MS). Multi-Elemental Solution IV (Merck KGaA)—traceable to NIST CRM—was used to develop calibration curves and accuracy checks.

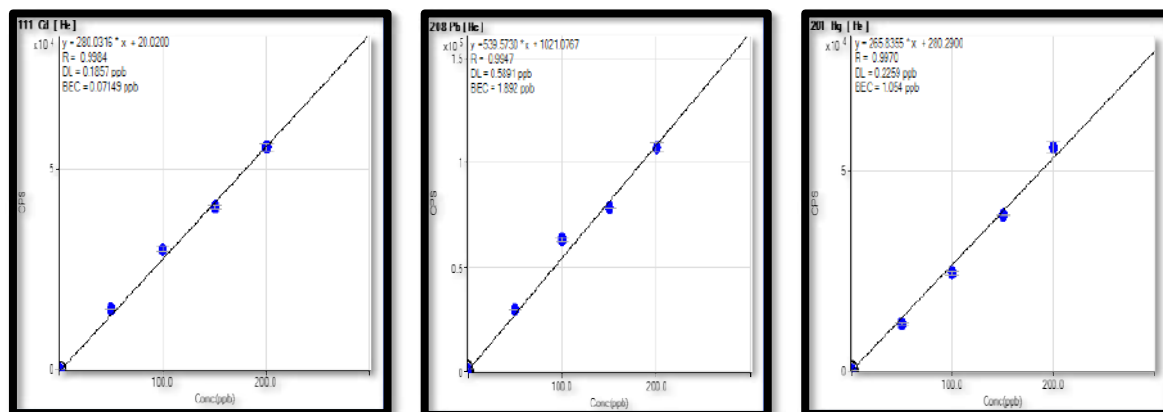


Figure 2 Calibration Curve of Cd, Pb, and Hg

Result and data processing: The spatial interpolation technique was in predicting values for cells in a raster. Inverse distance weighted (IDW) is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighbourhood of each processing cell. IDW interpolation was used to explicitly implements the assumption of concentrations in soil and water quality data that are close to one another are more alike than those that are farther apart. IDW was used to predict a value for any unmeasured location the measured values surrounding the predicted location.

4. RESULT AND DISCUSSION

The results that were obtained after the ICP- MS analysis are tabulated in Table 2. There are significant levels of heavy metals (Cd, Pb, Hg) in the recent studies of soil quality parameters in dump soils, according to the analysed results. Higher Cd, Pb, and Hg concentrations were recorded during analysis. The heavy metal content was generally higher in dump soil (DS1, DS2, DS3, DS4), borewells (BW1, BW2, BW3), and surface points (DAS1, DAS2, DAS3, SW1, SW2), as depicted in Table 2.

Table 2 Analytical Results

SI No.	Sampling Dates	Sampling ID	Cd (mg/L)	Pb (mg/L)	Hg (mg/L)
1	Surface Point Feb 2023	DAS1	0.0024	0.01	0.0007
2		DAS2	0.0003	0.0084	0.0004
3		DAS3	0.0025	0.0034	0.00006
4		SW1	0.0022	0.0007	0.0054
5		SW2	0.0029	0.094	0.0035
6		WBTP	0.00005	0.0008	0.018
7		WATP	0.0027	0.00003	0.014
8	Borewell Point Feb 2023	BW1	0.0043	0.00003	0.011
9		BW2	0.0063	0.0002	0.052
10		BW3	0.0033	0.0004	0.029

11		BWUB	0.0006	0.00003	0.0061
12		BWIM	0.0007	0.00003	0.0041
13		BWCW	0.0026	0.00003	0.004
1	Surface Point Feb 2025	CS A	0.0031	0.0500	0.0010
2		CS B	0.0026	0.0440	0.0008
3		DS1	0.0056	0.6310	0.0015
4		DS2	0.0062	0.6020	0.0018
5		DS3	0.0057	0.5810	0.0012
6		DS4	0.0061	0.5830	0.0012

4.1 Cd contamination

The results of the 2023 investigations on surface waters, borewells, and dump soils were compared to the findings of the current studies, as shown in the spatial interpolation below. The previous studies revealed that Cd ranges from 0.00005 to 0.063 mg/L, while the current studies concluded that there was a significant increase in Cd concentration at the dump site, as illustrated in the spatial interpolation diagram. The highest concentration of Cd was detected in borewells and surface points in 2023, with the concentration exceeding the WHO permissible limit of 0.003 mg/L. Additionally, Cd was detected at a higher level in dump soils (DS1-DS4) compared to control sites (CS A & CS B), which is scientifically evident as sources of Cd contamination were from the following: paint pigments, electroplated parts, Ni-Cd batteries, plastics, synthetic rubber, photographic and engraving processes, photoconductors, and photovoltaic cells, as most of the listed solid wastes were dumped at the dump site as shown below .



Figure 3 Solid Waste at the Site under Investigation.

The detection of Cd in borewells in February 2023 above the WHO maximum permissible limit is a concern for public health. Over time, exposure to low levels of Cd in drinking water can accumulate in the kidneys, leading to renal disease and brittle bones [12]. Cd tends to accumulate in the kidneys and is difficult for the body to eliminate. Therefore, kidney damage in older persons can result from lifetime low-level exposures to Cd as well as shorter, greater exposures [13]. Chest pain, coughing, vomiting, and diarrhea are some of the symptoms

that might result from drinking water with high levels of Cd.

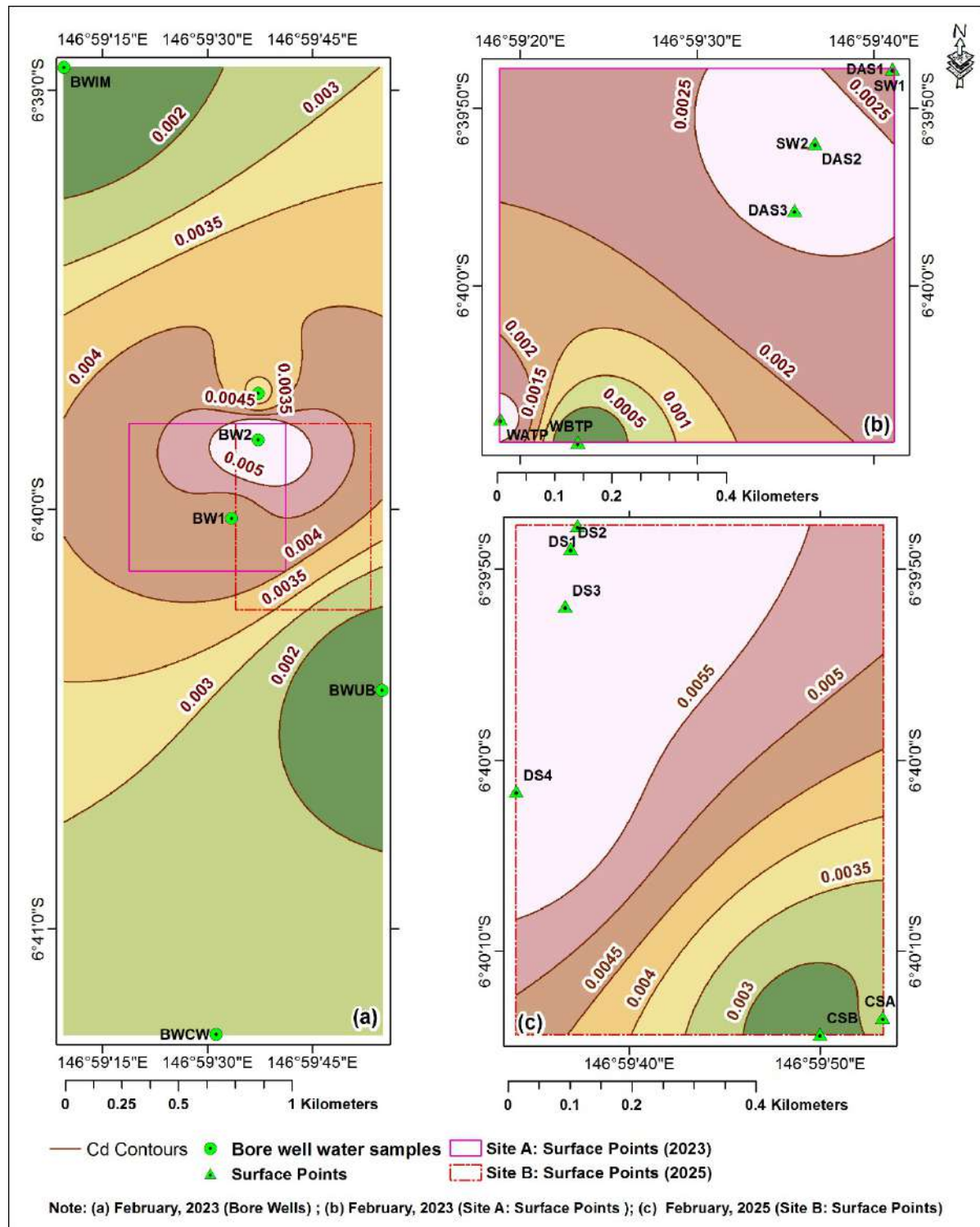


Figure 4 Spatial Interpolation of Cd in 2023 and 2025

The contaminated sites, according to the spatial distribution, are dump sites (DAS1, DAS2, DAS3, and SW2) and borewells (BW1, BW2, and BW3), according to 2023 data. The present investigation strongly confirms the previous studies, with the maximum concentration of 0.0062 mg/L detected at dump sites and a minimum of 0.0026 mg/L measured at the control site.

4.2 Pb Concentration 2023-2025

According to the spatial diagram, the most concentrated region was the ground point sampling site and BW1 and BW2, which are nearer to the dump site, as 2023 studies confirmed.

The current analytical results signify that soils at dump sites are severely contaminated, as illustrated by inverse distance weighted (IDW) interpolation; borewells (BW1, BW2, BW3), including surface waters (SW1, SW2), are within the Pb-contaminated zone.

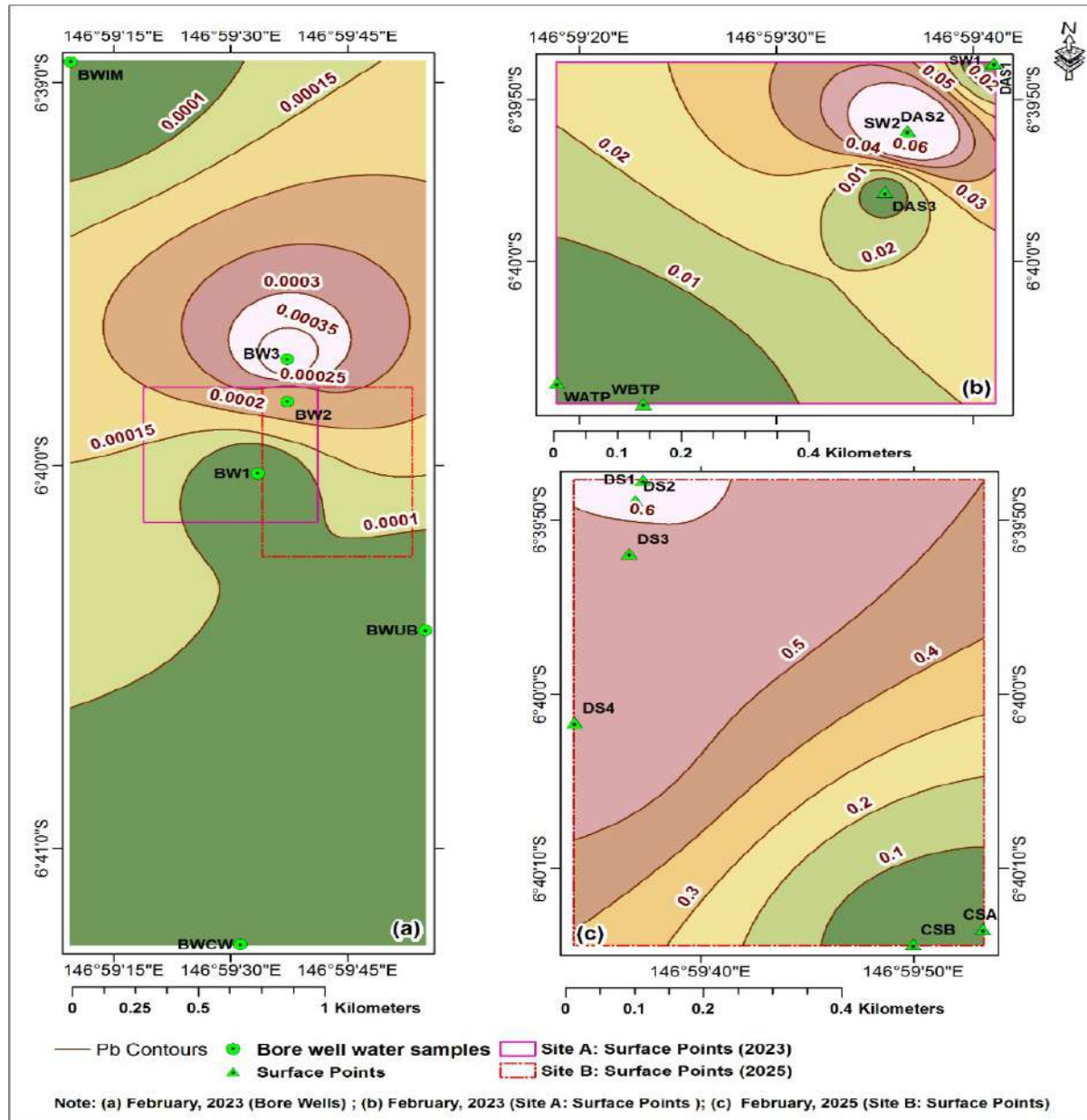


Figure 5 Spatial Interpolation of Pb in 2023 and 2025

PVC pipes used in agricultural and sanitation, recycled PVC lead paints, metal jewelry, lead batteries, lunchboxes, and other solid trash are some of the sources of lead contamination at the disposal site. As seen in the image below, the majority of the specified solid wastes are disposed of at the dump site in a way that does not safeguard the environment



Figure 6 Solid Trashed Buring at the Site Under Investigation.

According to studies done in 2023, leaching and percolation of heavy metals were significant closest to the dumping grounds and thus have affected BW in the vicinity around the dump. In comparison to soil samples from the control site (CS A & CS B), the dump soil had the greatest concentration of Pb.

Because Pb can cause major health issues if too much is consumed through drinking Pb- contaminated water, public health is concerned about the traces of Pb pollutants found in BW1, BW2, and WBTP. It may affect the synthesis of red blood cells, which deliver oxygen to every part of our body, and harm the kidneys and brain.

4.3 Hg Concentration 2023-2025

The maximum concentration of Hg was detected in DAS2 SW2, BW2 and WBTP in 2023. A range of 0.0012mg/L to 0.0018mg/L was measured in dump soils as depicted in the IDW interpolation diagram below. The WHO-permitted limit of 0.0006 mg/L Hg was exceeded at sample sites BW, SW, and DAS in the 2023 studies. Significant amounts of Hg are released close to the dump site due to improper waste segregation, as the image taken from the dump site below illustrates. Given that Hg is a persistent element in the environment, the municipal solid waste (MSW) that was disposed of may have contributed to the mercury pollution in the dump area. Batteries, measuring instruments like thermometers and barometers, electric switches and relays in machinery, lamps (including certain kinds of lights), dental amalgam, skin-lightening products, and other pharmaceutical and cosmetic items are some of the possible sources of Hg in bore wells that are being investigated



Figure 7 Solid Trash at the Site Under Investigation

According to spatial interpolation, DS1–DS4 are located within the polluted zone, as demonstrated by

recent investigations of dump soil. According to the BW data, the investigations came to the conclusion that Hg leaches out, percolates, and reaches groundwater. If Hg were present in drinking water, it may have a major negative impact on a person's health; this would be harmful. It will have an impact on the central nervous system and may harm the kidneys.

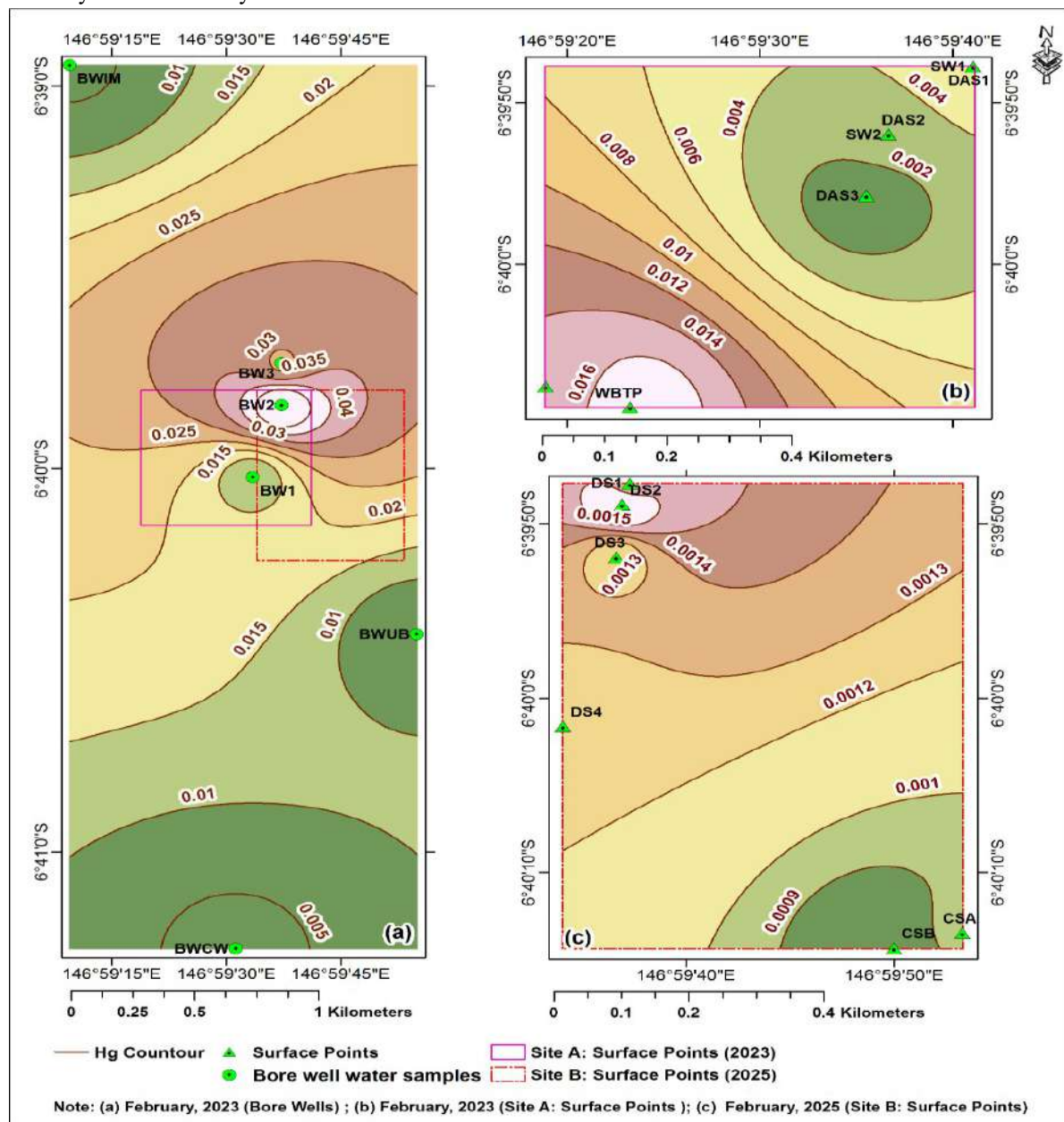


Figure 8 Spatial Interpolation of Hg in 2023 and 2025

CONCLUSION

Toxic heavy metal (Cd, Pb, Hg) investigation was conducted on the dump soils, a total of 4 soil samples from the dump site and 2 control soil samples away from the dump site were sampled. The control samples were extended from the dump site to the center of University's rugby field to enhance comparative analysis of heavy metal contamination of dump site soil and groundwater. Water and soil samples were collected in 2023, totaling 13 samples: 7 surface point samples and 6 borewell samples. Based on the analytical results from 2023, Cd, Pb, and Hg were detected in both surface points and borewells at concentrations above the WHO permissible limit. The present studies affirmed that soils at the dump site were contaminated with heavy metals, with Cd and Pb detected

at the higher concentrations, while the soil samples away from the dump site, that is university's rugby field soil, detected lower concentrations.

The investigation signifies that soils, surface and groundwater near and within the vicinity of the dump site are more prone to contamination than those away from the dump site.

The research carried out at the University of Technology dump site and borewell along the perimeter of the university campus in Lae, Morobe Province, Papua New Guinea, significantly proved that heavy metals (Cd, Pb, Hg) polluted the dump soil and thus contaminated borewells near the open dump. The notable concentration of Cd, Pb, and Hg highlights the urgent need for solid waste management disposal practices. Toxic heavy metals have the potential to threaten the environment and groundwater and put public health at risk.

RECOMMENDATION

The study highly recommends sustainable solid waste management practices and refraining from dumping at the site and near the borewell. The right thing to do is dumping at the designated area, which is the second Seven Dump, which is a CEPA-permitted dumping area in Lae City. PNG University of Technology, Morobe Provincial Health Authority, CEPA, and WPNG need to address this issue by funding further investigation and remediation processes to contain the pollution before it gets worse.

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From Artificial Intelligence to Artificial Intelligences

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Abstract: Artificial intelligence was over; artificial intelligences are booming around us. Artificial intelligence is significant for many people as a discipline, where Artificial intelligences have benefited all people, organizations, companies, and nations. This paper examines artificial intelligence, the evolution from AI to artificial intelligences. It looks at artificial intelligence systems and platforms, business intelligences as examples of artificial intelligences. The proposed approach in this paper might facilitate the research and development of AIs, artificial wisdoms, business intelligences, and business analytics.

Keywords: Artificial intelligence (AI), Artificial intelligences (AIs), artificial wisdom, business intelligences, and business analytics.

1. INTRODUCTION

We are in the age of artificial intelligence (AI) (Kissinger, Schmidt, & Huttenlocher, 2022) (Sun Z. , 2024). However, artificial intelligence was over! We are in the age of artificial intelligence (AIs) because artificial intelligences are booming around us (Sun Z. , 2024) (Kissinger, Schmidt, & Huttenlocher, 2022). Artificial intelligence is significant for many people as a discipline, whereas Artificial intelligences have benefited all people, organizations, companies, and nations. This leads to two interesting questions.

1. Why are Artificial intelligences?
2. What is the relationship between artificial intelligence and artificial intelligences?

This paper examines artificial intelligence, the evolution from AI to artificial intelligences. It looks at artificial intelligence systems and platforms, business intelligences as examples of artificial intelligences. The proposed approach in this paper might facilitate the research and development of AIs, artificial wisdom, business intelligences and business analytics.

The rest of this paper is organized as follows: Section 2 looks at the evolution of artificial intelligence. Section 3 examines artificial intelligences. Section 4 presents a calculus of artificial intelligences. Section 5 looks at BI and BIs and considers BIs as Applications of AIs. The final section ends this paper with a few concluding remarks and suggestions for future work.

2. EVOLUTION OF ARTIFICIAL INTELLIGENCE

(This section analyses evolution of artificial intelligence.)

Alain Turing published his seminal paper in 1950 (Turing, 1950). John McCarthy, a mathematics professor at Dartmouth defined AI as the “science and engineering of making intelligent machines” “in 1956 (McAfee & Brynjolfsson, 2017, p. 67; Tkaczyk, 2024). His definition can be updated as “science, engineering, technology, and systems of making and managing intelligent machines and systems”. From that time on, AI has become one of the most significant forces affecting our human beings, machines, systems, and platforms. AI has been one of the most rapidly developing fields in the last decade. We are immersed in the age of AI (Kissinger, Schmidt, &

Mundie, 2024). AI directly focuses on intelligence and wisdom (Sun Z. , 2024). However, since the late 1950s, AI researchers have found that knowledge-driven intelligence is important because of the development of expert systems and knowledge base systems (Sun Z. , 2024). In the past decade, data intelligence has become more important because of machine learning's resurgence and deep learning development (Kissinger, Schmidt, & Mundie, 2024) (Tkaczyk, 2024), thanks to the inception of ChatGPT (Mollick, 2024). There are many intelligences, for example, our bodily intelligences are composed of hearing intelligence, writing intelligence, and moving intelligence, which focus on the development of human-centered AI (Sun Z. , 2024).

Briefly, AI is a subfield of computer science and data science, concerned with symbolic reasoning and problem-solving (Sharda, Delen, & Turba, 2018). Technically, AI is concerned with imitating, extending, augmenting, amplifying, and automating the intelligent behaviors of human beings (Russell & Norvig, 2020) (Sun Z. , 2024). AI attempts not only to understand how humans think, understand, write, learn, listen, and act rationally and smartly, but also to build intelligent entities that can think, write, perceive, understand, predict, and manipulate a world.

Jenkins, et al. state that “the history of AI has included several waves of ideas” (Jenkins, Lopresti, & Mitchell, 2020). The first wave, from the 1950s to the 1980s, focused on logic and symbolic hand-encoded representations of knowledge, the foundations of so-called “expert systems”. The second wave, starting in the 1990s, focused on statistics and machine learning, in which, instead of hand-programming rules for behavior, programmers constructed “statistical learning algorithms” that could be trained on large datasets. In the wave of the last decade, AI research has largely focused on deep learning in machine learning. AI has experienced a resurgence recently, because the increasing computing power and algorithms have become increasingly refined (Mueller, 2016). Other reasons are that data-driven and market-oriented AI are becoming popular products around us; AI on social media has blossomed in these communities (Chowdhary, 2020). The current wave is that AI has been ubiquitous in the market. Market-driven AI is aimed at machines, systems, apps, and tools (Russell & Norvig, 2020) (Sun Z. , 2024) (Tkaczyk, 2024) (Mollick, 2024).

3. ARTIFICIAL INTELLIGENCE

(This section reviews AI and explores AIs as next-generation intelligences.)

Intelligence is not only a lasting topic for computer science, AI, intelligence computing, BI, and intelligent analytics, but also an exciting topic for industries, organizations, and businesses (Sun, Sun, & Strang, 2018) (Sun Z. , 2024).

AI has facilitated the development of intelligent services, intelligent manufacturing, intelligent systems (Russell & Norvig, 2020), intelligent chips, and intelligent analytics (Sun Z. , 2019). BI has improved competitive business and marketing performance, supported management decision-making of organizations, and produced trillion-level enterprises such as Google, Amazon, and Meta (Sabherwal & Becerra-Fernandez, 2011) (Howarth, 12, 2022). Industries continue to dominate frontier AI research and development; Generative AI investment skyrockets. China dominates industrial robotics: In 2013, China's installations accounted for 20.8% of the global total (Stanford , 2024). A lot of companies brand their products as AI products. Many social media brands do things as AI products and services. For example, ChatGPT-4, Gemini, and Claude 3 are impressively multimodal: They can generate fluent text in dozens of languages, process audio, and even explain memes (Stanford , 2024).

Artificial intelligence has been playing a significant role in making AI ubiquitous and upgrading economies and industries to intelligent ones. An artificial intelligence entity (AIE) is an intelligent entity in terms of a system, app, platform, or tool. For instance, the Nvidia GPU chips, DeepSeek, and ChatGPT. Data, intelligences, and analytics are the most important attributes of the AIE. Currently, data, analytics, and intelligences and their integration are also at the frontier for revolutionizing our work, life, business, management, and organization, as well as healthcare, finance, e-commerce, and web services (Tkaczyk, 2024) (Kissinger, Schmidt, & Mundie, 2024). Big data has become one of the most unprecedented and ever-increasing frontiers for innovation, research, and development in the computer industry and business (Sun Z. , 2024). Big data analytics, advanced analytics, and modern analytics have drawn increasing attention in academia, industry, and government (Sun Z. , 2024). Artificial intelligence entities are becoming a core business and analytic competency to transform business processes, reconfigure workforces, optimize infrastructure, and blend industries (Laney & Jain, 2017).

However, the current AI is a mixed intelligence and market-driven, although they are useful for AI research and development.

1. What is the next trend of artificial intelligence?
4. What is the relationship between artificial intelligence and artificial intelligences
5. How can we examine artificial intelligence entity?
6. What is the relationship among Artificial intelligence entities, data, analytics and intelligences?

All these three questions need to be addressed by academia, industries, and people.

Following on the book (Sun Z. , 2024) published by CRC press | Routledge | Taylor & Francis Group in 2024, this research delves into artificial intelligence and artificial intelligences.

4. ARTIFICIAL INTELLIGENCES

This section explores artificial intelligences.

4.1 Multiple Intelligences

Professor Howard Gardner provides the theory of Multiple Intelligences (MI) (Gardner, 2012). This consolidates the relationship between natural intelligences and artificial intelligences.

Gardner states that the single word intelligence is fundamentally limited and misleading. This is right for the theory of multiple intelligences (Gardner, 2012). It is also right for (natural) intelligences in AI. For example, how many intelligences are in our own body? there are at least 12 natural intelligences (Sun Z. , 2024). Furthermore, from a technological viewpoint, each of the 12 natural intelligences of our own body needs many different artificial intelligences (AIs) to imitate, augment, and simulate as we realized (Sun Z. , 2024, p. 138). In other words, many AIs are used to realize the human intelligence of our own body.

4.2 The Age of AI and AIs from the Books

Many books have used AIs although they have not explained why AIs and AI are different. For example, Kissinger et al (Kissinger, Schmidt, & Mundie, 2024). Bostrom (Bostrom, 2014), and Mollick (Mollick, 2024) have used AIs in their books. Sun differs AIs from AI based on the idea of Gardner's theory for Multiple Intelligences (MI) (Gardner, 2012) (Sun Z. , 2024).

Sun discusses intelligence, mind and wisdom in his book (Sun Z. , 2024). In fact, it is more important is that national and international intelligence, mind and wisdom are also important for a country, community, organisation and international ones. In such a way, we have big intelligence, big mind, and big wisdom. However, intelligence, mind and wisdom were mentioned in chapter 2 of Kissinger's book (Kissinger, Schmidt, & Huttenlocher, 2022).

Kissinger's book did not explicitly mention AIs. However, the authors really wrote AIs in the book (Kissinger, Schmidt, & Huttenlocher, 2022). We argued that AIs are based on the mulitiintelligence (Gardner, 2012) and a set of intelligences (Sun Z. , 2024).

4.3 Artificial Intelligences from the Scholars

Google Scholar search for "artificial intelligence" and "artificial intelligences" found 4,990,000 and 17,600 publications on June 11, 2025. This implies that artificial intelligence plays an important role in research and development, although artificial intelligences have also drawn important attention in the recent time.

Of 17,600 publications on "artificial intelligences are legal personhood artificial intelligences, skynet destructive, artificial intelligences moral agents, artificial intelligences robots, artificial intelligences suggestive drawing, artificial intelligences digital minds"

Then we analyzed the first 100 ranked by Google Scholar search and found that:

1. No authors explain AIs.
2. From the perspective of psychology and philosophy, Brožeka and Janik address the question of whether artificial intelligences can be moral agents based on internal, external, and moral agency (Brožeka & Janik, 2019). The paper concludes that machines cannot be considered moral agents. However, the research only mentioned “existing artificial agents, as well as the future ones which are constructed within the same ‘architectural’ paradigm, and their relationships with the external and internal conditions of moral agency. However, there are no relationships with artificial intelligences.
3. Sotala surveys four categories of factors that might give a digital mind, such as an upload or an artificial general intelligence, an advantage over humans (Sotala, 2012). It seems that no real exploration into artificial intelligences has been conducted, although artificial intelligences has not played a significant role in this research.
4. Fox uses multi-Intelligence (MI) to combine natural and artificial intelligences in hybrid beings and systems (Fox, 2017). From the references of Fox’ research (Fox, 2017), we have not found the AIs. Even so, Fox frames AI as a contributor to multi-intelligence (MI) in the setting of hybrid beings and/or systems. Fox’s idea leads us to extend natural intelligences and artificial intelligences and how to develop natural intelligences with artificial intelligences. Intelligences consists of natural and artificial one. What Professor Garder researched is natruaal intelligences of our body (Gardner, 2012). What we explores are artificial intelligences.
5. Levin considers artificial intelligences as a bridge toward /diverse intelligence and humanity’s future (Levin, 2025).

Overall, many scholars have used AIs to describe AI-related machines, systems, platforms, and apps. There is no yet a series of theories on what AIs are. One possibility for defining artificial intelligences as diverse human minds (Levin, 2025), However, human minds are at a meta (intelligence) level (Sun Z. , 2024).

Therefore, we define artificial intelligences as intelligences that human beings, machines, systems, platforms, and apps possess based on a set of intelligent systems, technologies, tools within applications. For example, artificial intelligences as intelligences that human beings possess based on a set of intelligent systems, technologies, and tools within applications. Human beings can have artificial intelligences such as data intelligences, knowledge intelligences, hearing intelligences, speaking intelligences, tasting intelligences, writing intelligences, moving intelligences, and more. Each of them hav been implemented using a set of intelligent systems, technologies, and tools (Sun Z. , 2024).

5. A CALCULUS OF ARTIFICIAL INTELLIGENCES

This section presents a calculus of artificial intelligences.

5.1 AI and AIs

Artificial Intelligences (AIs) include data intelligence, knowledge intelligence, wisdom intelligence, experience intelligence, analytics intelligence, big data intelligence, understanding intelligence, learning intelligence, to name a few (Sun Z. , 2024). For example, machine learning aims to develop learning intelligence. Expert systems aim to improve knowledge intelligence; big data analytics aim to provide analytics intelligence and insight to organizations and individuals. In such a way, we can easily understand metaintelligence as intelligence about intelligence.

We can differentiate intelligence from intelligences. We emphasize learning, understanding, thinking, connecting, and sharing as keys to intelligence (Sun Z. , 2024). We also highlight collective intelligence,

cooperation, collaboration, negotiation and bargaining as intelligences, as illustrated in Table 1 (Sun & Finnie, 2004).

Table 1. Artificial intelligence to Artificial Intelligences

Intelligence	Intelligences	Remarks
learning	collective intelligence	For collective work
understanding	cooperation	Cooperation intelligence
thinking	collaboration	collaboration intelligence
connecting	negotiation	negotiation intelligence
sharing	bargaining	Bargaining intelligence

At the moment, machine learning is still a data intelligence-driven technique. So that ChatGPT is a data intelligence technique that can bring about the same knowledge intelligence. Deep Seek is also an intelligent tool for providing data intelligence and knowledge intelligence to customers.

Based on the Gartner's research on the Hype Cycle for Artificial Intelligence (Jaffri, 2024), Generative AI (GenAI) receives much of the hype when it comes to AI. However, GenAI has yet to deliver on its anticipated business value for most organizations. GenAI has passed the peak of inflated expectations. Maybe it also reflects that another winter of AI will be upon us within a year. Similarly, the general problem solver was not very successful in 1957. GenAI also faces "general" challenges, including ethical and societal concerns, and nefarious uses like deep fakes and disinformation (Jaffri, 2024; Tkaczyk, 2024).

The composite AI is as follows:

1. Composite AI lays the foundation for future AI architectures. Composite AI represents the next phase in AI evolution. The original concept is a hybrid AI. Composite AI combines AI methodologies-such as machine learning, natural language processing and knowledge graphs - to create a more adaptable and scalable solution (Tkaczyk, 2024). For instance, integrating knowledge-based (rule-based) systems with machine learning allows enterprises to process unstructured data, thereby enhancing their ability to derive insights from diverse datasets.
2. AI Computing has become famous because Computing = AI science + AI engineering + AI technology + AI systems + AI + AI services (Sun Z. , 2024). This leads to AIE Computing = AIE science + AIE engineering + AIE technology + AIE systems + AIs + AIE services.
3. AI engineering and knowledge graphs. AI engineering. AI engineering approaches, such as DataOps, ModelOps, and DevOps, make it possible to deploy models into production in a structured, repeatable factory-model framework. Knowledge graphs are machine-readable representations of the physical and digital worlds.
4. Besides the above-mentioned, the hype cycle for Artificial Intelligence also includes autonomic systems, quantum AI, Embodied AI, multiagent systems, Decision Intelligence, and prompt engineering (Jaffri, 2024). This consists of IoTE (the Internet of intelligent everything). Furthermore, this also means that multiagent systems have been moving towards the market rather than at the theoretical level. We will look at a lot of multiagent systems in future work.

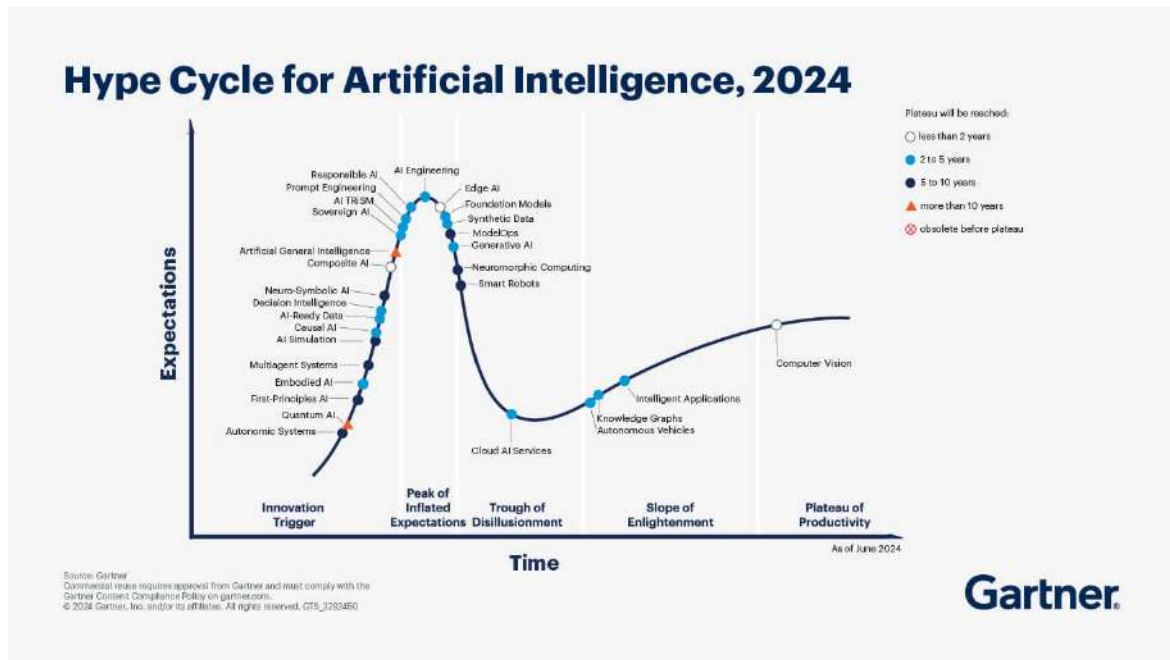


Figure 1.1 Gartner hype cycle for AI 2024.

Furthermore, one agent cannot dominate all in AI, but there are millions of AI agents; They will work together to complete almost all delegated tasks (Liu, 2025) (Scott & Stebbings, 2025).

5.2 Intelligences and Multi-intelligences

A model of artificial intelligences was introduced based on Multi-intelligence (MI) hybrid beings and systems (Fox, 2017), as illustrated in the following Figure 1.2, which has been edited and extended to intelligences and multintelligences.

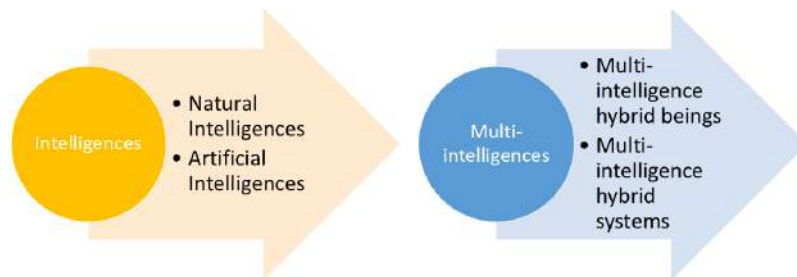


Figure 1.2. Intelligences and multintelligences

In this model, intelligences have been classified into natural intelligences and artificial intelligences. Multi-intelligences have been classified into multi-intelligence hybrid beings and multi-intelligence hybrid systems (Fox, 2017).

Natural intelligences are composed of human intelligences (Gardner, 2012), animal intelligences, social intelligences, and business intelligences (Sun Z. , 2024). Artificial intelligences have not been mentioned in the research of Fox. However, the intelligences contributed to multi-intelligences; which consists of multi-intelligence hybrid beings and multi-intelligence hybrid systems (Fox, 2017).

Multi-intelligences were used for exploring human intelligences since 1980 (Gardner, 2012). Human intelligences have even intelligences (Gardner, 2012). A human body has at least 12 natural bodily intelligences (Sun & Wei, 2024).

Based on Merriam-webster dictionary (Merriam-webster, 2025) Being has the following meaning:

a: the quality or state of having existence. Example: social events and natural events.

b: Something that actually exists: Example: life and animal.

c: A living thing, example: person.

We believe that Fox has covered all beings except the systems (Fox, 2017). Therefore, hybrid beings are related to human beings and animals (Fox, 2017).

Table 2. Multintelligences have the following characteristics.

Multintelligences	Characteristics	Examples
Multintelligences	includes the full range of natural and artificial intelligences, which are defined in fundamental terms, such as self-awareness, robust adaptation, and problem solving.	Human bodily intelligences, Multi-agent systems.
Multintelligences	considered in terms of whole systems of causal mechanisms and causal contexts encompassing the full range of variables that can contribute to intended and unintended consequences	A group of robots working in the production line- Robotic process automation.
Multintelligences	encompasses hybrid beings and hybrid systems having emergent properties that can be more than, and different from, the various types of intelligence, which they are comprised of.	Intelligent enterprise systems.

Robotic process automation (RPA), also known as software robotics, uses intelligent automation technologies to perform repetitive office tasks of human workers, such as extracting data, filling in forms, moving files, and more (IBM, 2025). RPA uses rule-based expert systems to perform business process activities at a high volume, freeing up human resources to prioritize more complex tasks. RPA enables CIOs and other decision makers to accelerate their digital transformation efforts and generate a higher return on investment (ROI) from their staff.

The difference between RPA and AI: RPA is a process-driven and rule-based system; it can only follow the rule-based processes. AI combines cognitive automation, rule-based expert systems, machine learning (ML), natural language processing (NLP), reasoning, hypothesis generation, and analysis, therefore, AIs are knowledge-based and data-based intelligences. AI bots use expert systems and machine learning to recognize patterns in data and make decisions (IBM, 2025).

5.3 From AI via AIs to AIIEs

The above model can be extended into the following model: from AI via Artificial intelligences to AIEs, as illustrated in Figure 1.3.

Human intelligence has been studied in artificial intelligence (Russell & Norvig, 2020). Both have been extended to intelligences, which consist of natural intelligences and artificial intelligences (Fox, 2017). Natural intelligences and artificial intelligences have been extended into multi-intelligences. (Fox, 2017). Multi-intelligences have been classed into multi-intelligence hybrid beings and multi-intelligence hybrid systems. They then are extended into artificial Intelligence entities. Artificial intelligence entities have been classified into AIE apps, AIE machines, AIE systems, AIE platforms (Kissinger, Schmidt, & Huttenlocher, 2022).

It is interesting to study this history based on Figure 1.3.

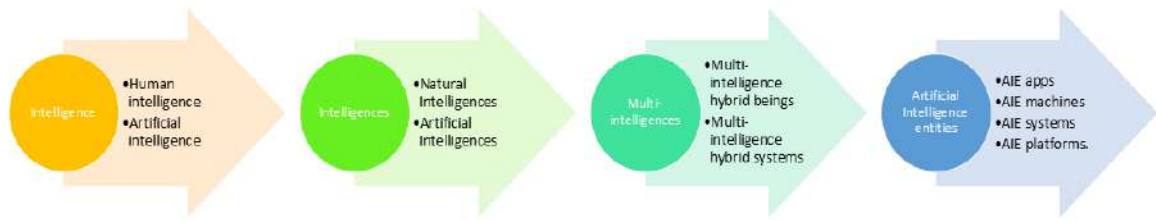


Figure 1.3 from AI via AIs to AIIEs

Therefore, from AI to AIs, intelligences are the real phenomena in the intelligence world, not only in human intelligences, but also in AIs. If humanity has its world. What is the intelligence world? Can we see that the intelligence world consists of a lot of intelligences.

Intelligences are also important from BI and BIs, see the latter section.

5.4 The Internet of Intelligences

When we discussed intelligences with application. We must explore The Internet of AIs. That is, The Internet of AIs consist of many different AIs which interacted with many different intelligent systems or agents. In other words, The Internet of AIs have been reflected by the integration of many The Internet of intelligent entities such as different intelligent systems or agents as shown in Figure 1.4. In other words, the Internet of AIs will be implemented by the Internet of intelligent entities, such as different intelligent systems or intelligent agents. At the same time, the internet of intelligent entities, such as different intelligent systems or intelligent agents, will produce The Internet of AIs. Figure 1.2

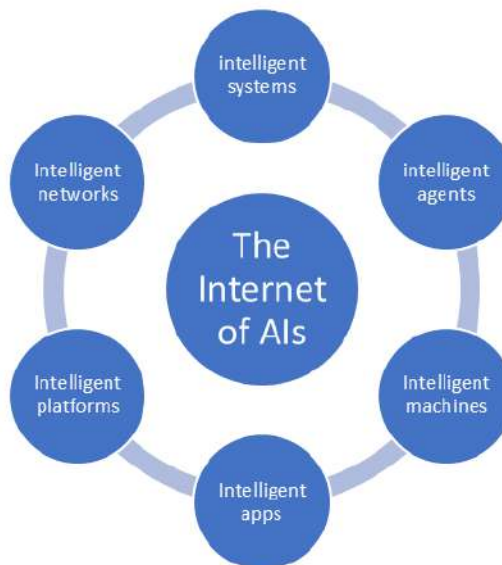


Figure 1.4 The internet of AIs and the internet of intelligent entities.

The Internet of Everything (IoE) expands the Internet of Things (IoT) by connecting people, processes, data, and things to create a more integrated and intelligent network. Then we have (Sun Z. , 2024).

$$\text{IoE} = \text{IoT} + \text{IoP} + \text{IoS} \quad (1)$$

Apply intelligent as an operation on both sides of (1), we have

$$\text{IoIE} = \text{IoIT} + \text{IoIP} + \text{IoIS}.$$

Where IoIE = The Internet of intelligent everything, IoIT as The Internet of intelligent things, IoIP = The Internet of intelligent people, IoIS = The Internet of intelligent services.

Furthermore, we have the Internet of intelligent entities as a part of IoIE, which produces the internet of AIs. That is,

$$\text{IoAIEs} \subset \text{IoIEs} \quad \text{produce IoAIs} \quad (2)$$

Where IoAIEs = the Internet of AI entities. IoIEs = the Internet of intelligent entities. IoAIs = the Internet of AIs.

6. FROM BUSINESS INTELLIGENCE TO BUSINESS INTELLIGENCES

This section looks at business intelligence to business intelligences and discusses the relation between business intelligences and artificial intelligences.

Commerce is buying and selling. Business consists of all activities related to buying and selling (Schneider, 2017). Business Intelligence (BI) was first coined by Luhn in 1958 when he developed a business intelligence system at IBM (Luhn, 1958). Business intelligence was then promoted by Dresdner since 1989 (Sun Z. , 2024). Business intelligence is the intelligence for making money from humans, machines, and systems in business activities using a set of machines, systems, technologies, and techniques (Laudon & Laudon, 2020). BI has important technology for developing business technologies and systems. The most fundamental technologies of BI consist of data mining, data warehousing, and data analytics (Sun Z. , 2024).

Only some indulge BI. Many already use BIs. That is, business consists of multiple intelligences, for example, BI consists of financial intelligence, agile business intelligence, 3commercial intelligence, competitive intelligence, market intelligence, social intelligence, mobile business intelligence, retail intelligence, real-time intelligence, visual business intelligence, location intelligence, sales intelligence, product intelligence, and more (Brooks, 2022). In reality, every business action requires BIs to promote the business activities.

Business Intelligences (BIs) are all the intelligences for making money from business humans, machines, and systems using a set of intelligent machines, intelligent systems, intelligent technologies, and intelligent techniques.

Therefore, there are a number of business intelligences that need to be imitated, augmented, and simulated using intelligent systems, such as market analytics and intelligence, e-commerce analytics and intelligence, Supply Chain analytics and intelligence, and more (Sun Z. , 2024; Brooks, 2022).

The relationship between AIs and BIs is that the BIs are the applications of AIs in the business domain whereas AIs are the generalization of BIs, as shown in Figure 1.5. Similarly, BI is the applications of AI, whereas AI is the generalization of BI.

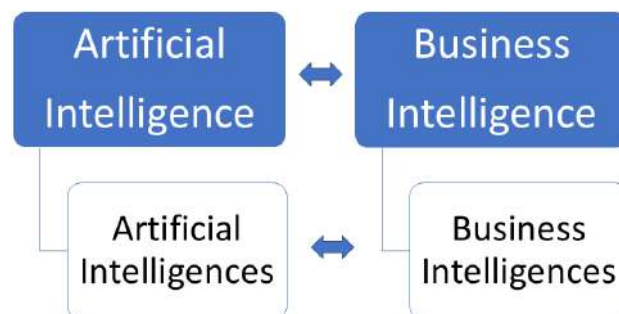


Figure 1.5 AIs and BIs

Intelligences are also important from BI and BIs. We will discuss BIs from BI in another project.

7. CONCLUSION

Artificial intelligence was over; artificial intelligences are booming around us. Artificial intelligence is significant for many people as a discipline; whereas Artificial intelligences have benefited all people, organizations, companies, and nations. This research examines artificial intelligence, the evolution from AI to artificial intelligences. It looks at artificial intelligence systems, platforms, and BIs as examples of artificial intelligences. The main contributions of this research consist of 1). Artificial intelligences are intelligences that human beings, machines, systems, platforms, and apps possess based on a set of intelligent systems, technologies, tools, with applications. 2). AIE Computing = AIE science + AIE engineering + AIE technology + AIE systems + AIs + AIE services. And 3) BIs are the applications of AIs in the business domain, whereas AIs are the generalization of BIs.

In future work, we will deliver into the relationships between the Internet of AIs and intelligent entities with applications in industries.

Scott said that models are no products. Only products can link the demands of users, the value of models can be occurred (Liu, 2025) (Scott & Stebbings, 2025). There is a general question: What are the relationships among algorithms, models and products. We will look at it in another paper.

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Estimation of Lifetime Lung Cancer Risk from Radon Inhalation in PNG

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Abstract. There are several known factors causing lung cancer. Exposure to nanoparticles, polycyclic aromatic hydrocarbons (PAHs) and inhalation of radioactive radon gas are the major sources. The World Health Organization (WHO) estimates that radon exposure accounts for approximately 3% to 14% of all lung cancer cases, depending on factors like average radon levels and smoking habits. Research in a Southeast Asian country, estimated 26% of lung cancer deaths in males and 28% in females. These were attributed by indoor radon exposure, with variations depending on local radon concentrations. Radon is the second leading cause of lung cancer in the United States, after cigarette smoking. The EPA estimates that about 21,000 people die each year as a result of radon-related lung disease. Radon is radioactive and can decay into cancer-causing radioactive progeny. These progenies stick onto the Trachea Bronchi region of lung and continuously irradiate the lung tissues unless they are translocated by some physiological process. Radon need to be measured for a long time in the indoor atmosphere to obtain a time averaged estimate of the inhalation dose to the inhabitants. Active radon measurements are more accurate even if they are difficult to deploy for measurements. In the present study, results of measurements of nearly a year long continuous indoor radon measurements at different locations in the city of Lae in PNG will be presented. Using the results of the measurement of indoor radon activity, excess lifetime risk due to the inhalation of radon will also be presented.

Key words: Radon, inhalation, radiation dose, excess cancer risk

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Dr Jojo has nearly 32 years of research and teaching experience in India and abroad. He has successfully carried out 10 funded research projects in India, one in Malaysia and 3 in Papua New Guinea. Successfully supervised 15 doctoral degrees, 4 M Phils and several Postgraduate students. He also has two patents to his credit. Published about 110 papers in referred journals and taken part in more than 100 conferences in various countries. He is the executive editor of the Interdisciplinary Journal of Papua New Guinea University of Technology and reviewer to several renowned journals. He is a member of several professional bodies like Institute of Physics (IoP, UK), South Pacific Environmental Radiation Association (SPERA, Australia), Hong Kong Chemical, Biological & Environmental Engineering Society (HKCBEEES, Hong Kong), The New York Academy of Sciences, (US), Malaysian Institute of Science (Malaysia), African Physical Society, (Ghana), All Kerala Astro-sciences Society (AKAS, India) and Nuclear Tracks Society of India. He has won several awards for teaching and research from different countries.

1. INTRODUCTION

Radon is the only radioactive gas in the uranium series and is a known indoor radioactive pollutant. Radon is produced from the radioactive decay of uranium (^{238}U), which is found in almost all natural materials. Radon is also found in water and escapes from the ground into the indoor air, where it decays into solid progenies. Radon supports 7 alpha active radio isotopes before it decays finally to ^{206}Pb . The building materials, the water supply, soil air, and natural gas can all be sources of radon inside homes (Nguyen Dinh Chau, 2019). The basements of the buildings allow for more opportunity for radon in soil gas to enter into the living space. Exposure to excess radon gas can result in lung cancer. Radon progenies become airborne attached to the aerosol particles in the air we breathe. When inhaled the daughter products of radon can get attached to the lung tissues. When the radioisotopes decay inside the lungs, radiation from these particles can damages lung tissues, and can lead to lung cancer. The onset of lung cancer would usually occur after several years of exposure. Although lung cancer can be treated, the survival rate is one of the lowest among other types of cancers.

Depending on the location, construction type and ventilation conditions radon may get accumulated. The majority of radon exposure in the indoor spaces is from radon entering the rooms from the ground. As a result, radon concentrations are found to be highest in the lowest levels of homes. Long-term exposure to elevated radon levels is the second leading cause of lung cancer after smoking (Dhanya Balakrishnan, 2021). The risk increases significantly for smokers exposed to radon. Based on the geological variability, some areas are naturally predisposed to higher radon levels due to the composition of soil and rocks beneath buildings. Therefore, monitoring ensures compliance with safety standards and helps to take mitigation measures like improving ventilation or sealing foundation cracks to reduce exposure and safeguard health. Estimation of the risk can essentially help to identify, evaluate, and manage potential hazards that could negatively impact individuals. Risk assessment can also guide to develop strategies to eliminate or minimize risks from exposure to higher concentrations of radon. The proportion of lung cancers ascribed to radon has been estimated in the range from 3 to 14%. With respect to the radon level and smoking habits, the risk of lung cancer increases approximately by 16% per 100 Bq m⁻³ for long-term exposure to indoor radon concentration (Morawska L, 2021).

2. METHODOLOGY

Indoor radon varies widely depending on several parameters related to the building materials, geology, atmospheric conditions and ventilation of the room. There are several factors determine the risk of lung cancer caused by radon exposure. Primarily, the concentration of radon in the indoor atmosphere where you spend most of our time. The amount of time one spends in the room, presence and nature of aerosols like cigarette of kitchen smoke, water droplets from air cooler and the like are the other confounding factors. The aerosols facilitate radon progeny to get attached to and become airborne. These progeny goes into the lungs while we inhale. To arrive at a reasonably good representative rate of radon concentration, time averaged long-term measurements are necessary.

There are several methods for long term assessment of indoor radon. Because of simplicity and ease of operation, in most investigations, passive alpha radiation detectors are being used. This method needs no supporting power supply or complicated methods of analysis. At the same time there are arguments that these methods lack reproducibility and precision.

In the present study, we have adopted active continuous measurement of indoor radon concentrations (Becquerels per cubic meter). Ten different locations in the city of Lae were chosen for the study. The device makes hourly measurements of indoor radon concentrations and stores in the data logger. Using the radon data, annual exposure to radon, inhalation dose and the inhalation cancer risks were determined.

3. EXPERIMENTAL

Radoneye+2 Smart radon monitors manufactured by Radon FTLab, Republic of Korea were used for the measurements of radon in the indoor atmosphere. RadonEye+2 device utilizes a pulsed ionization chamber equipped with a high-precision detection circuit to measure radon concentrations. It detects alpha particles emitted during the radioactive decay of radon gas, providing a real-time reading of radon activity concentration. It has a sensitivity of 0.5counts per minute per pCi per litre and has accuracy $\pm 10\%$ at 10pCi per litre. It automatically

takes measurement at every hour and has a storage capacity of data for one year. The device has inbuilt database working with Wi-Fi and Bluetooth connectivity.

Ten indoor locations in the city of Lae were selected to expose the Radoneye+2 detectors. Houses, offices, workplaces and labs were there among the exposure sites. The device measures radon, temperature and humidity of the indoor atmosphere, simultaneously.

The measurements were carried out from June 2024 to January 2025 in all the locations. The results of the continuous measurements were accessed using Bluetooth connectivity of a smartphone. The downloaded data was analyzed using Atmos Light -1.4.2.0 software to obtain the results.

The assessment of radon inhalation risk is based on the air exposure to decay products in units of potential alpha energy concentration (PAEC) in the environment. The unit of potential alpha energy exposure is the working level month (WLM). For domestic (i.e., residential) exposures, 1 WLM is equivalent to an indoor radon concentration of exposure at 185 Bq m^{-3} for a full year with 70% of time spent in the home. The SI unit of exposure replacing PAEC is the joule hour per cubic meter (J hr m^{-3}) and 1 WLM equals $0.0035 \text{ J h m}^{-3}$ (NRC., 1999)

Radon atoms and their short-lived progeny have high mobility. Radon's short lived radioactive daughter products get attached onto atmospheric aerosols (forming the "attached fraction" with a size from a few nanometers to a micrometer). Radon daughters, regardless of whether attached to aerosols or not, diffuse in the atmosphere. They may ultimately get deposited onto the ground or walls of buildings. Practically, the progenies never attain radioactive equilibrium with radon inside the room, completely. The equilibrium fractions of radon's short half-lived progeny are described by the "equilibrium factor", which ranges from 0 (when radon present in the air having no progeny) to 1 (when radon's short half-lived progenies are in the same concentration of radon). When a person is exposed to radon and its short half-lived progenies, whether attached to aerosols or not, the inhaled progeny may get deposited in the respiratory tract and irradiate it. The delivered dose depends on the location of the deposit, which itself is a function of particle size. Finer particles (in particular the unattached fraction) can reach the sensitive cells of the bronchial epithelium and the pulmonary alveoli of lungs and thereby deliver larger doses. Radon being a gas, is largely exhaled and therefore, it only weakly irradiates the lung tissues. Since 1987, the World Health Organization has recognized radon as a known cause of human lung cancer. Epidemiological studies on uranium miners have shown a risk of excess mortality due to lung cancer associated with radon exposure. More recent studies in the general population have shown that this risk is significant for continuous domestic exposure to radon at concentrations above approximately 200 Bq m^{-3} . The action of radon and its progenies, combined with smoking, leads to a higher lung cancer risk somewhere between the sum and the product of the two relative risks (BEIR IV, 1999).

3.1 Estimation of Radon Progeny concentrations

Inhalation of radon gas contributes relatively less dose to the lung as compared with its progeny. Inhalation of alpha emitting short-lived radon progeny and the subsequent deposition of this progeny on the bronchial tree of lungs delivers most of the radiation dose. Therefore, the health risk associated with the inhalation of radon gas depends on radon progeny levels. Radon progeny levels are determined using the equilibrium equivalent concentration (EEC) which is estimated from the measured radon gas concentration (Bq m^{-3}) and the equilibrium factor (F_{eq}). In the present study, we have applied radon equilibrium factor, 0.5 (Reshma Bhaskaran, 2017).

3.2 Lifetime lung cancer risk (LLCR)

There are several radon risk models in the literature. In all risk models, lifetime risk of radon-induced lung cancer increases with increased exposure to radon progeny. The lifetime risk estimates could vary significantly between the various risk models considered.

The alpha dose delivered to target cells in bronchial epithelium arises mainly from the short-lived decay products deposited on the bronchial airway surfaces. The decay products, however, are on the airway surfaces within about 20 to 30 μm of these target cells, and thus have a higher probability of hitting a target-cell nucleus.

The annual weighted equivalent dose from radon gas decaying in the lung has been calculated for the whole lung and bronchial epithelium (Sowby, 1981) (NCRP, 1987). The Annual effective dose gas dose itself is $7 \times 10^{-3} \text{ mSv y}^{-1}$ per Bq m^{-3} (ICRP 1981) or $5 \times 10^{-3} \text{ mSv y}^{-1}$ per Bq m^{-3} (NCRP 1987). The dose from ^{222}Rn gas is

lower by about a factor of 10 compared to the bronchial dose from the decay products deposited on the airways.

For the estimation of Lifetime Lung Cancer Risk (LLCR), the conversion factor proposed by fourth National Research Council Committee on Biological Effects of Ionizing Radiations (BEIR IV) was used.

Excess Lifetime Lung Cancer Risk of 2% per 148 Bqm^{-3} ($=0.56\text{WLM}$) was used (BEIR IV, 1988).

4. RESULTS AND DISCUSSION

Figure 1 shows a typical spectrum of radon measurement by the Radoney+2 detector. The graph shows the variation of radon concentration measured in Bqm^{-3} , continuously from mid-June 2024 to April 2025. There are incidences of sporadic spikes of radon concentration which is due to the environmental and subsurface soil radon emanation. The instrument is capable of continuous measurement of temperature and humidity which are not shown in the graph.

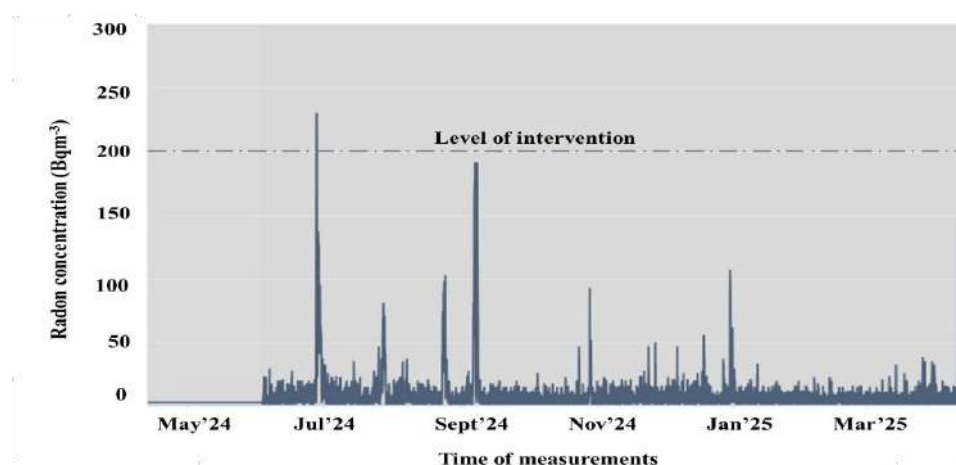


Figure 1 Spectrum of continuous radon measurement by Radoney+2

The data obtained from all the ten devices were compiled and used for determining the Lung Cancer Risk.

Table 1. Radon concentration, Annual Effective Dose and Lifetime Cancer Risk

Location	Av. Radon Concentration (Bqm^{-3})	AED ($\times 10^{-3} \text{ mSv y}^{-1}$)		Lifetime Lung Cancer Risk Percentage (%)
		Lungs	Bronchial	
1. House	10	50	70	0.14
2. House	14	70	98	0.19
3. House	13	65	91	0.18
4. Office	8	40	56	0.11
5. Office	10	50	70	0.14
6. Office	10	50	70	0.14
7. Office	14	70	98	0.19
8. Workplace	16	80	112	0.22
9. Workplace	12	60	84	0.16
10. Workplace	18	90	126	0.24
A.M.	12.5	62.5	87.5	0.17
S. D.	3.1	15.5	21.7	0.04

The results indicate that the average radon concentrations measured in the locations are that of a normal radiation environment, even if infrequent spikes were observed during measurements. The mean value of radon concentration at the locations ($12.5 \pm 3.1 \text{ Bq m}^{-3}$) was much lower than the global average of 40 Bq m^{-3} . For the

estimation of AED, the conversion factors, $7 \times 10^{-3} \text{ mSv y}^{-1}$ per Bq m^{-3} and $5 \times 10^{-3} \text{ mSv y}^{-1}$ per Bq m^{-3} were used for Bronchial epithelium and the whole lungs respectively. Conversion factor indicates that Bronchial epithelium is more vulnerable for the radiation dose with respect to the whole lungs in general.

The percentile life time cancer risk was estimated assuming 80% occupancy and average longevity of 70 years. The estimated Lifetime Lung Cancer risk was 0.17 ± 0.04 . The estimate risk factors agree with the results of other investigations conducted in various countries.

According to the WHO, the risk of lung cancer due to indoor radon exposure increases by 16% for each 100 Bq m^{-3} , and the dose-response correlation is linear. According to the US EPA, lifetime exposure to 74 Bq m^{-3} lead to 32 and 4 lung cancer cases per 1000 population, for smokers and non-smokers respectively.

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In Search of Indigenous Framework on Climate Change Education in the Vanuatu Education System.

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Abstract: Climate change has become the focus of attention in many countries of the world. Education is seen as a pivotal tool not only in bringing climate change issues to the fore of regional and international debates, but also in raising awareness about climate change in schools. In Vanuatu, Climate Change Education (CCE) has been included in the Vanuatu Education System including relevant policies and curriculum documents. This paper reports on the preliminary findings emanated from a qualitative case study recently carried out in Vanuatu. The purpose of the study was to find out if current official curriculum documents promote climate change concepts congruent to local settings, for example, the indigenous knowledge system, to promote sustainable development. Data was collected via interviews of key education and climate change officers; as well as by reviewing relevant educational documents, including educational policies and curriculum. Data collected was analysed through the content analytical tool. The preliminary findings show that the promotion of local climate knowledge in the curriculum is less emphasized. These findings will be articulated in the presentation. The paper then speculates on the best possible indigenous knowledge framework on climate change beyond the curriculum to promote climate change education and to ensure sustainable development for the Pacific people.

Keywords: Climate Change Education (CCE); Vanuatu National curriculum; Indigenous knowledge; Sustainable development

Author Biography:

Annette THEOPHILE is a senior lecturer at the School of Education, National University of Vanuatu. She is originally from Vanuatu and has been working in the field of education for over 20 years. Her background is in environmental science and science education and she has a strong interest in climate change education. She is passionate about helping students and teachers understand environmental issues and how they affect our communities. Annette trains future teachers who will go on to teach environmental science in both junior and senior secondary schools in Vanuatu. She believes in making education relevant to local contexts and helping young people become more aware of their environment.

1. INTRODUCTION

1.1 Background to the Study

Vanuatu, an archipelago of 83 islands, is rich in cultural diversity and indigenous knowledge. The Indigenous Knowledge (IK) remains highly valued and actively practiced by the people [Republic of Vanuatu] [Mercer et. al. 2010]. Vanuatu is also among the most vulnerable countries in the Pacific region exposed to impacts of climate change, including rising sea levels, extreme weather, and ecosystem degradation [Intergovernmental Panel on Climate Change].

Given the context, it is important that climate change responses, particularly through the formal education reflects and builds upon the experiences and Indigenous Knowledge Systems (IKS) of the local communities.

1.2 Statement of the Problem

The Vanuatu curriculum has integrated climate change content and Disaster Risk Reduction (DRR) into its science, geography and social science subjects and offers these to Kindergarten (K) to Year 13. Although IK is acknowledged for its role in sustainable environmental management and disaster preparedness [Nakashima et. al.] this knowledge is often left out of school curricula, which are mostly based on western scientific views [McCarter et. al. 2014]

1.3 Purpose of research

This research study investigates the extent to which IK, especially traditional early warning systems (TEWS), is represented in Vanuatu's Climate Change Education (CCE) framework. It also explores how an IK framework can be more effectively integrated into policy and classroom practices to support climate resilience and sustainable development. The research is guided by the following questions:

1. *How well is IK, particularly TEWS, integrated in the Vanuatu's CCE framework?*
2. *To what extent do curriculum and policy documents reflect local ecological and cultural contexts?*
3. *How can an IK framework contribute to climate resilience and sustainable development?*

2. LITERATURE REVIEW

IKS are understood as a body of knowledge, practices, and beliefs developed by Indigenous communities through long-term interaction with their environment. This knowledge is passed down orally through stories, rituals, and hands-on experiences, and is often holistic and deeply connected to nature [Sillitoe]. Researchers explain that, in the context of climate change, IKS includes early warning signs like cloud patterns, animal behaviour, and seasonal changes that help communities prepare for environmental hazards [Dei]. Similarly, traditional knowledge (TK) is defined as local knowledge held by Indigenous and local people, based on experience, adapted over time, and passed on through generations [McCarter et. al. 2011]. A recent Pacific study [Berkes] highlights how IK and TK support community resilience in the face of climate-related challenges, particularly in island nations. In Vanuatu, research show that both IK and TK play key roles in local adaptation strategies, and the two terms are often used interchangeably [Koya et. al.]. In this search, I will also use the terms IK and TK interchangeably, as both refer to local systems of understanding and responding to environmental changes.

The integration of IKS into formal education offers several benefits. It increases cultural relevance and student engagement [Koya et. al.] strengthens community-based resilience to climate risks [McCarter et. al.] and contributes to decolonizing education by acknowledging Indigenous epistemologies as valid and valuable [Warrick et. al.]. Furthermore, the IKS supports sustainability by promoting traditional practices of land stewardship and intergenerational knowledge transfer [Nakashima et. al.].

However, the incorporation of IK into education systems faces several challenges. Formal curricula often marginalize IKS in favor of Western scientific approaches [Mercer et. al.] and the oral nature of IK complicates its documentation and assessment in classroom settings [Battiste]. Epistemological tensions between holistic Indigenous worldviews and the compartmentalized structure of formal education further limit effective integration [Nunn 2023]. Additionally, while policy frameworks may acknowledge the value of IKS, educators are often not provided with adequate training or resources to implement it effectively [da Silva et. al.].

This research is framed within the IK Systems (IKS) theory, which recognizes the value of community-based, place-specific knowledge passed down through lived experience, environmental observation, oral traditions, and spiritual beliefs [Nakashima et. al.] [Matapo]. The theory challenges the dominance of western epistemologies and calls for a pluralistic curriculum that validates indigenous perspectives alongside scientific knowledge.

Using IKS theory as a foundation, this research critically examines the curriculum and policy documents in Vanuatu to assess whether and how IK is acknowledged, and how it is being applied in the classroom. The study also explores the perspectives of curriculum developers, educators, and climate professionals to understand

the opportunities and constraints in embedding IK into formal education.

To situate this research within the broader academic context, previous studies [Granderson] have explored similar questions using thematic approaches. One study investigated the role of TK in climate change adaptation by examining community-based resilience, the integration of IKS, and policy relevance [Ministry of Education and Training]. Another one explored local risk perception, TEWS, and education strategies for climate preparedness [Rarai et. al.]. Building on these works, the present study adopts a thematic framework that reflects both global insights and the specific realities of Vanuatu. Accordingly, findings will be analysed under three key themes: 1) Recognition of IK in national policies; 2) Incorporation of IK in curriculum development and implementation phases; 3) Opportunities for enhancing cultural resilience through education.

3. METHODOLOGY

This study employed a qualitative, exploratory approach grounded in a constructivist–interpretivist paradigm. This paradigm supports relational and contextual understanding, aligning well with Indigenous epistemologies and knowledge-sharing practices [Nunn et. al.].

Participants were selected using purposive sampling to ensure expertise in classroom teaching, curriculum development, climate change adaptation, and IKS.

The study involved the following individuals:

1. Four (4) curriculum coordinators – one (1) for primary and three (3) for junior and senior secondary levels.
2. Four (4) teachers – one from semi urban senior school, 1 from rural junior secondary school and 2 from urban senior secondary school.
3. One (1) officer from the Education in Emergency (EiE) program under the Vanuatu Ministry of Education and Training (MoET)
4. One (1) senior officer from the Van-KIRAP project under the Vanuatu Ministry of Climate Change

Two primary methods were used to collect data from the participants:

Document Analysis:

Key national policy and curriculum documents were reviewed, including the Vanuatu National Sustainable Development Plan (VNSDP 2030), the Vanuatu Climate Change and Disaster Risk Reduction (CCDRR) Policy 2016–2030, VAN-KIRAP Traditional Knowledge Strategy (2019–2024) Disaster Risk Reduction and Education in Emergency (DRR&EIE) policies, the Vanuatu National Curriculum Statement (VNCS) and subject syllabi for earth science, geography and junior Science. These documents were examined using Bowen’s qualitative content analysis method [Jones et. al.] to assess the presence or absence of IKS content, with a particular focus on TEWS.

Semi-Structured Interviews:

The interviews explored participants’ perceptions, experiences, and practices concerning the integration of IKS—particularly TEWS—into formal education. Interviews were audio-recorded with consent, transcribed verbatim, and analysed using an inductive approach to allow key ideas to emerge naturally [Bowen] followed by a deductive phase where responses were organised according to the study’s main themes. Recurring ideas were identified and grouped using a thematic analysis process [Braun et. al.].

4. RESULTS AND DISCUSSION

Document analysis shows that while national policies strongly recognize the importance of IK, this recognition is not yet fully reflected in the formal school curriculum. The VNSDP 2016–2030 document states that IK is vital for sustainable development, cultural identity and environmental resilience, hence calls for its preservation and integration across education and national planning.

Similarly, the Vanuatu Climate Change and Disaster Risk Reduction Policy (2016–2030) goes a step further by actively promoting the use of TK especially TEWS alongside scientific methods in community-based climate adaptation and disaster preparedness initiatives. At the education sector, IK is supported by the VNCS through its integration into curricula and articulation of its value under the theme “culture and values”.

Complementing these formal efforts by the education sector, stakeholder-driven frameworks such as the VAN-KIRAP Traditional Knowledge Strategy (2019–2024) adopt a more proactive approach by promoting the use of traditional climate indicators and TEWS in informal education, community awareness programs, and local climate services [Nowell et. al.]. Under this strategy, such tools as the Vanuatu National TK indicators Booklet and Climate Watch have been created to record validate share that community traditional forecasting signs. These efforts emphasize the role of TK in enhancing resilience at the grassroots level, particularly outside the formal school setting. Although the DRR and EIE framework encourages a more community-based and participatory approach to working with schools and community leaders to integrate TK into school readiness plans [VAN-KIRAP], official curricula remain vague on concrete steps to integrate TEWS into classroom learning, particularly in science-related subjects.

This mismatch between active initiatives and curriculum content highlights a persistent gap between recognition of IK at policy level and IK implementation at classroom level, despite promising efforts at the school-community interface through DRR programs.

At the level of curriculum development, coordinators confirmed that climate change and DRR issues appear in the senior school syllabi—mainly in earth science, geography, agriculture, and junior science topics, they are presented from a scientific perspective, with little or no reference to IK, especially TEWS. One coordinator noted that at the time of syllabi development, climate change and DRR were not pressing issues; hence there was little research to support the inclusion of IK. This explains why policy documents have recognized it forcefully but place very weak emphasis on TEWS-related IK in curriculum content. However, coordinators also mentioned that although TEWS is not explicitly stated in the syllabi it happens that teachers are verbally encouraged during curriculum workshops to bring TK into classroom activities where possible.

This shows a clear contrast between what happens at the national level and what is actually happening in the curriculum. While national policies support the integration of TK and scientific knowledge, there are no clear directives for curriculum developers, nor are there supporting resources or assessment tools. As a result, the current curriculum provides little guidance for teachers on how to incorporate IK-particularly TEWS or cultural practices into their subjects.

At the school level, teachers said that one reason IK, especially TEWS is not used in their teaching is because it is not included in the syllabus. As one teacher said, *“We don’t teach it because it’s not mentioned in the syllabus.”* They also explained that their busy timetable makes it hard to add extra content, and that TEWS is usually only taught or made known during special events like “Cultural Week.”

Teachers also mentioned that they lack enough knowledge about traditional practices and that their initial training did not prepare them to integrate TEWS into their related science lessons. As one explained, *“We don’t know enough about traditional knowledge, and during our training we weren’t taught how to include it in lessons.”* These comments show that even though national policies support the use of IK, it is still missing from classroom teaching because of limited curriculum content, lack of resources, and insufficient teacher training. The teachers expressed that they do not have adequate information regarding traditional practices and that their pre-service training did not equip them with the skills to integrate IK into their related science subjects. As one teacher said “we don’t know enough about traditional knowledge, and during our training we weren’t taught how to include it in lessons.

Despite these challenges, some positive opportunities were noted for better integrating TEWS into climate change and DRR content. Resources such as the school-Based Disaster Risk Reduction (SBDRR) handbook encourage learners to discuss local coping methods from the elders. Such activities also promote a more hands-on, experiential approach to learning.

The Van-KIRAP Traditional Knowledge Indicators Booklet is another useful tool. It records local weather signs and provides practical examples that can help teachers bring TEWS into climate and disaster lessons, especially in subjects like Earth Science and Geography.

5. CONCLUSION AND RECOMMENDATIONS

In conclusion, this study highlighted the gap between national policy support for IK, particularly TEWS and its practical integration into the formal education system in Vanuatu. While policies such as Vanuatu National Sustainable Development Plan (VNSDP 2016–2030), the Vanuatu Climate Change and Disaster Risk Reduction Policy (2016–2030), and the DRR & EiE Framework emphasize the importance of IK and TEWS in building community resilience to climate change and disasters, this vision is not adequately reflected in the implementation phases, that is, in the national curriculum and classroom practices. Though the VNCS encourages the inclusion of traditional knowledge in broad terms, Earth Science and Geography syllabi do not explicitly mention TEWS in their learning outcomes or how IK should be integrated. Such ambiguity leaves teachers with little direction on how to translate the policy intention into classroom practice.

Findings from the study also reveal that IK and TEWS are rarely included in the regular teaching in a classroom, except during School Cultural Week or Meteorology Department outreach days. Despite these challenges, there is significant potential for improvement. The study therefore recommends the following:

1. Incorporate IK and TEWS into teacher training programs with a focus on practical strategies for integration into science and geography lessons
2. Develop culturally relevant teaching and learning resources, drawing from resources like the Van-KIRAP Vanuatu National TK early indicators [VAN-KIRAP] and the school-Based DRR Handbook [Vanuatu Meteorology & Geo-Hazards Department]
3. Foster stronger partnerships between schools and local communities, involving TK holders in curriculum planning and delivery.
4. Revise the national curriculum to include IKS, especially TEWS, and provide clear guidelines for their implementation across subjects.

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Aligning University Courses to the PNG Government Digital Plan, A Challenge for the Universities in PNG

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Abstract: The Papua New Guinea Government Digital Plan 2023-2027 has set the path for its digital future agenda, focusing on transforming public service delivery, improve e-governance and build the national digital ecosystem. The Department of Information and Communications Technology (DICT) as the lead government department has developed this plan as well as supporting policy documents such as the Government Cloud Policy, Data Governance Policy, Digital Infrastructure Policy and etc. According to the plan's implementation schedule, the government wants to go paperless in 2026 and integration of AI technologies into public service systems and processes before 2027. This plan indirectly calls for and creates a demand for technically skilled labor force in emerging ICT fields like software engineering, data science, artificial intelligence, e-commerce and cybersecurity. Meeting this demand will challenge the universities in Papua New Guinea on two fronts. First is modernizing the universities themselves as institutions and integrate ICT technologies in their administration and core business of teaching and learning. This is highlighted in the Department of Higher Education, Research, Science and Technology (DHERST)'s policy document titled "Policy on Digitalization of PNG Universities Research Institutes. Second is to realign and modernize their IT program curricula to meet these digital demands in the industry. Therefore, this paper seeks to establish the status of IT related programs offered across seven universities in the country by analyzing the DHERST's 2025 Continuing Student List, of students studying in all the universities under the Tertiary Education Study Scheme (TESAS) scholarship Then the particular subject units of the respective IT programs observed from the respective institutional websites to see whether current trends in ICT like data analytics, e-commerce, software programming and AI were factored in the program subject unit structure. The results will generate informed awareness of the shortfall in IT program curriculum reform across all universities and help formulate corrective action. This will ensure the IT graduates are job ready when they enter the job market when the PNG Government Digital Plan implementation gets momentum.

Keywords: Digital Government, PNG Digital Government Plan, Course curriculum review, job readiness. IT Courses

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1. INTRODUCTION

Digital Government is as is defined as “ the use of digital technologies, as an integrated part of governments' modernization strategies, to create public value” OECD (2014). As governments of countries went through the changes brought about by different stages of world industrial revolutions, their systems of governing the state have also gone through similar progression processes. According to PricewaterhouseCoopers LLP (PwC) governments have evolved from Government 1.0 to Government 5.0. Government 1.0 (emerging)-government with standalone services, with no cross department integration, Government 2.0 (industrialization)-scaled adoption of digital services ensuring access to everyone, Government 3.0 (Automation)-refining operating models

to enhance efficiency, Government 4.0-(Digitalization)-whole-of-government alignment enabling citizens to interact with government and Government 5.0-(Personalization)-“ governments shift their mindsets towards the citizen models ,aligning their service delivery and government processes to citizens’ lives, rather than expecting the citizens to fit into governments’ processes”, PwC (2022)

A lot of the Digital Government efforts by countries around the world and the Pacific region are centered around the Organization for Economic Co-operation and Development (OECD)’s Digital Government Policy Framework. This framework elaborates on six dimensions of Digital Government which are digital by design, data-driven public sector, government as platform, open by default, user-driven and proactiveness, OECD (2020-10-07). The 38 member countries of the OECD and European Union participating in it as well means the Digital Government agenda is a global one, OCED (2025).

The implementation of the agenda for developing countries is important for three obvious reasons. Firstly, OECD countries have strong political and economic ties with developing countries. Secondly, OECD members are usually the first respondents to natural and manmade national emergencies in the developing countries. For example, the COVID-19 and various earthquakes in the South Pacific Island nations. These emergency response operations are often carried out in collaboration with respective national government and local governments. Thirdly, OECD member countries contribute significantly to development aid for developing countries under various aid programs. They are also active in setting global development agendas at the United Nations like the Sustainable Development Goals (SGDs) and supporting the various UN implementing agencies. Therefore, the Digital Government outcomes will not only be of benefit to individual countries but have an impact on all countries through that kind of relationship and collaboration.

The Papua New Guinea government is transitioning into this Digital Government agenda by passing the Digital Government Act 2022 which led to the development of the PNG Digital Government Plan 2023-2027. The implementation of this plan will require a lot of digitally skilled local workforce in both the public sector as well as in the ICT industry. Therefore, the ICT industry and the public sector “counts on the universities to produce the professionals with ICT practitioner skills. These are the capabilities required for researching, developing, designing, strategic planning, managing , producing, consulting, marketing, selling, integrating, installing, administering, maintaining, supporting and serving ICT systems.”, Baltac (2008). This paper aims to highlight the status of ICT courses offered across all the eight universities in the country and one private university which is soon to be registered as a university with DHERST. The main document analyzed was the 2025 Tertiary Study Assistance Scheme (TESAS) scholarship list of continuing students.¹ This document gives the national snapshot of all programs offered across the universities and number of students enrolled in them. The IT program’s particular subject units also analyzed from the respective institutional website information to see whether the units relate to the current ICT industry trends such as Data Analytics, Cyber Security, E-Commerce, Artificial Intelligence, Software Engineering which are some skills sets required by the government and the ICT industry.

2. THE PNG DIGITAL GOVERNMENT PLAN

The PNG Digital Government plan sets the road map for Papua New Guinea Government’s intension to digitalize how it conducts its business with its citizens (Government To Citizens-G2C), among its own departments and statutory organizations (Government to Government (G2G) and with businesses (Government to Business (G2B)). The main objective of the plan is to “ enhance, strengthen, and improve the performance and productivity of the public sector agencies to effectively deliver goods and services to citizens, business, and investors”, the whole of Government approach, DICT (2022).

The government made the development of this plan mandatory under Section 10 of the Digital Government Act 2022 (PNG 2025). This legislation dictates that the copy of the plan is to be circulated to all government bodies and the government bodies are to comply with the plan. Also, the government bodies are obliged to conduct an annual self-assessment of implementing the plan and submit the assessment report to the Minister Department of Information and Communications Technology (DICT) as the lead department. The

department is required to review the plan every five years or as advised through a National Executive Council (NEC) decision.

All heads of government organizations are required by law to submit the annual implementation assessment report to the Department of Information and Communications Technology. Failure to do that is an offense against the act.

To support the implementation of the plan, DICT has developed supporting strategic policies that span across the key areas of the plan. For example, the Digital Economic Policy and Strategy, Data Governance Policy, Government Cloud Policy, National Broadband Policy 2022 to 2027 etc.

To initiate the implementation, the government bodies will first build their systems through a Government Leased Cloud Infrastructure provided by commercial vendors and then later build On-Premises Data Centers as outlined in the Government Cloud Policy.

The major milestone targets for the first five years (2023-2027) of this plan includes all government bodies to go paperless by 2026, become a leader in cyber security in the Pacific, government services driven by AI and have electronic voting for the upcoming 2027 National General Elections.

3. CURRENT STATUS OF ICT PROGRAMS AT UNIVERSITIES IN PNG

3.1 DHERST Policy on Digitalization

In response to the PNG Government Digital Government plan, the Department of Higher Education, Research, Science and Technology (DHERST) released its adoption policy document “Policy on the Digitalization of Papua New Guinea Universities and Research Institutes” DHERST (2025). This policy highlights how Higher Education Institutions (HEIs) can integrate digital technologies into the core business of teaching and learning, research and administrative processes. One notable component of the plan is the deployment of the National Higher and Technical Education Management Information System (NHTEMIS).² These and other related policies capture future aspirations and intentions to innovate and develop the digital ecosystem for higher education institutions but there is no clarity on the implementation milestones.

One evidence of such vagueness is the very low number of IT programs offered across the eight universities in the country. Although the curriculum review and update are the prerogative of the universities, clear policy milestone directives are required to invoke the necessary decisions.

3.2 Current computer programs offered by universities in PNG

The current IT related programs offered at the main universities in Papua New Guinea is very low in terms of quantity, student enrollment and choice of subject unit components in the program structures. Out of the 134 total programs offered in universities, only ten are IT programs. This equates to 7% of the total programs. In terms of student enrollments, the total enrollment in 5296 students and 331 students are enrolled in the IT programs which is 2.6%. This figure represents the enrollment figures for a period of 3 years since the DHERST 2025 TESAS Continuing list consists only of 2nd, 3rd and 4th years. So, an average of 110 students will graduate in IT programs between 2025 and 2027.

Source: https://web.dherst.gov.pg/images/2025-pubs/digitalisation-policy/MPS-202501_Digitalisation%20Policy.pdf

Institution	Total Programs	Students	IT Programs	Enrollment
Papua New Guinea University of Technology	31	1234	2	107
University of Papua New Guinea	26	277	1	13
University of Goroka	16	753		
Pacific Adventist University	16	972	1	73
Divine Word University - Madang campus	15	598	2	57
PNG University of Natural Resources and Environment	8	630		
Innovative University of Enga - Faculty of Education	6	114		
Western Pacific University	5	99	3	49
IBSUniversity	4	106	1	32
University of Goroka - Sepik Campus	2	45		
Divine Word University - St. Benedicts Campus - Wewak	2	192		
Divine Word University - OLSH Kabaleo Rabaul Campus	1	170		
Divine Word University - St. Benedict School of Nursing	1	48		
Divine Word University - St. Mary's Vunapope Rabaul	1	58		
	134	5296	10	331

Source: DHERST TESAS 2025 Continuing student list.

Papua New Guinea University of Technology	
1	Bachelor of Business in Information Technology
2	Bachelor of Science in Computer Science
University of Papua New Guinea	
3	Bachelor of Science (Major in Mathematics, statistics & Computer Science
Pacific Adventist University	
4	Bachelor of Business (Accounting & Information System)
Divine Word University	
5	Bachelor of Information Systems
6	Bachelor of Mathematics & Computing Science
Western Pacific University	
7	Bachelor of Science in Computer Networks
8	Bachelor of Science in Computer Programming
9	Bachelor of Science in Cyber Security
IBSUniversity	
10	Bachelor of Information Technology

IT programs offered in universities

The IBS University, Western Pacific University and Bachelor of Business and Information and Technology from PNGUoT have all subject units that related to IT. Pacific Adventist University IT Program is a Double-Major and 50% of subject units are Accounting units and other 50% subjects units are IT. University of PNG's IT program, Divine Word University's Bachelor of Mathematics and Computer Science and the Bachelor of Science program from PNGUoT are more mathematics centered to build mathematics theories around computing.

This stagnation of IT program offerings at universities had persisted for some time. One critical computer skill for ICT practitioners is programming. According to (Cheong, Abuzo et al. 2025), students are introduced to

basic introductory computer programming subject at undergraduate when they enroll for a IT program. Usually as a one-off single subject unit rather than series of units in a Software Engineering program path. As a result, there is a lack of local software developers and engineers in the ICT industry in PNG.

Sun, Wei et al. (2024) studied the digital policy, digital technologies and development of computing education trends in PNG and highlighted that development of computing education has always been influenced by support from outside like the Australian Government which supported the curriculum review of the IT program at PNGUoT. “Most of master’s degree in IT are offered outside of PNG like Australia, New Zealand and other countries. Since, the arrival of internet in 1997, ICT industry is reliant on foreign companies and PNG is primarily an end user of ICT and digital technologies and services rather than a manufacturer “.

Manohar, Rao et al. (2010) emphasized the need for building the infrastructure and human resources necessary to implement e-government initiatives in PNG and concluded that “human capacity in PNG is to be geared upon on a large scale to meet the implementation and usage needs of e-government initiatives. The government should encourage academic institutions to cooperate with the ICT sector to ensure that the educational programs provide by such institutions improve the ICT skills of various job types.”

Sinebare (1999) foresaw the predicament of IT education and training in Papua New Guinea and recommended “There is neither a specific policy formulated, nor a curriculum guideline provided to cater for IT education and training in PNG. IT education and training in PNG should be given national attention by the government because of the potential in using IT in many aspects of social-economic aspects of the country and more importantly because of the potential to create a knowledge industry within the country. “

4. IT PROGRAMS AT SOMARE INSTITUTE OF LEADERSHIP AND GOVERNANCE (SILAG)

As implementation of the PNG Government Digital Plan gains momentum, the IT industry, private sector and the public sector will be competing for the limited number of IT graduates from the universities. This will also require upskilling and upgrading of existing public sector workforce in IT skills. Therefore, the institution mandated with the public sector employees training is the Somare Institute of Leadership and Governance (SILAG), formerly known as Pacific Institute of Leadership (PILAG) and initially known as Institute of Public Administration (IPA).

The PNG Government has already planned it to be elevated to a university status in 2027 Studyinpng (2024) and it will become Somare University of Public Service and start enrolling students direct from Grade 12. It will mainly offer programs related to the Government like Economics, Public Policy Development, International Relations and etc., (Studyinpng 2025). The current IT programs on offer at SILAG is almost the same state as the university programs. It has only one program called Diploma in Information Technology SILAG (2023). It does not have offer a IT program tailored for public sector IT leaders. Also, it doesn’t have any IT industry certification programs like Microsoft Certification, Cisco Network Certification etc.

5. NEED FOR IT PROGRAM CURRICULUM REVIEW AT UNIVERSITIES IN PNG.

Universities and SILAG as public sector training institute and upcoming university has a crucial role to play to prepare the necessary skilled IT labor force that will be required for the successful implementation of PNG Digital Government Plan. “Universities have a distinct role in producing the professionals needed by the ICT industry and they have to continue to strengthen their vital role in this respect” .Baltac (2008).

Proactive curriculum review is required from the universities to address the current low IT program offering at both the universities and at SILAG. “PNG nationals urgently require IT education and training from educational institutions to meet the country’s increasing needs. Computer education and computer studies have been left to chance”, Kelegai and Middleton (2002).

Curriculum can influence three elements. Teacher, student and environment. For example, a change in curriculum may require a new teacher expertise, it may also call for environment change in academic environment like computer labs, facilities and etc, Pumwa (2013).

European Union (EU), America and Asian countries are competing for top IT talents to maintain their economic and political status quo, Baltac (2008). And PNG's top cream of young intellectuals from the School of Excellence are being send overseas through the STEM scholarship program, PostCourierOnline (2024) and potential for brain-drain of PNG's talented future workforce is real. Therefore, universities need to critically relook at their IT program curriculums and align to the PNG Government Digital Plan.

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An Innovative Kalman Filter Based Beam-Steering Antenna Configuration for Maximum Power Transfer

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Abstract: Wireless power transfer (WPT) technology has become a challenging and popular subject for research and application in many disciplines, including electric vehicles, consumer electronics, biomedical systems (e.g. implants that may be charged using RF power to avoid battery replacement), battery less autonomous wireless sensor nodes in IoT and RFID. Although much of the research activity has focused on coupled systems such as capacitive and inductive WPT, more recently attention has also given to uncoupled WPT using RF signals and lasers. This paper addresses the challenge of maximum power transfer in WPT using RF signals in developing a transmitter and receiver multiple input multiple out (MIMO) system that is designed to act like beams that are narrow and touch at the tips like two dynamically connected beam tips to ensure maximum power transfer. Smart Beamforming Antennas are important for maximum power transfer for magnetic and electric power. This paper presents a nonlinear configuration of dipole arrays for forming a single beam in any desired direction to maximize the power transfer. We propose an eight-elements array structures to perform this single beam-steering functionality. Since antennas are bidirectional elements, beamforming in one direction means that the antenna will also have high receiving gain in that direction. Phase delay factors are optimized at the transmitter and receiver to form a single beam and then to steer the transmitter and receiver beams towards each other by optimizing using a Kalman filter-based algorithm. Phase shifters are added in the transmitter and receiver to obtain maximum directional gain. This configuration along with Kalman filter-based algorithm significantly increases the power transfer gain with operational simplicity.

Keywords: Wireless Power Transfer, Adaptive Antenna, Beam-steering

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1. INTRODUCTION

Wireless power transmission (WPT) technology is considered as one of the game-changing technologies. People will be able to become free from lacking electric power when electric power will be supplied wirelessly. Parallel

to Tesla's first WPT experiments, M. Hutin and M. Le-Blanc proposed an apparatus and method for powering an electrical vehicle (EV) inductively in 1894. EVs were developed during the period of time shortly after the steam engine, approximately one hundred years ago. Both inductive WPT which is a type of 'non-beam' WPT and the WPT via radio frequency beam which is called 'beam' WPT were started in the early 20th century. The present development of the WPT via radio frequency beam owes to William Brown in 1960s using microwave technology developed during the World War II. A turning point of the inductive WPT was in 2006, when Massachusetts Institute of Technology (MIT) demonstrated non-beam wireless power technology called resonance coupling. After the MIT's demonstration, a variety of WPT technologies including magnetic induction, resonance coupling, transmission via radio frequency beam, etc. are paid attention as game-changing technologies. It is considered that wireless power transmission (WPT) is defined as the transmission of power from a power source to an electrical load wirelessly using the electromagnetic field. It is also considered that WPT technologies utilize various mechanisms, such as transmission via radio frequency radiated transmissions in the far field (WPT beams) and near-field inductive, resonant and capacitive coupling (WPT non-beam).

Wireless sensor networks (WSNs) are one of the most rapidly developing information technologies and promise to have a variety of applications in next generation networks (NGNs). At the same time, sensor nodes can be located in the inaccessible places, or the concrete location of each sensor node can be unknown. Also, a WSN may consist of dozens, hundreds or even thousands of sensor nodes. Under these conditions charging of sensor nodes by the user is out of question. That is why a sensor node must have high energy efficiency in order to keep working on small and inexpensive battery for a few months and even years. This ultra-low-power operation can only be achieved by using low-power hardware components. Microwave power can drive a wireless sensor without a battery. Wireless power can be actively transmitted to sensors requiring electricity. In this circumstance, beam WPT technology can offer substantial improvements in some applications as compared to non-beam WPT, which utilizes inductive, resonant and capacitive coupling technologies. Beam WPT technology can be designed and implemented into many different sized electronic devices for the home and office, as well as the medical, industrial, retail and automotive industries, and it ensures interoperability across products. These devices include wearables, hearing aids, earbuds, Bluetooth headsets, Internet of Things (IoT) devices, smartphones, tablets, e-book readers, keyboards, mice, remote controls, rechargeable lights, cylindrical batteries, medical devices and any other device with similar charging requirements that would otherwise need a battery or a connection to a power outlet. It is quite possible to create a uniform microwave power density in a ubiquitous power source (UPS) room with antennas installed at the ceiling edges. However, because the UPS concept is based on a "wireless power source all the time and everywhere," the design of UPS is limited by safety issues associated with prolonged exposure to microwaves by human beings. The safety level set is under 1 mW/cm^2 for continuous exposure over the entire human body. To address this, a phased array should be used to reduce the total transmitting power and to reduce unexpected radiation at positions where power is not needed.

WPT is progressively being used in a wide range of applications such as medical devices, consumer electronics, electric vehicle charging, industrial automation, and remote power delivery due to its several advantages, including convenience, elimination of physical connectors and cords, and the potential for automation [N. Shinohara], [X. Lu et. al.]. Ongoing research and development efforts are focused on improving power transfer efficiency and addressing safety concerns to realize the full potential of wireless power transfer systems. The power transfer efficiency (PTE) of an RF wireless power transfer system provides crucial information for evaluating system efficiency, optimizing design parameters, ensuring safety, etc. To design a WPT system, it is necessary to analyze the power density at the receiver plane based on the transmitted power and evaluated path loss model to meet the goals of the system and its applications.

WPT using phased array antennas enables focused and steerable power delivery, offering advantages for various applications like charging multiple devices simultaneously or in challenging environments. By controlling the phase and amplitude of signals emitted from multiple antenna elements, a phased array can direct a concentrated beam of energy towards a specific receiver, maximizing power transfer efficiency and minimizing leakage to other areas. By adjusting the phase and amplitude of the signals, the array can create a focused beam of electromagnetic radiation that can be steered electronically, without physically moving the antenna. This focused beam can then be directed towards a receiver to wirelessly transfer power. This will enable enhanced direction-based power transfer. Wireless energy harvesting approaches are on the rise to address the energy crunch of low power IoT nodes. Space Division Multiple Access (SDMA), adaptive beamforming and, smart antennas

the are key technologies for current fifth-generation (5G) and future sixth-generation (6G) communication systems [Tian et. al.], [Agarwal et. al.]. A Smart Antenna or Adaptive Antenna is an antenna array aided by a processing system that operates on the transmitted power with the signal processing algorithms to enrich the system performances [Salunke et. al.]. Smart antennas are essential to boost the harvested energy in an energy harvesting system by maximizing reception in the received signal direction [Arif Obaid et. al. 2021], [Arif Obaid et. al. 2017]. Smart Antennas are also crucial to provide mobility support for many new and enhanced 5G applications and services such as Voice over 5G (Vo5G), self-driving automobiles, connected vehicles, virtual reality, IoT and Machine-to-Machine Communication (M2M) [Kausar et. al.]. Single beamforming beam-steering will completely avoid sidelobe radiations. Hence, single beamforming is achieved by combining signal streams from multiple elements of a non-linear antenna array in both constructive and destructive ways [Muirhead et. al.]. Beams are steered to the required directions and controlled by different configurations of antenna arrays with designated phase delays to respective elements. Advanced signal processing methods incorporated with artificial intelligence are used in beam-steering techniques to achieve the optimum power to the user while minimizing side lobe radiation. Hence, the efficiency improves as beamwidth is narrow down while sidelobe are minimized [Singh et. al].

A minimum of three dipoles are required make a non-linear configuration that can be used to steer a single beam in the azimuth angle range [K Pirapaharan et. al. 2016]. On the other hand, more elements promise a narrow beam with higher directivity. In this paper, a smart antenna has been proposed based on the antenna architecture described in [K Pirapaharan et. al. 2022]. The proposed smart antenna has the ability to maximize its directional gain by optimizing phase delay factors of its elements. Performance of this proposed antenna architecture has been proven with three dimensional solid patterns [K Pirapaharan et. al. 2023] using non-numerical optimization. The technique proposed in this paper is to study the competence of Kalman predictor based recursive algorithm with the non-numerical optimization method proposed in [K Pirapaharan et. al. 2023]. Thus, we have developed a comprehensive recursive method based on the Kalman predictor to solve this and presented in this paper.

2. NARROW BEAMFORMING BEAM-STEERING ANTENNA

Any arbitrary set of dipoles arranged in a uniform linear array produces a symmetrical radiation pattern on both sides of the plane on which the dipoles are placed. However, this arrangement cannot generate a single beam and steer it over the entire space surrounding the antenna. The proposed antenna [K Pirapaharan et. al. 2022] is a dipole antenna array that can form a single beam and steer the beam in any direction using the optimized phase delay factors. Many research studies show different types of techniques [Salunke et. al.], [K Pirapaharan et. al. 2022], [Senthilkumar et. al. 2016], [Griffiths] used for optimizing the phase shifters. Among them, machine learning and artificial intelligence-based techniques are significant in the optimization process. However, these models require high computational power and memory. This paper presents a system that uses Kalman predictor-based system to optimize the phase delay factors.

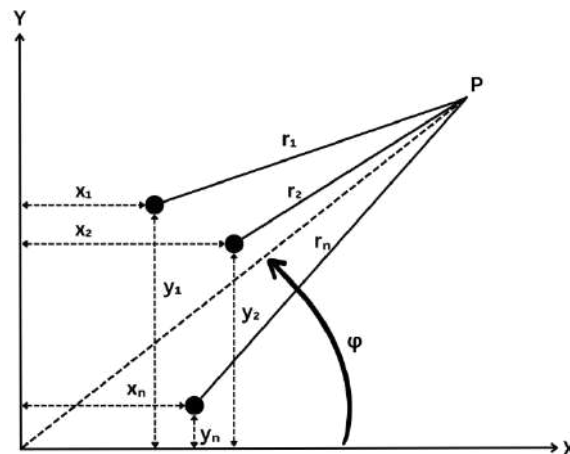


Fig.1. Schematic diagram of dipole placement in XY coordinates plane.

The radiated electric field at a particular point can be written in terms of antenna element current vectors $I_1, I_2, I_3, \dots, I_n$ for the N number of dipoles.

$$E = P_0 I_1 e^{-j\beta r_1} + P_0 I_2 e^{-j\beta r_2} + \dots + P_0 I_n e^{-j\beta r_n} \quad (1)$$

where $P_0 = Af(\theta)$. Substituting for spherical coordinate distances r_1, r_2 , and r_n by Cartesian X-Y coordinate distances, Equation (1) can be written as follows, recollecting that $AI_i = z_i$.

$$E = f(\theta) \left(z_1 e^{j\beta(x_1 \cos\varphi + y_1 \sin\varphi)} + z_2 e^{j\beta(x_2 \cos\varphi + y_2 \sin\varphi)} + \dots + z_n e^{j\beta(x_n \cos\varphi + y_n \sin\varphi)} \right) \quad (2)$$

where z_1, z_2 , and z_n are the complex weights that are proportional to the complex current vectors I_1, I_2 , and I_n , respectively. To achieve the objective of forming a resultant single beam, the values of the complex weights z_1, z_2 , and z_n need to be optimized such that the resultant radiated field must match a desired narrow beamwidth single beam function $f(\varphi) = \text{sinc}(\varphi - \varphi_0)$ and the angle φ_0 is the desired steering direction.

Considering the beam in the azimuthal plane, where $\theta = 90^\circ$ and $f(\theta)$ is a constant A , the normalized amplitude of the electric field is to be equal to desired beamforming function $f(\varphi) = \text{sinc}(\varphi - \varphi_0)$. Thus, the equation (2) is written as:

$$|z_1 h_1(\varphi) + z_2 h_2(\varphi) + \dots + z_n h_n(\varphi)| = \text{sinc}(\varphi - \varphi_0) \quad (3)$$

where $h_i(\varphi) = e^{j\beta(x_i \cos\varphi + y_i \sin\varphi)}$. Equation (3) to be evaluated to optimize the values of z_i in the space domain for varying azimuthal angle φ .

2.1 Optimizing Current Coefficients

The Kalman filter is a powerful algorithm used to estimate the state of a dynamic system. The filter works by combining a predictive model of the system's behavior with incoming measurements to produce a more accurate estimate of the system's state. It is a set of mathematical equations that provides an efficient recursive means to estimate the state of process, in the way that minimizes means of the squared error. Rewriting equation (3) in matrix form as below:

$$y(\varphi) = \text{sinc}(\varphi - \varphi_0) = H(\varphi)Z \quad (4)$$

$$\text{where, } Z = \begin{bmatrix} z_1 \\ \vdots \\ z_n \end{bmatrix} \text{ and } H(\varphi) = [h_1(\varphi) \quad \dots \quad h_n(\varphi)].$$

The Kalman predictor addresses the general problem of trying to estimate z_i of a discrete space control process that is governed by the linear stochastic difference equation. To formulate our governed equations to a discrete space control process, we specified the governed equations as below:

$$Z_k = Z_{k-1} + w_{k-1} \quad (5)$$

with the desired function

$$y_k = H_k Z_k + v_k \quad (6)$$

The random variables w_k and v_k represent the process noise and the desired noise, respectively. They are assumed to be independent of each other with normal probability distribution. Generally, the Kalman filter addresses the discrete controlled process governed by the linear stochastic difference equation. When the relationship in the process is non-linear, it is required linearize the covariance is referred to as *Extended Kalman Filter* (EKF). Due

to the non-linear nature of the desired function that we have obtained, we need to apply the process of extended Kalman filter.

Since the process and desired values are governed by the non-linear stochastic difference equations

$$Z_k = f(Z_{k-1}, w_{k-1}) \quad (7)$$

$$y_k = h(Z_k, v_k) \quad (8)$$

By approximating w_k and v_k to zero-value,

$$\tilde{Z}_k = f(\hat{Z}_{k-1}, w_{k-1} = 0) \quad (9)$$

$$\tilde{y}_k = h(\tilde{Z}_k, v_k = 0) \quad (10)$$

To estimate the process with non-linear desired relationship, we are rewriting new governing equation that linearize the estimate.

$$Z_k = \tilde{Z}_k + (Z_{k-1} - \hat{Z}_{k-1}) + Ww_{k-1} \quad (11)$$

$$y_k = \tilde{y}_k + H(Z_k - \tilde{Z}_k) + Vv_k \quad (12)$$

where, Z_k and y_k are the actual state and desired vectors. $\tilde{Z}_k$ and $\tilde{y}_k$ are the approximate state and desired vectors. $\hat{Z}_k$ the posteriori estimate of the state at step k . In addition, A , W , H and V are the Jacobian matrices of the partial derivatives as stated below.

$$A_{[i,j]} = \frac{\partial f_{[i]}(\tilde{Z}_{k-1}, 0)}{\partial Z_{[j]}} = I \quad (13)$$

$$W_{[i,j]} = \frac{\partial f_{[i]}(\tilde{Z}_{k-1}, 0)}{\partial w_{[j]}} \quad (14)$$

$$H_{[i,j]} = \frac{\partial h_{[i]}(\tilde{Z}_k, 0)}{\partial Z_{[j]}} \quad (15)$$

$$V_{[i,j]} = \frac{\partial h_{[i]}(\tilde{Z}_k, 0)}{\partial v_{[j]}} \quad (16)$$

Hence, the prediction error is given as,

$$\tilde{e}_{Z_k} = Z_k - \tilde{Z}_k \approx Z_{k-1} - \hat{Z}_{k-1} + Ww_{k-1} = Z_{k-1} - \hat{Z}_{k-1} + \varepsilon_k \quad (17)$$

and the desired value error,

$$\tilde{e}_{y_k} = y_k - \tilde{y}_k \approx H_k \tilde{e}_{Z_k} + Vv_k = H_k \tilde{e}_{Z_k} + \eta_k \quad (18)$$

The random variables w_{k-1} and v_k have the zero-mean value with the variance Q_{k-1} and R_k , respectively. Thus, the variance of ε_k and η_k can be given as $W_k Q_{k-1} W_k^T$ and $V_k R_k V_k^T$. Also, the priori estimate error covariance is then evaluated as,

$$P_k^- = E[\tilde{e}_{Z_k} \tilde{e}_{Z_k}^T] \quad (19)$$

Also, the estimate of $\hat{e}_k$ could be used along with equation (17) to obtain the posteriori state estimates for the original non-linear process as

$$\hat{Z}_k = \tilde{Z}_k + \hat{e}_k . \quad (20)$$

Given these approximations and letting the predicted value of $\hat{Z}_k$ be zero, the Kalman filter equation used to estimate $\hat{Z}_k$ is,

$$\hat{e}_k = K_k \tilde{e}_{Z_k} . \quad (21)$$

Substituting the results of equations (21) and (17) into equation (20),

$$\text{we get, } \hat{Z}_k = \tilde{Z}_k + K_k (Z_k - \tilde{Z}_k) . \quad (22)$$

Equation (22) can be used for the desired value update in the extended Kalman filter for the desired error covariance.

Hence the extensive EKF time update equations can be summarized as using priori notation as,

$$\hat{Z}_k^- = f(\hat{Z}_{k-1}, 0) \quad (23)$$

$$P_k^- = P_{k-1} + W_k Q_{k-1} W_k^T \quad (24)$$

$$K_k = P_k^- H_k^T (H_k P_k^- H_k^T + V_k R_k V_k^T)^{-1} \quad (25)$$

$$\hat{Z}_k = \hat{Z}_k^- + K_k (y_k - h(\hat{Z}_k^-, 0)) \quad (26)$$

$$P_k = (I - K_k H_k) P_k^- \quad (27)$$

The operation of the iterative solver could be employed as shown in Fig.2. as shown below.

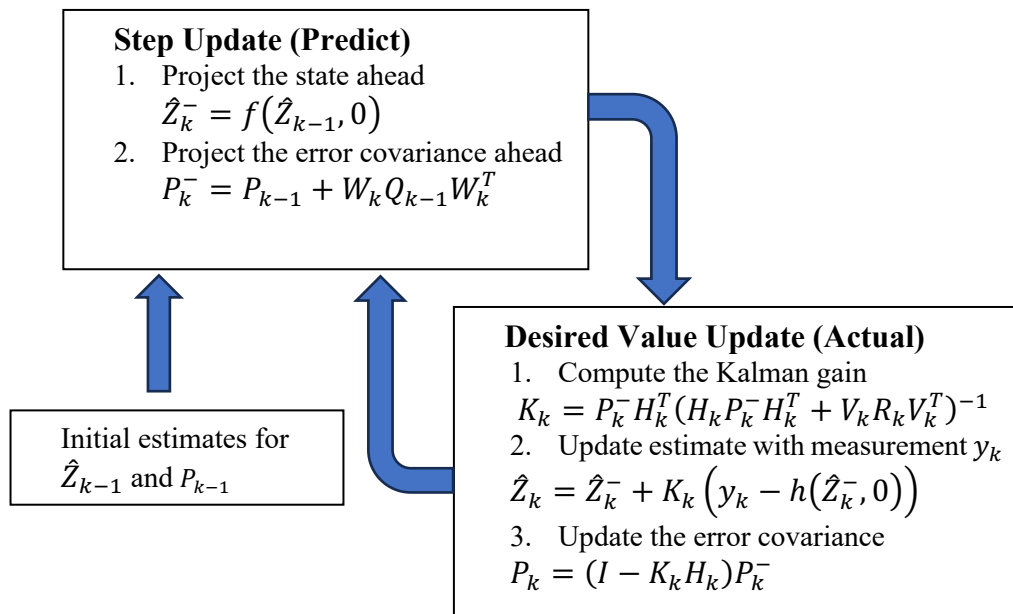


Fig.2. A complete picture of recursive algorithm to optimize the current coefficients.

Implementing the recursive algorithm shown in Fig.2, the phase delay factors (current coefficients) can be optimized.

3. NON-LINEAR PHASE ARRAY ANTENNA

It was shown in previous studies [K Pirapaharan et. al. 2016], [K Pirapaharan et. al. 2022] that linear arrays could not be used for producing single beam. Therefore, an 8-element non-linear antenna array model is proposed for these studies. It was proven in the literature [K Pirapaharan et. al. 2022], [K Pirapaharan et. al. 2023] that antenna array model can steer narrow beamwidth single beam in any direction with almost same directivity [K Pirapaharan et. al. 2022].

The proposed eight-element dipole antenna configuration from [K Pirapaharan et. al. 2022], shown in Fig.3, is used as the transmitter and is optimized to form a beam in arbitrarily selected directions. This antenna can steer the beam to any direction. These outcomes are already validated in [K Pirapaharan et. al. 2022], [K Pirapaharan et. al. 2023]. Here, we are going to study the competence of Kalman predictor based recursive algorithm developed in this paper with the non-numerical optimization method stated in [K Pirapaharan et. al. 2023] for the antenna configuration shown in Fig.3.

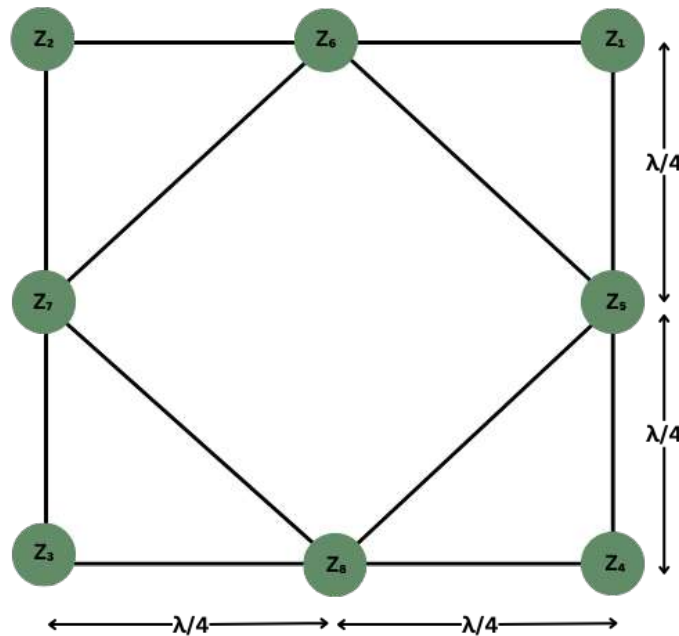


Fig. 3. Proposed eight-element dipole antenna.

4. NUMERICAL EVALUATIONS

The optimization of the phase delay factors is in progress as per the recursive model proposed in Fig.2. MATLAB® programing language is used to implement the code to evaluate the phase delay factors. Unfortunately, MATLAB® does not have an effective way to display three-dimensional solid shapes. Therefore, Wolfram Mathematica® will be used to model the relevant three-dimensional solid beam pattern. Initially, the phase delay coefficients will be optimized using extended Kalman predictor-based algorithm developed via MATLAB®. Subsequently, these coefficients will be used to display the three-dimensional solid shape radiation patterns.

5. CONCLUSIONS

WPT is playing a key role in modern power transfer applications, enabling steerable power transfer in challenging environments. A complete solution for this challenging issue was already given in [K Pirapaharan et. al. 2023], where a non-numerical method was provided to optimize the phase delay coefficients.

Here, we have proposed a comprehensive Kalman predictor based numerical solution to optimize the phase delay coefficient. Once the results stated in section 4 will be obtained, competence of Kalman predictor based recursive algorithm with the non-numerical optimization method could be analyzed.

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Digital Literacy at Divine Word University

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Abstract: Over the last two decades, Divine Word University, with its "paperless" university policy and the "one laptop per student" initiative has encouraged digital literacy among staff and students. Developments over time saw the introduction of online exams, and the expansion of the Moodle LMS across several campuses. In 2018 DWU conducted an exhaustive study with 289 student participants who were asked to complete sixteen assignments on the internet. The researchers noted necessary operational and formal skills, as well as the importance of developing information and strategic skills to ensure a meaningful and creative use of digital technologies. More recently, during and after the COVID pandemic, the university introduced new tools to support virtual teaching and learning, along with infrastructural upgrades to support those developments. The introduction of AI tools raises new issues of digital literacy, making AI literacy part of student learning. This presentation will identify the most recent issues for students learning digital literacy at Divine Word University.

Keywords: Digital competency, Digital literacy, AI literacy, Papua New Guinea, Divine Word University

Author Biography:

Philip Gibbs is President of Divine Word University in PNG. Originally from Aotearoa New Zealand, Prof. Gibbs is a Divine Word Missionary who has worked for over fifty years in Papua New Guinea. He holds an MBA from Divine Word University, and a Doctorate in Theology (STD) from the Gregorian University in Rome, Italy. His recent major academic work is in the field of social concerns, particularly Sorcery Accusation Related Violence in Papua New Guinea.

1. INTRODUCTION

Divine Word University (DWU) in Papua New Guinea has four faculties with 4,000 students in full-time and part-time programs (Diploma, Bachelor, and post-graduate programs, including Master's, and Doctorate. There are five campuses covering the main regions of the country: Madang, Port Moresby, Rabaul, Wewak, and, more recently, Mount Hagen. DWU has a vision to be recognized nationally and internationally by its value-based innovative application of technology to enhance learning and teaching, and to give the opportunity of higher education to as many learners as possible. Over the last two decades, Divine Word University, with its "paperless" university policy and the "one laptop per student" initiative, has encouraged digital literacy among staff and students. Developments over time have seen the introduction of online exams and the expansion of the Moodle LMS across campuses.

In 2018, researchers on the Madang campus conducted an important study to ascertain students' ability to work with digital technologies. More recently, during and after the COVID pandemic, the university introduced new tools to support virtual teaching and learning and upgraded its infrastructure to support those developments. Popular extracurricular courses offered include an eight-week course in Artificial Intelligence Literacy for Students and an eight-week course in Digital Citizenship.

This presentation traces several stages of the development in digital literacy and identifies the most recent issues for students becoming responsible digital citizens at Divine Word University.

2. EVALUATING DIGITAL SKILLS

In 2018, Divine Word University conducted an exhaustive study with 289 student participants who were asked to complete sixteen online assignments within a two-hour time period (Kolodziejczyk et al). The study utilized the framework of a study from the Netherlands (van Deursen et al). The research involved noting necessary operational and formal skills and the importance of developing information and strategic skills to ensure a meaningful and creative use of digital technologies.

Operational skills are the basic skills to operate digital media. In this category, students were expected to navigate an internet browser and operate an online search engine. Students were asked to go to the website of the National Statistical Office and locate final figures from the recent census. Most of the students were able to complete the two initial tasks, while the third task, involving locating, completing and saving a PNG Entry Permit Application Form, proved the most difficult, with only 3% completing it.

Formal skills enable us to handle the structure of digital media, including navigating the internet through hyperlinks and maintaining a sense of location while navigating the internet. Starting with the PNG Immigration & Citizenship Service Authority website, students were expected to navigate through internet websites by recognizing and using tabs and hyperlinks without getting disoriented and locating similar information in different website layouts. Students achieved only 13% completion across all tasks in this category.

Information skills involve locating information in digital media. Information skills are measured by locating required information by choosing an appropriate search system or website, the ability to define search queries, selecting information from search results, and evaluating information for accuracy of data and the reliability of the sources. One-third (30%) of students were able to complete all the tasks successfully. For example, one of the tasks was, "Imagine you are planning for a holiday trip overseas and you need to apply for a passport. Use a search engine (e.g. www.google.com.pg, or the one you use at home) to find the complete address to which you need to send your application if you live outside Port Moresby."

Strategic internet skills involve using the network's sources to achieve a specific goal and improve one's status in society. The strategic skills category required students to define search queries and select proper resources to decide whether to vote for a particular party, depending on the party's specific policies. Almost one-third (28%) of students successfully completed all tasks in this category.

Results of the digital skills study indicate that age and gender were not significant; however, performance was significantly different for students from the capital city as compared to those coming from a rural town or village environment, and performance improved as students moved through the four years of university training. Only 2% of year one students completed the formal skills tasks.

If operational and formal skills are necessary but not sufficient conditions for performing higher-level information and strategic skills, then tertiary institutions, particularly those facing the effects of the so-called digital divide, must ensure that those necessary skills are provided for. Having ensured digital competency at that level, further efforts can be made to develop information and strategic skills to ensure a meaningful and creative use of digital technologies.

Digital literacy is important in education, particularly tertiary education. Duncan- Howell (2012) has researched the nature of the digital competency exhibited by undergraduate students in an Australian University. She found that they had a high level of "digital comfort" but that did not necessarily translate from consuming content to creating content. She concluded that there is a strong need in higher education "for meaningful use of digital technologies as learning tools and the development of digital professional skills within programs that is beyond the current practice of being limited to LMS use and email" [Duncan-Howell].

The 2018 DWU research points to the need for training and formal schooling right from the first year of tertiary education in PNG, since a good number of students will come with little prior experience. Divine Word University meets a felt need by giving a laptop to every new fully registered student and providing formal coursework in the use of computers and the internet in their first semester at the university. The effect of such training may be seen in the relative improvement between first and second-year students in the DWU study.

3. DIGITAL INITIATIVES AT DWU

DWU has since developed various initiatives for technology enhanced teaching and learning leading from digital competency to the promotion of digital literacy.

- 3.1 Most exams at DWU are now online, and for this, a Safe Exam Browser is used to lock down the testing environment safely and restrict access to other websites, system functions, and applications. It prevents students from using unauthorized resources during an exam. Essentially, it turns the student's computer into a secure workstation for the exam duration.
- 3.2 Text-matching software (Turnitin) checks for plagiarism and helps students learn about proper citation and academic writing. It generates a Similarity Report that highlights any matching text, allowing us to assess whether the matches are properly cited or indicative of plagiarism.
- 3.3 Interactive activities utilizing HTML5 Package (H5P) enable creating interactive content like quizzes, drag-and-drop activities, videos, and presentations. Some lecturers use a tool called Menti meter, which allows presenters to create engaging experiences for their students' using polls, quizzes, and other interactive elements. Students can participate in real-time using their own devices, and results are displayed instantly, fostering active participation and feedback.
- 3.4 There are Integrative Open Educational Resources (OER) providing learning units available for skill development. Some students and staff use Coursera's microlearning modules which are short learning units available for skill development.
- 3.5 Virtual meetings using Zoom or Teams conveniently save on time and the cost of travel, and allow for international conferences that would otherwise be impossible.
- 3.6 AI-powered virtual assistants include Amazon Alexa, Apple Siri and Google Assistant. Some staff have been using Otter to transcribe and summarize meetings.
- 3.7 Social media, utilizing Facebook and WhatsApp groups, are popular
The University is also working to provide student and staff capacity-building initiatives and support.
- 3.8 DWU has an active Centre for Learning & Teaching with programs such as:
 - Training in online teaching pedagogies
 - Numeracy programs (Excel, Financial Modeling and Business Analysis)
 - AI Literacy
 - Self-paced online self-study skills programs
- 3.9 DWU also has the expansion of facilities for digital initiatives
 - A video studio with dedicated staff for developing online teaching materials
 - Lecture Capture System for simultaneous online lecture delivery
 - An integrated system of Student Data Management (University10) with Learning Management System (Moodle) and Student Financial System to enhance student experience and satisfaction

4. TRAINING IN DIGITAL CITIZENSHIP

Learning in new ways presents challenges such as cyberbullying, privacy issues, and misinformation. Training in digital citizenship (from Common Sense in UK) focuses on responsible use of technology so as to learn, create,

participate and think critically. Topics covered are as follows:

- 4.1 Finding a balance in digital life. How does it add or take away value from your life?
- 4.2. Privacy and security. Should DWU monitor social media? Can governments use data fairly or without violating our privacy?
- 4.3. Digital footprint and identity - one's public presence (not just self-promotion). Everyone who uses technology leaves a footprint behind, so it is important to always be careful when using any social media platform.
- 4.4. Relationships and communication. Strategies to avoid uncivil discourse. Respectful and constructive dialogue. Not making another person look bad and how to approach people we disagree with.
- 4.5. Cyber-bullying, digital drama and hate speech. How to make the online world safer?
- 4.6. News and media literacy. How best to read news online. Being wary of sensationalized headlines. Checking the source's reputation and biases, and looking for supporting evidence and multiple perspectives.

Student participants in this course took particular interest in issues of mass surveillance, including compulsory SIM card registration in PNG and the government's ban on Facebook, as happened for a month in 2018 and on March 24, 2025 (reputedly for a test under anti-terrorism laws).

Students debated whether the government should be able to access social media and cellphone information, and if so, under what circumstances? The students pointed out that the government's role should be to protect rights, not to restrict them. Any regulation should be transparent, legally justified, and aimed at addressing specific harms, not silencing voices or invading personal lives. People in PNG deserve both security and freedom, not one at the cost of the other.

A student wrote, "I never knew that my online behavior could leave a digital footprint that could affect my future till I attended the program and I wish the program could continue so I can learn more about being a digital citizen". Another adds, ". It prepares us not only to deal with our profession but also gives us enough knowledge to face the twenty-first century with its advanced technology

5. ARTIFICIAL INTELLIGENCE (AI)

With advances in technology, one interested in digital literacy must face the reality that today it is easy to access content fully generated by Artificial Intelligence (AI). However, it is considered dishonest and plagiarism to take and use AI-generated ideas and represent them as one's own. DWU has developed a Plagiarism and Integrity Policy to make clear the importance of academic honesty and integrity in all University endeavors by academic staff, researchers, administrators and students.

The University uses Turnitin electronic text-matching software and a web-based tool that compares submitted text against electronic text found on the publicly accessible Internet, published works, commercial databases, and other student assignments.

Students are instructed on how to legitimately access and reference AI-generated work and Academic staff should clearly specify their position on AI usage in any unit taught. The information should include under what circumstances AI use is permitted, if at all, and how students should cite or credit AI. Offenders can be given a warning and told that the work is to be revised and re-submitted.

DWU also has an Assessment Policy, which offers guidelines to provide transparency on using Artificial Intelligence (AI) in assessment practices so that assessment purposes and quality are maintained. According to that policy, GenAI should not be used for coursework and assessment except where authorized. The permission to use GenAI for coursework and assessment is granted by the Faculty Curriculum and Assessment Committee. For that purpose, a lecturer must explain the purpose, parameters of AI use, the assessment procedures and indicate in what ways the use of GenAI in the proposed assessment item supports the achievement of the unit learning outcomes.

It is noted that Bloom's taxonomy levels 1-2 are easily solved by GenAI. Instead, assessment should measure learners' critical thinking, problem-solving and reasoning skills using such methods as in-person

observation, assessment practices or interactive activities. The Assessment may encourage students to show their work-in-progress, for example, by asking for drafts, outlines, and notes to be submitted as part of formative assessment or requesting a student to provide an annotated bibliography to demonstrate sources of evidence used. It is acknowledged that there are circumstances when AI tools and other third-party assistance may be appropriate, including developing initial ideas for the purposes of critical examination or generating practice questions and summaries as part of revision and preparation for assessment.

5.1. AI Literacy for Students

DWU has a course titled AI Literacy for Students, which runs one hour per week for eight weeks of instruction. (Course content adapted from Commonsense.org in UK).

This much-appreciated online course includes a collection of quick lessons (twenty minutes or less!) that provide an introduction to AI and help address its social and ethical impacts, as well as academic integrity with reference to the University's academic policies. The aim is to help students think critically and be responsible and ethical users of AI.

6. THE WAY FORWARD

A few possible initiatives in digital literacy include the following.

- 6.1 Teaching and Learning may allow for digital learning ecosystem enhancement. For example, with Moodle upgrades, it is possible to integrate tools like Big Blue Button, as an open-source web conferencing system integrated into Moodle, specifically designed for online learning, allowing educators to create virtual classrooms where they can share audio, video, presentations, and collaborate with students in real-time.
- 6.2 There are also opportunities for Online Program Development, to convert selected undergraduate and postgraduate programs into fully online or hybrid formats, and developing micro-credentials and short professional development courses (e.g. for teachers, nurses, public servants).
- 6.3 As mentioned previously AI Tools such as ChatGPT, Grammarly, and Canva AI can be used in lesson planning, content generation and student support.
- 6.4 With research and scholarship there are moves to developing an open access digital research repository to host staff and postgraduate research outputs, theses and reports.
- 6.5 DWU intends to develop online research collaboration platforms, and is investigating the possibility of using platforms such as Notion or Microsoft Teams for cross-campus and international research projects.
- 6.6 For governance and Administration, a centralized system (e.g., Microsoft SharePoint) for managing agendas, minutes, policies, and board documents is possible.
- 6.7 The University can develop a data dashboard for university leadership with business intelligence (MS Power BI) to support evidence-based decision-making associated with student performance, enrolment trends, staff workload, services satisfaction, etc.).
- 6.8 For Student Experience and Support, DWU hopes to develop a Digital Wellbeing Hub offering mental health resources, counselling booking, and student support services. Full utilization of the Student Virtual University Portal will allow for easy access to timetable announcements, grades, student finance updates, etc. Faith-based digital resources encompass a wide range of online materials and platforms designed to support individuals and communities in their religious and

7. CONCLUSION

The 2018 DWU Digital Competency Study offered an important foundation by categorizing digital skills into operational and formal competencies, those essential for basic engagement

with digital tools. At the time, such competencies allowed individuals to browse, search, and navigate online environments with some confidence. These skills may be likened to obtaining a driver's license to operate a small manual vehicle in familiar territory—enabling one to move through familiar digital spaces with purpose but limited in scope and depth.

Eight years on, this analogy is no longer sufficient. The digital landscape has dramatically shifted, and with it, our expectations. The conversation has evolved from simply being competent to being *literate* in digital environments. Today, digital literacy encompasses much more than technical ability; it demands a deeper understanding of digital citizenship. This includes navigating complex issues like online privacy, cybersecurity, misinformation, and engaging in respectful communication in increasingly diverse and interconnected digital spaces.

Furthermore, the emergence of Artificial Intelligence has introduced ethical complexities—particularly in educational settings—requiring strong policies to safeguard academic integrity. As collaborative technologies and AI-driven tools become more integrated into our professional and academic lives, the challenges of secure communication, ethical use, and strategic collaboration become more pronounced.

To truly thrive in this environment, it is not enough to use digital tools competently; we must learn to use them strategically, meaningfully, and creatively. This means harnessing digital technologies not just for convenience or efficiency, but for innovation, ethical engagement, and transformative learning. Developing this higher-order literacy at Divine Word University involves critical thinking, adaptability, and a proactive attitude toward lifelong learning. In this sense, digital literacy is no longer just a skill set—it is a mindset and a way of being in a digitally mediated world.

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Innovative Technologies for Volcanic Hazard Mitigation in the Pacific Islands

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Abstract: Volcanic hazards pose significant risks to Pacific island nations, where remoteness, rugged terrain, and limited infrastructure hinder effective monitoring. This paper presents a multi- technology strategy adapted to these challenges, combining low-cost, innovative instruments with community-based monitoring approaches. Integrated through cloud-based platforms, these tools enable real-time data access, improved eruption forecasting, and more effective early warning systems. Field applications demonstrate how the combination of ground-based and satellite-based methods enhances resilience and supports community-level risk reduction. This scalable and transdisciplinary framework offers a practical pathway for strengthening volcanic hazard monitoring and response across the Southwest Pacific.

1. INTRODUCTION

The Southwest Pacific spans roughly 8,000 kilometers of the Pacific Ring of Fire (PRF), representing about 20% of its total length, and hosts 117 of the estimated 1,500 Holocene volcanoes along the PRF [Global Volcanism Program, 2024]. Approximately one-third of these volcanoes are submarine. Papua New Guinea has the highest concentration with 41 volcanoes, followed by New Zealand (24), Tonga (21), Vanuatu (12), Solomon Islands (8), Fiji (2), and others in claimed territories. Including the hotspot volcanoes of French Polynesia, which lie outside the PRF, raises the total to 122 (Table 1). These volcanoes are organized into volcanic regions such as the Bismarck Sea, Solomon Arc, Vanuatu Arc, Kermadec Arc, Taupo Arc, and others across Oceania (Fig. 1). Collectively, these regions cover over 10 million km²—about 7% of Earth’s total land surface, comparable in size to Europe. Excluding Australia, Oceania’s GDP is relatively small and concentrated mainly in New Zealand, while other island nations face challenges of geographic isolation, limited infrastructure, and scarce resources. This paper examines how innovative technologies can address these challenges to support ongoing volcanic monitoring and hazard mitigation across the Pacific Islands.

Table 1. List of volcanoes in the broader Southwest Pacific, organized by volcanic region and corresponding country. Data from ref. [Global Volcanism Program, 2024]

Volcano	A or S*	Last eruption	Volcanic region	Country
Southwest Pacific Volcanic Regions				
St. Andrew Strait	A	1957	Bismarck Sea	Papua New Guinea
Central Bismarck	S	1972	Bismarck Sea	Papua New Guinea
Lolo	A	Unknown but believe to be holocene	Bismarck Volcanic arc	Papua New Guinea
Witori	A	2012	Bismarck Volcanic arc	Papua New Guinea
Sulu Range	A	Unknown but believe to be holocene	Bismarck Volcanic arc	Papua New Guinea
Hargy	A	950	Bismarck Volcanic arc	Papua New Guinea

Bamus	A	1886	Bismarck Volcanic arc	Papua New Guinea
Ulawun	A	2025	Bismarck Volcanic arc	Papua New Guinea
Lolobau	A	1912	Bismarck Volcanic arc	Papua New Guinea
Rabaul	A	2014	Bismarck Volcanic arc	Papua New Guinea
Tavui	S	4946 BCE	Bismarck Volcanic arc	Papua New Guinea
Karkar	A	1979	Bismarck Volcanic arc	Papua New Guinea
Hankow Reef	S	Unknown but believe to be holocene	Bismarck Volcanic arc	Papua New Guinea
Long Island	A	1993	Bismarck Volcanic arc	Papua New Guinea
Umboi	A	Unknown but believe to be holocene	Bismarck Volcanic arc	Papua New Guinea
Ritter Island	A	2007	Bismarck Volcanic arc	Papua New Guinea
Sakar	A	Unknown but believe to be holocene	Bismarck Volcanic arc	Papua New Guinea
Langila	A	2025	Bismarck Volcanic arc	Papua New Guinea
Blup Blup	A	Unknown but believe to be holocene	Bismarck Volcanic arc	Papua New Guinea
Kadovar	A	2023	Bismarck Volcanic arc	Papua New Guinea
Bam	A	1960	Bismarck Volcanic arc	Papua New Guinea
Manam	A	2025	Bismarck Volcanic arc	Papua New Guinea
Dakataua	A	1895	Bismarck Volcanic arc	Papua New Guinea
Bola	A	Unknown but believe to be holocene	Bismarck Volcanic arc	Papua New Guinea
Garua Harbour	A	Unknown but believe to be holocene	Bismarck Volcanic arc	Papua New Guinea
Grummel-Garbuna-Welcker	A	2008	Bismarck Volcanic arc	Papua New Guinea
Lamington	A	1956	Trobriand Volcanic arc	Papua New Guinea

Hydrographers Range	A	Unknown but believe to be holocene	Trobriand Volcanic arc	Papua New Guinea
Managlas Plateau	A	Unknown but believe to be holocene	Trobriand Volcanic arc	Papua New Guinea
Victory	A	1935	Trobriand Volcanic arc	Papua New Guinea
Sessagara Hills	A	1944	Trobriand Volcanic arc	Papua New Guinea
Goodenough	A	Unknown but believe to be holocene	Trobriand Volcanic arc	Papua New Guinea
Iamalele	A	Unknown but believe to be holocene	Trobriand Volcanic arc	Papua New Guinea
Dawson Strait Group	A	1350	Trobriand Volcanic arc	Papua New Guinea
Lihi	A	Unknown but believe to be holocene	New Ireland Volcanic Arc	Papua New Guinea
Ambite	A	350	New Ireland Volcanic Arc	Papua New Guinea
Balbi	A	Unknown but believe to be holocene	Solomon Volcanic Arc	Papua New Guinea
Billy Mitchell	A	1580	Solomon Volcanic Arc	Papua New Guinea
Bagana	A	2025	Solomon Volcanic Arc	Papua New Guinea
Takuan Group	A	Unknown but believe to be holocene	Solomon Volcanic Arc	Papua New Guinea
Loloru	A	1050	Solomon Volcanic Arc	Papua New Guinea
Simbo	A	1910	Solomon Volcanic Arc	Solomon Islands
Kana Keoki	S	Unknown but believe to be holocene	Solomon Volcanic Arc	Solomon Islands
Coleman Seamount	S	Unknown but believe to be holocene	Solomon Volcanic Arc	Solomon Islands
Kavachi	S	2014	Solomon Volcanic Arc	Solomon Islands
Unnamed	S	Unknown but believe to be holocene	Solomon Volcanic Arc	Solomon Islands
Gallego	A	Unknown but believe to be holocene	Solomon Volcanic Arc	Solomon Islands
Savo	A	1847	Solomon Volcanic Arc	Solomon Islands
Tinakula	A	2024	Vanuatu Volcanic Arc	Solomon Islands
Ambae	A	2024	Vanuatu Volcanic Arc	Vanuatu
Ambrym	A	2024	Vanuatu Volcanic Arc	Vanuatu
Lopevi	A	2007	Vanuatu Volcanic Arc	Vanuatu
East Epi	S	2023	Vanuatu Volcanic Arc	Vanuatu
Kuwae	S	1974	Vanuatu Volcanic Arc	Vanuatu
Nguna-Emau	A	Unknown but believe to be holocene	Vanuatu Volcanic Arc	Vanuatu
Motlav	A	Unknown but believe to be holocene	Vanuatu Volcanic Arc	Vanuatu
Suretamatai	A	1966	Vanuatu Volcanic Arc	Vanuatu
Gaua	A	2022	Vanuatu Volcanic Arc	Vanuatu
Traitor's Head	S	1881	Vanuatu Volcanic Arc	Vanuatu
Yasur	A	2025	Vanuatu Volcanic Arc	Vanuatu
Gemini-Oscostar	S	1996	Vanuatu Volcanic Arc	Vanuatu
Matthew Island	A	1956	Vanuatu Volcanic Arc	Claimed territory
Hunter Island	A	1903	Vanuatu Volcanic Arc	Claimed territory
Taveuni	A	1550	Fiji Volcanic Arc	Fiji
Nabekelevu	A	1660	Fiji Volcanic Arc	Fiji
Tonga-Kermadec Volcanic Regions				
Niuafo'ou	A	1946	Northeast Lau Basin volcanic group	Tonga
Dugong	S	Unknown but believe to be holocene	Northeast Lau Basin volcanic group	Tonga
Lobster	S	Unknown but believe to be holocene	Northeast Lau Basin volcanic group	Tonga
Tafu-Maka	S	2008	Northeast Lau Basin volcanic group	Tonga

West Mata	S	2009	Northeast Lau Basin volcanic group	Tonga
Niuatahi	S	Unknown but believe to be holocene	Northeast Lau Basin volcanic group	Tonga
Unnamed	S	1932	Tofua Volcanic Arc	Tonga
Unnamed	S	Unknown but believe to be holocene	Tofua Volcanic Arc	Tonga
Unnamed	S	2017	Tofua Volcanic Arc	Tonga
Hunga Tonga-Hunga	A	2022	Tofua Volcanic Arc	Tonga
Ha'apai				
Fonuafo'ou	S	1936	Tofua Volcanic Arc	Tonga
Tofua	A	2025	Tofua Volcanic Arc	Tonga
Kao	A	1847	Tofua Volcanic Arc	Tonga
Lateiki	A	2017	Tofua Volcanic Arc	Tonga
Home Reef	S	2025	Tofua Volcanic Arc	Tonga
Late	A	1854	Tofua Volcanic Arc	Tonga
Unnamed	S	2019	Tofua Volcanic Arc	Tonga
Fonualei	A	1957	Tofua Volcanic Arc	Tonga
Tafahi	A	Unknown but believe to be holocene	Tofua Volcanic Arc	Tonga
Curacoa	S	1979	Tofua Volcanic Arc	Tonga
Unnamed	S	Unknown but believe to be holocene	Northern Kermadec volcanic arc	Tonga
Raoul Island	A	2006	Northern Kermadec volcanic arc	New Zealand
Monowai	S	2014	Northern Kermadec volcanic arc	New Zealand
Wright	S	Unknown but believe to be holocene	Middle Kermadec volcanic arc	New Zealand
Havre Seamount	S	2014	Middle Kermadec volcanic arc	New Zealand
Curtis Island	A	Unknown but believe to be holocene	Middle Kermadec volcanic arc	New Zealand
Macauley	A	4360	Middle Kermadec volcanic arc	New Zealand
Giggenbach	S	Unknown but believe to be holocene	Middle Kermadec volcanic arc	New Zealand
Clark	S	Unknown but believe to be holocene	Southern Kermadec Volcanic arc	New Zealand
Tangaroa	S	Unknown but believe to be holocene	Southern Kermadec Volcanic arc	New Zealand
Rumble V	S	Unknown but believe to be holocene	Southern Kermadec Volcanic arc	New Zealand
Rumble IV	S	Unknown but believe to be holocene	Southern Kermadec Volcanic arc	New Zealand
Rumble III	S	2008	Southern Kermadec Volcanic arc	New Zealand
Rumble II West	S	Unknown but believe to be holocene	Southern Kermadec Volcanic arc	New Zealand
Healy	S	1360	Southern Kermadec Volcanic arc	New Zealand
Brother	S	Unknown but believe to be holocene	Southern Kermadec Volcanic arc	New Zealand
Mayor Island	A	5060 BCE	Taupo Volcanic arc	New Zealand
Whakaari/White Island	A	2025	Taupo Volcanic arc	New Zealand
Okatiana	A	1981	Taupo Volcanic arc	New Zealand
Taupo	A	260	Taupo Volcanic arc	New Zealand
Tongariro	A	2012	Taupo Volcanic arc	New Zealand
Ruapehu	A	2007	Taupo Volcanic arc	New Zealand
Auckland Volcanic Field	A	1446	Western North Island volcanic province	New Zealand
Kaikohe-Bay of islands	A	400	Western North Island volcanic province	New Zealand
Taranaki	A	1800	Western North Island volcanic province	New Zealand

Hotspot Volcanic Regions

Teahitia	S1985	Society islands Hotspot Volcano Group	French Polynesia
Rocard	S1972	Society islands Hotspot Volcano Group	French Polynesia
Moua Pihaa	S1970	Society islands Hotspot Volcano Group	French Polynesia
Mehetia	AUnknown but believe to be holocene	Society islands Hotspot Volcano Group	French Polynesia
Macdonald	S1989	Austral-Cook Hotspot Volcano Group	French Polynesia
Vailulu'u	S2003	Samoa Hotspot Volcano Group	American Samoa
Ta'u	AUnknown but believe to be holocene	Samoa Hotspot Volcano Group	American Samoa
Ofu-Olosega	A1866	Samoa Hotspot Volcano Group	American Samoa
Tutuila	A440	Samoa Hotspot Volcano Group	American Samoa
Malumalu	SUnknown but believe to be holocene	Samoa Hotspot Volcano Group	American Samoa
Upolu	AUnknown but believe to be holocene	Samoa Hotspot Volcano Group	Samoa
Savaii	A1911	Samoa Hotspot Volcano Group	Samoa

* A and S stand for Aerial and Submarine edifices respectively

2. LOW-COST, INNOVATIVE NETWORKING OPTIONS FOR SMALL PACIFIC COUNTRIES

The goal is to develop a sustainable, affordable regional volcano monitoring system that enables data sharing, early warning, and research collaboration across Pacific island nations. Innovative low-cost instruments provide a practical means to monitor volcanic activity in remote or resource-limited areas by detecting seismic events, gas emissions, ground deformation, and thermal anomalies. Although less precise than high-end equipment, they reliably identify trends and deliver timely alerts. Their low power consumption and adaptability make them ideal for long-term, autonomous deployment. Importantly, these technologies empower community-based networks and strengthen local capacity for disaster preparedness. By expanding observational coverage and fostering regional cooperation, they have the potential to democratize volcanic monitoring and significantly enhance risk reduction across the southwest Pacific.

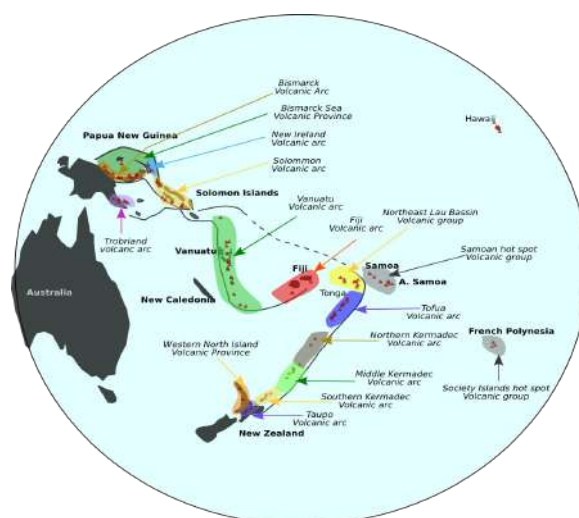


Fig. 1. The broader Southwest Pacific volcanic regions.

2.1 Seismic Sensors

A practical and cost-effective solution for monitoring seismic activity in Oceania is the Raspberry Shake (Fig.2), a compact seismograph built around the Raspberry Pi platform. With a unit cost ranging from approximately \$500 to \$800 USD, the Raspberry Shake is capable of recording both local and regional seismic events, including volcanic tremors and volcano-tectonic (VT) earthquakes. Its plug-and-play design makes it exceptionally easy to deploy, even in remote island environments with limited infrastructure. One of its most valuable features is its ability to stream data in real time to the global Raspberry Shake network (raspberrypishake.org), enabling integration with international seismic databases and supporting both local monitoring and broader scientific collaboration.

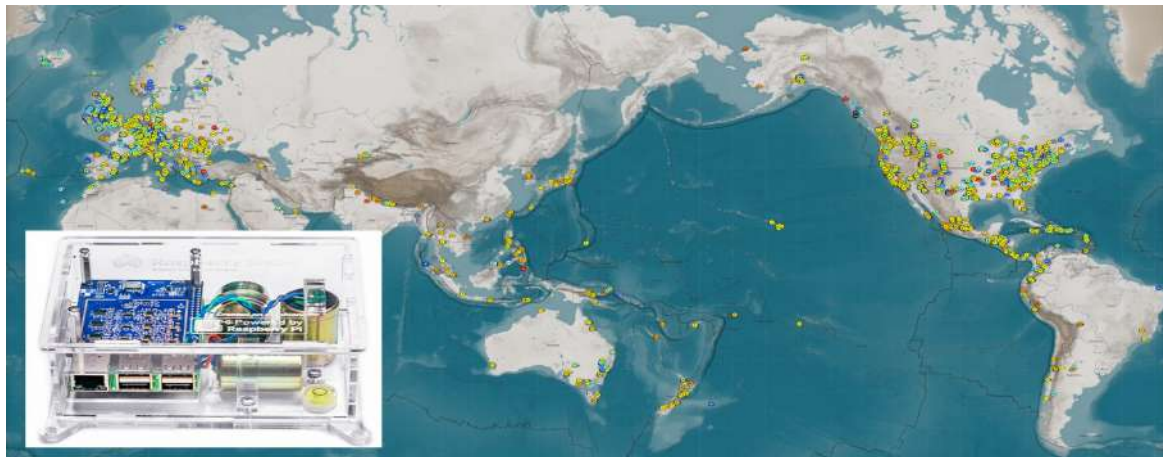


Fig. 2. Global Raspberry Shake network, highlighting the limited number of stations in the Southwest Pacific region. The inset displays a typical 3D Raspberry Shake seismic station, showcasing its compact and field-deployable design.

2.2 Infrasound Microphones

To detect acoustic signals associated with volcanic activity, such as explosions, gas venting, or even lahars, low-cost infrasound sensors can be assembled using custom-built electret or MEMS microphones. These sensors are typically housed in PVC enclosures with simple wind noise filters, allowing for effective outdoor deployment in harsh environments. Each sensor can be built for less than \$100 USD, not including the data logging system, making them an attractive option for budget-constrained observatories. They are easily integrated with low-power microcontrollers or with platforms like Raspberry Pi, to enable continuous recording and synchronization with other monitoring instruments. Despite their simplicity, these infrasound setups have proven effective in detecting and characterizing explosive volcanic activity in real time [Grangeon et. al.].



Fig. 3. Left: Schematic block diagram of the infrasound sensor, illustrating the key components including the MEMS microphone, capillary tube, reference cavity, electronic board, and connector. These elements are assembled within the protective housing shown in the right panel [Grangeon et. al.].

2.3 Thermal Cameras

Affordable thermal imaging for volcanic monitoring is possible with compact sensors like the FLIR Lepton (radiometric) or MLX90640, costing \$100-\$300 USD. Despite their low resolution and limited range (2-20 m), they are ideal for localized monitoring of vents and fumaroles. For a balance between cost and performance, Optris thermal cameras (e.g., PI 160, PI 400, Fig.4) offer higher resolution and radiometric imaging at \$1500-8000 USD, suitable for crater or dome surveillance [3]. These can be paired with Raspberry Pi 4 or mini-PC for automated data streaming, offering a cost-effective alternative to traditional FLIR systems in resource-limited regions like Oceania.

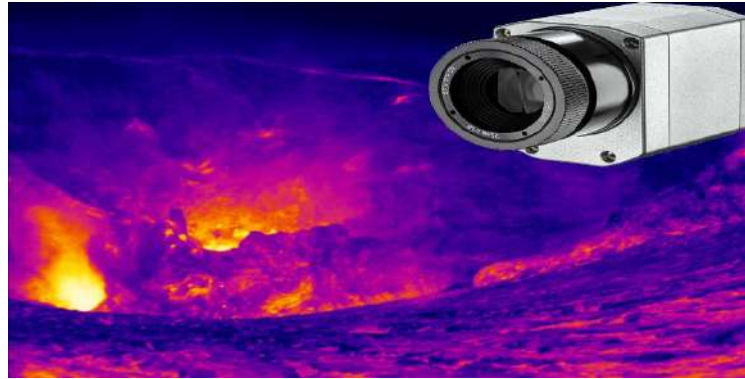


Fig. 4. Optris PI infrared camera — a compact device offering high optical and radiometric resolution, well-suited for reliable volcanic monitoring and research applications. Image obtained on Yasur volcano.

2.4 Inexpensive Gas Monitoring

Monitoring volcanic gas emissions is essential for understanding magmatic processes and forecasting eruptions. However, commercial MultiGAS instruments—used to measure key gases such as sulfur dioxide (SO_2) and carbon dioxide (CO_2), often cost over \$20,000 USD, limiting their accessibility in resource-constrained regions like much of Oceania. In response, low-cost MultiGAS prototypes have been developed using electrochemical sensors, bringing the total cost down to under \$2,000 USD. Among these, systems like piGAS (Fig.5) [Pering et. al.], a Raspberry Pi-based gas analyzer, have demonstrated the potential for robust, field-deployable monitoring at a fraction of the cost. Similarly, piCam, a low cost, low-power SO_2 camera (Fig.6) [Wilkes et. al.], enables imaging of gas plumes for flux estimation and degassing analysis. While these devices typically offer lower accuracy and shorter sensor lifespans compared to commercial-grade instruments, they remain valuable for detecting gas trends, establishing baselines, and supporting early warning systems. They can be easily integrated with microcontrollers or single-board computers (e.g., Raspberry Pi, Arduino) for automated data logging and wireless transmission, providing a flexible and scalable solution tailored to the needs of remote volcanic regions in the Pacific.

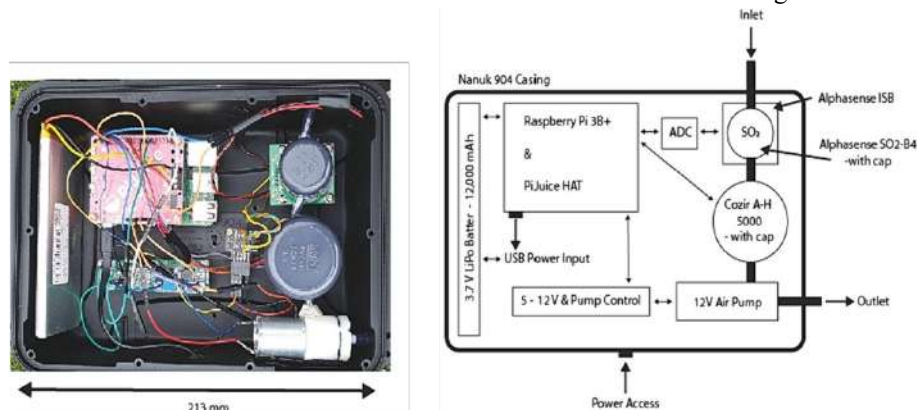


Fig. 5. PiGas, a low-cost approach to volcanic gas sampling [Pering et al., 2024].

2.5 Remote Sensing & UAVs

Remote sensing technologies offer powerful and cost-effective tools for volcano monitoring, especially in isolated or difficult-to-access regions. Freely available satellite data from platforms such as Sentinel, MODIS, and TROPOMI enable regular monitoring of thermal anomalies, ash plumes, and sulfur dioxide (SO₂) emissions. Additionally, ~~ISAR~~ (Interferometric Synthetic Aperture Radar) data allows for the analysis of ground deformation without the need for ground-based instrumentation, making it ideal for remote island volcanoes. Complementing satellite observations, small unmanned aerial vehicles (UAVs) or drones (Fig.7) provide flexible, close-range monitoring capabilities. Equipped with thermal cameras, gas sensors, or optical imagers, these drones can be used for gas sampling, thermal imaging, and high-resolution mapping of craters and lava flows. Basic UAV systems suitable for volcanic applications can be assembled or purchased for approximately \$1,000–\$2,000 USD, making them a practical and scalable option for observatories and research teams operating in the Pacific Islands and other resource-limited regions.

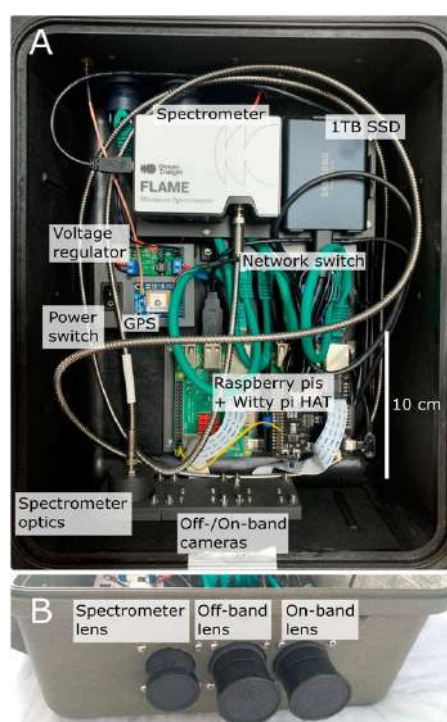


Fig. 6. (A) Low cost SO₂ camera housed inside a Peli Case. Below, a view of instrument optical systems [Wilkes et. al.].

2.6 Low-Bandwidth Data Transfer & Mesh Networks

In many parts of Oceania, reliable internet or cellular coverage is limited or absent, making traditional data transmission methods impractical for remote volcano monitoring. To address this, low-bandwidth communication technologies such as LoRa (Long Range Radio) and Wi-Fi relays can be employed to transmit data over rugged terrain and long distances with minimal power consumption. These systems can support local data storage and allow for intermittent uploads when connectivity becomes available—whether through mobile networks, satellite links, or manual data retrieval. To manage and visualize incoming data, open-source platforms like Grafana, ThingSpeak, or InfluxDB can be used to generate real-time dashboards and automated alerts. This approach enables reliable, low-cost data transmission and monitoring even in highly remote or infrastructure-poor regions, making it particularly well-suited to the geographical and logistical challenges of the Pacific Islands.



Fig. 7. Drones provide a practical solution for surveying hazardous or inaccessible volcanic terrain.

2.7 Community-Based Monitoring

In remote and resource-limited regions, engaging local communities in volcano monitoring offers a sustainable and effective strategy to enhance early warning capabilities. Through targeted training programs, community members can be taught to observe and document visual cues, such as changes in gas emissions, thermal anomalies, or unusual sounds, and to report these anomalies to local authorities or observatories (Fig.8). SMS-based alert systems provide a simple yet powerful means of sharing real-time warnings, especially in areas with limited internet access. Additionally, the use of mobile applications allows residents to log observations, receive basic volcano updates, and access educational resources about volcanic hazards. This participatory approach not only strengthens the resilience of local populations but also extends the observational reach of formal monitoring networks, creating a valuable bridge between scientific institutions and the communities most at risk.



Fig. 8. Community-based monitoring is a powerful tool for tracking environmental changes and hazards.

2.8 Capacity Building with Universities

Strengthening volcano monitoring in Oceania requires long-term investment in local expertise, and regional universities play a pivotal role in this effort. Institutions such as the University of New Caledonia (UNC), the University of the South Pacific (USP), and the University of Papua New Guinea (UPNG) serve as critical hubs for education, innovation, and applied research in Earth sciences. By integrating low-cost monitoring techniques—including seismic, gas, infrasound, thermal, and remote sensing technologies—into curricula and field-based training, these universities can equip students with practical skills tailored to the unique geophysical challenges of island environments. In addition to training, university departments can actively collaborate with

national observatories and international partners to design and implement monitoring networks, co-lead station installation and maintenance, and participate in real-time data analysis and hazard interpretation. Engaging students and early-career scientists in these efforts not only builds a sustainable, locally rooted technical workforce, but also fosters a sense of regional ownership and scientific leadership. Moreover, academic institutions provide a platform for transdisciplinary collaboration, linking geoscience with disaster risk reduction, environmental policy, and community outreach. These partnerships are vital for ensuring that volcano monitoring is not only technically effective but also socially inclusive and resilient in the long term.

3. CONCLUSION

Doing More with Less. In the context of limited financial and logistical resources, Pacific Island nations can still achieve meaningful progress in volcanic hazard mitigation by embracing low-cost technologies and leveraging local knowledge and institutional capacity. The integration of affordable sensors, remote sensing tools, open-source platforms, and community-based approaches enables the sustained, real-time monitoring of active volcanoes, even in remote and infrastructure-poor settings. Coupled with targeted training programs and partnerships with regional universities, these innovations can strengthen early warning systems, enhance scientific research, and build local resilience. Importantly, these solutions are scalable, adaptable, and inclusive, making them well-suited to the diverse challenges faced across Oceania. By doing more with less, the region can chart a path toward sustainable volcanic risk reduction, rooted in regional ownership, innovation, and long-term capacity building.

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Learning the Shoreline: A Very High-Resolution Approach to Reef Island Dynamics

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Abstract. Pacific atoll islets are often described as stable in global-scale studies, typically based on long-term shoreline proxies such as vegetation line or morphometrics like planform surface area. While informative, these approaches can obscure short-term, localized coastal dynamics – including changes in island shape and position – that are critical for ecosystem function, cultural practices, and coastal infrastructure resilience. This study presents a transferable, automated approach to shoreline monitoring using very high-resolution Pléiades imagery and a XGBoost classifier. The method integrates spectral indices and textural features to delineate the outer limit of emerged land, including vegetated areas, beaches, man-made surfaces, and beach rock. This shoreline definition supports fine- scale, spatially explicit monitoring of reef island dynamics, even in morphologically complex environments. Developed and tested on multiple atolls in French Polynesia (Tetiaroa, Tikehau, Hao, and Puka Puka), the model achieves high accuracy (mean Intersection over Union ≈ 0.99 ; Mean Absolute Positional Error ≈ 1.28 m) and demonstrates strong performance on both training and held-out sites, validating its spatial transferability. The extracted shorelines reveal subtle but significant island-scale changes in extent, configuration, and spatial position that remain undetected by conventional shoreline proxies and surface metrics. By enabling high- precision, scalable shoreline monitoring, this method provides a more nuanced understanding of atoll change processes. It supports Pacific efforts to move beyond narratives of passive loss toward frameworks of resilience and adaptation, while providing spatial tools tailored to low-lying island realities.

Keywords: Shoreline Monitoring, Atoll Islet Dynamics, Transfer Learning, Machine Learning, Remote Sensing, Pacific Islands

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1. INTRODUCTION

Atoll islands are among the most exposed landforms to climate threats such as sea-level rise, coastal erosion, and extreme events. Their low elevation, narrow shape, and dynamic structure make them highly sensitive to both short-term disturbances and long-term shifts. Monitoring these changes is vital for evaluating habitability, infrastructure risks, and ecosystem health.

Classic assessments often rely on coarse imagery, planform metrics, or proxies like the vegetation line. While useful for long-term trends, they often miss localized shoreline changes – such as *motu* (Tahitian term for islet) reshaping, sand movement (erosion and accretion), or artificial expansion – that matter to local stakeholders.

Increased availability in very high-resolution (VHR) satellite imagery and advances in machine learning enable detailed shoreline monitoring. However, most studies remain site-specific, requiring local training data that limits scalability across the Pacific's diverse island systems [Holdaway et al.].

This study evaluates a transferable shoreline classification approach using Pléiades imagery and an XGBoost model. Tested on diverse atoll settings in French Polynesia, it demonstrates high-precision, scalable monitoring. It is among the first to apply transfer learning to shoreline mapping on atolls, enabling cross-site classification without retraining.

2. STUDY AREA AND DATA

2.1 Geographic Context and Atoll Selection

Four atolls in French Polynesia – Tetiaroa in the Society Islands, and Tikehau, Puka Puka, and Hao in the Tuamotu Archipelago – were chosen for their contrasting geomorphologies, reef structures, and land use. These variations provide a robust test for the transferability of shoreline monitoring.

Climatic regimes vary slightly. The Tuamotus experience steady trade winds and low rainfall due to their flat, remote nature. In contrast, Tetiaroa receives higher and more variable rainfall due to its proximity to high volcanic islands in the Society group.

2.2 Atoll Characteristics

The four atolls also differ in their lagoon-ocean connectivity, shoreline configuration, and degree of human modification. These contrasts are important for evaluating model transferability.

Tetiaroa and Puka Puka are small closed atolls with no major passes. Tetiaroa is semi-managed, hosting an eco-resort and research station on one *motu*, while the others remain conserved. Puka Puka is minimally developed and largely covered by coconut plantations.

Tikehau and Hao are larger, open atolls, each with a major pass that enhances lagoon-ocean exchange. Tikehau includes both natural and built environments, including tourism infrastructure. Hao has undergone extensive military development, introducing artificial platforms and armoring that alter shoreline geometry.

2.3 Satellite Data

The image dataset includes Pléiades scenes acquired between 2016 and 2023. Four images were used for Tetiaroa (2016, 2019, 2022, and 2023), while a single image from 2022 was used for each of the three other atolls: Hao, Puka Puka, and Tikehau. All images were captured between May and July to minimize seasonal effects and delivered as Level 2A products (atmospherically corrected, co-registered, and pan-sharpened).

Scenes with minimal cloud and haze were prioritized. Partial cloud cover affected parts of Tetiaroa (2016, 2023) and Tikehau (2022), but most shorelines were cloud-free. For Hao and Tikehau, analysis focused on representative sections near main villages and adjacent *motu* to balance coverage and computational cost.

3. METHODS

3.1 Shoreline Reference Preparation

The term shoreline is conventionally defined as the physical interface between land and sea [Dolan et. al.]. In remote sensing applications, this often corresponds to the instantaneous land–water boundary visible in an image [Wicaksono et. al.]. However, this interface is inherently dynamic and scale- dependent, influenced by seasonality, tidal stage, wave run-up, sediment movement, and geomorphic variability. On atolls, additional complexity arises from narrow *motu*, irregularly shaped, water-retaining conglomerate platforms, and the presence of vegetation shadows – all of which can obscure the true extent of emerged land in VHR imagery.

The shoreline is operationally defined as the outer edge of emerged land visible in Pléiades imagery, encompassing vegetated zones, bare beaches, reef platforms, and artificial structures, but excluding submerged reef flats. Depending on land cover, the mapped shoreline corresponds to the beach toe, the vegetation line, or the stability line.

3.2 Classification Approach

A set of spectral indices and texture attributes was derived from the pan- sharpened Pléiades imagery to support land–water classification. Common shoreline indices and GLCM texture features (mean, contrast, entropy) from the NIR band were computed using a 3×3 window [Hall-Beyer, Vos, K et. al.].

Training data were selected via a clustering-based strategy inspired by [Zhang et. al.]. A representative region of interest was used to capture spectral variability, followed by separate k-means clustering for land and water classes. From each cluster, 1% of image pixels were randomly and equally sampled, yielding a balanced dataset split 80% for training and 20% for validation.

Model training was performed using the XGBoost classifier, with two- step Optuna-based hyperparameter tuning (initial coarse tuning, followed by cross-validated refinement). The composite objective combined log-loss and macro-F1 score to balance accuracy and generalizability.

The final classification produced a binary land–water raster. Postprocessing removed small artifacts and filled internal gaps to ensure shoreline continuity. Shorelines were then extracted using a marching squares algorithm with linear interpolation and compared to ground truth references for accuracy assessment [Vos, K, Bishop-Taylor et. al.].

3.3 Transfer Learning Setup

To evaluate the transferability of shoreline classification across space and time, a transfer learning strategy was applied. A single XGBoost model was trained on a composite dataset from Tetiaroa (2016, 2019, 2023), Hao (2022), and Puka Puka (2022). It was then tested on two held- out targets: Tetiaroa (2022), a temporally held-out scene, and Tikehau (2022), a spatially held-out atoll.

The same input features, sampling strategy, and shoreline extraction method were used across all configurations. Performance was evaluated using Intersection-over-Union (IoU), the proportion of shoreline predictions within 2 meters of the reference line (% within 2 m), and the 95th percentile of shoreline distance error. These metrics were used alongside conventional indicators such as MAPE and RMSE, which are more sensitive to extreme values. Percentile- and threshold-based indicators have also been employed in recent shoreline studies to complement standard accuracy metrics [Vos, K, Bishop-Taylor, Bengoufa et. al.].

4. RESULTS

The transfer learning model (TF) consistently matched or outperformed the per-image trained models (Original), including on temporally and spatially held-out scenes. The ‘Original’ models were trained and tested individually per image, whereas the TF model was trained once on five scenes and tested on two held-out targets. Table 1 summarizes shoreline classification accuracy across all test images. Fig. 1 illustrates this performance, showing *motu*-scale shoreline change on Tetiaroa.

The TF model maintained high Intersection-over-Union (IoU) scores—generally above 0.97—and exceeded 87% of predictions within 2 m of the reference shoreline in five of seven scenes. The 95th percentile error remained below 3.9 m in all but one case, confirming strong spatial delineation across varied atoll settings.

Table 1. Comparison of Original (O) vs. Transfer Learning (TF) model accuracy using IoU, %<2 m, and P95. Green = improvement, orange = deterioration, gray = no change. (* cloud corrected, + held-out scene)

Atoll-Year	IoU (O)	IoU (TF)	%< 2m (O)	%< 2m (TF)	P95 (O)	P95 (TF)
Tetiaroa 2016*	0.993	0.993	90.5	90.8	3.36	3.00
Tetiaroa 2019	0.992	0.993	88.8	90.6	5.36	2.99
Tetiaroa 2022+	0.994	0.992	93.2	88.4	2.28	2.87
Tetiaroa 2023*	0.994	0.994	93.9	93.5	2.15	2.20
Puka Puka 2022	0.993	0.993	81.4	81.8	5.42	4.99

Hao 2022	0.980	0.976	86.0	88.0	4.13	3.23
Tikehau 2022*+	0.966	0.972	83.0	87.1	4.19	3.84

Tetiaroa 2019 showed a particularly strong transfer performance, with the TF model outperforming the Original across all metrics. The 95th percentile error fell from 5.36 m (O) to 2.99 m (TF), and the % within 2 m improved from 88.8% to 90.6%. Similar results were observed in Tetiaroa 2016 – a training image – demonstrating stable performance with notable improvements over the original model, particularly in the 95th percentile error and % within 2 m.

In contrast, Tetiaroa 2022, a temporally held-out scene, showed slightly reduced performance (e.g., P95 = 2.87 m vs. 2.28 m, % < 2 m = 88.4% vs. 93.2%), though all metrics remained within a high or acceptable range. The spatially held-out site, Tikehau 2022, showed strong generalization: the TF model outperformed the Original across all indicators, including a drop in P95 from 4.19 m to 3.84 m.

While Mean Absolute Positional Error (MAPE) and Root Mean Square Error (RMSE) are commonly reported in shoreline studies [Vos, K, Bishop-Taylor, Bengoufa et. al.], they are sensitive to outliers and can overstate errors in the presence of visual obstructions or classification ambiguity. In Tetiaroa 2016, for instance, MAPE dropped from 2.55 m to 1.28 m and RMSE from 8.96 m to 3.84 m after excluding cloud-impacted segments. Although computed for completeness, MAPE and RMSE were supplemented with more robust spatial indicators. Across all non-training test scenes, the TF model achieved a mean MAPE of 1.28 m and a mean RMSE of 3.42 m, ranging from 1.25 m (Tetiaroa 2023) to 8.07 m (Tikehau).

5. DISCUSSION AND IMPLICATIONS

Results confirm that transfer learning enables stable, accurate shoreline classification across diverse atoll settings and timeframes. The TF model consistently achieved high IoU scores (>0.97) and low MAPE values, averaging 1.28 m overall and 1.44 m for the two held-out scenes (Tetiaroa 2022 and Tikehau 2022), demonstrating strong spatial and temporal generalization across varying island morphologies.

This consistency is especially valuable for atolls, where shorelines are narrow, complex, and sensitive to both natural and human pressures. The model’s performance without local retraining aligns with previous findings [Vos, K et. al.], which show that pretrained classifiers reduce workload, enhance repeatability, and enable scalable shoreline mapping. These advantages are critical in Pacific Island contexts, where annotated training data is limited and the need for adaptable, low-maintenance models is high, despite the growing demand for local environmental monitoring.

VHR imagery proved essential for capturing the fine-scale geomorphic variability of reef islands. As noted by [Holdaway et. al.], VHR imagery allows accurate delineation of narrow landforms and captures shoreline changes that coarser data miss. In this analysis, Pléiades images revealed subtle shoreline shifts, sediment redistribution, and *motu* reshaping – even when total land area remained unchanged. These patterns align with long-term shoreline dynamics observed on Tetiaroa (1955-2023) [Stoll, B et. al.]. For example, on the *motu* Tahuna Iti in Tetiaroa, extracted shorelines revealed localized erosion and accretion patterns not reflected in global-scale area metrics (see Fig. 1), highlighting the limits of planform surface metrics alone and the value of direct shoreline mapping.

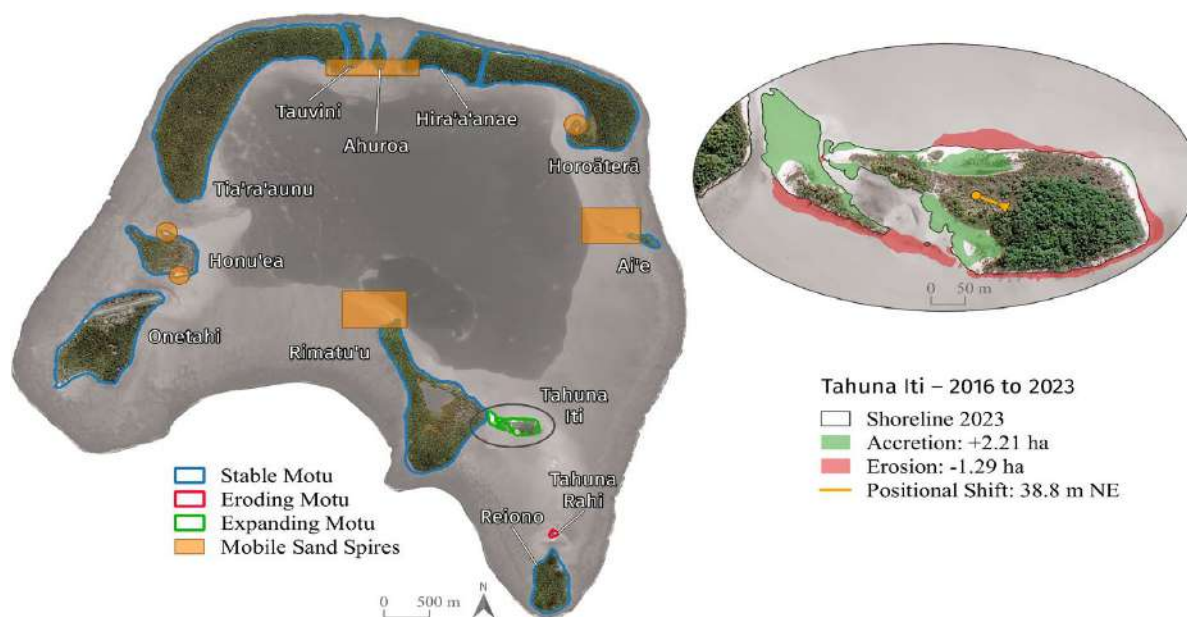


Fig. 1. *Motu*-scale shoreline changes on Tetiaroa between 2016 and 2023. Main map shows status of each *motu*: expanding (green), eroding (red), or stable (blue), with mobile sand spires in orange. The inset highlights Tahuna Iti, where 2.21 ha of accretion and 1.29 ha of erosion occurred, along with a 38.8 m northeastward shift of the shoreline over the 7-year period.

While robust across sites, some limitations remain. Cloud and shadow artifacts required manual correction, especially where spectral mixing obscured the shoreline. Corrections for water-level variability were not applied due to the absence of tide gauge data and beach profiles, which are often unavailable in remote atoll settings. These inputs are essential for implementing tidal normalization, as demonstrated in studies incorporating tide-based shoreline corrections [Vos, K et. al]. Some ambiguity also persists in transitional zones, such as tide pools and overhanging vegetation. Future work should broaden the training dataset to improve model adaptability across island types and timeframes.

The method provides an operational workflow aligned with regional adaptation goals. It supports moving beyond binary loss/gain narratives toward spatially nuanced insights – enabling resilience strategies grounded in fine-grained observation.

6. CONCLUSION

This study demonstrated the potential of transfer learning and VHR satellite imagery for automated, accurate shoreline detection in atoll environments. The proposed approach maintained high spatial accuracy, with a mean positional error of ≈ 1.28 m, and achieved robust accuracy on held-out sites without local data or retraining, demonstrating field- ready generalization. By integrating spectral and textural information, the method captures subtle shoreline changes that remain invisible in conventional metrics like land area. Despite some limitations related to cloud cover, tidal variability, and shoreline ambiguity, the workflow supports scalable and spatially explicit monitoring suited to the realities faced by Pacific islands. This workflow enables actionable, fine-scale monitoring that meets the operational needs of Pacific islands' managers.

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Perceptions of Health Extension Officer Students in Divine Word University on Medical Simulation Training as a Preparation Tool for Clinical Placement: A Mixed Methods Study

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Abstract: Medical simulation training is an increasingly vital educational strategy for preparing healthcare professionals to meet the complex demands of clinical environments. This study explores the perceptions of Health Extension Officer (HEO) students at Divine Word University (DWU) regarding the effectiveness of medical simulation training as a preparation tool for clinical placement. The study aligns with Papua New Guinea's desire to produce skilled and competent healthcare professionals and this view is a natural extension into the Pacific region's goal of harnessing innovative technologies to improve healthcare delivery and support sustainable development. A mixed-methods approach using a sequential explanatory research design was utilized, involving a survey of 101 students across three academic years, followed by focus group discussions (FGDs) with 24 participants. The survey assessed satisfaction, perceived skill development, and resource adequacy, while the FGDs provided in-depth perspectives on the integration of basic medical sciences, development of interpersonal and clinical skills, and suggestions for enhancing simulation training.

Findings revealed that students perceive simulation as a highly effective tool for building clinical competencies, especially in technical skills, decision-making, and teamwork, all within a safe, low-risk environment. Participants valued structured feedback and opportunities for hands-on practice. However, they identified the need for longer sessions, improved basic science integration, and standardized instructor training.

This study highlights the transformative potential of simulation-based learning in strengthening healthcare education across Papua New Guinea (PNG). By investing in simulation technologies and enhancing teaching methodologies, institutions can better prepare future health workers to serve rural and underserved communities, contributing to safer and more equitable health outcomes. The results hold implications not only for DWU and PNG but also for similar health systems across the Pacific, where resource limitations and workforce challenges demand innovative, context-relevant solutions. In conclusion, medical simulation training as a core educational strategy into training of clinical healthcare professionals supports PNG's efforts towards building a resilient and competent health workforce, in doing so illustrating one positive approach desired to enhance safe, efficient, and sustainable healthcare improvements across the Pacific region.

Keywords: medical simulation training, healthcare education, innovative teaching, divine word university

Author Biography:

John Benjamin has served at Divine Word University's Faculty of Medicine and Health Sciences in Papua New Guinea for the past 10 years. He has a background in clinical practice across various provincial hospitals and spent 8 years in the medical research environment focused on pharmacokinetics studies.

He is both humbled and happy for the opportunity to lend a voice into the vibrant discussions for the 2025 PIURN conference theme, sharing insights from a study on medical simulation training and how integrating appropriate technologies into medical education can strengthen healthcare delivery - aligning with the conference theme of "*Harnessing Technologies for the Safe and Sustainable Development of the Pacific*"

1. BACKGROUND AND CONTEXT

Innovative and smart healthcare education is increasingly necessary to address the growing clinical and workforce challenges in Papua New Guinea (PNG) and the Pacific. Factors such as limited clinical exposure, a high burden of disease, and constrained resources call for forward-thinking training strategies. Simulation-based education (SBE) is a globally recognized approach that bridges the divide between theory and practice [McGaghie].

Medical simulation training (MST) provides safe, controlled learning environments for students to develop technical and interpersonal skills without risking patient safety [Lateef]. It allows for repeated practice and real-time feedback, promoting confidence, communication, and clinical competence [Okuda, Issenberg].

1.1 Historical development and purpose

Simulation in healthcare traces back to 17th-century anatomical models [Bradley], progressing to tools like Resusci Anne in the 1960s [Linder]. Today, simulation is integral in clinical education, focusing on patient safety, decision-making, and readiness for professional practice through scenario-based learning [Rosen].

1.2 Types and emerging trends

MST encompasses various modalities—ranging from low-fidelity manikins to high-fidelity systems, standardized patients, virtual reality, and hybrid models. Newer developments include AI-based feedback [Edelson], cloud-based training platforms [Chick], and open-source solutions tailored to low-resource settings [Harder], broadening accessibility and equity in simulation delivery.

1.3 Student perceptions and impact

Literature indicates that students value simulation for hands-on learning, critical thinking, and clinical preparedness [Laschinger]. Key features of effective simulation include realism, feedback, and reflection [Jeffries]. Challenges, however, remain—particularly session limitations, equipment shortages, and variable instructional quality [Cook, Harder]. Despite these issues, student satisfaction remains high [Motola], especially when programs incorporate feedback for improvement [Kim].

1.4 Medical simulation in PNG and at DWU

Medical simulation in PNG is still emerging, with limited institutional integration and scarce region-specific research. Barriers such as under-resourced labs and faculty training gaps persist [Robinson]. Recognizing this, DWU under its 2016–2026 Strategic Plan, introduced MST into its Health Extension Officer (HEO) program in 2018 to enhance student readiness for clinical placement and workforce demands [Divine Word University: Strategic Plan 2016–2026].

1.5 Rationale

While MST's effectiveness is well-documented in high-income settings, its impact in low-resource environments like PNG is less understood. At DWU, MST was implemented to improve clinical preparedness; however, its effects on student learning outcomes, confidence, and readiness have not been formally evaluated. Understanding student perspectives is essential to refining MST, especially where training opportunities and resources are limited.

2. PURPOSE AND OBJECTIVES:

This study explored HEO students' perceptions of MST as a preparatory tool for clinical placements and identified factors influencing its effectiveness. The objectives were:

1. To assess overall satisfaction with MST
2. To explore perceptions of its role in skill acquisition and decision-making
3. To identify areas for improvement based on student feedback.

3. METHODS

An explanatory sequential mixed methods design was employed to explore both quantitative and qualitative student experiences [Creswell, Tashakkori et. al.].

3.1 *Phase 1: Quantitative*

All Year 2–4 HEO students enrolled in 2024 (N = 110) were invited to participate through stratified random sampling. A minimum sample size of 86 was calculated using Slovin's formula at a 95% confidence level [Yamane]. The survey tool, developed from validated MST evaluation instruments, comprised items under five themes: BMS learning, soft skills, clinical skills, skill transfer, and administration. Responses were recorded using a 5-point Likert scale and pilot-tested for reliability. Analysis using SPSS v16 included descriptive and inferential statistics (e.g., Spearman's correlation), with Cronbach's alpha of 0.948 indicating excellent internal consistency.

3.2 *Phase 2: Qualitative*

Twenty-four students were purposively selected for six focus group discussions (FGDs), stratified by year and gender. A semi-structured guide explored themes identified in the survey, such as realism, facilitator support, and learning barriers. Discussions were recorded, transcribed, and anonymized [Krueger et. al.]. Data were analyzed thematically using Braun and Clarke's framework [Braun et. al.]. Codes and themes were integrated with quantitative findings to enhance interpretation through triangulation [Creswell et. al.].

3.3 *Theoretical Framework:*

This study is underpinned by multiple learning theories. Social Cognitive Theory supports skill acquisition through observation and modeling [Bandura], while Situated Learning Theory emphasizes context-based practice [Lave]. Kolb's Experiential Learning Theory describes a cyclical process of doing, reflecting, and adapting [Kolb 1984] suitable for advanced learners [Kolb 2018]. Cognitive Load Theory, which promotes aligning instructional design with learner capacity [Sweller] – this final theory was most applicable across all three-year groups of this study.

3.4 *Ethics Approval:*

The study received ethical clearance from the Faculty of Medicine and Health Sciences Research Committee (FRC/MHS/88-24) and the DWU Research Ethics Committee (DWU REC-13/24). Informed consent was obtained, and data were securely stored in accordance with ethical guidelines [Israel et. al.].

4. RESULTS

4.1 *Phase 1: Quantitative Findings*

A total of 101 students participated, including 31 second-year, 30 third-year, and 40 fourth-year students, exceeding the minimum sample size for a 95% confidence level.

4.1.1 *Primary Analysis: Overall Perceptions of MST –*

Students' responses clustered around five key themes:

- **Basic Medical Science (BMS) Learning:** 70.3% agreed simulation reinforced BMS knowledge, though only 39.6% believed it was adequately covered beforehand. This highlights pre-simulation instructional

gaps.

- **Interpersonal Soft Skills:** Professionalism was highly rated (84.2% agreement), with teamwork also positively evaluated (Median = 4). However, communication skills received mixed reviews, with 29.7% agreeing, 19.8% strongly agreeing, and 19.8% disagreeing.
- **Core Clinical Skills:** While 69.3% affirmed improved bedside skills, clinical reasoning scored lower (Mean = 3.35), with 26.7% neutral and 11.9% in disagreement.
- **Skill Transfer to Practice:** A majority (73.3%) felt simulation prepared them for clinical placement, but only 20% agreed it aided preparation for post-residency training (Mean = 2.63), suggesting limited perceived long-term benefit.
- **Simulation Administration:** High satisfaction was reported with teaching quality (71.3%) and instructor knowledge (88.1%). Assessment activities were also positively rated (Median = 4).

A summary of the descriptive analysis of survey study items can be noted on *Table-1* while a highlight of the best and worst perceptions by the HEO students of the MST under the five key themes can be noted on *Table-2*.

4.1.2 Secondary Analysis: Correlation Findings

Spearman correlation revealed strong associations: teamwork and communication ($r_s = 0.715$), simulation relevance and clinical performance ($r_s = 0.530$), and teaching effectiveness and placement readiness ($r_s = 0.514$). Moderate correlations reinforced links between BMS knowledge, professionalism, and teamwork. *Table-3* illustrates further the correlation between these variables.

Table-1: Descriptive analysis of survey study items showing frequency, percentages, mean and median.

Q No.	Statement	SD (%)	D (%)	N (%)	A (%)	SA (%)	Median	Mean
1	My understanding of basic medical science content I learnt prior to the medical simulation sessions did help when attending these sessions.	7 (6.9%)	7 (6.9%)	16 (15.8%)	46 (45.5%)	25 (24.8%)	4	3.75
2	My knowledge in basic medical sciences was enhanced when attending the medical simulation training sessions.	6 (5.9%)	8 (7.9%)	18 (17.8%)	28 (27.7%)	41 (40.6%)	4	3.92
3	Basic medical science content was adequately covered by the time regular medical simulation training sessions commenced.	8 (7.9%)	17 (16.8%)	24 (23.8%)	40 (39.6%)	12 (11.9%)	4	3.31
4	Performing medical simulation training sessions improved my communication skills for history taking.	9 (8.9%)	20 (19.8%)	22 (21.8%)	30 (29.7%)	20 (19.8%)	3	3.32
5	Performing medical simulation training sessions improved my bedside exam skills for patient examinations.	11 (10.9%)	3 (3.0%)	17 (16.8%)	38 (37.6%)	32 (31.7%)	4	3.76
6	I was able to develop judgment and critical clinical reasoning skills from the medical simulation sessions.	10 (9.9%)	12 (11.9%)	27 (26.7%)	37 (36.6%)	15 (14.9%)	4	3.36
7	I was able to develop professional attitudes and attributes from the medical simulation sessions to apply into the clinical placement.	4 (4.0%)	3 (3.0%)	9 (8.9%)	24 (23.8%)	61 (60.4%)	5	4.33
8	Medical simulation sessions advanced my skills to work as part of a team.	10 (9.9%)	7 (6.9%)	19 (18.8%)	34 (33.7%)	31 (30.7%)	4	3.68
9	Planned activities covered during medical simulation sessions were relevant to what we observed during clinical placement.	3 (3.0%)	6 (5.9%)	16 (15.8%)	42 (41.6%)	34 (33.7%)	4	4.00
10	In general, the medical simulation teaching is conducted effectively so the session aims are achieved each time.	7 (6.9%)	9 (8.9%)	13 (12.9%)	39 (38.6%)	33 (32.7%)	4	3.82
11	The simulation teaching team are knowledgeable in their role.	0 (0.0%)	4 (4.0%)	8 (7.9%)	39 (38.6%)	50 (49.5%)	4	4.34
12	During clinical placement, I was able to perform some procedures well due to being exposed to them in simulation training.	6 (5.9%)	5 (5.0%)	16 (15.8%)	44 (43.6%)	30 (29.7%)	4	3.86
13	The skills and knowledge I learned during simulation training prepared me well for clinical placement.	7 (6.9%)	8 (7.9%)	23 (22.8%)	40 (39.6%)	23 (22.8%)	4	3.64
14	Overall, I feel that the medical simulation training component was beneficial to support my clinical placement.	4 (4.0%)	14 (13.9%)	15 (14.9%)	25 (24.8%)	43 (42.6%)	4	3.88
15	The skills and knowledge I learned during simulation training have equipped me well to consider further training after my residency (4th years only).	8 (20.0%)	9 (22.5%)	14 (35.0%)	8 (20.0%)	1 (2.5%)	3	2.63
16	Performing assessment activities (e.g., OSCE) in the simulation room will support my clinical skills training and preparation for clinical placement.	0 (0.0%)	6 (5.9%)	18 (17.8%)	36 (35.6%)	41 (40.6%)	4	4.11

Note: SA = Strongly Agree (5), A = Agree (4), N = Neutral (3), D = Disagree (2), SD = Strongly Disagree (1).

Weighted average = Sum of means / No. of survey items = 59.71/16 = 3.73

Table-2: Best and worst perceptions noted by HEO students according to the key themes.

Key Theme	Best Perceptions	Worst Perceptions
Prior Basic Medical Science (BMS) Learning Experience	68.3% agreed that simulation reinforced BMS knowledge (Median = 4).	Some students (23.8%) felt BMS content was not adequately covered before simulations (Mean = 3.31).
Development of Interpersonal Soft Skills	84.2% agreed that simulation effectively fostered professionalism (Mean = 4.33).	Communication skill improvement had mixed responses, with 19.8% disagreeing (Median = 3).
Development of Core Clinical Skills	69.3% (combined agreement) felt simulation improved bedside exam. skills (Mean = 3.75).	Clinical reasoning skills had variability, with 26.7% neutral and 11.9% disagreeing (Mean = 3.35).
Transfer of Clinical Skills to Practice	73.3% felt prepared to perform procedures during clinical placement (Median = 4).	Limited impact on future training, with only 20.0% agreeing that simulation prepared them for post-residency training (Mean = 2.63).
Perception of the Administration of Simulation Training	88.1% expressed high confidence in the knowledge of instructors (Mean = 4.34).	No major negative perception reported under this theme.

Table-3: Relationships between different variables utilizing Spearman's coefficient correlation

Variables	n	Spearman's p	p-value
Performing medical simulation training sessions improved my communication skills for history taking (Q4) & I was able to develop professional attitudes and attributes from the medical simulation sessions to apply into the clinical placement (Q7)	101	0.436	< 0.000
My understanding of basic medical science content (Anatomy, Biochemistry, Physiology and Pharmacology) I learnt prior to the medical simulation sessions did help when attending these sessions (Q1) & Basic medical science content was adequately covered by the time regular medical simulation training sessions commenced (Q3)	101	0.501	< 0.000
I was able to develop professional attitudes and attributes from the medical simulation sessions to apply into the clinical placement (Q7) & Medical simulation sessions advanced my skills to work as part of a team (Q8)	101	0.508	< 0.000
In general, the medical simulation teaching is conducted effectively so the session aims are achieved each time (Q10) & Overall, I feel that the medical simulation training component was beneficial to support my clinical placement (Q14)	101	0.514	< 0.000
Planned activities covered during medical simulation sessions were relevant to what we observed during clinical placement (Q9) & During clinical placement I was able to perform some procedures well due to being exposed to them in simulation training (Q12)	101	0.530	< 0.000
Medical simulation sessions advanced my skills to work as part of a team (Q8) & Performing medical simulation training sessions improved my communication skills for history taking (Q4)	101	0.715	< 0.000

4.2 Phase 2: Qualitative Findings

Thematic analysis revealed five key themes: perceived benefits, challenges and limitations, preparedness for clinical placement, program administration, and overall perceptions and recommendations, each reflecting distinct aspects of students' experiences with medical simulation training.

Perceived benefits: Students praised MST for improving confidence and essential clinical skills.

- *"The SIM Lab helped me build to be confident... you get a good idea how to perform it."* (Yr. 2 male)
- *"It strengthens the theoretical knowledge of basic medicine... through hands-on practicals"* (Yr. 3 male).

Challenges and limitations: Key issues included overcrowding, equipment shortages, and limited practice time.

- *"Only one simulation room... and not enough equipment for students to practice."* (Yr. 4 male)

- “We sometimes rush to complete procedures which we have to do critically” (Yr. 3 female)

Preparedness for clinical placement: Many students reported feeling well-prepared for clinical procedures after simulation. A second-year female student reflected,

- “I felt confident when I was asked to palpate a pregnant mother... because we had already practiced in the simulation room.”

Program administration: Students appreciated teaching quality but raised concerns about inconsistent facilitation. Calls for increased session frequency were common. One third year male student remarked,

- “Some instructors explained too much and we ran out of time.”

Overall perception and recommendations: Students valued the realism of simulation

- “It really simulates the feeling of being in a real hospital” (Yr. 2 female).

They recommended more sessions, better equipment, and OSCE integration. Several also emphasized the need for improved BMS preparation:

- “We need to learn Anatomy and Physiology well in Year 1 and 2 to help our simulation training” (Yr. 3 female).

5. DISCUSSION

This study affirms that MST is perceived as an essential preparation tool by HEO students at DWU. Although most students felt simulation reinforced BMS knowledge, the low rating (39.6%) for prior BMS coverage highlights a critical need for better integration of foundational sciences. These findings are supported by earlier studies [McGaghie, Al-Elq] and are consistent with Robinson et al., who observed similar issues in Pacific contexts where students often begin simulation with limited scientific grounding.

Interpersonal skills, particularly professionalism and teamwork—were widely recognized as benefits of MST, with a notable correlation between teamwork and communication ($r_s = 0.715$). Although history-taking communication received mixed feedback, students consistently reported simulation as confidence-building. This aligns with the work of Jeffries and Kolb 1984, who emphasize the value of experiential learning in developing soft skills.

Technical competence in bedside procedures was affirmed across both quantitative and qualitative data. However, the relatively lower score for clinical reasoning (Mean = 3.35) suggests a need for more decision-focused scenarios. This supports recommendations by Issenberg et al., that high-fidelity simulations with critical thinking components are key to fostering deeper learning.

Most students (73.3%) reported that simulation helped them prepare for clinical placement, confirming its importance as a bridge between classroom and practice. While teaching quality was generally rated highly, students noted logistical challenges including inconsistent facilitation and time constraints—echoing barriers previously reported in the Pacific region by Robinson et al., such as space limitations and equipment shortages.

In summary, MST was viewed as significantly enhancing student confidence, clinical competence, and overall preparedness. To maximize its effectiveness, improvements in BMS integration, scenario complexity, and consistent delivery are recommended.

5.1 Study Limitations

This single-institution study had a limited sample size, which affects the generalizability of findings. Self-reported data may be influenced by recall bias or social desirability. The scope focused on selected clinical skills rather than the full competency spectrum. Variation in BMS preparedness among students likely shaped their simulation perceptions. Additionally, equipment shortages, inconsistent teaching, and limited time posed learning barriers. The study measured only short-term simulation outcomes, leaving long-term impacts unexplored. Despite these constraints, findings offer critical insights to guide simulation-based education in similar low-resource contexts.

6. CONCLUSION

This mixed methods study presents the first formal evaluation of MST perceptions among HEO students at DWU. The results confirm simulation's value in strengthening clinical skills, building confidence, and enhancing preparedness for rural practice in PNG. These outcomes reinforce the importance of investing in simulation infrastructure and instructional design. Moreover, the positive feedback supports broader regional strategies to develop a skilled, adaptable healthcare workforce across the Pacific.

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Assessing the Water Balance and Groundwater Drying Trends in Papua New Guinea: The Potential of Soil and Water Conservation for Recharge Restoration

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Abstract: Groundwater stress is becoming more prevalent in Papua New Guinea, particularly in rural and peri-urban areas where shallow aquifers are essential for subsistence. This study does a quantitative water balance assessment to better understand the causes of these drying trends. The research looks into the imbalance between recharge and outflow rates in critical regions of PNG by assessing climatological and hydrological data such as rainfall, evapotranspiration, surface runoff, and groundwater extraction. Furthermore, the study assesses the effectiveness of soil and water conservation (SWC) techniques in mitigating aquifer depletion. Contour farming, vegetative cover, recharge ponds, and check dams are all being considered for their ability to improve groundwater recharge rates. Preliminary findings suggest that implementing targeted SWC treatments, particularly in highland and deforested areas, can dramatically increase groundwater recharge capacity. Finally, the study makes practical recommendations for incorporating SWC methods into local watershed and water resource management programs. This attempts to manage rising groundwater stress and maintain the long-term usage of this critical resource in Papua New Guinea.

Keywords: Groundwater; Water Balance; Recharge; Soil and Water Conservation (SWC); Papua New Guinea (PNG)

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1. INTRODUCTION

Accessible freshwater comes from streams, lakes, and underground sources [Downing et. al.]. The Papua New Guinea may experience a scarcity of water which is needed to meet the population and industrial needs [Jensen et. al.]. Thus, ground water can be mentioned as precious natural assets that support economic development and ecological diversity [Downing et. al.]. Flow dynamics of lakes is dependent on groundwater level, which is given a current focus globally [Ajami, Ala-aho et. al.]. Therefore, measures should be taken to rehabilitate and manage vulnerability of the lakes. Groundwater is often withdrawn to support man's activities that will support life such as use in agricultural activities, the industries in preparing their goods and households in the municipalities and cities by operating extraction wells which in the long run exhaust the resource [Fan et. al.]. The measures must rescue the water ecology, dependent farming systems and contribute to the economy [Kløve et. al.]. The analysis of water balance is one of the methods to determine the groundwater inflow [Batelaan et. al.]. Temperature increment and unreliability of precipitation may not be the only factor to vary the lake water balance, both natural and anthropogenic activities affecting the fluctuation of water depth over time. Balancere, analyzing the lake water

balance through proper techniques will be essential for the establishment of mitigation strategies. Therefore, this study aims to bridge this gap by combining water balance assessment with evaluation of SWC potential in restoring groundwater recharge in selected areas of PNG. Unregulated extraction can lead to lowered water tables, reduced well yields, increased pumping costs, and potential saltwater intrusion in coastal areas [White et. al.]. Hence, the groundwater holds immense significance for Papua New Guinea, particularly in rural areas where it frequently serves as the most reliable and safest source of freshwater [Bourke et. al.]. Moreover, in some regions, particularly during prolonged dry seasons and El Niño events, communities relying on shallow wells and springs are experiencing water shortages, indicating a potential decline in local groundwater tables [Allen et. al.]. Sustainable management and protection of these vital groundwater resources are therefore crucial for the well-being and development of rural Papua New [Alamgir et. al.]. Furthermore, environmental impacts from mining and inadequate waste management practices pose a threat to groundwater quality, potentially reducing the availability of usable groundwater [Schofield et. al.]. The increasing demand for freshwater due to population growth, agricultural expansion, and industrial activities in Papua New Guinea necessitates the sustainable management of groundwater resources to prevent depletion [Carrard et. al.]. Thus, there is a greater influence on groundwater quality, water balance, discharge, and ecology of lake during the study of wetlands and groundwater fed lakes that the water level fluctuation in such regions has an effect on the shallow lakes that highly depend on the ground water discharge [Teweldebrihan et. al.].

Water balance studies are essential for quantifying inflows, outflows, and storage changes in a hydrological system. They offer insight into managing freshwater resources, planning for agriculture, and predicting the effects of climate variability. In tropical and arid areas alike, soil water content plays a key role in vegetation, nutrient cycling, and runoff regulation. In PNG, these dynamics are poorly monitored, requiring further research and modeling. To address this, PNG needs a groundwater-specific management framework that integrates hydrological science, traditional knowledge, and community engagement. SWC methods can serve as an entry point for such a framework, delivering co-benefits for climate adaptation, food security, and public health. Capacity-building and investment in monitoring infrastructure are essential. Several examples from Southeast Asia and Sub-Saharan Africa illustrate the success of soil and water conservation (SWC) in boosting groundwater recharge. In Ethiopia's Tigray region, stone bunds and trench systems led to a 30–60% increase in soil moisture and groundwater levels. In India's Maharashtra state, check dams and farm ponds helped reverse declining water tables within a decade. These low-tech solutions demonstrate potential for application in PNG's diverse terrain. In Papua New Guinea, pilot efforts in the Highlands have introduced vetiver grass strips and gully plugs to reduce erosion and increase infiltration. Although under-documented, anecdotal reports from agricultural officers suggest visible improvements in soil retention and well reliability in trial villages. A formal monitoring framework could scale these efforts with data-driven targeting.

The purpose of this study is to examine the water balance and groundwater drying trends in PNG by examining climatological and hydrological data to better understand the imbalance between recharge and outflow rates. It also looks into how soil and water conservation techniques like contour farming and recharge ponds might help with groundwater recharge. Therefore, the review study findings indicate that implementing targeted SWC strategies, particularly in highland and deforested areas, can dramatically increase groundwater recharge capacity, providing practical recommendations for sustainable water resource management in Papua New Guinea.

2. LITERATURE REVIEW

The groundwater studies in Papua New Guinea (PNG) and the wider Pacific region have been crucial in understanding the availability, quality, and sustainability of this vital resource for island communities [White, Bourke, Carrard et. al.]. These studies have highlighted the generally good groundwater potential in many parts of PNG, while also identifying complexities related to hard rock aquifers and the need for integrated approaches in resource evaluation [Wambrauw]. Across the Pacific, a significant focus has been on the unique hydrogeology of small island states, particularly atoll islands, where thin freshwater lenses are vulnerable to saltwater intrusion due to over-pumping and rising sea levels [White et. al.]. Consequently, regional studies have also aimed to develop consistent hydrogeological classifications that show different climate scenarios on island groundwater sustainability, emphasizing the critical role of groundwater for both ecosystems and human populations in the Pacific [Sapala et. al.]. As a result, the interaction of surface-groundwater would affect the quality, ecology,

biology and chemistry of lake water [Fleckenstein, Green et. al.]. Groundwater serves as a vital source of drinking water, especially in rural communities, and supports ecosystems [Griebler et. al.]. However, recent field observations and community reports indicate that wells and springs in parts of the Highlands and coastal regions are experiencing lower yields and seasonal drying, attributed to both climatic variability and land use change. Globally, water balance models have proven effective in diagnosing regional hydrological stress by quantifying inputs (precipitation), outputs (evapotranspiration, runoff), and changes in storage (groundwater). In parallel, the adoption of soil and water conservation (SWC) techniques has been widely promoted in Sub-Saharan Africa and Southeast Asia as a sustainable solution for enhancing water infiltration and reducing surface runoff [FAO, Rockström et. al.].

Research in these contexts has explored sustainable extraction methods like horizontal wells and infiltration galleries, alongside assessments of aquifer vulnerability to climatic variations and anthropogenic contamination [Machiwal, Banerjee et. al.]. Most lakes generally receive inflow from groundwater through their bed laterally or vertically via seepage from the aquifer [Poff et. al.]. Hence, understanding SWC dynamics is crucial for drought monitoring, land degradation assessment, and developing strategies for water-scarce agriculture [Teweldebrihan et. al.]. Despite the nation's high annual rainfall—often exceeding 2,000 mm in many regions—groundwater resources have increasingly shown signs of stress, particularly in areas with growing population pressure, land degradation, and limited infrastructure for sustainable water management. Studies in PNG have largely focused on surface water hydrology, with limited data available on long-term groundwater monitoring [Wambrauw]. These include contour bunds, mulching, afforestation, and check dams—all of which contribute to increased groundwater recharge. While SWC practices have been promoted in PNG's agricultural development programs, their hydrological impact remains under-explored [Prentice et. al.].

3. MATERIALS & METHODS

The methodology combined meta-analysis of relevant hydrological studies with trend analysis using secondary datasets. Literature was sourced via Web of Science and Scopus, focused on PNG's groundwater, climate, and conservation, and groundwater extraction. SWC methods were evaluated based on their recharge potential, drawn from both regional and international case studies.

The primary source involved leveraging a previously published systematic review database [Sapala et. al.], which specifically focused on PNG and provided an extensive collection of relevant literature, including studies pertinent to the PNG Potential of Soil and Water Conservation (SWC) for Recharge Restoration and its catchment. However, recognizing that this PNG-centric database might lack broader basin-wide information, a supplementary, customized literature search was executed. This secondary search utilized prominent online scientific article search engines, namely Scopus and Web of Science (www.webofscience.com). The search strategy employed two categories of terms: firstly, terms directly referencing the Water Balance and Groundwater Drying Trends in Papua New Guinea, such as “PNG groundwater,” “PNG water balance,” “soil and water conservation,” “Recharge,” “Restoration,” “PNG surface water,” “River,” “Lake,” and “water balance.” Secondly, terms related to specific Water-Energy-Food-Ecosystem (WEFE) [Abera et. al.] components relevant to the basin were utilized, including “PNG groundwater,” “groundwater trend,” “PNG river basin,” “groundwater drying trend,” “Nexus,” “WEFE,” “WFE,” “Food,” “Water,” “Energy,” “Ecosystem,” “Environment,” “water volume,” “water quality,” “hydrology,” “water balance,” “climate change,” “Livelihoods,” “Agriculture,” “aquatic ecosystem,” “groundwater,” “human impact,” “rainfall trend,” “climate change,” “hydrochemical,” “physicochemical,” “groundwater trend,” “surface water trend,” “evapotranspiration,” “river inflow,” “fauna,” “flora,” “watershed,” “catchment,” “basin,” “water resource,” and “irrigation.” This meticulous dual-pronged approach ensured a comprehensive collection of literature, effectively covering both the spatial and thematic dimensions of Water Balance and Groundwater Drying Trends issues within Papua New Guinea.

4. RESULTS & DISCUSSION

Meta-analysis of 125 studies emphasized recurring themes: falling groundwater tables, decreased spring yields, and dry wells. Soil and water conservation (SWC) techniques like contour bunds, vegetative strips, and check dams have shown success in improving infiltration and restoring water balance. In PNG, where deforestation and

shifting agriculture are prevalent, these methods can stabilize soil and improve aquifer recharge. As illustrated in Figure 2, the thematic focus of these investigations was primarily decided by the authors' keywords. The most regularly used terms included "water balance," "lake," "runoff," "irrigation," and "sedimentation." This significance stems from a strong research focus on the hydrological cycle, surface water dynamics, and human interventions (such as irrigation) that have a direct impact on water supply and quality. Moreover, other relevant keywords, such as "soil erosion," "water quality," "groundwater," "environmental assessment," "sustainability," "water levels," "Groundwater Drying Trends," and "rivers," emphasize the interconnection of these issues. The collective use of these terms suggests that scientific attention has been primarily directed toward understanding the intricate interactions between terrestrial and aquatic ecosystems, recognizing their profound interconnectedness, especially in the face of changing climatic conditions and land use practices affecting water resources in Papua New Guinea.

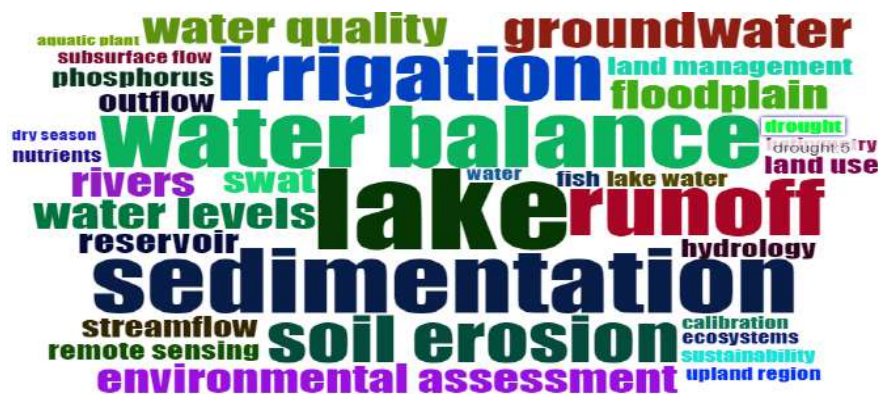


Fig 1. A word cloud including the author's selected keywords from the meta-analysis publications. Each word's size and prominence correspond to how frequently it appears in the selected articles.

Analysis of climatological and hydrological data shows a mismatch between rainfall patterns and groundwater recharge. PNG's rainfall has a bimodal distribution, with peaks in March and December, and drier periods from May to August as shown in Fig 2. However, increasing groundwater extraction and land-use changes reduce infiltration, especially in highland and coastal regions.

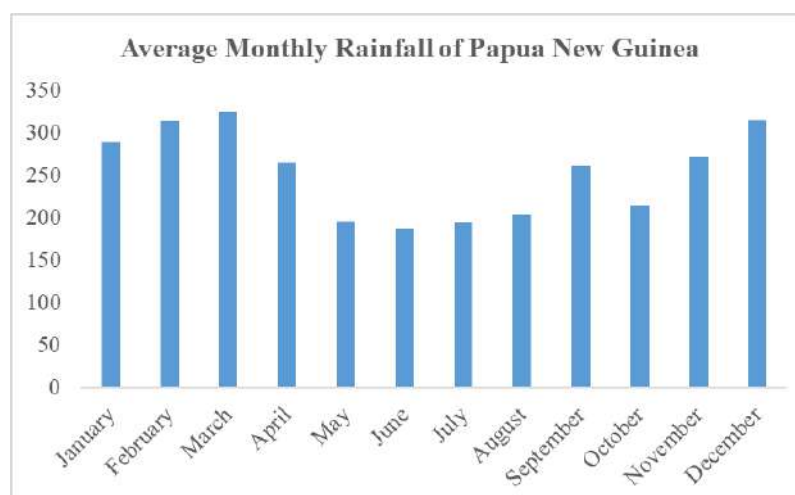


Fig 2. Papua New Guinea rainfall – monthly average

The Fig 3 on next page depicts the average yearly rainfall from 1957 to 2024, which remained within an approximate range of 170 mm to 500 mm. Interestingly, while the bold blue line representing year-to-year changes shows periods of increase and decline, the overall trend line (represented by the dotted black straight line) for both precipitation and groundwater levels reveals a noticeable growing trend over this extended period. Thus, the blue

dots represent the yearly average rainfall, with the maximum annual average rainfall recorded in 2012 at 274 mm. This thorough temporal analysis emphasizes the dynamic character of PNG's hydrological patterns, as well as the current surge in scientific research targeted at understanding and tackling these critical environmental issues.

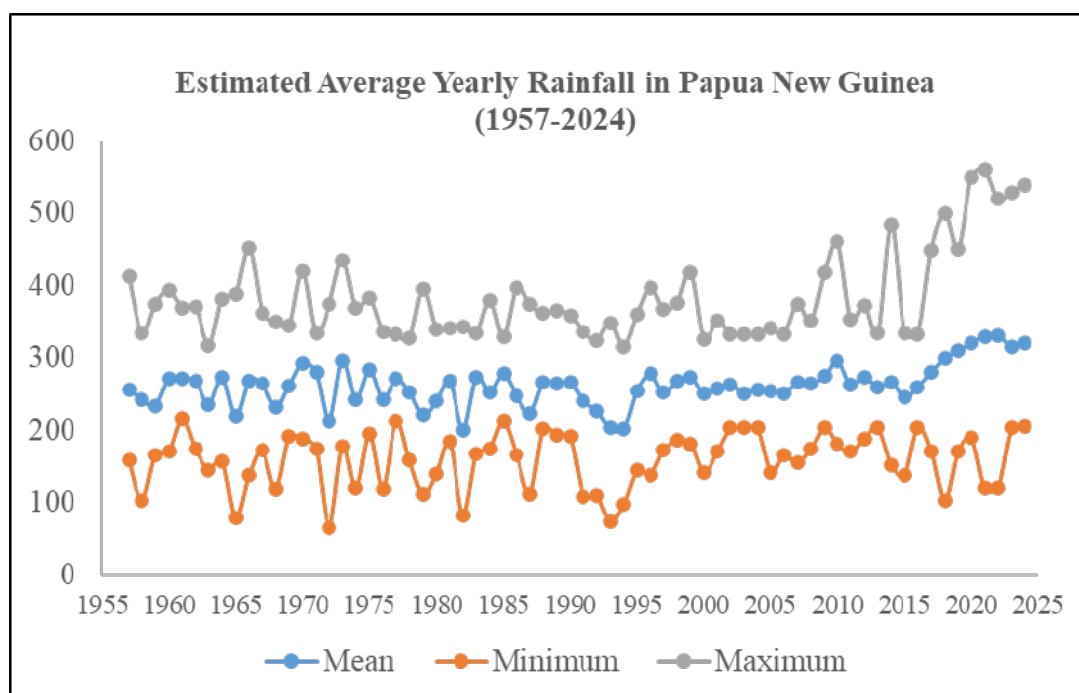


Fig 3: A review of Papua New Guinea's anticipated rainfall pattern from 1957 to 2024.

Stakeholder analysis highlighted key actors: local communities, provincial governments, NGOs, and academic researchers. Local ownership and capacity building are vital for sustainable SWC implementation. Incorporating SWC into local watershed and climate adaptation policies can provide long-term benefits.

The sophistication and range of methodological techniques in academic inquiry have grown significantly over time, particularly during the second half of the 2000s. Prior to the 2000s, research relied heavily on confirmatory and inferential analysis, aiming to establish links and draw conclusions from observable data. This foundation eventually evolved toward more robust numerical and physical-based modeling, which enabled more precise simulation and prediction of complex processes. Following that, a shift happened toward geospatial-based analysis, which uses spatial data and technologies to discover patterns and correlations across geographic areas. Despite these significant methodological advances, there is still a significant gap in the broad adoption of nexus-based analysis. While promising, just a few recent research has used this comprehensive approach, and it has yet to emerge as a common tool for analyzing interrelated systems.

The review study on the Water Balance and Groundwater Drying Trends in Papua New Guinea NEXUS demonstrates a stakeholder analysis in which various articles identify entities involved and their respective numbers of research studies, presumably representing individual participants or relevant entities within each category (Fig 4).

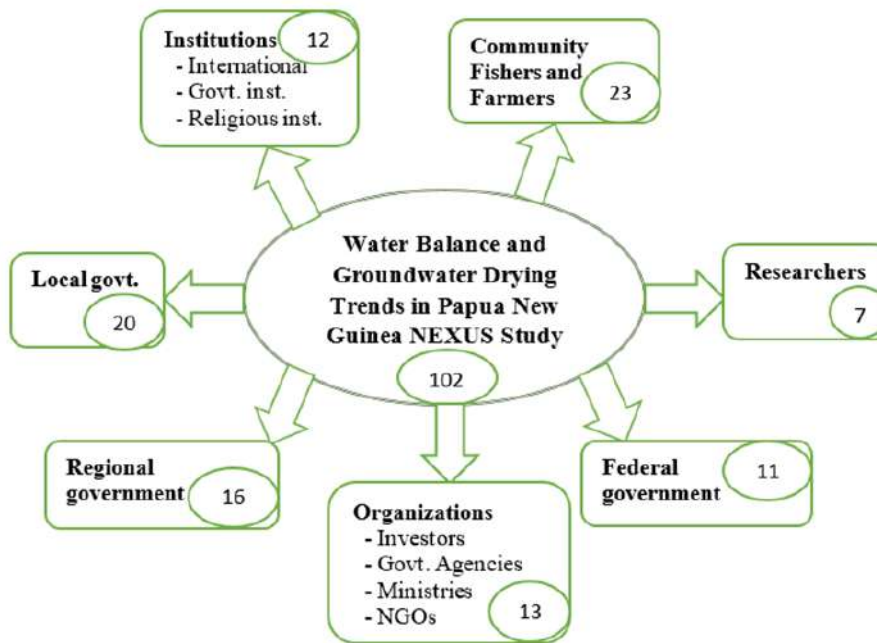


Fig 4. Stakeholder's involvement in the WEF-NEXUS studies

The primary issues of the "Water Balance and Groundwater Drying Trends in Papua New Guinea NEXUS Study" are central to this study, with 102 articles chosen from the 250 papers obtained for the review study that are closely related to the study. Several significant stakeholder groups have been found around this core in various research. According to 23 articles, "Community Fishers and Farmers" are an important group, emphasizing the importance of grassroots participation and the direct influence of water trends on livelihoods. On the other side, 20 articles titled "Local government" account for the critical role of local administrative authorities in tackling these concerns. Thus, around 16 research show that "regional government" follows, emphasizing the need for a multi-tiered governmental system. Furthermore, 13 articles focusing on "Organizations" include a varied range of entities such as investors, government agencies, ministries, and NGOs, implying a coordinated effort across many organizational levels. "Institutions," which include international, government, and religious organizations, has 12 articles, indicating the involvement of established bodies with greater reach and influence. Finally, 11 studies show that "Federal government" has, indicating national-level engagement, and "Researchers" with 7 articles are critical for giving scientific expertise and analysis to the study. This schematic diagram successfully illustrates the study's multifaceted nature, emphasizing the importance of collaboration and input from a diverse range of stakeholders in addressing water balancing and groundwater drying trends in Papua New Guinea.

5. CONCLUSION & RECOMMENDATIONS

Groundwater drying trends in Papua New Guinea pose serious risks to water security, especially in rural and highland regions. Despite high annual rainfall, localized depletion is rising due to land-use changes, population pressure, and inadequate recharge. This study shows that soil and water conservation (SWC) techniques can significantly improve groundwater recharge.

We recommend prioritizing SWC strategies in water-stressed regions, supported by hydrological monitoring and stakeholder collaboration. Further integration into development plans and climate resilience policies is essential for ensuring sustainable water supply in PNG.

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Modeling and Mechanobiology of the Mitral Valve

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Abstract. In this study, we have used a fluid structure interaction to model the blood flow in the mitral valve and its leaflets. Using CT images, we have made a real geometry of the mitral valve, and SolidWorks was used to make the model. The real boundary conditions were used, and the diastolic phase of the heart was modeled for 0.5 seconds. The hyper elastic material properties were used both for the left ventricle and the mitral. ANSYS software was used to perform numerical simulations. The hemodynamic parameters, including blood velocity, pressure, and shear stresses, were analyzed. The results obtained were compared to the existing literature. The displacements and strain of the left ventricle tissue were also studied.

Keywords: Mitral; simulation; mechanobiology; velocity; pressure; stress; strain

1. INTRODUCTION

The heart has four valves, including the mitral valve. This valve is between the left atrium and ventricle. The low-pressure blood flows from the left atrium to the left ventricle, and there is no backflow when the pressure of the left ventricle increases during the pumping of blood in the cardiovascular system. The valve has an annulus, two asymmetrical leaflets, and a chordal rope that connects the leaflets to the left ventricular wall. There are many numerical simulations for modeling the function of the mitral valve, as stated below:

Collia et al., 2022 used a computational fluid dynamics study to investigate mitral regurgitation. They also introduced a simplified model for mitral valve modeling to investigate the clinical relevance of left ventricular function using fluid dynamics [Collia et. al. 2019]. Meschinie et al., investigated the effects of natural and prosthetic mitral valves on the flow structure in healthy and abnormal left ventricles. In another attempt, Miller et al [4] studied prolapse of the mitral valve with mild mitral regurgitation. Finally, Meschini et al., investigated the effects of mitral muscles on the flow in the left heart ventricle. In this study, we have used the fluid-structure interaction method (FSI) to obtain the hemodynamic parameters of blood flow during mitral valve opening and closure by ANSYS software and a patient-specific model.

2. MATERIALS AND METHODS

The mitral geometry is patient-specific, where the CT scans of ten adults with a normal mitral valve geometry were extracted. The sample was a 45-year-old male. The model of the valve was shown in Fig.1. Different dimensional indices were calculated for each leaflet, including leaflet length, width, thickness, and curvature radius. The final dimensions were chosen by consulting a cardiologist, thus, all the dimensions needed to create the finite element model are mentioned in the table. The mitral valve has two identical leaflets, and the model was built using CATIA V5R21. Tissues were assumed hyper elastic and anisotropic with large deformations, as the alignment of the collagen fibres in the leaflet tissue showed an anisotropic response to stress-strain. Simulations were performed by the software ANSYS using a staggered Cartesian grid as shown in Fig.2. We have simulated the model for cardiac cycles at 0.8 s. The fluid density and viscosity were assumed to be 1050 kg/m³ and 0.04 Poise, respectively [Prot V et. al.]. The tissue module of elasticity was assumed to be 1.5 MPa with a

Poisson's ratio of 0.4 [Prot V et. al.]. The meshing was conducted using shell elements. We applied a time-dependent physiologic pressure curve to the leaflets over the whole cardiac cycle. The contraction of the annulus was modelled using nodal displacements applied to the nodes belonging to the annulus from the maximum area to the minimum. Moreover, the motion of the papillary muscles was fixed and not considered, and the edge of each leaflet was free for displacement. The friction coefficient between the leaflets was assumed equal to 0.05. Our aims were to develop a 3D model of the mitral valve using fluid–structure interactions to study the normal function of the valve by noting the relation between the leaflets and blood flow. We used ANSYS for all numerical simulations to show the outcomes of the presented complex model.

3. RESULTS AND DISCUSSIONS

Fig.3 shows the velocity streamlines of the blood flow, and Fig.4 shows the pressure distribution contour at $t=0.8s$. The maximum velocity occurs at 0.8 s in diastole when the maximum flow rate passes from the mitral. The difference between the inlet of the mitral and its outlet (entering to aorta) is shown in Fig.5. The pressure of the inlet flow to the mitral is greater than that of the outlet to allow blood flow to the aortic valve. Ejection fraction is one of the important parameters that presents the performance of the myocardium. It also demonstrates the efficiency of the heart. It refers to the volume of blood that has been ejected to the left ventricle at the end of diastole. The difference between the end of systolic and diastolic volumes refers to stroke volume. We have calculated the ejection fraction from our model using the following relation:

$$E_f = \frac{SV}{EDV} = \frac{EDV - ESV}{EDV} \times 100 \quad (1)$$

Where EDV refers to end diastolic volume, ESV to end systolic volume, and SV to stroke volume. We obtained the following values:

$$EDV = 138.68 \text{ ml}$$

$$ESV = 62.19 \text{ ml}$$

$$SV = 76.49 \text{ ml}$$

$$EF = 55.53\% \text{ ml}$$

The normal physiological range of ejection fraction is 55-70 % [Cheng et. al.]. Another calculated factor is the cardiac output. The cardiac output is the total volume of blood that is ejected to the aorta by the left ventricle in each heart cycle. The normal range of the cardiac output is between 4 to 8 liters/min. We used the following relation to calculate the cardiac output:

$$\text{Cardiac output} = \text{Stroke volume} * \text{heart rate}$$

For a normal person whose heart rate is 75 beats per minute for 0.8 s, the cardiac output is 5.74 liters/min. We have also calculated the maximum stress in mitral leaflets equal to 1.6 MPa at the end of the time. Furthermore, we found out that the strain ranges are in good agreement with Morganti *et al.*, who employed a nonlinear hyperplastic material to present the mechanical properties of the mitral leaflet. Our predicted results should be discussed as well as there are many factors that are considered for applying these findings to clinical applications. In our model, we have considered a linear elastic material property for the leaflets and their muscles. But experiments have shown that mitral leaflets are not linear. We will consider this limitation in our future studies.

4. CONCLUSIONS

In this study, we introduced a three-dimensional model to study the hemodynamic parameters of blood passing through the mitral. We made a geometry and applied the inlet pressure variation to it during a cardiac cycle. The

results can be used by the medical and biomechanical experts regarding the variation of velocity and pressure in the mitral valve leaflets during the function of the mitral valve.

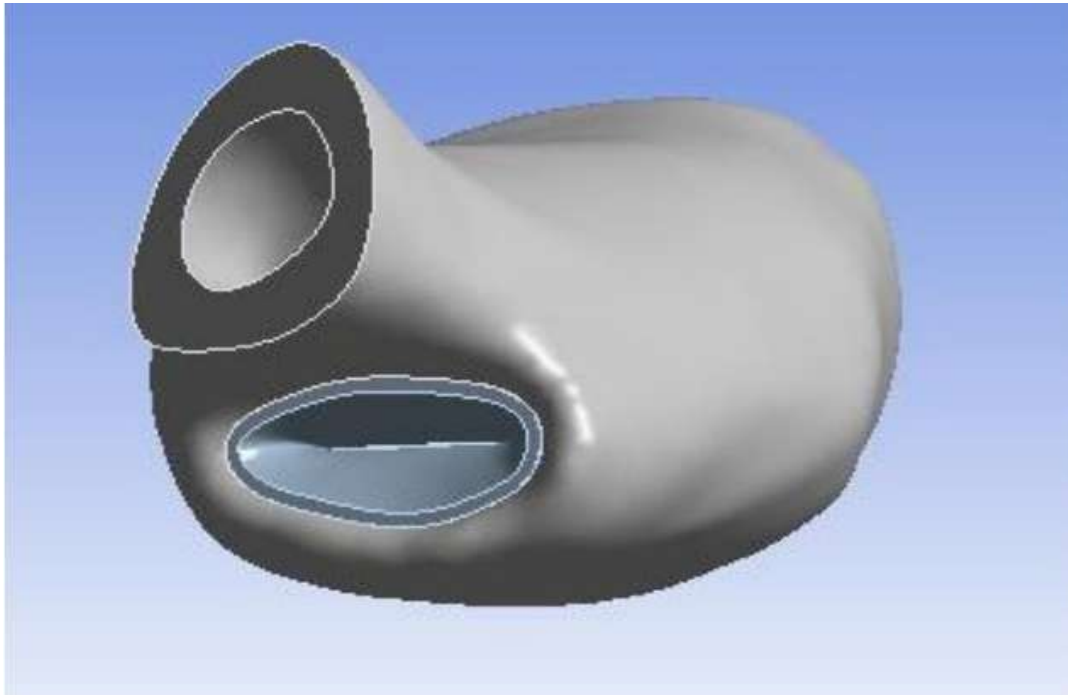


Fig.1 The geometry of mitral valve and left ventricle.

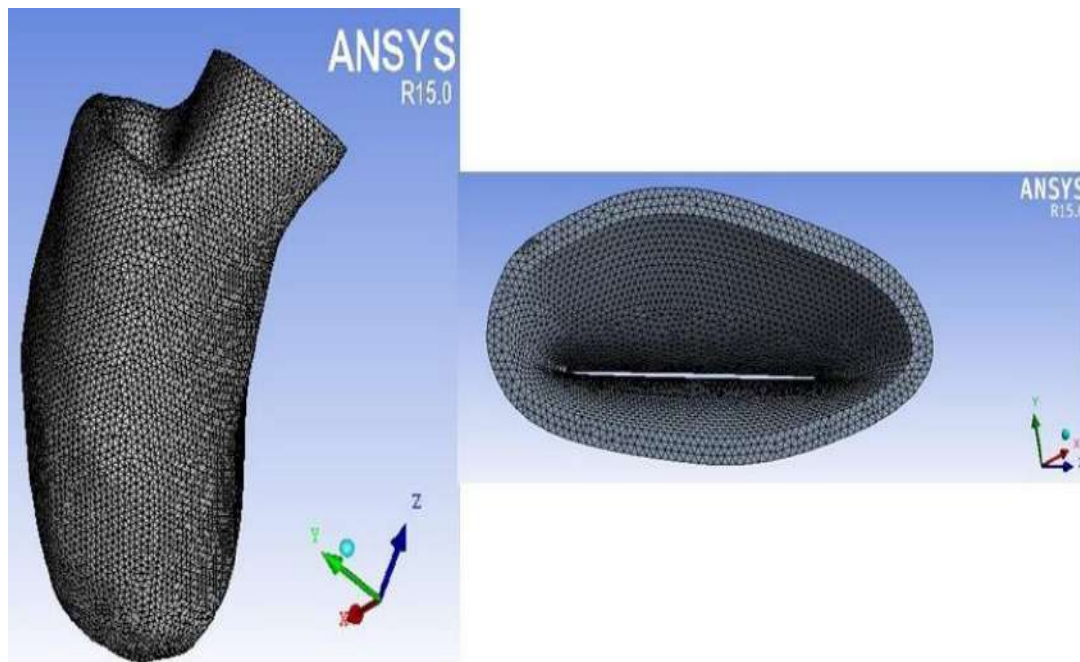


Fig.2 The mesh of the model.

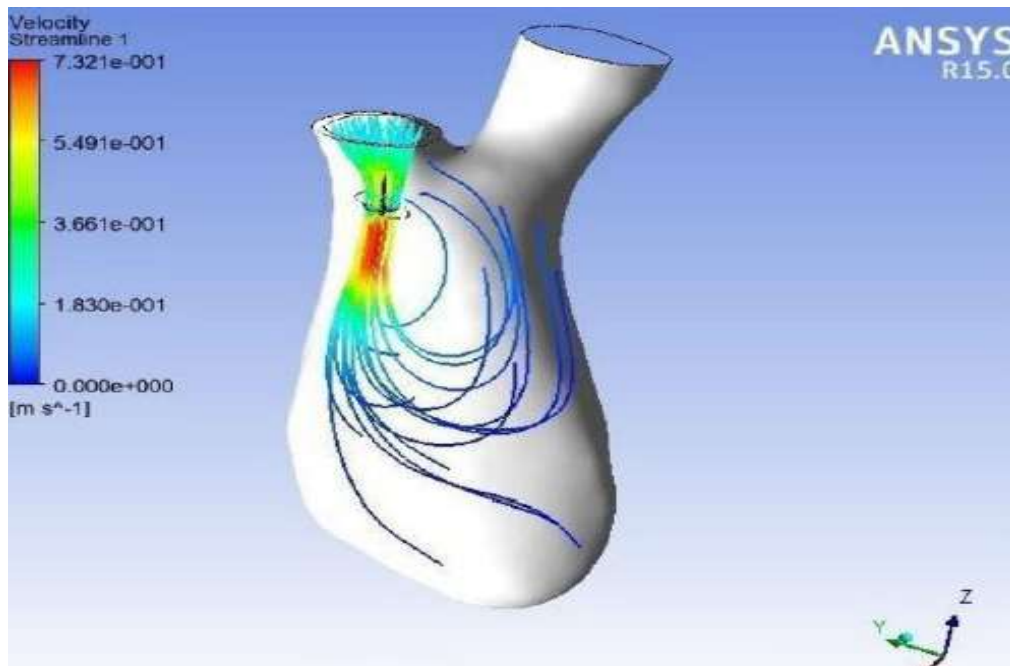


Fig.3 The velocity streamlines

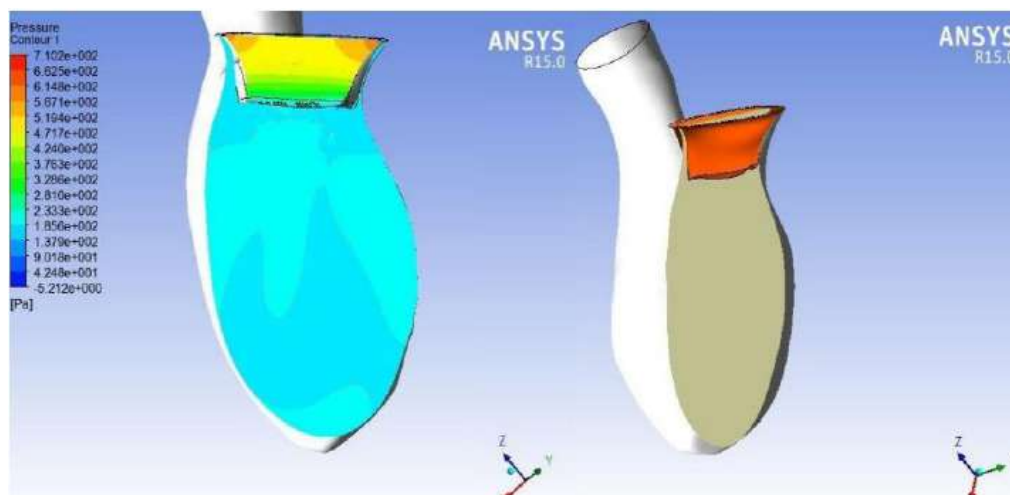


Fig.4 The pressure distribution in mitral and left ventricle.

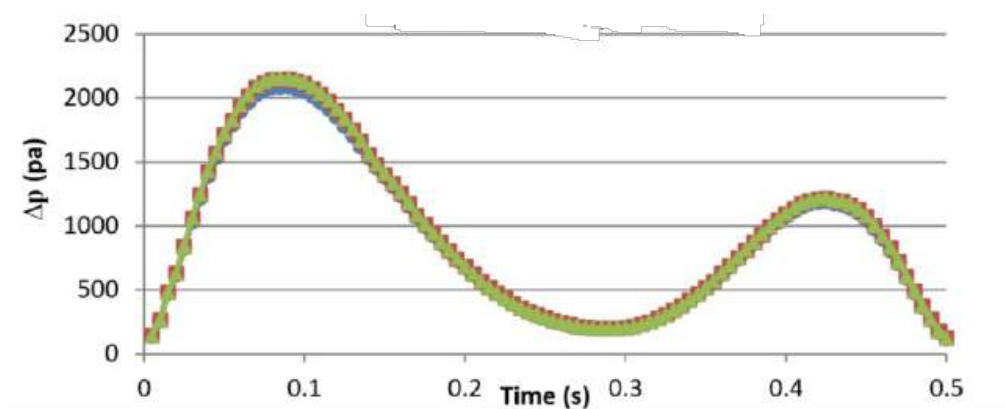


Fig.5 The difference in pressure between the inlet and outlet of the mitral.

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Assessing the Downstream Impacts of Soil Sedimentation Caused by Small-Scale Alluvial Mining in Atamo, Central Bougainville

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Abstract: The sedimentation of soils resulting from small-scale alluvial gold mining poses major environmental and socio-economic problems for the communities concerned. This study examines the extent and consequences of soil erosion caused by mountain gold mining in the Atamo area of Central Bougainville, Papua New Guinea. Using qualitative methods, including field surveys, interviews with local communities, the study documents sediment accumulation in river basins, which has disrupted natural water flows, damaged infrastructure, and altered aquatic ecosystems. The issue is further exacerbated by the presence of climate change, where irregular and extreme rainfall events accelerate soil erosion and sediment transport from mining sites into waterways. Key findings show that sediment deposition has resulted in the diversion of rivers, road deterioration, and a deterioration of water quality for human consumption. The study also highlights the lack of awareness among miners about sediment management and the absence of formal mitigation strategies. The report concludes that soil sedimentation is a threat to environmental sustainability and hinders the livelihood and mobility of the communities concerned. The document recommends the introduction of effective erosion control measures, reforestation, and regulatory frameworks to manage mining practices and protect the ecosystems downstream.

Keywords: Soil sedimentation, alluvial mining, environmental degradation, water flow disruption, Atamo, Bougainville, small-scale mining, river ecosystems

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Rodney Biri hails from the Central of Autonomous Region of Bougainville (AROB), Papua New Guinea (PNG) and is currently a postgraduate student studying soil science under Division of Agriculture and Rural Development at the University of Goroka, PNG. He also serves as a part-time tutor, tutoring undergraduate students in research, basic statistics, and soil and land management courses. Rodney has presented papers at national and international conferences, with his research focusing on sustainable land management, alluvial mining impacts, and climate-related pest management. He is attached with Center for Natural Resource Research and Development (CNRRD) and actively involved in Plant Health Clinics and agricultural training for farmers across PNG, contributing to community resilience and sustainable development

1. INTRODUCTION

Small-scale alluvial gold mining, a significant economic activity in Atamo, Bougainville, Papua New Guinea (PNG), poses major environmental and socio-economic challenges, particularly due to soil sedimentation. This activity is prevalent across many developing nations, serving as a vital livelihood source but often incurring substantial geo-environmental and socio-economic risks (Frontiers, 2025; IIED, 2004). In 2001, around 80,000 - 100,000 miners were engaged to alluvial mining producing 4.0 tons annually at the value of PGK100m and about 90% of these miners were categorized as grassroots (Susapu & Crispin, 2001). Small-scale mining has become a prevalent economic activity across various provinces in PNG over the past two decades. This sector has attracted both positive and negative criticisms, with reports highlighting its significance in local economy as well as its

adverse impacts on communities and the environment.

A study conducted by Suwamaru in 2019 discussed numerous challenges faced by local miners in the Autonomous Region of Bougainville (AROB), encompassing issues related to education, economic factors, and other livelihood impacts. Most studies conducted in other fields, particularly those assessing socio-economic settings, also identified alluvial mining activities as an alternative source of income, even for communities primarily engaged in agricultural activities such as cocoa and coconut farming.

This study is conducted specifically to understand how soil sedimentation, a direct consequence of upstream mining activities, has been profoundly affecting downstream communities and other non- miners living nearby as shown in figure 1 below. It aims to shed light on the cascading environmental and socio-economic challenges faced by these vulnerable populations due to altered river systems and compromised natural resources.



Figure1. Alluvial mining. A new livelihood activity in the Atamo community

1.1 Research Aim

To examine the extent and consequences of soil erosion caused by mountain gold mining in the Atamo area of Central Bougainville, Papua New Guinea.

1.2 Research Objective

To provide a detailed assessment of how soil sedimentation resulting from small-scale alluvial gold mining in the Atamo area specifically affects the environment and communities situated downstream.

2. LITERATURE REVIEW

2.1 Introduction

The Autonomous Region of Bougainville (AROB), a resource-rich province in Papua New Guinea (PNG), has a long history of alluvial mining, with practices deeply ingrained since colonial periods (Suwamaru, 2019). While the precise origins of small-scale mining in Bougainville are not officially recorded, it is believed to have intensified around the 1990s following the closure of the Panguna Mine, suggesting its emergence as a post-crisis livelihood strategy. This literature review synthesizes existing knowledge on the impacts of small-scale mining in PNG, specifically focusing on arguments relevant to soil sedimentation.

Despite numerous studies assessing small-scale mining impacts in PNG, the primary focus has often been on recognized mining areas in specific provinces. However, unregistered operations are widespread across the country, with a 2011 survey by Mek estimating over 43,000 grassroots individuals actively engaged in mining across 17 provinces. While small-scale mining serves as a significant source of livelihood, offering an alternative to traditional agricultural pursuits like cocoa and coconut farming (Bainton et al., 2020), its economic benefits are often overshadowed by severe environmental consequences, particularly those related to soil sedimentation.

2.2 Environmental Impacts

The environmental impacts of small-scale mining are multiple and severe, notably including deforestation, destruction of natural vegetation, exposure of topsoil, and subsequent soil erosion. Javia and Siop (2010) highlight these risks, underscoring the detrimental effects of unregulated mining practices on the environment and local ecosystems. These impacts are frequently exacerbated by miners' lack of awareness and disregard for proper environmental management. Previous studies have also noted the careless handling of toxic chemicals such as mercury by miners within PNG (Bainton et al., 2020), a practice often linked to the physical disruption of land and water bodies that contributes to sedimentation. The environmental contamination and social disruptions arising from small-scale mining are widespread, with various provinces experiencing severe effects; for instance, water contamination and habitat degradation in Sepik Province.

2.3 Water Contamination and Sedimentation

The widespread use of mercury for gold extraction by alluvial miners in PNG significantly contributes to the degradation of water bodies, leading to river and water pollution. Javia and Siop (2010) reported that approximately 80%-90% of small-scale miners utilize mercury across alluvial and hard rock sites. Romulus Masiu (2021) reported complaints from communities in central Bougainville regarding mercury contamination of their waterbodies, which was later confirmed by a NARI water quality assessment in 2023. This assessment revealed alarming levels of mercury contamination in the Bovo and Tupukas Rivers, originating from alluvial mining operations upstream. While mercury represents chemical contamination, the physical disruption of riverbeds and banks during mining, often associated with mercury use, directly causes the release of vast amounts of sediment. This leads to persistent turbidity and the physical alteration of river systems, impacting both water quality and aquatic habitats.

2.4 Regulatory Gaps and Environmental Degradation

A significant concern is that many small-scale mining operations function without proper registration and fail to adhere to national mining policies. Javia and Siop (2010) point to a lack of specific legislation governing the small-scale mining sector in PNG, unlike in other countries with similar activities. This regulatory void contributes to the proliferation of unregulated mining activities, which directly exacerbates environmental degradation, including widespread soil erosion and sedimentation. Despite some estimates of registered miners (Mek, 2011), the undocumented operations pose a substantial challenge to effective environmental management and control of sedimentation impacts.

3. METHODOLOGY

The study was carried out in the small-scale mining communities in Atamo, Eivo-Torau one of the Constituency in the Panguna District, Autonomous Region of Bougainville, PNG. Atamo is located 6° 15' S (Longitude) and 155° 26' E (Latitude) with an elevation of 1,000 masl (Figure 2)

The population of the people in this area is about 8,000. Major socio-economic or livelihood activities in the area include farming, petty trading, teaching, pmv operation and small-scale gold mining. Majority of the people are engaged in small scale mining and farming which includes selling food stuffs. This place is well known for its quantity and quality gold production from small scale mining.

The study employed a qualitative approach through field surveys and active observation to explore the impact of soil sedimentation to downstream communities. Primary data was gathered via direct observation and taking photograph as well as in-depth interviews with 20 key informants (teachers, chiefs) and structured questionnaires administered to 10 community elders and 10 primary teachers. Secondary data was obtained from existing literature on small-scale mining in PNG and other developing countries. This approach allows for in-depth understanding and interpretation of the experiences, perceptions, and perspectives of individuals and communities affected by mining activities.



Figure. 2. Map showing active Small scale mining in Atamo area. Source: Google LLC. (2025).Google Earth [software].Retrieved from <https://www.google.com/earth/>

4. RESULTS AND DISCUSSION

The observations in the Atamo area revealed significant and pervasive impacts directly attributable to soil sedimentation originating from upstream small-scale alluvial gold mining sites. These impacts manifest in several critical ways affecting the environment and downstream communities.

4.1 Deterioration of Water Quality

The continuous influx of sediment has severely compromised water quality, rendering it perpetually turbid and dirty (Biri et al., 2024). This constant murkiness indicates a high suspended sediment load, which is a direct consequence of inadequate erosion control at mining sites. Such chronic turbidity reduces light penetration into the water column, impacting aquatic plant life and the overall health of the river ecosystem (Divine Word University, 2018). Similar problems are widely reported in other developing countries, where artisanal and small-scale gold mining significantly increases turbidity and suspended solids, making rivers unsuitable for consumption and devastating aquatic ecosystems (Muringaniza et al., 2022). For instance, studies in Zimbabwe and Ghana have consistently shown that unregulated mining activities lead to substantial increases in these parameters, severely degrading water quality (Macdonald et al., 2015).



Figure 3. A river showing highly turbid and dirty water, affected by soil sedimentation residue from mining activities

4.2 Impact on Marine Life

The excessive soil sedimentation has had a devastating effect on aquatic life within the affected waterways (Biri et al., 2024). Downstream communities reported a drastic decline in fish populations, with some lamenting that

the river is now "nothing" (Biri et al., 2024). This significant reduction in aquatic biodiversity is primarily attributed to habitat degradation caused by pervasive sediment deposition, which smothers crucial spawning grounds, alters benthic environments, and disrupts the delicate aquatic food chain. Furthermore, high sediment loads can directly harm fish gills, further contributing to their diminished populations (Divine Word University, 2018). Similar pervasive issues are observed in other contexts, where mining-induced sedimentation alters aquatic habitats and leads to significant declines in fish and invertebrate populations (Masocha et al., 2019). For instance, numerous studies highlight how elevated suspended sediment concentrations can cause direct harm to fish gills, reduce growth rates, and severely impact spawning success, ultimately leading to shifts in community structure and population size (Muringaniza et al., 2022).

4.3 Damage to Infrastructure

The accumulation of soil sediment has significantly impacted local infrastructure, most notably the road network (see figure 4 A.). The road connecting various communities in Atamo, originally constructed to follow natural water flow patterns, has visibly deteriorated and broken in sections due to altered hydrology and water raise caused by sediment build-up (see figure 4.B). This poses considerable logistical challenges and safety concerns for local residents, disrupting their mobility and access to essential services.



Figure 4. a) Ariel View of disrupted water flow pattern; b) Road affected due to water flow disturbance; c) Road affected due to sedimentation

4.4 Alteration of River Flow Patterns

The soil sedimentation has directly caused the backflow of water and significantly altered the normal running river ways. Sediment deposition has led to a reduction in river channel capacity, forcing the water to seek new

paths and creating new, often unstable, water running flows. This disruption to the natural hydrology of the river system not only exacerbates flooding in certain areas but also prevents the river from following its historical course, impacting traditional land use patterns and potentially causing further erosion in newly formed channels. This situation aligns with observations in other mining regions where sediment accumulation causes problems with water flow and contributes to environmental degradation (ResearchGate, 2003; AJOL, 2018).



Figure 5. River flow pattern disrupts by continuous soil accumulation at bottom

5. CONCLUSION

The examination of small-scale alluvial gold mining in the Atamo area has unequivocally demonstrated that soil sedimentation poses a profound and multi-layered threat to both environmental integrity and community well-being. While small-scale mining provides vital income opportunities for local populations, the uncontrolled nature of these activities leads to severe environmental consequences, specifically evidenced by the pervasive impacts of sedimentation. The degradation of water quality, the decimation of aquatic ecosystems, the damage to crucial infrastructure, and the irreversible alteration of natural river courses collectively highlight an urgent need for intervention. Similar pattern of environment degradation and socio-economic challenges have been observed across the developing countries due to unregulated alluvial gold mining activities. Countries like Zimbabwe and Ghana reported degradation of water quality due to elevated turbidity and suspension of solids resulting to disrupts of natural water flows (Muringaniza et al., 2022 Masocha et al., 2019).

These findings reinforce that the problem of sedimentation from artisanal mining is not unique to Atamo but is a widespread challenge in many regions where such activities occur, often exacerbated by a lack of awareness, inadequate regulation, and limited implementation of mitigation strategies. Addressing these issues requires a comprehensive and integrated approach, emphasizing the critical importance of effective erosion control measures, the restoration of affected habitats, and the establishment of robust policy frameworks. Ultimately, safeguarding the long-term ecological health of the rivers and ensuring the sustainable well-being of downstream communities necessitates a balance between economic development and stringent environmental stewardship.

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Utilizing Non-fungible Token (NFT) Technologies to Preserve Cultural Histories and Artefacts

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Abstract: Non-fungible tokens (NFTs) are blockchain-based tokens that each represent a unique asset in digital format. It is an irrevocable digital certificate of ownership and authenticity for a given asset, that is securely stored for future authorized access. This research explored NFT technology as a solution for the universal problem of digitization writing over and erasing important Pacific histories, artefacts, and stories. The research developed methodology to harness the new technology for the social and cultural preservation of artefacts and histories. The methods used addressed the challenges with applying the technology and the challenges of capturing authentic socio-cultural histories. The new digital format has application in all the Pacific cultures and people groups for the preservation of what is culturally important and the transmission to future generations. The safe and sustainable development of the Pacific requires the adoption of new technologies in ways that integrate traditional knowledges into the new opportunities and solutions for real challenges.

Keywords: Non-fungible tokens (NFTs), Authenticity, Cultural Assets, Pacific heritage, Technology opportunity

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Rev Dr. Vili is the Vice-Chancellor of CUP and under his leadership, the university has continued to grow steadily, celebrating its 21st year in 2025. He credits this progress to God's grace and the dedication of the CUP community. In addition, he serves as Director of International Affairs, actively engaging in strategic partnerships and Memoranda of Understanding (MOUs) with institutions across the United States, New Zealand, Australia, Samoa, and Papua New Guinea. Dr Saulala's work is driven by his faith, vision for academic excellence, and unwavering belief in the transformative power of Christian education. As CUP moves forward, he remains committed to fostering growth, international collaboration, and strong leadership in the Pacific.

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1. INTRODUCTION

The Pacific islands are exposed to many natural and social challenges that destroy and erode Pacific ways of life. Tsunamis, volcanoes, typhoons, and rising sea levels are natural hazards that all too regularly destroy whole villages and islands so that there is nothing left. More subtly digitization and instant communications are written over and erasing important Pacific histories, artefacts, and stories [Kaji et. al]. The internet and the mobile phone have brought many social advantages, but they also bring influences that replace social and cultural relationships that support the very fabric of being Pacific [Campbell et. al]. In this research we explore the potential for using non-fungible token (NFT) technology to preserve important artefacts and stories for the next generations. An NFT creates a unique representation of something and cannot be replaced.

The challenge and exploration in this research are identifying the features of NFT technology that best fit socio-cultural preservation and assessing the worth of such a project [Johnson et. al]. Contemporary technologies can be used to sustain or to destroy Pacific lifestyles and ways of living. If precious artefacts and memories are committed to digital technologies what are the chances that they too will be lost, destroyed or become redundant and inaccessible? There is also the question of methodology and how to procure, collect, and select artefacts. What is important in one village may not be so in another. To resolve the issue, we chose to implement a grounded theory so that the preservation of artefacts would be systematic and yet inclusive of the differing perspectives and expectations of custodians [Glaser et. al]. The methods used addressed the challenges with applying the technology and the challenges of capturing authentic socio-cultural histories.

This paper is structured to first review NFT technology and the potential to preserve socio-cultural artefacts. The third section then discusses grounded methodology for collecting socio-cultural data for preservation. The fourth section explores the scope of using technology to effectively store and protect sensitive information. The issues of data integrity, access, and protection are discussed. The fifth section evaluates NFT technology as a viable option for preservation. The research concludes by restating the assertion that the safe and sustainable development of the Pacific requires the adoption of new technologies in ways that integrate traditional knowledges into the new opportunities and solutions to meet real survival challenges.

2. NFT TECHNOLOGY

A fungible item is a product or commodity that is replaceable by another identical item or a mutually interchangeable item. Consequently, a non- fungible item is the opposite where the item is unique. A non-fungible token (NFT) is a unique digital identifier that is recorded in blockchain technology and is used to certify ownership and authenticity [Chen and Zhang]. This means any digitized item can be preserved in a unique form and with a unique identifier for ownership. It cannot be copied, changed, substituted, or subdivided to alter the original record. However, ownership may be transferred to, for example, a library or museum for safekeeping and public viewing. These features make NFT technology applicable to the preservation of social, cultural, and linguistic artefacts. NFT is an evolving opportunity for artifact preservation but must still overcome acceptance and legal hurdles to be fully useful [Morales et. al]. The legal rights conveyed by an NFT can be challenged because the ownership of an NFT as defined by the blockchain has no inherent legal meaning and does not necessarily grant

copyright, intellectual property rights, or other legal rights over the associated digital file. This is a current limitation that is expected to change overtime and through legal challenges. Hence, an NFT does not currently restrict the sharing or copying of the associated digital file or prevent the creation of links that reference identical files, but it does register a unique identifier.

NFTs can be readily created by anyone with access to the Internet and with money to invest [Zhang and Kumar]. They can be created by anybody and require little or no coding skill but rather compliance with easy-to-follow workflow forms. The NFT is a unique identifier that references digital files such as artworks, photos, videos, audio files and so on. Hence, the NFT is created and registered and then points to the associated file or files. The creation of an NFT involves several key steps for registering the unique identifier on a blockchain of choice, and the creation of the associated files. First, the artefact is selected and saved for later linking to the unique identifier. Then a blockchain platform that supports NFTs must be selected and the workflow system understood [Perez et. al]. The platform guides the user through the process of minting the NFT, which involves generating a unique token that verifies ownership and authenticity on the blockchain. The final step is to link the associated file or files. Each platform has associated costs that are paid in cryptocurrencies. The associated costs are for gas fees for minting and transactions, and if promoted to reach a wider audience there are further fees.

To create greater consistence for interoperability between NFT blockchain platforms and for simplifying the transfer of ownership rights there are several standardization protocols [Thompson et. al]. These protocols have been promoted for interoperability such as the first widely accepted non- fungible token standard, ERC-721 [O'Connor et. al]. It had an early version of the standard that was updated to formalize to define the term Non-Fungible Token (NFT). It also established a standard for smart contracts where tokens have unique attributes and ownership details, ensuring no two tokens are alike. There are also derivative standards such as Ethereum ERC-1155 that are increasing the reach and usability of NFTs [Kumar et. al]. NFT is an evolving and developing technology that is emerging from research and commercialization of blockchain technologies. Many of the related projects are pioneering works that allow versatility and the emergence of numerous use cases, such as for museum and archival works [Chen et. al]. The ERC-721 is recognized for having fundamentally changed the use of digital verification, authentication, and ownership. Hence, we see NFT technology as being an edge cutting technology that can easily be used in the Pacific to preserve artifacts, histories, and linguistic forms. Standardization and greater numbers of service supplier options are making the technology more accessible and easier to use.

3. DEVELOPING METHODOLOGY

The research developed methodology to harness the new technology for the social and cultural preservation of artefacts and histories. To enter the research field a Grounded methodology was adopted and developed to manage the scope of many different data types [Corbin et. al]. Grounded theory is a qualitative research methodology focused on developing theories directly from systematically gathered and analyzed data. The theories we were looking for are constructs that best capture artifacts into categories and manageable data groups for future access. Unlike traditional approaches that start with a preconceived hypothesis or design, grounded theory emphasizes inductive reasoning, allowing concepts and theories to emerge organically through close examination of participant experiences or phenomena by the participants and the researcher [McGhee et. al]. It allows listening to the participants and systematic emergence of categories and themes to collect and to store the stories and other artefacts. Researchers typically collect data through conversations, observations, or documents, and then engage in active coding processes—such as open, axial, and selective coding—to identify patterns, categories, and relationships within the data [Charmaz]. This iterative process continues until the researcher reaches theoretical saturation, where no new insights are emerging.

The main purpose of Grounded theory is the creation of theory by discovery from data. The theory creation mechanism is an endless loop of data collection, and critical reflection, and cessation of the loop when no new relationships are being discovered [Lee and Kim]. It is a proactive and intentional methodology that seeks to discover valuable relationships and their representation as meaningful abstractions. This is done by analyzing collected data to discover social and behavioural patterns in relation to guiding issues and problem statements. Theory is systematically generated to account for patterns of behaviour, stories, and material artefacts. The theory is relevant for the story tellers and narrative but remains problematic for those

involved. The theories are open to revision and amendment by data and feedback and represent a continuous cycle of emergent discourse [Patel et. al]. By emphasizing constant comparison and refinement, Grounded theory helps researchers build a robust framework that is deeply rooted in empirical evidence but is sufficiently coherent to carry forward holistic understandings of the core story lines and ways many people view diverse artefacts. The methodology is widely used across social sciences, nursing, education, and other fields, where understanding complex, nuanced human behaviors and social processes is essential. It systematically applies sets of methods to generate an inductive theory about a substantive area so that it may be communicated, opened for viewing, and made accessible. Grounded theory facilitates the emergence of theory, and it allows researchers to inductively theorize meaningful relationships from the data context. The primary goal of grounded theory is to produce a well- grounded, contextually relevant theory that explains how and why a particular phenomenon occurs. It delivers a framework in which communication may occur, and the diversity of data types have representation. It is particularly useful in areas where existing theories are inadequate or nonexistent. The following simple sequence defines researcher actions [Mills et. al]:

- collect data
- identify key pivot points
- code by method (see Table 1)
- form concepts
- create categories
- actively use the theory-data loop until saturation occurs

By emphasizing constant comparison and refinement, grounded theory helps researchers build a robust framework that is supported by empirical evidence. Table 1 gives a summary of required data analysis actions [Denzin et. al]. Prior to data analysis data collection tools and techniques are prepared and made ready for the field work.

Table 1. Data analysis actions.

Data Analysis	Action
Open Coding	Break down, examine, conceptualize, categorize data
Constant Comparison	Compare emerged codes against new and existing ones for data reduction
Axial Coding	Assemble and establish links between concepts to create broader themes and theme categories of recurring, steady, major and minor
Selective Coding	Identify main themes, concern or problem
Core Category Consolidation	Compile all evidence
Theoretical Saturation	Stop data collection & analysis. No new information is emerging.

4. PRESERVING SOCIO-CULTURAL ARTEFACTS

Preserving socio-cultural artefacts is essential for maintaining the historical identity and cultural heritage of communities [Lee and Patel]. Artefacts include traditional clothing, tools, artwork, and religious items. Also, today digital photos, recordings, writings, and other memorabilia capture the histories. These serve as tangible links to the past, offering insights into the customs, beliefs, and lifestyles of different generations. Proper preservation ensures that future generations can learn from and appreciate their cultural roots and observe changing social expectations and ways. Intergenerational connections can foster a sense of continuity, identity and pride within communities [Garcia and Nguyen]. Besides the many tangible artefacts that contribute to cultural heritage and community there are intangible artefacts such as oral histories, lived recollections of events and relationships, and the fabrics found in stories and songs. These intangible elements are critical for the interpretation of artefacts, understanding of contexts, and enlivening material items.

One of the key aspects of preserving socio-cultural artefacts involves careful conservation techniques [Lee et. al]. This includes collection, selection and storage. For tangible artefacts controlling environmental

conditions such as temperature, humidity, and light exposure are critical to prevent deterioration. Similarly with non-tangible artefacts usually held in digital formats consideration of magnetic and electrical interference, host material lifetimes, and accessibility when technologies and formats change. Additionally, employing non-invasive conservation methods helps maintain the artefacts' integrity. Proper storage in archival-quality materials and periodic maintenance is vital to prevent damage from pests, mold, or physical wear and tear. Cultural institutions such as museums, libraries, art galleries, and archives play a crucial role in the preservation process. They utilize specialized facilities and expertise to safeguard artefacts while making them accessible to the public for educational and research purposes. Collaborative preservation efforts with local communities also ensure that cultural artefacts are maintained with respect for their original significance and socio-cultural dignity.

Raising awareness and the public profiling of socio-cultural artefacts is vital for their preservation. Promotion enhances the importance of the artefacts and the care they can expect. High profile items receive the greatest level of care whereas other less prominent items can fall into neglect and to destruction [Rivera et. al]. Educational programs, exhibitions, and digital archiving can help highlight their value and encourage active use. By fostering a collective sense of responsibility, societies can better protect their cultural heritage, ensuring these artefacts continue to tell their stories for generations to come. Digitally stored socio-cultural artefacts, including NFTs, require special attention for preservation. The potential for damage, loss, corruption, and theft is high. Digital works can be stored on physical media or placed in the Cloud for storage [Zhang et. al].

Physical media has the same risks as any physical artefact in terms of exposure to detrimental natural effects, degradation of host materials but also technology obsolescence. Cloud storage has the advantage of remote storage and multiple images for preservation. The disadvantages are service costs and supplier integrity but many of the physical storage risks are removed.

5. IS AN NFT PROJECT WORTHWHILE?

The use of non-fungible tokens (NFTs) to preserve social, cultural, and linguistic artifacts is a problematic that has strengths and weaknesses. NFTs are blockchain-based tokens that each represent a unique asset in digital format. Linked to the token are the related artefact files which may be of any type. As a new and evolving technology, NFTs hosts are developing applications and strategies to overcome some of the earlier and current operational limitations. Rapid growth of NFT marketplaces and platforms has pushed developers to resolve many challenges and to make it easier for non-technical people to own NFTs. However, the technology still faces challenges around cost, copyright issues, and host stability. As the ecosystem matures, ongoing developments aim to address these concerns, making NFTs a dynamic and transformative repository for digital artefacts with the potential to reshape how ownership and value are managed in the digital age. Table 2 summarizes the key strengths and weaknesses of NFTs when used to preserve artefacts [García et. al].

Table 2 summarizes the key strengths and weaknesses of NFTs

Strengths	Weaknesses
Digital Provenance	Setup Costs
Blockchain Security	Digital Obsolescence
Global Access	Legal and Copyright Issues
Ownership Verification	Volatility
Standardization	Limited Physical Links
Cost-Effective Storage	Prior Art Risks
Fractional Ownership	Accessibility Barriers
Preservation Replicas	Legal Rights
Enhanced Engagement	Fakes and Scams
Organization Support	Integrity Sensitivities

The main question to now answer is if an NFT project is worthwhile? The technology is new and rapidly evolving into more usable formats with the potential to create universal digital storage and archival capacities. It also has security and ownership features that permit inter- generational transfer of knowledge. The technology architecture does not limit the data types or file scopes that maybe attached to the unique identifier allowing

substantial retention of archival information. These value propositions suggest that an NFT project can offer distinctive utility value for the retention and storage of archival information. The grounded methodology for collecting and preparing socio-cultural and linguistic information outlined in section 3 builds a strong and active community of contributors who share in the knowledge construction and long-term engagement. The technology coupled with a workable implementation methodology presents a feasible case for adoption.

We see an NFT project as being a partnership project that takes an emerging technology as a long-term vision to create an important opportunity for preserving our histories. As Table 2 suggests it is not a perfect solution but many of the negative risks are less than the material risks of natural disaster, digital value stripping, and total loss that have occurred in recent years. NFT is an opportunity to secure part of our heritage, but it is not a complete answer. The NFT project must proceed in partnership with other projects that are already preserving artefacts, oral histories, and language in digital archives and living systems such as school curriculums and local customs. However, to ignore the NFT technology is to limit what may be passed to future generations. It is a current opportunity and one of the paths to the future.

6. CONCLUSION

The use of non-fungible tokens (NFTs) to preserve social, cultural, and linguistic artifacts is a problematic that has strengths and weaknesses. Many of the strengths are greater than the vulnerabilities exposed by the recent natural and digital destruction of Island lifestyles and memorabilia. This research explored NFT technology as a solution for the universal problem of digitization writing over and erasing important Pacific histories, artefacts, and stories. The research developed methodology to harness the new technology and to provide a context for implementation. The new digital format has application in all the Pacific cultures and people groups for the preservation of what is culturally important and the transmission to future generations. The safe and sustainable development of the Pacific requires risk taking and the adoption of new technologies in ways that integrate traditional knowledges into the new opportunities as solutions for real challenges.

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Applying Design Thinking Methodology to include meaningful Social and Cultural input to Mobile phone application software development

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Abstract: Today everyone has access to mobile phone technologies and the use of mobile technologies for business, socializing, and entertainment. However, many mobile phone applications are generic and lack sensitivity to the social and cultural expectations of Pacific users. In this research we explored the design thinking research methodology to design inclusive mobile phone applications. The integration of traditional knowledge, customs, languages and forms of art are critical to developing mobile solutions for today's challenges. This research contributes methodology, and the elaboration of methods in action to solve communication problems in current mobile phone applications. It also challenges many of the contemporary mobile phone application development methods and theories to be user centric. The harnessing of mobile technologies for the safe and sustainable development of the Pacific requires sensitivity to the Pacific and the many cultures, languages, and customs that new technologies are to host and not replace.

Keywords: Methodology, Mobile Phone, Applications, Software development, Cultural sensitivities

Author's Biography:

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The Rev Dr Saulala travelled from Tonga for his undergraduate education at the University of Auckland and then Florida and California USA, to complete diplomas and bachelor's degrees. He then returned to the Pacific and completed a Master of Business Administration (Management) from the University of the South Pacific in Suva, Fiji in 2011. He then began higher research degrees earning a Master of Philosophy with a thesis titled: "Comparing Banking and National Financial Data: A Case Study", where he analyzed the financial performance of the ANZ Bank in Tonga from 2008 to 2015. He then completed a Doctor of Philosophy (PhD) with a dissertation titled: "An Evaluation of Universities' Management Systems and Business Systems". His research involved a comparative analysis of the systems used by Melbourne University, Edith Cowan University, Auckland University of Technology, and Christ's University in Pacific.

Rev Dr. Vili is the Vice-Chancellor of CUP and under his leadership, the university has continued to grow steadily, celebrating its 21st year in 2025. He credits this progress to God's grace and the dedication of the CUP community. In addition, he serves as Director of International Affairs, actively engaging in strategic partnerships and Memoranda of Understanding (MOUs) with institutions across the United States, New Zealand, Australia, Samoa, and Papua New Guinea. Dr Saulala's work is driven by his faith, vision for academic excellence, and unwavering belief in the transformative power of Christian education. As CUP moves forward, he remains committed to fostering growth, international collaboration, and strong leadership in the Pacific.

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Dr. George Maeakafa is a distinguished scholar and practitioner in the field of Forensic Investigation in Computer Science. His PhD is in digital forensic sciences. He has published extensively in peer-reviewed academic journals and international conferences, including contributions to IEEE, Google Scholar-indexed journals, and various professional and university-hosted symposiums and proceedings. His research

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1. INTRODUCTION

The mobile phone has become a universal technology for business, socialization, and entertainment. It is universally accessible, readily accessible, and in people's hands for instant communication [Chen and Zhao]. These utility features are moderated by the service quality and the functionality of applications that may or may not be helpful to the user's expectations. Often the in the Islands the Internet connections can be unpredictable but also the content and intentions of the application information are unacceptable. Unacceptable content may include phishing attacks, bullying, and offensive materials [Huang et. al]. Technology hence opens opportunities that facilitate a better quality of life, but they must be balanced with the drag factors of potential social, economic and personal harms. Our attention is on the development of software for mobile phone applications and the research question, In whose interest has the application been developed?

Many contemporary software development methodologies claim to be customer or user centric. A more careful analysis of these methodologies shows that most are developer centric and the customer or user is only a theoretical construct or figurative symbol [Martinez et. al]. Most methods talk about consultation at different phases in software development, but the feedback is interpreted into developer language and constructs. Much of the feedback from customers and end users raises problems with the software application, intended use and performance expectations that fall beyond the developer's theoretical framework for solutions therefore a cookie cutter output is delivered. To be cost effective a developer must work with templates and standardized methods to deliver many outputs in the working week. Social and cultural sensitivities, difficult logical contradictions and non-standardized alterations remain out of scope. We believe that the safe and sustainable development of the Pacific requires customized mobile phone applications that not only meet the user expectations for technical performance but also carry forward languages, histories, and cultural expectations.

In this research we evaluated contemporary software development methodologies and then introduced a new theory for software development. The Design Thinking (DT) methodology has a long history in the Arts but has little attention in software development, engineering and the sciences [Brown 2021]. DT requires emersion in the context of intended software use to first identify the user's current concerns, aggravations, anger and software points of failure, to initiate the search for solutions. The starting point is not requirements as in most contemporary methodologies but rather the emotionally charged perceptions of dissatisfied users. DT then provides a structured four phase methodology to bring application solutions for real people. The paper is structured into sections that present contemporary software development theories. Section 2 evaluates these theories using the research question and the DT solution is presented in Section 3. Section 4 has a use case from our field work developing a mobile phone application for a local community that demonstrates the DT methodology in action. Finally, we conclude that it is time for a change and for the development of social, cultural, and user- friendly software applications.

2. SOFTWARE DEVELOPMENT METHODS

Software development methods are structured approaches used to plan, execute, and manage the making of software applications [Garcia and Chen 2021]. The methods theoretically allow the management and control of the competing ambitions of the developers and the intended users by setting scopes, requirements, and negotiated outcomes. However, economics and capability impact the degree of flexibility, variability and user satisfaction that may be delivered. The following subsections briefly review common methods and in the following section 3 they are analyzed to answer the research question.

2.1 SDLC

The Software Development Life Cycle (SDLC) is a long-standing structured process used for planning, creating, testing, and deploying software applications [Garcia and Chen 2021 IEEE]. It has been the starting point for many other methods. The main stages include:

- Requirement Gathering and Analysis where the needs of users and stakeholders are identified and documented.
- System Design is where architectural and detailed design specifications based on requirements are created.
- Implementation (Development) requires writing the actual code and building the software according to the design.
- Testing verifies that the software functions correctly and is free of defects through various testing methods.
- Deployment releases the software to users making it operational.
- Maintenance provides ongoing support, bug fixes, and updates.

2.2 Waterfall

The Waterfall model has many SDLC features and adds a linear set of steps with sequential processes that manage the creation of software applications [7]. In this approach, each phase—such as requirements gathering, design, implementation, testing, and maintenance—must be completed before moving on to the next. It emphasizes thorough documentation and a clear, fixed scope, making it suitable for projects with well-defined requirements but less adaptable to changes during development. End users are typically consulted primarily during the initial requirements gathering phase to define the project scope and specifications. However, once the requirements are set and the project moves into subsequent phases such as design and implementation, user involvement tends to be limited or minimal. The structured nature does not usually facilitate ongoing user feedback or involvement throughout the development process. End users are generally not consulted during later stages such as testing or deployment, which can make it challenging to adapt to changing needs or identify issues that only become apparent after extensive development.

2.3 RAD, Agile

Rapid Application Development (RAD) is a software development methodology that emphasizes quick development and iteration of prototypes over extensive planning and documentation [8]. The primary goal of RAD is to deliver functional software rapidly by involving users throughout the development process, allowing for continuous feedback and adjustments. This approach is particularly suitable for projects where requirements are expected to evolve or are not fully understood at the outset, enabling developers to adapt quickly to changing needs and priorities. RAD typically involves the use of iterative development cycles, where small portions of the system are built, tested, and refined in quick succession. It relies heavily on user involvement, often through workshops and frequent demonstrations, to ensure that the final product aligns closely with user expectations. By prioritizing speed and flexibility, RAD can significantly reduce development time and improve user satisfaction, making it a popular choice for prototypes, small to medium-sized projects, and applications requiring rapid deployment.

Agile development methods adopt many of the features in RAD. It focusses on iterative progress, collaboration, and flexibility [Smith and Lee]. Agile approaches, such as Scrum or Kanban, break down projects into smaller, manageable units called sprints or cycles, allowing teams to deliver functional components incrementally. This method encourages frequent feedback, continuous improvement, and adaptability to changing requirements, making it ideal for dynamic projects where customer needs may evolve. Continuous user engagement is a core principle. Agile emphasizes delivering small, functional parts of the software in short cycles called sprints or iterations, typically lasting from one to four weeks. This allows teams to continuously refine and improve the product based on user input and changing requirements, making the development process more responsive and efficient [Kim et. al]. Agile methods foster close collaboration among developers, stakeholders, and end users,

enabling faster delivery of valuable features and a higher likelihood of meeting evolving user expectations.

3. STRENGTHS AND WEAKNESSES OF METHODS

Selecting a development method depends on a project scope, budgets, problem complexity, and degrees of flexibility in outcomes. Some methods are best suited to the mass production of software applications and others to customize for end user purposes [Software]. Our research question, In whose interest has the application been developed? Guides the analysis of each method introduced in section 2. Table 1 provides a comparative analysis.

Table 1. Interests' management in software development methods. Features

Features	SDLC	Waterfall	RAD/Agile
User	Figurative Abstract	Figurative Abstract	Figurative Participant
User Involvement	Low	Low	High
User Feedback	Low	Low	High
Data Processing	Developer	Developer	Negotiated
Cost Efficiency	High	High	Low

4. A DESIGN THINKING SOLUTION

Table 1 shows that the opportunity to customize and implement Pacific content into mobile phone applications is limited by the methodology selected. The SDLC and Waterfall methods are developer centric, and all data representations are reinterpreted into the methodology. A user is a figurative abstraction that is made to fit the method requirements regardless of variations or ill-fitting expectations. The RAD/Agile methods are more accommodating of user variations and expectations but can become expensive and resource challenged. The methods themselves are end-user-facing but encounter the same economic and capability challenges SDLC and Waterfall manage by selecting and dictating requirements. The problem each method faces is in defining and choosing the requirements to be implemented. Requirements become rapidly abstracted, captured into developer languages, and separated from the user expectations for satisfying use. The solution is to get closer to the user expectations and the personalized use they wish to make of a software application [Boehm].

Design Thinking (DT) is a methodology that starts any project by becoming emotionally connected to the challenges people face in the use of technology [Liedtka]. The researcher and developer are not looking for requirements but rather where people hurt, feel, and emotionally connect to the software and the world around them through software. In this way a solution cannot be forced onto users as an interpretation of what the developer thinks is best or is economically viable for a project. The first phase of DT is emersion where primary and secondary data must be collected from the potential users of a software application and the context of use [Plattner et. al]. The driving force is the human emotional energies that are looking for a software solution. The second phase of DT is to define what expectations the users have for potential solutions. Eight sequential resolution actions are taken with the users to clarify and define their expectation for solutions. In phase 3 the processes for ideation are followed with the users to list ideas for what the solutions can look like, and then to prioritize them for the best ideas that cohere with their perceptions for experiential satisfaction [Kolko]. Phase 4 takes the top three most diverse satisfaction ideas and produces prototype applications for the users to test and to decide the best fitting solutions. In phase 5 the users can choose and own a solution [Brown and katz 2022].

5. USE CASE EXAMPLE

The local community has three major festivals per year to bring together members and to reach out into the wider community. These have been very successful events in the past but have now grown rapidly in popularity and stakeholders. The festivals each feature a week of events that are in multiple locations, often simultaneously, and represent the entity groups within the community. These groups represent different villages, churches and traditional tribal affiliations. There is food, dance, music, competitions, and plenty of festivity but each stakeholder requires authentic communication to represent their own cultural identifications. In the past organization was done

through elders, and verbal communication. However, conflicts and time clashes arose last year, creating confusion for the participants and the organizers. A project team was formed and the creation of a mobile phone application proposed as the solution.

We immediately advised a DT development approach and the participation of representative experts from each cultural and functional elements of the festival. This was not what the project team expected. They expected a cookie cutter app model that they could take and use as an instant solution to all the previous problems. We had to first promote the value of a DT approach to meet the cultural and communication expectations of the whole community, and the possibility of arriving at a spot where the maximum number of clear communications could occur within the diversity of expectations. DT phase 1 started using experts from each of the cultural, social, administrative, performance, and stall holder representations. This was 45 people in total, and we divided them into 5 areas of responsibility and held communication sessions with each. Because we were only listening to expert opinion ethics approval was given. It also meant we could listen to problems, points of conflict, and feel the positive and negative energies around each of the issues. Phase 1 data collection included [Schrage]:

- Walk through to understand each expert network relationships
- A day in the life of each expert
- Generative sessions and hurt points
- Culture expressions and expectation articulation
- Conversations with each expert
- Secondary data from the previous website

In phase 2 all the responsibility groups came together to interpret the perspective data of phase 1. The following facilitation techniques were used in a progressive sequence to formulate the visualization of a solution [Brown and Katz]:

- Insight Cards
- Affinity Diagrams
- Conceptual Maps
- Guiding Criteria
- Personas
- Empathy Maps
- User Expectation list
- The solution visualization

In phase 3 the visual solution of phase 2 is now an artefact and aspiration for implementation. The full group now brainstorms ideas for implementation. These are listed and then prioritized using phase 2 guiding criteria, personas, and value network coherence. The strategic matrix formed has the top 10 performing ideas and 3 are to be chosen for their diversity, distinction and potential community appeal. Phase 4 takes the three diverse ideas and builds three mobile phone app prototypes. We used Google Dev Suite to build and Play Store to host the prototypes for the full group to download and test [Brown et. al, Smith et. al]. In phase 4 the user testing and feedback occurred. Consensus occurred when voting mechanisms were added to the administration elements so everyone could bid on the best locations and time slots. Similarly, the user interface added the 9 different ethnic requirements by a choice menu to arrive at one app for release to the community in phase 5.

6. DISCUSSION

The DT mobile phone application development methodology has strengths and weaknesses as do the other methods reviewed. Our research question guided us towards questioning who owned the apps and whose interest was the app released. The core issues of value erosion and cultural replacement in digital media can be addressed.

The DT methodology breaks from the software development traditions of cookie cutter mass production software and pushes extreme end user participation and ownership. The RAD/Agile methods present middle ground in the tension between developer and end user property ownership. Each method attempts to bring the user perspectives into software development while maintaining degrees of control over the build processes and content ownership. Given the technical and professional expertise required to produce a commercial mobile phone app developers must play a significant role. However, we challenge the assumption that social, cultural, and linguistic values must be suspended when an app is produced. DT is an extreme case where full control can be handed to the end user and inclusive sensitivities included.

DT can produce inclusive mobile phone apps but has the drag factor of complexity. The developers and process facilitators must immerse themselves in the social context of technology use and represent the user's perspectives in the users' own conceptual languages. SDLC and Waterfall remove the complexity by simply enforcing the app development methodology to produce a cost-efficient developer product. The DT use case demonstrates and shows inclusive software development complexity. It requires multiple techniques and phases to build applications that represent and are owned by the end users. To transfer ownership of the app and the content is a complex facilitation process in which the participants negotiate and accept compromises that are socially constructed. This is a different perspective than the requirements modelling of SDLC that reconstructs the social and cultural realities into technical concepts and linguistic structures. The cost, however, is time and resources. In DT most resources focus on facilitating end user participation and knowledge building exercises. Little time is spent on the build of prototypes that is passed to automation design and coding tools that only require supervision of a developer.

Table 2 compares DT as a software development methodology with the others previously reviewed.

Features	SDLC	Waterfall	RAD/Agile	Design Thinking
User	Figurative Abstract	Figurative Abstract	Figurative Participant	Central motivator
User Involvement	Low	Low	High	High
User Feedback	Low	Low	High	High
Data Processing	Developer	Developer	Negotiated	User
Cost Efficiency	High	High	Low	Low
Flexibility	Low	Low	High	High
Cultural Engagement	Low	Low	Mediated	High
Linguistic Sensitivity	Low	Low	Mediated	High
Emotional Engagement	Low	Low	Low	High

7. CONCLUSION

Mobile phone technologies have become a universal phenomenon that everyone has access. However, questions must be asked regarding the positive and negative impacts of communication opportunities. Sensitivity to the user social and cultural contexts is often absent from many mobile phone applications that are generic, mass-produced, and owned by other people and interest groups. In this research we have briefly reviewed the results and shown that alternative software development methods are available to customize, sensitize, and pass ownership of the app to the end user. This is particularly important to Pacific users who represent many social, cultural, and linguistic traditions that are seldom recognized in generic software apps. The integration of traditional knowledge, customs, languages and forms of art are critical to developing mobile solutions for today's challenges. This research contributes methodology, and the elaboration of methods in action to solve communication problems in current mobile phone application development. It also challenges many of the contemporary mobile phone application development methods and theories to change the way they work. The harnessing of mobile technologies for the safe and sustainable development of the Pacific requires sensitivity to the Pacific and the many cultures, languages, and customs that new technologies are to host and not replace.

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Animal Health Capacity Building in Papua New Guinea: A Comprehensive Approach to Strengthening Animal and Wildlife Health Systems Through Biosecurity, One Health, and Cross-Border Collaboration

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Abstract: Papua New Guinea (PNG) occupies a critical position in regional biosecurity as a biodiversity hotspot and geographical nexus between Southeast Asia, Australia, and the Pacific Islands, yet faces unprecedented challenges in animal and wildlife health management. This comprehensive review examines the interconnected challenges confronting PNG's animal health systems and their impacts on public health, economic stability, food security, cultural preservation, and regional biosecurity. Through systematic analysis of geographical vulnerabilities, infrastructural constraints, and systemic limitations, this review reveals critical gaps in PNG's capacity to manage emerging infectious diseases. The research identifies four strategic pillars for transformation:

1. Developing a sustainable veterinary workforce through innovative training and community-based networks,
2. Establishing robust disease surveillance systems integrating traditional knowledge with modern technologies,
3. Strengthening diagnostic capabilities through strategic partnerships and point-of-care solutions, and
4. Fostering cross-sectoral collaboration through One Health frameworks and transboundary partnerships.

Recent disease incursions, including Newcastle Disease (ND) and African Swine Fever (ASF) outbreaks, demonstrate PNG's vulnerability and the urgent need for enhanced preparedness. With only four qualified veterinarians serving over 9 million people and limited diagnostic capacity concentrated in Port Moresby, PNG's current animal health infrastructure is inadequate for addressing transboundary disease risks threatening national and regional security. The review emphasizes exceptional opportunities for PNG-Australia-Indonesia-Pacific Island Countries collaboration for mutual biosecurity enhancement, coordinated disease prevention, and knowledge exchange across shared ecological boundaries. By adopting integrated One Health approaches that honour indigenous knowledge systems, leverage digital technologies, and establish strategic multilateral partnerships, PNG can transform its animal health landscape from a regional vulnerability into a cornerstone of Pacific biosecurity. This framework addresses immediate capacity gaps while positioning PNG to manage climate-induced disease emergence, protect culturally significant species, ensure food security for rural communities, and contribute to global health security. The study provides a comprehensive roadmap for sustainable animal and wildlife health system development with significant implications for public health resilience, economic development, biodiversity conservation, and regional stability across the Asia-Pacific region.

Keywords: animal health systems, capacity building, One Health, biosecurity, wildlife disease surveillance, PNG-Australia collaboration, transboundary disease management, zoonotic diseases, Pacific Island partnerships.

1. INTRODUCTION

Papua New Guinea (PNG) occupies a strategically critical position at the intersection of Southeast Asia, Australia, and the Pacific Islands, serving as both a biodiversity hotspot containing approximately 7% of the world's species and a natural corridor for wildlife migration and human movement (Barrows et al. 2009; EU 2025). This unique geographical position, combined with the global reality that 75% of emerging infectious diseases originate from animal sources, positions PNG as a crucial frontline in protecting regional and global health security (FAO 2022; Nichol 2024). However, despite this critical role, PNG faces unprecedented challenges in animal and wildlife health management that threaten both national biosecurity and regional stability.

The COVID-19 pandemic and recent outbreaks of Newcastle Disease (ND), avian influenza and African Swine Fever (ASF) have demonstrated that animal health extends far beyond veterinary concerns to encompass national security, economic stability, and public health protection (PHARMAPlus 2021; NAQIA 2013; Jonduo et al. 2012). For PNG, these challenges are compounded by complex geographical and socioeconomic factors including rugged terrain, limited infrastructure, cultural diversity spanning over 800 languages, and significant resource constraints (FAO et al. 2022; MexicoHistorico.com 2025).

This comprehensive review examines PNG's animal and wildlife health systems through four critical dimensions: workforce development and capacity building; disease surveillance and early warning systems; diagnostic infrastructure and laboratory capacity; and cross-sectoral collaboration through One Health approaches. The analysis recognizes that these components must function as an integrated system to effectively protect human, animal, and environmental health. The significance of strengthening PNG's animal health systems extends beyond immediate health considerations to encompass food security for the 85% of the population engaged in subsistence agriculture, preservation of cultural practices where animals hold spiritual significance, and regional biosecurity for the broader Asia-Pacific region (Ayalew et al. 2011; Bourker et al. 2009). PNG's traditional ecological knowledge systems, developed over millennia, offer valuable insights that can enhance modern veterinary approaches when effectively integrated. Employing a One Health framework that recognizes the interconnections between human, animal, and environmental health, this review provides a strategic roadmap for transforming PNG's animal health systems from current vulnerabilities into robust, resilient frameworks (Destoumieux-Garzón et al. 2018; Rüegg et al. 2018). As PNG continues economic development and regional integration, combined with climate change altering disease patterns, strengthening these systems represents both a national imperative and a crucial contribution to Asia-Pacific regional stability and global health security.

2. LITERATURE SEARCH METHODOLOGY

A comprehensive literature search was conducted using primary databases including Google Scholar, PubMed, ScienceDirect, and Google searches. All sources were systematically organized using EndNote X9 reference management software.

The search strategy employed targeted keyword combinations: "Papua New Guinea animal health," "Wildlife health systems PNG," "Biosecurity Papua New Guinea," "One Health Pacific Islands," "Veterinary capacity building," "Zoonotic disease surveillance," and "Animal health infrastructure developing countries." Inclusion Criteria:

- Published 2000-2025
- Focus on animal or wildlife health in PNG
- English language
- Relevant to biosecurity, health systems, or veterinary infrastructure

The initial search identified 148 potential sources from peer-reviewed journals, government reports, conference proceedings, webpage, newspaper article, reports, academic thesis and unpublished papers. Following screening, total of 72 sources was cited. The search incorporated both academic literature and grey literature from organizations including the National Agriculture and Inspection Authority (NAQIA), World Health Organization (WHO), and Food and Agriculture Organization (FAO), World Organization for Animal Health (WOAH) and other concerned organizations and institutions. Personal experience through workshop attendance, consultative meetings, and discussions provided additional practical insights into animal and wildlife health challenges and

capacity-building opportunities in PNG.

3. CHALLENGES FOR ANIMAL-WILDLIFE HEALTH IMPROVEMENTS IN PNG

3.1 Geographical and Logistical Challenges for Capacity Building

PNG's strategic location creates a complex web of biosecurity vulnerabilities that extend far beyond traditional border control measures. The country's 700-kilometer porous land frontier with Indonesia's Papua provinces serves as a historically significant pathway for traditional movement that largely bypasses formal health screening protocols (Horwood et al. 2018). These informal border crossings, while culturally and economically important for local communities, create substantial challenges for monitoring and controlling potential disease introduction from regions with different disease profiles and varying levels of animal health surveillance.

The eastern maritime boundaries between Bougainville and the Solomon Islands, combined with the southern Torres Strait connections to Australia, establish PNG as a critical nexus in regional disease transmission pathways (Horwood et al. 2018). This geographical positioning, while advantageous for trade and cultural exchange, places PNG at the intersection of multiple migratory routes for both wildlife and disease vectors. The country's location along major bird migration corridors, combined with its role in regional trade networks, creates ideal conditions for the rapid spread of transboundary diseases such as highly pathogenic avian influenza, rabies, and emerging zoonotic pathogens (Jonduo et al. 2012).

These geographical challenges are compounded by PNG's internal topographical complexity, characterized by mountainous terrain, dense tropical forests, and extensive river systems that create natural barriers to surveillance and response efforts (Cleary et al. 2022). The resulting isolation of many rural communities' limits access to veterinary services, disease reporting mechanisms, and emergency response capabilities, creating pockets of vulnerability that could serve as undetected reservoirs for emerging diseases (Brioude et al. 2014; Alamgir et al. 2019).

3.2 Critical Knowledge and Information Deficits

The foundation for effective animal health management requires robust, contemporary data on disease prevalence, risk factors, and system performance. PNG faces significant challenges in this regard, with much of the available information dating from historical studies conducted decades ago that no longer reflect current conditions, population dynamics, or emerging threats (Aur lie 2017; Brioude et al. 2017). This knowledge vacuum persists despite PNG's historically favourable disease profile, where geographical isolation and limited livestock introductions have historically protected the country from many diseases common in tropical regions (Aur lie 2017; Ayalew et al. 2011).

The absence of systematic, contemporary data collection hampers evidence-based policy development, resource allocation decisions, and international collaboration efforts. Without reliable baseline data on animal populations, disease prevalence, and system capacity, it becomes impossible to measure progress, identify emerging trends, or demonstrate the impact of interventions to potential funding partners and collaborating institutions.

3.3 Severe Infrastructure and Human Resource Constraints

PNG's animal health infrastructure represents one of the most significant bottlenecks in system performance, with critical shortages across all essential components (Alamgir et al. 2019; Fabila-Kavana 2024). The country currently employs fewer than ten registered veterinarians to serve a population of over 9 million people and their livestock—a ratio that falls dramatically short of international standards and regional benchmarks (WOAH 2023). This workforce shortage is compounded by geographical distribution challenges, with most qualified personnel concentrated in urban centers while most livestock and wildlife interactions occur in remote rural areas.

Laboratory diagnostic capacity remains severely constrained and geographically concentrated, with the primary NAQIA facility in Port Moresby serving as the main diagnostic hub for the entire country (ACIAR 2020).

This centralization creates substantial delays in sample processing, limits surveillance coverage in remote areas, and constrains rapid response capabilities during disease outbreaks. The combination of limited personnel, inadequate infrastructure, and geographical barriers creates a perfect storm that hampers effective disease detection, diagnosis, and control across PNG's diverse landscapes (Brioudes et al. 2015).

3.4 Historical Patterns of Underinvestment and Policy Neglect

The current state of PNG's animal health systems reflects decades of systematic underinvestment and policy prioritization that favoured other sectors over agricultural and veterinary services. During the 1980s and 1990s, when many foundational investments in health infrastructure were made, animal health received significantly less attention compared to human health services, education systems, and extractive industries that promised immediate economic returns (Bourker et al. 2009).

This pattern of underinvestment has perpetuated into recent decades, with animal health services receiving approximately 2% of the national agricultural budget—a figure that reflects the low political priority assigned to veterinary services despite their critical importance for food security, public health, and economic stability (NAQIA 2023; Lin-stukey 2025). The lack of sustained investment has created a cycle where limited capacity constrains system performance, which in turn reduces political support for increased funding, perpetuating the resource constraints that limit system effectiveness.

3.5 Escalating Disease Risks and Public Health Implications

The convergence of global travel, climate change, and intensifying human-animal interactions has dramatically increased the risk profile for disease emergence and transmission in PNG. Recent outbreaks, including ND in poultry populations and the devastating ASF epidemic that has decimated highland pig populations, demonstrate PNG's acute vulnerability to transboundary diseases and the cascading impacts these outbreaks can have on rural communities (PHARMAPlus 2021; Raitano 2010; NAQIA 2013).

The public health implications extend far beyond immediate animal losses, encompassing food security threats for communities dependent on livestock for protein and income, economic disruption that can persist for years after outbreaks are controlled, and potential for zoonotic transmission that could affect human populations with limited access to healthcare services. With approximately 80% of PNG's population living in rural areas with frequent animal contact, the potential for zoonotic spillover events represents a constant and growing threat that current surveillance and response systems are inadequately equipped to address (Horwood et al. 2019; NRI 2019; The National 2019).

With approximately 75% of emerging infectious diseases in humans originating from animals, the interface between animal health and public health represents a critical vulnerability in global health security (Nichol 2024; Gummow 2010; Jones et al. 2008). This vulnerability is magnified in regions with close human-wildlife contact, limited surveillance capacity, and underdeveloped health infrastructure, characteristics that are particularly relevant to PNG's context (Mackenzie et al. 2019).

Recent zoonotic outbreaks have demonstrated the catastrophic global consequences of insufficient animal health monitoring and response systems, providing stark reminders of the interconnectedness of animal and human health. The COVID-19 pandemic, with its origins linked to wildlife, has resulted in millions of deaths and unprecedented economic disruption worldwide, highlighting the severe consequences of gaps in early detection and containment systems (De Sadeleer et al. 2020; Holmes et al. 2021).

Similarly, Nipah virus outbreaks in Southeast Asia, transmitted from fruit bats to humans often via intermediate pig hosts, have caused fatal encephalitis with case fatality rates of 40-75%, demonstrating the lethal potential of zoonotic pathogens (Gurley et al. 2017; ECDC 2025). Within PNG itself, endemic zoonoses including leptospirosis, brucellosis, and Q fever continue to affect rural communities with limited access to diagnostic and treatment facilities, creating ongoing public health challenges (WOAH 2020; NAQIA 2011).

4. BROADER IMPACTS AND REGIONAL IMPLICATIONS OF ANIMAL HEALTH CHALLENGES

4.1 Transboundary Biosecurity Vulnerabilities and Regional Disease Transmission

PNG's animal health challenges create vulnerabilities that extend far beyond national borders, particularly affecting neighbouring countries through shared ecological systems and migration pathways (CSIRO 2022; Post Courier 2024; WOAHA 2019; World Bank 2022). The porous nature of PNG's borders with Indonesia and the natural wildlife corridors connecting PNG to Australia create pathways for disease transmission that cannot be effectively controlled through traditional border security measures alone (DAFF 2024; Horwood et al. 2018).

Recent disease incursions have demonstrated these vulnerabilities in stark terms. The ASF outbreak, which has devastated smallholder pig populations with mortality rates exceeding 90% in affected communities, poses direct threats to Australia's substantial pig industry valued at approximately AUD 5.3 billion annually (APL 2023; PHARMA Plus 2021; Puana 2021). Similarly, the Newcastle Disease outbreaks have highlighted the potential for rapid transmission of highly contagious diseases across regional poultry systems (Raitano 2010; NAQIA 2008).

These transboundary risks are amplified by climate change, which is altering vector distributions and creating new pathways for disease transmission. Rising temperatures are enabling disease vectors to survive in previously unsuitable habitats, while changing precipitation patterns affect wildlife behaviour and migration routes, potentially creating novel transmission opportunities that existing surveillance systems are not designed to detect or respond to effectively (Chen et al. 2024; Caminade et al. 2019).

4.2 Economic Disruption and International Trade Consequences.

Animal disease outbreaks create immediate and long-term economic disruption that extends far beyond direct animal losses. For PNG, where agriculture sustains the livelihoods of over 85% of the population and contributes significantly to export earnings, disease outbreaks can have devastating economic consequences at both household and national levels (DAL 2020; Upton 2004).

The economic impacts manifest through multiple pathways: direct losses from animal mortality and reduced productivity, market access restrictions following disease notifications, substantial costs for disease control and eradication efforts, and ripple effects throughout related industries including feed suppliers, processors, and retailers. These immediate impacts are often compounded by long-term consequences, as international market access restrictions can persist well beyond successful disease control, creating prolonged economic disruption (Upton 2004; WTO 2022).

For rural communities, where livestock often serve as both income sources and savings mechanisms, disease outbreaks can create immediate poverty and food insecurity that persists long after animal populations recover. The disproportionate impact on women, who often manage livestock and depend on animal sales for household expenses and educational costs, adds gender equity dimensions to the economic consequences of inadequate animal health systems.

4.3 Food Security and Nutritional Resilience Challenges

Animal diseases directly threaten food security by reducing the availability of animal-source foods that provide essential micronutrients often lacking in plant-based diets (FAO 2009). For PNG's rural communities, where livestock serve multiple functions beyond simple protein production, disease outbreaks create cascading effects across nutritional security, income stability, and social systems.

The nutritional impacts are particularly severe for vulnerable populations, including children and pregnant or lactating women who benefit significantly from animal-source proteins and micronutrients essential for proper development. Disease outbreaks also disrupt integrated farming systems where animals provide traction power and organic fertilizer for crop production, creating broader agricultural productivity impacts that affect overall food system resilience (Neumann et al. 2003; Paro et al. 2024).

Recent outbreaks have demonstrated these multifaceted impacts clearly (Puana 2021; NAQIA 2013;

PHARMA Plus 2021). The ASF epidemic has not only eliminated protein sources for affected communities but has also disrupted traditional social systems where pigs play central roles in ceremonial exchanges, conflict resolution, and community governance structures (Hide 2003; Bourker et al. 2009).

4.4 Environmental Conservation and Biodiversity Protections Challenges

PNG's exceptional biodiversity—hosting approximately 7% of global species diversity within its terrestrial and marine ecosystems—faces increasing threats from inadequate animal health systems that fail to address disease transmission between domestic animals and wildlife populations (EU 2025; UNDP 2017). Disease spillover events can threaten endangered species, disrupt critical ecosystem functions, and undermine conservation efforts that depend on healthy wildlife populations (Smith et al. 2009).

The limited understanding of wildlife disease ecology in PNG constrains the development of effective conservation strategies and hampers efforts to predict and prevent disease-related biodiversity losses. Inappropriate disease control measures, including indiscriminate wildlife culling or habitat destruction, can cause long-term ecological damage that undermines both conservation goals and ecosystem service provision (Gummow 2010).

The loss of ecosystem services due to disease-related wildlife population declines affects everything from pollination and seed dispersal to natural pest control and nutrient cycling, creating cascading effects that extend far beyond immediate conservation concerns to affect agricultural productivity and environmental resilience (Smith et al. 2009).

4.5 Cultural and Social Impacts

Animals hold profound cultural significance in PNG's diverse societies, serving functions that extend far beyond economic value to encompass spiritual beliefs, social status, traditional governance, and community identity. The loss of culturally significant animals due to disease outbreaks can disrupt social cohesion, traditional governance structures, and cultural practices that have sustained communities for generations (Upton 2004; Bourker et al. 2009).

In highland societies, pigs represent not merely livestock but embodiments of wealth, social status, and spiritual connection that plays central roles in traditional exchange systems, ceremonial practices, and conflict resolution mechanisms (Hide 2003; Ayalew et al. 2011; Robby et al. 2019). Wildlife species feature prominently in totemic relationships, traditional knowledge systems, and spiritual practices across PNG's diverse cultural landscape, forming integral components of indigenous worldviews and customary governance systems (Mack 2021).

The disruption of these cultural dimensions through disease outbreaks creates impacts that extend far beyond immediate economic losses to affect community identity, traditional authority structures, and intergenerational knowledge transmission systems that form the foundation of PNG's rich cultural heritage (Tideman and Gosler 2010).

4.6 Climate Change Amplification Effects

Climate change is systematically amplifying the challenges facing PNG's animal health systems through multiple interconnected pathways that create new vulnerabilities while exacerbating existing constraints. Shifting temperature and precipitation patterns are altering the geographic distribution of disease vectors, expanding their range into previously unsuitable habitats and extending transmission seasons for vector-borne diseases (Caminade et al. 2019; Thomas et al. 2017).

Extreme weather events place considerable stress on animal populations while creating environmental conditions that favour pathogen transmission and survival. These changing conditions facilitate the emergence of novel pathogens through increased wildlife-domestic animal interactions during resource scarcity, while enabling existing pathogens to adapt to new hosts as ecological niches shift (Chen et al. 2024).

For PNG, where climate vulnerability is exceptionally high due to geographical exposure and limited adaptation capacity, these climate-animal health interactions present additional challenges for sustainable

livestock production and wildlife conservation. Rising sea levels threaten coastal livestock systems, while changing rainfall patterns disrupt traditional seasonal grazing and breeding cycles that have sustained PNG's pastoral communities for generations (Chen et al. 2024; UNDP 2017; Thomas et al. 2017).

5. OPPORTUNITIES FOR ANIMAL-WILDLIFE HEALTH IMPROVEMENTS AND CAPACITY BUILDING.

5.1 Innovate Workforce Development and Training Solutions

Addressing PNG's critical shortage of animal health professionals requires innovative, multi-tiered approaches that combine immediate capacity building with long-term sustainable workforce development. The current workforce of four qualified veterinarians and eleven animal health officers is fundamentally inadequate for PNG's needs, but creative solutions can rapidly expand effective coverage while building toward sustainable long-term capacity (NAQIA 2011; WOA 2023; Reid et al. 2010).

Community-Based Paraprofessional Networks: Developing networks of trained community animal health workers can extend basic veterinary services to remote areas while creating pathways for career advancement in animal health fields. These networks leverage existing community structures and traditional knowledge systems while providing formal training in disease recognition, basic treatment protocols, and reporting mechanisms (Riviere-Cinamond et al. 2003).

Academic Program Integration: The PNG University of Natural Resources and Environment's institutionalization of a Paraveterinary Program represents a significant step toward systematic workforce development (PNGUNRE 2020; PNGUNRE 2023). Expanding this model to other educational institutions and integrating animal health components into existing agricultural and health programs can create multiple pathways for workforce entry and development.

Digital Learning Platforms: Leveraging PNG's expanding mobile network coverage (approximately 47% of the population) to deliver distance learning programs, diagnostic support, and continuing education can overcome geographical barriers while providing ongoing professional development for distributed workforce members (Kemp 2025).

Regional Exchange Programs: Establishing formal exchange programs with Australia, Indonesia, and other Pacific Island countries can provide advanced training opportunities while building networks for ongoing collaboration and knowledge sharing (NAQIA 2008; NAQIA 2023; Bessler et al. 2024).

5.2 Technology-Enhanced Surveillance and Early Warning Systems

Modern surveillance approaches can overcome PNG's geographical and resource constraints through innovative integration of traditional knowledge systems with digital technologies and community-based reporting networks (WHO 2024; Woods et al. 2019).

Participatory Digital Surveillance: Expanding the existing ACIAR-developed syndromic reporting template through mobile phone applications and SMS-based systems can enable real-time reporting from remote communities while providing immediate feedback and guidance to reporters (ACIAR2021).

Integrated One Health Surveillance: Developing surveillance systems that simultaneously monitor human, animal, and environmental health indicators can maximize resource efficiency while providing comprehensive early warning capabilities for emerging threats (Benedetti et al. 2024).

Community Sentinel Networks: Training teachers, church leaders, and community health workers as disease sentinels can create extensive coverage networks that leverage existing community structures

while providing sustainable surveillance capacity.

Regional Data Sharing Platforms: Establishing secure, real-time data sharing platforms with neighbouring countries can enable coordinated responses to transboundary threats while providing mutual early warning capabilities for emerging diseases (ACDC 2024).

5.3 Strategic Diagnostic Capacity Enhancement

Maximizing PNG's limited diagnostic capacity requires strategic approaches that combine infrastructure development with innovative service delivery models and regional partnerships.

Point-of-Care Diagnostic Networks: Implementing field-deployable diagnostic technologies can extend testing capabilities to remote areas while reducing dependence on centralized laboratory facilities. Solar-powered diagnostic units with satellite connectivity can overcome infrastructure limitations in rural areas.

Laboratory Network Optimization: Creating formal networks among existing facilities (NAQIA, PNGIMR, university laboratories) with standardized protocols and shared resources can maximize collective capacity while ensuring quality standards and efficient resource utilization. **Regional Reference Laboratory Partnerships:** Establishing formal agreements with advanced laboratories in Australia and other regional countries can provide backup diagnostic support for complex cases while facilitating knowledge transfer and capacity building.

Mobile Diagnostic Services: Developing mobile diagnostic units that can provide periodic coverage to remote areas can extend services while building local capacity through training and technology transfer.

5.4 Cross-Sectoral One Health Integration

Implementing integrated One Health approaches can maximize limited resources while addressing the interconnected nature of human, animal, and environmental health challenges in PNG.

Institutional Coordination Mechanisms: Establishing formal One Health coordination platforms that bring together veterinary services, public health agencies, environmental management organizations, and traditional governance structures can create synergies that enhance collective capacity while respecting cultural protocols.

Integrated Training Programs: Developing training programs that address human, animal, and environmental health as interconnected systems can create workforce members capable of addressing complex challenges while maximizing training resource efficiency.

Community-Based One Health Networks: Training community members to recognize and respond to health threats across the human-animal-environment interface can create comprehensive coverage while leveraging traditional ecological knowledge and community governance systems.

Research and Innovation Hubs: Establishing collaborative research programs that address One Health challenges can generate locally relevant knowledge while building institutional capacity and international partnerships.

6. CONCLUSION

The journey towards robust animal and wildlife health systems in PNG represents a complex yet crucial endeavour with profound implications for national and regional well-being. This comprehensive analysis has illuminated the

intricate challenges facing PNG's animal health landscape, revealing not just obstacles but also extraordinary opportunities for transformative change.

The convergence of geographical vulnerabilities, limited infrastructural capacities, and emerging global health dynamics demands a holistic, strategic approach to animal health management. PNG's unique position at the intersection of diverse ecological systems and cultural contexts provides both a challenge and a unique opportunity for innovative health system development.

The proposed strategies – ranging from workforce development and enhanced surveillance to cross-sectoral collaboration and indigenous knowledge integration – offer a comprehensive roadmap for systemic transformation. By embracing the One Health approach, PNG can develop a resilient, adaptive animal health system that not only addresses immediate challenges but also anticipates and mitigates future risks.

7. ENHANCED RECOMMENDATIONS FOR STRATEGIC IMPLEMENTATION

Based on this comprehensive analysis, the following strategic recommendations provide a roadmap for transforming PNG's animal and wildlife health systems:

7.1 Immediate Priority Actions (0-2 Years)

Establish a National Animal Health Workforce Development Initiative: Create a comprehensive strategy combining emergency short-term training programs for immediate capacity building, integration of veterinary content into existing educational curricula at universities and technical colleges, establishment of community-based paraprofessional networks leveraging traditional governance structures, and development of digital learning platforms utilizing PNG's expanding mobile network coverage.

Implement Technology-Enhanced Surveillance Systems: Expand the existing ACIAR syndromic reporting template through mobile applications and SMS-based systems, establish community sentinel networks utilizing teachers, church leaders, and community health workers, create integrated One Health surveillance platforms monitoring human-animal-environment interfaces simultaneously, and develop real-time data sharing mechanisms with neighbouring countries for coordinated early warning.

Optimize Existing Diagnostic Infrastructure: Formalize collaborative networks among NAQIA, PNGIMR, and university laboratories with standardized protocols and shared resources, establish formal agreements with regional reference laboratories in Australia and Pacific countries for emergency diagnostic support, implement point-of-care diagnostic technologies for remote area deployment, and develop mobile diagnostic services providing periodic coverage to underserved regions. 499

7.2 Medium-Term Transformational Goals (2-5 Years)

Create a Regional Pacific Animal Health Partnership: Establish a formal multilateral collaboration framework between PNG, Australia, Indonesia, and Pacific Island countries focused on capacity building, knowledge exchange, coordinated disease surveillance, and emergency response coordination, with shared funding mechanisms and standardized protocols for transboundary disease management.

Develop Indigenous Knowledge Integration Programs: Create systematic approaches for incorporating traditional ecological knowledge into modern animal health systems, establish community-based surveillance networks that respect cultural protocols while enhancing disease detection capabilities, and develop culturally appropriate health interventions that honour traditional values while addressing contemporary challenges.

Establish National One Health Coordination Mechanisms: Create formal institutional platforms

bringing together veterinary services, public health agencies, environmental management organizations, and traditional governance structures, implement integrated training programs addressing human-animal-environment health interconnections, and develop community-based One Health networks capable of addressing complex challenges across sectors.

7.3 Long-Term Sustainable Development (5-10 Years)

Establish PNG Veterinary College: Create domestic veterinary education capacity through partnership with regional universities, develop specialized programs addressing PNG's unique geographical and cultural context, establish research programs generating locally relevant knowledge, and create pathways for advanced specialization in wildlife health, zoonotic diseases, and tropical veterinary medicine.

Build Comprehensive Diagnostic Networks: Develop distributed laboratory capacity with regional hubs providing specialized services, establish biosafety level 3 facilities for high-risk pathogen research, create next-generation sequencing capabilities for pathogen characterization, and implement quality assurance programs meeting international standards.

Create Innovation and Research Hubs: Establish collaborative research programs addressing One Health challenges specific to PNG and the Pacific region, develop technology solutions appropriate for resource-limited tropical settings, create knowledge transfer mechanisms facilitating rapid adoption of innovations, and build international partnerships supporting long-term capacity development.

Implement Comprehensive Policy Frameworks: Develop national animal health legislation meeting international standards while respecting traditional governance systems, establish sustainable financing mechanisms reducing dependence on external funding, create regulatory frameworks supporting private sector engagement while maintaining public sector oversight, and implement performance monitoring systems enabling evidence-based policy adaptation.

These enhanced recommendations provide a comprehensive framework for transforming PNG's animal and wildlife health systems from current vulnerabilities into robust, resilient capabilities that can protect national interests while contributing to regional and global health security. Success will require sustained commitment, innovative approaches, and collaborative partnerships, but the potential benefits—for PNG, the Pacific region, and global health security—justify the investment and effort required for this critical transformation.

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Psychological Impacts of Gender-based Violence against Women in Hula Community

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Abstract: This paper examines the issue of Gender-based violence (GBV) as a serious problem that affects women psychologically in Papua New Guinea (PNG). These effects include hindering freedom of movement and community participation by women. The aim is to develop an understanding of such negative effects on women and girls, as a case study that was conducted in Hula village of Central Province, PNG. The purpose of the study was to identify the main forms of violence against women in the community, the possible causes and their psychological consequences, identify and recommend strategies to reduce and prevent these captioned issues. The research involved 20 key informant interviews with community leaders and three focus groups within a small group of men and women including the teachers from an elementary school in the village. The main findings from the study highlights the psychological effects of gender-based violence committed against women, either single or married. The major contributing factors of gender-based violence identified are lack of food and money, alcohol consumption, pure jealousy, adultery and other contributing factors such as misuse of social media. These contributing factors have extensively contributed to gender-based violence having greater impact on women's mental health. Consequently, the women are unable to participate fairly in social activities. The study is important as it highlighted the proportion of GBV prevalence at the community level.

Keywords: psychological violence; psychological effects and social media

Author Biography:

My name is Aiga Ian and I am recently being appointed as a *Teaching Fellow* with the Social Work Strand at the University of Papua New Guinea. I have a *Bachelor of Arts in Social Work* and *Bachelor of Arts with Honors in Social Work*. I worked as a part-time Project Officer with Equal Playing Field, local Non-government Organization from 2017 – 2019 assisting in the project delivery of Equal Playing Field for Schools program and School Action Groups. I also assisted in Monitoring and Evaluation, Child Protection, Office Administration, Events organization, Training and Facilitation of change-makers and teachers. I was involved with National Statistical Office when they rolled out the Population Data Project called Socio-Demographic and Economic Survey project in partnership with United Nations Population Fund in 2022. I took part as a Field Data Collection Officer, which the project was a success (See UNFPA Papua New Guinea Website for the report).

In addition, I have volunteered and engaged in community service with different organizations such as PNG Olympic Committee at 2015 Pacific Games (July 4 2015 – July 18 2015), Young Women's Christian Association (July 13 – July 14 2017), Sanap Wantaim Campaign under United Nations Women's office (April 2016 – December 2018), Equal Playing Field (April 22 2016 – May 19 2017), Public Service Sports Program PNG Sports Foundation (October 12 2018), Trukai Industries Limited Fun Run (June 16 2019) and currently volunteers with Scripture Union PNG Port Moresby and Central area (February 2020 – Present) bringing the gospel of Jesus Christ to primary and secondary schools in Port Moresby and Central province. My research interest areas are Gender-based violence, youths, governance, climate change, social welfare issues, and labor mobility.

1. INTRODUCTION

Gender-Based Violence occurs in all societies of the world in all forms, within the home or in the wider community and it affects women and girls disproportionately. While Gender-Based Violence (GBV) is frequently directed at females, it can also be directed at other men and boys (Mkandawire, 2009; Eves, 2006, p. 13). Although GBV is difficult to measure, small-scale studies and evidence suggest that GBV is severe and widespread, and in some instances worsening (Goa, 2009). Despite the Government interventions to address Gender-based violence through the Papua New Guinea National Strategy to Prevent and Respond to Gender-based violence 2016 – 2025, Family Protection Act Amended 2022 and other relevant laws and policies, there remain several or many challenges that inhibit the substantial reduction of GBV (Goa, 2009).

Therefore, it was the intention of this study to investigate the psychological impacts of GBV on women, aiming to (1) to explore the major contributing factors of GBV on women, (2) to identify the main psychological impacts of GBV on women and (3) to propose solutions to address psychological impacts of GBV against women.

2. LITERATURE REVIEW

GBV in Papua New Guinea (PNG) is multifaceted. There are many studies on gender-based violence (Mboho & Udoh, 2018; FHI 360, 2019; Ganster-Breidler, 2010; Mkandawire, 2009; Gibbs et al., 2020; Medecins Sans Frontieres, 2016). Among these studies, Mboho & Udoh (2018) specified GBV as encompassing physical, sexual, psychological, emotional, and financial violence. Social violence is among the other types of violence (Consultative Implementation & Monitoring Council, 2017) women and men experience in PNG, particularly in families and communities.

The contributing factors of GBV are numerous. For instance, lack of economic empowerment and economic independence leaves many women experiencing GBV (Macintyre, 2000; Goa, 2009; Mboho & Udoh, 2018). Furthermore, there are harmful traditional practices (Mkandawire, 2009) that tolerate GBV in our communities. These can have negative psychological impacts on women. In addition, many perpetrators use male privilege and normative use of violence in relationships (Gibbs et al., 2020) to get away with GBV.

The magnitude of the GBV problem is remarkably high. Human Rights Watch (2015) reported that PNG is one of the world's most dangerous places for women to live in. Intimate relationship physical violence is accompanied by psychological abuse (Mkandawire, 2009). Moreover, the perpetration of GBV against women by men affects women's health and well-being (Ganster-Breidler, 2010). Ganster-Breidler (2010) used a cross-sectional survey covering four PNG provinces i.e. Western Highlands, Eastern Highlands, Madang and the Autonomous Region of Bougainville. Some of the major health and wellbeing issues associated with violence against women that were highlighted in the survey were depression, suicide, murder, sexually transmitted diseases (HIV/AIDS), substance abuse, physical injuries, high mortality rate, sudden death of women, high blood pressure and mental health issues (Ganster-Breidler, 2010). Similarly, a report by Médecins Sans Frontières (2011) further confirmed that victims of IPV and sexual violence in PNG risk “serious long-term physical and emotional harm”, with many survivors suffering from “depression, suicidal thoughts and attempts, anxiety, phobias and post-traumatic stress disorder”, as well as risk of HIV and other sexually transmitted diseases (p. 2). Existing literature highlights GBV's relations to poverty, alcohol abuse, and patriarchal structures (Jewkes et al., 2017; Ganster-Breidler, 2010), however limited knowledge gaps identified on the impacts of GBV on women's mental health. By positioning survivors' expressions, this study addresses these gaps and aligns with the United Nations' Sustainable Development Goals (SDGs) on gender equality and well-being.

3. METHODOLOGY

This study utilized a qualitative research approach where collection of data and analyzing of data were non-numerical (Bhandari, 2020), with purposive sampling of 44 participants. Semi-structured interviews were conducted with 20 key informants representing the twelve sections of the community. In addition, three focus group discussions consisting of male group, female group and community elementary teachers were conducted.

In this study, the method of data analysis utilized is thematic analysis. Thematic analysis is a method for

analyzing qualitative data that entails searching across a data set to identify, analyze, and report repeated patterns (Braun and Clarke 2006). First, data collectors prepared, organized the data collected in the field, transcribed the interviews and typed up the field summary notes. Then data collected was reviewed and explored. The data was examined for patterns or repeated ideas that emerged. After data was reviewed and explored, a data coding system was developed. Based on the initial ideas, a set of codes were established that applied to categorize the data collected. Key informant's interviews were coded KII and focus group discussions were coded FGD. The next process was assigning the codes to the data and identifying recurring themes. Codes were linked together into cohesive, overarching themes (Bhandari, 2020; Braun and Clarke 2012).

This research progressed after receiving research ethical clearance from the School of Humanities and Social Sciences (SHSS) Research Ethics Committee at the University of Papua New Guinea. The research was carried out in Hula community. Data collection only proceeded with informed consent from the participants and participants' anonymity was ensured. In addition, the potential of biased opinions was expected, thus, research assistants were recruited to address biased information. The current sample of the study is a great representation of the community.

4. FINDINGS OF THE STUDY

The key themes that emerged from data analysis on the research topic were major contributing factors to GBV with four sub-themes, the effects of GBV on women's mental health and GBV barriers on women.

Major contributing factors to GBV

The key informants and focus groups were asked to highlight the major contributing factors to GBV against women in the community. The key informants and focus groups highlighted four major contributing factors: alcohol consumption; adultery offenses; shortage of money and food; and pure jealousy in relationships; as well as other contributing factors that impact women.

GBV Associated with alcohol consumption. It is highlighted that there is a relationship between alcohol consumption and GBV. Alcohol consumption contributes to the prevalence of GBV against women by men (Jewkes et al.'s, 2017). The key informants' and focus groups emphasized that alcohol consumption was common in the community, both factory-produced and homemade, contributed directly and indirectly to many problems including GBV against women. For instance, alcohol consumption led married couples to fight from drinking together. Some married women drinking with other men obtained beat ups from their men (partners). In addition, one of the focus groups reported that alcohol consumption was the main contributing factor to GBV. For instance:

Focus group members mentioned, "drinking is the main contributing factor to gender-based violence" (FGD 2).

GBV and shortage of money and food. The key informants and focus groups mentioned that shortages of money and food contributed to GBV in families, especially against women. For instance, lack of money leads to gender-based violence (KII01). Ganster-Breidler (2010) reported that men who had money problems somehow caused GBV. Although the impacts on women were not clearly outlined, the research finding clearly affirms the research proposition on the above.

Furthermore, women expect men to provide for them on most occasions. It is evident in the natural ability of men to provide for women (English Standard Version Bible, 2001, Genesis 3:17). When men are not responsible to provide for women, then women find alternative means to survive. For example:

When men fail to provide necessities or there is no provision of money for women, women go out of their way to have sexual affairs with other men □ i.e., just to find money to provide food for their survival and of their children (KII13).

Violence is not always caused by stress but may be one way that some people respond to stress (Seltzer & Kalmuss, 1988). Couples in poverty may be more likely to experience domestic violence, due

to increased stress and conflicts about finances and other aspects (Jewkes, 2002).

GBV and pure jealousy in relationships. Furthermore, pure jealousy within marriages was discovered to be also one of the major contributing factors of GBV based on key informant interviews and focus group discussions. In terms of jealousy, women may go out and spend time with their families, and upon returning, men may have a lot of questions about their whereabouts. There may be disagreement between the two parties. One party might not agree with the other party □ i.e., further resulting in violence.

The respondents further stated that men did not want women to hang around because other men would see them and take an interest in them. This was men's pure jealousy over women. These findings also further confirm the impacts of jealousy by men on women psychologically resulting in lack of freedom of movement, arguments, and violence.

GBV and adultery offenses. In addition, adultery offenses were discovered to be one of the main contributing factors of GBV against women in key informant interviews and focus group discussions. Men towards women and vice versa committed adultery offenses. One of the many reasons for adultery offenses was the dissatisfaction feeling some men and women had in marriage that led them to commit adultery. For example:

...Some of them have extra marital affairs in the community. If they are not satisfied with one partner, they decide to go find another partner (KII12).

Adultery offenses associated with womanizing was part of the reason why women are bashed up. For instance:

Womanizing can be part of it, if they are having an affair with someone else; the wife gets the beating for an unsuccessful relationship (KII16).

Overall, key informants and focus groups stated that the prevalence of adultery offenses was mostly linked to food and money shortages and the avenging of affairs. As a result, men committed physical violence against women.

Other GBV contributing factors. The other contributing factors also highlighted by the key informants were too much freedom of movement, a lack of parental guidance and assistance, negative social learning in family upbringing (Viejo et al., 2018), lack of respect, and misuse of social media platforms. These other contributing factors were briefly mentioned and not discussed in-depth.

4.1 Impacts of GBV on women's mental health

The key informants and focus groups were asked to also highlight the impacts of GBV on women's mental health in the community. This question was asked to address the research question and gap on impacts of GBV on women's mental health (Ganster-Breidler, 2010; Richardson et al., 2018). Drawing from the respondents' answers, there were a number of negative psychological impacts highlighted.

The continuous beating by men led to women experiencing depression, overthinking, excessive worry, thoughts of committing suicide, suicidal attempts and committing of suicide. The continuous beating by men caused women traumatized mentally, did not look after their children well and did not make decisions well. They had mental illness and mental suppression, had self-preservation, lived in fear and pain, troubled and were careful not to make mistakes. Women were not sure what to do, they did not seek assistance, they did not seek the right people and they thought that people hated survivors. Women did not share their problems with the service providers and their families.

They suffered and were silenced to think that no one will assist (Hermkens, 2008). They were socially isolated and there was no sense of enjoyment. They kept their talents hidden and did not participate in development activities and lacked progression. They developed trust issues and behavioral changes in the community. Health wise, women lost weight, got physically sick, they had anxiety and some eventually die (death) (Ganster-Breidler, 2010; Medecins Sans Frontieres, 2016). Women lacked personality and outspokenness, psychotic; out of control mentally, shameful and women left abusive relationships for better mental health reasons (Hermkens, 2008).

Interestingly, GBV instilled doubt in some young women, so they are scared of getting married in the future.

5. DISCUSSION AND ANALYSIS OF FINDINGS

GBV is evident in the communities supporting other empirical research evidence (Fox, 2011; Darko et al., 2015; FHI 360, 2014; Medicines Sans Frontiers, 2016). GBV is evident in the sense that not only physical violence is accounted for; however, it includes emotional or psychological violence, sexual violence, financial violence and social violence (PNG National Strategy 2016-2025; McCloskey, 2016; Mboho & Udoh, 2018; Equal Playing Field, 2019; Consultative Implementation & Monitoring Council, 2017; KII05; Care 2015, p. 3). In addition, the key informants and focus groups highlighted four major contributing factors to GBV in the Hula community. The main findings are alcohol consumption (Jewkes et al., 2017), adultery offenses, shortage of food and money (Ganster-Breidler, 2010), and pure jealousy in relationships (Ganster-Breidler, 2010) with other contributing factors like misuse of social media.

Alcohol consumption, both from factory-made and homemade i.e., contributes directly and indirectly to GBV against women. The study revealed that men under the influence of alcohol, resort to violence, disturb women's peace, sometimes abuse women, and misuse money on alcohol not providing sufficient family needs for their families (KII01; KII03; KII06). The present results agree with Jewkes et al.'s (2017) empirical evidence on alcohol consumption outcomes. According to Jewkes et al. (2017), the number of drinks typically consumed, binge drinking by men and women, caused failure to do what was normally expected, and guilt or remorse after drinking. Alcohol consumption leads men and women to unnecessary acts, including, perpetration of violence out of unconsciousness.

Furthermore, food and money shortages contributed to GBV against women. These results are consistent with the claim that food and money problems lead to GBV occurrence (Ganster-Breidler, 2010). It is evident in this study that life is difficult in the village with everything dependent on money. The people in the Hula community rely on their marketing, fishing, fuel businesses, small trade stores and other little businesses to generate sufficient income for their survival. Most people in the community do not make gardens and work the land (KII03). There is also a land shortage in the community and life becomes difficult for them because of lack of food and money. With the money shortage experienced in some families, it then leads to violence against women (Jewkes, 2002). Similarly, women commit adultery with the hope of gaining monetary funds to survive. They see that they do not get the sufficient support from the men; instead, they get into adulterous relationship to make pressing ends. Consequently, the pressure of food and money shortages always leads to GBV.

However, adultery offenses are one of the major contributing factors of GBV. This finding was disturbing and shocking. According to Eves (2006) & INA (2000) cited by Acosta (2019), sexual jealousy, including the husband's adultery, is a common cause of family violence against women, particularly in rural areas, and the wife is beaten if she complains or enquires about it. Although, this is similar in nature as "womanizing can be part of it, if a man is having an extra marital affair with another woman, his wife is bashed for an unsuccessful relationship" (KII16). This study demonstrates that women affected by GBV related to adultery are unable to participate and express themselves freely in the community. The conduct of adultery acts in the contemporary village setting has worsened the social and psychological wellbeing of women and children. This study confirms that adultery acts committed against men by women exist for two reasons. First, women face financial difficulties in order to support their family's daily food budget and their children. For instance, some women do not receive financial support from men, or men do not provide for them. The second reason is married men going out of marriage and lying to young women or single mothers. It further evident that some women taking revenge on men for marriage affairs and womanizing they committed. It clearly shows that sometimes acts of adultery offenses committed by women are forced upon them because of the situation they encountered with the means to survive, family negligence, and parental responsibilities. Overall, it can be concluded that adultery offenses often resulted in arguments and jealousy and the majority of such cases, have seen men committing physical violence against women.

Furthermore, pure jealousy within marriages was discovered to be a contributing factor to GBV against women. This finding is supported by Ganster-Breidler (2010). Ganster-Breidler (2010) briefly highlighted jealousy as a contributing factor to GBV. Obviously, women need their social space to relax and have a good time. Women may go out and spend time with their families, and be involved in other social activities. Upon returning home, men may have many questions about their whereabouts (KII07). This shows that men are jealous and

overprotective over women. However, it may not be true to some men. Interestingly, some men do not want women to hang around because other men would see them and take an interest in them (KII03). Women's social interactions are severed with the ill-treatment they experience from men. They get cut off from everyone because men's jealousy occurs frequently or multiple times. Nevertheless, there may be disagreement between the two parties. One party might not agree with the other party, further resulting in violence. The jealousy trend might be the other way around. Women may be jealous of the men, which could lead to more arguments and further resulting in violence. Therefore, men and women should control their jealousy and bad thoughts (KII06) to avoid GBV prevalence.

5.1 Impacts on women's mental health

The research highlights the various psychological effects of gender- based violence (GBV) on women's mental health. The perpetration of GBV against women by men affects women's health and well-being (Ganster-Breidler, 2010). Tenacious abuse, particularly physical violence, causes significant emotional pain, resulting in depression, anxiety, and thoughts of suicide (Ganster-Breidler, 2010). Women endure trauma that disrupts their daily functioning, influencing their parenting, decision-making, and overall mental health. The descriptions of mental suppression and self-preservation indicate a state of hypervigilance, where women exist in continuous fear and suffering, further increasing their psychological suffering (Médecins Sans Frontières, 2011). This is consistent with existing research (Ganster- Breidler, 2010; Hermkens, 2008), which highlights how GBV challenges women's independence and mental strength, leaving them ensnared in cycles of abuse and silence.

The reported experiences of social isolation and a lack of enjoyment demonstrate that GBV damages not only the individual but also disturbs community engagement and development. Women withdraw from social interactions, hide their abilities, and avoid participating in developmental activities due to shame, fear, and distrust. This isolation fosters a sense of hopelessness, as women feel unsupported and believe that seeking assistance is meaningless (Hinton & Earnest, 2010). The changes in behavior and issues with trust further distance them from their communities, continuing cycles of abuse and marginalization. The physical health consequences, like weight loss and chronic illnesses, intensify their mental health challenges, creating a vicious cycle where psychological and physical decline are interconnected (Médecins Sans Frontières, 2016).

Importantly, the consequences of GBV as a long-term ripple effect on future generations, as young women who are exposed to or witness such violence develop fears about marriage and intimate relationships (Viejo et al., 2018). There is internalized doubt that shape how they view relationships. Furthermore, the choice of some women to leave abusive relationship for mental health reasons, although a positive step emphasizes the drastic measures needed to escape such circumstances (Hermkens, 2008). These findings highlight the critical need for comprehensive interventions that not only ensure immediate safety but also provide long-term mental health support, enhance community awareness, and foster systemic changes to dismantle the structures that sustain GBV (Richardson et al., 2018).

5.2 Limitation of the study

Research respondents provided the expected answers to the research questions. The study's primary flaw was the selection of research techniques that were used. Data for the research project were collected using focus group discussions and semi-structured questionnaire interviews with key informants. The key informants actively participated, whereas focus group discussions saw less involvement.

5.3 Further Research

The social and psychological welfare of women and children was poor because of adultery actions being committed in the modern village environment. Further research is required on GBV against single mothers contributing to rising adultery issues in the community setting. Further in-depth research is also required on GBV impacts on men and women's mental health in Papua New Guinea.

6. CONCLUSION AND RECOMMENDATIONS

The results of this research provide supporting evidence that GBV is evident in communities and that women suffer most from the prevalence of GBV, whether in public or private life. The main research findings on the contributing factors are contributing to the existing knowledge on alcohol consumption, adultery, food and money shortage and pure jealousy. Alcohol consumption of both factory and homemade beverages lead men and women to committing GBV. The adultery acts ended up in women avenging the affairs of men leading to GBV. Shortage of food and money are a major contributor to the increase of GBV. This clearly demonstrates that women primarily are affected when they do not receive the appropriate support from men, which controversially resulted in men getting jealousy, and put restriction on women to socialize. This was evident in this case study, which resulted in GBV issues in marriage relationships. The negative impacts of GBV on women's mental health include suicidal thoughts and attempts, trauma, death, anxiety, depression and self-preservation. Women leave abusive relationships to get away from being abused. Women also suffer the most in terms of emotional, psychological, and physical abuse. The findings in this case study provide the analysis on the ways in which to address GBV in the community and other communities. It is therefore important to take note on the following recommendations:

- 1) Conduct more regular awareness and advocacy on GBV emphasizing negative psychological impacts. Strengthen law and order in the community inclusive of tougher laws to prosecute perpetrators.
- 2) Churches should prioritize GBV, preach more about GBV; church must take the lead. Church to continue to run crusades, outreach programs, counseling and bible classes. Establish a Council of Churches in the Hula community.
- 3) Build safe houses for women, which can include counseling centers, and to engage professionals to manage it and be supported by the government. Survivors of violence must be placed in a conducive environment to share their narratives (Acosta, 2019)

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An analysis of Cultural Intelligence in Different Regions of Papua New Guinea based on Physics Education

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Abstract. Cultural intelligence is important in a globalized world where people from different cultures interact effectively. The cultural factors that influence education in Papua New Guinea are language barriers, traditional knowledge in science, the teaching methods, students' attitude towards science and the societal or family expectations. In our study, we selected physics education because physics is the study of matter and energy which is closely associated with the environment and supports all branches of engineering. Cultural quotient has been calculated in different regions of PNG by conducting a survey on first-year university students from different regions taking physics. Cultural quotient was found to be higher in Highland's region and lower in Islands region. Remedial methods have been suggested to improve the cultural quotient in all regions of PNG.

Keywords: Papua New Guinea, Physics Education, Cultural Intelligence, Language.

Author Biography:

Michael Gaoma is a passionate educationist with over twenty years of experience in teaching and training. He holds a Bachelor of Science degree from the University of Papua New Guinea, Post Graduate Diploma in Education from the University of Goroka and Master of Education from Charles Sturt University, NSW, Australia. Currently, Michael works at the Papua New Guinea University of Technology as a lecturer in the School of Applied Physics. He is also a final year PhD student. His study focusses on embracing cultural intelligence to improve physics education here in Papua New Guinea. Michael is a skilled team player through professional networking and collaborative spirit. He is also heavily involved in students' holistic development programs and activities.

1. INTRODUCTION

Papua New Guinea is a country in the Pacific that has a population of over 10, 000, 000 with 7,000 different cultures and over 830 distinct native languages. About 20% of the population live in urban centers while 80% of it represents the rural dwellers. The significantly biased population disparity between the urban and the rural inhabitants is geographically dispersed by rugged mountains and ranges. In addition to this, the scabrous geographical landscape of the country has muddy swamps and deadly flowing rivers. The cultural and geographical diversity and linguistic complexity are more specific and unique in the four regions of the country.

Papua New Guinea is divided into four regions called *Southern*, *Islands*, *Momase* and *Highlands*. Each of the four regions have several of both unique and common cultures and languages. Culture plays a significant role in shaping the people's behavior, beliefs, and values in these four regions of the country. Some of the cultural norms are unique to a specific region while others are common to the four regions. For example, traditional dressing and reconciliation are unique but the respect for elders and family values are common in the four regions. One of the key functions of cultural norms is to provide a sense of belonging and identity to individuals within the respective regions. The four regions also embrace the common universal cultural values such as love and justice and the specific one like welcoming strangers into their communities and homes. Cultural values are the key principles or morals that underpin regionalism and culturalism in Papua New Guinea. Local Papua New

Guinean students bring regionalism and culturalism into classrooms at all levels of education system and keep them alive. Kukari (2004) noted that being deeply rooted in their cultural belief systems, both the religious and cultural beliefs influence the way students learn in Papua New Guinea. Hence the efforts to determine the levels of cultural quotient (CQ) in the four regions are highly desirable.

Cultural intelligence (CQ) is the ability to effectively understand, adapt, and work in different cultural contexts. It encompasses four components, including Cognitive CQ, based on knowledge, Metacognitive CQ, based on strategy, Motivational CQ, based on drive and Behavioral CQ, based on action, which help individuals navigate and succeed in culturally diverse environments. According to Ott & Michailova (2016) Cultural Intelligence (CQ), is an individual's capability to function and manage effectively in culturally diverse situations and settings. Experts in cultural intelligence can perform an important function in helping members of different cultural backgrounds to be more effective in multicultural settings. They can also use their skills for effective communication by bridging language barriers and resolving different communication styles. Cultural Intelligence can be used as a tool to mediate the high levels of relationship and process related conflict arising from different cultural misunderstandings. It can also be used to reduce the time that culturally diverse teams take to reach a conclusion. Dogra & Dixit (2018) stated that 'Cultural Intelligence gives an insight on understanding why some of the individuals are able to cope and succeed in a diverse environment than others' (p. 1). Thomas (2017) found that culturally intelligent people are at a distinct advantage and they are more likely to make correct determinations for the reasons why people who were culturally different behaved as they did.

Cultural intelligence plays a vital role in successful global leadership. It is essential for global leaders to effectively navigate diverse international environments. Understanding global business etiquette is crucial for respecting cultural differences and fostering positive relationships. Leaders with high cultural intelligence are better equipped to lead diverse teams and drive inclusive work environments. Effective cross-cultural engagement strategies enable global leaders to communicate and collaborate seamlessly across cultures. Developing cultural intelligence helps leaders to overcome challenges related to cross-cultural communication. Leadership is the ability and capacity to influence others and is the exercise of authority and making decisions (Bass, 1990).

Choosing physics to understand and embrace the role of cultural intelligence to improve physics education in multicultural classroom settings is vital and necessary. Physics is the multidisciplinary and unifying discipline in the field of natural sciences, engineering and technology. Physics deals with the study of the nature, the basic laws that govern the natural phenomena and the behaviour of matter. The fundamental focus of physics is the study of the relationship between matter and energy which underpins the other areas of study. Matter is composed of elementary particles that interact through fundamental forces.

In physics, there is a wide range of branches such as mechanics, heat, light, sound condensed matter, atomic and molecular physics, elementary particle physics, astrophysics, nanophysics and so on. It is the most difficult science subject having inseparable progressive levels of mathematics with the global trend of declining statistics of students' enrollment. The research in physics includes semiconductor devices that became the heart of the modern technology. Physics concepts are applied to develop and improve infrastructure and services in health, energy, technology, environment, communication, bioscience, space science education, transport, meteorology and entertainment and so on. These sectors play a vital role for sustainable growth of the world. Physics education plays a significant role in educating and training educationists, technical and professional experts who contribute in local, national and global transformation with creative and innovative visions, ideas and skills. Windschitl (2009) "explained that physics education can offer a rich context for developing many 21st-century skills, such as critical thinking, problem solving, and information literacy especially when instruction addresses the nature of science and promotes use of science practices. ...these skills not only contribute to the development of a well-prepared workforce of the future but also give individuals life skills that help them succeed hence are skills enhance effective leadership skills".

Cultural Quotient (CQ) for physics education is a measure of the subject content and learning environment which align with the students' cultural context and values. It gives the student's familiarity with applications or examples. It depicts how well the teaching methods accommodate with diverse cultural backgrounds. Also, it reflects the student's motivation in learning physics shaped by his cultural experience.

In this paper we calculated the cultural quotient of physics education in the four different regions of Papua New Guinea. We analyzed the cultural intelligence by conducting a survey among the first- year university

students taking physics. The data collected was entered into Google Forms as a survey administration software and used the Google Sheets for effective sorting in spreadsheets. We also proposed measures to develop cultural intelligence among students in regions whose cultural quotient scores are low.

2. METHODOLOGY

The number of students who took part in the study from the four regions of Papua New Guinea is given in Table 1.

Table 1. The number of students who took part in the study from the four regions of Papua New Guinea.

		REGIONS				TOTAL	
INSTITUTION		SOUTHERN	MOMASE	HIGH LANDS	ISLANDS		
UPNG	Male	6	15	33	3	57	
	Female	3	12	14	11	40	97
UNI TECH	Male	13	10	24	4	51	
	Female	6	12	10	4	32	83
UoG	Male	5	7	28	3	43	
	Female	1	0	4	0	5	48
TOTAL	Male	24	32	85	10	151	228
	Female	10	24	28	15	77	
	TOTAL	34	56	113	25	228	

The survey questionnaire accommodates and explains four different categories. They are 1) learning and understanding physics, 2) aspirations of physics education, 3) influences of English language in learning physics and 4) physics knowledge from the community. The cultural factors that influence physics education in Papua New Guinea are 1) language barrier, 2) interactions of physics concepts with indigenous knowledge, 3) the perception of physics in Papua New Guinea's cultural values and 4) the family or societal expectations that impact the physics education. To calculate CQ, we took some indicators based on 1) understanding the concepts of physics with culturally relevant examples, 2) curriculum flexibility to include local phenomena and availability of teaching and learning resource materials, 3) students' interest, participation and motivation in physics and 4) culturally relevant teaching styles (story telling). To quantitatively evaluate the responses of specific cultural backgrounds, a Likert-scale system is used to measure the student's attitude and engagement of physics education. For measuring qualitative responses related to cultural relevance and engagement, we assigned weightage points based on the depth of the relevant responses (Ang et al., 2007). This is tabulated in Table 2.

Table 2. The assigned weightages for categories 1) Learning and understanding physics, 2) Aspirations of Physics education, 3) Influence of English language in learning Physics and 4) Physics knowledge from the community.

Categories	Indicators	Weightage
1. Learning and understanding physics	There are just too many formulas and equations to remember and understand in physics	1.0
	There are just too many symbols and constants to remember and understand their meanings in physics	1.0
	It was difficult to tell my peer group the problems I had in learning physics in Grades 11 and 12 because physics was just difficult.	1.0
	It was difficult to tell my physics teacher the problems I had in learning physics in Grades 11 and 12 because physics was just difficult.	1.0
	It was difficult for me to participate in Grades 11 and 12 physics classes discussions because physics itself was just difficult.	1.0
	If a student is weak in physics, then that student is also weak in other science subjects	1.0

	If a student is strong in physics, then that student is also strong in other science subjects.	1.0
	I was told by family friends at home that physics was going to be a difficult subject to learn in grades 11 and 12 and that was when I began to get scared of learning physics.	1.0
	I was told by my school friends that physics was going to be a difficult subject to learn in grades 11 and 12 and that was when I began to get scared of learning physics.	1.0
	I was told by my grade 11 physics teacher that physics was going to be a difficult subject to learn and that was when I began to get scared of learning physics.	1.0
2. Aspirations of physics education	Physics is unheard of at primary and high school levels until you reach grade 11	1.5
	Physics is just naturally difficult regardless of how much effort you put in to understand	1.5
	Applying physics in real life experiences is hardly seen or heard of in grades 11 and 12.	1.5
	Future career opportunities in Physics are not common and not popular in grades 11 and 12.	1.5
	Future career opportunities in Physics are not known in grades 11 and 12.	1.5
	I was forced by the education system to take up physics in grade 11	1.5
3. Influences of English language in learning physics	It is not easy to learn physics from other sources apart from the physics teacher	2.0
	The language translation process from mother tongue to motu or tok pisin then to English makes it much more difficult to understand physics.	2.0
	It was difficult for me to share my views on teaching and learning physics in Grades 11 and 12 because it was also difficult for me to use the language and expressions of physics.	2.0
	Because physics was difficult to learn, I would have learnt better if my physics teacher was from the same region as I am.	2.0
4. Physics knowledge from learning physics the community	I have family members who graduated in physics and other sciences and engineering and that encouraged me to study physics even the subject was challenging.	1.5
	The difficulty of physics was only a challenge. I appreciated learning new techniques, ideas and methods of solving problems and that encouraged me to continue studying physics at university level.	1.5
	In physics I learnt new ideas and things which not many people know and do and this makes me feel proud and unique to continue study physics at university level.	1.5
	Laws of physics are laws of life	1.5

From the score of each indicator, a weighted average of the overall CQ is calculated using the formula

$$CQ = \frac{\sum(W_i \times D_i)}{\sum W_i}$$

where W_i = weight assigned to each indicator and D_i = average score for each indicator.

Similarly, weighted average CQ levels for the four categories for each region were determined using the same formula (Ang et al., 2007).

3. RESULTS AND DISCUSSION

Table 3: The weighted average of the CQ levels for the four regions under study.

Region	Weighted Average CQ Levels
Southern	14.24
Momase	14.75
Highlands	52.27
Islands	9.56

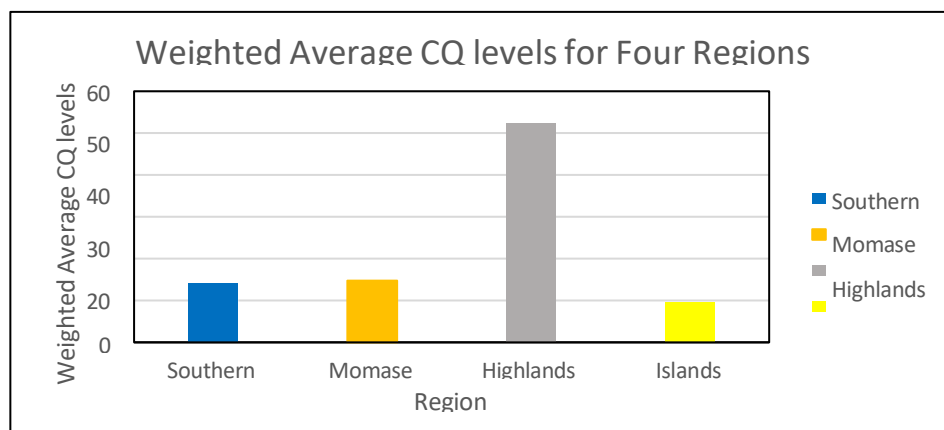


Fig. 1: The weighted average Cultural Quotient levels in the four regions.

Table 4: The weighted average of the CQ levels for the four categories for the four regions under study.

Categories	Weighted Average CQ Levels			
	Southern	Momase	Highlands	Islands
1	13.7	13.3	51.9	8.8
2	12.2	11.5	42.3	7.2
3	7.5	9.0	32.3	5.0
4	27.3	29.8	94.5	20.5

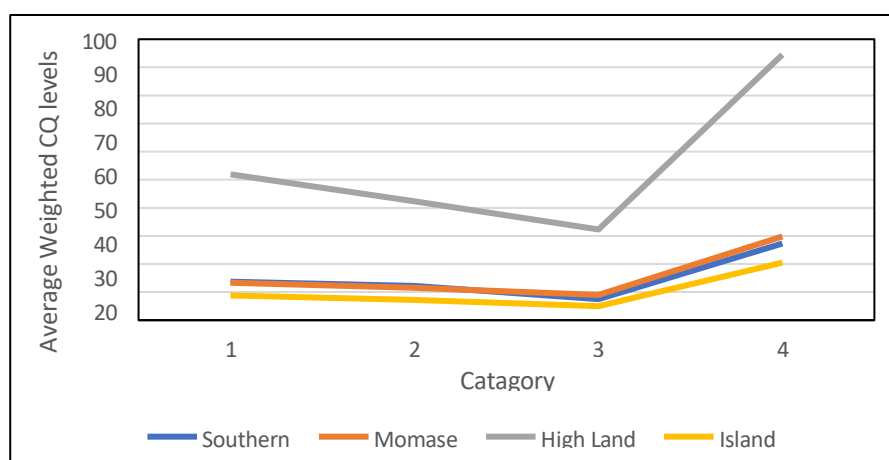


Fig. 2: The weighted average CQ levels based on the four categories

Table 3 shows that Highlands Region has the highest weighted average CQ level of 52.27. Momase Region, Southern Region and Islands region have their weighted average CQ levels as 14.75, 14.24 and 9.56 respectively. Fig. 1 shows the significant disparity between the weighted average CQ levels of Highlands Region and the other three regions. This study highlights that culture does influence the way students learn physics in Papua New Guinea with varying levels of CQ across the four regions. This finding aligns with Kukari (2004) who found that classrooms for teaching and learning in Papua New Guinea are polarized by religious and indigenous cultural beliefs.

Fig. 2 and Table 4 show two significant findings of this study. One is the uniform behaviour of each of the graphs for the four regions. This means that students in Papua New Guinea bring both commonly shared and unique cultural beliefs into their grades 11 and 12 physics classrooms. They also face common challenges and difficulties in learning physics. The impacts of these challenges also vary across the four regions. The other observation is that for all the four regions there is significant decrease in the weighted average CQ levels for

category three. The Highlands region has relatively the highest weighted average CQ level for this category compared to the other three regions. This study shows how English language affects students learning physics in Papua New Guinea. Language barriers cause fragmentations in physics classrooms in Papua New Guinea when it comes to interpretations, discussions and thought processing of physics concepts. This finding is supported by Morales (2015) who reported that culture and language integration in the teaching and learning processes of physics concepts allow students to develop positive attitude to science, their culture, and native language.

Physics classrooms in Papua New Guinea settings mean more than teaching and learning environment. The dynamics of linguistic and cultural diversity play a significant part in shaping both the teachers' and students' attitudes towards physics. These unseen forces are what both physics teachers and students need to contain to have meaningful and lifelong teaching and learning. Some of the recommendations to enhance the cultural Intelligence are given below.

- Introduce cultural awareness in schools and universities.
- Conduct cultural competency workshops and training programs in schools and communities.
- Promote cross-cultural interactions like Community events, multicultural festivals and intergroup dialogues that share their customs, food, music and traditions.
- Government and private organizations can organize exchange programs that allow people to travel, live and work in different cultural settings.
- Encourage multicultural programs in media.
- Identify community leaders and empower them to foster empathy and open-mindedness.
- Utilize technology to enhance cultural practices on a global perspective.
- Celebrate diverse cultural programs and encourage reflective practices.

4. CONCLUSION

CQ levels vary significantly across the four regions of Papua New Guinea. A critical highlight in this study is the weighted average of the CQ levels for the influence of English language in teaching and learning physics in Papua New Guinea. In our study, we observed that average cultural quotient is high in the high land region compared to other regions. In this paper we highlighted the remedial measures to improve the CQ levels across the four regions. PNG is known for its cultural diversity with different traditions, customs and life patterns. We recommend to run Physics teacher's upskilling programs to develop and implement appropriate pedagogies for physics teaching and learning in Grades 11 and 12 at in multicultural settings. Also, embrace cultural and language integration in physics curriculum to capture local phenomena.

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Community-Driven Adoption of Industry 4.0 Technologies for Sustainable and Resilient Food Production

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Abstract. Industry 4.0 technologies such as artificial intelligence (AI) and digital twins offer significant opportunities for improving sustainability and efficiency in food production. However, their adoption remains limited, especially among small and medium-sized enterprises (SMEs) and in contexts where manual operations are still necessary. This research presents a community-driven framework to support the integration of these technologies in local food production and agricultural systems. By combining technical development with community engagement, the research addresses both operational optimization and existing digital skill gaps. This research contributes to the broader digital and green transition by aligning advanced technologies with local needs, ensuring that innovation is inclusive, practical, and socially grounded.

Keywords: Industry 4.0, Digital twin, Community-Driven, Agricultural system, Sustainability

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Doctor Shiva Abdoli is a researcher and lecturer in the School of Mechanical and Manufacturing Engineering, UNSW. She was educated in several International Universities. She received her second master's in production engineering and management in 2014 from Royal Institute of Technology, KTH University, Sweden and her PhD in 2019 from UNSW. Subsequently, she was working as a post-doctoral fellow in UNSW before starting as an Associate Lecturer of Mechanical and Manufacturing Engineering in 2020. She also has industry experience as a Production line manager and Project coordinator. Her research interests are in Systems Engineering, System of Systems, Complex System design, Product-System design, Industry 4.0, Sustainable Production-Logistic Systems, Environmental impact analysis, and Circular Economy.

1. INTRODUCTION

1.1 Objectives

The agricultural sector faces the dual challenge of increasing production efficiency while adhering to environmental sustainability and social inclusion goals. Industry 4.0 promotes digitalization with key enabling technologies including Artificial Intelligence (AI), Digital Twin (DT), Internet of Things, and cloud computing [1]. Proper application of Industry 4.0 technologies has proved to be effective in improving performance in various contexts including manufacturing. It is crucial to bring up the human elements; in developing technological solutions to ensure new developed technological solutions will not have a negative impact on society and particularly the local communities also support them. Yet, there is not much research done in integrating human needs and traditional knowledge when developing new technologies for food production and agricultural systems [2,3]. The green paradox concept refers to this phenomenon when the technological solutions developed to promote sustainable development leads to a negative impact because of not having a holistic approach and not including human behavior and social aspects in applying those technologies [4]. Despite the transformative potential of Industry 4.0, the agricultural sector has been slow in adoption of Industry 4.0 technologies.

In response to these challenges and needs, this paper aims to address this gap by proposing an innovative

framework that allows responsible digital transformation that leverages the capabilities of Industry 4.0 tools in a community and socially responsible manner. The aim is to co- develop solutions that are technically advanced, socially inclusive, and environmentally sustainable.

1.2 Background

Industry 4.0 encompasses a suite of technologies that enable cyber- physical integration, data-driven analysis, and real-time decision support [5]. Key technologies include:

- Digital twins (DT): Virtual replicas of physical systems that simulate, predict, and optimize performance.
- Artificial intelligence (AI): Algorithms that enable machines to learn from data and support intelligent decision-making.
- Reinforcement learning (RL): A subset of machine learning where agents learn optimal actions by interacting with the environment and receiving feedback.
- Cyber-Physical Systems (CPS): Integrated systems in which physical processes are monitored and controlled by computer- based algorithms tightly coupled via networks.
- Cloud Computing: On-demand access to computing resources that enables scalable processing, data storage, and remote collaboration essential for real-time analytics and distributed digital twin deployment.
- Internet of Things (IoT): A network of physical devices embedded with sensors and connectivity that enables real-time data collection and interaction across systems. has applied these technologies to manufacturing and logistics, applications in agriculture remain fragmented. Moreover, a few approaches systematically incorporate community knowledge and behavioural dynamics into AI training and system design.

While existing works have applied these technologies on manufacturing and logistics sectors, their applications in agriculture remain fragmented. Limited research has been done for systematically incorporating community knowledge and social aspects into AI training and system design.

2. CONCEPTUAL FRAMEWORK

The proposed framework is structured around three pillars: socio- technical systems modeling, AI-based optimization, and community knowledge integration.

2.1 System-of-Systems Architecture

Agricultural systems are complex systems, due to including many sub elements that dynamically interact with each other [6,7]. Systems Engineering (SE) discipline focuses on the whole system and the interactions between its elements. Hence, this research proposes using SE to analyze an agricultural system that might lead to an underperforming when applying Industry 4.0 technologies. In the proposing framework, the agricultural system is conceptualized as a System-of-Systems (SoS) comprising interdependent subsystems such as production modules, logistics, labour allocation, and energy management [8]. Each subsystem is modeled as a module with a hierarchical structure to break down and manage the complexity of such a large-scale system.

This paper suggests modelling the architecture of an agricultural system by defining two categories of processes: transformative and supportive. The first category refers to processes that their functions contribute to transformation of inputs to outputs, such as planting, fertilizing, or harvesting processes. The second one refers to processes that their functions support the first category or are implemented to improve an agricultural system performance such as data acquisition for maintenance planning. Processes from both categories can interact with each other. A process can have physical or operational enablers to deliver its functions. Interactions between processes are defined by indicating type of interactions among their functions, such as data or physical exchange. This allows defining interactions at functional space of an agriculture system, shown in Fig. 1.

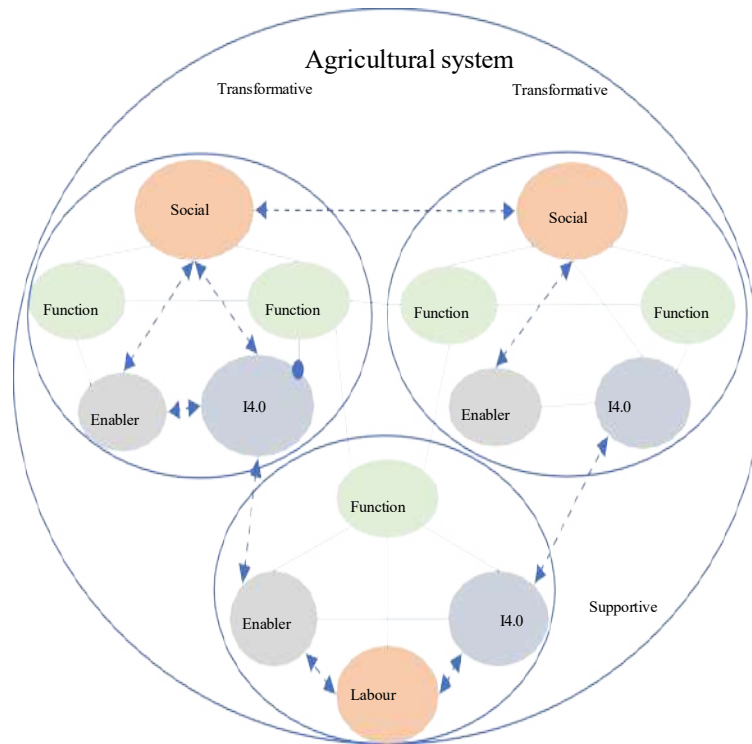


Fig. 1. SoS architecture of an agricultural system

2.2 Modelling the interactions in SoS Architecture

Application of Industry 4.0 may require adding supportive processes which expand the scale of an agriculture system. Implementing new technologies in transformative processes also increases the system complexity due to forming new interactions between enablers. Here, the consequences of integration of Industry 4.0 technologies in an agriculture system are discussed.

This paper suggests an innovative approach by developing DT of an agriculture system with a State-based Modelling formalism (SM). SM demonstrates a system with a set of states, transitional conditions between them, and consequent actions. This paper suggests modelling an agriculture system at the highest level of hierarchy as a parent state that includes transformative and supportive processes. The modelled states for processes (called process-states) can include substates to embody their needed enablers (called enabler-states) to deliver their functions. Transitions between process-states and enabler-states can be defined to embody the logic of interactions between processes and enablers.

The resultant DT model has a nested state structure, which the higher levels embody an agriculture system and its processes, while detailed modelling can be defined for enabler-states. A process-state can include several sub states to embody various types of enablers including Industry 4.0 and human. Each enabler-state can be further decomposed to model the disciplinary details, their behaviour, and their interactions with other enabler-states. The enabler-states can model a specific enabler from two perspectives: first, modelling the dynamic behaviour of each enabler in its discipline at the system level to model its interactions with other enablers such as the movement of a human when loading a part on a machine, and second, providing a module for encapsulating its own specific behaviour such as the kinematic of a machine or modelling the behaviour of a human.

Such structure allows holistic and multidisciplinary modelling of an agriculture system. The proposed DT can embody different types of processes based on the levels of Industry 4.0 application (transformative and supportive processes) and different types of enablers (human and technical). State models can be simulated, mostly based on discrete event simulation (DES) approach [7]. Agriculture systems in general operate based on discrete events, hence, DES approach matches perfectly to simulate the dynamic interactions between enablers in DT of an agriculture system. Interoperation between enablers and process states can be modelled by defining proper variables and parameters. Since the nested state's structure allows encapsulating the modelling details of operators

and Industry 4.0 technologies while their interactions can be modelled at a higher system level, the proposed approach allows observing the impact of including potential Industry 4.0 technology on both operators and overall performance of an agriculture system.

2.3 Socio-Technical System of Systems Digital Twin

This research considers an agriculture system a socio-technical system, because human, social, and technical components interact dynamically within it and its performance is determined by technical elements, including industry 4.0 technologies, and their interaction quality with human systems. This study places these human-technology interactions at the center of its modeling efforts.

To ensure a human-centered approach, this research suggests innovative modelling parameters to be implemented in the proposed DT and introduces Interaction Type (IT) parameters that capture how social or human elements engage with technological components. Three dimensions of interaction are defined:

- Functional role: In functional dimension three types of interactions can exist between a social aspect and an Industry 4.0 technology to deliver a function: independent co-existence, (IE), independent cooperation (IC), and dependent collaboration (DC).
- Interaction modality: In interaction modality, two types of interactions can be defined: physical (P) and information (I).
- Temporal pattern: In temporal domain, two types of interactions can be defined as: sequential (S), concurrent (C), and feedback (F).

For example, independent co-operation with exchanging information in a sequential manner, or (IC, I, S). However, some might not sound feasible, such as (IE, P, F). This research suggests defining this Interaction Type parameter, IT_{pi} = (function, physics, timing) for all the process-states in the proposed DT, where ‘p’ refers to a specific process and ‘i’ refers to a specific Industry 4.0 technology. This enhances awareness about the existence of interactions that can lead to consequences. Otherwise, the interactions maybe overlooked, and their unintended consequences can negatively impact human or AS performance.

This research suggests modelling specific parameters indicating various social needs in the proposed Digital Twin. The social needs can include safety, health, belonging, esteem, and self-actualization. This research suggests defining a parameter called Interaction Consequence on social needs, to indicate the level of social needs satisfaction because of interactions as given in Equation (1).

$$ICH_{pi} = \{[IT_{pi}], [\text{level of needs' satisfaction}]\} \quad (1)$$

Various qualitative and quantitative approaches can be used to define the level of satisfaction, such as Likert Scale, surveys, and fuzzy logic.

2.4 Reinforcement Learning for Community Driven and Socially Responsible Development

The proposed digital twin framework integrates a reinforcement learning (RL) model as a central decision support system. RL is particularly effective for learning optimal strategies in environments characterized by uncertainty, complexity, and dynamic interactions — all of which are prevalent in agricultural production and supply chain systems.

In the proposed framework, RL agents interact with a high-fidelity simulation environment generated from the digital twin. This environment models real-world agricultural workflows using discrete- event and state-based simulation methods. Agents observe system states composed of variables such as energy consumption, crop yield, environmental conditions, equipment availability, labour status, and sustainability metrics.

Each agent operates within a Markov Decision Process (MDP), where the state space includes continuous and categorical features and the action space spans operational decisions such as irrigation levels, resource allocation, worker assignment, and scheduling. The agents are trained to maximize a composite reward function that can incorporate various related parameters such as:

- Crop yield efficiency
- Resource and energy optimization (evaluated using life cycle analysis metrics [8])
- Operational costs
- Social and ethical considerations derived from community preferences
- Penalty terms for rule violations (e.g., exceeding carbon thresholds or worker fatigue levels)

Deep Reinforcement Learning (DRL) techniques such as Proximal Policy Optimization (PPO) or Deep Deterministic Policy Gradient (DDPG) can be employed to manage the complexity of continuous, multi-objective decision spaces. These methods leverage neural networks to approximate policy and value functions and are trained through extensive interaction with simulation. Model performance is assessed based on learning stability, convergence speed, and long-term generalizability across diverse agricultural scenarios.

2.5 Community Knowledge Integration into RL Policy

To ensure responsible and inclusive digital transformation, traditional and local community knowledge is explicitly integrated into the RL framework. This process bridges qualitative social knowledge with quantitative learning systems, allowing the RL agent to develop policies that are both effective and socially legitimate. The integration process involves several stages:

1. **Knowledge Acquisition:** Community workshops and expert panels are conducted to elicit experiential knowledge. Data are structured into three key categories:
 - Behavioural rules: If-then patterns and cultural norms around farming operations
 - Environmental observations: Indicators of seasonal changes, weather, pest conditions
 - Adaptive strategies: Local responses to past disruptions or climatic extremes
2. **Policy Shaping:** Collected heuristics guide the initialization of the RL agent's policy network. This can be achieved through:
 - Initial biasing of the action selection probabilities
 - Constraints in the exploration space to prevent culturally unacceptable actions
 - Prioritized replay based on context relevance
3. **Reward Shaping:** Community priorities — such as soil preservation, water conservation, or labour fairness — are translated into additional reward terms or reshaped reward functions. These are assigned weights based on feedback from stakeholder consultation using methods like fuzzy logic or weighted Delphi consensus scoring.
4. **Simulation Constraints:** Practices deemed essential or non- negotiable (e.g., bans on certain chemical use, ceremonial land-use boundaries) are modelled as hard constraints in the environment. RL agents cannot violate these constraints during training or execution, ensuring cultural integrity is preserved.

This hybridized RL setup — combining technical optimization with socio-cultural alignment — allows the system to learn context-aware policies that generalize across different agricultural setups while respecting local wisdom. It also strengthens trust in AI-assisted decision- making by ensuring transparency and inclusion in the model development process. The proposed approach takes a step in covering the explained research gap while having a direct societal impact by empowering communities with new competencies and fosters a co-development approach where traditional knowledge contributes to the research process.

3. IMPLEMENTATION AND TOOLCHAIN

The proposed framework employs a modular digital twin model that can be built in various platforms such as

MATLAB Simulink and Sim Events for discrete events and state-based modeling. Key components include:

- Baseline simulation of agricultural workflows.
- Scenario testing (e.g., equipment failure, weather variation).
- RL agent training using model-integrated reward functions.
- Agent based modelling within state -based modelling architecture to simulate human behaviour, labour interactions, and decision-making routines.
- Interface modules to evaluate interventions such as automation, renewable energy integration, or logistics reconfiguration.

4. CONCLUSION AND FUTURE WORK

The presented framework bridges the gap between advanced Industry 4.0 technologies and socially responsible digital transformation in agriculture. By integrating reinforcement learning with community- derived knowledge into a modular digital twin system, the approach enables context-aware optimization while preventing unintended consequences of decontextualized technology deployment. This research fosters inclusive digital transformation by embedding local knowledge and values into advanced optimization tools. It addresses systemic challenges in technology adoption by:

- Empowering communities to influence AI behaviour.
- Providing decision support tools tailored to local contexts.
- Promoting sustainable, resilient agricultural practices aligned with net-zero goals.

Future work will explore the implementation of the proposed framework on a real case study to validate it. Also, cyber-physical integration with real-time sensor data, expanding applicability to other critical sectors such as logistics, water management, and renewable energy systems can be further explored.

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An Assessment of Heavy Metals Contamination in Freshwater Sediments and Fish and Cyanide in Sediment around Gold Ridge mine site, Solomon Islands

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Abstract: Heavy metals in riverine sediments around Gold Ridge mine site ranged from 0.71 ± 0.09 to $726.73 \pm 0.86 \mu\text{g g}^{-1}$. Out of all the metals that were investigated in the area, only arsenic metal claimed the highest concentrations for all sites within the area with values exceeding those of the WHO and EPA guidelines. The moderate type of contamination was shown for cyanide in sediments with values of 0 to $4.41 \pm 0.35 \mu\text{g g}^{-1}$ which exceeded the WHO limit of $1 \mu\text{g g}^{-1}$. The values of metals recorded for the two selected fish species Gobiidae, *Belobranchus belobranchus* and *Rhyacichthys aspro* ranged from under 0 to $2.59 \pm 0.38 \mu\text{g g}^{-1}$. The use of these fish species as bio-indicators of heavy metal contamination in rivers around gold ridge proved them suitable to use as bio-indicators for future studies in the area. The sequential extraction of heavy metal in sediments indicated that most metals were present in the non-resistance fraction, a fraction that was readily available to move in the environment. Comparing the present study to the baseline study in the same area, indicated a simple % ration of, Cu (17%), Pb (78%), and Cr (54%), Cd (no data) and as (55%) were noted for all metals in the sediments. The present study confirms a significant increase of metals over years in rivers around the Gold Ridge mine site. The highest levels of metals and cyanide in riverine sediment around gold ridge mine site, compared to other Pacific studies, are attributed to the discharge of wastewater from the tailing dam in the area.

Keywords: Pollution, heavy metals, cyanide, sediments, sequential extraction, Gold Ridge mine

Author Biography:

The presenter for this PIURN conference presentation is Mr. Timothy Aihunu, an Assistant Lecturer in Chemistry at the School of Science and Technology, Solomon Islands National University (SINU). He holds a Bachelor of Education degree in Chemistry and Education from the University of the South Pacific (USP). Since joining SINU, Mr. Aihunu has contributed to teaching undergraduate chemistry courses and supporting student research in environmental science, particularly in the area of environmental pollution and sustainability.

The main author of the study, Dr. Dickson Michael Boboria, a Senior Lecturer in Chemistry at SINU with extensive expertise in Analytical Chemistry. He holds a PhD in Analytical Chemistry, a Master of Science and a Bachelor of Science degree. Dr. Boboria has led several environmental monitoring and assessment projects in the Solomon Islands, with a strong research focus on chemical pollutants in aquatic ecosystems and their implications for public and ecological health.

Together, Mr. Aihunu and Dr. Boboria will present findings from their recent study titled “*An Assessment of Heavy Metals Contamination in Freshwater Sediments and Fish and Cyanide in Sediment Around Gold Ridge Mine Site, Solomon Islands.*” This research evaluates the levels of selected toxic elements and cyanide in river sediments and aquatic organisms near the Gold Ridge mining site. The study provides important scientific data to inform environmental policy, risk assessments and the sustainable management of freshwater resources in the region.

1. INTRODUCTION

Mining activities, particularly gold mining, can cause long-term contamination of freshwater environments with toxic and persistent pollutants such as heavy metals and cyanide. Cyanide, commonly used in gold extraction, and heavy metals can accumulate in sediments, which act as reservoirs for these pollutants, eventually affecting aquatic life and human health through bioaccumulation in edible fish.

The Gold Ridge mine, an open-pit gold mine in Guadalcanal, Solomon Islands, has experienced significant environmental challenges, including heavy metal and cyanide pollution in surrounding rivers. Past operations led to contamination of river sediments, and incidents such as the 2014 flash flood and uncontrolled dam discharge in 2016 further elevated risks for downstream communities that rely on the rivers for water and food. Previous studies focused on total heavy metal levels in sediments, especially arsenic, but did not assess metal bioavailability or contamination in aquatic organisms. This study aims to fill that gap by investigating the current levels of heavy metals and cyanide in sediments and in two commonly consumed fish species, *Belobranchus belobranchus* and *Rhyacichthys aspro*, to assess potential ecological and human health risks.

Using sediment quality guidelines (SQGs) and pollution indices like the Enrichment Factor (EF) and Geo-accumulation Index (Igeo), the study also includes sequential extraction analysis to determine the mobility and environmental risk of these metals. With the mine reopening in 2022, updated risk assessments are crucial for ensuring the safety and well-being of the local population.

2. MATERIALS AND METHODS

2.1 Study Area and Sampling Sites

Sampling was conducted in the upper catchment of the Metapona River, including Tinahula and Savohio Rivers. Seventeen sites were sampled for sediments (including controls), and fish samples were collected at four locations where two target species were present. A total of 21 stations were sampled

2.2 Sediment Sampling and Digestion for Metal Analysis

Triplicate sediment samples were collected, preserved at -20°C , oven-dried, homogenized, sieved, and digested using nitric acid and hydrogen peroxide. Samples were analyzed by Atomic Absorption Spectroscopy (AAS) with appropriate quality checks and certified reference materials.

2.3 Sediment Sampling for Cyanide Analysis

Cyanide was analyzed in the same sediment samples collected for heavy metals. Samples were stored at $\leq 6^{\circ}\text{C}$ and extracted with NaOH before analysis using titration methods. Complex and free cyanide forms were distinguished through a distillation process involving chlorinated and unchlorinated samples.

2.4 Total Cyanide and Reflux Distillation

The USEPA Method 9010 was used to determine total cyanide via reflux distillation and titration. This process distinguished between chlorinated and unchlorinated forms and eliminated interferences using specific reagents. Accuracy was validated using recovery tests and reproducibility studies, yielding 98–99% recovery.

2.4 Fish Sampling and Digestion for Metal Analysis

Forty fish samples were collected from four river sites. Muscle tissues were dissected, oven-dried, digested with nitric acid and hydrogen peroxide, filtered and analyzed for metal content using AAS.

2.5 Quality Control

Certified reference materials were used for sediments, fish tissues, and cyanide samples. Blanks and triplicates ensured accuracy. Detection limits and coefficients of variation were reported.

2.6 Sequential Extraction

To assess metal bioavailability, the BCR sequential extraction method was applied. Metals were separated into four fractions (bioavailable, reducible, oxidizable and residual) and analyzed by AAS.

3. RESULTS AND DISCUSSION

3.1 Total metal contamination

Table 1: Mean contents ($\mu\text{g g}^{-1}$) of heavy metals in ($\pm$) standard deviation and pH for the riverine sediments at 16 sites around the Gold Ridge mine.

Sites	Cu	Pb	Cr	Cd	As	pH
Tinahula Bridge S1	103.3 7 ± 1.60	142.44 ± 0.620	59.71 ± 1.31	$1.77 \pm$ 0.260	$512.03 \pm$ 0.490	7.63
Tinahula Bridge S2	71.07 ± 1.35	166.72 ± 2.14	59.72 ± 1.31	$2.19 \pm$ 0.070	$726.73 \pm$ 0.860	9.12
Tinahula Bridge S3	113.0 1 ± 1.36	183.79 ± 1.24	81.06 ± 2.91	$2.45 \pm$ 0.030	$655.88 \pm$ 0.590	8.91
Tinahula Bridge S4	55.94 ± 0.620	$16.17 \pm$ 0.390	36.02 ± 0.410	$1.15 \pm$ 0.090	$619.14 \pm$ 2.95	7.82
Tinahula mid-stream	44.05 ± 0.630	$15.49 \pm$ 1.73	28.86 ± 0.310	$1.22 \pm$ 0.250	$344.22 \pm$ 0.430	7.92
Mean	59.980	53.850	33.270	1.20	223.690	
% recovery	96	93	90	93	97	
LOD	0.42	0.62	0.36	0.22	0.33	
CV	2.1	0.8	1.2	0.5	1.5	

The total metal contamination analysis revealed that heavy metal concentrations in river sediments were highest near the Gold Ridge mining area and decreased downstream. The upper stream sites near the Tinahula Bridge (S1–S3), close to the tailing dam discharge point, were the most contaminated. Mean concentrations across all sites were: Copper (Cu): 39.53–103.37 $\mu\text{g/g}$, Lead (Pb): 12.10–183.79 $\mu\text{g/g}$, Chromium (Cr): 18.53–81.06 $\mu\text{g/g}$, Cadmium (Cd): 0.71–2.45 $\mu\text{g/g}$ and Arsenic (As): 42.11–726.73 $\mu\text{g/g}$. The contamination pattern followed the order: $\text{As} > \text{Pb} > \text{Cu} > \text{Cr} > \text{Cd}$, with arsenic being the most dominant and widespread metal. High arsenic levels were attributed to weathering and mineral formation at the site, as well as interactions with aluminum (Al) and iron (Fe) hydroxides under alkaline conditions ($\text{pH} \sim 8$), which enhance as retention in sediments.

Sites near the discharge point had higher pH and Al levels (7000–13000 mg/kg), promoting arsenic precipitation and sorption. The data also showed a notable increase in metal concentrations compared to a previous study (Albert et al., 2016), with percentage increases for Cu (17%), Pb (78%), Cr (54%), and as (55%). Cadmium was not assessed in the earlier study. These increases are linked to ongoing effluent discharges from the abandoned tailing dam during heavy rains and flooding, resulting in metal accumulation in sediments. Downstream and marine sites exhibited lower as levels, likely due to dilution and sediment partitioning. Comparison with similar mining-impacted sites in the Pacific further emphasized the significant contamination at the Gold Ridge site.

3.2 Sequential extraction of heavy metals in sediments from freshwater areas

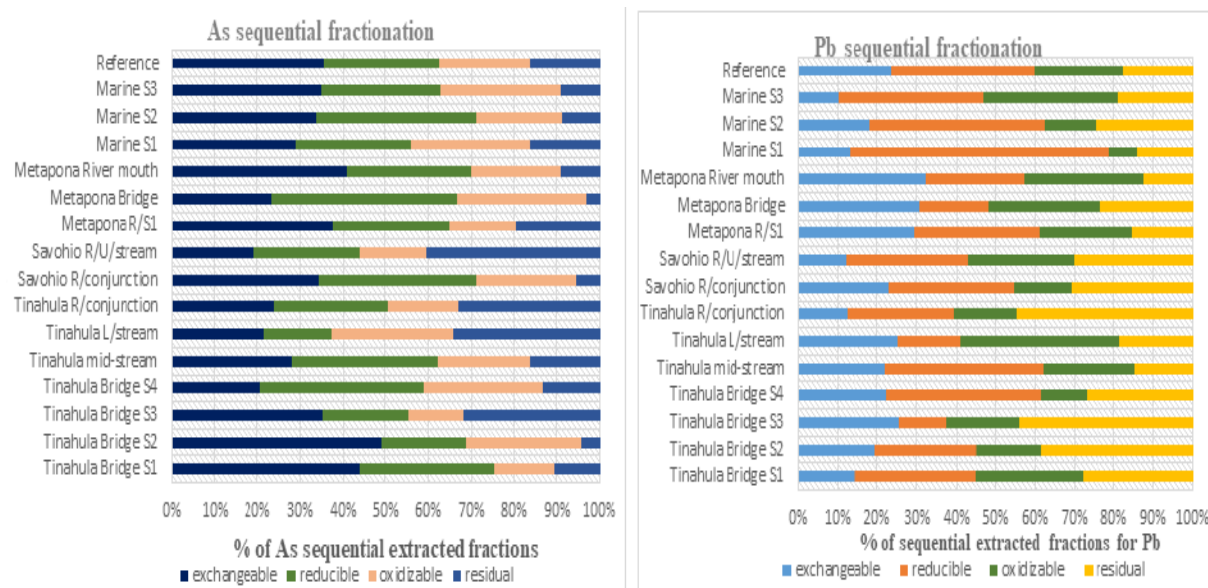


Figure 1: showing the Sequential extraction for As, Pb, Cu, Cr, and Cd in freshwater sediments around the Gold Ridge mine.

The analysis of total heavy metals in river sediments near the Gold Ridge mine revealed elevated concentrations of metals, particularly in areas close to the mining discharge points. The upstream sites near the Tinahula Bridge (S1–S3) were identified as the most contaminated, largely due to their proximity to the tailings dam where mining wastewater is released.

Metal concentrations and patterns ranged as follows, Copper (Cu): 39.53–103.37 $\mu\text{g/g}$, Lead (Pb): 12.10–183.79 $\mu\text{g/g}$, Chromium (Cr): 18.53–81.06 $\mu\text{g/g}$, Cadmium (Cd): 0.71–2.45 $\mu\text{g/g}$ and Arsenic (As): 42.11–726.73 $\mu\text{g/g}$. The order of metal abundance was $\text{As} > \text{Pb} > \text{Cu} > \text{Cr} > \text{Cd}$, with arsenic (As) being the most dominant contaminant. The elevated metal levels, especially near Tinahula Bridge, confirm direct influence from *mining discharges*, tailings dam overflow and hydrological factors like flooding and sediment transport. Arsenic levels were notably high due to secondary mineral formation and weathering, interaction with high aluminum (Al) content, enhancing as adsorption and alkaline pH (~ 8) at discharge sites promoting arsenic precipitation and reducing leaching.

The spatial distribution of Arsenic levels decreased downstream (Savohio River confluence to Metapona River and marine sites) due to dilution from river confluence and attenuation through sediment partitioning. A temporal comparison to Albert et al. (2016), metal concentrations significantly increased as Pb (78%), Cr (54%), As (55%), Cu (17%), while Cd was not analyzed in the earlier study. The increase reflects ongoing pollution from the abandoned tailings dam, particularly during heavy rainfall and flooding. A comparison was also done with other Pacific mining-impacted sites, affirming that heavy metal contamination at Gold Ridge is substantial and persistent, posing continued environmental risks.

3.3 Cyanide in sediments

Table 2: Mean levels ($\mu\text{g g}^{-1}$) of cyanide in ($\pm$) standard deviation for the Gold Ridge River sediments obtained for all sites in this study.

Stations	Total cyanide	Free cyanide	Amended cyanide	pH
Tinahula Bridge S1	2.06 $\pm$ 0.18	0.74 $\pm$ 0.02	1.32	9.71

Tinahula Bridge S2	3.33 ± 0.31	1.16 ± 0.03	2.17	9.83
Tinahula Bridge S3	4.41 ± 0.35	2.18 ± 0.06	2.24	10.23
Tinahula Bridge S4	0.94 ± 0.05	0.31 ± 0.03	0.63	7.92
Tinahula mid-stream	0.85 ± 0.15	0.31 ± 0.02	0.54	7.53
Tinahula L/ stream	0.78 ± 0.01	0.59 ± 0.02	0.19	6.52
Metapona Bridge	0.49 ± 0.09	0.36 ± 0.02	0.14	6.52
Reference site	0	0	0	7.31
Mean	0.940	0.403	0.535	
EPA	0.1			Department of Environment and Conservation, 2010
Proposed levels in Great Lakes sediment	0.25			Ogoyi et al., 2011
Background levels	1			Albert et al, 2016

The study assessed total, free, and bound cyanide levels in riverine sediments near the Gold Ridge mine. Cyanide concentrations ranged from 0 to 4.41 µg/g for total, 0 to 2.18 µg/g for free, and 0 to 2.24 µg/g for bound cyanide. Most sites showed cyanide levels below 1 mg/kg, except for Tinahula Bridge sites (S1–S3), where levels exceeded 1 mg/kg due to direct discharge from the mine’s tailing dam.

Higher cyanide concentrations at these sites were linked to high pH values (above 9), which enhance cyanide stability. The poor structural integrity of the tailing dam and environmental conditions (e.g., rain and flooding) contributed to cyanide seepage into sediments.

Downstream from these discharge points, cyanide levels dropped below 1 mg/kg due to natural degradation processes (oxidation, photodecomposition), lower pH (6–7), and possible dilution or transport by floodwaters. At the marine site (Marine S3), cyanide was undetectable, suggesting complete degradation or no contamination from the tailings.

CONCLUSION

The study concludes that open-pit mining at Gold Ridge poses a significant risk of environmental contamination. Elevated levels of heavy metals (especially arsenic) and cyanide were detected in river sediments, exceeding 2011 baseline levels. While contamination is moderate compared to some neighboring countries, it remains a concern due to the mobility of metals found in non-resistant forms, making them prone to environmental movement during disturbances.

Contaminant concentrations were highest near the mine and decreased downstream, influenced by flooding and water dynamics. Fish species used as bio-monitors confirmed sediment contamination, with arsenic levels in fish exceeding FAO/WHO safety limits. Statistical analyses (correlation and PCA) indicated that the contaminants originate from mining activities.

The study recommends public awareness and immediate mitigation measures to prevent further degradation of river systems around the Gold Ridge area.

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From Suspicion to Trust: ICP Blockchain's Role in PNG Aid Accountability

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Abstract: This paper is written to combat corruption, the ministerial slowness, and the overall lack of real-time control within Papua New Guinea's (PNG's) current centralized Charity aid system in distributing aid throughout the country. These problems concerning the structure of how Papua New Guinea (PNG) aids distribution, they are big cause of widespread mishandling of resources resulting to a big decline in donor trust, which has drastically impacted development process at the ground level (local Level) and up with a high decreased in external support. In contrast, there is hope through blockchain platforms such as Internet Computer Protocol (ICP). Ethereum and etc. ICP is one of the current top tiers in Public Blockchain technology in operation today. The purpose of the study is to see the benefits of ICP in PNG aid distribution in terms of its function's accountability and transparency. The study will also be examining the possibility of deploying such a system into Papua New Guinea's technological ecosystem especially its possibility, advantage, and any draw backs that comes with deploying this workable blockchain based solution, a thorough analysis of academic papers and research papers having ICP or block chain based solution used around the world on aid system or aid distribution will be examined. Given the thorough analysis and overview of PNG,s economy in terms of corruption and blockchain application of several papers, it is seen that blockchain may greatly impose an increase in transparency by offering immutable ledger capabilities that build donors confidence with real time fund tracking, this will revolutionize and reduce the number of administrative workloads through the use of automated smart contracts. Moreover, there are still underlying issues regarding the country's inadequate infrastructure, level of digital literacy and the necessary framework needed to guide implementation of this blockchain technology to successful adaptation. Despite the country's status as a third world country and still developing, PNG has the capacity to turn things around if proper studies is carried out to pinpoint the weakness in our economy and focus the solution on technological innovations to change it, by doing so improving its economy and country's state in general. So, in order to promote blockchain as one revolutionary tool that may restore faith in the humanitarian sector of Papua New Guinea, the study ends with strategic policy proposals for the incorporation into the assistance management frameworks.

Keywords: Blockchain, Internet Computer Protocol (ICP), Charity and aid distribution, Realtime Monitoring, Decentralized

Author Biography:

Daniel Yatukoman is a Final Year Bachelor of Computer Science Student at the PNG University of Technology; he's a Papua New Guinea native and reigns from the province of East Sepik. He has a desire for academic works and leadership experience, he has served key student representative roles, such as chairman of East Sepik Student and Staff Association of PNG UOT and Class representative for the Mathematics and Computer Science School. Daniel as a keen interest for technological innovations by using blockchains as a means of solutions to problems, due to its decentralized nature and chain structure for enhancing transparency, security and accountability in aid distribution. His recent studies were focused on a new blockchain technology called Internet Computer protocol and its ability to transform charity systems in Papua New Guinea. In addition, Daniel is currently working on this this project both theoretically and practically, in practical he's trying to deploy the system as his final year project. The system will enable real time monitoring allowing donors to know how their money is being used. This system will help bring trust back into charity and aid in Papua New Guinea.

1. INTRODUCTION

Over the years, humanitarian relief aid groups with charitable foundations and originations have been a life line to people in need worldwide. In Papua New Guinea (PNG) aid distribution plays a crucial role in solving many of PNG's developing needs in terms of poverty, health inequalities, natural catastrophes and the overall restricted access to basic infrastructures and educations. Papua New Guinea being the second largest island in the world faces a lot of socioeconomic difficulties as a result of it being a developing country. Most of the development that occurs to better life in the county comes from aid year in and year out, but even with the increasing amount of aid coming into the nation from both foreign and domestic sources, the performance of the current distributing system is declining over the years. The continuous misappropriation of funds, the secretive nature of financial transactions, and the high level of corruption throughout the different sectors are major issues facing Papua New Guinea in its assistance environment. These issues diminish the trust among donors and the public, when reports of money being embezzled hold up in payments, and a lack of oversight of the financial transactions. Furthermore, these issues are the direct result of the current centralized management system of charitable resources, this system does not cater for oversight or gives everyone hands on experience. Since the creation of blockchain technology, it has opened up many new avenues for redefining the traditional ways in how financial and governance institutions can impose accountability and transparency in the way it operates. Blockchain presents a source of fascination by providing solutions on how to track the source, flow, and use of charity funds because of its decentralized, immutable, and tamper-proof ledger characteristic. Through the use of smart contracts, it reduces reliance on any go between, by ensuring adherence to funding requirements, and enables donors and stakeholders to track transactions in real time. These developments could significantly influence an increase in data integrity, operational effectiveness, and trust during aid distribution procedures.

2. Charity and aid Problems in PNG compared to the pacific

Charity and aid problems is not just a problem PNG faces rather it's a problem where pacific island sisters are also facing it. The same issues as well were together, the Pacific islands depend on aid highly to maintain a healthy economy. Together all the pacific islanders depend on aid highly to maintain a healthy economy due to their landmasses and how scattered they are to each other. This is seen by the graph of "ODA-to-GNI ratio in Pacific Island Nations (2022)", reveals the degree of dependency on aid or assistance, where ODA assess the Official Development Assistance (ODA) as percentage to the Gross National Income (GNI). ODA measures how much assistance is given by donor countries and GNI is the measure of how much a person or residents of a country earns in a year.

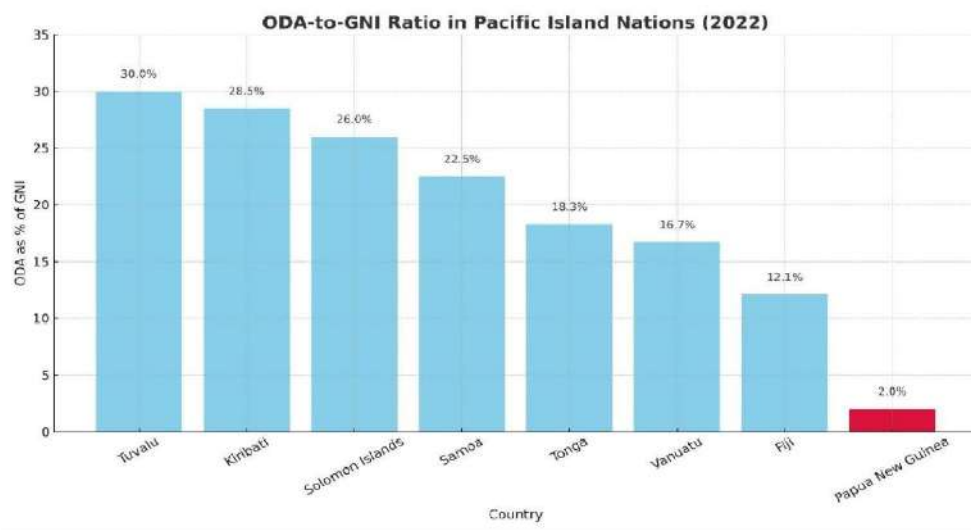


Figure 1 Shows a ratio between ODA and GNI in 2022

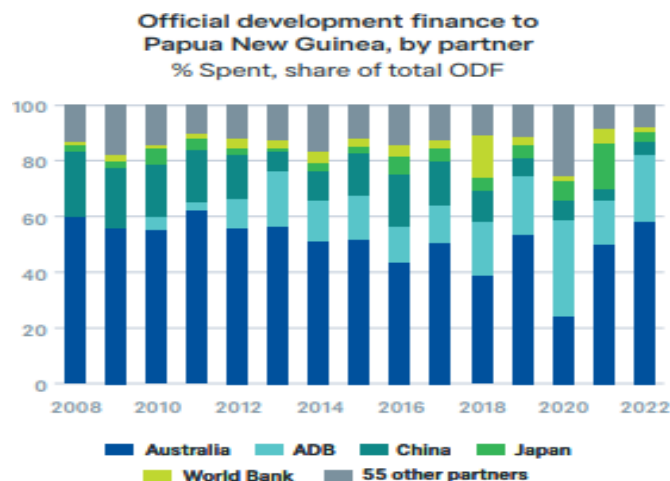


Figure 2 Shows the ODF up to 2022 from outsiders to PNG

PNG unlike its Pacific family has a low percentage of ODA to GNI Indicating a problem on the way it does its managing, the same is also seen in its Official development Finance (ODF). The inefficiencies and confusion involved in the nation's aid distribution operations are closely tied to its vast geographic area, spread out population, and lack of modern infrastructure. Take for example in 2024 a severe landslide in Enga Province up in the Highlands Of Papua New Guinea, that left thousands of people homeless and killed at least over another 2,000. During that time there were a lot of issues faced in bringing aid to the people, a lot of groundwork has to be down on how to roll out the aid due to the lack of trusted sources, we need a system that will ensure check and balances so we can ensure aid can be given without disturbances. In PNG, the usual traditional aid distribution networks have faced a lot of challenges that made it hard to carry out aid distribution such as infrastructure constraints, logistical challenges, and worries about financial misuse. Additionally, the implementation of blockchain technology is not only advantageous but also required to guarantee that the limited aid reaches people most in need without loss, delay, or manipulation.

3. LITERATURE REVIEW

Ongoing studies being carried out by researchers and professionals alike are looking into blockchain implications and how blockchain technology might be used in various ecosystems, the need to implement blockchain technology into systems worldwide is increasing in systems such as aid distribution and charity. There is a severe need for more open and accountable aid processes by implementing a decentralized system, especially it is very critical in the context of Papua New Guinea (PNG), where the institutional and administrative ineffectiveness frequently occurs and disrupt governance systems. The current issues facing PNG's aid system are seen in this literature study, along with the possibilities of blockchain being a solution, in particular the Internet Computer Protocol (ICP) being the new kid in the block in terms of blockchain technologies.

3.1 Existing Studies and theories

The occurring flaws in PNG's aid management systems or how it operates on service delivery are called to attention in a number of reports. PNG has a high amount of development needs as a result of its towering corruption as seen in the study done in 2025 by businesses and investors saying that we rate 30/100 on the corruption perception index where 0 is most corrupt and 100 is least corrupt (Transparency International Papua New Guinea, 2025 Feb 12).

Jackson (2020), who look into the vulnerability generated by emergency food aid programs among Indigenous people of Western Province in PNG, offers extra analysis of a serious need of help in aid delivery. Jackson said when aid is not received properly it steers into intransparency and adaption, leading to an increase dependency leading to a weakened resilience. The results being portrayed concerning are the reasons why we need a tool for aid organizations to help facilitate and improve the current system.

Blockchain-build solutions are becoming more famous as a solution to these issues. A study by IJRASET talks about a blockchain-based fundraising platform that operates on Internet Computer (ICP) and Ethereum. The paper points out the benefits of ICP, including its ability to make cheap transaction costs, decentralized governance, high scalability because of its Chain Key Technology, and a high support for real-time money tracking through smart contracts (2024 IJRASET). These characteristics under take the three main obstacles that was mentioned by Jackson: inefficiency, a need of local accountability, and absence of flexibility. Additionally, IJRASET study also talks about how to set up technologies that enable donors to confirm the validity of charities, such as the blockchain's affiliation of government-issued tax exemption certificates. This greatly improves institutional openness and donor confidence, two things that traditional platforms do not offer at hand.

PNG continues to be at a disadvantage especially when it's approaching its silver jubilee independence, in terms of factual and implementation-oriented research, despite the wide spread of achievements in blockchain-driven transparency in other countries worldwide. (Pennington, 2024) found fault with how Australia's aid to PNG and the operations involved in it especially its lack for procedures and policies to introduce an open public-private delivery with a all-inclusive beneficiary accountability. In spite of the fact that aid initiatives commonly require a number of parties, right now there is currently no proper centralized technology infrastructure to monitor and validate the course of funds at each stage, this is where blockchain can provide a solution to that problem.

To mitigate and provide a solution to PNG's crisis in charity and aid the need for technologies like blockchain need to be used. Many of the operational issues that are faced in PNG regarding charity and aid are with its centralized nature where there is only a main point of monitoring, now can be resolved with the intervention of blockchain technology, which is decentralized, transparent, and impenetrable in nature and structure. Having said that about its potential, there is still a severe inadequacy about the best way to apply blockchain technology in the particular social, economic, and policy landscape of PNG. Aid distribution is more likely to continue to suffer from the inefficiencies and a lack of accountability in the absence of a systematic and evidence-driven approach as a result of not enough technology integration. In addition, this study will be integrating a blockchain system into one of Papua New Guineas (PNG) key sectors for development, which is the aid and charity distribution sector. Blockchain in non-profit or NGO creates a system where everything is open and permanent, this makes it easy to see where donation are going(webisoft, 2025 Feb 22).The study will hope to provide insight into blockchain and its effect on parts of the world and how applicable it can be to PNG by comparing the results of its application worldwide. Blockchain is an untapped technology in PNG's Tech Industries, hence by analyzing the different types of blockchain out there a evidence driven approach of integration can occur.

Major systems like Ethereum and Bitcoin are usually the first thing that pops to mind when the term blockchain is mentioned and are usually the subject of current blockchain write ups and studies. Internet Computer Protocol (ICP) was released by Dfinity in 2021 now offers an entirely new alternative architecture and it has received little to no attention at all about its possibilities since most platforms are sticking to other blockchain technologies. In a short span of time the Internet Computer Protocol (ICP) outperforms its other counter parts in resolving the issues faced by its predecessors, which involves proper distinctive balance between scalability, security, and speed. Due to the use of Chain Key Technology as one of the fundamental technologies behind ICP, with chain key technologies, web apps may be created without depending on external cloud infrastructure with proper threshold cryptography.

4. INTERNET COMPUTER VS OTHER BLOCKCHAINS

Blockchain is a distributed ledger made up of a list of entries, or blocks, that are dispersed among the nodes in a peer-to-peer (P2P) network. In essence, blockchain is a type of data storage. The information in the blockchain is organized into a series of blocks, each of which has a distinct cryptographic hash that represents the information it contains. It is therefore endowed with the characteristics of decentralization, immutability, security, efficiency, and transparency. There are four types of blockchains out there namely Public, Private, Consortium and Hybrid blockchain. We will be looking at the different types of public blockchains.

Table 1 below shows the comparison among all the other Public blockchains

Blockchain Finality)	Consensus Mechanism	Speed (Block)	Scalability	Transaction Fee
<i>Internet Computer</i>	Threshold Relay (PoS variant)	1-2 seconds (update calls),	Unlimited subnets, infinite scalability	Fixed (0.0001 ICP)
		milliseconds (query calls)		
<i>Ethereum</i>	Currently PoW, transitioning to PoS	Variable block time, high transaction finality time	Limited, improving with Ethereum 2.0 (64 shards)	Dynamic (gasbased)
<i>Cardano</i>	Ouroboros (PoS)	Not specified	Limited, awaiting Hydra Layer 2 solution	Not specified
<i>Solana</i>	Proof of Stake with Proof of History	Fast block time, 13 seconds transaction finality	Sacrifices decentralization, data stored offchain	Not specified
<i>Binance Smart Chain</i>	Proof of Authority	Fast block time	Sacrifices decentralization	Similar to Ethereum (gas-based)
<i>Zilliqa</i>	PBFT with PoW	Not specified	Limited	Not specified
<i>Algorand</i>	Pure Proof of Stake	Fast transaction finality	Limited, uses IPFS for data storage	Fixed (0.001 ALGO)
<i>Avalanche</i>	Avalanche Consensus (PoS variant)	Fast transaction finality	Scalable with subnets, uses decentralized storage	Not specified
<i>Polkadot</i>	NPoS (Nomination Proof of Stake)	Not specified	Limited to about 100 parachains	Not specified

Consensus Mechanism-The way in which the confirmation and the accuracy of the data being entered into a ledger is called consensus. By doing this, all network transactions are updated and the next block to be added is accurately reflected. Invalid data or double-spending are avoided as a result.

Speed- is the time taken to do transaction of money from one account to another is directly tied to the speed of the blockchain.

Scalability- The power of how blockchain can be used for future expansion and the increase in transaction. This means that scalability depends on how a blockchain performance is tied to its adaptation and speed, if it undergoes adaptation and picks up speed its an increase in scalability.

Transaction Fee- it's how Miners do Proof of Work and validators do Proof of Stake in doing so this can assist in confirming the amount of transactions that are being compensated with transaction fees.

In figure 3 ICP ranks highest in terms of Consensus Mechanism, Speed, Scalability and Transaction Fee when compared to its predecessors.

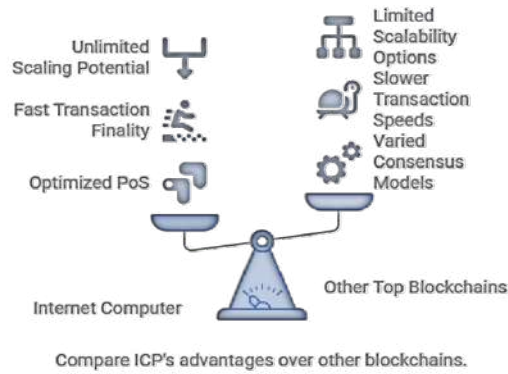


Figure 3 Gives a summary of ICP among all the other Public blockchains¹

Figure 4 shows how powerful Internet Computer Protocol (ICP) reigns supreme over the other blockchain technology making it a suitable candidate technology to use for the platform as mentioned by its characters such as.

- ✦ *Decreased Transaction Costs:* ICP paves a way forward for digital purchases by allowing for minimal transactions to take place, by doing so it helps to make sure aid delivery is paramount without too much overhead costs to run the platform itself.
- ✦ *Enhanced Scalability:* The parameters on how to do aid delivery varies depending on needs so ICP's scalability nature allows to meet the changing humanitarian initiatives.
- ✦ *Advanced Smart Contract Capabilities:* ICP's smart contracts stand out from the other conventional blockchain technology, making it a suitable feature for the charity and aid platforms.
- ✦ *Decentralized Governance:* ICP's decentralized nature makes transparency a key component needed for aid distribution by ensuring stake holder's trust.
- ✦ *Smooth Integration:* ICP can operate in new environments given its compatibility with current systems, making it suitable for integration with any new system.

These results imply that ICP has a great deal of promise to increase the effectiveness and openness of PNG's aid distribution system.

5. INTERNET COMPUTER PROTOCOL ADAPTATION ON FINANCE SYSTEM

ICP can be adapted into PNG's current system given it follows the financial regulations and policies that are in place by Bank of PNG. The Bank of PNG already has an online system already in place called KATS commonly known as Kina Automated Transfer System, used by the commercial banks operating within PNG (Bank of Papua New Guinea). KATS allows for this bank to have online monetary transactions so ICP's adaptation is possible with this system in play.

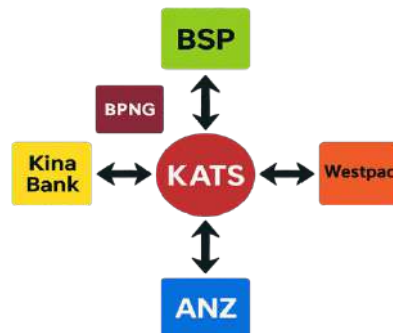


Figure 4 Shows a relationship between different banks and KATS

The three main payment options that KATS operate on are;

1. **Real Time Gross Settlement (RTGS):** It's a method for settling payments separately in a real time fashion, this means it facilitates not just high value but rather time sensitive transactions as well, by doing so RTGS can make sure that resources that are available right away by allocating money to partner groups or disaster relief efforts in a charity platform

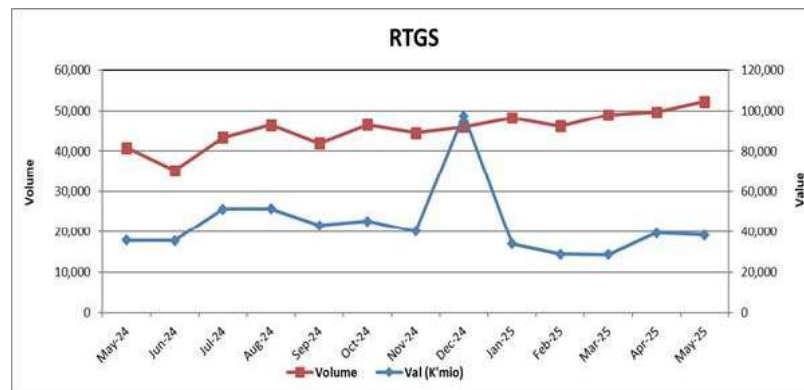


Figure 5 RTGS Chart. 1: Values & Volumes by Real Time Gross Settlement (RTGS) Payments (Bank of PNG, n.d)

2. *Straight Credits:* Straight credits emerge as a quiet hero, it's a technology that focuses on low transactions, it allows for support payments to flow effortlessly landing into bank accounts by allowing transmission of funds to recipients concurrently.

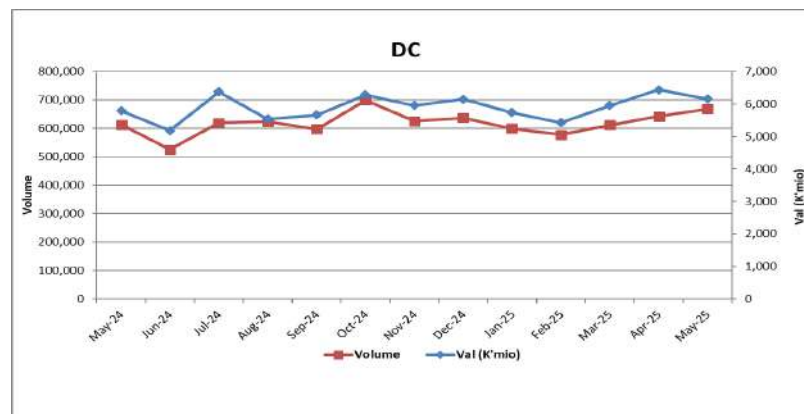


Figure 6 Chart. 3: Values & Volumes by Direct Credit (DC) Payments

3. *Processing of Checks:* Checks are currently not used as much as before in the country, as a result of technology such as electronic payment methods. However, KATS allows for check processing nonetheless, due to the need for access to banks without digital banking.

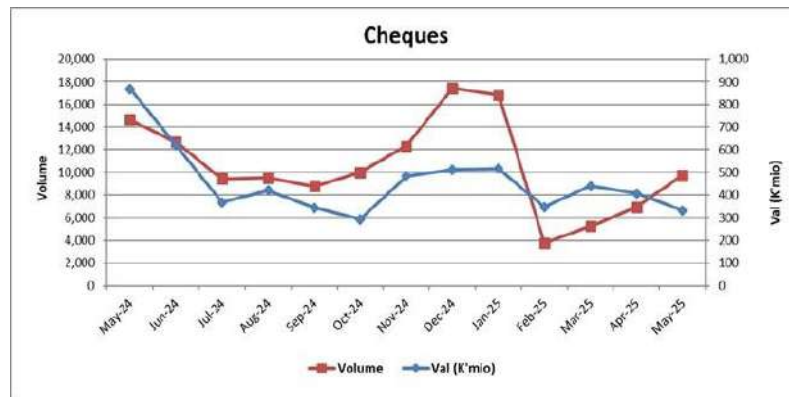


Figure 7 Chart. 3: Values & Volumes by Cheques Payments (Bank of PNG. N.d)

The charity platform can guarantee endorsement by following PNG's financial guidelines, in doing so it increases the rate of transparency, and fast track and strengthens the dependability of aid distribution by connecting with Kina Automated Transfer System (KATS). This allows for better fund tracking and overall reporting, will make it possible for integration, which would be in line with top standards for accountability in non-profit operations.

6. CONCLUSION/ RECOMMENDATION

In this Study ICP was thoroughly studied for its implications on its usage and how that can be beneficial to PNG aid distribution system. By proving that with every transaction that takes place it is unchangeable and traceable, this is possible with ICP's immutable ledger system improving accountability and transparency by lowering the chances of corruption and malpractice. On top of that, with a country identifying as a third world country with limited infrastructure and poor economy, ICP is financially a practical choice for assistance distribution because of its minimal transaction fees, basically meaning that a huge portion of money reach targeted beneficiaries with less administrative cost. ICP's built environment makes it possible for high scalability that may be adjusted to fit into PNG's vast landmass and regions that are isolated, given the level of connectivity and infrastructure. Furthermore, having real time transaction tracking will help to identify wrong doings and bring trust to humanitarian efforts. These results portray a great trust to PNG's aid distribution through the means of transparency.

This study is also vital as a result of influencing aid distribution through the policies in place and bypassing the traditional way of aid delivery. The study creates strong standing points about introducing blockchain into PNG's aid systems by showcasing the benefits of ICP as a game changer. Since it's a game changer it adds to the larger research talks about using cutting-edge technologies to improve the way in which humanitarian aid operations are organize, especially in conditions where negligence of governance and logistics are major issues.

A range of applicable suggestions was brought forward in spite of how the results of ICP can be put into action driven initiatives. First, viability, efficiency, and scalability of ICP driven aid distribution might be measured by doing a pilot project in a chosen area of PNG. Secondly, to make sure the integration of the system follows policies and regulations of all parties involved such as, NGOs, Local communities and government agencies is critical. Thirdly, increasing of funds for training efforts to technical staffs and local staff will increase the sustainable effectiveness of the blockchain based system. Finally, it is of dire importance to work out any ethical or legal issues by following a governance framework that supports the incorporation of a blockchain technology into the current centralized system.

By carrying follow up studies in the near future would share more light into the ongoing benefits of blockchain system specifically ICP in the long run, this will help with future works and development on assistance distribution sector to make it more efficient and transparent in nature. Basically, to get the best out of aid distribution system and refine it, it's better to do comparison of ICP's efficiency with other top tier blockchain systems that are in the field of humanitarian outreach to see their potential as well. Experimenting with how other cutting-edge technology can be integrated with ICP such as mobile platforms, biometric identification system

could drastically improve the accessibility and the inclusiveness of aid distribution. When implementing the system several key factors regarding PNG's infrastructure, population density, and the regional governance structures will be considered with ICP's scalability and how ICP uses its scalability to navigate these factors. Stakeholders may use ICP has a way forward to revolutionize aid distribution in PNG and guarantee more efficient and fair humanitarian relief delivery by following these suggestions and area for further studies.

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Is there any Impact of Credit Management Practices on Bank Performance in PNG

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Abstract: Credit Management and Bank Lending practices were the paramount influential activities performed by every bank globally. These activities become major determinant factors for banking performance in commercial banks and private financial institutions in Papua New Guinea (PNG). Most banks have achieved unfavorable results due to a lack of effective credit management and lending practices. According to observations from various annual reports of commercial banks, default risk in terms of existing bad debt has resulted from poor credit management and lending practices. The primary objective of this study is to assess the impact of credit management and bank lending practices on the performance of banks. Specifically, the research examined the effects of interest rates, loan amounts, and loan terms on loan repayment by commercial banks in Papua New Guinea (PNG). The target population for this study was all commercial banks in PNG; however, due to the unavailability of publicly accessible annual reports, only four commercial banks were evaluated based on the available information from the financial years 2016 to 2023. Remarkably, the loans and advances section of the report has been evaluated in conjunction with the lending rate for the loan term available on the banks' website. This research adopted a regression model for the data analysis. The study findings showed that loan amount and loan term (lending practices) have a positive significant effect on loan repayment (banking performance). In contrast, interest rates (Credit Management) have a significant adverse effect on banking performance. The overall study highlights the proactive approach to managing credit risk and promoting transparent lending procedures to sustain banking performance. Several recommendations made in this study aim to improve the efficiency of credit management and lending practices, thereby enhancing the performance of banking.

Key Words: Credit Management, Lending Practices, Banking Performance, Interest Rates, Loan Amount, Loan Terms.

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Dr Viswanadham Nadiminti has vast experience in the higher education sector, with over one and a half decades of post-Ph. D. experience, having worked in four countries. He holds an M. Com in Accounting, an MBA in Finance, and PhD in Commerce from India. Published 25 papers in peer-reviewed journals and five books published, attended 20 international conferences around five countries. Successfully guided 5 Ph.D.'s as a principal supervisor and 140 supervisions of master's dissertations. Two significant major projects were completed, and he worked as Head of the department, external examiner, principal mentor for junior researchers' projects, and master's course coordinator.

1. INTRODUCTION

The Institute of Credit Management (ICM) was previously known as the Institute of Creditmen, which was founded in the United States (US) in 1939, as publications on Credit Management were only found there [Bullivant]. The Chartered Institute of Credit Management (CICM) came into existence after a Royal Charter was granted in 2014 to the ICM, which was previously known as the Institute of Credit Management and was founded in 1939 [BOROUGH]. The term "credit" has existed for over 3,000 years, predating the establishment of the ICM [Bullivant]. Major US companies recognized the importance of credit existence and the need for management and control in the 1960s, as it had a direct impact on accounts receivable [Edwards]. Lending performance was

relatively determined by the credit management process [Mirach]. Generally, credit management refers to the entire lending process, from identifying prospective customers to the successful or unsuccessful repayment of the credit [Mirach]. From a specific banking sector perspective, credit management encompasses activities such as accepting applications, loan appraisal, loan approval, monitoring, and recovery of non-performing loans [Shekhar]. However, from a commercial perspective, credit is money that a bank lends to earn interest in return [Achou]. In addition, a bank plays a vital role in implementing monetary policy in a country's economy, as widely agreed upon [Charles 1995].

Furthermore, it is also noted that commercial banks control the money supply through central bank policy. Similarly, the rate of interest and credit frequency affect a borrower's behaviour, which ultimately impacts the country's economic activities [Mansoor Dailam]. Generally, banks hold a larger portion of financial institutions in an economy [Mburu Irene et. al]; therefore, their performance can influence a country's economy [Bohnstedt]. In PNG, there was tremendous demand for credit in financial institutions from 1985 till recent years, based on a World Bank report. Small and Medium Enterprises (SMEs) in PNG have been moderate employers and contribute 50% of the GDP within the economy, according to [Wendy Morona].

The importance of credit management was emphasized by [Charles 1999] as follows: credit management requires special consideration. It is the determinant of the outcome of banks' performance. Similarly, credit management is vital, as lending is considered equivalent to investing in a borrower [10]. In the study by [Moch] for the bank in Indonesia, they employed two standard measures of credit risk: (i) the ratio of loan loss reserves to non-performing loans (LLR_NPL), and (ii) the ratio of net non-performing loans to total loans (NPL Net). Credit risk cannot be eliminated, but it can be minimized and mitigated through the process of investment diversification [Moch].

Credit management issues were present at both macro and micro levels, which determine the success or failure of every business, and in particular, financial institutions where lending is the primary activity for generating income, according to the study [Mirach].

In the PNG context, according to an update from the World Bank under the Papua New Guinea section, the rate of non-performing loans increased from the lowest of 2.5 per cent in 2008 to the highest of 6.16 per cent in 2021, resulting in a loss for the banks. Therefore, while managing those credit risks related to collecting, there are other factors such as corporate governance itself, state regulatory framework, principal factors, the cost involved in following up the credit and, of course, the uncertainty involved in the theft of the manual credit history of tracking the customers due to the lack of Technology. This research aims to provide insights into how factors under credit management and bank lending practices affect the banking performance of the various commercial banks in PNG. Due to the unavailability of financial information from other commercial banks, this study's findings are based solely on the annual reports of four commercial banks.

1.1 Objectives of the study

- To analyse credit management and its effect on banking performances
- To evaluate the effect of lending practices on banking performances

2. LITERATURE REVIEW

2.1 Theoretical Framework

The financial portfolio theory will be used in this project. In general, the Modern Portfolio Theory (MPT) was first proposed by economist Harry Markowitz in 1952. This theory superseded traditional stock selection, and its demonstration is likely to result in a portfolio with relatively low volatility [Markowitz]. Additionally, the review article by [Surtee] presents its findings on how recent investors have utilized the MPT, along with various risk-reward ratios, aiming to minimize risk while maximizing returns, drawing on available sources and strategies. Similarly, financial portfolio theory was found to be the most reliable approach for the bank lending process, aiming to achieve its set goals [Bennett]. He also found diversification to be a helpful strategy.

Credit management and banking performance:

According to [İncekara], the future of financial institutions and their financial stability depend mainly on the bank's ability to manage credit risk. He also emphasized that various factors influence credit risk, and his study suggested that the borrower's inability to repay the loan on time has become the primary factor affecting bank credit risk, resulting in high non-performing loans across multiple banks in the UAE, where all traditional banks were vulnerable to risk. Similarly, [Oranefo] studies suggest that in every banking industry, special attention should be given to credit administration for lending activities to make them a significant or core revenue-earning mechanism.

H1: Credit Management (Interest Rate) has an adverse significant effect on the Banking performance (Loan Repayment).

Lending practices and banking performance:

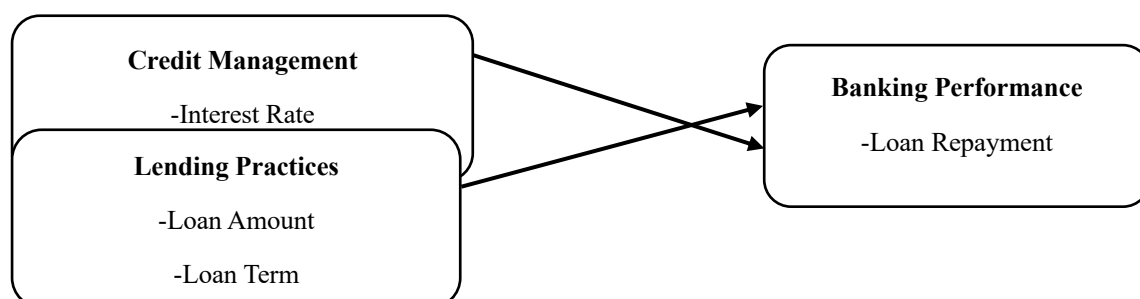
According to [Jose], his study found that lending procedures have been considered an important technique by most banks in tracking or detecting potential credit risk associated with borrowers before granting permission to lend excess finance, and it also helps identify the borrower's creditworthiness before the funds fall into the wrong hands. Likewise, capital control through monetary policy also strengthens bank lending in a way that debt inflows increase foreign reserves, and it avoids more lending towards riskier firms [Fabiani].

H2: Lending practices (Loan Amount) have a positive significant effect on the banking performance (Loan Repayment).

2.2 Research gap

Based on several global literature from experienced scholars and their findings related to the research title "Credit Management and Bank Lending Procedures" in general, several queries remain unanswered, and clarity is needed from different perspectives across different countries. The various perspectives arose from different understandings based on the types of government, the country's legal system, its level of economic development, technological aspects, and the different types of banks with their respective credit management systems. Despite those differences, credit management and lending practice were the main determinants of banking performance. However, the effectiveness and efficiency of these two major determinants were influenced by other factors, including lending policy, innovative Technology, political factors, global issues, interest rates, and others. There is likely no common practice that can be adopted globally, but it is the least likely for commercial banks to operate within a particular nation. Although banks compete with one another, this research aims to propose the most suitable lending policy that would be most satisfying from both the banks and the borrower's perspectives. This research aims to fill the gap by providing insights into the factors that affect the banking performance of commercial banks in Papua New Guinea (PNG), as no article related to this topic has been published to date.

2.3 Conceptual Framework



3. METHODOLOGY

3.1 Research Design

This research employs a quantitative and descriptive research design to analyze the factors influencing overall banking performance, loan performance and repayment within the context of credit management and bank lending procedures in Papua New Guinea.

3.2 Data Collection

Secondary data were utilized for this analysis, which included data collected from publicly available financial reports, credit bureau datasets, and bank lending records. The selection criteria include datasets containing non-performing loans (NPL), debt-to-equity ratio, interest rate, loan amount, and the loan term. The data was extracted from bank annual reports.

3.3 Sample size

This study aims at the Four (4) commercial banks in PNG. Notably, the study focuses on the movement of financial performance and position, as well as loan performance, from the financial year 2016 to 2023.

3.4 Model specification

Multiple linear regression has been employed to analyze the variables in this study.

Multiple linear regression

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \epsilon$$

- Y: Dependent variable
- β_0 : Intercept/Constant
- $\beta_1, \beta_2, \dots, \beta_n$: Coefficients for the independent variables
- $X_1, X_2, \dots, X_n$: Independent variables
- ϵ : Error term

Specification of model for this study

- **Dependent Variable:** Loan Repayment Amount (Y)
- **Independent Variables:**
 - Loan Amount (X_1)
 - Interest rate (X_2)
 - Loan Term (X_3)

3.5. Data Analysis

Table 1: Data Analysis Summary

Objective number	Objective	purpose	Method of achievement
1	To analyze credit management and its effect on banking performances.	To determine how interest rates in credit management systems are associated with banking performance.	Conduct linear regression analysis using interest rate as independent variable and banking performance as a dependent variable
2	To evaluate the effect of lending practices on banking performances.	To identify the relationship between loan term and loan amount required in lending procedure associated with banking performance.	Use linear regression analysis to assess how loan term and loan amount allowed affect loan repayment amount.

Source: Researcher, 2024

3.6 Validity

The data entry was done using SPSS software to extract the necessary figures for the correlation between the dependent and independent variables. The coefficient obtained from the SPSS has been used in the multiple linear regression formula to reveal the positive and negative relationships among the different variables.

4. DATA ANALYSIS AND DISCUSSION

Multiple linear regression analysis was conducted using SPSS software to identify and examine the relationship between credit management and bank lending practices, as well as their impact on banking performance in terms of loan performance. Only four banks were used as a sample size due to the availability of their annual reports from 2016 to 2023.

4.1 Data analysis and interpretation

Table 2: Descriptive statistics for Credit Management and Bank Lending Practices

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
LoanRepayment	32	488487	14802133	3642527.1	4900590
InterestRate	32	0.06	0.12	0.0956	0.01564
LoanAmount	32	491874	15448042	3805899.4	5167198
LoanTerm	32	1	8	4.5	2.32795
Valid N (listwise)	32				

Source: Researcher, 2024

The above result shows the general average mean and the standard deviation for different variables under the descriptive statistics. The result shows the General mean for the loan term, which is 4.5 years, with a minimum of 1 year and a maximum of 8 years, along with a standard deviation of 2 years. Similarly, the other variables follow the same procedures. The model summary results are presented in Table 3 below.

Table 3: Model summary for credit management and bank lending practices and its effect on banking performance.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error
1	1.000a	1	1	0
a) Predictors: (Constant)InterestRate, LoanTerm, LoanAmount				

b. Dependent variable: Loan Repayment

Source: SPSS Version 20, 2024

According to the data displayed in the model summary in Table 3 above, the R-squared value is 1. This demonstrates the perfect fit of the model, indicating that loan performance for the four commercial banks in Papua New Guinea is strongly dependent on these four variables: interest rate, loan amount, and loan term. Based on this model and data analysis.

The research also computed ANOVA analysis to confirm the models' efficacy and validity in illuminating the connection between commercial banks' loan performance in terms of loan repayment and credit management and bank lending procedures in terms of three (3) independent variables represented as Interest Rate, Loan Amount and Loan Term. Table 4 below presents the findings of the study's ANOVA model.

Table 4: ANOVA for Credit Management and Bank Lending practices and its effect on banking performance.

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.44451E+14	3	2.482E+14	181516	.000b
	Residual	38278774890	28	1.367E+09		
	Total	7.44489E+14	31			
a Dependent Variable: LoanRepayment						
b Predictors: (Constant), LoanTerm, LoanAmount, InterestRate						

Source: SPSS Version 20, 2024

Table 4 above shows that the p-value is less than 0.05 and F = 181516. The p-value of 0.000 suggests that the null hypothesis for this analysis can be rejected. This shows that at least one group or variable mean is significantly different from others. This research also further analyzed the coefficient test. The Model coefficient is shown in table 5 below.

Table 5: Coefficient for Credit Management and Bank Lending practices and its effect on Banking Performance

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	93607.1	41629.438		2.249	0.033
	InterestRate	-1E+06	469386.129	-0.003	-2.298	0.029
	LoanAmount	0.948	0.001	1	732.386	0
	LoanTerm	9829.94	3173.264	0.005	3.098	0.004
a Dependent Variable: LoanRepayment						

b) Predictors: (Constant), Interest Rate, Loan Amount, Loan Term

Source: SPSS Version 20, 2024

From the research coefficient, the model developed is,

$$Y = 93607.1 + (-1E+06) \chi_1 + 0.948\chi_2 + 9829.94\chi_3 + \epsilon$$

Where Y is Average Loan Repayment, X1 is Interest Rate, X2 is Loan Amount, and X3 is Loan Term.

Table 3 above shows that the Interest Rate (Beta 1 = -1E+06, $p < 0.05$) has a significant and positive effect on banking performance. This is followed by the Loan Amount, with a beta coefficient of 0.948 ($p < 0.05$), indicating that the loan amount has a negative and significant impact on banking performance. Finally, the loan term (Beta 3 = 9829.94, $p < 0.05$) predicted that the Loan Term has a positive and significant influence on banking performance. Table 6 below displays the correlations for the variables.

Table 6: Correlation between credit management and bank lending practices and its effect on each variable.

		Loan Repayment	Interest Rate	Loan Amount	Loan Term
Pearson Correlation	Loan Repayment	1.000	.024	1.000	.119
	Interest Rate	.024	1.000	.026	.425
	Loan Amount	1.000	.026	1.000	.116
	Loan Term	.119	.425	.116	1.000
Sig. (1-tailed)	Loan Repayment	.000	.448	.000	.258
	Interest Rate	.448	.000	.445	.008
	Loan Amount	.000	.445	.000	.264
	Loan Term	.258	.008	.264	.000
N	Loan Repayment	32	32	32	32
	Interest Rate	32	32	32	32
	Loan Amount	32	32	32	32
	Loan Term	32	32	32	32

Source: SPSS Version 20, 2024

The results in Table 6 above depict the correlations between the variables of credit management and bank lending practices, expressed in terms of Interest Rate, Loan Amount, and loan term, which determine banking performance as measured by loan repayment. Based on the results of the correlation analysis for this study, a strong correlation exists between Loan Amount and Loan Repayment, with a Pearson correlation of 1. A weak correlation exists between Interest Rate and Loan Amount, with correlations of 0.024 and 0.119, respectively.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study concludes that bank's lending policies and credit management are positive condition factors in determining how banks function, particularly in loan repayment. The further results suggest that loan length and amount exert a positive influence on loan repayment. The higher the amount (in PNG Kina) and the longer the loan period, the more likely banks are to receive loan repayments on time. This positive correlation re-emphasizes the importance of structured lending processes in maintaining financial stability.

Higher interest rates can discourage borrowers from making their loan payments on time, potentially leading to an increase in non-performing loans. This occurs because elevated interest rates negatively affect the ability to repay loans. The banking sector must manage interest rates carefully, as the observed negative relationship between interest rates and loan repayment underscores the need for this approach. The (R-square=1) in the model summary shows that the model is a perfect fit for the study as well as the variable are the perfect fit to determine the banking performance. This suggests that enhancements or improvements in credit management and lending practices have a greater likelihood of enhancing the performance of the banking sector in Papua New Guinea.

Technology and macroeconomic factors are also becoming qualitative measures that can influence commercial banks' decision-making. In conclusion, transparent credit management systems and lending practices are needed to ensure the growth and profitability of commercial banks.

5.2 Recommendation

5.2.1 Managerial Implication

Managers should be considerate in structuring the loan, modifying the credit policy, and adopting relevant Technology.

5.2.2 Economic Implications

Support for SMEs

As the country is in the development stage, SMEs make a significant contribution to the country's GDP. According to the fact stated above in the introduction, SMEs contribute 50% of the economy's GDP. Hence, improving accessibility to finance their operations and allowing favourable lending terms can enhance their performance, and as a result, it leads to larger economic growth.

Interest Rate Adjustment

Regulators or bank managers should consider setting an affordable interest rate to prevent it from becoming a hindrance to borrowers. With this, the interest rate must encourage repayment while simultaneously covering the risk of default by commercial banks.

5.2.3 Society Implications

Financial Inclusion

In every developing country, including Papua New Guinea (PNG), one of the significant issues that individuals and businesses encounter is difficulty in accessing finance to meet their daily needs. Financial inclusion is made possible with the help of FinTech, allowing borrowers to access funds without geographical limitations. By doing this, banks lessen poverty and promote financial independence in rural areas. That should be done through investing in FinTech.

5.2.4 Policy Implications

Sustainable Banking Practices

Every commercial bank should prioritize profitability, sustainability, and stability. Implementing suitable policies that cover what banks need to achieve and what they require to be minimized should be necessary.

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Exploring the Role of Pasin-Lotu in the Peace Process in Bougainville

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Abstract: Some studies have revealed that the role of women and *pasin-tumbuna*¹ were important peace mechanisms in the Bougainville crisis. However, it is often forgotten that the women and peacemakers involved were active members of the Christian churches and that the Bougainville traditional customs were already blended with the Christian faith. It has been argued that little was said about the role of *Pasin-lotu*² in the *peace process*³, and the primary objective of this article is to bring this essential aspect of the journey to peace into view. An interpretive paradigm provided a theoretical framework for this study, and a qualitative approach was used to collect, analyse, and interpret data. Melanesian *tok-stori*⁴ and personal interviews were used for data collection. An inductive thematic analysis procedure guided the data interpretation. It was revealed that *Pasin-lotu* drove the spirit of confession and forgiveness, and reconnected the divided people. This faith enhanced the peace negotiations, added meaning to the reconciliation, and brought stability to the peace process. *Pasin-lotu* emerged from the findings as another essential driver of peace that helped to end the Bougainville Crisis.

Keywords: Pasin-lotu, Pasin-tumbuna, Peace process

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1. INTRODUCTION

The paper explores the role of Pasin-lotu in the peace process in Bougainville. The first subsections provide the scope of the study and the problem statement. The main section presents the literature review, the research methods and procedures and the major findings. The final section includes the overall conclusion followed by acknowledgments and list of references.

1.1 Scope of the Study

The purpose of this study was to explore the role of Pasin-lotu and see if it influenced aspects of the peace negotiation and reconciliation process that helped to end the Bougainville crisis. Guided by the key research question ‘What was the role of Pasin-lotu in the peace process?’, the author focused on six specific objectives; the motivation behind peace negotiations, the peacemakers’ sources of strength, the strategies in peace negotiation, the approach taken in the reconciliation process, the outcomes of the reconciliation and the views of the people about future peace for Bougainville.

The target population was individuals directly involved and those with a fair knowledge [Mertens, 2005] of the peace process. This study selected twelve participants from the target population as a sample frame.

¹ (Tok-Pisin) refers to traditional customs or indigenous cultures.

² (Tok-Pisin) refers to the Christian faith or ways of Christianity.

³ refers to the peace negotiation and reconciliation process.

⁴ (Tok-Pisin) refers to Indigenous storytelling or narrative.

1.2 Problem Statement

Some studies surrounding the Bougainville crisis established the role of women, their matrilineal cultures, and pasin-tumbuna as essential drivers of the peace process [Sirivi 2004]. However, [George, 2018] argued that these women and peacemakers at the forefront of the peace negotiations were members of the Christian church. Kabui [2005] claimed that the Bougainville traditions were blended with the Christian faith before the crisis and has been largely ignored. Little was said about the role of Pasin-lotu in the peace process.

2. LITERATURE REVIEW

The Autonomous Region of Bougainville (AROB) in PNG was located North of the Solomon archipelago in the Pacific Region. From the prehistoric past until today, Bougainville has maintained some of its traditions and matrilineal cultures. The village elders and hereditary chiefs were customarily respected, and women were culturally recognized as mama-graun. When the first Europeans arrived, the Christian missionaries had contact with the people, and Christian faith blended with cultural traditions and was deeply embedded in contemporary societies.

2.1 The Role of Pasin-Tumbuna in Peacemaking

Bougainville's ancestral customs held traditional societies together in peace and harmony before the early missionary's contact. According to Oliver [1991] some critical elements in the traditional conflict, peace, and reconciliation processes were respecting women as clan leaders and using village elders and chiefs as peacemakers. In the context of this study, the ancestral traditions and practices are referred to as pasin-tumbuna, for example, the use of namel-marn as peacemakers, the bel-kol as cooling down payments, and bel-gut as compensations.

Village Elders and Chiefs as Middlemen. In peace negotiations, the conflicting parties would identify a namel-marn to facilitate the bel-kol as a token of understanding toward an open face-to-face reconciliation. Carl & Garasu [2002] confirmed that injuries would be communicated to both sides often by a neutral person or party as a peacemaker. The bel-kol as a cooling down payment would be passed through the namel-marn as a token of trust and the demonstration of the willingness of the offending party to admit guilt and pay compensation. Because traditional conflicts involve many groups, peace and reconciliation are achieved by involving the entire community.

Women as Mama-graun. In Bougainville's traditional society, women had an essential place in the family and a vital role in the life of a clan. Mama-graun means the land ownership and clan leadership descend through the matrilineal lines from a mother to a daughter [Hamnett, 1977]. Women tend to be seen as customary landowners and clan leaders and each person was identified according to their membership in their mother's clan. Most villages were matrilineal but, at the same time, tended to be quite patriarchal [O'Callaghan, 2002]. Within the matrilineal culture, men were looked upon as village elders and chiefs and, to some extent, were the custodians of the land.

2.2 Introduction of Pasin-Lotu in Bougainville

Pasin-lotu as the Christian faith was introduced by early missionaries to the Bougainvilleans more than 80 years before the Bougainville crisis. Faith blended with customs and was embedded in the culture. Bougainvilleans embraced the Christian faith as they faced the new challenges of the modern world.

Cultural Assimilation and Blending. Acculturation occurred when the Christian faith, came into contact with indigenous traditions. Bougainvilleans accepted and incorporated the Christian faith with some aspects of their unique cultures and traditions. Laracy [1999] observed Missionaries had succeeded

to the point where Christian identity seemed almost to be coincident with Bougainville identity. The ability to forgive others and forget the past was much greater than vengeance, which was most common in traditional society. The aim of the missionaries being in Bougainville was to plant the Christian Church firmly among the people [Oliver, 1991]. Consequently, the Christian religion blended smoothly with indigenous customs and traditions.

2.3 Bougainville Crisis

The Bougainville crisis started in 1988 and was fought between the Papua New Guinea Defense Force (PNGDF), its ally, the Bougainville Resistance Force (BRF), and the Bougainville Revolution Army (BRA). The crisis started due to the Landowner's disagreement over resource exploitation and uneven distribution of Panguna copper mine benefits [Regan, 2018]. The people were divided, and the society was torn apart as men took up arms and joined the BRA, which opposed the Conzinc Riotinto Australia (CRA) and fought over the Panguna copper mine. With different views of what to achieve, Dorney, [2003] said, others joined BRF and stood with PNGDF to defend the national government's sovereignty over the mine.

Peace Challenges. Peace negotiations seemed complicated and challenging when the BRA could no longer listen to government and trust the CRA. Sadly, Sohia [2002] stated that the genuine offer by the national and provincial government to bring meaningful negotiations with the militant groups has not been accepted, even though provincial leaders gave their total support. In October 1994, the national government called a peace conference in Arawa, the capital. The BRA and the Bougainville Interim Government (BIG) leaders refused to attend. Still, it was significant to women's groups who had the opportunity to meet and air their views.

Pasin-tumbuna as a Peace Mechanism. Bougainville's pasin-tumbuna significantly drove aspects of the peace and reconciliation process in war-torn societies. According to Tanis [2002], the traditional spiritual beliefs of the people provided the underlying principles of Osikaiaang, Sipungeta, and Me'ekamui. These conventional principles guided the efforts of the war and later became the basis of peace and reconciliation. The first step was for every Bougainvillean to recognize him or herself as Indigenous or Osikaiaang and to understand that the only way to live together again in peace was to reconcile and reunite. Tanis said the process was Sipungeta, which demanded that holiness, peace, and reconciliation start from the roots, from one's inner self to the families, then to the clans, and later to the nation. Tanis added, the people must put the spirit of the dead to rest, and if this can be done, the homeland can indeed be me'ekamui – a holy place where the creator dwells amongst his people. In other words, this understanding was consistent with the Christian worldview. Bougainville's traditional beliefs compelled people to make peace.

Matrilineal Culture as a Peace Mechanism. In the midst of the Bougainville civil war, women stood together, initiated peace, and contributed to some aspects of the peace process. Women's peace effort was honored and respected because they were the landowners, the issue BRA fought to reclaim and defend. The women have always been the voice of sanity and peace and have been very instrumental in convincing their sons to get rid of the guns [Havini, 2004]. In other words, women played an important role in negotiating peace and driving common sense into the minds of the divided men.

Women as Peacemakers. As early as 1990, Bougainville women stood together during the war and played essential roles in initiating peace. Individual women used their authority as mothers of the land, matrilineal status as leaders in the family and the clan to negotiate peace with their communities. Women used their influence as a medium between warring factions to maintain constructive dialogue toward peace [Saovana-Spriggs, 2007]. When women went to the battlefields and talked to the young men, the effect was potent, Howley [2002] said there is a relationship between the mother and her son which is more powerful than between the boy and his father. Women successfully got their sons and husbands to

return to the villages. Howley said, “A woman has a position in the life of the young men which goes back to his childhood and carries respect and authority which they cannot ignore”.

Women and their Faith. Women marched and negotiated, and Garasu [2002] claimed that they prayed for peace. An indication that the faith contributed to the peace movement. After this, the women again organized an all-night peace vigil to protest silently against the war. An all-night peace vigil showed that the women were sacrificing their usual sleeping time to keep watch, pray, and fast at night, an indication that faith was vital to the peace process. It was not safe then, but Garasu said, “Women learned to have faith and trust each other again as they marched and sang Christian hymns of peace. All these are clear indication that Pasin-lotu was driving the peace effort.

3. METHODS AND PROCEDURES

An interpretive paradigm provided a theoretical framework for this research. A qualitative approach was used for data collection, analysis, and interpretation [Creswell, 2004]. Melanesian tok-stori and personal interviews were procedures for data collection. A purposive sampling was used to select the participants who were believed to be the key informants who could provide precise information about the peace process. A total of twelve participants were involved in this study. An inductive thematic analysis procedure [Yin, 2009] guided the data interpretation.

4. DATA ANALYSIS AND RESULTS

4.1 Motivation behind peace negotiations

The peacemakers, motivated by their love for children, negotiated peace to protect children from inheriting the spirit of war and protect their future against the rise of spiritism. Data sources revealed a growing sympathy to protect children from the negative influence of the war, discourage children recruitment, and protect them against the rise of natural healing powers and ritual practices in the crisis. If the war were prolonged, ritual practices and healing powers would divert people away from their Christian faith and destroy the future of their children.

The peacemakers were also motivated to negotiate peace because they wanted to restore moral values in the war-torn society. Data sources revealed that there was a growing concern to stop the rise of killings and murder cases, stop the increase in rape, and stop the destruction of churches in the Bougainville crisis. Peacemakers saw the need to negotiate peace because thousands of innocent lives were lost, relatives rose against relatives, many young women were forced raped, and churches that stood as the pillars of change, faith, and peace were burnt to the ground.

4.2 Peacemakers’ sources of strength

The neutral position of the churches determined church leaders’ role as peacemakers and became the basis of unity. The unity of the churches created mutual trust and understanding between different armed factions, gave confidence to the peacemakers, and sustained them throughout the peace negotiation process. The peacemakers’ prayer and fasting guided and directed their path toward restoring peace. Peacemakers used God’s word to strengthen themselves, and their answered prayers sustained them in enduring the challenges of peace negotiations.

These results showed that the neutrality and unity of the churches provided moral strength, and the word of God and peacemakers’ faith provided spiritual strength in the peace negotiation process.

4.3 Strategies in peace negotiation

The results showed that the church network provided access to the opposing armed camps, and faith reconnected the divided men. The peacemakers used church networks to walk through different warring factions, and they used their faith connections to drive the message of peace and reconnect the divided people. Faith was a driver

of peace between the peacemakers and the divided factions. These findings revealed that the Christian faith was essential in influencing aspects of the peace negotiation process.

4.4 Approach taken in the reconciliation process

The findings revealed an integrative approach to the reconciliation process. The peacemakers used faith-oriented counseling to enhance the bel-kol process before face-to-face reconciliation. Many sensitive cases between different parties were settled by integrating customs and Christian faith. The integration of faith drove the spirit of confession and forgiveness and added meaning to the reconciliation process. These findings showed that the Christian faith influenced some aspects of the reconciliation process.

4.5 Outcomes of the reconciliation

This study showed that the ability to forgive and confess in the reconciliation process brought restoration. The war victims' willingness to forgive others brought healing to their trauma, wounds, and brokenness. Others were revived from their shame and a feeling of unworthiness. The perpetrators' genuine confession of their war crimes brought a sense of peace. The perpetrators were relieved from their war guilt, and murderers recovered from their haunted feelings of taking human lives. Reconciliation reconnected the divided people, reunited families, and mended the disintegrated clans and tribes. These findings revealed that faith was essential in influencing some aspects of the reconciliation process.

Contrary to the above results, it was also revealed that some people who were not part of the reconciliation process ignored justice, and some sacrificed their healing for peace. Young people traded their futures for homebrew, drugs, and negative behaviors.

4.6 People's views about future peace

The results revealed that a new covenant and government-church partnership are the people's views. The new covenant rectified by the spilled blood of those who were killed and murdered in the crisis shows that some people have a spiritual worldview about independence aspirations and future peace for Bougainville. The government-church partnership to provide Christian education and faith-based healthcare indicates that Pasin-lotu, as the Christian faith, has an essential influence on the people's views about their development aspirations and the future peace for Bougainville.

5. CONCLUSION

Finally, Pasin-lotu emerged from the findings as an essential peace mechanism and another driver of the peace negotiation and reconciliation process that helped to end the Bougainville Crisis. Christian faith drove the spirit of confession and forgiveness, and reconnected the divided people. This faith added meaning to the reconciliation and brought stability to the peace process. Thus, this paper highlights this important aspect of the peace process.

6. RECOMMENDATION

In the course of undertaking this study, the researcher discovered a number of areas that would benefit from further investigation. The following five have been identified for their importance in contributing to further knowledge.

- 1) Specific research studies on puripuri and galas-marn could be conducted to obtain in-depth knowledge of their sources and effectiveness in the crisis.
- 2) More research studies should be conducted into the unresolved cases not included in the reconciliation process to assess their implication on social problems.
- 3) Conduct research into the level of Christian faith during and after the crisis.
- 4) Conduct more research into how the Christian faith shaped the people's views about the independence aspirations of the people.

- 5) More research studies could be conducted into the connections between herbal plants and Indigenous healing powers.

ACKNOWLEDGEMENTS

I acknowledged God for His strength given so that I could continue to write. I want to acknowledge the School of Research and Postgraduate Studies and the School of Humanities, Education and Theology (SoHET), PAU, for financial assistance towards this research and my travel to the 6th PIURN conference.

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6th PIURN

Pacific Islands Universities
Regional Network
CONFERENCE



“Harnessing technologies for the safe and sustainable development of the Pacific”



PROGRAM BOOKLET

July 1st – July 3rd, 2025

**Papua New Guinea
University of Technology**

Welcome

It is with great pleasure that we welcome you to the 6th Pacific Islands Universities Regional Network (PIURN) Conference, held from 1st to 3rd July 2025 in Lae, Papua New Guinea. This year's theme, "Harnessing Technologies for the Safe and Sustainable Development of the Pacific," reflects our shared commitment to innovation, resilience, and collaboration across our diverse island communities.

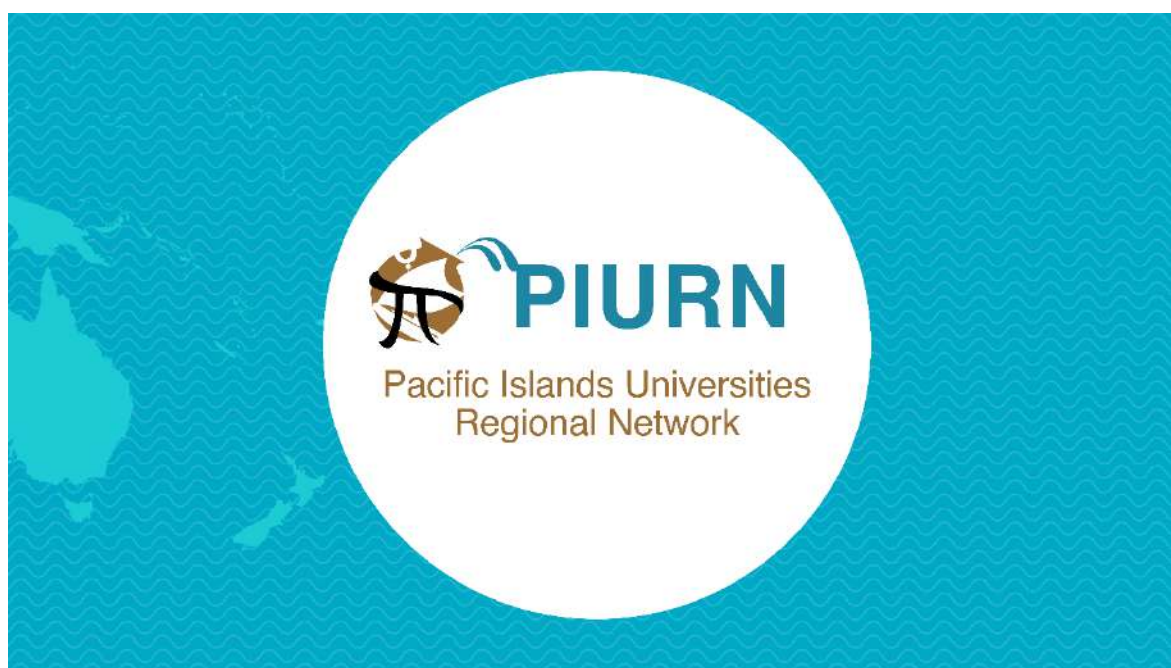
As we gather scholars, researchers, students, and practitioners from across the Pacific and beyond, we celebrate the spirit of interdisciplinary exchange and cultural richness that defines our region. The conference offers a platform to explore traditional knowledge alongside cutting-edge science, and to forge partnerships that will shape a more sustainable future for our islands.

We extend our heartfelt gratitude to all participants, presenters, and partners who have made this event possible. May your time here be filled with meaningful dialogue, new connections, and inspiration.

Welcome to PIURN 2025—where knowledge meets purpose.

Booklet briefs

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	9am	9.30am	10am	10.30am	11am	11.30am	12pm	12.30 pm	1pm	1.30pm	2pm	2.30pm	3pm	3.30pm	4pm	4.30pm	5pm	5.30pm	6pm						
	Registration : from 7:30am Duncanson Hall		Morning tea			Plenary Session - Island Innovation Unveiled: Transforming Transportation, Health, and Resilience Duncanson Hall				Lunch				Session 1 - Artificial Intelligence (AI) – Its application in the Pacific Duncanson Hall				Session 7 - Pacific Sustainable Development – Perceptions of challenges and transformations Duncanson Hall				Get together- Cocktail Night New Dining Hall			
	Opening Ceremony Duncanson Hall		Morning Tea							Session 2 - Technologies for Climate- Smart Commercial Production Of Crops & Livestock RK Lecture Theater				Session 3 - Quality Education and Human Resource Development - Primary Education RK Foyer									Session 4 - Natural Resources Exploration Mine Pit		
						Session 12 – Climate Smart Agriculture - Forestry and Forest Preservation Duncanson Hall				Lunch				Session 17 - Tropical, Communicable Diseases and Health Management Duncanson Hall				Session 18- Enablers Of Socio-Economic Growth, Sustainability and Conflict Management for the Rural and Isolated Population RK Lecture Theater				Session 19 – Environment sciences – Impacts of Construction & Management RK Foyer			
						Session 13 - Quality Education and Human Resource Development – Higher Education RK Lecture Theater								Session 22 – Urban transformation and challenges in the Pacific Duncanson Hall				Session 23 - Smart Environment and Industry RK Lecture Theater				Session 24 - Quality Education and Human Resource Development – Impacts of technology RK Foyer			
						Plenary Session – Regional Research Initiatives Duncanson Hall													BREAK						
Tuesday 1 July																									
Wednesday 2 July																									

Thursday 3 July	Plenary COP 31 Duncanson Hall	Morning tea	Session 15 - Renewable Green Energy Harnessing <i>Mine Pit</i>	Lunch Do-it yourself Solar Installation <i>Duncanson Hall Foyer</i>	Session 20 - Agricultural Policies, Rural Development, Market Access <i>Mine Pit</i> Session 21 – Higher Education to enhance well being <i>Civil AV Room</i>	Session 25 – Sustainability, Environmental Sciences and Technology <i>Mine Pit</i> Session 26 - Food Security & Nutrition <i>Haus Europa HELT1</i>	Closing Dinner 7PM – New Dining Hall
			Session 16 - Environmental Monitoring and Disaster Management <i>Civil AV Room</i>				
			Roundtable on Safe, Sustainable, and accessible transportation <i>RK Foyer</i>				
			Session 27 – Climate Change, risk and transformations <i>Duncanson Hall</i>				
			Session 28 – Social and Economical Transformation in the Pacific <i>RK Lecture Theater</i>				
			Session 29 - Social & Information Technology <i>RK Foyer</i>				
			Session 30 - Sustainable Development, through Culture and Indigenous Knowledge <i>Mine Pit</i>				
			Session 31 - Technology, Connectivity, and Innovation in Pacific Education and Society <i>Civil AV Room</i>				
			Session 32 - Policy, Higher Education, and Institutional Transformation <i>Haus Europa HELT1</i>				

Program Session Schedule - Tuesday 1 July

- **Registration:** 7:30am – 9.00am
 - **Opening Ceremony :** 9.00am-10.30am
 - **Morning Tea :** 10.30am – 11.00am
 - **Plenary Session** – Island Innovation Unveiled: Transforming Transportation, Health, and Resilience
11.00am-12.00pm - *Duncanson Hall*
 - **Lunch :** 12.15pm – 1.30pm
 - **Sessions 1 – 6**
 - **Afternoon Tea :** 3.15pm – 3.30pm
 - **Sessions 7 – 11**
 - **Roundtable** - Digital Strategies for the Pacific: Building a Secure and Prosperous Future |
Stratégies numériques pour le Pacifique : construire un avenir sûr et prospère
3.30pm – 5:15pm - *RK Foyer*
 - **Get together - Cocktail :** 6.00pm – *New Dining Hall*
-

Session 1 - Artificial Intelligence (AI) – Its application in the Pacific | Intelligence artificielle (IA) – Son application dans le Pacifique

1.30pm – 3.15pm
Duncanson Hall

Challenges in Artificial Intelligence Development in Higher Education in Pacific Islands: A literature review from a Papua New Guinea Perspective | Défis du développement de l'intelligence artificielle dans l'enseignement supérieur dans les îles du Pacifique: une revue de littérature selon la perspective de la Papouasie-Nouvelle-Guinée
Oko, Jerome
Divine Word University

From Artificial intelligence to Artificial Intelligences | De l'intelligence artificielle aux intelligences artificielles
Sun, Zhaozhao
Papua New Guinea University of Technology

Divine Word University, Centre for Learning & Teaching approaches in harnessing technology to contribute to a safer and sustainable development in the pacific | Les approches du Centre d'apprentissage et d'enseignement de l'Université Divine Word dans l'exploitation de la technologie au service

d'un développement plus sûr et durable dans le Pacifique

Arro, Hobson ; Airi, Picky
Divine Word University

Digital Education: Status Quo, Developments, Impacts and Challenges at STEMP, USP | Éducation numérique : état actuel, évolutions, impacts et défis à la faculté des sciences, technologies, ingénieries et mathématiques, Université du Pacifique Sud
Sharma, Bibhya
The University of the South Pacific

Session 2 - Technologies for Climate-Smart Commercial Production Of Crops & Livestock | Technologies pour une production commerciale de cultures et de bétail intelligente face au climat

1.30pm – 3.15pm
RK Lecture Theater

Mini Taro Cratering Machine- Design Optimisation: This Document Shows the Methods, Software Workflow, and Algorithm to Perform Design Optimisation | Optimisation de la conception d'une machine de creusement pour mini-taro : ce document présente les méthodes, le flux de travail logiciel et l'algorithme utilisés pour l'optimisation de la conception

Mohamed, Aezeden
Papua New Guinea University of Technology

Investigating the agricultural importance of piggery sludge use under humid lowland tropical agro-climatic conditions in Papua New Guinea | Étude de l'importance agricole de l'utilisation des boues de porcherie sous climat agroécologique tropical humide de basse altitude en Papouasie-Nouvelle-Guinée
Kasa, Levy ; Michael, Patrick
Papua New Guinea University of Technology

Coffee Berry Borer (*Hypothenemus hampei*) surveillance and monitoring: An infestation level assessment using the 30-tree sampling method. A final year student project | Surveillance et suivi du scolyte des baies du caféier (*Hypothenemus hampei*) : évaluation du niveau d'infestation à l'aide de la méthode d'échantillonnage des 30 arbres – projet de fin d'études
Kome, Mesack
University of Goroka

Enhancing the Competitiveness of Papua New Guinea's Arabica Coffee Industry through a Regionally Tailored Computer Vision Model for Optimal Cherry Ripeness Detection | Renforcement de la compétitivité de l'industrie du café Arabica de Papouasie-Nouvelle-Guinée grâce à un modèle régionalisé de vision par ordinateur pour la détection optimale de la maturité des cerises
Chen, Guofu
Papua New Guinea University of Technology

Parametric Analysis and Iterative Engineering Blueprints for Low-Cost Sago Bark Processing Machine | Analyse paramétrique et plans d'ingénierie itératifs pour une machine de traitement à faible coût de l'écorce de sagou
Syed, Shoeb; Mohamed, Aezeden
Papua New Guinea University of Technology

Session 3 - Quality Education and Human Resource Development - Primary Education - Développement de la qualité de l'éducation et des ressources humaines – Education Primaire

1.30pm – 3.15pm
RK Foyer

Promoting Cross-disciplinary Education in the Pacific using Sports | Promouvoir l'éducation interdisciplinaire dans le Pacifique grâce au sport
Roosen, Andy
The University of the South Pacific

An investigation into the current infrastructure capacity of remote Jimi Secondary School in Jiwaka Province, Papua New Guinea and its impact on grade 12 students' enrolment | Étude sur la capacité actuelle des infrastructures du lycée Jimi, dans province de Jiwaka, PNG, et son impact sur l'inscription des élèves de terminale
Kupil, Rex
University of Papua New Guinea

Integrating Indigenous knowledge for Inclusive Education in curriculum documents for year four to year six levels in Vanuatu education | Intégration des savoirs traditionnels pour l'éducation inclusive dans les programmes scolaires de primaire du Vanuatu
Tari, Brent
The University of the South Pacific

Church as a literacy hub: Investigating the functional literacy level of Rural Households in Papua New Guinea | L'Église comme centre d'alphabétisation : enquête sur le niveau d'alphabétisation fonctionnelle des ménages ruraux en Papouasie-Nouvelle-Guinée
Napasu, Alice
Pacific Adventist University

Science Technology Engineering and Mathematics (STEM) Education: A report on how students at the primary school engage in STEM education lessons | Éducation en science, technologie, ingénierie et mathématiques (STEM) : rapport sur la participation des élèves du primaire dans les leçons des différentes matières
Sinnou, Annette
Divine Word University

Virtual Nakamal: A Digital Storytelling Hub for Teaching Comprehension Skills Through Vanuatu's Indigenous Knowledge Systems to Junior High School Students | Nakamal virtuel : une plateforme de narration numérique pour l'enseignement des compétences de compréhension à travers les savoirs autochtones du Vanuatu aux élèves de seconde
Timothy, Marie-Elsie
National University of Vanuatu

Session 4 - Natural Resources Exploration |
Explorer les ressources naturelles

1.30pm – 3.15pm

Mine Pit

Biological screening of Xanthostemon and Myrtaceae essential oils from Oceania and of synthetic triketone analogues | Étude biologique des huiles essentielles de Xanthostemon et de Myrtaceae d'Océanie et d'analogues synthétiques de triketone

Wau, Jayson¹³; Lebouvier, Nicolas², Terceve, Olivia², Guentas, Linda²; Medevielle, Valérie²; Timi, David¹; Pocquet, Nicolas⁴; Oelgemoller, Michael¹ 5

¹Papua New Guinea University of Technology;

²Université de la Nouvelle Calédonie ; ³James Cook University ; ⁴Institut Pasteur Nouvelle Calédonie ; ⁵ Hochschule Fresenius gGmbH

Acid treated betel nut husk for dye removal: adsorbent characterization, adsorption isotherms and kinetic studies | Écorce de noix de bétel traitée à l'acide pour l'élimination de colorants : caractérisation de l'adsorbant et études cinétiques

Kaup, Philip; Ku, Salvina

Papua New Guinea University of Technology

A comparative assessment of marita (Pandanus conoideus) and its production challenges and opportunities for further research and development in Papua New Guinea | Évaluation comparative du marita (Pandanus conoideus) et de ses défis de production ainsi que des opportunités de recherche et développement en Papouasie-Nouvelle-Guinée

Anton, Jonah¹² ; Amben, Stanley¹; Ahizo, Jeremiah²; Michael, Patrick²

¹National Agriculture Research Institute; ²

Papua New Guinea University of Technology

Chemical and Biological Investigation of the PNG Xanthostem species of the MYRTACEAE family | Étude chimique et biologique de l'espèce Xanthostem de la famille des MYRTACÉES en PNG

Anis, Stephanie¹; Timi, David¹; Lebouvier, Nicolas²; Maino, Macquin¹; Bau, Billy¹; Wau, Jayson¹; Oelgemoller, Michael³

¹Papua New Guinea University of Technology;

²Université de la Nouvelle Calédonie ; ³James Cook University

Session 5 - Climate Change, Variability and Sea Level Rise Impacts | Impacts du changement climatique, de la variabilité et de l'élévation du niveau de la mer

1.30pm – 3.15pm

Civil AV Room

In search of indigenous knowledge framework on climate change education in the Vanuatu education system | À la recherche d'un cadre de savoirs autochtones pour l'éducation au changement climatique dans le système éducatif du Vanuatu

Theophile, Annette

National University of Vanuatu

Spatial and Temporal Wave Climate Variability and Trends in Fiji: Insight from Four Decades of Hindcast Data | Variabilité spatiale et temporelle du climat des vagues et tendances aux Fidji : aperçu issu de quatre décennies de données rétrospectives

Muna, Lency¹; Espejo, Antonio²; Wandres, Moritz²; Ganachaud, Alexandre³; Singh, Awnesh⁴; Dumas, Pascal¹; Damlamian, Hervé²

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Human Habitability and Economic Growth in Pacific Island Countries | Habitabilité humaine et croissance économique dans les pays insulaires du Pacifique

Gajewski, Jean-Francois

Université de la Nouvelle Calédonie

Innovative climate change communication and education for vulnerable communities in PNG: A Case Study | Communication et éducation innovantes sur le changement climatique pour les communautés vulnérables en PNG : une étude de cas

Tiu, Sangion Appiee ; Mathias, Hannah ; Kally, Julie

University of Goroka

Harnessing Data Innovation to Map Sea Level Rise Impact for Effective Policy and Planning | Exploiter l'innovation en matière de données pour cartographier l'impact de l'élévation du niveau de la mer en vue d'une politique et d'une planification efficaces

El Saeed, Ahmed

UN Global Pulse

Session 6 – Culture between Tradition and Modernity | La Culture entre Tradition et Modernité

1.30pm – 3.15pm
Haus Europa HELT1

Bridging Generations: Ethnochemistry and Traditional Knowledge as Catalysts for Sustainable Scientific Innovation | Relier les générations : l'ethnochimie et les savoirs traditionnels comme catalyseurs d'une innovation scientifique durable

Aknonero, Ronald ; Pok, Matthew
Innovative University of Enga

Giving modern names to learning practices and principles that already existed in Indigenous Island Cultures | Attribuer des noms modernes à des pratiques et principes d'apprentissage déjà présents dans les cultures insulaires autochtones et traditionnelles

Elisha, Leeroy
Pacific Adventist University

An analysis of Cultural Intelligence in Different Regions of Papua New Guinea based on Physics Education | Analyse de l'intelligence culturelle dans différentes régions de Papouasie-Nouvelle-Guinée basée sur l'enseignement de la physique

Pereira, Felix ; Gaoma, Michael ; Maino, Macquin

Papua New Guinea University of Technology

Towards the digital transition of Pacific languages: an online application for collaborative dictionary management | Vers la transition numérique des langues du Pacifique : une application web pour la gestion collaborative des dictionnaires

Tokotoko, Jannai ; Dotte, Anne-Laure
Université de la Nouvelle-Calédonie

Utilizing non-fungible token (NFT) technologies to preserve cultural histories and artefacts | Utilisation des technologies de jetons non fongibles (NFT) pour préserver les histoires culturelles et les artefacts historiques

Saulala, Vili ; Maekafa, Georges
Christ's University in Pacific

Afternoon Tea : 3.15pm – 3.30pm

Session 7 - Pacific Sustainable Development – Perceptions of challenges and transformations | Développement durable dans le Pacifique - Perceptions des défis et des transformations

3.30pm – 5:15pm
Duncanson Hall

Integration of traditional knowledge in developing solutions for challenges facing the Pacific: Is the law an appropriate tool? Some answers from Vanuatu, Fiji and New Caledonia | Intégration des savoirs traditionnels dans la résolution des défis du Pacifique : le droit est-il un outil adapté ? Cas du Vanuatu, Fidji et Nouvelle-Calédonie
Albanese, Vaiome; Joachim, Claire
Université de la Nouvelle Calédonie

Overcoming Ethical Issues in Managing Government-Funded Projects in Papua New

Guinea | Surmonter les problèmes éthiques dans la gestion des projets financés par le gouvernement en Papouasie-Nouvelle-Guinée
Glama, David

Divine Word University

Dynamics of Socio-Religious Transformation in Lifou (New Caledonia): From the Traditional Drehu Order to Missionary and Post-Missionary Hegemony | Dynamiques de transformation socio-religieuse à Lifou (Nouvelle-Calédonie) : de l'ordre Drehu traditionnel à l'hégémonie missionnaire et post-missionnaire

Wejieme, Zenon ; Rigo, Bernard
Université de la Nouvelle Calédonie

The Way of the Spear (Makaravi) as an Indigenous Cultural Framework for Community Development in Post-conflict Bougainville: Promoting Holistic and Sustainable Development | La voie de la lance (Makaravi) comme cadre culturel

traditionnel pour le développement communautaire dans le post-conflit Bougainville : promouvoir un développement holistique et durable

Kokinai, Clare^{1 2}

¹Massey University; ²Pacific Adventist University

Session 8 – Characteristics of environmental component - Caractéristiques de la composante environnementale

3.30pm – 5:15pm

RK Lecture Theater

Experimental Investigation on laminated wooden composites of selected Papua New Guinean woods for sustainable structures | Étude expérimentale sur les composites en bois stratifié à partir de bois sélectionnés de Papouasie-Nouvelle-Guinée pour des structures durables

Patra, Alak Kumar; Singh, Arun Kumar; Sil, Dibul

Papua New Guinea University of Technology

Assessing the Downstream Impacts of Soil Sedimentation Caused by Small-Scale Alluvial Mining in Atamo, Central Bougainville | Évaluation des impacts en aval de la sédimentation des sols causée par l'exploitation minière alluviale artisanale à Atamo, au centre de Bougainville

Biri, Rodney; Ndrewou, Alois; Mesimato, Eric

University of Goroka

Settling and rheological properties of dilute and concentrated suspended particulate matter from contrasted soils of New Caledonia | Propriétés de décantation et rhéologiques des matières particulaires en suspension diluées et concentrées issues de sols contrastés de Nouvelle-Calédonie

Meyer, Michael¹; Tileya, Sambrid^{1 2}; Kato, Alexandre¹; Metayer, Cyrille¹; Mathian, Maximilien¹; Pattier, France¹; Juillot, Farid²

¹Université de la Nouvelle Calédonie ; ²Institut de Recherche pour le Développement

A Review on the Role of Green Manure in Sustaining Soil Fertility and Crop Productivity in Papua New Guinea | Bilan sur le rôle de l'engrais vert dans le maintien de la fertilité des sols et de la productivité agricole en Papouasie-Nouvelle-Guinée

Kaupa, Phili ; Rao, Rajashekhar

Papua New Guinea University of Technology

Beta-carotene Concentrations of Seven Varieties of Pandanus Conoideus Oil in Lufa District, Eastern Highlands and Jimi District, Jiwaka Provinces of Papua New Guinea | Concentrations de bêta-carotène dans sept variétés d'huile de Pandanus conoideus dans le district de Lufa (Hautes-Terres orientales) et le district de Jimi (province de Jiwaka), Papouasie-Nouvelle-Guinée

Pok, Matthew^{1 2}; Aknonero, Ronald¹; Gise, Baro²

¹University of Goroka; ²Innovative University of Enga

An analysis of genetic variation among Galip nut (Canarium indicum) accessions from four Islands of Papua New Guinea | Analyse de la variation génétique parmi les noix de bétel (Canarium indicum), provenant de quatre îles de Papouasie-Nouvelle-Guinée

Hannett, Godfrey^{1 2}; Leonard, Kalava²; Wallace, Helen³; Okpul, Tom¹

¹Papua New Guinea University of Technology;

²PNG National Agricultural Research Institute;

³Queensland University of Technology

Session 9 - Climate Change & Biodiversity, Including Land Degradation, Livestock Health | Changement climatique et biodiversité - Dégradation des sols, la santé du bétail

3.30pm – 5:15pm

Haus Europa HELT1

Comparative study of the population and population density of sea star species along the intertidal zone of Honiara City and West Guadalcanal in Solomon Islands | Etude comparative de la population et de la densité de population des espèces d'étoiles de mer le long de la zone intertidale de la ville de Honiara et de l'ouest de Guadalcanal aux Îles Salomon

Rofeta, John

Solomon Islands National University

Preliminary Results on Development of Sustainable and Biodegradable Food Packaging Films Using the Peels of Indigenous Banana Plant *Musa ingens* from Enga Province of Papua New Guinea | Résultats préliminaires sur le développement de films d'emballage alimentaire durables et biodégradables à partir des pelures de la plante de bananier endémique *Musa ingens* de la province d'Enga, Papouasie-Nouvelle-Guinée
Gopalakrishnan, Janarthanan ; Iparam, Jamilah
 Papua New Guinea University of Technology

Age and growth of the shortfin mako shark (*Isurus oxyrinchus*) in the North Pacific Ocean: A Multi-model Approach | Âge et croissance du requin-taupe bleu (*Isurus oxyrinchus*) dans l'océan Pacifique Nord : une approche multi-modèles
Gwaibo, Goriga
 PNG University of Natural Resources and Environment

Measurements of Cs-137 in Spanish Mackerel (*Scomberomorus Commerson*) from the marine environment of Milne Bay Province, Papua New Guinea | Mesures de Cs-137 dans le maquereau espagnol (*Scomberomorus commerson*) issu du milieu marin de la province de la baie de Milne, Papouasie-Nouvelle-Guinée
Barau, Nelson ; Koibi, Sheena
 Pacific Adventist University

Enhancing Animal Health Capacity in Papua New Guinea: Establishing the Faculty of Para Veterinary Sciences at a Higher Education Institution | Renforcement des capacités en santé animale en Papouasie-Nouvelle-Guinée : création d'une faculté des sciences para-vétérinaires dans un établissement d'enseignement supérieur
Tringin, Stephanie; Robby, Sinafa
 PNG University of Natural Resources and Environment

Animal Health Capacity Building in Papua New Guinea: A Comprehensive Approach to Strengthening Animal and Wildlife Health Systems Through Biosecurity, One Health, and Cross-Border Collaboration | Renforcement des capacités en matière de santé animale en Papouasie-Nouvelle-Guinée : Une approche globale pour renforcer les systèmes de santé animale et de la faune sauvage par la biosécurité, « une seule santé » et la collaboration transfrontalière

Robby, Sinafa^{1 2}; Tringin, Stephanie¹; Puana, Ilagi³; Kapo, Nime⁴; Maino, Macquin²
¹PNG University of Natural Resources and Environment; ²Papua New Guinea University of Technology; ³ National Agriculture Quarantine and Inspection Authority; ⁴ Food and Agriculture Organisation

Session 10 - Mathematics and Computer Science | Mathématiques et Informatique

3.30pm- 5.15pm
Mine Pit

Algebraic word problem solving competencies: A case study of pre-service student teachers | Compétences en résolution de problèmes algébriques : une étude de cas sur les enseignants stagiaires
Uln, John
 Divine Word University

Wireless Computing in all Area: A Mathematical Approach | Informatique sans fil dans toutes les zones : une approche mathématique
Singh, Arun
 Papua New Guinea University of Technology

The values conveyed by the junior secondary school mathematics textbooks: Towards rethinking mathematics education in the Pacific | Les valeurs véhiculées par les manuels de mathématiques du secondaire : vers une reconsidération de l'enseignement des mathématiques dans le Pacifique
Mwaraksurmes, Amton
 The University of the South Pacific

Network Automation with Python: A Practical Guide | Automatisation des réseaux avec Python : un guide pratique
Wera, Dawa
 Papua New Guinea University of Technology

STEM teacher education: Challenges in the Post-graduate Diploma in Education program in training STEM teachers for Secondary and High Schools in Papua New Guinea | La formation des enseignants en STEM : Défis du programme de diplôme universitaire en éducation pour la formation des enseignants en STEM dans les collèges et lycées en Papouasie-Nouvelle-Guinée
Hagoiya, John
 University of Goroka

From Suspicion to Trust: ICP Blockchain's Role in PNG Aid Accountability | De la suspicion à la confiance : Le rôle de l'ICP Blockchain dans la responsabilisation de l'aide à la PNG

Yatukoman, Daniel

Papua New Guinea University of Technology

Session 11 - Science & Engineering education and growth | L'éducation et le développement dans le domaine des Sciences et des Sciences de l'ingénierie

3.30pm – 5:15pm

Civil AV Room

Biosorption of Chromium from Aqueous Solutions Using Garcinia cymosa f. pendula Leaf Powder: A Study on Equilibrium and Kinetics | Biosorption du chrome dans les solutions aqueuses à l'aide de poudre de feuilles de Garcinia cymosa f. pendula : étude sur l'équilibre et la cinétique

Tera, Joseph Kotera ; Yekula, Prasanna Kumar ; Lem, Jim Pae

Papua New Guinea University of Technology

An Innovative Kalman Filter Based Beam-Steering Antenna Configuration for Maximum Power Transfer | Configuration innovante d'antenne à orientation de faisceau basée sur un filtre de Kalman pour un transfert de puissance optimal

Pirapaharan, Kandasamy¹ ; Kunsei, Herman¹ ; Saharani, Shaafrida² ; Hoole, Paul³

¹ Papua New Guinea University of Technology;

² University Kebangsaan Malaysia; ³Wessex Institute of Technology

Identification of Nitzschia navis-varingica (Bacillariophyceae), a diatom producing amnesic shellfish poisoning-toxins from Papua New Guinea | Identification de Nitzschia navis-varingica (Bacillariophyceae), une diatomée productrice de toxines responsables de l'intoxication amnésique par les coquillages en Papouasie-Nouvelle-Guinée

Puilingi, Clyde¹ ; Lim, Po Teen² ; Yamashita, Mari-Yotsu³ ; Kotaki, Yuichi³

¹Solomon Islands National University ;

²University of Malaya; ³Tohoku University

Modeling and mechanobiology of mitral valve | Modélisation et mécanobiologie de la valve mitrale

Hassani, Kamran¹ ; Aghaeiboorkheili, Mohsen²

¹Witwatersrand university; ²Papua New Guinea University of Technology

Applying Design Thinking Methodology to include meaningful social and cultural input to mobile phone application software development | Application de la méthodologie de la Pensée Design pour intégrer des apports sociaux et culturels significatifs dans le développement d'applications mobiles

Saulala, Vili ; Maekafa, Georges

Christ's University in Pacific

Advancing the Aerospace Sector in the Pacific | Avancer dans le secteur aérospatial dans le Pacifique

Carter, George

Australian National University

Roundtable - Digital Strategies for the Pacific: Building a Secure and Prosperous Future | Stratégies numériques pour le Pacifique : construire un avenir sûr et prospère

3.30pm – 5:15pm

RK Foyer

Kanhere, Salil¹; Sanagavaparu, Lalit Mohan² ; Mirou, Benson³ ; Kula, Winifred⁴ ; Woruba, Russel⁵

¹University of New South Wales; ²Quick Heal Technologies; ³Papua New Guinea University of Technology; ⁴Digital ICT Cluster; ⁵PNG Department of Information and Communications

Get together - Cocktail: 6.00pm

Program Session Schedule - Wednesday 2 July

- **Plenary Session – Regional Research Initiatives in the Region** | Les initiatives régionales pour la recherche dans la région
9.00am – 10.00am - *Duncanson Hall*
 - **Morning Tea** : 10.00am – 10.30am
 - **Sessions 12 - 16**
 - **Roundtable : Safe, Sustainable, and accessible transportation** | Table ronde sur les transports sûrs, durables et accessibles
10.30am – 12.15am - *RK Foyer*
 - **Lunch** : 12.15 – 1.30pm
 - **Sessions: 17 - 21**
 - **Afternoon Tea** : 3.15pm – 3.30pm
 - **Sessions: 22 - 26**
-

Session 12 – Climate Smart Agriculture - Forestry and Forest Preservation | Agriculture intelligente face au climat - Sylviculture et préservation des forêts

10.30am – 12.15am
Duncanson Hall

Natural Forest Seed Collection for Banking of Least Explored Tree Species in (Papua) New Guinea | Collection de graines forestières naturelles pour la conservation des espèces d'arbres les moins étudiées en (Papouasie) Nouvelle-Guinée
Sosanika, Gibson
Papua New Guinea University of Technology

On the impact of exotic naturalized trees in the landscapes of Papua New Guinea -the situation in Bulolo and Wau | Sur l'impact des arbres exotiques naturalisés dans les paysages de Papouasie-Nouvelle-Guinée – Le cas de Bulolo et Wau
Maiguo, Eko ; Maino, Macquin ; Okpul, Tom
Papua New Guinea University of Technology

Comparative Analysis of Tree Diversity, Composition, and Structure in Selectively Logged Lowland Tropical Forests: A Case Study from Isabel Island, Solomon Islands |

Analyse comparative de la diversité, de la composition et de la structure des arbres dans les forêts tropicales de plaine exploitées de manière sélective : étude de cas sur l'île d'Isabel, Îles Salomon

Hiro, Carlos

Solomon Islands National University

Coastal Trees and Traditional Knowledge A Pacific Blueprint for Sustainability | Arbres côtiers et savoirs traditionnels : Plan d'action du Pacifique pour le développement durable
Katovai, Dawnie¹ ; Katovai, Eric² ; Pene, Sarah¹ ; Ngai, Junita³

¹The University of the South Pacific, ²Solomon Islands National University; ³ Pacific Women Lead Enabling Services

Utilizing agriculture education and extension programs as conduits in Plant Health Clinic training | Utilisation de l'éducation agricole et des programmes de vulgarisation comme vecteurs de formation en clinique phytosanitaire
Ndrewou, Alois; Biri, Rodney; Iyeho, Audrey
University of Goroka

Session 13 - Quality Education and Human Resource Development – Higher Education

| Développement de la qualité de l'éducation et des ressources humaines – Enseignement Supérieur

10.30am – 12.15am

RK Lecture Theater

A descriptive study on the challenges faced in delivering and coordinating the Postgraduate master's in education leadership and Change (MELC) program at the Faculty of Education and Humanities, Solomon Islands National University (SINU) | Etude descriptive sur les défis rencontrés dans la prestation et la coordination du programme de master en leadership éducatif et changement (MELC) à la Faculté d'éducation et des sciences humaines, Université Nationale des Îles Salomon (SINU)

Ariku, Emelda

Solomon Islands National University

User Perspective of Academic Library Services in the 21st Century. A Case Study in a Tertiary Institution in Papua New Guinea | Perspective des usagers sur les services des bibliothèques universitaires au XXI^e siècle : étude de cas en PNG

Iga, Geena

Pacific Adventist University

1 Course, 13 Nations: Practical Takeaways for Networked Course Design and Delivery – A Model for Pacific Island Universities | 1 cours, 13 nations : enseignements pratiques pour la conception et la mise en œuvre de cours en réseau – un modèle pour les universités des îles du Pacifique

O'Neill, Kathleen¹; Kangelieva, Janara²

¹Innovative University of Enga ; ²American University of Central Asia

Perceptions of Undergraduate students on critical reading: A case study | Perceptions des étudiants de premier cycle sur la lecture critique : une étude de cas

Katovai, Rufina; Elisha, Judy; Tikomaimaleya, Laveti

Pacific Adventist University

Investigating the Impact of Nomophobia on University Students and Motivation for Learning in a Faith-Based Higher Education Institution in Papua New Guinea | Étude de l'impact de la nomophobie sur les étudiants universitaires et leur motivation à apprendre

dans un établissement d'enseignement supérieur confessionnel en Papouasie-Nouvelle-Guinée

Siwani, Mcshibah; Kundiamry, Sirimbo; Tommbe, Rachael; Pondi, Kepha

Pacific Adventist University

Session 14 - Education – Culture, Tradition and Gender Equality - Culture, tradition et égalité des genres

10.30am – 12.15am

Haus Europa HELT1

Perception of Religious Leaders on the Preamble and Section 45(1) of the PNG Constitution | Perception des leaders religieux sur le préambule et l'article 45(1) de la Constitution de la PNG

Ninkama, Ben

Divine Word University

The Cultural Significance of the Korokoro Bird in Kwara'ae Traditional Knowledge and Beliefs | La signification culturelle de l'oiseau Korokoro dans les savoirs et croyances traditionnels Kwara'ae

Misalo, Patterson

The University of the South Pacific

Exploring the Role of Pasin-Lotu in the Peace Process in Bougainville | Explorer le rôle du Pasin-Lotu dans le processus de paix à Bougainville

Wantip, Kenny

Pacific Adventist University

Harnessing ICT to Bridge Gender Gaps in Access to Higher Education in Papua New Guinea | Exploiter les TIC pour combler les écarts selon le genre dans l'accès à l'enseignement supérieur en Papouasie-Nouvelle-Guinée

Zvavahera, Promise

Institute of Business Studies Papua New Guinea

Documenting Barriers to Female Leadership in STEM at Selected Pacific Island Universities | Documentation des obstacles à la participation des femmes à des postes de direction en science, technologie, ingénierie et mathématique dans les universités sélectionnées des îles du Pacifique

Brodie, Gilianne^{1,3}; Amosa, Patila²; Lako, Jimaima³; Souchon, Mathilde¹; Ali Chand,

Zakia³, Faluaburu, Merry⁴, Huppatz, Kate⁵, Mishra, Margaret¹

¹The University of the South Pacific; ²National University of Samoa; ³Fiji National University; ⁴Solomon Islands National University; ⁵Western Sydney University

Psychological impacts of gender-based violence against women in hula community | Impacts psychologiques de la violence basée sur le genre contre les femmes dans la communauté de Hula

Ian, Aiga

University of Papua New Guinea

Session 15- Renewable Green Energy Harnessing | Exploitation des énergies vertes renouvelables

10.30am – 12.15am

Mine Pit

Combined Clean Energy Production | Production combinée d'énergie propre

Muirhead, Alan¹; Amai, Wilfred²; Betasolo, Mirzi³

¹University of New South Wales; ²University of Papua New Guinea; ³Papua New Guinea University of Technology

Physics-Based Technologies for Climate Action and Sustainable Development: Local Solutions for the Pacific | Technologies basées sur la physique pour l'action climatique et le développement durable : solutions locales pour le Pacifique

Kuali, Michael

Solomon Islands National University

Challenges and pathways to facilitate the energy access transition in the Pacific | Défis et voies pour faciliter la transition vers l'accès à l'énergie dans le Pacifique

Santagata, Edoardo¹; Rawali, Many²; Geller, Joshua¹; Datt, Alvin³; Bruce, Anna¹; Macgill, Iain¹

¹University of New South Wales; ²University of Papua New Guinea; ³The University of the South Pacific

Renewable Resources for Sustainable Power Generation: Green Synthesis of Zinc Oxide for Dye-Sensitized Solar Cells | Ressources renouvelables pour une production d'énergie durable : synthèse verte de l'oxyde de zinc pour cellules solaires sensibilisées aux colorants

Metayer, Cyrille ; Masson, Eric ; Cannamela, Guillaume; Meyer, Michael ; Sinyeue, Cynthia ; Lebouvier, Nicolas ; Dicko, Hamadou ; Huguenin, Joris ; Quiniou, Thomas ; Boyer, Jean-Marc

Université de la Nouvelle Calédonie

A Review of Agroforestry-Phytoremediation Systems for Land Restoration and Livelihood Enhancement: Insights for the Porgera Mine Environment, Papua New Guinea | Revue des systèmes d'agroforesterie-phytoremédiation pour la restauration des terres et l'amélioration des moyens de subsistance : perspectives pour l'environnement de la mine de Porgera, Papouasie-Nouvelle-Guinée

Rungwa, Stanley¹; Kumar Yekula, Prasanna²; Unsworth, William³; Timi, David²; Harakuwe, Anthony⁴

¹Innovative University of Enga; ²Papua New Guinea University of Technology; ³Center for International Forestry Research; ⁴University of Goroka

Session 16 - Environmental Monitoring and Disaster Management | Surveillance de l'environnement et gestion des catastrophes

10.30am – 12.15am

Civil AV Room

Determination of Rainfall-Runoff Relationship for Wadi Dayqah Catchment, Oman | Détermination de la relation pluie–ruissellement pour le bassin versant de Wadi Dayqah, Oman

Sana, Ahmad

Papua New Guinea University of Technology

Plate Configuration Deduced from Earthquake Mechanism and Crustal Deformation around Sagami Bay | Configuration des plaques déduite du mécanisme des séismes et de la déformation de la croûte autour de la baie de Sagami

Nelson, Daniel¹; Ryoya, Ikuta²

¹University of Papua New Guinea; ²Shizuoka University

Innovative Technologies for Volcanic Hazard Mitigation in the Pacific Islands | Technologies innovantes pour l'atténuation des risques volcaniques dans les îles du Pacifique

Bani, Philipson¹; Ricardo, William²

¹Institut de Recherche pour le Développement ;
²Vanuatu Meteorology and Geohazards Department

Impacts of significant earthquake on food systems during the emergency phase and future recommendation- Case study for Port Vila, Vanuatu, Southwest Pacific | Impacts d'un séisme majeur sur les systèmes alimentaires durant la phase d'urgence et recommandations futures – Étude de cas de Port Vila, Vanuatu, Pacifique Sud
Tigona, Robson
National University of Vanuatu

Advances in air quality research in Pacific Island Countries: Current and emerging challenges | Progrès de la recherche sur la

qualité de l'air dans les pays insulaires du Pacifique : défis actuels et émergents
Mani, Francis¹; Dansie, Andrew²; Hilly, Jimmy²; Shah, Sofia²

¹The University of the South Pacific; ²University of New South Wales

Unraveling floating marine debris in two coastal cities of Papua New Guinea: Sentinel 2 spectral analysis | Analyse des déchets marins flottants dans deux villes côtières de Papouasie-Nouvelle-Guinée : analyse spectrale Sentinel-2
Muthuswamy Ponniahb, Jonathan¹; Gopalakrishnana, Janarthanan²

¹Instituto Politécnico Nacional, ²Papua New Guinea University of Technology

Roundtable : Safe, Sustainable, and accessible transportation | Table ronde sur les transports sûrs, durables et accessibles

10.30am – 12.15am
RK Foyer

Molesworth, Brett¹; Dixit, Vinayak¹; Ortlaf, Joachim²; Holemba, Gibson³; Kintau, Joseph⁴; Buidal, Emerson⁵

¹University of New South Wales; ²Air Nuigini; ³PNG Department of Works and Highways; ⁴NG Road Fund; ⁵PNG Accident Investigation Commission

Lunch : 12.15 – 1.30pm

Session 17. Tropical, Communicable Diseases and Health Management | Maladies tropicales, maladies transmissibles et gestion de la santé

1.30- 3.15pm
Duncanson Hall

Malaria Distribution and Trends in Under Five Children in Honiara (2018-2024): Strategic Insights and Implications for Malaria Elimination by 2030 in the Solomon Islands | Distribution et tendances du paludisme chez les enfants de moins de cinq ans à Honiara (2018-2024) : perspectives stratégiques pour l'élimination du paludisme d'ici 2030 dans les Îles Salomon
Bugoro, Hugo
Solomon Islands National University

Implementation of tuberculosis infection prevention and control in rural Papua New Guinea: Towards prioritising action | Mise en œuvre de la prévention et du contrôle de la tuberculose en zone rurale en Papouasie-Nouvelle-Guinée : vers une priorisation des actions

Marme, Gigil¹; Kuzma, Jerzy¹; Zimmerman, Peta-Ann²; Harris, Neil²; Rutherford, Shannon²

¹Divine Word University; ²Griffith University

Estimation of lifetime lung cancer risk from radon inhalation in Lae, PNG | Estimation du risque de cancer du poumon à vie lié à l'inhalation de radon à Lae, Papouasie-Nouvelle-Guinée

Jojo, Panakal; Kolkoma, David; Pereira, Felix
Papua New Guinea University of Technology

The Role of Faith-based Organizations on the prevention of Cardiovascular Diseases in Solomon Islands: A Qualitative Study |

Rôle des organisations religieuses dans la prévention des maladies cardiovasculaires aux Îles Salomon : une étude qualitative

Sione, Alfred

Solomon Islands National University

Traditional Child Medicine in the South Pacific: New Caledonia, Vanuatu and French Polynesia |

Médecine traditionnelle pour enfants dans le Pacifique Sud : Nouvelle-Calédonie, Vanuatu et Polynésie Française

Tudal, Rosalie¹; Chassagne, Francois²; Palaud, Berry³; Michon, Pascal¹; Vivier, Anne-Sophie¹; Hnawia, Edouard²

¹National University of Vanuatu ; ²Institut de Recherche pour le Développement ; ³Vanuatu Agriculture College

Understanding the experience of menopause in Kwaio, Solomon Islands: a qualitative study |

Comprendre l'expérience de la ménopause chez les femmes, Kwaio, Îles Salomon : une étude qualitative

Harrington, Relmah^{1 2}; Esau, Dorothy³; Foroasi, Emma³; Cheer, Karen²; Devlin, Sue²; Maclaren, Michelle²

¹Solomon Islands National University; ²James Cook University; ³Baru Conservation Alliance

Session 18- Enablers Of Socio-Economic Growth, Sustainability and Conflict Management for the Rural and Isolated Population | Faciliter la croissance socio-économique, la durabilité et la gestion des conflits pour les populations rurales et isolées.

1.30- 3.15pm

RK Lecture Theater

Faith-based Organisations and Community Water Management in the Solomon Islands: Results of an Action Research Intervention in Isabel and Western Province |

Organisations religieuses et gestion communautaire de l'eau aux Îles Salomon : résultats d'une intervention de recherche-action dans les provinces d'Isabel et de l'Ouest

Benjamin, Collin¹; Funubo, Sheilla¹; Bugoro, Hugo¹; Panda, Nixon¹; Love, Mark²

¹Solomon Islands National University; ²Griffith University

Strengthening the systems through the WASH Five Year Plan: A study on comprehensive understanding of the challenges, opportunities, and strategies for strengthening WASH systems in the districts of Papua New Guinea |

Renforcer les systèmes à travers le Plan quinquennal WASH : étude sur la compréhension globale des défis, opportunités et stratégies pour le renforcement des systèmes WASH dans les districts de Papouasie-Nouvelle-Guinée

Kanini, Donald

University of Papua New Guinea

A Customary Land Data Model for a Re-engineered Land Administration System in Papua New Guinea: Promoting Equity and Sustainable Development |

Modèle de données foncières coutumières pour un système de gestion foncière réorganisé en Papouasie-Nouvelle-Guinée : promouvoir l'équité et le développement durable

Antonio, Wycliffe

Papua New Guinea University of Technology

Application of traditional knowledge and skills for social conflict resolution between organizations and landowners: lessons from a female's experience in the oil palm industry |

Application des savoirs et compétences traditionnels à la résolution de conflits sociaux entre organisations et propriétaires fonciers : leçons tirées de l'expérience d'une femme dans l'industrie de l'huile de palme

Mendano, Senny ; Ndrewou, Alois

University of Goroka

Integrating kapor and photovoice research methods |

Intégration des méthodes de recherche kapor et photovoice

Bomai, Witne Dick

University of Goroka

Session 19 – Environment sciences – Impacts of Construction & Management - Sciences de l'environnement - Impacts de la construction et de la gestion

1.30pm- 3.15pm

RK Foyer

Vibration mode analysis of a 100 m simply-supported steel beam bridge via POD of FEM |

Analyse des modes de vibration d'un pont en poutre d'acier simplement appuyée de 100 m via POD et FEM

Tikil, Japath¹; Telue, Yaip²; Dunstan, Samuel¹

¹Papua New Guinea University of Technology;
²Lutheran University

An assessment of heavy metals contamination in freshwater sediments and fish and cyanide in sediment around Gold Ridge mine site, Solomon Islands | Évaluation de la contamination par les métaux lourds des sédiments d'eau douce et des poissons et du cyanure dans les sédiments autour du site minier de Gold Ridge, Îles Salomon

Aihunu, Timothy
Solomon Islands National University

An assessment of heavy metals contamination in marine sediments and fish in Honiara Harbor, Solomon Islands | Évaluation de la contamination par les métaux lourds dans les sédiments marins et les poissons du port de Honiara, Îles Salomon

Boboria, Dickson
Solomon Islands National University

Enhancing Weather Forecast Accuracy in the Solomon Islands: A Machine Learning-Based Statistical Analysis of Climate Change Using Smart Classifier Algorithms | Amélioration de la précision des prévisions météorologiques aux îles Salomon : Analyse statistique du changement climatique basée sur l'apprentissage automatique à l'aide d'un algorithme de classification intelligent
Kale, Timothy¹ ; Ohzahata Satoshi²

¹Solomon Islands National University ; ²The University of Electro Communications Japan

Integrating Digital Technologies and Traditional Knowledge for Safer and More Sustainable Pacific Ports | Intégration des technologies numériques et des savoirs traditionnels pour des ports plus sûrs et plus durables dans le Pacifique

Wamamberi Judah
PNG Pors Corporations Ltd

Session 20 - Agricultural Policies, Rural Development, Market Access | Politiques agricoles, développement rural, accès aux marchés

1.30pm- 3.15pm
Mine Pit

Low tech vs High tech? What path for agriculture in Oceania's SIEs | Low tech vs

High tech? Quelle voie pour l'agriculture dans les petits États insulaires océaniques

Blaise, Séverine
Université de la Nouvelle Calédonie

Pacific short stories on traditional agriculture to the sustainable development in the Pacific | Histoires courtes du Pacifique sur l'agriculture traditionnelle et le développement durable dans le Pacifique

Vutiala, Lina
National University of Vanuatu

Post-Harvest Handling Practices, Market Accessibility, and Economic Impacts on Coastal Communities in Lau Lagoon, Malaita Province, Solomon Islands | Pratiques de manutention post-récolte, accessibilité au marché et impacts économiques sur les communautés côtières de Lau Lagoon, province de Malaita, Îles Salomon

Solo, Madeline Kili
Solomon Islands National University

Bridging Traditional Knowledge and Food Safety Technologies: Pathways for Market Access of Papua New Guinea Frozen Taro | Relier les savoirs traditionnels et les technologies de sécurité alimentaire : voies d'accès au marché pour le taro surgelé de Papouasie-Nouvelle-Guinée

Gomuna, Naomi ; Okpul, Tom
Papua New Guinea University of Technology

The Role of Aquatic Foods Distribution Channel Actors in the Solomon Islands: A Honiara Central Market (HCM) Reflection | Le rôle des acteurs des circuits de distribution des aliments aquatiques aux Îles Salomon : une réflexion autour du marché central de Honiara (HCM)

Saepioh, Kezyiah¹ ; Gomeese, Chelcia²
¹Solomon Islands National University ;
²University of Wollongong

Albacore tuna (Thunnus alalunga) habitat and variability in French Polynesia | Habitat du thon blanc (Thunnus alalunga) et sa variabilité en Polynésie Française

Guinard, Melina¹ ; Maamaatuaiahutapu, Keitapu¹ ; Raapoto, Hirohiti²

¹Université de la Polynésie Française ;
²IFREMER

Session 21 - Higher Education to enhance well being - L'enseignement supérieur et l'amélioration du bien-être

1.30pm- 3.15pm
Civil AV Room

Towards a Holistic Gupela Sindaun Model of Care in Nursing for Papua New Guinea: The Dynamics of Cultural and Christian Beliefs in Nursing Practice | Vers un modèle holistique de soins Gupela Sindaun en soins infirmiers pour la Papouasie-Nouvelle-Guinée : les dynamiques des croyances culturelles et chrétiennes dans la pratique infirmière
Kuman, Gabriel
Divine Word University

Nursing Students' Satisfaction with Community Health Nursing (CHN) program in Higher Education Institution in Papua New Guinea | Satisfaction des étudiants en soins infirmiers à l'égard du programme de soins infirmiers de santé communautaire (CHN) dans un établissement d'enseignement supérieur en Papouasie-Nouvelle-Guinée
Minnala, Vowari Marian¹ ; Pondi, Kepha²
¹University of Papua New Guinea; ²Pacific Adventist University

Effectiveness of lifestyle interventions for obesity prevention among adolescents in Pacific Islands Countries and Territories | Efficacité des interventions sur le mode de vie pour la prévention de l'obésité chez les adolescents dans les pays et territoires insulaires du Pacifique
Galy, Olivier¹ ; Urvoy, Marie-Jeanne¹ ; Bertrand, Solene² ; Caillaud, Corinne³ ; Bay, Jacquie⁴ ; Frayon, Stéphane¹ ; Wattelez,

Guillaume¹ ; Allman Farinelly, Margaret³, Raubenheimer, David³ ; Novotny, Rachel⁵ ; Okely, Anthony⁶

¹Université de la Nouvelle Calédonie; ²Pacific Community ; ³University of Sydney ; ⁴University of Auckland ; ⁵University of Hawaii; ⁶University of Wollongong

Centering Pacific culture in developing culturally tailored health programs and policies for Pacific Islander communities in Australia | Centrer la culture pacifique pour l'élaboration de programmes et de politiques de santé adaptés culturellement pour les communautés des îles du Pacifique en Australie
Palu, Aliyah; Trieu, Kathy ; Hackett, Maree; Hunter, Kate
The George Institute for Global Health

Machine Learning for Data-Driven Demand Forecasting of TB drugs | Apprentissage automatique pour la prévision de la demande en médicaments antituberculeux basée sur les données
Helebi, Peter
Papua New Guinea University of Technology

Influence of Metacognition Activity and Metacognition Awareness on Metacognition Knowledge in students in a Higher Educational Institution in Papua New Guinea | Influence de l'activité métacognitive et de la conscience métacognitive sur les connaissances métacognitives chez les étudiants d'un établissement d'enseignement supérieur en Papouasie-Nouvelle-Guinée
Potjepat, Gracelyn¹ ; Pondi, Kepha² ; Kyi, Khin²
¹University of Papua New Guinea; ²Pacific Adventist University

Afternoon Tea : 3.15pm – 3.30pm

Session 22 - Urban transformation and challenges in the Pacific - Transformation urbaine et ses défis dans le Pacifique

3.30pm- 5.15pm
Duncanson Hall

Living Without Electricity in Urban Communities in PNG: The Case of 8-Mile Settlement | Vivre sans électricité dans les

communautés urbaines de PNG : le cas du quartier informel 8-Mile
Dilu, Loretta
University of Papua New Guinea

Public Servant's Perception of the Auditor General's Office in Reducing Financial Fraud in the National Capital District of PNG | Perception des fonctionnaires du Bureau de l'Auditeur général dans la lutte contre la fraude

financière dans le District de la Capitale nationale de la PNG

Rinny, Delka ; Pondi, Kepha ; Kyi, Khin
Pacific Adentist University

An Analytical study of Traffic Congestion in Honiara | Étude analytique des embouteillages à Honiara

Bukah, Misifea
Solomon Islands National University

An Assessment of PNG Government's Connect PNG Program: A Socioeconomic Survey of the Baiyer-Madang Road | Évaluation du programme Connect PNG du gouvernement : enquête socio-économique sur la route Baiyer-Madang

Starza, Paul
Papua New Guinea University of Technology
Urban Challenges, Digital Opportunities: Language Transmission in Port-Vila's urban settlements | Défis urbains et opportunités numériques : la transmission des langues dans les quartiers urbains informels de Port-Vila
Vandeputte, Leslie
National University of Vanuatu

Session 23 - Smart Environment and Industry - Industrie 4.0 et environnement intelligent
3.30pm- 5.15pm
RK Lecture Theater

The opportunities and challenges of using electronic monitoring (EM) on seabird bycatch in longline fisheries | Opportunités et défis liés à l'utilisation du suivi électronique (EM) des prises accessoires d'oiseaux marins dans les pêcheries à palangre

Gwaibo, Regina
PNG University of Natural Resources and Environment

Development of a Digital Twin to Model and Evaluate Transportation Infrastructure | Développement d'un jumelage numérique pour modéliser et évaluer les infrastructures de transport

Dixit, Vinayak; Molesworth, Brett ; Varughese, George
University of New South Wales

Improving Project Outcomes by Integration Fast-tracking Technique and Triangle Management through Building Information Modelling (BIM) | Amélioration des résultats

des projets par l'intégration de la technique d'accélération et de la gestion en triangle via la modélisation des informations du bâtiment

Sauwa, Lincoln; Kisokau, Stephanie ; Akui, Donovan ; Khoshnava, Meysam
Papua New Guinea University of Technology

Improve Cost Overruns factors in Construction Contract Administration (CCA) Through Building Information Modeling (BIM) | Amélioration des facteurs de dépassement des coûts dans la gestion des contrats de construction grâce à la modélisation des informations du bâtiment

Akui, Donovan ; Khoshnava, Meysam ; Sauwa, Lincoln; Kisokau, Stephanie
Papua New Guinea University of Technology

Session 24- Quality Education and Human Resource Development – Impacts of technology - Développement de la qualité de l'éducation et des ressources humaines – Les impacts de la technologie
3.30pm- 5.15pm

RK Foyer

Enhancing Medical Education through Digital Innovation at Divine Word University (DWU) | Amélioration de l'enseignement médical grâce à l'innovation numérique à l'université Divine Word

Kuzma, Jerzy
Divine Word University

Bridging the Digital Divide: A Comparative Study of Perceived Attributes of Student Engagement in Online Teaching and Learning in Two Universities in Papua New Guinea | Combler la fracture numérique : étude comparative de l'engagement des étudiants dans l'apprentissage en ligne dans deux universités de PNG

Selvi, Thamarai
University of Goroka

Research Report on Operational Challenges and Technological Integration at UPNG Open College: Insights from the 2024 Half-Yearly Report | Rapport de recherche sur les défis opérationnels et l'intégration technologique à l'Université Nationale de Papouasie-Nouvelle-Guinée : enseignements du rapport semestriel 2024

Olga, Anna; Lahui-Ako, Boe ; Ramo, John
University of Papua New Guinea

Perceptions of Health Extension Officer students in Divine Word University on medical simulation training as a preparation tool for clinical placement: A mixed methods study | Perceptions des étudiants en santé communautaire de l'Université Divine Word sur la simulation médicale comme outil de préparation au stage clinique : une étude par méthodes mixtes
Benjamin, John
Divine Word University

Exploring Relevance and Benefits of OBE TV Lessons to PNG and the factors affecting broadcasting of TV Lessons in TV School Media Center now e-learning Division | Explorer la pertinence et les avantages des leçons télévisées OBE pour la PNG, ainsi que les facteurs affectant leur diffusion au Centre médiatique scolaire TV, désormais Division e-learning
Dick, Joyce ; Openg, Asaku
Divine Word University

Between frustrations and opportunities: Experiences of Undergraduate Students in Writing Research proposals in a Tertiary Institution in Papua New Guinea | Entre frustrations et opportunités : expériences des étudiants de premier cycle dans la rédaction de propositions de recherche dans un établissement d'enseignement supérieur en Papouasie-Nouvelle-Guinée
Saguba, Lorna ; Napasu, Alice
Pacific Adventist University

Session 25 – Sustainability, Environmental Sciences and Technology - Durabilité, sciences et technologies de l'environnement

3.30pm- 5.15pm
Mine Pit

Smart and Integrated Techniques for Climate-Resilient Road Infrastructure Planning and Management in the Mountainous Regions of Papua New Guinea | Techniques intelligentes et intégrées pour une planification et une gestion résilientes des infrastructures routières en région montagneuse en Papouasie-Nouvelle-Guinée
Sekac, Tingneyuc¹ ; Sindang, Charlie Kevy² ; Jana, Sujoy Kumar¹

¹Papua New Guinea University of Technology;

²Morobe Provincial Administration

Contamination of Dump Soils by Toxic Heavy Metals: An Emerging Risk to Groundwater Quality | Contamination des sols de décharge par des métaux lourds toxiques : un risque émergent pour la qualité des eaux souterraines
Ape, John; Bathula, Srikanth; Samanta, Sailesh
Papua New Guinea University of Technology

Harnessing Fuzzy Algebra and Mathematical Modelling for Safe and Sustainable Development in the Pacific Region | Exploiter l'algèbre floue et la modélisation mathématique pour un développement sûr et durable dans le Pacifique
Kotti, Ramanuja ; Kale, Timothy
Solomon Islands National University

Learning the Shoreline: A High-Resolution Approach to Reef Island Dynamics | Comprendre le littoral : une approche haute résolution de la dynamique des îles récifales
Fischer, Tobias; Stoll, Benoit
Université de la Polynésie Française

Using drones for coastal surveillance: an innovative approach to coastal management in Oceania | L'utilisation des drones pour la surveillance du littoral : une approche innovante de la gestion côtière en Océanie
Dumas, Pascal
Université de la Nouvelle Calédonie

Spatial Analysis of Agricultural Health and Drought Conditions using Multispectral Satellite Image | Analyse spatiale de la santé agricole et des conditions de sécheresse à l'aide d'images satellitaires multispectrales
Samanta, Sailesh
Papua New Guinea University of Technology

Session 26 – Food Security & Nutrition - Sécurité alimentaire et nutrition

3.30pm- 5.15pm
Haus Europa HELT1

Biofortification of staple crops in Papua New Guinea towards a sustainable future ensuring food and nutrient security | Biofortification des cultures de base en Papouasie-Nouvelle-Guinée pour assurer la sécurité alimentaire et nutritionnelle

Arcot, Jayashree¹ ; Yalambing, Lydia² ; Lee, Alice¹

¹University of New South Wales; ²Papua New Guinea University of Technology

The roles of organic matter of varying nutrient content use as amendment in composted mounds on sweet potato tissue accumulation of micronutrients | Rôle de la matière organique avec différents teneurs en nutriments utilisée comme amendement dans les monticules compostés sur l'accumulation de micronutriments dans les tissus des patates douces

Peter, Topas ; Michael, Patrick

Papua New Guinea University of Technology

The roles of cogon grass biochar application on sandy loam soil chemistry and sweet potato tissue composition of nutrients under humid lowland tropical agroclimatic conditions in Papua New Guinea | Rôles de l'application de biochar de l'herbe cogon sur la chimie des sols limoneux et la composition nutritionnelle de la patate douce dans des conditions agroclimatiques tropicales humides de basse altitude en Papouasie-Nouvelle-Guinée

Michael, Patrick

Papua New Guinea University of Technology

Transport Processes of Nitrate (NO₃⁻) in Relation to Ground and Surface water Contamination from Perennial Tree Crop Systems in Papua New Guinea: A Review | Processus de transport du nitrate (NO₃⁻) en lien avec la contamination des eaux souterraines et de surface par les systèmes de cultures pérennes en Papouasie-Nouvelle-Guinée : une revue

Hati, Hefung ; Ndrewou, Alois ; Biri, Rodney
University of Goroka

Organic matter amendment of swidden fields to maximize the yield of sweet potato along an altitudinal gradient in Papua New Guinea | Amendement des jachères avec de la matière organique pour maximiser le rendement de la patate douce le long d'un gradient altitudinal en Papouasie-Nouvelle-Guinée

Sui, Shen

Papua New Guinea University of Technology

Variations of ploidy levels among taros in Papua New Guinea (PNG) | Variations des niveaux de ploïdie chez les taros en Papouasie-Nouvelle-Guinée

Wawah, Lisapho¹ ; Mark, Warendo¹ ; Campbell, Bradley² ; Okpul, Tom¹

¹Papua New Guinea University of Technology;

²University of Queensland

Program Session Schedule - Thursday 3 July

- **Plenary Session – Road to COP31** | Le chemin vers la COP31
9.00am – 10.00am - *Duncanson Hall*
 - **Morning Tea** : 10.00am – 10.30am
 - **Sessions: 27 - 32**
 - **Lunch** : 12.15pm – 1.30pm
 - **Do it yourself Solar Installation provided by PNGUoT Student Volunteers:** 12.15pm – 1.30pm
Duncanson Hall
 - **Closing Ceremony** : 1.30pm-2.15pm
Duncanson Hall
 - **Closing Dinner** : 7.00pm – *New Dining Hall*
-

Session 27 – Climate Change, risk and transformations - Changement climatique, risques et transformations

10.30- 12.15pm
Duncanson Hall

Mataeina'a Systems in Tahiti: Researching Land-Use Practices of the Past for a Regenerative Future | Systèmes Mataeina'a à Tahiti : recherche sur les pratiques d'utilisation passées des terres pour un avenir durable
Wheeler, Vehia^{1 2}

¹Australian National University ; ²Université de la Polynésie Française

Ozone Depletion and Climate Change Action in the Pacific | Appauvrissement de la couche d'ozone et action contre le changement climatique dans le Pacifique

Olatona, Dapsy

Papua New Guinea University of Technology

Food and forestry biomass, an alternative for the removal of hexavalent chromium under natural conditions | Biomasse alimentaire et forestière, une alternative pour l'élimination du chrome hexavalent dans des conditions naturelles

Sinyeue, Cynthia; Yalcin, Redwane; Desriaux, Isabelle; Lemestre, Monika; Monin, Aurélie; Lebouvier, Nicolas; Gunkel Grillon, Peggy

Université de la Nouvelle Calédonie

Assessing the Water Balance and Groundwater Drying Trends in Papua New Guinea: The Potential of Soil and Water Conservation for Recharge Restoration | Évaluation du bilan hydrique et des tendances d'assèchement des eaux souterraines en Papouasie-Nouvelle-Guinée : le potentiel de la conservation des sols et de l'eau pour la restauration de la recharge

Betasolo, Mirzi; Teweldebrihan, Meseret Dawit

Papua New Guinea University of Technology

A water balance assessment of the drying trend of groundwater-dependent Lake Haramaya and the potential role of soil and water conservation in its restoration | Évaluation du bilan hydrique de la tendance à l'assèchement du lac Haramaya dépendant des eaux souterraines et rôle potentiel de la conservation des sols et de l'eau dans sa restauration

Teweldebrihan, Meseret Dawit; Betasolo, Mirzi

Papua New Guinea University of Technology

Session 28 – Social and economical Transformation in the Pacific - Transformations sociales et économiques dans le Pacifique

10.30am- 12.15pm
RK Lecture Theater

Strategies for Pacific Island Sports in the run-up to the 2032 Olympic and Paralympic

Games | Stratégies pour le sport dans les îles du Pacifique en vue des Jeux olympiques et paralympiques de 2032

Roosen, Andy¹; Burchell, Alison²; Cobley, Stephen³

¹The University of the South Pacific; ²Solomon Islands National Sports Council; ³University of Sydney

Understanding the Ballot Box: Attitudes and Social Factors Shaping Voting Behavior Among Solomon Islands National University Students | Comprendre les urnes: attitudes et facteurs sociaux influençant le comportement électoral parmi les étudiants de l'Université Nationale des Îles Salomon

Siota, Jerry

Solomon Islands National University

The Internet Penetration Challenges in Smaller Island States | Défis liés à la couverture Internet dans les petits États insulaires

Smith Hinge, Kevin

National University of Vanuatu

Challenging traditional airline business models to ensure the sustainable development of airlines in the Pacific | Remettre en question les modèles économiques traditionnels des compagnies aériennes pour assurer leur développement durable dans le Pacifique

Molesworth, Brett ; Kondie, Dane

University of New South Wales

Green-gold Entrepreneurship in the Pacific: Leveraging Survival Technology? | L'entrepreneuriat de l'or vert dans le Pacifique : Tirer parti de la technologie de survie ?

Kogapo, Jobo

The University of the South Pacific

Is there any Impact of Credit Management Practices on Bank Performance in PNG? | Les pratiques de gestion du crédit ont-elles un impact sur les performances des banques en PNG ?

Moses, Elish ; Nadiminti, Nadham Viswa

Papua New Guinea University of Technology

Session 29 - Social & Information Technology - Technologies sociales et de l'information

10.30am- 12.15pm

RK Foyer

Knowledge, Attitudes, and Practices of Students towards E-Learning (Moodle) at the Solomon Islands National University (SINU): A Cross-Sectional Study |

Connaissances, attitudes et pratiques des étudiants vis-à-vis de l'apprentissage en ligne (Moodle) à l'Université nationale des Îles Salomon (SINU) : une étude transversal

Junior Fafekona, Pressly ; Panda, Nixon ; Harrington, Relmah; Tauriki, Sira; Arufoa, Belinda; Odilia Toge, Jemimah Mary; Hunumeme

Solomon Islands National University

Aligning University Courses to the PNG Government Digital Plan, A Challenge for the Universities in PNG | Adapter les cours universitaires au Plan numérique du gouvernement de PNG : un défi pour les universités en Papouasie-Nouvelle-Guinée

Erapae, Tuai

Pacific Adventist University

Exploring teacher's and parent's perceptions about mobile phone and its impact on primary and secondary students |

Perceptions des enseignants et des parents sur l'impact des téléphones portables chez les élèves du primaire et du secondaire

Openg, Asaku

Divine Word University

Data lifecycle to support sustainable research in the Pacific | Cycle de vie des données pour soutenir la recherche durable dans le Pacifique

Wattelez, Guillaume ; Latour, Marie ; Galy, Olivier

Université de la Nouvelle Calédonie

Community-Driven Adoption of Industry 4.0 Technologies for Sustainable and Resilient Food Production | Adoption communautaire des technologies de l'industrie 4.0 pour une production alimentaire durable et résiliente

Abdoli, Shiva

University of New South Wales

Session 30- Sustainable Development, through Culture and Indigenous Knowledge - Le développement durable par la culture et les savoirs traditionnels

10.30am- 12.15pm

Mine Pit

Exploring the role of traditional culture in promoting sustainable development in Sinisbai, Western Highlands Province, Papua New Guinea | Explorer le rôle de la culture traditionnelle en faveur du développement durable à Sinisbai, Province des Hautes-Terres occidentales, Papouasie-Nouvelle-Guinée

Sumb, Allan

Divine Word University

Indigenous research methodologies through the humanities: the bridge between natural science and social sciences | Méthodologies de recherche autochtones par les sciences humaines : le pont entre sciences naturelles et sociales

Kula Semos, Maretta

Divine Word University

Academic Research and University Outreach, a few case studies in Madang (Papua New Guinea) | Recherche universitaire et engagement communautaire : quelques études de cas à Madang (Papouasie-Nouvelle-Guinée)

Garnier, Nicolas

Divine Word University

Creative Visual Research and Local Strategies for Social Change | Recherche visuelle créative et stratégies locales pour le changement social

Langa, Wilma

Papua New Guinea University of Technology

Old technology, new technology: the archive of Ruth and Mack Ruff | Anciennes et nouvelles technologies : les archives de Ruth et Mack Ruff

James, Kari; Temu, Deveni

Australian National University

The history of India and its relation with Pacific Islands | L'histoire de l'Inde et ses relations avec les îles du Pacifique

Patra, Alak Kumar; Jana, Sujoy Kumar

Papua New Guinea University of Technology

Session 31 - Technology, Connectivity, and Innovation in Pacific Education and Society - Technologie, connectivité et innovation dans l'éducation et la société du Pacifique

10.30am- 12.15pm

Civil AV Room

Leveraging Data Integration using APIs for Enhanced Data Analytics in Papua New Guinea | Exploiter l'intégration des données via les Interfaces de programmation d'applications pour améliorer l'analyse des données en Papouasie-Nouvelle-Guinée

Kalan, Steward ; Bhojan, Rajendra

Papua New Guinea University of Technology

A culturally responsive technology-enabled learning platform for Vanuatu primary school in-service teachers | Une plateforme d'apprentissage technologiquement et culturellement adaptées pour les enseignants en formation continue du primaire au Vanuatu

Morris, Eiffrel

National University of Vanuatu

Assessing the Readiness in ICT Integration in faith-based Secondary Schools in Port Moresby, Papua New Guinea | Évaluation de la préparation à l'intégration des TIC dans les écoles du secondaires confessionnelles de Port Moresby, Papouasie-Nouvelle-Guinée

Tuka Nennek, Hilda ; Pondi, Kepha

Pacific Adventist University

Evaluating Internet Speed, Accessibility, and Connectivity in the Solomon Islands: A Mixed-Methods Survey Study | Évaluation de la vitesse, de l'accessibilité et de la connectivité d'Internet aux Îles Salomon : une enquête à méthodes mixtes

Waihuru, John ; Kale, Timothy ; Pituvaka, Wanderlyn; Alick, Dewin

Solomon Islands National University

Adolescents' use of digital technology for health: Insights from New Caledonia | Utilisation des technologies numériques par les adolescents pour la santé : aperçus de la Nouvelle-Calédonie

Amon, Krestina¹; Forsyth, Rowena¹; Peralta, Louise¹; Partridge, Stephanie¹; Chen, Juliana¹; Wattelez, Guillaume²; Galy, Olivier²; Caillaud, Corinne¹

¹University of Sydney; ²Université de la Nouvelle Calédonie

Technology Innovation for Active lives: insights from adolescents from New Caledonia and Australia | Innovation technologique pour une vie active : perspectives d'adolescents de Nouvelle-Calédonie et d'Australie

Caillaud, Corinne¹; Gonzalez, Sophie¹; Amon, Krestina¹; Forsyth, Rowena¹; Peralta, Louise¹; Ahmadpour, Naseem¹

**Partridge, Stephanie¹; Chen, Juliana¹;
Wattelez, Guillaume²; Galy, Olivier²;**

¹University of Sydney; ²Université de la
Nouvelle Calédonie

**Session 32 Policy, Higher Education, and
Institutional Transformation - Politique,
enseignement supérieur et transformation
institutionnelle**

**10.30am- 12.15pm
Haus Europa HELT1**

**Repositioning the PNG University of
Technology for National Impact: The Role of
Higher Education in Advancing Livelihoods
through Science, Technology, and Policy in
Papua New Guinea |** Repositionner
l'Université Technologique de PNG pour un
impact national : le rôle de l'enseignement
supérieur dans l'amélioration des moyens de
subsistance à travers la science, la technologie
et les politiques en Papouasie-Nouvelle-Guinée
Renagi, Ora ; Olatona, Dapsy
Papua New Guinea University of Technology

Digital Literacy at Divine Word University |
La littératie numérique à l'Université Divine
Word
Gibbs, Philipp
Divine Word University

**The transition of secondary students into
higher tertiary education: the perspectives
of Divine Word University, Madang
province, Papua New Guinea |** La transition

des élèves du secondaire vers l'enseignement
supérieur : les perspectives de l'Université
Divine Word, province de Madang, Papouasie-
Nouvelle-Guinée

Wohemani, Rhonda¹ ; Ariku, Emelda²

¹Divine Word University ; ²Solomon Islands
National University

**Implementing Voter and Elections
education in the Fiji context |** Eduquer les
électeurs sur les élections dans le contexte des
Fidji

Bhim, Mosmi
Fiji National University

**Empowering Pacific Island Universities for
Safe and Sustainable Development through
Geospatial Technologies |** Renforcer les
capacités des universités des îles du Pacifique
pour un développement sûr et durable grâce
aux technologies géospatiales

**Massenet, Jean¹; Huynh, Frederic¹;
Durieux, Laurent²; Despinoy, Marc²;
Winchester, Pearl²**

¹Data Terra ; ²Institut de Recherche pour le
Développement

**Exploring the Transition Experience of
International Students at the Solomon
Islands National University in 2024: A
Mixed-Methods Study |** Explorer l'expérience
de transition des étudiants internationaux à
l'Université nationale des Îles Salomon en 2024
: une étude à méthodes mixtes

**Keboy, Jamesford ; Poloso, Mariella ;
Dereveke, Marineth ; Palapu, Rudgard ;
Benjamin, Collin; Lifoia, Clement**
Solomon Islands National University

Do it yourself Solar Installation: PNGUoT Student Volunteers will demonstrate Solar Installation up
to 500 watts for your personal use with dedicated equipment and auto-transfer switch (ATS) -
12.15pm – 1.30pm

Duncanson Hall Foyer

Lunch : 12.15pm – 1.30pm

Closing Ceremony: 1.30pm-2.15pm
Duncanson Hall

Closing Dinner : 7.00pm

About the Papua New Guinea University of Technology (PNGUoT)

As Papua New Guinea's leading institution for applied science and engineering, the Papua New Guinea University of Technology (PNGUoT) plays a pivotal role in shaping the region's innovation landscape. Located in Lae, Morobe Province, PNGUoT is committed to producing world-class graduates through excellence in teaching, cutting-edge research, and the practical application of science and technology.

With a vision to be "a leader in scientific research and technological innovation that is impacting society," PNGUoT is a natural partner for the Pacific Islands Universities Research Network (PIURN). The university's strategic priorities align with PIURN's mission to foster collaborative research that addresses the unique challenges and opportunities of the Pacific region.

PNGUoT's vibrant academic community includes faculties in engineering, natural resources, applied sciences, and business studies, supported by a growing portfolio of postgraduate programs and research initiatives. The university is also home to specialized centers such as the Confucius Institute and the Department of Open and Distance Learning, which extend its reach across the country and beyond.

Guided by values of professionalism, diversity, innovation, and ethical leadership, PNGUoT welcomes collaboration with regional and international partners. For PIURN students and researchers, PNGUoT offers a dynamic environment to explore shared challenges—from climate resilience and sustainable development to digital transformation and indigenous knowledge systems.

PNGUoT's engineering programs are on track for full international accreditation under the Washington Accord, with provisional accreditation already granted by Engineers Australia. This milestone reflects the university's commitment to aligning its curriculum with global standards and enhancing the international mobility of its graduates.

The university actively fosters global partnerships, including a recent collaboration with Charleston Southern University in the United States. This partnership supports joint research, student and faculty exchanges, and shared initiatives in renewable energy and climate change—areas of critical importance to the Pacific region.

Support services at PNGUoT are robust and student-centered. The Matheson Library offers extensive academic resources, while the Department of Open and Distance Learning (DODL) and ICT Services ensure flexible and accessible learning opportunities. The university also provides housing, sports facilities, scholarships, and international exchange programs to support student success.

With a mission to be "a leader in scientific research and technological innovation that is impacting society," PNGUoT is proud to host the 6th PIURN Conference. It welcomes students and researchers from across the Pacific to engage in meaningful dialogue, collaborative research, and shared solutions for the region's most pressing challenges.





About the Pacific Islands Universities Regional Network (PIURN)

The Pacific Islands Universities Regional Network (PIURN) has been established in 2013. The consortium brings together 15 Member Universities from the Pacific Islands Countries and Territories:

- The University of the South Pacific
- The University of New Caledonia
- Christ's University in Pacific (Tonga)
- Divine Word University
- Fiji National University
- National University of Samoa
- National University of Vanuatu
- Pacific Adventist University
- University of Fiji
- The University of French Polynesia
- The Papua New Guinea University of Natural Resources and Environment
- The Papua New Guinea University of Technology
- The University of Papua New Guinea
- Solomon Islands National University

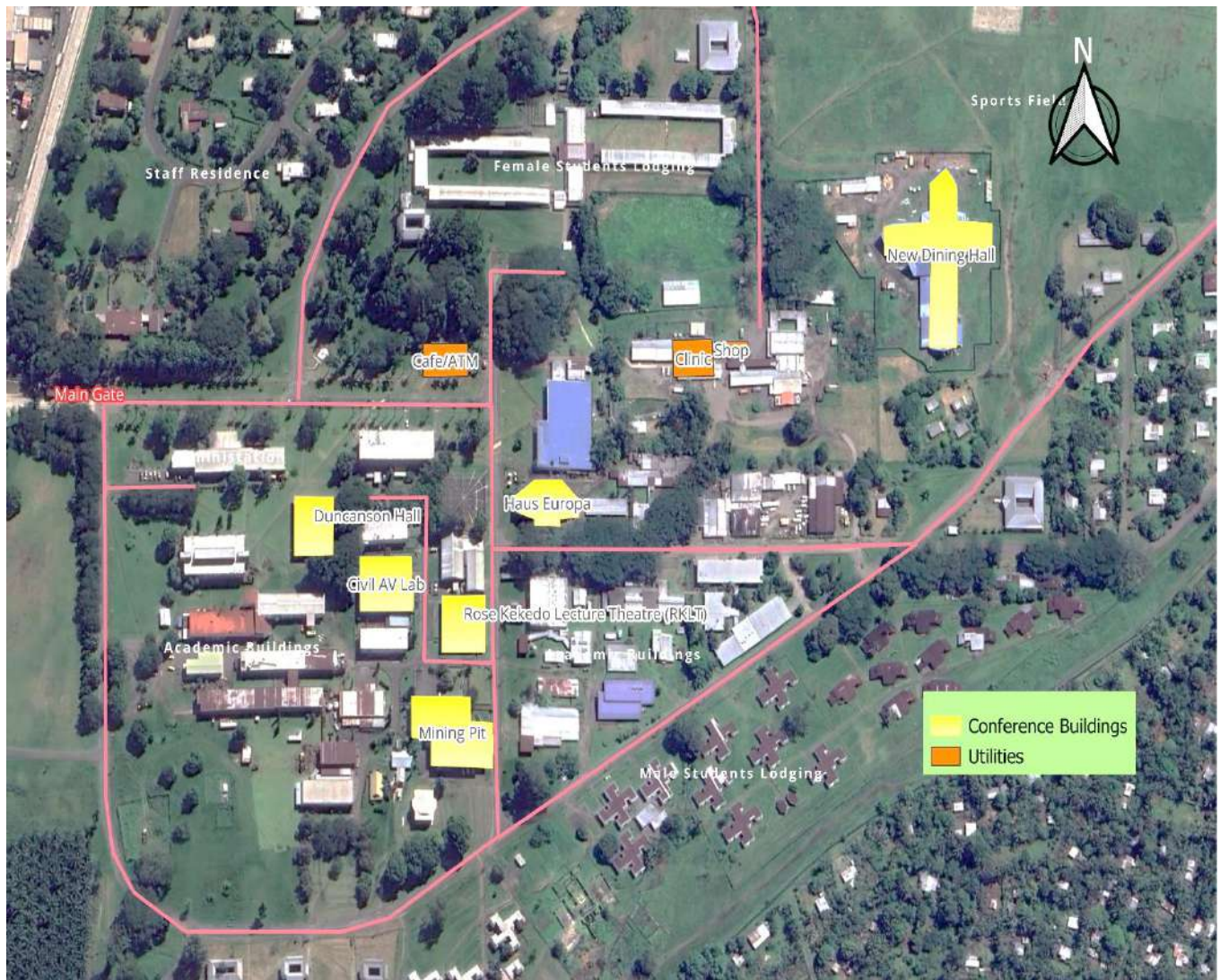
PIURN is identified today as a powerful level for the development of regional research and training initiatives in and for the Pacific Region. 2025 marked the launch of the first regional PIURN Call for Proposals to promote and strengthen scientific cooperation across the region. This collaborative initiative is led by a consortium of 6 PIURN member universities and aims to build research capacity in alignment with PIURN's core mission.

PIURN Biennial Conferences highlight not only the work of academics and students from the region but are a platform to showcase regional initiatives and build scientific partnerships. After University of New Caledonia (2014), National University of Samoa (NUS), University of French Polynesia (2018), Solomon Islands National University (2021) and The University of the South Pacific Cook Islands Campus (2023), the Papua New Guinea University of Technology is hosting the 6th PIURN Conference, bringing this regional scientific gathering in the country for the first time, coinciding with Papua New Guinea's 50th anniversary of independence.

The vision of the network is **“to collectively empower the Pacific Universities to become key contributors to finding solutions for challenges facing the region”**.

To serve its vision, PIURN's mission is **“to empower the new generation of Pacific leaders, researchers and professionals to better serve the needs and aspirations of the Pacific communities, in accordance with the education, research and technology pillar of the 2050 Strategy for the Blue Pacific Continent”**.

How to get to your presentation room (colored yellow)



EMERGENCY and INFORMATION NUMBERS

- Conference Editorial Office:..... 7429 88882
- Transport Coordinator (Mr Jack Yaro):..... 73528125
- Registration Coordinator (Ms Camilla Yanabis):..... 71207666
- UNITECH SECURITY - 4734444 / 74930599 (DC) / 75779344 (BM),
- UNITECH AMBULANCE - 4734444 / 74930599 (DC) / 75779344 (BM)
- LAE METRO POLICE - 7090330
- LAE FIRE SERVICE - Hotline:1100 Mobile: 7355 2947 Lan: 4720252 / 4724333
- ST. JOHN AMBULANCE - 111 (TOLL FREE)
- UNITECH HOUSING - 7215 3665/ 711 84541

TRANSPORT PICK UP AND DROP OFF SCHEDULE

Nadzab Airport Pick up and Drop off Schedule						
Day	Morning: Pick-up Time	Mid-day: Pick-up Time	Mid-day: Pick-up Time	Afternoon: Pick-up Time	Drop off Location	Pick up bus & Reminders
Saturday 28 June	7:00 am	10:30 am	2:00 pm	5:30 pm	Hotels/designated accommodations.	Booth set up at Nadzab Airport & Guard Dog bus available.
Sunday 29 June	7:00 am	10:30 am	2:00 pm	5:30 pm	Hotels/designated accommodations.	Booth set up at Nadzab Airport & Guard Dog bus available.
Monday 30 June	7:00 am	10:30 am	2:00 pm	5:30 pm	Hotels/designated accommodations.	Booth set up at Nadzab Airport & Guard Dog bus available.
Tuesday 01 July	7:00 am	10:30 am	2:00 pm	5:30 pm	Hotels/designated accommodations.	Booth set up at Nadzab Airport & Guard Dog bus available.
Pick up and drop off from Hotels to Conference Venue (Unitech Campus)						
Day	Morning: Pick-up from Hotels	Drop-off location	Afternoon: Pick-up Time	Afternoon: Pick-up location	Pick up bus	Notes/Reminders
Tuesday 01 July	7:00 am	Conference venue (Unitech)	8:30 pm	New Mess Car park	Security bus service /VIP bus	Bus will be standby at Admin Car park.
Wednesday 02 July	8:00 am	Conference venue (Unitech)	5:00 pm	Admin Car park	Security bus service /VIP bus	Bus will be standby at Admin Car park.
Thursday 03 July	8:00 am	Conference venue (Unitech)	5:00 pm	Admin Car park	Security bus service /VIP bus	Bus will be standby at Admin Car park.
Pick up and drop off for Cocktail & Close-up Dinner (Unitech Mess)						
Day	Pick-up from Hotels	Drop-off location	Pick-up Time	Drop-off location	Bus Service	Notes/Reminders
Tuesday 01 July	Cocktail night (Unitech Mess)		8:30 pm	Hotels/designated accommodations.	Security bus service /VIP bus	Bus will be standby at New Mess Car park.
Thursday 03 July	6:30 pm	New Mess Car park	9:30 pm	Hotels/designated accommodations.	Security bus service /VIP bus	Bus will be standby at New Mess Car park.
Drop-off runs for Nadzab Airport After the Conference						
Day	Morning: Pick-up from Hotels	Morning: Pick-up from Hotels	Mid-day: Pick-up from Hotels	Afternoon: Pick-up from Hotels	Drop-off location	Pick up bus & Reminders
Friday 04 July	4:00 am	7:00 am	11:00 am	3:00 pm	Nadzab Airport	Guard Bus will be standby at hotel Car park.
Saturday 05 July	4:00 am	7:00 am	11:00 am	3:00 pm	Nadzab Airport	Guard Bus will be standby at hotel Car park.
Sunday 06 July	4:00 am	7:00 am	11:00 am	3:00 pm	Nadzab Airport	Guard Bus will be standby at hotel Car park.

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Ora Renagi^{1*} Dapsy Olatona²	Repositioning the PNG University of Technology for National Impact: The Role of Higher Education in Advancing Livelihoods Through Science, Technology, and Policy in Papua New Guinea.
Allan Sumb^{1*}	Exploring the role of Traditional Culture in promoting Sustainable Development in Sinsibai, Western Highlands Province, Papua New Guinea
Ben Ninkama^{1*}	Perception of Religious Leaders on the Preamble and Section 45(1) of the Papua New Guinea Constitution
Jerome Oko^{1*}	Teachers' content knowledge, teaching methods and their encouragements that influence Grade 10 students' mathematics learning in Port Moresby, Papua New Guinea
Sana^{1*} Al-Abri²	Determination of Rainfall-Runoff Relationship for Wadi Dayqah Catchment
Arun Kumar Singh^{1*} Wera Dawa¹	Wireless Computing in all Area: A Mathematical Approach
Geena Iga Kusun^{1*} Zedaiah Kanau² Cindy Lola² Ita Kemba²	User Perspective of Library Services in the 21st Century in a Tertiary Based Learning Institution
Zénon WEJIEME^{1*}	Dynamics of Socio-Religious Transformation in Lifou (New Caledonia): From the Traditional Drehu Order to Missionary and Post-Missionary Hegemony
Jonah Anton^{1,2,3,*} Jeremiah Ahizo⁴ Stanley Amben¹ Patrick Michael^{2,3}	A comparative assessment of marita (<i>Pandanus conoideus</i>) production challenges and opportunities for further research and development in Papua New Guinea – A Review
Annette Tsibois Sinnou^{1*}	Science Technology Engineering and Mathematics (STEM) Education: A report on how students at the primary school engage in STEM education lessons
Lina Vutiala^{1*}	Pacific short stories on Traditional Agriculture to the Sustainable Development in the Pacific
Steward Kalan Rajendran Bhojan	Leveraging Data Integration using APIs for Enhanced Data Analytics in Papua New Guinea
*A. J. Tikil¹ Y. Telue² S. Dunstan³	Vibration Mode Analysis of a 100m Simply-supported Steel Beam Bridge via POD of FEM
M. Guinard¹ K. Maamaatuaiahutapu² H. Raapoto³	Albacore tuna (<i>Thunnus alalunga</i>) habitat and variability in French Polynesia
W. Dawa A. Singh	Python for Network Automation: A Comparative Study of Tools, Architectures, and Industry Use Cases
¹Wohemani, R. ²Ariku, E.	The Transition of Secondary Students into Higher Tertiary Education: The Perspective of Divine Word University, Madang Province, Papua New Guinea
Eko Maiguo Macquin Maino Tom Okpul	On the Impact of Exotic Naturalized Trees in the Landscapes of Papua New Guinea - the situation in Bulolo and Wau

Jamilah Iparam *Janarthanan Gopalakrishnan	Preliminary Results on Development of Sustainable and Biodegradable Food Packaging Films Using the Peels of Indigenous Banana Plant <i>Musa ingens</i> from Enga Province of Papua New Guinea
John Ape¹ Srikanth Bathula^{2*} Sailesh Samanta³	Contamination of dump soils by toxic heavy metals: An emerging risk to groundwater quality
Zhaohao Sun, Francisca Pambel	From Artificial Intelligence to Artificial Intelligences
Jojo Panakal John^{1*} David Kolkoma¹ Felix B Pereira¹ Theophile^{1*}	Estimation of Lifetime Lung Cancer Risk from Radon Inhalation in PNG
Tuai Erapae^{1*}	Aligning University Courses to the PNG Government Digital Plan, A Challenge for the Universities in PNG
K. Pirapaharan^{1*} H. Kunsei¹ S. Saharani² P.R.P. Hoole³ Philip Gibbs^{1*}	An Innovative Kalman Filter Based Beam-Steering Antenna Configuration for Maximum Power Transfer
P. Bani^{1*}, R. William² I. Itikarai³, C.J. Roga⁴ B. John⁴, J. Bengwali⁴ J. Niroa², D. Tari² S.Cevuar², E. Peter² R. Vatu², M. Estonia² S. Mule²	Digital Literacy at Divine Word University
T. Fischer^{1*} B. Stoll¹	Innovative Technologies for Volcanic Hazard Mitigation in the Pacific Islands
J. Benjamin^{1*} J. Kuzma¹	Learning the Shoreline: A Very High-Resolution Approach to Reef Island Dynamics
Mirzi L. Betasolo^{1*} Meseret Dawit Teweldebrihan¹	Perceptions of Health Extension Officer Students in Divine Word University on Medical Simulation Training as a Preparation Tool for Clinical Placement: A Mixed Methods Study
K. Hassani^{1*} D. Kolkoma² M. Aghaeiboorkheili³	Assessing the Water Balance and Groundwater Drying Trends in Papua New Guinea: The Potential of Soil and Water Conservation for Recharge Restoration
Rodney Biri^{1*} Alois Ndrewou² Hefung Hati¹ Eric Mesimato¹	Modeling and Mechanobiology of the Mitral Valve
Vili Saulala^{1*} George Maeakafa² Brian Cusack³	Assessing the Downstream Impacts of Soil Sedimentation Caused by Small-Scale Alluvial Mining in Atamo, Central Bougainville
	Utilizing Non-fungible Token (NFT) Technologies to Preserve Cultural Histories and Artefacts

Vili Saulala^{1*} George Maeakafa² Brian Cusack³	Applying Design Thinking Methodology to include meaningful Social and Cultural input to Mobile phone application software development
Sinafa Robby^{1,2*} , Stephanie Tringin¹ , Ilagi Puana³ Nime Kapo⁴ Macquin Maino²	Animal Health Capacity Building in Papua New Guinea: A Comprehensive Approach to Strengthening Animal and Wildlife Health Systems Through Biosecurity, One Health, and Cross-Border Collaboration
Aiga Ia^{1*}	Psychological Impacts of Gender-based Violence against Women in Hula Community
Michael Gaoma¹ Felix Pereira² Macquin Maino³	An analysis of Cultural Intelligence in Different Regions of Papua New Guinea based on Physics Education
S. Abdoli^{1*}	Community-Driven Adoption of Industry 4.0 Technologies for Sustainable and Resilient Food Production
D. M. Boboria^{1*} M. Maata² F. Mani² T. Aihunu¹	An Assessment of Heavy Metals Contamination in Freshwater Sediments and Fish and Cyanide in Sediment around Gold Ridge mine site, Solomon Islands
Daniel Yatukoman^{1*} Arun Singh¹	From Suspicion to Trust: ICP Blockchain's Role in PNG Aid Accountability
A. Elish Moses¹ B. Dr. Viswa Nadham^{1*}	Is there any Impact of Credit Management Practices on Bank Performance in PNG
Kenny Wantip^{1*}	Exploring the Role of Pasin-Lotu in the Peace Process in Bougainville

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