IDENTIFICATION AND PRIORITISATION OF ADAPTATION TECHNOLOGIES FOR PAPUA NEW GUINEA

TECHNOLOGY NEEDS ASSESSMENT

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IDENTIFICATION AND PRIORITISATION OF ADAPTATION TECHNOLOGIES FOR PAPUA NEW GUINEA

REPORT I

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This document is an output of the Technology Needs Assessment (TNA) project of PAPUA NEW GUINEA, funded by the Global Environment Facility (GEF), implemented by the United Nations Environment Program (UNEP), and executed through the UNEP Copenhagen Climate Centre in collaboration with the University of the South Pacific (USP). The present report is the output of a fully country-led process, and the views and information contained herein are a product of the TNA team led by the Climate Change and Development Authority (CCDA), Ministry of Environment, Conservation and Climate Change, Papua New Guinea.

Foreword

Like many developing nations, Papua New Guinea faces urgent and complex challenges as the impacts of climate change continue to intensify. Our unique geography, cultural diversity, and reliance on natural ecosystems for livelihoods and development make us particularly vulnerable to climate-induced risks such as rising sea levels, flooding, drought, and the increased frequency of extreme weather events. These challenges threaten our communities, infrastructure, food systems, and national development aspirations.

The Government of Papua New Guinea has taken decisive steps to strengthen the country's climate resilience and sustainable development pathways. Central to these efforts is the **Technology Needs Assessment (TNA)**—a global initiative under the United Nations Framework Convention on Climate Change (UNFCCC), supported by the Global Environment Facility (GEF), and implemented through the United Nations Environment Programme (UNEP) and the UNEP Copenhagen Climate Centre.

This TNA report represents a critical milestone for Papua New Guinea. Through a participatory, evidence-based process, we have identified and prioritised climate adaptation technologies in two key sectors: **agriculture** and **infrastructure**. These sectors are vital for our economy and well-being, and are the most vulnerable to climate change impacts. The TNA process has enabled us to assess technological options, evaluate barriers to implementation, and formulate actionable strategies aligned with our national goals and international commitments, including the Paris Agreement and our Nationally Determined Contributions (NDCs).

This report results from collaboration among government agencies, civil society organisations, technical experts, and community stakeholders. It reflects a shared commitment to building a more resilient, equitable, and sustainable future for all Papua New Guineans. The findings and recommendations contained herein provide a solid foundation for the development of the Barrier and Enabling Framework (BAEF) and Technology Action Plans (TAPs) that will guide future investments and mobilise international climate finance.

On behalf of the Government of Papua New Guinea, I sincerely thank all partners and stakeholders who contributed to this important work. Let this report serve as a planning tool and a catalyst for collective action toward climate-resilient development across our nation.

OFFICE OF THE MANAGING DIRECTOR
MS. DEBRA SUNGI
Acting Managing Director

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List of Abbreviations

ACIAR	Australian Centre for International Agricultural Research
AFP	Agroforestry Practices
CAPEX	Capital Expenditure
CCDA	Climate Change and Development Authority (PNG)
CIEWS	Climate Information and Early Warning Systems
CPI	Coastal Protection Infrastructure
CRI	Climate-Resilient Infrastructure
CSA	Climate-Smart Agriculture
C-RCVs	Climate-Resilient Crop Varieties
DRR	Disaster Risk Reduction
EERI	Energy-Efficient and Renewable Infrastructure
ENSO	El Niño-Southern Oscillation
EST	Environmentally Sound Technology
EWS	Early Warning Systems
FAO	Food and Agriculture Organization of the United Nations
FRIT	Flood-Resilient Infrastructure Technology
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GoPNG	Government of Papua New Guinea
IFAD	International Fund for Agricultural Development
IPM	Integrated Pest Management
LDC	Least Developed Country
LRI	Landslide-Resistant Infrastructure
MCA	Multi-Criteria Analysis
MECCC	Ministry of Environment, Conservation and Climate Change
MTDP	Medium-Term Development Plan
NAP	National Adaptation Plan
NCCDMP	National Climate Compatible Development Management Policy
NDC	Nationally Determined Contribution
NSC	National Steering Committee
PNG	Papua New Guinea
PHM	Post-Harvest Management
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SB	Seed Banking
SDG	Sustainable Development Goal
SWG	Sectoral Working Group
SWMS	Sustainable Water Management Systems
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UNEP	United Nations Environment Programme
UNEP-CCC	UNEP Copenhagen Climate Centre
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USP	University of the South Pacific
WMO	World Meteorological Organization

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Executive Summary

Papua New Guinea (PNG) is increasingly facing the adverse effects of climate change, which pose significant risks to its agriculture systems, infrastructure, public health, and overall sustainable development. As a geographically and ecologically diverse country with a largely rural and vulnerable population, PNG is highly susceptible to extreme weather events, sea-level rise, flooding, and landslides. The country's dependence on climate-sensitive sectors such as agriculture and its exposure to natural hazards underscore the urgent need for climate-resilient technologies and systematic adaptation planning.

In response to these challenges, the Government of Papua New Guinea, through the **Climate Change and Development Authority (CCDA)** and in partnership with the **United Nations Environment Programme (UNEP)** and the **UNEP Copenhagen Climate Centre**, implemented the **Technology Needs Assessment (TNA) Project** under the Global Environment Facility (GEF).

The TNA aims to support PNG in identifying, prioritizing, and enabling climate adaptation technologies that align with its development priorities and commitments under the Paris Agreement and Nationally Determined Contributions (NDCs).

The primary objectives of the TNA project include:

(i) Identifying and prioritizing climate adaptation technologies through stakeholder-driven processes.
(ii) Assessing barriers to technology acquisition, deployment, and diffusion.
(iii) Developing Technology Action Plans (TAPs) that specify implementation activities, regulatory frameworks, and financial mechanisms for climate adaptation.
(iv) Enhancing national capacity to mainstream climate resilience through technology prioritization and market assessment tools.

Sector Selection

The agriculture and infrastructure sectors were strategically chosen for adaptation technology assessment due to their significant vulnerability to climate change and their critical role in supporting national development goals. This selection was informed by comprehensive vulnerability assessments that identified the specific risks these sectors face. Furthermore, the alignment with key national development frameworks, such as the Medium-Term Development Plan (MTDP III), Vision 2050, and the National Adaptation Plan, underscores the importance of integrating adaptation efforts into broader developmental strategies. These frameworks emphasize sustainable growth, resilience building, and the need for innovative solutions to enhance both agricultural productivity and infrastructure robustness in the face of environmental challenges.

Agriculture Sector: Technology Prioritisation

The agriculture sector supports over 85% of the population but is severely impacted by climate variability, particularly droughts, erratic rainfall, pest outbreaks, and declining soil fertility. Using **Multi-Criteria Analysis (MCA)**, six adaptation technologies were assessed and prioritised:

1st Climate-Smart Agriculture (CSA) – Highest ranked (Score: 6,327)
Integrated practices that enhance productivity, soil and water conservation, and resilience to extreme weather.
2nd Climate Information and Early Warning Systems (CIEWS) – (Score: 5,833)
Provides timely climate data for informed farming decisions and risk reduction.
3rd Post-Harvest Management (PHM) – (Score: 5,410)
Reduces food losses through improved storage and processing.
4th Climate-Resilient Crop Varieties & Seed Banking (C-RCVs & SB) – (Score: 5,376)
Focuses on crop varieties resistant to heat, drought, and pests.
5th Agroforestry Practices (AFP) – (Score: 5,250)
Combines agriculture and tree systems for soil conservation and income diversification.
6th Sustainable Water Management Systems (SWMS) – (Score: 2,394)
Includes rainwater harvesting and efficient irrigation technologies.

Infrastructure Sector: Technology Prioritisation
PNG's infrastructure sector is increasingly affected by floods, landslides, sea-level rise, and cyclones. Key adaptation technologies were evaluated through stakeholder consultations and MCA, resulting in the following rankings:
1st Climate-Resilient Infrastructure (CRI) – Highest ranked (Score: 6,608)
Design and rehabilitation of roads, buildings, and utilities to withstand climate impacts.
2nd Early Warning Systems (EWS) – (Score: 6,167)
Real-time monitoring and alerts to support emergency response and disaster preparedness.
3rd Energy-Efficient and Renewable Infrastructure (EERI) – (Score: 5,329)
Promotes the use of renewable energy and green construction methods.
4th Flood-Resilient Infrastructure Technology (FRIT) – (Score: 5,325)
Includes improved drainage systems and flood-proof construction in high-risk zones.
5th Coastal Protection Infrastructure (CPI) – (Score: 5,167)
Seawalls, mangrove rehabilitation, and erosion control to protect coastal communities.
6th Landslide-Resistant Infrastructure (LRI) – (Score: 3,129)
Focused on slope stabilization and infrastructure resilience in mountainous areas.

Among the prioritized technologies the agriculture sector, **Climate-Smart Agriculture (CSA)** was identified as the top technology due to its integrated approach that enhances productivity, promotes soil and water conservation, and increases resilience to climate shocks such as droughts and pest infestations. The second priority was **Climate Information and Early Warning Systems (CIEWS)**, which enable farmers to access timely and location-specific climate data. This information helps inform planting schedules, pest control strategies, and risk management practices. In the infrastructure sector, **Climate-Resilient Infrastructure (CRI)** was recognized as the most critical technology. This focuses on upgrading and designing infrastructure—such as roads, public buildings, and utilities—to withstand climate extremes like flooding and landslides. Additionally, **Early Warning Systems (EWS)** are essential for providing real-time hazard alerts, which support rapid emergency responses and help reduce loss of life and property during natural disasters. These selected technologies represent impactful and context-specific solutions tailored to the most vulnerable sectors in Papua New Guinea.

CHAPTER 1
INTRODUCTION

1. 1 About the TNA Project

Technology Needs Assessments (TNAs) were directly referenced in the Paris Agreement, which acknowledged the importance of widespread technological change in reducing emissions and stabilizing atmospheric concentrations of GHGs. Multilateral support to developing countries to conduct effective TNAs and implement Technology Action Plans (TAPs) has become instrumental to the UNFCCC process. Through the Global Environment Facility (GEF) funded TNA project, UNEP and UNEP Copenhagen Climate Centre (UNEP-CCC) work in partnership with developing countries to determine their technology priorities for mitigating and adapting to climate change.

The TNA project aims to articulate a range of specific actions that stakeholders - including governments - can pursue to enable the transition to low-carbon and climate-resilient economies. The TNA project also acts as a bridge to private and public investment sources. The TNA project follows a country driven approach. A designated national institution takes the lead, involving a wide range of stakeholders in the process. Working with regional centres of excellence in climate change mitigation and adaptation, the project offers support to participating countries in the form of national, regional, and global capacity building workshops, technical support missions, and technical backstopping throughout the process

Learning from the first round of TNAs, more emphasis was placed on standardization of a TNA methodology and process, including an approach that would produce implementable actions. In response, the Poznan Strategic Program on Technology Transfer was developed with three funding windows, namely: (i) technology needs assessments (TNAs), (ii) pilots for priority technology projects, and (iii) diffusion of successfully demonstrated technologies. Article 10 of the Paris Agreement notes the importance of technology for implementing adaptation and adaptation actions. The objectives of accelerating, encouraging and enabling technological innovation for an effective, long-term response to climate change within the broader sustainable development framework would be supported by the Technology Mechanism of the UNFCCC (UNFCCC, 2021).

Under window (i), 102 countries have been supported to carry out TNAs through four funding phases. The Global TNA Project supported 36 countries between 2009 and 2013, 26 countries between 2014 and 2018, 23 countries between 2018 and 2020, including mainly Least Developed Countries and Small Island Developing States, and 17 new Least Developed Countries and Small Island Developing States as of 2020. Papua New Guinea forms part of the last cohort of countries.

The main objectives of the TNA project are:

1. To identify and prioritise through country-driven participatory processes, technologies that can contribute to mitigation and adaptation goals of the participant countries, while meeting their national sustainable development goals and priorities (TNA).
2. To identify barriers hindering the acquisition, deployment, and diffusion of prioritised technologies.

3. To develop Technology Action Plans (TAP) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption, and diffusion of selected technologies in the participant countries.

The TNA project involves in-depth analysis and prioritisation of technologies, analysis of potential barriers hindering the transfer of prioritised technologies, and issues related to potential market opportunities at the national level. National Technology Action Plans (TAPs) agreed by all stakeholders at the country level will be prepared consistent with both the domestic and global objectives. Each TAP, which will outline essential elements of an enabling framework for technology transfer consisting of market development measures, institutional, regulatory and financial measures, and human and institutional capacity development requirements, will also include a detailed plan of action to implement the proposed policy measures and estimate the need for external assistance to cover additional implementation costs. Thus, the detailed action plan will serve as the base for the subsequent preparation of fundable project ideas.

The ultimate aim of the TNA project is to use a robust process and methodology to enhance Papua New Guinea's preparedness to leverage international climate finance to adopt or scale up environmentally sound technologies (ESTs) for low-carbon, climate-resilient development. In the case of Papua New Guinea, the TNA process will serve as a means to support the implementation of its Nationally Determined Contribution (NDC). The adaptation TAPs that will be developed can be used to inform the design of Papua New Guinea's NDC Action Plan.

The TNA methodology, process, and tools can significantly enhance a country's capacity to mainstream climate change. Experience has shown that human and institutional capacity building serves their institutionalisation and increased country ownership (Deenapanray & Traerup, 2022). Consequently, the Papua New Guinea TNA project will deliver targeted training and supporting materials to national stakeholders on all aspects of the methodology, process and tools for technology prioritisation and market assessment. Access and links to data on technologies developed and tested in similar countries – i.e. Small Island Developing States - and made available to all participant countries through the Global TNA Project website.

1.2 Existing National Policies on Climate Change Adaptation and Their Development Priorities

1.2.1 National Circumstances

Papua New Guinea (PNG) faces many challenges from climate change that are deeply rooted in its geographical context, socio-economic structure, and inherent vulnerability to natural disasters. Geographically, PNG is the largest state in the Pacific Islands, encompassing an impressive land area of 463,000 square kilometres alongside a substantial 2.4 million square kilometres exclusive economic zone. The country consists of the eastern half of the island of New Guinea, four significant islands, and approximately 600 smaller islets and atolls. Many ecosystems characterise this vast and diverse land, including towering mountain glaciers, lush tropical rainforests, expansive coral reefs, and intricate wetland areas. These ecosystems are incredibly rich and house an estimated 7% of the world's biodiversity. However, this invaluable biodiversity is increasingly jeopardised by deforestation, significant land-use changes, and various climate-related stressors (GFDRR, 2011).

Figure 1 Map of Papua New Guinea
(Source: WorldAtlas, 2021)

The socio-economic framework of PNG presents additional challenges. The nation has a predominantly rural demographic, with 87% of its population of 6.7 million residing in rural areas. These regions ' access to markets, essential services, and economic opportunities is exceedingly limited, contributing to widespread poverty. More than half of the population lives below the poverty line, with a significant number of individuals earning less than $1 per day (world Bank, 2021). This economic hardship heightens their vulnerability to the adverse impacts of climate change, making it imperative for the government and international organizations to take action (GFDRR, 2021). Agriculture plays a significant role in this structure, accounting for the employment of 85% of the population and contributing approximately 30% to the nation's GDP. Most agricultural practices are heavily dependent on rainfall, which increases the sector's susceptibility to climate variability, particularly through alterations in precipitation patterns and the frequency of extreme weather events (IFAD, 2021).

Climate variability in PNG is predominantly shaped by the El Niño-Southern Oscillation (ENSO) phenomenon, which can result in severe droughts, flooding, and other extreme weather occurrences. The impact of climate change has become glaringly evident, as the country has recorded an increase of 0.5°C in mean near-surface temperatures since the mid-20th century. Rainfall patterns have also exhibited significant variability, with notable reductions reported in certain regions (World Bank, 2021). These climatic changes have led to a marked rise in the frequency of natural disasters, including catastrophic landslides, destructive cyclones, and pervasive flooding. Moreover, rising sea levels pose an increasing threat to coastal communities through mechanisms such as saltwater intrusion and land submergence, further intensifying these populations' overall vulnerability (GoPNG, 2021)

Coastal zones are particularly susceptible, facing imminent risks from sea-level rise and intensified storm surges. The agricultural sector is also under significant strain, suffering from diminished productivity due to soil degradation, increased water stress, and rising pest infestations (UN, 2021). The ongoing loss of biodiversity and reduction in key freshwater resources further complicate the nation's efforts to build resilience against climate impacts (World Bank, 2021).

In terms of emissions, PNG's greenhouse gas (GHG) profile is dominated by land use, land-use change, and forestry (LULUCF), along with agriculture. Approximately 89% of its total emissions arise from deforestation, forest degradation, and expansion of subsistence farming and shifting cultivation (GoPNG, 2020). Although PNG has relatively low per capita emissions, its vast forest cover—about 77% of the land area—makes LULUCF central to its mitigation strategy. Projections estimate further warming of 1.1°C to 2.6°C by 2100 and increased rainfall variability, threatening food security, ecosystems, and infrastructure (PACCSAP, 2022).

In response, PNG has adopted a range of adaptation and mitigation measures. Climate-Smart Agriculture (CSA) practices—such as soil conservation, agroforestry, and integrated pest management—have been introduced in selected provinces through partnerships with the National Agricultural Research Institute (NARI) and international agencies (NARI, 2019). The forestry sector is implementing REDD+ readiness programs to curb deforestation and enhance forest carbon sinks, supported by new monitoring systems and local engagement (GoPNG, 2020). Climate Information and Early Warning Systems (CIEWS) have also been piloted in disaster-prone areas like East New Britain, integrating real-time weather forecasting, drought alerts, and local dissemination tools (FAO, 2021).

Other national strategies emphasize sustainable land and water management, community-driven disaster risk reduction, and the promotion of renewable energy (World Vision PNG, 2021). Strengthening local capacity and fostering inclusive participation remain at the core of the government's climate agenda (GoPNG, 2020). Through these combined efforts, PNG is working toward a more climate-resilient and sustainable development trajectory (UNDRR, 2019).

1.2.2 National Strategies, Policies and Actions Related to Climate Change

PNG has established several national strategies and policies to tackle climate change by proactively addressing climate change through various strategies, policies, and actions aimed at adaptation and mitigation. These efforts align with its national development goals and international commitments, particularly under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement.

National Climate Compatible Development Management Policy (NCCDMP) 2014-2024 is a comprehensive framework to address climate change through integrated mitigation and adaptation strategies. It aims to balance environmental sustainability with economic development by reducing greenhouse gas emissions, enhancing resilience to climate impacts, and promoting sustainable livelihoods. The policy emphasises the integration of climate considerations into national and sectoral development plans, including energy, forestry, agriculture, and infrastructure. It also prioritises community-based adaptation, ecosystem conservation, renewable energy adoption, and sustainable resource management (CCDA, 2014). The policy's vision is "A Robust and Sustainable Economy for Papua New Guinea through a Low Carbon Pathway and Green Economic Growth." The mission is to build a climate-resilient and carbon-neutral pathway for climate-compatible development in Papua New Guinea.

National Adaptation Plan (NAP) 2023 is a strategic framework designed to address the country's vulnerabilities to climate change and integrate adaptation measures into national and sectoral development planning. It addresses the country's diverse climate vulnerabilities by implementing targeted adaptation strategies across key sectors such as:

1. **Coastal Flooding and Sea Level Rise**: Mitigating risks through early warning systems and coastal protection strategies.
2. **Inland Flooding**: Addressing impacts on rural and urban settlements through resilient infrastructure.
3. **Food Security**: Promoting climate-resilient agricultural practices to combat food insecurity.
4. **Cities and Climate Change**: Enhancing urban planning to withstand extreme weather events.
5. **Climate-Induced Migration**: Developing plans for human settlement and migration due to climate impacts.
6. **Damage to Coral Reefs**: Protecting marine biodiversity and fisheries affected by ocean acidification and warming.
7. **Malaria and Vector-Borne Diseases**: Strengthening health systems to manage the spread of climate-sensitive diseases.
8. **Water and Sanitation**: Ensuring sustainable and resilient water supply systems.
9. **Landslides**: Implementing soil and slope stabilization techniques in vulnerable areas.

These measures aim to increase resilience among 10% of the population, enhance health responses for all citizens, and build climate-resilient infrastructure to support long-term sustainable development (GoPNG, 2023).

Papua New Guinea National REDD+ Strategy (2017 – 2027), this regulation aims to address climate change adaptation and mitigation through the sustainable management of its forest resources. It has a transformative vision to achieve a low-emission, green development pathway. The vision is "to catalyse transformational change within the forest and land use sector towards a new responsible economy with lower GHG emissions, stronger long term economic growth and community livelihoods and the effective conservation of biodiversity and ecosystem services while ensuring that Papua New Guinea's forest resources are used sustainably and equitably for the benefit of current and future generations" (GoPNG, 2017).

PNG REDD+ Strategy:

1. Enabling Conditions: Establishing a framework that supports government, civil society, and private sector actions to achieve REDD+ goals.
2. Mainstreaming REDD+: Integrating REDD+ principles into national policies and programs to reduce deforestation and forest degradation.
3. Sustainable Development: Enhancing forest carbon stocks, conserving biodiversity, and supporting sustainable livelihoods.
4. Global Recognition and Support: Leveraging the United Nations Framework Convention on Climate Change (UNFCCC) REDD+ mechanism for financial and technical assistance.

Medium-Term Development Plan (MTDP III) 2018-2022 aims to secure the future through inclusive, sustainable economic growth (GoPNG, 2018). It is structured around eight Key Result Areas (KRAs) that align with the broader Papua New Guinea Development Strategic Plan 2, such as:

1. **Increased Revenue and Wealth Creation:** Enhancing economic productivity and job creation.
2. **Quality Infrastructure and Utilities:** Developing resilient transport, energy, and water infrastructure.
3. **Sustainable Social Development:** Promoting education, health, and welfare improvements.
4. **Improved Law, Justice, and National Security:** Strengthening governance and reducing crime.
5. **Improved Service Delivery:** Ensuring accessibility and efficiency in public services.
6. **Improved Governance:** Promoting transparency and accountability in government operations.
7. **Responsible Sustainable Development:** Balancing economic growth with environmental preservation.
8. **Sustainable Population:** Managing population growth to align with resources and infrastructure capacity.

The MTDP III sets ambitious targets, including:

1. Doubling internal revenue by increasing export earnings and reducing import dependency.
2. Increasing infrastructure investments from 5% to 12% of the capital expenditure.
3. Achieving universal access to quality education and healthcare.
4. Promoting climate-resilient practices in agriculture and infrastructure.
5. Enhancing connectivity through new national highways, ports, and energy projects.
6. Reducing youth unemployment through skills training and business incubation centers.

1.3 Vulnerability Assessments in the Country

PNG vulnerability assessments are critical for understanding the country's susceptibility to climate change impacts and natural hazards. These assessments inform the development of strategies and policies to reduce risks, enhance resilience, and adapt to changing environmental conditions. Below is an overview of the key elements, findings, and PNG vulnerability assessment approaches.

Geographic and Environmental Vulnerabilities, PNG's geographic and environmental characteristics make it one of the most vulnerable countries to climate change and natural disasters. PNG's extensive coastline and low-lying islands are highly susceptible to sea level rise, storm surges, and coastal erosion the highlands are prone to landslides, flooding, and extreme weather events, which affect agricultural productivity and infrastructure, and PNG is home to rich ecosystems such as coral reefs, mangroves, and rainforests, which are highly sensitive to climate change impacts, including ocean acidification, deforestation, and rising temperatures (RCCC, 2024) (GoPNG, 2017)

Sector-Specific Vulnerability Assessments, the vulnerability assessments have been conducted across various sectors, identifying critical areas of concern:

a. **Agriculture and Food Security**
The agriculture sector, supporting over 85% of PNG's population, is highly sensitive to climate variability. Subsistence crops—such as sweet potatoes, taro, and bananas—are increasingly affected by droughts, frost, and unpredictable rainfall. Rising temperatures and frequent extreme weather events threaten crop yields and food availability. Weak infrastructure, such as inadequate roads and limited market access, further hampers food distribution and farmer resilience (GoPNG, 2018).

b. **Health**
Climate change increases health risks through the expansion of vector-borne diseases (e.g., malaria, dengue) into higher altitudes and previously unaffected areas due to warmer temperatures and changing precipitation patterns. Waterborne illnesses like cholera and diarrhoea are also rising, driven by flooding and poor sanitation. Rural and remote communities face greater exposure due to limited access to clean water and hygiene services (GoPNG, 2018).

c. **Infrastructure**
Critical infrastructure—including roads, bridges, and housing—is highly exposed to extreme weather. Monsoon rains cause flooding and erosion, weakening structural foundations. Coastal areas face additional threats from sea-level rise and storm surges, while landslides disrupt transport routes and isolate communities. Informal settlements are especially vulnerable, exacerbating risks for marginalized groups (GoPNG, 2018).

d. **Transport**
The transport sector is essential for linking communities to essential services and markets but is regularly disrupted by climate-related events. Heavy rainfall, poor drainage, and landslides damage roads and sever connections, particularly in mountainous and coastal regions. Sea-level rise and coastal erosion undermine the viability of critical transport infrastructure such as ports and bridges (GoPNG, 2018)

1.4 Sector Selection

Papua New Guinea (PNG) prioritized the **agriculture** and **infrastructure** sectors for climate change adaptation due to their high vulnerability and critical role in national development. This selection aligns with the country's strategic frameworks, including the Medium-Term Development Plan (MTDP III) and Vision 2050, which emphasize building resilience and promoting sustainable growth.

Selecting priority sectors for climate change adaptation in Papua New Guinea involves carefully evaluating national development priorities and identifying sectors most vulnerable to climate impacts. This approach aligns with national goals to ensure resilience and sustainability in areas essential to the island's development and community well-being. The following sections outline the climate impacts on vulnerable sectors, the sector selection process, and the results.

The selection of agriculture and infrastructure as a structured process informed priority sectors:

1. **Vulnerability Assessment**: Comprehensive evaluations of sector-specific vulnerabilities were conducted to identify areas most at risk from climate change impacts, such as extreme weather events, rising temperatures, and sea-level rise (GoPNG, 2018).
2. **Stakeholder Engagement**: Consultations with government agencies, local communities, and development partners ensured that sector priorities reflected diverse perspectives and addressed the needs of vulnerable populations (RCCC, 2024).
3. **Alignment with National Priorities**: Sectors were evaluated based on their contribution to the economy, livelihoods, and critical services, ensuring alignment with PNG's sustainable development objectives.
4. **Cross-Sectoral Interdependencies**: The selection process also considered the interconnectedness of sectors, particularly the cascading impacts of climate change on food security, health, infrastructure, and transportation.

Results of Sector Selection

Based on the assessments and stakeholder consultations, the following sectors were identified as priorities for climate adaptation:

1. **Agriculture**:
   - *Vulnerability* : Highly exposed to drought, floods, and variable climate.
   - *Relevance* : Central to rural economies, food production, and national livelihoods.

2. **Infrastructure**:
   - *Vulnerability* : Highly exposed to coastal and inland climate hazards.
   - *Relevance* : Essential for connectivity, economic resilience, and access to services.

The selection of agriculture and infrastructure as priority sectors reflects their high vulnerability to climate change impacts and their centrality to PNG's development priorities. By focusing on these sectors, PNG aims to build resilience, reduce risks, and promote sustainable development in the face of increasing climate challenges.

1.5 Methodology for Selection of Technologies

After selecting agriculture and infrastructure as the leading sectors for adaptation, the TNA team carried out the following steps to select the technologies in the final stage.

(i) **Fact Sheet Analysis—**The consultants undertook desktop reviews and formulated fact sheets for all potential technologies under each sector identified for adaptation. These fact sheets were emailed to the potential workshop participants for further input and review.

(ii) **Participate in the Introductory Workshop for adaptation.**

(a) **Factsheet**—The TNA coordinator and the consultants presented and discussed the Technology fact sheets with the workshop participants. On some occasions, the workshop participants added more technologies to the list prepared for deliberation during the workshop.

(b) **Multi-Criteria Analysis (MCA)**—The identified technologies were evaluated using the Multi-Criteria Analysis (MCA) tool for decision-making. Consultants examined the performance, scoring, and decision matrices. Each technology was categorized by capital expenditures (CAPEX), operational, and maintenance costs, which were weighed against benefits like economic impact, social costs, climate change, and technology diffusion. Performance marks were assigned based on cost: more expensive technologies received lower scores (e.g., 20%), while cheaper options received higher scores (e.g., 90%). This scoring approach was consistent across all matrices. The scores totalled 100, with the technology having the highest aggregate score given the highest priority.

(c) **Sectorial Working Group (SWG)** —Each sectorial working group was given at least two weeks to review and analyse the results for their respective sectors.

(d) **Validation Workshop**—After two weeks, the SWG presented the Final prioritised technology for each sector with any amendment (if any). The participants discussed and approved the final list as recommended by the working group.

(e) **TNA Steering Committee**—At this stage, consultants compiled the prioritized technology into a formal report and submit it through the TNA Secretary to the SC for further review and scrutiny. After the SC review and endorsement, the report is submitted to the UNEP CCC as the final report of prioritised technologies for the PNG

CHAPTER 2
INSTITUTIONAL ARRANGEMENT FOR THE TNA AND THE STAKEHOLDER INVOLVEMENT

The institutional arrangement has been established with three key considerations in mind: (1) the guidance note on the institutional arrangement proposed for the TNA project (Traerup et al., 2018), (2) the existing institutional structures in Papua New Guinea for managing and coordinating climate change activities, and (3) the limited pool of human resources in Papua New Guinea. Section 1.2.1 discusses how the small population size constrains the scope and scale of stakeholder engagement. Additionally, the remoteness of the TNA Adaptation Consultant, who is based in the Solomon Islands, has further limited stakeholder engagement efforts.

2.1 National TNA Team

Through the Climate Change and Development Authority of the Ministry of Environment, Conservation and Climate Change (MECCC), the Government of Papua New Guinea has partnered with UNEP (United et al.) and UNEP/CCC (Copenhagen Climate Centre) to implement the 'Technology Needs Assessment' (TNA)—Phase IV. The implementation is supported by GCF (Global Environment Facility) funding and technical support from the University of the South Pacific.

Figure *2* shows the institutional arrangement to manage the TNA project in Papua New Guinea. The institutional arrangement for the Technology Needs Assessment (TNA) in Papua New Guinea (PNG) ensures a structured, collaborative, and inclusive process to address climate change adaptation and mitigation. At the forefront is the Climate Change and Development Authority (CCDA), which serves as the lead agency overseeing the TNA process. The CCDA ensures alignment with PNG's national development goals, climate policies, and international commitments, including the Paris Agreement. Supporting the CCDA is the National Steering Committee (NSC), which provides strategic guidance and oversight. The NSC ensures that selected technologies align with national socio-economic and climate resilience priorities while resolving policy or implementation issues as they arise.

The TNA Coordinator plays a critical role in facilitating communication between the NSC and the Sectoral Working Groups (SWGs). These working groups are divided into two main focus areas: SWGs for Adaptation, which assess technologies to address vulnerabilities in agriculture, water resources, and infrastructure, and SWGs for Mitigation, which focus on greenhouse gas reduction technologies in energy, forestry, and transportation. Both SWGs conduct feasibility studies, cost-benefit analyses, and alignment checks with national policies, reporting their recommendations to the NSC.

To ensure efficient operations, the TNA Support Team provides logistical and operational support to the SWGs, assisting with research, data analysis, and stakeholder engagement. Complementing this structure is Project Assurance and Technical Support, provided by UNEP Copenhagen Climate Centre and the TNA Regional Centre, which offers technical expertise, capacity building, and guidance on international best practices.

This interconnected framework fosters collaboration among diverse stakeholders, including government agencies, local communities, the private sector, and international organizations. It ensures that PNG's TNA process is participatory, technically sound, and strategically aligned with national and global climate goals. This approach strengthens PNG's ability to identify and implement climate-resilient technologies that support sustainable development and enhance its climate adaptation and mitigation efforts.

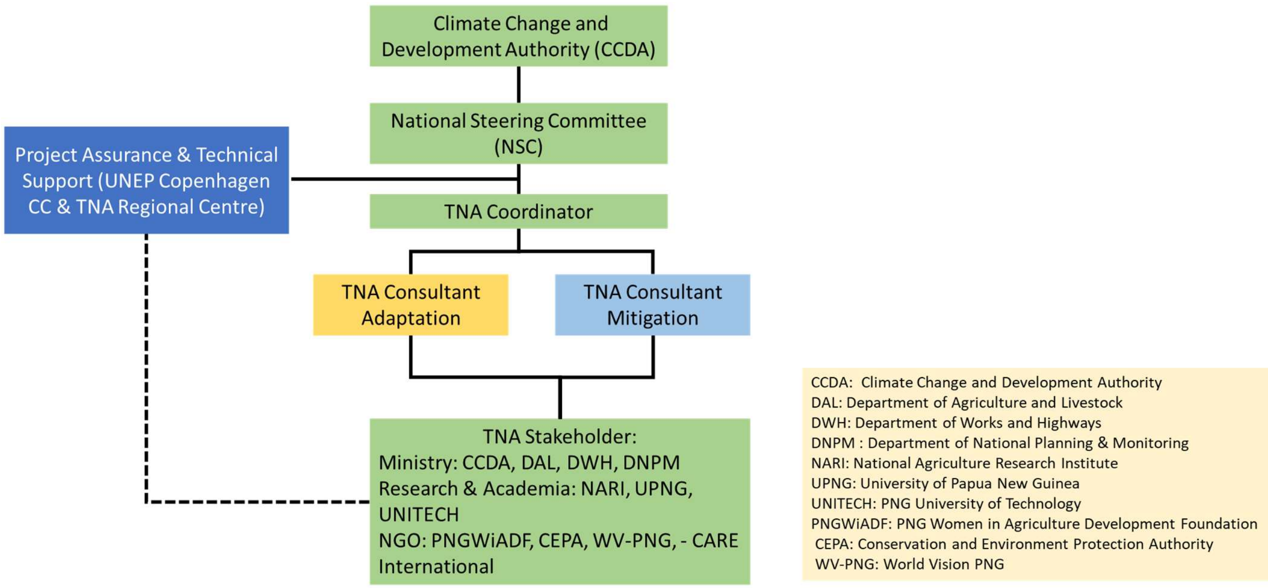

Figure 2 Institutional arrangement for the TNA project in Papua New Guinea.

2.2 Stakeholder Engagement Process Followed in TNA – Overall Assessment

The stakeholder engagement process for the Technology Needs Assessment (TNA) in Papua New Guinea (PNG) is designed to ensure inclusivity, transparency, and alignment with national climate and development goals. This process emphasizes meaningful collaboration among key stakeholders to identify, prioritize, and implement climate technologies for adaptation and mitigation.

- **General Process and Approach Stakeholder Identification**, the first step involves identifying diverse stakeholders across sectors relevant to climate change adaptation and mitigation. Stakeholders include government agencies, private sector actors, civil society organizations, academic and research institutions, development partners, and local communities. This broad representation ensures the inclusion of perspectives from all relevant sectors and vulnerable groups.
- **Formation of Collaborative Platforms**, collaborative platforms, such as the **National Steering Committee (NSC)** and **Sectoral Working Groups (SWGs)**, are established to facilitate structured engagement. These platforms allow for targeted discussions on sector-specific priorities, including adaptation needs in agriculture and infrastructure and mitigation strategies in energy and forestry. The composition of SWGs is:

  Government ministry:
  - Climate Change and Development Authority (CCDA)
  - Department of Agriculture and Livestock (DAL)

	• Department of Works and Highways • Department of National Planning & Monitoring (DNPM)
Research & Academia:	• National Agriculture Research Institute (NARI) • University of Papua New Guinea (UPNG) • PNG University of Technology (UNITECH)
Civil Society & NGOs	• PNG Women in Agriculture Network • Conservation and Environment Protection Authority (CEPA) • World Vision PNG • CARE International

- **Participatory Decision-Making**: Stakeholder engagement is guided by a participatory approach, where stakeholders actively contribute to discussions and decisions on technology priorities. Workshops, focus group discussions, and technical consultations are organized to gather input, validate findings, and build consensus on technology recommendations.
- **Capacity Building**, capacity-building sessions are conducted to familiarize stakeholders with the TNA process, methodologies, and expected outcomes. This step ensures that all participants have the knowledge and tools to contribute meaningfully to the process.
- **Sectoral Analysis and Prioritization**, stakeholders collaborate to assess sectoral vulnerabilities, identify technology needs, and prioritize solutions based on feasibility, cost-effectiveness, and alignment with national goals. Their inputs are critical in ensuring that the selected technologies address PNG's specific climate challenges and development priorities.
- **Validation and Reporting**, draft outputs from the TNA process are shared with stakeholders for validation to ensure accuracy and comprehensiveness. Feedback is incorporated into final recommendations, which are then presented to the NSC for approval and integration into national climate strategies.
- **Monitoring and Feedback**, Stakeholder engagement extends beyond the initial stages of the TNA. A mechanism is established for ongoing monitoring and feedback, ensuring stakeholders remain involved throughout the implementation and evaluation phases.

2.3 Consideration of Gender Aspects in the TNA Process

Considering the gender aspect in the Technology Needs Assessment (TNA) process is crucial, as climate change affects all members of society in different ways. In the Pacific region, including Papua New Guinea, cultural, social, and religious factors influence distinct gender roles, which vary across communities and provinces. One vital element of the social structure is the relationship between men and women, which shapes how responsibilities, resources, and decisions are distributed within families and communities. Understanding these power dynamics is essential to designing climate adaptation strategies that are both equitable and effective.

During the TNA stakeholder workshop in Papua New Guinea, 83% of the participants were male, while 17% were female. This gender disparity was primarily due to the limited availability of female stakeholders on the scheduled workshop dates, not a lack of intention to include diverse representation. Nevertheless, the TNA process actively promotes and encourages the meaningful involvement of both women and men in decision-making, particularly when identifying and prioritizing adaptation technologies.

Future consultations and implementation phases will seek to improve gender balance by engaging women's groups, local networks, and community representatives to ensure their voices are adequately heard. To enhance women's participation in future stages of the TNA process, targeted engagement will be pursued through collaboration with women’s organizations, flexible scheduling, and the inclusion of female representatives in stakeholder working groups.

CHAPTER 3
ADAPTATION TECHNOLOGY PRIORITISATION FOR THE AGRICULTURE SECTOR

3.1 Key Climate Change Vulnerabilities in Agriculture Sector

The agriculture sector in Papua New Guinea (PNG) is the backbone of the national economy and a vital pillar of rural livelihoods, supporting approximately 86% of the population through subsistence farming and smallholder-based cash crop production (FAO, 2024). It contributes over 25% to the national Gross Domestic Product (GDP) and provides around 80% of employment, underscoring its central role in household sustenance, national food security, and macroeconomic stability (World Bank, 2021; GoPNG, 2020).

Despite this importance, PNG's agriculture is highly vulnerable to climate change. The frequency and intensity of extreme weather events—particularly droughts, floods, and frost—have grown in recent years, with direct and damaging consequences for agricultural productivity. During the 2015–2016 El Niño, for example, widespread drought and frost led to severe food shortages affecting more than 2.7 million people, predominantly in the Highlands region (OCHA, 2016). Staple crops like sweet potatoes, taro, and bananas, which rely on regular rainfall and stable temperatures, experienced significant yield losses. In contrast, intensified rainfall events have led to waterlogging, riverbank flooding, and topsoil erosion, degrading arable land and increasing vulnerability to landslides and downstream sedimentation (GoPNG, 2018).

Soil degradation further compounds the climate stress. Studies show that PNG loses an estimated 50–100 tons of topsoil per hectare per year in highland farming areas due to unprotected slopes and heavy rainfall (IFPRI, 2024). This reduces land fertility and forces farmers to clear additional forested land, triggering deforestation and further environmental vulnerability.

Rising temperatures and shifting precipitation patterns are also expanding the habitat range of pests and diseases. For example, sweet potato weevil infestations and fungal outbreaks have become more frequent, reducing crop viability and food supply consistency (FAO, 2024).

Compounding these biophysical impacts is the limited resilience of traditional farming systems. Many smallholder farmers continue to rely on age-old, low-input agricultural practices that are ill-equipped to adapt to unpredictable climate conditions. According to IFPRI (2024), fewer than 15% of PNG farmers have adopted climate-resilient or improved farming techniques. The adoption of drought-tolerant varieties, soil conservation methods, or irrigation systems remains very low, particularly in remote rural areas.

Moreover, infrastructure challenges—including poorly maintained rural roads and limited storage facilities—contribute to post-harvest losses and market inaccessibility. Landslides and heavy rains frequently block critical routes, isolating communities. The EU-STREIT programme has reported that over 7,000 cocoa and vanilla farmers in East Sepik and Sandaun provinces experienced increased market access only after strategic road rehabilitation, highlighting the importance of resilient infrastructure (FAO, 2022).

Collectively, these climate-related impacts result in declining crop yields, reduced income, and heightened food insecurity, especially for rural populations who depend heavily on agriculture. Addressing these challenges requires a multifaceted response, including:

- Promotion of climate-smart agricultural practices,
- Investment in resilient infrastructure, and
- Development of early warning systems and risk management strategies.

These measures are essential for PNG to safeguard its agricultural productivity and support rural resilience in the face of escalating climate threats.

3.2 Decision Context

The decision-making context for the agriculture sector in Papua New Guinea (PNG) under the Technology Needs Assessment (TNA) process is shaped by the sector's critical importance to food security, rural livelihoods, and economic development. Agriculture supports over 85% of PNG's population, with most rural communities relying on subsistence farming and small-scale cash crop production. However, the sector faces significant challenges due to climate change, which impacts agricultural productivity, market access, and the resilience of farming systems (GoPNG, 2018)

Climate change presents a pressing threat to the sector, with increasing temperatures, erratic rainfall patterns, and extreme weather events such as droughts, floods, and frost severely affecting crop yields. The reliance on traditional farming methods further exacerbates the sector's vulnerability, as these practices are not designed to cope with climatic shocks' growing frequency and intensity. Given these challenges, decision-makers must prioritize adaptation technologies that enhance resilience, productivity, and sustainability in the agriculture sector (ACIAR, 2019; IFAD, 2021)

The PNG agriculture sector's TNA process focuses on identifying and prioritizing technologies that align with national development goals, including those outlined in the **Medium-Term Development Plan (MTDP)** and **Vision 2050**. These goals emphasize food security, poverty alleviation, and sustainable rural development. Technologies such as climate-resilient crop varieties, sustainable land management practices, and improved irrigation systems are being considered to address vulnerabilities and enhance the sector's adaptive capacity. Decision-making is also influenced by the need to integrate traditional knowledge with modern technologies, ensuring solutions are culturally appropriate and effective in local contexts (GoPNG, 2018; GoPNG, 2020).

Furthermore, the decision context is informed by international commitments, such as PNG's Nationally Determined Contributions (NDCs) under the Paris Agreement, prioritising adaptation in the agriculture sector. Stakeholder engagement is central to the TNA process, involving farmers, government agencies, NGOs, and development partners to ensure that identified technologies address immediate and long-term needs. The outcomes of the TNA process aim to guide investments in climate-smart agriculture, improve rural livelihoods, and enhance the resilience of PNG's food systems to climate change (GoPNG, 2020).

3.3 An Overview of Existing Adaptation Technology in Agriculture Sector

Papua New Guinea (PNG) has implemented several adaptation technologies in the agriculture sector to address the impacts of climate change. These technologies focus on enhancing resilience, increasing productivity, and supporting food security. These technologies integrate traditional practices with modern innovations to address vulnerabilities such as extreme weather events, pests, and soil degradation.

a. **Climate-Resilient Crop Varieties,** PNG has introduced drought- and flood-resistant varieties of staple crops such as sweet potatoes, taro, and bananas to withstand climate variability. These crops are bred for higher resilience against water stress and extreme temperatures, helping to stabilize yields in challenging conditions (ACIAR, 2021; Bourke & Harwood, 2009).

   Extent of Adoption: These varieties have been introduced through research institutions and agricultural extension programs, but the scale of adoption among the estimated 3.5 to 4 million subsistence farmers remains unquantified. Uptake is likely concentrated in vulnerable areas such as the Highlands and flood-prone lowlands, but lacks detailed data on geographic coverage or number of farming households reached (GoPNG, 2020).

b. **Agroforestry Systems**, Farmers in PNG have adopted agroforestry practices that integrate trees with agricultural crops. This approach improves soil fertility, reduces erosion, and provides additional income through the cultivation of timber, fruits, and nuts. Agroforestry also helps mitigate the effects of extreme weather by acting as natural windbreaks and providing shade (Martini et al., 2021).

   Extent of Adoption: Agroforestry is practiced at the community level, particularly in regions with high erosion risk and forest dependency. While not centrally documented, it is considered a common practice among traditional farming systems, especially in East Sepik, Oro, and parts of the Highlands, contributing to diversified livelihoods ((Konedobu, 1995).

c. **Improved Irrigation Systems**, to address erratic rainfall patterns, localized irrigation systems have been introduced, including small-scale drip and sprinkler systems. These technologies help optimize water use and ensure consistent crop growth during dry periods (ADB, 2019).

   Extent of Adoption: Irrigation system deployment remains localized and primarily supported through NGO or donor-funded pilot projects. Adoption is limited to areas where water scarcity is pronounced, such as Central Province and parts of the Highlands. National-scale expansion is constrained by topography, cost, and technical capacity (FAO, 2022)

d. **Sustainable Land Management,** PNG has promoted soil conservation techniques such as contour farming, terracing, and cover cropping to reduce soil erosion and enhance fertility. These practices help maintain long-term agricultural productivity and minimize land degradation (Kiup, Swan and Field, 2025)

Extent of Adoption: SLM practices are being promoted through agricultural training and demonstration sites. Adoption is moderate and tends to occur in hilly or erosion-prone farming areas, particularly where soil fertility is declining. However, systematic monitoring of uptake and area coverage is lacking (GoPNG, 2020).

e. **Integrated Pest Management (IPM),** Techniques have been introduced to manage pests and diseases exacerbated by climate change. These methods include the use of biological controls, crop rotation, and improved pest monitoring to reduce dependency on chemical pesticides (SPREP, 2009)

   Extent of Adoption: IPM is in early stages of introduction in PNG, with limited implementation primarily in areas facing severe pest outbreaks (e.g., cocoa pod borer in East New Britain). Broader adoption is constrained by farmer awareness, technical training availability, and extension service coverage (FAO, 2022).

f. **Traditional Knowledge Integration,** many rural communities in PNG continue to use traditional agricultural practices, such as shifting cultivation and intercropping, to adapt to environmental changes. These practices are combined with modern techniques to create culturally appropriate and sustainable adaptation strategies (Mertz et al., 2009)

   Extent of Adoption: This is among the most widely adopted adaptation approaches across PNG. Traditional farming knowledge remains the foundation of agricultural decision-making, especially in remote areas where formal extension services are limited. Its integration with modern practices is increasing through participatory agricultural development programs (GoPNG, 2020).

g. **Climate Information Services,** Access to weather forecasting and climate information has been improved to help farmers plan for planting and harvesting seasons. Early warning systems and mobile-based advisories provide critical updates on extreme weather conditions (SPREP, 2020; FAO, 2021).

   Extent of Adoption: Climate services are expanding, with increasing availability of mobile alerts and radio bulletins in selected regions. However, accessibility is uneven—remote inland and island communities still face major information gaps. National meteorological capacity and infrastructure development are ongoing to support broader dissemination (Highcommission.gov.au, 2019)

3.4 Adaptation Technology Options for the Agriculture Sector and the Benefits

Papua New Guinea's National Adaptation Plan (NAP) 2023 outlines a suite of adaptation technologies to enhance resilience in agriculture and food systems. These options aim to address vulnerabilities such as extreme weather, pest outbreaks, soil degradation, and water scarcity, while promoting sustainable and climate-resilient livelihoods.

Climate-Smart Agriculture (CSA) encompasses sustainable farming practices such as conservation agriculture, crop rotation, intercropping, and integrated nutrient and water management. These approaches improve soil fertility, conserve water, reduce land degradation, and increase productivity. For instance, conservation tillage combined with legume rotation has shown yield increases in the PNG Highlands while enhancing resilience to drought (FAO, 2021). Country-level field studies from the National Agricultural Research Institute (NARI) suggest that CSA practices are scalable, particularly for smallholders engaged in root crop and maize production in climate-vulnerable zones (NARI, 2022).

Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB) are central to food security. Drought- and heat-tolerant sweet potato varieties like *Waghi Besta* and *Guala* are already being cultivated in the Highlands and could be upscaled with proper extension and seed distribution (Bourke & Harwood, 2009). For bananas, *Yangoru Aibika* and flood-tolerant taro varieties have been tested under stress conditions in lowland areas. However, there is a need to import or develop additional resilient varieties, particularly for staple crops like maize and legumes, which are increasingly affected by climate-induced pests. The Seed Bank (SB), led by NARI, serves as a genetic reservoir but requires long-term investment in infrastructure and community-based seed multiplication networks to ensure access and (*SPC,* 2023; GoPNG, 2023).

Sustainable Water Management Systems (SWMS) encompass a cluster of technologies aimed at securing water availability. These include:

1. **Rainwater harvesting**, which is actively promoted in East New Britain and Central Province,
2. **Drip irrigation**, piloted in drought-prone areas such as parts of Morobe and Enga, and
3. **Watershed management**, involving reforestation, contour planting, and riparian zone protection.

   Each component plays a distinct role in water conservation and climate resilience. For example, rainwater tanks coupled with drip irrigation systems have demonstrated 30–40% water savings in smallholder vegetable production plots (ADB, 2019). TNA technology fact sheets (TFS) should be tailored to these specific sub-technologies rather than to the broad SWMS category.

Agroforestry Practices (AFP), integrating trees with crops and/or livestock, are gaining traction across PNG due to their ecological and livelihood co-benefits. In areas like Oro and Milne Bay, farmers cultivate fruit trees (e.g., breadfruit, citrus) alongside root crops, contributing to food diversity and soil regeneration. Traditional practices like *kuk* agroforestry have long supported nutrient cycling and shade regulation (Allen & Bourke, 2001). These systems offer potential for scale-up, especially where land degradation or monocropping has reduced productivity.

Climate Information and Early Warning Systems (CIEWS) provide farmers with real-time weather alerts and seasonal forecasts, enabling them to make informed decisions about planting and harvesting. In PNG, the National Weather Service, in partnership with BoM Australia, has piloted SMS-based weather advisories in select districts. These services have been linked with positive outcomes, such as timely crop planting and reduced exposure to flood damage (Highcommission.gov.au, 2019). However, service coverage remains uneven, and expansion into inland and island regions is a priority.

Post-Harvest Management (PHM) technologies are underutilized in PNG despite their proven benefits. Country-level assessments indicate that up to 30% of perishable produce is lost post-harvest due to poor handling and inadequate storage (Mohamed et al., 2024). Technologies such as solar drying, evaporative coolers, and improved packaging are available and have shown success in pilot trials. Investing in PHM infrastructure and farmer training, particularly in high-output provinces like Eastern Highlands and Western Highlands, could significantly reduce losses and improve farmer incomes (Mohamed et al., 2024).

Table 1 The Option and Benefit of Technology Option for Agriculture Sector

Technology	Description	Benefits	References
Climate-Smart Agriculture (CSA)	Sustainable farming practices like conservation agriculture and integrated farming systems enhance soil fertility improve water conservation and promote crop rotation.	• Improves soil health and moisture retention. • Reduces land degradation and enhances crop yields. • Builds resilience to erratic rainfall and prolonged droughts. • Ensures sustainable food production.	GoPNG, 2023
Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB)	Development and promotion of drought-, heat-, and pest-resistant crop varieties; preservation of diverse seed varieties for future use and breeding programs.	• Stabilizes agricultural production under climate stress. • Enhances food security and livelihoods for farmers. • Safeguards genetic diversity to adapt crops to regional climate challenges.	GoPNG, 2023, Henry, 2023
Sustainable Water Management Systems (SWMS)	Includes rainwater harvesting, drip irrigation, and effective watershed management to adapt to changing precipitation patterns and ensure water availability for agriculture.	• Provides reliable water supply during droughts. • Minimizes water wastage with efficient irrigation. • Maintains healthy ecosystems and mitigates impacts of floods and droughts.	GoPNG, 2023
Agroforestry Practices (AFP)	Integrating trees and shrubs with crops and livestock to enhance biodiversity, stabilize soil, and provide alternative income sources through timber and non-timber forest products.	• Enhances biodiversity and soil health. • Provides alternative income streams (timber, fruits). • Acts as a natural buffer against extreme weather.	GoPNG, 2023, USDA.gov, 2024
Climate Information and Early Warning Systems (CIEWS)	Systems that provide timely weather and climate forecasts to help farmers prepare for extreme weather and manage risks effectively.	• - Informs planting, irrigation, and harvesting decisions. - Reduces vulnerability to extreme weather. - Enhances food security and resilience at both individual and community levels.	UNEP, 2023, WMO, 2024

Post-Harvest Management (PHM)	Technologies and practices to reduce post-harvest losses, such as improved storage, transport, and training programs for value addition and quality maintenance.	• Reduces food spoilage and increases shelf life. • Improves farmer incomes through value addition. • Enhances economic growth and contributes to national food security.	SPC, 2024, World Bank, 2016, Kaminski and Christiaensen, 2014

3.5 Criteria and Process of Technology Prioritisation For Agriculture Sector

Six technologies were evaluated and assessed based on criteria established through stakeholder consultations. A Multi-Criteria Analysis (MCA) was used to prioritize these technologies for the agriculture sector. In collaboration with stakeholders, the following seven criteria were identified:

(i) Cost: This includes both capital costs and operational and management expenses.
(ii) Institutional/Political Coherence: This criterion assesses alignment with national regulations.
(iii) Environmental Impact: This includes the protection of environmental resources.
(iv) Social Impact: This focuses on gender balance, improving health, and preserving cultural heritage.
(v) Economic Impact: This involves improving economic performance.
(vi) Climate Related Factors: Carbon sequestration, reducing vulnerability & building climate resilience.
(vii) Technology-related Factors: This assesses rapid technology diffusion and the maturity and effectiveness of the technologies.

These criteria guided the thorough evaluation process to ensure a comprehensive understanding of each technology's potential impact.

During the scoring process, stakeholders in the agriculture sector utilized the Technology Fact Sheets and drew on their experiences to discuss each criterion. They collectively assigned individual scores. Consequently, a performance matrix was created in **Table 3.** The scoring occurred after reviewing the information in the Technology Fact Sheets and the stakeholders' experiences. **Table 2** outlines the criteria, sub-criteria, sources of performance judgment, value justifications, preferred values, and weights used in the prioritization process for the agriculture sector.

Table 2 MCA Criterion, Value, Preferred and Weight for Agriculture Sector

Number	Criterion	Sub Criterion	CODE	Source of Performance Judgment	Value Justification	Value Preferred	Weight
I	Cost	Capital Cost	A.	Capital Cost	0= very high cost ---> 100 = very low cost	lower	10
		Operation &Management	B.	Operation &Management	0= very high cost ---> 100 = very low cost	lower	10
II	Institutional/Political	Coherence with national regulation	C.	Coherence with national regulation	0=very low --->100=very high	higher	10
III	Environmental	Protect of environment resources	D.	Protect of environment resources	0=very low --->100=very high	higher	10
IV	Social	Gender Balance (1-5)	E.	Gender Balance (1-5)	1=very low --->5=very high	higher	5
		Improve Health	F.	Improve Health	0=very low --->100=very high	higher	5
		Preserve Cultural Heritage	G.	Preserve Cultural Heritage	0=very low --->100=very high	higher	5
V	Economic	Improve economic performance	H.	Improve economic performance	0=very low --->100=very high	higher	10
VI	Climate Related	Carbon sequestration	I.	Carbon sequestration	0=very low --->100=very high	higher	5
		Reduce vulnerability & Build climate resilience	J.	Reduce vulnerability & Build climate resilience	0=very low --->100=very high	higher	10
VII	Technology	Rapid technology diffusion	K.	Rapid technology diffusion	0=very low --->100=very high	higher	10
		Maturity & effectiveness	L.	Maturity & effectiveness	0=very low --->100=very high	higher	10

Table 3 MCA Performance Matrix for Agriculture Sector

NO	Types of Technology Adaptation	I		II	III	IV			V	VI		VII	
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
1	Climate-Smart Agriculture (CSA)	20	35	70	80	4	80	75	85	70	90	75	70
2	Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB)	45	45	90	75	4	75	80	80	60	85	70	80
3	Sustainable Water Management Systems (SWMS)	50	40	75	85	3	80	65	75	70	80	65	65
4	Agroforestry Practices (AFP)	35	30	85	90	3	65	65	80	85	85	70	70
5	Climate Information and Early Warning Systems (CIEWS)	30	20	90	70	4	85	70	70	50	90	85	65
6	Post-Harvest Management (PHM)	35	40	80	75	4	75	70	85	60	85	70	80

Table 4 Scoring Matrix for Agriculture Sector

NO	Types of Technology Adaptation	I		II	III	IV			V	VI		VII	
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
1	Climate-Smart Agriculture (CSA)	100.0	40.0	0.0	50.0	100.0	75.0	66.7	100.0	57.1	100.0	60.0	33.3
2	Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB)	16.7	0.0	100.0	25.0	100.0	50.0	100.0	66.7	28.6	50.0	40.0	100.0
3	Sustainable Water Management Systems (SWMS)	0.0	20.0	25.0	75.0	0.0	75.0	0.0	33.3	57.1	0.0	20.0	0.0
4	Agroforestry Practices (AFP)	50.0	60.0	75.0	100.0	0.0	0.0	0.0	66.7	100.0	50.0	40.0	33.3
5	Climate Information and Early Warning Systems (CIEWS)	66.7	100.0	100.0	0.0	100.0	100.0	33.3	0.0	0.0	100.0	100.0	0.0
6	Post-Harvest Management (PHM)	50.0	20.0	50.0	25.0	100.0	50.0	33.3	100.0	28.6	50.0	40.0	100.0

The scoring matrix presented in **Table 4** was developed by evaluating the preferred values alongside the scores generated through a specific formula below:

Higher Value

$$Y_i = \frac{X_i - X_{min}}{X_{max} - X_{min}} * 100$$

Lower Value preferred

$$Y_i = \frac{X_{max} - X_i}{X_{max} - X_{min}} * 100$$

- Xi = the original value or raw performance score of a technology for a particular criterion.
- Xmax = the highest value among all technologies for that criterion.
- Xmin = the lowest value among all technologies for that criterion.

These values are used in normalization formulas to convert different criterion scales into a common 0–100 or 0–1 scale, which allows fair comparison across criteria. Depending on whether a higher or lower value is preferred:

If higher value is preferred (e.g., effectiveness, social benefit):
Normalized Score $=\frac{Xi-X\ min}{Xmax-Xmi}\ x\ 100$

If **lower value is preferred** (e.g., cost):
Normalized Score $=\frac{Xm}{Xmax-Xmi}\ x\ 100$

Below are the detailed steps involved in performing calculations for each table:

Step 1: Identify the Raw Score (Xi)
From Table 3 (Performance Matrix), CSA's Capital Cost (Column A) = **20**

Step 2: Normalize the Score
From Table 3, the **minimum** capital cost score (Xmin) = 20 (CSA)
The **maximum** capital cost score (Xmax) = 50 (SWMS)

As **lower cost is preferred**, use this normalization:
Normalized Score $=\frac{Xmax-Xi}{Xmax-Xmi}\ x\ 100 = \frac{50-20}{50-2}\ x\ 100$

This corresponds to Table 4 (Scoring Matrix), Cell A1 = **100**

Step 3: Multiply by Weight
From Table 2, weight for Capital Cost = **10**
So, final score for Table 5, Cell A1 = 100 x 10 = 1000
This explains how **Cell A1 = 1000** in Table 5.

The same process is followed for every other cell in Table 5: normalize the score from Table 3 → check the preference direction → multiply by the weight → place in Table 5.

Table 5 Decision Matrix for Agriculture Sector

NO	Types of Technology Adaptation	I		II	III	IV			V	VI		VII		Total
		A	B	C	D	E	F	G	H	I	J	K	L	
1	Climate-Smart Agriculture (CSA)	1000	400	0	500	500	375	333	1000	286	1000	600	333	6,327
2	Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB)	167	0	1000	250	500	250	500	667	143	500	400	1000	5,376
3	Sustainable Water Management Systems (SWMS)	0	200	250	750	0	375	0	333	286	0	200	0	2,394
4	Agroforestry Practices (AFP)	500	600	750	1000	0	0	0	667	500	500	400	333	5,250
5	Climate Information and Early Warning Systems (CIEWS)	667	1000	1000	0	500	500	167	0	0	1000	1000	0	5,833
6	Post-Harvest Management (PHM)	500	200	500	250	500	250	167	1000	143	500	400	1000	5,410

3.6 Result of Technology Prioritisation for Agriculture Sector

The prioritisation of adaptation technologies for the agriculture sector was carried out through a structured Multi-Criteria Analysis (MCA), integrating inputs from key stakeholders and expert evaluations. **Table 6** presents the final ranking of six proposed adaptation technologies based on their aggregated scores across economic, social, environmental, and technical criteria. The results underscore the technologies with the highest potential to enhance climate resilience, ensure food security, and support sustainable agricultural practices in the face of growing climate risks.

Table 6 Prioritizing Technology for Agriculture Sector

No	Types of Technology Adaptation	Total	Rank
1	Climate-Smart Agriculture (CSA)	6,327	1
2	Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB)	5,376	4
3	Sustainable Water Management Systems (SWMS)	2,394	6
4	Agroforestry Practices (AFP)	5,250	5
5	Climate Information and Early Warning Systems (CIEWS)	5,833	2
6	Post-Harvest Management (PHM)	5,410	3

1. **Climate-Smart Agriculture (CSA) – Score: 6,327**
   CSA ranks as the top-priority technology due to its integrated approach to improving productivity, enhancing resilience, and reducing greenhouse gas emissions. CSA combines sustainable land and water management, climate-resilient crop techniques, and improved farming practices, making it highly effective across diverse agro-ecological zones.
   Key Benefits: Increased agricultural yield, enhanced resilience to climate shocks, improved soil and water conservation, and reduced emissions.

2. **Climate Information and Early Warning Systems (CIEWS) – Score: 5,833**
   CIEWS holds the second position, highlighting its critical role in equipping farmers with timely and accurate weather and climate data. It supports anticipatory action and informed decision-making in farming operations.
   Key Benefits: Enhanced preparedness for climate extremes, reduced crop and livelihood losses, and improved climate-informed planning.

3. **Post-Harvest Management (PHM) – Score: 5,410**
   Ranked third, PHM focuses on reducing post-harvest losses through improved storage, processing, and distribution systems. It is vital in securing food availability and reducing waste along the value chain.
   Key Benefits: Improved food security, extended shelf life of produce, reduced economic losses, and greater resource efficiency.

4. **Climate-Resilient Crop Varieties and Seed Banking (C-RCVs & SB) – Score: 5,376**
   This technology ranks fourth and promotes the use of crop varieties that are tolerant to drought, pests, and diseases, along with the conservation of local seed diversity.

Key Benefits: Enhanced crop adaptability, preservation of genetic diversity, and increased resilience to environmental stressors.

5. **Agroforestry Practices (AFP) – Score: 5,250**
   Agroforestry combines trees with crops and/or livestock in farming systems, offering both ecological and economic benefits. Despite its lower rank, it remains a valuable nature-based solution.
   Key Benefits: Improved soil fertility, biodiversity enhancement, carbon sequestration, and diversified income sources.

6. **Sustainable Water Management Systems (SWMS) – Score: 2,394**
   Although ranked lowest, SWMS are foundational for long-term agricultural sustainability, particularly in areas with water scarcity. The score suggests challenges in feasibility or current uptake.
   Key Benefits: Efficient water use, reduced irrigation stress, and support for rain-fed and irrigated farming systems.

Based on the MCA scoring results and stakeholder consensus, **Climate-Smart Agriculture (CSA)** and **Climate Information and Early Warning Systems (CIEWS)** emerged as the top two prioritized adaptation technologies for the agriculture sector. These technologies were selected due to their integrated benefits: CSA promotes sustainable land and water use, increased productivity, and improved resilience, while CIEWS enhances decision-making through timely weather and climate forecasts, thereby reducing agricultural losses. Similarly, for the infrastructure sector, **Climate-Resilient Infrastructure (CRI)** and **Early Warning Systems (EWS)** were identified as top priorities. CRI focuses on strengthening infrastructure to withstand climate impacts like flooding and landslides, while EWS supports rapid disaster preparedness and response. These four technologies represent the most impactful, feasible, and contextually relevant solutions to address PNG's urgent climate adaptation needs.

CHAPTER 4
ADAPTATION TECHNOLOGY PRIORITISATION FOR THE INFRASTRUCTURE SECTOR

4.1 Key Climate Change Vulnerabilities in Infrastructure Sector

The infrastructure sector in Papua New Guinea (PNG) faces critical challenges due to climate change. As a geographically diverse and disaster-prone nation, PNG's infrastructure, including transportation networks, housing, and public utilities, is increasingly vulnerable to extreme weather events, rising sea levels, and other climate-related impacts. These vulnerabilities not only disrupt economic activities but also hinder access to essential services for rural and urban communities (Kiele et al., 2013; World Bank, 2021; Feruglio, 2024).

Prolonged and intense rainfall is a significant issue in PNG, often leading to severe flooding that damages the country's infrastructure. Roads, bridges, and drainage systems frequently wash away, disrupting transportation networks and isolating rural communities, which limits access to essential services (World Bank, 2021). Flooding also results in waterlogging and sediment buildup that compromise the structural integrity of infrastructure foundations. The most affected areas are typically low-lying regions with inadequate drainage systems, which leads to costly maintenance and reconstruction efforts. This cycle of damage and repair poses ongoing challenges for local governments and communities as extreme weather events become more frequent and severe (GoPNG, 2023).

Papua New Guinea's expansive coastline makes its infrastructure, such as roads, ports, and housing, highly vulnerable to rising sea levels and coastal erosion. These environmental challenges damage critical facilities, disrupt trade, and hinder connectivity for island and coastal communities. Ports, essential for importing and exporting goods, are facing rising maintenance costs and operational issues. Meanwhile, coastal erosion threatens housing and services in low-lying areas, risking displacement of families and weakening community resilience (UNDRR, 2023).

Heavy rainfall combined with PNG's steep and mountainous terrain significantly increases the risk of landslides. Landslides frequently destroy roads and bridges, cutting off remote communities and delaying the transportation of goods and services. Deforestation and poor land management practices exacerbate soil instability, further endangering infrastructure, particularly in highland regions. These events impose additional costs for repairs and maintenance and economic losses due to transportation delays (World Bank, 2021).

Cyclones, which are becoming more frequent and intense due to climate change, bring heavy rains and strong winds that cause widespread destruction. Poorly constructed buildings, roads, and power lines are particularly vulnerable, with cyclones often leading to prolonged power outages and communication disruptions. Informal settlements and rural areas are disproportionately affected due to weaker infrastructure, which exacerbates recovery challenges. Cyclone damage significantly impedes emergency response efforts and economic activities (World Bank, 2021; USAID, 2024).

Rapid urbanization has led to the expansion of informal settlements, often in high-risk areas such as floodplains and coastal regions. These settlements are characterized by poorly constructed housing and inadequate infrastructure, making them highly susceptible to flooding, erosion, and storm damage. Additionally, insufficient drainage systems in urban centres exacerbate flooding during heavy rainfall, affecting both informal and formal housing areas. The lack of urban planning amplifies these vulnerabilities, creating further challenges for sustainable development (Kiele et al., 2013; Leger, Visser and Aleker, 2017).

Rising temperatures in PNG accelerate the degradation of materials used in roads, bridges, and buildings. Asphalt roads become prone to softening and cracking, while concrete structures experience thermal stress, reducing their lifespan and increasing maintenance costs. This heat stress places additional strain on already limited infrastructure resources, requiring more frequent and costly repairs to maintain functionality (ADB, 2014).

Climate change presents significant risks to PNG's infrastructure sector, threatening its functionality and sustainability. Flooding, coastal erosion, landslides, cyclones, and heat stress are among the most pressing challenges. These vulnerabilities highlight the urgent need for climate-resilient infrastructure investments, improved urban planning, and robust disaster management strategies to minimize damage and ensure long-term economic and social resilience.

4.2 Decision Context

The Technology Needs Assessment (TNA) process for the infrastructure sector in Papua New Guinea (PNG) plays a critical role in addressing the country's urgent climate vulnerabilities. With infrastructure acting as the backbone of economic growth and service delivery, strengthening its resilience is imperative for achieving the sustainable development goals and the objectives of the National Adaptation Plan (NAP) 2023.

Over 85% of PNG's population is rural-based, yet the road access rate is below 20% during all-weather conditions, severely limiting year-round connectivity (GFDRR, 2011). Infrastructure in PNG—including roads, bridges, ports, energy, housing, and water supply systems—is highly exposed to climate hazards such as flooding, sea-level rise, extreme heat, landslides, and cyclones.

Key Climate Vulnerabilities and Recommended Technologies:

1. Flooding and Extreme Rainfall Between 2000 and 2020, PNG experienced at least 7 major flood events, displacing over 280,000 people and damaging roads, schools, and hospitals (GFDRR, 2011). Infrastructure suffers from sedimentation, erosion, and foundation weakening, leading to high reconstruction costs—estimated at USD 200 million per annum in lost infrastructure functionality (World Bank, 2021).

2. Coastal Erosion and Sea-Level Rise More than 85% of PNG's population lives within 10 km of the coast (GoPNG, 2023), placing ports, roads, and public facilities at risk. Sea-level rise in the Pacific has accelerated to 7 mm/year, compared to the global average of 3.2 mm/year (SPREP, 2021).

3. Landslides PNG's rugged topography makes it highly susceptible to landslides. In 2022, landslides in the Highlands region resulted in the destruction of more than 30 km of highway and isolation of communities for weeks (UNDRR, 2019).

4. Cyclones and Windstorms While less frequent than in other Pacific nations, cyclones in PNG are becoming more intense. Cyclone Guba (2007) caused USD 200 million in damage and affected over 145,000 people (UNOCHA, 2007).

5. Urbanization and Informal Settlements By 2030, PNG's urban population is expected to reach 25% of the total population, with rapid growth in informal settlements. These areas lack proper zoning, drainage, and resilient infrastructure (Nao and Kutan, 2022)

6. Rising Temperatures and Heat Stress Climate projections indicate that annual average temperatures in PNG will rise by 1.5–2.0°C by 2050, leading to material degradation in asphalt and concrete (CSIRO and SPREP, 2021)

The TNA process identifies technologies that align with the Medium-Term Development Plan (MTDP III) and Vision 2050, which emphasise resilient infrastructure as a key development enabler. The integration of low-carbon and climate-resilient technologies will contribute not only to reduced climate risk but also to long-term economic efficiency, reduced maintenance costs, and equitable service delivery, especially in remote and vulnerable regions

4.3 An Overview of Existing Adaptation Technology of Infrastructure Sector

Papua New Guinea has implemented various adaptation technologies within the infrastructure sector to address the growing impacts of climate change, focusing on resilience enhancement, minimizing infrastructure damage, and promoting sustainable development. As a geographically diverse country, PNG faces numerous climate-related challenges, such as flooding, sea-level rise, landslides, and rising temperatures, which affect the country's transportation networks, housing, and public utilities. Adopting innovative adaptation technologies aims to address these challenges, ensuring that PNG's infrastructure remains functional and sustainable for the long term.

One of the primary adaptation strategies in PNG's infrastructure sector is the development of **flood-resistant infrastructure**. This technology includes elevated roads, bridges with reinforced foundations, and improved drainage systems. These measures are particularly important for low-lying areas and regions prone to heavy rainfall, which often results in flooding and waterlogging. Flood-resistant infrastructure prevents the disruption of transportation networks, ensuring that vital routes remain accessible, even during extreme weather events. It also reduces maintenance costs by minimizing damage to infrastructure, while enhancing connectivity, especially for rural communities that depend on these networks for access to essential services. As flood risks continue to increase, these flood-resistant solutions are crucial for ensuring the resilience of PNG's infrastructure (GoPNG, 2023).

In PNG, **coastal protection technologies** play a pivotal role in safeguarding critical infrastructure along the country's extensive coastline. These technologies include the construction of seawalls, mangrove restoration, and beach nourishment efforts, which help to mitigate the effects of rising sea levels and coastal erosion. These measures are especially important for protecting ports, roads, and communities located in coastal regions, which are highly vulnerable to storm surges and rising sea levels. By fortifying these areas, PNG not only protects its infrastructure but also ensures the resilience of local communities. Coastal protection is vital for maintaining trade routes, safeguarding livelihoods, and reducing the risk of infrastructure collapse in the face of climate change (UNDRR, 2023).

Landslide mitigation is another key area of focus for PNG's infrastructure adaptation efforts. Technologies such as retaining walls, slope stabilization measures, and reforestation programs in highland regions are essential to reducing the risks posed by landslides, particularly in steep terrains. Heavy rainfall and deforestation increase the likelihood of landslides, which can destroy roads and bridges and isolate remote communities. By investing in landslide mitigation measures, PNG can reduce the risk of infrastructure destruction and maintain vital connections to its more isolated regions. These technologies are critical for ensuring that remote communities in the highlands continue to have access to essential services, while also protecting vital infrastructure from being washed away (World Bank, 2021).

In urban areas, **advanced urban drainage systems** are essential for managing stormwater and reducing flooding during heavy rainfall. Technologies such as permeable pavements and advanced drainage networks are increasingly being used to prevent waterlogging and flooding in urban centers, particularly in informal settlements that often lack sufficient infrastructure. These systems help minimize the flood risks in densely populated areas, where inadequate drainage exacerbates the impact of rainfall. Improved drainage technologies not only protect urban infrastructure but also enhance the resilience of informal settlements, ensuring that residents in high-risk areas are better protected against climate-related disasters (Kiele et al., 2013).

Early warning systems are also a critical component of PNG's adaptation strategy in the infrastructure sector. Integrated meteorological and geological monitoring systems provide real-time data on weather and geological events, enabling the country to anticipate risks and respond more effectively. These systems are instrumental in guiding evacuations and implementing preventive measures, reducing infrastructure damage and improving disaster preparedness. By providing timely alerts and information, early warning systems help PNG manage climate-related risks and protect vulnerable infrastructure from the devastating effects of extreme weather events (UNEP, 2023).

PNG's existing adaptation technologies in the infrastructure sector offer vital solutions for mitigating the impacts of climate change. From flood-resistant infrastructure to coastal protection and heat-resilient materials, these technologies are key to reducing vulnerabilities and ensuring the long-term sustainability of the country's infrastructure systems. As PNG continues to face climate challenges, expanding and integrating these technologies into broader development strategies will be crucial for building resilience across the nation, protecting communities, and supporting sustainable economic growth.

4.4 Adaptation Technology Options for the Infrastructure Sector and the Benefits

Papua New Guinea's (PNG) **National Adaptation Plan (NAP) 2023** outlines a forward-looking strategy for integrating climate-resilient technologies into the infrastructure sector. These planned technologies aim to address anticipated climate challenges while enhancing the sustainability and resilience of critical systems in the coming decades. A key focus is on **climate-resilient building and utility infrastructure**, with plans to develop and rehabilitate buildings, power facilities, and essential utilities according to enhanced climate-resilient standards. This approach ensures that infrastructure will withstand extreme weather and rising sea levels, safeguarding critical services (GoPNG, 2023).

Some adaptation technologies can be implemented for climate change adaptation in PNG, such as:

Flood-resilient Infrastructure Technology (FRIT) aims to address the significant challenge of heavy rainfall and flooding in PNG, which disrupts transportation, damages infrastructure, and isolates communities. Advanced drainage systems are a critical component of FRIT, designed to efficiently manage stormwater, reduce waterlogging, and protect infrastructure foundations (CCDA, 2023).

Coastal protection infrastructure (CPI) such as seawalls, levees, and engineered barriers to minimize the impacts of sea-level rise and storm surges. These measures will safeguard housing, ports, and trade hubs while reducing the displacement of vulnerable populations (UNDRR, 2023). Together, these planned adaptation technologies aim to build a more resilient infrastructure sector in PNG, ensuring sustainable development and alignment with the country's priorities outlined in NAP 2023 and its international climate commitment

Landslide-resistant Infrastructure (LRI) in PNG typically incorporate slope stabilisation and retaining walls to prevent the displacement of soil and debris during heavy rainfall or seismic activities. These measures protect roads, bridges, and housing, especially in areas prone to soil erosion and high rainfall intensity. These measures are particularly vital in PNG's highland regions, such as the Eastern Highlands and Simbu Province, where communities are especially vulnerable to the impacts of landslides. The construction of landslide-resistant infrastructure, along with the promotion of sustainable land-use practices, plays a pivotal role in maintaining accessibility to remote areas and safeguarding the livelihoods of rural populations (World Bank, 2021)

Early warning systems (EWS), these systems are designed to provide timely alerts for extreme weather events, such as storms, floods, and droughts, which have become increasingly frequent and severe due to climate change. The goal is to reach an estimated 6 million people, representing 70% of PNG's population, by the year 2030 (GoPNG, 2020). This initiative aims to enhance disaster preparedness through improved communication channels, community training, and access to real-time data. By implementing these advanced systems, PNG hopes to significantly reduce the potential for loss of life and property, thereby increasing resilience to climate-related disasters (UNEP, 2023).

Energy-efficient and renewable infrastructure (EERI) by integrating solar panels and renewable energy systems into future public and private projects. This initiative seeks to decrease reliance on unstable energy sources and enhance the resilience of the power sector against climate change disruptions, ensuring a reliable energy supply for its citizens (GoPNG, 2023). This initiative is twofold: first, to significantly reduce the nation's reliance on unstable and non-renewable energy sources that are susceptible to market fluctuations and geopolitical tensions; and second, to strengthen the energy sector's resilience against potential disruptions caused by climate change. By investing in renewable energy solutions, PNG aims to create a more stable and sustainable energy landscape that can withstand these challenges, ensuring a reliable power supply for all its citizens (GoPNG, 2023).

Table 7 The Option and Benefit of Technology Option for Infrastructure Sector

Technology	Description	Benefits	References
Flood-resilient Infrastructure Technology (FRIT)	The technology reduces the adverse effects of heavy rainfall and flooding, frequently damaging infrastructure and disrupting communities. A key component of FRIT is the development of advanced drainage systems designed to manage stormwater effectively and prevent waterlogging	• Year-Round Accessibility • Economic Stability • Community Resilient	Works.gov.pg, 2020 GoPNG, 2023
Coastal Protection Infrastructure (CPI)	Construction of seawalls, levees, and engineered barriers to safeguard coastal communities and infrastructure from rising sea levels and storm surges.	• Protects housing, ports, and trade hubs. • Reduces displacement of vulnerable populations. • Safeguards economic activities in coastal areas.	UNDRR, 2023, GoPNG, 2023
Landslide-Resistant Infrastructure (LRI)	Engineering solutions such as retaining walls, slope stabilization, and reforestation to prevent landslides in high-risk mountainous regions.	• Prevents destruction of roads and infrastructure. • Maintains connectivity in rural and highland areas. • Reduces economic losses from road closures and transportation delays.	World Bank, 2021, Kiele et al., 2013
Early Warning Systems (EWS)	Systems provide timely and accurate information about extreme weather events, leveraging meteorological data and technology to alert communities and responders.	• Enhances disaster preparedness, reducing loss of life and property. • Informs better planning and evacuation strategies. • Build resilience at community and national levels.	UNEP, 2023, GoPNG, 2023

Technology	Description	Benefits	References
Energy-Efficient and Renewable Infrastructure (EERI)	Integration of renewable energy systems, such as solar panels, and energy-efficient technologies in public and private infrastructure.	• Reduces reliance on non-renewable energy sources. • Enhances resilience to power outages caused by climate events • Promotes sustainable development and reduces greenhouse gas emissions.	ADB, 2014, GoPNG, 2023
Climate-resilient infrastructure (CRI)	Development and rehabilitation of buildings, roads, and utilities to meet climate-resilient standards and withstand extreme weather and rising sea levels.	• Protects essential infrastructure from damage. • Ensures continuity of critical services like healthcare and education. • Reduces long-term maintenance and repair costs.	World Bank, 2021, GoPNG, 2023

4.5 Criteria and Process of Technology Prioritisation For Infrastructure Sector

A multi-criteria analysis (MCA) was carried out to effectively select technologies for the infrastructure sector in an inclusive and context-sensitive manner. This approach was developed through extensive stakeholder consultations to incorporate technical considerations and local knowledge. Six technologies were shortlisted for evaluation based on their potential to improve infrastructure, enhance climate resilience, and achieve positive socio-economic outcomes.

Seven key **evaluation criteria** were collaboratively defined to guide the appraisal. Each criterion encompasses specific sub-elements to ensure a holistic understanding of the technologies' benefits and trade-offs:

1. Cost Efficiency
   This includes capital investment and operational & maintenance costs, enabling the assessment of financial feasibility over the project lifecycle.
2. Institutional and Political Coherence
   Evaluates the alignment of each technology with existing national policies, regulations, and institutional mandates, ensuring smooth implementation and scalability.
3. Environmental Impact
   Measures the extent to which the technology preserves or enhances natural ecosystems, including protecting water bodies, land, and biodiversity.
4. Social Impact
   Assesses the technology's influence on gender inclusion, public health outcomes, and the preservation of cultural heritage, all of which are critical for equitable and sustainable adoption.
5. Economic Benefits
   Focuses on the potential of each technology to boost livelihoods, generate employment, and strengthen local economies through improved productivity or cost savings.
6. Climate-Related Contributions
   Looks at how well the technology contributes to carbon sequestration, reduces vulnerability, and builds long-term climate resilience in vulnerable areas.
7. Technological Readiness and Diffusion
   Considers the maturity of the technology, its effectiveness, and the likelihood of rapid adoption and replication in similar contexts.

During the scoring process, stakeholders in the infrastructure sector consulted the Technology Fact Sheets, drew from their experiences, and deliberated on each criterion. They collectively assigned individual scores for each criterion and then averaged these scores to create a performance matrix. **Table 9** illustrates this matrix, scoring based on discussions around the information provided in the technology fact sheets and the stakeholders' respective experiences. Additionally, **Table 8** outlines the criteria, sub-criteria, sources of performance judgment, value justifications, preferred values, and weights used in the prioritization process for the infrastructure sector.

Table 8 MCA Criterion, Value, Preferred and Weight for Infrastructure Sector

Number	Criterion	Sub Criterion	CODE	Source of Performance Judgment	Value Justification	Value Preferred	Weight
I	Cost	Capital Cost	A.	Capital Cost	0= very high cost ---> 100 = very low cost	lower	10
		Operation &Management	B.	Operation &Management	0= very high cost ---> 100 = very low cost	lower	10
II	Institutional/Political	Coherence with national regulation	C.	Coherence with national regulation	0=very low --->100=very high	higher	10
III	Environmental	Protect of environment resources	D.	Protect of environment resources	0=very low --->100=very high	higher	10
IV	Social	Gender Balance (1-5)	E.	Gender Balance (1-5)	1=very low --->5=very high	higher	5
		Improve Health	F.	Improve Health	0=very low --->100=very high	higher	5
		Preserve Cultural Heritage	G.	Preserve Cultural Heritage	0=very low --->100=very high	higher	5
V	Economic	Improve economic performance	H.	Improve economic performance	0=very low --->100=very high	higher	10
VI	Climate Related	Carbon sequestration	I.	Carbon sequestration	0=very low --->100=very high	higher	5
		Reduce vulnerability & Build climate resilience	J.	Reduce vulnerability & Build climate resilience	0=very low --->100=very high	higher	10
VII	Technology	Rapid technology diffusion	K.	Rapid technology diffusion	0=very low --->100=very high	higher	10
		Maturity & effectiveness	L.	Maturity & effectiveness	0=very low --->100=very high	higher	10

Table 9 MCA Performance Matrix for Infrastructure Sector

NO	Types of Technology Adaptation	I		II	III	IV			V	VI		VII	
		A	B	C	D	E	F	G	H	I	J	K	L
1	Flood-resilient Infrastructure Technology (FRIT)	40	50	55	85	3	85	80	85	75	90	70	60
2	Coastal Protection Infrastructure (CPI)	45	55	50	85	4	85	80	85	85	85	80	60
3	Landslide-Resistant Infrastructure (LRI)	35	50	50	70	3	80	80	85	70	80	80	60
4	Early Warning Systems (EWS)	20	45	60	80	4	80	80	70	45	85	85	70
5	Energy-Efficient and Renewable Infrastructure (EERI)	30	35	60	70	3	80	50	85	50	80	80	80
6	Climate-resilient infrastructure (CRI)	35	45	55	85	4	80	80	85	75	90	75	70

Table 10 MCA Scoring Matrix for Infrastructure Sector

NO	Types of Technology Adaptation	I		II	III	IV			V	VI		VII	
		A	B	C	D	E	F	G	H	I	J	K	L
1	Flood-resilient Infrastructure Technology (FRIT)	20.0	25.0	50.0	100.0	0.0	100.0	100.0	100.0	75.0	100.0	0.0	0.0
2	Coastal Protection Infrastructure (CPI)	0.0	0.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	50.0	66.7	0.0
3	Landslide-Resistant Infrastructure (LRI)	40.0	25.0	0.0	0.0	0.0	0.0	100.0	100.0	62.5	0.0	66.7	0.0
4	Early Warning Systems (EWS)	100.0	50.0	100.0	66.7	100.0	0.0	100.0	0.0	0.0	50.0	100.0	50.0
5	Energy-Efficient and Renewable Infrastructure (EERI)	60.0	100.0	100.0	0.0	0.0	0.0	0.0	100.0	12.5	0.0	66.7	100.0
6	Climate-resilient infrastructure (CRI)	40.0	50.0	50.0	100.0	100.0	0.0	100.0	100.0	75.0	100.0	33.3	50.0

Step 1: Raw Performance Scores (Table 9)
This table contains the **original (raw) scores** for each adaptation technology across 12 sub-criteria. These scores were assigned collectively by stakeholders during the MCA session, based on:

- Literature
- Technology Fact Sheets (TFS)
- National experiences
- Expert judgment

Each sub-criterion (e.g., Capital Cost, Environmental Protection) was scored on a **0–100 scale**, except Gender Balance (1–5 scale). These values represent **Xi** in the formula below.

Step 2: Score Normalisation (Table 10)
This step's goal is to transform all raw scores into a uniform scale (0–100) for comparison using **Min-Max normalization**.
The scoring matrix, illustrated in **Table 10**, was meticulously developed based on key preferred values, alongside scores calculated using a designated formula below specifically designed for this purpose.

Higher Value

$$Y_i = \frac{X_i - X_{min}}{X_{max} - X_{min}} * 100$$

Lower Value preferred

$$Y_i = \frac{X_{max} - X_i}{X_{max} - X_{min}} * 100$$

- Xi = the original value or raw performance score of a technology for a particular criterion.
- Xmax = the highest value among all technologies for that criterion.
- Xmin = the lowest value among all technologies for that criterion.

These values are used in normalization formulas to convert different criterion scales into a common 0–100 or 0–1 scale, which allows fair comparison across criteria. Depending on whether a higher or lower value is preferred:

If **higher value is preferred** (e.g., effectiveness, social benefit):
Normalized Score $= \frac{Xi - X\ min}{Xmax - Xmin}\ x\ 100$

If **lower value is preferred** (e.g., cost):
Normalized Score $= \frac{Xmax - Xi}{Xmax - Xmin}\ x\ 100$

Example: From Table 9 to Table 10 (One Cell)
Let's take **FRIT's Capital Cost (Raw Score = 40)** and calculate its normalized score:
Raw Values for Capital Cost:

- FRIT: 40 (**Xi**)
- Max (Xmax): 45 (CPI)
- Min (Xmin): 20 (EWS)

Since **Capital Cost is a "lower-is-better"** criterion, we apply formula B:

Normalized Score $= \frac{Xmax-}{Xmax-Xmin}\ x\ 100 = \frac{45-40}{40-20}\ x\ 100 = 20$

So FRIT's normalized capital cost = **20**→ this appears in Table 4.

Step 3: Decision Matrix (Table 11)
This is the final weighted score for each technology. Each cell in this table is calculated as:
Final Score=Normalized Score **(Table 4)**×Weight **(from Table 8)**
All weighted scores across the 12 sub-criteria are summed to generate the **final MCA score** (last column).

Example: FRIT Total Score Calculation

From Table 10:

- Capital Cost normalized = 20
- Weight from Table 8 = 10

Then:

20×10=200(shown in Table 11)

Repeat this for each of the 12 criteria, sum them:

FRIT's Final Score=200 + 250 +500+1000+...=5,325

Summary of Table Linkages

Table	**Content**	**Input**
Table 9	Raw performance scores (**Xi**)	Assigned during stakeholder workshop
Table 10	Normalized scores	From Table 9 using min-max formula
Table 11	Weighted scores	From Table 10 × Weights in Table 8
Table 12	Final ranking	Summation of Table 11 scores

Table 11 MCA Decision Matrix for Infrastructure Sector

NO	Types of Technology Adaptation	I		II	III	IV			V	VI		VII		Total
		A	B	C	D	E	F	G	H	I	J	K	L	
1	Flood-resilient Infrastructure Technology (FRIT)	200	250	500	1000	0	500	500	1000	375	1000	0	0	5,325
2	Coastal Protection Infrastructure (CPI)	0	0	0	1000	500	500	500	1000	500	500	667	0	5,167
3	Landslide-Resistant Infrastructure (LRI)	400	250	0	0	0	0	500	1000	313	0	667	0	3,129
4	Early Warning Systems (EWS)	1000	500	1000	667	500	0	500	0	0	500	1000	500	6,167
5	Energy-Efficient and Renewable Infrastructure (EERI)	600	1000	1000	0	0	0	0	1000	63	0	667	1000	5,329
6	Climate-resilient infrastructure (CRI)	400	500	500	1000	500	0	500	1000	375	1000	333	500	6,608

4.6 Result of Technology Prioritisation for Infrastructure Sector

A comprehensive Multi-Criteria Analysis (MCA) was carried out to evaluate and prioritize crucial adaptation technologies within the infrastructure sector. This thorough and collaborative process brought together a diverse group of sector experts and local stakeholders who meticulously assessed each technology's relevance, feasibility, and potential impact in climate change adaptation. The final ranking, presented in **Table 12**, showcases the prioritisation based on a detailed composite scoring system that reflects the collective insights and expertise gathered throughout the evaluation.

Table 12 Prioritizing Technology for Infrastructure Sector

No	Types of Technology Adaptation	Total	Rank
1	Flood-resilient Infrastructure Technology (FRIT)	5,325	4
2	Coastal Protection Infrastructure (CPI)	5,167	5
3	Landslide-Resistant Infrastructure (LRI)	3,129	6
4	Early Warning Systems (EWS)	6,167	2
5	Energy-Efficient and Renewable Infrastructure (EERI)	5,329	3
6	Climate-resilient infrastructure (CRI)	6,608	1

The selected technologies address critical climate vulnerabilities, including floods, coastal erosion, landslides, and energy system instability. Each prioritised technology plays a unique role in strengthening climate resilience and ensuring the long-term sustainability of infrastructure systems. The summary below outlines the key technologies and their associated benefits:

1. **Climate-Resilient Infrastructure (CRI) – Score: 6,608**
   CRI is the top-ranked technology, emphasizing the need for infrastructure systems that are designed, built, and maintained to withstand the impacts of climate change. It includes climate-proof roads, drainage systems, and public utilities.
   Key Benefits: Reduced infrastructure damage, improved service continuity, and long-term savings in maintenance and recovery costs.

2. **Early Warning Systems (EWS) – Score: 6,167**
   EWS is prioritized second for its critical role in risk reduction and disaster preparedness. It enables real-time monitoring and timely dissemination of alerts for climate hazards such as floods, storms, and landslides.
   Key Benefits: Saved lives, reduced economic losses, faster emergency responses, and enhanced community preparedness.

3. **Energy-Efficient and Renewable Infrastructure (EERI) – Score: 5,329**
   EERI ranks third, supporting the shift toward sustainable energy systems and infrastructure that minimise emissions and enhance energy security. This includes solar-powered facilities, green buildings, and efficient public lighting.
   Key Benefits: Lower energy costs, reduced carbon footprint, and increased access to clean energy.

4. **Flood-Resilient Infrastructure Technology (FRIT) – Score: 5,325**
   Ranking fourth, FRIT targets flood-prone areas with engineering solutions such as elevated roadways, reinforced embankments, and improved drainage systems. Key Benefits: Reduced flood damage, safer transportation networks, and improved urban and rural resilience.

5. **Coastal Protection Infrastructure (CPI) – Score: 5,167**
   CPI is fifth in the prioritisation, focusing on interventions like seawalls, revetments, and mangrove restoration to buffer coastlines against erosion and storm surges. Key Benefits: Reduced coastal erosion, protection of livelihoods and settlements, and natural barrier reinforcement.

6. **Landslide-Resistant Infrastructure (LRI) – Score: 3,129**
   LRI is ranked sixth, indicating a lower relative priority or implementation feasibility. It involves slope stabilization, retaining walls, and improved drainage in landslide-prone zones.
   Key Benefits: Increased safety in mountainous areas, reduced risk to transportation routes, and protection of critical assets.

CHAPTER 4
SUMMARY AND CONCLUSION

The Technology Needs Assessment (TNA) Project for Papua New Guinea (PNG) was designed to identify, evaluate, and prioritise climate change adaptation technologies in two critical sectors: **agriculture** and **infrastructure**. Employing a **Multi-Criteria Analysis (MCA)** framework, **six adaptation technologies in each sector** were assessed against a comprehensive set of criteria, including cost, institutional and political coherence, environmental impact, social inclusion, economic potential, climate resilience, and technological readiness.

The MCA process was informed by extensive stakeholder consultations, including bilateral meetings, sectoral working groups, and validation workshops. Technology Fact Sheets were developed and iteratively refined to support informed scoring and discussion across all criteria. Final prioritisation results were reviewed and endorsed by the National Steering Committee (NSC), with support from the Climate Change and Development Authority (CCDA), UNEP, and the UNEP Copenhagen Climate Centre (UNEP-CCC).

The following technologies were ranked as priority adaptation options for PNG's agriculture and infrastructure sectors:

Agriculture Sector:
- **First-ranked technology**: Climate-Smart Agriculture (CSA) – Score: 6,327
- **Second-ranked technology:** Climate Information and Early Warning Systems (CIEWS) – Score: 5,833

Infrastructure Sector:
- **First-ranked technology**: Climate-Resilient Infrastructure (CRI) – Score: 6,608
- **Second-ranked technology**: Early Warning Systems (EWS) – Score: 6,167

These results underscore the urgent need to invest in nature-based and engineered solutions that address PNG's exposure to climate hazards and strengthen its adaptive capacity. The prioritised technologies provide a roadmap for enhancing food security, protecting infrastructure, and building climate-resilient communities.

CHAPTER 5
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CHAPTER 6
LIST OF ANNEXES

Annexe 1: List of General Stakeholders Involved

TNA WORKSHOP PARTICIANTS LIST - PNG CLIMATE CHANGE AND DEVELOPMENT AUTHORITY

DATE: 25 MARCH 2025: VENUE - CCDA

NAMES	ORGANISATION/DEPT	SIGNATURE
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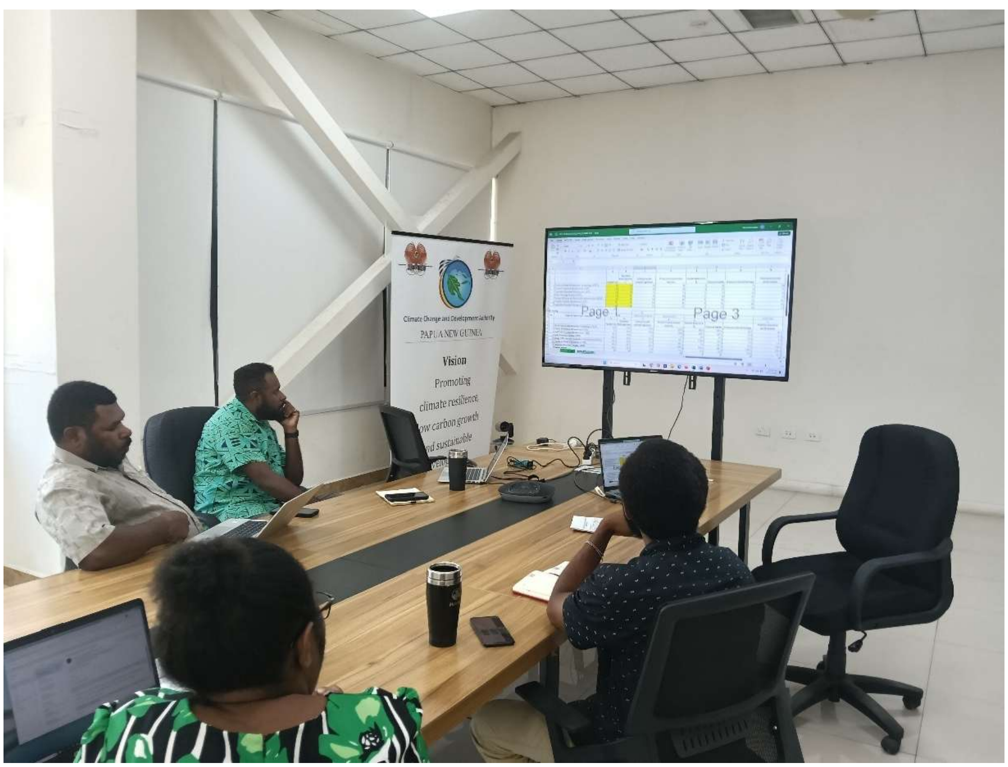
Annexe 2 Working Group Workshop



Annexe 3 Technology Factsheets for Selected Technologies - Climate-Smart Agriculture (CSA)

Climate-Smart Agriculture (CSA)	
1.0 Sector	Agriculture
2.0 Technology Characteristics	
2.1 Technology Name:	Rainwater Harvesting System
2.2 Introduction:	Background Implementing smart agriculture technology in Papua New Guinea (PNG) is essential for addressing the challenges posed by climate change, particularly in the agriculture sector. Agriculture in PNG is predominantly subsistence-based, with a majority of the population relying on it for food security and livelihoods. However, the sector is highly vulnerable to the impacts of climate change, including rising temperatures, changing rainfall patterns, extreme weather events, and sea-level rise. These factors threaten agricultural productivity and exacerbate food insecurity. Smart agriculture technologies, such as climate-resilient crops, precision farming, and sustainable land management practices, offer a pathway to enhance the resilience of smallholder farmers to these climatic challenges. By utilizing technologies like remote sensing, mobile advisory services, and automated irrigation systems, farmers can optimize inputs, maximize yields, and reduce crop losses[1].

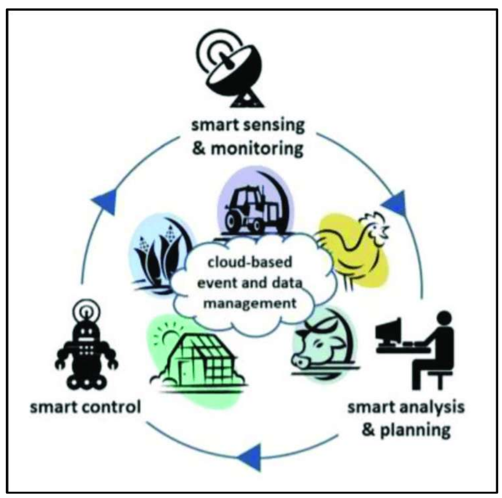


Figure The smart farm conceptual framework [2]

[1] Bourke, R.M. (2018). *Impact of climate change on agriculture in Papua New Guinea*. [online] Available at: https://www.researchgate.net/publication/327930392_Impact_of_climate_change_on_agriculture_in_Papua_New_Guinea/link/625676045eed656b74132272/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19.

[2] Delgado, J.A., Short, N.M., Roberts, D.P. and Vandenberg, B. (2019). Big Data Analysis for Sustainable Agriculture on a Geospatial Cloud Framework. *Frontiers in Sustainable Food Systems*, [online] 3. doi:https://doi.org/10.3389/fsufs.2019.00054.

	Examples of relevant technologies include precision agriculture tools like GPS and drones, real-time weather forecasting systems, mobile platforms for market and pest management information, and resilient crop varieties designed to withstand drought, floods, or other climate stressors. The implementation of these technologies aligns with efforts to make agriculture more sustainable and productive, even under changing climatic conditions[34]. **Climate Rationale for the Technology** Smart agriculture in Papua New Guinea (PNG) helps farmers adapt to climate change and protects them from its impacts. The agriculture sector relies on natural rainfall and good weather, making it sensitive to changes like rising temperatures, shifting rainfall patterns, and extreme weather. These issues reduce productivity and increase food insecurity, especially for smallholder farmers. It also improves food security and livelihoods for rural communities. To maximize benefits, it is crucial to address barriers like limited technology access and inadequate infrastructure. Tailored programs that consider PNG's diverse cultures are essential for successful smart agriculture initiatives [5]. Important smart agriculture technologies help farmers use resources more effectively and increase productivity. These include precision farming, automated irrigation, and real-time weather monitoring. For example, weather forecasts help farmers decide when to plant and harvest, which reduces losses from sudden weather changes. Using drought-resistant and flood-tolerant crops also ensures food production during tough conditions. These technologies support both adaptation to climate change and sustainability by lowering greenhouse gas emissions[6]
2.3 Technology Characteristics/ Highlights:	Implementing smart agriculture technologies in Papua New Guinea (PNG) requires careful consideration of cost and technological complexity to ensure suitability for local farmers.

[3] Delgado, J.A., Short, N.M., Roberts, D.P. and Vandenberg, B. (2019). Big Data Analysis for Sustainable Agriculture on a Geospatial Cloud Framework. *Frontiers in Sustainable Food Systems*, [online] 3. doi: https://doi.org/10.3389/fsufs.2019.00054.

[4] GSMA (2019). Landscaping New Opportunities for Digital Agriculture in Papua New Guinea. [online] Available at: https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/wp-content/uploads/2019/09/Landscaping-New-Opportunities-for-Digital-Agriculture-in-Papua-New-Guinea.pdf.

[5] Bourke, R.M. (2018). *Impact of climate change on agriculture in Papua New Guinea*. [online] Available at: https://www.researchgate.net/publication/327930392_Impact_of_climate_change_on_agriculture_in_Papua_New_Guinea/link/625676045eed656b74132272/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

[6] The World Bank (2024). *Climate-Smart Agriculture*. [online] World Bank. Available at: https://www.worldbank.org/en/topic/climate-smart-agriculture.

There are a few bullet points, i.e., low/high cost, advanced technology, low technology.	Below is a categorization of various technologies based on their cost and complexity[7]: **<u>Low-Cost, Low-Technology Solutions:</u>** 1. Agroforestry Practices: Integrating trees with crops to improve soil fertility and provide additional income sources. This practice is traditional and requires minimal financial investment. 2. Organic Farming: Utilizing natural fertilizers and pest control methods to enhance sustainability. It relies on locally available resources and indigenous knowledge. **High-Cost, Advanced Technology Solutions:** 1. Precision Agriculture Tools: Employing GPS, drones, and remote sensing for monitoring and managing crops. These technologies require significant investment and technical expertise. 2. Automated Irrigation Systems: Implementing systems that use sensors and automated controls to optimize water usage. While efficient, they involve higher costs and maintenance. **Low-Cost, Advanced Technology Solutions**: 1. Mobile-Based Advisory Services: Providing farmers with access to market information, weather updates, and best practices through mobile applications. With increasing mobile penetration, these services are becoming more accessible and affordable. 2. Weather Forecasting Tools: Offering real-time weather information to assist farmers in planning agricultural activities. These tools can be accessed via mobile devices at a relatively low cost. **High-Cost, Low-Technology Solutions:** • Infrastructure Development: Building roads, storage facilities, and markets to improve access and reduce post-harvest losses. Although not technologically complex, such infrastructure projects require substantial financial resources.
2.4 Institutional and Organizational Requirement:	• Papua New Guinea Department of Agriculture and Livestock (DAL): Coordinate research, development, and dissemination of smart agriculture practices nationwide and provide technical support and capacity-building programs for farmers and extension workers. • National Agriculture Research Institute (NARI): Research smart agriculture and collaborate with international research organisations to introduce innovative farming technologies. • Climate Change and Development Authority (CCDA): Facilitate access to international climate funds, such as the Green Climate Fund, for supporting smart agriculture

[7] Delgado, J.A., Short, N.M., Roberts, D.P. and Vandenberg, B. (2019). Big Data Analysis for Sustainable Agriculture on a Geospatial Cloud Framework. Frontiers in Sustainable Food Systems, [online] 3. doi:https://doi.org/10.3389/fsufs.2019.00054.

	projects, and monitor and evaluate the impacts of climate-smart initiatives on agricultural productivity and resilience. • Provincial and Local-Level Governments: Implement, provide logistic support and monitor agricultural programs and projects at the community level. • Non-Governmental Organizations (NGOs): Advocate for sustainable agricultural practices, and provide training and technical assistance. • International Organizations and Donors: Provide financial and technical support for smart agriculture initiatives • Private Sector and Agribusinesses: Develop and distribute smart agriculture technologies, provide market access and supply chain solutions for farmers, and invest in agricultural infrastructure, such as storage facilities and transport systems.
3.0 Implementation assumption	
3.1 Endorsement by Experts: How the technology will be implemented and diffused across sectors	The implementation and diffusion of smart agriculture technology in Papua New Guinea (PNG) require a coordinated, multi-sectoral approach. Experts emphasize that successful adoption hinges on tailored strategies that address PNG's unique socio-economic and geographic conditions. Below are the key steps and mechanisms through which smart agriculture technology can be implemented and diffused across sectors: 1. Establish a **robust policy and institutional framework**. Developing clear policies, such as the *National Agriculture Policy 2021–2030*, and introducing regulatory frameworks can encourage investments in smart agriculture while ensuring sustainable practices. Inter-agency coordination across agriculture, environment, climate change, education, and infrastructure sectors is crucial to align efforts and create a cohesive strategy. 2. **Capacity building and training** are vital to the success of smart agriculture technologies. Workshops, field demonstrations, and e-learning initiatives should be prioritized to equip farmers with the skills needed to use new technologies effectively. Strengthening agricultural extension services is essential for providing hands-on training, particularly in rural areas. 3. **Partnerships with universities, vocational centres, and technical institutions** can help develop a skilled workforce to manage and disseminate smart agriculture solutions. 4. **Infrastructure development** is a foundational requirement for scaling smart agriculture technologies. Expanding mobile and internet connectivity is essential for accessing digital platforms that provide weather updates, pest control information, and market data. 5. **Improvements to physical infrastructure**, such as roads, storage facilities, and irrigation systems, are necessary to support agricultural operations. Renewable energy solutions,

	such as solar-powered technologies, are particularly important for powering agricultural systems in remote and underserved areas. 6. **Financial support** for overcoming economic barriers to adoption. Providing subsidies and grants can help farmers afford smart agriculture tools, while microfinance schemes enable smallholder farmers to invest in technology.
3.2 Adequacy for current climate: Explain the technology could have some improvements in country environment	• Smart agriculture technologies are important for Papua New Guinea (PNG) to adapt to climate change and protect the environment. As temperatures rise and extreme weather increases, these technologies help make farming more efficient and sustainable.One key benefit is better soil and land management. Tools like soil sensors and precision farming help prevent soil damage, erosion, and nutrient loss. Practices such as agroforestry and crop rotation keep the soil healthy, which supports long-term farming success. • Smart irrigation systems, like automated drip irrigation and soil moisture sensors, help farmers use water wisely and reduce waste. This is especially important with unpredictable rainfall and droughts. Smart agriculture also helps protect forests and biodiversity. By improving the yield on existing farmland with climate-resilient crops, farmers are less likely to cut down forests, which preserves wildlife and plant life. • Real-time weather forecasts and early warning systems help farmers make quick decisions about planting and harvesting, reducing losses from extreme weather. • By using these technologies, PNG can tackle the challenges of climate change, ensuring sustainable farming while protecting its natural ecosystems for future generations.
3.3 Size of beneficiaries group: Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	• Smart agriculture technologies have the potential to reach approximately 80% of PNG's rural population, directly benefiting subsistence farmers while indirectly improving food security for urban populations.
4.0 Costs	
4.1 Cost to implement adaptation options: Capital Cost	**Agroforestry Practices** • **Capital Cost:** \$100–\$300 per hectare • **Category:** Low-cost, low-technology • **Number of Projects:** 50,000 hectares • **Total Estimated Cost:** \$15,000,000 Agroforestry integrates trees with crops to improve soil fertility and provide additional income sources. This

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low-tech solution has a modest cost, making it feasible for large-scale implementation.
Organic Farming

Capital Cost: $50–$150 per farmer
Category: Low-cost, low-technology
Number of Projects: 9,400,000 farmers
Total Estimated Cost: $1,410,000,000
This involves using natural fertilizers and pest control, relying on locally available resources. The high number of targeted farmers reflects the widespread potential adoption across PNG.

Precision Agriculture (GPS)

Capital Cost: $3,000–$10,000 per unit
Category: High-cost, advanced technology
Number of Projects: 1,000 units
Total Estimated Cost: $10,000,000
GPS technology aids in precise crop monitoring and resource management, requiring significant investment but offering advanced solutions for climate resilience.

Precision Agriculture (Drones)

Capital Cost: $5,000–$20,000 per unit
Category: High-cost, advanced technology
Number of Projects: 100 units
Total Estimated Cost: $2,000,000
Drones are utilized for crop monitoring and data collection, representing an efficient but cost-intensive technology.

Automated Irrigation Systems

Capital Cost: $1,500–$10,000 per system
Category: High-cost, advanced technology
Number of Projects: 1,000 systems
Total Estimated Cost: $10,000,000
These systems optimize water use with sensors and automation, addressing water scarcity issues and improving agricultural efficiency.

Mobile Advisory Services

Capital Cost: $10–$50 per farmer annually
Category: Low-cost, advanced technology
Number of Projects: 940 systems
Total Estimated Cost: $47,000
Mobile platforms provide farmers with market information, weather updates, and best practices at a low cost.

Weather Forecasting Tools

Capital Cost: $200–$10,000 depending on scale
Category: Low-cost, advanced technology
Number of Projects: 22 stations (one per province)
Total Estimated Cost: $1,100,000
Weather forecasting stations provide real-time data to

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	assist farmers in planning and adapting to climate variability. **Infrastructure Development (Roads)** • **Capital Cost:** $100,000–$500,000 per project • **Category:** High-cost, low-technology • **Number of Projects:** 500 kilometers of roads • **Total Estimated Cost:** $250,000,000 Road development enhances access to markets and reduces post-harvest losses, making it essential for rural agricultural development. **Infrastructure Development (Storage)** • **Capital Cost:** $10,000–$50,000 per unit • **Category:** High-cost, low-technology • **Number of Projects:** 50 storage facilities • **Total Estimated Cost:** $2,500,000 Storage facilities reduce post-harvest losses and enhance food security, ensuring better agricultural value chain management. • The overall total cost for implementing all the technologies for smart agriculture in Papua New Guinea is estimated to range between **$4.58 billion USD** (low-cost scenario) and **$12.86 billion USD** (high-cost scenario)
4.2 Additional costs to implement adaptation option, compared to "business as usual"	**1. Technology Acquisition** • Cost Estimate: $600 million–$1.8 billion USD (20% of the total 5-year cost) • Advanced technologies like GPS systems, drones, and automated irrigation systems require significant annual investments to initiate and expand implementation. **2. Capacity Building and Training** • Cost Estimate: $94 million–$376 million USD (20% of the total 5-year cost) • Training programs ensure farmers and extension workers acquire the necessary skills to adopt and implement smart agriculture technologies. **3. Infrastructure Development** • Cost Estimate: $50.5 million–$100 million USD (20% of the total 5-year cost) • Building roads, storage facilities, and other infrastructure to support smart agriculture technologies. **4. Digital and Communication Platforms** • Cost Estimate: $40 million–$80 million USD (20% of the total 5-year cost) • Investments in mobile advisory services, weather forecasting systems, and digital platforms for farmers to access information and guidance. **5. Research and Development (R&D)** • Cost Estimate: $50 million–$100 million USD

	• Annual costs for developing climate-resilient crops, sustainable farming practices, and localized solutions. **6. Monitoring and Evaluation (M&E) Systems** • Cost Estimate: $10 million–$30 million USD • Costs for operating and refining monitoring systems to track the effectiveness of smart agriculture interventions. **7. Renewable Energy Integration** • Cost Estimate: $1 million–$2 million USD • Integration of renewable energy solutions like solar-powered irrigation systems. The additional costs for implementing smart agriculture technologies in PNG over a one-year period range between **$845.5 million USD** and **$2.49 billion USD**, compared to the "business as usual" scenario. These investments address climate adaptation, productivity, and sustainability challenges in PNG's agriculture sector
4.3 Operational and Maintenance Cost	The operational and maintenance (O&M) costs for implementing smart agriculture technologies in Papua New Guinea (PNG) over a one-year period are critical to sustaining the benefits of these technologies. Below is a breakdown of the estimated O&M costs for each category: **1. Technology Acquisition (GPS, Drones)** o O&M Cost Estimate: $1.2M–$2.4M USD annually o Advanced tools such as GPS and drones require ongoing maintenance, repairs, and software updates to remain functional and effective. **2. Automated Irrigation Systems** o O&M Cost Estimate: $1M USD annually o Maintenance includes repairs of irrigation pipelines, sensors, and solar-powered components to ensure optimal water usage. **3. Roads (Infrastructure Development)** o O&M Cost Estimate: $5M–$12.5M USD annually o Regular maintenance of rural roads is essential to sustain market access and reduce post-harvest losses. **4. Storage Facilities** o O&M Cost Estimate: $125K–$250K USD annually o Maintenance includes repair and upkeep of storage units to prevent spoilage and ensure efficient use. **5. Mobile Advisory Services** o O&M Cost Estimate: $9.4M–$47M USD annually o Costs cover ongoing software updates, server maintenance, and customer support for mobile-based platforms providing farmers with information. **6. Weather Forecasting Tools** o O&M Cost Estimate: $110K–$220K USD annually o Maintenance includes recalibration of weather stations, replacement of sensors, and operational support.

	7. Solar-Powered Irrigation Systems o O&M Cost Estimate: $250K–$500K USD annually o Includes maintenance of solar panels, batteries, and irrigation infrastructure to ensure reliability. **8. Capacity Building and Training** o O&M Cost Estimate: $94M–$376M USD annually o Refresher training and support programs for farmers and extension workers to adapt to evolving technology and practices. The total O&M costs for smart agriculture technologies in PNG for a one-year period range from **$111.09M** to **$440.87M USD**, depending on the scale and complexity of the systems deployed. These costs reflect the need for consistent maintenance, infrastructure support, and training to sustain the technologies and their benefits
4.4 cost of GHG reduction	• Implementing smart agriculture in Papua New Guinea (PNG) offers significant potential for reducing greenhouse gas (GHG) emissions through various mechanisms. Practices such as agroforestry and conservation agriculture enhance soil carbon sequestration, increasing carbon storage in soils. Precision farming techniques reduce excessive fertilizer use, thereby lowering nitrous oxide emissions. Improved livestock management and the adoption of methane-reducing feed additives contribute to methane emission reductions. Additionally, integrating renewable energy sources, like solar-powered irrigation, enhances energy efficiency by reducing reliance on fossil fuels. The GHG reduction potential of smart agriculture is estimated at approximately 0.5 to 2 tons of CO_2 equivalent (CO_2e) per hectare per year, depending on the specific practices implemented[8]. • With approximately 6 million hectares of agricultural land in PNG, applying smart agriculture technologies to 80% of this area—equivalent to 4.8 million hectares—could result in substantial emission reductions. The implementation costs for these technologies are projected to range between $4.23 billion and $12.44 billion USD over a 5-year period, emphasizing the need for strategic investment and large-scale adoption to achieve climate goals[9].
4.5 lifetime	a comprehensive smart agriculture system in PNG, the implementation lifetime is expected to be 15–25 years, assuming: • Regular maintenance is performed.

[8] www.mckinsey.com. (2023).What climate-smart agriculture means for smallholder farmers | McKinsey. [online] Available at: https://www.mckinsey.com/industries/agriculture/our-insights/what-climate-smart-agriculture-means-for-smallholder-farmers

[9] Climate-Smart Agriculture a Call to Action. (213). Available at: https://www.worldbank.org/content/dam/Worldbank/document/CSA_Brochure_web_WB.pdf.

	• Components like tools, systems, and infrastructure are upgraded periodically.
5.0 Benefits	
5.1 <u>Development impact, indirect /benefits</u>	• Improved Food Security: Enhanced agricultural productivity ensures reliable food supplies for PNG's growing population. • Rural Development: Infrastructure development, such as roads and storage facilities, supports local economies and improves market access. • Technology Adoption: Exposure to modern farming practices builds the capacity of farmers and strengthens PNG's agricultural sector. • Climate Resilience: Adoption of climate-smart practices reduces the vulnerability of rural communities to extreme weather events..
5.2 Economic benefits:	• Increased Productivity: Precision farming and improved resource management lead to higher yields and reduced waste. • Cost Savings: Efficient use of water, fertilizers, and energy lowers input costs for farmers. • Market Access: Enhanced connectivity and infrastructure enable farmers to sell products at competitive prices, increasing incomes. • Job Creation: Technology-driven agriculture creates opportunities for employment in services such as equipment maintenance, advisory services, and agribusiness.
5.3 Social benefits:	• Poverty Reduction: Improved incomes from increased productivity and market access help alleviate poverty in rural areas. • Empowered Communities: Training and education initiatives build local capacities and foster self-reliance among farmers. • Gender Inclusion: Technology and training programs provide opportunities for women in agriculture, promoting gender equality. • Health and Nutrition: Improved crop diversity and productivity contribute to better nutrition and health outcomes.
5.4 Environment benefits:	• Sustainable Land Use: Practices like agroforestry and conservation agriculture prevent soil erosion and improve soil fertility. • Reduced GHG Emissions: Efficient farming practices, renewable energy adoption, and reduced fertilizer use contribute to lower greenhouse gas emissions. • Biodiversity Conservation: Preservation of forests and integration of sustainable practices protect PNG's rich biodiversity.

	• Water Conservation: Smart irrigation systems optimize water usage, ensuring sustainable resource management..
6.0 Local context	
6.1 Opportunities and Barriers: Barriers to implementation and issues such as the need to adjust other policies.	Opportunities 1. Climate Change Adaptation and Resilience • Smart agriculture helps mitigate the impacts of climate change, such as erratic rainfall and extreme weather, by improving resource efficiency and introducing climate-resilient crops. • Opportunity to leverage international climate finance (e.g., Green Climate Fund) for adaptation initiatives. 2. Technology Advancements • Growing availability of low-cost technologies like mobile advisory platforms and IoT-based sensors makes adoption more feasible. • Increasing penetration of mobile networks in rural areas provides a platform for digital agricultural solutions. 3. Market Access and Value Chain Development • Improved infrastructure, storage, and logistics offer opportunities to connect farmers with larger markets and reduce post-harvest losses. • Potential to develop export-oriented agriculture sectors with higher-value crops. 4. Capacity Building and Education • Opportunity to train farmers in modern practices, creating a skilled workforce and fostering innovation in the agricultural sector. 5. Government and Donor Support • National policies like the National Agriculture Policy 2021–2030 prioritize smart agriculture. • Strong partnerships with international donors, NGOs, and the private sector can drive implementation. 6. Environmental Conservation • Agroforestry and conservation agriculture reduce deforestation and promote sustainable land use, aligning with global sustainability goals. • Smart agriculture supports biodiversity preservation through sustainable practices. 7. Economic Growth Potential • Increased productivity and efficiency create opportunities for agribusiness and entrepreneurship, boosting rural economies. Barriers 1. Limited Infrastructure • Inadequate roads, storage facilities, and irrigation systems hinder access to markets and adoption of advanced technologies.

	2. High Initial Costs • Significant upfront investment required for precision farming tools, automated systems, and infrastructure development may be unaffordable for many farmers. 3. Lack of Awareness and Training • Limited understanding of smart agriculture technologies among farmers and a lack of skilled extension workers to provide technical support. 4. Digital Divide • Poor connectivity in remote areas limits the reach of mobile-based advisory services and real-time weather forecasting tools. 5. Cultural and Linguistic Diversity • PNG's diverse cultural landscape requires tailored solutions that consider local traditions, languages, and farming practices. 6. Land Tenure Issues • Complex customary land ownership systems can pose challenges for land use planning and implementation of large-scale smart agriculture projects. 7. Limited Access to Finance • Smallholder farmers often lack access to credit and financial resources to invest in new technologies. 8. Climate Risks • The increasing frequency and intensity of extreme weather events could disrupt implementation efforts and damage infrastructure.
6.2 Status: Status of technology in the country	The status of Climate-Smart Agriculture (CSA) technologies in PNG is mixed. Low-cost solutions like agroforestry and composting are being adopted, but medium- and high-cost technologies, such as cold storage and precision agriculture, are still rare due to high costs, limited infrastructure, and technical challenges. Progress is being made through policies and training programs, but more support is needed to scale these technologies. Improved funding, stronger policies, and better infrastructure can help farmers and businesses adopt CSA technologies and reduce the impact of climate change on agriculture
6.3 Timeframe: Specify timeframe for implementation	Short-term (1-2 years): Awareness and education programs can be launched to inform communities about the benefits of rainwater harvesting and provide training on system maintenance. 1. Short-Term (1–3 Years) : Focus on groundwork, pilot projects, and capacity building. Activities: • Conduct baseline assessments of existing agricultural practices, infrastructure, and climate challenges.

	• Implement pilot projects to test low-cost and low-technology solutions, such as agroforestry, organic farming, and basic irrigation systems. • Establish mobile advisory services and weather forecasting tools for targeted regions. • Build farmer awareness and provide training programs on smart agriculture practices. • Strengthen government policies and strategies, such as the National Agriculture Policy 2021–2030, to integrate smart agriculture into development plans. Expected Outcomes: • Initial adoption of climate-smart practices by a subset of farmers. • Improved understanding of technology suitability and challenges. 2. Medium-Term (4–10 Years) : Expand adoption and strengthen infrastructure and institutional support. Activities: • Scale up successful pilot projects to cover larger areas and more farmers. • Introduce advanced technologies such as precision farming tools (GPS, drones, IoT-based sensors) and automated irrigation systems. • Develop essential infrastructure, including roads, storage facilities, and renewable energy systems, to support smart agriculture. • Enhance digital platforms for real-time market, weather, and advisory services. • Build partnerships with the private sector, NGOs, and international donors to secure funding and technical expertise. • Launch research and development (R&D) initiatives for localized climate-resilient crop varieties. Expected Outcomes: • Widespread adoption of smart agriculture practices across PNG's major agricultural regions. • Increased productivity, reduced environmental impact, and enhanced farmer incomes. • Significant improvements in infrastructure and institutional capacity. 3. Long-Term (11–20 Years) : Achieve full integration and sustainability of smart agriculture technologies. Activities: • Expand smart agriculture technologies to all agricultural regions, ensuring inclusivity for smallholder farmers. • Establish robust monitoring and evaluation (M&E) systems to track progress and refine strategies.

	• Foster continuous innovation in agricultural technologies and practices through R&D. • Institutionalize capacity-building programs to ensure sustained knowledge transfer to future generations of farmers. • Integrate PNG's agricultural systems into global markets by producing high-quality, climate-smart products. Expected Outcomes: • Full implementation of smart agriculture technologies nationwide. • Sustainable and resilient agricultural systems adapted to climate change. • Enhanced food security, environmental conservation, and rural economic growth.
6.4 Acceptability to local stakeholders: Where the technology will be attractive to stakeholders	The overall acceptability of smart agriculture technologies in PNG is **medium to high**, depending on the stakeholder group. Low-cost, easily adaptable technologies have a higher likelihood of acceptance, whereas advanced and high-cost technologies may face resistance without sufficient funding, capacity building, and awareness campaigns.

Annexe 4 Technology Factsheets for Selected Technologies - Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB)

Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB)	
1.0 Sector	Agriculture
2.0 Technology Characteristics	
2.1 Technology Name:	**Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB)**
2.2 Introduction:	**<u>Background</u>** Papua New Guinea (PNG) is confronting considerable agricultural challenges due to its heightened vulnerability to climate change impacts. The country is experiencing rising temperatures, which can affect crop yields and livestock health. Erratic rainfall patterns are causing uncertainty in water availability, making it difficult for farmers to plan their planting and harvesting schedules. Prolonged droughts have led to water shortages, negatively impacting food production and securing livelihoods for many rural communities. Additionally, extreme weather events like floods and cyclones pose further threats by damaging infrastructure, destroying crops, and displacing farming families.As these environmental challenges intensify, there is a pressing need for adaptive strategies and support to help communities manage the impacts of climate change on their agricultural practices.[10]. To achieve long-term food security and enhance resilience to climate change, it is crucial to adopt Climate-Resilient Crop Varieties (C-RCVs). These varieties are specifically developed to thrive under changing environmental conditions, such as increased temperatures, unpredictable rainfall, and the prevalence of pests and diseases. Additionally, establishing robust Seed Banking (SB) systems is vital for preserving the genetic diversity of these C-RCVs. Such systems enable the long-term storage of seeds, ensuring that they remain available for future planting and can be accessed during times of agricultural distress. By prioritizing both the adoption of C-RCVs and the development of seed banks, we can create a more sustainable agricultural framework that safeguards food resources and supports farmers in adapting to climate challenges. [11]. **<u>Climate Rationale for the Technology</u>** Papua New Guinea (PNG), highly vulnerable to climate change due to its dependence on subsistence agriculture and exposure to extreme weather, requires robust strategies to ensure agricultural resilience. Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB) technologies are vital for

[10] GoPNG (2023). PAPUA NEW GUINEA NATIONAL ADAPTATION PLAN. [online] Papua New Guinea: Climate Change and Development Authority Port Moresby. Available at: https://unfccc.int/documents/628062

[11] Henry, D. (2023). Q&A: Seedbanks – critical for climate adaptation - CIFOR-ICRAF Forests News. [online] CIFOR-ICRAF Forests News. Available at: https://forestsnews.cifor.org/84624/seed-banks-critical-for-climate-adaptation

	adapting to erratic rainfall, rising temperatures, and extreme weather events, ensuring stable crop production and recovery pathways for farmers. These technologies address food security by enhancing yields under suboptimal conditions and supporting nutritional diversity. They also preserve PNG's unique agro-biodiversity, enabling future breeding efforts and ecosystem resilience. By safeguarding livelihoods, improving community-based seed access, and aligning with global commitments like the Paris Agreement and Sustainable Development Goals (SDGs), C-RCVs and SB technologies are integral to PNG's long-term climate adaptation and sustainable development.
2.3 Technology Characteristics/ Highlights: There are a few bullet points, i.e., low/high cost, advanced technology, low technology.	Low-cost, low-technology options for implementing Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB) in PNG focus on accessible, community-driven solutions. **Community-based seed banks** are simple systems for collecting, storing, and distributing seeds, promoting farmer-led conservation and reducing dependency on external inputs. Similarly, **traditional crop breeding** leverages local knowledge to select resilient varieties, ensuring minimal costs and increasing acceptability among farmers by building on existing practices. Medium-cost, medium-technology options provide scalable and impactful solutions. **Regional seed banks** serve as centralized facilities for long-term seed storage, supporting disaster recovery and ensuring the availability of diverse crop varieties. Additionally, **improved irrigation systems**, such as drip irrigation, enhance the growth of resilient crops by optimizing water use in drought-prone areas, contributing to better resource efficiency. High-cost, advanced technology options are focused on long-term sustainability and scientific precision. **Cryopreservation and genetic seed banking** utilize ultra-low temperature storage to preserve rare and indigenous genetic material, critical for future breeding efforts. **Genetic engineering and biotechnology**, employing tools like CRISPR and marker-assisted selection, enable the precise development of crop varieties tailored to specific climate stresses, offering significant potential for climate adaptation despite their higher costs and complexity
2.4 Institutional and Organizational Requirement:	The successful implementation of Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB) technologies in Papua New Guinea (PNG) hinges on a robust institutional and organizational framework. This begins with a strong policy and regulatory framework that integrates these technologies into PNG's National Agriculture Policy (2021–2030), the National Adaptation Plan, and climate strategies. Clear guidelines for seed conservation, crop breeding, and biotechnology are essential, supported by regulations to ensure seed quality and safety. Government agencies like the Department of Agriculture and Livestock (DAL), Climate Change and Development Authority (CCDA), and the National Agriculture Research Institute (NARI) must coordinate efforts, allocate resources, and facilitate access to international funding mechanisms such as the Green Climate Fund. Research and development (R&D) are critical for tailoring climate-resilient crops to PNG's diverse agroecological zones. Institutions like NARI should advance techniques in cryopreservation and genetic seed banking, while

	collaborations with international organizations such as CGIAR and FAO can bring cutting-edge expertise and funding to the table. Capacity building is equally important, with training programs for farmers on sustainable practices, participatory breeding, and seed preservation. Expanding agricultural extension services will also enable farmers to adopt new technologies effectively. Infrastructure development is foundational. A tiered network of community-based, regional, and national seed banks equipped with proper storage and transport facilities is needed. This includes a national cryopreservation facility for rare genetic material and improved irrigation systems, such as drip irrigation, to support resilient crop growth in drought-prone areas. Community engagement is essential for success. Local leaders and farmer organizations should be involved in decision-making to foster trust and participation. Participatory breeding initiatives can ensure that the technologies are relevant to local needs. Awareness campaigns will educate communities about the benefits of C-RCVs and SB technologies. Monitoring, evaluation, and reporting systems must be established to track progress, measure impacts, and refine strategies. Platforms for stakeholder feedback will further improve implementation.
3.0 Implementation Assumption	
3.1 Endorsement by Experts: How the technology will be implemented and diffused across sectors	• Experts endorse the multi-pronged approach for the implementation and diffusion of Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB) technologies in PNG. Their support highlights the importance of integrating these technologies across economic, scientific, and community frameworks to address climate challenges effectively. • The implementation and diffusion of Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB) technologies in Papua New Guinea (PNG) require a multi-sectoral and phased approach. This strategy incorporates policy integration, research and development (R&D), capacity building, infrastructure development, and community engagement to address climate challenges effectively. **1. Policy and Institutional Framework** **Integration into National Policies**:Incorporate C-RCVs and SB technologies into PNG's National Agriculture Policy (2021–2030) and climate adaptation strategies to align efforts across sectors. **Institutional Coordination**: Collaboration between key government agencies such as the Department of Agriculture and Livestock (DAL), Climate Change and Development Authority (CCDA), and the National Agriculture Research Institute (NARI) ensures policy alignment and program implementation. **International Partnerships**:Leverage funding from global mechanisms like the Green Climate Fund to finance initiatives. **2. Research and Development (R&D)** **Tailored Crop Varieties**: Develop resilient crop varieties suited to PNG's diverse agroecological zones, addressing specific climate stresses like drought, flooding, or salinity.

	Seed Conservation Technology: Utilize advanced seed banking techniques, such as cryopreservation, to preserve rare and indigenous genetic material for future breeding. **Global Collaboration**: Partner with organizations like CGIAR and FAO to access cutting-edge technology and expertise. **3. Capacity Building and Knowledge Sharing** **Training Programs**: Train farmers, extension workers, and seed bank managers on C-RCVs and SB technologies. **Knowledge Platforms**: Establish platforms for sharing knowledge, best practices, and research findings among stakeholders. **Education and Awareness**: Conduct awareness campaigns to promote the importance of resilient crops and seed banks. **4. Infrastructure Development** **Seed Bank Network**: Create a tiered network of community-based, regional, and national seed banks to ensure accessibility and scalability. **Storage and Transport**: Develop infrastructure for efficient seed storage and transport, including cold storage facilities where necessary. **Digital Platforms**: Implement digital tools to connect farmers with resources, monitor seed bank inventories, and streamline distribution. **5. Community Engagement** **Participatory Breeding Initiatives**: Involve farmers in the selection and breeding of climate-resilient varieties to ensure relevance and adoption. **Local Leadership**: Engage community leaders and farmer organizations to foster trust and encourage participation. **Cultural Integration**: Align efforts with local traditions and knowledge to enhance acceptance and sustainability. **6. Cross-Sectoral Integration** **Agriculture and Education**: Include climate-resilient agriculture in school curriculums to build awareness among younger generations. **Health Sector**: Link food security improvements from resilient crops to better nutritional outcomes. **Private Sector Involvement**: Partner with businesses to scale seed bank operations and invest in resilient crop production. **7. Monitoring and Evaluation** **Progress Tracking**: Implement monitoring systems to evaluate the effectiveness of C-RCVs and SB initiatives, refine strategies, and ensure long-term sustainability. **Impact Assessment**: Conduct regular assessments to measure the impact on climate resilience, food security, and agricultural productivity.
3.2 Adequacy for current climate: Explain the technology could have some improveme	• The implementation of Climate-Resilient Crop Varieties (C-RCVs) and Seed Banking (SB) technologies has the potential to significantly improve Papua New Guinea's (PNG) environment. By conserving biodiversity, these technologies protect indigenous plant species, ensuring ecological stability and maintaining the genetic diversity critical for future adaptation. Community-based and cryopreserved seed banks safeguard rare and endangered species, preventing their extinction. Similarly, the adoption of

nts in country environment	resilient crop varieties reduces reliance on monocropping, fostering diverse agricultural ecosystems that enhance ecological balance[12]. • Sustainable land and water management are additional benefits. Drought-tolerant crops and improved irrigation systems, such as drip irrigation, optimize water use, reducing pressure on water resources in vulnerable areas. Soil erosion and salinity-resistant crops enhance soil health and minimize the need for chemical inputs, further protecting natural resources. Additionally, the development of high-yielding, resilient crops reduces the need for agricultural expansion, preventing deforestation and land degradation. These measures collectively support the preservation of forests, which are vital for carbon sequestration and climate regulation[13]
3.3 Size of beneficiaries group: Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	• **Entire Population Benefit**: The WRS would serve all residents of Papua New Guinea (around 1,600 to 2,000 people), ensuring reliable access to clean water for daily needs. • **Support for Key Sectors**: The system would aid farmers, businesses, and industries by providing consistent water supply, boosting agriculture, food security, and economic growth. • **Enhanced Public Services**: Public institutions like schools and healthcare centers would benefit from reliable water access, improving community services and overall welfare.
4.1 Cost to implement adaptation options: Capital Cost	**1. Low-Cost, Low-Technology Options** **Community-Based Seed Banks:** • Capital Cost: USD $500–$5,000 per seed bank • Quantity: 500–1,000 seed banks • Total Estimated Cost: USD $250,000–$5,000,000 • These seed banks will be distributed in rural villages or farming clusters, ensuring localized seed access and reducing dependency on external sources. **Traditional Crop Breeding Programs:** • Capital Cost: USD $1,000–$10,000 per program

[12] Fao.org. (2025). Available at: https://openknowledge.fao.org/server/api/core/bitstreams/2a93b016-586d-4cac-93d9-7b0c8ece96fa [Accessed 19 Jan. 2025].
[13] PACC -PNG. (n.d.). Available at: https://www.sprep.org/attachments/Climate_Change/PACC/5th_MPR_Meeting_2014/country_presentations/PACC_MPR_2014_PNG.pdf [Accessed 19 Jan. 2025].

- Quantity: 50–100 programs
- Total Estimated Cost: USD $50,000–$1,000,000
- Each program will focus on developing climate-resilient crops tailored to PNG's diverse agroecological zones.

2. Medium-Cost, Medium-Technology Options

Regional Seed Banks:

- Capital Cost: USD $50,000–$250,000 per facility
- Quantity: 10–20 facilities
- Total Estimated Cost: USD $500,000–$5,000,000
- Regional seed banks will act as centralized hubs for long-term seed storage, serving multiple communities or provinces.

Improved Irrigation Systems (e.g., Drip Irrigation):

- Capital Cost: USD $500–$2,500 per hectare
- Quantity: 10,000–20,000 hectares equipped
- Total Estimated Cost: USD $5,000,000–$50,000,000
- Focused on drought-prone areas, these systems will optimize water use and improve agricultural productivity.

3. High-Cost, Advanced Technology Options

Cryopreservation and Genetic Seed Banking Facilities:

- Capital Cost: USD $100,000–$500,000 per facility
- Quantity: 1–3 facilities
- Total Estimated Cost: USD $100,000–$1,500,000
- A national cryopreservation facility, with potential satellite centers, will preserve rare and indigenous genetic material for long-term use.

Genetic Engineering and Biotechnology Programs:

- Capital Cost: USD $1,000,000–$5,000,000 per program
- Quantity: 3–5 programs
- Total Estimated Cost: USD $3,000,000–$25,000,000
- These programs will focus on staple crops like sweet potato, taro, and rice, leveraging advanced tools like CRISPR to enhance climate resilience.

The combined capital cost for implementing these technologies in PNG ranges from **$8.9 million to $87.5 million**, depending on the scale and complexity of deployment. This phased approach prioritizes affordable community-driven solutions while strategically investing in high-cost, advanced technologies to ensure long-term sustainability and climate resilience.

4.2 Additional costs to implement adaptation option, compared to “business as usual”

Technology	**BAU Practices**	**Incremental Cost Justification**	**Quantity**	**Additional Cost per Unit**	**Total Incremental Cost (USD)**
Community-Based Seed Banks	Informal seed-saving practices	Reliable infrastructure reduces crop	500–1,000 seed banks	$500–$5,000	$250,000 – $5,000,000

		failure risk.			
Traditional Crop Breeding	Natural selection with no scientific inputs	Systematic breeding ensures climate resilience.	50–100 programs	$1,000–$10,000	$50,000–$1,000,000
Regional Seed Banks	Local seed systems	Centralized hubs ensure long-term seed availability.	10–20 facilities	$50,000–$250,000	$500,000–$5,000,000
Improved Irrigation Systems	Rain-fed or inefficient irrigation	Optimized systems improve water efficiency.	10,000–20,000 hectares	$500–$2,500 per hectare	$5,000,000–$50,000,000
Cryopreservation Facilities	Conventional seed banks	Advanced storage preserves rare genetic material.	1–3 facilities	$100,000–$500,000	$100,000–$1,500,000
Genetic Engineering Programs	Traditional breeding	Precision breeding addresses climate-specific issues.	3–5 programs	$1,000,000–$5,000,000	$3,000,000–$25,000,000
Policy and Institutional Costs	Weak or fragmented frameworks	Policy integration ensures sustainability.	National coordination	$500,000–$1,000,000	$500,000–$1,000,000
Training Programs	Minimal farmer training	Capacity building promotes technology adoption.	50–200 programs	$50,000–$200,000	$2,500,000–$40,000,000

The total incremental cost of implementing these adaptation options ranges from **$11.9 million to $128.5 million**, depending on the scale and depth of the interventions. These investments are critical for addressing climate resilience, improving agricultural productivity, and ensuring sustainable development in Papua New Guinea.

4.3 Operational and Maintenance Cost	**1. Low-Cost, Low-Technology Options** **Community-Based Seed Banks**: • **Quantity**: **500–1,000 seed banks** • **O&M Cost per Unit**: USD **$100–$500** annually. • **Total Annual Cost**: USD **$50,000–$500,000**. • Includes seed inventory management, basic maintenance, and local staff wages. **Traditional Crop Breeding Programs**: • **Quantity**: **50–100 programs** • **O&M Cost per Unit**: USD **$500–$2,000** annually. • **Total Annual Cost**: USD **$25,000–$200,000**. • Covers field trials, ongoing training, and farmer collaboration. **2. Medium-Cost, Medium-Technology Options** **Regional Seed Banks**: • **Quantity**: **10–20 facilities** • **O&M Cost per Unit**: USD **$10,000–$50,000** annually. • **Total Annual Cost**: USD **$100,000–$1,000,000**. • Includes utility bills (electricity for climate control), facility upkeep, and staff salaries. **Improved Irrigation Systems (e.g., Drip Irrigation)**: • **Quantity**: **10,000–20,000 hectares equipped** • **O&M Cost per Hectare**: USD **$50–$150** annually. • **Total Annual Cost**: USD **$500,000–$3,000,000**. • Includes maintenance of irrigation equipment and periodic system checks. **3. High-Cost, Advanced Technology Options** **Cryopreservation and Genetic Seed Banking Facilities**: • **Quantity**: **1–3 facilities** • **O&M Cost per Unit**: USD **$20,000–$100,000** annually. • **Total Annual Cost**: USD **$20,000–$300,000**. • Covers electricity (liquid nitrogen systems), equipment maintenance, and highly skilled technical staff. **Genetic Engineering and Biotechnology Programs**: • **Quantity**: **3–5 programs** • **O&M Cost per Unit**: USD **$100,000–$500,000** annually. • **Total Annual Cost**: USD **$300,000–$2,500,000**. • Includes lab operations, consumables (e.g., reagents), and research staff wages. **4. Policy and Institutional Costs** **Policy and Institutional Framework**: • **Annual Cost**: USD **$100,000–$500,000**. • Covers policy monitoring, stakeholder meetings, and coordination among government agencies. **Training and Capacity Building**: • **Quantity**: **50–200 training programs annually** • **Cost per Program**: USD **$5,000–$20,000** annually. • **Total Annual Cost**: USD **$250,000–$4,000,000**.

	• Includes training materials, workshops, and follow-up support. The annual operational and maintenance costs for these technologies range from **$1.3 million to $12 million**, depending on the scale and complexity of the adaptation measures. These recurring costs are necessary to ensure the long-term functionality, sustainability, and effectiveness of the C-RCVs and SB technologies in PNG
4.4 cost of GHG reduction	The cost of reducing greenhouse gas (GHG) emissions in Papua New Guinea (PNG) depends on the technology used and the scale of the project. Low-cost options include community seed banks and traditional crop breeding. These methods increase crop resilience and reduce the need for fertilisers. They can reduce emissions by 0.1 to 1 ton of CO_2e each year per unit, the Medium-cost options, like regional seed banks and better irrigation systems, can cut emissions by 0.1 to 5 tons of CO_2e annually per unit. And the high-cost options can lower emissions by 5 to 20 tons of CO_2e each year per facility[14] [15] [16]. Papua New Guinea's NDC is in line with the National Climate Compatible Development Management Policy which aims to reduce greenhouse gas emissions to 50 percent by 2030 against the 2015 baseline and to be carbon neutral by 2050. The Second NDC commits to increase level of renewables in the energy mix to 78 percent of the installed capacity, up from 30 percent in 2015. It also pledges to reduce 860 gigatons of CO2 equivalent emissions from deforestation and forest importation, and to attain a total forest carbon stock value of 17.6 billion tons CO2 by 2030[17].
4.5 lifetime	• The lifetime of these technologies varies widely, from short-term programs (5–15 years) to durable infrastructure solutions (20–50 years). Longevity depends on consistent maintenance, adequate funding, and regular upgrades, ensuring the long-term sustainability of C-RCVs and SB initiatives in PNG.
5.1 Development impact, indirect /benefits	• **Strengthened Food Security**: Improved access to resilient crops and diverse seeds ensures consistent agricultural productivity, reducing the risk of hunger and malnutrition. • **Climate Adaptation**: Enhances the ability of PNG's agriculture sector to withstand climate challenges, such as droughts, floods, and pest outbreaks. • **Biodiversity Conservation**: Protects indigenous plant species, preserving genetic diversity critical for long-term resilience. • **Capacity Building**: Training programs and knowledge-sharing initiatives empower farmers, researchers, and local communities.

[14] Popova, E., Shukla, M., Kim, H.H. and Saxena, P.K. (2015). Plant Cryopreservation for Biotechnology and Breeding. *Advances in Plant Breeding Strategies: Breeding, Biotechnology and Molecular Tools*, pp.63–93. doi:https://doi.org/10.1007/978-3-319-22521-0_3.

[15] Geyik, Ö., Hadjikakou, M. and Bryan, B.A. (2022). Climate-friendly and nutrition-sensitive interventions can close the global dietary nutrient gap while reducing GHG emissions. Nature Food. doi:https://doi.org/10.1038/s43016-022-00648-y.

[16] Laborde, D., Mamun, A., Martin, W., Piñeiro, V. and Vos, R. (2021). Agricultural subsidies and global greenhouse gas emissions. Nature Communications, 12(1). doi:https://doi.org/10.1038/s41467-021-22703-1.

[17] Ndcpartnership.org. (2015). *Papua New Guinea | NDC Partnership*. [online] Available at: https://ndcpartnership.org/country/png [Accessed 19 Jan. 2025].

	• **Institutional Strengthening**: Policy integration and infrastructure development improve governance and coordination in the agricultural sector.
5.2 Economic benefits:	• **Increased Crop Yields**: Resilient crop varieties improve productivity, translating into higher incomes for farmers. • **Cost Savings**: Reduced reliance on external inputs like fertilizers and pesticides lowers production costs. • **Disaster Recovery**: Seed banks provide a safety net for rapid agricultural recovery after natural disasters, minimizing economic losses. • **Job Creation**: Implementation of seed banks, breeding programs, and irrigation systems generates employment in farming, research, and infrastructure development. • **Market Opportunities**: Promotes trade and export of high-quality, resilient crops, boosting PNG's agricultural economy
5.3 Social benefits:	• **Community Empowerment**: Community-based seed banks and participatory breeding initiatives foster local ownership and engagement. • **Improved Nutrition**: Diverse and resilient crops enhance food availability and dietary quality, addressing malnutrition. • **Knowledge Transfer**: Training programs enhance local skills, ensuring long-term benefits for farmers and agricultural workers.
5.4 Environment benefits:	• **Reduced Deforestation**: High-yielding, resilient crops minimize the need for agricultural expansion into forested areas. • **Soil and Water Conservation**: Improved irrigation systems and resilient crop varieties reduce soil erosion and optimize water use. • **Lower GHG Emissions**: Reduced reliance on fertilizers, pesticides, and energy-intensive farming practices minimizes agricultural emissions.
6.1 Opportunities and Barriers: Barriers to implementation and issues such as the need to adjust other policies.	Opportunities 1. Climate Adaptation Potential: C-RCVs and SB technologies enhance agriculture's resilience to climate change impacts such as droughts, floods, and pests. The technologies offer long-term solutions to sustain food security and agricultural productivity. 2. Global Support for Climate Action: Access to international funding mechanisms, such as the Green Climate Fund and Global Environment Facility (GEF), supports the implementation of climate adaptation technologies. 3. Community Engagement: Local farmers are actively involved in seed conservation and crop breeding, leveraging indigenous knowledge and promoting ownership. 4. Advances in Agricultural Technologies: Innovations such as genetic engineering (e.g., CRISPR) and cryopreservation open pathways for more precise and effective climate-resilient solutions. 5. Biodiversity Conservation: Seed banking supports the preservation of indigenous crop varieties, which are critical for maintaining ecosystem health and agricultural diversity. 6. Policy Momentum: PNG's existing policies, such as the National Agriculture Policy (2021–2030) and climate adaptation strategies, provide a foundation for integrating these technologies. Barriers to Implementation

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1. Policy and Regulatory Challenges: Inadequate alignment of agricultural, environmental, and climate policies hinders coordinated implementation, and Lack of seed certification frameworks and biotechnology regulations delays adoption.
2. Institutional Weaknesses: Limited capacity and resources in key government institutions like the Department of Agriculture and Livestock (DAL) and the Climate Change and Development Authority (CCDA) slow progress; and Weak coordination among stakeholders results in duplication of efforts and resource inefficiencies.
3. High Initial Costs: Advanced technologies such as cryopreservation and genetic engineering require significant capital investments, making them less accessible for immediate implementation.
4. Technical Knowledge Gaps: Insufficient expertise in advanced technologies like CRISPR, marker-assisted selection, and cryopreservation limits their deployment; and Farmers lack training on the use and maintenance of technologies such as improved irrigation systems.
5. Community Acceptance: Resistance to adopting new technologies due to cultural preferences, lack of awareness, or skepticism about benefits.
6. Infrastructure Deficits: Lack of adequate storage facilities, transport systems, and reliable energy sources hampers the establishment of seed banks and irrigation systems.
7. Climate Finance Accessibility: Bureaucratic processes and technical requirements limit PNG’s ability to access and utilize international climate funding efficiently.
</td></tr>
<tr><td>6.2 Status:

Status of technology in the country</td><td>PNG has progressed in some areas (from early stage to developing) of C-RCVs and SB technologies, but significant gaps remain in infrastructure, technical expertise, and policy implementation. Focused investments, capacity building, and policy alignment are critical to advancing these technologies to higher levels of adoption and impact</td></tr>
<tr><td>6.3 Timeframe:

Specify the timeframe for implementation</td><td>
• Short-Term (1–3 Years)
  o Community-based seed banks, traditional crop breeding, policy integration, initial training programs.
  o Focus on: Awareness, foundational infrastructure, and pilot testing.
• Medium-Term (4–7 Years)
  o Regional seed banks, improved irrigation systems, advanced training programs.
  o Focus on : Scaling low- and medium-cost solutions, regional expansion.
• Long-Term (8–15 Years)
  o Cryopreservation, genetic engineering, advanced R&D, institutional strengthening.
  o Focus : High-cost technologies, sustainability, and full integration.
</td></tr>
<tr><td>6.4 Acceptability to local stakeholders:</td><td>The level of attractiveness for C-RCVs and SB technologies is high to very high for most stakeholders, particularly farmers, community leaders, the government, and research institutions. The private sector's engagement is moderate but can be enhanced with financial incentives and partnerships.</td></tr>
</table>

Where the technology will be attractive to stakeholder s	These technologies highly attract international donors due to their alignment with global biodiversity and climate adaptation goals

Annexe 5 Technology Factsheets for Selected Technologies - Post-Harvest Management (PHM)

<table>
<tr><th colspan="2">Post-Harvest Management (PHM)</th></tr>
<tr><td>1.0 Sector</td><td>Agriculture</td></tr>
<tr><td colspan="2">2.0 Technology Characteristics</td></tr>
<tr><td>2.1 Technology Name:</td><td>Post-Harvest Management (PHM)</td></tr>
<tr><td>2.2 Introduction:</td><td><u>Background</u>
PHM is essential in Papua New Guinea (PNG) to reduce agricultural losses, ensure food security, and improve farmers' incomes. Post-harvest management in Papua New Guinea (PNG) involves the activities that take place after a crop is harvested to preserve and add value to the agricultural commodities. These activities include storage, processing, packaging, handling, and transportation[18]. JICA has already started the PHM initiatives like rice post-harvest techniques developed which focus on harvesting, drying, milling, and storage to improve rice quality and reduce losses[19]. Sustainable pre-cooling and cold storage technologies, such as solar chillers, have also been introduced through projects like those from Black Stump Technologies to address post-harvest challenges in remote areas[20].

Stages of a whole post-harvest system (Spurgeon, 1977)[21]
<table>
<tr><td>(01)</td><td>HARVESTING
handling</td></tr>
<tr><td>(02)</td><td>THRESHING</td></tr>
<tr><td>(03)</td><td>DRYING
transport and distribution</td></tr>
<tr><td>(04)</td><td>STORING</td></tr>
<tr><td>(05)</td><td>PROCESSING</td></tr>
<tr><td>(06)</td><td>PRIMARY PROCESSING
cleaning, classification, dehulling, pounding, grinding, packaging, soaking, winnowing, drying, sieving,
whitening, milling</td></tr>
<tr><td>(07)</td><td>SECONDARY PROCESSING
mixing, cooking, frying
moulding, cutting, extrusion</td></tr>
<tr><td>(08)</td><td>PRODUCT EVALUATION
quality control: standard recipes</td></tr>
<tr><td>(09)</td><td>PACKAGING
weighing, labelling, sealing</td></tr>
<tr><td>(10)</td><td>MARKETING
publicity, selling,
distribution</td></tr>
<tr><td>(11)</td><td>USE
recipes elaboration:</td></tr>
</table>
</td></tr>
</table>

[18] mlipen (2025). Potential of post-harvest R&D in PNG | The National. [online] Thenational.com.pg. Available at: https://www.thenational.com.pg/potential-of-post-harvest-rd-in-png/ [Accessed 19 Jan. 2025].
[19] JICA. (2015). GUIDELINES FOR ESTABLISHING SMALLHOLDER RICE EXTENSION IN PAPUA NEW GUINEA A MODEL FARMER APPROACH TO EXTENSION PROVISIONING. Available at: https://www.jica.go.jp/Resource/png/english/activities/c8h0vm00008t2xqj-att/activity10_01.pdf.
[20] Abhijith and Pazhoor, S.-B. (n.d.). Available at: https://www.blackstumptechnologies.com.au/sites/default/files/2023-08/Presentation-Cold-Storage-PNG.pdf
[21] www.fao.org. (n.d.). *CHAPTER 2 - POST-HARVEST SYSTEM AND FOOD LOSSES*. [online] Available at: https://www.fao.org/4/ac301e/AC301e03.htm.

<table>
<tr>
<td></td>
<td>
<table>
<tr><td></td><td>traditional dishes
new dishes</td></tr>
<tr><td>(12)</td><td>CONSUMER PREFERENCES
product evaluation, consumer education</td></tr>
</table>
<u>Climate Rationale for the technology</u>
Post-Harvest Management (PHM) technologies are crucial for mitigating the impacts of climate change on agriculture in Papua New Guinea (PNG). They help reduce food losses caused by rising temperatures, humidity, and unpredictable weather, ensuring crops remain marketable and food security is maintained. Technologies such as improved storage facilities, pre-cooling systems, and cold chains extend the shelf life of produce, enabling farmers to adapt to market disruptions and extreme weather events. By minimizing waste, PHM lowers greenhouse gas emissions from decomposing food and reduces the need for repeat farming, thus cutting the carbon footprint. Additionally, energy-efficient solutions like solar-powered storage promote sustainable resource use, while preserving crop value protects farmer incomes and biodiversity. Implementing PHM is a climate-smart strategy that enhances resilience and sustainability in PNG’s agricultural systems
</td>
</tr>
<tr>
<td>2.3 Technology Characteristics/ Highlights:

There are a few bullet points, i.e., low/high cost, advanced technology, low technology.</td>
<td>
1. Low-Cost, Low-Technology Options

Characteristics:

Simple, affordable solutions accessible to smallholder farmers.
Designed for localized, small-scale implementation.

Highlights:

Improved On-Farm Storage: Traditional storage solutions (e.g., ventilated cribs) to reduce pest and mold damage.
Basic Drying Techniques: Solar drying for grains and vegetables, reducing spoilage and improving shelf life.
Manual Threshers: Efficient processing tools to minimize crop damage during threshing.

2. Medium-Cost, Medium-Technology Options

Characteristics:

Scalable solutions with moderate infrastructure requirements.
Balances cost with performance for wider applicability.

Highlights:

Regional Cold Storage Units: Refrigeration facilities for fruits and vegetables, extending shelf life in regional markets.
Improved Packaging Materials: Hermetic bags and modified atmosphere packaging to reduce spoilage.
Efficient Milling Equipment: Machines for rice, maize, and other staples to enhance processing efficiency.

3. High-Cost, Advanced Technology Options

Characteristics:

Precision-driven solutions requiring significant capital investment and technical expertise.
Best suited for large-scale, commercial operations.

Highlights:

Solar-Powered Cold Chains: Renewable energy-based systems for remote and off-grid locations.
Automated Sorting and Grading Systems: Technology to improve product quality and market readiness.

</td>
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</table>

	o **Pre-Cooling Technologies**: Advanced cooling systems for perishable produce to ensure freshness during transport and storage.
2.4 Institutional and Organizational Requirement:	1. **National Government Stakeholders**: Central government institutions and agencies responsible for policy-making, funding allocation, and regulatory oversight. • **Department of Agriculture and Livestock (DAL)**: Leads the formulation and implementation of PHM policies and strategies. • **Climate Change and Development Authority (CCDA)**: Aligns PHM with climate resilience and adaptation objectives. • **National Agriculture Research Institute (NARI)**: Conducts research and develops region-specific PHM solutions. 2. **Local Government Stakeholders**: Provincial and district-level authorities responsible for implementing national policies at the community level. • **Provincial Agriculture Departments**: Facilitate farmer training, build local infrastructure, and monitor PHM adoption. • **District Development Authorities (DDAs)**: Oversee community-based storage and transportation improvements. • **Local Ward Councils**: Engage directly with farmers to promote awareness of PHM practices. 3. **Non-Governmental Organizations (NGOs) Stakeholders**: Independent organizations that work with communities to provide training, resources, and advocacy for PHM improvements. • **Oxfam PNG**: Supports smallholder farmers with training and tools for post-harvest handling. • **World Vision**: Provides community-based capacity building for food security and agricultural resilience. • **Save the Children**: Advocates for food security through improved post-harvest practices. 4. **Private Sector Stakeholders**: Businesses and enterprises involved in the development, supply, and operation of PHM technologies and services. • **Cold Storage Providers**: Companies that establish and manage cold storage facilities for fresh produce. • **Agri-Tech Innovators**: Firms developing technologies such as solar dryers, automated sorting systems, and hermetic packaging. • **Agribusinesses**: Large-scale buyers and exporters who depend on effective PHM to maintain product quality. 5. **Donor Agencies and International Partners Stakeholders**: Multilateral, bilateral, and international organizations providing financial and technical support for PHM projects. • **Green Climate Fund (GCF)**: Provides funding for PHM projects aligned with climate adaptation. • **Food and Agriculture Organization (FAO)**: Offers technical assistance and capacity-building initiatives. • **Australian Centre for International Agricultural Research (ACIAR)**: Collaborates on PHM research and development in PNG. • **World Bank**: Funds infrastructure projects such as cold chains and rural roads.

3.0 Implementation assumption	
3.1 Endorsement by Experts: How the technology will be implemented and diffused across sectors	1. **Policy Support**: Government-led initiatives play a key role in promoting PHM technologies through subsidies, grants, and strategic integration into the **National Agriculture Policy (2021–2030)**. Policies should focus on incentivizing private sector investments in cold storage and processing facilities, while also establishing quality standards for storage, packaging, and transportation. 2. **Training and Capacity Building**: Equipping local communities with the necessary skills to operate and maintain PHM technologies is critical. Training programs should target farmers, cooperatives, and extension workers, covering topics like proper drying techniques, storage management, and the use of low-cost tools such as solar dryers and hermetic bags. NGOs and local governments can collaborate to deliver these programs effectively. 3. **Pilot Projects**: Localized pilot systems should be implemented to demonstrate the effectiveness of PHM technologies in different regions of PNG. For example, establishing small-scale cold storage units in rural farming communities can showcase the benefits of reducing spoilage and extending shelf life. Successful pilots foster community trust and provide a scalable model for broader adoption. 4. **Sector Integration**: PHM technologies should be integrated across key sectors. In agriculture, cold chains and improved storage ensure marketable produce. In trade, PHM enhances food quality for export markets. In education, agricultural curricula should include PHM practices to prepare future generations. Monitoring and evaluation systems should track adoption rates and identify areas for improvement. 5. **Public-Private Partnerships (PPPs)**: Encourage collaboration between the government and private sector to co-invest in large-scale PHM infrastructure such as regional cold storage hubs and processing plants. Private companies can also introduce advanced technologies, such as solar-powered refrigeration, while leveraging public funding to offset costs. 6. **Donor Agency Collaboration**: Engage international organizations like FAO, ACIAR, and the World Bank to secure funding, technical assistance, and expertise. Donors can support the scaling of successful pilot projects and infrastructure development, particularly in remote and underserved areas.
3.2 Adequacy for current climate: Explain the technology could have some improvements in country environment	• Using Post-Harvest Management (PHM) technologies in Papua New Guinea (PNG) can greatly help the environment. These technologies reduce waste, support sustainability, and protect biodiversity. • Cold storage, solar-powered drying systems, and hermetic storage help cut down on food losses from spoilage, pests, and poor storage. This reduction lowers organic waste in landfills and decreases methane emissions. • PHM technologies save important resources like water, soil, and energy. They lessen the need for more farming to make up for losses. Solar-powered cold chains further decrease reliance on fossil fuels. • Better post-harvest handling means we need fewer chemical preservatives and pesticides. This minimizes contamination of soil and water.

	• PHM extends the shelf life of produce, which helps reduce the need to clear more land for farming. This protects natural ecosystems and prevents deforestation. • Efficient logistics and storage solutions lower the carbon footprint of agricultural supply chains. They also help recycle by-products for composting or bioenergy, supporting circular economy practices.
3.3 Size of beneficiaries group: Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	• The widespread adoption of PHM technologies in PNG has the potential to benefit millions of smallholder farmers and numerous agribusinesses, thereby strengthening the agricultural sector and contributing to the nation's economic development.
4.0 Costs	
4.1 Cost to implement adaptation options: Capital Cost	**1. Low-Cost, Low-Technology Options** • Examples: Solar dryers, manual threshers, hermetic bags, community-based storage units. • Capital Cost per Unit: USD $100–$5,000. • Estimated Implementation Scale: o Solar Dryers: ~5,000 units for smallholder farmers. o Hermetic Bags: ~50,000 units distributed to farmers. • Total Capital Cost: USD $500,000–$10,000,000. **2. Medium-Cost, Medium-Technology Options** • Examples: Regional cold storage units, improved milling quipment, bulk drying facilities. • Capital Cost per Unit: USD $5,000–$50,000. • Estimated Implementation Scale: o Regional Cold Storage Units: ~20 facilities across key agricultural hubs. o Improved Milling Equipment: ~100 machines distributed to cooperatives and SMEs. • Total Capital Cost: USD $2,000,000–$10,000,000. **3. High-Cost, Advanced Technology Options** • Examples: Solar-powered cold chains, automated sorting systems, pre-cooling technologies. • Capital Cost per Unit: USD $50,000–$500,000. • Estimated Implementation Scale: o Solar-Powered Cold Chains: ~5 facilities for high-value export crops like coffee and cocoa. o Automated Sorting Systems: ~10 units for large-scale agribusinesses. • Total Capital Cost: USD $3,000,000–$15,000,000. The total capital cost for implementing PHM technologies in PNG ranges from **$8 million to $45 million**, depending on the scale and complexity of the interventions. A phased approach, prioritizing low-cost, high-impact solutions while progressively introducing medium-

	and high-cost technologies, will ensure efficient resource allocation and maximum impact on food security and agricultural sustainability.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	**1. Low-Cost, Low-Technology Options** • **Examples**: Solar dryers, hermetic bags, manual threshers, community seed banks. • **BAU Practices**: Traditional open-air drying, non-airtight storage, and manual handling with high spoilage rates. • **Additional Costs**: USD **$100–$5,000** per unit. • **Total Additional Costs**: USD **$500,000–$10,000,000**. **2. Medium-Cost, Medium-Technology Options** • **Examples**: Regional cold storage, improved milling equipment, bulk drying facilities. • **BAU Practices**: Reliance on inadequate local storage facilities and inefficient processing methods. • **Additional Costs**: USD **$5,000–$50,000** per facility or unit. • **Total Additional Costs**: USD **$2,000,000–$10,000,000**. **3. High-Cost, Advanced Technology Options** • **Examples**: Solar-powered cold chains, automated sorting systems, pre-cooling technologies. • **BAU Practices**: Limited to conventional cooling methods (if available) and manual sorting, resulting in inefficiencies. • **Additional Costs**: USD **$50,000–$500,000** per unit or facility. • **Total Additional Costs**: USD **$3,000,000–$15,000,000**. **4. Training and Capacity Building** • **Examples**: Farmer training programs, extension worker capacity building. • **BAU Practices**: Limited or informal training that does not cover advanced PHM technologies. • **Additional Costs**: USD **$50,000–$200,000** per training program. • **Total Additional Costs**: USD **$2,500,000–$10,000,000**. **5. Institutional and Policy Costs** • **Examples**: Policy integration, regulatory frameworks, and monitoring systems. • **BAU Practices**: Fragmented or inadequate policies that do not address PHM needs. • **Additional Costs**: USD **$500,000–$1,000,000** for policy development and implementation. The additional costs for implementing PHM technologies in PNG compared to BAU practices range from **$8.5 million to $46 million**. These investments address inefficiencies in the current system, delivering long-term benefits such as reduced losses, enhanced quality, and increased market access. While the upfront

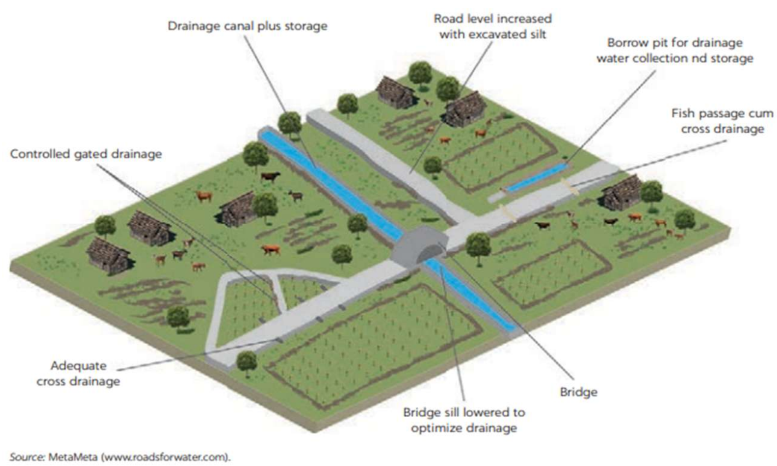
	costs are significant, the economic, social, and environmental gains far outweigh the expenses over time
4.3 Operational and Maintenance Cost	1. **Low-Cost, Low-Technology Options :** Solar dryers, hermetic bags, manual threshers, community-based storage units, with the cost per unit USD **$50–$300** annually. **Estimated Implementation Scale**: **Solar Dryers**: 5,000 units. **Hermetic Bags**: 50,000 units. **Total Annual O&M Cost**: USD $275,000–$1,500,000. Key Costs include routine maintenance (e.g., cleaning, minor repairs), and replacement of small components or damaged bags. 2. **Medium-Cost, Medium-Technology Options:** Regional cold storage units, improved milling equipment (20 facilities), and bulk drying facilities (100 units). O&M Cost per Unit: USD $2,000–$10,000 annually **Total Annual O&M Cost**: USD **$240,000–$1,200,000**. Key Costs: Energy expenses (e.g., electricity or fuel), and regular servicing of mechanical parts and equipment repairs. 3. **High-Cost, Advanced Technology Options:** Solar-powered cold chains (5 facilities), and automated sorting systems (10 units). O&M Cost per Unit: USD $10,000–$50,000 annually. **Total Annual O&M Cost**: USD **$150,000–$750,000**. Key Costs: Maintenance of solar systems, refrigeration units, and sorting machines, and Skilled technicians for repairs and servicing. The total annual O&M costs for PHM technologies in PNG, excluding training and policy costs, range from **$665,000 to $3,450,000**.
4.4 cost of GHG reduction	• The cost of greenhouse gas (GHG) reduction through Post-Harvest Management (PHM) technologies in Papua New Guinea ranges from USD $50 to $1,000 per ton of CO_2e reduced, depending on the type of technology. Low-cost solutions, such as solar dryers and hermetic bags, reduce 0.1–0.5 tons of CO_2e per unit annually at a cost of $50–$300 per ton by minimizing food waste and related methane emissions. Medium-cost options, like regional cold storage and improved milling, can reduce 1–5 tons of CO_2e per unit at $100–$500 per ton by improving energy efficiency and reducing spoilage. High-cost technologies, such as solar-powered cold chains and automated sorting systems, achieve the highest reductions (5–20 tons CO_2e per unit) but at a higher cost of $200–$1,000 per ton, leveraging renewable energy and advanced systems. Prioritizing scalable and energy-efficient technologies ensures PNG can balance affordability with significant environmental benefits[22].
4.5 lifetime	• The lifetime of PHM technologies in PNG ranges from 5 to 30 years, depending on the complexity and quality of the system. Regular maintenance and proper handling are crucial for maximizing the lifespan of these technologies, ensuring long-term benefits for food security and agricultural sustainability.
5.0 Benefits	

[22] IEA. (2020). *GHG abatement costs for selected measures of the Sustainable Recovery Plan – Charts – Data & Statistics*. [online] Available at: https://www.iea.org/data-and-statistics/charts/ghg-abatement-costs-for-selected-measures-of-the-sustainable-recovery-plan.

5.1 Development impact, indirect /benefits	• Improved Food Security: PHM technologies reduce post-harvest losses, ensuring a stable food supply and better nutrition. • Rural Development: Infrastructure investments in PHM facilities (e.g., cold storage and processing units) create employment opportunities in rural areas.
5.2 Economic benefits:	• Higher Incomes for Farmers: Reduced losses and improved produce quality increase market prices and farmer revenues. • Cost Savings: Improved storage and handling reduce the need for repeat cultivation, saving resources like seeds, fertilizers, and labor. • Value Addition: Processing technologies such as milling and drying enable farmers to sell value-added products, boosting profitability.
5.3 Social benefits:	• Community Empowerment: Community-based PHM facilities foster local ownership and participation in decision-making. • Health Improvements: Proper storage and handling reduce contamination, leading to safer and more nutritious food.
5.4 Environment benefits:	• Reduced Food Waste: By minimizing losses, PHM technologies lower the environmental impact of decomposing organic matter in landfills, reducing methane emissions. • Conservation of Resources: Efficient post-harvest practices conserve water, soil, and energy by preventing the need for repeated cultivation. • Lower GHG Emissions: Renewable energy-powered cold storage and efficient logistics systems reduce the carbon footprint of agriculture. • Biodiversity Preservation: Reducing the need for agricultural expansion into forests protects natural ecosystems and biodiversity.
6.0 Local context	
6.1 Opportunities and Barriers: Barriers to implementation and issues such as the need to adjust other policies.	Opportunities 1. Improved Food Security: PHM technologies reduce post-harvest losses, ensuring a stable food supply and better nutrition for communities. 2. Market Expansion: Enhanced produce quality and shelf life enable farmers to access regional and export markets, boosting income and trade. 3. International Funding and Support: Organizations like FAO, ACIAR, and the Green Climate Fund offer financial and technical assistance for PHM projects. 4. Local Capacity Building: Training programs empower farmers and communities, fostering ownership and long-term sustainability. 5. Technological Advancements: Affordable and renewable energy-powered technologies, such as solar dryers and cold chains, provide scalable solutions for rural areas. 6. Climate Resilience: PHM reduces food waste and GHG emissions while conserving resources, aligning with climate adaptation goals. Barriers 1. High Initial Costs: Advanced technologies like solar-powered cold chains and automated systems require significant capital investment, limiting accessibility. 2. Limited Infrastructure: Poor road networks, inadequate storage facilities, and unreliable electricity hinder the effective implementation of PHM technologies. 3. Knowledge Gaps: Farmers and stakeholders lack awareness and technical expertise to adopt and maintain PHM systems effectively.

	4. Policy and Coordination Challenges: Weak regulatory frameworks and fragmented coordination among government agencies slow progress. 5. Cultural Resistance: Traditional practices and skepticism about new technologies can reduce acceptance among local communities. 6. Maintenance and Sustainability Issues: Without proper training and funding for maintenance, PHM technologies risk becoming non-functional over time.
6.2 Status: Status of technology in the country	**Technology Status** The status of Post-Harvest Management (PHM) technologies in Papua New Guinea is mixed. Simple, low-cost solutions like solar dryers and storage bags are gradually being adopted by small farmers, but more advanced and medium-cost technologies like cold storage and automated systems are still rare due to high costs, poor infrastructure, and limited support. While some progress is being made with government and NGO efforts, more focus on training, funding, and private sector involvement is needed to expand these technologies and reduce post-harvest losses effectively.
6.3 Timeframe: Specify timeframe for implementation	**1. Short-Term (1–3 Years)** Focus: Introducing low-cost, simple technologies and building foundational support. Outcome: Reduced post-harvest losses at the community level and improved farmer awareness. **2. Medium-Term (4–7 Years)** Focus: Scaling medium-cost technologies and strengthening regional infrastructure. Outcome: Improved storage and logistics systems reduce spoilage and increase market access. **3. Long-Term (8–15 Years)** Focus: Deploying advanced technologies and achieving nationwide integration. Outcome: Nationwide adoption of PHM technologies, enhanced export capacity, and long-term sustainability.
6.4 Acceptability to local stakeholders: Where the technology will be attractive to stakeholders	PHM technologies are **highly attractive** to farmers, community leaders, governments, NGOs, and donors due to their potential to improve food security, reduce losses, and support climate resilience.

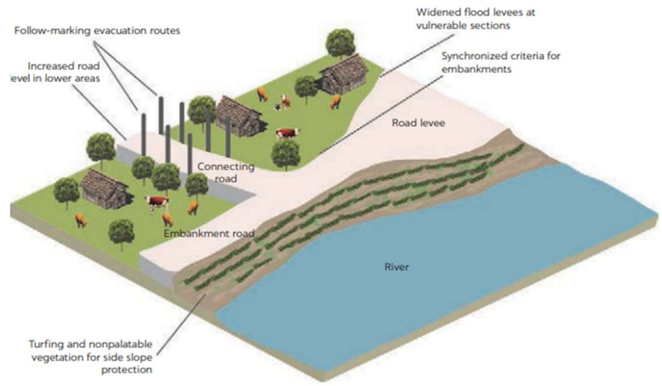
Annexe 6 Technology Factsheets for Selected Technologies - Flood-resilient Infrastructure Technology (FRIT)

Flood-resilient Infrastructure Technology (FRIT)	
1.0 Sector	Infrastructure
2.0 Technology Characteristics	
2.1 Technology Name:	**Flood-resilient Infrastructure Technology (FRIT)**
2.2 Introduction:	**Background** Papua New Guinea (PNG) experiences frequent flooding due to its tropical climate, heavy rainfall, and extensive river networks. Many communities, particularly in low-lying areas, face significant disruptions to transportation and infrastructure due to floods. Flood-resilient infrastructure Technology (FRIT) is a crucial adaptation measure to enhance infrastructure durability and accessibility. This technology includes elevated roads, bridges with reinforced foundations, and improved drainage systems, ensuring uninterrupted connectivity during extreme weather events.  **Improved practices in low-lying coastal areas**[23] **Climate Rationale for the technology** PNG is highly vulnerable to climate change-induced weather extremes, including increased rainfall intensity and rising sea levels. Flooding and waterlogging threaten roads, bridges, and essential services, disrupting economic activities and livelihoods. Implementing FRIT mitigates these risks by improving resilience, reducing repair and maintenance costs, and enhancing accessibility, especially in rural and flood-prone areas.
2.3 Technology Characteristics/ Highlights:	• **Elevated Roads:** Constructed above flood levels to prevent submersion.

[23] Van Steenbergen, F., Arroyo-Arroyo, F., Rao, K., Hulluka, A., Woldearegay, K. and Deligianni, A. (n.d.). INTERNATIONAL DE VELOPMENT IN FOCUS Green Roads for Water Guidelines for Road Infrastructure in Support of Water Management and Climate Resilience. [online] Available at: https://documents1.worldbank.org/curated/en/102951623742853259/pdf/Green-Roads-for-Water-Guidelines-for-Road-Infrastructure-in-Support-of-Water-Management-and-Climate-Resilience.pdf.

<table>
<tr>
<td>There are a few bullet points, i.e., low/high cost, advanced technology, low technology.</td>
<td>

- **Reinforced Bridges:** Designed with stronger foundations to withstand high water flow.
- **Improved Drainage Systems:** Efficient stormwater management to prevent waterlogging.
- **Cost Considerations:** Costs vary depending on location, materials, and design complexity. Low-cost solutions include simple culverts and embankments, while advanced structures involve high-strength materials and engineering techniques.
- **Technological Level:** A mix of traditional and modern engineering solutions tailored to local conditions.



Source: MetaMeta (www.roadsforwater.com).

Recommended practices for roads combined with flood embankments[24]
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<tr>
<td>2.4 Institutional and Organizational Requirement:</td>
<td>

- Local Government (Department of Works & Highways - DoWH): Develop regulations to encourage flood-resilient infrastructure and establish construction standards.
- NGOs/Community Groups: Engage in awareness programs and provide flood-resistant infrastructure installation and maintenance training.
- Private Sector: Partner in providing installation services and maintenance support for resilient infrastructure.
- Donor Agencies: Offer funding and technical assistance to expand flood-resilient infrastructure projects in PNG.
</td>
</tr>
<tr>
<td colspan="2">3.0 Implementation assumption</td>
</tr>
<tr>
<td>3.1 Endorsement by Experts: How the technology will be implemented and diffused across sectors</td>
<td>

FRIT is endorsed by climate adaptation and infrastructure specialists, emphasizing its role in mitigating flood risks. Successful implementation requires:

- Capacity-building programs for engineers and local authorities.
- Integration into national and regional development policies.
- Pilot projects in flood-prone regions to demonstrate effectiveness.
- Public-private partnerships to enhance investment and scalability.
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<td>3.2 Adequacy for current climate:</td>
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- While FRIT significantly improves infrastructure resilience, further refinements are needed to suit PNG’s unique environment. Challenges include:
    - High construction costs in remote areas.
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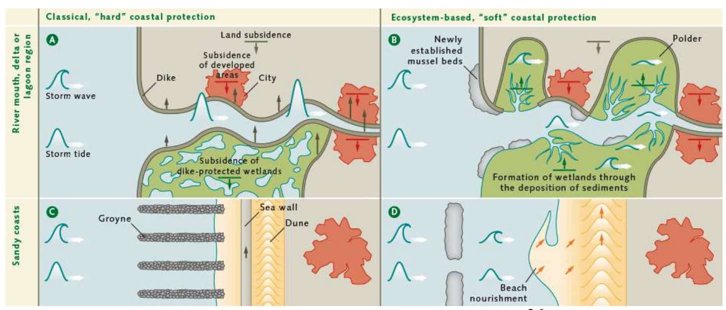
[24] Van Steenbergen, F., Arroyo-Arroyo, F., Rao, K., Hulluka, A., Woldearegay, K. and Deligianni, A. (n.d.). *INTERNATIONAL DE VELOPMENT IN FOCUS Green Roads for Water Guidelines for Road Infrastructure in Support of Water Management and Climate Resilience*. [online] Available at: https://documents1.worldbank.org/curated/en/102951623742853259/pdf/Green-Roads-for-Water-Guidelines-for-Road-Infrastructure-in-Support-of-Water-Management-and-Climate-Resilience.pdf.

Explain the technology could have some improvements in country environment	○ Maintenance and sustainability of drainage systems. ○ Need for community engagement in infrastructure planning. Adapting designs based on local hydrological data and locally available materials can enhance long-term viability.
3.3 Size of beneficiaries group: Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	RIT benefits a large portion of PNG's population by ensuring uninterrupted access to roads and essential services. Key beneficiaries include: • Rural and urban communities in flood-prone regions (2.6 million people)[25]. • Farmers and traders relying on transportation networks for economic activities. • Emergency services that require functional roads during disasters. • Government agencies responsible for infrastructure maintenance. By protecting critical transport networks, FRIT supports sustainable development and enhances resilience for a broad spectrum of stakeholders
4.0 Costs	
4.1 Cost to implement adaptation options: Capital Cost	• Elevated Roads**:** $1,000,000 - $5,000,000 per km • Reinforced Bridges: $2,000,000 - $10,000,000 per bridge (depending on span and materials) • Drainage Systems: $500,000 - $3,000,000 per system • Total Estimated Cost per Project: $500,000 - $10,000,00
4.2 Additional costs to implement adaptation option, compared to "business as usual"	• Material Costs: $300,000 - $2,500,000 additional per km for flood-resistant materials. • Engineering and Design Costs: $250,000 - $2,000,000 per project for specialized hydrological modelling and resilient design techniques. • Land Acquisition Costs: $200,000 - $2,000,000 per km where expansion or relocation is required.
4.3 Operational and Maintenance Cost	• Routine Maintenance: $50,000 - $200,000 annually per km of road • Bridge Inspections and Repairs: $100,000 - $500,000 annually per bridge • Drainage System Upkeep: $10,000 - $100,000 per year.
4.4 cost of GHG reduction	• Indirect benefits through reduced transportation disruptions and increased efficiency • Avoided carbon emissions from alternative longer routes or infrastructure failures
4.5 lifetime	• Lifespan of 30-50 years, with regular maintenance.
5.0 Benefits	
5.1 Development impact, indirect /benefits	• Increased trade, improved disaster response capacity, and enhanced economic growth.

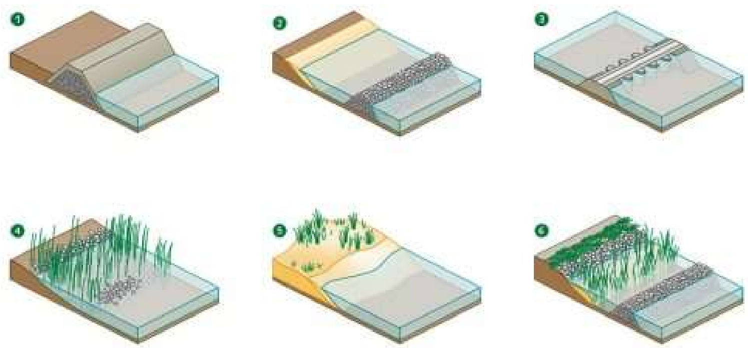
[25] Adaptation Fund. (2021). Enhancing adaptive capacity of communities to climate change-related floods in the North Coast and Islands Region of Papua New Guinea. [online] Adaptation Fund. Available at: https://www.adaptation-fund.org/project/enhancing-adaptive-capacity-of-communities-to-climate-change-related-floods-in-the-north-coast-and-islands-region-of-papua-new-guinea/.

5.2 Economic benefits:	• Reduced maintenance costs, improved supply chain reliability, and increased property values
5.3 Social benefits:	• Enhanced connectivity, better access to healthcare and education, and increased safety during floods.
5.4 Environment benefits:	• Reduced erosion and sedimentation, improved water management, and decreased infrastructure-related environmental damage.
6.0 Local context	
6.1 Opportunities and Barriers: Barriers to implementation and issues such as the need to adjust other policies.	**Opportunities to Implement the Project:** • Availability of international climate adaptation funding. • Government recognition of the need for climate-resilient infrastructure. • Potential for public-private partnerships to share costs and expertise. • Emerging innovations in resilient infrastructure technology that reduce costs over time. • Community-driven projects enhancing local ownership and sustainability. **Barriers**: • High initial investment costs. • Need for policy adjustments to integrate flood-resilient infrastructure into existing frameworks. • Limited technical expertise and skilled workforce for specialized infrastructure projects.
6.2 Status: Status of technology in the country	**Technology Status** • Currently in the early adoption phase with pilot projects in select regions. • Recognized as a critical component of climate adaptation by national development plans.
6.3 Timeframe: Specify timeframe for implementation	• Short-term (1-3 years): Feasibility studies, pilot projects, policy adjustments. • Medium-term (4-10 years): Scaling up implementation, integrating with national infrastructure plans. • Long-term (10+ years): Nationwide adoption and continuous improvements.
6.4 Acceptability to local stakeholders: Where the technology will be attractive to stakeholders	• High acceptability among communities affected by flooding. • Support from government agencies due to its alignment with national development priorities. • Requires ongoing engagement and capacity-building efforts for successful local adoption.

Annexe 7 Technology Factsheets for Selected Technologies - Coastal Protection Infrastructure (CPI)

Coastal Protection Infrastructure (CPI)	
1.0 Sector	Infrastructure
2.0 Technology Characteristics	
2.1 Technology Name:	**Coastal Protection Infrastructure (CPI)**
2.2 Introduction:	**<u>Background</u>** Papua New Guinea (PNG) has an extensive coastline that is increasingly threatened by climate change-induced sea level rise, coastal erosion, and extreme weather events. Many coastal communities rely on marine resources for their livelihoods and are at risk of displacement due to coastal degradation. Coastal Protection Infrastructure (CPI) is essential for safeguarding these communities, preserving ecosystems, and ensuring economic stability. CPI includes seawalls, mangrove restoration, breakwaters, and beach nourishment to mitigate coastal erosion and storm surges.  **alternative coastal protection[26]** **<u>Climate Rationale for the technology</u>** Rising sea levels, frequent tropical storms, and increasing coastal erosion threaten PNG's coastal regions. CPI helps protect infrastructure, residential areas, and critical ecosystems by reducing wave energy and preventing shoreline retreat. Implementing CPI enhances the resilience of coastal communities by mitigating the adverse impacts of climate change on their livelihoods, homes, and local economies
2.3 Technology Characteristics/ Highlights: There are a few bullet points, i.e., low/high cost, advanced technology, low technology.	• **Seawalls and Breakwaters:** Hard infrastructure solutions to absorb wave energy and prevent coastal flooding. • **Mangrove Restoration:** Nature-based solution that enhances coastal resilience by stabilizing shorelines and providing natural storm protection. • **Beach Nourishment:** Artificial replenishment of beaches to counteract erosion. • **Cost Considerations:** Costs vary based on the scale of implementation, materials, and technology used. Low-cost approaches include community-led mangrove restoration, while

[26] Worldoceanreview.com. (2017). *Coping with rising sea levels «World Ocean Review*. [online] Available at: https://worldoceanreview.com/en/wor-5/improving-coastal-protection/coping-with-rising-sea-levels/.

	high-cost solutions involve engineered seawalls and offshore breakwaters. • **Technological Level:** Combination of traditional knowledge and modern engineering solutions for long-term sustainability.  **Coastal Defence Methods[27]** Besides the classical coastal defence methods such as dikes (1), breakwaters (2), and barriers in river estuaries (3), ecosystem-based measures are being increasingly implemented today. These include the creation of man-made marshes (4) that collect fresh sediment, sand-fill areas (5) that promote the formation of sands and dunes along the coasts, and the installation of coastlines in harmony with nature (6) where species-rich green belts can develop behind structures that serve as breakwaters.
2.4 Institutional and Organizational Requirement:	• **Local Government (Department of Environment and Conservation - DEC, and National Fisheries Authority - NFA):** Develop policies and regulations for coastal protection and resource management. • **NGOs/Community Groups:** Engage in awareness programs, community-based restoration efforts, and sustainable coastal management training. • **Private Sector:** Provide expertise, funding, and technological support for infrastructure projects. • **Donor Agencies:** Support through financial aid, technical assistance, and research collaborations to improve coastal resilience.
3.0 Implementation assumption	
3.1 Endorsement by Experts: How the technology will be implemented and diffused across sectors	CPI is supported by environmental and engineering experts, emphasizing its role in safeguarding PNG's coastlines. Key recommendations include: • Capacity-building programs for local engineers and policymakers. • Integration of CPI into national and regional coastal management plans. • Demonstration projects to assess effectiveness in different coastal environments.

[27] Worldoceanreview.com. (2017). *Coping with rising sea levels «World Ocean Review*. [online] Available at: https://worldoceanreview.com/en/wor-5/improving-coastal-protection/coping-with-rising-sea-levels/.

	• Strengthening partnerships between government, private sector, and community organizations for sustainable implementation.
3.2 Adequacy for current climate: Explain the technology could have some improvements in country environment	**Adequacy for Current Climate** While CPI provides essential protection, there are challenges in implementation: • High costs associated with engineered infrastructure solutions. • Maintenance of constructed CPI elements to ensure long-term functionality. • Need for site-specific designs tailored to PNG's diverse coastal landscapes. Enhancing CPI with ecosystem-based approaches such as mangrove conservation and coral reef protection can improve its effectiveness and adaptability.
3.3 Size of beneficiaries group: Technology that provides small benefits to a larger number of people will often be favoured over those that provide larger benefits but to fewer people.	CPI benefits a significant portion of PNG's coastal population, including: • Communities residing in low-lying coastal areas. • Fishing and tourism industries reliant on healthy coastal ecosystems. • Infrastructure developers and local businesses at risk from coastal hazards. • Government agencies responsible for climate adaptation and disaster risk management. CPI protects coastal assets and contributes to sustainable economic development, disaster resilience, and environmental conservation.
4.0 Costs	
4.1 Cost to implement adaptation options: Capital Cost	• Seawalls: $2,000,000 - $15,000,000 per km • Breakwaters: $3,000,000 - $20,000,000 per structure • Mangrove Restoration: $50,000 - $500,000 per hectare • Beach Nourishment: $500,000 - $5,000,000 per km • Total Estimated Cost per Project: $200,000 - $20,000,000
4.2 Additional costs to implement adaptation option, compared to "business as usual"	• Material Costs: $400,000 - $3,000,000 additional per km for enhanced materials. • Engineering and Design Costs: $300,000 - $2,500,000 per project for specialized coastal modelling and resilient design techniques. • Land Acquisition Costs: $250,000 - $2,000,000 per km where expansion or relocation is required.
4.3 Operational and Maintenance Cost	• Routine Seawall and Breakwater Maintenance: $50,000 - $500,000 annually per km. • Mangrove Conservation and Monitoring: $5,000 - $50,000 per year per hectare. • Dredging and Sand Replenishment (Beach Nourishment): $100,000 - $1,000,000 per km every 3-10 years.
4.4 cost of GHG reduction	• **Cost of GHG Reduction:** Indirect benefits through carbon sequestration (e.g., mangrove restoration) and reduced damage to coastal infrastructure.
4.5 lifetime	• **Lifetime:** 20-50 years, depending on material durability and maintenance efforts.
5.0 Benefits	

5.1 Development impact, indirect /benefits	• Strengthened resilience of coastal economies, improved disaster preparedness, and enhanced biodiversity.
5.2 Economic benefits:	• Protection of fisheries, tourism industry stability, and reduced costs associated with coastal damage.
5.3 Social benefits:	• Preservation of cultural heritage sites, reduced displacement risk, and improved community safety
5.4 Environment benefits:	• Enhanced coastal biodiversity, improved water quality, and natural buffer zones against extreme weather events.
6.0 Local context	
6.1 Opportunities and Barriers: Barriers to implementation and issues such as the need to adjust other policies.	**Opportunities:** 1. Availability of international climate finance and donor funding. 2. Government recognition of CPI as a priority in climate adaptation strategies. 3. Potential for public-private partnerships to share costs and expertise. 4. Increasing community engagement in coastal conservation initiatives. 5. Advancements in nature-based solutions reduce dependency on expensive infrastructure. **Barriers:** 1. High capital costs for large-scale engineered solutions. 2. Need for multi-sectoral coordination in planning and implementation. 3. Limited technical expertise in advanced coastal engineering within PNG. 4. Policy and regulatory gaps for sustainable coastal zone management.
6.2 Status: Status of technology in the country	**Technology Status** • CPI is in the early adoption phase, with some pilot projects implemented in high-risk coastal areas. • Recognized as an essential adaptation measure in PNG's national climate policies. • Increasing integration of ecosystem-based approaches with infrastructure development.
6.3 Timeframe: Specify timeframe for implementation	• Short-term (1-3 years): Site assessments, feasibility studies, and pilot project implementation. • Medium-term (4-10 years): Expansion of CPI projects, policy integration, and community engagement. • Long-term (10+ years): Nationwide adoption, monitoring, and continuous improvement of CPI strategies.
6.4 Acceptability to local stakeholders: Where the technology will be attractive to stakeholders	• High acceptability among coastal communities vulnerable to erosion and sea-level rise. • Strong support from environmental organizations and research institutions. • Government agencies prioritize CPI due to its role in disaster risk reduction and economic stability. • Requires ongoing awareness and education initiatives to ensure community involvement and sustainability.

Annexe 8 Technology Factsheets for Selected Technologies - Landslide-resistant Infrastructure (LRI)

Landslide-resistant Infrastructure (LRI)	
1.0 Sector	Infrastructure
2.0 Technology Characteristics	
2.1 Technology Name:	**Landslide-resistant Infrastructure (LRI)**
2.2 Introduction:	**Background** Papua New Guinea (PNG) is prone to landslides due to its mountainous terrain, heavy rainfall, and seismic activity. Many communities, roads, and essential infrastructure are at risk of damage or destruction from landslides, leading to economic losses, transportation disruptions, and loss of life. Landslide-Resistant Infrastructure (LRI) is critical for ensuring the resilience and safety of infrastructure in landslide-prone areas. LRI includes slope stabilization techniques, retaining walls, proper drainage systems, and improved land use planning to mitigate landslide risks.  **Landslide-Resistant Infrastructure[28]** **Climate Rationale for the technology** Heavy rainfall, earthquakes, and deforestation contribute to frequent landslides in PNG, endangering communities and infrastructure. LRI helps mitigate these risks by reinforcing slopes, improving drainage, and adopting engineering solutions to enhance stability. By implementing LRI, PNG can reduce disaster impacts, protect livelihoods, and enhance infrastructure resilience against climate change-related extreme weather events

[28] Kamal, M., Hossain, F., Ahmed, B., Md. Zillur Rahman and Sammonds, P. (2023). Assessing the effectiveness of landslide slope stability by analysing structural mitigation measures and community risk perception. *Natural Hazards*, 117(3), pp.2393–2418. doi:https://doi.org/10.1007/s11069-023-05947-6.

2.3 Technology Characteristics/ Highlights: There are a few bullet points, i.e., low/high cost, advanced technology, low technology.	• **Slope Stabilization:** Use of vegetation cover, geotextiles, and engineered reinforcement to prevent soil erosion and slippage. • **Retaining Walls:** Constructed to support unstable slopes and reduce soil movement. • **Proper Drainage Systems:** Channeling rainwater to minimize soil saturation and pressure on slopes. • **Landslide Monitoring Systems:** Use of sensors and early warning mechanisms to detect land movement and alert communities. • **Cost Considerations:** Costs vary depending on the location, topography, and materials used. Low-cost solutions include vegetation-based stabilization, while high-cost solutions involve advanced geotechnical engineering and reinforced infrastructure. • **Technological Level:** Combination of traditional practices and modern engineering solutions for long-term sustainability.
2.4 Institutional and Organizational Requirement:	• **Local Government (Department of Works & Highways - DoWH, National Disaster Centre - NDC):** Develop policies, regulations, and emergency response plans for landslide-prone areas. • **NGOs/Community Groups:** Conduct awareness campaigns, provide training, and engage in community-led slope stabilization efforts. • **Private Sector:** Involvement in the design, construction, and maintenance of landslide-resistant infrastructure. • **Donor Agencies:** Financial and technical support for implementing large-scale LRI projects and capacity building.
3.0 Implementation assumption	
3.1 Endorsement by Experts: How the technology will be implemented and diffused across sectors	LRI is widely endorsed by disaster risk reduction and infrastructure experts, emphasizing its role in reducing landslide impacts. Key recommendations include: • Capacity-building programs for engineers, planners, and local authorities. • Integration of LRI into national infrastructure and land-use planning. • Pilot projects in high-risk areas to assess effectiveness and adaptability. • Public-private partnerships for investment and technical expertise
3.2 Adequacy for current climate: Explain the technology could have some improvements in country environment	• **While LRI significantly reduces landslide risks, challenges remain:** • High costs for engineered solutions in remote areas. • Maintenance and sustainability of drainage and slope reinforcement measures. • Need for community engagement in land-use practices to prevent deforestation and soil degradation. Enhancing LRI with nature-based solutions, such as agroforestry and reforestation, can improve long-term effectiveness**.**
3.3 Size of beneficiaries group:	• Communities residing in landslide-prone mountainous regions. • Transportation networks relying on stable road infrastructure. • Emergency services that require safe routes for disaster response.

Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	• Government agencies responsible for disaster risk management and infrastructure maintenance.
4.0 Costs	
4.1 Cost to implement adaptation options: Capital Cost	• **Slope Stabilization Measures:** \$50,000 - \$500,000 per site • **Retaining Walls:** \$100,000 - \$2,000,000 per km • **Drainage Systems:** \$50,000 - \$1,000,000 per system • **Landslide Monitoring Systems:** \$10,000 - \$500,000 per system (includes installation of sensors and monitoring stations) • **Total Estimated Cost per Project:** \$300,000 - \$10,000,000 per project
4.2 Additional costs to implement adaptation option, compared to "business as usual"	• **Material Costs:** \$200,000 - \$2,000,000 additional per km for reinforced slope stabilization and resilient materials. • **Engineering and Design Costs:** \$150,000 - \$1,500,000 per project for geotechnical analysis, hydrology studies, and resilient design techniques. • **Land Acquisition Costs:** \$100,000 - \$1,500,000 per km where expansion or relocation is required.
4.3 Operational and Maintenance Cost	• Routine Maintenance: \$50,000 - \$250,000 annually per km of road with landslide-prone areas. • Retaining Wall Inspections and Repairs: \$100,000 - \$500,000 annually per km. • Drainage System Upkeep: \$20,000 - \$150,000 per year. • Landslide Monitoring and Early Warning System Maintenance: \$10,000 - \$100,000 annually.
4.4 cost of GHG reduction	• Indirect benefits through reduced deforestation, soil erosion prevention, and enhanced vegetation cover.
4.5 lifetime	• 25-50 years, depending on construction quality and maintenance efforts.
5.0 Benefits	
5.1 <u>Development impact, indirect /benefits</u>	• Increased resilience of transportation networks, improved disaster preparedness, and reduced economic losses from infrastructure damage.
5.2 Economic benefits:	• Lower maintenance and repair costs, improved market access, and protection of businesses in affected regions.
5.3 Social benefits:	• Safer communities, reduced landslide casualties, and enhanced mobility for rural populations.
5.4 Environment benefits:	• Reduced soil erosion, improved watershed management, and increased vegetation coverage.

6.0 Local context	
6.1 Opportunities and Barriers: Barriers to implementation and issues such as the need to adjust other policies.	**Opportunities**: 1. Availability of international disaster risk reduction funding. 2. Growing government interest in climate-resilient infrastructure development. 3. Potential for public-private partnerships to drive investment and innovation. 4. Increasing community awareness of landslide risks and prevention measures. 5. Advancements in geotechnical engineering improving cost-effectiveness over time. **Barriers**: 1. High capital investment required for engineered solutions. 2. Need for multi-sectoral coordination in planning and execution. 3. Limited expertise and skilled workforce for landslide engineering solutions. 4. Challenges in enforcing land-use regulations to prevent deforestation and slope destabilization.
6.2 Status: Status of technology in the country	**Technology Status** • LRI is in the early adoption phase, with some slope stabilization and retaining wall projects implemented in high-risk areas. • Recognized as a critical measure in PNG's disaster risk reduction and climate adaptation plans. • Increased research and pilot projects focusing on integrating nature-based solutions with engineered approaches.
6.3 Timeframe: Specify timeframe for implementation	• Short-term (1-3 years): Site assessments, feasibility studies, and pilot project implementation. • Medium-term (4-10 years): Expansion of LRI projects, policy integration, and community engagement. • Long-term (10+ years): Nationwide adoption, continuous monitoring, and improvement of LRI strategies.
6.4 Acceptability to local stakeholders: Where the technology will be attractive to stakeholders	• High acceptability among communities affected by landslides and road disruptions. • Strong support from government agencies due to its role in protecting infrastructure and reducing disaster costs. • Requires continuous awareness and education initiatives for community participation and sustainability.