Climate-Resilient Green Growth in Milne Bay Province

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Climate-Resilient Green Growth in Milne Bay Province

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LIST OF ABBREVIATIONS

°C	degrees Celsius
2G	second generation mobile phone network standard (narrowband)
3G	third generation mobile phone network standard
4G	fourth generation mobile phone network standard
ACIAR	Australian Center for International Agricultural Research
ADB	Asian Development Bank
AFOLU	agriculture, forestry, and other land use
ANU	Australian National University
APERC	Asia Pacific Energy Research Centre
BoM	Australian Bureau of Meteorology
CCDA	Climate Change and Development Authority
CFE-DM	Center for Excellence in Disaster Management and Humanitarian Assistance
CIF	Climate Investment Fund
CIFOR	Center for International Forestry Research
cm	centimeter
COVID-19	coronavirus disease 2019
CRGG	Climate Resilient Green Growth (Project)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAL	Department of Agriculture and Livestock
DNPM	Department of National Planning and Monitoring
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
GDP	gross domestic product
GEF	Global Environment Facility
GGGI	Global Green Growth Institute
GHG	greenhouse gas
GoPNG	Government of Papua New Guinea
GSMA	Groupe Speciale Mobile Association
ha	hectare
HLPE	High Level Panel of Experts on Food Security and Nutrition
hPa	hectopascal
ICF	Inner City Fund
IDMC	Internal Displacement Monitoring Centre
IEA	International Energy Agency
IMF	International Monetary Fund
IOM	International Organization for Migration
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
ITU	International Telecommunication Union

kg	kilogram
km	kilometer
km^2	square kilometer
kt	kilotonne
kWh	kilowatt hour
LED	light-emitting diode
LLG	local-level government
MBPA	Milne Bay Provincial Authority
mm	millimeter
MPA	marine protected area
MW	megawatt
ND-GAIN	Notre Dame Global Adaptation Initiative
NOAA	National Oceanic and Atmospheric Administration
NRC	Norwegian Refugee Council
NSO	National Statistics Office
NSWG	New South Wales Government
OECD	Organisation for Economic Co-operation and Development
Ω_a	Ohm of aragonite
PES	payment for ecosystem services
PGK	Papua New Guinea Kina
PNG	Papua New Guinea
RCP	representative concentration pathways
REDD+	Reducing emissions from deforestation and forest degradation
RSPO	Roundtable on Sustainable Palm Oil
SE4All	Sustainable Energy for All
SPREP	Secretariat of the Pacific Regional Environment Programme
t	tonne
TNC	The Nature Conservancy
TV	television
UN OCHA	United Nations Office for the Coordination of Humanitarian Affairs
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
US$	United States dollar
WASH	water, sanitation, and hygiene
WCS	Wildlife Conservation Society
WHO	World Health Organization
WWAP	World Water Assessment Programme

LIST OF CHEMICAL SYMBOLS

Ca^{2+}	calcium ion
$CaCO^3$	aragonite
CH_4	methane
CO_2	carbon dioxide
CO_3^{2-}	carbonate ion
H^+	hydrogen ion
H_2CO_3	carbonic acid
HCO_3^-	bicarbonate ion
N_2O	nitrous oxide

Executive summary

The Climate Resilient Green Growth (CRGG) assessment shows that Milne Bay Province is exposed to the adverse impacts of climate change, as evidenced in an increase in temperature, rise in sea levels, growing ocean acidity, and potential changes in rainfall. At the same time, the province's population and economy are very sensitive to these phenomena, given their dependence on sectors that experience considerable impacts from climate change—particularly agriculture and fishing. Finally, low income levels and a lack of essential infrastructure such as transportation, health, electricity, water, and sanitation also mean their capacity to adapt to the adverse impacts of climate change is limited.

The CRGG assessment demonstrates that there are ample opportunities for fostering climate-resilient green growth in Milne Bay Province. Based on available data and research, and consultation with local stakeholders, the assessment identifies four priority areas for the province to enhance its resilience towards the adverse impacts of climate change:

- Agriculture;
- Electricity access;
- Fishing; and
- Transportation.

For each priority area, the assessment identifies several interventions that could help strengthen resilience against climate change.

Agriculture

Given the dominance of smallholder farming, interventions to strengthen resilience against climate change in the agriculture sector will have to focus on improving productivity without shifting to large-scale industrial farming, as this would undermine the livelihoods of smallholder farmers and cause major environmental damage.

This requires more research into climate-resilient crops and agricultural techniques—including options for crop rotation, intercropping and agroforestry—that are suitable for specific locations in Milne Bay Province. Successfully disseminating such climate-resilient agricultural practices requires systematic improvements in extension services. Furthermore, regardless of whether the occurrence and intensity of drought are directly related to climate change, reducing its negative effects will benefit agricultural productivity and food security. For that purpose, putting in place provincial-level drought contingency plans is regarded as a useful instrument, if such a plan outlines practical provisions, identifies how these provisions will be implemented, and designates specific entities to implement them. Complementarily, water management systems such as rainwater harvesting, water storage, and micro-irrigation will be important for improving smallholder farmers' resilience by reducing the impact of drought. In addition, deforestation reduces agricultural productivity and exacerbates the impact of climate change on agriculture. Participation in international certification schemes for commercial logging and piloting initiatives to reduce emissions from deforestation and forest degradation (REDD+) at community level are options for conserving forests in Milne Bay Province. Finally, continued adherence to international certification schemes would allow for commercial agriculture to contribute to environmental conservation, improve socioeconomic conditions for the workforce, and fetch higher prices.

Electricity supply

Access to electricity is limited and service is often unreliable in Milne Bay Province. While climate change is unlikely to affect existing supply, increasing access to electricity can play an essential role in strengthening adaptive capacity in Milne Bay Province, as it would have positive effects on many other aspects related to resilience, such as poverty, health, education, and job creation. Given the province's geography, the technical challenges, and the high costs of establishing a new electricity network or extending an existing grid, this assessment concludes that off-grid solutions present the most viable option for increasing access to electricity in the province. Among the available technologies—including ocean, geothermal, biomass, wind, and solar—solar photovoltaic systems are considered the most feasible option for off-grid electrification. Solar mini-grids represent an option for towns, hospitals, schools, and administrative buildings, where trained onsite technicians for operation and maintenance and spare parts can be readily available. For household electrification, solar home systems appear to be the more suitable option, showing several advantages over larger mini-grid designs. The assessment identifies reliability and affordability as the two main challenges for successfully deploying solar home systems and puts forward suggestions on how to address them, including quality control, financial support mechanisms, and strengthening the domestic market.

Fishing

Fish and other marine species are a crucial protein source and fishing represents an important economic activity in the province. However, fish stocks in Papua New Guinean waters are declining, triggering concerns that coastal communities will face increasing food scarcity during the coming decades. Coupled with the adverse impacts of climate change, population growth, more destructive fishing methods, high returns on particular species such as sea cucumbers, and habitat degradation from agriculture, logging, and mining activities all contribute to declining fish stocks. However, options for directly reducing the adverse impacts of climate change on fisheries are limited. Therefore, interventions should focus on reducing stress from other factors—particularly human activity—on the marine environment to strengthen its resilience towards climate change.

This assessment recommends that interventions focus on the sustainable exploitation of marine resources in coastal waters. Establishing community-driven, locally managed marine protected areas is a promising means for encouraging sustainable marine resource use. Furthermore, with mangroves serving as nursery grounds and habitats for many marine species, their conservation through payment for ecosystem services can play a crucial role. Aquaculture represents another option for reducing pressure on marine resources while creating income-earning opportunities for coastal communities. Finally, local authorities, supported by donor funding and external technical expertise, should investigate whether tourism can present an alternative to fishing as a source of income.

Transport

The limited reach and poor condition of transport infrastructure is a major constraint to inclusive economic growth, isolating large numbers of Papua New Guineans from markets, income-earning opportunities, healthcare facilities, and education services. Given Milne Bay Province's geography—with its numerous small islands and atolls—road and maritime transport play important roles in the movement of people and goods. However, most households rely on non-motorized transportation, which means that they either walk or use boats without motors. The province's geography, combined with limited resources, leaves little room for interventions. Therefore, this assessment recommends that the Milne Bay Provincial Administration set realistic targets and focus on maintaining existing roads rather than build new infrastructure. Furthermore, prioritizing investment into transport infrastructure in the areas that attract tourists could help increase the number of non-cruise tourists who visit the province, which would raise local incomes and government revenue. Some of that additional revenue could then be used to support the maintenance, upgrading, and expansion of the province's transport infrastructure.

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Hohit Seyoum Gebreegziabher	Project Officer (Papua New Guinea)

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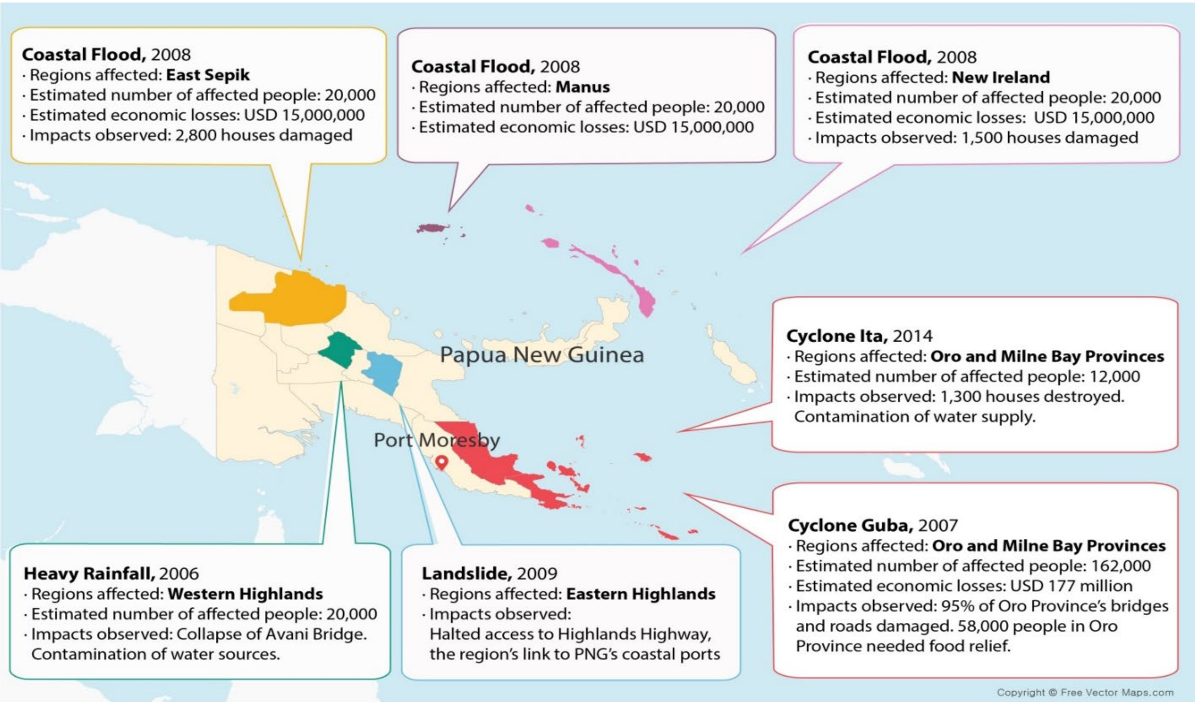
1. Background

Papua New Guinea is highly exposed to climate change, as evidenced in rising temperatures and sea levels, changes in rainfall, increased ocean acidity, and less frequent but more intense droughts and cyclones (BoM and CSIRO 2014; ADB 2013b). At the same time, the country's population and economy are very sensitive to these phenomena, given their dependence on sectors that experience considerable impacts from climate change, such as fisheries and agriculture. Finally, their ability to cope with the adverse impacts of climate change is also compromised by the country's lack of essential transport, health, electricity, water, and sanitation infrastructure (GGGI 2019b, Figure 1).

The government of Papua New Guinea has recognized climate change as one of the country's greatest challenges. Environmental sustainability and adaptation to the adverse impacts of climate change represent one of the key pillars of its Vision 2050. Specifically, the document recognizes the challenges that climate change poses to food security and public health (GoPNG 2009).

Figure 1. Climate-related disasters in Papua New Guinea (2006–2014)



Source: Based on IOM 2015, CFE-DM 2016, GoPNG and UN Country Team in Papua New Guinea 2017

The Climate Resilient Green Growth (CRGG) project aims to address these challenges by strengthening Papua New Guinea's capacity to mitigate its contribution to climate change and adapt to the adverse impacts of climate change by: (1) supporting the preparation of provincial development plans and budgets; (2) designing relevant projects and interventions; and (3) establishing and operationalizing a financial mechanism for long-term financing of such projects.

To achieve these goals, it is pertinent to determine what climate resilience means in Papua New Guinea at the outset of the project. For that purpose, this assessment uses a transparent and evidence-based methodology to identify priorities for enhancing resilience towards the adverse impacts of climate change and relevant interventions to address these priorities.

Given the country's geographical, economic, and cultural diversity, a provincial approach is regarded as more advantageous than a centralized option. As such, the CRGG project was piloted in three provinces: Enga, Milne Bay, and New Ireland.

This report presents the results of the CRGG assessment of Milne Bay Province. It describes the priorities for enhancing resilience towards the adverse impacts of climate change in the province and how these priorities have been identified. Finally, it proposes a set of interventions for coping with the adverse impacts for each priority.

Ultimately, the aim is for the Milne Bay Provincial Administration to incorporate the identified priorities into its development plans and budgets. Furthermore, the findings of the assessment will contribute to developing relevant interventions under Component 2 of the CRGG project (Figure 2).

Figure 2. CRGG project overview

Component 1: Provincial CRGG planning	**Component 2: CRGG project preparation**	**Component 3: Enabling financing for CRGG**
Output 1.1: Workplans for provincial CRGG mainstreaming	Output 2.1: Selection of provincial CRGG priorities for further development	Output 3.1: Identification of barriers to accessing finance for CRGG
Output 1.2: Provincial CRGG assessments	Output 2.2: Workplans and budgets for CRGG project preparation	Output 3.2: Tailored solutions to address the identified barriers
Output 1.3: Mainstreaming of CRGG priorities into provincial development plans and budgets and identification of projects	Output 2.3: CRGG project designs and funding proposals	Output 3.3: Implementation of solutions to reduce barriers to accessing finance for CRGG
Output 1.4: Replication plan to roll out CRGG planning in additional provinces	Output 2.4: Replication plan to roll out project preparation in additional provinces	Output 3.4: Medium-term investment strategy for CRGG financing

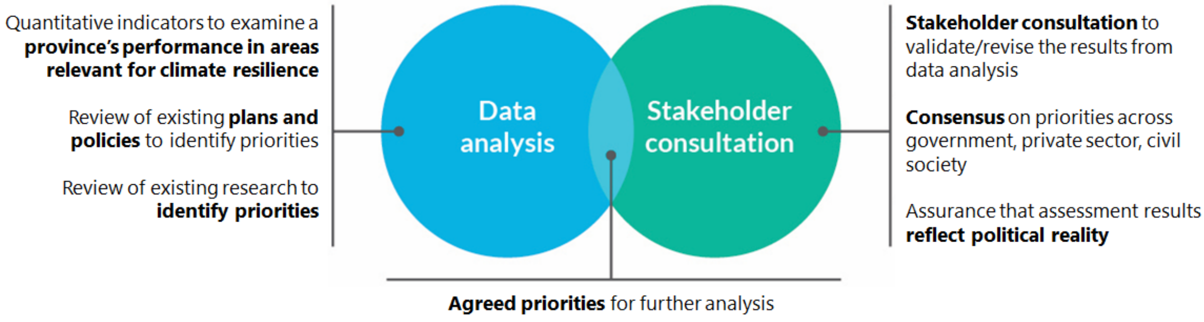
Source: GGGI

2. Methodology

Climate resilience is a broad concept, encompassing not only different economic sectors but also different levels of intervention. Furthermore, what climate resilience means in individual provinces and how it can be translated into specific actions depends on a wide range of factors. These include a province's economic structure, geography, endowment with natural assets, and social characteristics. Given the broad nature of the concept, there is a need to define what climate-resilient green growth means in a specific province's context by identifying and systematically assessing related priorities.

For that purpose, the Global Green Growth Institute (GGGI) has developed the CRGG Assessment Methodology, which combines data analysis and stakeholder consultation (Figure 3). The methodology permits the evaluation and prioritization of a province's challenges resulting from the adverse impacts of climate change. It also helps identify opportunities for mitigating a province's contribution to—and strengthening its resilience towards—climate change.

Figure 3. Conceptual schematic of the CRGG Assessment Methodology



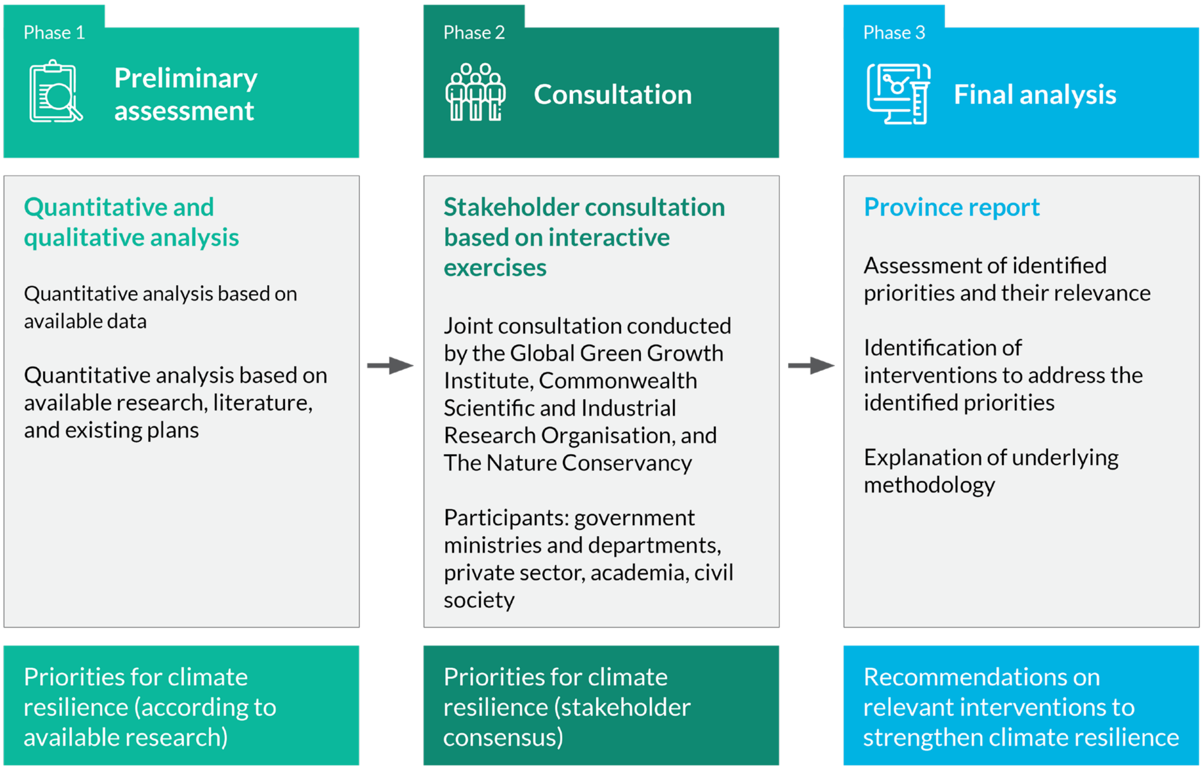
Source: GGGI

The CRGG assessment consists of the following three phases:

1. A preliminary assessment based on data analysis and literature review;
2. Consultation with stakeholders to validate, revise and add granularity to the findings of the preliminary assessment; and
3. A final analysis covering the identified priorities and including the development of recommendations to address these priorities (Figure 4).

This design aims to ensure that the assessment process is systematic, objective, and participatory.

Figure 4. Overview of the CRGG process in Milne Bay Province



Source: GGGI

2.1 PRELIMINARY ASSESSMENT

The preliminary assessment serves as a starting point for identifying the priorities for climate-resilient green growth, considering the selected province's socioeconomic characteristics, geography, and climatic conditions. It relies on two principal aspects:

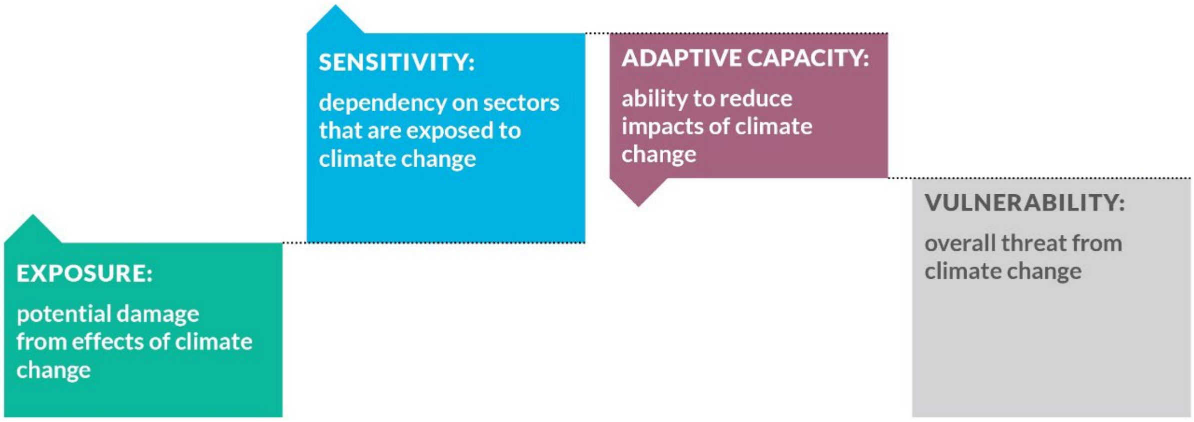
1. Understanding the relevant sources of greenhouse gas (GHG) emissions to mitigate the province's contribution to climate change; and
2. Evaluating a province's vulnerability to climate change to strengthen its resilience.

First, to determine the potential for mitigation and possible options for reducing GHG emissions, the assessment identifies relevant sources of GHG emissions and trends. Key indicators include a province's total GHG emissions, carbon intensity, carbon stock and potential for carbon sequestration, per capita emissions, and a sectoral breakdown of emissions. Depending on data availability, the preliminary assessment is designed to consider the two most important greenhouse gases, namely carbon dioxide (CO_2) and methane (CH_4).[1] Furthermore, to assess a province's potential for mitigating its contribution to climate change, the preliminary assessment considers its total primary energy supply, electricity mix, and the population's access to clean fuels and technologies for cooking.

Second, to systematically assess a province's vulnerability to the adverse impacts of climate change, the preliminary assessment distinguishes between three aspects of vulnerability, namely exposure, sensitivity, and adaptive capacity (Figure 5). This disaggregation is largely based on the Notre Dame Global Adaptation Initiative (ND-GAIN) Index (Chen et al. 2015).

[1] In 2010, global GHG emissions consisted of: 65% CO_2 from fossil fuel combustion and industrial processes; 11% CO_2 from forestry and other land use; 16% CH_4; 6.2% N_2O; and 2% fluorinated gases (IPCC 2014).

Figure 5. Conceptual framework for assessing vulnerability



Source: GGGI

A province is regarded as exposed to climate change when it is subject to major changes in climate and weather patterns. Relevant phenomena to be considered under exposure include: rise in temperature, changes in rainfall, occurrence of drought, rise in sea level, increase in ocean acidity, and occurrence of cyclones. A province is considered as sensitive to this exposure when its economy and population rely on sectors that are susceptible to climate change-related phenomena, such as agriculture and fisheries.

A province also has adaptive capacity, which is defined as its ability to reduce the adverse impacts of climate change, despite its level of exposure and sensitivity. Measuring adaptive capacity considers a province's poverty rates, access to electricity, reliability of transportation network, and access to and quality of health services, among others. Exposure and sensitivity increase a province's overall vulnerability to climate change, whereas adaptive capacity reduces its overall vulnerability. As part of the analysis, the assessment aims to identify means to reduce vulnerability by increasing a province's adaptive capacity.

2.2 CONSULTATION

As part of the CRGG assessment, stakeholders are given a leading role in determining the scope and content of the final analysis. Their input is essential for identifying priorities and developing recommendations that consider local conditions. Stakeholders include representatives from government, academic institutions, the private sector, civil society, and development partners.

While stakeholder engagement occurs throughout the entire assessment process, there is a concerted effort to systematically gather feedback from a broad range of constituents through an interactive workshop following the preliminary assessment. This workshop brings together 30–60 participants. Given the importance of stakeholder input for shaping the assessment, this systematic participatory process is essential to ensure broad consensus on priorities and potential remedies that are to be addressed in the final analysis.

CRGG consultation workshops usually rely on a combination of Delphi survey and group discussions (see Appendix E). However, because several other organizations—including the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and The Nature Conservancy (TNC)—were also conducting analysis on climate change and socially inclusive development in the province, the Milne Bay assessment followed a different format. Working with these other organizations, GGGI helped lead a joint stakeholder consultation process to identify priority interventions for supporting climate-resilient and socially inclusive development in the province. The workshop was divided into four sessions (Figure 6), described below.

Session 1 aimed to explore the different factors influencing future development in Milne Bay Province. As such, it consisted of a mix of presentations and interactive group work. The presentations introduced a wide range of drivers of change, including climate change, population growth and macroeconomic trends. [2] They also emphasized the uncertainty inherent to any projections and highlighted geographical differences within the province. Participants were then asked to identify the most important impacts of climate change and how these are connected to other influences. For that purpose, participants wrote the drivers of change they had identified onto Post-it Notes. The facilitators placed these notes on a whiteboard, grouping them in the following themes: climate change, natural resources, technology, infrastructure, social and politics, and economics. Session 1 concluded with a discussion of which themes participants regarded as most prominent and whether there were important geographical differences.

Figure 6. The consultation process in Milne Bay Province

Session 1: Identify the different factors influencing future development

Session 2: Explore possible futures, considering uncertainty in the drivers of change

Session 3: Identify the strengths and weaknesses in the province's adaptive capacity to respond to climate change and other major factors influencing future development

Session 4: Identify and prioritize interventions to reach the best-case scenario and avoid the worst-case scenario

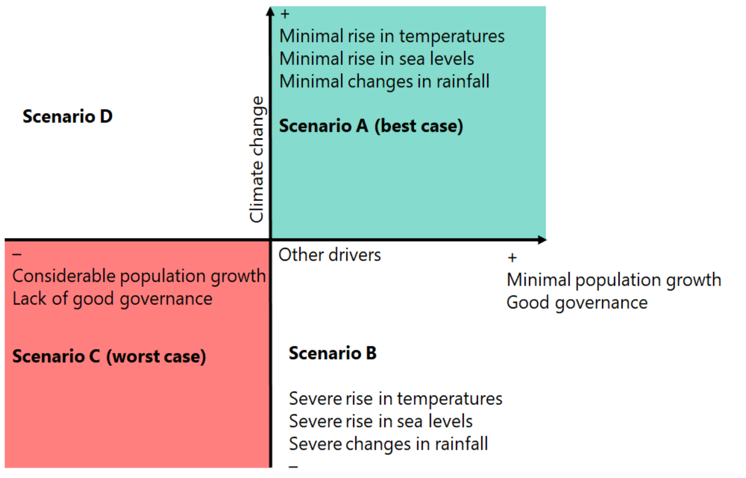
Source: GGGI

In Session 2, participants explored possible futures for Milne Bay Province, considering the uncertainty in the drivers of change they had identified in Session 1. The most prominent drivers of change were visualized in a two-dimensional matrix, with the impacts of climate change considered on the y-axis and other important drivers determining the x-axis. This matrix provided participants with four different starting points to envision Milne Bay Province in 2050 (Figure 7):

- Scenario A (best case): minimal impacts from climate change and positive impacts from other drivers;
- Scenario B: severe impacts from climate change and positive impacts from other drivers;
- Scenario C (worst case): severe impacts from climate change and negative impacts from other drivers; and
- Scenario D: minimal impacts from climate change and negative impacts from other drivers.

Participants were divided into six groups and allocated one of the four scenarios. They were then asked to create a visual representation of Milne Bay under the conditions of their scenario. Session 2 concluded with each group presenting their drawings.

Figure 7. Scenario matrix



Source: GGGI

The aim of Session 3 was to identify the strengths and weaknesses of Milne Bay Province's adaptive capacity to respond to climate change and other major factors influencing the province's future development. The session started with a presentation that provided an overview of the social, human, natural, financial, physical, and political determinants of adaptive

[2] For the workshop, drivers of change were defined as 'any natural or human-induced factor that directly or indirectly causes a change in Milne Bay'.

capacity. Following the presentation, facilitators divided participants into groups reflecting different regions within Milne Bay Province. Each group was asked to list adaptive capacity strengths and weaknesses, based on the categories introduced earlier. Session 3 concluded by displaying and discussing the results of each group in plenary.

Concluding the workshop, Session 4 aimed to identify and prioritize interventions to reach the best-case scenario and avoid the worst-case scenario (Figure 7). Participants remained divided into the groups from Session 3. First, each group identified relevant interventions, considering the uncertainty of different impacts leading to different scenarios as well as Milne Bay Province's strengths and weaknesses to adapt to the different impacts. Then, group members scored these interventions based on the following criteria:

- No regrets: interventions are beneficial under any scenario;
- Feasibility and costs: interventions are politically, technically, and financially feasible;
- Gender and social inclusion: interventions are beneficial for gender and social equality; and
- COVID-19 recovery: interventions address the economic shock induced by the COVID-19 pandemic.

Session 4 concluded with a plenary discussion, examining overlaps and differences between the groups' results.

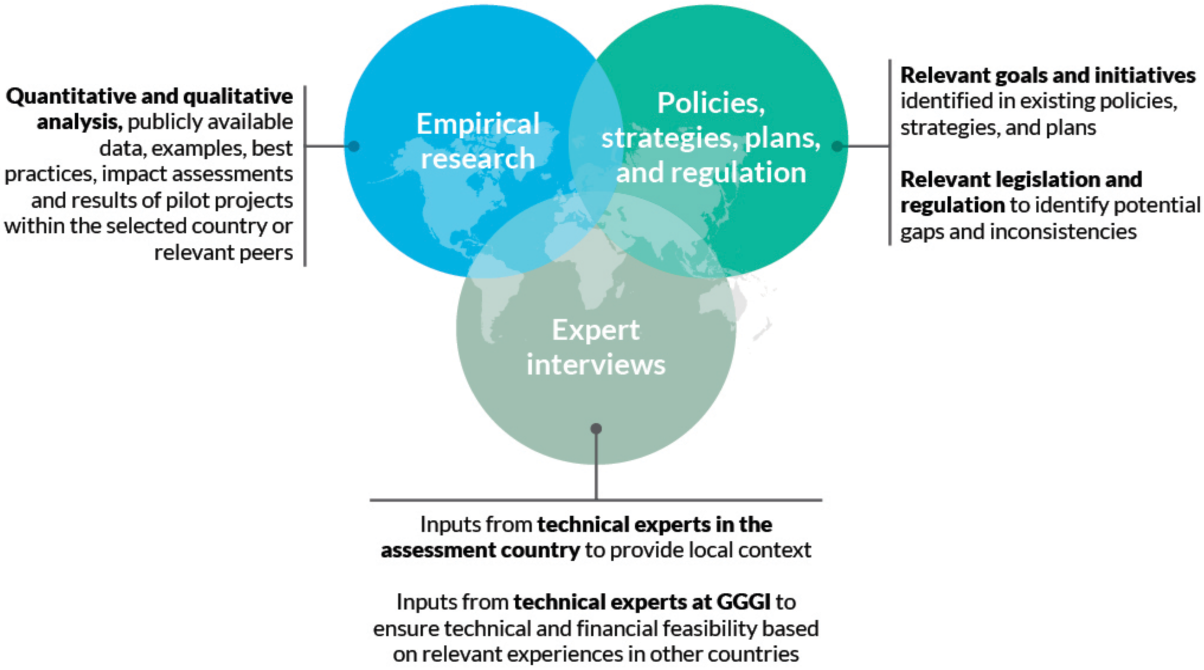
2.3 FINAL ANALYSIS

Building on the results of the consultation workshop, the final analysis identifies specific opportunities and barriers to climate-resilient green growth for each of the selected priorities. This analysis is built around a set of recommendations, ranging from changes in policy, to strengthening regulation and enforcement to identifying technical interventions and specific projects.

Recommendations are developed based on three kinds of input (Figure 8):

- Empirical research: The recommendations are informed by quantitative and qualitative analysis drawn from existing research and based on publicly available datasets. Furthermore, they rest on inference from examples, best practices, impact assessments, and results of pilot projects within the selected province, country, or relevant peers.
- Policies, strategies, plans, and regulations: The current policy and regulatory framework is reviewed considering existing policy, legislation, regulation, and institutional arrangements. This allows for the identification of relevant goals and initiatives and determination of potential gaps, inconsistencies, or obstacles within the current legislative, regulatory, and institutional setup.
- Expert interviews: A crucial input to developing the recommendations is a series of interviews with technical experts in the province from government, academia, the private sector, and civil society, who are consulted on specific issues within their area of expertise. These interviews serve multiple purposes. They address any gaps that remain after reviewing the literature, legislation, and regulation; clarify issues where the information gathered from documents is ambiguous; verify the recommendations that the assessment team is proposing; provide further context; and reflect the most recent developments that might not yet be available in written documents. In addition to local experts, technical experts from within GGGI provide their input to ensure that important aspects and trade-offs have not been overlooked, verify that recommendations are technically feasible and cost effective, and share relevant experiences from other countries.

Figure 8. Schematic of inputs to the final analysis



Source: GGGI

3. Preliminary assessment

The preliminary analysis served as a starting point for defining what climate-resilient green growth means in Milne Bay Province, identifying relevant priorities and possible remedies. For that purpose, it considers the province's contribution to mitigating climate change and its capacity to cope with the adverse impacts of climate change.

To assess Milne Bay Province's options for mitigation, the preliminary assessment relied on understanding the relevant sources of greenhouse gas emissions. To evaluate its vulnerability to climate change and identify means to strengthen its resilience, the preliminary assessment considered three elements: the province's exposure to climate change-related phenomena, the province dependence on economic activities that are susceptible to these phenomena, and the province's adaptive capacity to cope with the adverse impacts of climate change.

3.1 MITIGATION

To assess the potential for mitigation and possible remedies to reduce greenhouse gas emissions, the assessment first identified relevant sources of GHG emissions and trends. Given the paucity of available data and considerable uncertainty regarding its reliability, the assessment of mitigation options had to rely on estimates. GHG emission data is only available at a national—not provincial—level; and even these national-level estimates and their sectoral breakdown are only indicative.

As a result, the preliminary assessment focused on identifying relevant sources of GHG emissions and potential mitigation options. The assessment did not consider other indicators—such as carbon intensity, emissions per capita, existing carbon stocks, or the potential for carbon sequestration—as any such estimates would have been compromised by the low quality of available data (see Box 1).

Total national GHG emissions are comparatively low. Given the large extent of the country's forests, it can be deduced with reasonable certainty that the country is a net carbon sink (GoPNG 2014). Papua New Guinea's forests cover more than two-thirds of its land mass, and together with forests in the neighboring Indonesian province of Papua, comprise the third largest tract of intact tropical forest in the world (Babon and Gowae 2013). As a result, they represent one of the world's largest carbon storages.

There are two principal sources of GHG emissions in Papua New Guinea. First, the energy sector—including all activities that involve fossil fuel combustion (IPCC 2006)—accounts for an estimated 45% of the country's total CO_2 emissions. Second, agriculture, forestry, and other land use (AFOLU) account for approximately 55% of total CO_2 emissions (Table 1).

Table 1. Estimated CO_2 emissions by sector (kilotonnes)

Source	Energy	Industrial processes and product use	Agriculture, forestry, and other land use	Waste
GoPNG 2014	2,436 kt	61 kt	11,754 kt	0 kt
GoPNG 2018	11,806 kt	35 kt	14,370 kt	0 kt

Source: GGGI

Available information on economic activity and energy use also indicates that these two sectors are responsible for most of Milne Bay Province's GHG emissions. First, a nearly 2% decrease in forest cover between 2002 and 2014 (Bryan and Shearman 2015) implies the relevance of the AFOLU sector's GHG emissions. An analysis of historical deforestation, degradation and land use covering selected areas of Milne Bay Province identified logging, agricultural activity, reliance on fuelwood, and settlement expansion as the main drivers behind deforestation (Österreichische Bundesforste AG 2014; in-country interviews). Second, fossil fuel combustion for electricity generation and transport are identified as the main sources of GHG emissions in the energy sector. For example, electricity generation is dominated by diesel (ADB 2009). Low electricity access and motorization rates (NSO and ICF 2019) have kept GHG emissions from the energy sector comparatively low, limiting the potential for reducing these emissions. However, should access increase, electricity generation from renewable sources, public transport, and energy efficiency measures will become relevant for capping future increases in emissions.

Box 1. Data availability

The level and sectoral breakdown of GHG emissions in Papua New Guinea was estimated based on data published in the government's second national communication to the United Nations Framework Convention on Climate Change (UNFCCC) and more recent estimates made available to GGGI by the Climate Change and Development Authority (CCDA). To simplify the assessment, the estimates only include CO_2 emissions, as they represent over 95% of the country's GHG emissions (GoPNG 2014; GoPNG 2018). Although the combination of these two sources provides a more accurate sectoral breakdown of the country's GHG emissions, the estimates remain largely indicative. Their reliability is highly uncertain, and the available data does not allow for analyzing trends or making projections.

First, the assessment used CCDA figures for GHG emissions from the energy sector, as Papua New Guinea's nationally determined contribution highlights that emissions from the energy sector are most likely underreported in the second national communication (GoPNG 2016).

Table 2. Estimates of forest cover and forest cover loss

Source	Period	Total forest cover estimate	Total deforestation over period	Mean annual deforestation rate
Bryan and Shearman 2015	2002–2014	71%	-1.3%	-0.11%
GoPNG 2017a	2000–2015	77.8%	-0.7%	-0.05%
FAO 2019a	2000–2015	74.1%	-0.1%	-0.01%

Source: Compiled by GGGI

Second, GHG emissions from AFOLU are subject to considerable uncertainty (GoPNG 2017b; UNDP 2018) because data and statistics on land use, forest cover, forest cover change, and drivers of deforestation are often inconsistent or incomplete. The extent of uncertainty is exemplified by the considerable discrepancies between recent estimates of forest cover and deforestation rates from 2000 to 2015 (Table 2).

Third, given the country's comparatively low level of total GHG emissions and the large extent of its forests, it can be deduced with reasonable certainty that Papua New Guinea is a net carbon sink (GoPNG 2014). However, estimates for the amount of carbon stored in the country's forests and sequestered each year suffer from a paucity of information. For example, there is no country-specific data for carbon stocks in non-forest land. Due to the lack of reliable data for estimating carbon accumulation in regrowth, Papua New Guinea's Forest Reference Level considers the country's carbon stocks after deforestation to be zero (GoPNG 2017a). This assessment uses a combination of studies and the IPCC guidelines to determine approximate factors to gauge carbon sequestration, but more reliable data is required to increase the accuracy of those estimates (Bryan et al. 2010; Fox et al. 2010; Babon and Gowae 2013; GoPNG 2017a).

Available studies show the high variability in estimates using the examples of average total biomass in unlogged or logged rainforests (Table 3). Such differences can have severe implications—for example, when attempting to estimate the quantity of embedded CO_2 in above- and below-ground biomass—and highlight the need for more reliable data. The National Forest Inventory intends to address this data gap and make a significant improvement to collect and share this data (in-country interviews).

Table 3. Average total biomass of rainforests, according to various studies (tonnes per hectare)

Source	Forest type	Disturbance level	Average total biomass
Bryan et al. 2010	Rainforest	Unlogged	358 t/ha
Fox et al. 2010	Tropical rainforest	Primary	223 t/ha
Bryan and Shearman 2015	Rainforest (specific to Kamula Doso site)	Unlogged	372 t/ha
Bryan et al. 2010	Rainforest	Logged	146 t/ha
Fox et al. 2010	Tropical rainforest	Logged	161 t/ha
Bryan and Shearman 2015	Rainforest (specific to Kamula Doso site)	Logged	252 t/ha

Source: Compiled by GGGI

Beyond the paucity of data about GHG emissions and carbon sequestration, numerous other important indicators are either unavailable or unreliable for Papua New Guinea as a whole and Milne Bay Province specifically. For example, there is considerable uncertainty about the country's population size. According to the 2011 census, the national population more than doubled between 1980 and 2011, to 7.3 million, and annual population growth increased from an estimated 2.2% in 1980 to approximately 3.1% in 2011 (NSO 2011). More recent estimates suggest a total population of 8.8 million people in 2019 (World Bank 2020b), with the annual growth rate declining from 2.4% in 2008 to 2.0% in 2019 (World Bank 2020c). However, in-country interviews suggested that population growth might be significantly higher than indicated by official statistics, with the country's total population possibly being considerably higher than 10 million people.

3.2 VULNERABILITY

To systematically assess Milne Bay Province's vulnerability to the adverse impacts of climate change, the preliminary assessment distinguished between three aspects of vulnerability: exposure, sensitivity, and adaptive capacity (Figure 5).

3.2.1 Exposure

Exposure to climate change refers to the extent to which the economy and population is subject to major changes in climate and weather patterns. Possible phenomena for assessing a province's exposure include: rise in temperature, changes in rainfall, occurrence of drought, rise in sea level, increase in ocean acidity, and occurrence of cyclones. Of these six phenomena, the assessment found that three were relevant for Milne Bay Province: increase in temperature, rise in sea level, and increase in ocean acidity. There is a high confidence that these phenomena are closely related to climate change and that they occur in Milne Bay. In contrast, there is little confidence in the results of the rainfall and drought projections.

Finally, there is only a low to medium confidence that climate change affects the occurrence of cyclones and how future cyclone patterns might evolve (Table 4).

Table 4. Climate change-related phenomena and their impact in Milne Bay Province

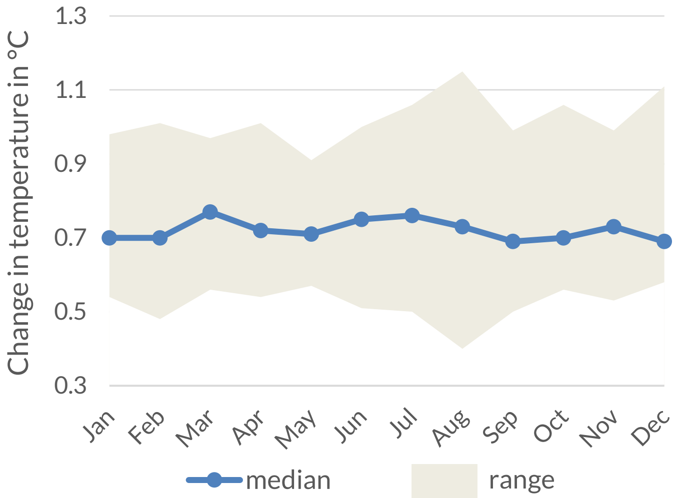
Phenomenon	Confidence	Potential impacts
Rise in temperature	Very high	Decreased yield and quality of agricultural crops Reduced fish catch and increased degradation of coral reefs Increase in vector-borne and respiratory diseases
Rise in sea level	Very high	Increase in coastal flooding, decrease in agricultural productivity, and damage to infrastructure Contamination of drinking water Degradation of coral reefs
Increase in ocean acidity	Very high	Degradation of coral reefs Reduced productivity of coastal fisheries
Change in rainfall	Low	Damage to infrastructure Decrease in agricultural productivity Degradation of coral reefs Increase in vector and water borne diseases
Occurrence of drought	Low	Decrease in agricultural productivity Reduced access to drinking water and reduced food security
Occurrence of cyclones	Low-medium	Destruction of infrastructure Decrease in agricultural productivity Reduced fish catch and increased degradation of coral reefs

Source: GGGI

Rise in temperature

Temperatures in Papua New Guinea have increased during the 20th century and mean monthly air temperature is projected to increase by 0.9°C by 2030 (BoM and CSIRO 2011; Allen and Bourke 2009). Although there is limited long-term data on temperatures for Milne Bay Province, monthly average temperatures are projected to increase by 0.5–1°C over the next two decades, and daily maximum temperatures are estimated to increase by approximately 3°C by the end of the century (Allen and Bourke 2009, World Bank 2020a; Figures 9 and 10).

Figure 9. Projected change in monthly temperature in Milne Bay Province (2020–2039)

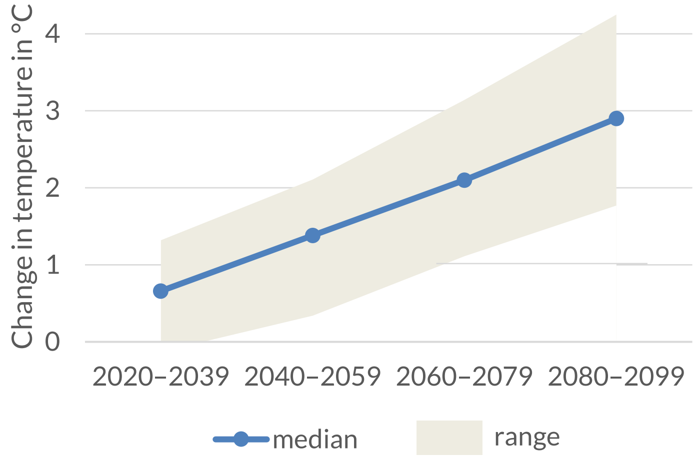


Source: World Bank 2020a

Increasing temperatures are expected to particularly affect agriculture, fish catch, and public health. First, increasing temperatures can lead to lower yield and crop quality due to decreased photosynthesis, higher water stress, and increased exposure to pests and diseases (GEF, UNDP, and SPREP 2009; Jaramillo et al. 2011; Kudela 2009; Moretti et al. 2010). For example, sweet potato is one of the most important food crops Milne Bay Province. Tuber formation in sweet potato is significantly reduced at temperatures above 34°C. Maximum temperatures in the province are projected to reach this threshold, with the risk of considerably reducing sweet potato yield (Allen and Bourke 2009; Grigg and Nadelko 2020; Hay et al. 2003).

Second, sea surface temperatures are projected to increase, leading to reduced fish catch. Both oceanic and coastal fish are expected to be affected. Oceanic fish, such as tuna, are likely to relocate beyond Papua New Guinean waters, while coastal fish stocks will deplete due to loss of habitat—as thermal stress causes coral bleaching and reef degradation—and food, with the decline in phytoplankton and food web organisms (Bell et al. 2011; Drew, Amatangelo, and Hufbauer. 2015; Leisz 2009). The loss of marine biodiversity will likely directly affect Milne Bay Province, where fish is a crucial protein source and fishing is an important economic activity (Bell et al. 2009; Oxford Business Group 2018).

Figure 10. Projected change in maximum daily temperature in Milne Bay Province (2020–2099)



Source: World Bank 2020a

Finally, temperature can play an important role in malaria transmission, influencing mosquito abundance, development, biting rate, and survival (Park et al. 2016; Table 5). Okuneye, Eikenberry, and Gumel (2019) expect the impact of higher temperatures to be considerable in areas with marginal malaria potential, but limited in areas where malaria is endemic. Although there are no dedicated studies for the impact of higher temperatures on malaria incidences in Milne Bay Province, with a reported 438 malaria incidences per 1,000 people in 2016, it is by far the province with the highest malaria incidence in Papua New Guinea (followed by West Sepik Province, with 293 incidences) and is considerably higher than the national average of 105 per 1,000 people (GoPNG 2017c). As a result, it is assumed that the impact of higher temperatures on malaria incidences would be moderate.

Table 5. Time trend of malaria incidence and climate (1996–2008)

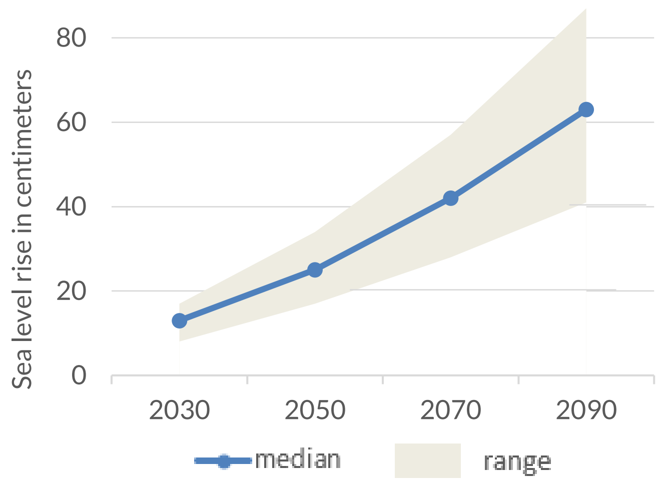
Location	Average increase per year			
	Incidence	Rainfall	Minimum temperature	Maximum temperature
Western Province	-3.1%	-1.4%	+0.1%	+0.0%
Port Moresby (national capital)	-6.1%	+0.4%	+0.1%	-0.1%
Eastern Highlands Province	+4.8%	+3.2%	+0.3%	+0.1%
East Sepik Province	-0.5%	-1.7%	+0.1%	+0.1%
Madang Province	+0.5%	-0.3%	+0.3%	+0.1%

Source: Park et al. 2016

Rise in sea level

Sea levels in Papua New Guinea waters are expected to rise under all emissions scenarios, with projections suggesting a rise of 7–17cm by 2030, 7–34cm by 2050, and 41–87cm by 2100 (BoM and CSIRO 2014; World Bank 2020a; Figure 11). Sea level rise refers to the average relative sea level over a sufficiently extended period to average out transients, such as waves and tides (BoM and CSIRO 2014). Rising sea levels can lead to coastal flooding, salinization, and land erosion (CFE-DM 2016; Connell 2015; Ganpat and Isaac 2014). Estimates suggest that the impacts associated with rising sea levels might affect up to 30% of Papua New Guinea's population (NRC and IDMC 2013). Milne Bay Province will be particularly affected, as large parts of the province are low and most communities are located close to the coast or on small islands and atolls, making them intrinsically susceptible to coastal flooding and sea water intrusion (Busilacchi 2020; Grigg and Nadelko 2020).

Figure 11. Projected increase in sea level in Papua New Guinea (2030–2090)



Source: World Bank 2020a

First, agriculture will likely be one of the most affected sectors from inundation, salinization, and erosion of farmlands, particularly during storm surges. Sea water flooding often has a long-lasting effect on soil salinity and suitability for plant growth. Over the longer term, sea level rise is likely to change water quality parameters and contaminate groundwater reserves (D'Haeyer et al. 2017; Ganpat and Isaac 2014; Skewes et al. 2011).

Second, sea level rise has an impact on the marine environment, as many nursery grounds for commercially important fish and shellfish are located in shallow reefs near the coast and within mangrove forests (CIF 2012). Mangrove forests, offering protection from storms, are projected to decrease by up to 60% by 2100 under a high emissions scenario (Bell et al. 2011), while the growth rates of coral reefs may not be able to keep up with the rapid rise in sea levels (Perry et al. 2018).

Increase in ocean acidity

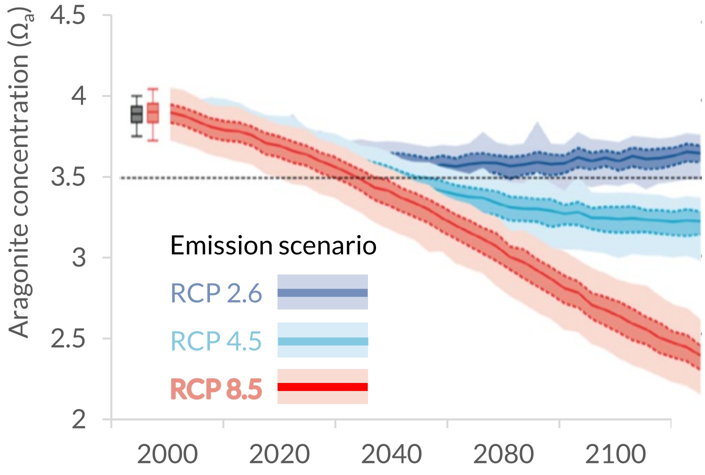
Higher CO_2 concentrations in the atmosphere cause more CO_2 to be absorbed by the world's oceans. As more CO_2 dissolves in the sea, it forms carbonic acid (H_2CO_3), which breaks into hydrogen ions (H^+) and bicarbonate ions (HCO_3^-). A higher concentration of hydrogen ions translates into a decrease in ocean pH level.[3] This process is commonly known as ocean acidification.

Ocean acidification has a negative impact on marine organisms that build skeletons and shells. These organisms rely on aragonite ($CaCO_3$) to build their skeletons and shells. Aragonite is formed from calcium and carbonate ions (Ca^{2+} and CO_3^{2-}), both of which are naturally dissolved in sea water. Both calcium and hydrogen ions tend to bond with carbonate ions, but hydrogen has a greater attraction to carbonate than calcium. As a result, higher concentrations of hydrogen ions lead to lower aragonite levels. When a hydrogen and carbonate ion bond, they form a bicarbonate ion ($HCO3^-$). Many corals and other organisms are unable to extract carbonate ions, which they need to build their skeletons and shells, from bicarbonate (NOAA 2020; Smithsonian Institution 2018).

[3] The pH level reflects the hydrogen ion concentration, with higher amounts of hydrogen ions translating to higher acidity and a lower pH value (NOAA 2020).

By 2000, aragonite concentrations in Papua New Guinean waters had declined to 3.8–4.0 Ω_a.[4] They are projected to continue declining, reaching levels below 3.5 Ω_a —often regarded as a critical threshold—by 2030 (BoM and CSIRO 2011; Figure 12). Corals and crustaceans use aragonite to build and maintain their skeletons. Decreases in ocean pH and aragonite saturation levels would increase the fragility of these organisms and reduce their ability to recover from disturbance, such as storm surges and attacks from other marine organisms. Even if organisms are able to build their shells and skeletons in more acidic water, they may have to spend more energy in the process, taking away resources from other activities like reproduction. If hydrogen ion (H^+) concentration reaches a level where there are insufficient molecules for them to bond with, they can even begin breaking existing calcium carbonate molecules apart, dissolving shells that already exist (NOAA 2020; Smithsonian Institution 2018). When atmospheric concentrations of CO_2 are higher than 450 parts per million, aragonite concentration could fall to levels that make it impossible for corals to sustain building their skeletons, resulting in the erosion of coral reefs (Bell et al. 2011). This would have severe impacts on fisheries, food security, coastal protection, and tourism as corals provide a habitat for many other marine organisms (CFE-DM 2016; Johnson, Bell, and Gupta 2015).

Figure 12. Projected decrease in aragonite saturation in Papua New Guinean waters



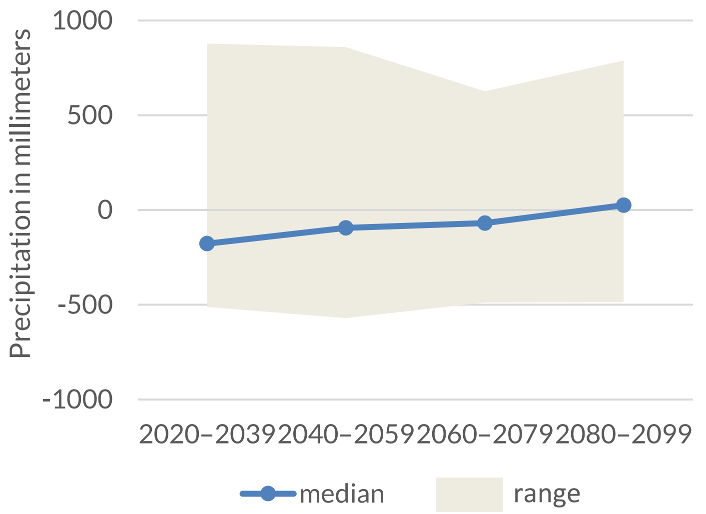
Source: BoM and CSIRO 2011

Note: RCP=representative concentration pathways, scenarios for different greenhouse gas concentration trajectories, several of which were used in the Fifth IPCC Assessment as a basis for

Changes in rainfall

In Milne Bay Province, there is considerable uncertainty about precipitation trends, as variability in rainfall trends over the years and complexity of rainfall patterns render forecasting difficult. Median results show little change in both annual and monthly distribution of rainfall (Allen and Bourke 2009; BoM and CSIRO 2011; World Bank 2020a, Figures 13 and 14). A considerable increase in rainfall would particularly affect agriculture, transportation, fisheries, infrastructure, and public health.

Figure 13. Projected change in annual rainfall in Milne Bay Province



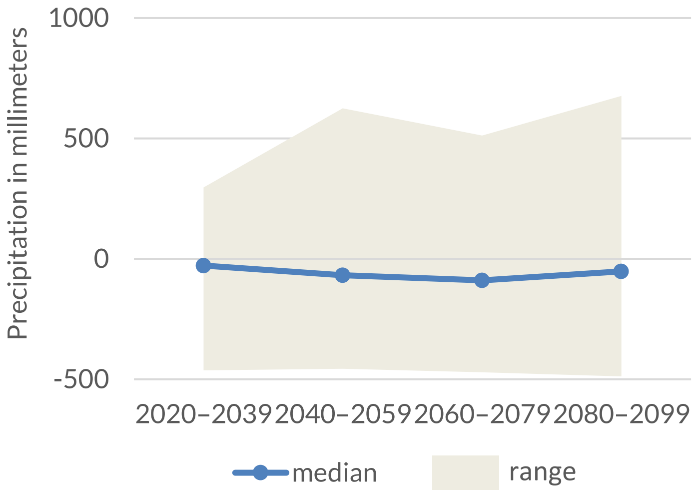
Source: World Bank 2020a

First, changes in rainfall patterns affect planting time, growing stages, harvest periods, and post-harvest crop storage, likely reducing

[4] The unit used to measure aragonite saturation is represented by the Greek letter omega (Ω).

agricultural yield (Ganpat and Isaac 2014; World Bank 2011). Optimum annual rainfall for most crops in Papua New Guinea is 1,800–3,500 mm, with one to three consecutive drier months. An increase in annual rainfall to more than 3,500 mm would lead to low levels of bright sunshine, waterlogged soils, and leaching of soil nutrients, reducing productivity for most crops (Allen and Bourke 2009).

Figure 14. Projected change in maximum monthly rainfall in Milne Bay Province



Source: World Bank 2020a

Milne Bay Province shows considerable geographical variation in annual rainfall. On average, yearly rainfall levels amount to an estimated 3,000–3,500 mm (Allen and Bourke 2009). Most projections suggest increases of less than 20% and decreases of less than 10% by 2080, which would have only marginal effects on agricultural productivity. However, extreme scenarios result in rainfall increases of up to 35% and decreases of as low as -25% (Grigg and Nadelko 2020; World Bank 2020a). Such extreme changes in rainfall would have detrimental impact on agricultural productivity.

Second, higher maximum daily rainfall is expected to increase inland flooding, damaging infrastructure and blocking important transport arteries (ADB 2019; CFE-DM 2016). There is insufficient data to systematically assess the potential economic losses associated with damage caused by increased rainfall, but figures for individual events show considerable losses (IOM 2015; CFE-DM 2016; GoPNG and UN Country Team in Papua New Guinea 2017).

Third, higher amounts of rainfall and more rainfall-induced floods threaten corals by causing higher turbidity and nutrient enrichment in coastal waters. Higher sediment and nutrient loads delivered to coastal reefs reduce their photosynthesis. They also create favorable conditions for epiphytic algae, which compete with corals, affecting coral growth and recovery after storm damage (Bell et al. 2011).

Finally, information on the impact of climate change on public health in Milne Bay Province is sparse. While the negative effect on vector-borne diseases, such as malaria, is considered limited (Okuneye, Eikenberry, and Gumel 2019), higher levels of rainfall could lead to a deterioration of hygiene and sanitation, causing an increase in water-borne diseases (WHO 2012).

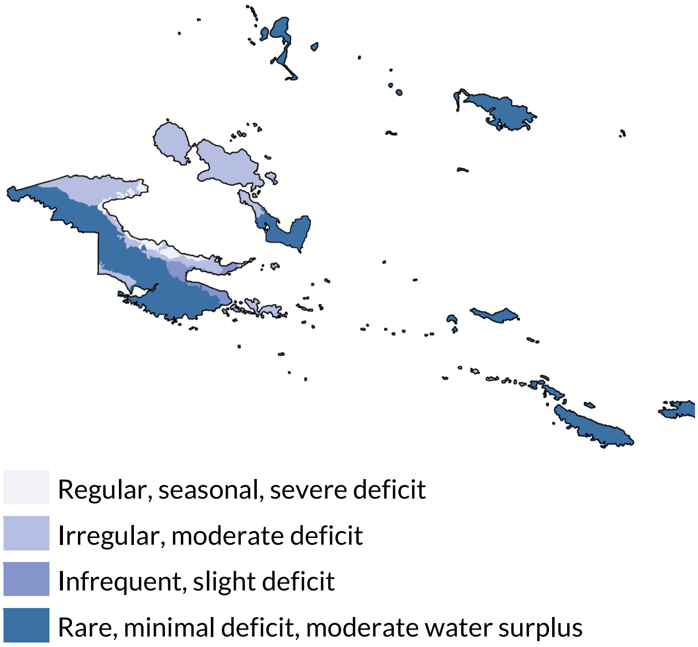
Occurrence of drought

Projections do not suggest a considerable increase in the occurrence of drought, except for extreme scenarios in which annual rainfall levels decrease by as much as 25%. In most projections, the decrease in rainfall is limited to approximately 10% (Grigg and Nadelko 2020; World Bank 2020a). In line with rainfall levels, Milne Bay Province shows considerable geographical variability in the occurrence of drought, measured by soil water deficit. The northern parts of the province—including Trobriand, Collingwood Bay, Northern Owen-Stanley, and Alotau—have historically experienced irregular, moderate soil water deficits, while the rest of the province is characterized by moderate water surpluses (Allen and Bourke 2009; Figure 15).

Projections suggest a possible increase in the intensity of droughts in years impacted by the El Niño Southern Oscillation (ENSO) phenomenon. [5] El Niño years are generally drier, whereas La Niña years tend to experience higher precipitation levels (BoM and CSIRO 2014). From 1876 to 2015, five ENSO events with severe impacts to agriculture have occurred. The two most recent events—in 1997 and 2015—were accompanied by severe food shortages in the small and often remote islands of Milne Bay Province (Bourke, Bryant, and Lowe 2016).

However, while ENSO is a major variable in projecting future climate, the relationship between the phenomenon and climate change is subject to debate. In particular, the difficulty in predicting the ENSO phenomenon has implications for the level of uncertainty in climate projections for drought (BoM and CSIRO 2014).

Figure 15. Soil water deficit and surplus in Milne Bay Province



Source: Allen and Bourke 2009

Occurrence of cyclones

Milne Bay Province is regularly affected by tropical cyclones, which are defined as weather systems with wind speeds of more than 34 knots and pressure below 985 hPa (BoM 2020; Tan and Fang 2018; WMO 2017). Projections suggest a decrease in frequency but an increase in intensity of tropical cyclones. However, there is low confidence in attributing changes in tropical cyclone activity to human influence due to low understanding of the physics between anthropogenic drivers of climate and tropical cyclone activity, and the low level of agreement between studies around the relative importance of internal variability and anthropogenic and naturally occurring effects. Furthermore, insufficient data, differences across published projections of tropical cyclone activity, and the large role of natural variability result in low-to-medium confidence in projections of changes in tropical cyclone intensity and frequency (IPCC 2013; Knutson et al. 2020).

If cyclones affecting Milne Bay Province were to increase in intensity, this would likely have repercussions for agriculture, infrastructure, marine ecosystems, and public health. However, given the uncertainty regarding their future intensity and the interaction between frequency and intensity, the preliminary assessment did not attempt to quantify these effects.

[5] The ENSO phenomenon is a periodic fluctuation in sea surface temperature (El Niño and La Niña) and the air pressure of the overlying atmosphere (Southern Oscillation) across the equatorial Pacific Ocean (NOAA n.d.) During El Niño years, rainfall increases over the tropical Pacific Ocean and usual winds that blow from east to west ("easterly winds") weaken or even reverse their direction ("westerly winds"). During La Niña, rainfall decreases over the central tropical Pacific Ocean and usual easterly winds along the equator become stronger (L'Heureux 2014).

3.2.2 Sensitivity

Sensitivity to climate change refers to the extent to which the economy and population rely on sectors and activities that are susceptible to climate change-related phenomena. To assess the province's sensitivity, the preliminary assessment considered the following sectors and activities: agriculture, forestry, fishing, tourism, mining electricity supply, transportation, and water supply and sanitation.

Like Papua New Guinea in general, Milne Bay Province is characterized by a dual economy. The export-oriented extractive industry and commercial agricultural plantations provide a large share of gross domestic product (GDP), while more than 80% of the population lives in rural areas with minimal services and infrastructure, mainly relying on subsistence agriculture (ADB 2019; IMF 2017; UNDP, UNEP, and GEF 2018). As a result, the province's agriculture and fishing sectors show a high sensitivity to climate change. On top of this, its electricity, transport, water, and sanitation infrastructure are regarded as susceptible to the adverse impacts of climate change (Table 6).

Table 6. Sectors affected by climate change

Sector	Relevance	Sensitivity to climate change
Agriculture	High share of population engaged subsistence agriculture Sale of agricultural commodities as the most important source of income for rural population	Adverse impacts of climate change likely to further increase existing agricultural pressure
Forestry	Commercial logging is an important contributor to local economy	Forestry sector not considered as susceptible to the adverse impacts of climate change, but amplifying the adverse impacts of climate change
Fishing	Fish as an alternative source of protein and an important source of income	Considerable impact of climate change on fish stocks
Tourism	Tourism is an important contributor to the local economy	Tourism indirectly affected by loss of (marine) biodiversity due to climate change
Mining	Mining used to represent a major contributor to local economy and employment, but large-scale operations have ceased for now	Commercial mining operations largely unaffected by climate change Small-scale mining considered to be susceptible to climate change
Transportation	Low access to road transportation and low vehicle ownership rates Maritime transport is of high importance	Quality of road infrastructure is low and likely susceptible to negative impacts of climate change
Electricity supply	Low electricity access rate	Electricity supply not considered as susceptible to the adverse impacts of climate change since electricity generation largely relies on diesel generators
Water supply and sanitation	Access to protected drinking water sources and improved sanitation is limited, particularly in rural areas	Unprotected water sources and unimproved sanitation can be affected by climate change, causing health hazards

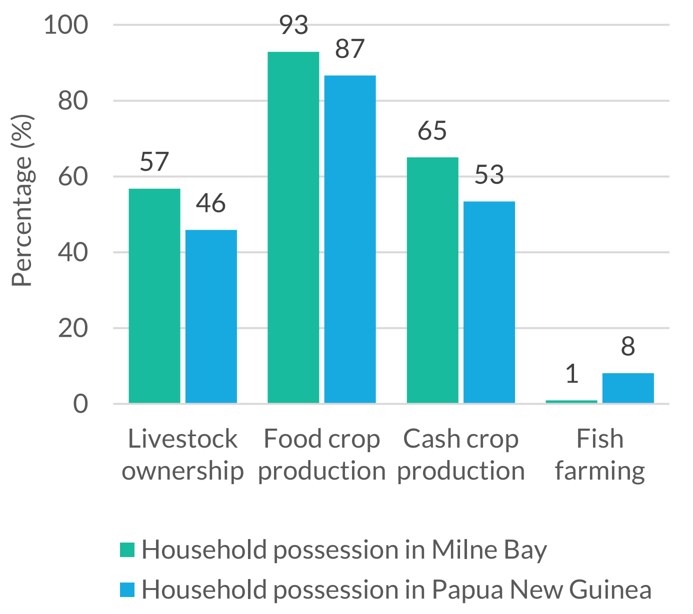
Source: GGGI

Agriculture

Milne Bay Province's economy is dominated by subsistence farming, with an estimated 90% of households engaged in growing food crops, vegetables, fruits, and root crops—including cassava, sweet potato, yam, corn, pumpkin, beans, pitpit, aibika banana, pawpaw, pineapple, watermelon, and Malay apple—and approximately two-thirds of all households are engaged in producing cash crops such as oil palm and copra (Bourke and Harwood 2009; NSO and ICF 2019; Howes et al. 2019; Figure 16).

Commercial agriculture has experienced a gradual decline over the past two decades, affecting cocoa and coconut/copra. Major remaining commercial plantations include oil palm and copra (MBPA 2019).

Figure 16. Livestock ownership, food, and cash crop production and fish farming at province and national levels



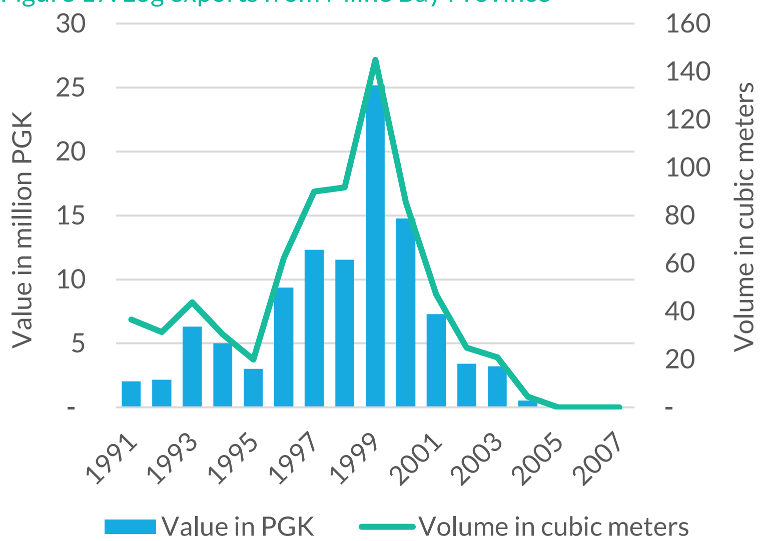
Source: NSO and ICF 2019

Most of the land in Milne Bay Province is considered to be of low to medium quality, with only an estimated 20% of land area being of high quality (Allen and Bourke 2009). While land use intensity has been low historically (Allen and Bourke 2009), most arable land is already under strong agricultural pressure as a result of rapid population growth (Busilacchi 2020). Adverse impacts of climate change—such as higher temperatures and precipitation levels—can further increase this pressure.

Forestry

Although it has experienced a decline, commercial forestry still plays an important role in Milne Bay Province's economy (Bryan and Shearman 2015; Bun, King, and Shearman 2004; in-country interviews). At its peak in the late 1990s, log exports from Milne Bay Province accounted for nearly 7% of Papua New Guinea's total log exports (Bourke and Harwood 2009; Figure 17). The sector creates formal employment in rural areas and provides much-needed infrastructure—particularly roads and bridges—as part of community service obligations that are often part of concession agreements (in-country interviews). Logging concessions continue to be awarded in the form of forest management agreements and, while other concession arrangements such as local forest areas and timber rights purchases are no longer issued, they are still in use (in-country interviews).

Figure 17. Log exports from Milne Bay Province



Source: Bourke and Harwood 2009

Logging activities are generally conducted in natural forests with little plantation forestry or reforestation (in-country interviews). As a result, they were an important driver behind Milne Bay's forest cover loss: in 2014, an estimated 10% of the province's rainforest area had been logged (Bryan and Shearman 2015). While the forestry sector is not directly affected by climate change, logging activities amplify the impact of climate change by reducing the essential ecosystem services forests provide.

Fishing

Fish represents an important protein source, with people in Papua New Guinea's coastal regions consuming up to 53 kg of fish each per year (ADB 2014; Bell et al. 2009; Friedman et al. 2008; Gillet 2009; Govan 2018). Estimates suggest that approximately 15–20% of households in Milne Bay Province are engaged in fishing (Preston 2001; Kaly 2006). Although these figures are based on data from the 1990s, it is generally regarded as unlikely that fishing activities have changed substantially (Gillet 2009). Fishing also represents an important source of income in some parts of the province (Kaly 2006). However, the relevance and output of commercial fishing in Milne Bay are limited, as many initiatives fail for economic and technical reasons. Exported species include trochus, sea cucumbers, lobsters, prawns, and sharks. Finally, information about fish farming is both limited and conflicting, with estimates ranging from less than 10 to nearly 300 fish farms (MBPA 2019).

Tourism

While Papua New Guinea's tourism sector is fragmented and there is little available data at provincial level, diving accounts for an estimated two-thirds of tourist arrivals (ADB 2014). Since the mid-1980s, Milne Bay Province has witnessed a steady increase in the number of visitors (in-country interviews). For 2018–2019, the province registered an estimated 34,000–35,000 visitor arrivals per year, more than 90% of whom were tourists arriving on cruise ships (PNG Tourism Promotion Authority 2020). The main ports of call in the province are Trobriands Islands, Samarai, and Alotau, the provincial capital (in-country interviews). However, income from tourism is limited as most tourists stay on cruise ships rather than local hotels or guest houses, limiting their contribution to the local economy.

Given its abundant marine resources, Milne Bay Province has considerable potential for marine recreation and ecotourism. The PNG Tourism Promotion Authority identified Milne Bay as one of the five model provinces for sustained impact ecotourism projects (MBPA 2019). However, its tourism industry is small and lacks transport, accommodation, and other relevant infrastructure (in-country interviews).

There is insufficient information to assess the impact of climate change on tourism. However, it is assumed that tourism might be negatively affected by the loss of biodiversity due to climate change, particularly the loss of marine biodiversity.

Mining

With the closure of the Misima gold mine, mining operations ceased in Milne Bay Province (NRI 2010). Several sites for new operations have been under exploration for years, most importantly two gold projects on Woodlark Island and Normanby Island (Knapon and Bailie 2018) and a new gold project on Misima Island (Kingston Resources n.d.; NS Energy n.d.). However, it is uncertain whether these projects will become operational. In addition, estimates suggest that approximately 1,000 people in Misima and Woodlark Districts are engaged in alluvial mining (Susapu and Crispin 2001). However, this estimate is outdated, and little information is available on the scale of these operations.

Climate change is considered unlikely to have major direct impact on mining. Changes in the frequency and intensity of storms might affect mining operations (NSWG 2020), but there is considerable uncertainty around the extent of their impact. Generally, artisanal mining is expected to be more impacted by climate change than commercial mining operations (Sharma et al. 2013). However, there is a paucity of information on the scope of artisanal mining in Milne Bay Province.

Transportation

With little information available on the relevance of maritime and air transport, low ownership rates and low passenger numbers, the assessment of the transport sector focused on road transport in Milne Bay Province.

Milne Bay has a single provincial road on the main island, stretching from Buibui through Gurney airport and Alotau to the East Cape and Taupota. This road provides a vital link for populations located in the north and east of the province, including numerous smaller islands, to the main produce market, shops, and services at Alotau (World Bank 2016). There are no roads connecting the province to other parts of Papua New Guinea. As a result, inter-province travel and exchange of goods rely on maritime and air transport. The quality of the road network is generally low and susceptible to adverse impacts of climate change, particularly heavy rainfall, which causes flooding and erodes road foundations. Of the estimated 1,000 km of total road in the province, only a fraction is sealed (MBPA 2019; World Bank 2013).

Table 7. Vehicle ownership in Milne Bay Province

	Bicycle	Motorcycle	Car/truck	Boat with motor
Milne Bay total	7%	1%	3%	6%
Milne Bay urban	22%	3%	20%	10%
Milne Bay rural	5%	<1%	<1%	5%

Source: NSO and ICF 2019

However, the adverse impact of climate change on road transport is somewhat limited by the population's low access to road transport (Bourke and Harwood 2009) and low vehicle ownership rates, with less than 5% of the population owning a car, truck, or motorcycle (NSO and ICF 2019; Table 7).

Given the province's geography, maritime transport is of high importance. With approximately 50 operational jetties, small boat travel allows for improved access and interconnectivity. However, connectivity and accessibility vary, as reflected in the time taken to reach the nearest service center. While residents of Misima Island, Wagawaga, and Sagaria require less than four hours' boat travel to reach the nearest service center, people living on most other islands require four to eight hours, and those on Yanaba, Alcester, and Budibudi Islands are located more than a day's boat travel away (MBPA 2019). In addition, fuel costs are a severe constraint on the population's ability to travel. While weather conditions make small boat travel dangerous at certain times of year (Allen and Bourke 2009), the extent to which climate change will affect maritime transport is uncertain.

Three operators provide an aviation service within the province and between the provincial capital Alotau and the national capital, Port Moresby. The province has 26 designated airstrips, but only a few are operational (MBPA 2019). There was no available data on passenger numbers, distance traveled, and cargo amounts for the preliminary assessment.

Electricity supply

Due to the paucity of information on off-grid systems, the assessment focused on utility-scale electricity generation when considering the sensitivity of Milne Bay Province's electricity supply.

The province's electricity is mainly generated from diesel, with a 3 megawatt (MW) diesel-fired powerplant at Alotau and a 2–3 MW diesel-fired power plant at Samarai (ADB 2009; Figure 18). In addition, it is assumed that there are several auto-producers, including oil palm developments near Sagarai and both former and future commercial mining sites. However, no information is available on the installed electricity generation capacity at these sites. Most likely, auto-producers largely rely on diesel to generate electricity.

None of the existing power systems are considered to be directly susceptible to negative impacts of climate change. Furthermore, if climate change were to cause increased electricity outages, the share of affected population would be comparatively low, given low access rates to electricity. Survey data from NSO and ICF (2019) suggests that only approximately 13% of Milne Bay Province's population has access to electricity. This is reflected in equally low appliance ownership, with only approximately a quarter of households owning a radio and less than 10% owning a television, refrigerator, or computer (NSO and ICF 2019).

Figure 18. Power plants in Milne Bay Province

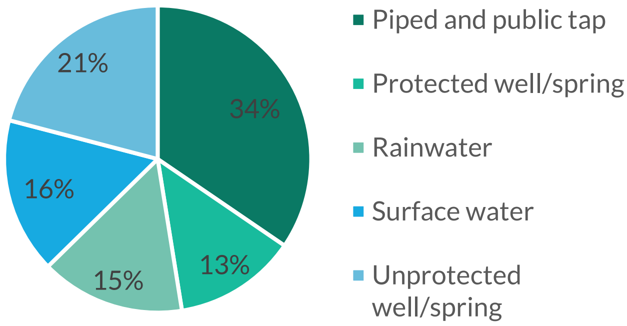
Source: GGGI

Water supply and sanitation

To evaluate the sensitivity of water supply and sanitation, the assessment considered the population's access to protected drinking water sources and improved sanitation facilities.

Prolonged rainfall, flooding, and an increase in drought can affect unprotected water sources and unimproved sanitation, causing health hazards (IOM 2016). More than one-third of the rural population relies on unprotected sources of drinking water (Figure 19). Particularly in rural areas, water supply and sanitation are susceptible to the impacts of climate change. While in urban areas, drinking water is almost exclusively piped or provided through public taps, rural areas rely on a diverse mix of sources, including pipes and public taps (34%), protected wells and springs (13%), rainwater (15%), surface water (16%), and unprotected wells and springs (21%) (NSO and ICF 2019).

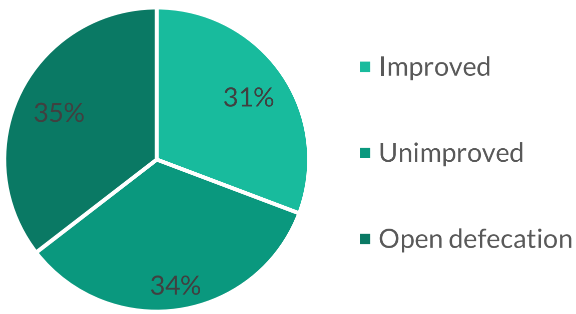
Figure 19. Source of drinking water in Milne Bay Province



Source: NSO and ICF 2019

Only an estimated one-third of the population has access to improved sanitation (Figure 20). While these are common in urban areas, where approximately 90% of the population have access, approximately two-thirds of the rural population rely on unimproved sanitation and open defecation (NSO and ICF 2019).

Figure 20. Sanitation facilities in Milne Bay Province



Source: NSO and ICF 2019

3.2.3 Adaptive capacity

Adaptive capacity refers to the extent to which the population is able to cope with the adverse impacts of climate change, despite its level of exposure and sensitivity. To assess Milne Bay's adaptive capacity, the assessment considered the following features: poverty rates; access to electricity; access to water and sanitation; reliability of the transport network; access to and usage of information and communication technologies; access to and quality of health services; education and labor skills; and deforestation as a proxy for ecosystem services.

Reflective of Papua New Guinea in general, a high share of Milne Bay Province's population lives in rural areas with minimal services and infrastructure (ADB 2019; IMF 2017; UNDP, UNEP, and GEF 2018). Poverty, limited access to and low quality of services are the defining features for the province's capacity to cope with the adverse impacts of climate change. As a result, interventions should focus on reducing poverty and improving services to strengthen the population's resilience to climate change. In particular, increased access to electricity is regarded as a crucial feature that could bring about progress in many other areas (Table 8).

Table 8. Adaptive capacity in Milne Bay Province

Feature	Relevance	Status
Poverty	Poverty is a defining feature for adaptive capacity, as many means of adaptation require some financial investment	Large share of population dependent on subsistence farming Limited opportunities for cash income
Access to electricity	Access to electricity is fundamental for development and the availability of other services and income-generating activities	Low access to electricity
Access to water	Water is an essential substance for all living organisms Water sustains plant life, a source of food and provider of important ecosystem services	Somewhat limited access to protected sources of drinking water in rural areas Agriculture largely rainfed with limited deployment of irrigation
Transportation	A reliable transportation network increases the ability to adapt to the adverse impacts of climate change	Limited access and low quality of road network Important role of marine transport constrained by limited capacity, fuel costs, and aging equipment
Information and communication	Mobile phone services to communicate and access information are an important means to overcome infrastructure barriers and strengthen adaptive capacity	Mobile phone connectivity depends on location and is expensive Limited access to formal finance
Health service	Climate change can have severe impacts on health, particularly when combined with weak health infrastructure	Limited access to and low quality of health services
Education and labor skills	Education is crucial for social inclusion and economic growth Level of education is a critical determinant for an individual's income	Low completion rates for all levels of education Labor skills are focused on agriculture

	and skill levels across the workforce as a defining feature for economic development	
Deforestation	Forest resources play an important economic role Forests provide essential ecosystem services	Comparatively low rate of deforestation

Source: GGGI

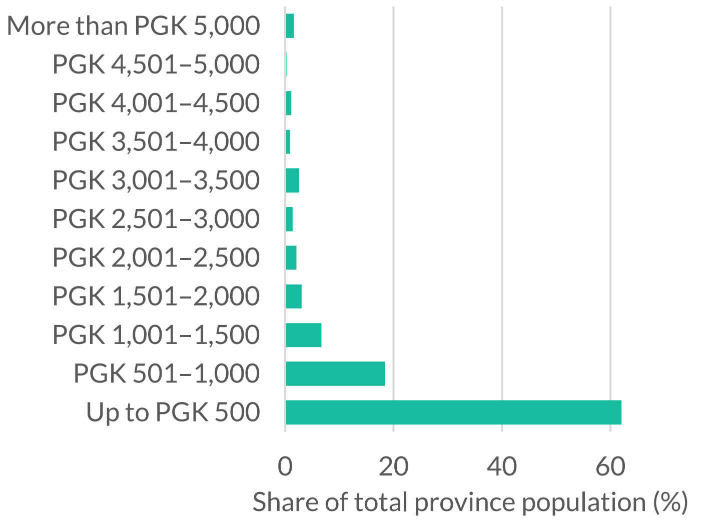
Poverty

Within the context of the CRGG assessment, poverty relates to material wealth and cash income. Many means of adaptation require some level of financial investment. Therefore, poverty severely reduces adaptive capacity. As such, any increase in opportunities for earning cash income would strengthen the population's resilience to the adverse impacts of climate change.

Milne Bay Province is characterized by a dual economy. The large majority of the population depends on subsistence farming, while mining operations and commercial agricultural plantations account for a large share of GDP and provide pockets of high income for a limited number of people (ADB 2019; IMF 2017; UNDP, UNEP, and GEF 2018).

Recent data for income levels in Milne Bay Province are not available. As a result, the preliminary assessment had to rely on household income data collected in preparation of the Alotau Urban Development Plan. According to the survey data, nearly two-thirds of the population earn less than PGK500 per month (Aleker n.d.; Figure 21). While data collection for the survey was limited to Alotau District, given the high share of subsistence farming across the province, it is assumed that income levels are rather lower in other parts of Milne Bay. This assessment is in line with results from a household survey conducted by the National Fisheries Authority in Milne Bay Province, concluding that average monthly income varies between PGK100 and PGK600 (Kaly 2006).

Figure 21. Estimated monthly income of Milne Bay population



Source: Aleker n.d.

Access to electricity

Access to electricity—fundamental for economic development and availability of numerous other services, such as lighting, use of appliances, and communication—is limited. It is estimated that less than 15% of the province's population has access to electricity (NSO and ICF 2019), and the service is often unreliable.

As a result, electrification can play an essential part in strengthening adaptive capacity in Milne Bay Province. In particular, the preliminary assessment identified off-grid electrification as an opportunity to strengthen adaptive capacity, including water pumping and irrigation, storage, drying, and refrigeration (IRENA 2016a).

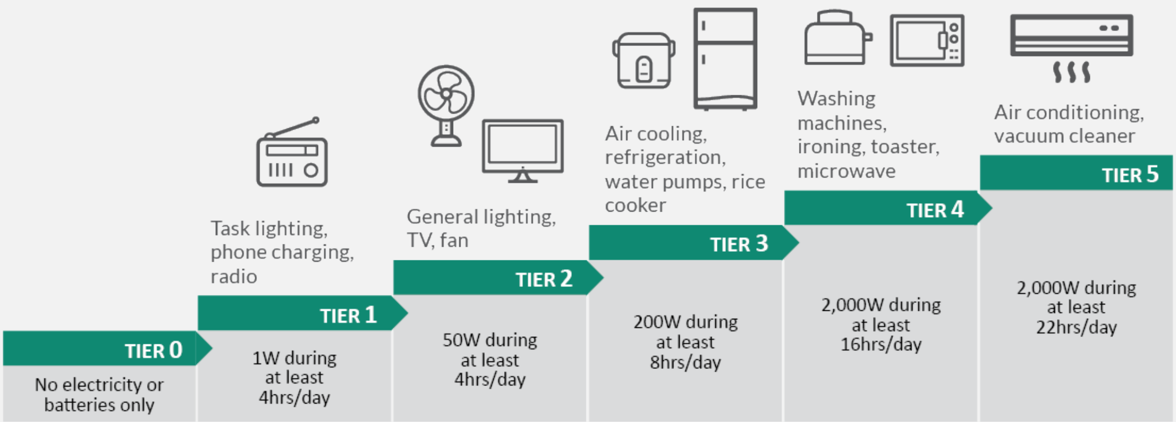
However, it is important not to regard access to electricity as a binary measure—that is, whether a household has access to electricity or not. Quantity, reliability, and affordability are also decisive criteria when assessing access to electricity and considering possible interventions (see Box 2). For example, demand and affordability are crucial factors for determining whether or not off-grid systems are a suitable source of supply.

Box 2. Defining access to electricity

There is no universally agreed-on definition of 'access to electricity'. Traditionally, access to electricity has been measured on the basis of household connections to the national electricity grid. This approach limits assessing access to electricity to a binary measure (that is, a household either has or does not have access). The measure is insufficient to capture issues such as quantity, quality, adequacy, and affordability of the service. Nor does it capture progress in electrification through off-grid solutions. However, a lack of data often confines the analysis to the binary metric, particularly in developing countries where access is an issue (SE4All 2013; Lighting Global 2016; Lighting Global 2018).

A more accurate metric would measure the degree of access to electricity along various dimensions. Recent efforts to move to more granular metrics include the International Energy Agency's (IEA) Energy Access Outlook 2017, which covers renewable off- or mini-grid connections that have sufficient capacity to provide a minimum of energy services for several lights, phone charging, and a radio (IEA 2017a; IEA 2017b).[6] The UN's Sustainable Energy for All (SE4All) Multi-Tier Framework for Measuring Electricity Access seeks to capture access not as a binary measure but as a continuum of service levels considering capacity, duration of supply, reliability, quality, affordability, legality, and safety. For that purpose, the framework distinguishes between six tiers of electricity access (Figure 22; SE4ALL 2013).

Figure 22. SE4All's Multi-Tier Framework for Electricity Access



Source: Adapted from Lighting Global 2016

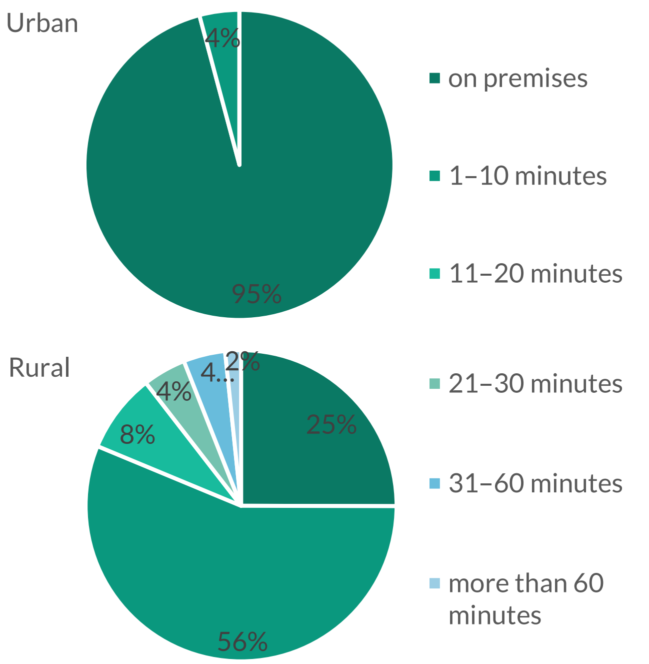
[6] For the full definition, see IEA 2017b.

Access to water

The preliminary assessment considered access to drinking water and the availability of water for economic activities, principally agriculture. Water is an essential substance for all living organisms, delivering nutrients and oxygen and discharging metabolic wastes (Popkin, D'Anci, and Rosenberg 2010; WWAP 2012). It also sustains plant life, which in turn provides essential ecosystem services and serves as a food source (Cosgrove and Rijsberman 2000; FAO 2019b; UN Water 2019). Therefore, access to water represents a defining feature for assessing adaptive capacity.

In Milne Bay Province, a comparatively small share of the population has no immediate access to drinking water. In urban areas, practically the entire population requires less than 10 minutes to access a drinking water source, and an estimated 95% has access on premises. In rural areas, approximately one-fifth of the population lives more than 10 minutes away from a drinking water source. Of particular concern are the approximately 6% of people who require more than 30 minutes (NSO and ICF 2019; Figure 23).

Figure 23. Time taken to reach a drinking water source



Source: NSO and ICF 2019

Agriculture, which forms the economic backbone of Milne Bay Province, is largely rainfed. Historically, most areas are characterised by moderate soil water surpluses, and only the northern parts of the province experience irregular, moderate soil water deficits (Allen and Bourke 2009; Figure 15). Nevertheless, droughts are perceived as a severe risk factor for agricultural output and food security (MBPA 2019; in-country interviews).

Transportation

A reliable transportation network increases the ability to adapt to the adverse impacts of climate change as it allows for the provision of needed goods and the mobility of people.

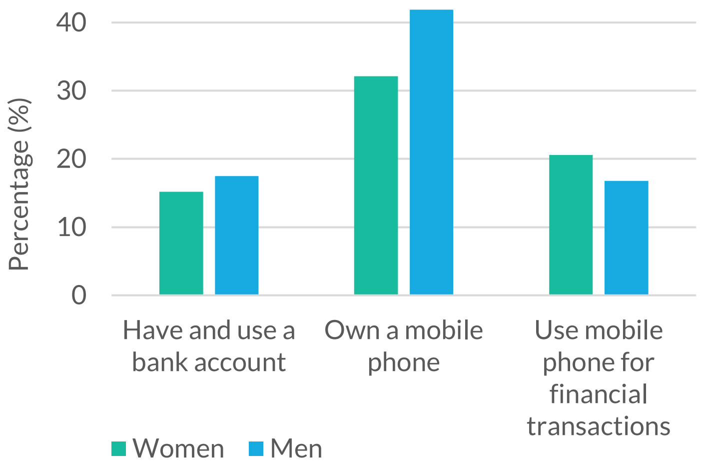
Although a systematic assessment of road quality in Milne Bay Province was not available for the preliminary assessment, aggregated data for Papua New Guinea suggests that the quality of the road network in Milne Bay Province is moderate to low. In particular, non-national roads are in poor condition (Slattery, Dornan, and Lee 2018). Furthermore, accessibility is limited as a result of the province's geography and the lack of infrastructure (Bourke and Harwood 2009).

Given the province's geography, maritime transport plays an important role in the movement of people and goods, although fuel costs are a severe constraint on the population's ability to travel. As noted for sensitivity, estimates suggest that residents of Misima Island, Wagawaga, and Sagaria require less than four hours' travel to reach the nearest service center. People from other islands require between four hours and more than a day to travel by boat (MBPA 2019). The general paucity of data capturing sea freight and passenger transport prevents a more detailed assessment.

Improved road access, quality of road network, and conditions for maritime transport would strengthen adaptive capacity in the short and long term. In the short term, they would reduce the disruption experienced during extreme weather events, while in the long term, they would allow for increased access to services and markets.

Information and communication

Figure 24. Mobile phone ownership and access to finance in Milne Bay Province



Source: NSO and ICF 2019

In the preliminary assessment, 'access to mobile phone network' served as a proxy to evaluate the availability and use of modern means of information and communication. Over the past decade, the possibility of using mobile phone services to communicate and access information has become an important means for overcoming basic infrastructure and service barriers. In that context, access to mobile phone network can be regarded as a means to strengthen adaptive capacity. For example, farmers and vendors can use mobile phones to determine prices and sell their goods, among other uses (Baumüller 2015; GSMA 2019; Trendov, Varas, and Zeng 2019). At the same time, mobile money transfer has become an important means to facilitate financial transactions (GSMA 2019; Jack and Suri 2011), particularly in countries where physical access to banks or other financial institutions is limited. Mobile technology is also helping to tackle limitations in many other sectors, including health, education, water, and sanitation (GSMA 2019; USAID 2014).[7]

In Papua New Guinea, mobile phone coverage has expanded from less than 3% of the population in 2006 to approximately 90% in 2019 (De Rosbo 2020). However, service outages are common, bandwidth is limited, and affordability remains an issue (ITU 2017). In Milne Bay Province, an estimated 60–80% of the population are covered by the mobile network (MBPA 2019). Rural districts are limited to 2G, with 3G and 4G available in urban areas (in-country interviews). Furthermore, only an estimated third of the province's population owns a mobile phone, and less than 20% use their phones for financial transactions (NSO and ICF 2019; Figure 24).

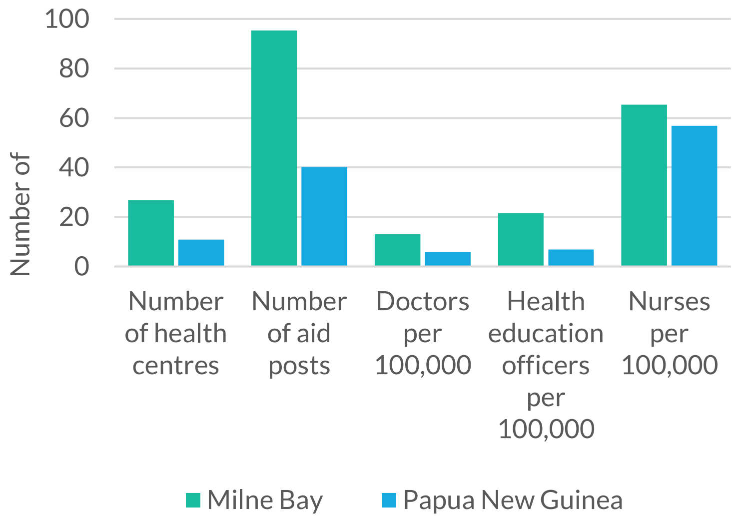
Health service

The preliminary assessment considered health infrastructure and quality of health services as important determinants for adaptive capacity (Figure 25). Climate change can have severe impacts on health, particularly when combined with poor health infrastructure and weak health systems (WHO 2013; WHO 2009).

[7] While many of the available studies assessing the relevance of using mobile phone services were conducted in sub-Saharan Africa, their findings are considered relevant for Papua New Guinea, given the similar socioeconomic and geographical conditions.

For example, climate change-related phenomena—such as rising temperatures and changes in precipitation—can cause increases in vector- and waterborne diseases (Park et al. 2016). According to WHO (2002), health patterns usually disadvantage the poor, who tend to die earlier and are subject to higher levels of morbidity. Given the comparatively high poverty rate in Milne Bay Province—and in Papua New Guinea in general—improvements in health services can play an important role in strengthening adaptive capacity.

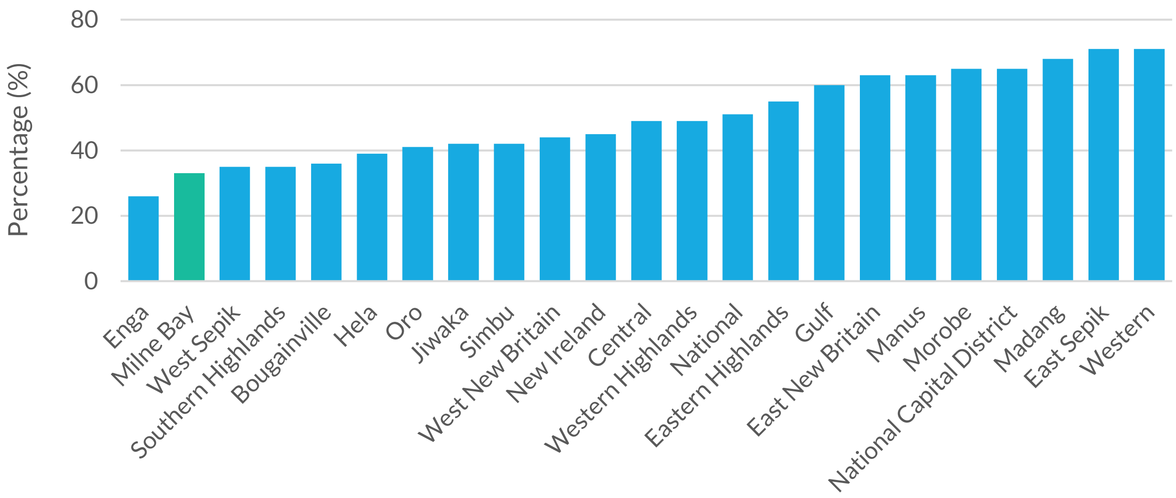
Figure 25. Health service indictors for Milne Bay Province



Source: NSO and ICF 2019

Available data shows that access to and quality of health services in Milne Bay Province are limited, particularly in rural areas. Health services generally suffer from a lack of financial resources, qualified personnel, medical equipment, and supplies (GoPNG 2017c; Figure 26), weakening resilience to the adverse impacts of climate change.

Figure 26. Share of months that health facilities have adequate medical supplies, by province (2016)



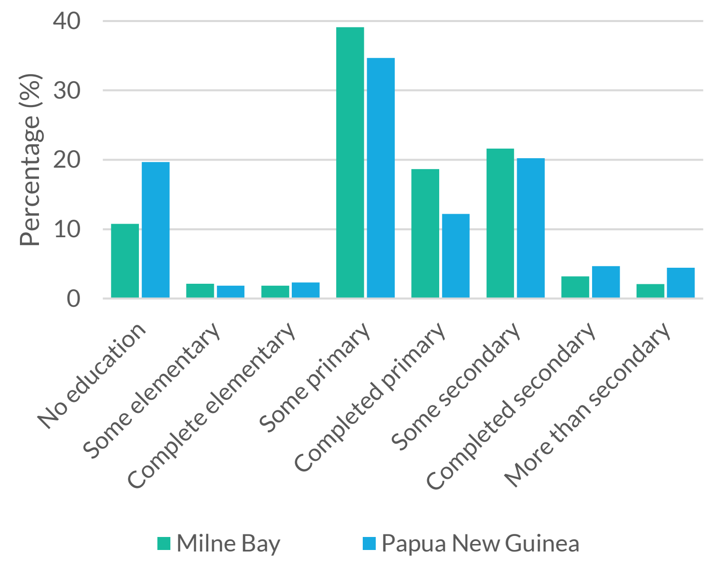
Source: GoPNG 2017c

Education and labor skills

Education and labor skills are important features determining a population's ability to cope with the adverse impacts of climate change. Level of education is a critical determinant for income on an individual level, while skill levels across the workforce are a defining feature for a country's level of economic development (UNESCO 2004).

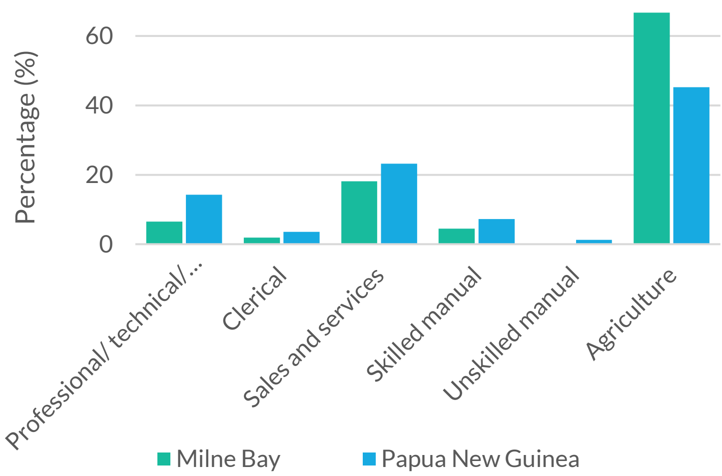
Completion rates—used as a measure for education—are low for all levels of education in Milne Bay Province (NSO and ICF 2019; Figure 27). While the share of people in the province with no education is considerably lower than the average for Papua New Guinea, an estimated three out of five people did not progress beyond primary education. Approximately one in five received some secondary education, but only a fraction of those completed secondary education. Differences between completion rates for women and men appear to be marginal in Milne Bay Province (NSO and ICF 2019).

Figure 27. Share of population by level of education



Source: NSO and ICF 2019

Figure 28. Share of population by occupation



Source: NSO and ICF 2019

Looking at occupations, labor skills in Papua New Guinea are concentrated in the agriculture sector, and in Milne Bay Province, the share of people engaged in the sector is even higher than the country's average. This is reflected in lower shares of employment in other occupations (Figure 28). It is noteworthy that the share of women working agriculture sector is lower (62%) than the share of men (74%), while the sales and service sector is dominated by women (NSO and ICF 2019).

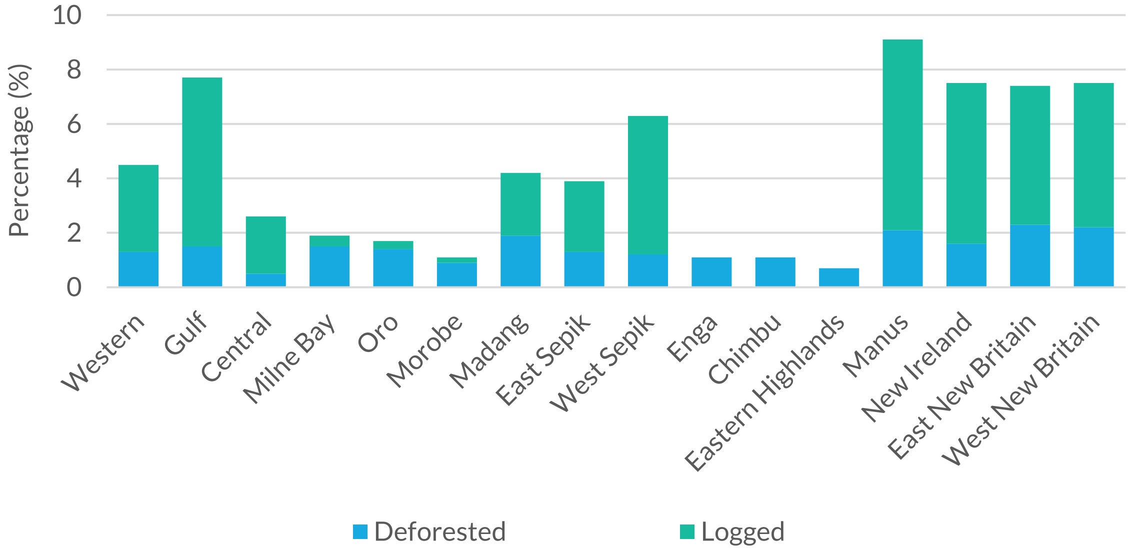
As a result, when capacity building is targeted towards teaching relevant skills and knowledge, it is regarded as an important vehicle for strengthening adaptive capacity in Milne Bay Province.

Deforestation

Forests represent a crucial resource for coping with the adverse impacts of climate change. They provide essential ecosystem services, including carbon sequestration and storage, nitrogen fixation, increased soil carbon, protection against soil erosion, improved water quality and regulation, and refuge for biodiversity and edible pollinators (HLPE 2017; Matthews et al. 2000; UNECE n.d.). Furthermore, forests play an important economic role in sustaining the livelihoods of rural populations (Dawson et al. 2014; World Bank 2008) and provide essential fuelwood to meet households' energy needs (NSO and ICF 2019).

Estimates suggest that, from 2002 to 2014, forest cover in Milne Bay Province decreased by nearly 2%. While considerable, this loss in forest cover is moderate when compared to other coastal and island provinces in the country, such as Manus (9.1%), Gulf (7.7%), and New Ireland (7.6%) where considerable logging activity is taking place (Bryan and Shearman 2015; Figure 29). Deforestation in Milne Bay Province is driven by agricultural activity, the population's reliance on fuelwood as the principal energy source and, to a lesser degree, logging. Continued population growth is expected to result in further deforestation as demand for agricultural land grows and energy consumption increases (Österreichische Bundesforste AG 2014; in-county interviews).

Figure 29. Share of forest area deforested and logged (2002–2014), by province



Source: Bryan and Shearman 2015

4. Consultation

Gathering input from a broad range of stakeholders through an interactive workshop was an essential part of the CRGG assessment. Usually, GGGI conducts a dedicated workshop to gather the relevant results for the CRGG assessment from stakeholders (see Appendix E). However, in the case of Milne Bay Province, the Milne Bay Provincial Administration, the CCDA, the Australian Department of Foreign Affairs and Trade, CSIRO, TNC, and GGGI all needed input from the same group of stakeholders, and therefore organized a joint consultation workshop.

Held in the provincial capital Alotau from 29 to 30 September 2020, this workshop gathered approximately 30 participants from different departments and agencies of the Milne Bay Provincial Administration, civil society, and the private sector (Figures 30 and 31). During the four sessions of the two-day workshop, participants identified priorities for climate resilience and relevant interventions in the specific context of Milne Bay Province. The participant list and workshop agenda are provided in Appendices A and B of this report.

Figure 30. Plenary session and group discussions during the consultation workshop

Source: GGGI

4.1 DRIVERS OF CHANGE

To help participants identify the factors influencing future development in Milne Bay Province, Session 1 consisted of a mix of presentations and interactive group work. In several remote presentations, a group of CSIRO experts introduced a wide range of drivers of change, including climate change, population growth and macroeconomic trends.[8] They also emphasized the uncertainty inherent to any projections and highlighted the geographical differences within the province. Participants were then asked to identify the most important impacts of climate change and how these are connected to other influences. For that purpose, participants wrote the drivers of change they had identified onto Post-it Notes. The facilitators

[8] For the workshop, drivers of change were defined as 'any natural or human-induced factor that directly or indirectly causes a change in Milne Bay'.

placed these on a whiteboard, grouping them in the following themes: climate change, natural resources, technology, infrastructure, social and politics, and economics (Table 9). Session 1 concluded with a discussion among participants of which themes they regarded as most prominent and whether there were important geographical differences.

Table 9. Drivers of change in Milne Bay Province identified by participants

Climate	Politics and social	Economics	Natural resources	Infrastructure	Technology
Changes in seasons	Elections, changes in leadership	Poverty and employment	Overexploitation of marine resources	Health	Communication (mobile phone, internet)
Changes in rainfall	Corruption	Agriculture	Logging	Water	Access to information
Rise in sea level	Education	Tourism	Mining	Sanitation	
	Health		Agriculture	Waste	
	Unemployment				
	Law and order				

Source: GGGI

4.2 SCENARIOS

In Session 2, participants explored possible futures for Milne Bay Province, considering the uncertainty in the drivers of change they had identified in Session 1. For that purpose, the most prominent drivers of change were visualized in a two-dimensional matrix, with the impacts of climate change considered on the y-axis and other important drivers determining the x-axis. This matrix provided participants with four different starting points to envision Milne Bay Province in 2050 (Figure 7):

- Scenario A (best case): minimal impacts from climate change and positive impacts from other drivers;
- Scenario B: severe impacts from climate change and positive impacts from other drivers;
- Scenario C (worst case): severe impacts from climate change and negative impacts from other drivers; and
- Scenario D: minimal impacts from climate change and positive impacts from other drivers.

Participants were divided into six groups. They were each allocated one of the scenarios (with two groups looking at scenarios B and C) and asked to create a visual representation of Milne Bay under the conditions of their scenario. Session 2 concluded with each group presenting their drawings.

The results of this exercise are provided in Appendix C.

4.3 ADAPTIVE CAPACITY

The aim of Session 3 was to identify the strengths and weaknesses of Milne Bay Province's adaptive capacity to respond to climate change and other major factors influencing the province's future development. At the start of the session, a GGGI expert gave a remote presentation, introducing the concept of adaptive capacity and providing an overview of the different social, human, natural, financial, physical, and political determinants of adaptive capacity.

Following the presentation, facilitators divided participants into the same six groups as in Session 2. Each group was asked to consider a different region within Milne Bay Province and list their region's adaptive capacity strengths and weaknesses, based on the categories introduced earlier. Session 3 concluded by displaying and discussing the results of each group in the plenary.

Figure 31. Workshop discussions

Source: GGGI

4.4 INTERVENTIONS TO STRENGTHEN CLIMATE-RESILIENT GREEN GROWTH

Concluding the workshop, Session 4 aimed to identify and prioritize interventions to reach the best-case scenario and avoid the worst-case scenario (Figure 7). Participants remained divided into their six groups reflecting the different regions within Milne Bay Province. Session 4 built on the results of the previous sessions. First, each group identified relevant interventions, considering the uncertainty of different impacts leading to different scenarios (results of Sessions 1 and 2) and Milne Bay Province's strengths and weaknesses to adapt to the different impacts (results of Session 3). Then, group members scored these interventions based on the following criteria:

- No regrets: interventions are beneficial under any scenario;
- Feasibility and costs: interventions are politically, technically, and financially feasible;
- Gender and social inclusion: interventions are beneficial for gender and social equality; and
- COVID-19 recovery: interventions address the economic shock induced by COVID-19 pandemic.

Session 4 concluded with a plenary discussion, examining overlaps and differences between the groups' results.

Most of the suggested interventions can be grouped into four categories: agriculture, access to electricity, fishing, and transport (Table 9). The principal results are summarized in Table 10 and presented in this chapter. More details on the suggested interventions are provided in Appendix D.

In summary, the six groups identified various interventions related to agriculture, including recording existing techniques and practices to adapt to climate change and other pressures; agroforestry, intercropping and introducing more resilient crops; and strengthening access to finance. To improve access to electricity, two groups highlighted the importance of renewable energy sources. To support fisheries and the extraction of marine resources, participants identified access to finance and mangrove rehabilitation as relevant interventions. Finally, several groups identified a strong need to improve the existing transport network. However, none of the groups provided more detailed suggestions for improvements or how they can be achieved.

Table 10. Suggested interventions, by category

Agriculture		Access to electricity		Fishing		Transportation	
Record existing techniques and practices	(1)	Electrification using renewable sources	(2)	Access to finance	(2)	Improve transport infrastructure	(3)
Climate-resilient agriculture	(1)			Rehabilitation of mangroves	(1)		
Access to finance	(1)			Tourism as an alternative source for income	(2)		
Rainwater harvesting	(1)						

Source: GGGI

Note: The numbers in parentheses indicate how many groups identified the intervention for that sector.

In addition, participants identified tourism as an important economic activity that should be developed further. In response, the final analysis considers relevant aspects of tourism under the categories identified above. For example, the analysis of fisheries considers the extent to which tourism can provide an alternative source of income, while transportation considers whether tourism can help improve and finance transport infrastructure.

Furthermore, two groups highlighted that improvements in education would be strong enablers for economic development in Milne Bay Province but made no concrete suggestions for specific improvements or how they could be achieved. Therefore, the final analysis discusses education and labor skills within the four categories identified above.

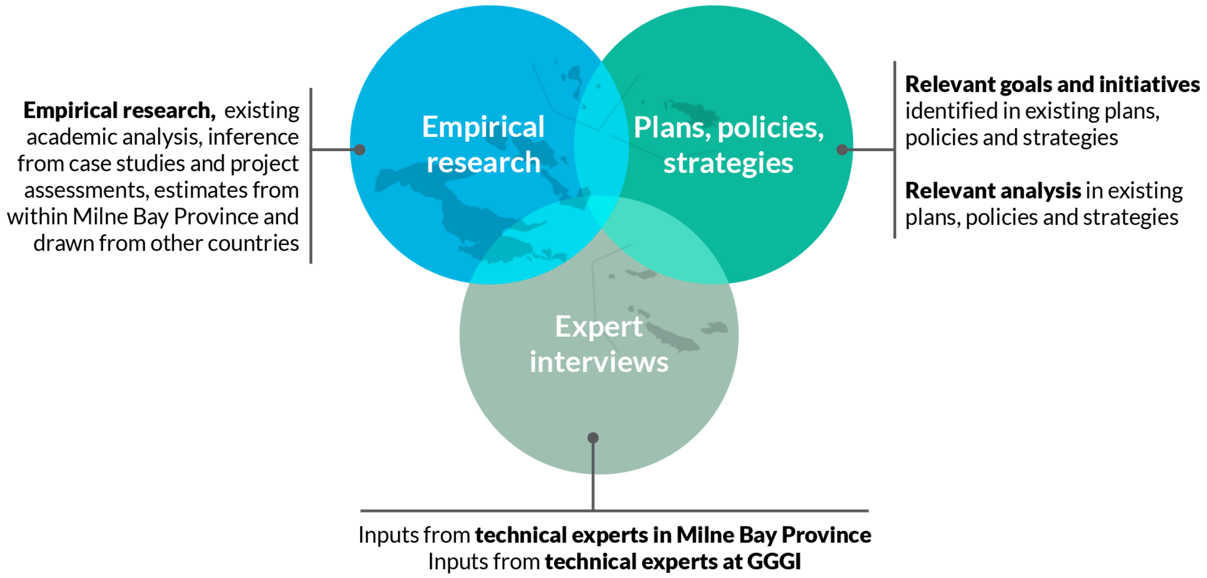
Finally, participants identified the political representation of women and the establishment of a land registry to avoid land disputes that delay infrastructure projects as two means to strengthen the enabling environment. Given their broad and cross-cutting nature, the final analysis highlights barriers and potential options for both of these issues, but does not discuss them to the same level of detail as the four main categories identified above.

5. Final analysis

This final analysis aims to define what climate-resilient green growth means in Milne Bay Province. For that purpose, it determines relevant elements of climate resilience and provides guidance on interventions to strengthen climate resilience for each of those elements. The identified priorities—as outlined in Chapter 4—serve as a starting point for the final analysis; but it is not limited to them. Where necessary, the final analysis also considers aspects that are closely related to these priorities, as suggested during the consultation workshop or identified as part of the preliminary assessment.

The final analysis is based on three principal sources of information (Figure 32). First, it draws on existing empirical research, case studies and estimates from within Papua New Guinea, and relevant examples from other countries. A lack of reliable data and uncertainty of planned projects being implemented represented a considerable challenge to conducting the analysis. This is an obstacle highlighted throughout the analysis and reflected in the recommendations. Second, the final analysis considers existing policies, strategies, plans, regulations, goals, and initiatives identified in these documents as well as any relevant analyses they contain. Finally, it is informed by technical experts within GGGI and feedback from technical experts in Milne Bay Province, including representatives from government departments, the private sector, academia, and development partners.

Figure 32. Schematic of inputs to the final analysis



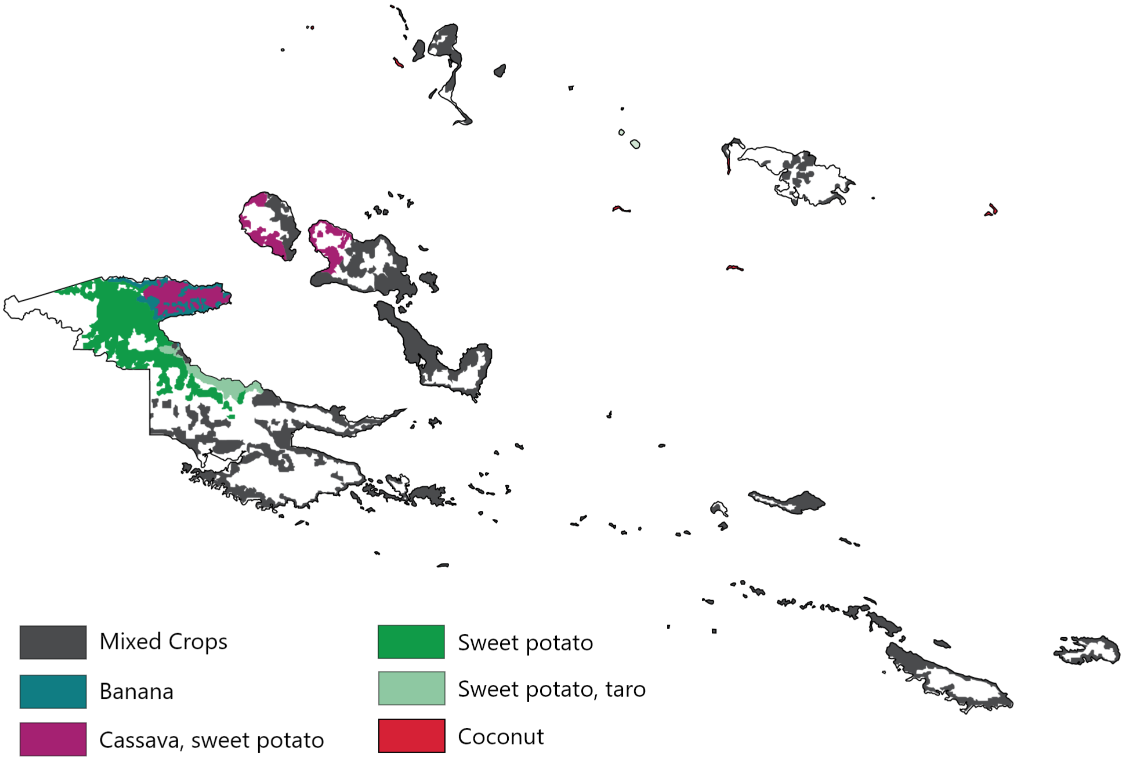
Source: GGGI

This chapter discusses the identified priorities, explaining their relevance for climate resilience and offering guidance on interventions and avenues to strengthen climate resilience.

5.1 AGRICULTURE

Agriculture is the dominant economic activity in Milne Bay Province, characterized by smallholder farmers producing mostly staple food crops—vegetables, fruits, and root crops such as cassava, sweet potato, yam, corn, pumpkin, beans, pitpit, aibika banana, pawpaw, pineapple, watermelon, and Malay apple—for household consumption, combined with some cash crops as a source of income (Figure 33). Estimates suggest that approximately 90% of the province's population are engaged in producing food crops (Skewes et al. 2011; NSO and ICF 2019; Howes et al. 2019). Approximately two-thirds of

Figure 33. Distribution of most important staple food crops in Milne Bay



Source: Bourke and Harwood 2009

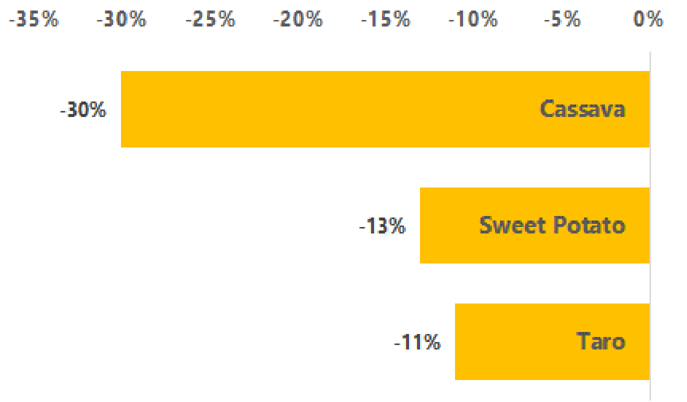
households engage in cash crop production (NSO and ICF 2019), most importantly oil palm and copra, but their output is low (MBPA 2019). Large-scale commercial cocoa and copra farming have gradually declined over the past two decades, but major commercial plantations remain, including oil palm and, to a considerably lesser extent, copra (MBPA 2019).

Milne Bay Province has a total land area of 14,125 km^2, 20–30% of which are considered arable. The arable land is concentrated on the main island, the Asapoi Valley on Fergusson Island, and the east coast of Goodenough Island. (Allen and Bourke 2009; MBPA 2019). While land use intensity has been historically low (Allen and Bourke 2009), rapid population growth means that most arable land has more recently come under strong agricultural pressure. In particular, on the province's very small islands, high population densities result in environmental degradation and poor crop performance (Bourke 2001a; Busilacchi 2020).

These challenges are exacerbated by the adverse impacts of climate change—such as increasing temperatures, changes in rainfall patterns, and rising sea levels—which can reduce yield and crop quality. Negative effects are expected along the entire production chain, affecting planting time, growing stages, harvest periods, and post-harvest crop storage (Ganpat 2014; GEF, UNDP, and SPREP 2009; Jaramillo et al. 2011; Kudela 2009; Moretti et al. 2010; World Bank 2011).

First, Allen and Bourke (2009) suggest that temperature increases in the province will likely reduce productivity in the lowlands. However, the magnitude of the potential impact is uncertain. Some estimates suggest considerable declines in yield for sweet potato (13%), cassava (30%), and taro (11%) in Papua New Guinea (Hay et al. 2003; Figure 34). Sweet potato is one of the most important staple food crops in Milne Bay Province, and tuber formation in sweet potato is significantly reduced at temperatures above 34°C. Maximum temperatures in the province are projected to reach this threshold, which could considerably reduce sweet potato yield (Allen and Bourke 2009; Grigg and Nadelko 2020; Hay et al. 2003).

Figure 34. Projected decrease in cassava, sweet potato, and taro yield in Papua New Guinea



Source: Hay et al. 2003

Second, while climate models suggest little change in rainfall levels for Milne Bay Province, these projections are subject to considerable uncertainty (BoM and CSIRO 2014; World Bank 2020a). Milne Bay Province shows considerable geographical variability in annual rainfall. On average, yearly rainfall amounts to an estimated 3,000–3,500 mm (Allen and Bourke 2009). Most projections suggest possible increases of less than 20% and possible decreases of less than 10% by 2080, which would have only marginal effects on agricultural productivity. However, extreme scenarios project rainfall increases of up to 35% and decreases as low as -25% (Grigg and Nadelko 2020; World Bank 2020a). Such extreme changes in rainfall would have detrimental impact on agricultural productivity.

Some locations in Milne Bay Province, including Cape Vogel and Goodenough Island, are characterized by a prolonged annual dry season, with less than 2,000 mm rainfall per year (Allen and Bourke 2009). In these places, higher rainfall levels associated with climate change would increase people's food security. Areas where rainfall is already high, increases to more than 3,500 mm a year are expected to reduce productivity for most crops, due to low levels of bright sunshine, waterlogged soils, and leaching of soil nutrients. Lower tuber yields would undermine food security, while lower oil palm yields would affect income of some farmers (Allen and Bourke 2009; Mogina 2001).

Independent of their connection to climate change, droughts are often perceived as a threat to agriculture (MBPA 2019). Albeit infrequent, droughts have a severe impact on crop yields and are often accompanied by pests, diseases, and bushfires (Allen and Bourke 2009). Projections do not suggest a considerable increase in the occurrence of drought, except for extreme scenarios in which annual rainfall levels might decrease by as much as 25%. In most projections, the possible decrease in rainfall is limited to approximately 10% (Grigg and Nadelko 2020; World Bank 2020a). In line with rainfall levels, Milne Bay Province shows considerable geographical variability in drought occurrence, as measured by soil water deficit. Generally, the northern parts of the province—including Trobriand, Collingwood Bay, Northern Owen-Stanley, and Alotau District—have historically experienced irregular, moderate soil water deficits, while the rest of the province is characterized by moderate water surpluses (Allen and Bourke 2009).

Finally, in low-lying areas, sea level rise might cause inundation, salinization, and erosion of farmlands, particularly during storm surges. Sea water flooding often has a long-lasting effect on soil salinity and suitability for plant growth. Furthermore, over the longer term, sea level rise is likely to change water quality parameters and contaminate groundwater reserves (Ganpat and Isaac 2014; Skewes et al. 2011). However, there is mixed evidence of sea level rise affecting agriculture, with coastal erosion and freshwater contamination being recorded mostly on small islands and atolls (Allen and Bourke 2009).

Under these conditions, the main challenge for the agriculture sector is improving productivity without shifting to large-scale industrial farming, which would undermine smallholder farmers and potentially cause major environmental damage. The traditional smallholder farming system has successfully intensified land use over the last decades by growing more productive crops, shortening fallow periods and extending cropping periods, composting, and crop rotation to maintain soil fertility, soil tillage, drainage, mounding, and irrigation, among others (Bourke 2001b). However, population growth outpaces productivity gains from intensification in some areas, while environmental degradation limits the potential for intensification (Butler et al. 2009). The production of monoculture cash crops—such as oil palm—by some smallholders further increases agriculture pressure, due to reduced land availability for food crops. While income from cash crops allows for the purchase of food, that income is subject to price fluctuations and impacts from pests and extreme weather events (ACIAR 2019).

Such a complex challenge will require a nuanced response that accounts for local conditions at specific locations. While formulating such targeted interventions goes beyond the scope of this assessment, it is possible to provide some guidance on potential interventions addressing the adverse impacts associated with climate change.

First, strengthening the sector's resilience to climate change will require identifying the crops that cope best with the changing climatic conditions. There are several factors that give cause for some optimism concerning the prospects of successfully adapting crop choices. The current mix of crops already provides Milne Bay's farmers with some resilience against the adverse impacts of climate change. Furthermore, farmers have demonstrated their ability to shift to alternative crops. For example, cassava and potato have become increasingly important since the 1980s, while the importance of taro has declined (Bourke 2001b; Bourke 2012; Hunter et al. 2001; Singh et al. 2001). In addition, there are examples of successful breeding programs to increase crops' resistance against specific threats. In particular, the development of high-yielding varieties of taro has helped reduce the threat of the taro leaf blight disease in Papua New Guinea. The success is largely credited to close collaboration between farmers, regional and international organizations, and local universities and research institutions (Singh et al. 2012). One important obstacle, however, is the lack of dissemination of relevant technologies and practices at provincial level. For example, although there have been extensive research and breeding programs in Papua New Guinea to develop early maturity and high-yielding sweet potato varieties with resistance to drought and prevalent diseases, and acceptable culinary traits (Cuthbert 2016; Kapal et al 2003; Kapila et al, 2010; Wamala and Akanda 2010), the transfer and distribution of these technologies and practices at provincial level has been less successful (Ivahupa 2001; in-country interviews).

Beyond the choice of crops, options for crop rotation, agroforestry and intercropping—that is, identifying the combination of species that deliver the highest mutual benefits and productivity increases—should also be explored. For example, trials have shown multiple benefits of changes in smallholder oil palm replanting practices, with positive impacts on land utilization, continuity of income, access to finance, and environmental sustainability (ACIAR 2019).

Second, past droughts have had severe impacts on agriculture in Milne Bay Province (Humphrey, Ernest, and Demerua 2001; Table 11). Over the long term, agricultural production in Milne Bay Province will likely remain susceptible to drought during ENSO events. Regardless of whether the occurrence and intensity of drought is directly related to climate change, reducing its negative effects will benefit agricultural productivity and food security.

Allen and Bourke (2009) suggest putting in place drought contingency plans. Such plans can be designed at provincial level. Contingency planning is currently limited. Following the 2015 drought, national government agencies and disaster relief organizations established several recovery and response plans, such as the Papua New Guinea El-Niño Agriculture Recovery Plan 2016–2017 (DAL and FAO 2016). However, these plans only address short-term recovery after a drought has occurred and are not designed as contingency plans for future droughts. In 2019, the United Nations designed a multi-hazard contingency plan for Papua New Guinea to efficiently coordinate national government and relief agency disaster responses. Yet, while the plan identifies several measures that are relevant for responding to a future drought, it offers no details on who would implement these measures and how they would do so (UNICEF and UN OCHA 2019).

Table 11. Summary of 1997 drought and frost impact

Province	Percentage of population severely and critically affected by drought	
	October 1997	December 1997
Central	24	50
Eastern Highlands	10	74
Gulf	11	58
Madang	3	42
Milne Bay	**29**	**60**
Morobe	12	55
New Ireland	0	19
Simbu	0	100
Western	50	74
Western Highlands	9	21

Source: Allen and Bourke 1997a; Allen and Bourke 1997b

Although the Milne Bay Provincial Administration has formulated several proposals in response to future droughts in the province (Jonathon 2001), there is no contingency plan for a future drought event. Despite identifying food security projects in drought-prone islands as a priority, the *Provincial Disaster Risk Management Strategy* does not include specific provisions on how to cope with future droughts, other than stipulating that (MBPA 2020):

> *An Emergency Operations Centre […] is to be activated when impacted communities report Category 2 stage and [r]elief assistance must be rendered to them when they reach Drought Category 3 to 5.*

However, there are few provisions on how this emergency operations center would operate, including the decision making for whether a single agency or multiple agencies should intervene in a given event.

As a result, drought response largely remains ad hoc. In addition, past relief efforts have failed to increase long-term resilience, with farmers relying on government assistance rather than putting in place measures to cope with a drought (Mogina 2001).

Third, improving water management will be an important aspect of reducing the impact of drought. Irrigation systems are not common in Papua New Guinea, given that most of the country is characterized by excessive, rather than insufficient, soil moisture. There is evidence that irrigation was more common in the past, when taro was an important staple crop in locations with marked annual seasonal rainfall patterns, including some areas of Milne Bay Province (Bourke 2001b). According to Bourke, the Rabaraba-Wamira area on the main island is one of the few places where irrigation is used for growing taro and cassava. Of course, other areas of the province may also benefit from irrigation at times of drought. In that context, large-scale irrigation systems are not considered a suitable option for farmers, due to high upfront costs and the considerable technical and management skills required. Instead, water storage and micro-irrigation systems—potentially in combination with off-grid renewables—are regarded as the preferred option for strengthening the resilience of smallholder farmers, improving their agricultural productivity, and increasing their access to electricity, drinking water, and improved sanitation facilities (Bang and Sitango 2003; Hughes et al 2009; Sitapai 2012; Ramakrishna and Saese 2009).

Fourth, the successful dissemination of climate-resilient agricultural practices—such as modified crops, water storage, and small-scale irrigation—requires systematic improvement of extension services (ADB 2013a). For example, the World Bank (2014) estimates that disseminating advanced techniques with adequate timely support to farmers could improve coffee yields in Papua New Guinea by 30–50%. A project involving smallholder farmers in Eastern Highlands and Morobe Provinces also showed that improved agricultural support services increase agricultural productivity and smallholder incomes, and help make agricultural practices more sustainable (ADB 2013a).

While there is little information available about the quality of extension services in Milne Bay Province, it has been reported that it has declined over the last few decades, due a combination of lack of funding, a paucity of qualified personnel, and insufficient dissemination of information to and from smallholder farmers (Kagena 2001). Given that provincial and district administrations play an important role in providing extension services, many of these shortcomings can be effectively addressed at provincial or local levels.

Fifth, deforestation has a negative impact on agricultural productivity and exacerbates the adverse impacts of climate change on agriculture. Forests provide essential ecosystem services, including nitrogen fixation, increased soil carbon, protection against soil erosion, improved water quality and regulation, refuge for biodiversity and hosting edible pollinators (HLPE 2017; Matthews et al. 2000; UNECE n.d.). Furthermore, the commercial forestry sector continues to play an important role in the local economy, creating formal employment in rural areas and providing much-needed infrastructure (in-country interviews). Finally, forests also play an essential role in providing fuelwood to meet households' energy needs (NSO and ICF 2019).

There is little plantation forestry or reforestation in Milne Bay Province, where logging activities are mainly conducted in natural forests (in-country interviews). Therefore, forest conservation will require a reduction in either logging activity or the ecological impact of logging through the enforcement of international certification schemes. The Forest Stewardship Council, Programme for the Endorsement of Forest Certification, and International Tropical Timber Organization have all developed and widely endorsed forest certification schemes. Adhering to their sustainable logging practices could strengthen access to global markets for Milne Bay timber (Cuthbert et al. 2016; GoPNG n.d.; Meidinger 2003).[9]

In addition, REDD+ represents another option for reducing environmental degradation and generating income in Milne Bay Province. The Milne Bay Integrated Provincial Development Plan 2018–2022 envisioned a REDD+ project by 2021 but did not provide any details on the scope or location of that project (MBPA 2019). As of early 2021, no REDD+ projects had been planned for the province (in-country interviews). As REDD+ in Papua New Guinea moves from its readiness to its implementation phase, there is an opportunity to develop a community-level pilot project in Milne Bay Province to address issues that have been proven to hamper progress on

Table 12. Area of oil palm plantation in Papua New Guinea

Location	Commercial	Smallholder	Total
West New Britain	45,254 ha	38,476 ha	83,730 ha
Oro	8,892 ha	11,958 ha	20,850 ha
Milne Bay	**11,306 ha**	**1,900 ha**	**13,206 ha**
Ramu	10,207 ha	260 ha	10,467 ha
New Ireland	5,689 ha	2,237 ha	7,926 ha

Source: OPIC 2015

[9] National and private certification schemes, however, should be viewed with caution. These encourage sustainable forest management to differing degrees, as each has its own standards (Durst et al. 2006; Global Forest Atlas 2018). Several nationally certified forests, such as those under the Malaysian Timber Certification Scheme, have been criticized for their unclear environmental and social protection standards (Global Forest Atlas 2018). Similar criticism has been directed towards Papua New Guinea's Logging Code of Practice (Bryan and Shearman 2015).

a national scale, such as governance, monitoring, reporting and verification systems, and stakeholder participation (Babon 2011; Fisher et al. 2015; Leggett 2011; in-country interviews).

Finally, as with commercial logging, adhering to international certification schemes would allow for commercial agriculture to contribute to environmental conservation, improve socioeconomic conditions for the workforce, and fetch higher prices. In Milne Bay, commercial plantations are limited and dominated by oil palm (MBPA 2019; Table 12). Papua New Guinea's palm oil industry has a track record of complying with standards set by the Roundtable on Sustainable Palm Oil (RSPO),[10] which has limited the conversion of primary forest areas into oil palm plantations. However, there is a notable risk that expanding production will undermine adherence to these standards, particularly as new market entrants are not obliged to produce according to international certification standards (Babon and Gowae 2013; Cuthbert 2016; FCPF 2018; Filer 2012; GoPNG 2017a).

[10] For more information on the RSPO, please refer to https://www.rspo.org/

5.2 ACCESS TO ELECTRICITY

In Milne Bay Province, less than 15% of the population has access to electricity and the service is often unreliable (NSO and ICF 2019). The province's electricity mix consists primarily of diesel, with a 3 MW diesel-fired power plant at Alotau and a 2–3 MW diesel-fired power plant at Samarai (ADB 2009; Figure 18). In addition, it is assumed that there are several auto-producers, including oil palm developments near Sagarai and on former and future commercial mining sites. However, there is no information available on the installed electricity generation capacity or the fuel used at these sites. Most likely, auto-producers also largely rely on diesel to generate electricity. As a result, none of the existing power systems are considered directly susceptible to negative impacts of climate change.

While climate change is unlikely to affect existing supply, increasing access to electricity can play an essential role in strengthening adaptive capacity in Milne Bay Province as it would have positive effects on many other aspects related to resilience, such as poverty, health, education, and job creation (IRENA 2017a; IRENA 2017b; IRENA 2016a; IRENA 2016b; Lighting Global 2016; UNEP 2014). For example, case studies from multiple countries—ranging from Nigeria in the west to Indonesia in the east—show that replacing candle and kerosene lighting with electrical lighting and being able to charge phones domestically both have significant cost-saving potential (Lighting Global 2018; Lighting Global 2016). Furthermore, access to electricity helps increase productivity through water pumping and irrigation, reduce post-harvest losses by improving storage, drying, refrigeration, and ultimately contributes to greater food security (IRENA 2016a).

Given the low electrification rate, the province's geography, the technical challenges, and high costs related to establishing a new electricity network or extending an existing grid, this assessment regards off-grid renewable energy solutions as the most viable choice for increasing access to electricity in Milne Bay.[11]

There is no single national electricity grid in Papua New Guinea. Instead, there are three separate main networks and several smaller local grids. The main networks consist of:

- The Port Moresby Grid, which is the largest by peak demand and capacity but geographically compact;

[11] Technical challenges and high costs are driven by the absence of a provincial grid, the lack of legislative and regulatory certainty, a complex customary system of land tenure, and a shortage of skilled labor (Adam Smith International 2018; ADB 2015a; GEF, UNDP, and SPREP 2009; IHA 2018; IRENA 2013; Kaur and Segal 2017; Kuna and Zehner 2015; Lawrence 2017).

- The Ramu Grid, which has the second largest capacity but the most geographically extended network; and
- The Gazelle Grid, the third largest network, which supplies parts of East New Britain Province (Adam Smith International 2018; APERC 2017; Kuna and Zehner 2015; Lowy Institute 2017; in-country interviews).

There have been suggestions to connect Milne Bay to the Port Moresby Grid (APERC 2017). However, this is considered unrealistic, as grid connection costs would likely exceed US$1,000 per household (The Earth Institute and Economic Consulting Associates 2017). When coupled with residential customers' low ability and willingness to pay, this raises questions over whether the investment costs of grid extension could ever be recovered. At the same time, the electricity needs of many households in the province may not be as high as those of grid-connected homes.[12] In addition, grid extension would only allow for electricity to be provided to households on the main island, neglecting a large share of the province's population residing on the outer islands.

Potential technologies for off-grid electrification in Milne Bay Province include ocean, geothermal, biomass, wind, and solar. Of these, this assessment considers solar energy as the most feasible option. First, although an ongoing assessment of ocean currents in the Coral Sea led by the University of PNG suggests a large potential for ocean energy in the area, this is not regarded as a suitable option because the technology is at an early development stage and commercially unviable, with prototypes being tested (Ernst & Young et Associés 2016; European Commission 2013; IEA 2020; IRENA 2020; IRENA 2018). Furthermore, the potential sites in Milne Bay Province are located far from the load centers, further undermining their commercial viability (in-country interviews).[13]

Second, two main geothermal sites have been identified in Milne Bay Province, both located on Fergusson Island (Mosusu 2015). The Milne Bay Integrated Provincial Development Plan 2018–2022 envisioned installing 156 MW of electricity generation capacity from geothermal energy by 2022 (MBPA 2019). However, the obstacles for such large-scale electricity infrastructure are considerable and past projects have experienced substantial cost overruns or failed entirely. Geothermal plants require an anchor load—a sufficiently large demand center—to be cost-effective. However, Milne Bay Province's geothermal sites are located far from larger population centers (Mosusu 2015). In addition, Papua New Guinea lacks an appropriate regulatory framework for geothermal energy, which has hindered its exploitation (McCoy-West et al. 2011; GoPNG 2014; in-country interviews).[14] Given the isolated locations of geothermal resources and the high upfront costs of exploration and drilling, geothermal energy appears to be most suitable for supporting mining and other industrial activities rather than supplying electricity to population centers (in-country interviews).

Third, biomass is considered to be a viable option, when a predictable and cost-competitive supply of feedstocks is available, and when in a facility using biomass is located in the proximity of a sufficiently large anchor load to ensure that electricity is taken up. Given these conditions, in Milne Bay Province, biomass for electricity generation is regarded as feasible in combination with large-scale agricultural processing, such as oil palm and coconut plantations. For example, New Britain Palm Oil Ltd.

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[12] Managing customer expectations might be a challenge for off-grid electrification, particularly for solar household systems. If households expect a full-range service of lighting and multiple appliances, including a TV, refrigerator, and air conditioner, their aspirations will not be met. In-country interviewees suggested that expectations are largely dependent on location and income. The more remotely customers are located, the lower their ability to pay and the lower their service expectations. In large parts of the country, these are limited to lighting and communication (in-country interviews).

[13] APERC (2017) referred to a 5 MW pilot project for ocean energy. However, in-country interviews confirmed that no pilot project has been planned.

[14] The only recorded geothermal plant in Papua New Guinea is located at the Lihir Gold Mine in New Ireland Province, where a 6 MW backpressure plant was commissioned in 2003, and in 2007, power generation was expanded to a capacity of 56 MW. However, the plant's capacity was reduced when some wells had to shut down due to mining operations moving into the area. Information on current capacity varies, putting it between 5 and 17 MW. The plant demonstrates the considerable potential for cost savings when fossil fuels are replaced by suitable renewables. Until 2003, about two-thirds of the mine's required electricity was produced from thermal generation (mainly fuel oil), with the remaining third coming from hydro. When operating at full capacity, the geothermal plant displaced electricity generation from fuel oil, with cost savings amounting to approximately US$2 million per year (Booth and Bixley 2005; McCoy-West et al. 2011; in-country interviews).

commissioned two biogas digester facilities—in Mosa and in Kumbango—both using palm oil mill effluent to generate electricity (New Britain Palm Oil Limited 2017; TÜV Rheinland 2011). Beyond supplying the processing site, a facility could provide nearby populations with access to electricity, if demand is sufficient and customers are able to pay.

Finally, considering costs, the complexity of project development, logistics, technical expertise, and other factors, this assessment considers solar energy to be more suitable than wind power for off-grid electrification (Table 13).

Currently, there is no utility-scale wind park in Papua New Guinea and no available information on any stand-alone off-grid installations. Neither the country's utility company, PNG Power Limited, nor independent power producers have experience in constructing and operating wind turbines, and skilled labor is lacking. All this makes it difficult to attract any private sector financing.

APERC (2017) assumes that stand-alone off-grid wind turbines are a suitable alternative to electrify remote communities. Stand-alone systems are considered technically simpler, circumventing some of the obstacles that grid-connected wind parks would face, such as landownership issues. However, given their small scale, stand-alone wind turbines lose their cost advantage on a kWh basis, while still being more technically complex than small-scale solar systems.

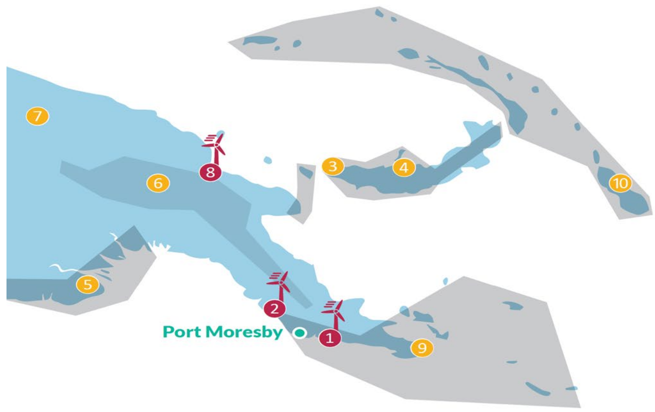
Table 13. Comparison between solar and wind power projects

	Wind	Solar
Local conditions	Local testing of conditions required	Local testing of conditions only required for large systems
Complexity of project development	Developing and installing wind parks is more complex, in terms of both technology and project management	Solar projects are technically and administratively simpler
Logistics and installation	Transport of heavy equipment is a challenge due to lack of infrastructure	Somewhat established distribution networks, though reaching remote areas is a challenge (albeit simpler than for wind power)
Local market and technical expertise	No experience in constructing and operating wind turbines	Existing market with 10–20 companies and proven technology
Costs	Globally, electricity from wind power is cheaper on a kilowatt hour (kWh) basis, but costs in Papua New Guinea are uncertain	Globally, electricity costs from solar power are higher on a kWh basis, but absolute costs are lower as projects are likely smaller

Source: Compiled by GGGI

In addition, there is limited data on whether and where wind conditions in Papua New Guinea are suitable for electricity generation. Confirming earlier estimates (IRENA 2013), a wind resource mapping study identified several areas that might be suitable for wind turbine installation, based on their comparatively high wind speeds. These include the Highlands, Dura Island, the region south and east of Port Moresby (including Milne Bay), the central spine of New Britain and some coastal areas, Umboi Island, and the island chain from Bougainville Island to Latangai Island and Manus (World Bank 2015a; World Bank 2015b; Figure 35). However, local measurements are necessary to determine the accuracy of the modeling results, configure the model, and obtain a sound understanding of the uncertainty associated with the results.[15] Local measurements showed considerably lower expected power density than the preliminary modeling results, highlighting the need for local verification of wind conditions (World Bank 2019).

Figure 35. Potential areas for wind power infrastructure and selected measurement sites



	Province	Area
1	Central	Kamal village and Launakalana agricultural station
2	Central	Liquefied natural gas plant
3	West New Britain	Bagal and Kakumo villages
4	West New Britain	New Britain Palm Oil plantations
5	Western	Ture-Ture, Oriomo and Mabaduan villages
6	Highlands	Ponowi village
7	East Sepik	Tring, Yawasoro and Angoram villages, Wewak town
8	Morobe	UMI station, Markham Valley
9	Milne Bay	Siasiada and Kaigulan villages, Nube village, oil palm nursery
10	Bougainville	Buka and Bougainville islands

Sources: World Bank 2015a; World Bank 2019

Note: Locations in yellow indicate to selected measurement sites. Locations in red indicate locations where data was collected.

This assessment concludes that off-grid electrification through solar photovoltaic systems represents the most suitable means for providing basic electricity services in areas where grid extension is expensive or physically difficult (APERC 2017; IRENA 2017a; IRENA 2017c; Lighting Global 2018; OECD/IEA 2014; Samanta and Aiau 2015). In-country interviewees widely regarded solar mini-grids as a viable option for towns, hospitals, schools, and administrative buildings, where trained onsite technicians for operation and maintenance and spare parts are readily available.

For household electrification, solar home systems appear to be more suitable, showing several advantages compared to mini-grid designs. First, in Papua New Guinea, stand-alone systems are approximately four times cheaper on a per kWh basis than mini-grids, which often struggle to provide affordable services while recovering costs.[16] Second, household systems are considerably easier to operate and require little maintenance with no need for a trained electrician. Third, mini-grids require buy-in from local stakeholders to agree on and abide by ownership and land use arrangements for panel installation. Finally, household systems are regarded as less prone to vandalism and theft than larger systems (Table 14).

Standalone photovoltaic systems range from individual to larger household packages—with options for several lights, phone charging, TV, water heating, and solar crop drying for smallholders—and community lighting (APERC 2017; IRENA 2013; in-country interviews). While 12-volt appliances such as LEDs, radios, and TVs have become more efficient, refrigeration and air condition still require considerably larger systems with multiple panels.

[15] Given the high costs, data collection was limited to three locations of the 10 initially identified sites (in-country interviews).
[16] The uniform electricity tariff level is insufficient to recover the costs of mini-grids. However, if higher tariffs were charged, potential consumers would often be unable to afford covering the actual costs.

Table 14. Comparison between solar household systems and solar-powered mini-grids

	Solar household systems	Solar-powered mini-grids
Application	Basic electricity access, including lighting, phone charging, TV, fans	Fully solar powered (coupled with storage) or partially solar powered (hybrid) grids to replace diesel generators
Installation	Proper installation required to avoid dismantling and reselling	Requires land to be found for installing panels (except in schools, hospitals, and government buildings, which often have land readily available)
Operation and maintenance	Simple to operate, little maintenance required without the need for trained electricians	Trained electrician and spare parts required to maintain 240-volt systems
Ownership	Private ownership	Community ownership; requires buy-in from local communities
Costs	System costs are competitive when considering the entire life cycle, but upfront (installation) costs are comparatively high Subsidy required for low-income households	Current tariffs are insufficient for recovering costs; potential consumers cannot afford actual costs Subsidy required

Source: Compiled by GGGI

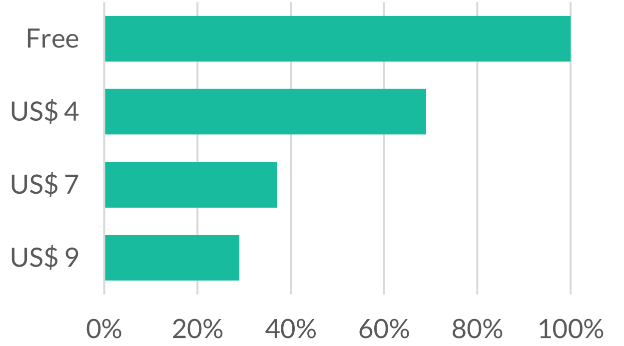
Two of the main challenges for the successful deployment of solar household systems are reliability and affordability. First, according to in-country interviewees, many of the technical challenges have been largely resolved through improved system design and wiring. However, the Papua New Guinean market is characterized by a large share of open market component-based solar systems. These systems offer several advantages to consumers—for example, they are generally cheaper on a per-watt basis and are more flexible than plug-and-play solar home systems. However, without vetting suppliers, open market component-based systems tend to have high failure rates (Lighting Global 2018; in-country interviews). Strengthening quality control—by applying global standards to off-grid solar equipment entering the national market—would prevent the adoption of substandard equipment. In turn, this would help minimize the risk of negative consumer perception, as failure of cheap equipment undermines the industry's reputation (Lighting Global 2016; Lighting Global 2018; in-country interviews). It is unlikely that certified products will ever be able to compete with the low prices of component-based systems. In-country interviewees indicated that quality control initiatives should therefore be accompanied by information campaigns focused on a simple message: while quality products may have higher upfront costs, they ultimately save money because they last much longer.[17]

Second, although solar home systems are cost-competitive when considering the entire life cycle, comparatively high upfront costs remain an issue. Given the high costs of transportation and setting up new distribution points in Papua New Guinea, these upfront costs are unlikely to fall considerably. Whichever financing model is chosen, affordability and financing will depend on location and need to consider different customer segments. In-country interviewees confirmed that the longer the distance from the existing networks, the lower a household's ability to pay. They highlighted the need for subsidies, with subsidy amounts increasing with distance from the network (in-country interviews).

[17] It was suggested that such awareness raising can be done most effectively and at limited cost through short and pointed messages via social media. TV and radio were regarded as less effective, as the market is fragmented (in-country interviews).

Where cash income is available, solar household systems are already affordable. However, cash-starved rural communities with limited productive use cannot afford systems at market prices. Although there are no comparable studies for Milne Bay Province or Papua New Guinea, field research in Kenya confirms that consumers respond strongly to price differences (Rom, Günter, and Harrison 2017; Figure 36). Therefore, support mechanisms such as vouchers and discounts are regarded as useful tools for supporting these consumers while indiscriminate financial support is seen as problematic (Lighting Global 2018).

Figure 36. Take-up of solar lanterns at different prices in Kenya



Source: Rom, Günter, and Harrison 2017

At the same time, past experience in Papua New Guinea has shown the importance of attaching a cost to the equipment. When systems were provided free of charge, people often resold them.[18] However, attaching a cost to the equipment, while ensuring it remains affordable, will require some innovative ideas. In-country interviewees suggested bartering as an option or attaching non-monetary conditions to installing equipment. These could include participating in vaccinations and trainings[19] or contributing labor to community projects.

Finally, private companies should be allowed to play a larger role in the electricity sector. This is particularly relevant for Milne Bay Province, where electrification is expected to largely be driven by off-grid solutions. Papua New Guinea already has a growing domestic market for solar home systems, with an estimated 10–20 solar companies currently operating in the country (in-country interviews). A conducive policy environment can play a critical role in stimulating such activity. Lighting Global (2018) ranks policy—together with finance—among the aspects with the highest impact on facilitating private sector engagement for successfully deploying off-grid solar infrastructure. While much of that policy environment would have to be established at national level, there are relevant measures at provincial level. For many grids and larger systems, the provincial administration can define equipment standards in public tenders for systems supplying schools, hospitals, and administrative buildings, enter into concessional agreements and maintenance contracts with service providers (mini-grids), and liaise between development partners, local institutions and communities. For home and pico systems,[20] the provincial administration can support the design of financing models, organize vocational trainings for locals on how to operate solar home systems, and support awareness campaigns to highlight the advantages of solar equipment to avoid the resale of subsidized products.

[18] Rather than simply hand out or sell systems at a discount, it is also better to ensure they are properly installed. Customers are much less likely to dismantle or resell equipment once they have experienced the benefits.

[19] WASH (water, sanitation, and hygiene) trainings were explicitly mentioned. For more information on WASH, see UNICEF 2016.

[20] Pico systems generally include individual lanterns and simple multi-light systems (and may enable mobile charging) below an 11-Watt maximum capacity. Solar home systems generally refer to systems that are larger than 11 Watts and can typically power several lights and energy-efficient appliances, including radios and TVs (Lighting Global 2018).

5.3 FISHING

Fish and other marine species are a crucial protein source in Milne Bay Province, with estimates suggesting that up to 53 kg of fish are consumed per person per year (ADB 2014; Bell et al. 2009; Friedman et al. 2008; Gillet 2009; Govan 2018).[21] Fishing also represents an important source of household income in the province, with approximately a third of households deriving some of their income from selling fish, even though the scale of commercial fishing is small (Kaly 2006). According to a 2006 survey, reef fish represent by far the most important category as a source of food or income for households in Milne Bay Province (Kaly 2006; Table 14). Fish farming, first introduced into the province in the mid-1990s, remains at an early stage of development (Ponia and Mobiha 2002; in-country interviews).

Despite their prominent role as sources of food and income, there is limited data on the catch, domestic sale, consumption, and export of

Table 14. Fish species caught by households in Milne Bay Province for food or sale

	Number of households	Share of households
Reef fish	423	76%
Tuna	187	34%
Pelagic fish	158	28%
Deepwater fish	88	16%
Mackerel	51	9%
King fish	45	8%
Longtom/pike	31	6%
Trevallies/scads	28	5%
Mullet	23	4%
Surgeonfish	21	4%
Sharks	17	3%
Emperors	16	3%
Barramundi	13	2%
Groupers/trout	10	2%
Barracuda	6	1%

Source: Kaly 2006

Note: Pelagic fish live in the pelagic zone of ocean or lake waters, which is neither close to the bottom nor near the shore.

[21] Estimates for fish consumption in the coastal regions of Papua New Guinea range from 5 to 53 kg, highlighting the considerable uncertainty in available data (compare ADB 2014; Bell et al. 2009; Friedman et al. 2008; Gillet 2009; Govan 2018).

marine resources. Data for the tuna industry over the past two decades is considered to be comparatively reliable, as a result of catch log sheets and observer programs. There is no similar level of reporting for artisanal fisheries, for which data is generally only collected as part of specific donor projects. Data on some coastal commercial fisheries—such as lobster, reef finfish, sea cucumbers, and trochus—is also regarded as comparatively reliable, but only covers quantities for export and not local consumption. Finally, data on subsistence fisheries is not systematically collected and the existing information is largely outdated (Gillet 2009).[22] Therefore, this assessment largely relies on inference from individual case studies conducted in Milne Bay Province.

Fish stocks in Papua New Guinean waters are declining, triggering concerns that coastal communities in Milne Bay Province will face increasing food scarcity during subsequent decades. Population growth, more efficient (and more destructive) fishing methods, high returns on particular species such as sea cucumbers, habitat degradation from agriculture, logging, and mining activities—alongside the adverse impacts of climate change—all contribute to this decline (ADB 2014; Booth, Nagombi, and Boslogo 2019; Govan 2017; Kaly 2006).

The combined impacts of climate change are projected to cause oceanic fish—particularly tuna—to relocate and the populations of coastal and demersal fish and invertebrates to decline due to habitat and food loss (Bell et al. 2011; Table 15).

Table 15. Projected changes in fisheries production in Papua New Guinea under different GHG emissions scenarios

Category	Projected change under different scenarios (%)			Climate change-related causes
	B1/A2 2035	B1 2100	A2 2100	
Skipjack tuna	3.1	-10.6	-30.2	Relocation to areas further east within the Pacific due to changes in temperature, currents, and food chains
Bigeye tuna	-4.5	-13	-27.9	Relocation to areas further east within the Pacific due to changes in temperature, currents, and food chains
Demersal fish	-3.5	-20	-35	Habitat loss and reduced recruitment due to increasing sea surface temperature and reduced currents
Nearshore pelagic fish	0	-10	-17.5	Reduced production of zooplankton in food webs for non-tuna species
Targeted invertebrates	-3.5	-10	-20	Habitat degradation and declines in aragonite saturation due to ocean acidification
Inter/subtidal invertebrates	0	-5	-10	Declines in aragonite saturation due to ocean acidification

Source: Bell at al. 2011

Notes: Demersal fish are bottom-dwelling fish associated with coral reefs, mangroves, and seagrass. Scenarios B1 and A2 represent low (B1) and high (A2) GHG emissions scenarios from the IPCC Fourth Assessment Report for 2035 and 2100. Under the B1 scenario, CO_2 concentrations in the atmosphere are projected to reach 400–450 parts per million by 2035, and 500–600 parts per million by 2100. Under the A2 scenario, the projections for 2035 are the same, but CO_2 concentrations increase to 750–800 parts per million by 2100.

[22] Gillet (2009) provides a detailed discussion about gaps in available data and estimation methods.

First, warmer sea surface temperatures are expected to affect oceanic and coastal fish species, as well as invertebrates (Bell et al. 2011; Drew, Amatangelo, and Hufbauer 2015). Economically, tuna is Milne Bay Province's most significant fish resource. Although catch numbers disaggregated by province are not available, total catch for Papua New Guinea averages 150,000–200,000 million tonnes a year, which represents about 10% of the global catch (Oxford Business Group 2018). However, the country's tuna yield is expected to decrease, as skipjack and bigeye tuna populations relocate to areas further east within the Pacific due to changes in temperature, currents, and food chains (Bell et al. 2011). Stocks of demersal fish and non-tuna nearshore pelagic fish species—such as Spanish mackerel, rainbow runner, wahoo, and mahimahi or common dolphinfish—are also expected to decrease as higher temperatures lead to habitat loss, reduced recruitment, and reduced production of zooplankton in food webs (Bell et al. 2011). While some species may be able to adapt to the temperature changes by settling larvae in places with cooler temperatures, such adaptation will be difficult for species that depend on coral reefs if there are no reefs available within the relocated optimal temperature range (Bell et al. 2011; Drew, Amatangelo, and Hufbauer 2015).

Second, sea level rise is problematic for fisheries in Papua New Guinea because many nursery grounds for commercially important fish and shellfish are located in shallow reefs near the coast and within mangrove forests (CIF 2012), both areas that are extremely vulnerable to coastal flooding and storm surges. Mangrove trees, which offer protection from storms, are projected to decrease by 60% by the end of the century under a high emissions scenario (Bell et al. 2011), while the growth rate of coral reefs—important habitats for the country's fish species—may not be able to keep up with the rise in sea level (Perry et al. 2018).

Third, higher concentrations of CO_2 in the atmosphere cause more CO_2 to be absorbed by the world's oceans, decreasing the pH and causing aragonite saturation levels to fall (see Section 3.2.1). This process is commonly referred to as ocean acidification (Bell et al. 2011). Aragonite concentrations in Papua New Guinean waters have declined from 4.5 Ω_a in the late 18th century to approximately 3.8–4.0 Ω_a in 2000. Ocean acidity is projected to continue increasing, with maximum aragonite concentration expected to fall below 3.5 Ω_a by 2030 (BoM and CSIRO 2011). Coral reefs and calcifying invertebrates—including molluscs, crustaceans, and echinoderms—are highly vulnerable to increases in ocean acidity, as they rely on aragonite to build their shells and skeletons (Bell et al. 2011; Ries, Cohen, and McCorkle 2009). Lower aragonite levels will likely weaken and degrade coral reefs, while calcifying invertebrates are expected to form thinner shells and show lower rates of growth and survival than they would under normal pH conditions (Bell et al. 2011; CME-Programme 2018; Gazeau et al. 2013; Shirayama and Thornton 2005; Watson et al. 2012).

Finally, higher amounts of rainfall and a rise in rainfall-induced floods increase turbidity and enrich nutrient levels in coastal waters. The resulting higher sediment and nutrient loads reduce photosynthesis in coastal reefs and create favorable conditions for epiphytic algae, which compete with corals, affecting coral growth and recovery after storm damages (Bell et al. 2011).

There are limited options for interventions to directly reduce the adverse impacts of climate change on fisheries. Therefore, interventions should focus on reducing stress from other factors—particularly human activity—on the marine environment to strengthen its resilience towards climate change.

First, this assessment recommends focusing the limited available resources on the sustainable exploitation of marine resources in coastal waters. The relocation of tuna populations due to changes in temperature, currents, and food chain can only be limited by reducing the expected increase in surface water temperatures. However, this issue has to be addressed at global, not national—and much less, provincial—level. In addition, while the Papua New Guinean authorities could establish stricter catch quotas for tuna in an effort to preserve populations, enforcing such provisions is considered virtually impossible. Estimates suggest that foreign vessels operating under access arrangements that allow them to fish in Papua New Guinean waters accounted for more than three-quarters of the tuna catch in 2010 (ADB 2014). The national government simply has insufficient resources to monitor foreign fishing vessels and enforce catch quotas in the country's waters.

Second, the development of coastal fisheries has not met expectations in the past due to several challenges to the effective and sustainable management of coastal fisheries. These include (Govan 2017):

- The complexity and diversity of coastal fisheries, ecosystems, and coastal communities;
- The logistics of managing geographically extended coastlines and near-shore marine areas;
- A lack of reliable data, feasibility assessments, and monitoring and evaluation for interventions, which has undermined decision making and reduced effectiveness;
- Limited alternatives for income generation and sustaining livelihoods in coastal communities;
- The paucity of suitable financing arrangements for developing small-to-medium-scale commercial activities;
- A lack of marketing and transport infrastructure to enable small-to-medium-scale commercial activities;
- Limited coordination within and between authorities and across levels of government;
- Public funding and services that are not adequately tied to desired outcomes; and
- Limited capacity at all levels of government.

The National Fisheries Authority's *Roadmap for Coastal Fisheries and Marine Aquaculture* was meant to address these challenges. However, inadequate funding, a lack of capacity, and allegations of misuse of funds mean that implementation of the roadmap is falling short of its ambitions (WCS n.d.; in-country interviews).

Establishing community-driven, locally managed marine protected areas (MPAs) is identified as one promising option for implementing the ambitious strategy. The Milne Bay Integrated Provincial Development Plan 2018–2022 envisioned establishing 20 community-managed marine areas by 2022 (MBPA 2019) but a lack of funding has inhibited progress towards this target (in-country interviews).

The few examples of locally managed MPAs—including the Nuakata, Iabam and Pahilele Community Marine Managed Area and the Wiyaloki Nataole and Panabala Community Managed Marine Area— are largely led by nongovernmental organizations and donor agencies. Furthermore, information on individual initiatives, their effectiveness and shortcomings is limited (Araea and Wangunu 2011; Wangunu 2013). Therefore, this assessment provides a generic overview of possible advantages of locally managed MPAs, but it does not draw lessons from past initiatives.[23]

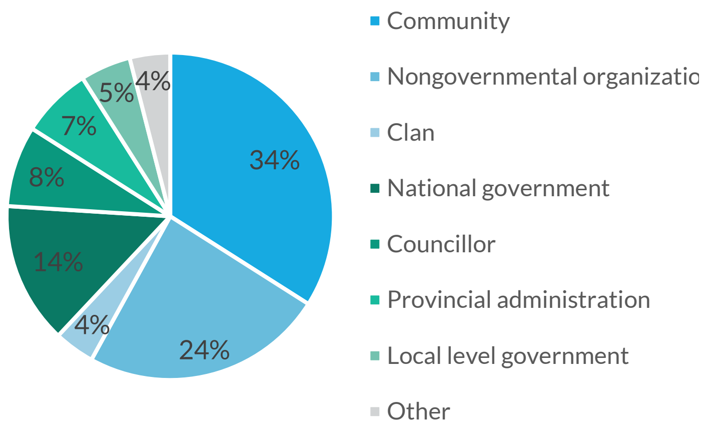
Locally managed MPAs are particularly effective when located in coastal waters, due to their high biodiversity and their crucial function for many species' reproduction (in-country interviews). They can address several causes of declining fish stocks, including overfishing of larger, more vulnerable reef fish species at infant and juvenile stages, and the use of spear guns. Increased spear gun use is causing declines in algal grazer populations—such as surgeonfish, rabbitfish, and parrotfish—potentially leading to a shift from coral-based habitats to algae-dominated systems. Initiatives such as a night-time spear gun ban could be a simple and pragmatic measure to manage their use and conserve the marine environment, but require support from the entire local community (Booth, Nagombi, and Boslogo 2019).

Establishing locally managed MPAs would provide fishermen with the opportunity to exercise effective control over fishing grounds in their area. Survey data on fisheries in Milne Bay Province indicates that such control is lacking. Almost half of the respondents stated that they have no control over fishing grounds (reef tenure); a quarter said they had some control over fishing grounds in their area; and the remainder did not know whether they had any tenure rights over fisheries in their area (Kaly 2006).[24]

Locally managed MPAs are also an opportunity to address the perceived lack of effective fishing rules, which is often attributed to the lack of enforcement and effective control over fishing grounds. Finally, community-managed MPAs align closest to the perception of existing governance for fisheries. The overwhelming majority of survey respondents (92%) stated that that they were aware of certain rules or laws governing fishing in their area, and almost two-thirds attributed fishing rules to local communities, nongovernmental organizations, or clans (Kaly 2006, Figure 37), all of which are generally local-level institutions.

[23] A forthcoming publication will provide more detailed information on locally managed MPAs in Milne Bay Province (Mitchell 2021).
[24] 25% of respondents stated that they have some kind of control over fishing grounds, 33% said they have some control in theory but none in reality, 15% said they have no control, and 27% did not know whether they had any control (Kaly 2006).

Figure 37. Originators of fishing rules



Source: Kaly 2006

Third, mangrove conservation can play a crucial role in managing sustainable coastal fisheries. As well as providing many coastal communities in Milne Bay Province with protection from storm surges, timber for building, firewood, traditional medicines, and recreational opportunities, mangroves serve as nursery habitats for important coral reef fisheries and provide perennial habitats for other marine species, such as mud crabs and shellfish (ADB 2014; Kinch 2007; Skewes et al. 2011). One approach to conserving mangrove forests as vital ecosystems is through payment for ecosystem services (PES). The rationale behind PES schemes is that ecosystems provide essential services that can be valued in monetary terms, but users do not value these services unless they pay for them. Therefore, owners or custodians of these ecosystems should be remunerated for ensuring that the ecosystem in question retains the ability to provide its services. For example, mangrove forests serve as nurseries for juvenile shrimp. Under a PES scheme, the annual licensing fee that shrimp fishers pay could include a component that accounts for the nursery services mangroves provide. This share of the total fee can be used to pay mangrove forest owners as an incentive to ensure their sustainable management. Such PES schemes provide incentives for conservation without negatively impacting the government budget (ADB 2014).

Fourth, aquaculture represents another option for reducing pressure on marine resources while creating income-earning opportunities for coastal communities. There is little and at times conflicting information on aquaculture in Milne Bay Province. Estimates suggest that there are approximately 250–300 fish farms in the province, with a very limited output. Obstacles to fish farming include the lack of fish feed, limited access to markets, and a paucity of technical skills and knowledge about fish farming practices and technologies among farmers (MBPA 2019; in-country interviews).

Introducing sea cucumber mariculture is identified as a promising opportunity, particularly when focusing on high-value species, such as sandfish.[25] Sea cucumbers are used in various cuisines and have medicinal value. *Bêche-de-mer*—the dried body wall of sea cucumber—is a valuable marine export commodity and important income-earning opportunity in Milne Bay Province (Kinch et al. 2008; Skewes et al. 2002), contributing an estimated PGK 12–15 million to the local economy (Vari 2020). However, in October 2009, in response to overfishing, the National Fisheries Authority imposed a moratorium on sea cucumber fishery across the country (Hair et al. 2019; Skewes et al 2002).[26] Instead of lifting the moratorium and replacing it with ceilings for total allowable catch or export restrictions (Barclay, Fabinyi and Kinch 2017), provincial authorities could launch a pilot project for farming sea cucumbers. Acknowledging that mariculture interventions have risks and that many externally supported projects fail (Barclay et al. 2016; von Essen et al. 2013), any pilot project should focus on identifying effective

[25] Mariculture is the farming of marine organisms for food and other products such as pharmaceuticals, food additives, jewelry (for example, cultured pearls), nutraceuticals, and cosmetics, either in the natural marine environment, or in land- or sea-based enclosures, such as cages, ponds, or raceways. Sea cucumber mariculture is known as holothuriculture (Phillips 2009).

[26] The fishery was reopened in 2017 for less than two months (Hair et al. 2019). Other sources claim that the moratorium was lifted entirely in 2017 and replaced with maximum fishing limits (total allowable catch) between 1 October and 15 January of the following year and for specific species. In addition, trade in undersized and broken up *beche-de-mer* pieces is banned (Polon 2004; in-country interviews). However, survey results from New Ireland Province suggest that fisheries do not adhere to total allowable catch quotas (Hair et al. 2018). Furthermore, there is insufficient data to determine total allowable catch quotas. As a result, the current closed season—scheduled from October 2020 to January 2021—remained in place in March 2021 (in-country interview).

management practices, resolving technical issues, and addressing social barriers for communities to adopt sea cucumber mariculture (Hair et al. 2019).

Finally, this report recommends investigating to what extent tourism can present a potential alternative to fishing as a source of income. While Papua New Guinea's tourism sector is fragmented and little data is available at provincial level, given its abundant marine resources, Milne Bay Province is assumed to have considerable potential for marine recreation and ecotourism. However, despite the growing number of visitors, income from tourism is limited as only a fraction of visitors stays in local hotels or guest houses, while the overwhelming majority arrives and stays on cruise ships (PNG Tourism Promotion Authority 2020). This constrains their contribution to the local economy. The *2017 Papua New Guinea International Visitor Survey* found that each visitor to Milne Bay Province spends an average of PGK 848 (US$259) per day, or PGK 10,442 (US$3,189) during their whole trip (Milne 2018). However, these figures do not include visitors arriving on cruise ships, for whom spending levels are likely considerably lower. Comparatively high satisfaction rates of non-cruise visitors—85% reported being satisfied or very satisfied (Milne 2018)—suggest that existing offers for tourist activities and infrastructure do not represent the main bottleneck. Rather, to expand income opportunities from tourism, it is necessary to attract more visitors who do not visit the province exclusively via cruise ships.

Box 3. Land ownership

Land acquisition is a major obstacle for numerous infrastructure projects in Papua New Guinea, including power plants, transmission and distribution lines, and roads (Adam Smith International 2018; Hughes 2000; IRENA 2013; GEF, UNDP, and SPREP 2009; World Bank 2018; in-country interviews). Establishing property rights is challenging due to the country's customary decentralized land tenure system. Under this system, land can be attributed to an individual or group of individuals, but ownership and changes in ownership are generally not documented. As a result, property boundaries are not clearly established and competing claims on land are common, which makes formally establishing landownership a complex and lengthy process. Transferring ownership or land use rights is equally complex and fraught with risks of misconduct. Together, these issues lead to major delays in infrastructure projects and often considerably increase their financial costs as (multiple) landowners expect compensation (APREC 2017; Chand 2017; CIFOR 2011; Hughes 2000; IOM 2014; IRENA 2013; GEF, UNDP, and SPREP 2009; in-country interviews).

The consequences of this decentralized and undocumented system of land tenure are exemplified by the uncertainty around how much land falls under customary ownership. Numerous reports state that 97% of Papua New Guinea's land area is communally owned (Pat 2003; PNGFA 2009; Page et al. 2016; Scudder, Herbohn, and Baynes 2018). This figure is also generally cited by local stakeholders, despite growing evidence that considerable amounts of land have been removed from customary ownership (Filer 2014). This has occurred, most notably, through Special Agricultural Business Leases, issued until 2011 but still in effect. Under these leases, 5.1 million hectares—corresponding to more than 10% of the country's land area—were attributed to mostly foreign corporations for long-term leases of usually 99 years, for agricultural development (Filer 2014; Bryan and Shearman 2015).

This assessment agrees that efforts should continue to reform the customary land ownership system, so that property and land use rights can be codified in formal registries. However, formalizing and documenting land ownership is regarded as a lengthy, complex and contentious process that cannot be led by a provincial administration.

5.4 TRANSPORT

Data on transportation in Milne Bay Province is generally scarce: there is some information available for road transport, but data for other modes of transport is scarce. Vehicle ownership rates are low, and most households rely on non-motorized means of transportation, including walking and canoes. According to the *Demographic and Health Survey 2016–18*, only approximately 3% of households in the province own a car or truck, while 6% own a boat with a motor (NSO and ICF 2019; Table 16). In comparison, the results of a 2006 survey suggest that the vast majority of households located in coastal areas own a boat without motor (Kaly 2006. There is virtually no use of domesticated animals to transport people or goods (Hughes 2000).

Table 16. Vehicle ownership in Milne Bay Province

	Bicycle	Motorcycle	Car/truck	Boat with motor
Milne Bay total	7%	1%	3%	6%
Milne Bay urban	22%	3%	20%	10%
Milne Bay rural	5%	<1%	<1%	5%

Source: NSO and ICF 2019

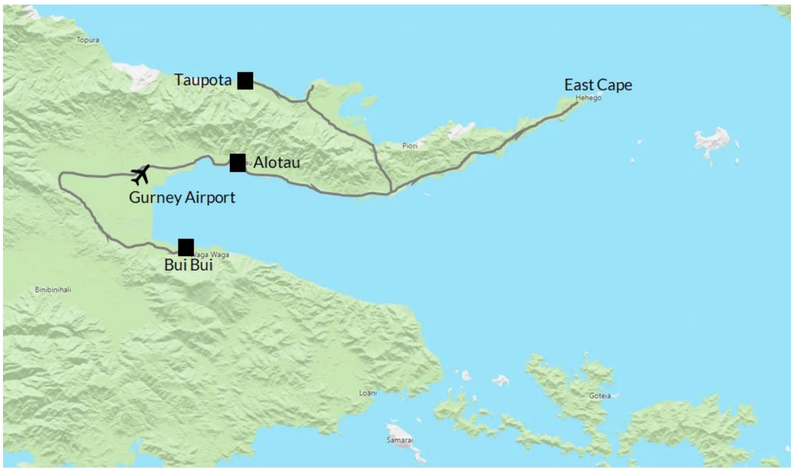
Milne Bay has a single provincial road on the main island, stretching from Buibui through Gurney airport and Alotau to the East Cape and Taupota (Figure 38). There are no roads connecting the province to other parts of Papua New Guinea. As a result, inter-province travel and exchange of goods rely on maritime and air transport.

While data was not available for a systematic assessment of road quality in Milne Bay Province, aggregated data for Papua New Guinea suggests that the quality of the road network is considered moderate to low (Slattery, Dornan, and Lee 2018). Of the estimated 1,000 km of total road length, only a fraction is sealed (MBPA 2019; World Bank 2013). The province's geography and lack of infrastructure mean that accessibility is limited (Bourke and Harwood 2009).

Improving road access and the quality of the road network in Milne Bay Province would have both short- and long-term benefits for climate resilience. In the short term, it would reduce disruption from extreme weather events, particularly flooding and landslides caused by heavy rainfall. For example, strong winds interrupt vital boat travel while heavy rainfall can temporarily disrupt road transport (Radio New Zealand 2018; in-country interviews), leading to fuel and food shortages, causing business activities to slow down, and reducing access to services, including schools and hospitals.

In the medium to longer term, it is generally agreed that an improved road network would increase access to services and markets, and reduce business costs, equally benefiting women and men (ADB 2015b; Slattery, Dornan, and Lee 2018). For example, Milne Bay's East Cape Road provides a vital link for populations located in the north and east of the province, including numerous smaller islands, to the main produce market, shops, and services at Alotau (World Bank 2016).

Figure 38. Provincial road in Milne Bay Province



Source: GGGI 2021

Successive national governments have recognized the economic and social importance of road infrastructure. For example, the *Medium Term Development Plan* (2018–2022) notes that (DNPM 2018):

> *Effective delivery of goods, services and the conduct of socioeconomic activities are enhanced by a good transport infrastructure and service network. Good and reliable transport infrastructure can turn local markets into more large scale commercial markets connecting them to domestic urban and global markets and contribute to increase exports. Productivity of different industries can be enhanced with more flow of goods and services.*

It is noteworthy that the main beneficiaries of improved access and quality of roads tend to be private motor vehicle owners and higher-income farmers and sellers. Benefits to the poorer segments of society are fewer, given low motorization levels, limited access to the road network, and their reliance on walking to access cash-earning opportunities, education, and healthcare services (Gibson and Rozelle 2003; Hughes 2005; Slattery, Dornan, and Lee 2018). Yet, although only a limited number of people would directly benefit from improved connectivity and road conditions, large numbers would benefit indirectly. For example, several studies in Papua New Guinea have shown a correlation between a household's income and its distance from the nearest road (Gibson and Rozelle 2003; Jusi, Asigau, and Laatunen 2008).

There are several reasons for the poor state of the road infrastructure, foremost of which are a combination of low levels of funding and deficient management. While successive national governments have recognized road infrastructure as a priority, this has not been reflected in adequate funding levels. Insufficient budget allocation has been exacerbated by inconsistent planning and poor budget execution, with government funding often directed toward building new infrastructure or rehabilitating and upgrading low-priority roads rather than routine maintenance, despite conclusive evidence that maintenance is more cost-effective (Slattery, Dornan, and Lee 2018; ADB 2015b; ADB 2007). The limited number of qualified private contractors, the challenging topography, and high levels of rainfall represent additional burdens (ADB 2015b; Slattery, Dornan, and Lee 2018). These issues are magnified at subnational level, where policy direction is lacking, funding and management of non-national roads is fragmented, and funding and capacity constraints are even more severe (Slattery, Dornan, and Lee 2018).

This situation has important implications for prioritizing scarce resources for land transport. Options for a response to these issues at provincial level are limited, given Milne Bay's geography and dispersed population and the provincial administration's limited resources and capacity. Therefore, this assessment recommends that the Milne Bay Provincial Administration set realistic targets and focus on maintaining existing roads rather than building new infrastructure.

While on paper, maintenance takes precedence over new infrastructure construction and rehabilitating or upgrading non-priority roads, there is mixed evidence that this happens in practice. There is an obvious need to translate the importance of road maintenance—as reflected in policies and plans—into action. There is clear evidence that new infrastructure projects are often not cost-effective (Slattery, Dornan, and Lee 2018), due in part to complex negotiations with landholders over land acquisition, compensation, and royalties (Hughes 2000). Furthermore, the benefits of new or upgraded road infrastructure are often lost when necessary subsequent maintenance is neglected (Slattery, Dornan, and Lee 2018; ADB 2015b; ADB 2007).

Given Milne Bay Province's geography, maritime transport and aviation play important roles in moving people and goods. However, fuel costs are a severe constraint on the population's ability to travel by boat, while only a few of the province's 26 designated airstrips are operational (MBPA 2019). The general paucity of data capturing passenger numbers, cargo amounts, and distance traveled prevents a more detailed assessment.

The province's numerous small islands and atolls present a challenge that cannot be changed. This geographical reality, combined with limited resources, leaves little room for interventions. Therefore, this assessment suggests prioritizing transport infrastructure in the areas that attract tourists. This can help to increase the number of non-cruise tourists who visit the province, increasing local incomes and government revenue. Some of that additional revenue could then be used to support the maintenance, upgrading, and expansion of the province's transport infrastructure.

Box 4. Political representation of women

Women's political participation is widely regarded as a fundamental prerequisite for democracy and gender equality. It facilitates women's direct engagement in public decision making and contributes to ensuring issues that disproportionally affect women—such as sexual harassment, rape, divorce, and domestic violence—are included in the political agenda (Asiedu et al. 2018; Devlin and Elgie 2008; UN Women n.d.).

Studies have shown that a range of factors influence women's access to parliaments. These can be grouped into three broad categories: political, socioeconomic, and cultural (Paxton and Kunovich 2003; Tremblay 2007). However, the mechanisms of how these factors interact and the causality behind them is not well understood. In addition, there is no homogenous and consistent set of variables that can explain the share of women in legislative bodies. Rather, these factors vary according to a country's or region's context (Tremblay 2007), making it difficult to design remedies to address them.

In the absence of addressing the underlying factors, advocates argue that increasing the number of women in decision-making positions through quotas for candidates, reserved seats for women in parliaments, and voluntary gender parity on candidate lists is an effective way of increasing their political representation (Asiedu et al. 2018; Dahlerup 2005; UN Women n.d.). [27] For example, introducing gender quotas is considered responsible for increasing female representation in parliaments across Africa (Asiedu et al. 2018).

[27] There are few concrete suggestions for increasing political representation of women other than increasing their number in decision-making bodies, despite calls for additional measures (compare UN Women n.d.). Suggested measures are generally formulaic, calling for participatory, responsive, equitable, and inclusive decision making, without specifying what the processes look like. Similarly, capacity building of female leaders is often advocated as a means to increase the representation of women (compare UN Women n.d.), but there is little detail on how these trainings will achieve the desired "transformative leadership".

However, there are ideological and practical obstacles to designing and implementing mandatory quotas. While proponents regard quotas as effective instruments for increasing women's participation in parliament, critics emphasize that quotas are against the principles of equal opportunity and democracy. Furthermore, they argue that quotas for women will likely be followed by demands for quotas for other groups, undermining the electorate's free choice among candidates (Asiedu et al. 2018; Dahlerup, 2005).

On the practical side, determining the appropriate quota size represents an obstacle to their effectiveness and legitimacy. While some authors argue that 30% representation constitutes a "critical mass" for women to shape the political agenda, there is no consensus in the literature on what constitutes a critical share that would enable women to exert their influence effectively (Child and Krook 2008; Dahlerup 1988; Grey 2006; Lovenduski 2001; Kanter 1977).

In conclusion, it is beyond the scope of this assessment to suggest a practical and politically legitimate way to increase women's political representation. This assessment can only highlight some of the considerations associated with the existing means to promote the participation of women in political decision-making processes.

6. Conclusion

The CRGG assessment shows that Milne Bay Province is exposed to the adverse impacts of climate change, as evidenced in an increase in temperature, a rise in sea levels, growing ocean acidity, and potential changes in rainfall. The province's population and economy are also very sensitive to these phenomena, given their dependence on sectors that experience considerable impacts from climate change—particularly agriculture and fishing. Finally, low income levels in the province, coupled with a lack of essential transportation, health, electricity, water, and sanitation infrastructure, means that people's capacity to adapt to the adverse impacts of climate change is limited.

Based on available data and research and consultation with local stakeholders, this assessment identifies agriculture, access to electricity, fishing, and transportation as four priority areas for Milne Bay Province to enhance its resilience towards the adverse impacts of climate change. For each of these priorities, it outlines several possible interventions that could contribute to strengthening resilience in the province.

Agriculture: Given the dominance of smallholder farming, strengthening resilience against climate change in the agriculture sector should focus on improving productivity without shifting to large-scale industrial farming, which would take away smallholder farmers' livelihoods and cause major environmental damage. More research is needed into climate-resilient crops and agricultural techniques—including options for crop rotation, intercropping and agroforestry—that are suitable for specific locations in Milne Bay Province. Successfully disseminating climate-resilient agricultural practices requires systematic improvements in extension services; and successfully implementing these practices requires improved access to formal finance. Furthermore, regardless of whether the occurrence and intensity of drought is directly related to climate change, reducing its negative effects will benefit agricultural productivity and food security. For that purpose, putting in place drought contingency plans at provincial level would be useful, if they outline practical provisions, identify how these provisions will be implemented, and designate specific entities to implement them. Complementarily, improving water management will be important for reducing the impact of drought. In particular, rainwater harvesting, water storage, and micro-irrigation could make smallholder farmers more resilient. In addition, deforestation reduces agricultural productivity and exacerbates the impact of climate change on agriculture. Participating in international certification schemes for commercial logging and piloting community-level REDD+ initiatives are two options for conserving forests in Milne Bay Province. Finally, continued adherence to international certification schemes would allow for commercial agriculture to contribute to environmental conservation, improve socioeconomic conditions for the workforce, and fetch higher prices.

Electricity supply: Access to electricity is limited and service is often unreliable in Milne Bay Province. Although climate change is unlikely to affect existing supply, increasing access to electricity can play an essential role in strengthening adaptive capacity in the province, as it would have positive effects on other aspects of resilience, such as poverty, health, education, and job creation. Given the province's geography, the technical challenges, and the high costs related to establishing a new electricity network or extending an existing grid, this assessment concludes that off-grid solutions are the most viable option for increasing access to electricity in Milne Bay Province. Of the available technologies, solar photovoltaic systems are considered most feasible for off-grid electrification. In towns, hospitals, schools, and administrative buildings, solar mini-grids would be most suitable, with trained onsite technicians for operation and maintenance and spare parts readily available. For household electrification, solar home systems appear to have several advantages over larger mini-grid designs. Finally, the assessment identifies reliability and affordability as two of the main challenges for successfully deploying solar home systems and puts forward suggestions on how to address them through quality control, financial support mechanisms, and strengthening the domestic market.

Fishing: Fish and other marine species are a crucial protein source and fishing represents an important economic activity in the province. However, fish stocks in Papua New Guinean waters are declining, triggering concerns that coastal communities will face increasing food scarcity during the coming decades. Population growth, more destructive fishing methods, high returns on particular species such as sea cucumbers, and habitat degradation from agriculture, logging, and mining activities—coupled with the adverse impacts of climate change—all contribute to declining fish stocks. However, as options for directly reducing the adverse impacts of climate change on fisheries are limited, this assessment recommends aiming interventions at reducing stress from other factors—particularly human activity—on the marine environment to strengthen its resilience towards climate change. In particular, it suggests that interventions to reduce human stress factors and encourage the sustainable exploitation of marine resources should focus on coastal waters. Establishing community-driven, locally managed MPAs is identified as a promising means for encouraging sustainable marine resource use. Furthermore, with mangroves serving as nursery grounds and habitats for many marine species, conserving mangrove forests through PES can also play a crucial role. Aquaculture is considered to represent another option for reducing pressure on marine resources, which would also create income-earning opportunities for coastal communities. Finally, the assessment recommends that, with support from donor funding and external technical expertise, local authorities investigate whether tourism can present an alternative to fishing as a source of income.

Transport: The limited reach and poor condition of transport infrastructure is a major constraint to inclusive economic growth, isolating large numbers of Papua New Guineans from markets, income-earning opportunities, healthcare facilities and education services. Given Milne Bay Province's geography, with its numerous small islands and atolls, road and maritime transport play important roles in the movement of people and goods. However, most households rely on non-motorized transportation, which means that they either walk or use boats without motors. Combined with limited resources, the province's geographical reality leaves little room for interventions. Therefore, this assessment recommends that the Milne Bay Provincial Administration set realistic targets and focus on maintaining existing roads rather than build new infrastructure. Furthermore, it suggests prioritizing investment into transport infrastructure in those areas that attract tourists, to help attract more non-cruise tourists to the province, increasing local incomes and government revenue. Some of this additional revenue could then be used to support the maintenance, upgrading, and expansion of the province's transport infrastructure.

Ultimately, there are ample opportunities to foster climate-resilient green growth in Milne Bay Province. Through the CRGG project, GGGI will help the Milne Bay Provincial Administration translate some of the recommendations outlined in this report into practice and develop bankable projects.

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Appendices

APPENDIX A. PARTICIPANT LIST

	Name	Affiliation
1	Ivan Maraka	Alotau Urban local-level government (LLG)
2	Lulu Osembo	Milne Bay Provincial Administration, Planning Unit
3	Misa Lionel	Milne Bay Provincial Administration, Planning Unit
4	Wesley Katobwau	Milne Bay Provincial Administration, Works Supervision Unit
5	William Vincent	Milne Bay Provincial Administration, Works Supervision Unit
6	Jane Iobu	Alotau Women in Maritime Association
7	Monty Wagapani	Milne Bay Provincial Administration, Transport Authorities
8	Hannah Oreho	Milne Bay Provincial Administration, Works Supervision Unit
9	John Demerua	Milne Bay Provincial Administration, Department of Agriculture and Livestock
10	Skipper Christopher	Milne Bay Provincial Administration, Department of Agriculture and Livestock
11	Jack Purai	Alotau United Church Water project
12	Anthony Yogi	New Britain Oil Palm
13	Roslyn Dalele	Milne Bay Provincial Assembly
14	Sioni	Milne Bay Tourism Bureau
15	Oa Naime	PNG Water Ltd
16	David Mitchell	Alotau Eco Custodian Advocates
17	Samuel Aloysius	PNG Forestry Authority
18	Dickson Kenans	Coffee Industry Corporation, DAL
19	Maleta Tokwakwakasi	Villink Tours & Events
20	Maxine Nadile	Egwalau Tours
21	Noah Tougaloidi	Bou Cooperatives
22	Kamane Keme	Mangrove conservation community representative
23	Angela Nelson	Buhutu Women's Association
24	Ashan Numa	Milne Bay Provincial Administration
25	Alfred Kidilon	Milne Bay Province government
26	Noel Dibela	PNG Forestry Authority
27	Paul Naolai	Media
28	Diane Kawi	National Development Bank
29	Martha Eimba	Sea Women of Melanesia
30	Lilly Abraham	Huhu LLG

APPENDIX B. WORKSHOP AGENDA

Climate Resilient and Socially Inclusive Development Pathways for Milne Bay Province

Green Growth Institute
The Nature Conservancy
CSIRO

Date: Tuesday 29th and Wednesday 30th September 2020
Location: Alotau International Hotel

Workshop objective:
to identify priority interventions to achieve climate resilient and socially inclusive development for future generations in Milne Bay Province

AGENDA

Day 1 Tuesday 29th September

Start 9.00

Session 1: What are the most important impacts of climate change? How are they connected to other drivers of change?

Session 2: What are the possible futures for Milne Bay Province?

Finish: 4.30

Day 2 Wednesday 30th September

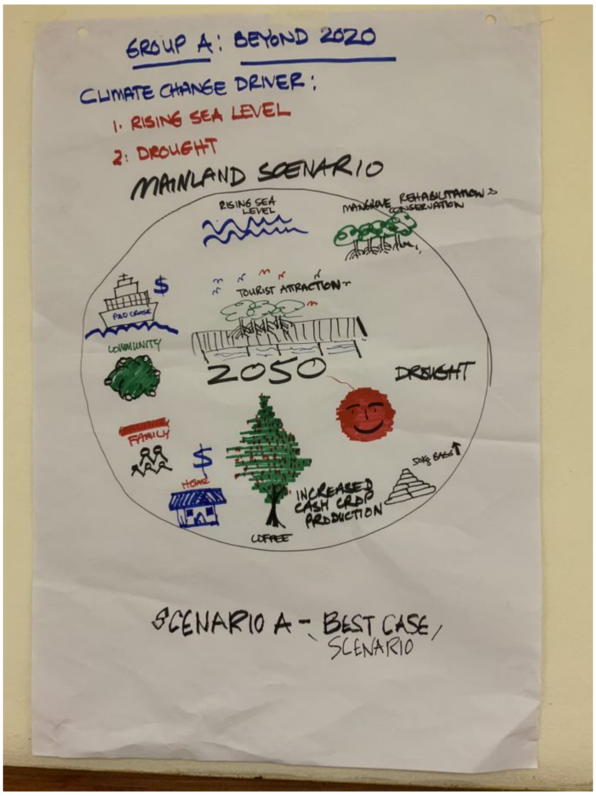
Start 9.00

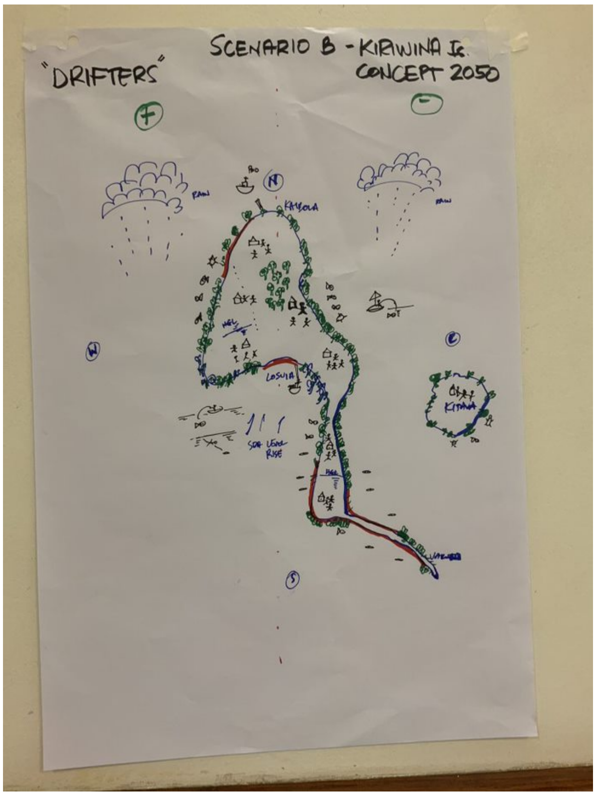
Session 3: What is the adaptive capacity of the province today?

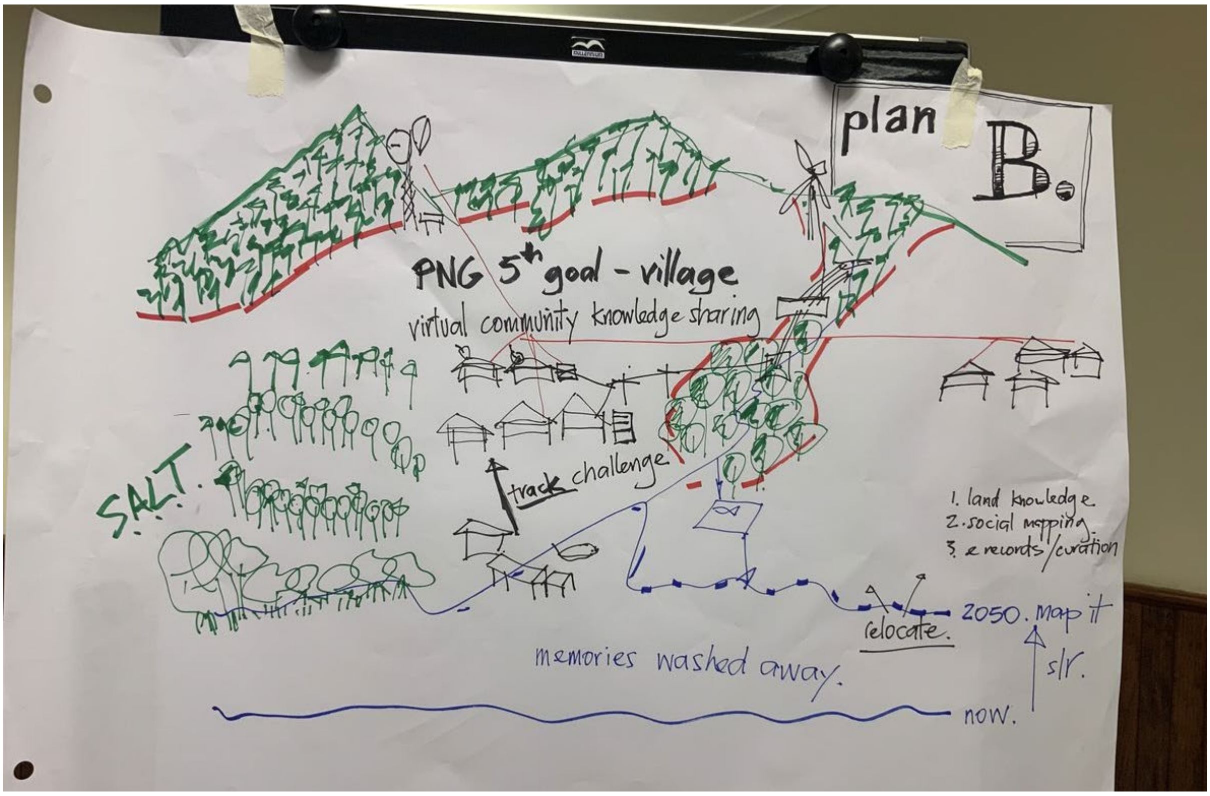
Session 4: What are the priorities to strengthen climate resilience?

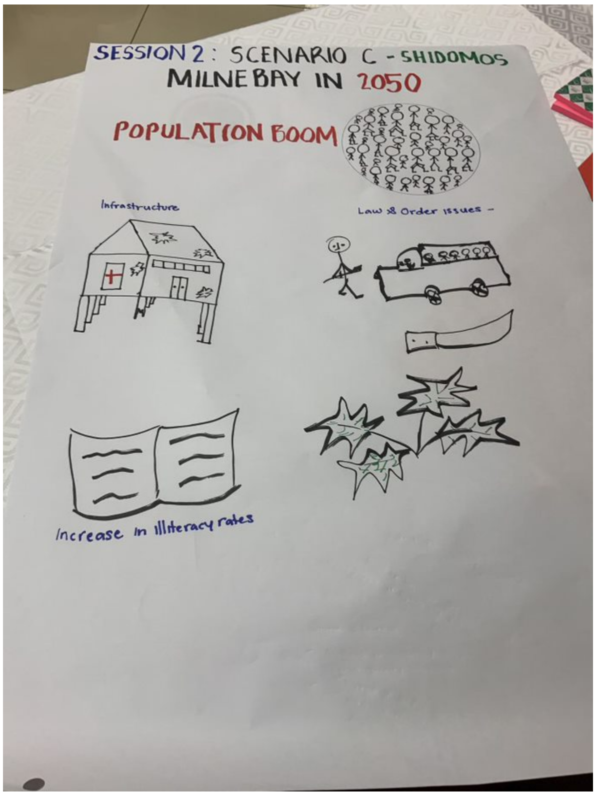
Finish: 4.30

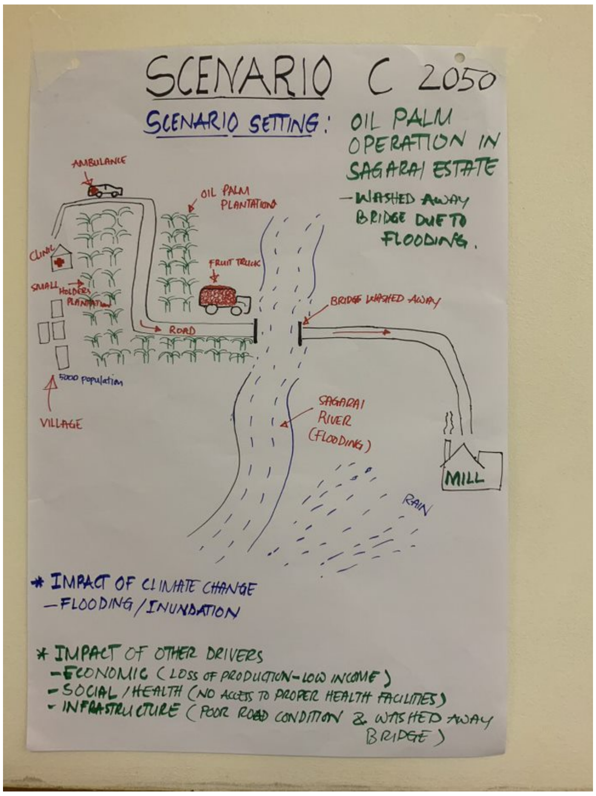
APPENDIX C. MILNE BAY PROVINCE 2050 SCENARIOS








SESSION 2: SCENARIO C - SHIDOMOS
MILNE BAY IN 2050
POPULATION BOOM
Infrastructure
Law & Order issues -
Increase in illiteracy rates


SCENARIO C 2050
SCENARIO SETTING: OIL PALM OPERATION IN SAGARAI ESTATE
- WASHED AWAY BRIDGE DUE TO FLOODING.
AMBULANCE
OIL PALM PLANTATION
CLINIC
FRUIT TRUCK
ROAD
BRIDGE WASHED AWAY
VILLAGE
SAGARAI RIVER (FLOODING)
MILL
RAIN
* IMPACT OF CLIMATE CHANGE
- FLOODING / INUNDATION
* IMPACT OF OTHER DRIVERS
- ECONOMIC (LOSS OF PRODUCTION - LOW INCOME)
- SOCIAL / HEALTH (NO ACCESS TO PROPER HEALTH FACILITIES)
- INFRASTRUCTURE (POOR ROAD CONDITION & WASHED AWAY BRIDGE)


DELTA FORCE
SCENARIO D
MV KUA

APPENDIX D. INTERVENTIONS IDENTIFIED BY BREAKOUT GROUPS

Table 17. Summary of results of session 4

Sector	Intervention	Adaptive capacity (strength and weakness)	no regrets	feasibility and costs	gender and social	COVID recovery	Score	# groups
Agriculture	Recording of existing strategies to adapt to climate change	Strong communities	4	4	4	0	12	1
	Support for agriculture	Lack of access to finance, economic diversification	4	4	5	5	18	1
	Climate smart agriculture	Increase agricultural productivity	5	5	5	4	19	1
Access to electricity	Electrification using renewable energy sources	Available sources	4.7	3	4	2.3	14	2
Fishing	Support for fisheries	Lack of access to finance, economic diversification	4.5	3.5	4	5	17	2
	Rehabilitate/plant mangroves	Deforestation	5	5	5	0	15	1
Tourism	Support for tourism	Lack of access to finance, economic diversification	4.5	3.5	4	5	17	2
Transport	Transport infrastructure, improve market access	Lack of access to goods and services	5	4	5	3.5	17.5	2
	Flood response (buffer zones, drainage, relocation, dams)	N/A	5	3	5	0	13	1
Water	Rainwater harvesting	Limited access to safe drinking water	5	3	3	3	14	1
Communication	Improve communication infrastructure	Unreliable communication infrastructure	5	4	3	3	15	2
Political participation	Additional representative (constituency) in national parliament	N/A	5	5	4	0	14	1
	Strengthen political representation of women	Gender inequality	4	2.7	4.7	2.7	14	3
Education	Improved education	Shortage of skills	5	3.5	5	2.5	16	2
Legal	Establishment of land registry	Avoid land disputes, project delay	5	4.5	5	1	15.5	2

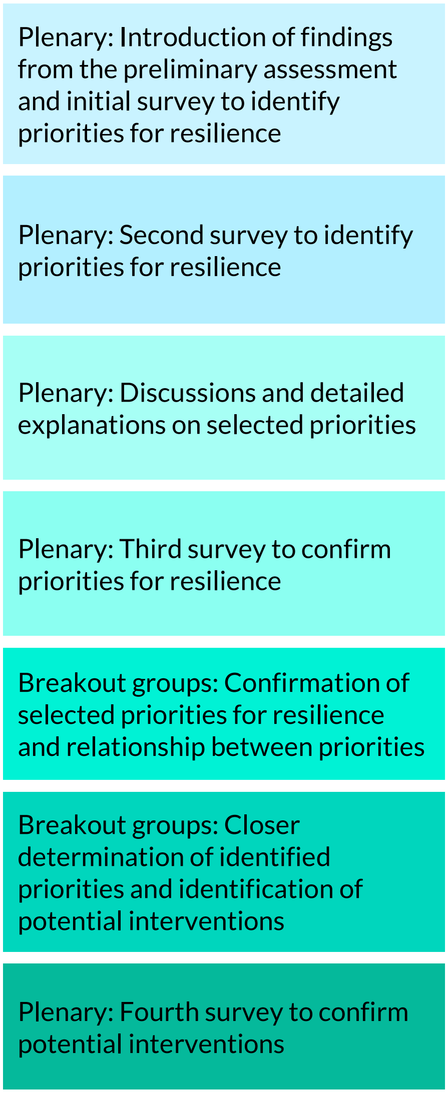
Source: GGGI

APPENDIX E. THE USUAL CRGG WORKSHOP FORMAT

As part of the CRGG assessment, stakeholders are given a leading role in determining the scope and content of the final analysis. Their input is essential for identifying priorities and developing recommendations that consider local conditions. While stakeholder engagement occurs throughout the entire assessment process, there is a concerted effort to systematically gather feedback from a broad range of constituents through an interactive workshop for 30–60 participants following the preliminary assessment. This systematic participatory process is essential to ensure broad consensus on priorities and potential remedies that are addressed in the final analysis.

CRGG consultation workshops usually rely on a combination of Delphi survey and group discussions. But, as discussed in Section 2.2, the Milne Bay assessment followed a different format. This appendix describes the usual format followed for stakeholder consultation workshops in the CRGG process.

Figure 39. The usual CRGG consultation process



Source: GGGI

There is a large spectrum of weighting and prioritization techniques in the context of multi-criteria decision-making methods,[28] and there is no objective or correct way to determine priorities or assign weights. A methodology's suitability depends on the multi-criteria problem it is meant to solve and the purpose for which it is employed (Ananda and Herath 2009; Roszkowska 2013; Zardari et al. 2015). Therefore, a methodology's characteristics—its transparency, its complexity of calculating results, and the costs involved—are, in many cases, just as important as technical soundness. There are several frequently used methodologies for assigning weights to different options, and each has its advantages and disadvantages when considering transparency, complexity, technical soundness, cost and so on (OECD and the Joint Research Centre of the European Commission 2008; Zardari et al. 2015).

As part of the CRGG assessment, stakeholder consultation relies on the Delphi method to identify priorities. The Delphi method is a systematic, interactive, and multiple-stage survey methodology that relies on a panel of experts. It was originally developed to systematically gather expert opinions and evaluate events and trends, based on consent or dissent among participants (Okoli and Pawlowski 2004; Turoff and Linstone 1975; Vorgrimler 2003). Of all the available weighting methodologies, the Delphi method was the best match for the basic requirements of the CRGG assessment, which include:

- Engaging stakeholders and reflecting their opinions in the identified priorities;
- Being simple, transparent and easy for participants to understand;
- Sharing results among all participants instantaneously;
- Providing immediate feedback and repetition of the survey; and
- Requiring the least time possible.

[28] Popular techniques include pairwise comparisons as the basis for the analytic hierarchy process, the budget allocation method, trade-off weighting method, rank ordering centroid, and the Delphi method (OECD and the Joint Research Centre of the European Commission 2008; Zardari et al. 2015).

The usual CRGG consultation workshop takes participants through several steps (Figure 39). First, it introduces the results of the preliminary assessment separately for the three categories of climate resilience—exposure, sensitivity, and adaptive capacity (see Section 2.1). At this stage, participants are asked for their initial feedback on the preliminary assessment results and select three priorities for each category. Second, there is another round of feedback in which participants can select up to nine priorities across all three categories. Third, the plenary discusses the selected priorities and any prominent results from the preliminary assessment. This discussion is supported by presenting the audience with a more detailed analysis covering the selected areas. Participants are then asked for a third time to select nine priorities to confirm or revise the earlier results.[29]

In the second part of the workshop, participants are divided into smaller breakout groups to consolidate the results of the plenary survey, define the identified priorities more closely, and suggest remedies to address these priorities. Past experiences have shown that participants appreciate this interactive session of small group discussions, while the results provide additional insights to determine the direction of the final analysis.

To guide the discussions, breakout groups are given two specific tasks. First, they are asked to verify whether their group agrees with the priorities selected by the plenary, choosing alternative priorities if they do not agree. In addition, they are asked to identify possible relationships between the selected priorities across the three categories (exposure, sensitivity, and adaptive capacity). Second, each group is asked to identify possible remedies and interventions. For that purpose, participants are given a list of possible interventions and asked to identify relevant measures to strengthen resilience for each of the relationships they selected in the first task. The list of choices is based on the results of the preliminary assessment, a literature review, and input from GGGI thematic experts. Beyond these preselected options, participants are encouraged to suggest further measures.

[29] Three consultation rounds have proven sufficient for building consensus around priorities (GGGI 2019a).

ABOUT THE GLOBAL GREEN GROWTH INSTITUTE (GGGI)

Based in Seoul, Republic of Korea, the Global Green Growth Institute (GGGI) is a treaty-based international, inter-governmental organization that supports developing country governments transition to a model of economic growth that is environmentally sustainable and socially inclusive. GGGI delivers programs for more than 30 Members and partners—in Africa, Asia, the Caribbean, Europe, Latin America, the Middle East and the Pacific—with technical support, capacity building, policy planning and implementation, and by helping to build a pipeline of bankable green investment projects.

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