Climate-Resilient Green Growth in Enga 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
ADB	Asian Development Bank
AFOLU	agriculture, forestry and other land use
ANU	Australian National University
APEC	Asia-Pacific Economic Cooperation
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
CH_4	methane
CDWAI	Community Development Workers Association Inc
CO_2	carbon dioxide
CRGG	Climate Resilient Green Growth (Project)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAL	Department of Agriculture and Livestock
DDA	district development authorities
DNPM	Department of National Planning and Monitoring
ECA	Economic Consulting Associates
EITI	Extractive Industries Transparency Initiative
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
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
IBRD	International Bank for Reconstruction and Development
ICF	Inner City Fund
IEA	International Energy Agency
IHA	International Hydropower Association
IMF	International Monetary Fund
IOM	International Organization for Migration
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency

IRF	International Road Federation
ITU	International Telecommunication Union
km	kilometer
kt	kilo tonne
kWh	kilowatt hour
LED	light-emitting diode
m	meter
MW	megawatt
N_2O	nitrous oxide
ND-GAIN	Notre Dame Global Adaptation Initiative
NEFC	National Economic and Fiscal Commission
NOAA	National Oceanic and Atmospheric Administration
NRSC	National Road Safety Council
NSO	National Statistics Office
OECD	Organisation for Economic Co-operation and Development
PGK	Papua New Guinea Kina
RAMS	Road Asset Management System
SE4All	Sustainable Energy for All
SPREP	Secretariat of the Pacific Regional Environment Programme
t	tonne
TV	television
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
UN OCHA	United Nations Office for the Coordination of Humanitarian Affairs
USAID	United States Agency for International Development
WASH	water, sanitation, and hygiene
WHO	World Health Organization
WWAP	World Water Assessment Programme

Executive summary

The Climate Resilient Green Growth (CRGG) assessment shows that Enga Province is exposed to the adverse impacts of climate change, as evidenced in a rise in temperature 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. 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 Enga 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;
- Water;
- Electricity supply; 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 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 will require more research into climate-resilient crops and agricultural techniques—including options for intercropping and agroforestry—that are suitable for specific locations in Enga Province. Furthermore, improving water management will be important for strengthening resilience, as it reduces the impact of droughts. For example, improving water storage and micro-irrigation systems—and potentially combining these with off-grid renewables—could make smallholder farmers more resilient. Successfully disseminating such climate-resilient agricultural practices requires systematic improvements in extension services, while successfully implementing them will require improved access to formal finance. Finally, any such interventions should be complemented by improving access to—and the quality of—electricity supply and transport infrastructure, to reduce post-harvest losses.

Water

The assessment discusses three aspects of water supply and sanitation that are likely to be affected by climate change: accessibility of drinking water, sanitation, and agriculture. Improving access to—and the quality of—drinking water and sanitation will require strengthening the enabling environment and putting in place the necessary infrastructure. Strengthening the enabling environment includes articulating targets, priorities and approaches; establishing clear roles and responsibilities among the government agencies involved in the sector; and setting up budget mechanisms for allocating and tracking expenditure. Relevant infrastructure includes boreholes, water harvesting systems, storage facilities, handwashing facilities, and pit latrines. Schools have been identified as a potential priority for such infrastructure. Finally, the agriculture sector is confronted with the prospect of too much water, and a risk of too little water. Improving water management—including storage and irrigation—will be an important aspect to cope with potential changes in rainfall and the occurrence of drought.

Electricity supply

Electricity supply in Enga Province—particularly electricity generated from hydropower—is susceptible to the adverse impacts of climate change. At the same time, access to electricity represents an important means to strengthen resilience against climate change. Increasing both the reliability of existing supply and access to electricity would have a positive effect on poverty, health, and education. Off-grid electrification through solar photovoltaic systems offers a viable alternative for providing basic electricity services in areas where grid extension is expensive or physically difficult. In that context, solar mini-grids have been identified as an option for towns, hospitals, schools, and administrative buildings, with trained technicians and spare parts available for operation and maintenance. For household electrification, solar home systems appear to be the more suitable option, showing several advantages compared to larger mini-grid designs. Two of the main challenges for the successful deployment of solar household systems are reliability and affordability. The former could be addressed by enforcing national-level quality standards, but the latter will require local solutions, with in whose design the provincial administration actively involved in designing financing options.

Transport

Both freight and passenger transport are dominated by road and non-motorized transport. The limited reach and poor condition of land 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. The quality of the road network might deteriorate further due to the adverse impacts of climate change, particularly if there is an increase in heavy rainfall and associated flooding. Given its limited resources and capacity, it is recommended for the Enga Provincial Administration to set realistic targets and focus on maintaining non-national roads rather than build new infrastructure. Stronger coordination between the provincial government and district development authorities would help the administration prioritize the maintenance of existing infrastructure. This will require addressing several interrelated issues, including clarifying responsibilities for managing and maintaining non-national roads, resolving the disparity between allocated responsibilities and distribution of funds, and allocating funding based on technical and economic assessments, rather than political considerations.

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Timothy Lawton	Environment and Climate Change Officer, Division of Natural Resources
Keith Yaen	Senior Officer, Division of Agriculture and Livestock

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Jan Stelter, Senior Analyst (GGGI), was responsible for carrying out the CRGG assessment in Enga Province and drafting of this report. Trevor Blanchard Galgal, Provincial Officer (GGGI) and Feelgeun Song, Modelling Officer (GGGI), supported the assessment by gathering relevant literature, conducting stakeholder interviews and being responsible for the logistics of the consultation workshop.

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Hohit Seyoum Gebreegziabher	Project Officer (Papua New Guinea)
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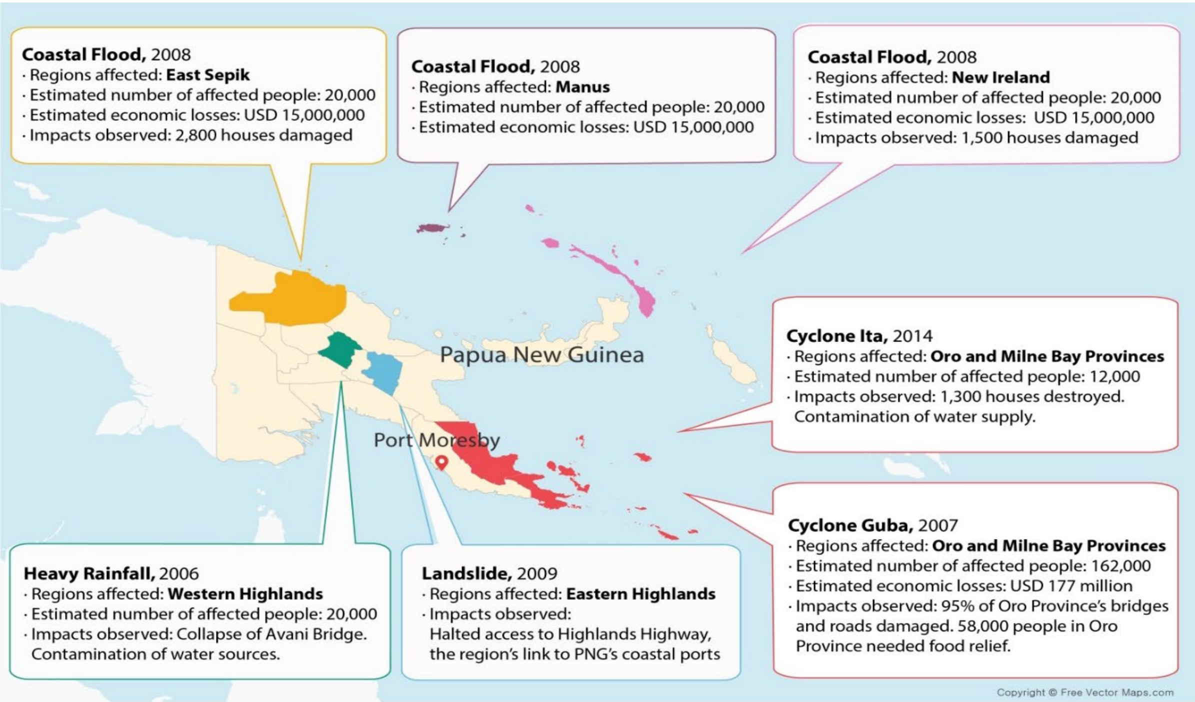
1. Background

Papua New Guinea is highly exposed to climate change, as evidenced in higher 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 Enga 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 Enga 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

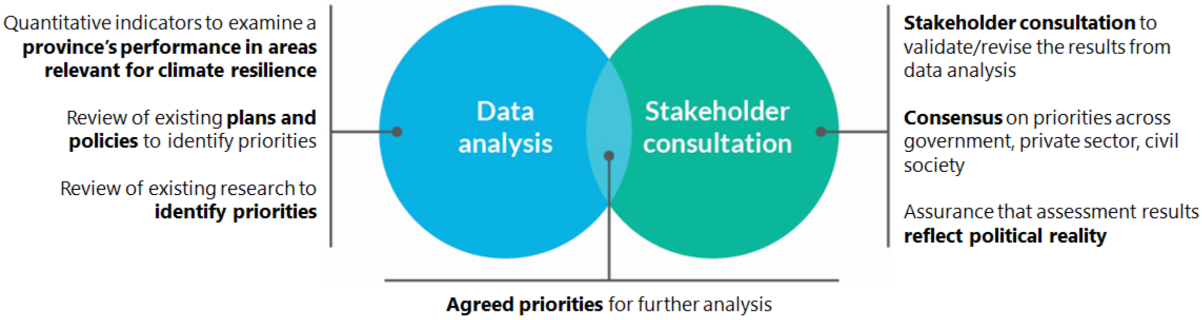
Source: GGGI

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, 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



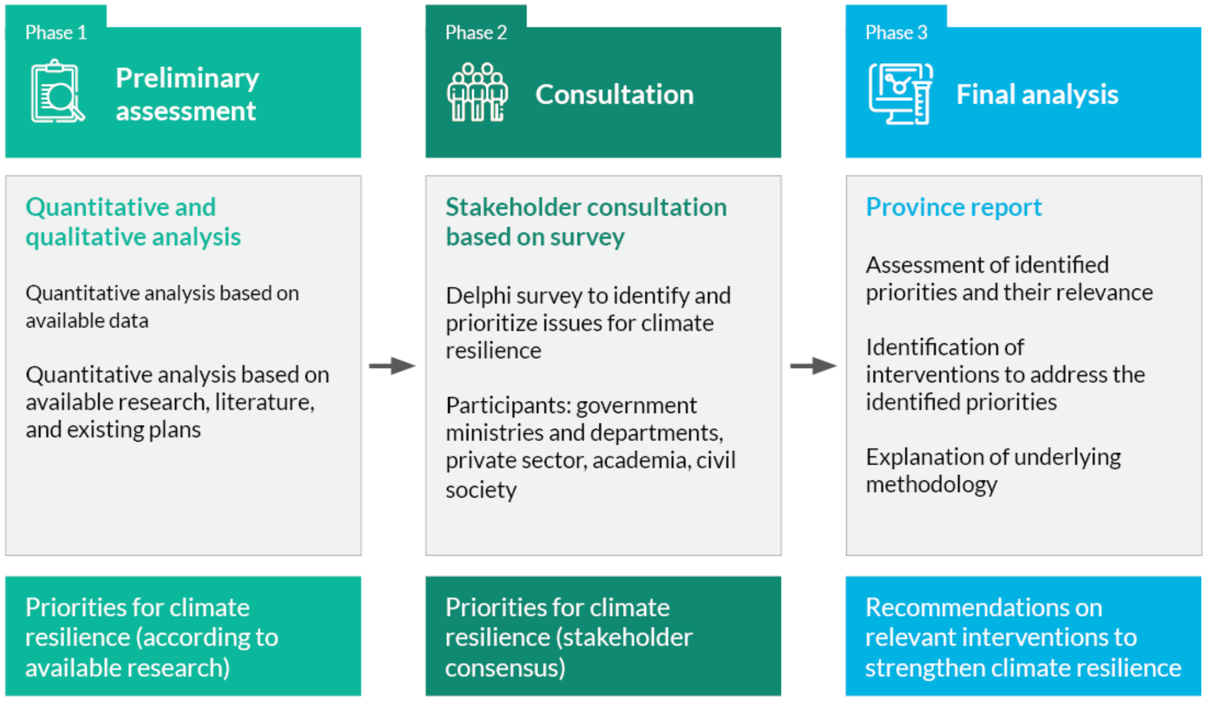
Source: GGGI

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



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:

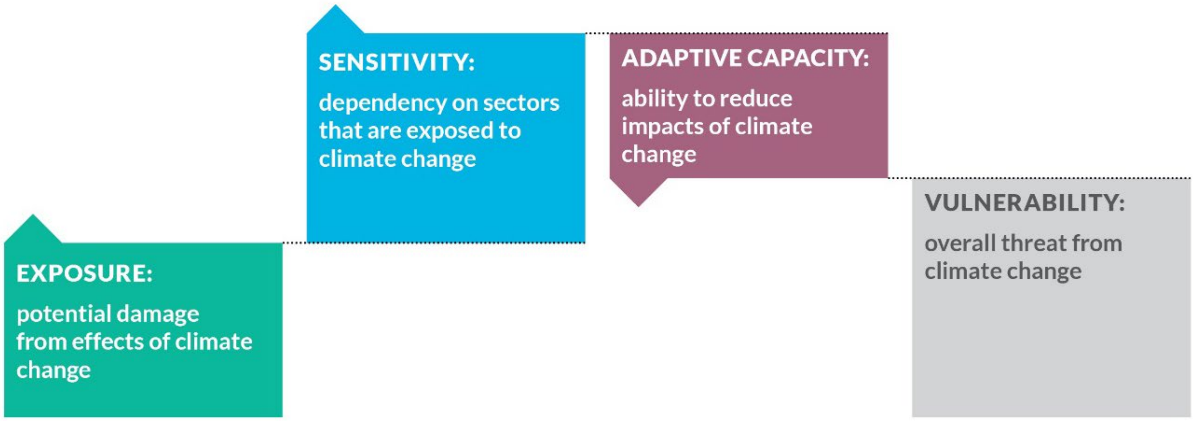
1. Understanding the relevant sources of greenhouse (GHG) gas emissions to mitigate the province's contribution to climate change; and
2. Evaluating a province's vulnerability to climate change to strengthen its resilience.

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 events 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.

There is a large spectrum of weighting and prioritization techniques in the context of multi-criteria decision-making methods.[2] 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 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

[2] 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).

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.

The consultation workshop takes participants through the following steps (Figure 6). 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.[3]

Figure 6. The consultation process

Source: GGGI

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 that they have selected in the first task. The list of choices is based on the results of the preliminary

[3] Three consultation rounds have proven to be sufficient to build consensus around priorities (GGGI 2019a).

assessment, a literature review, and input from GGGI thematic experts. Beyond these preselected options, participants are encouraged to suggest further measures.

Appendix D contains a detailed overview of the two tasks given to the breakout groups and the preselected set of options.

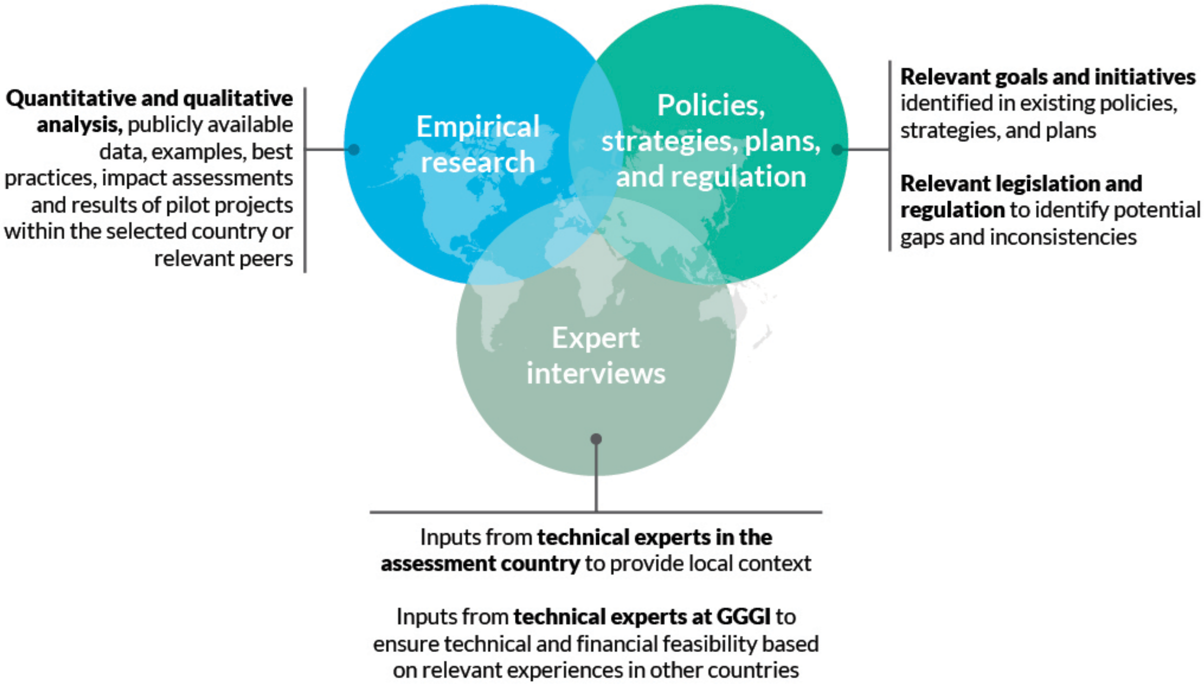
2.3. Final analysis

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 7):

- 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 7. 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 Enga 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 Enga 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: compiled by GGGI

Similarly, available information on economic activity and energy use indicates that these two sectors are responsible for most of Enga Province's GHG emissions. First, a 1.1% decrease in forest cover between

2002 and 2014 (Bryan and Shearman 2015) implies the relevance of the AFOLU sector's GHG emissions. In-country interviews identified agricultural activity and the reliance on fuelwood as the main drivers behind deforestation. Second, the literature also points to the combustion of fossil fuels for electricity generation and transport as being principally responsible for GHG emissions from the energy sector. For example, some of Enga Province's electricity supply comes from the Ramu grid, where diesel accounts for a considerable share of electricity generation (ADB 2009).

Low electricity access and motorization rates (NSO and ICF 2019) limit the potential of reducing GHG emissions from the energy sector. However, should access increase, electricity generation from renewable sources, public transport and energy efficiency measures will become relevant for capping the increase of 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 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).

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).

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

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 Enga 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 2020a), with the annual growth rate declining from 2.4% in 2008 to 2.0% in 2019 (World Bank 2020b). 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 Enga Province's vulnerability to the adverse impacts of climate change, the preliminary assessment distinguished between three aspects of vulnerability, namely exposure, sensitivity, and adaptive capacity (Figure 5).

3.2.1. Exposure

Exposure to climate change refers to Enga Province being 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, only the first three were found to be relevant for Enga Province—that is, rise in temperature, changes in rainfall, and occurrence of drought. Rise in sea level, increase in ocean acidity and occurrence of cyclones were not considered relevant, given the province's landlocked location (Table 4).

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

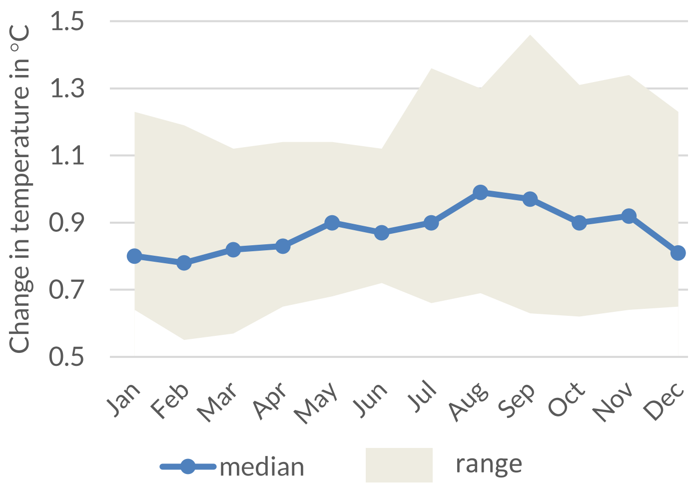
Phenomenon	Confidence	Potential impacts
Rise in temperature	Very high	Decreased yield and quality of agricultural crops Increase in vector-borne and respiratory diseases Reduced habitat of montane bird species
Change in rainfall	High	Increase in flooding and damage to infrastructure Decrease in agricultural productivity Increase in vector and water-borne diseases
Occurrence of drought	Medium	Decrease in agricultural productivity Reduced access to drinking water and reduced food security
Rise in sea level	Very high	Not relevant for Enga Province
Increase in ocean acidity	Very high	Not relevant for Enga Province
Occurrence of cyclones	Medium	Not relevant for Enga Province

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). There is limited long-term data on temperatures for the highlands. However, the maximum temperature at Aiyura (Eastern Highlands Province) increased by 0.75°C during the period 1977–2001, and projections suggest rising monthly average temperatures and maximum daily temperatures in Enga Province (Allen and Bourke 2009, World Bank 2020, Figure 8 and 9).

Figure 8. Projected change in monthly temperature in Enga Province (2020–2039)

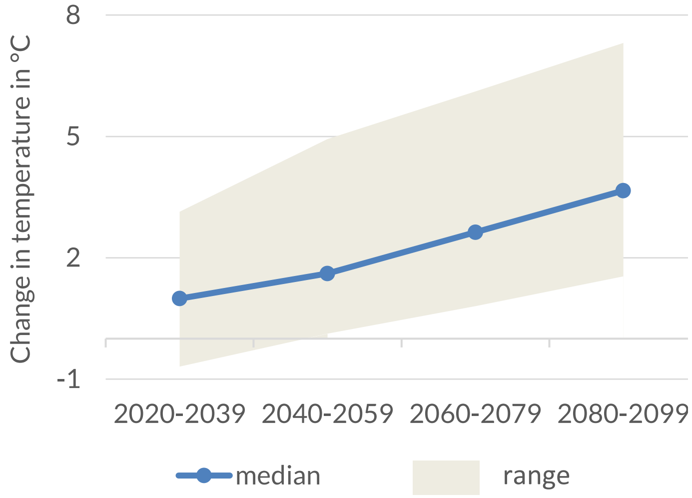


Source: World Bank 2020

Increasing temperatures are expected to particularly affect agriculture, public health, and biodiversity. 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 such as taro blight and coffee rust, particularly at higher altitudes (GEF, UNDP and SPREP 2009; Jaramillo et al. 2011; Kudela 2009; Moretti et al. 2010). In Enga Province, temperature rises will likely reduce productivity in the lowlands and main highland valleys but increase productivity above 2,000 meters (Allen and Bourke 2009).

Second, historically, a large share of Enga Province's population lives at altitudes that preclude malaria transmission (Mueller et al. 2006). However, Park et al. (2016) suggest that malaria incidence is increasing with the rise in monthly minimum and maximum temperatures, which creates a more favorable environment for vector mosquitoes up to an altitude of 1,600 meters. Further increase in temperatures can lead to higher malaria prevalence even above 1,600 meters (Park et al. 2016).

Figure 9. Projected change in maximum daily temperature in Enga Province (2020–2099)



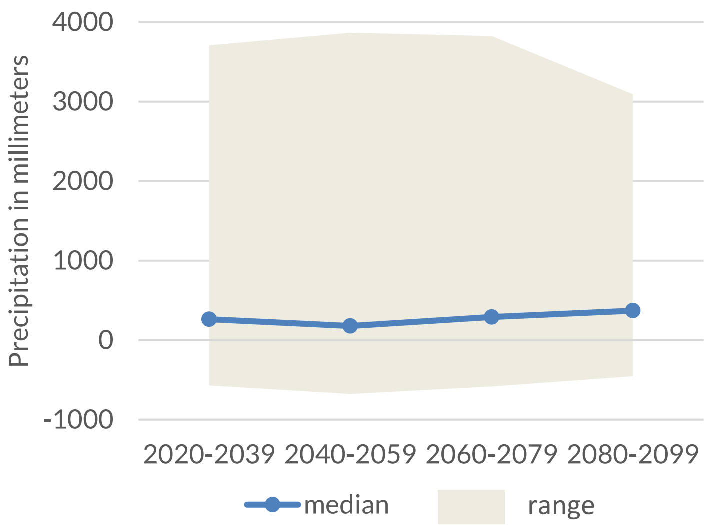
Source: World Bank 2020

Third, increasing temperatures may also reduce habitats for montane species of tropical birds. Physiological boundaries for tropical birds are narrow, limiting their ability to cope with changing climate. Changes in temperature may push tropical birds over their physiological limits, causing them to shift to higher elevations or to become locally or globally extinct (Shoo et al. 2006; Hilbert et al. 2004; Colwell et al. 2008; Gasner et al. 2010; Mack 2009)

Changes in rainfall

In Enga Province, average annual and maximum daily rainfall are expected to increase. However, these projections are subject to considerable uncertainty as variability in rainfall trends over the years and complexity of rainfall patterns makes it difficult to forecast rainfall (Allen and Bourke 2009; BoM and CSIRO 2011; World Bank 2020, Figure 10 and 11).

Figure 10. Projected change in annual rainfall in Enga Province



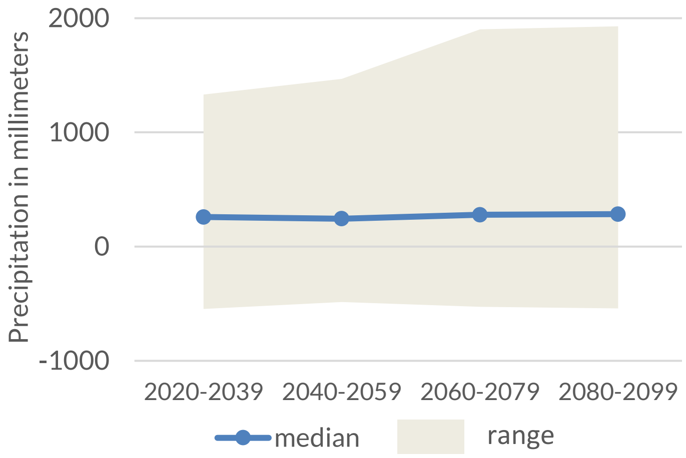
Source: World Bank 2020

Changes in rainfall are expected to particularly affect agriculture, transportation, and public health.

First, changes in rainfall patterns affect planting time, growing stages, harvest periods, and post-harvest crop storage, likely reducing agricultural yield (Ganpat and Isaac 2014; World Bank 2011). Optimum annual rainfall for most crops in Papua New Guinea is 1,800–3,500 millimeters, with one to three consecutive drier months. An increase in annual rainfall to more than 3,500 millimeters would lead to low levels of bright sunshine, waterlogged soils, and leaching of soil nutrients, reducing productivity for most crops (Allen and Bourke 2009).

Second, an increase in maximum daily rainfall is expected to increase inland flooding, damaging infrastructure and blocking important arteries of transport (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).

Figure 11. Projected change in maximum monthly rainfall in Enga Province



Source: World Bank 2020

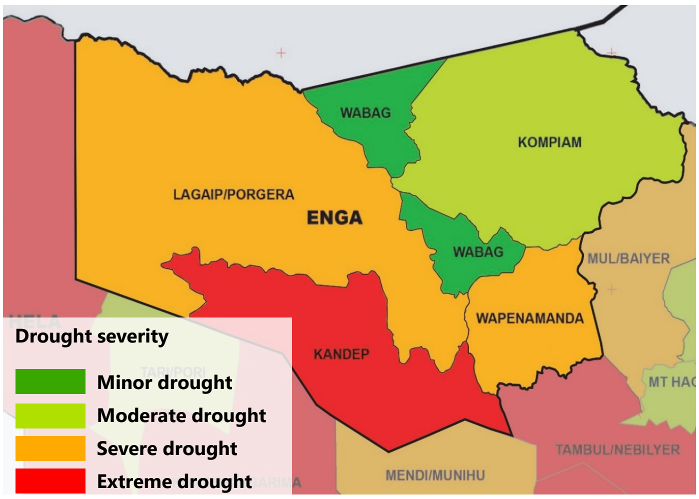
Third, information on the impact of climate change on vector-borne diseases in Enga Province is sparse. However, studies in Eastern Highlands Province indicate that, as with rising temperatures, increased rainfall leads to expanded habitats of vector mosquitoes, causing a rise in the number of malaria cases (Park et al. 2016).

Occurrence of drought

Historically, Papua New Guinea's Highlands Region has experienced rare water deficits and is characterized by moderate to large soil water surpluses (Allen and Bourke 2009).

Projections suggest a possible increase in the intensity of droughts and frosts (particularly above 1,700 meters) in years impacted by the El Niño Southern Oscillation (ENSO) phenomenon.[4] 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 (Bourke, Bryant and Lowe 2016).

Figure 12. Drought-affected districts in Enga Province during the 2015 ENSO



Source: IOM 2016b

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 droughts (BoM and CSIRO 2014).

[4] 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 of Enga Province 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, fishing, mining, tourism, electricity supply, transportation, and water supply and sanitation.

Like Papua New Guinea in general, Enga Province is characterized by a dual economy. The export-oriented extractive industry provides a large share of GDP, while more than 80% of the country's 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 sector shows a high sensitivity to climate change. On top of this, the province's electricity, transport, water and sanitation infrastructure is regarded as susceptible to the adverse impacts of climate change (Table 5).

Table 5. Sectors affected by climate change

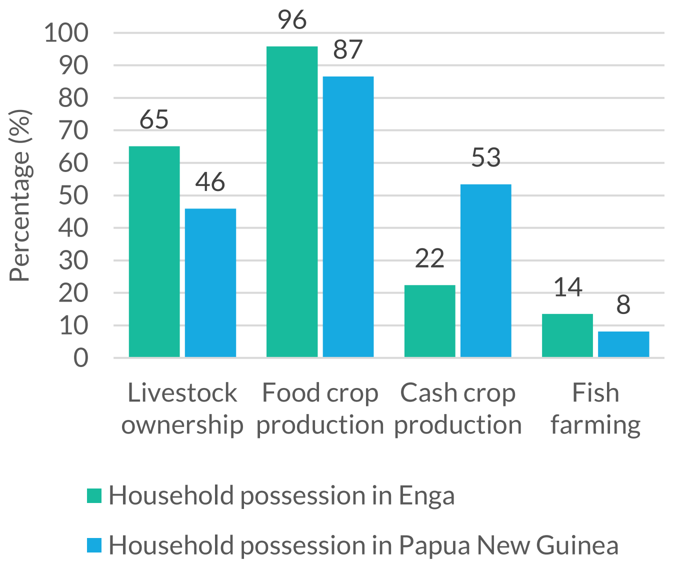
Sector	Relevance	Sensitivity to climate change
Agriculture	High share of population engaged subsistence agriculture High share of economic output from agriculture	Adverse impacts of climate change likely to further increase existing agricultural pressure
Fishing	Fish represents an alternative source of protein	Impact of climate change on fish farming subject to uncertainty and dependent on the location
Mining	Mining represents a major contributor to local economy and employment	Commercial mining operations largely unaffected by climate change Small-scale mining expected to be susceptible to climate change
Tourism	Tourism is an important contributor to the local economy	Tourism indirectly affected by loss of biodiversity due to climate change
Transportation	Access to transportation and vehicle ownership are low	Low quality road infrastructure likely to be susceptible to negative impacts of climate change
Electricity supply	Electricity access rate is low	Hydropower susceptible to the adverse impacts of climate change
Water supply and sanitation	Access to safe water and improved sanitation is limited, particularly in rural areas	Unprotected water sources and unimproved sanitation susceptible to adverse impacts of climate change, causing health hazards

Source: GGGI

Agriculture

Enga's economy is dominated by subsistence farming, with farmers producing large quantities of starch crops (sweet and Irish potatoes), and smaller quantities of banana, corn, taro, yams, and other tropical vegetables (ADB 2016; Allen and Bourke 2009). Coffee represents the major cash crop. The sale of coffee, food crops, and firewood provides a source of low to moderate income for some smallholder farmers (World Bank 2019; Figure 13).

Figure 13. Livestock ownership, food and cash crop production and fish farming at province and national levels

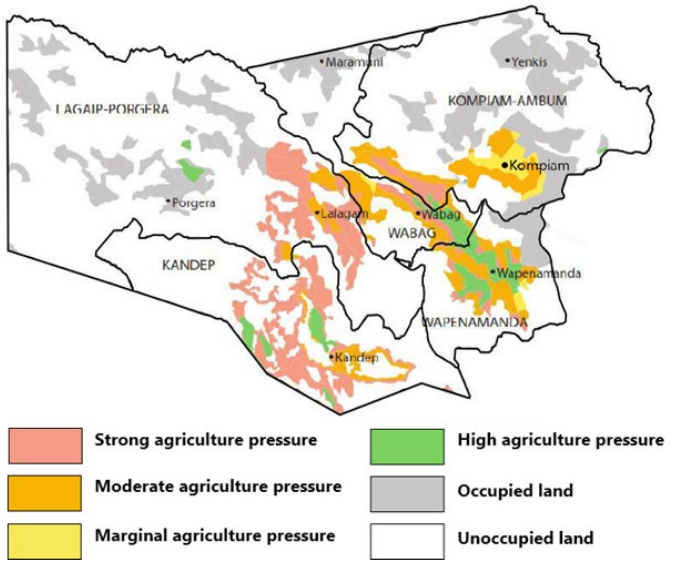


Source: NSO and ICF 2019

A comparatively small area of land in Enga Province is considered to have high agricultural potential. The concentration of both population and agricultural activity at altitudes above 2,000 meters, in areas prone to drought and frost, seriously affects agricultural productivity and food security (ADB 2016; World Bank 2019).

Most arable land is already under strong agricultural pressure due to rapid population growth leading to shorter fallow periods (ADB 2016; Figure 14). Adverse impacts of climate change—such as higher temperatures and precipitation levels—can further increase this pressure.

Figure 14. Areas of agriculture pressure in Enga Province



Source: ADB 2016

Fishing

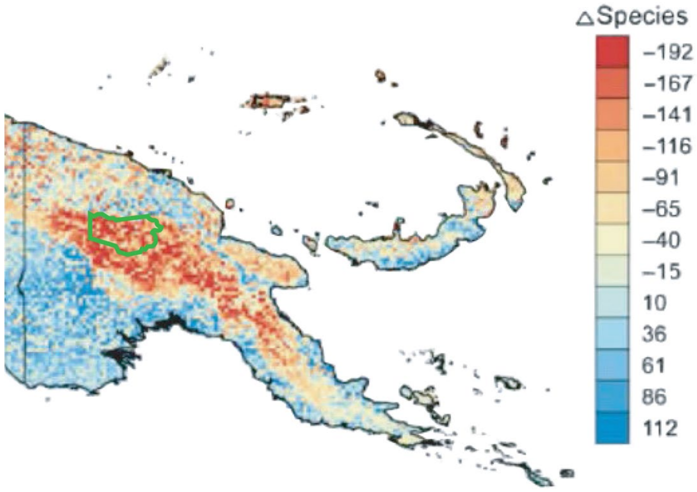
Inland fisheries and aquaculture represent an important source protein for approximately 14% of households in the province (NSO and ICF 2019). Semi-intensive and extensive pond polyculture of tilapia and carp are most common. There are few intensive trout farms, due to high infrastructure costs and intensive management requirements (in-country interviews).

The impact of climate change on fish farming is subject to uncertainty and dependent on location within Enga Province. For example, although an increase in temperature should enable tilapia to be farmed at increasingly higher altitudes (Bell et al. 2011), drought, flooding and rising temperatures also represent threats for existing fish farms in the province (Soto et al. 2018 in-country interviews).

Tourism

The tourism sector in Enga Province generates an estimated PGK 500,000 annually from international tourists visiting the province (in-country interviews). Tourism is largely focused on the province's biodiversity and local cultural heritage (Poole 2018), with the Enga Cultural Show, bird watching, salt ponds, the Take Anda Cultural Center, and rare orchid species among the main attractions.

Figure 15. Projected change in number of species



Source: Cámara-Leret et. al. 2019

As a foundation for the tourist sector, biodiversity is negatively impacted by climate change, reducing the number of species found in the province as well as the habitat of the remaining species. For example, Cámara-Leret et. al. (2019) estimate that Papua New Guinea will have 30–100 fewer species by ecoregion by 2070, and that Enga Province will be among the most severely affected regions (Figure 15). Furthermore, they estimate that nearly two-thirds of all species will have smaller geographic ranges by 2070 as result of climate change (Cámara-Leret et. al. 2019).

Mining

Mining in Enga Province includes both large-scale commercial and artisanal mining. In 2019, Porgera was the only operational mine in the province, exporting approximately PGK 1.9 billion in gold and silver in 2018 (PNG EITI 2019). Through payments to employees, purchases from local suppliers, payments to government, and community investments, the mine forms an important economic backbone for the province (Barrick Gold Corporation 2012). In addition, there are an estimated 4,000-5,000 artisanal miners in the province, of Papua New Guinea's 80,000—100,000 artisanal miners (Crispin 2003; in-country interviews). Generally, small-scale mining is expected to be more impacted by climate change than commercial mining operations (Sharma et al. 2013).

Transportation

With little information available on the relevance of maritime and air transport, low ownership rates and low passenger numbers, the assessment focuses on road transport in Enga Province.

Table 6. Vehicle ownership in Enga Province

	Bicycle	Motorbike	Car/ truck	Boat with motor
Total	5%	0%	4%	0%
Urban	2%	0%	2%	0%
Rural	29%	0%	22%	0%

Source: NSO and ICF 2019

The quality of the road network is generally low, making it susceptible to adverse impacts of climate change. In particular, heavy rainfall causes flooding and erodes road foundations. However, the adverse impact of climate change on road transport is somewhat limited as access to road transport is low. While road transport plays a dominant role in moving goods from and into the province, only a small share of the population benefits from road transportation, particularly motorized transport. Although the province is comparatively well connected to other provinces, an estimated 40% of its population lives more than 5 kilometers from a national road (Allen and Bourke

2009). In addition, vehicle ownership rates are low, with only 4% of population owning a car or truck (NSO and ICF 2019; Table 6).

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 Enga Province's electricity supply.

The province's electricity mix consists of hydro, diesel, and natural gas, with power supplied by the Ramu grid and several large auto-producers (Figure 16). The former has the second largest capacity of Papua New Guinea's three main electricity networks, (after the Port Moresby grid), but geographically, it is the most extended. It has an estimated generation capacity of 87 MW for hydropower and 35 MW for diesel (ADB 2009; APERC 2017). The Porgera Mine is a large auto-producer of electricity, generating electricity from natural gas (62 MW) and diesel (13 MW) to support its operations and service its workers (ADB 2009).

Figure 16. Electricity infrastructure in the Ramu grid

Source: Adapted from ECA 2015

Hydropower in particular can be directly susceptible to negative impacts of climate change. With hydropower being used for supplying the baseload in the Ramu grid, there are concerns that climate change could lead to increased outages, when electricity output from hydropower plants is affected by a lack of water in the dry season and clogging at times of heavy rainfall.[5]

However, if climate change were to cause more electricity outages, low access rates to electricity in the province mean that the share of affected population would be comparatively low. Survey data from NSO and ICF (2019) suggests that only approximately 12% of Enga Province's population have access to

[5] There is disagreement around the extent to which electricity generation from hydropower is affected during the dry season and by heavy rainfall. PNG Biomass (2017) mentions the Ramu-1 power project, where water levels at the dam suffered a five-meter drop in August 2015, after two months of dry weather. Some interviewees mentioned that there was power rationing in Port Moresby during the dry season in 2017. However, other interviewees regarded these episodes as exceptions and were confident that electricity supply from hydropower was reliable, independent of weather and climatic conditions.

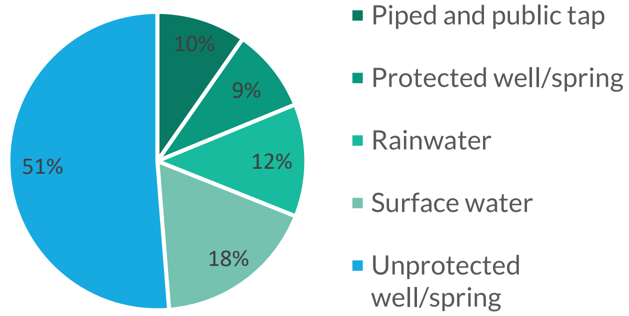
electricity. This is also reflected in equally low appliance ownership: only approximately one-fifth of the households own a radio and less than 15% own a TV, refrigerator, or computer (NSO and ICF 2019)

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.

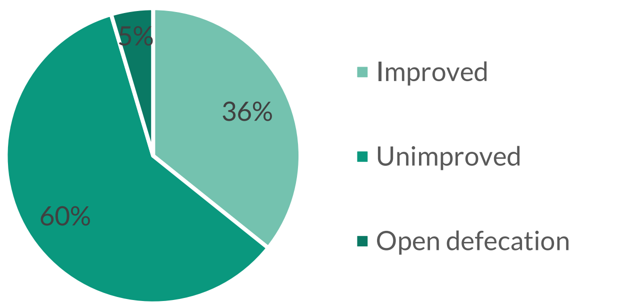
Prolonged rainfall, flooding and an increase in droughts can affect unprotected water sources and unimproved sanitation, causing health hazards (IOM 2016a). Particularly in rural areas, water supply and sanitation are susceptible to the impacts of climate change. Less than one-third of the rural population in Enga Province has access to protected sources of drinking water and improved sanitation (Figure 17 and 18). Urban areas are mostly supplied by piped drinking water, while the large majority of the rural population depends on unprotected sources. Similarly, improved sanitation facilities are common in urban areas, but limited in rural areas (NSO and ICF 2019).

Figure 17. Source of drinking water in Enga Province



Source: NSO and ICF 2019

Figure 18. Sanitation facilities in Enga Province



Source: NSO and ICF 2019

3.2.3. Adaptive capacity

Enga Province's adaptive capacity refers to its ability to cope with the adverse impacts of climate change, despite its level of exposure and sensitivity. To assess the province'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 Enga 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 7).

Table 7. Adaptive capacity in Enga 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, the availability of lighting, use of appliances, 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	Limited access to protected sources of drinking water 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 road access Low quality of road network
Information and communication	Mobile phone services to communicate and access information are an important means to overcome infrastructure and service barriers	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 health infrastructure and health systems are weak	Limited access to health services Low quality of health services
Education and labor skills	Education is a critical determinant for an individual's income and skills across the workforce	Low completion rates for all levels of education Labor skills focused on agriculture
Deforestation	Forest resources play an important economic role and provide essential ecosystem services	Comparatively low rate of deforestation

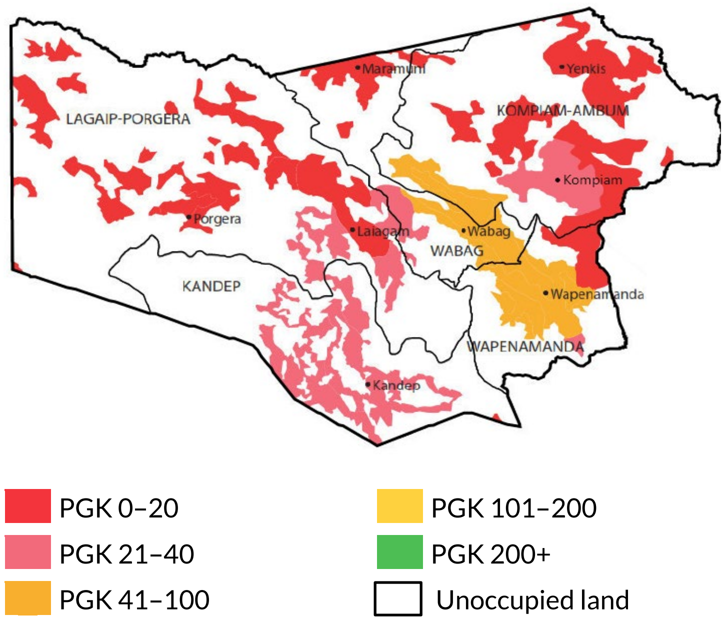
Source: GGGI

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.

Average annual cash income is less than PGK 200 per person (Figure 19). The large majority of Enga Province's population depends on subsistence farming with limited cash income from paid employment—in public service, gold mining or sawmills—and selling fresh produce at local roadside markets (ADB 2016).

Figure 19. Average annual cash income per person in Enga Province

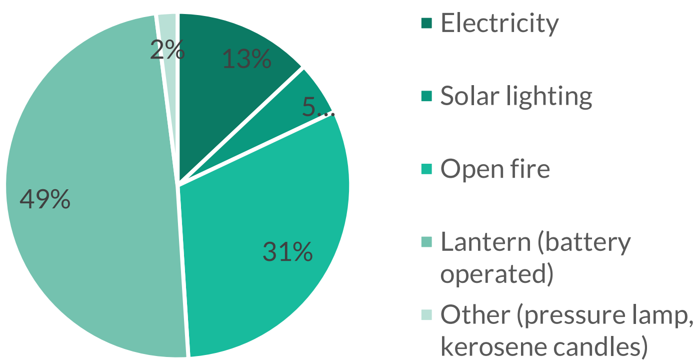


Source: ADB 2016

Access to electricity

Access to electricity is fundamental for economic development and the availability of numerous other services, such as lighting, use of appliances, and communication. Access to electricity in Enga Province is limited—only an estimated 10% of the population have access to electricity (NSO and ICF 2019)—and the service is often unreliable. As a result, electrification can play an essential in strengthening adaptive capacity in the province.

Figure 20. Main source of lighting in Enga Province



Source: NSO and ICF 2019

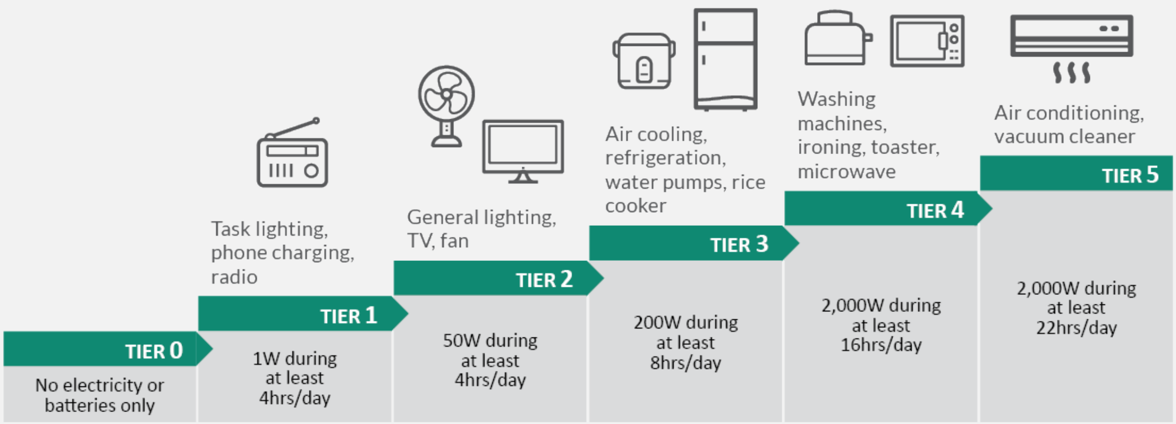
However, it important not to regard access to electricity as a binary measure—that is, whether a household has access to electricity or not. Quantity, reliability and affordability are also decisive criteria when assessing access to electricity and considering possible interventions (see Box 2). For 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 (i.e., 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 (Angelou et al. 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 21; Angelou et al. 2013).

Figure 21. 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 2019; UN Water 2019). Therefore, access to water represents a defining feature for assessing adaptive capacity.

In Enga Province, a considerable share of the population has no immediate access to drinking water (Figure 22). Unprotected springs are the most common source for drinking water, and half of the province's population requires more than 20 minutes to access the nearest source (NSO and ICF 2019; in-country interviews).

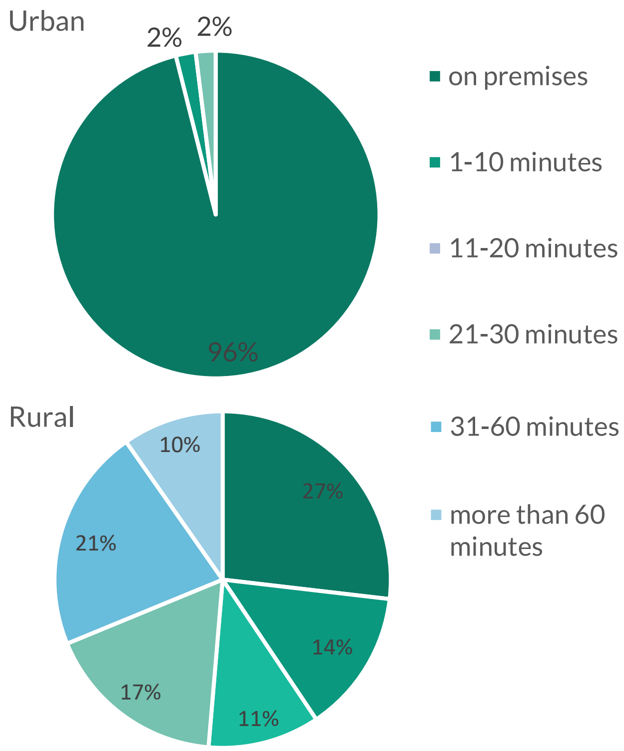
Agriculture forms the economic backbone of Enga Province. Agriculture is largely rainfed, and while historically, a large share of the soils in the province has moderate surplus of water (Allen and Bourke 2009), droughts have a severe impact on agricultural output and food security. Therefore, water storage and irrigation systems are important means to improve access to water and increase adaptive capacity.

Transportation

A reliable transportation network increases the ability to adapt to the adverse impacts of climate change, allowing for the movement of goods and people.

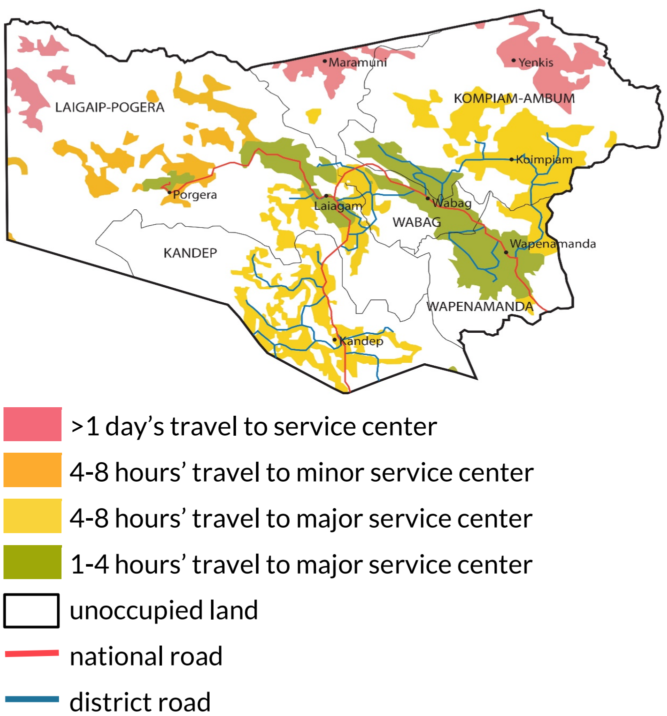
The quality of the road network in Enga Province is regarded as moderate to low. Although national roads are considered to be in comparatively good condition, district roads are in poorer condition (in-country interviews). Furthermore, accessibility is limited, with an estimated 40% of the population living more than 5 kilometers away from a national road

Figure 22. Time taken to reach a drinking water source



Source: NSO and ICF 2019

Figure 23. Access to transport services in Enga Province



Source: ADB 2016

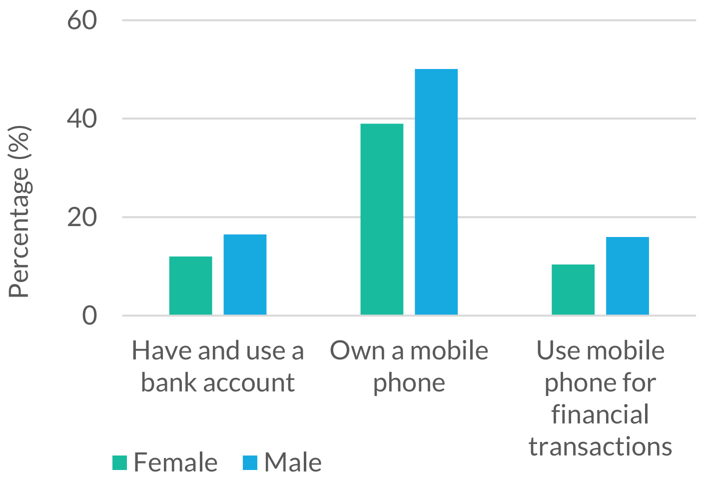
(Allen and Bourke 2009), which often means that people need to travel more than four hours to reach the nearest service center (Figure 23).

Improving both access to and the quality of the road network would strengthen adaptive capacity in the short and long term. It would reduce short-term disruptions during extreme weather events and allow for increased access to services and markets in the longer term.

Information and communication

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]

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



Source: NSO and ICF 2019

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 Enga Province, rural districts are limited to 2G, with 3G and 4G only available in urban areas (in-country interviews). Furthermore, although approximately half of the province's population owns a mobile phone, only an estimated 15% use their phones for financial transactions (NSO and ICF 2019; Figure 24).

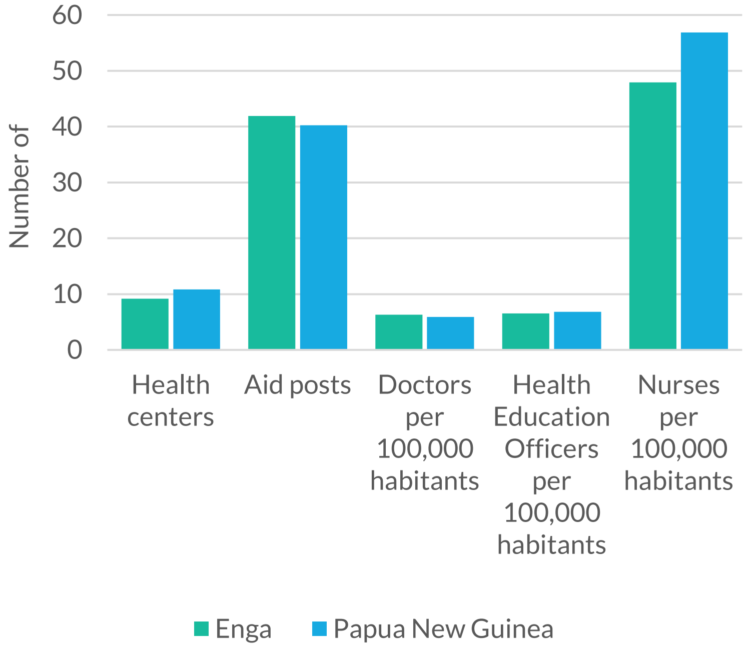
Health service

The preliminary assessment considered health infrastructure and quality of health services as important determinants for adaptive capacity. 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 show disadvantages for the poor, who tend to die earlier and are subject to higher levels of morbidity. Given the comparatively high poverty rate in Enga 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 Enga Province



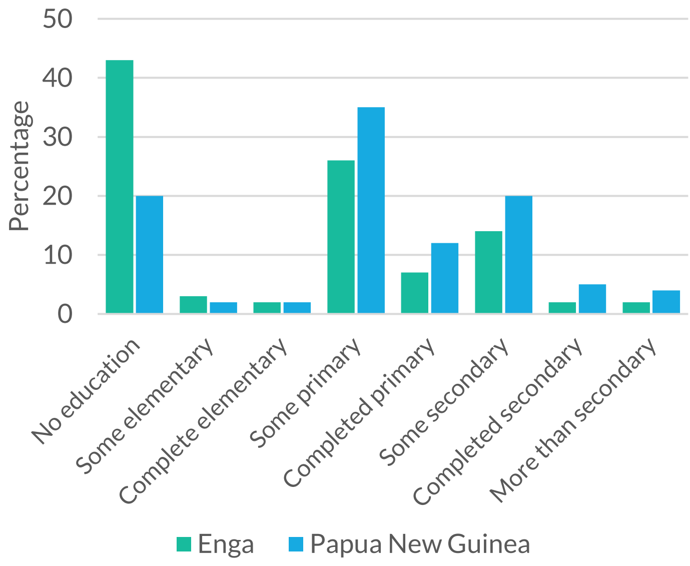
Source: NSO and ICF 2019

Available data shows that access to and quality of health services in Enga Province is limited, particularly in rural areas. Health services generally suffer from a lack of financial resources, qualified personnel, medical equipment, and supplies (Mako 2013), weakening resilience towards the adverse impacts of climate change.

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).

Figure 26. Share of population by level of education

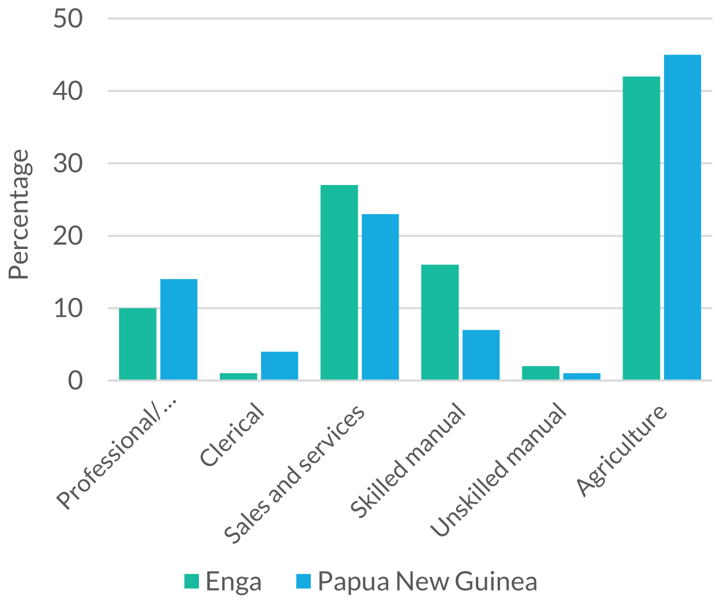


Source: NSO and ICF 2019

Completion rates—used as a measure for education—are low for all levels of education in Enga Province (NSO and ICF 2019; Figure 26). Two in five people in the province have not received any formal education, compared to the national average of one in five. Although completion rates are similar for women and men in Enga Province, literacy rates show there is a considerable gap in attainment between women (48%) and men (61%) (NSO and ICF 2019).

Looking at occupations, it is clear that labor skills in both Enga Province and more widely in Papua New Guinea are concentrated in the agricultural sector, while the share of workforce with a technical or managerial background is small (Figure 27). It is noteworthy that the agriculture sector is dominated by women, while men represent the bulk of the manual labor workforce (NSO and ICF 2019).

Figure 27. Share of population by occupation



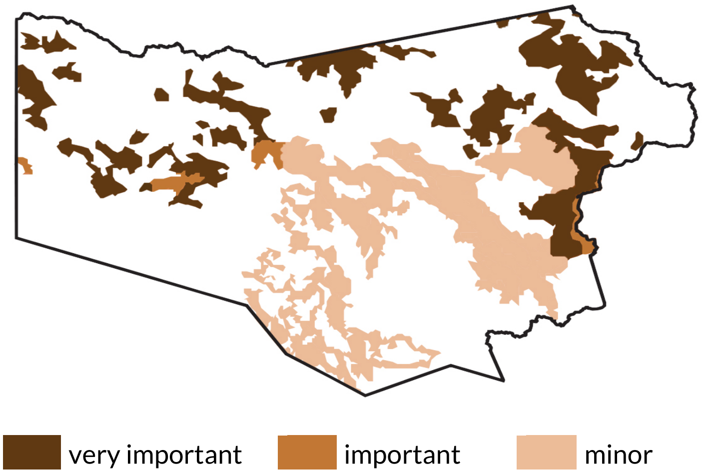
Source: NSO and ICF 2019

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 Enga Province. Capacity building should focus on the agricultural sector—including techniques for coping with the adverse impacts of climate change—as well as professional, technical and managerial skills in the construction, transportation and electricity sectors.

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; Mattews 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).

Figure 28. Importance of burning to clear vegetation for agriculture



Source: NSO and ICF 2019

From 2002 to 2014, forest cover in Enga Province decreased by 1.1%. While considerable, this loss in forest cover is moderate when compared to the country's coastal and island provinces, such as Manus (9.1%), Gulf (7.7%), and New Ireland (7.6%) where considerable logging activity is taking place (Bryan and Shearman 2015). Deforestation in Enga Province is driven by agricultural activity and the population's reliance on fuelwood as the principal energy source. Continued population growth is expected to result in further deforestation as demand for agricultural land grows and energy consumption increases (in-county interviews).

4. Consultation

Gathering input from a broad range of stakeholders through an interactive Delphi survey-based workshop was an essential part of the CRGG assessment. The workshop served to identify priorities for climate resilience and relevant interventions in the specific context of Enga Province. Coupled with the presenting the results of the preliminary analysis, this systematic participatory process helped ensure broad stakeholder consensus around priorities and interventions. The consultation process also helped compensate for any lack of relevant data and ensure the assessment results were aligned with existing provincial policies. This chapter summarizes the workshop proceedings and presents its results.

The CRGG consultation workshop, held in Wabag on 1 September 2020, brought together approximately 60 participants, representing different departments and agencies of the Enga Provincial Administration and representatives of civil society and the private sector (Figure 29).[8] The participants list and the workshop agenda are provided in Appendices A and B of this report.

The workshop was organized by the Enga Provincial Administration, the Climate Change and Development Authority, and the Australian Department of Foreign Affairs and Trade, in collaboration with GGGI.

Figure 29. Plenary session and group discussions during the consultation workshop

Source: GGGI

4.1. Priorities for climate-resilient green growth

To identify priorities for climate-resilient green growth in Enga Province, workshop participants took part in a series of interactive consultation rounds. Based on the Delphi method, these followed a sequence of presenting the results of the preliminary assessment, discussion and survey. In each round, participants were asked to choose up to nine priorities from a set of 24 possible choices (Table 8). The 24 options were based on a list of preselected categories across the three aspects of vulnerability considered in the preliminary assessment: exposure, sensitivity, and adaptive capacity.

[8] There were approximately 50 additional participants who only attended the introductory session. These are not included here.

Table 8. Survey choices to identify priorities for climate-resilient green growth

Exposure		Sensitivity		Adaptive capacity	
1	Rise in temperature	8	Agriculture	16	Poverty
2	Change in rainfall	9	Fishing	17	Access to electricity
3	Occurrence of drought	10	Mining	18	Access to water
4	Rise in sea level	11	Tourism	19	Transportation
5	Increase in ocean acidity	12	Transportation	20	Information and communication
6	Occurrence of cyclones	13	Electricity supply	21	Health service
7	Other	14	Water supply and sanitation	22	Education and labor skills
		15	Other	23	Deforestation
				24	Other

Source: GGGI

Between each consultation round, participants received further information based on the results of the preliminary assessment and provided their own insights into the topics. Prior to the first consultation round, the key findings from the preliminary assessment were presented regarding Enga Province's exposure, sensitivity, and capacity to adapt to the adverse impacts of climate change. The plenary discussions before the second and third consultation rounds focused on the aspects that participants had prioritized during the previous round.

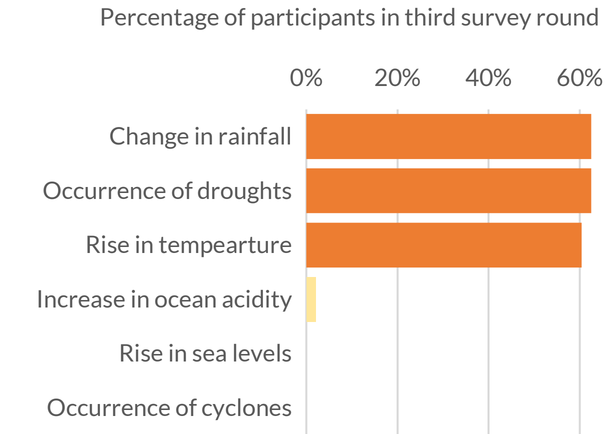
Each aspect was introduced by providing additional context and more detailed information from the preliminary assessment to stimulate the discussion.

The consultation rounds were supported by an electronic survey system, allowing participants to voice their opinion anonymously. Discussing the results after each round allowed them to adjust their assessment based on additional information and feedback within the group.

Participants identified the following priorities for climate-resilient green growth in Enga Province:

- For exposure, rise in temperature, change in rainfall, and the occurrence of drought as climate change-related phenomena (Figure 30);

Figure 30. Priorities for exposure identified by participants



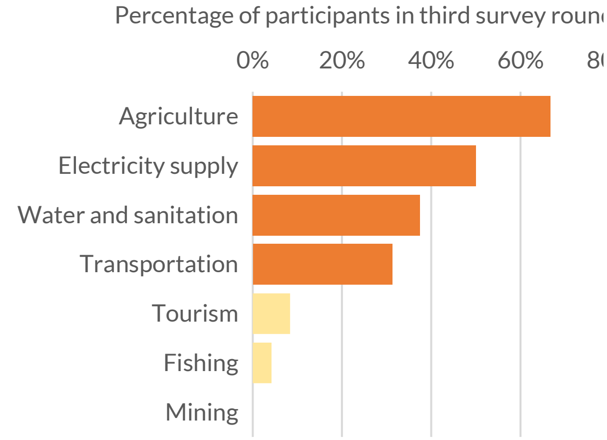
Source: GGGI

- For sensitivity, agriculture, electricity supply, water and sanitation, and transportation as the sectors and activities most susceptible to the adverse impacts of climate change (Figure 31); and
- For adaptive capacity, poverty, access to water and sanitation, access to electricity, and transportation as the defining features for coping with the adverse impacts of climate change (Figure 32).

The identified priorities remained remarkably stable between the multiple survey rounds. The most noteworthy changes in participants' feedback concerned the priorities for adaptive capacity, where poverty was initially identified as by far the most important feature determining the province's ability to cope with climate change. While remaining the highest priority in absolute numbers, its relative importance decreased in favor of access to electricity, access to water and sanitation, and transportation. Furthermore, although more than one-third of participants initially regarded deforestation as an essential consideration for adaptive capacity, this number dropped to one-fifth by the third and final survey round.

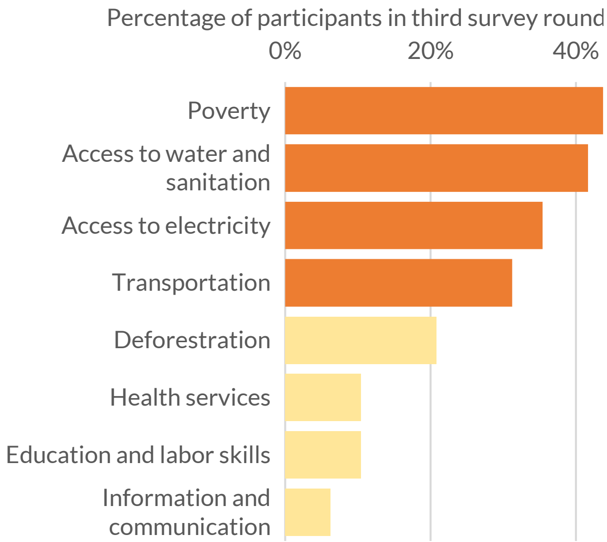
It is noteworthy that participants identified agriculture as by far the sector that is most sensitive to the adverse impacts of climate change. Appendix C provides a detailed overview of the changes in survey results between consultation rounds.

Figure 31. Priorities for sensitivity identified by participants



Source: GGGI

Figure 32. Priorities for adaptive capacity identified by participants



Source: GGGI

4.2. Interventions to strengthen climate-resilient green growth

Figure 33. Workshop discussions

Source: GGGI

In the second part of the workshop, participants were divided into four breakout groups (Figure 33), each led by a local facilitator. All four groups were asked to complete the following two tasks:

Task 1. Please discuss whether you agree with the priorities selected in the plenary. If you disagree, please indicate the priorities for your group. Please indicate any connections between the priorities across the three categories of exposure, sensitivity, and adaptive capacity.

Task 2. For each connection between the priorities that you have identified in task 1, please identify measures to strengthen resilience.

To identify measures to strengthen resilience towards the adverse impacts of climate change in the context of Enga Province, participants were provided with a list of 14 possible interventions. They could either choose from these options or define their own measures.

In summary, it is noteworthy that participants regarded several interventions as relevant for strengthening resilience against climate change in multiple sectors. First, the most prominent example is off-grid electrification. Second, participants saw a strong connection between the agriculture and water sectors, suggesting a range of similar interventions for both. Third, participants regarded establishing policies, plans, standards and regulation, and access to finance, as preconditions for implementing many of the suggested measures.

Together with the findings of the preliminary assessment, the results of the workshop determined the scope and direction of the final analysis. The priorities selected during the consultation workshop were well aligned with and reinforced the priorities identified in the preliminary analysis. The strong consensus on these priorities across different stakeholders further underlined their relevance. The identified interventions provided additional granularity to guide the final analysis.

The principal results of the group discussions are summarized in Table 9 and presented in this chapter. More details on the modalities of the group discussions are provided in Appendix D, while the results of individual breakout groups are summarized in Appendix E.

Table 9. Suggested interventions, by sector

Agriculture		Water		Electricity supply		Transportation	
Off-grid electrification	(2)	Off-grid electrification	(1)	Off-grid electrification	(3)		
Forest conservation	(3)	Forest conservation	(1)				
Climate-resilient agriculture	(3)	Climate-resilient agriculture	(1)				
		Policy, standards, regulation	(2)	Standards, regulation	(1)	Standards, regulation	(1)
Access to finance	(1)	Access to finance	(1)	Access to finance	(1)		
Irrigation	(1)	Irrigation	(2)				
Transportation	(1)					Transport infrastructure	(1)
Intercropping	(2)						
Agroforestry	(2)						
		Early warning and awareness	(2)				
						Drainage	(1)

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

4.2.1. Agriculture

All four groups identified the agriculture sector as susceptible to the adverse impacts of climate change. The high importance attributed to agriculture is in line with the results from the plenary discussion and preliminary assessment. Participants regarded rising temperatures as a concern for the sector, followed by drought—despite the limited evidence that climate change is related to the occurrence of drought—and change in rainfall.

Participants regarded adopting new practices and establishing infrastructure to increase resilience to the adverse impacts of climate change as essential. Suggested practices and techniques included forest conservation and agroforestry, as forests deliver important ecosystem services for agriculture, making the sector more resilient. Similarly, participants regarded intercropping—that is, growing two or more crops on the same field at the same time—as an option to increase resilience.

Concerning the infrastructure and equipment, participants considered that off-grid electrification, introducing irrigation, and increasing access to transportation can all play an important role in making agriculture more resilient to climate change. Access to finance was mentioned as an important enabler, allowing farmers to introduce some of the necessary equipment and infrastructure, such as electricity and irrigation.

4.2.2. Water

All four groups regarded water supply and sanitation as being susceptible to the adverse impacts of climate change. This matched with the results of the preliminary assessment, which showed that a high share of population in Enga Province relies on unprotected sources for drinking water and unimproved sanitation facilities, both of which can be affected negatively by climate change. Similarly, participants agreed with the preliminary assessment in identifying increased rainfall, rising temperatures and prolonged droughts as the principal hazards.

When discussing water and sanitation, all groups focused more strongly on water supply—specifically drinking water and water used for agriculture—than sanitation. Group views on measures to make water usage more resilient to climate change varied considerably.

With a largely rainfed agriculture sector, two groups identified adopting water-saving practices and infrastructure, such as irrigation and storage, as possible interventions. One group emphasized the importance of forest conservation for water storage and regulation. Another group saw a potential role for off-grid electrification as a means to support water pumps and irrigation, making drinking water supply and crop production less susceptible to reduced rainfall. Finally, identifying several enablers to cope with the negative impacts of climate change on water supply, groups gave equal importance to establishing and enforcing policies, standards, and regulations, and providing early warning and enhancing awareness.

4.2.3. Electricity supply

Three groups identified electricity supply as a priority. Participants pointed out the dual nature of electricity supply, with existing supply—particularly electricity generation from hydropower—being susceptible to the adverse impacts of climate change and access to electricity representing an important means for strengthening resilience. In that context, participants reasoned that increasing both the reliability of existing supply and access to electricity would have a positive effect on numerous other aspects related to resilience, including poverty, health, and education.

Referring to Enga province's geography, low income levels and dispersed population, three of four groups regarded off-grid electrification as a viable means of increasing access to electricity. In addition, participants advocated for access to finance as a prerequisite for households and businesses to make the necessary investments, and strengthening standards and regulation for off-grid equipment to increase access to electricity.

4.2.4. Transportation

As with electricity, three groups regarded transportation as both susceptible to the adverse impacts of climate change and a means to strengthen Enga Province's adaptive capacity. With a focus on road transport, participants agreed that higher rainfall in particular could lead to further deterioration of the already strained road network.

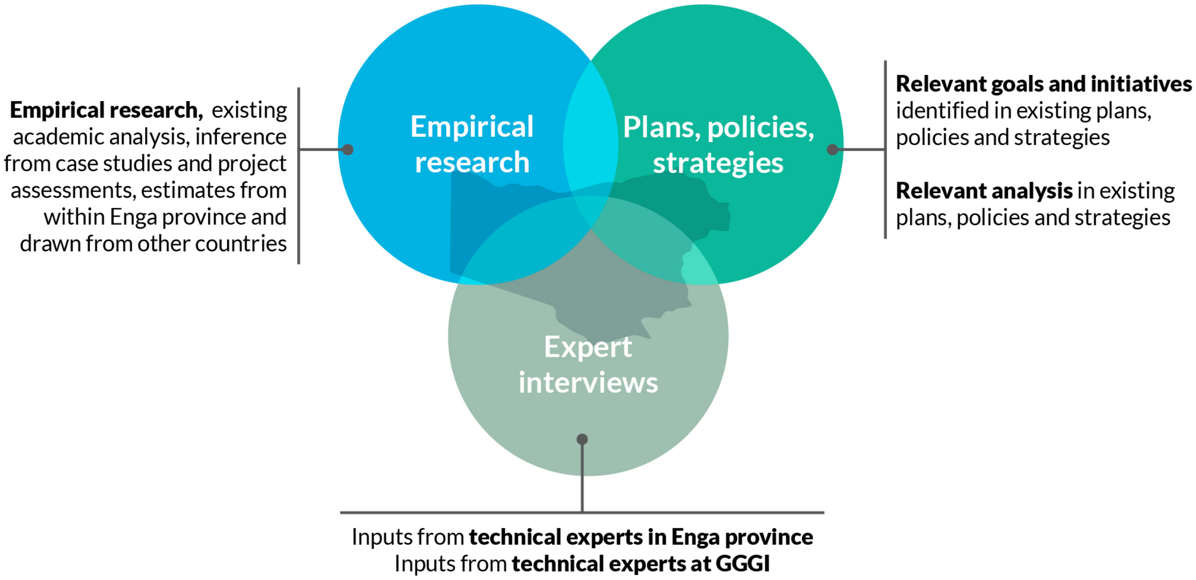
While there was strong consensus around the need to improve both access to road transport and the quality of the transportation network, there were few suggestions for measures that would allow for such improvements.

5. Final analysis

This final analysis aims to define what climate-resilient green growth means in Enga 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 34). 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 Enga Province, including representatives from government departments, the private sector, academia, and development partners.

Figure 34. 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 Enga Province, characterized by smallholder farmers producing mostly subsistence crops for household consumption combined with some cash crops as a source of income. Estimates suggest that more than 90% of the province's population are engaged in producing food crops (NSO and ICF 2019). Agricultural productivity is generally low. Smallholder farming is characterized by mixing different yield crops—including sweet potatoes, Irish potatoes, yam, taro, banana and corn—and small trees as a source of firewood in gardens of five hectare or less (World Bank 2018). Coffee represents the major cash crop. Selling coffee, food crops, and firewood provides a source of low to moderate income for some smallholder farmers (World Bank 2019. The population involved in commercial farming is very limited (Loukos, Arathoon and Zibi 2019).

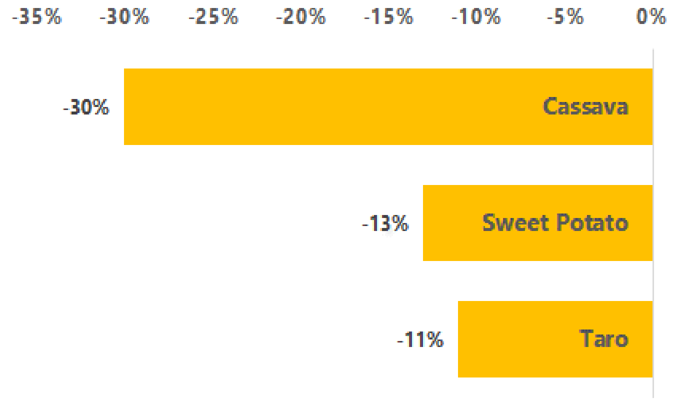
Enga Province has one of the most rugged terrains in Papua New Guinea, with steep slopes, ridges, and v-shaped valleys. As a result, only a comparatively small area of land in the province is considered to have high agricultural potential, and options for expanding cultivated land are limited. Similar to other central highland areas, this leads to high land use intensity (ADB 2016; Saunders 1993; World Bank 2019). Continued population growth is expected to perpetuate this trend (Allen, Bourke and Hanson 2001; Malleux and Lanly 2008; Wohlt 2004; in-country interviews).

Enga is among the provinces with the highest population growth rate in Papua New Guinea. However, land use intensity and population growth only cause limited deforestation, due to the province's topography and predominant agricultural practices. These practices are characterized by comparatively short fallow periods, agroforestry, and using large compost mounds to plant sweet potatoes and other vegetables (Kapal, Taraken, and Sirabis 2010; Malleux and Lanly 2008). Between 2002 and 2014, forest cover in Enga Province decreased by 1.1% (Bryan and Shearman 2015).

The challenges causing low agricultural productivity have been exacerbated by the adverse impacts of climate change, such as rising temperatures and changes in rainfall patterns. The crops cultivated in Enga Province have shown very limited tolerance to those impacts, with decreased photosynthesis, higher water stress, and increased exposure to pests and diseases—particularly at higher altitudes. This could lead to lower yields and crop quality. The negative effects are expected to occur along the entire production chain, affecting planting time, growing stages, harvest periods, and post-harvest crop storage (Ganpat and Isaac 2014; GEF, UNDP and SPREP 2009; Jaramillo et al. 2011; Kudela 2009; Moretti et al. 2010; World Bank 2011).

First, traditional agriculture practices in Enga Province are often bound to predictable climate conditions of the Highlands Region, which has little seasonality and low temperature variations throughout the year (Pain 1981). Allen and Bourke (2009) suggest that temperature increases in the province will likely reduce productivity in lowlands and main highland valleys but increase productivity above 2,000 meters. Climate models have projected a 13% decline in yield in sweet potato, 11% in taro, and 30% in cassava in Papua New Guinea (Hay et al. 2003; Figure 35).

Figure 35. Projection for decrease in yield of cassava, sweet potato, and taro in Papua New Guinea



Source: Hay et al. 2003

Second, historically, Papua New Guinea's Highlands Region has experienced rare water deficits and been characterized by moderate to large soil water surpluses (Allen and Bourke 2009). With 2,500–3,500 millimeters of annual rainfall, agriculture is largely rainfed and there are practically no water management systems in place (Allen et al. 2002; Allen and Bourke 2009; FAO 2012; Pain 1981). Projections for average annual and monthly maximum rainfall show large variations (BoM and CSIRO 2014; Allen and Bourke 2009; World Bank 2020). However, Allen and Bourke (2009) suggest that, if rainfall were to increase to more than 3,500 millimeters a year, this would reduce productivity for most crops, due to low levels of bright sunshine, waterlogged soils, and leaching of soil nutrients.

A potential decline in rainfall and an increase in droughts could have even more severe impacts. Projections suggest a possible increase in the intensity of droughts and frosts—particularly above 1,700 meters—in years impacted by the ENSO phenomenon (BoM and CSIRO 2014). In Enga Province, population and agriculture activity are concentrated in altitudes above 2,000 meters; areas which are prone to drought and frost (ADB 2016; World Bank 2019). As a result, the two most recent ENSO events in 1997 and 2015 had severe impacts on agriculture and were accompanied by acute food shortages (Bourke, Allen 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 (BoM and CSIRO 2014).

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 contributed to preserving biodiversity (Biodiversity International 2014) but has come under pressure from a combination of limited arable land, a growing population, and the adverse impacts of climate change.

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. Considering possible combinations of the environmental conditions of altitude (temperature), soil water deficit, and inundation, Allen and Bourke (2009) identified 14 different agricultural environments in Papua New Guinea. Four of these agricultural environments are present in Enga Province, as well as the uninhabited very high-altitude environment that is not used for agriculture. Within each of these environments, there are considerable differences in soil fertility and slope, which impact on crop suitability. However, these categories can serve as a starting point to identify suitable locations for crops or agricultural practices that have proven successful elsewhere.

In Enga Province, the main staple crops are tubers, particularly sweet and Irish potatoes. Both are susceptible to drought, frost, excess soil moisture, pests and diseases as a result of changing climatic conditions (Kanua et al 2016; Cobon et al. 2016; CDWAI 2016; Gurr et al. 2016; Okonya and Kroschel 2016). 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 droughts and prevalent diseases, and acceptable culinary traits (Kapal et al 2003; Kapila et al, 2010; Wamala and Akanda 2010). However, a lack of funding and extension services from provincial government has meant that there has been no technology transfer or distribution of newly developed hybrid varieties of sweet potatoes to farmers in the past decade (in-country interviews).

Second, improving water management will be an important aspect of reducing the impact of drought. Regardless of whether or not the occurrence and intensity of drought is directly related to climate change, reducing its negative effects will benefit agricultural productivity and food security in the province. In that context, large-scale irrigation systems are not considered to be 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 possibly increasing access to electricity, drinking water, and improved sanitation facilities (Bang and Sitango 2003; Hughes et al 2009; Sitapai 2012; Ramakrishna and Saese 2009).

Third, the successful dissemination of climate-resilient agricultural practices—such as water storage and small-scale irrigation—requires systematic improvement in extension services (ADB 2013a). For example, the World Bank (2014) estimates that disseminating advanced techniques with adequate timely support to farmers could improve yields of coffee 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. Given that provincial and district administrations play an important role in providing extension services, these results underline the importance of building the capacity of staff at those levels. In addition, the project demonstrated that including private service providers improves flexibility and cost-effectiveness of extension services (ADB 2013a).[9]

Fourth, increasing access to formal finance is another decisive means to improve agricultural productivity and resilience to climate change. Loans can serve as operational capital, allowing farmers to acquire seedlings, pesticides, fertilizer, and equipment, and replace aging trees to increase productivity (Loukos, Arathoon and Zibi 2019). However, geographical coverage of the formal financial sector in Enga Province is limited, with estimates suggesting that less than 20% of the population have and use a bank account (NSO and ICF 2019). Increasing access to formal financial services is particularly relevant in rural areas, where farmers pay high capital costs of informal lending. Mobile banking services are of limited relevance as an alternative, given low bandwidth, high costs, and low literacy rates (Highet et al. 2019; Loukos, Arathoon and Zibi 2019). Only an estimated 10% of the population of Enga Province uses mobile phones for financial transactions (NSO and ICF 2019).

Finally, post-harvest losses need to be reduced. Estimates suggest that such losses amount to 30–50% due to poor handling and packaging, poor transport infrastructure, lack of storage, and lack of local processing of food, among others (Chang and Kewa 2014). Chang et al 2013; Chang and Spriggs 2007; Pue et al 2018). High post-harvest losses undermine food security and reduce earnings from cash crops. For example, estimates suggest that approximately 40% percent of Papua New Guinea's coffee production is lost due to poor refrigeration and transportation, while high transportation costs place an additional strain on revenues (Coffee Industry Corporation 2008). Improving access to—and the quality of—electricity supply (Section 5.3) and transport infrastructure (Section 5.4) will help reduce post-harvest losses.

[9] These findings are supported by other case studies (compare Sitapai 2012; Sitapai 2011).

5.2. Water

Climate change has a potential impact on rainfall levels and water availability. In Enga Province, average annual and maximum daily rainfall are both expected to increase. However, these projections are subject to considerable uncertainty as variability in rainfall trends over the years and complexity of rainfall patterns makes it difficult to forecast rainfall (Allen and Bourke 2009; BoM and CSIRO 2011; World Bank 2020).

Projections also suggest a possible increase in the intensity of droughts and frosts—particularly above 1,700 meters—in years experiencing an ENSO event (BoM and CSIRO 2014). The two most recent ENSO events in 1997 and 2015 were accompanied by severe droughts, leading to food shortages, reduced access to and quality of drinking water, and reduced electricity supply from hydropower, which caused outages. In 1997, the Porgera Mine in Enga Province had to close for several weeks due to a lack of water for processing operations. The slump in mineral exports resulted in a severe loss of foreign currency to the country's economy (Allen and Bourke 2009). However, while ENSO is a major variable in projecting future climate, the relationship between the phenomenon and climate change is subject to debate. In addition, the difficulty in predicting the ENSO phenomenon has implications for the level of uncertainty in climate projections for droughts (BoM and CSIRO 2014).

This assessment discusses three aspects that are likely to be affected by changes in rainfall: accessibility of drinking water, sanitation, and agriculture.

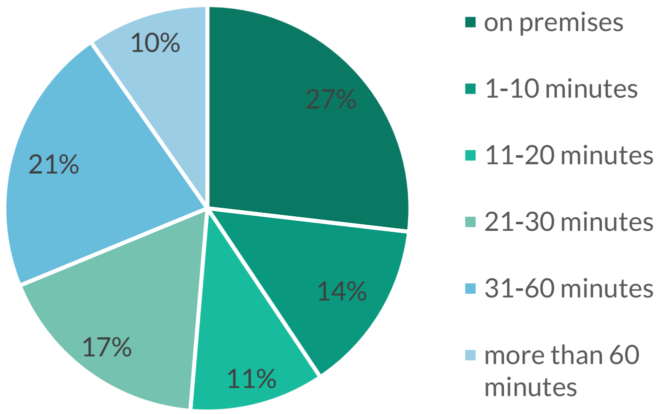
First, prolonged rainfall, flooding and an increase in droughts can affect unprotected sources of drinking water, causing health hazards (IOM 2016a). Enga Province is characterized by limited access to protected sources of drinking water.[10] Urban areas are mostly supplied by piped drinking water, while household surveys suggest that more than two-thirds of the rural population depend on unprotected sources (NSO and ICF 2019).[11]

[10] Protected sources of drinking water include: pipes into a dwelling or yard plot, pipes to a neighbor, public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, rain water, tanker trucks or carts with small tanks, and bottled water. Unprotected sources include unprotected dug wells, unprotected springs, surface water, and any other source not listed as a protected source (NSO and ICF 2019).

[11] Other surveys come to similar results. For example, a 2015 survey found that 85% of assessed communities in Enga, Simbu and Jiwaka provinces rely on unprotected water sources; more than two-thirds do not treat their drinking water; and almost half of all respondent households had someone who had suffered from diarrhea in the four weeks before the survey (IOM 2016b). Similarly, a 2013 survey found that two-fifths of respondents accessed water through

Moreover, an estimated three-quarters of Enga Province's rural population does not have access to drinking water at home. Approximately one-quarter require 10–30 minutes to access a source of drinking water; one-fifth require 30–60 minutes; and still 10% require more than 60 minutes (NSO and ICF 2019; Figure 36).

Figure 36. Time taken to reach drinking water source in rural areas



Source: NSO and ICF 2019

Drilling boreholes and building water harvesting systems and storage facilities for schools and villages would improve drinking water quality and reduce distances and time taken to access water (ICRC 2017; IOM 2016b). However, it is also important to ensure new installations are accompanied by a maintenance plan, as a lack of maintenance is the main reason for systems failing (IOM 2016b; World Bank 2017). As far back as the 1980s, field reports showed that, the more sophisticated the systems are, the higher their failure rates over time. As a result, it is recommended to focus on simple systems that require minimum maintenance, such as handpumps and solar pumps, and to abstract water from surface water sources where possible (Baumann 2000; Wohlfahrt and Kukyuwat 1982; expert interview).

In addition, it is suggested that systems or infrastructure be built on government-owned land in the vicinity of health facilities, schools, and churches to avoid conflict over land rights and ownership (IOM 2016b). Systems could also be installed in combination with off-grid electricity systems (see Section 5.3). Finally, any installation of infrastructure should be accompanied by education and training on safe water treatment and storage of water (IOM 2016b; WaterAid 2013). Making such trainings mandatory would attach a non-monetary price to the infrastructure. This is considered particularly relevant when water supply is established in combination with the installation of off-grid electricity systems.

Second, limited access to improved sanitation facilities could be exacerbated if rainfall, flooding, or droughts increase (IOM 2016a). Again, rural areas in Enga Province, where less than one-third of the population has access to improved sanitation, would be most affected (NSO and ICF 2019). Centralized sewage systems, run by Water PNG and Eda Ranu, are limited to major cities and towns, and often only serve the central business district, major institutions and hospitals. Decentralized systems for improved sanitation—such as household septic tanks and improved pit toilets—are common outside the areas served by sewer networks. These are managed by individual households, public institutions, churches, and the private sector (IBRD 2015).

Several studies have concluded that the existing enabling environment needs to be strengthened. This includes articulating targets, priorities and approaches towards sanitation, establishing clear roles and responsibilities between government agencies involved in the sector, and setting up budget mechanisms for allocating and tracking expenditures. Many, though not all, of these issues can be addressed at subnational level (IBRD 2015; World Bank 2017).

Implementation generally suffers from insufficient finance allocated to the sector, weak monitoring systems, paucity of qualified technicians and managers, and insufficient maintenance of infrastructure (IBRD 2015; World Bank 2017). Given these constraints, there is a clear need to prioritize interventions.

an unimproved source, with respondents located in rural areas more likely to use an unimproved source than those from urban areas (WaterAid 2013).

One option for prioritization is gathering more information about the situation in Enga Province, including surveys asking people about their needs, preferences, and practices. This would help ensure sanitation options are acceptable and enable the development of relevant pilot projects (IBRD 2015). Alternatively, interventions could be focused on schools, fewer than half of which are equipped with handwashing facilities with soap and water. Interventions at schools should include two elements: installing and maintaining infrastructure—including rainwater collection systems, handwashing facilities, and basic pit latrines—and hygiene trainings (UNICEF and WHO 2018). The educational aspect is particularly important for improving hygiene practices beyond the vicinity of schools. Children who learn safe water, sanitation and hygiene habits at school can reinforce positive behaviors at home and in their communities (UNICEF and WHO 2018). Surveys have shown that, once households are convinced of the value of sanitation, they invest in it and maintain it World Bank 2017.

Third, the threat to food security in Papua New Guinea tends to come from too much, rather than too little, water. However, food supply problems caused by excessive rainfall are more subtle, as their effect is often delayed. This makes them harder to identify and measure. Food shortages caused by drought, on the other hand, are obvious, immediate, and easy to attribute. Therefore, improving food security should consider threats from all environmental causes, not only drought (Allen and Bourke 2009).

With 2,500–3,500 millimeters of annual rainfall, agriculture in Enga Province is largely rainfed and there is practically no water management system (Allen and Bourke 2009; Allen et al. 2002; FAO 2012; Pain 1981). Historically, Papua New Guinea's Highlands Region has experienced rare water deficits and is characterized by moderate-to-large soil water surpluses (Allen and Bourke 2009). Projections for average annual and monthly maximum rainfall show large variations (BoM and CSIRO 2014; Allen and Bourke 2009 World Bank 2020). However, if annual rainfall were to increase to more than 3,500 millimeters, the associated low levels of bright sunshine, waterlogged soils, and leaching of soil nutrients would lead to lower productivity for most crops (Allen and Bourke 2009; Bourke 2018).

The impact of a decline in rainfall and an increase in droughts is often more immediate. Projections suggest a possible increase in the intensity of droughts and frosts—particularly above 1,700 meters—in years impacted by the ENSO phenomenon (BoM and CSIRO 2014). In Enga Province, population and agricultural activity are both concentrated in altitudes above 2,000 meters, areas that are prone to drought and frost (ADB 2016; World Bank 2019). In the past, strong ENSO events have been accompanied by significantly reduced rainfall in usually wet areas and prolonged dry seasons in areas that are seasonally dry, severely reducing food production (Allen and Bourke 2009). For example, the two most recent events in 1997 and 2015 had severe impacts on agriculture and resulted in acute food shortages (Bourke, Allen and Lowe 2016).

Improving water management is an important aspect for reducing the impact of droughts. Regardless of whether or not drought occurrence and intensity are directly related to climate change, reducing their adverse impacts will be beneficial for agricultural productivity and food security in Enga Province. For that purpose, combing traditional practices with climate-smart agriculture will likely be required.[12] For example, for some 300 years, farmers in Papua New Guinea's Highlands Region have prepared composted mounds to counteract the risk of frosts and soil-borne pests and diseases, reduce soil erosion, and facilitate multiple successive harvests of sweet potatoes and other vegetables (Kapal et al 2003; Taraken 2012; Taraken and Ratsch 2009; Taranet 2017). This and other practices can be combined with climate-smart interventions, such as water harvesting and storage, different irrigation techniques, agroforestry and intercropping (ACIAR 2018; FAO 2018; FAO 2013).

In that context, large-scale irrigation systems are not considered suitable in Enga Province, due to high upfront costs and considerable technical and managerial requirements. Instead, water storage and micro-irrigation systems are considered a viable option for strengthening the resilience of smallholder farmers

[12] There is no clear definition of climate-smart agriculture. FAO (2018) describes it as a concept resting on three pillars: (1) sustainably increasing productivity and yields without compromising the functional integrity of the ecosystem services on which agriculture depends; (2) strengthening the resilience of communities to adapt to climate change and reducing vulnerability; and (3) reducing and potentially sequestering GHG emissions. The term does not refer to a single specific agricultural technology or practice that can be universally applied; rather, it is an approach that requires site-specific assessments to identify suitable agricultural production technologies and practices (FAO 2013).

(Sitapai 2012). For example, in the Lamari Valley, in Eastern Highlands Province, famers traditionally used bamboo pipes traversing several hundred meters to irrigate grassland and forest taro gardens. Although the use of bamboo irrigation pipes had declined by the early 1990s, they were used again in the 1997 drought (Allen and Bourke 2009). Similar systems might be suitable for Enga Province in times of drought.

Over the long term, agricultural production in Enga Province will likely remain susceptible to droughts during ENSO events. Therefore, 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-Nino Agriculture Recovery Plan 2016–2017 (DAL and FAO 2016). However, these plans only address short-term recovery after a drought 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 disaster responses by the national government and relief agencies. Yet, while the plan identifies several measures that are relevant for responding to a future drought, it provides no details on how and by whom these measures would be implemented (UNICEF and UN OCHA 2019).

5.3. Electricity supply

The electricity supply in Enga Province is susceptible to the adverse impacts of climate change, particularly when generated from hydropower. At the same time, access to electricity represents an important means to strengthening resilience against climate change. Making supply more reliable and increasing access to electricity would both 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 technical challenges and high costs related to grid extension, off-grid renewable energy solutions appear to be particularly relevant in Enga Province.[13] Grid connection costs in the province 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 investment costs for 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

[13] Technical challenges and high costs are driven by the state of the current grid, the province's rugged terrain, 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).
In addition, grid extension would require considerable additional electricity generation capacity, a large share of which would likely consists of hydropower. Although Papua New Guinea has a large potential for hydropower—and hydropower plays an important role in the country's electricity mix (IRENA 2013; GoPNG 2014)—large-scale hydropower projects are viewed with caution. The obstacles for such large-scale electricity infrastructure are considerable—particularly the condition of the existing electricity grid and questions of land ownership—and past hydropower projects have experienced considerable cost overruns or failed entirely (in-country interviews). Finally, large-scale hydropower plants can also have significant and unavoidable negative environmental and social impacts, including forced land acquisition and population displacement; changes in river regimens (which can affect fish, plants, and wildlife), and flooding of land and wildlife habitats (through the creation of reservoirs). While the nature and severity of such impacts are highly site-specific and tend to vary in scale according to the size and type of the project, large-scale plants generally have an environmentally disruptive impact.

homes.[14] Grid extension is considered a suitable option in the Lagaip and Lai valleys, which are among the most densely populated and intensively cultivated areas in Papua New Guinea (ADB 2016). With some of the population in these areas already connected to the Ramu grid, for the remainder to access the network would largely require extending distribution lines rather than building new transition lines.

Off-grid electrification through solar photovoltaic systems offers a viable alternative 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). Regarding system sizes, in-country interviewees widely regarded solar mini-grids as an option for towns, hospitals, schools, and administrative buildings, with trained onsite technicians for operation and maintenance and spare parts readily available.

For household electrification, solar home systems appear to be the more suitable option, showing several advantages compared to larger mini-grid designs. First, stand-alone systems are approximately four times cheaper on a per kWh basis than mini-grids, offering a clear price advantage over mini-grids, which often struggle to provide affordable services while recovering costs.[15] 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 stakeholder to agree on and abide by ownership and land use arrangements for installing the panels. Finally, household systems are regarded as less prone to vandalism and theft than larger systems (Table 10).

Table 10. 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) 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

[14] 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).

[15] The uniform electricity tariff level is insufficient to recover costs of mini-grids. However, if higher tariffs were charged, potential consumers would often be unable to afford covering the actual costs.

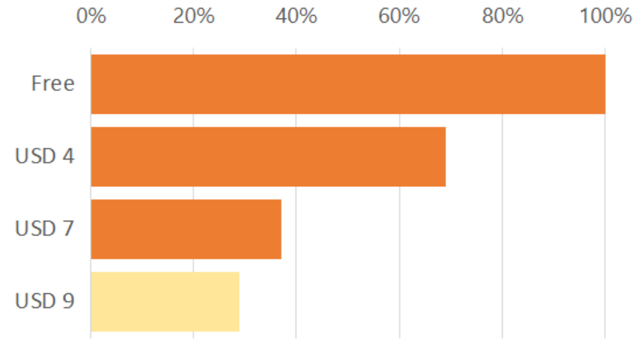
Standalone photovoltaic systems range from individual to larger household packages—with options for several lights, phone charging, TV, water heating, and solar crop drying for smallholders—and community lighting (APERC 2017; IRENA 2013; in-country interviews). While 12-volt appliances such as LEDs,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

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.[16]

Second, although solar home systems are cost-competitive when considering the entire life cycle, comparatively high upfront costs remain an issue. Given high costs of transportation and setting up new distribution points in Papua New Guinea, 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).

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 Enga Province or Papua New Guinea, field research in Kenya confirmed that consumers responded strongly to price differences (Rom et al. 2017; Figure 37). 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 37. Take up of solar lanterns electricity at different prices



Source: Rom et al. 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.[17] 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

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

[17] 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.

installing equipment. These could include participating in vaccinations and trainings[18] or contributing labor to community projects.

Finally, private companies should be allowed to play a larger role in the electricity sector. While this might be politically controversial when it comes to grid-connected infrastructure, enabling private sector participation in the off-grid sector is regarded as more feasible and can contribute substantially to achieving the government's ambitious goals.[19]

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.

[18] WASH (water, sanitation and hygiene) trainings were explicitly mentioned. For more information, see UNICEF 2016.
[19] For an overview of the official goals regarding electrification, see DNPM 2018, GoPNG 2016 and GoPNG 2009.

5.4. Transport

In Enga Province, freight and passenger transport are dominated by road and non-motorized transport. Data on transportation is generally scarce, with some information being available for road transport, but a paucity of data for other modes of transport. Walking is the only alternative to motorized transport, as there is virtually no use of domesticated animals to transport people or goods (Hughes 2000).

Improving road access and the quality of road network in Enga Province would have both short- and long-term benefits for climate resilience. First, in the short term, it would reduce the disruption caused by extreme weather events, particularly flooding and landslides caused by heavy rainfall. For example, when the Highlands National Highway—which connects Enga to other provinces—gets temporarily cut off, this leads to fuel shortages, price increases and food shortages, causing business activities and government services slow down. When district and provincial roads are damaged or impassable, rural communities are often stranded, temporarily losing access to services from urban centers, including schools and hospitals (Kageni 2020; Kepson 2013; Radio New Zealand 2016; in-country interviews).

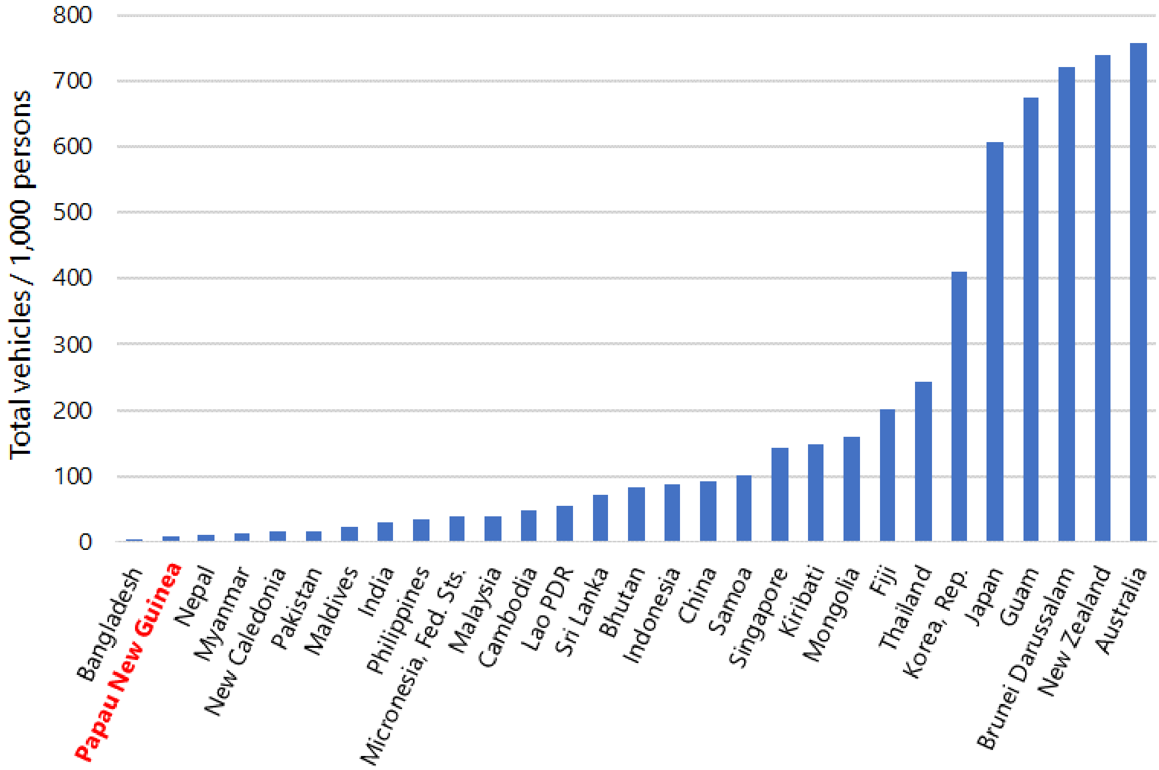
Second, in the medium to longer term, it is generally agreed that an improved road network would increase access to services and markets, and reduce business costs, equally benefiting women and men (ADB 2015b; ADB 2007; Slattery, Dornan and Lee 2018). Roads are the economic arteries in Papua New Guinea's Highland Region, including Enga Province. They connect the fertile and resource-rich Highlands Region with the coast—particularly the port of Lae—allowing coffee, tea and mineral exports, and the distribution of food, heavy machinery and other imports. (ADB 2007; Hughes 2000). 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 often limited, given—for example—their reliance on walking for accessing cash-earning opportunities, education and health services (Gibson and Rozelle 2003; Hughes 2005; Slattery, Dornan and Lee 2018).

Motorization levels in Enga Province are very low, in line with low national rates. Data from the International Road Federation (2017) indicates an ownership rate of 9 vehicles per 1,000 people (Figure 38). [20] Similarly, according to the Demographic and Health Survey 2016–18, only 4% of households in Enga Province own a car or truck (NSO and ICF 2019).[21]

Figure 38. Motorization rates in APEC countries



Source: IRF 2017

Although the number of people who would directly benefit from improved connectivity and road conditions is limited, 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 12 separate road networks in Papua New Guinea, excluding roads on the smaller islands. (Slattery, Dornan and Lee 2018). Enga Province is connected to the largest network, and, as a result, comparatively well connected to other provinces. However, road access is limited, with estimates

[20] According to IRF (2017), as of 2007, only 9 out of 1,000 people owned a motorized road vehicle in Papua New Guinea, compared to 87 out of 1,000 in Indonesia (2015), 55 out of 1,000 in Lao PDR (2014), and an average of 72 out of 1,000 across lower middle-income countries. Although more recent data is not available and vehicle ownership in Papua New Guinea might have increased considerably between 2007 and 2015, anything less than a seven-fold increase over those eight years would still put the country far behind ownership levels in peer countries. Its low level of vehicle ownership is corroborated by other sources (see NRSC 2011).

[21] There are several reasons behind these low levels of motorization. First, disposable incomes are comparatively low, at less than PGK 200 per person per year. The large majority of Enga Province's population depends on subsistence farming and has limited cash income from paid employment and the sale of fresh foods at local roadside markets (ADB 2016). Second, many countries in the Western Pacific Region have high numbers of motorized two-wheel vehicles, which often account for a high proportion of their vehicle fleet. Road users in Papua New Guinea, on the other hand, tend to purchase four-wheeled vehicles, which are considerably more expensive than motorcycles and scooters (NRSC 2011).

suggesting that 40% of the province's population lives more than 5 kilometers from a national road (Allen and Bourke 2009).

There is a distinction between national, national priority and non-national roads. National roads fall under the responsibility of national government, while lower levels of government are responsible for all other roads. National priority roads are those considered to provide the greatest economic and social benefits to the greatest number of people (Slattery, Dornan and Lee 2018).

Much of Papua New Guinea's national road network is in poor condition. According to the Visual Road Condition Survey in 2014 and 2015, only an estimated 15% of national priority roads and 10% of national non-priority roads are in good condition. Approximately two-thirds of national priority roads and more than half of national non-priority roads are in very poor condition (Table 11; Slattery, Dornan and Lee 2018).[22]

Table 11. Condition of national road network

	Good	Fair	Poor	Very poor	Total length
Overall	13%	7%	21%	59%	8,695 km
Priority roads	15%	9%	9%	67%	4,296 km
Non-priority roads	10%	5%	33%	53%	4,399 km

Source: Slattery, Dornan and Lee 2018

According to information provided by the Enga Provincial Administration, national roads in Enga Province are mostly in a good condition (Division of Works and Technical Services 2020; Table 12). However, the extent to which this assessment can be compared to results of the Visual Road Condition Survey in 2014/2015 is uncertain.[23]

Table 12. Condition of road network in Enga Province

	Good	Fair	Poor	Total length
National roads (highways)	88%	12%	0%	137 km
Non-national roads	0.2%	36%	64%	754 km

Source: Division of Works and Technical Services, 2020

Approximately two-thirds of Papua New Guinea's road network consists of non-national roads that fall under the responsibility of subnational levels of government. There is no comprehensive data on the total lengths of non-national roads nor their condition. However, estimates suggest that there are 22,000 kilometers of non-national roads in Papua New Guinea, and it is generally agreed that these are in a poorer

[22] Results from the Visual Road Survey are based on Slattery, Dornan and Lee 2018. GGGI was not able to obtain a copy of the survey.

[23] The Visual Road Condition Survey 2014/2015 defines road condition in terms of a 'ride quality index' that reflects the acceptable level of surface roughness at different levels of traffic, with higher levels of roughness being considered more tolerable at lower levels of traffic. Determining road conditions has been an issue in the past. Problems with the reliability of data in Department of Works and Implementation's Road Asset Management System (RAMS) are well documented and the need to verify road condition data repeatedly identified. According to RAMS, which relies on visual assessments by the Department of Works and Implementation's provincial engineers, 46% of national priority roads are in good condition and less than 10% of national priority roads are in poor condition, compared the Visual Road Condition Survey's figures of 15% and more than 75%, respectively (Slattery, Dornan and Lee 2018).

state than the national network (Slattery, Dornan and Lee 2018; in-country interviews). According to the National Economic and Fiscal Commission (2005), their poor quality reduces accessibility for entire districts. Data from the Enga Provincial Administration suggests that approximately two thirds of non-national roads in the province—which include trunk roads, feeder roads, and access roads—are in poor condition (Division of Works and Technical Services 2020; Table 12).

The low quality of the road network means it is likely to be susceptible to the adverse impacts of climate change, should those include an increase in heavy rainfall and associated flooding. The limited reach and poor condition of land transport infrastructure is a major constraint to inclusive economic growth, isolating many Papua New Guineans from markets and income-earning opportunities, healthcare and education services (Slattery, Dornan and Lee 2018). Projections suggest that, without increased funding, road conditions will decline further (Slattery, Dornan and Lee 2018).

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, 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, a 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, since national roads are under the auspices of the national government. Given its limited resources and capacity, it is recommended that the Enga Provincial Administration set realistic targets and focus on maintaining non-national roads rather than building new infrastructure.

While on paper, maintenance takes precedence over construction of new infrastructure and the rehabilitation or upgrading of 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 to complex negotiations with landholders over land acquisition, compensation and royalties, among others (Hughes 2000). Furthermore, the benefits of new or upgraded road infrastructure are often lost due to neglect of necessary subsequent maintenance (Slattery, Dornan and Lee 2018; ADB 2015b; ADB 2007).

To prioritize the maintenance of existing infrastructure, strengthening coordination between provincial authorities and district development authorities (DDAs) is recommended. Spending on roads is divided between the national Department of Works, provincial governments, and district administrations, but coordination between these levels of government is weak at best. For example, in Enga Province, there is little coordination and consultation between the provincial administration and DDAs regarding budgets, tendering, and the issuing of contracts for road construction and maintenance—with the notable exception of Wabag DDA (Slattery, Dornan and Lee 2018; in-country interviews).

Improving coordination will require addressing several interrelated issues. First, responsibilities for managing and maintaining non-national roads need to be clarified. The 2013 National Transport Strategy envisages a gradual process whereby roads are transferred to national government responsibility (Department of Transport 2013). However, the government's 'Determination of Service Delivery Functions and Responsibilities' stipulates that non-national roads fall under the responsibility of provincial governments (Duncan, Cairns and Banga 2017; Slattery, Dornan and Lee 2018). There is a clear contradiction between these provisions.

Second, the disparity between the allocation of responsibility and the distribution of funding needs to be resolved. Existing provisions are at odds with the trend that funding for non-national roads has been increasingly allocated to the district rather than provincial or national level (Slattery, Dornan and Lee 2018).

Third, funding allocations should be based on technical and economic assessments, instead of political considerations. The current practice of district service improvement programs—which leave funds at the direct disposal of Members of Parliament for developing projects in their district—undermines accountability and coordination. Most of this funding is directed toward building new roads or rehabilitating roads, rather than recurrent activities like maintenance (Dornan 2015; Dornan et al. 2016; Slattery, Dornan and Lee 2018).

6. Conclusion

The CRGG assessment shows that Enga Province is exposed to the adverse impacts of climate change, as evidenced in a rise in temperature and potential changes in rainfall. The province's population and economy are also extremely sensitive to these phenomena, given their dependence on sectors that experience considerable impacts from climate change—particularly agriculture. Finally, socioeconomic conditions in the province—characterized by low income levels and a lack of essential infrastructure, including transportation, health, electricity, water, and sanitation—limit its capacity to adapt.

Based on available data and research as well as consultation of local stakeholders, the assessment identifies agriculture, water, electricity supply and transportation as four priority areas for Enga Province to enhance its resilience towards the adverse impacts of climate change. For each of these priorities, it outlines a number of 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 must 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 required into climate-resilient crops and agricultural techniques—including options for intercropping and agroforestry—that are suitable for specific locations in Enga Province. Furthermore, improving water management will be important for strengthening resilience, as it reduces the impact of droughts. For example, improving water storage and micro-irrigation systems—and potentially combining these with off-grid renewables—could make smallholder farmers more resilient. Successfully disseminating such climate-resilient agricultural practices requires systematic improvements in extension services; successfully implementing them will require improved access to formal finance. Finally, any such interventions should be complemented by improving access to—and the quality of—electricity supply and transport infrastructure, to reduce post-harvest losses.

Water: The assessment discusses three aspects of water supply and sanitation that are likely to be affected by climate change: accessibility of drinking water, sanitation, and agriculture. Improving both access to and quality of drinking water and sanitation will require strengthening the enabling environment and putting the necessary infrastructure in place. The former will require clear targets, priorities and approaches towards sanitation; clear roles and responsibilities among the different government agencies involved in the sector, and budget mechanisms to allocate and track expenditure. The latter includes boreholes, water harvesting systems, storage facilities, handwashing facilities, and pit latrines. Schools have been identified as a potential priority for such infrastructure. Finally, with the agriculture sector confronting the prospect of both too much and too little water, improving water management—including storage and irrigation—will be important for coping with potential changes in rainfall and drought occurrence.

Electricity supply: Enga Province's electricity supply—particularly when generated from hydropower—is susceptible to the adverse impacts of climate change. Yet, access to electricity also represents an important means for strengthening resilience against climate change. Increasing both the reliability of the supply and access to electricity would have a positive effect on many other aspects related to resilience, such as poverty, health, education, and job creation. Off-grid electrification through solar photovoltaic systems offers a viable alternative for providing basic electricity services in areas where grid extension is expensive or physically difficult. Solar mini-grids are an option for towns, hospitals, schools, and administrative buildings, with onsite trained technicians for operation and maintenance and readily available spare parts. For household electrification, solar home systems appear to be more suitable, showing several advantages over larger mini-grid designs. Two of the main challenges for successfully deploying solar household systems are reliability and affordability. The former can be addressed by enforcing quality standards at a national level, but the latter will require local solutions, with the provincial administration actively involved in their design.

Transport: Freight and passenger transport are dominated by road and non-motorized transport. The limited reach and poor condition of road infrastructure are major constraints to inclusive economic growth across the country, isolating large numbers of Papua New Guineans from markets, income-earning opportunities, healthcare facilities and education services. The quality of the road network might deteriorate further due to the adverse impacts of climate change, particularly if there is an increase in heavy rainfall and associated flooding. Given its limited resources and capacity, Enga Provincial Administration should set realistic targets and focus on maintenance of non-national roads rather than build new infrastructure. To prioritize the maintenance of existing infrastructure, coordination between the provincial authorities and DDAs must be strengthened. This will require addressing several interrelated issues, such as clarifying responsibilities for managing and maintaining non-national roads; resolving the disparity between the allocation of responsibility and the distribution of funding; and basing funding allocations on technical and economic assessments, not political considerations.

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

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Appendices

Appendix A. Participants list

	Name	Affiliation
1	Mr. Johannes Yola	Coffee Farmers Association of Kompiam District
2	Mr. Timothy Lawton	Enga Provincial Administration, Natural Resources Division
3	Mr. Peter Dennis	Small business owner
4	Ms. Kim Arut	Miok Tropical Tours (tourist operator)
5	Ms. Joana Sai	Enga Women in Agriculture Association
6	Mr. James Titus	Education Department
7	Mr. Joseph Iso	Operational Health, Safety and Environment
8	Ms. Lespina Pupun	Enga Women in Climate Change
9	Mr. Ben Sarett	Enga Provincial Administration, Planning Division
10	Mr. Eric Sarut	Climate Change Development Authority
11	Mrs. Rose Kundal	Health Department
12	Mr. Sakarias Pakembo	Enga Provincial Administration, Commerce, Culture and Industry Division
13	Mr. Leslie Yala	Enga Provincial Administration, Planning Division
14	Mr. Kips Ponga	Bank of South Pacific
15	Mr. Ronnie Tirone	Enga Provincial Administration, Agriculture and Livestock Division
16	Mr. Abraham Nane	Enga Provincial Administration, Agriculture and Livestock Division
17	Mr. Samual Lakolyo	Cooperative Association
18	Mr. Kingsten Okka	Coffee Industry Corporation
19	Mr. Cornelius Yombonakali	Agro Farmers Association
20	Mr. Sam Mek	Coffee Industry Corporation
21	Mr. Bush Keene	Acacia Holdings Ltd (private sector)
22	Mr. John Masili	Enga Provincial Health Authority
23	Mrs. Dorothy Kukum	Enga Provincial Administration, Community Development Division
24	Ms. Olivia Kukum	Friends of the Mission (civil society organization)
25	Mr. Mose Yandane	Enga Provincial Administration, Human Resources Division
26	Mr. Pati Kingal	National Development Bank
27	Ms. Davinah Apupuni	Enga Provincial Administration, Agriculture and Livestock Division

	Name	Affiliation
28	Mrs. Margaret Potane	Enga Provincial Administration, Commerce, Culture and Industry Division
29	Mr. Simon Yopo	Enga Provincial Administration, Natural Resources Division
30	Mr. Pinganome None	Enga Provincial Administration, Agriculture and Livestock Division
31	Mr. Wilson Guhe	National Agriculture Quarantine Inspection Authority
32	Mr. Heni Nigani	National Agriculture Quarantine Inspection Authority
33	Mr. Frank Kame	Lemben Landowners Association
34	Mr. Wiap Pyawa	Yengis-Wapi Local Government
35	Mr. Johannes Pakatul	National Agriculture Research Institute
36	Mr. Kud Sitango	National Agriculture Research Institute
37	Mr. Justin Katao	National Broadcasting Corporation
38	Mr. Leslie Kili	National Broadcasting Corporation
39	Dr. Betty Koka	Enga Provincial Health Authority
40	Mr. Arnold Pingin	National Development Bank
41	Mrs. Peam Yakali	Sirunki High School
42	Mr. Jericho Sanga	Ambum-Wali Local Government
43	Mr. Elizah Lita	National Forest Authority
44	Mr. Mathew Takasone	National Forest Authority
45	Mrs. Susie Bannah	Small business owner, Sirunki Honey
46	Mr. Raphael Tamean	Enga Provincial Administrion
47	Mr. Melepa Yakili	Enga Provincial Administrion, Lands Division
48	Mr. Chris Lakaio	Enga Provincial Administration, Agriculture and Livestock Division
49	Mr. Keith Yaen	Enga Provincial Administration, Agriculture and Livestock Division
50	Mr. Paul Ira	Disability Services
51	Mr. Kenny Keith	Disability Services
52	Ms. Nancy Lasela	Women's Group Representative
53	Ms. Serah Sipani	Enga Provincial Administration, Legal Services Division
54	Ms. Margaret Kameso	Kwima Stationary (private sector)
55	Mr. William Kameso	Pandalian New Generation Association
56	Mr. Francis Lara	Pandalian New Generation Association
57	Mr. Chris Paiya	Catholic Church

	Name	Affiliation
58	Mr. Philip Mona	Mountain Eco Services (private sector)
59	Mrs. Theresa Maekson	Enga Provincial Administration, Natural Resources Division
60	Mr. Billy Amean	Enga Provincial Administration, Natural Resources Division
61	Mrs. Arome Kyasak	Enga Provincial Administration, Commerce, Culture and Industry Division
62	Mr. Peter Pumbu	Catholic Diocese of Wabag

Appendix B. Workshop agenda

CLIMATE-RESILIENT GREEN GROWTH IN ENGA PROVINCE
CONSULTATION WORKSHOP

1 September 2020
Wabag, Enga Province, Papua New Guinea

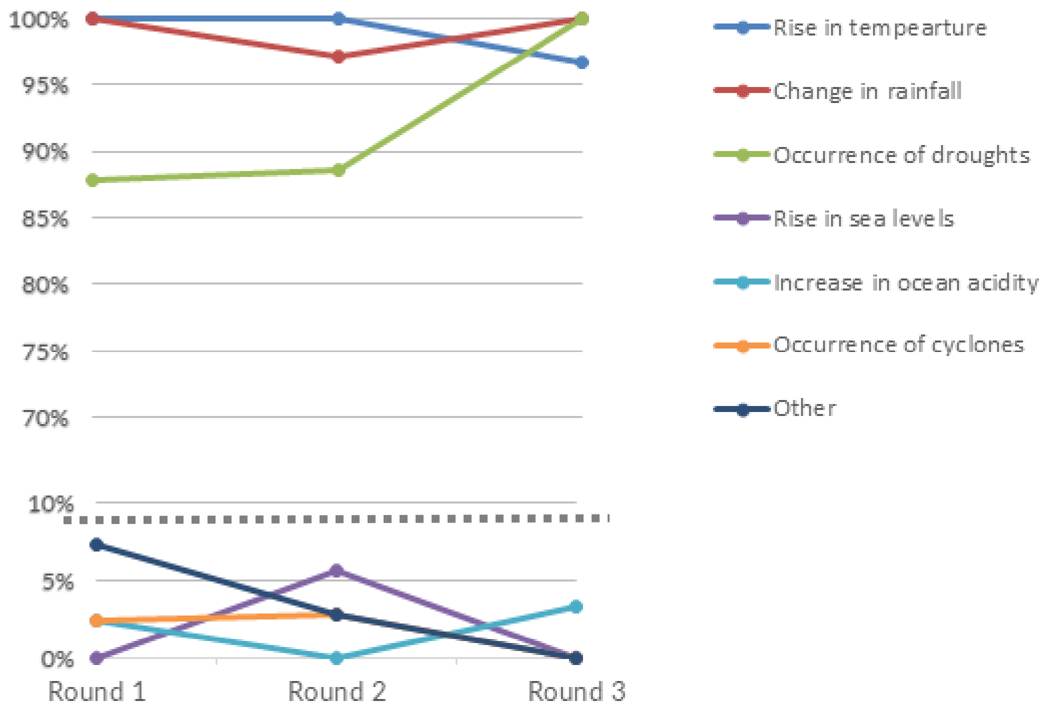
Agenda

1. Opening remarks
2. Introduction of climate-resilient green growth
3. Guided plenary discussion, including stakeholder survey rounds 1 and 2
4. Guided plenary discussion, including stakeholder survey round 3
5. Guided group discussion
6. Consensus building, including stakeholder survey round 4
7. Closing remarks

Time	Item(s)	Note(s)
8:30 – 9:00	• Participant registration	
9:00 – 9:15	**1. Opening remarks** • Remarks from Enga Provincial Administrator • Remarks from CCDA Representative • Remarks from GGGI Country Representative	
9:15 – 10:00	**2. Introduction of climate-resilient green growth** • Overview of methodology • Q&A and interactive exercise	Mr. Trevor Galgal, Provincial Officer, GGGI Mr. Jan Stelter, Senior Analyst, GGGI
10:00 – 10:45	**3. Guided plenary discussion** • Identification of climate change priorities • Stakeholder survey – rounds 1 and 2	Mr. Trevor Galgal Mr. Jan Stelter
10:45 – 11:00	*Coffee break and group photo*	
11:00 – 12:15	**4. Guided plenary discussion** • Identification of climate change priorities • Stakeholder survey – round 3	Mr. Trevor Galgal Mr. Jan Stelter
12:15 – 13:30	*Lunch*	
13:30 – 15:30	**5. Guided group discussion** • Refinement of climate change priorities	Selected facilitators
15:30 – 15:45	*Coffee break*	
15:45 – 16:15	**6. Consensus building** • Confirmation of climate change priorities • Stakeholder survey – round 4	Mr. Trevor Galgal Mr. Jan Stelter
16:15 – 16:30	**7. Closing remarks**	CCDA, Enga Provincial Administration and GGGI

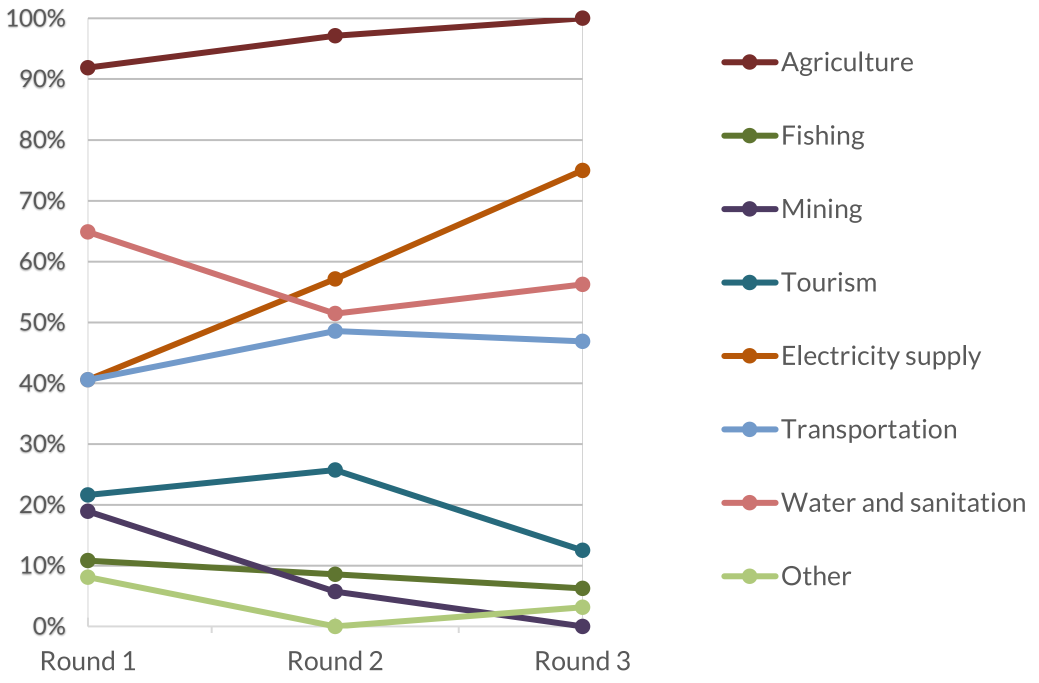
Appendix C. Changes in survey results

Figure 39. Changes in survey results for exposure



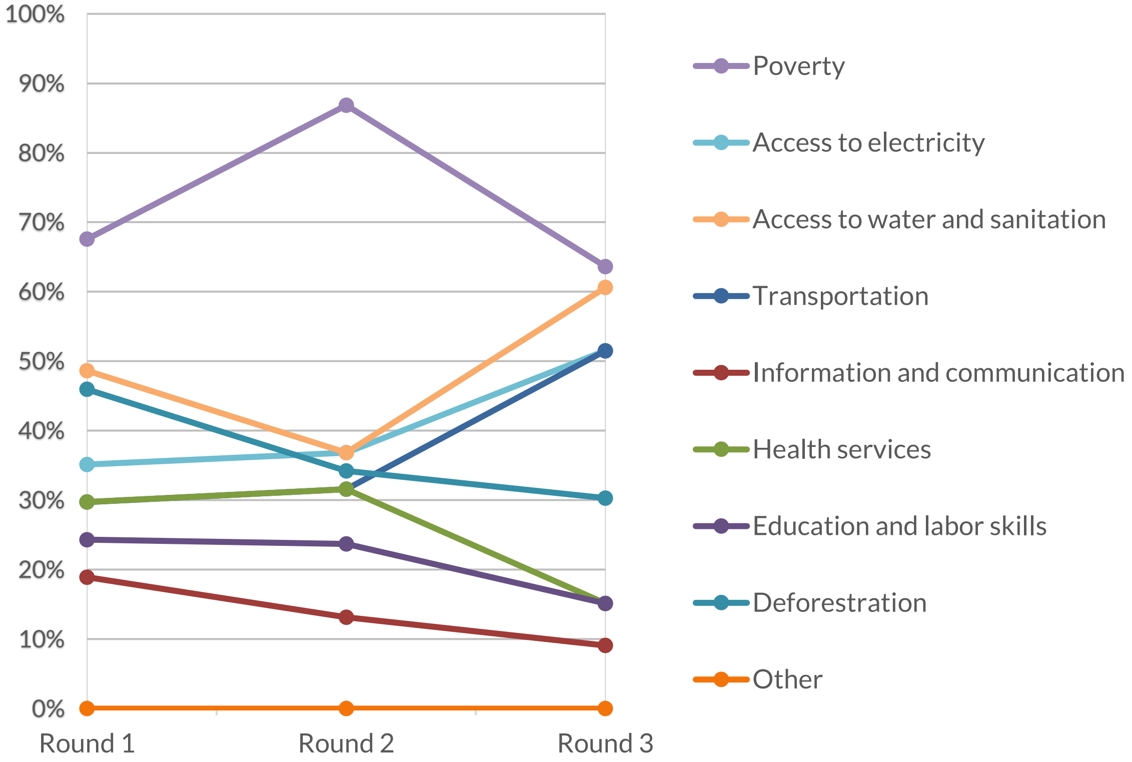
Source: GGGI

Figure 40. Changes in survey results for sensitivity



Source: GGGI

Figure 41. Changes in survey results for adaptive capacity



Source: GGGI

Breakout Group Tasks

Task 1: Priorities for resilience (45 minutes)

Please discuss whether you agree with the priorities selected in the plenary. If you disagree, please indicate the priorities for your group. Please indicate the connection between the priorities across the three categories of exposure, sensitivity and adaptive capacity.

Relationships between priorities for resilience			
Category	Exposure	Sensitivity	Adaptive capacity
Relationship 1			
Relationship 2			
Relationship 3			

Task 2: Strengthen resilience (45 minutes)

Please select the relationships you have identified in task 1. For each relationship, please identify measures to strengthen resilience. You can choose from the measures listed below or suggest different measures. The list of measures is also shown on a slide in the plenary.

Measure to strengthen resilience			
Relationships agreed in task 1			
Measure 1			
Measure 2			
Measure 3			

14 measures:

1. Coastal protection
2. Forest conservation
3. Drainage and wastewater infrastructure
4. Climate-resilient agriculture
5. Agroforestry
6. Intercropping
7. Irrigation
8. Off-grid electrification
9. Early warning
10. Transport infrastructure
11. Standards and regulation
12. Access to finance for private sector
13. Data collection and monitoring
14. Other

Appendix E. Results of group discussions

Group 1

Group 1 agreed with the priorities identified in the plenary session and identified a total of four relationships between those priorities.

Relationship between priorities	Rationale behind choice	Related interventions
Rise in temperature/ change in rainfall/ occurrence of drought – agriculture – poverty	Rise in temperature regarded as certainly affecting crop productivity and subsequently poverty Potential increase in rainfall would likely increase soil erosion and nutrient loss, given Enga Province's steep terrain If droughts were to become more severe and/or more frequent as a result of climate change, this was considered to have a severe impact on food security and poverty, as evidenced by the droughts in 2015 and 1997 Importance of subsistence farming in Enga Province Reducing poverty as an important means to enable farmers to adapt to climate change	Climate-resilient agriculture, including intercropping, agroforestry and forest conservation Access to finance for farmers Improvements in transport infrastructure to support access to markets Off-grid electricity to as a means to raise living standards, increase productivity and ultimately reduce poverty Early warning for droughts, including data collection and monitoring through weather stations Drainage and wastewater infrastructure; and standards and regulation also considered relevant, but the group did not provide any additional information on these choices
Change in rainfall/ occurrence of drought – water and sanitation – access to water	Reduced rainfall, more severe and/or more frequent droughts regarded as having severe impact on water and sanitation—for example, access to water was significantly reduced during 2015 drought in Enga Province Impact considered as particularly severe in combination with continued population growth	Early warning, including data collection and monitoring through weather stations Access to finance for private sector for irrigation, storage and wastewater infrastructure Off-grid electrification; and standards and regulation also considered relevant, but the groups did not provide any additional information on these choices
Change in rainfall/ occurrence of drought – electricity supply – access to electricity	Electricity transmitted and distributed via the Ramu network in Enga Province is large supplied from hydropower. Therefore, electricity supply was regarded as susceptible to changes in rainfall patterns and/or occurrence of drought	Early warning for droughts, including data collection and monitoring through weather stations Off-grid electricity, in particular deployment of mini hydro and solar photovoltaic systems to provide local solutions that are independent of large hydropower dams, supported by access to finance for private sector and

		relevant policies, regulations and standards
Change in rainfall – transportation – access to transportation	A potential increase in rainfall regarded as causing additional soil erosion, flooding and landslides, which could damage transport infrastructure and, as a result, reduce accessibility, particularly in rural areas in Enga Province. Maintenance and improvement of transport infrastructure considered as a crucial element to strengthen adaptive capacity to climate change	Drainage and sealing of roads regarded as crucial measures to make infrastructure more resilient In this context, standards and regulations for constructing roads need to be improved and more finance needs to be made available

Group 2

Group 2 agreed with the priorities identified in the plenary session and identified a total of three relationships between those priorities.

Relationship between priorities	Rationale behind choice	Related interventions
Rise in temperature – agriculture – poverty	Rise in temperature would affect crop productivity, crop quality and food security Rise in temperature exacerbates existing pressures, including population growth High dependence on agriculture for food security and income generation in Enga Province means that any reduction in productivity will increase poverty and reduce adaptive capacity	Climate-resilient agriculture and forest conservation as means to adapt to the adverse impacts of climate change Access to finance for framers and encouragement of private sector activity as important means to reduce poverty and ultimately strengthen adaptation Off-grid electricity to as a means to raise living standards, increase productivity and ultimately reduce poverty
Change in rainfall/ occurrence of drought – electricity supply – access to electricity	Electricity transmitted and distributed via the Ramu network in Enga Province is large supplied by hydropower Electricity supply is regarded as susceptible to changes in rainfall patterns and/or occurrence of drought, potentially leading to clogging of water intake (increase in rainfall) or insufficient water levels (decrease in rainfall/increase in drought)	Off-grid electricity, particularly through the deployment of mini hydro and solar photovoltaic systems to provide local solutions that are independent of large hydropower dams, supported by access to finance for private sector and households
Change in rainfall/ occurrence of drought – water and sanitation – access to water	2015 drought greatly affected Enga Province, when frost and drought destroyed many crops and water was very scarce, particularly in communities at higher altitudes As a result, thousands of people migrated to lower altitudes and closer to urban centers to find food and water	Access to finance for private sector for irrigation, storage and wastewater infrastructure Climate-resilient agriculture, including agroforestry and forest conservation to reduce impact of drought as forests help store water, increase soil moisture, etc. Off-grid electrification and standards and regulation were considered relevant, but the group did not provide any additional information on these choices

Group 3

Group 3 agreed with the priorities identified in the plenary session and identified a total of three relationships between those priorities. The group emphasized that that there are further relationships that they consider relevant and that many of the relationships affect one another.

Relationship between priorities	Rationale behind choice	Related interventions
Rise in temperature – agriculture – poverty	Enga Province is heavily dependent on agriculture There is evidence already that a rise in temperature is affecting the production of certain food crops grown at high altitude. The decline in crop yield will eventually lead to increased poverty, with no surplus food to sell in a situation of already limited access to market However, some perceive that a rise in temperature is also beneficial for the agriculture sector. For example, coffee production has increased in the last decade due to increases in temperature. In the past, coffee yield was very poor even though it was widely grown in Enga Province.	Climate-resilient agriculture, including irrigation and agroforestry
Rise in temperature/change in rainfall – water and sanitation – access to water	Most communities in rural areas and some urban centers depend on freshwater springs and small creeks for drinking, cooking and cleaning Higher temperatures and lower rainfalls regarded as leading to dried up springs and water resources, limiting access to water	Irrigation as an important measure to improve resilience in agriculture against potential water shortages, supported by access to finance for farmers and households, policy, and regulation and standards
Change in rainfall/ occurrence of drought – electricity supply – access to electricity	Electricity transmitted and distributed via the Ramu network in Enga Province is largely supplied by hydropower. Therefore, electricity supply was regarded as susceptible to changes in rainfall patterns and/or occurrence of drought	Early warning for droughts, including data collection and monitoring through weather stations Off-grid electricity to provide local solutions independent of large hydropower dams, supported by access to finance for private sector and relevant regulations and standards

Group 4

Group 4 agreed with the priorities identified in the plenary session and identified a total of three relationships between those priorities.

Relationship between priorities	Rationale behind choice	Related interventions
Rise in temperature – agriculture – poverty	Rise in temperature regarded as reducing crop productivity and subsequently yield, ultimately increasing poverty	Intercropping and forest conservation as means to strengthen resilience against the adverse impacts of climate change Forest conversation also a means to reduce GHG emissions and potentially a source of revenue (REDD+)
Change in rainfall – transportation – access to transportation	A potential increase in rainfall regarded as causing additional soil erosion, flooding and landslides that can damage road infrastructure and, as a result, reduce accessibility, particularly in rural areas in Enga Province	Maintenance and improvement of transport infrastructure considered as a crucial element to strengthen adaptive capacity to climate change, with drainage and sealing of roads regarded as crucial measures to make transport infrastructure more resilient In this context, improvement in standards and regulations for constructing roads required
Change in rainfall/ occurrence of drought – water and sanitation – access to electricity	Reduced rainfall, more severe and/or more frequent droughts regarded as having severe impact on water supply, particularly for agriculture, undermining food security	Early warning, including data collection and monitoring through weather stations Access to electricity—particularly solar and pico-hydro power for water pumps to support irrigation, but also sanitation and other services—to cope with the consequences of drought Awareness was also considered relevant, but the group did not provide any additional information on that choice

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