# CLIMATE RISK ASSESSMENT

REPORT

## FOCUSING ON HELA AND SOUTHERN HIGHLANDS PROVINCES, PAPUA NEW GUINEA

2023

This Climate Risk Assessment (CRA) focusing on Hela and Southern Highlands Provinces was supported by the UN Peacebuilding Fund and implemented within the framework of the '*Preventing Climate-Induced Conflicts Through Empowered Women Leadership'* Project, under the UNDP-led, UN Highlands Joint Programme for Peace and Development (HJP). The HJP is the UN's flagship peacebuilding programme in the Highlands of Papua New Guinea. The programme supports the region in achieving the Sustainable Development Goals through initiatives to create peaceful and enabling conditions in Hela and Southern Highlands provinces.

The Regional Integrated Multi-Hazard Early Warning System (RIMES) is an intergovernmental institution owned and managed by its member states, for building capacities in the generation and application of user-relevant early warning.

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## Acronyms

| | |
|---|---|
| ACCESS | Australian Community Climate and Earth System Simulator |
| AHP | Analytic Hierarchy Process |
| AUC | Area Under Curve |
| CBDRM | Community-Based Disaster Risk Management |
| CCDA | Climate Change Development Authority |
| CDD | Consecutive Dry Days |
| CDF | Cumulative Distribution Function |
| CEPA | Conservation and Environment Protection Authority |
| CHIRPS | Climate Hazards Group InfraRed Precipitation with Station |
| CMIP | Coupled Model Intercomparison Project |
| CPDP | Community Peace for Development Plans |
| CRA | Climate Risk Assessment |
| CRM | Climate Risk Management |
| CWD | Consecutive Wet Days |
| DAL | Department of Agriculture and Livestock |
| DEM | Digital Elevation Model |
| DHI | Drought Hazard Index |

| | |
|---|---|
| DM | Disaster Management |
| DMPGM | Department of Mineral Policy and Geohazards Management |
| DRM | Disaster Risk Management |
| ERA | European ReAnalysis |
| ESRI | Environmental Systems Research Institute |
| FAO | Food and Agriculture Organization |
| FF | Far-future |
| GBV | Gender-Based Violence |
| GCM | Global Climate Model/General Circulation Model |
| GCS | Geographic Coordinate System |
| GFDL | Geophysical Fluid Dynamics Laboratory |
| GIS | Geographical Information System |
| GYPI | Gender and Youth Promotion Initiative |
| HadGEM | Hadley Centre Global Environment Model |
| HP | Hela Province |
| INFORM | Index for Risk Management |
| IOM | International Organization for Migration |
| ITCZ | Intertropical Convergence Zone |
| KACE | Korea Meteorological Administration Advanced Community Earth-System Model |
| KMA | Korea Meteorological Administration |
| LLG | Local Level Government |
| LNG | Liquefied Natural Gas |
| MF | Mid-future |
| MK | Mann-Kendall |
| NARI | National Agriculture Research Institute |
| NDC | National Disaster Center |
| NDVI | Normalized Difference Vegetation Index |
| NIMS | National Institute of Meteorological Sciences |
| NF | Near-future |
| NGO | Non-Government Organization |
| NOAA | National Oceanic and Atmospheric Administration |
| NSO | National Statistics Office |
| NWS | National Weather Service |
| PLWD | People Living with Disabilities |
| PMGO | Port Moresby Geophysical Observatory |
| PNG | Papua New Guinea |
| POM | Port Moresby |
| PRCPTOT | Total Precipitation |
| RIMES | Regional Integrated Multi-Hazard Early Warning System for Africa and Asia |
| ROC | Receiver Operating Characteristic |
| Rx1day | Highest One-day Precipitation |
| Rx5day | Five Consecutive Days Rainfall |
| R99p | Number of Extremely Wet Days |
| SARV | Sorcery Accusation Related Violence |
| SHP | Southern Highlands Province |
| SPCZ | South Pacific Convergence Zone |
| SPEI | Standardized Precipitation Evapotranspiration Index |
| SPI | Standardized Precipitation Index |
| SRTM | Shuttle Radar Topography Mission |
| SSP | Shared Socioeconomic Pathway |
| TN | Daily Minimum Temperature |
| TNN | Minimum of Minimum Temperature |
| TPDC | Tari Pori Development Corporation |
| TX | Daily Maximum Temperature |
| UNDP | United Nations Development Programme |
| WGS | World Geodetic System |
| WPM | West Pacific Monsoon |

## EXECUTIVE SUMMARY

The United Nations Development Programme (UNDP) and International Organization for Migration (IOM) are jointly implementing gender-transformational conflict prevention interventions in Hela and Southern Highlands under the UN Peacebuilding Fund-supported project "Preventing Climate-Induced Conflicts Through Empowered Women Leadership". The project aims to empower women leaders to become conflict-sensitive community resilience activists by conducting trainings, sharing best practices, strengthening inclusive peacebuilder networks and supporting gender equality. It also supports efforts to raise awareness of women's rights, increase access to information resources as well as advance the inclusion of women in community decision-making.

To guide these interventions, UNDP commissioned the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) to conduct a *Downscaled Climate Risk Assessment focusing on Hela and Southern Highlands Provinces* to help identify high-risk communities and customize interventions to enhance community resilience against climate shocks. The assessment was expected to inform the drafting of provincial and sub-provincial development plans, including the Community Peace for Development Plans (CPDPs).

The climate risk assessment was conducted over a period of approximately 6 months. It included i) desk review, context profiling, and development of the technical approach and methodology, ii) national inception meeting as well as provincial and community consultation workshops, iii) qualitative and quantitative hazard and vulnerability assessment and mapping, and iv) provincial and national validation workshops.

As show in the table below[1], the results of the climate risk assessment indicate the potential for increased rainfall, maximum and minimum temperatures, and extreme events that would enhance the likelihood of landslides, floods and drought (and possibly frost) events in both provinces.

| | Hazard | Hela | SHP |
|---|---|---|---|
| 1 | Precipitation | Expected to increase between 10 to 26% for all scenarios and time periods | Expected to increase between 9.2 to 22.57% for all scenarios and time periods |
| 2 | Maximum temperature | Expected to increase between 0.68 and 2.37°C for all scenarios and time periods | Expected to increase between 0.71 and 2.45°C for all scenarios and time periods |
| 3 | Minimum temperature | Expected to increase between 0.52 and 2.1°C | Expected to increase between 0.42 and 1.96°C |
| 4 | Flood | Flood depth is expected to increase by 0.3 to 1.38m; flood area is likewise expected to increase | Flood depth is expected to increase by 0.05 to 0.83m; flood area is likewise expected to increase |
| 5 | Five Consecutive Days Rainfall (Rx5day) | Expected to increase between 38.57% to 56.09% for all scenarios and time periods | Expected to increase between 37% to 42.44% for all scenarios and time periods |
| 6 | Number of Extremely Wet Days (R99p) | Expected to increase between 20 to 266% for all scenarios and time periods | Expected to increase by up to 238% for all scenarios and time periods |
| 7 | Maximum One Day Rainfall (Rx1day) | Expected to increase between 14 to 36% for all scenarios and time periods | Expected to increase between 10 to 44% for all scenarios and time periods |
| 8 | Consecutive Wet Days (CWD) | Expected to increase by an average of 3 to 5 days for all scenarios and time periods | Expected to increase by an average of 2 to 40 days for all scenarios and time periods |

[1] The assessment utilized two scenarios (i.e., SSP245 and SSP585), and three time periods – near future (2023-2048), mid future (2049-2074), and far future (2075-2100).

| | Hazard | Hela | SHP |
|---|---|---|---|
| 9 | Drought | - Drought duration is projected to increase by more than 2 weeks in the mid future, but decrease for near and far future<br>- Drought intensity is projected to increase for all scenarios and time periods<br>- Drought severity is expected to increase in the mid future, but decrease slightly in the far future | - Drought duration is projected to decrease for all scenarios and time periods<br>- Drought intensity is projected to increase for all scenarios and time periods<br>- Drought severity is expected to slightly increase in the near future, but decrease in mid and far future |
| 10 | Consecutive dry days (CDD) | Expected to increase by an average of 4 to 6 days for all scenarios and time periods | Expected to increase by an average of 3 to 10 days for all scenarios and time periods |
| 11 | Landslide | Approximately 45% of the mountainous areas are classified in the high to very high rainfall-induced landslide hazard zones, and about 18% are in the high to very high earthquake-induced landslide hazard zones. | |

The population, especially women, girls and children, in both provinces are already fragile and highly vulnerable due to years of conflict, violence, dependence on natural resources, limited livelihood options, lack of education and access to government support and services, and exposure to a wide array of hydro-meteorological hazards. Without existing capacity in the communities and local authorities to mitigate, prepare for, and manage current risks, the projected changes in the intensity and frequency of hazards are expected to adversely impact the already strained natural resources, cause food and water insecurity and push people further into poverty and marginalization.

In the absence of established rules and implementation processes for land registration/ownership and development, and within the context of relatively weak governance and support mechanisms, there is a high possibility of displacement, instability and conflicts increasing. Unfortunately, conflicts make communities, particularly women and children, even more vulnerable to climate change and its impacts. In order to address the impacts of climate change risks, recommendations are proposed for sub-national governments to take action to ensure food and water security, livelihoods, law enforcement, disaster risk reduction and management, infrastructure and services, community development, land use, policy and strategy, and research.

# 1. Introduction

Papua New Guinea (PNG) is the largest island country in the Pacific region with a total area of 462,840 square kilometers. [1] It is a tropical country located in the "Pacific Ring of Fire", which is also surrounded by warm seas over which winds flowing to the country come from. The temperature of the ocean surrounding the country has a strong influence on its average monthly temperatures. [2] The general temperature in the country ranges from 14°C in the Highlands to 32°C in the coastal areas, averaging between 26°C to 28°C. The Highlands areas are cool whole year round. [3, 4] However, this may change as temperatures in PNG are projected to increase by 0.4 to 1.0°C by 2030. [2]

Generally, PNG is hot and humid, but this may significantly vary in some areas due to the country's mountainous topography and the two (2) major air streams flowing over it (i.e., southeast trade winds and northwest monsoon). [3] PNG's wet season occurs between December to April, while the dry season occurs from May to October. Most rainfall in the country comes from the West Pacific Monsoon (WPM), which is also affected by the Intertropical Convergence Zone (ITCZ), and to a lesser extent, by the South Pacific Convergence Zone (SPCZ). [2] The average monthly rainfall in the country ranges between 250 – 350 mm. Annual rainfall in many areas exceeds 2,500 mm, with the heaviest events occurring in the Highlands. [4] The average annual and seasonal rainfall is projected to increase with more extreme rainfall days over the course of the 21st century, consistent with the expected intensification of the WPM and the ITCZ. Weather patterns in the country are also influenced by the El Niño and La Niña conditions within the regional climatic pattern. [2]

Given the country's unique geo-climate conditions, PNG is affected by various natural hazards including earthquakes, volcanic eruptions, tsunamis, cyclones, river, urban and coastal flooding, landslides, and drought. [3, 5] An average of 23 cyclones passed within 400 km of Port Moresby during a 41-year period between 1969 and 2010. This occurred more often during neutral phases of the El Niño-Southern Oscillation. Projections suggest that the number of tropical cyclones will decrease by the end of the 21st Century, but there is a possible shift towards more intense categories. [2]

PNG is ranked as one of the most disaster-prone countries in the world. [3] In the 2022 INFORM Risk Index, PNG had an overall risk of 5.9/10, which is considered "high" risk. It is the 22nd most at risk out of 191 countries. [6]

## 1.1. Climate Risk Assessment of Hela and Southern Highlands Provinces

In order to reduce the risks and potential impacts of climate-induced disasters, the United Nations Development Programme (UNDP) and International Organization for Migration (IOM) are jointly implementing gender-transformational conflict prevention interventions in Hela and Southern Highlands under the UN Peacebuilding Fund-supported project "Preventing Climate-Induced Conflicts Through Empowered Women Leadership". The project aims to empower women leaders to become conflict-sensitive community resilience activists by conducting trainings, sharing best practices, strengthening inclusive peacebuilder networks and supporting gender equality. It also supports the efforts to raise awareness of women's rights, improve access to information resources as well as advance the inclusion of women in community decision-making. .

To guide the interventions, UNDP commissioned the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) to conduct a *Downscaled Climate Risk Assessment focusing on Hela and Southern Highlands Provinces* to help identify high-risk communities and customize interventions to enhance community resilience against climate shocks. The assessment was expected to inform the drafting of provincial and sub-provincial development plans, including the Community Peace for Development Plans (CPDPs). In particular, it aimed to:

- Identify climate-induced risks (e.g., increased rainfall and temperature variability, extreme weather conditions) and their probable effects within the microclimates that exist within Hela and Southern Highlands;
- Determine likely physical, social, economic and environmental impacts of current and anticipated changes in climatic conditions with a focus on food and water security, and subsistence livelihoods;
- Identify the intersection between extant vulnerabilities and probable physical impacts highlighting gender disaggregated impacts (i.e., women and men), physical displacement and potential contributions to local inter-/intra-group conflicts;
- Identify specific vulnerabilities of women in relation to the identified risks, with a distinct focus on different subgroups of women (elderly, pregnant, PLWD, female headed households).

The assessment approach and methodology involved the following:

1. Context profiling, which included literature and policy reviews to identify the climate-related risks, institutional set-ups, and socio-economic settings in the pilot provinces;
2. Development of approach and methodology for the climate risk assessment that includes data collection and management, assessment of hazards, vulnerabilities, and risks. The overall approach is climate-focused multi-hazard risk assessment that uses climate data overlaid with quantitative and qualitative vulnerability information.
3. Risk assessment to identify the elements at risk, with consideration to the specific vulnerabilities of women and subgroups (elderly, pregnant, PLWD, female headed households); and
4. Development of gender-responsive risk reduction recommendations for possible climate risk management (CRM) interventions.

RIMES conducted background research and submitted the context profile in December. In February 2023, an inception meeting was conducted with technical agencies and stakeholders to discuss the assessment methodology and data requirements. This was followed by provincial and community consultation workshops in Hela and Southern Highlands Provinces, which helped i) develop participatory hazard and risk matrices, and ii) identify and prioritize vulnerability indicators[2].

Following the completion of the climate risk assessment and risk mapping, national and provincial validation workshops were conducted to review the outcomes of the hazard, exposure and social vulnerability assessments including their linkages with displacement and conflict, and discuss the identified impacts of current and anticipated changes in climatic condition on food and water security, and subsistence livelihoods[3]. The validation workshops also aimed to identify entry points and priority areas to be integrated in current and future climate security resilience building strategic frameworks and plans in Hela and Southern Highlands Provinces.

## 1.2. Organization of the Report

This report outlines the methodology, process and outputs of the climate risk assessment conducted in Hela and Southern Highlands Provinces (SHP). It comprises of seven (7) chapters. Chapter 2 presents the climate-related risks and socio-economic contexts of Hela and SHP. Chapter 3 outlines the assessment methodology and process. Chapters 4 and 5 detail the hazard, exposure, and vulnerability assessment results for Hela and SHP respectively. Chapter 6 discusses the relations between climate, conflict and gender, while Chapter 7 outlines the conclusions, limitations, and recommendations of the assessment.

[2] See Appendix A for the list of representatives who participated in the national inception meeting and provincial workshops.
[3] See Appendix B for the list of representatives who participated in the national and provincial validation workshops.

## 2. Climate-related Risks and Socio-Economic Context

Southern Highlands Province (SHP) is located at elevations ranging from about 100 to 2,200 meters above sea level. It has tropical rainforest climate (Classification: Af)[4] with an annual average temperature of 17.03°C. The province generally receives about 713.39 millimeters of precipitation and has about 359.72 rainy days (98.55% of the time) annually. [7] Hela Province (HP) is likewise located in the Highlands of Papua New Guinea with elevations ranging from 200 to 1,900 meters above sea level. It covers an area of 10,498 $km^2$ and is comprised of three districts that were previously part of Southern Highlands Province. Indeed, SHP and HP were governed as one province until 2012, when they were separated. The two provinces are located at the end of the Highlands Highway. [8] According to the 2011 census, the combined total population of the provinces is 758,326 (509,488 in Southern Highlands and 248,838 in Hela). Both provinces have large youth populations under the age of 18 (37% in SHP and 32% in HP). Women comprise 48% of the population in both provinces of which 2.1% are elderly (i.e., 65 years and above). [9]

The topography of the land is extremely mountainous and rugged with two thirds comprising mainly of mountains, foothills and deep isolating valleys. A third of the land is of volcanic origin with large extinct volcanoes such as Mounts Bosavi and Sisa. The unique topography germinated a highly rich ethnolinguistic evolution with more than 16 distinctly different languages used in the two provinces combined.

Communities in both provinces are dependent on subsistence agriculture, which can be highly affected by climate. [8] In lower altitudes of the provinces, the climate is humid and semitropical but at higher altitudes, temperatures are lower and some areas are prone to sudden severe frosts, which are considered calamitous for food and cash crops. In 1994, food and cash crops were reported to be destroyed by frost and other nature-induced hazards including floods, landslides and drought. [10]

Disaster risk in the provinces is characterized by various parameters that extend beyond the domains of the environment, climate change and development, into political and social aspects. The people of the two provinces continue to live largely traditional lives characterized by clan and tribal affiliations. Many tribes consider themselves as autonomous and recognize no higher authority except a tribe leader who commands authority and is responsible for giving orders on tribe-related issues. For the tribe, the overall welfare of its members is paramount; wantok-ism is the vehicle to ensure this, through an intricate system of exchanging social capital (i.e., food, money, shelter, security, access to services, adoption, and employment). [8] The concept of ward members and councilors was only recognized upon its introduction in 1995. Ward members and councilors became well respected within local communities, where they work closely with traditional leaders to resolve issues and make decisions concerning tribes and clans.

A 2022 research conducted by Conciliation Resources identified conditions conducive to inter-/intra-communal conflicts. In particular, fighting is customarily considered a legitimate way of resolving

[4] Tropical rain forests have a type of tropical climate in which there is no dry season—all months have an average precipitation value of at least 60 mm (2.4 in). In rainforest climates the dry season is very short, and rainfall is normally heavy throughout the year. One day in a tropical rainforest climate can be very similar to the next, while the change in temperature between day and night may be larger than the average change in temperature during the year. When tropical rain forest climates are more dominated by the Intertropical Convergence Zone (ITCZ) than the trade winds (and with no or rare cyclones), so usually located near the equator, they are also called equatorial climates. Otherwise, when they are more dominated by the trade winds than the ITCZ, they are called tropical trade-wind climates. In pure equatorial climates, the atmospheric pressure is low, almost constant so the (horizontal) pressure gradient is low. Consequently the winds are rare and usually weak (except sea and land breezes in coastal areas) while in tropical trade-wind climates, often located at higher latitudes than the equatorial climates, wind is almost permanent which incidentally explains why rainforest formations are impoverished compared to those of equatorial climates due to their necessary resistance to strong winds accompanying tropical disturbances.

conflicts in these provinces. The fights are usually triggered by interpersonal disagreements over land, grave accusations, and insults. However, traditional fights sometimes lead to casualties, which have massive repercussions as revenge killings are also prevalent as a "balancing of the ledger" act [11]. The influx of money, high-powered firearms, and weaponry also contribute to more violence. Fighting has shifted from traditional to more advanced ways within the context of limited institutions and authorities as well as weak law enforcement.

While the effects of climate change do not directly cause violent conflict, it can further multiply risks known to contribute to insecurity, overburden limited community and state resources, and make the already vulnerable communities more desperate and susceptible. Recent major disasters resulting from natural hazards in the Highlands clearly highlight the risks faced by communities in Southern Highlands and Hela provinces. These include, among others, the devastating 7.5 magnitude earthquake in 2018 which affected over 544,000 people in Hela, Southern and Western Highlands, and Enga provinces. Similarly, there were severe widespread food and water shortages during El Niño events in 1997 and again in 2015/2016. During the 2015/2016 El Niño, an estimated 180,000 people, of which a majority were located in Southern Highlands and Hela provinces, were assessed to have experienced severe food insecurity requiring humanitarian assistance. [8]

# 3. Assessment Methodology

The climate risk assessment approach and methodology involved the following activities conducted over a period of approximately 6 months[5].

**Desk review and context profiling**. In December 2022, RIMES conducted a review of literature and developed a context profile report highlighting the prevailing hazards, exposure and vulnerability in Hela and SHP. The report also provided information on the stakeholders, and the institutional, policy and legal framework for early warning, disaster management and climate response.

**Development of the technical approach and methodology**. An outline of the risk assessment approach and methodology as well as the data requirements was presented in the context profile report. However, the details on the assessment process, data sources and access, indicators and their weights were finalized during the national and provincial consultations.

**National Inception Meeting**. Conducted in February 2023, the meeting gathered representatives from the National Weather Service (NWS), Department of Mineral Policy and Geohazards Management (DMPGM), Conservation and Environmental Protection Authority (CEPA), Department of Agriculture and Livestock (DAL), National Mapping Bureau (NMB), National Statistics Office (NSO) and Climate Change Development Authority (CCDA). The meeting i) generated feedback from stakeholders on the methodology, data availability, and other technical details related to the mapping and assessment of hazards, vulnerability and risks affecting Hela and Southern Highlands; ii) discussed coordination strategies for data access; and iii) developed an agreed plan and timeline for the assessment.

**Provincial Consultation Workshops and Meetings with 'Pilot Wards'[6]**. The provincial workshops were held in Tari and Mendi in February 2023 with representatives from the province, district and pilot wards. The workshop allowed participants to i) discuss hazard priorities, identify vulnerability indicators and develop risk matrices; ii) determine the rates and weights assigned for different vulnerability indicators; and iii) develop participatory hazard and risk maps.

The meetings with representatives from pilot wards were conducted on-site for pilot communities in SHP, and in Tari for pilot communities in Hela. These meetings focused on a discussion of the main hazards affecting the pilot wards, their vulnerabilities, coping capacities and resources. Ward representatives developed participatory hazard and resource maps, indicating the areas, infrastructures or settlements exposed to, and/or affected by hazards as well as the assets and resources they have access to.

**Hazard Assessment and Mapping**. The technical assessment and mapping was conducted using the methodology outlined in sections 3.2 to 3.7 for climate trends and projections, flood, drought and frost, rainfall- and earthquake-induced landslide, exposure and vulnerability. This process helped identify what/where are the at-risk areas, infrastructures and settlements, and to which extent.

**Provincial and National Validation Workshops**. The provincial validation workshops were held in Tari and Mendi while the national workshop was held in Port Moresby. Representatives from the province, district, pilot wards, NGOs, civil society organizations, and faith-based organizations attended the provincial workshops while national representatives from NWS, DMPGM, CCDA, NSO, CEPA and DAL

[5] The activities, particularly the national and provincial workshops as well as community meetings, were conducted in close coordination with UNDP PNG.

[6] The pilot wards targeted within the climate risk assessment correspond to the target communities of the 'Preventing Climate Induced Conflicts through Empowered Women Leadership' Project in Hela and Southern Highlands Provinces.

participated in the national workshop held in May. The provincial validation workshop allowed participants to i) review the outcomes of the hazard and exposure assessments; ii) discuss the identified impacts of current and anticipated changes in climatic condition on food and water security, and subsistence livelihoods; and iii) within the UNDP project framework, identify priority areas where assessment outcomes could be used in the development of climate and gender-sensitive peace and security strategies and provincial action plans. On the other hand, the national workshop focused on a technical review of the hazard and exposure assessment results as well as discussion on the potential adoption of the assessment methodology and results in agency operations of for instance, CCDA.

## 3.1. Baseline Information

Baseline data gathered include administrative boundaries, land use/land cover, digital elevation model (DEM), previous disaster damage data and relevant hazard-related data. These were all used as inputs to the hazard, exposure and vulnerability assessments, which in turn were utilized to generate the risk assessments. Risk assessment outputs were then validated with key technical agencies and stakeholders.

Census and demographic data were provided by the National Statistics Office (NSO). The population and household information used in the exposure and vulnerability assessments corresponds to the 2011 census. Other baseline data including administrative boundaries used in the assessment were downloaded from global data sources.

PNG Provinces are composed of Districts, which consist of smaller administrative boundaries called Local-Level Government (LLGs) units. LLGs are further divided into wards, but there is no administrative boundary separating the wards. Typically, provinces are composed of less than 10 districts. Districts on the other hand, are normally comprised of two (2) to five (5) LLGs, which in turn are made up of wards ranging between three (3) to as much as 30.

## 3.2. Climate Trends and Projections

Climate trends and projected future climate in Hela and the Southern Highlands were characterized using historical long-term (at least 30 years) quality-controlled observation data combined with global observed climate datasets and high-resolution gridded datasets. Figure 3-1 shows the process for assessing the projected climate and trends in climate extremes relevant to drought, frost and flood.

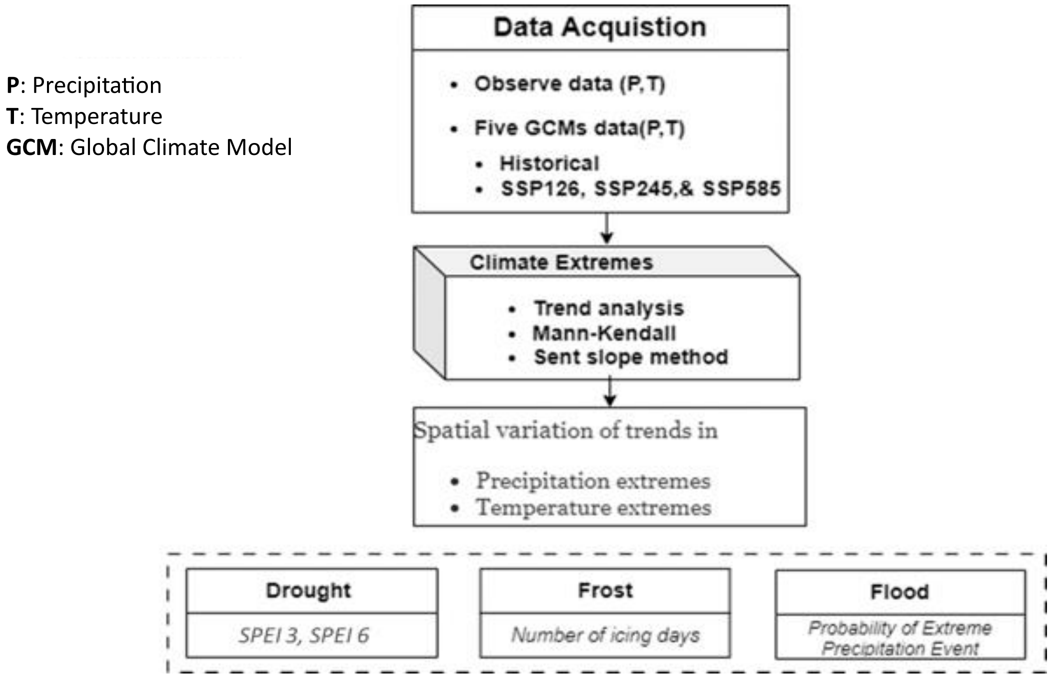



Figure 3-1. Process for assessing projected future climate and trends

**Quantifying historical trends in precipitation and temperature extremes**. The approach used a popular nonparametric rank-based test, Mann–Kendall (MK) test (Mann 1945; Kendall 1975), which is generally applied for detecting a monotonic trend in hydro-meteorological variables like streamflow (Ganguly et al. 2015) and precipitation (Hamed 2008). Likewise, Sen's slope estimator (Sen 1968) was combined with the MK test to quantify the magnitude of extreme precipitation index trends. Trends in annual rainfall will be quantified for selected indices during both historical and future periods.

**Bias correction using quantile mapping**. Comparative analyses of various bias correction methods have found that quantile mapping is superior for temperature and rainfall to other methods (Teutschbein and Seibert, 2012; Teng et al., 2015; Smitha et al., 2018). The basic concept of quantile mapping is to match the cumulative distribution function (CDF) of the climate model with the observation and generate the correction function, which is applied to future time series. It can be expressed as:

$$Va(cor),i=Fobs-1(FGCM(Var(raw),i)) \text{ ... EQ 1}$$

where, Var refers to any climatic variables such as temperature, rainfall from the climate model for any day i; Fobs-1 and FGCM are the inverse CDF of the observed climatic variable and CDF of the corresponding output of the model during the reference period. Bias correction of the rainfall is carried out using the empirical CDF, which avoids making any assumptions on distribution fitting and corrects both rainfall intensity and frequency (Boé et al., 2007; Themeßl et al., 2011). The method has been more effective in reducing biases than using the theoretical distribution (Gudmundsson et al., 2012). For the future rainfall values which are larger than those during the reference period, the correction factor for the highest quantile is used (Boé et al., 2007; Themeßl et al., 2012). The CDF for the temperature is constructed using the Gaussian distribution (Teutschbein & Seibert, 2012). Theoretical distribution is a better choice when frequent extrapolation, as in the case of the future temperature, is required. Observed data from 1981-2020 for CMIP6 and 1981-2014 for CMIP6 are used for the bias correction.

**Characterization of precipitation and temperature extremes**. ClimPACT2 was used for calculating 16 core climatic indices. Among the eight precipitation indices, RX1day and RX5day are the absolute indices that indicate conditions for high antecedent soil moisture, which may cause flooding and landslides in the mountainous region. PRCPTOT, also an absolute index, represents general wet and dry conditions of the year. R20mm, CDD and CWD are duration-based indices and represent the frequency of high or low rainfall. CDD and CWD also indicate the conditions of water availability. R95pTOT and R99pTOT are percentile indices that depict the occurrence and contribution of extreme rainfall to the total precipitation.

For the eight extreme temperature indices, TXx, TXn, TNx, and TNn are absolute values and general indicators for the identification of temperature extremes. TX90p and TN90p are percentile-based indices, which show the ratio of extreme temperature days occurring in a year. Finally, duration-based indices like SU and WSDI are also used to gauge the frequency and continual occurrence of extreme temperatures. These indices will be used to characterize the historical as well as future climatic data through various trend analyses and spatial distribution mapping.

**Data used**. Observed daily precipitation (P) and temperature (both maximum and minimum, Tmax and Tmin) data provided by the National Weather Service (NWS) include 5 stations – Mendi UC, Mendi CM, Tari 2 Mission, Tari High School, Tarinumu Plantation. However, these are significantly lacking and/or incomplete. For most stations, data is available from 1954 to 1977 (see Table 3-1). As observed time series data is not available beyond 1977, gridded daily precipitation (P) and temperature (both maximum and minimum, Tmax and Tmin) were used (see Table 3-2). Data quality was assessed based on the average annual as well as monthly values. Finally, the data length of 1991–2020 was considered for precipitation and temperature and will be selected for further analysis of climatic extremes.

**Table 3-1. Meteorological data from NWS**

| | Index No. | Station Name | Tmax | Tmin | Rainfall |
|---|---|---|---|---|---|
| 1 | 70005 | Mendi UC | 1977, 1978 | 1977, 1978 | 1954, **1955, 1956,1957, 1958, 1959,1960, 1961, 1962, 1963, 1964, 1965, 1966**, 1967, 1968, **1972**, 1973, **1974**, 1977 |
| 2 | 70038 | Mendi CM | 1979, 1980, 1981, 1982, 2005, 2006, 2007, 2008, 2010, 2011 | 1979, 1980, 1981, 1982, 2005, 2006, 2007, 2008, 2010, 2011 | 1979, 1980, 1981**, 1982**, 1991, 1992, 1998, **1999**, 2005, 2006, 2007, 2008, 2010, 2011 |
| 3 | 70034 | Tari 2 Mission | - | - | 1956, 1957, 1958, 1959, **1960, 1961,** 1962, 1963 |
| 4 | 70024 | Tari High School | - | - | **1974,1998,1999** |
| 5 | 55021 | Tarinumu Plantation | - | - | 1957, 1958, 1959,1960,1961, 1962, **1963**, 1964, **1965,** 1966, **1967, 1968, 1969**, 1970, 1971, 1972, 1973, 1974, 1975, 1976 |

Note: Years in bold have complete data.

**Selection of gridded product**. A review of literature was conducted, and high-resolution gridded rainfall and temperature product in the region was checked. It was found that ERA 5 precipitation product is overestimating the total yearly precipitation mean compared to the climate knowledge portal data while CHIRPS rainfall product was able to capture the yearly and monthly trend in mean. Therefore, CHIRPS daily precipitation product was chosen.

**Table 3-2. Meteorological data collected**

| Dataset | Variable | Input Data | Frequency | Spatial Resolution | Temporal Coverage |
|---|---|---|---|---|---|
| CHIRPS | Rainfall | Infrared Cold Cloud Duration (CCD) observations, satellite imagery, and ground-based observed rainfall Interpolation techniques | Daily | 0.25° × 0.25° | 1981-Present |

| Dataset | Variable | Input Data | Frequency | Spatial Resolution | Temporal Coverage |
|---|---|---|---|---|---|
| ERA-5 | Rainfall, Max and Min Temperature | ECMWF atmospheric reanalysis of the global climate | Daily | 0.25° × 0.25° | 1979-Present |

**Projection of future climate**. Five sets of GCMs were chosen from the NEX-GDDP-CMIP6 dataset, which is comprised of global downscaled climate scenarios derived from the General Circulation Model (GCM) based on the study by Nishant et, al. (2022) ACCESS-CM2, GFDL-CM4, GFDL-ESM4 (NOAA), HadGEM3-GC31-LL (Hadley Centre), and KACE-1-0-G, tend to show consistently good performance for precipitation and temperature extremes for Australian Continent, where PNG lies. Based on the quality of historical observed data, the precipitation and temperature data from the period 1981–2014 are used for bias correction and baseline period of 1995–2020. Analysis for two shared socio-economic pathways (SSP245, SSP585) the future period (2021–2100) was divided into three periods: 2023–2048 (near-future, NF), 2049–2074 (mid-future, MF), and 2075–2100 (far-future, FF).

**Table 3-3. Detail of GCMs name, institute, and variant use for projection**

| GCM Name | Institution | Variant label |
|---|---|---|
| ACCESS-CM2 | Commonwealth Scientific and Industrial Research Organization/Australia | r1i1p1f1 |
| GFDL-CM4 | NOAA Geophysical Fluid Dynamics Laboratory/USA | r1i1p1f1 |
| GFDL-ESM4 | NOAA Geophysical Fluid Dynamics Laboratory/USA | r1i1p1f1 |
| HadGEM3-GC31-LL | Met Office Hadley Centre/UK | r1i1p1f3 |
| KACE-1-0-G | National Institute of Meteorological Sciences/Korea Meteorological Administration (NIMS/KMA) | r1i1p1f1 |

## 3.3. Flood

Due to lack of data available to conduct hydrodynamic modelling, the assessment of flood depth and extent utilized data from World Resources Institute's Aqueduct Floods Tool, and the Global Flood Hazard Frequency and Distribution dataset developed by the World Bank. The dataset uses a combination of satellite imagery, digital elevation models, and hydrological models to estimate the likelihood, frequency, depth and extent of floods globally, based on the return period. For this assessment, the 100-year return period flood was used as baseline.

Participatory flood hazard assessments were also conducted. These involved discussions with stakeholders on the areas typically affected by floods. Participants in these discussions included representatives from provincial and district-level government agencies, NGOs and civil society organizations. They were asked to locate rivers, identify the nature of flood hazards and areas affected, then rate the floods according to frequency and impact with 1 as least and 5 as most. Many of the identified flood locations are in riverine areas. Figure 3-2 shows the river and drainage map of Hela and SHP. One of the major rivers in Hela flow from east-to-east crossing the northern part of Hela from Koroba/Kopiago. Another big drain starts in Tari/Pori district, passes through Komo/Margarima and enters Nipa/Kutubu. Similarly, SHP has large drainage density from Hela and Enga provinces. In particular, the Enga drain enters Mendi/Munihu, flows from western Imbonggu and passes the border of Nipa/Kutubu and Kagua/Erave. This is the drainage which causes flood in the region.

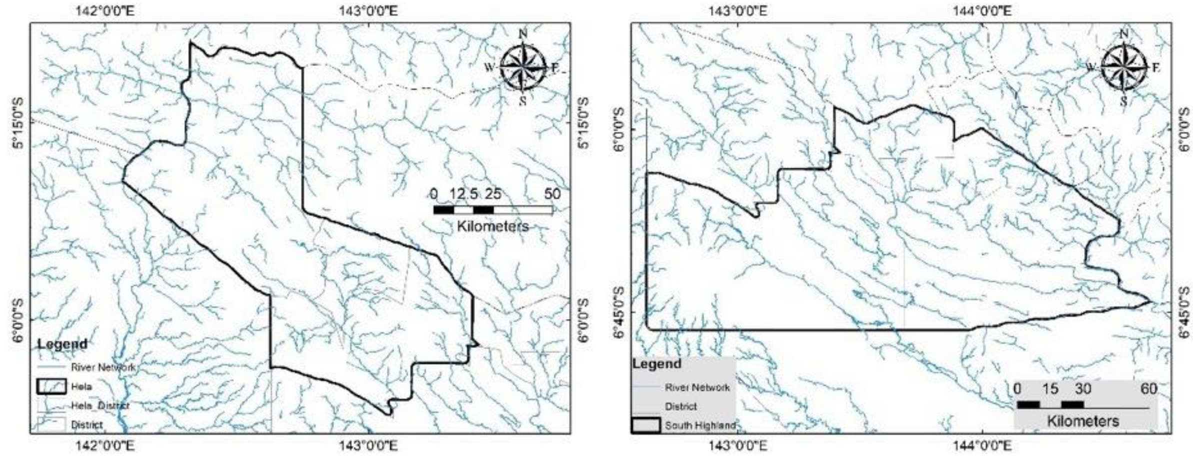


Figure 3-2. River and drainage map of Hela and SHP

**Flood index**. The assessment examined various precipitation indices expected to enhance the potential for flooding. This includes Rx5day (maximum 5-Day precipitation), R99p (number of extremely wet days), Rx1day (highest one-day precipitation amount), and CWD (consecutive wet days).

- The Rx5day index represents the maximum 5-day rainfall amount within a given period. It represents conditions for high antecedent soil moisture that may lead to floods. The index was used to determine the probability of flood hazard for a particular return period. It provides insights into prolonged extreme rainfall events and helps in analyzing the potential for longer-term impacts such as riverine flooding.
- The R99p index reflects the amount of precipitation when the rainfall is more than 99$^{th}$ percentile of the data. An increase in R99P signifies higher thresholds for extreme 1-day precipitation events. This suggests that more intense and rare rainfall events are becoming more frequent. Such intense precipitation can overwhelm drainage systems, cause rapid runoff, and contribute to flash floods. The increased magnitude of extreme precipitation events, as indicated by R99P, amplifies the potential for flooding.
- The Rx1day index represents the maximum amount of rainfall received within a single day. An increase in the Rx1day index indicates that intense rainfall events are becoming more extreme. Such heavy precipitation within a short duration can quickly saturate the soil and lead to increased surface runoff, overwhelming drainage systems and potentially causing localized or widespread flooding.
- The CWD index represents consecutive days with rainfall above a specified threshold. An increase in the CWD index implies longer durations of wet periods, which can saturate the soil and elevate groundwater levels. Sustained wet conditions can increase the moisture content in the soil, reducing its capacity to absorb further rainfall. As a result, subsequent rainfall events during these prolonged wet periods are more likely to contribute to surface runoff and potentially lead to flooding.

## 3.4. Drought and Frost

The Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) were used to assess drought in the pilot provinces. The SPI is based on precipitation data and measures on how abnormal or extreme the precipitation is compared to the long-term average for a specific location and time period. It provides an indication of the departure of precipitation from normal conditions, allowing for the assessment of drought severity. The SPI can be calculated at various time scales, such as 1 month, 3 months, 6 months, and 12 months. The SPEI, on the other hand, incorporates both precipitation and evapotranspiration data to assess drought conditions. Evapotranspiration is the combined loss of water through evaporation from the land surface and transpiration from plants. By considering both precipitation and evapotranspiration, the SPEI provides a more comprehensive measure of drought that accounts for the balance between water supply and demand. Similar to the SPI, the SPEI can be calculated at various time scales.

The assessment of drought also included analysis of future scenarios for the following:

- Duration: length of time over which a region experiences a drought condition
- Severity: degree, extent or magnitude of a drought event
- Intensity: ratio of the severity to the duration

**Drought index**. The Consecutive Dry Days (CDD) index was used to identify trends in the maximum number of consecutive days with less than a specific threshold of rainfall. The CDD index helps in quantifying the length of dry spells, which is important for assessing the severity and persistence of drought events. It provides insights into the consecutive days with little to no rainfall within a specified time period, which can lead to soil moisture depletion, reduced water availability, and ecological stress.

**Frost index**. The analysis of frost focused on the annual count of days when TN (daily minimum temperature) < 0°C. The analysis indicated that the lowest minimum of minimum temperature is only 5°C, which is not very conducive to frost. Nevertheless, provincial stakeholders reported the incidence of frost in 1982, 1997, and 2015/2016. This highlights the following limitations:

- *Spatial variability*. Temperature data used in the analysis might not be representative of the specific locations where frost occurred. The TNN variable is an average of minimum temperatures across the entire region, but temperatures can vary widely within a region, especially in areas with topographic or microclimatic differences.
- *Timing.* Frost can occur when temperatures drop below freezing, which can happen even if the monthly minimum temperature does not fall below 5°C. It is possible that the community experienced frost hazard during a specific time of day or season when temperatures were lower than the monthly minimum.
- *Local conditions.* Frost hazard can also be influenced by local conditions such as humidity, wind speed, and cloud cover. These factors can make temperatures feel colder than they actually are and increase the likelihood of frost formation.

Since reported frost events occurred during El Nino years, further analysis on TNN was conducted for the years 1982, 1997, 2002 and 2015. El Nino is considered to increase the risk of frost in certain regions of the tropics and subtropics. During El Nino years, there are warmer than average day time temperatures that decrease the cloud cover. Reduced cloud cover subsequently leads to cooler-than-average night-time temperatures that are conducive to the formation of frost.

## 3.5. Landslide

The landslide assessment was conducted to enhance understanding of the causative factors and mechanics of landslide events, determine the probability of landslide occurrence, and identify the impacts and potential recommendations for reducing such impacts.

Assessment of both rainfall- and earthquake-induced landslides used the Analytic Hierarchy Process (AHP) approach. AHP provides a flexible and easily understandable way of analyzing and solving problems by making approximate assumptions. Although this method is considered to be semi-quantitative, it can be effectively used for medium-scale assessments of landslide susceptibility.

The AHP method was used for the pairwise comparisons and determine the weight factor of various indicators for landslide hazard.

**Rainfall-induced landslide**. Indicators used to assess rainfall-induced landslides include geology, NDVI, altitude, lineament, distance to river, distance to road, precipitation, slope, landform, and aspect. The pairwise comparisons are considered successful when the consistency ratio is less than 10%. In the rainfall-induced landslide assessment, the consistency ratio of the pairwise comparisons for geology, NDVI, altitude, lineament, distance to river, distance to road, precipitation, slope, landform, and aspect were calculated to be 8.6, 3.5, 2.8, 3.6, 0.7, 4.1, 3.8, 1.1, 7.0, and 1.7%, respectively[7]. Table 3-4 shows the results of the pairwise comparison of selected factors.

**Table 3-4. Factors selected for pairwise comparisons**

| | Description | Geology | NDVI | Distance to River | Distance to Road | Precipitation | Slope | Altitude | Landform | Aspect | Lineament |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Geology | 1.0 | 5.0 | 3.0 | 5.0 | 0.5 | 2.0 | 5.0 | 3.0 | 5.0 | 2.0 |
| 2 | NDVI | 0.2 | 1.0 | 2.0 | 2.0 | 0.5 | 0.2 | 3.0 | 0.5 | 3.0 | 0.3 |
| 3 | Distance to river | 0.3 | 0.5 | 1.0 | 2.0 | 0.2 | 0.2 | 2.0 | 1.0 | 0.5 | 0.3 |
| 4 | Distance to road | 0.2 | 0.5 | 0.5 | 1.0 | 0.2 | 0.2 | 0.2 | 0.5 | 0.5 | 0.2 |
| 5 | Precipitation | 2.0 | 2.0 | 5.0 | 5.0 | 1.0 | 2.0 | 5.0 | 3.0 | 6.0 | 0.3 |
| 6 | Slope | 0.5 | 5.0 | 5.0 | 5.0 | 0.5 | 1.0 | 5.0 | 5.0 | 4.0 | 2.0 |
| 7 | Altitude | 0.2 | 0.3 | 0.5 | 5.0 | 0.2 | 0.2 | 1.0 | 0.2 | 1.0 | 0.3 |
| 8 | Landform | 0.3 | 2.0 | 1.0 | 2.0 | 0.3 | 0.5 | 2.0 | 1.0 | 5.0 | 0.5 |
| 9 | Aspect | 0.2 | 0.3 | 2.0 | 2.0 | 0.2 | 0.3 | 1.0 | 0.2 | 1.0 | 0.2 |
| 10 | Lineament | 0.5 | 4.0 | 4.0 | 5.0 | 3.0 | 0.5 | 3.0 | 2.0 | 5.0 | 1.0 |

**Earthquake-induced landslide**. Indicators used to assess earthquake-induced landslide include geology, NDVI, distance to river, distance to road, PGA value, slope, altitude, landform, aspect, and distance to lineament. Table 3-5 presents the main factor pairwise comparison based on Yi et al. (2019) and expert opinion. The list of main factors is the same as the analysis for rainfall-induced landslide, except that the precipitation factor was replaced with Peak Ground Acceleration (PGA) factor. Additionally, the weight value for distance to lineament was adjusted since earthquake-induced landslides are typically associated with distance to lineament – areas near the lineament are more prone to landslides compared to those far from the lineament.

Following suggestions from Pavel and Vacareanu (2023), the PGA values with return period of 475 years was used in the assessment. The seismic hazard map pertains to a magnitude 7.5 earthquake that took place in 2018 along the Southern Highlands Thrust Fault (SHTF), which is recognized as a region with elevated seismic activity. The SHTF spans both the Hela and Southern Highland provinces and exhibits a convergent motion, causing deformation at a rate of 10 mm/year (Ghasemi et al., 2020).

The pairwise comparisons are considered successful when the consistency ratio is less than 10%. In the earthquake-induced landslide assessment, the consistency ratio of the pairwise comparison for the main factors as well as the PGA value is 8.2 and 3.3% respectively[8]. Table 3-5 shows the results of the pairwise comparison of selected factors.

**Table 3-5. Factors selected for pairwise comparisons**

| | Description | Geology | NDVI | Distance to River | Distance to Road | PGA value | Slope | Altitude | Landform | Aspect | Lineament |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Geology | 1.0 | 5.0 | 3.0 | 5.0 | 0.5 | 2.0 | 5.0 | 3.0 | 5.0 | 0.5 |
| 2 | NDVI | 0.2 | 1.0 | 2.0 | 2.0 | 0.2 | 0.2 | 3.0 | 0.5 | 3.0 | 0.3 |
| 3 | Distance to river | 0.3 | 0.5 | 1.0 | 2.0 | 0.3 | 0.2 | 2.0 | 1.0 | 0.5 | 0.5 |
| 4 | Distance to road | 0.2 | 0.5 | 0.5 | 1.0 | 0.2 | 0.2 | 0.2 | 0.5 | 0.5 | 0.3 |
| 5 | PGA value | 2.0 | 5.0 | 4.0 | 5.0 | 1.0 | 0.5 | 5.0 | 4.0 | 5.0 | 0.5 |
| 6 | Slope | 0.5 | 5.0 | 5.0 | 5.0 | 2.0 | 1.0 | 5.0 | 5.0 | 4.0 | 1.0 |
| 7 | Altitude | 0.2 | 0.3 | 0.5 | 5.0 | 0.2 | 0.2 | 1.0 | 0.2 | 1.0 | 0.2 |

[7] See Appendix 3 for the detailed pairwise comparisons at factor level, and the resulting maps.
[8] See Appendix 3 for the detailed pairwise comparisons at factor level, and the resulting maps.

| | Description | Geology | NDVI | Distance to River | Distance to Road | PGA value | Slope | Altitude | Landform | Aspect | Lineament |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | Landform | 0.3 | 2.0 | 1.0 | 2.0 | 0.3 | 0.5 | 2.0 | 1.0 | 5.0 | 0.5 |
| 9 | Aspect | 0.2 | 0.3 | 2.0 | 2.0 | 0.2 | 0.3 | 1.0 | 0.2 | 1.0 | 0.3 |
| 10 | Lineament | 2.0 | 4.0 | 2.0 | 4.0 | 2.0 | 1.0 | 5.0 | 2.0 | 4.0 | 1.0 |

Following the pairwise comparison, a weighted calculation was performed to generate the landslide hazard index and map using the following formula.

$$H = \sum_{i=1}^{n} (Score_i \; x \; W_i)$$

where: H = hazard score
$Score_i$ = score for each criterion
$W_i$ = weight for the criterion
n = total number of criteria
i = criteria number
$W_1 + W_2 + \ldots + W_n = 1$

The index was classified using three methods: natural break, geometric interval, and quantile. Landslide hazard maps generated by the geometric interval classification method was used based on its high R-index value (see Table 3-6).

**Table 3-6. Landslide index classification**

| | Index classification | Rainfall-induced landslide | Earthquake-induced landslide |
|---|---|---|---|
| 1 | Geometric interval | 81% | 82% |
| 2 | Natural break | 70% | 77% |
| 3 | Quantile | 61% | 74% |

The landslide hazard maps were generated after the weighted calculation of all parameters. The maps comprised of five hazard categories – very low, low, moderate, high, and very high. The landslide hazard maps were compared with the country's landslide inventory. Validation was conducted using the area under curve (AUC) of the receiver operating characteristic (ROC). The value of the AUC was estimated at 67% and 78% for rainfall- and earthquake-induced landslide respectively (see Figure 3-3). These values are more than the minimum required value of 65%. Therefore, the landslide hazard maps are reasonable.

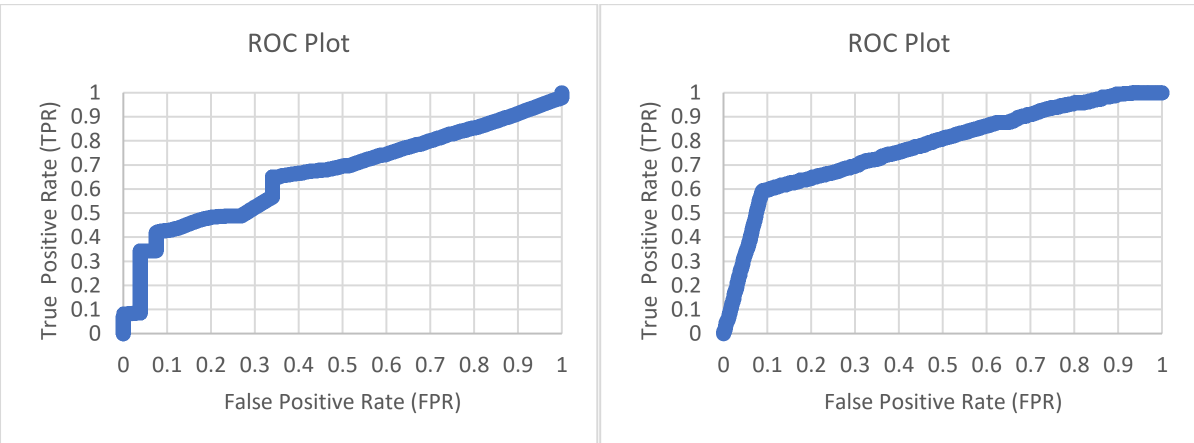



**Figure 3-3. ROC plot of rainfall-induced (left) and earthquake-induced (right) landslide hazard map**

## 3.6. VULNERABILITY

Vulnerability is comprised of three elements: i) exposure, both spatial and temporal; ii) sensitivity: physical, ecological, social, economic, cultural, and institutional; and iii) lack of resilience, in terms of ability to adjust (to climate change), reduce potential impacts, take advantage of opportunities, cope with consequences, or recover.

Exposure assessment was done by overlaying the location of population centers, dwellings, critical infrastructure and facilities, community assets, and economic activities with hazard maps.

The assessment of sensitivity and lack of resilience shall be indicator-based, the identification of which will consider the climate-gender-social conflict nexus. These indicators include age, literacy levels, gender and various subgroups (e.g., female-headed households, elderly, PLWD, etc.).

Vulnerability indicators and their assigned weights were identified and defined during the provincial workshops. Each indicator was scored, and the score and assigned weight are multiplied. Adding these products shall give the total score for the type of vulnerability being considered. For example:

$$V_{social} = \sum_{i=1}^{n} (Score_i \; x \; W_i)$$

where:

$V_{social}$ = social vulnerability score
$Score_i$ = score for each indicator (e.g. female-headed household, the elderly, etc.)
$W_i$ = weight for the indicator
n = total number of indicators
i = indicator number
$W_1 + W_2 + \ldots + W_n = 1$

Scores are then mapped using GIS tools.

## 3.7. RISK

Risk assessment employs the risk model equation using the outputs from the hazard and vulnerability assessments:

$$\text{Risk} = f\,(\text{hazard, vulnerability})$$

Results could be re-classified using integers for a risk index. GIS tools will be used for mapping. Feedback from a validation workshop, involving key stakeholders from the inception meeting, shall be used to refine the assessments.

## 3.8. CHALLENGES AND LIMITATIONS

One of the key challenges in conducting the CRA is the absence of updated and reliable data. For instance, the data provided by the NSO is PNG's 2011 census, which is more than a decade old. Hydrological data from CEPA is comprised of water level and rainfall data from the 1970's and filled with various gaps. Similarly, meteorological data from NWS was filled with numerous gaps. Due to these limitations, the analysis relied heavily on globally available data.

**Uncertainty in climate projections**. Another challenge is the uncertainty associated with climate projections, particularly at the local level. This uncertainty makes it difficult to accurately predict the timing, intensity, and spatial distribution of extreme weather events that enhance the incidence of floods, droughts, and frost.

**Limitations of the AHP and landslide susceptibility mapping method**. The landslide susceptibility assessment used AHP, which relies on existing literature and expert opinion comparing the relative importance of factors. It is important to note that the comparison of factors from one area may not accurately represent the specific conditions found in another area. Therefore, it is crucial to consider the statistical information associated with each parameter before conducting the analysis. In addition, the parameters obtained from spatial information, such as satellite images, rainfall data, geological maps, and landslide inventories, need to be validated through field observations. The process of mapping landslide inventories using satellite imagery is also constrained by the lack of available satellite images in certain areas. Consequently, the landslide hazard map may not be validated in these specific regions. For future study, it is imperative to validate the landslide hazard map through fieldwork, particularly in areas where satellite imagery is unavailable.

**Significant data gaps in the vulnerability assessment**. The vulnerability assessment was significantly constrained by the lack of sufficient data at LLG levels for various variables like crop area; livestock population; population growth rate; poverty rate; number of internally displaced and abused people; rate of patriarchy, outmigration, landlessness, wantok practices; level of social cohesion; number of security officers and police; level of government financial capacity and support; number of church- and women-led organizations and programs, among others. On the other hand, LLGs appear to be on the same level when it comes to the number of households dependent on agriculture as a livelihood; the lack of evacuation centers; limited to no access to forecasts, early warning and hazard information.

# 4. HAZARD, EXPOSURE AND VULNERABILITY ASSESSMENT IN HELA

Hela is a province located in the Highlands of PNG. It is a newly established province comprised of three (3) districts and 12 LLGs including its capital, Tari. Established in 2012, the province covers an area of 10,498 sq km. Its population is estimated at about 248,838 according to the 2011 National Population and Housing Census, with a growth rate of 2.7% per annum from 2000. The province accounts for 3.4% of PNG's total population.

## 4.1. BASELINE INFORMATION

Figures 4-1 shows Hela's location and the boundaries of its 12 LLGs.

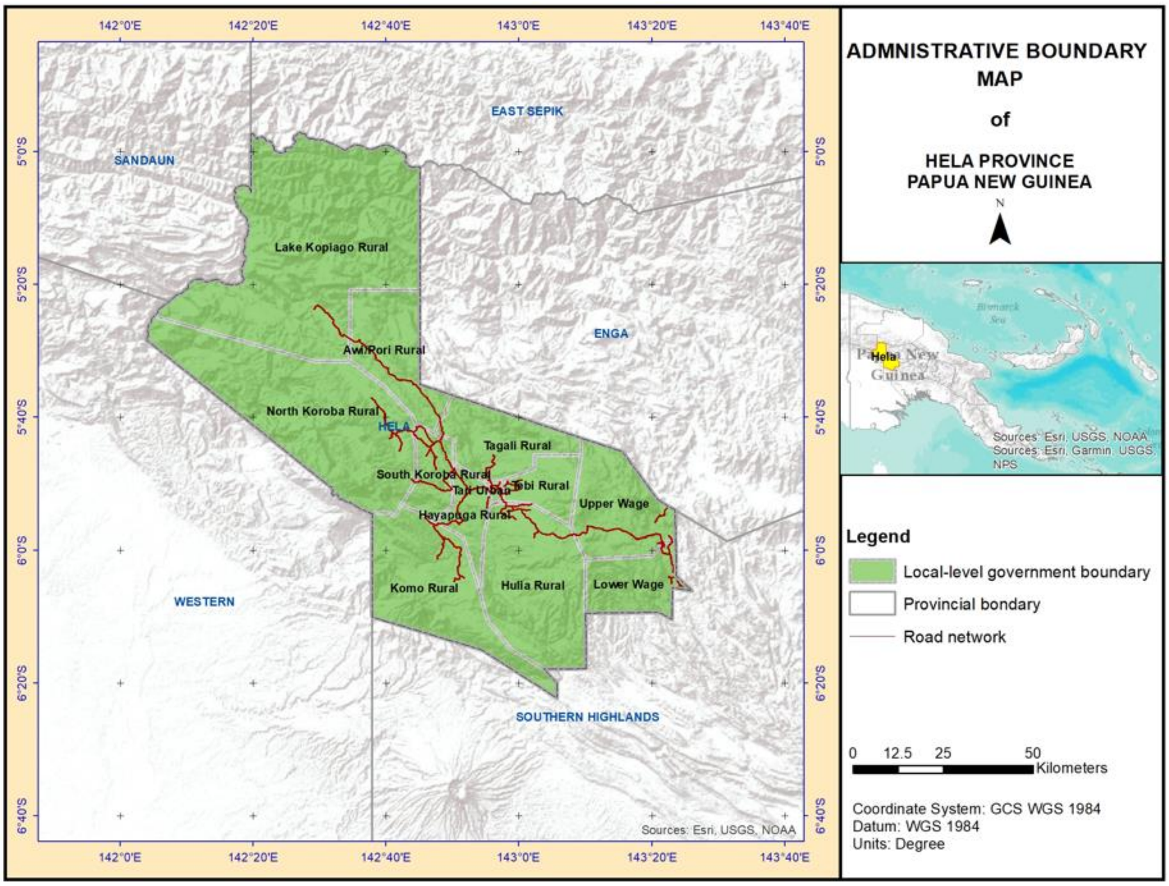



**Figure 4-1. Administrative boundaries of Hela Province**

Topography and/or elevation information in Hela was generated using the global DEM Shuttle Radar Topography Mission (SRTM, https://lta.cr.usgs.gov/SRTM1Arc), which has a 30-meter resolution. Figure 4-2 shows the elevation in the province. On the other hand, The ESRI (https://livingatlas.arcgis.com/landcover/) 10-meter resolution land cover was used to generate land use/land cover map of Hela (Figure 4-3).

Figure 4-4 shows the locations of settlements in Hela. The map shows that settlements are distributed across the province. Komo/Magarima District is the most populated comprising 39% (96,153) of the province's total population of 249,439 in 2011. This is followed by Tari/Pori District (32%) and Koroba/Kopiago (30%). [12] Of the total population in the province, 48.40% are women, 26.5% are aged 0 to 14 years old, while 2.6% are aged 65 years old and above. [9] Table 4-1 lists the population and population density of LLGs.

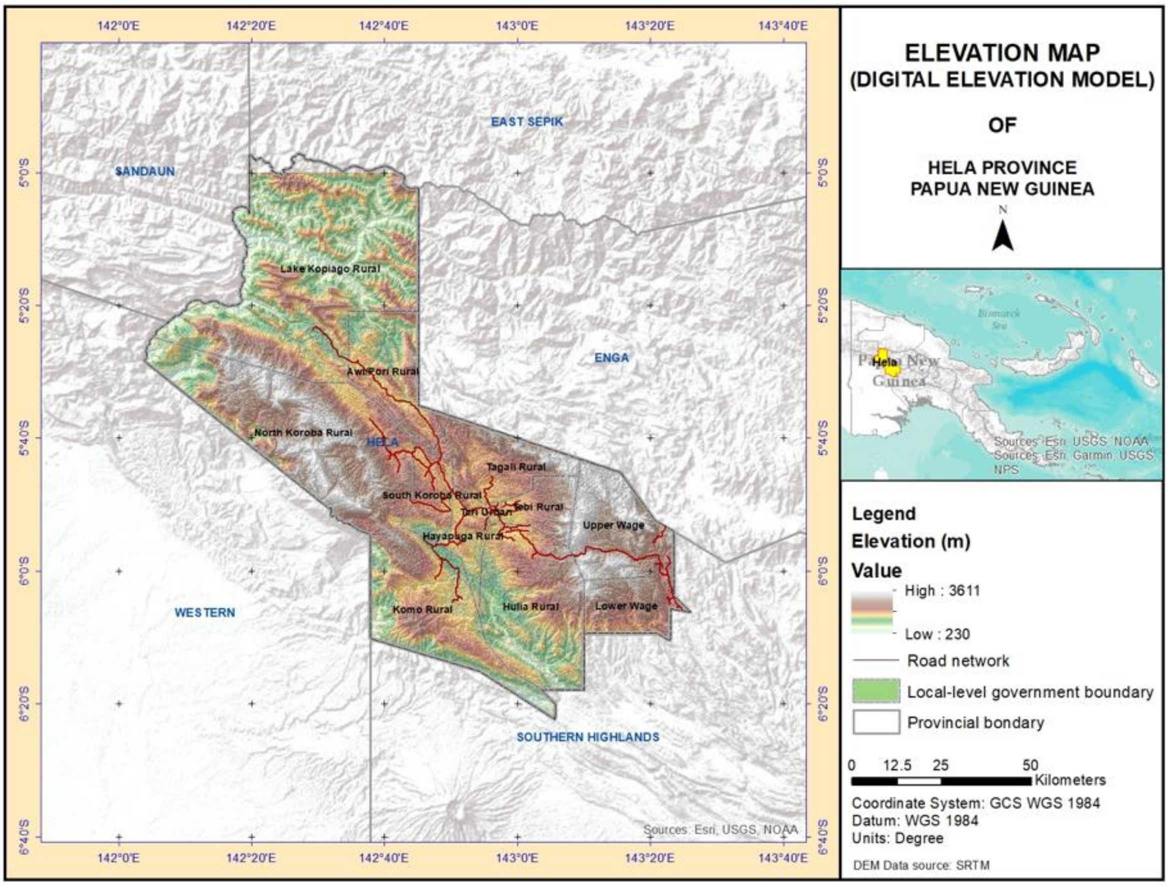



**Figure 4-2. Elevation map of Hela Province**

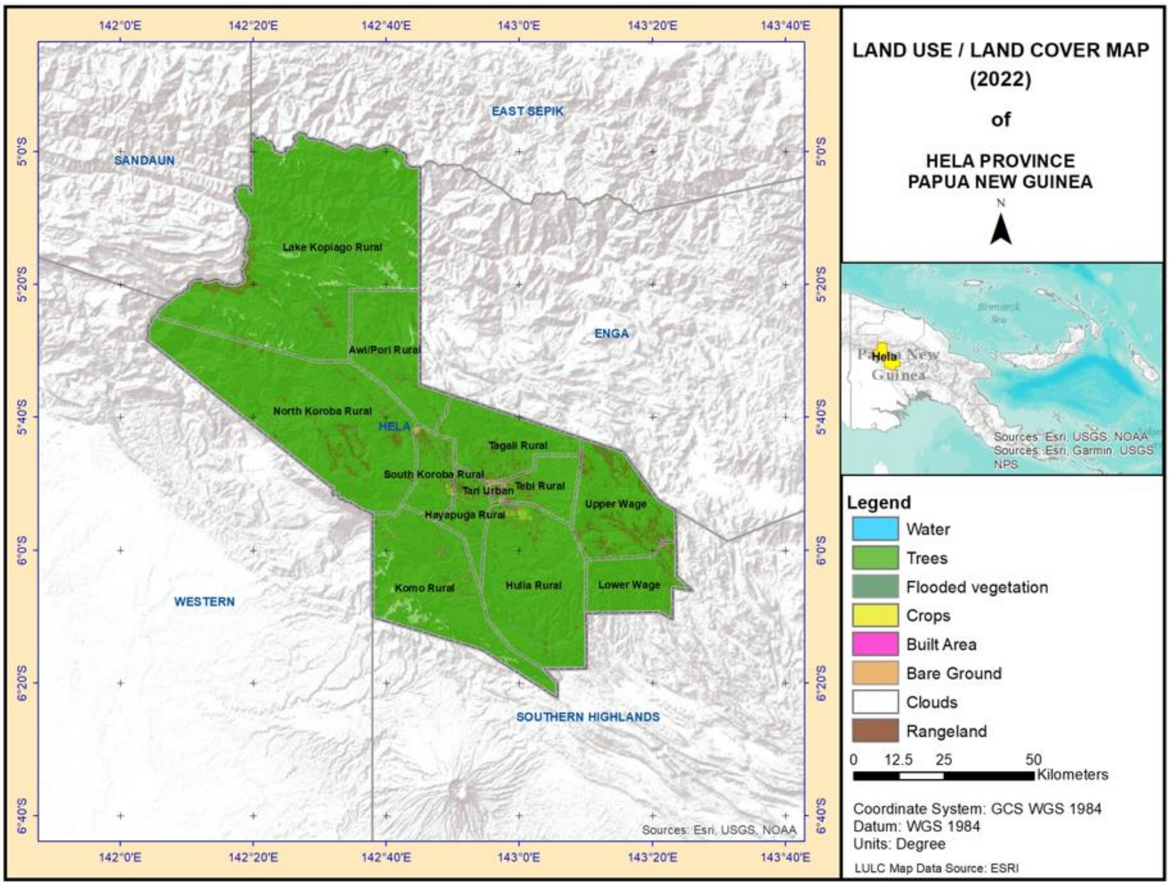



**Figure 4-3. Land use/land cover map of Hela Province**

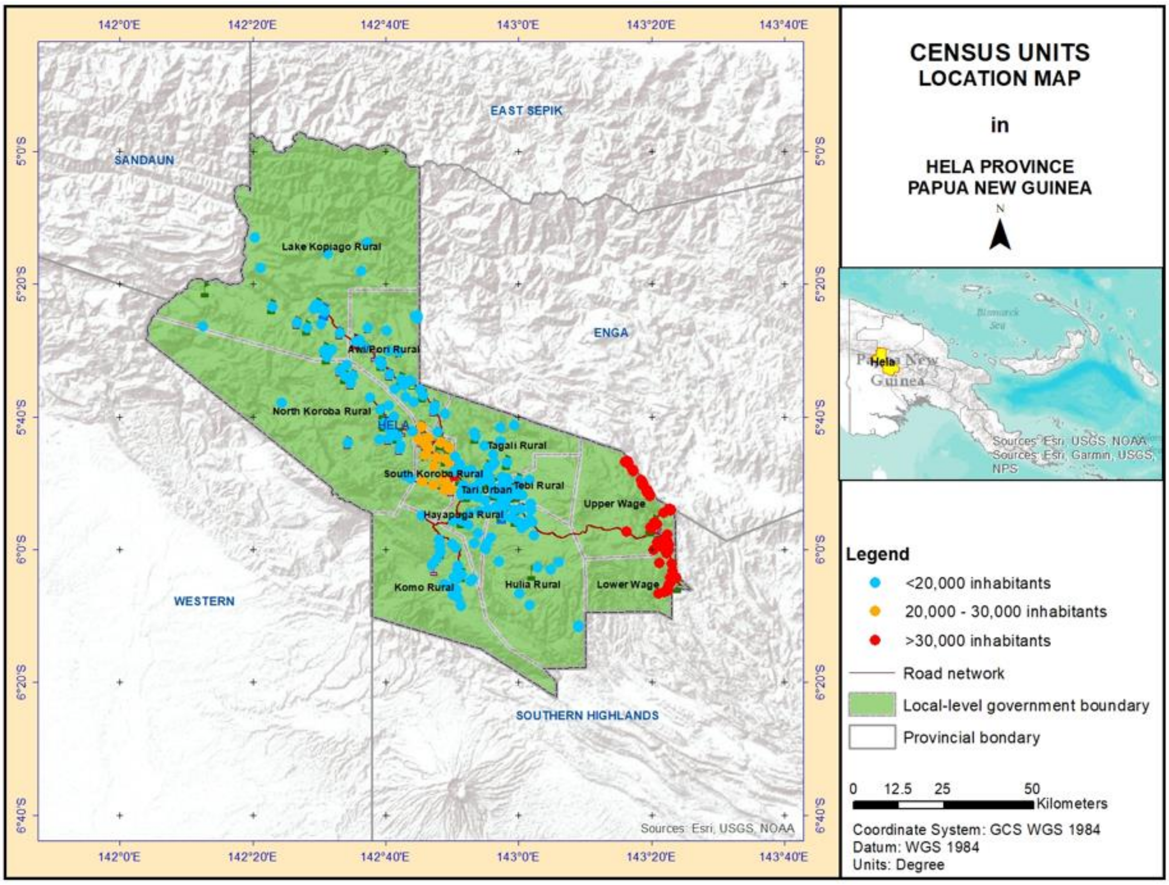



**Figure 4-4. Settlement areas in Hela Province**

**Table 4-1. Province boundaries and population data**

| District | District Capital | LLG | Population | Area | Density |
|---|---|---|---|---|---|
| Komo/ Magarima District | Magarima | • Hulia Rural | 41,642 | 1,115.70 | 37.32 |
| | | • Komo Rural | 18,907 | 1,041.36 | 17.38 |
| | | • Lower Wage | 20,654 | 408.07 | 50.61 |
| | | • Upper Wage | 14,950 | 670.91 | 22.28 |
| | | Total | 96,153 | 3236.04 | 127.59 |
| | | Percentage/Average | 38.55% | 33.14% | 31.90 |
| Korobo/ Kopiago District | Korobo | • Awi/Pori Rural | 21,198 | 617.12 | 34.35 |
| | | • Lake Kopiago Rural | 18,088 | 2,745.81 | 6.59 |
| | | • North Koroba Rural | 13,631 | 1,850.87 | 7.36 |
| | | • South Koroba Rural | 20,928 | 253.86 | 82.44 |
| | | Total | 73,845 | 5,467.66 | 130.74 |
| | | Percentage/Average | 29.60% | 55.99% | 32.69 |
| Tari/Pori District | Tari | • Hayapuga Rural | 18,047 | 235.23 | 76.72 |
| | | • Tagali Rural | 10,672 | 534.94 | 19.95 |
| | | • Tari Urban | 39,279 | 22.27 | 1,763.76 |
| | | • Tebi Rural | 11,443 | 268.08 | 42.69 |
| | | Total | 79,441 | 1,060.52 | 1,903.12 |
| | | Percentage/Average | 31.85% | 10.87% | 475.78 |

The table shows that population density across the LLGs range between a low of 6.59 persons per km$^2$ in Lake Kopiago Rural to as high as 1,763.76 persons per km$^2$ in Tari Urban. Figure 4-5 compares the population with road length as well as the number of health and learning facilities in each LLG.

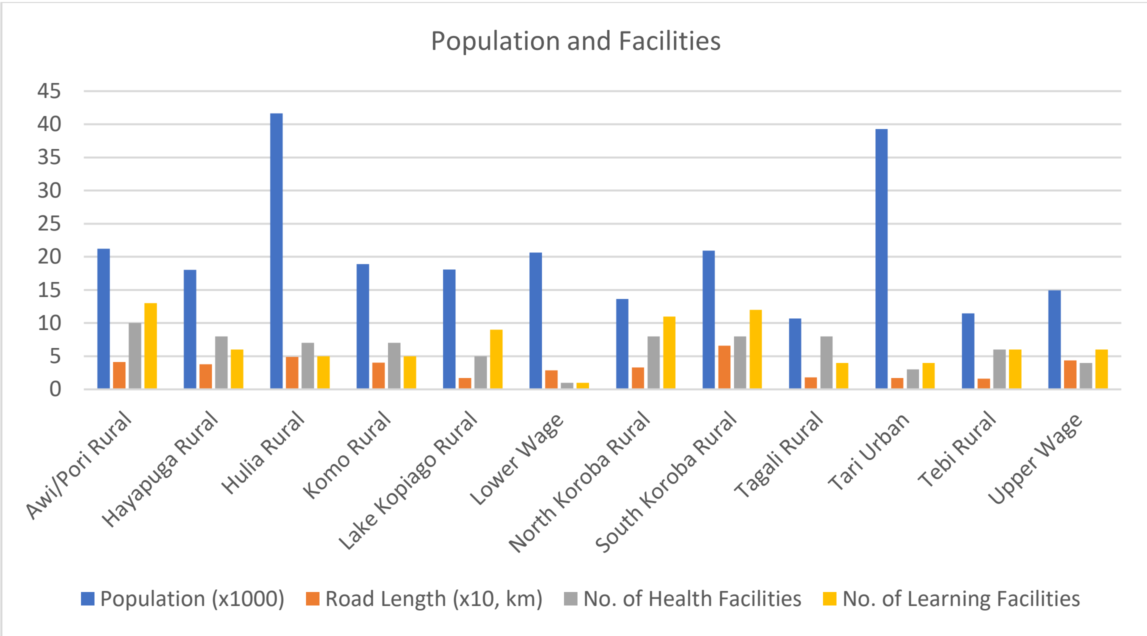



**Figure 4-5. Population and facilities in Hela Province**

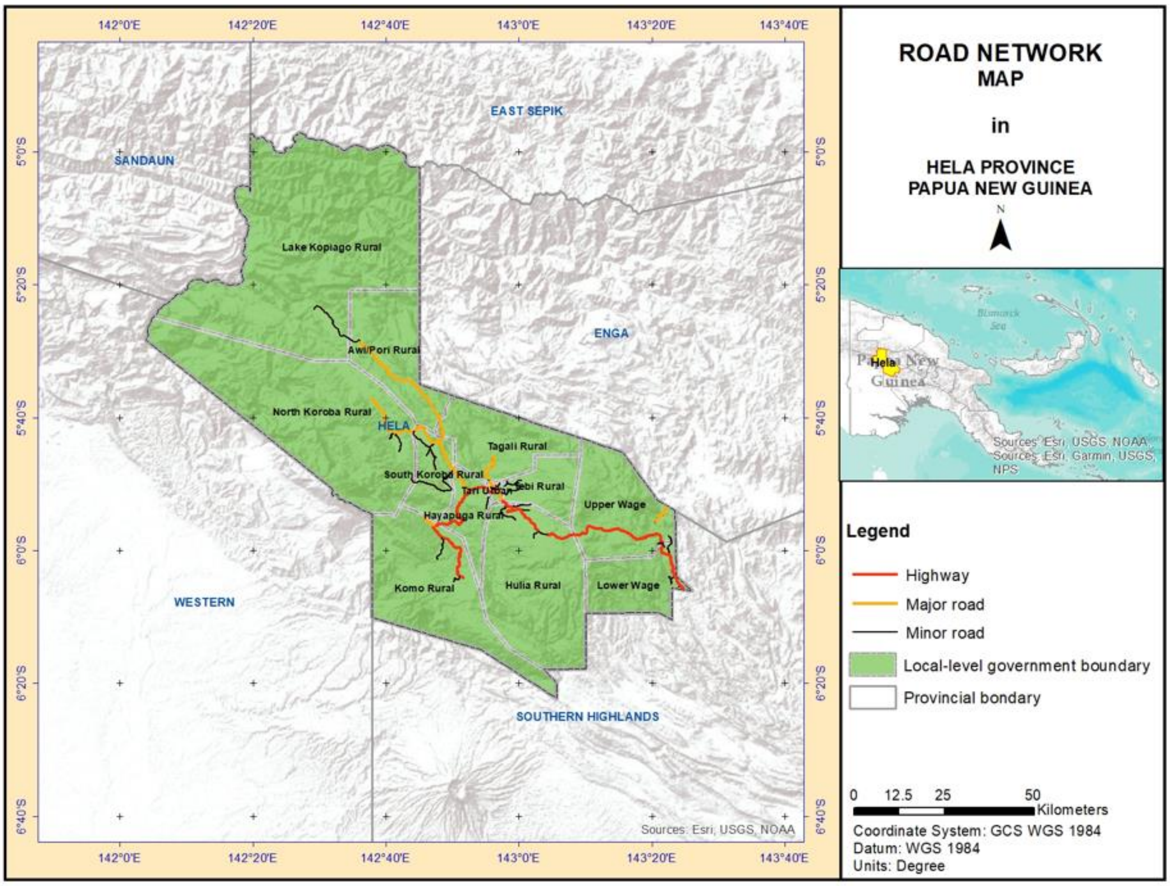



**Figure 4-6. Road network in Hela Province**

In total, Hela has 407 kilometers of road length, 75 health facilities, and 82 learning facilities. Lower Wage has the lowest number of health and learning facilities at only one (1) of each. In contrast, the LLG of Awi/Pori Rural has the highest number of health (10) and learning facilities (13). This is followed by North and South Koroba with 11 and 12 learning facilities respectively. South Koroba also has more than 65 kilometers of road, the highest in the province.

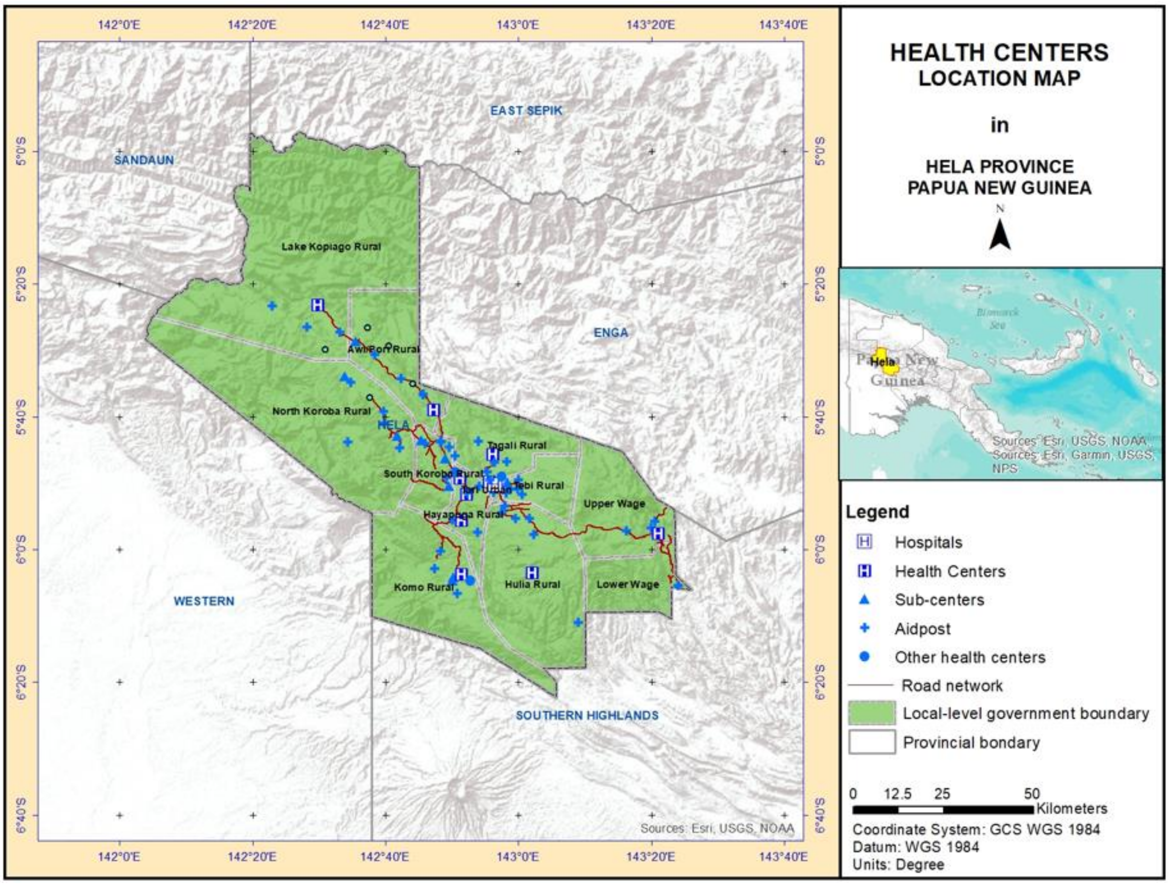



**Figure 4-7. Health facilities in Hela Province**

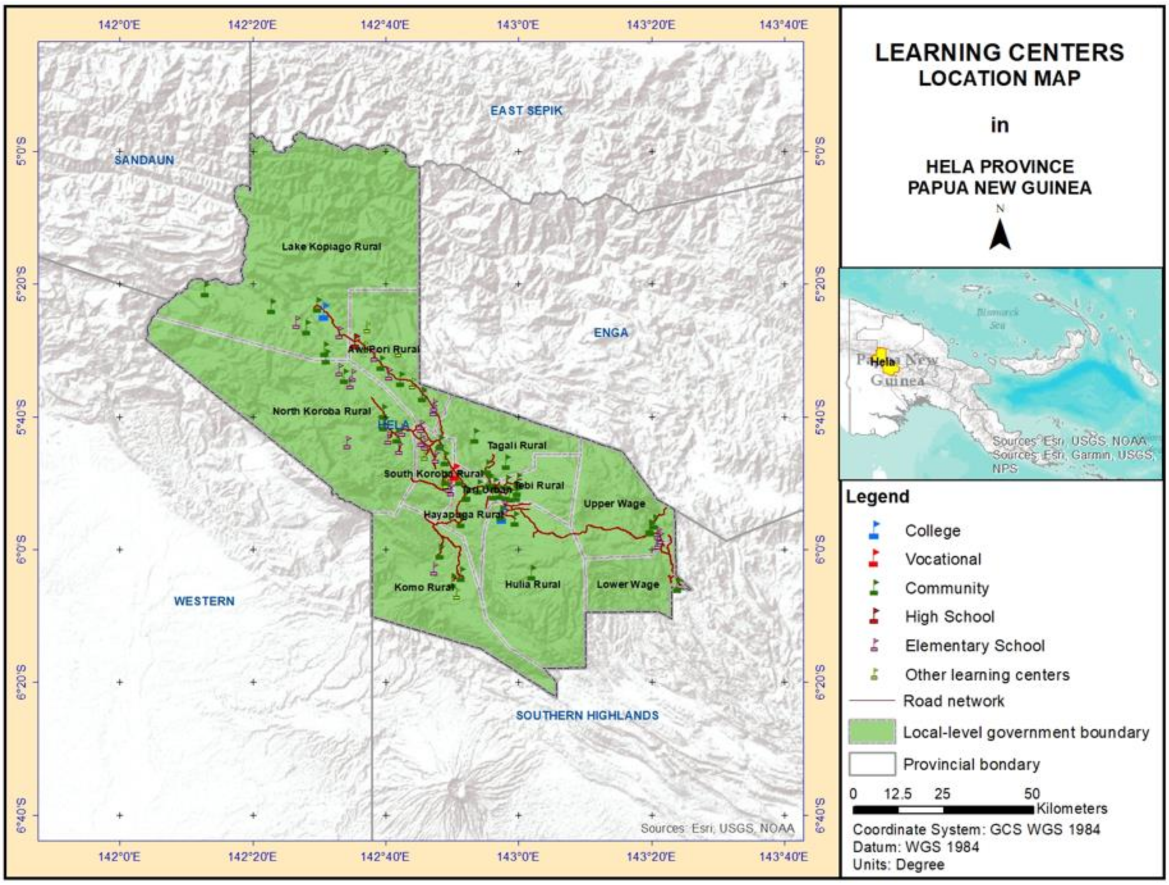



**Figure 4-8. Learning facilities in Hela Province**

The figures show that roads, health centers and schools are established across Hela, generally in Tari and nearby LLGs. Figure 4-9 shows the average distance of settlements within LLGs to relevant facilities.

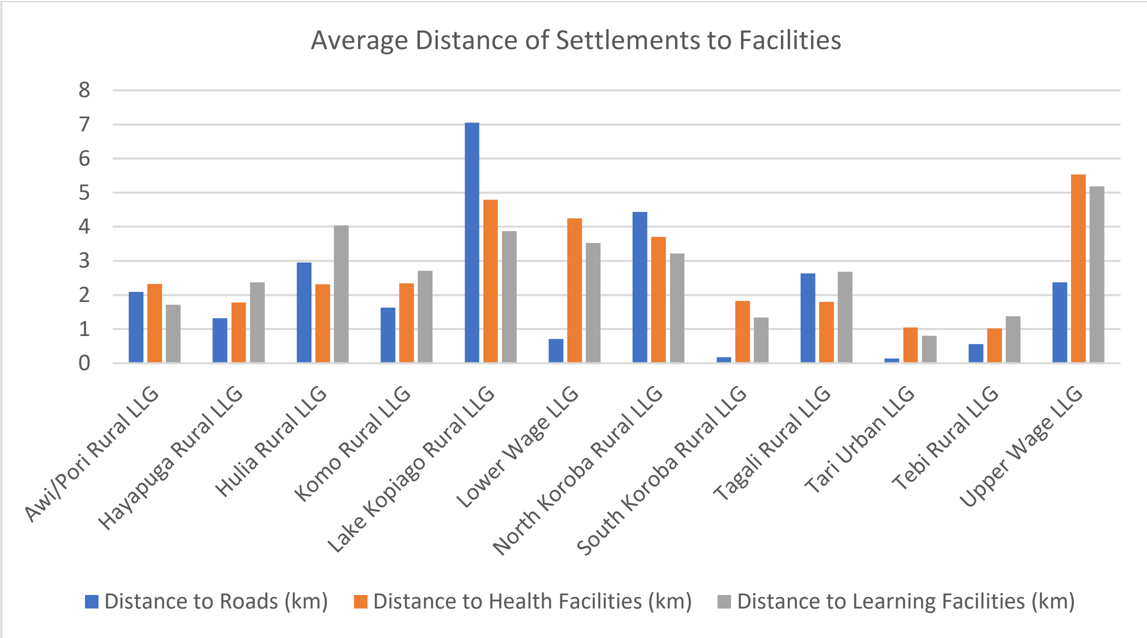



**Figure 4-9. Average distance of settlements to facilities**

The figure above shows the average distance of various settlements within each LLG to roads, health facilities, and learning facilities. Settlements in Lake Kopiago Rural, Upper Wage and North Koroba Rural are the farthest to critical facilities. On average, people living in Lake Kopiago Rural are seven (7) kilometers away from roads, while those in Upper Wage are more than five (5) kilometers away from health and learning facilities.

## 4.2. Climate Trends and Projections

Hela receives an average of 3,203mm of rainfall annually, spatially varying between 2,436mm to 4,518mm across the province with Koroba-Kopiago district receiving more rainfall than others. The maximum temperature in the province varies from 15 to 26.5°C while minimum temperature varies between 3°C and 22°C. The lowest temperature is observed during the month of August. Figure 4-10 shows the monthly rainfall, and maximum and minimum temperatures, while Figure 4-11 shows the spatial variation of annual rainfall in the province. In general, precipitation in the province is expected to increase in the future (see Figure 4-12).

- **Precipitation in Near Future (2023-2048)**. Under SSP245, precipitation is expected to increase by about 10.69% (320mm), varying spatially from 7% to 15% across the province. The average percentage change in precipitations is higher at 13.52% with province-specific variations ranging from 11% to 16% under the SSP585 scenario.
- **Precipitation in Mid Future (2049-2074)**. Precipitation is expected to increase by 13.93%, with spatial variation of 10% to 20% under SSP245, while in SSP585 scenario the precipitation is projected to rise by 17.02% with spatial variation of 13% to 23%.
- **Precipitation in Far Future (2075-2100)**. Precipitation is expected to increase by 16.39% under SSP245, and by 26% under SSP585 scenario. The spatial variation is from 14% to 20%, and 23% to 33% for SSP245 and SSP585 respectively.

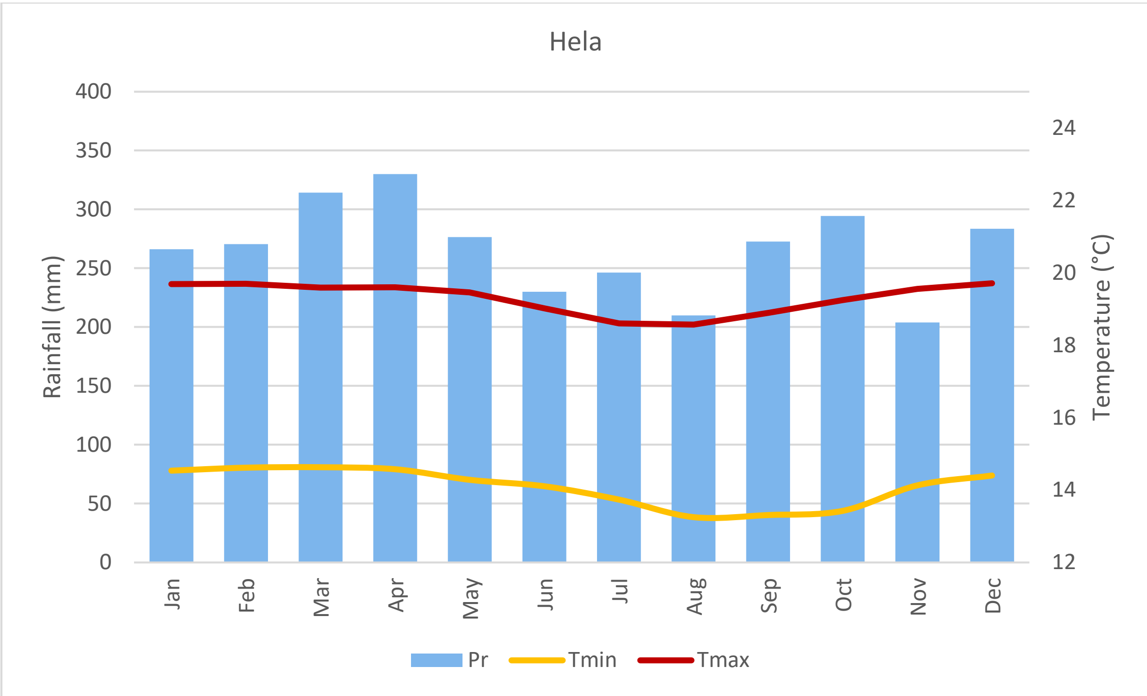



**Figure 4-10. Average monthly rainfall, max and min temperatures in Hela, 1995–2020**

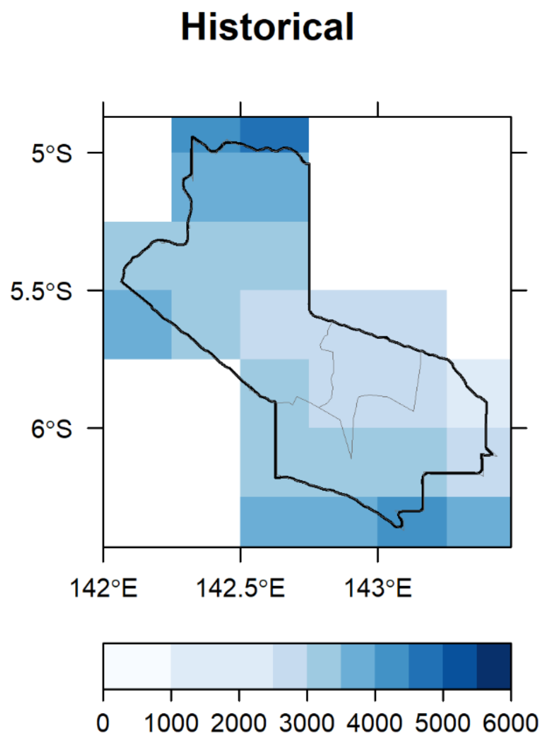



**Figure 4-11. Spatial variation of annual rainfall**

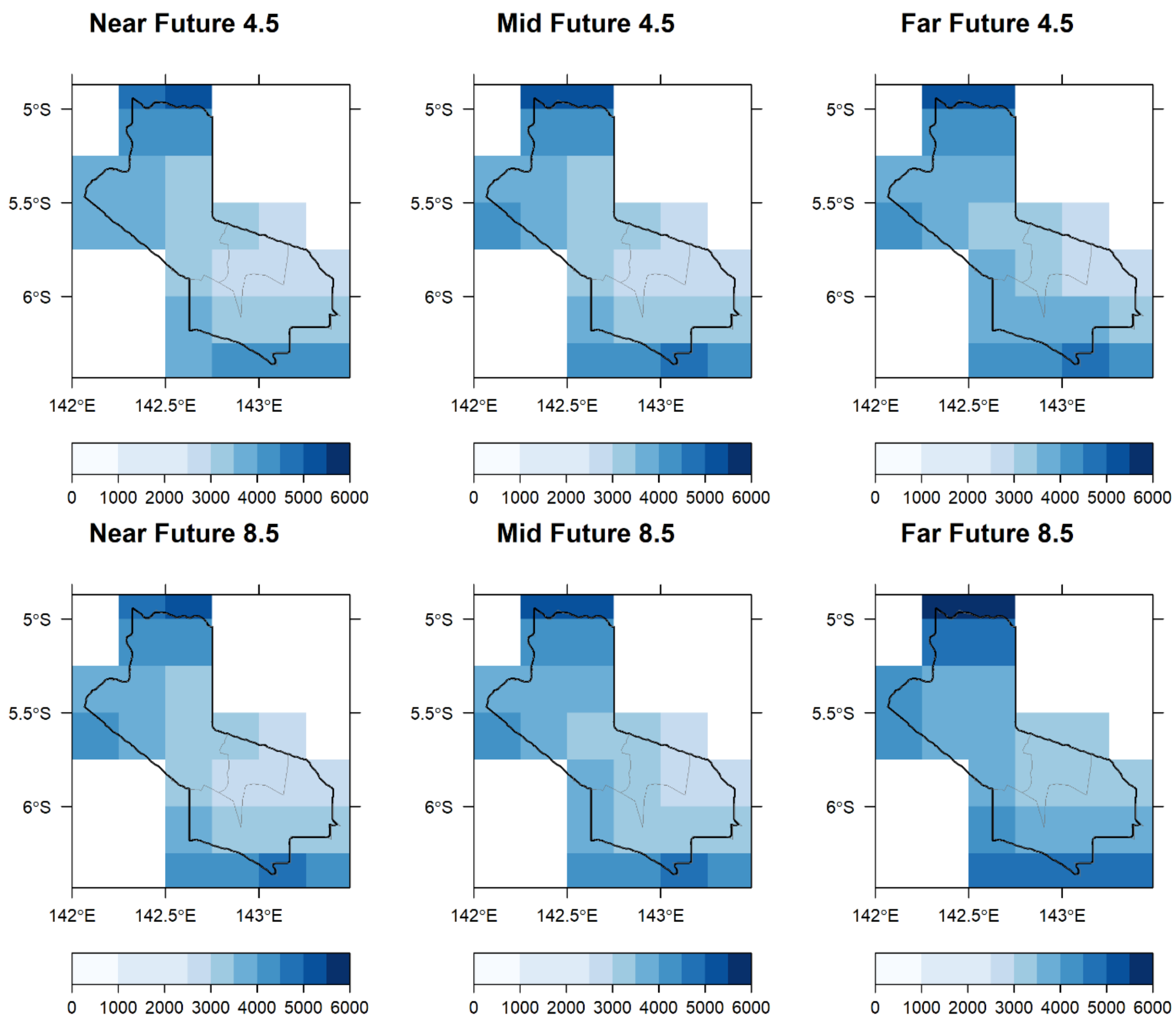



Figure 4-12. Average annual precipitation in Hela, near, mid and far future under SSP245 and SSP585

The mean annual maximum temperature in Hela ranges from 14.68°C to 24.89°C. In general, the average maximum temperature is expected to increase in the future. Figure 4-13 shows maximum temperatures for baseline, near, mid, and far future under SSP245 and SSP585.

- **Maximum Temperature in Near Future (2023-2048)**. Under SSP245, maximum temperature is expected to increase by about 0.68°C, with province-specific variation ranging from 0.54°C to 0.85°C. Under SSP585 scenario, maximum temperature is expected to rise by 0.8°C, varying spatially from 0.64°C to 1 °C.
- **Maximum Temperature in Mid Future (2049-2074)**. Average maximum temperature is expected to increase by 1.11°C, with spatial variation of 0.9°C to 1.38°C under SSP245, while in SSP585 scenario the average maximum temperature is projected to rise by 1.64°C, with spatial variation of 1.34°C to 2.02°C.
- **Maximum Temperature in Far Future (2075-2100)**. Maximum temperature is expected to increase by 1.23°C under SSP245, and by 2.37°C under SSP585 scenario. The spatial variation is from 0.9°C to 1.32°C, and 1.94°C to 2.84°C for SSP245 and SSP585 respectively.

Similarly, the mean annual minimum temperature in Hela ranges from 11.07°C to 21.81°C. In general, the average minimum temperature is expected to increase with the western part of Hela experiencing slightly warmer cold nights in the future. Figure 4-14 shows minimum temperatures for baseline, near, mid, and far future under SSP245 and SSP585.

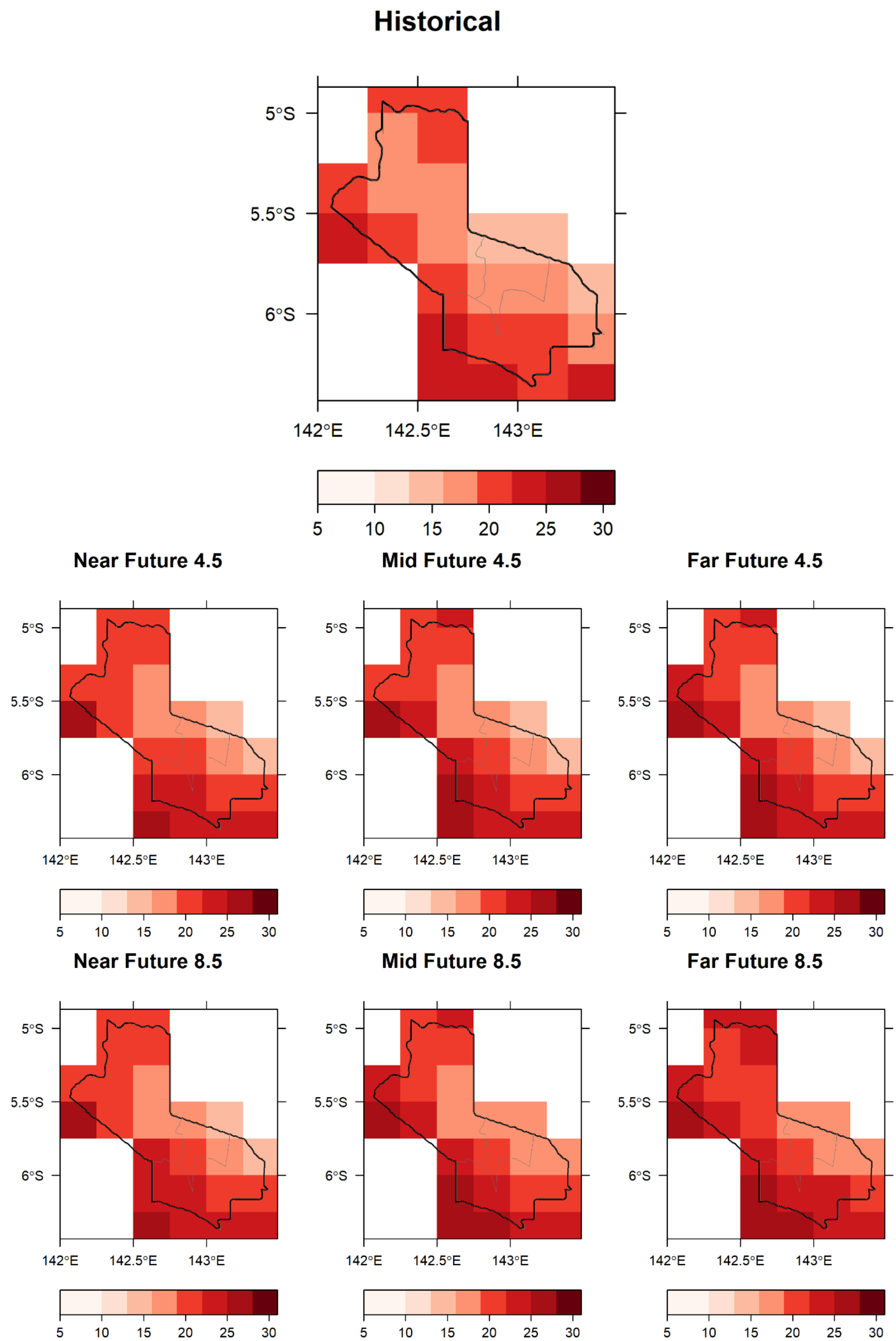



Figure 4-13. Average annual maximum temperature in Hela, near, mid and far future under SSP245 and SSP585

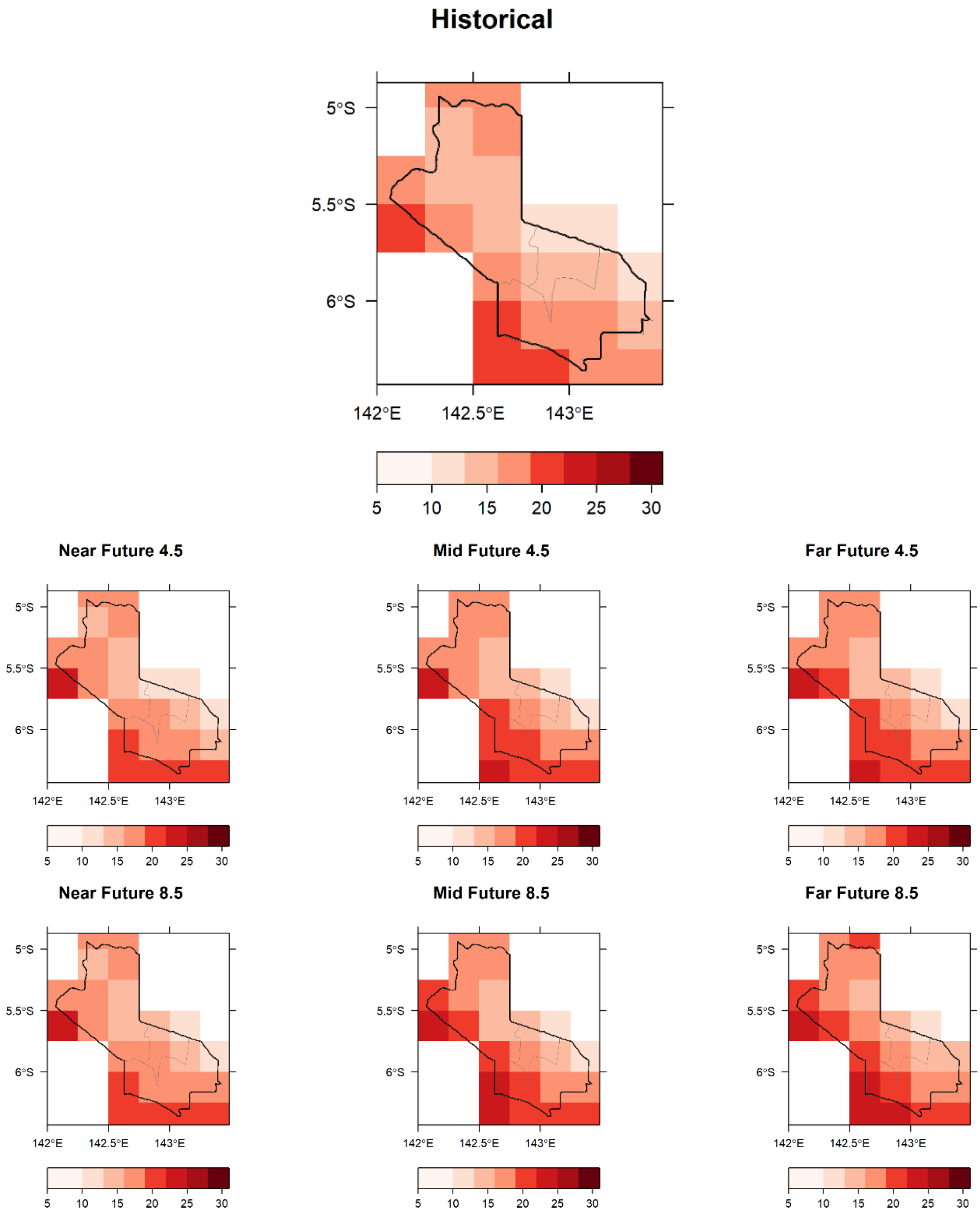
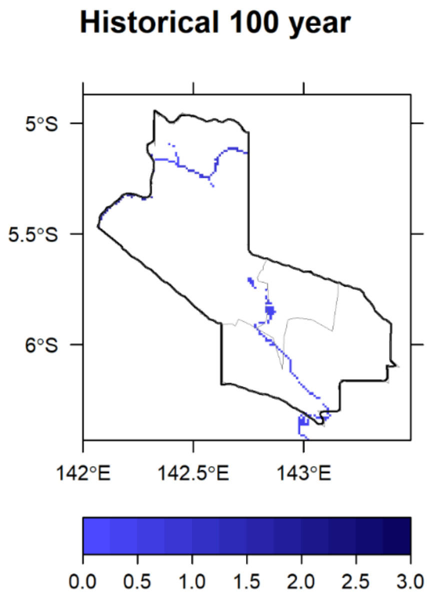



**Figure 4-14. Average annual minimum temperature in Hela, near, mid and far future under SSP245 and SSP585**

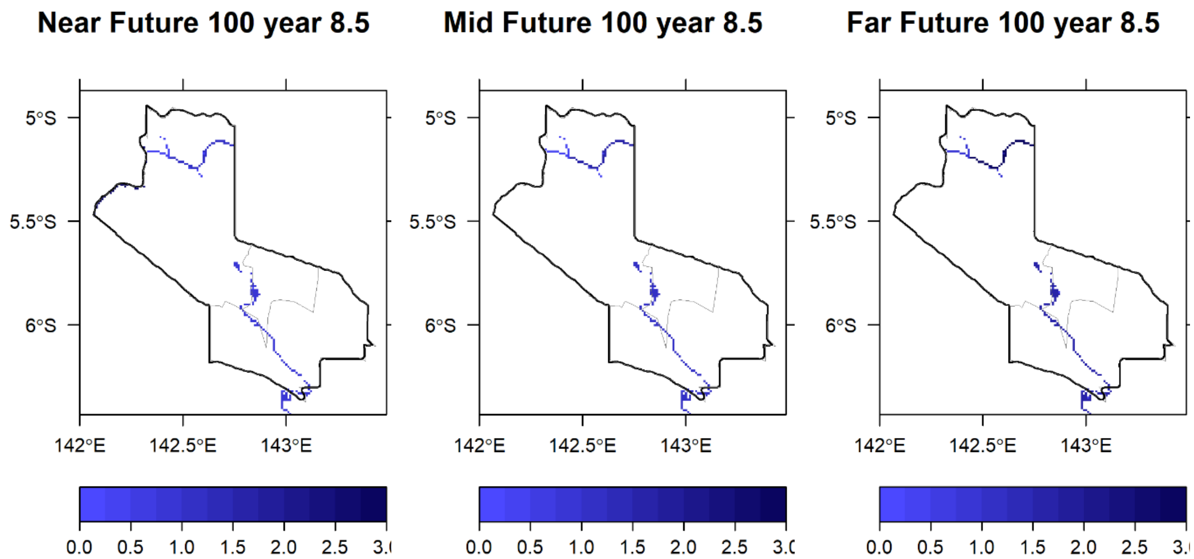
- **Minimum Temperature in Near Future (2023-2048)**. Under SSP245, minimum temperature is expected to increase by about 0.52°C, with province-specific variation ranging from 0.38°C to 0.72°C. Under SSP585 scenario, minimum temperature is expected to rise by 0.62°C, varying spatially from 0.45°C to 0.84°C.
- **Minimum Temperature in Mid Future (2049-2074)**. Average minimum temperature is expected to increase by 0.91°C, with spatial variation of 0.7°C to 1.21°C under SSP245, while in SSP585 scenario the average minimum temperature is projected to rise by 1.38°C, with spatial variation of 1.09°C to 1.76°C.
- **Minimum Temperature in Far Future (2075-2100)**. Minimum temperature is expected to increase by 0.99°C under SSP245, and by 2.1°C under SSP585 scenario. The spatial variation is from 0.77°C to 1.29°C for SSP245.

## 4.3. FLOOD

The baseline for maximum flood depth In Hela for a 100-year return period flood event is 1.66m. The ensemble model indicates that the maximum depth in the future will increase by 0.33m to 0.75m under SSPRCP4.5 scenario and by 0.3m to 1.38m for SSPRCP8.5 scenario. Figure 4-15 shows the spatial extent of the 100-year return period flood, while Table 4-2 indicates the flood area and depth for baseline in the near, mid, and far future.




GFDL-ESM2M model projected flood depth and area




2.5 m depth (1.72 sq km) > 3m depth(3.43 sq km) > 3m depth (4.29 sq km)

**Figure 4-15. Flood depth and extent for 100-year return period flood in Hela for baseline, near, mid, and far future**

**Table 4-2. Flood depth (m) and area (sqkm) for 100-year flood in Hela for baseline, near, mid, and far future**

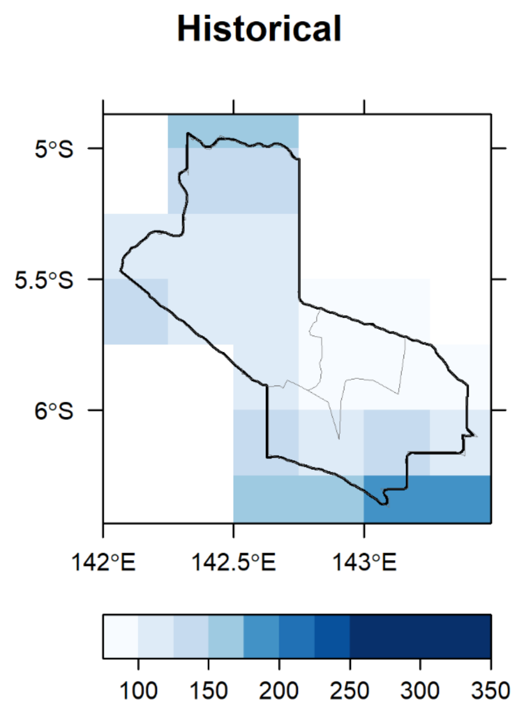
| | SSPRCP4.5 | | | SSPRCP8.5 | | |
|---|---|---|---|---|---|---|
| Scenario | Near | Mid | Far | Near | Mid | Far |
| Historical depth | 1.66m (215.62sqkm) | | | | | |
| NorESM1-M | 2.05m (215.62sqkm) | 1.77m (215.62sqkm) | 1.96m (215.62sqkm) | 2.05m (215.62sqkm) | 1.95m (215.62sqkm) | 2.66m (216.48sqkm) |

| Scenario | SSPRCP4.5 Near | Mid | Far | SSPRCP8.5 Near | Mid | Far |
|---|---|---|---|---|---|---|
| GFDL-ESM2M | 2.63m (217.34sqkm) | 2.60m (217.34sqkm) | 3.58 (219.05sqkm) | 2.50m (217.34sqkm) | 3.32m (219.05sqkm) | 5.41m (219.91sqkm) |
| HadGEM2-ES | 1.60m (215.62sqkm) | 1.95m (215.62sqkm) | 1.95 (215.62sqkm) | 1.74m (215.62sqkm) | 1.92m (215.62sqkm) | 1.90m (215.62sqkm) |
| IPSL-CM5A-LR | 2.50m (216.48sqkm) | 2.64m (217.34sqkm) | 3.36 (218.20sqkm) | 2.19m (216.48sqkm) | 2.64m (216.48sqkm) | 3.88m (216.48sqkm) |
| MIROC-ESM-CHEM | 1.18m (215.62sqkm) | 1.19m (215.62sqkm) | 1.20 (215.62sqkm) | 1.33 (215.62sqkm) | 1.20m (215.62sqkm) | 1.33m (215.62sqkm) |
| **Average** | **1.99m (216.13sqkm)** | **2.03m (216.31sqkm)** | **2.41 (216.82sqkm)** | **1.96m (216.13sqkm)** | **2.21m (216.48sqkm)** | **3.04m (216.82sqkm)** |

**Five Consecutive Days Rainfall (Rx5day)**. The baseline for Rx5day (Five Consecutive Days Rainfall) for Hela is 118.21mm, with spatial variability of 87.25mm to 162.34mm. In both SSP245 and SSP585 scenarios, trends indicate potential for a significant increase in five-day consecutive rainfall amount in the near, mid, and far future.

- **Rx5day in Near Future (2023-2048)**. Under SSP245, Rx5day is expected to increase by 38.9%, with province-specific variation ranging from 21.44% to 61.44%. Under SSP585 scenario, Rx5day is expected to rise by 44.94%, varying spatially from 33.58% to 69.79.
- **Rx5day in Mid Future (2049-2074)**. Rx5day is expected to increase by 38.57%, with spatial variation of 30.61% to 54.75% under SSP245, while in SSP585 scenario Rx5day is projected to rise by 45.07%, with spatial variation of 33.93% to 60.23%.
- **Rx5day in Far Future (2075-2100)**. Rx5day is expected to increase by 44.9% (36.13-55.59%) under SSP245, and by 56.09% (45.08-69.48%) under SSP585 scenario.

Figure 4-16 shows the highest five-day precipitation amount in Hela for baseline, near, mid, and far future under SSP245 and SSP585.



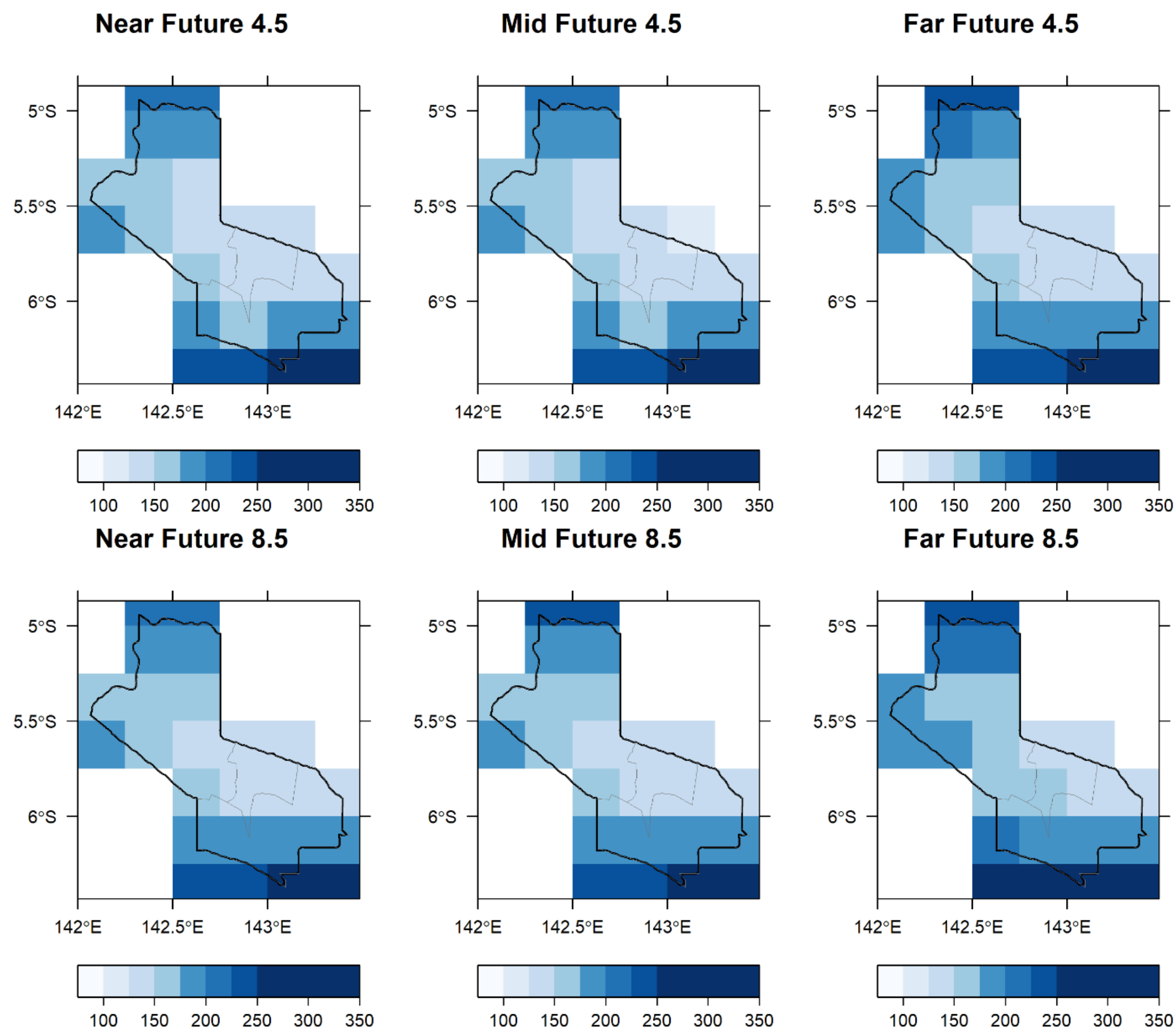



Figure 4-16. Five consecutive days rainfall in Hela for baseline in mm, and percentage increase for near, mid, and far future under SSP245 and SSP585

**Number of Extremely Wet Days (R99p)**. Hela has a baseline R99p value of 92mm. In the SSP245 scenario, the projected R99p values range between 71mm to 127mm for near to far future. In the SSP585 scenario, the R99p values range between 57mm to 218mm for near to far future. This indicates potential increase of 20% to 266% compared to the baseline.

Table 4-3. Increase in R99p from baseline value

| Scenario | Near | Mid | Far |
|---|---|---|---|
| Baseline | | 92mm (62 to 130mm) | |
| SSP245 | 71mm (25 to 141mm) | 98mm (53 to 143mm) | 127mm (68 to 164mm) |
| SSP585 | 57mm (20 to 158mm) | 112mm (56 to 198mm) | 218mm (143 to 266mm) |

**Maximum One Day Rainfall and Consecutive Wet Days (Rx1day and CWD)**. The maximum 1-day precipitation in Hela is projected to increase by 14% to 36%. Similarly, the consecutive wet days is projected to increase by an average of 3 to 5 days.

Table 4-4. Percentage increase in Rx1day, and number of days increase in CWD from baseline

| Scenario | Near | Mid | Far | Near | Mid | Far |
|---|---|---|---|---|---|---|
| Baseline | | Rx1day 49.49mm (36.51-67.69mm) | | | CWD 35 days (27-60 days) | |

| Scenario | Near | Mid | Far | Near | Mid | Far |
|---|---|---|---|---|---|---|
| SSP245 | 20.43% (14.12-34.83%) | 22.14% (18.15-33.12%) | 23.09% (19.27-29.91%) | 4 (-11 to 12) days | 4 (-14 to 10) days | 3 (-14 to 9) days |
| SSP585 | 20.63% (14.49-35.51%) | 24.23% (18.81-36.24%) | 29.82% (25.23-35.58%) | 4 (-8 to 15) days | 2 (-14 to 11) days | 5 (11 to 18) days |

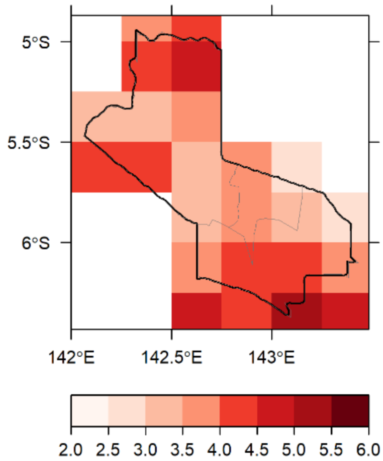
## 4.4. Drought and Frost

The assessment of drought involved analysis of its duration, intensity and severity using SPEI and SPI, while the assessment of frost focused on the analysis of the minimum of minimum temperature (TNN).

### 4.4.1 Drought

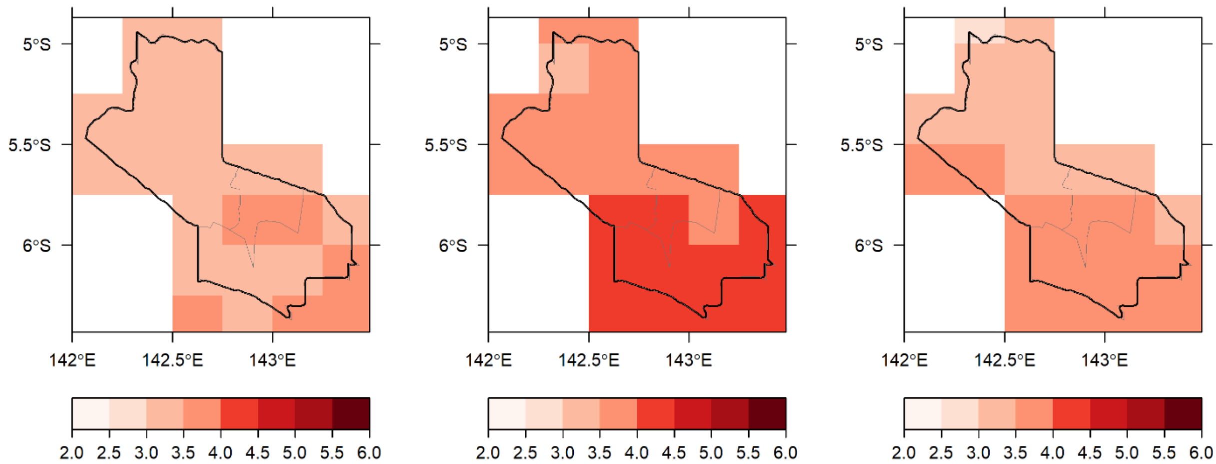
**Duration**. The duration of drought for baseline period is on average 4 months – minimum duration of 2.8 months and maximum duration of 5.14 months. Based on SPEI analysis in the mid future, the duration is projected to increase by more than 2 weeks for both SSP245 and SSP585 scenarios. In the far future, the duration is expected to decrease under SSP245 scenario although it is projected to remain the same under SSP585 scenario.

**Baseline**




**SSP245**

Near Mid Far




**SSP585**

Near Mid Far

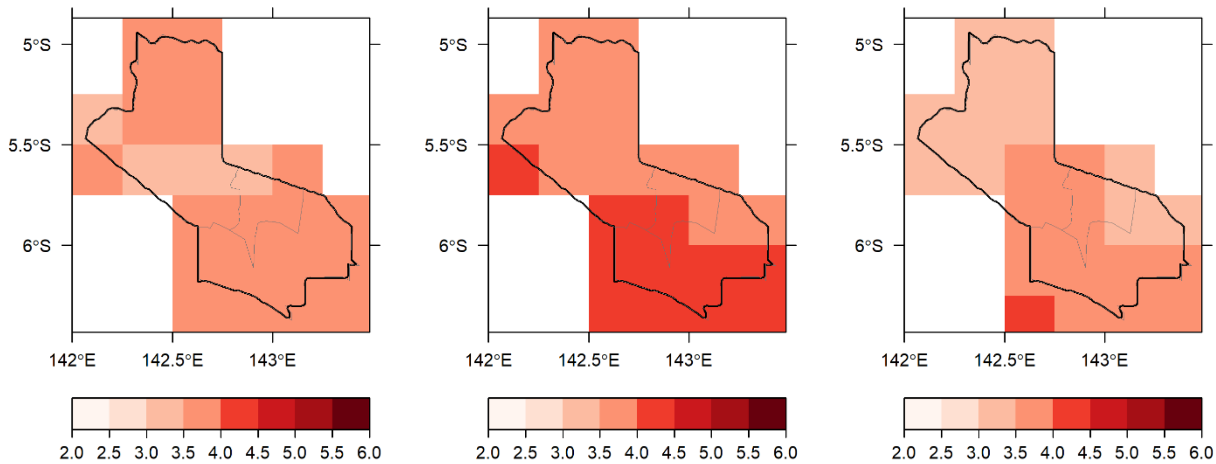
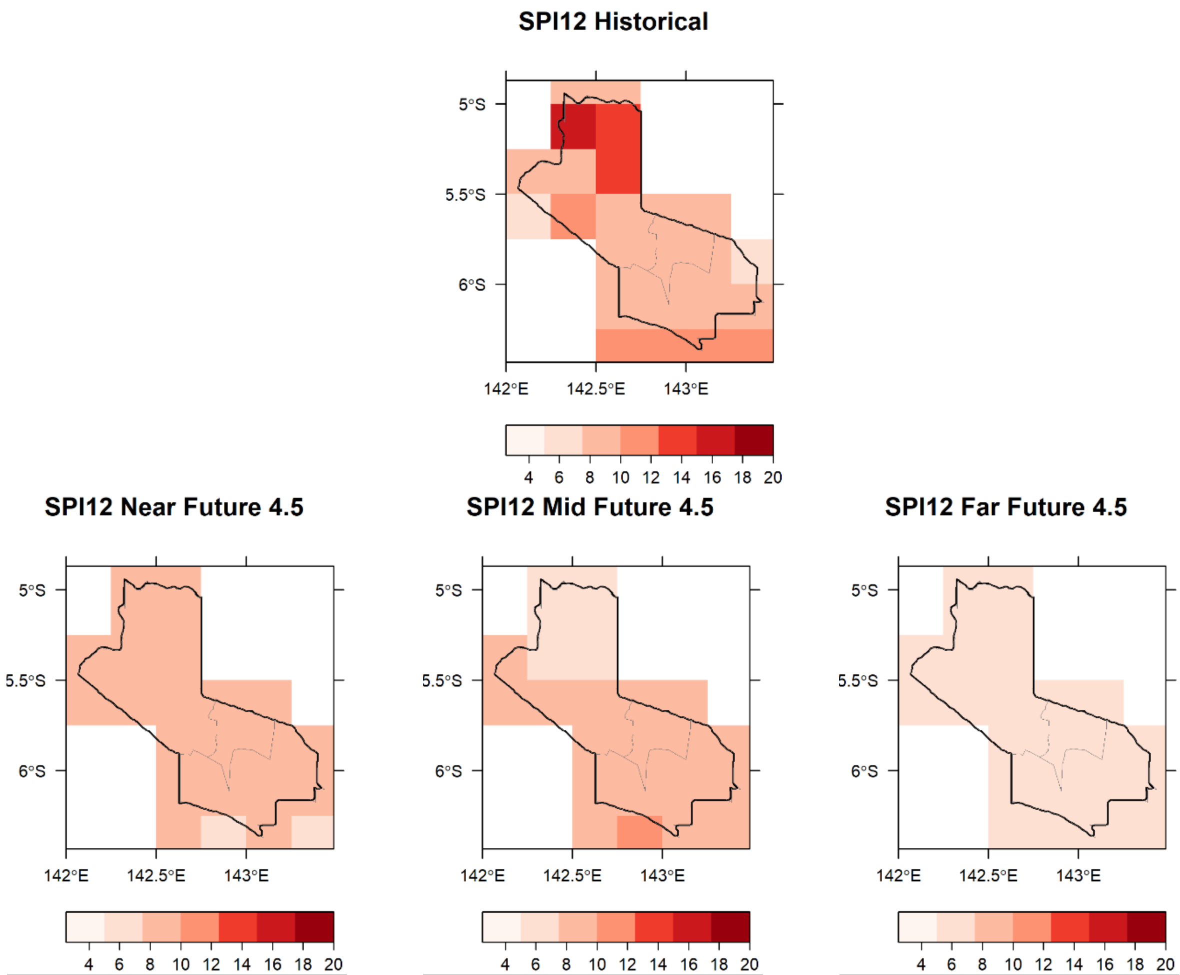



**Figure 4-17. Duration of drought based on SPEI**

Analysis of drought duration based on SPI3, SPI6, and SPI12[9] yielded relatively similar results. Figure 4-18 shows the analysis using SPI12, where the length of drought is expected to become shorter for all scenarios. This means that the period of time during which below-normal precipitation conditions persist will be shorter.




[9] Refer to Appendix 4 for the results of analysis based on SPI.

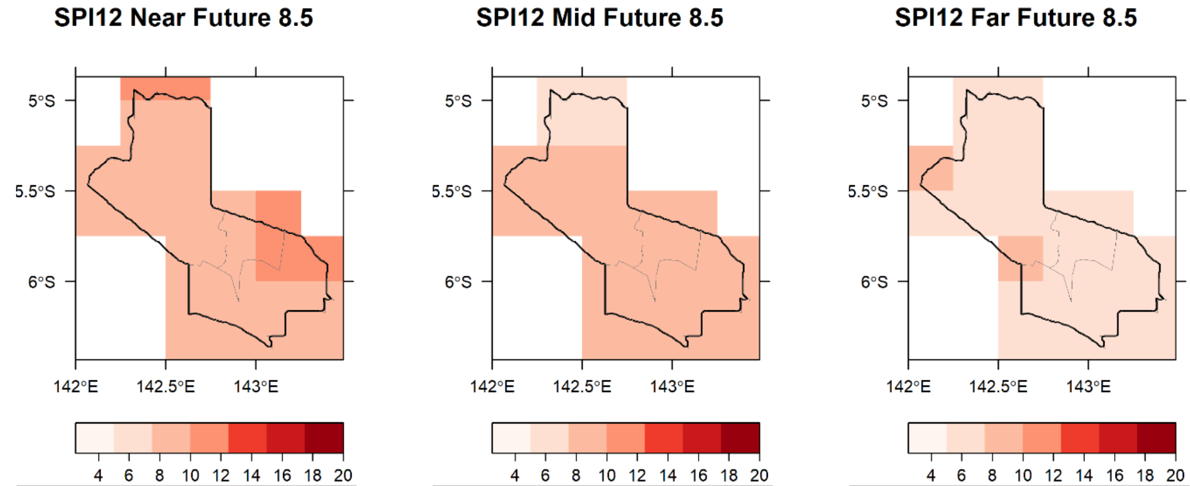
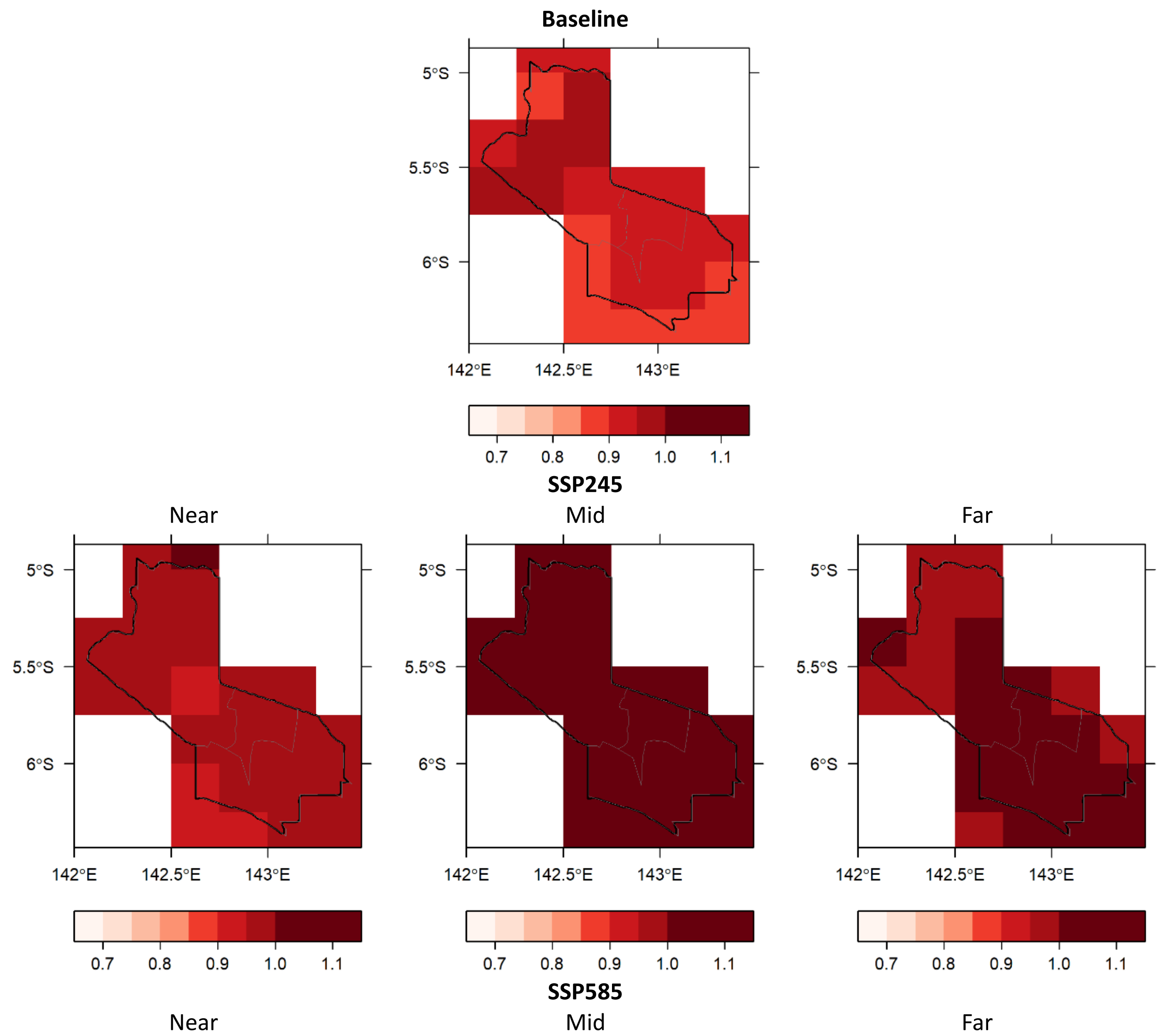



Figure 4-18. Duration of drought based on SPI12

**Intensity**. The overall projections for SSP245 and SSP585 show that the intensity of drought is projected to increase in near, mid, and far future with very high intensity for mid and far future scenarios.



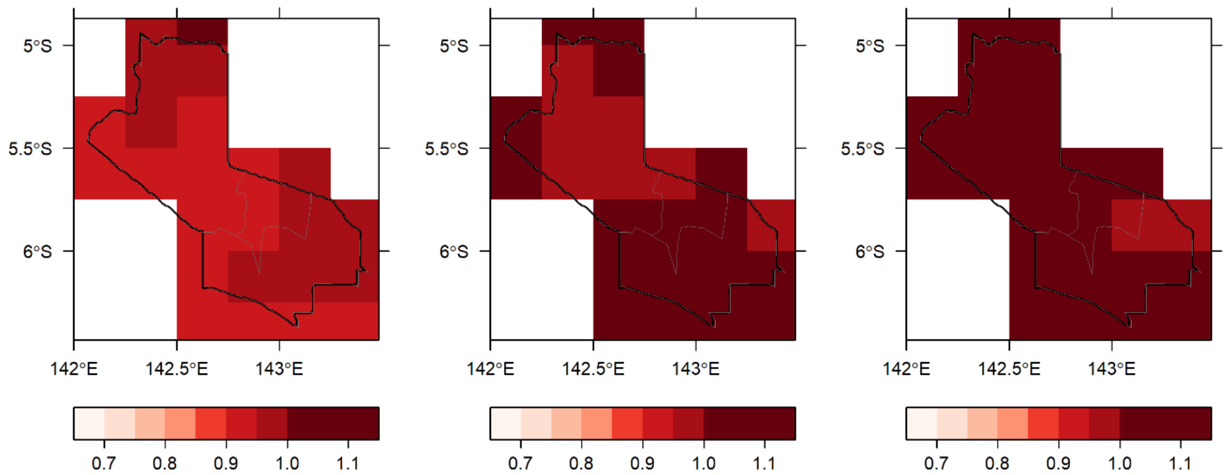
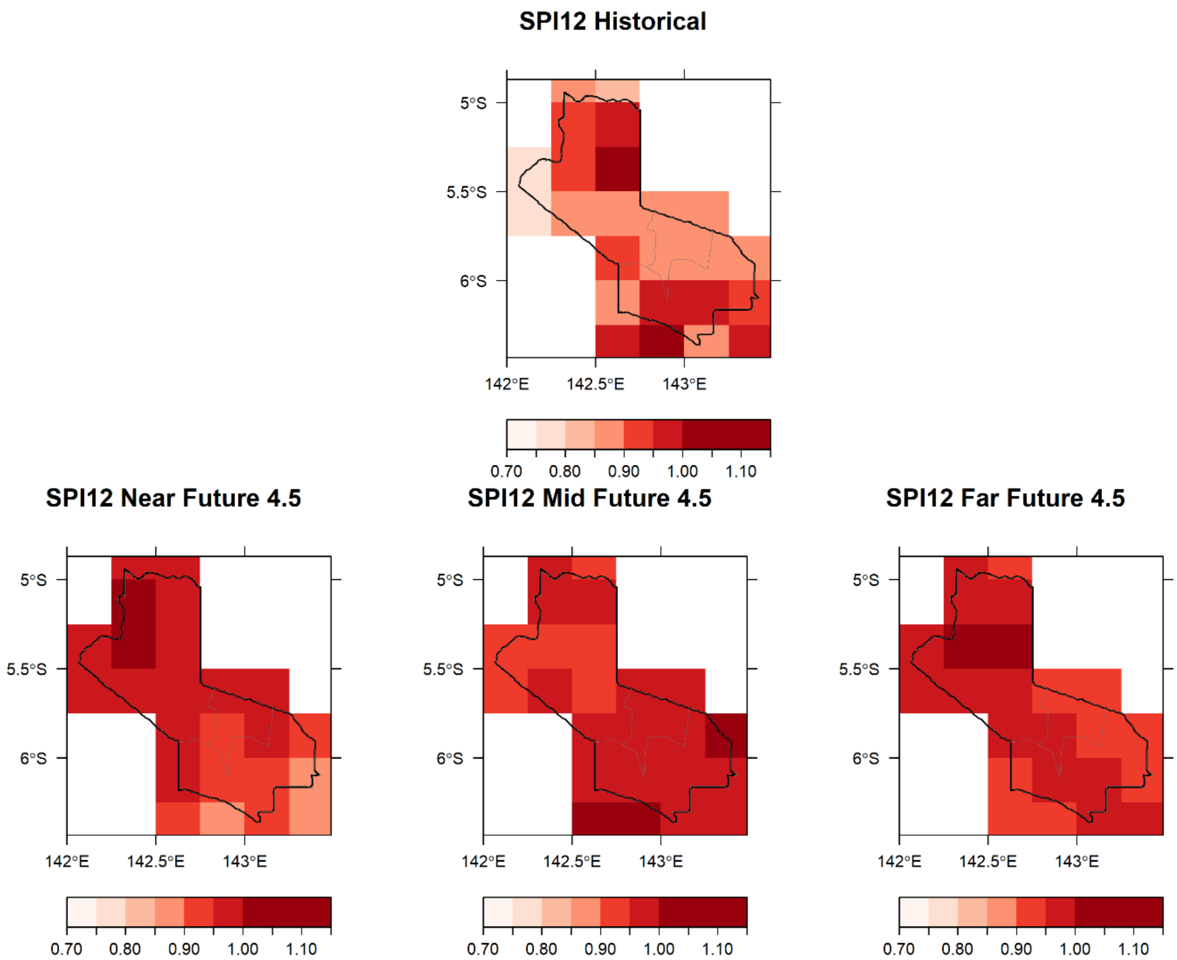



Figure 4-19. Intensity of drought based on SPEI

The analysis of drought intensity based on SPI3, SPI6 and SPI12[10] yielded similar results. In particular, the analysis using SPI3 and SPI6 indicate very intense droughts in the mid and far future for both SSP245 and SSP585 scenarios. For SPI12, the analysis indicates overall more intense drought with slightly less intensity in the far future for SSP585.




[10] Refer to Appendix 5 for the results of analysis based on SPI.

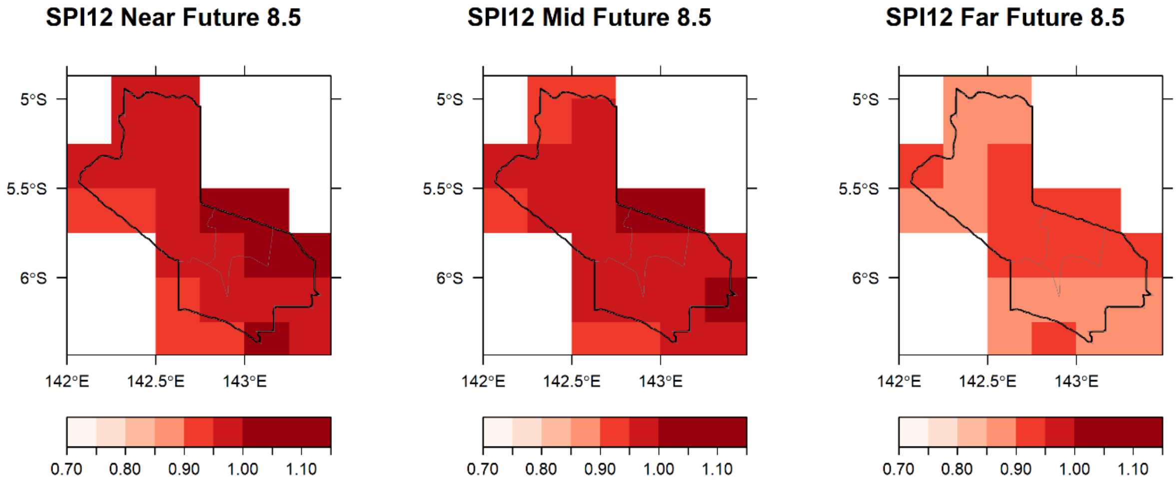
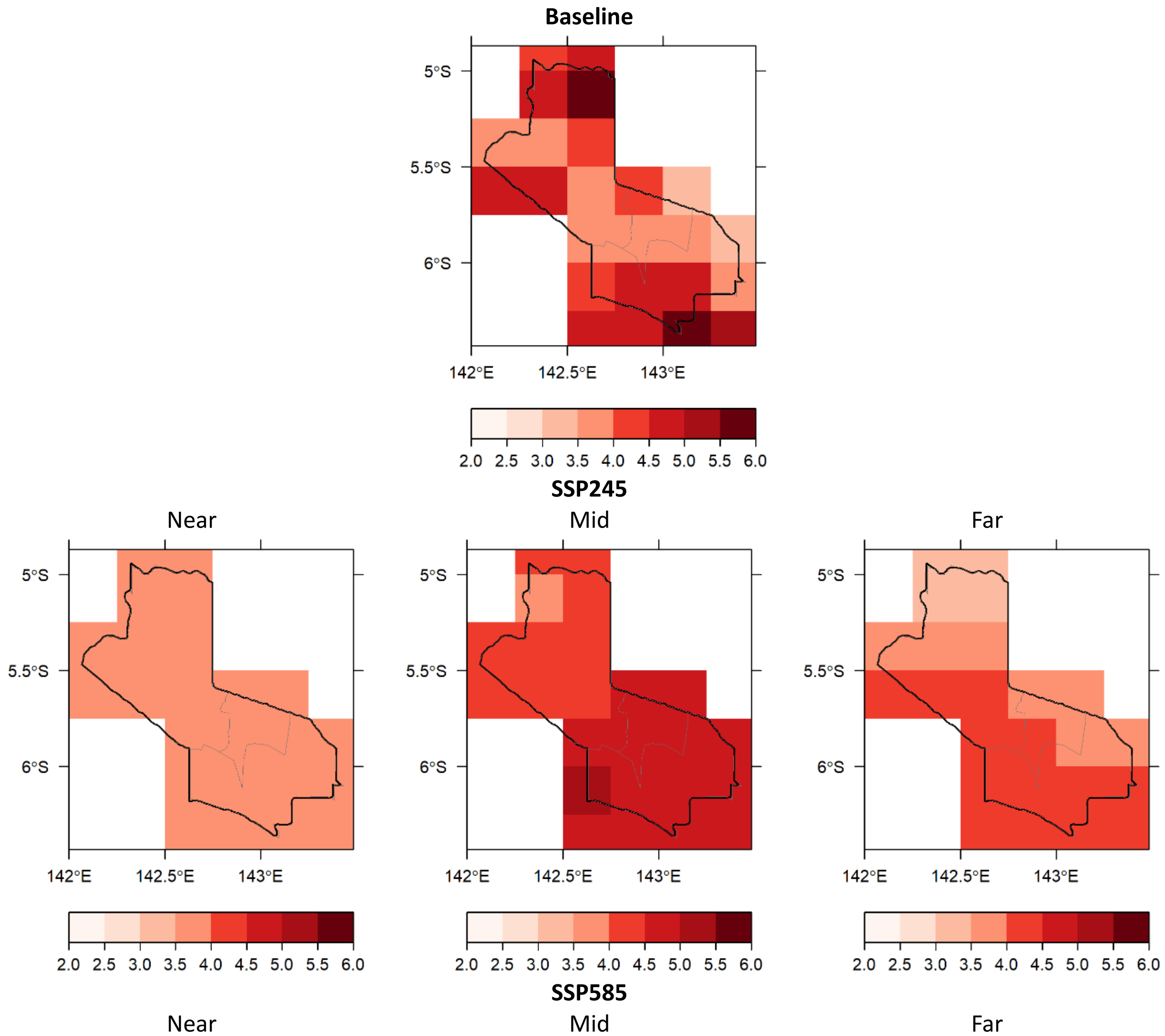


Figure 4-20. Intensity of drought based on SPI12

**Severity**. Based on SPEI analysis, the severity of drought is expected to increase in the mid future, but decrease slightly in the far future in both SSP245 and SSP585 scenarios.



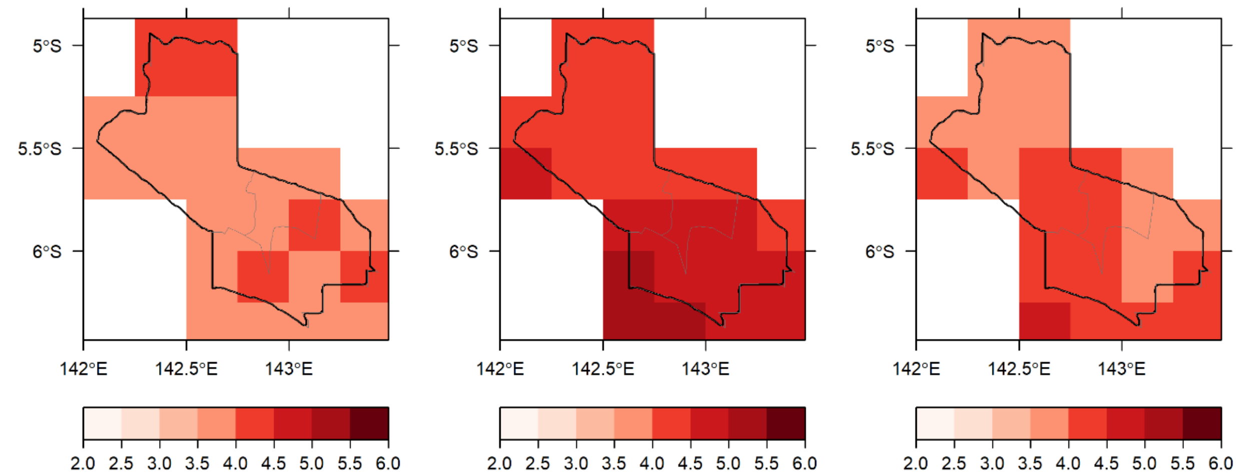
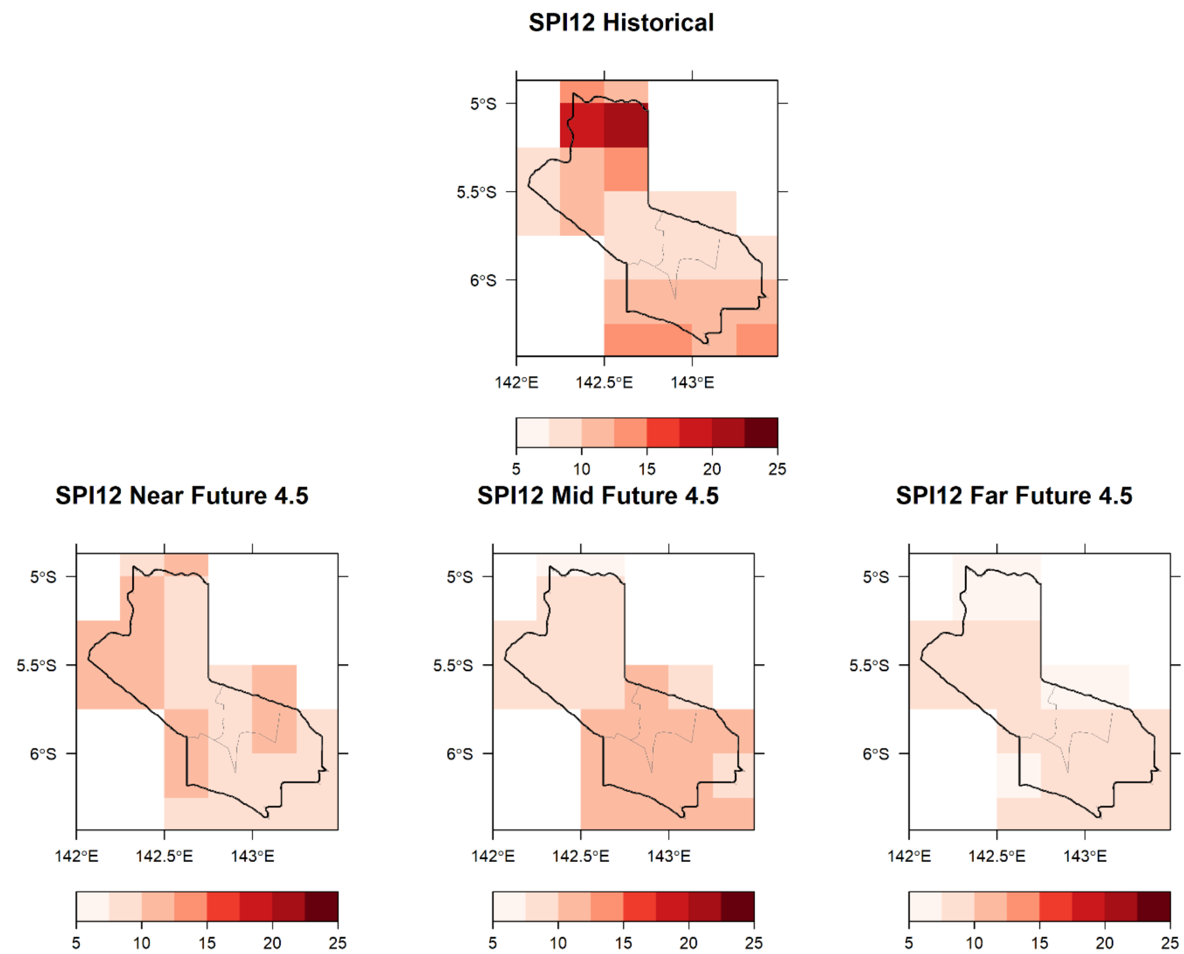



**Figure 4-21. Severity of drought based on SPEI**

Analysis of drought severity based on SPI3, SPI6 and SPI12[11] yielded similar results. In particular, the analysis using SPI3 indicate more severe droughts in the mid future and less severe drought in the far future for both SSP245 and SSP585 scenarios. However, the analysis using SPI6 and SPI12 indicate relatively less severe overall impact for all future scenarios.




[11] Refer to Appendix 6 for the results of analysis based on SPI.

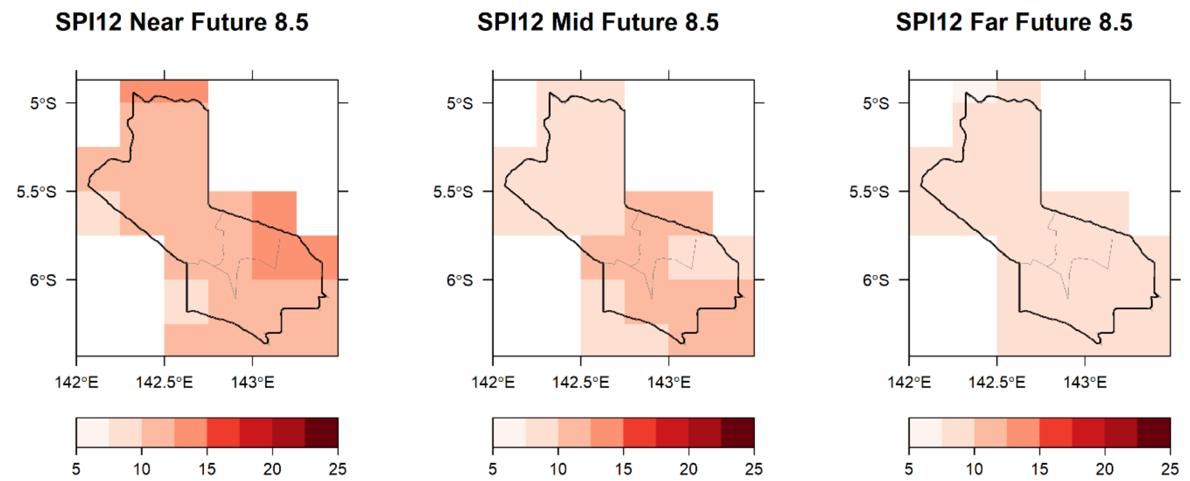


Figure 4-22. Severity of drought based on SPI12

Analysis of the probability of moderate drought occurring was conducted using SPEI6. The results are inconclusive for Hela. Under the SSP245 scenario, the probability for occurrence is projected to decrease. Similarly for SSP585, drought probability is expected to decrease in the near and far future, but expected to increase in the mid future in the southern part of the province (see Figure 4-23).

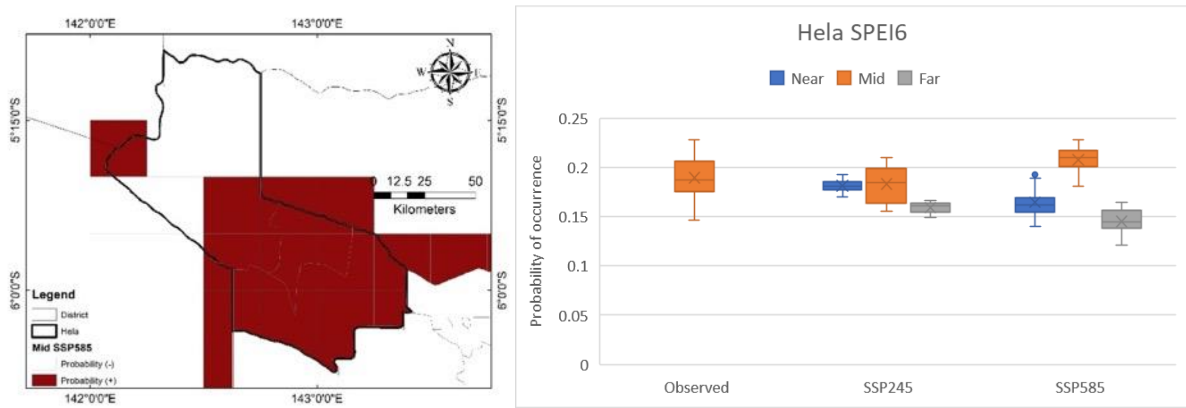


Figure 4-23. Probability of moderate drought in Hela

Analysis of consecutive dry days (CDD) index indicate potential increase of an average 4 to 6 days in the number of CDD for all scenarios.

Table 4-5. Increase in CDD from baseline value

| Scenario | Near | Mid | Far |
|---|---|---|---|
| Baseline | | 7 days (5 to 9 days) | |
| SSP245 | 4 days (3 to 5 days) | 5 days (4 to 6 days) | 6 days (3 to 8 days) |
| SSP585 | 4 days (3 to 5 days) | 5 days (3 to 7 days) | 6 days (3 to 9 days) |

### 4.4.2 Frost

Frost is considered a major hazard in Hela. Provincial stakeholders noted the occurrence of frosts along with droughts and highlighted the 1997 and 2015 frosts as particularly significant in terms of impact. These years coincide with the incidence of very strong El Nino, which is associated with the occurrence of drought and frosts in high altitude areas of the province. El Nino generally cause warmer than average maximum temperatures and decrease the cloud cover, which often leads to cooler-than-average night-time temperatures. Figure 4-24 shows the minimum of minimum temperature (TNN) analysis as well as elevation of Hela while Figure 4-25 compares the TNN anomaly in Hela for El Nino years 1982, 1997, 2002 and 2015.

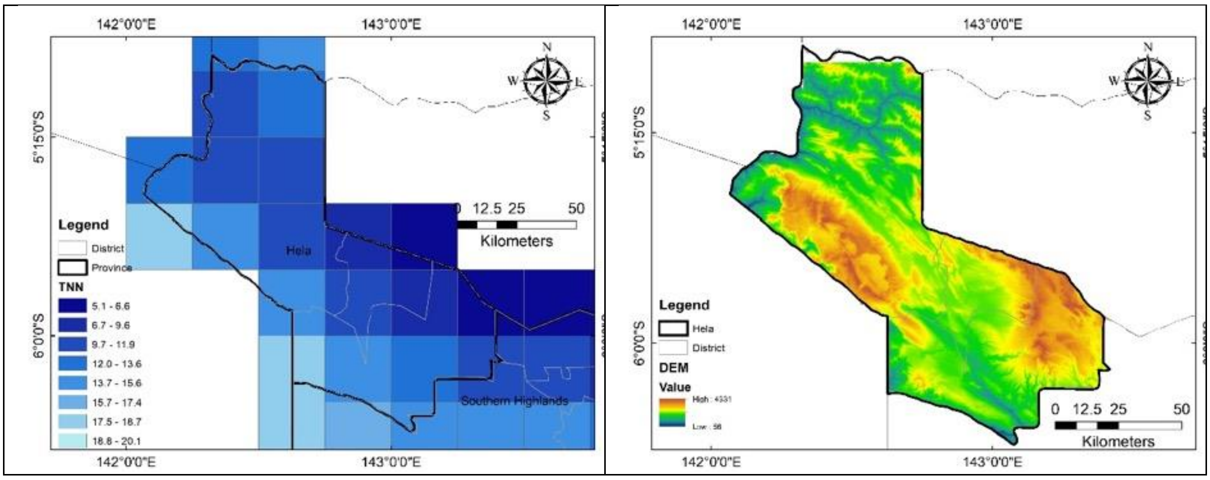


Figure 4-24. Minimum of minimum temperature and elevation of Hela

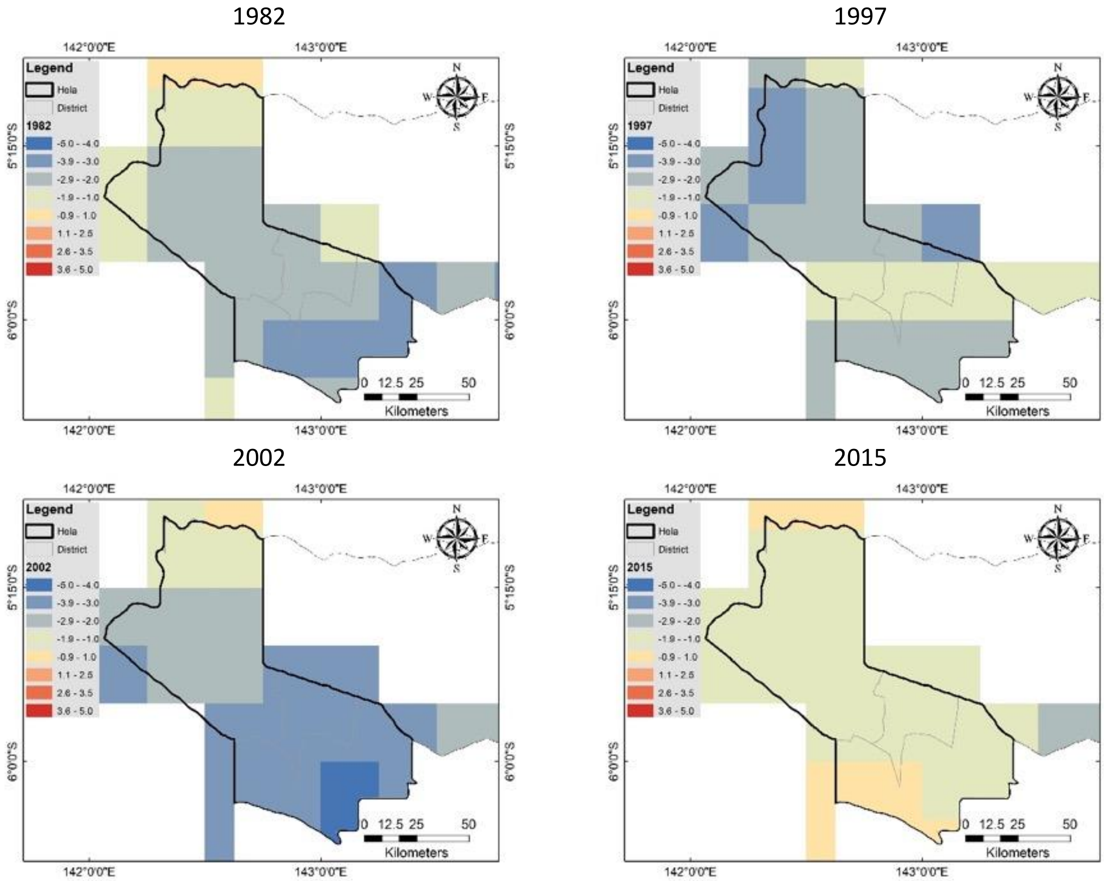


Figure 4-25. TNN anomaly for select El Nino years

The analysis of TNN indicates daily minimum temperatures of 5°C to 7°C particularly in high altitude areas northeast of Hela (i.e., Tagali Rural, Tebi Rural and Upper Wagi). This decreases during El Niño years, with 2002 having the largest temperature drop of up to -4°C to -5°C. These temperature drops indicate conditions conducive for the incidence of frost.

## 4.5. Landslide

Figures 4-26 and 4-27 show the rainfall- and earthquake-induced landslide hazard maps for Hela province.

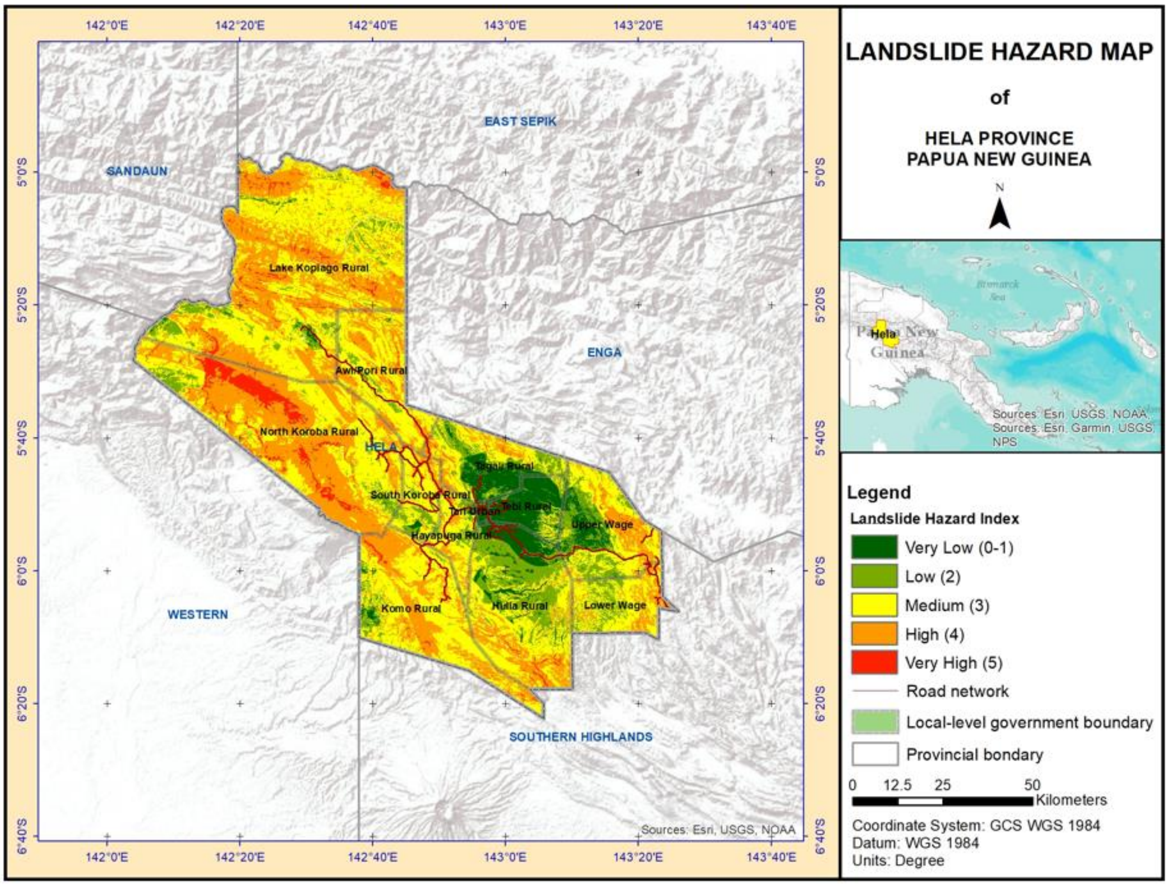



**Figure 4-26. Rainfall-induced landslide hazard map of Hela**

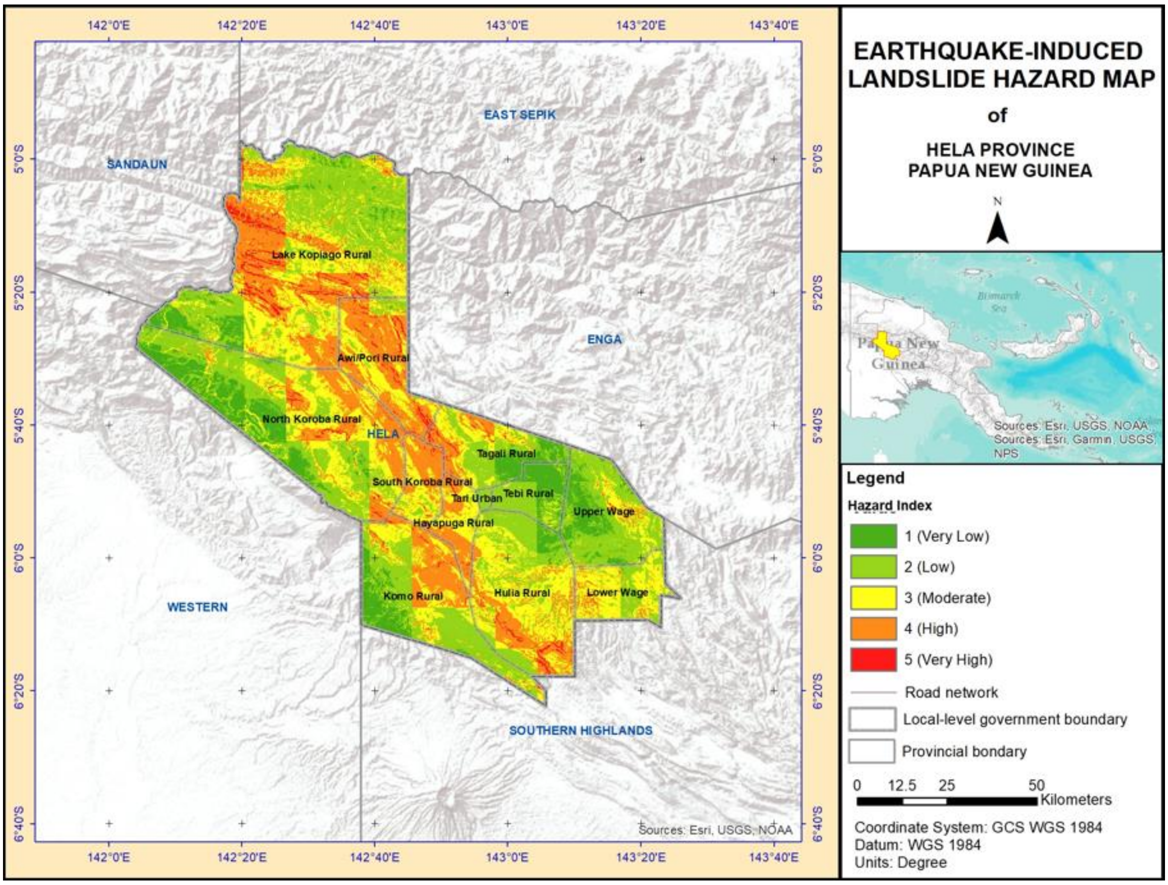



**Figure 4-27. Earthquake-induced landslide hazard map of Hela**

The rainfall-induced landslide hazard map indicates high to very high hazard on the north and western areas of the province. The lineaments and geological characteristics in this area contribute to intensified weathering process, resulting in the accumulation of a thicker soil layer compared to neighboring regions. Mineral compositions of rocks in diverse geological conditions also influence soil thickness. This thick soil layer increases susceptibility to landslides. Consequently, landslides are more prominent in areas with weak rock layers and in close proximity to lineaments. Figure 4-26 shows that approximately 45% of the mountainous areas in Hela are classified in the high to very high landslide hazard zones.

On the other hand, Figure 4-27 presents the earthquake-induced landslide map, which indicates that approximately 18% of the areas in Hela are classified in the high to very high earthquake-induced landslide hazard zones. Majority of the zones classified as having high and very high seismic hazards are situated along the lineament in a Northwest-Southeast direction. This indicates the significant impact of the active fault, which is represented by the lineament, as well as the concentration of PGA values along this fault. These combined factors designate this area as a high-hazard zone for earthquake-induced landslides.

## 4.6. Vulnerability

The assessment of vulnerability in Hela included indicators for exposure, sensitivity and adaptive capacity. In the provincial workshop conducted on 9 February in Mendi, stakeholders identified and rated the following indicators. However, many of the indicators identified and rated do not have the required data at LLG levels. For this reason, the indicators for vulnerability analysis were amended and ratings were subsequently adjusted.

**Table 4-6. Indicators for exposure, sensitivity and adaptive capacity**

| Component | Category | Indicator | Rating | Remarks |
|---|---|---|---|---|
| Exposure | Population | -Census units/settlements exposed | -N/A | -Based on actual exposure |
| | Livelihood | -Crop area in hectares<br>-Livestock population/area in hectares | -N/A | -N/A |
| | Critical infrastructure | -Roads<br>-Health facilities<br>-Learning facilities | -N/A | -Based on actual exposure |
| Sensitivity | Socio-economic | -Population growth rate<br>-Illiteracy rate<br>-Women-led household<br>-Population of elderly (65 over) and children (15 & below)<br>-Poverty rate<br>-Household dependent on agriculture as livelihood<br>-Youth population (15-39 years) creating social issues | -1.07%<br>-4.19%<br>-7.86%<br>-12.03%<br>-10.11%<br>-3.12%<br>-9.72% | -No data at LLG levels<br>-Rating adjusted to 6.93%<br>-Rating adjusted to 34.33%<br>-Rating adjusted to 44.05%<br>-No data at LLG levels<br>-No data at LLG levels<br>-Rating adjusted to 14.68% |
| | Socio-cultural | -Number of violent conflicts<br>-Number of internally displaced and abused people<br>-Outmigration<br>-Polygamy, which increases incidence of family conflicts, gender-based violence and sorcery accusation related violence (SARV) cases | -23.55%<br>-15.02%<br>-1.77%<br>-11.54% | -No data at LLG levels |
| Adaptive Capacity | Socio-economic | -Households with access to alternative livelihoods (e.g., employment in government offices, LNG facilities, | -14.78%<br>-4.83% | -No data at LLG levels<br>-Rating adjusted to 100% |

| Component | Category | Indicator | Rating | Remarks |
|---|---|---|---|---|
| | | healthcare, education, services and other sectors)<br>- Average distance to roads, health and learning facilities | | |
| | Infrastructure | - Number and capacity of evacuation centers and temporary shelters<br>- Access to forecasts, early warning and hazard information | -9.62%<br>-33.52% | - Most LLGs do not have evacuation sites/shelters nor access to forecasts, EW and hazard information |
| | Institutional | - Number of security officers and police<br>- Number of church- and women-led organizations and programs<br>- Community-based programs (e.g., seedbanks of NARI and FAO, community-based interventions by UNDP and IOM, UN Women, etc.) | -4.56%<br>-17.93%<br>-14.76% | - Insufficient data at LLG levels |

### 4.6.1 Exposure

Tables 4-7 to 4-9 provide details on the elements exposed to different flood and landslide hazard levels, while Figures 4-28 and 4-29 show the census units and critical facilities exposed to both hazards.

**Table 4-7. Exposure of population and critical facilities to flood hazards**

| | LLG | | 0.00m | 0.01 to 0.025m | 0.251 to 0.50m | Total |
|---|---|---|---|---|---|---|
| 1 | Awi/Pori Rural LLG | Population | 17,873 | | | 17,873 |
| | | Health Centers | 10 | | | 10 |
| | | Schools | | | | |
| 2 | Hayapuga Rural LLG | Population | 11,947 | 2,993 | 2,623 | 17,563 |
| | | Health Centers | 4 | 3 | 1 | 8 |
| | | Schools | | 3 | 1 | 4 |
| 3 | Hulia Rural | Population | 17,768 | | | 17,768 |
| | | Health Centers | 7 | | | 7 |
| | | Schools | | | | |
| 4 | Komo Rural | Population | 14,629 | 1,186 | | 15,815 |
| | | Health Centers | 7 | | | 7 |
| | | Schools | | | | |
| 5 | Lake Kopiago Rural | Population | 14,533 | | | 14,533 |
| | | Health Centers | 5 | | | 5 |
| | | Schools | | | | |
| 6 | Lower Wage | Population | 16,361 | | | 16,361 |
| | | Health Centers | 1 | | | 1 |
| | | Schools | | | | |
| 7 | North Koroba Rural | Population | 16,828 | | | 16,828 |
| | | Health Centers | 8 | | | 8 |
| | | Schools | | | | |
| 8 | South Koroba Rural | Population | 11,129 | 7,950 | 2,364 | 21,443 |
| | | Health Centers | 2 | 5 | 1 | 8 |
| | | Schools | | 5 | 3 | 8 |
| 9 | Tagali Rural | Population | 14,194 | | | 14,194 |
| | | Health Centers | 8 | | | 8 |
| | | Schools | | | | |
| 10 | Tari Urban | Population | 8,824 | | | 8,824 |
| | | Health Centers | 3 | | | 3 |
| | | Schools | | | | |
| 11 | Tebi Rural | Population | 13,433 | | | 13,433 |

| LLG | | | 0.00m | 0.01 to 0.025m | 0.251 to 0.50m | Total |
|---|---|---|---|---|---|---|
| | | Health Centers | 6 | | | 6 |
| | | Schools | | | | |
| 12 | Upper Wage | Population | 17,587 | | | 17,587 |
| | | Health Centers | 4 | | | 4 |
| | | Schools | | | | |
| | Total | Population | 175,106 | 12,129 | 4,987 | 192,222 |
| | | Health Centers | 65 | 8 | 2 | 75 |
| | | Schools | | 8 | 4 | 12 |

**Table 4-8. Exposure of census units and critical facilities to rainfall-induced landslide hazards**

| LLG | | | Very Low | Low | Medium | High | Very High | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | Awi/Pori Rural LLG | Census Unit | | 4 | 69 | 17 | | 90 |
| | | Population | | 869 | 13,974 | 3,030 | | 17,873 |
| | | Road (m) | | 746.06 | 32,771.73 | 6,035.74 | 1,833.75 | 41,387.28 |
| | | Health | | | 8 | 2 | | 10 |
| | | Schools | | | 12 | 1 | | 13 |
| 2 | Hayapuga Rural LLG | Census Unit | | 8 | 11 | 2 | | 21 |
| | | Population | | 5,524 | 9,600 | 2,098 | | 17,222 |
| | | Road (m) | 951.68 | 3,397.59 | 24,905.24 | 8,331.39 | 92.32 | 37,678.22 |
| | | Health | | 1 | 7 | | | 8 |
| | | Schools | | 1 | 5 | | | 6 |
| 3 | Hulia Rural LLG | Census Unit | 38 | 25 | 7 | 2 | | 72 |
| | | Population | 9,721 | 4,409 | 835 | 160 | | 15,125 |
| | | Road (m) | 34,551.91 | 13,790.35 | 452.08 | | | 48,794.34 |
| | | Health | 6 | 1 | | | | 7 |
| | | Schools | 5 | | | | | 5 |
| 4 | Komo Rural LLG | Census Unit | | 4 | 32 | 15 | | 51 |
| | | Population | | 1,117 | 9,949 | 4,749 | | 15,815 |
| | | Road (m) | | 113.54 | 27,130.60 | 13,045.23 | | 40,289.38 |
| | | Health | | | 3 | 4 | | 7 |
| | | Schools | | | 3 | 2 | | 5 |
| 5 | Lake Kopiago Rural LLG | Census Unit | 17 | 45 | 99 | 43 | | 204 |
| | | Population | 901 | 3,237 | 8,080 | 2,315 | | 14,533 |
| | | Road (m) | 1,662.02 | 6,252.92 | 4,413.00 | 4,784.95 | | 17,112.89 |
| | | Health | | 1 | 3 | 1 | | 5 |
| | | Schools | | 3 | 4 | 2 | | 9 |
| 6 | Lower Wage LLG | Census Unit | | | 29 | 47 | | 76 |
| | | Population | | | 7,625 | 8,010 | | 15,635 |
| | | Road (m) | | | 8,202.53 | 20,401.04 | | 28,603.58 |
| | | Health | | | 1 | | | 1 |
| | | Schools | | | 1 | | | 1 |
| 7 | North Koroba Rural LLG | Census Unit | | 6 | 51 | 28 | | 85 |
| | | Population | | 1,151 | 9,650 | 5,646 | | 16,447 |
| | | Road (m) | | 2,306.29 | 24,015.43 | 6,798.73 | | 33,120.45 |
| | | Health | | | 4 | 4 | | 8 |
| | | Schools | | | 7 | 4 | | 11 |
| 8 | South Koroba Rural LLG | Census Unit | | 6 | 34 | 33 | | 73 |
| | | Population | | 967 | 11,562 | 8,193 | | 20,722 |
| | | Road (m) | | 3,727.64 | 36,469.22 | 25,649.56 | | 65,846.42 |
| | | Health | | | 3 | 5 | | 8 |
| | | Schools | | | 5 | 7 | | 12 |
| 9 | Tagali Rural LLG | Census Unit | 11 | 3 | 4 | 6 | | 24 |
| | | Population | 5,448 | 1,727 | 2,276 | 3,516 | | 12,967 |

| LLG | | | Very Low | Low | Medium | High | Very High | Total |
|---|---|---|---|---|---|---|---|---|
| | | Road (m) | 5,987.87 | 6,440.17 | 296.89 | 5,298.56 | | 18,023.50 |
| | | Health | 4 | 3 | | 1 | | 8 |
| | | Schools | 2 | 1 | | 1 | | 4 |
| 10 | Tari Urban LLG | Census Unit | 16 | | | | | 16 |
| | | Population | 8,824 | | | | | 8,824 |
| | | Road (m) | 11,101.25 | 5,953.69 | | | | 17,054.94 |
| | | Health | 2 | 1 | | | | 3 |
| | | Schools | 3 | 1 | | | | 4 |
| 11 | Tebi Rural LLG | Census Unit | 17 | 1 | | | | 18 |
| | | Population | 12,536 | 661 | | | | 13,197 |
| | | Road (m) | 14,485.38 | 1,777.84 | | | | 16,263.22 |
| | | Health | 6 | | | | | 6 |
| | | Schools | 6 | | | | | 6 |
| 12 | Upper Wage LLG | Census Unit | | 18 | 53 | 17 | | 88 |
| | | Population | | 6,019 | 9,223 | 2,345 | | 17,587 |
| | | Road (m) | 19.57 | 11,413.29 | 24,389.75 | 7,647.46 | | 43,470.07 |
| | | Health | | 1 | 1 | 2 | | 4 |
| | | Schools | | | 3 | 3 | | 6 |
| | Total | Census Unit | 99 | 120 | 389 | 210 | | 818 |
| | | Population | 37,430 | 25,681 | 82,774 | 40,062 | | 185,947 |
| | | Road (m) | 68,759.69 | 55,919.39 | 183,046.48 | 97,992.66 | 1,926.07 | 407,644.28 |
| | | Health | 18 | 8 | 30 | 19 | | 75 |
| | | Schools | 16 | 6 | 40 | 20 | | 82 |

**Table 4-9. Exposure of census units and critical facilities to earthquake-induced landslide hazards**

| LLG | | | Very Low | Low | Medium | High | Very High | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | Awi/Pori Rural LLG | Census Unit | | | 28 | 62 | | 90 |
| | | Population | | | 6,168 | 11,705 | | 17,873 |
| | | Road (m) | | | 17,706 | 20,251 | 3,332 | 41,289 |
| | | Health | | | 3 | 7 | | 10 |
| | | Schools | | | 6 | 7 | | 13 |
| 2 | Hayapuga Rural LLG | Census Unit | | 1 | 9 | 11 | | 21 |
| | | Population | | 677 | 6,360 | 10,185 | | 17,222 |
| | | Road (m) | | 990 | 12,387 | 23,650 | 574 | 37,600 |
| | | Health | | | 2 | 6 | | 8 |
| | | Schools | | | 2 | 4 | | 6 |
| 3 | Hulia Rural LLG | Census Unit | | 40 | 28 | 4 | | 72 |
| | | Population | | 10,062 | 4,654 | 409 | | 15,125 |
| | | Road (m) | 2,926 | 42,079 | 3,702 | | | 48,707 |
| | | Health | | 6 | 1 | | | 7 |
| | | Schools | | 5 | | | | 5 |
| 4 | Komo Rural LLG | Census Unit | | 3 | 12 | 36 | | 51 |
| | | Population | | 673 | 3,301 | 11,841 | | 15,815 |
| | | Road (m) | | | 2,482 | 37,232 | 489 | 40,203 |
| | | Health | | | | 7 | | 7 |
| | | Schools | | | | 5 | | 5 |
| 5 | Lake Kopiago Rural LLG | Census Unit | | 46 | 77 | 81 | | 204 |
| | | Population | | 3,631 | 5,829 | 5,073 | | 14,533 |
| | | Road (m) | | 5,609 | 5,141 | 6,317 | | 17,067 |
| | | Health | | 1 | 2 | 2 | | 5 |
| | | Schools | | 3 | 3 | 3 | | 9 |
| 6 | Lower Wage LLG | Census Unit | | 30 | 46 | | | 76 |
| | | Population | | 7,224 | 8,411 | | | 15,635 |

| LLG | | | Very Low | Low | Medium | High | Very High | Total |
|---|---|---|---|---|---|---|---|---|
| | | Road (m) | | 9,573 | 18,527 | 471 | | 28,571 |
| | | Health | | 1 | | | | 1 |
| | | Schools | | 1 | | | | 1 |
| 7 | North Koroba Rural LLG | Census Unit | 8 | 7 | 10 | 60 | | 85 |
| | | Population | 984 | 1,366 | 1,877 | 12,220 | | 16,447 |
| | | Road (m) | | | 9,152 | 23,882 | 7 | 33,041 |
| | | Health | | 1 | 1 | 6 | | 8 |
| | | Schools | | 1 | 2 | 8 | | 11 |
| 8 | South Koroba Rural LLG | Census Unit | | | 14 | 59 | | 73 |
| | | Population | | | 3,456 | 17,266 | | 20,722 |
| | | Road (m) | | | 10,165 | 55,286 | 251 | 65,701 |
| | | Health | | | 2 | 6 | | 8 |
| | | Schools | | | 3 | 9 | | 12 |
| 9 | Tagali Rural LLG | Census Unit | | 13 | 5 | 5 | 1 | 24 |
| | | Population | | 6,589 | 2,494 | 3,038 | 846 | 12,967 |
| | | Road (m) | | 7,844 | 4,856 | 4,731 | 556 | 17,987 |
| | | Health | | 6 | 1 | 1 | | 8 |
| | | Schools | | 3 | | 1 | | 4 |
| 10 | Tari Urban LLG | Census Unit | | 16 | | | | 16 |
| | | Population | | 8,824 | | | | 8,824 |
| | | Road (m) | | 15,068 | 1,954 | | | 17,022 |
| | | Health | | 2 | 1 | | | 3 |
| | | Schools | | 3 | 1 | | | 4 |
| 11 | Tebi Rural LLG | Census Unit | | 18 | | | | 18 |
| | | Population | | 13,197 | | | | 13,197 |
| | | Road (m) | | 15,942 | 291 | | | 16,233 |
| | | Health | | 6 | | | | 6 |
| | | Schools | | 6 | | | | 6 |
| 12 | Upper Wage LLG | Census Unit | 6 | 71 | 11 | | | 88 |
| | | Population | 2,409 | 13,615 | 1,563 | | | 17,587 |
| | | Road (m) | 550 | 37,740 | 5,091 | 34 | | 43,415 |
| | | Health | | 3 | 1 | | | 4 |
| | | Schools | | 4 | 2 | | | 6 |
| | Total | Census Unit | 14 | 245 | 240 | 318 | 1 | 818 |
| | | Population | 3,393 | 65,858 | 44,113 | 71,737 | 846 | 185,947 |
| | | Road (m) | 3,476 | 134,846 | 91,453 | 171,854 | 5,208 | 406,837 |
| | | Health | | 26 | 14 | 35 | | 75 |
| | | Schools | | 26 | 19 | 37 | | 82 |

About 17,116 people are directly exposed to flooding in Hela, of which 10,314 (60.26%) are from South Koroba Rural, 5,616 (32.81%) from Hayapuga Rural and the remaining 1,186 (6.93%) from Komo Rural. In addition, about 10 health centers and 12 schools are exposed to flooding, all of which are from Hayapuga Rural and South Koroba Rural LLGs. No roads are exposed.

Table 4-8 indicates that about 40,062 people are exposed to high rainfall-induced landslide susceptibility level, of which 8,193 (20.45%) come from South Koroba Rural, 8,010 (19.99%) from Lower Wage, and 5,646 (14.09%) from North Koroba Rural. Similarly, about 99,919 meters of road, 19 health centers and 20 schools are exposed to high rainfall-induced landslide susceptibility levels.

Similarly, Table 4-9 indicates that about 71,737 people are exposed to high earthquake-induced landslide susceptibility level, of which 17,266 (24%) come from South Koroba Rural, about 16-17% each from North Koroba Rural (12,220), Komo Rural (11,841) and Awi/Pori Rural (11,705). Similarly, about 171,854 meters of road, 35 health centers and 37 schools are exposed to high earthquake-induced landslide susceptibility levels.

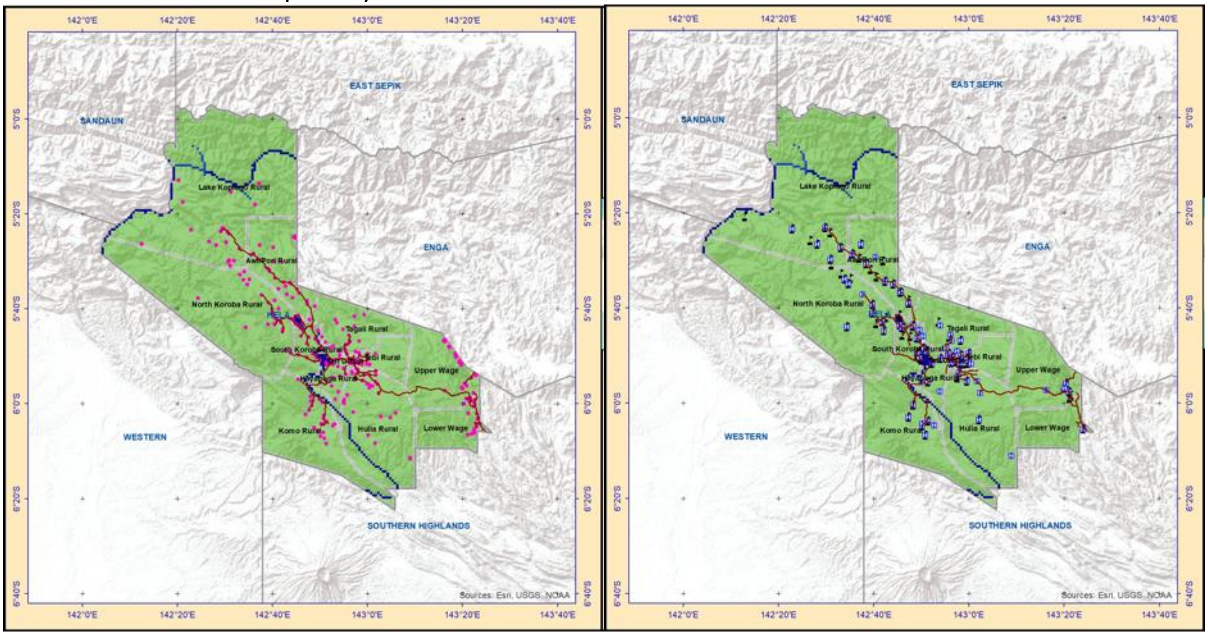



**Figure 4-28. Exposure of census units and critical facilities to flood hazards**

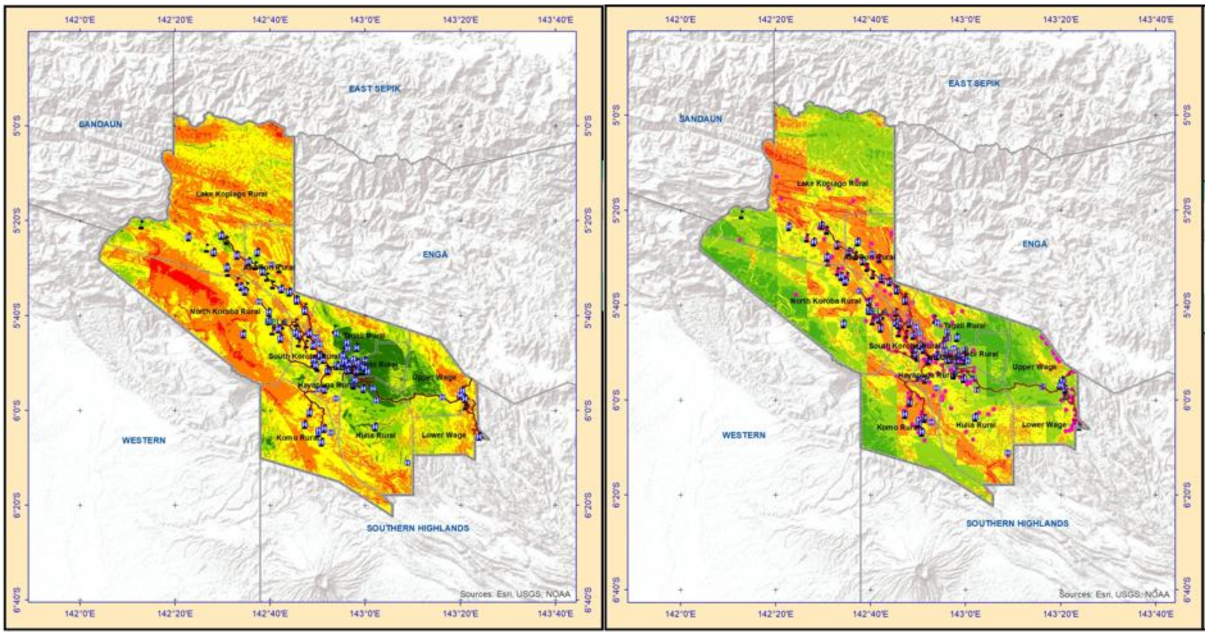



**Figure 4-29. Exposure to rainfall-induced (left) and earthquake-induced (right) landslide hazards**

## 4.6.2 Vulnerability Index

The vulnerability index was expected to integrate indicators of sensitivity and adaptive capacity outlined in Table 4-6. But due to limitations of data up to LLG level, analysis was conducted only for four indicators of sensitivity - illiteracy rate, women-led household, population of elderly (65 over) and children (15 & below), and youth population (15-39). Consequently, the weights and ratings for these indicators were adjusted to 6.93% for illiteracy rate, 34.33% for women-led household, 44.05% for elderly and children population, and 14.68% for youth population. Initial data on conflicts from January 2021 to present is taken from the Armed Conflict Location and Event Data Project (https://acleddata.com/). Details of the conflicts are shown in Table 4-10, while locations are overlaid with the sensitivity map shown in Figure 4-30. The table shows that majority of the conflicts are political, categorized as either riots, battles and violence against civilians, and comprised of armed clashes among rioters, armed groups, tribal or clan militia. Although conflicts during the last three years are distributed across the three districts, Figure 4-30 shows that these are concentrated in the central areas of the province including in Tari.

**Table 4-10. Conflicts in Hela**

| | Date | Type | Actors | Location | Casualty | Remarks |
|---|---|---|---|---|---|---|
| 1 | 28-Jan-21 | Political violence – violence against civilians, sexual violence | Unidentified Clan Militia, civilians, women | Mulipi, Tari-Pori | 3 | women targeted: girls |
| 2 | 28-Jan-21 | Strategic developments – other | Civilians, refugees/IDPs | Hoiebia, Tari-Pori | 0 | |
| 3 | 28-Jan-21 | Political violence – battles, armed clashes | Unidentified Clan Militia | Pii Nakia, Tari-Pori | 4 | |
| 4 | 30-Jan-21 | Political violence – battles, armed clashes | Unidentified Clan Militia | Mulipi, Tari-Pori | 6 | |
| 5 | 3-Feb-21 | Political violence – violence against civilians, attacks | Unidentified Clan Militia, civilians | Hamboli, Tari-Pori | 1 | |
| 6 | 27-Feb-21 | Political violence – battles, armed clashes | Unidentified Tribal Militia, Police Forces | Langome, Komo-Magarima | 0 | |
| 7 | 27-Feb-21 | Political violence – battles, armed clashes | Unidentified Tribal Militia, Police Forces | Langome, Komo-Magarima | 1 | |
| 8 | 4-Apr-21 | Political violence – battles, armed clashes | Engan Communal Militia, Tari Communal Militia, Kopiago Communal Militia | Kopiago, Koroba-Kopiago | 2 | |
| 9 | 7-May-21 | Political violence – riots, mob violence | Rioters, vigilante group, civilians, women | Margarima, Komo-Magarima | 1 | crowd size around 8; women targeted: accused of witchcraft, sorcery |
| 10 | 8-Aug-21 | Strategic developments – disrupted weapons use | GoPNG, Communal Militia Group, O Kiru Tribal Militia, Libe Tribal Militia, Ayago Tribal Militia, Igo Agau Tribal Militia | Tari, Tari-Pori | 0 | |
| 11 | 29-Mar-22 | Political violence – battles, armed clashes | Linabini Clan Militia, Police Forces | Tari, Tari-Pori | 1 | |
| 12 | 29-Mar-22 | Political violence – riots, mob violence | Rioters | Langome, Komo-Magarima | 0 | |
| 13 | 24-Jun-22 | Strategic developments – change to group/activity | Unidentified Armed Group | Tari, Tari-Pori | 0 | |
| 14 | 4-Jul-22 | Political violence – riots, mob violence | Rioters, Independent Politicians – PANGU: Pangu Party | Yambaraka, Komo-Magarima | 3 | |
| 15 | 6-Jul-22 | Demonstrations – protests, peaceful protests | Protesters | Tari, Tari-Pori | 0 | crowd size around 30 |
| 16 | 17-Jul-22 | Political violence – riots, mob violence | Rioters, Independent Politicians – PANGU: Pangu Party | Hone, Komo-Magarima | 2 | |

| | Date | Type | Actors | Location | Casualty | Remarks |
|---|---|---|---|---|---|---|
| 17 | 27-Jul-22 | Political violence – riots, mob violence | Rioters, Independent Politicians – PANGU: Pangu Party | Margarima, Komo-Magarima | 0 | |
| 18 | 26-Oct-22 | Political violence – violence against civilians, attacks | Unidentified Armed Group, civilian, Police Forces | Margarima, Komo-Magarima | 1 | |
| 19 | 1-Dec-22 | Political violence – riots, mob violence | Rioters, Aura Clan Group, Pina Clan Group | Laite, Komo-Magarima | 2 | |
| 20 | 11-Dec-22 | Political violence – battles, armed clashes | Unidentified Communal Militia | Umimi, Koroba-Kopiago | 6 | |
| 21 | 15-Dec-22 | Political violence – battles, armed clashes | Wakiria Communal Militia, Kanimu Communal Militia | Hujanoma 2, Koroba-Kopiago | 17 | |
| 22 | 3-Jan-23 | Strategic developments – agreement | Wakiria Communal Militia, Kanimu Communal Militia | Koroba Station, Koroba-Kopiago | 0 | |
| 23 | 11-Jan-23 | Political violence – violence against civilians, attacks | Unidentified Clan Militia, civilians | Kopiago, Koroba-Kopiago | 1 | |
| 24 | 7-Mar-23 | Political violence – violence against civilians, sexual violence | Unidentified Armed Group, civilians, women | Betege 1, Koroba-Kopiago | 0 | women targeted: girls |
| 25 | 23-Jun-23 | Political violence – battles, armed clashes | Erebo Communal Militia, Police Forces, Military Forces | Erebo, Koroba-Kopiago | 0 | |

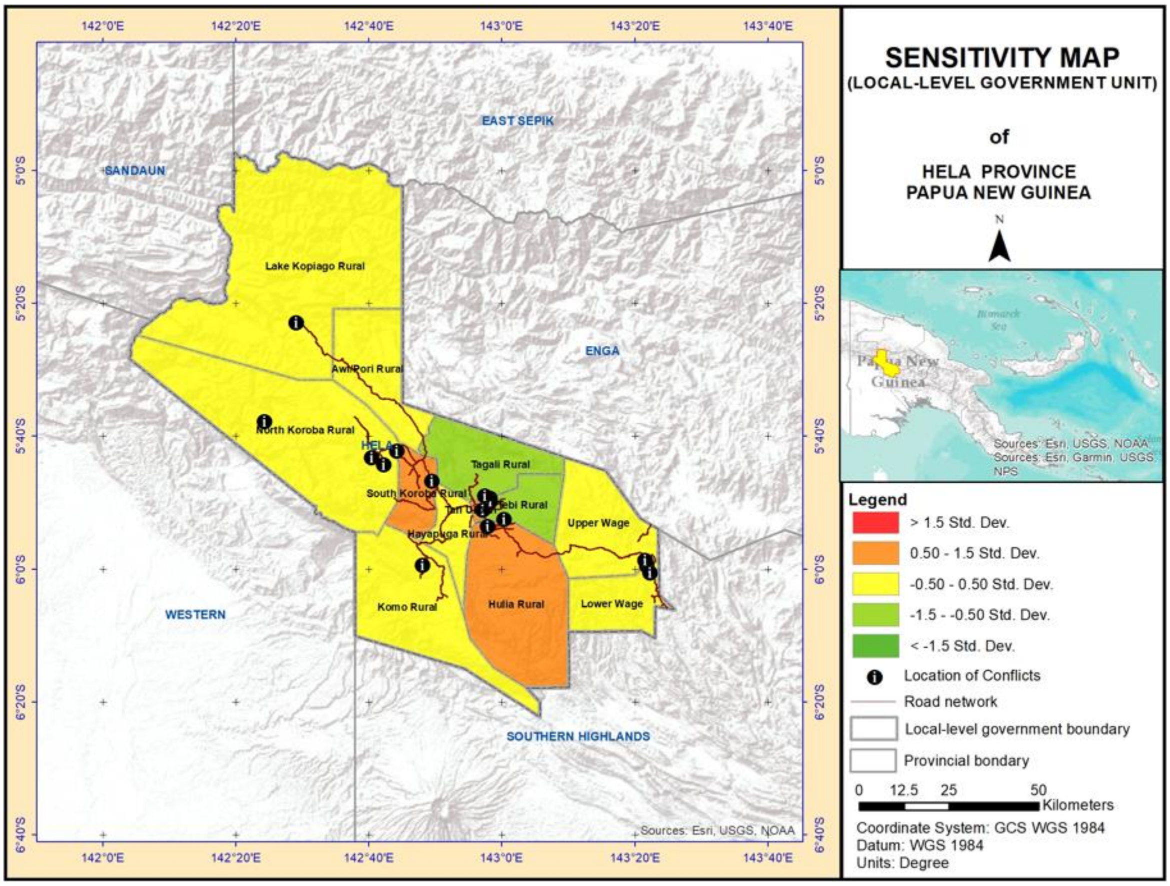



**Figure 4-30. Sensitivity map with locations of conflicts**

Figure 4-30 shows that Hulia Rural at 1.48 standard deviation is most sensitive, followed by Tari Urban and South Koroba Rural at 1.23 and 0.55 standard deviation respectively.

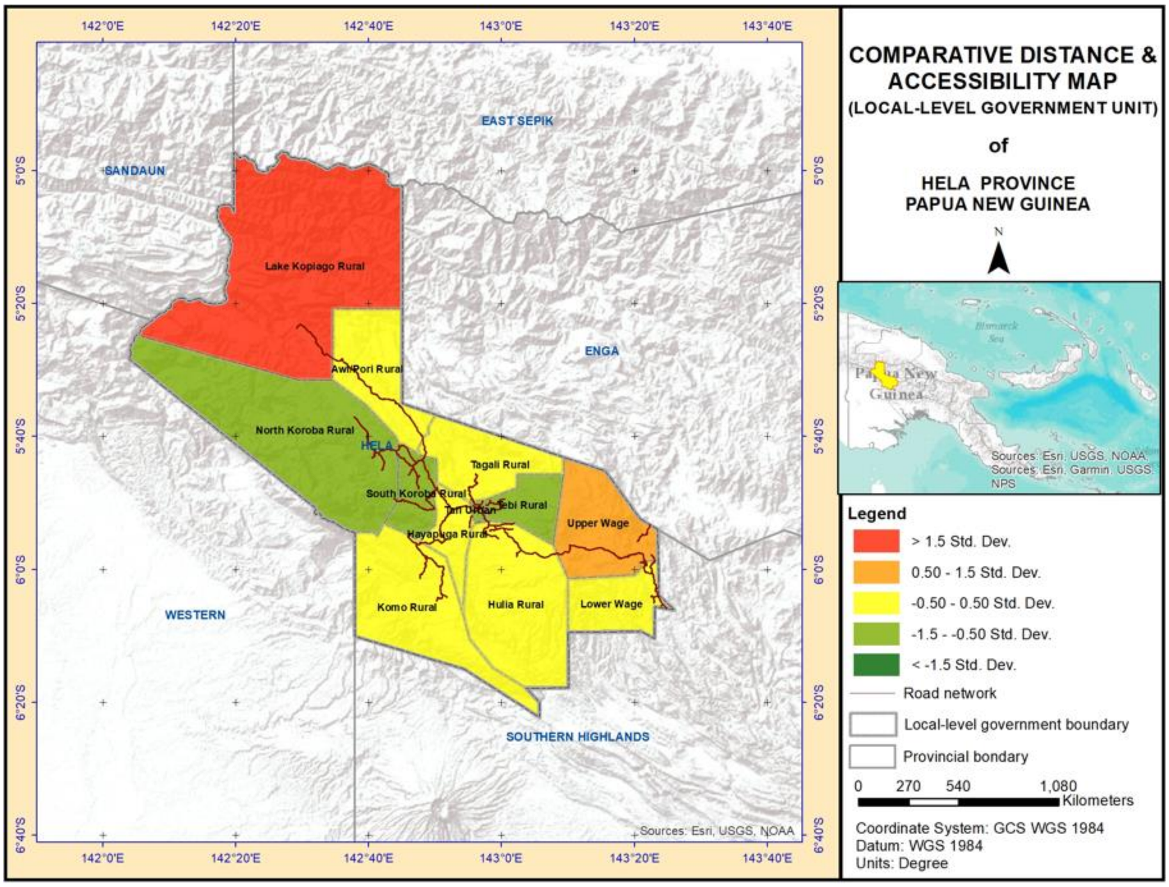



**Figure 4-31. Comparative distance and accessibility map**

Data was insufficient to analyse indicators of adaptive capacity, hence the analysis focused only on the distance of settlements to critical facilities like roads, health centers and schools. Figure 4-31 shows the most inaccessible and remote settlements in Lake Kopiago Rural at 1.93 standard deviation, followed by Upper Wage and North Koroba Rural at 1.3 and 0.89 standard deviation respectively.

### 4.6.3 Gender Considerations

Out of the 249,449 total population in Hela Province in 2011, 48.33% or 120,554 are women while 51.65% or 263,523 are men. Despite the almost similar number of women and men in the province, there are large discrepancies in the gender equality index in Hela as cultural beliefs continue to disempower women who remain excluded in community discussions, decision-making and planning around natural resource management. For instance, decision-making during or after disasters is typically considered a man's role while women are culturally obligated to follow with very limited, if any, voice or influence. [13]

On the other hand, the assessment results indicate the potential for more extreme events that will likely exacerbate local tensions. Unfortunately, climate change and conflicts disproportionately affect women, girls, and children. They have limited rights to access/manage property, land, or other assets. They are also the usual victims of violence, with very limited access to critical services like education and healthcare. For instance, in 2018, a large-scale conflict arose due to retaliation from the death of a young man in search for alternative water source due to water scarcity brought by prolonged drought. Due to retaliation killings and destruction of community property and assets, women and children were displaced from their homes, and took shelter close to Tari town. Some women were subjected to assault while looking for a safe place in Tari. Many feared for their lives and for their young girls' safety against assault and rape. [13]

## 4.7. Pilot Wards

The pilot communities in Hela are Idauwi, Paipali and Tengo. Consultations with representatives from these wards were held on 17 February 2023. Representatives drew maps of their ward, that would indicate the location of settlements, critical facilities, and food and water sources. They also discussed the hazards affecting their community as well as the mechanisms they typically take to minimize or manage the impacts of these hazards.

### 4.7.1 Idauwi

Idauwi Ward is part of the Hayapuga Rural LLG in Tari Pori District. Based on the NSO's 2011 National Population and Housing Census, the total population of the ward is 1,958, of which, 47.70% are women. In a survey conducted by IOM in 2023, the population estimates are almost the same but with lesser percentage of children at 18%.

About 90% of the Idauwi Ward population are subsistence farmers growing sweet potatoes, vegetables and pigs while the remaining 10% are employed in mining areas. There are three (3) elementary[12] and three (3) primary schools located within the ward, one (1) health center, one (1) aid post and three (3) churches. There are no secondary schools, high schools nor colleges in Idauwi. Students attend secondary education in other wards, and university in other provinces like Eastern or Southern Highlands.

About 70% of the ward population can read and write. An estimated 80% completed elementary and primary school, 40% completed secondary school, and about 15% to 20% have college degrees.

Two major rivers pass through the ward, namely Tagali and Tupiaga. These are the main sources of water for the residents' food gardens and for household consumption.

Figure 4-32. Participatory map of Idauwi ward

In terms of hazards, residents consider earthquake, flood and landslides relevant in terms of damage to properties and food gardens, and sometimes casualties. The landslide that occurred in 2014, for instance, killed about 25 people. Inter-/intra-communal conflict is also prevalent causing displacement of people. Major causes of conflicts include land disputes, political or election-related violence and youth fights. Churches that are present in the ward play a vital role in conflict resolution and peacebuilding since they are highly respected by community members.

Locals suggest that natural gas extraction near the Tagali and Tupiaga rivers (i.e., Nogoli and Angore LNG well pads), produces foamy white powder and bubbles in the rivers. Villagers alleged that these are chemical risks and are no longer inclined to get water and fish downstream of the river where the foamy white powder and bubbles are observed. According to ward representatives, the forests have

[12] Elementary School – Grades 1 to 3; Primary School – Grades 4 to 8; Secondary School – Grades 9 to 12.

also dried up in areas where drilling is done by the LNG mining. Villagers suggest that complaints on these issues do not get sufficient traction since vocal complainants are offered jobs or money by the LNG companies.

### 4.7.2 Paipali

Paipali ward is part of Tari Urban LLG in Tari/Pori District. It is located about two to three kilometers from Tari Town, the provincial capital of Hela. The total population of the ward is about 3500, which is 25% less when compared to the 2011 census data. Based on the IOM survey, there are now lesser children at 15.37% and more elderly at 34.52% of the total ward population. These trends may be due to migration, displacement or other factors resulting from conflicts.

About 80% of the ward population are subsistence farmers while the rest are engaged in selling and other jobs. Paipali had churches, an elementary school and health center, which were damaged or burned due to conflicts that occurred four years ago. The remains of churches are still being used for worship. The elementary school is currently not operational so elementary students stopped studying. Secondary schoolers typically go to the ward's secondary school. They also have options to attend another high school about 2km away from the ward or in Tari, which is about 10km away.

Ward members who graduated university work either in the private sector or in government as civil servants and politicians. This includes the current Prime Minister who is a Paipali ward member. Ward members who have completed education between the 14-year war period are considered to be doing well, working either in POM or overseas.

The ward has access to stores, construction and electricity services. The construction company Tari Pori Development Corp (TPDC) previously operated an aid post accessible to community members. This is no longer operational at present. About 20% of the ward's population have electricity connection through PNG Power. A defense base is also present in the ward.

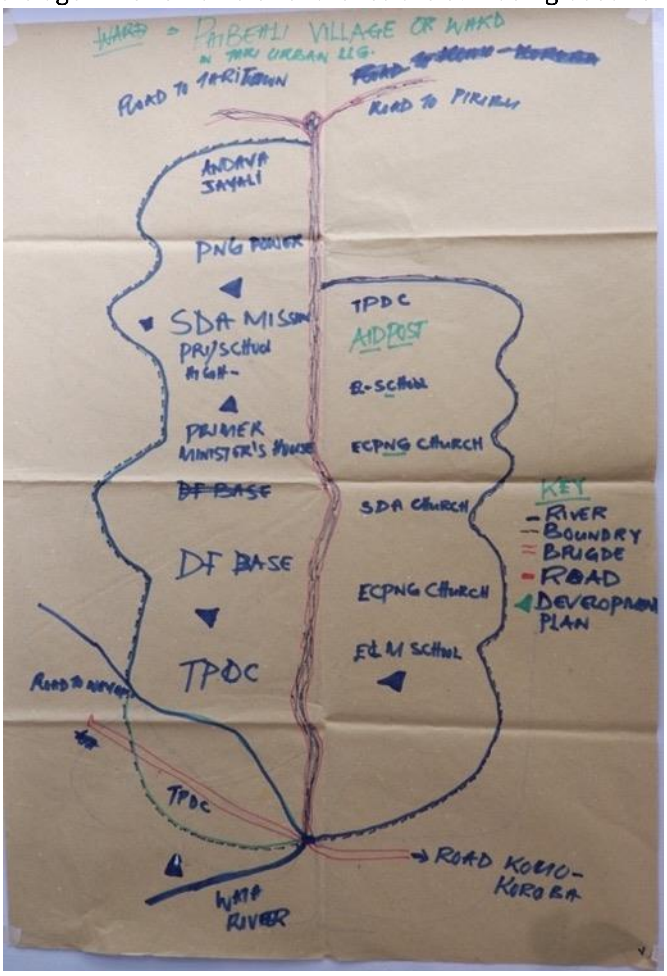



Figure 4-33. Participatory map of Paipali ward

Due to the 14-year conflict, only about 30% of the ward's population had formal education at primary level. The first conflict occurred about 14 years ago. When people tried to recover and resettle, new conflicts emerged. The last one happened 4 years ago resulting in burning of homes, churches, health facilities and schools. The main causes of conflicts include land disputes, the provincial elections of 2002 and 2011, and youths who use drugs and have access to firearms.

Now, the conflicts are considered dormant as the four (4) tribes agreed to not engage in fighting anymore. The presence of the defense base within the ward also helps in preventing and/or managing conflicts.

The ward plans to rebuild the school and construct a center for women. Given the lack of government support or budget, ward leaders are working internally to collect the necessary resources and contributions from ward members.

In terms of hazards, residents consider floods, landslides, drought and frost important. Floods usually damage the food gardens, walkways and bridges that connect students to schools. About 9 years ago, three children drowned while crossing Wata River's strong current brought about by heavy rainfall. Villagers are now more vigilant in monitoring the river's water level during heavy rains, and avoid danger zones during these events. In addition, they grow several food gardens in various areas to ensure they will continue to have food when some of their crops are affected by flooding.

Earthquake-induced landslide is a concern, with the most recent one occurring in 2018. This caused houses and roads to collapse. While drought and frost are important, ward representatives consider their magnitude and impacts minimal. They do not usually experience long dry periods, and even when they do, they have access to Wata River. The ward also worries about the hot steam and potential volcanic activity in one of their water sources. Villagers claim that bubbles come out from the water producing bad smell. People with food gardens near the creek report that their crops wilted due to the water. Hence, they go to other creeks to fetch water for their gardens.

### 4.7.3 Tengo

Tengo Ward is located at the Upper Wage LLG in Komo/Magarima District. The ward has an estimated total population of 4,000 to 5,000, including more than 400 displaced people. This is more than four times the recorded total population in 2011.

The number of households is estimated at 820, about 46 of which are headed by women. The estimates reflect household size of six (6), which according to ward representatives indicates a swell in population due to polygamy and teenage marriage.

Almost all the villagers are subsistence farmers. Many also sell sweet potato, cabbage, firewood and copper in Tengo market for cash. A few ward members are health and education workers who serve in institutions outside the ward.

Ward residents do not have access to the power grid. They generally rely on solar power for lighting and wood fire for heating during cold weather. Drinking water is sourced from the creeks (i.e., Dapipi and Margarima), which originate from the bushes. Residents consider the water clean and no longer filter nor boil it, noting that there are no villagers living near the area.

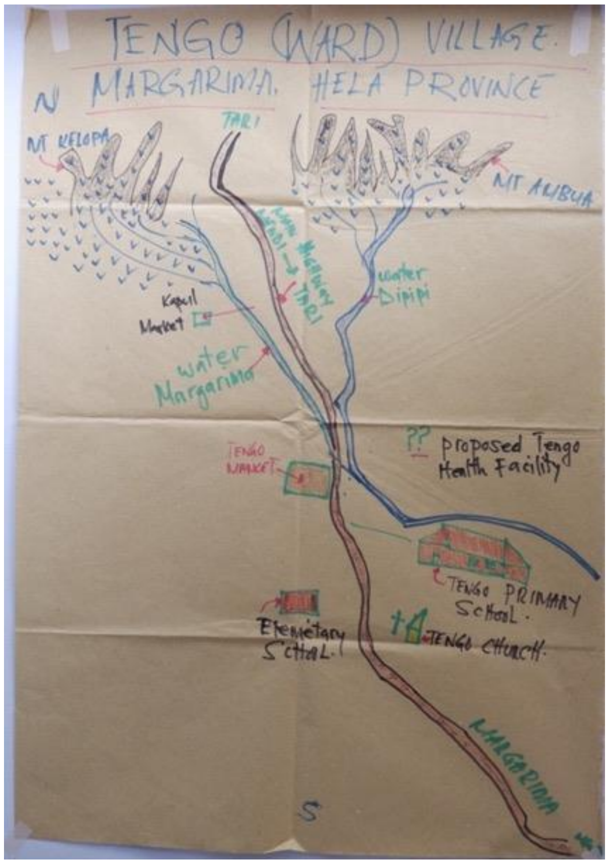



Figure 4-34. Participatory map of Tengo ward

Tengo ward has three (3) elementary schools, and one (1) primary school with eight (8) teachers handling more than 200 students. The ward has no secondary school, so students typically stay in Magarima, which is about three (3) hours away, for secondary level schooling. Higher level students attend college and/or university in Goroka and POM.

Ward representatives indicate that in general, about 50% of students complete elementary schooling, 30% to 40% graduate primary studies, 20% finish secondary schooling and about 5% earn a college degree. The ward has more than 10 nurses, about 10 to 12 teachers, and 4 to 5 engineers, indicating improvement in terms of educational attainment and work opportunities. However, most of the older population, typically farmers, do not know how to read and write.

The ward does not have a health facility. There used to be an aid post in the 1970s to 1980s, but this stopped operating since the 1990s. A health facility is proposed by villagers, but this has not received any government support. In the absence of a health facility, an ambulance/mobile clinic visits the ward once every 2 to 3 months to provide health-related services to villagers.

In terms of natural hazards, residents consider riverine flooding, landslides, earthquakes, drought and frost as critical. Riverine floods damage food gardens and bridges, consequently preventing children from crossing rivers to attend school. Earthquakes cause damage to schools and houses. The 2018 earthquake in particular resulted in the destruction of schools and collapse of houses. It also induced landslides, which caused deaths. While reports of damages were submitted to the Provincial Disaster Coordinator (PDC), ward representatives indicated that they did not receive government support. At that time, people were forced to live in the bushes and other remote areas, and received some assistance from UNICEF, which provided food, and set up water tanks, temporary tent-classrooms and communal toilet facilities for the children.

During the dry season, which usually lasts 2 to 3 months, villagers experience drought and frost, which affect their food gardens. Ward representatives indicated that residents typically suffer from food insecurity due to crop loss from drought and frost. To cope, residents seek help from relatives working in Tari or Magarima, or wait for food aid from the government. Food aid was provided during the 1997 and 2007 drought events, but was not repeated after 2007 according to ward representatives.

Ward residents have limited access to cellphones and do not have radios. Most, if not all, residents do not get early warning information. However, some of the churches provide information and guidance on issues affecting the villagers during earthquakes, floods and other disasters. At present, about 60% to 70% of the ward population are Catholic, with about 6 to 7 active churches.

Ward residents do not get government support in terms of disaster response. The defense force is usually felt during conflicts, but hardly during natural disasters. Given limited to no resources nor support from the government, ward councilors are unable to do anything to prepare for, or manage, disasters and the impacts. Sometimes villagers move to Tari or Magarima for their safety. In cases where people die, ward leaders typically use their own money and/or resources to assist families of the deceased with burial costs.

### 4.7.4 Gender Considerations in the Pilot Wards

The findings from the UNDP project focus group discussions (FGDs) conducted in Tengo indicate that gender inequality persists when it comes to decision-making and access to basic services such as education. Women are assigned traditional household roles like family carer, but have limited voice or influence in decision-making, for example at schools and churches. Women’s roles are constrained to raising children, managing food gardens and generating some income by selling garden produce. On the other hand, men are assigned to activities considered “higher value”, including taking on household leadership roles and contributing to community decision-making. When men are involved in communal conflicts, they likewise neglect their traditional roles as heads of the household. As a result, women take on additional roles of providing for the entire family in order to survive. [14]

While the impacts of climate variability/change as well as the continuing intra-/inter-communal conflicts affect both genders, women and girls are disproportionately affected. They are physically more vulnerable, have limited access to learning opportunities or healthcare services and become targets of sexual and/or sorcery-accusation related violence (SARV). In addition, women and girls are sometimes considered men’s property and pressured into early and arranged marriages in exchange for firearms or land, which can result in further gender-based abuse and violence. [14]

# 5 Hazard, Exposure and Vulnerability Assessment in SHP

Southern Highlands is a province in the Highlands region of PNG. It is comprised of five districts and 20 LLGS including its capital, Mendi. SHP covers an area of 15,089km$^2$, home to 510,245 people according to the 2011 National Population and Housing Census, with a growth rate of 3.2% per annum from 2000. The province accounts for 7.02% of PNG's total population.

## 5.1. Baseline Information

Figure 5-1 shows SHP's location as well as the boundaries of its 20 LLGs.

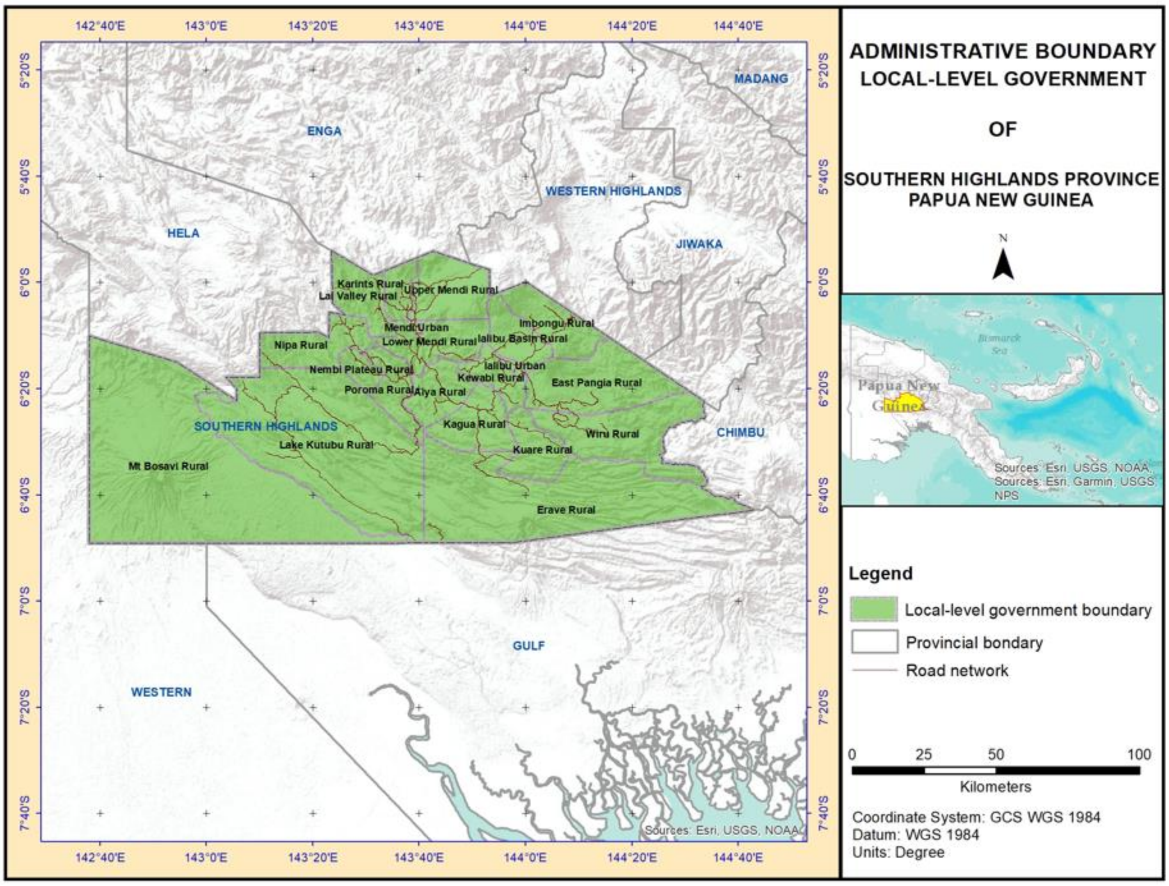



**Figure 5-1. Administrative boundaries of SHP**

Topography and/or elevation information in SHP was generated using the global DEM Shuttle Radar Topography Mission (SRTM, https://lta.cr.usgs.gov/SRTM1Arc), which has a 30-meter resolution. Figure 5-2 shows the elevation in the province. On the other hand, The ESRI (https://livingatlas.arcgis.com/landcover/) 10-meter resolution land cover was used to generate land use/land cover map of SHP (Figure 5-3).

Figure 5-4 shows the locations of settlements in SHP. The map shows that settlements are distributed across the province. The most populated district is Nipa/Kutubu, comprising 28.81% (147,005) of the province's total population of 510,245 in 2011. This is followed by Mendi/Munihi with 28.81% (144,629), Imbonggu with 15.87% (80,994), Kagua/Erave with 14.53% (74,139) and Ialibu/Pangia with the lowest population of 63,478 (12.44%). [15] Out of the total population in the province, 48.40% are women, 29.6% are between the ages 0 and 14, while 2.5% are aged 65 years old or above. [9] Table 5-1 lists the population and population density of LLGs.

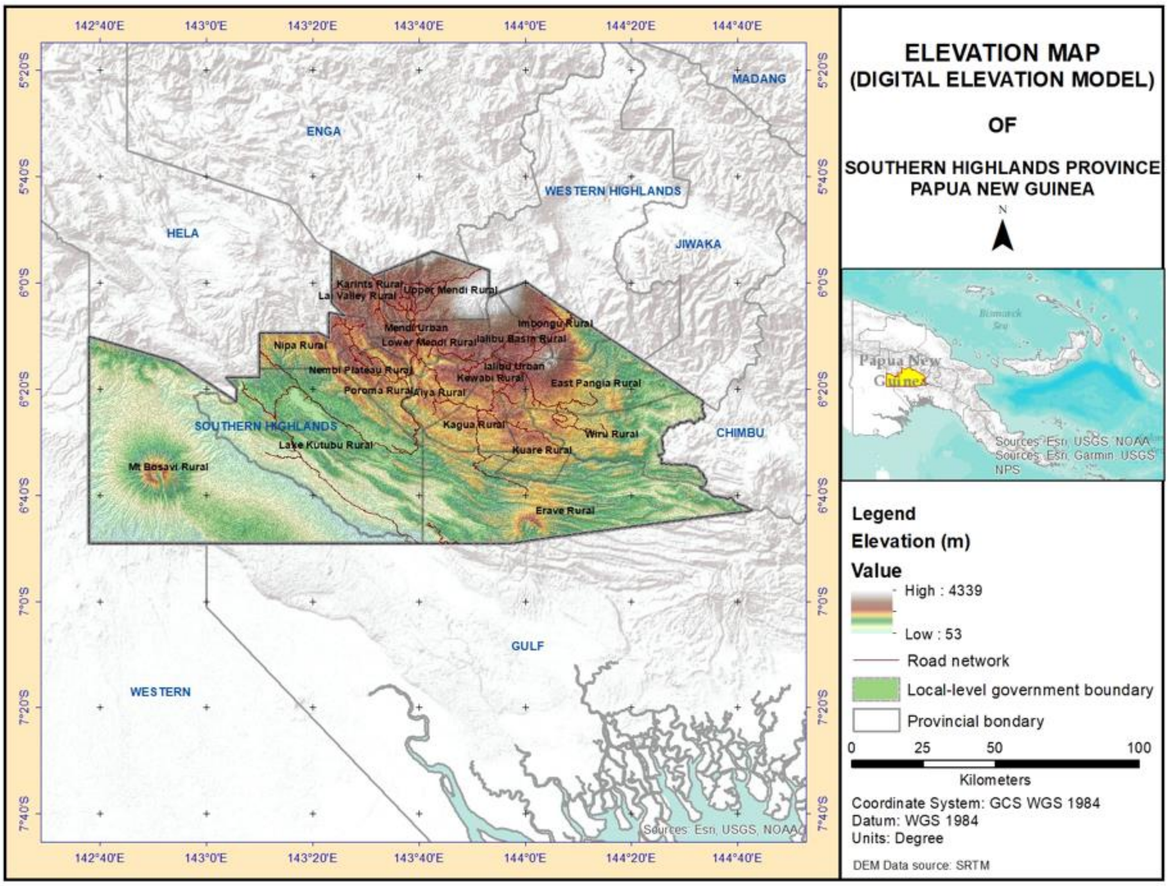



**Figure 5-2. Elevation map of SHP**

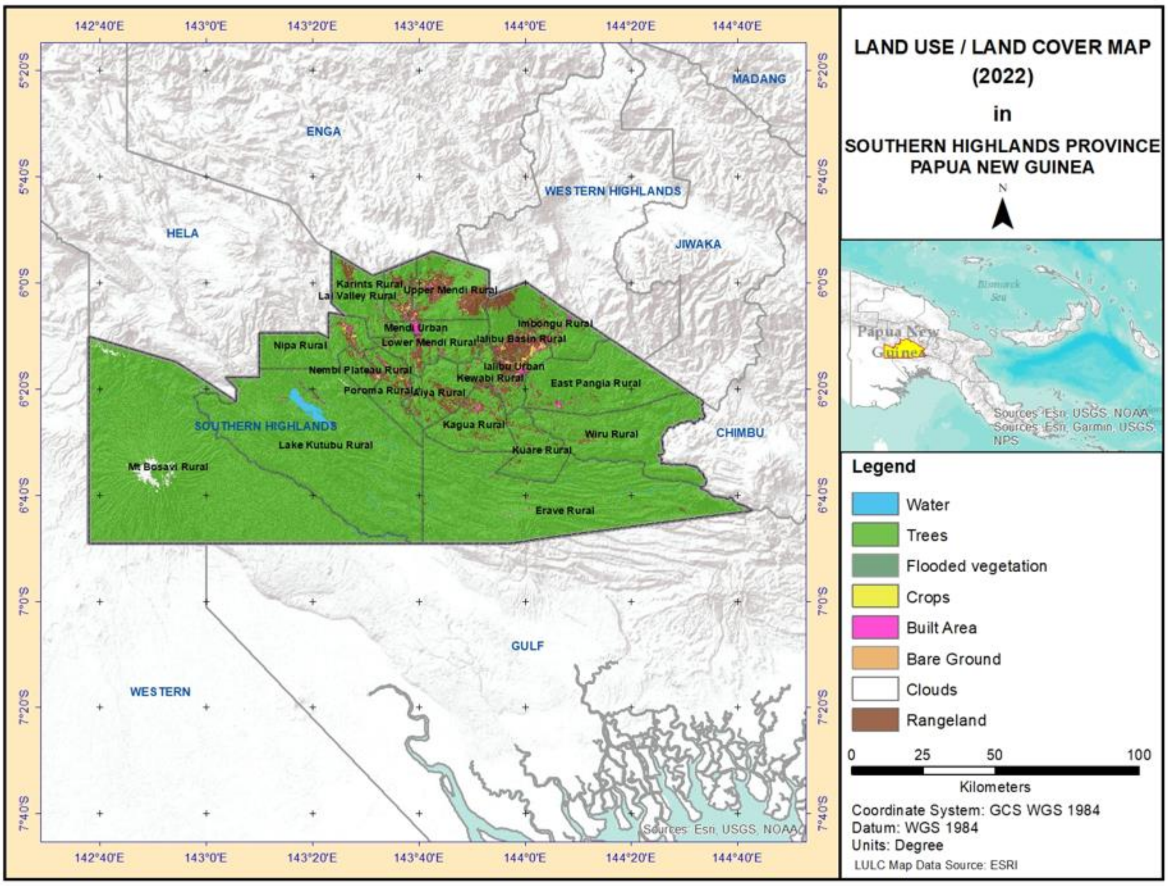



**Figure 5-3. Land use/land cover map of SHP**

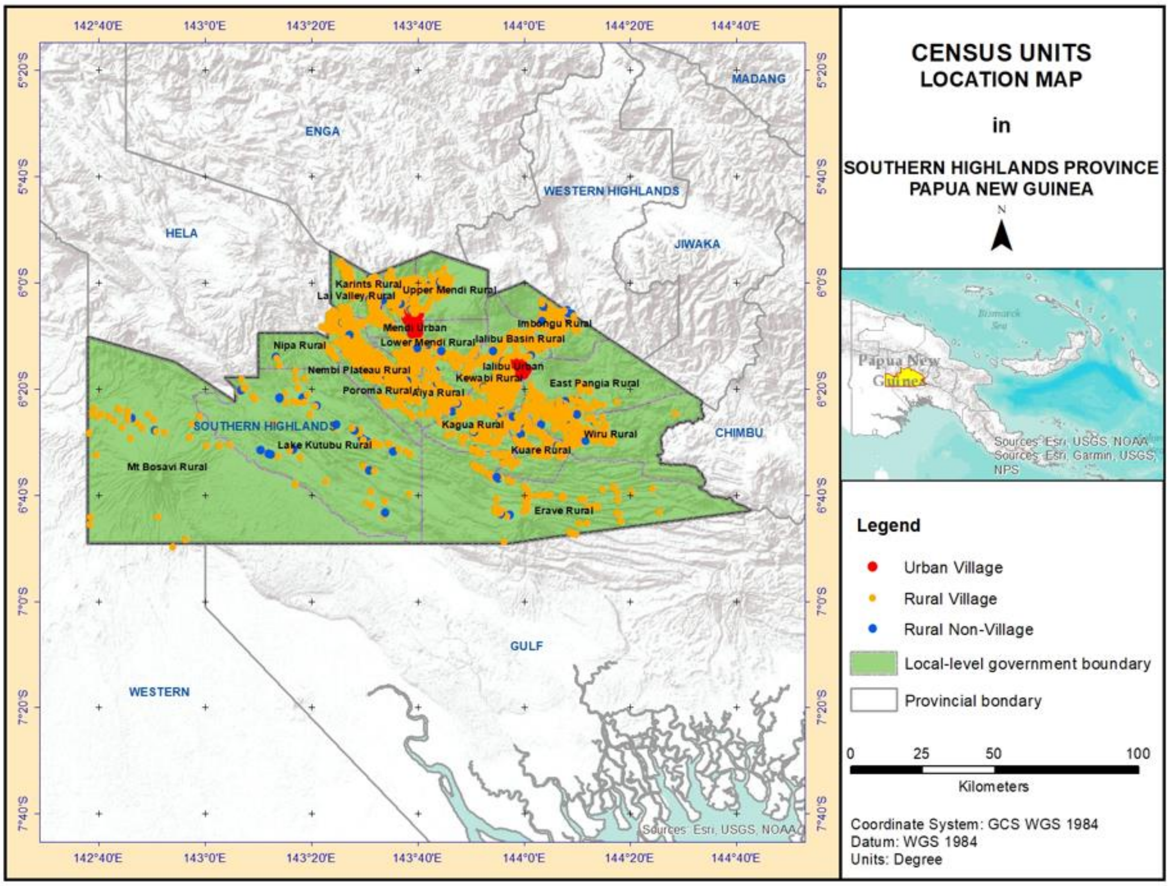



**Figure 5-4. Settlement areas in SHP**

**Table 5-1. Province boundaries and population data**

| District | District Capital | LLG | Population | Area (sq km) | Density |
|---|---|---|---|---|---|
| Ialibu/Pangia District | Ialibu/Pangia | • East Pangia Rural | 15,580 | 903.79 | 17.24 |
| | | • Ialibu Urban | 6,914 | 32.27 | 213.92 |
| | | • Kewabi Rural | 14,300 | 256.14 | 55.83 |
| | | • Wiru Rural | 26,684 | 943.23 | 28.29 |
| | | Total | 63,478 | 2,135.43 | 315.28 |
| | | Percentage/Average | 12.44% | 13.49% | 78.82 |
| Imbonggu District | Imbonggu | • Ialibu Basin Rural | 23,014 | 330.44 | 69.65 |
| | | • Imbonggu Rural | 25,156 | 461.29 | 54.53 |
| | | • Lower Mendi Rural | 32,824 | 483.95 | 67.83 |
| | | Total | 80,994 | 1,275.68 | 192.01 |
| | | Percentage/Average | 15.87% | 8.06% | 64.00 |
| Kagua/Erave District | Kagua | • Erave Rural | 15,952 | 2,430.13 | 6.56 |
| | | • Kagua Rural | 27,338 | 456.98 | 59.82 |
| | | • Kuare Rural | 10,075 | 363.96 | 27.68 |
| | | • Aiya Rural | 20,774 | 358.14 | 58.00 |
| | | Total | 74,139 | 3,609.19 | 152.06 |
| | | Percentage/Average | 14.53% | 22.80% | 38.01 |
| Mendi/Munihi District | Mendi | • Karints Rural | 34,194 | 191.42 | 178.63 |
| | | • Lai Valley Rural | 55,096 | 375.52 | 146.72 |
| | | • Mendi Urban | 21,135 | 15.16 | 1,394.13 |
| | | • Upper Mendi Rural | 34,204 | 549.19 | 62.28 |
| | | Total | 144,629 | 1,131.29 | 1,781.76 |
| | | Percentage/Average | 28.34% | 7.15% | 445.44 |
| Nipa/Kutubu District | Nipa | • Lake Kutubu Rural | 16,070 | 2,798.85 | 5.74 |
| | | • Mount Bosavi Rural | 15,136 | 3,942.04 | 3.84 |

| District | District Capital | LLG | Population | Area (sq km) | Density |
|---|---|---|---|---|---|
| | | • Nembi Plateau Rural | 25,216 | 139.74 | 180.45 |
| | | • Nipa Rural | 48,573 | 486.95 | 99.75 |
| | | • Poroma Rural | 42,010 | 309.08 | 135.92 |
| | | Total | 147,005 | 7,676.66 | 425.7 |
| | | Percentage/Average | 28.81% | 48.50% | 85.14 |

The table shows that population density across the LLGs ranges between a low of 3.84 to 6.56 persons per km$^2$ in Mount Bosavi Rural, Lake Kutubu Rural and Erave Rural respectively, to as high as 1,394.13 persons per km$^2$ in the capital, Mendi.

Figure 5-5 compares the population with road length as well as the number of health and learning facilities in each LLG. In total, SHP has 1,172 kilometers of road length, 113 health facilities, and 166 learning facilities.

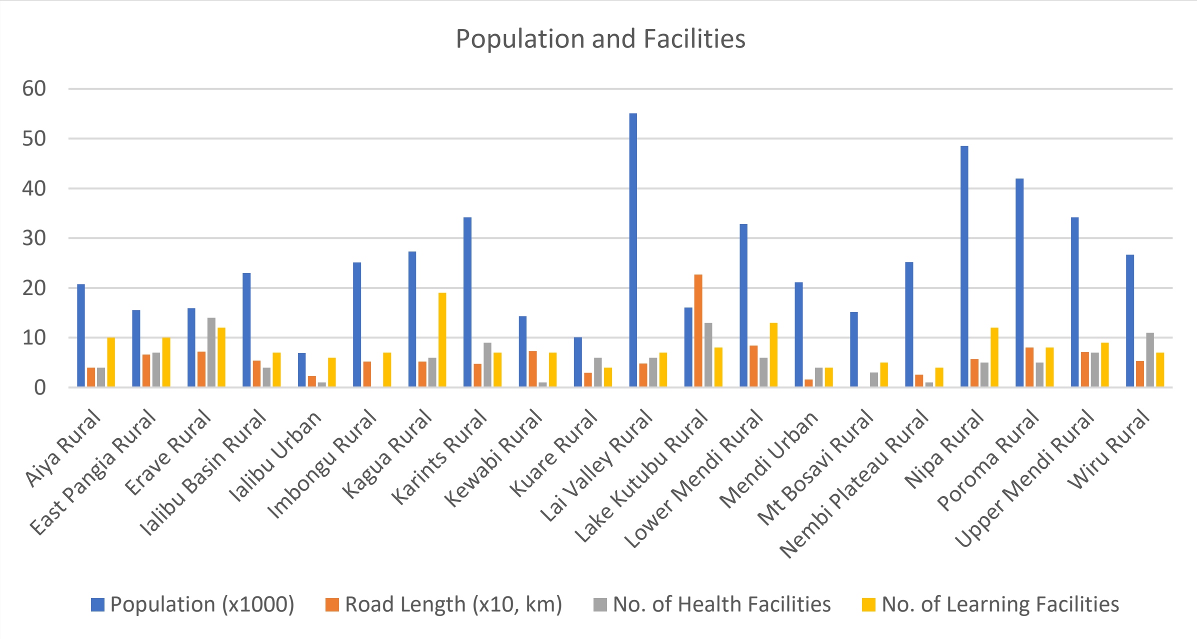



**Figure 5-5. Population and facilities in SHP**

There appear to be no roads in Mt. Bosavi Rural and no health facilities in Imbongu Rural. In contrast, the LLG of Lake Kutubu Rural has more than 200 kilometers of road. Erave Rural and Lake Kutubu Rural have the highest numbers of health facilities at 14 and 13 respectively, while Kagua Rural has the highest number of learning facilities at 19. This is followed by Lower Mendi Rural (13), Erave Rural (12) and Nipa Rural (12).

Figures 5-6 to 5-8 show the location of roads, health and learning facilities in SHP. The majority of these critical facilities are established along the western side of SHP.

Figure 5-9 reveals the average distance of settlements within LLGs to roads, health facilities and learning facilities. Settlements in Mt Bosavi Rural are the furthest away from roads at about 28.84 km, health facilities at 10.26 km and learning facilities at 10.73 km on average. This is followed by those in Kuare Rural and Wiru Rural, which on average are more than three (3) kilometers away from roads. Likewise, residents of Imbongu are more than eight (8) kilometers away from health facilities, while students in Lake Kutubu Rural are more than six (6) kilometers away from learning facilities.

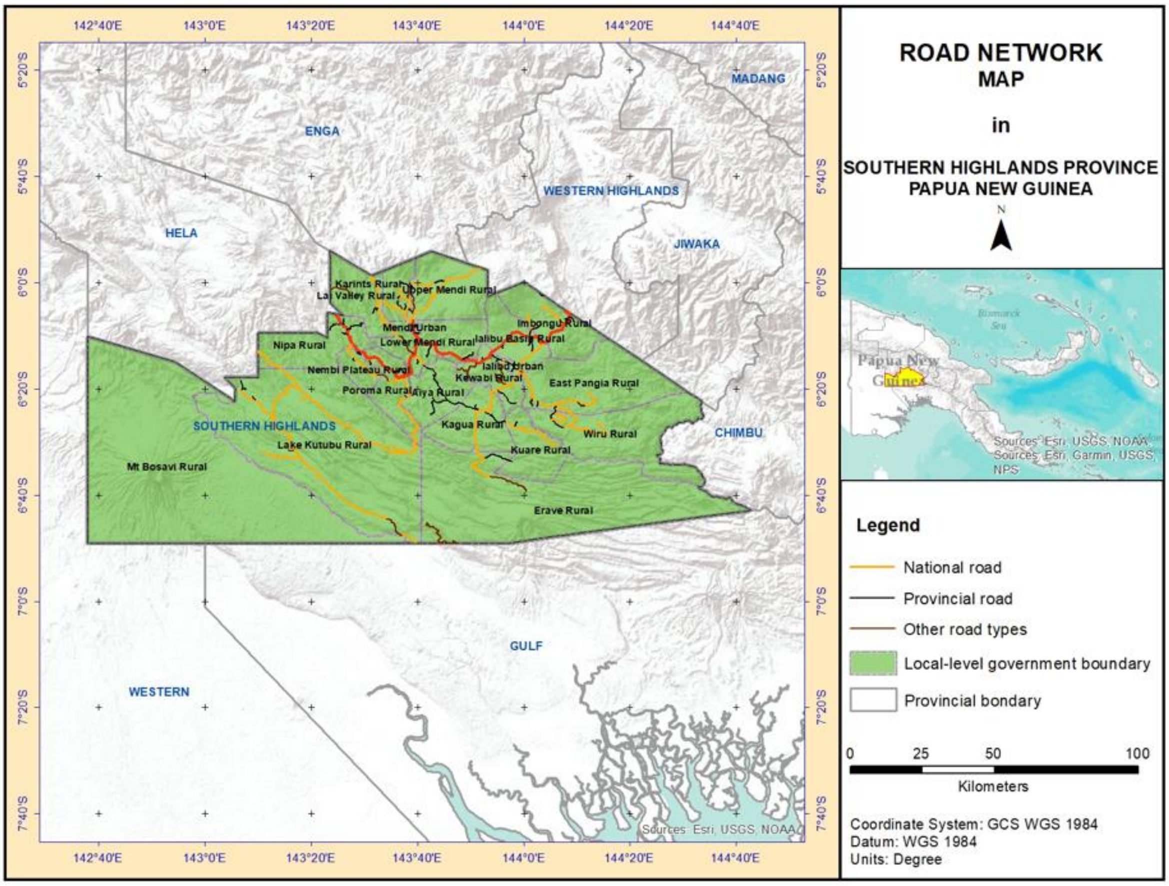



**Figure 5-6. Road network in SHP**

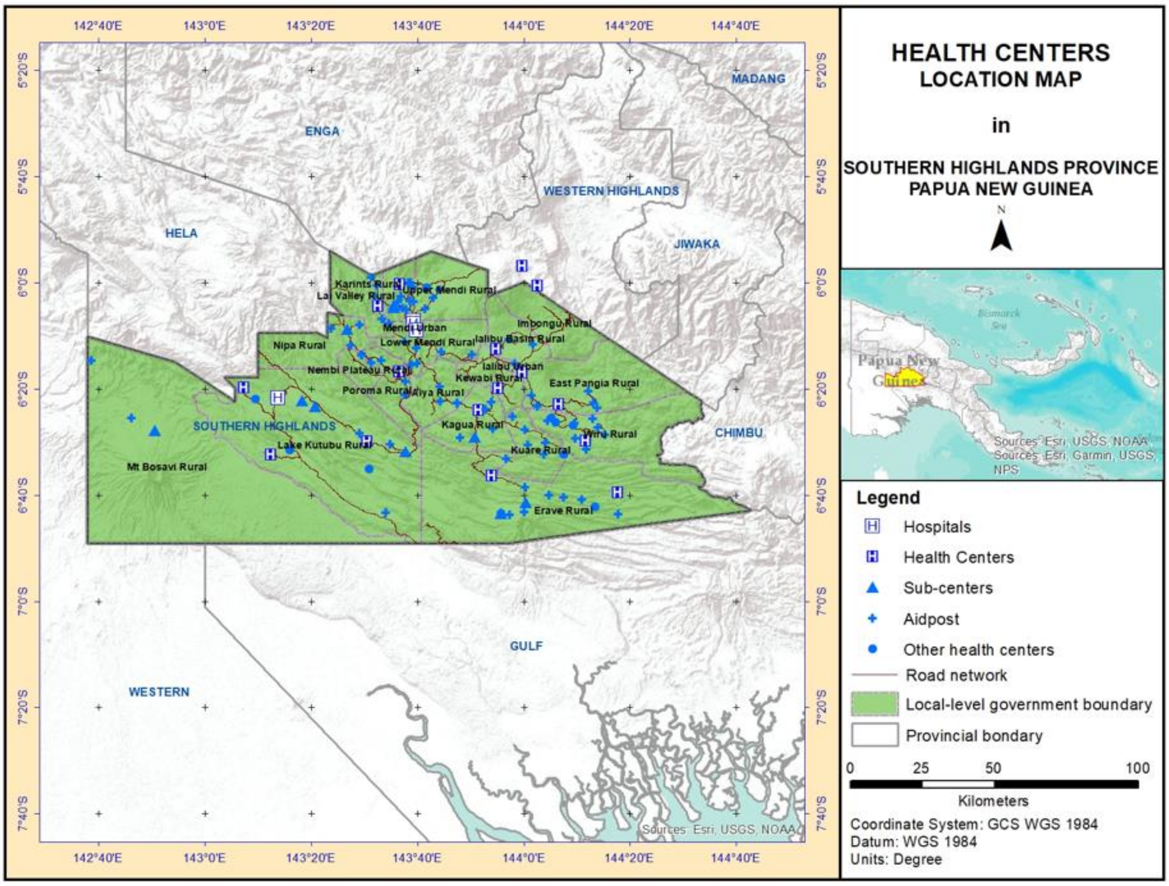



**Figure 5-7. Health facilities in SHP**

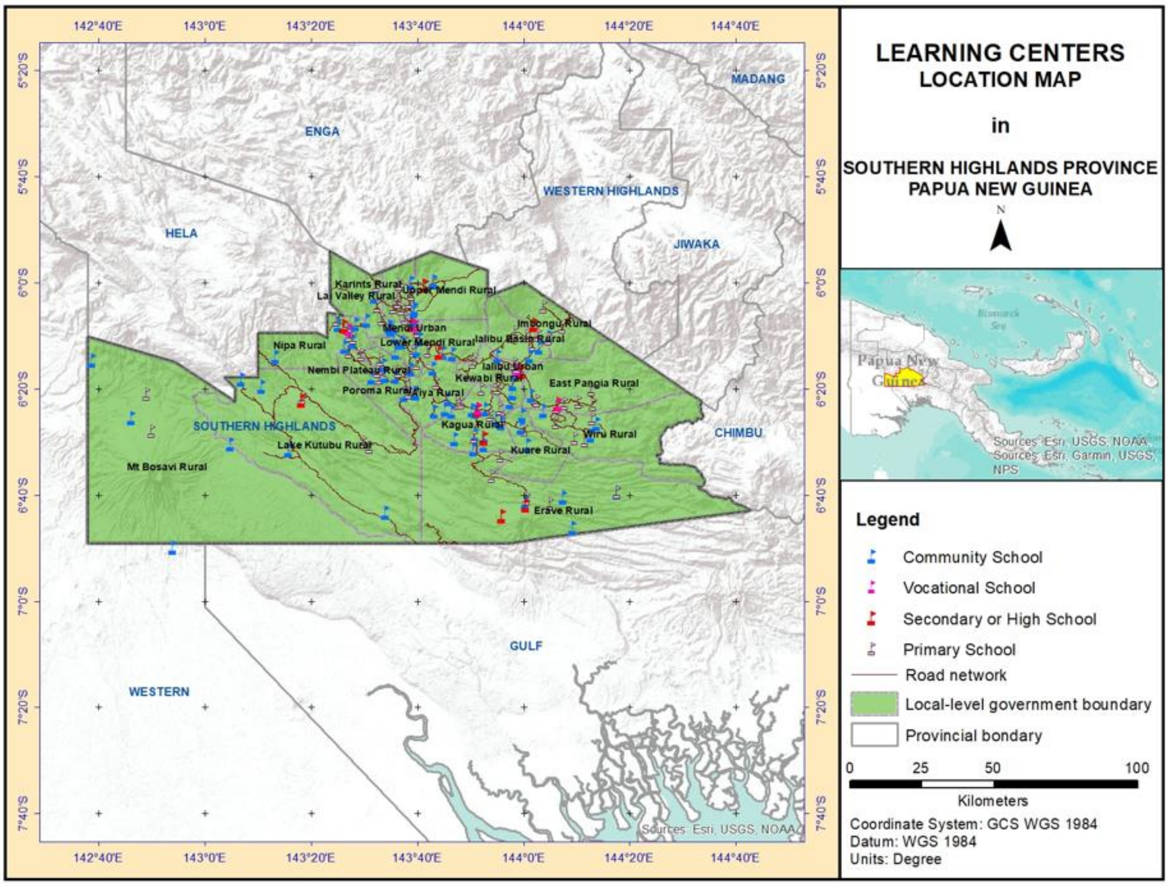



Figure 5-8. Learning facilities in SHP

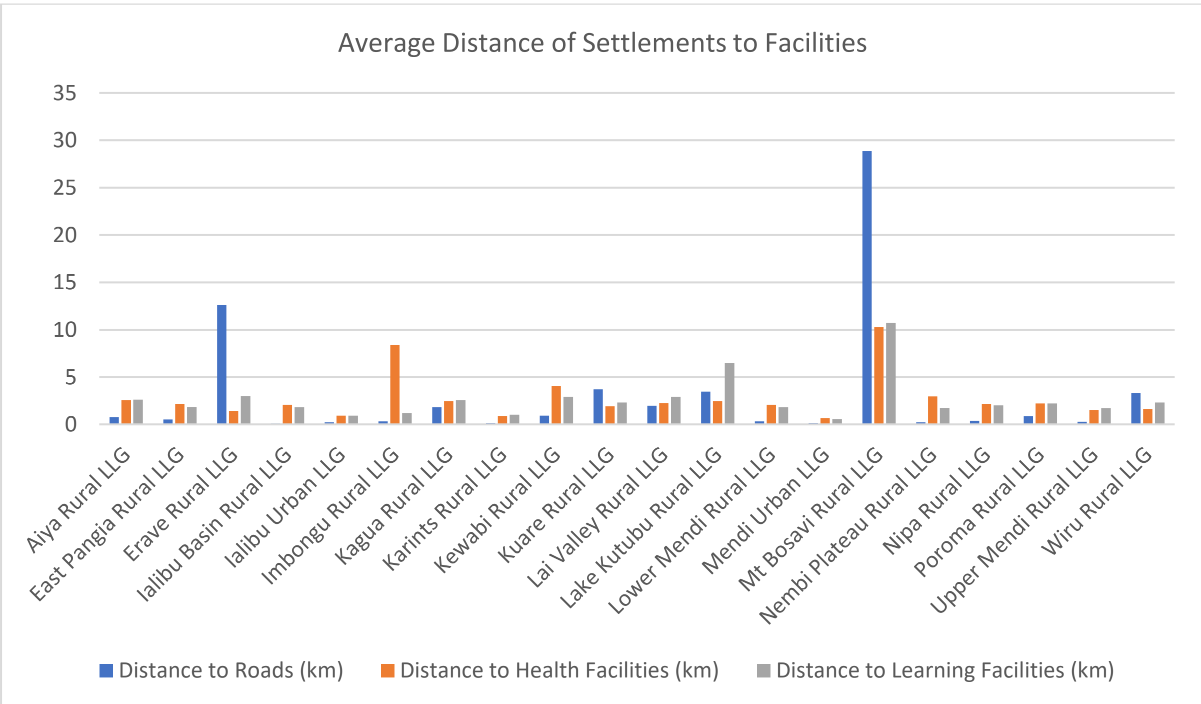



Figure 5-9. Average distance of settlements to facilities

## 5.2. Climate Trends and Projections

SHP receives an average of 3,591mm rainfall annually, spatially varying between 2,339mm to 4,599mm across the province with Nipa-Kutubu district receiving more rainfall than others. The maximum temperature in the province varies from 13°C to 28°C, while minimum temperature varies between 2°C and 23°C. The lowest temperatures are observed during the month of August. Figure 5-10 shows the monthly rainfall, maximum and minimum temperatures, while Figure 5-11 shows the spatial variation of annual rainfall in the province. In general, precipitation in the province is expected to increase in the future (see Figure 5-12).

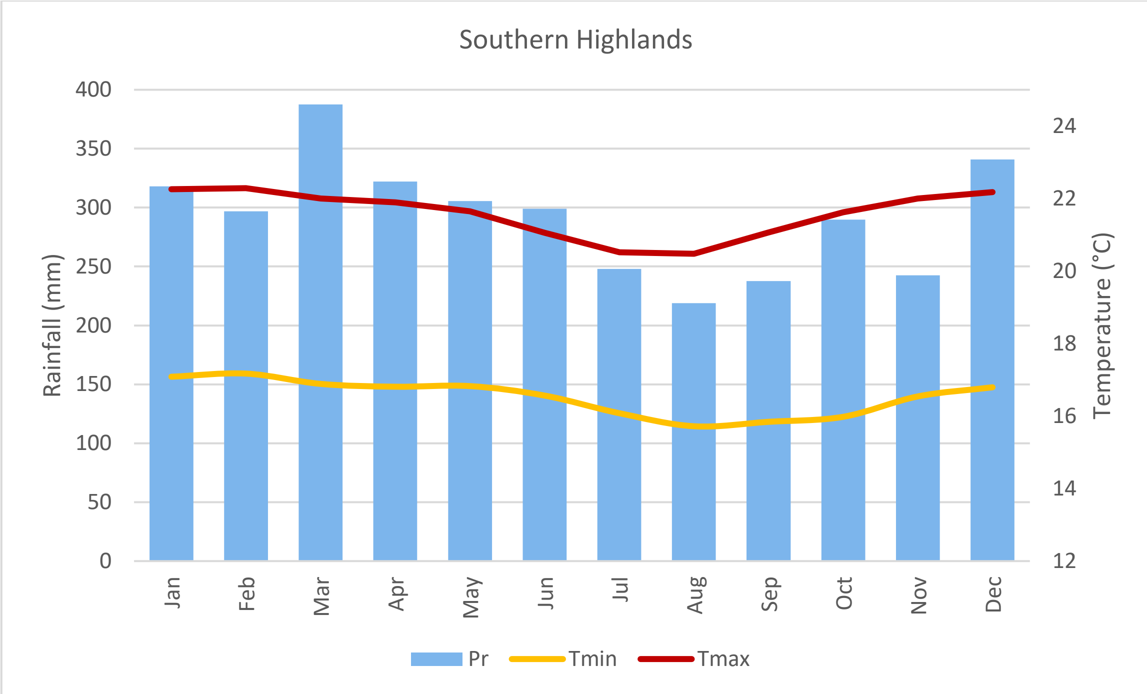



**Figure 5-10. Average monthly rainfall, max and min temperatures in SHP, 1995-2020**

- **Precipitation in Near Future (2023-2048)**. Under SSP245, precipitation is expected to increase by about 9.2% (320mm), varying spatially from 1% to 14% across the province. The average percentage change in precipitations is higher at 12.78% with province-specific variations ranging from 6% to 17% under the SSP585 scenario.
- **Precipitation in Mid Future (2049-2074)**. Precipitation is expected to increase by 11.34%, with spatial variation of 5% to 14% under SSP245, while in SSP585 scenario the precipitation is projected to rise by 14.08% with spatial variation of 8% to 17%.
- **Precipitation in Far Future (2075-2100)**. Precipitation is expected to increase by 14.36% under SSP245, and by 22.57% under SSP585 scenario. The spatial variation is from 8% to 19%, and 14% to 31% for SSP245 and SSP585 respectively.

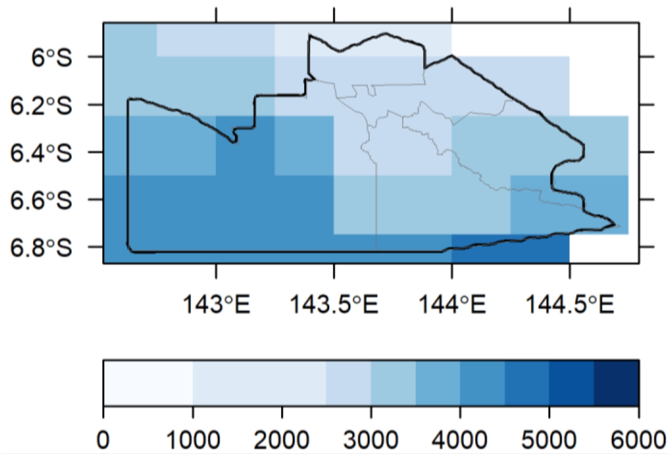



**Figure 5-11. Spatial variation of annual rainfall**

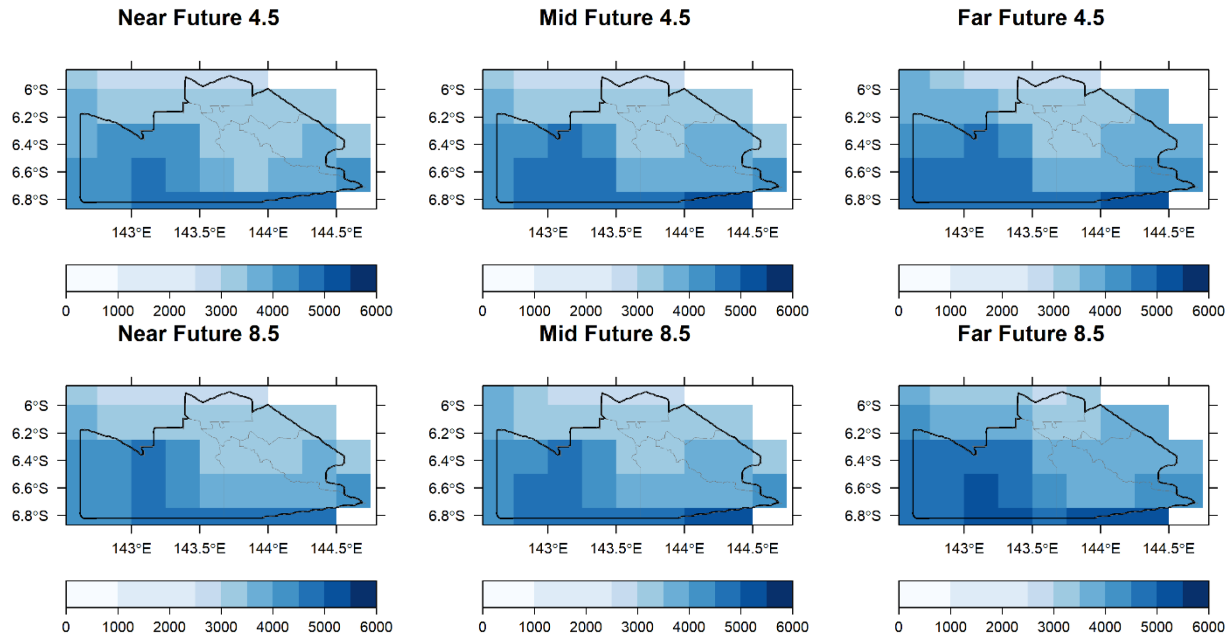
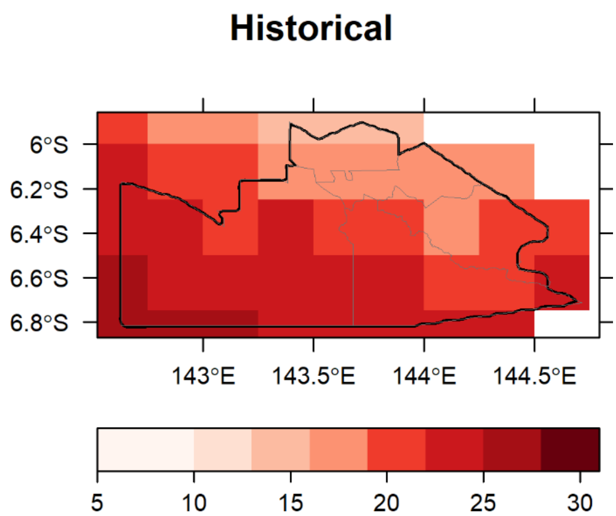



**Figure 5-12. Average annual precipitation in SHP, near mid and far future under SSP245 and SSP585.**

The mean annual maximum temperature in SHP ranges between 13.78-25.89°C. In general, the average maximum temperature is expected to increase in the future. Figure 5-13 shows the maximum temperatures for baseline, near, mid, and far future under SSP245 and SSP585.

- **Maximum Temperature in Near Future (2023-2048)**. Under SSP245, maximum temperature is expected to increase by about 0.71°C, with province-specific variation ranging from 0.58°C to 0.95°C. Under SSP585 scenario, maximum temperature is expected to rise by 0.85°C, varying spatially from 0.71°C to 1.15°C.
- **Maximum Temperature in Mid Future (2049-2074)**. Average maximum temperature is expected to increase by 1.16°C, with spatial variation of 0.98°C to 1.53°C under SSP245, while in SSP585 scenario the average maximum temperature is projected to rise by 1.73°C, with spatial variation of 1.47°C to 2.26°C.
- **Maximum Temperature in Far Future (2075-2100)**. Maximum temperature is expected to increase by 1.31°C under SSP245, and by 2.45°C under SSP585 scenario. The spatial variation is from 1.09°C to 1.78°C, and 2.11°C to 3.14°C for SSP245 and SSP585 respectively.



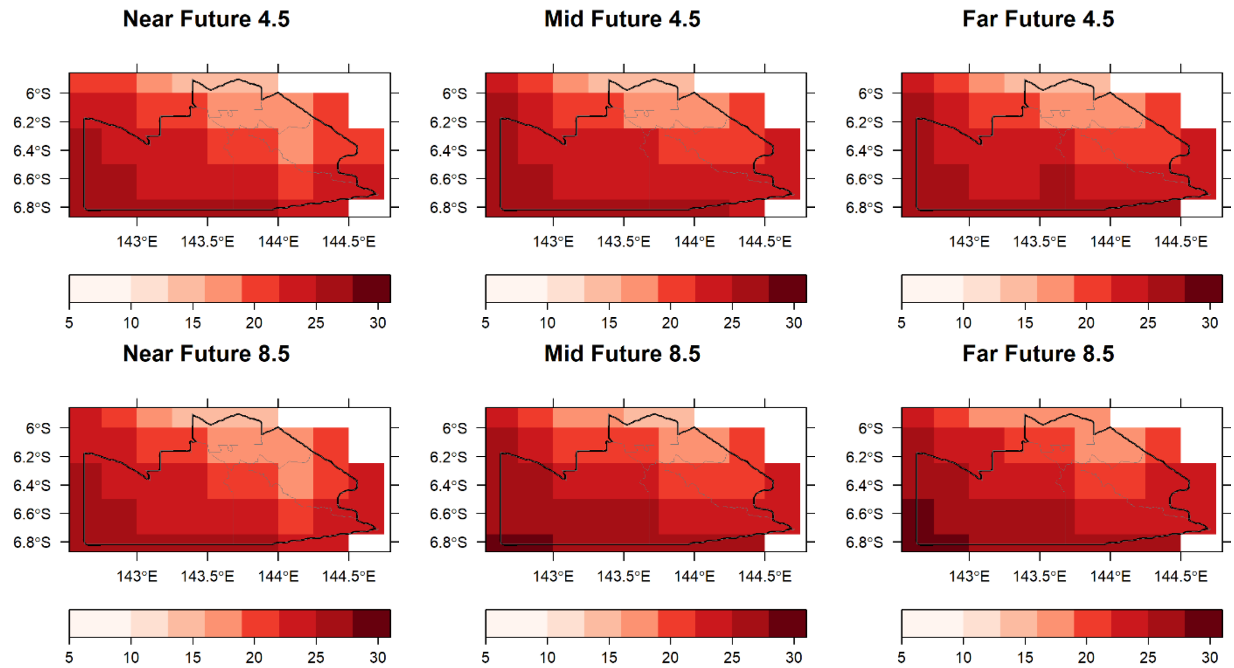
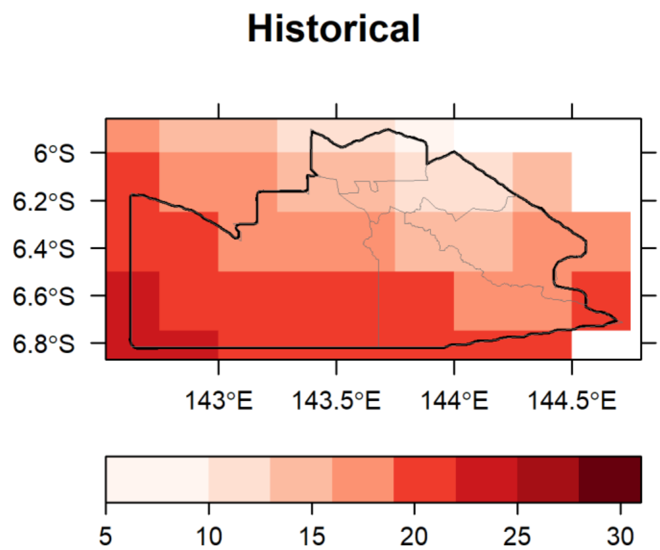



Figure 5-13. Average annual maximum temperature in SHP, near, mid and far future under SSP245 and SSP585

The mean annual minimum temperature in SHP ranges from 9.74°C to 22.77°C. In general, the average minimum temperature is expected to increase with the southwestern part experiencing slightly warmer cold nights in the future. Figure 5-14 shows minimum temperatures for baseline, near, mid, and far future under SSP245 and SSP585.

- **Minimum Temperature in Near Future (2023-2048)**. Under SSP245, minimum temperature is expected to increase by about 0.42°C, with province-specific variation ranging from 0.27°C to 0.68°C. Under SSP585 scenario, minimum temperature is expected to rise by 0.53°C, varying spatially from 0.34°C to 0.79°C.
- **Minimum Temperature in Mid Future (2049-2074)**. Average minimum temperature is expected to increase by 0.8°C, with spatial variation of 0.57°C to 1.13°C under SSP245, while in the SSP585 scenario the average minimum temperature is projected to rise by 1.26°C, with spatial variation of 0.94°C to 1.16°C.
- **Minimum Temperature in Far Future (2075-2100)**. Minimum temperature is expected to increase by 0.91°C under SSP245, and by 1.96°C under the SSP585 scenario. The spatial variation is from 0.64°C to 1.21°C for SSP245.



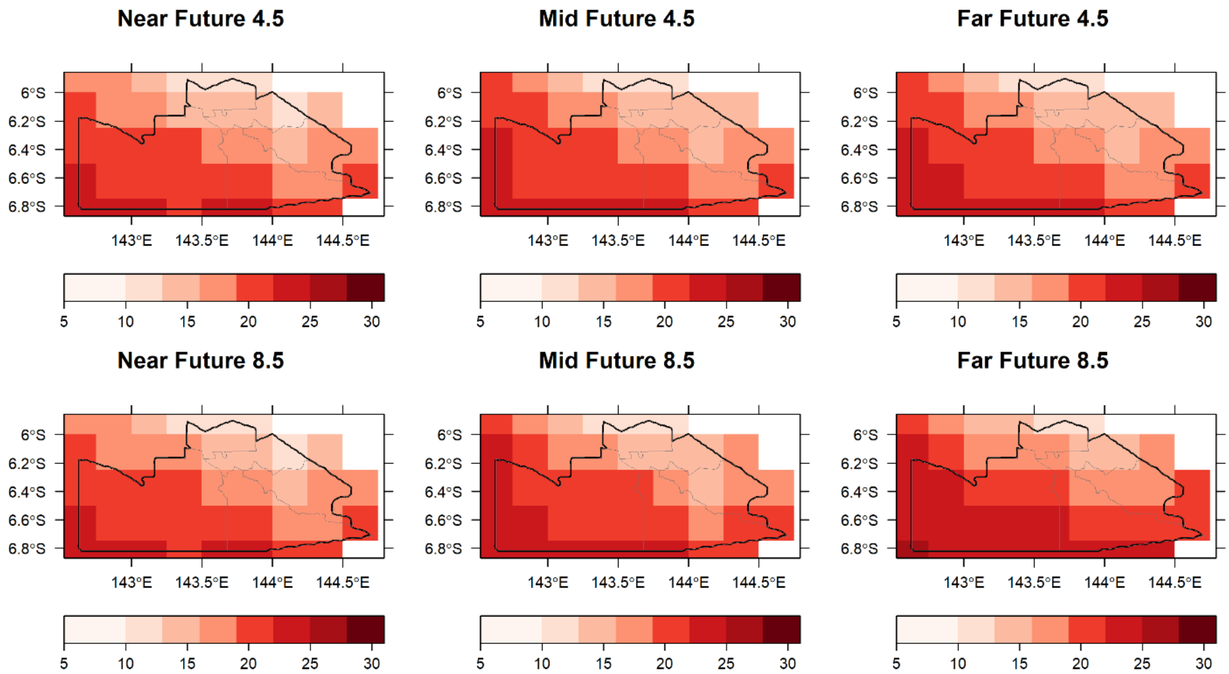
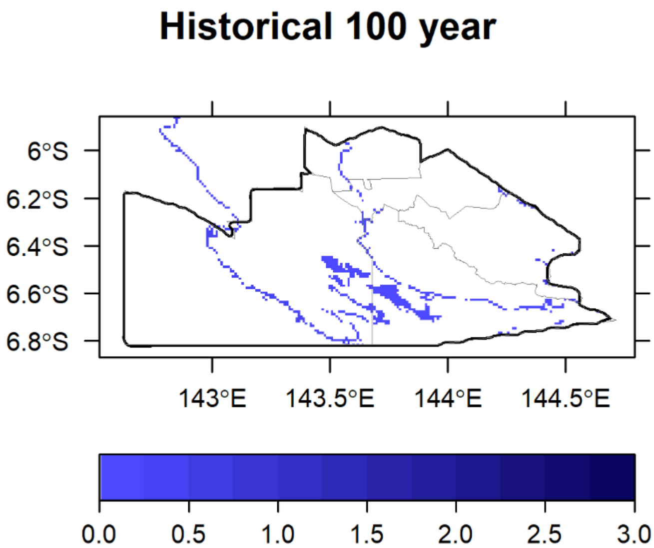


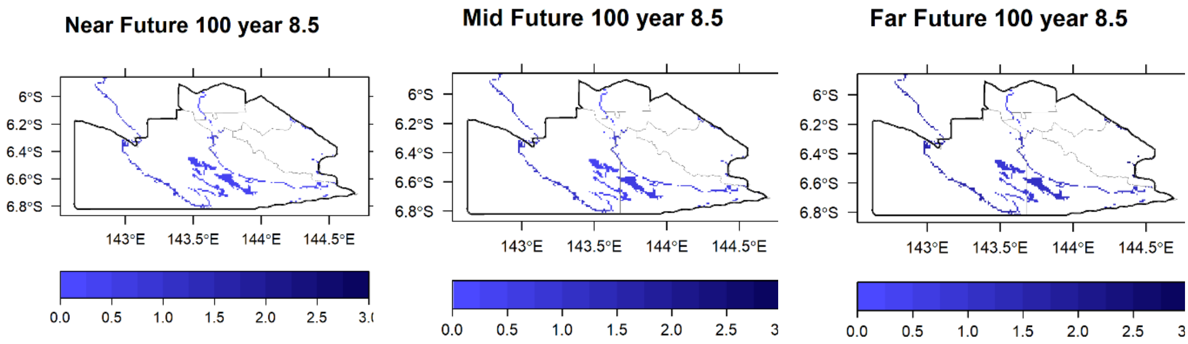

**Figure 5-14. Average annual minimum temperature in SHP, near, mid, and far future under SSP245 and SSP585**

## 5.3. FLOOD

The baseline for maximum flood depth In SHP for a 100-year return period flood event is 1m. The ensemble model indicates that the maximum depth in the future will increase by 0.05m to 0.14m under SSPRCP4.5 scenario and by 0.18m to 0.83m for SSPRCP8.5 scenario. Figure 5-15 shows the spatial extent of the 100-year return period flood, while Table 5-2 indicates the flood area and depth for baseline, near, mid, and far future.




GFDL-ESM2M model projected flood depth and area




1.18 m depth (5.16 sq km) | 1.79 m depth (7.74 sq km) | > 3m depth (18.04 sq km)

**Figure 5-15. Flood depth and extent for 100-year return period flood in SHP for baseline, near, mid, and far future**

**Table 5-2. Flood depth (m) and area (sqkm) for 100-year flood in SHP for baseline, near, mid and far future**

| | SSPRCP4.5 | | | SSPRCP8.5 | | |
|---|---|---|---|---|---|---|
| Scenario | Near | Mid | Far | Near | Mid | Far |
| Historical depth | 1.19m (780sqkm) | | | | | |
| NorESM1-M | 1.19m (780.86sqkm) | 1.14m (780.00sqkm) | 1.15m (780.00sqkm) | 1.37m (782.58sqkm) | 1.32m (780.86sqkm) | 1.57m (784.30sqkm) |
| GFDL-ESM2M | 1.37m (786.02sqkm) | 1.42m (786.88sqkm) | 1.72m (786.88sqkm) | 1.18m (785.16sqkm) | 1.79m (787.74sqkm) | 3.97m (798.04sqkm) |
| HadGEM2-ES | 1.3m (780.00sqkm) | 1.17m (780.00sqkm) | 1.19m (780.86sqkm) | 1.3m (780.86sqkm) | 1.38m (782.58sqkm) | 1.36m (780.86sqkm) |
| IPSL-CM5A-LR | 1.46m (784.30sqkm) | 1.56m (784.30sqkm) | 1.82m (786.02sqkm) | 1.17m (780.00sqkm) | 1.53m (783.44sqkm) | 2.31m (786.02sqkm) |
| MIROC-ESM-CHEM | 0.89m (779.15sqkm) | 0.83m (779.15sqkm) | 0.79m (779.15sqkm) | 0.92m (779.15sqkm) | 0.83m (779.15sqkm) | 0.89m (779.15sqkm) |
| **Average** | **1.24m (782.07sqkm)** | **1.22m (782.07sqkm)** | **1.33m (782.58sqkm)** | **1.19m (781.55sqkm)** | **1.37m (782.75sqkm)** | **2.02m (785.67sqkm)** |

**Five Consecutive Days Rainfall (Rx5day)**. The baseline for Rx5day for SHP is 168.46mm, with spatial variability of 86mm to 238.81mm. In both SSP245 and SSP585 scenarios, trends indicate potential for significant increase in five-day consecutive rainfall amount in the near, mid, and far future.

- **Rx5day in Near Future (2023-2048)**. Under SSP245, Rx5day is expected to increase by 40.42%, with province-specific variation ranging from 20.31% to 55.86%. Under SSP585 scenario, Rx5day is expected to rise by 43.58%, varying spatially from 23.34% to 60.53.
- **Rx5day in Mid Future (2049-2074)**. Rx5day is expected to increase by 37%, with spatial variation of 23% to 45.47% under SSP245, while in SSP585 scenario Rx5day is projected to rise by 40.32%, with spatial variation of 26.16% to 52.06%.
- **Rx5day in Far Future (2075-2100)**. Rx5day is expected to increase by 42.44% (21.52-52.77%) under SSP245, and by 54.95% (37.06-71.72%) under SSP585 scenario.

Figure 5-16 shows the highest five-day precipitation amount in SHP for baseline, near, mid and, far future under SSP245 and SSP585.

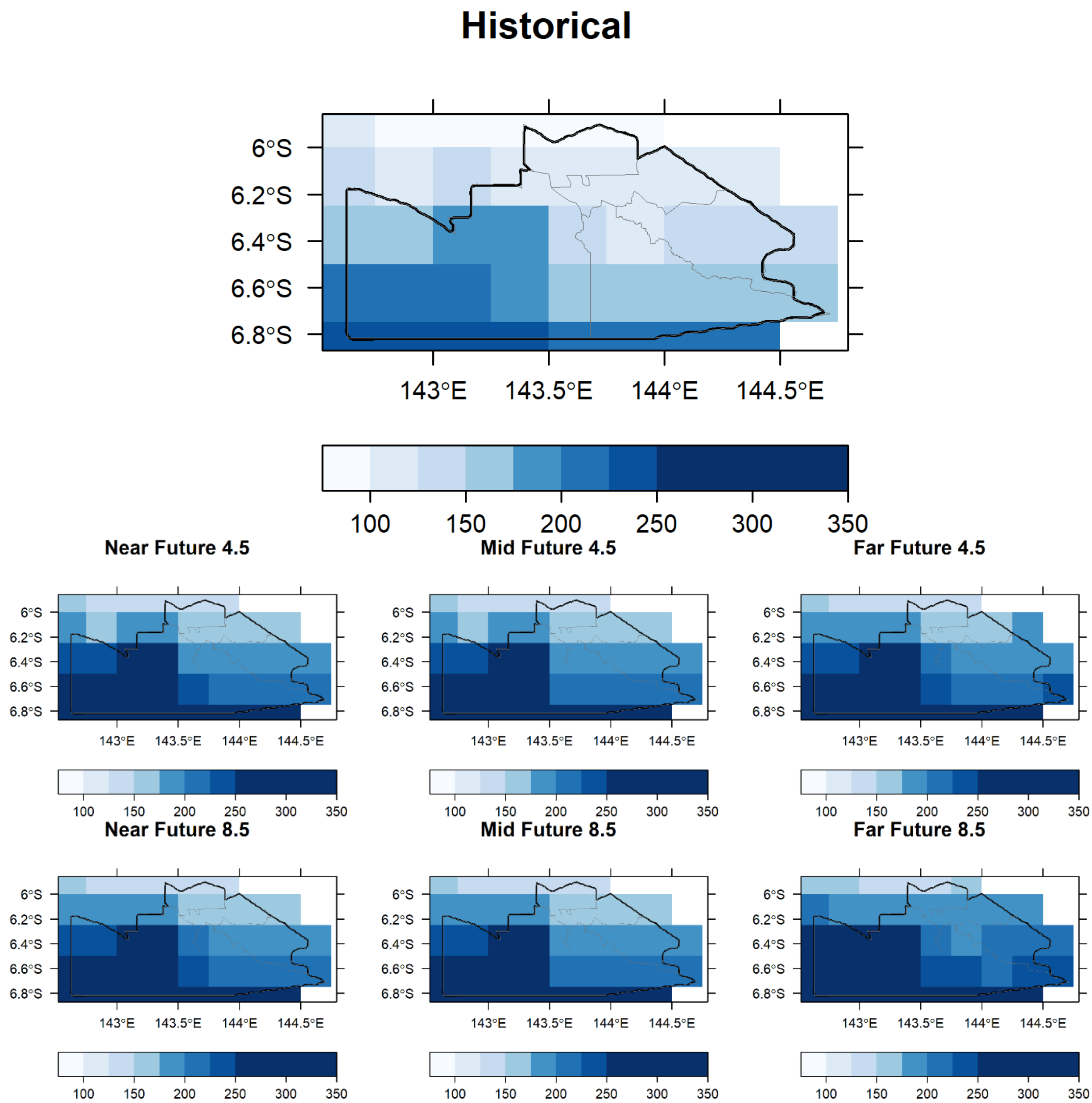



**Figure 5-16. Five consecutive days rainfall in SHP for baseline in mm, and percentage increase for near, mid, and far future under SSP245 and SSP585**

**Number of Extremely Wet Days (R99p)**. SHP has a baseline R99p value of 168mm. In the SSP245 scenario, the projected R99p values range between 39mm to 60mm for near to far future. In the SSP585 scenario, the R99p values range between 44mm to 125mm for near to far future. This indicates potential increase of up to 238% compared to the baseline.

**Table 5-3. Increase in R99p from baseline value**

| Scenario | Near | Mid | Far |
|---|---|---|---|
| Baseline | | 168mm (63 to 272mm) | |
| SSP245 | 52mm (-1 to 124mm) | 39mm (3 to 110mm) | 60mm (1 to 128mm) |
| SSP585 | 44mm (-6 to 129mm) | 68mm (32 to 125mm) | 125mm (32 to 238mm) |

**Maximum One Day Rainfall and Consecutive Wet Days (Rx1day and CWD)**. The maximum 1-day precipitation in SHP is projected to increase by 10% to 44%. Similarly, the consecutive wet days is projected to increase by an average of 2 to 40 days.

Table 5-4. Percentage increase in Rx1day, and number of days increase in CWD from baseline

| Scenario | Near | Mid | Far | Near | Mid | Far |
|---|---|---|---|---|---|---|
| Baseline | Rx1day 71.04mm (35.37-103.31mm) | | | CWD 35 days (25-44 days) | | |
| SSP245 | 27.33% (16.79-45.43%) | 24.63% (17.29-36.99%) | 25.26% (10.19-36.43%) | 2 (-14 to 8) days | 3 (-14 to 9) days | 40 (35 to 51) days |
| SSP585 | 27.37% (16.65-45.89%) | 30.94% (22.03-42.39%) | 33.65% (22.27-44.79%) | 3 (-13 to 12) days | 4 (-10 to 16) days | 38 (30 to 52) days |

## 5.4. Drought and Frost

The assessment of drought involved analysis of its duration, intensity and severity using SPEI and SPI, while the assessment of frost focused on the analysis of the minimum of minimum temperature (TNN).

### 5.4.1 Drought

**Duration**. The duration of drought for baseline period is on average 4 months – minimum duration of 2.8 months and maximum duration of 5.14 months. Based on SPEI analysis the duration is projected to decrease for all scenarios.

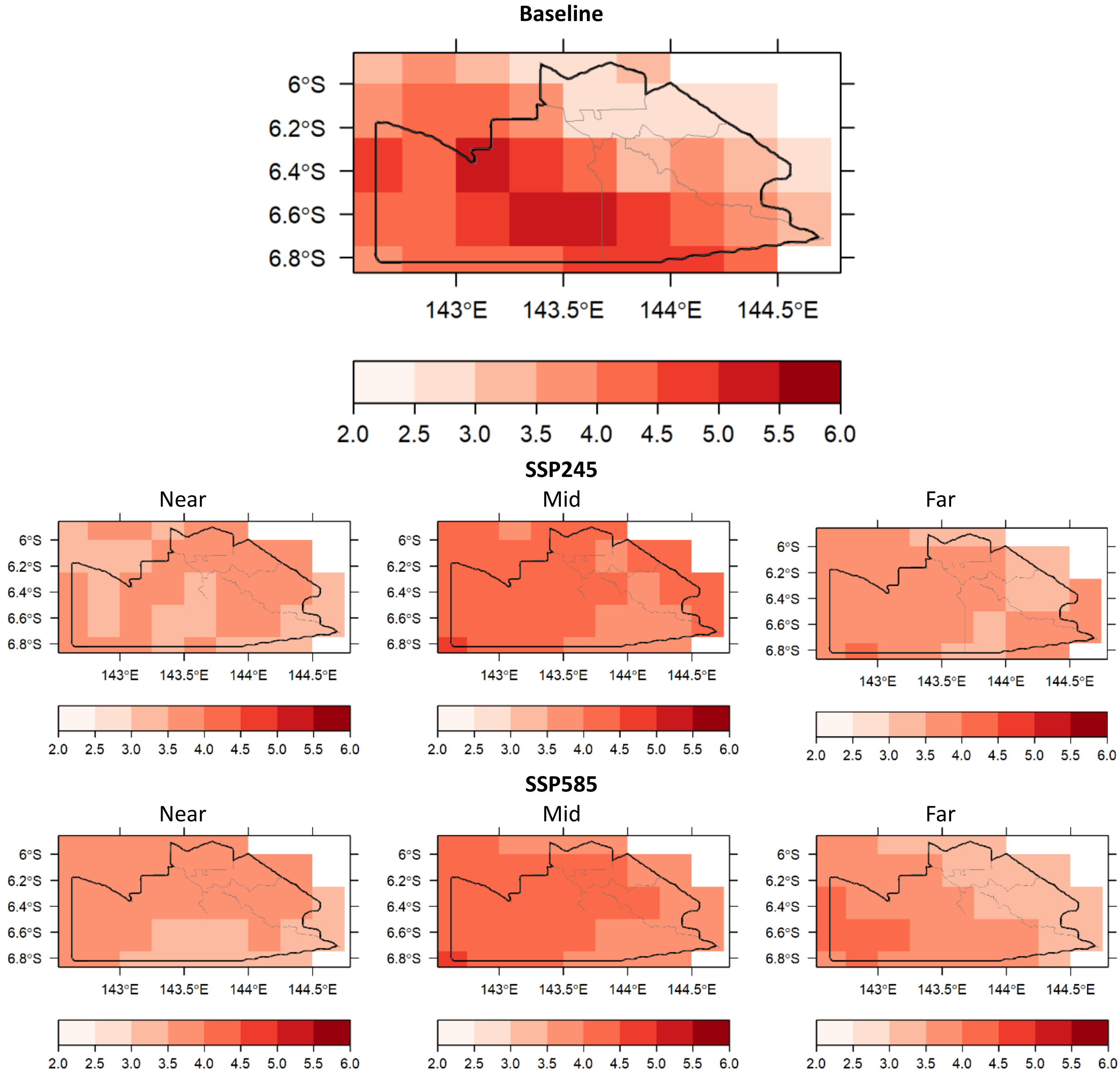



Figure 5-17. Duration of drought based on SPEI

Analysis of drought duration based on SPI3, SPI6, and SPI12[13] yielded relatively similar results. Figure 5-18 shows the analysis using SPI12, where the length of drought is expected to become shorter for all scenarios. This means that the period of time during which below-normal precipitation conditions persist will be shorter.

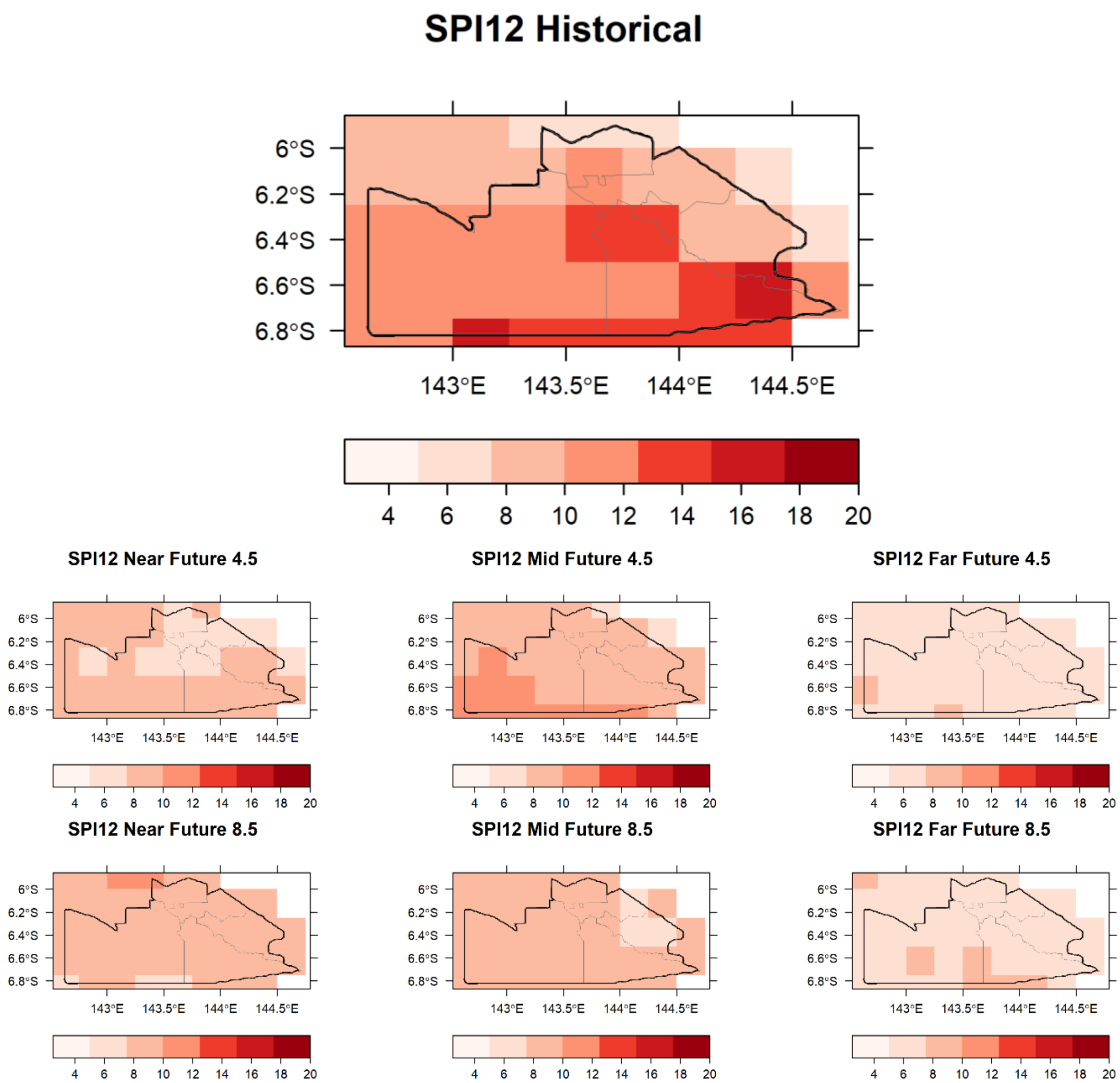



Figure 5-18. Duration of drought based on SPI12

**Intensity**. The overall projection for SSP245 and SSP585 show that the intensity of drought is projected to increase in near, mid and far future with very high intensity for mid and far future scenarios.

The analysis of drought intensity based on SPI3, SPI6 and SPI12[14] yielded similar results. In particular, the analysis using SPI3 and SPI6 indicate very intense droughts in the mid and far future for both SSP245 and SSP585 scenarios. For SPI12, the analysis indicates overall more intense drought with slightly less intensity in the far future for SSP585 (see Figure 5-20).

[13] Refer to Appendix 4 for the results of analysis based on SPI.
[14] Refer to Appendix 5 for the results of analysis based on SPI.

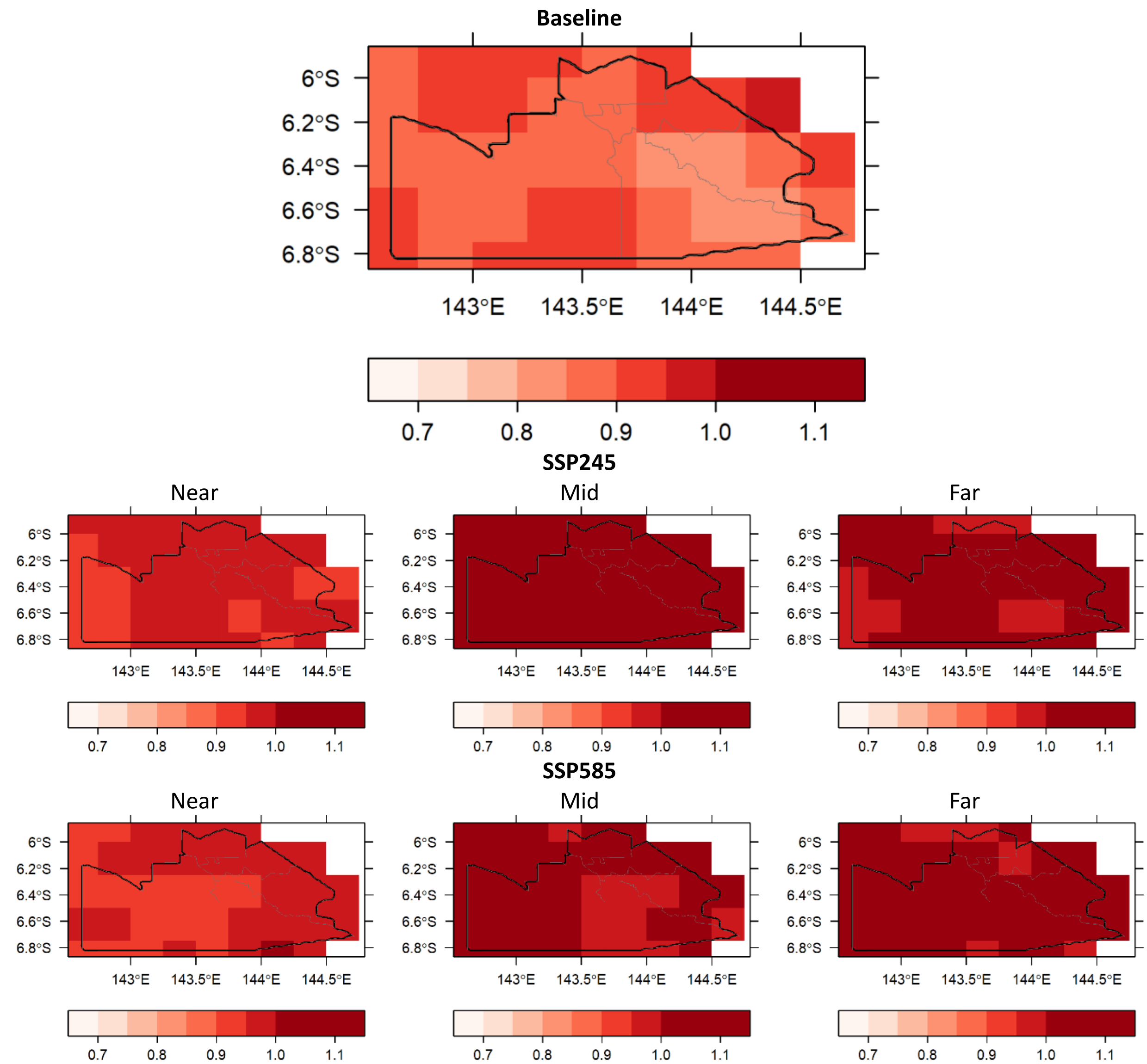
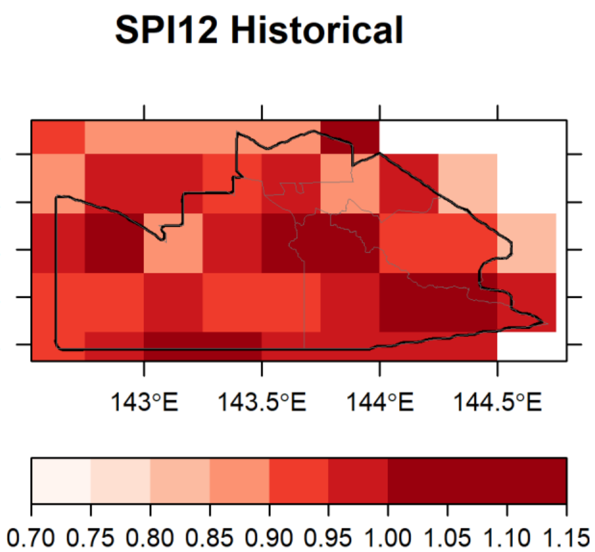


Figure 5-19. Intensity of drought based on SPEI



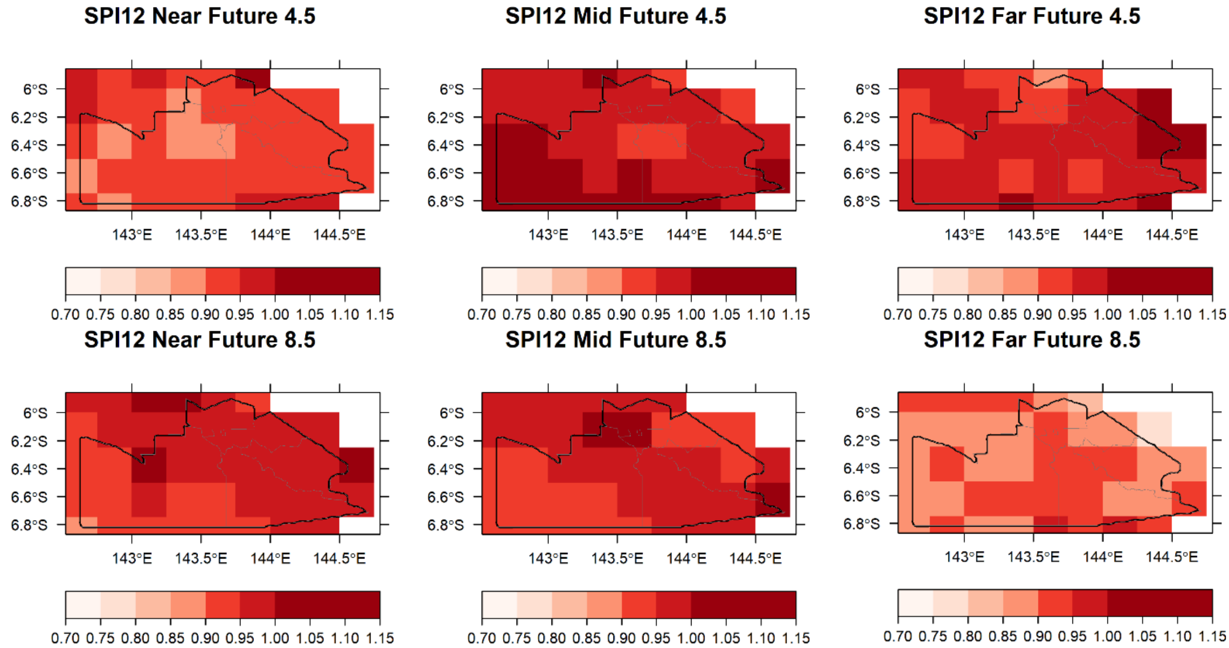
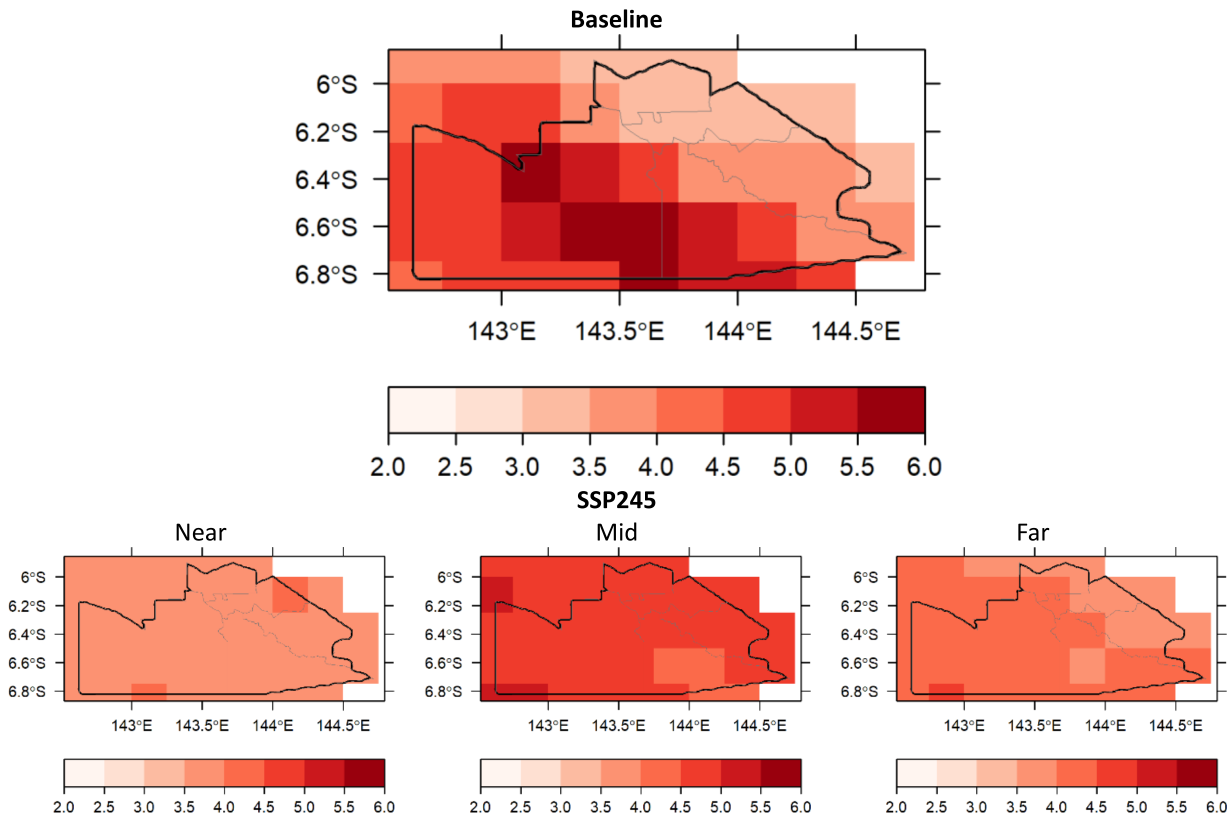


Figure 5-20. Intensity of drought based on SPI12

**Severity**. Based on SPEI analysis, the severity of drought is expected to slightly increase in the mid future, but decrease in the near and far future in both SSP245 and SSP585 scenarios.




SSP585

Near Mid Far

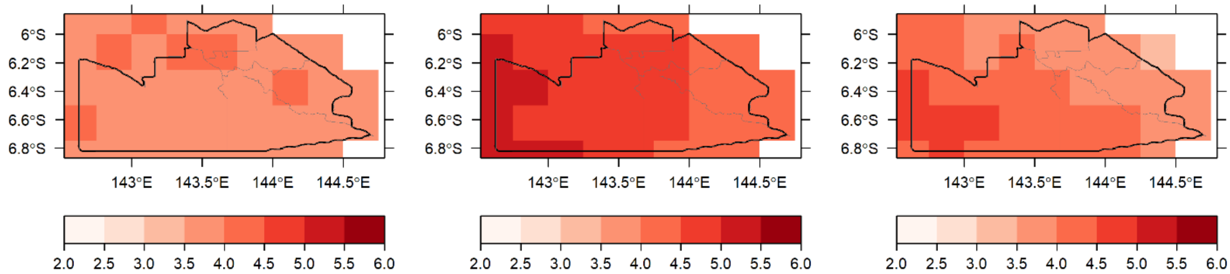


Figure 5-21. Severity of drought based on SPEI

Analysis of drought severity based on SPI3, SPI6 and SPI12[15] yielded similar results. In particular, the analysis using SPI3 indicate more severe droughts in the mid future and less severe drought in the near and far future for both SSP245 and SSP585 scenarios. However, the analysis using SPI6 and SPI12 indicate relatively less severe overall impact for all future scenarios.

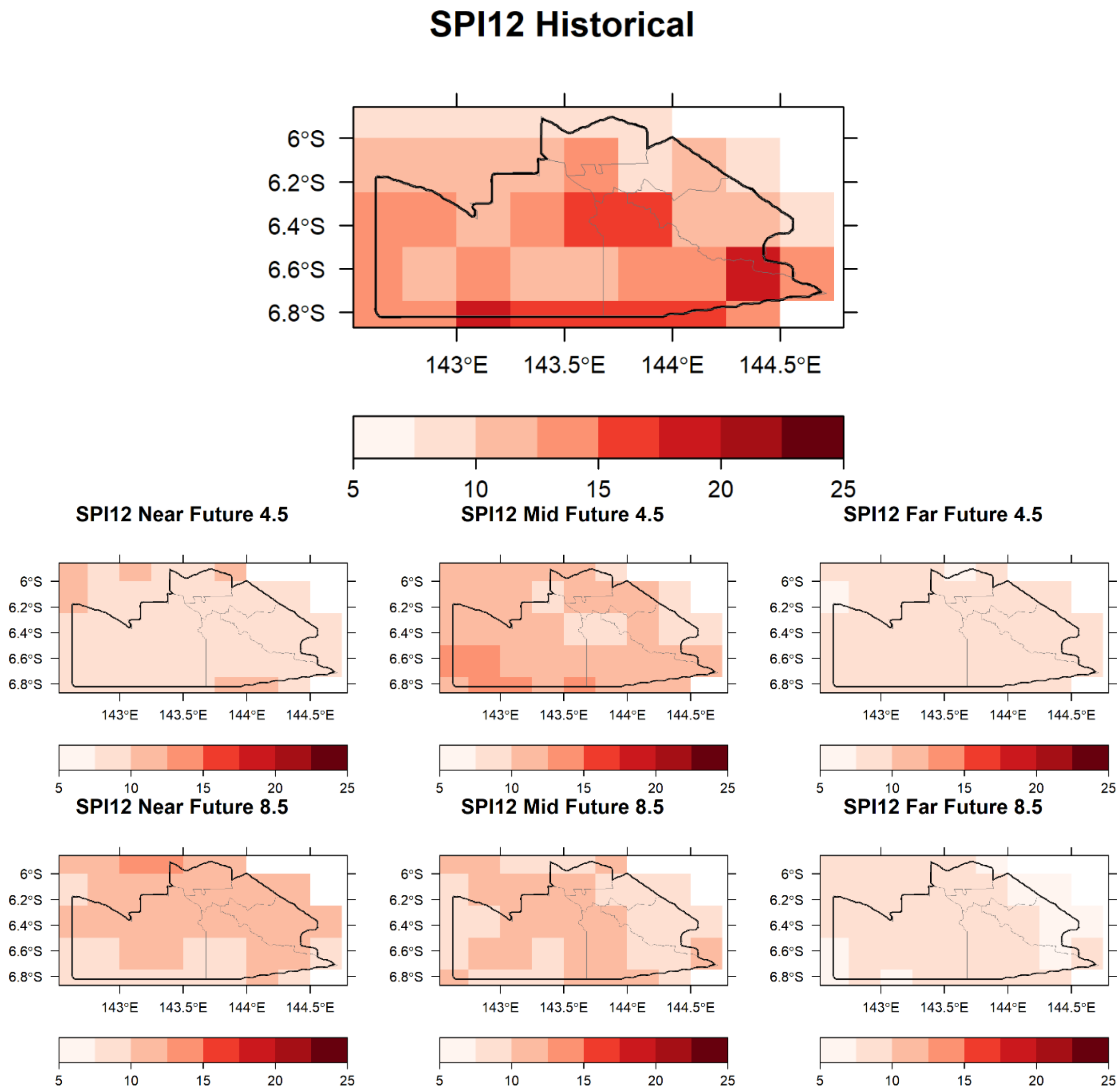


Figure 5-22. Severity of drought based on SPI12

[15] Refer to Appendix 6 for the results of analysis based on SPI.

Analysis of the probability of occurrence of moderate drought was conducted using SPEI 6. The results indicate potential decrease in the probability of occurrence of moderate drought in the near and far future, but potential increase in the mid future for SSP245 and SSP585 scenarios.

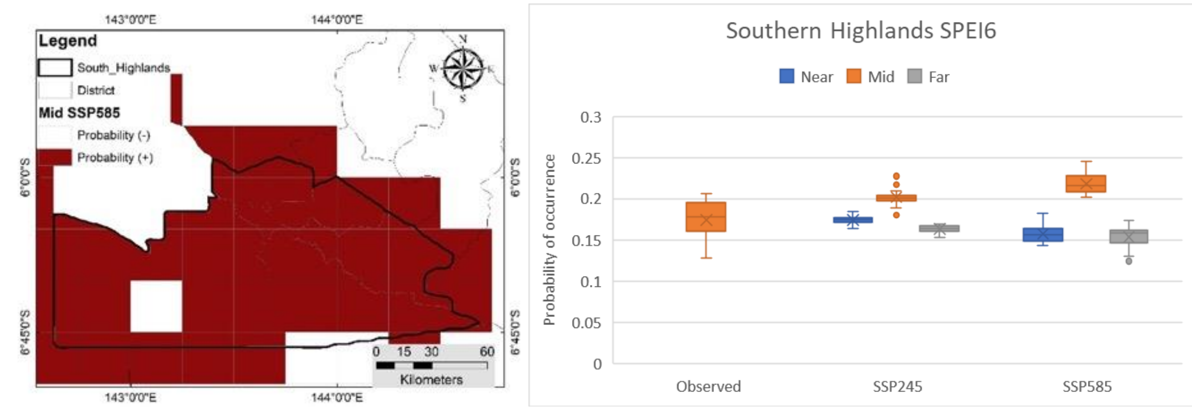



Figure 5-23. Probability of moderate drought in SHP

Additional analysis of consecutive dry days (CDD) index indicate potential increase of an average 3 to 10 days in the number of CDD for all scenarios.

Table 5-5. Increase in CDD from baseline value

| Scenario | Near | Mid | Far |
|---|---|---|---|
| Baseline | | 10 days (8 to 13 days) | |
| SSP245 | 3 days (0 to 6 days) | 5 days (2 to 8 days) | 7 days (4 to 14 days) |
| SSP585 | 3 days (0 to 6 days) | 5 days (3 to 8 days) | 10 days (6 to 16 days) |

### 5.4.2 Frost

Provincial stakeholders consider frost as a major hazard in SHP. Previous frost events were typically observed together with droughts. Frosts were reported in 1977, 1982, 1997 and 2015/2016, with the latter two considered significant in terms of impact. These years coincide with the incidence of very strong El Nino, which is associated with the occurrence of drought and frosts in high altitude areas of the province.

In general, El Nino causes warmer than average maximum temperatures, and decreases the cloud cover which often leads to cooler-than-average night-time temperatures. Figure 5-24 shows the minimum of minimum temperature (TNN) analysis as well as elevation of SHP while Figure 5-25 compares the TNN anomaly in SHP for El Nino years 1982, 1997, 2002 and 2015.

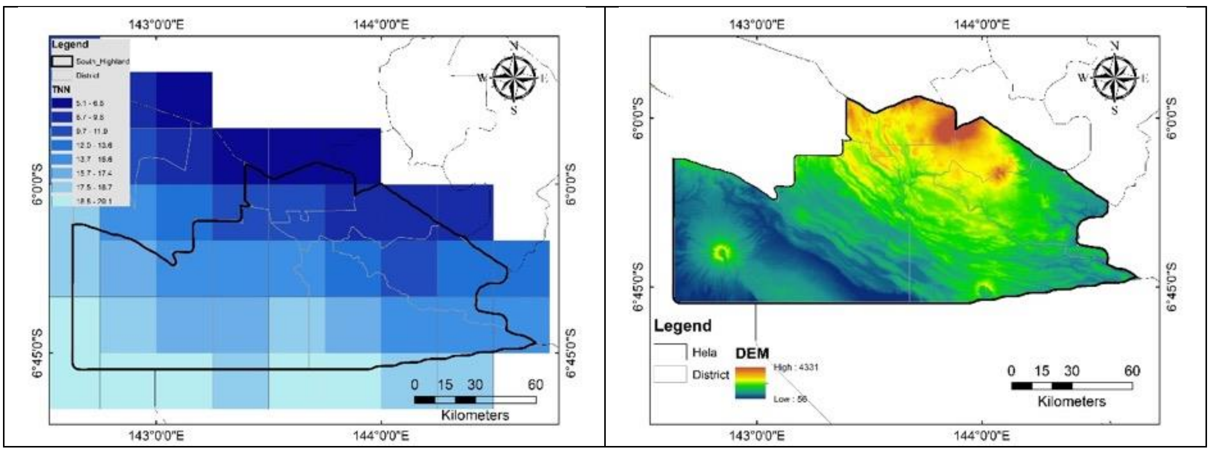



Figure 5-24. Minimum of minimum temperature and elevation of SHP

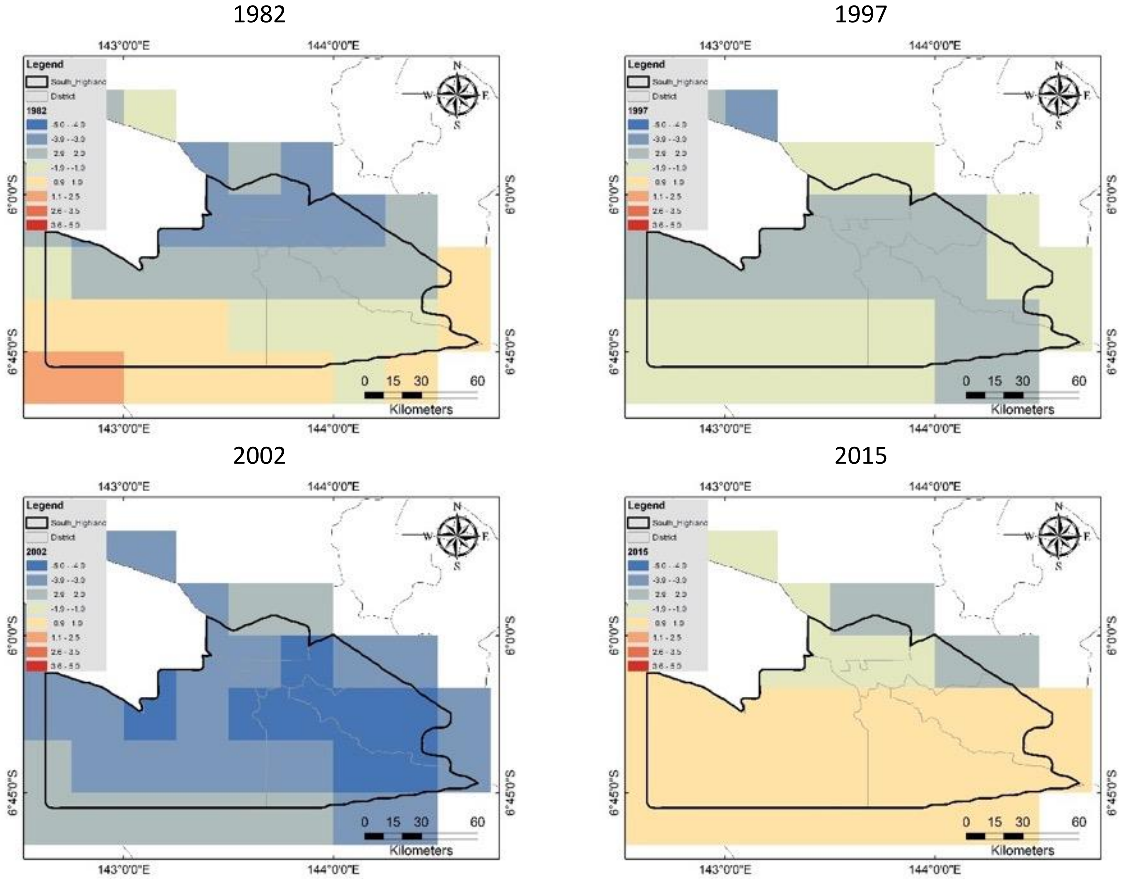



**Figure 5-25. TNN anomaly for select El Nino years**

The analysis of TNN indicates daily minimum temperatures of 5°C to 7°C, particularly in high altitude areas north of SHP (i.e., Karints Rural, Upper Mendi Rural, Imbongu Rural). This decreases during El Niño years, with 2002 having the largest temperature drop of up to -4°C to -5°C. These temperature drops indicate conditions conducive for the incidence of frost.

## 5.5. Landslide

The rainfall-induced landslide hazard for SHP indicates high to very high hazard on the central and southern areas of SHP (see Figure 5-26). The lineaments and geological characteristics in this area contribute to intensified weathering processes, resulting in the accumulation of a thicker soil layer compared to neighboring regions. Mineral compositions of rocks in diverse geological conditions also influence soil thickness. This thick soil layer increases susceptibility to landslides. Consequently, landslides are more prominent in areas with weak rock layers and in close proximity to lineaments. Figure 5-26 shows that approximately 45% of the mountainous areas in SHP are classified in the high to very high landslide hazard zones.

On the other hand, Figure 5-27 presents the earthquake-induced landslide map, which indicates that approximately 18% of the areas in SHP are classified in the high to very high earthquake-induced landslide hazard zones. Majority of the zones classified as having high and very high seismic hazards are situated along the lineament in the central areas of the province, aligned with a Northwest-Southeast direction. This indicates the significant impact of the active fault, which is represented by the lineament, as well as the concentration of PGA values along this fault. These combined factors designate this area as a high-hazard zone for earthquake-induced landslides.

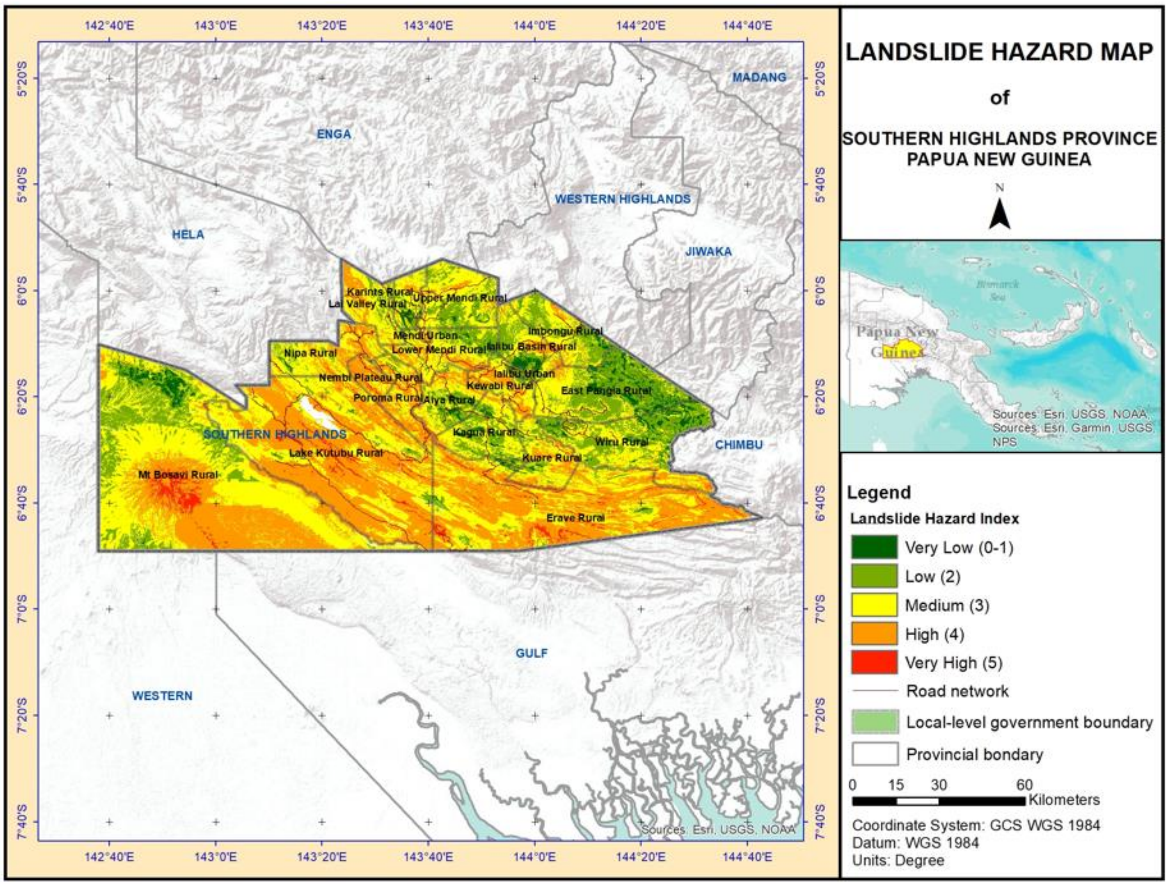



**Figure 5-26. Rainfall-induced landslide hazard map of SHP**

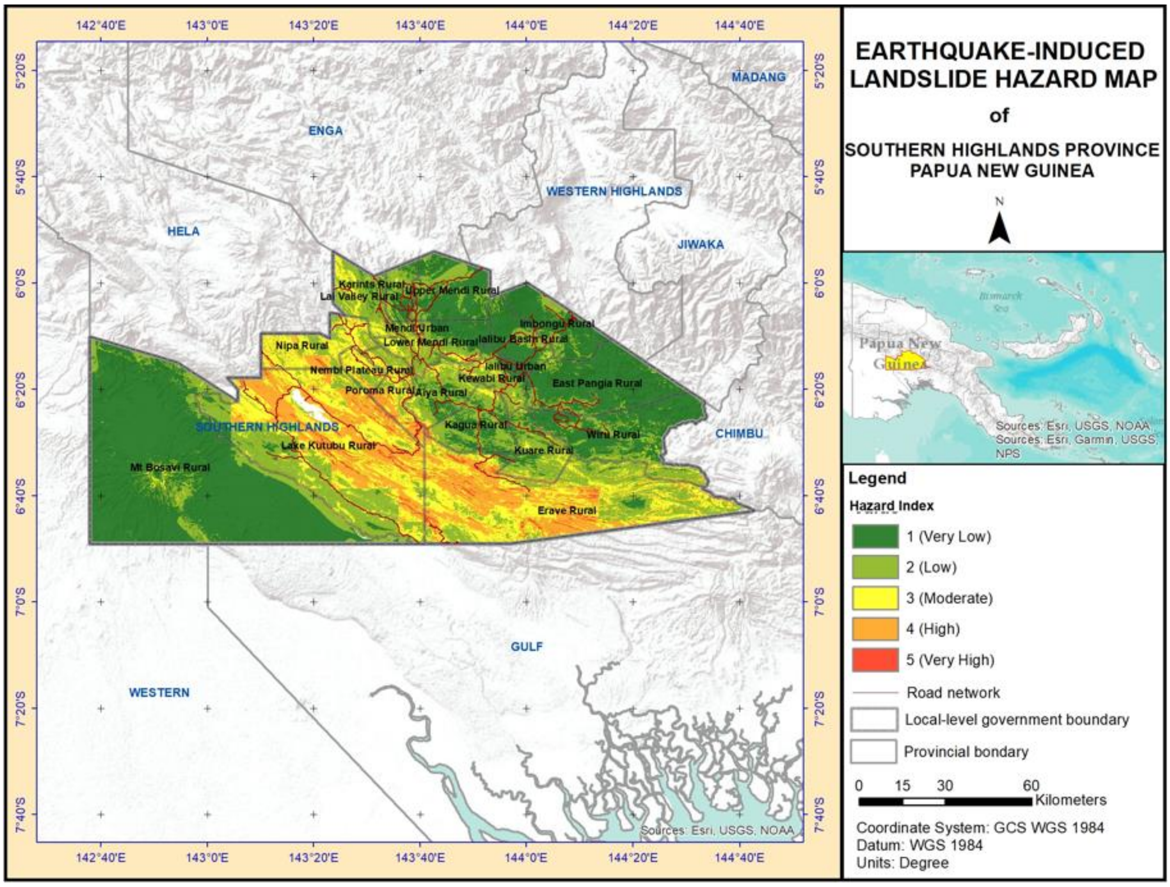



**Figure 5-27. Earthquake-induced landslide hazard map of SHP**

## 5.6. Vulnerability

The assessment of vulnerability included indicators for exposure, sensitivity and adaptive capacity. In the provincial workshop conducted on 9 February in Mendi, stakeholders identified and rated the following indicators. However, many of the indicators identified and rated do not have the required data at LLG levels. For this reason, the indicators for vulnerability analysis were amended and ratings were subsequently adjusted.

**Table 5-6. Indicators for exposure, sensitivity and adaptive capacity**

| Component | Category | Indicator | Rating | Remarks |
|---|---|---|---|---|
| Exposure | Population | -census units/settlements exposed | -N/A | -Based on actual exposure |
| | Livelihood | -Crop area in hectares<br>-Livestock population or area in ha | -N/A | -N/A |
| | Critical infrastructure | -Roads<br>-Health facilities<br>-Learning facilities | -N/A | -Based on actual exposure |
| Sensitivity | Socio-economic | -Population growth rate<br>-Illiteracy rate<br>-Women-led household<br>-Orphan-led household<br>-Population of elderly (65 over, children (15 & below), PWD<br>-Poverty rate<br>-Household dependent on agriculture as livelihood | -1.10%<br>-2.43%<br>-12.77%<br>-15.91%<br>-10.96%<br>-8.95%<br>-6.15% | -No data at LLG levels<br>-Rating adjusted to 4.55%<br>-Rating adjusted to 31.82%<br>-Rating adjusted to 31.82%<br>-Rating adjusted to 31.82%<br>-No data at LLG levels<br>-No data at LLG levels |
| | Socio-cultural | -Number of violent conflicts<br>-Number of internally displaced and abused people<br>-Patriarchal society<br>-Outmigration<br>-Landlessness<br>-Wantok system | -7.87%<br>-9.78%<br>-3.35%<br>-1.72%<br>-10.59%<br>-8.42% | -No data at LLG levels |
| Adaptive Capacity | Socio-economic | -Households with access to alternative livelihoods<br>-Average distance to roads, health and learning facilities<br>-Extended family system/social cohesion | -11.04%<br>-2.41%<br>-5.39% | -No data at LLG levels<br>-Rating adjusted to 100%<br>-No data at LLG levels |
| | Infrastructure | -Number and capacity of evacuation centers, temporary shelters/churches<br>-Access to forecasts, early warning and hazard information | -6.26%<br>-36.18% | -Most LLGs do not have evacuation centers, temporary shelters nor access to forecasts, EW and hazard information |
| | Institutional | -Number of security officers and police<br>-Government financial capacity and support – PSIP, DSIP, LLGSIP<br>-Number of church- and women-led organizations and programs<br>-SARV Awareness Program<br>-CBDRM and CPDP planning and implementation at ward levels | -2.37%<br>-3.88%<br>-12.5%<br>-10.45%<br>-9.52% | -Insufficient data at LLG levels |

### 5.6.1 Exposure

Tables 5-7 to 5-9 provide details on the elements exposed to different flood and landslide hazard levels, while Figures 5-28 and 5-29 show the census units and critical facilities exposed to both hazards.

**Table 5-7. Exposure of population and critical facilities to flood hazards**

| | LLG | | 0.00m | 0.01 to 0.025m | Total |
|---|---|---|---|---|---|
| 1 | Aiya Rural LLG | Population | 17,378 | | 17,378 |
| | | Health Centers | 4 | | 4 |
| | | Schools | 5 | | 5 |
| 2 | East Pangia Rural LLG | Population | 13,677 | | 13,677 |
| | | Health Centers | 7 | | 7 |
| | | Schools | 6 | | 6 |
| 3 | Erave Rural LLG | Population | 10,221 | | 10,221 |
| | | Health Centers | 13 | 1 | 14 |
| | | Schools | 7 | 3 | 10 |
| 4 | Ialibu Basin Rural LLG | Population | 15,443 | | 15,443 |
| | | Health Centers | 4 | | 4 |
| | | Schools | 5 | | 5 |
| 5 | Ialibu Urban LLG | Population | 5,479 | | 5,479 |
| | | Health Centers | 1 | | 1 |
| | | Schools | 1 | | 1 |
| 6 | Imbongu Rural LLG | Population | 25,654 | | 25,654 |
| | | Health Centers | | | |
| | | Schools | 4 | | 4 |
| 7 | Kagua Rural LLG | Population | 18,111 | | 18,111 |
| | | Health Centers | 6 | | 6 |
| | | Schools | 11 | | 11 |
| 8 | Karints Rural LLG | Population | 20,169 | | 20,169 |
| | | Health Centers | 9 | | 9 |
| | | Schools | 8 | | 8 |
| 9 | Kewabi Rural LLG | Population | 13,348 | | 13,348 |
| | | Health Centers | 1 | | 1 |
| | | Schools | 3 | | 3 |
| 10 | Kuare Rural LLG | Population | 7,451 | | 7,451 |
| | | Health Centers | 6 | | 6 |
| | | Schools | 4 | | 4 |
| 11 | Lai Valley Rural LLG | Population | 27,194 | 4,875 | 32,069 |
| | | Health Centers | 5 | 1 | 6 |
| | | Schools | 1 | 3 | 4 |
| 12 | Lake Kutubu Rural LLG | Population | 10,052 | 833 | 10,885 |
| | | Health Centers | 9 | 4 | 13 |
| | | Schools | 2 | 2 | 4 |
| 13 | Lower Mendi Rural LLG | Population | 18,989 | | 18,989 |
| | | Health Centers | 5 | 1 | 6 |
| | | Schools | 6 | 4 | 10 |
| 14 | Mendi Urban LLG | Population | 17,128 | | 17,128 |
| | | Health Centers | 4 | | 4 |
| | | Schools | 7 | | 7 |
| 15 | Mt. Bosavi | Population | | | |
| | | Health Centers | 3 | | 3 |
| | | Schools | 3 | | 3 |
| 16 | Nembi Plateau Rural LLG | Population | 16,333 | | 16,333 |
| | | Health Centers | 1 | | 1 |
| | | Schools | 4 | | 4 |
| 17 | Nipa Rural LLG | Population | 42,638 | | 42,638 |
| | | Health Centers | 5 | | 5 |
| | | Schools | 7 | | 7 |
| 18 | Poroma Rural LLG | Population | 20,962 | 1,037 | 21,999 |
| | | Health Centers | 5 | | 5 |

| LLG | | | 0.00m | 0.01 to 0.025m | Total |
|---|---|---|---|---|---|
| | | Schools | 4 | 1 | 5 |
| 19 | Upper Mendi Rural LLG | Population | 27,047 | | 27,047 |
| | | Health Centers | 7 | | 7 |
| | | Schools | 5 | | 5 |
| 20 | Wiru Rural LLG | Population | 18,295 | | 18,295 |
| | | Health Centers | 11 | | 11 |
| | | Schools | 8 | | 8 |
| | Total | Population | 345,569 | 6,745 | 352,314 |
| | | Health Centers | 106 | 7 | 113 |
| | | Schools | 101 | 13 | 114 |

**Table 5-8. Exposure of census units and critical facilities to rainfall-induced landslide hazards**

| LLG | | | Very Low | Low | Medium | High | Very High | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | Aiya Rural LLG | Census Unit | 5 | 72 | 66 | | | 143 |
| | | Population | 629 | 9,306 | 7,443 | | | 17,378 |
| | | Road (m) | 6,458.23 | 16,838.50 | 13,364.83 | 3,624.65 | 140.02 | 40,426.23 |
| | | Health | | 3 | 1 | | | 4 |
| | | Schools | | 3 | 2 | | | 5 |
| 2 | East Pangia Rural LLG | Census Unit | | 15 | 70 | | | 85 |
| | | Population | | 2,324 | 11,353 | | | 13,677 |
| | | Road (m) | | 10,750.89 | 55,857.20 | 275.67 | | 66,883.77 |
| | | Health | | 1 | 6 | | | 7 |
| | | Schools | | 1 | 5 | | | 6 |
| 3 | Erave Rural LLG | Census Unit | | 15 | 64 | 25 | | 104 |
| | | Population | | 1,218 | 7,799 | 2,558 | | 11,575 |
| | | Road (m) | 2,741.49 | 5,347.94 | 19,171.99 | 40,270.21 | 5,191.91 | 72,723.54 |
| | | Health | | 1 | 9 | 4 | | 14 |
| | | Schools | | 1 | 7 | 2 | | 10 |
| 4 | Ialibu Basin Rural LLG | Census Unit | 4 | 16 | 36 | 35 | | 91 |
| | | Population | 902 | 3,861 | 6,272 | 4,408 | | 15,443 |
| | | Road (m) | 2,166.38 | 13,893.40 | 21,322.94 | 16,822.11 | | 54,204.82 |
| | | Health | | 1 | 2 | 1 | | 4 |
| | | Schools | | 1 | 2 | 2 | | 5 |
| 5 | Ialibu Urban LLG | Census Unit | | 22 | 11 | | | 33 |
| | | Population | | 3,138 | 2,341 | | | 5,479 |
| | | Road (m) | 3,674.72 | 15,552.15 | 4,138.37 | | | 23,365.23 |
| | | Health | | 1 | | | | 1 |
| | | Schools | | 1 | | | | 1 |
| 6 | Imbongu Rural LLG | Census Unit | | 5 | 32 | 4 | | 41 |
| | | Population | | 3,782 | 19,533 | 2,339 | | 25,654 |
| | | Road (m) | | 14,040.69 | 30,348.00 | 8,133.29 | | 52,521.99 |
| | | Health | | | | | | |
| | | Schools | | | 3 | 1 | | 4 |
| 7 | Kagua Rural LLG | Census Unit | 8 | 34 | 39 | 5 | | 86 |
| | | Population | 1,529 | 8,674 | 7,224 | 684 | | 18,111 |
| | | Road (m) | 2,925.81 | 18,595.03 | 28,812.11 | 2,198.69 | | 52,531.64 |
| | | Health | | 2 | 4 | | | 6 |
| | | Schools | 1 | 4 | 6 | | | 11 |
| 8 | Karints Rural LLG | Census Unit | 11 | 21 | 29 | 11 | | 72 |
| | | Population | 2,564 | 6,059 | 8,390 | 3,156 | | 20,169 |
| | | Road (m) | 8,529.78 | 16,592.03 | 15,814.87 | 7,343.35 | | 48,280.04 |
| | | Health | 2 | 3 | 4 | | | 9 |
| | | Schools | 3 | 1 | 4 | | | 8 |
| 9 | | Census Unit | | 19 | 44 | 61 | | 124 |

| LLG | | | Very Low | Low | Medium | High | Very High | Total |
|---|---|---|---|---|---|---|---|---|
| | Kewabi Rural LLG | Population | | 1,765 | 4,762 | 6,821 | | 13,348 |
| | | Road (m) | | 5,204.19 | 27,585.69 | 41,351.07 | | 74,140.95 |
| | | Health | | | | 1 | | 1 |
| | | Schools | | | 2 | 1 | | 3 |
| 10 | Kuare Rural LLG | Census Unit | | 29 | 47 | 16 | | 92 |
| | | Population | | 1,859 | 4,442 | 1,150 | | 7,451 |
| | | Road (m) | | 6,128.89 | 20,470.06 | 3,068.53 | | 29,667.48 |
| | | Health | | | 5 | 1 | | 6 |
| | | Schools | | | 3 | 1 | | 4 |
| 11 | Lai Valley Rural LLG | Census Unit | 2 | 19 | 72 | 4 | | 97 |
| | | Population | 539 | 6,977 | 23,713 | 840 | | 32,069 |
| | | Road (m) | | 5,798.27 | 31,708.49 | 11,100.06 | | 48,606.82 |
| | | Health | | 2 | 4 | | | 6 |
| | | Schools | | 2 | 2 | | | 4 |
| 12 | Lake Kutubu Rural LLG | Census Unit | | | 22 | 29 | 2 | 61 |
| | | Population | | | 4,601 | 4,246 | 856 | 10,885 |
| | | Road (m) | | 1,112.49 | 51,794.35 | 167,018.45 | 8,879.17 | 228,804.46 |
| | | Health | | | 5 | 6 | 1 | 12 |
| | | Schools | | | 1 | 2 | | 3 |
| 13 | Lower Mendi Rural LLG | Census Unit | | | 79 | 59 | | 138 |
| | | Population | | | 10,285 | 8,704 | | 18,989 |
| | | Road (m) | | 3,238.82 | 45,798.30 | 35,405.46 | 586.46 | 85,029.03 |
| | | Health | | | 2 | 4 | | 6 |
| | | Schools | | | 6 | 4 | | 10 |
| 14 | Mendi Urban LLG | Census Unit | | | 21 | 18 | | 39 |
| | | Population | | | 9,340 | 7,788 | | 17,128 |
| | | Road (m) | | | 9,690.79 | 6,580.14 | | 16,270.93 |
| | | Health | | | 3 | 1 | | 4 |
| | | Schools | | | 5 | 2 | | 7 |
| 15 | Mt Bosavi Rural LLG | Census Unit | 4 | 15 | 33 | 2 | | 54 |
| | | Population | 310 | 1,696 | 4,452 | 192 | | 6,650 |
| | | Road (m) | | | | | | |
| | | Health | | 1 | 2 | | | 3 |
| | | Schools | | 2 | 1 | | | 3 |
| 16 | Nembi Plateau Rural LLG | Census Unit | | | 5 | 16 | | 21 |
| | | Population | | | 4,579 | 11,754 | | 16,333 |
| | | Road (m) | | | 2,561.94 | 23,549.85 | | 26,111.79 |
| | | Health | | | 1 | | | 1 |
| | | Schools | | | 2 | 2 | | 4 |
| 17 | Nipa Rural LLG | Census Unit | | | 27 | 215 | 1 | 243 |
| | | Population | | | 4,075 | 38,341 | 222 | 42,638 |
| | | Road (m) | | | 23,474.67 | 34,305.44 | | 57,780.11 |
| | | Health | | | 1 | 4 | | 5 |
| | | Schools | | | 1 | 6 | | 7 |
| 18 | Poroma Rural LLG | Census Unit | | 7 | 99 | 140 | | 246 |
| | | Population | | 742 | 9,525 | 11,732 | | 21,999 |
| | | Road (m) | | 102.61 | 15,123.74 | 64,620.52 | 1,662.45 | 81,509.32 |
| | | Health | | | | 5 | | 5 |
| | | Schools | | | 2 | 3 | | 5 |
| 19 | Upper Mendi Rural LLG | Census Unit | | 6 | 15 | 6 | | 27 |
| | | Population | | 5,357 | 16,443 | 5,247 | | 27,047 |
| | | Road (m) | 52.19 | 11,737.17 | 45,877.23 | 14,579.05 | | 72,245.64 |
| | | Health | | 1 | 4 | 2 | | 7 |

| LLG | | | Very Low | Low | Medium | High | Very High | Total |
|---|---|---|---|---|---|---|---|---|
| | | Schools | | | 4 | 1 | | 5 |
| 20 | Wiru Rural LLG | Census Unit | | 66 | 68 | | | 134 |
| | | Population | | 8,053 | 10,242 | | | 18,295 |
| | | Road (m) | | 22,550.72 | 29,288.28 | 2,082.94 | | 53,921.95 |
| | | Health | | 5 | 6 | | | 11 |
| | | Schools | | 6 | 2 | | | 8 |
| | Total | Census Unit | 34 | 361 | 879 | 646 | 3 | 1931 |
| | | Population | 6,473 | 64,811 | 176,814 | 109,960 | 1,078 | 360,318 |
| | | Road (m) | 26,548.61 | 167,483.78 | 492,203.86 | 482,329.48 | 16,460.01 | 1,185,025.74 |
| | | Health | 2 | 21 | 59 | 29 | 1 | 112 |
| | | Schools | 4 | 22 | 60 | 27 | | 113 |

**Table 5-9. Exposure of census units and critical facilities to earthquake-induced landslide hazards**

| LLG | | | Very Low | Low | Medium | High | Very High | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | Aiya Rural LLG | Census Unit | 51 | 92 | | | | 143 |
| | | Population | 5,944 | 11,434 | | | | 17,378 |
| | | Road (m) | 15,103 | 21,807 | 2,253 | 785 | | 39,947 |
| | | Health | 1 | 3 | | | | 4 |
| | | Schools | 1 | 4 | | | | 5 |
| 2 | East Pangia Rural LLG | Census Unit | 20 | 65 | | | | 85 |
| | | Population | 3,176 | 10,501 | | | | 13,677 |
| | | Road (m) | 18,559 | 47,623 | | | | 66,182 |
| | | Health | 1 | 6 | | | | 7 |
| | | Schools | 1 | 5 | | | | 6 |
| 3 | Erave Rural LLG | Census Unit | 15 | 18 | 53 | 18 | | 104 |
| | | Population | 1,218 | 2,631 | 6,123 | 1,603 | | 11,575 |
| | | Road (m) | 5,380 | 10,779 | 27,107 | 24,698 | 3,905 | 71,870 |
| | | Health | 1 | 4 | 8 | 1 | | 14 |
| | | Schools | 1 | 3 | 6 | | | 10 |
| 4 | Ialibu Basin Rural LLG | Census Unit | 37 | 54 | | | | 91 |
| | | Population | 7,594 | 7,849 | | | | 15,443 |
| | | Road (m) | 23,713 | 29,900 | 1 | | | 53,613 |
| | | Health | 2 | 2 | | | | 4 |
| | | Schools | 2 | 3 | | | | 5 |
| 5 | Ialibu Urban LLG | Census Unit | 33 | | | | | 33 |
| | | Population | 5,479 | | | | | 5,479 |
| | | Road (m) | 22,832 | 276 | | | | 23,108 |
| | | Health | 1 | | | | | 1 |
| | | Schools | 1 | | | | | 1 |
| 6 | Imbongu Rural LLG | Census Unit | 14 | 27 | | | | 41 |
| | | Population | 9,362 | 16,292 | | | | 25,654 |
| | | Road (m) | 31,584 | 20,203 | 179 | | | 51,966 |
| | | Health | | | | | | |
| | | Schools | 1 | 3 | | | | 4 |
| 7 | Kagua Rural LLG | Census Unit | 42 | 39 | 5 | | | 86 |
| | | Population | 10,744 | 6,683 | 684 | | | 18,111 |
| | | Road (m) | 13,471 | 36,308 | 2,043 | 113 | | 51,935 |
| | | Health | 2 | 4 | | | | 6 |
| | | Schools | 5 | 6 | | | | 11 |
| 8 | Karints Rural LLG | Census Unit | 43 | 29 | | | | 72 |
| | | Population | 12,198 | 7,971 | | | | 20,169 |
| | | Road (m) | 31,529 | 15,318 | 840 | | | 47,687 |
| | | Health | 7 | 2 | | | | 9 |

| | LLG | | Very Low | Low | Medium | High | Very High | Total |
|---|---|---|---|---|---|---|---|---|
| | | Schools | 5 | 3 | | | | 8 |
| 9 | Kewabi Rural LLG | Census Unit | 25 | 85 | 14 | | | 124 |
| | | Population | 2,485 | 9,645 | 1,218 | | | 13,348 |
| | | Road (m) | 9,776 | 45,913 | 17,573 | 45 | | 73,306 |
| | | Health | | 1 | | | | 1 |
| | | Schools | | 3 | | | | 3 |
| 10 | Kuare Rural LLG | Census Unit | 30 | 49 | 13 | | | 92 |
| | | Population | 2,727 | 3,934 | 790 | | | 7,451 |
| | | Road (m) | 7,762 | 21,145 | 439 | | | 29,346 |
| | | Health | 1 | 4 | 1 | | | 6 |
| | | Schools | 1 | 2 | 1 | | | 4 |
| 11 | Lai Valley Rural LLG | Census Unit | 15 | 76 | 5 | 1 | | 97 |
| | | Population | 5,739 | 25,041 | 1,017 | 272 | | 32,069 |
| | | Road (m) | 2,301 | 35,372 | 10,145 | 174 | | 47,992 |
| | | Health | 1 | 5 | | | | 6 |
| | | Schools | 1 | 3 | | | | 4 |
| 12 | Lake Kutubu Rural LLG | Census Unit | | 17 | 13 | 21 | 2 | 53 |
| | | Population | | 2,450 | 2,913 | 3,484 | 856 | 10,885 |
| | | Road (m) | 582 | 65,308 | 62,433 | 94,247 | 3,206 | 225,777 |
| | | Health | | 2 | 5 | 4 | 1 | 12 |
| | | Schools | | | 2 | 1 | | 3 |
| 13 | Lower Mendi Rural LLG | Census Unit | 4 | 94 | 40 | | | 138 |
| | | Population | 1,172 | 12,372 | 5,445 | | | 18,989 |
| | | Road (m) | 2,227 | 60,779 | 19,882 | 972 | 149 | 84,009 |
| | | Health | | 4 | 2 | | | 6 |
| | | Schools | | 9 | 1 | | | 10 |
| 14 | Mendi Urban LLG | Census Unit | | 26 | 13 | | | 39 |
| | | Population | | 11,033 | 6,095 | | | 17,128 |
| | | Road (m) | | 9,724 | 6,350 | | | 16,073 |
| | | Health | | 3 | 1 | | | 4 |
| | | Schools | | 5 | 2 | | | 7 |
| 15 | Mt Bosavi Rural LLG | Census Unit | 47 | 7 | | | | 54 |
| | | Population | 5,797 | 853 | | | | 6,650 |
| | | Road (m) | | | | | | |
| | | Health | 2 | 1 | | | | 3 |
| | | Schools | 3 | | | | | 3 |
| 16 | Nembi Plateau Rural LLG | Census Unit | | 4 | 17 | | | 21 |
| | | Population | | 4,093 | 12,240 | | | 16,333 |
| | | Road (m) | | 1,925 | 22,865 | 989 | | 25,779 |
| | | Health | | 1 | | | | 1 |
| | | Schools | | 2 | 2 | | | 4 |
| 17 | Nipa Rural LLG | Census Unit | | 34 | 197 | 12 | | 243 |
| | | Population | | 5,894 | 34,487 | 2,257 | | 42,638 |
| | | Road (m) | | 8,525 | 42,273 | 6,225 | | 57,023 |
| | | Health | | 1 | 3 | 1 | | 5 |
| | | Schools | | 1 | 5 | 1 | | 7 |
| 18 | Poroma Rural LLG | Census Unit | | 104 | 134 | 8 | | 246 |
| | | Population | | 8,942 | 12,527 | 530 | | 21,999 |
| | | Road (m) | | 13,612 | 43,775 | 19,801 | 3,317 | 80,504 |
| | | Health | | | 5 | | | 5 |
| | | Schools | | 2 | 3 | | | 5 |
| 19 | | Census Unit | 7 | 20 | | | | 27 |
| | | Population | 6,614 | 20,433 | | | | 27,047 |

| LLG | | | Very Low | Low | Medium | High | Very High | Total |
|---|---|---|---|---|---|---|---|---|
| | Upper Mendi Rural LLG | Road (m) | 25,052 | 45,603 | 727 | | | 71,383 |
| | | Health | 2 | 5 | | | | 7 |
| | | Schools | 1 | 4 | | | | 5 |
| 20 | Wiru Rural LLG | Census Unit | 106 | 28 | | | | 134 |
| | | Population | 13,324 | 4,971 | | | | 18,295 |
| | | Road (m) | 34,668 | 18,697 | | | | 53,365 |
| | | Health | 8 | 3 | | | | 11 |
| | | Schools | 8 | | | | | 8 |
| | Total | Census Unit | 489 | 868 | 504 | 60 | 2 | 1923 |
| | | Population | 93,573 | 173,022 | 83,539 | 8,146 | 856 | 360,318 |
| | | Road (m) | 244,537 | 508,817 | 258,884 | 148,049 | 10,578 | 1,170,865 |
| | | Health | 29 | 51 | 25 | 6 | 1 | 112 |
| | | Schools | 31 | 58 | 22 | 2 | | 113 |

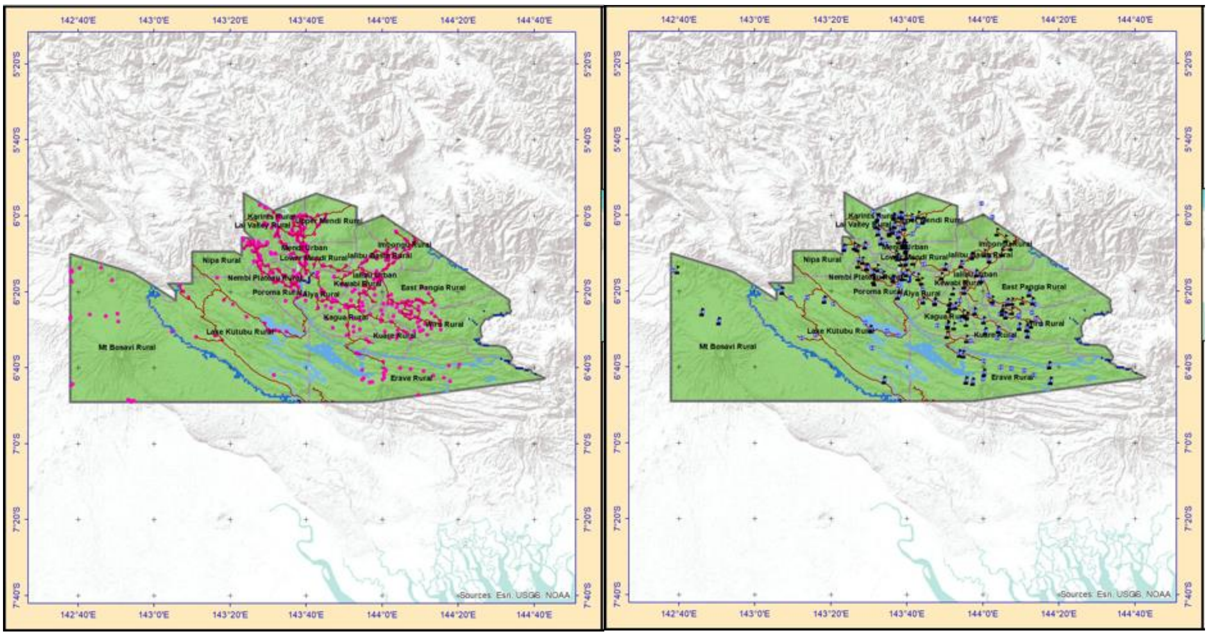


**Figure 5-28. Exposure of settlements and critical facilities to flood hazard**

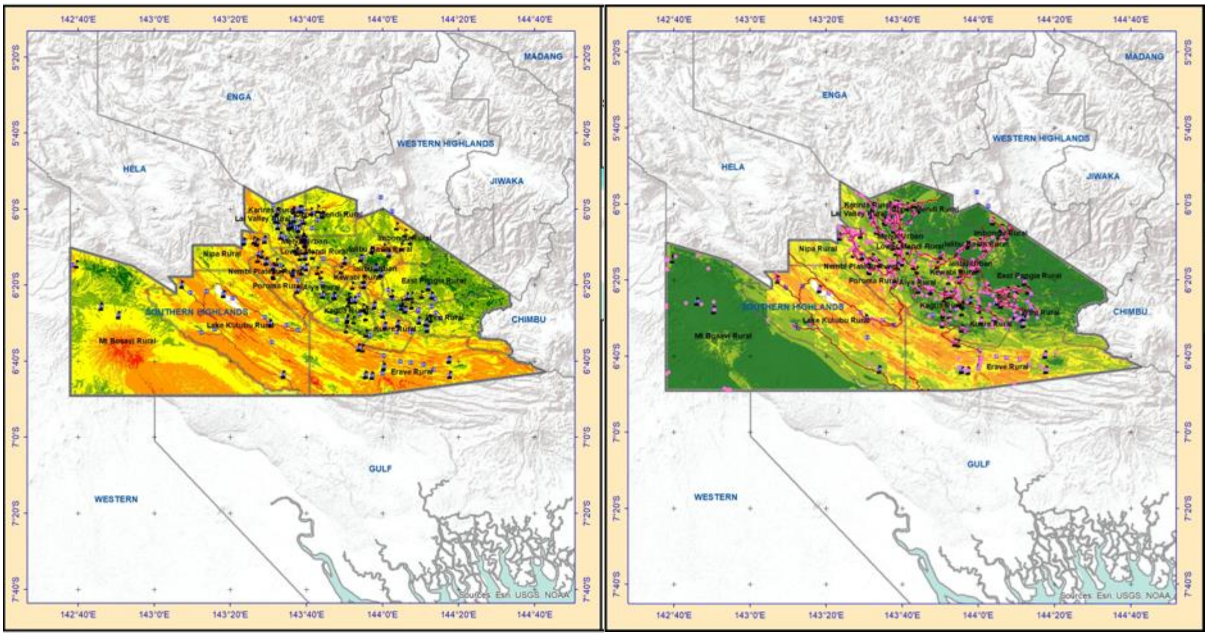


**Figure 5-29. Exposure to rainfall-induced (left) and earthquake-induced (right) landslide hazards**

About 6,745 people are directly exposed to 0.25m flooding in SHP, of which 4,875 (72%) are from Lai Valley Rural LLG, 1,037 (15%) from Poroma Rural and the remaining 833 (12%) from Lake Kutubu Rural. In addition, about 7 health centers and 13 schools are exposed to 0.25m flooding. No roads are exposed.

Table 5-8 shows that 111,038 people are exposed to high/very high rainfall-induced landslide susceptibility levels, of which 38,341 (34.73%) are from Nipa Rural, 11,754 (10.59%) from Nembi Plateau Rural and another 11,732 (10.57%) from Poroma Rural. Similarly, about 498,789 meters of road, 30 health centers and 27 schools are exposed to high/very high rainfall-induced landslide susceptibility levels.

Table 5-9 shows that only 9,002 people are exposed to high/very high earthquake-induced landslide susceptibility levels, of which 4,340 (53%) are from Lake Kutubo Rural, 2,257 (27.7%) from Nipa Rural and another 1,603 (19.67%) from Erave Rural. Similarly, about 158,627 meters of road, 7 health centers and 2 schools are exposed to high/very high earthquake-induced landslide susceptibility levels.

### 5.6.2 Vulnerability Index

The vulnerability index was expected to integrate indicators of sensitivity and adaptive capacity outlined in Table 5-6. But due to limitations of data up to LLG level, analysis was conducted only for four indicators of sensitivity – illiteracy rate, women-led household, orphan-led household and population of elderly (65 and over) and children (15 and below). Consequently, the weights and ratings for these indicators were adjusted to 4.55% for illiteracy rate, and 31.82% each for the other three (3) indicators. Initial data on conflicts from January 2021 to present is taken from the Armed Conflict Location and Event Data Project (https://acleddata.com/). Details of the conflicts are shown in Table 5-10, while locations are overlaid with the sensitivity map shown in Figure 5-30. The table shows that majority of the conflicts are political, categorized as either riots, mob violence including attacks against civilians, and comprised of clashes among rioters, vigilante groups, armed groups, tribal or clan militia. However, there are also demonstrations and peaceful protests organized by religious groups, health workers, teachers, students, and women. Twenty of the 23 recorded conflicts from January 2021 to July 2023 occurred in Mendi-Munihu and Nipa-Kutubu districts. At least 11 of the 23 conflicts recorded from January 2021 to July 2023 occurred in Mendi.

**Table 5-10. Conflicts in SHP**

| | Date | Type | Actors | Location | Casualty | Remarks |
|---|---|---|---|---|---|---|
| 1 | 13-Mar-21 | Strategic developments – agreement | Kemb Tribal Militia, Komea Tribal Militia | Nipa, Nipa-Kutubu | 0 | |
| 2 | 7-May-21 | Demonstrations – riots, violent demonstrations | Rioters, Civilians, Health Workers | Mendi, Mendi-Munihu | 0 | |
| 3 | 12-May-21 | Demonstrations – peaceful protest | Protesters, Women | Mendi, Mendi-Munihu | 0 | |
| 4 | 10-Aug-21 | Demonstrations – peaceful protest | Protesters, Catholic Christian Group, Health Workers, Students, Labor Group | Mendi, Mendi-Munihu | 0 | |
| 5 | 8-Sep-21 | Demonstrations – peaceful protest | Protesters, Women | Mendi, Mendi-Munihu | 0 | |
| 6 | 8-Nov-21 | Political violence – riots, mob violence | Rioters, Civilians, Health Workers | Mendi, Mendi-Munihu | 0 | |
| 7 | 22-Dec-21 | Political violence – riots, mob violence | Rioters, Vigilante Group, Civilians, Women | Pawayamo, Kagua-Erave | 3 | women targeted: accused of witchcraft/sorcery |

| | Date | Type | Actors | Location | Casualty | Remarks |
|---|---|---|---|---|---|---|
| 8 | 13-Mar-22 | Strategic developments – agreement | 3-in-1 Tribal Militia, 6-in-1 Tribal Militia | Ilalibu, alibu-Pangia | 0 | |
| 9 | 2-Jun-22 | Political violence – violence against civilians, attacks | Unidentified Armed Group, Civilians, PNC: People's National Congress | Poroma, Nipa-Kutubu | 0 | |
| 10 | 24-Jun-22 | Demonstrations – peaceful protest | Protesters, Students, Teachers, Evangelical Christian Group, Labor Group | Mendi, Mendi-Munihu | 0 | crowd size more than 3,000 |
| 11 | 30-Jun-22 | Political violence – riots, mob violence | Rioters, PANGU: Pangu Party, PNC: People's National Congress; Independent Politicians | Nipa Station, Nipa-Kutubu | 0 | |
| 12 | 30-Jun-22 | Political violence – riots, mob violence | Rioters, PANGU: Pangu Party | Nipa Station, Nipa-Kutubu | 0 | |
| 13 | 18-Aug-22 | Strategic developments – Looting/property destruction | Unidentified Armed Group, Police Forces | Mendi, Mendi-Munihu | 0 | |
| 14 | 18-Aug-22 | Political violence – riots, mob violence | Rioters, PANGU: Pangu Party, PNC: People's National Congress; Independent Politicians | Mendi, Mendi-Munihu | 3 | |
| 15 | 26-Aug-22 | Political violence – riots, mob violence | Rioters, Civilians | Mendi, Mendi-Munihu | 0 | |
| 16 | 29-Aug-22 | Demonstrations – peaceful protest | Protesters, Tungsup Communal Group, Labor Group | Mendi, Mendi-Munihu | 0 | |
| 17 | 21-Sep-22 | Political violence – riots, mob violence | Rioters, Vigilante Group, Civilians, Women | Melant, Mendi-Munihu | 1 | women targeted: accused of witchcraft/sorcery |
| 18 | 10-Feb-23 | Political violence – battles, armed clashes | Unidentified Armed Group, Police Forces | Musula, Nipa-Kutubu | 0 | |
| 19 | 19-Feb-23 | Political violence – violence against civilians, abduction/forced disappearances | Pina Clan Militia, Hetaruku Clan Militia, Pi Clan Militia, Alo Clan Militia, Taburuma Clan Militia, Hambuali Clan Militia, Civilians, Teachers | Fogomaiyu, Nipa-Kutubu | 0 | |
| 20 | 18-Apr-23 | Demonstrations – riots, violent demonstrations | Rioters | Lama Sawmill, Ialibu-Pangia | 0 | |
| 21 | 7-Jun-23 | Political violence – violence against civilians, sexual violence | Unidentified Armed Group, Civilians, Women, Students | Waragu, Nipa-Kutubu | 0 | women targeted: girls |
| 22 | 7-Jun-23 | Strategic developments – Looting/property destruction | Unidentified Armed Group, Civilians, Teachers | Waragu, Nipa-Kutubu | 0 | |
| 23 | 22-Jun-23 | Strategic developments – agreement | Herep 1 Communal Militia, Herep 2 Communal Militia | Mendi, Mendi-Munihu | 0 | |

Figure 5-30 shows that Poroma Rural at 1.78 standard deviation is most sensitive, followed by Karints Rural and Nipa Rural at 1.18 and 0.82 standard deviation respectively.

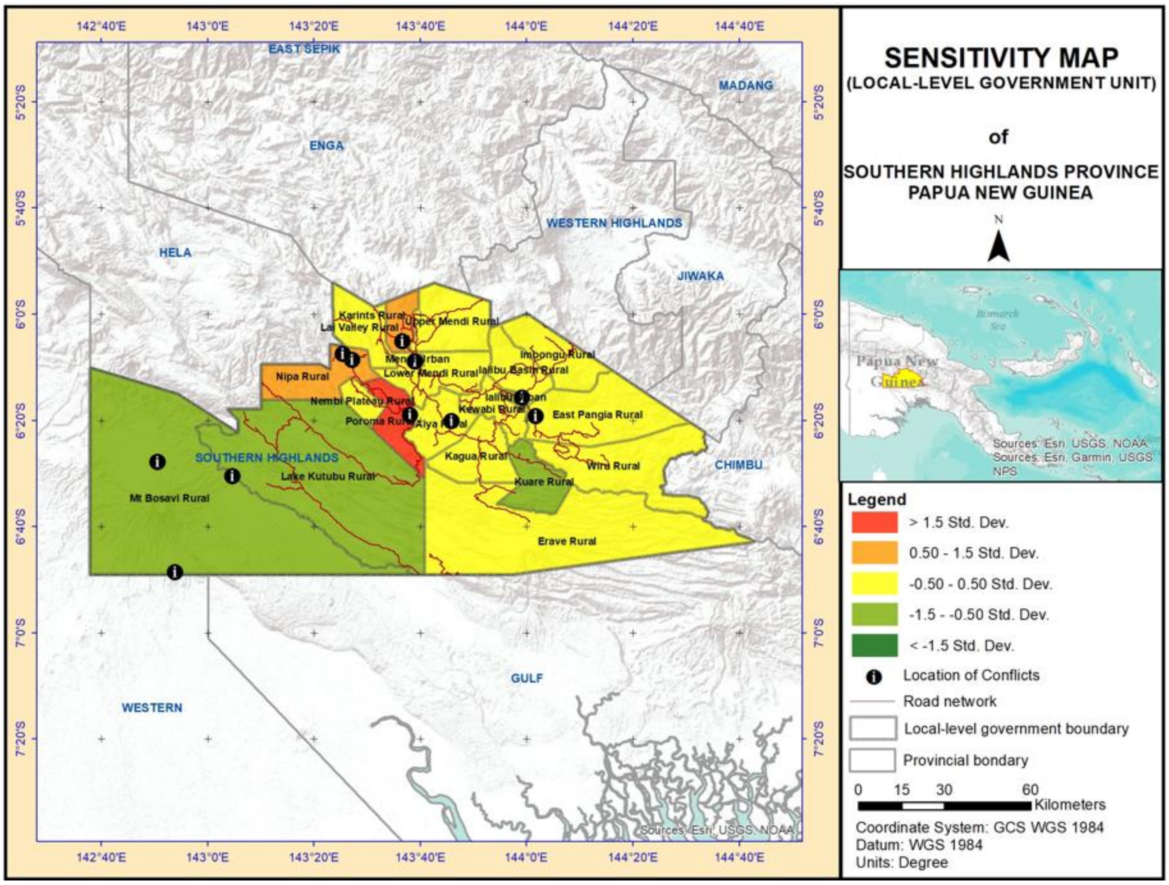



**Figure 5-30. Sensitivity map with locations of conflicts**

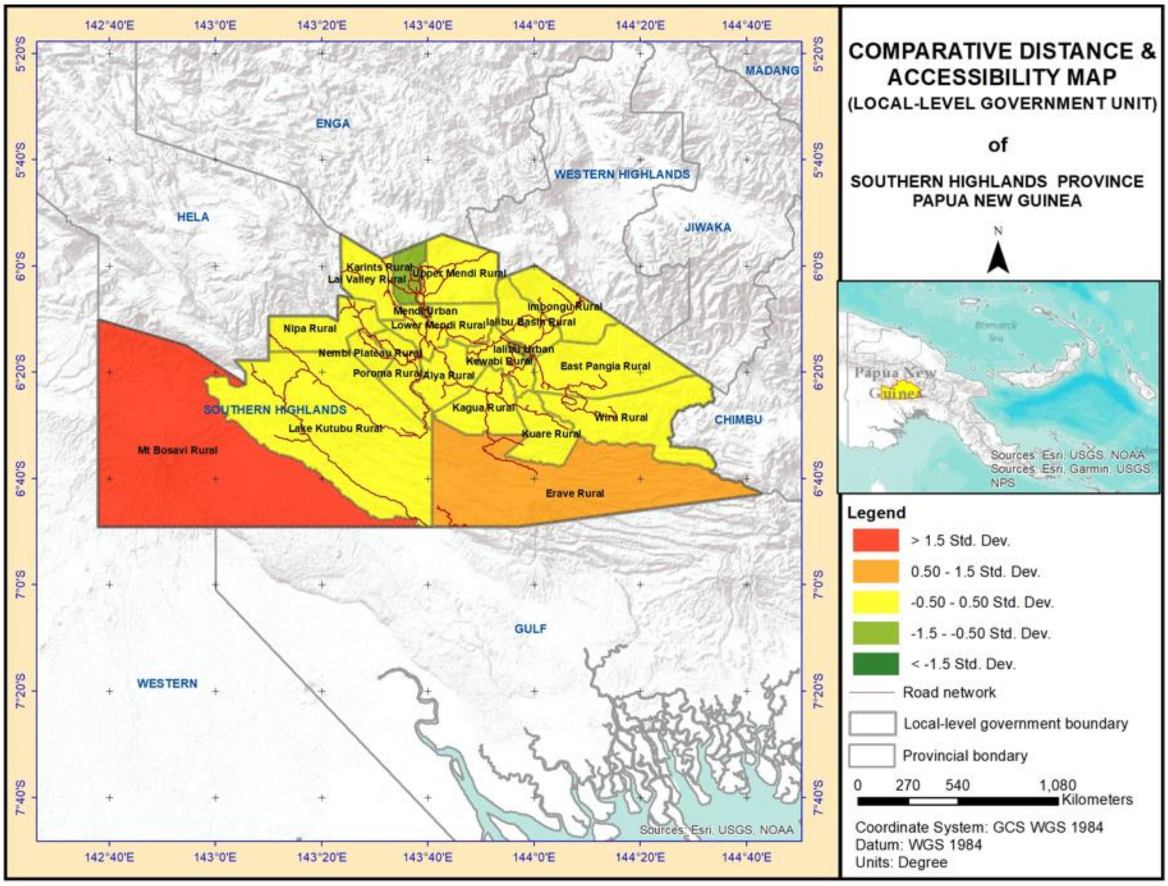



**Figure 5-31. Comparative distance and accessibility map**

Since data was insufficient to analyse indicators of adaptive capacity, the analysis focused only on the distance of settlements to critical facilities like roads, health centers and schools. Figure 5-31 shows the most inaccessible and remote settlements in Mt. Bosavi Rural at 3.97 standard deviation, followed by Erave Rural at 0.83 standard deviation.

### 5.6.3 Gender Considerations

Women and men in SHP have traditional roles. Women, which constituted 48.35% (246,722) of the 510,245 total population in the province in 2011, are considered the caregivers responsible for providing food and water to their families, while men typically hold leadership roles at household and/or community levels. In terms of decision-making, women have limited, if any, voice and influence. The project baseline report prepared by UNDP indicates that only about 5% are recognized as empowered women[16] who contribute to discussions, decision-making and planning in relation to resource management. But unlike in Hela, the potential for SHP women to be engaged is more evident as community leaders and members allow some women to contribute to discussions. After the 2021 landslide in Topa, for instance, the female principal of the local primary school participated in a community dialogue and was able to influence the decision to shelter women and children at the school ground where they had access to water tanks. [13]

However, the disproportionate impact of climate-induced hazards on women also remains evident. After the 2021 landslide, women were subjected to traditional restrictions on the use of the main river and had to walk further to the mountains to fetch water. [13] This placed additional pressure on women and girls and increased their exposure to harassment and/or assault by men.

Food and water insecurity due to extreme weather events like drought could increase the potential of conflicts and further impact women and children. Indeed, some disputes were reported to have been triggered by decisions relating to the management and distribution of relief food and water, which were supervised by community leaders, many of whom are men. Men typically receive the supplies, which in some cases resulted in conflicts/disputes with other men in the community and/or household. Similarly, anecdotal reports in Kagua indicate high levels of displacement due to inter-community conflicts. [13] Such displacement puts women and girls at an increased risk of physical and sexual abuse or violence as they move to other neighboring villages to seek refuge.

## 5.7. Pilot Wards

The pilot communities in SHP are Maipata 1 and 2, and Pira 1 and 2. Consultations with representatives from these wards were held on 10 February 2023. Representatives drew maps of their ward, that would indicate the location of settlements, critical facilities, and food and water sources. They also discussed the hazards affecting their community as well as the mechanisms they typically take to minimize or manage the impacts of these hazards.

### 5.7.1 Maipata 1 and 2

Maipata 1 and 2 are located in Aiya Rural LLG in the Kagua/Erave District. The 2011 census data indicates that Maipata has a total population of 1,173, of which 47% are women. But recent surveys conducted by UNDP and IOM indicate that Maipata 1 and 2 have an estimated population of 8,735, which is more than 7 times the 2011 population. Maipata 1 has 5,126 residents, 78% of which are children between the ages of 0 and 15, and about 6% are elderly. On the other hand, Maipata 2 has 3,609 residents, of which 19.40% are children and 2.77% are elderly.

[16] Empowered women are recognized and respected by community leaders and members due to their higher level of literacy, social or professional stature, or positions within the church.

Portions of the Ulu and Kagua rivers flow within Maipata 1, providing water source for the villagers. Three (3) major rivers flow within Maipata 2, namely Ulu, Kata and Olaga. In terms of natural hazards, Maipata 1 villagers consider frost as a major concern given its significant impact on food gardens, which are the primary source of nutrition. Residents indicated that frost occurs several months a year, impacting the food supply of the villagers. Landslides are also common and they impact food gardens particularly in areas near the mountain range, such as Walidamu village. Riverine flooding is another hazard of concern for ward residents. When the Ulu and Kagua rivers overflow, villages between these two rivers usually experience floods, which damage houses, crops and food gardens. In some cases, villagers could not cross the river and access food supplies, schools and other critical facilities.

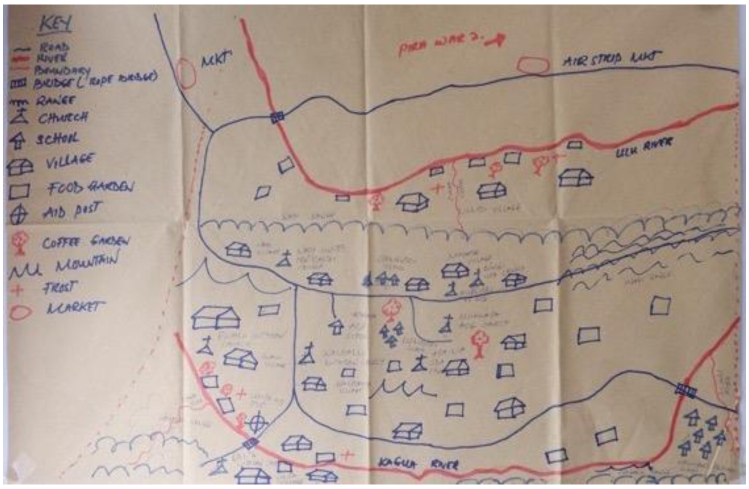



Figure 5-32. Participatory map of Maipata 1 ward


Figure 5-33. Participatory map of Maipata 2 ward

There were cases when the ward lost mothers, because the floods prevented them from bringing pregnant women to hospitals. When rivers overflow, people typically move to the mountains for safety. When food is scarce due to natural hazards that impact the food supply, villagers search for wild animals and plants (e.g., wild yam) in the bushes.

The hazards of most concern in Maipata 2 are drought, landslide and frost, which have critical impacts on food gardens. Landslides are common since they are situated on higher grounds. In addition to the damages it poses to food gardens, landslides endanger homes and facilities, including schools and churches.

When impacted by hazards, villagers go to the bushes and other areas in search for food and other resources. In addition, they seek help from relatives based outside the ward for cash or food.

### 5.7.2 Pira 1 and 2

Pira 1 and 2 are part of Aiya Rural LLG in Kagua/Erave District. Based on the 2011 census data, Pira ward has a total population of 1,046, of which 46.37% are female, and about 28% children (15 years old and below).

Based on the ward-level survey conducted by UNDP and IOM, Pira 1 has an estimated population of 5,126, of which 78.03% are children and 5.85% elderly, while Pira 2 has an estimated population of

3,609, comprised of 19.40% children and 2.77% elderly. These numbers are more than 8 times the 2011 census data. Pira 1 is situated between Pira 2 and Maipata 2. The ward has 4 schools (i.e. 3 elementary and 1 primary school) and churches. The ward has bush roads that are used to access the market. Almost all ward members have food gardens.

Figure 5-34. Participatory map of Pira 1 ward

The ward is divided by the Ulu river, which branches into smaller rivers or creeks – Pata, Yaguta and Yasa. Because of the fertile soil and ease of access to water, villagers plant coffee, banana, cacao, peanut, etc. along the riverbanks. Ward residents consider frost, landslide, riverine flood and drought as critical hazards in terms of impact. When affected by these hazards, they cope by collecting wild animals and plants from the bushes to survive.

Pira 2 is bordered by Maipata 2 and Pira 1. The ward is located in the mountains and food gardens can be seen almost everywhere in the ward. Hazards of most concern in Pira 2 are landslides, floods and frost. About two (2) weeks of continued rainfall can cause landslides in mountainous areas, and floods in low-lying areas as riverbanks overflow. When floods occur, many food gardens are inundated or washed away, leaving residents without food. Floods also damage wooden bridges, thus stranding people without access to food and critical facilities.

Ward residents claimed that frost is a common occurrence in the ward particularly during the months of March to June. The hazard can happen as early as February and sometimes in October and December. When frost happens, crops typically do not give good harvest. Farmers usually leave the plants without any remedies and are often discouraged from continuing planting during such seasons. Drought is a problem in some areas, but its impact is negligible especially in areas near the Ulu river, which is the ward's source of water for agriculture and household consumption.


Figure 5-35. Participatory map of Pira 2 ward

The residents cope by seeking help from relatives working in town centers for financial and food support. Those without relatives are compelled to move away from floods and/or frosts to survive.

### 5.7.3 Gender Considerations in the Pilot Wards

The UNDP-led focus group discussions conducted in the targeted communities in SHP revealed that women are becoming more overburdened with household roles due to extreme weather events and inter-/intra-communal conflicts. During conflicts, for instance, men are engaged in fights, leaving their traditional household roles including the provision of proper shelter for the family. This forces women to take on the additional roles of providing shelter and income for the family. In addition, women and girls are culturally considered property, and sometimes offered in exchange for firearms or land. This is evident among families affected by conflicts and/or disasters. Families displaced due to inter/intra-communal conflicts and/or disasters like landslides sometimes offer young women for marriage in exchange for land to settle and set up food gardens. [13]

Health and safety are also major concerns among women and children during and after extreme events. For instance, drought and water shortages limit or totally cut off access to water for personal hygiene especially during their menstrual period, and for food gardens. The increased distance from water sources also increases security risks. In particular, women and girls fetching water are exposed to sexual and gender-based violence. [13]

# 6 Climate-Gender-Conflict Nexus

The population of both Hela and SHP have suffered from years of conflict and violence and an array of extreme hazard events including floods, drought, frost, earthquakes and landslides. To this day, they face compounding risks that local authorities and communities do not have the capacity to mitigate, prepare for, or manage. Even in the absence of extreme events, the population in both provinces is already fragile, highly dependent on strained natural resources including water, with limited livelihood options due to lack of education and access to government support and services. Livelihoods are dominated by subsistence farming and agriculture-related activities such as selling or trading produce and cooked meals. Other options that employ a small percentage include mining, education, health, and services sectors. Table 6-1 summarizes some of the pre-existing and underlying conditions and gaps relating to governance, poverty, conflict, gender and other structural inequities.

**Table 6-1. Context and gaps**

| Context | Remarks |
|---|---|
| **Food and Water Security**<br>-Food is primarily sourced from gardens<br>-There is no piped water in both Hela and SHP; People typically get water for household consumption, and crop and livestock production, from rivers or streams; very few residents have rain- or river-fed water tanks and wells. | -Access to resources, particularly food and water, depends on the season. During the wet season, rainwater is useful for household consumption and food gardens, but the heavy rains and floods can also damage crops (e.g., "kau-kau") and food gardens, thereby reducing yields.<br>-During the dry season, residents have limited access to water for domestic consumption. Personal hygiene, particularly during menstruation, is taken for granted.<br>-Most residents do not have rainwater harvesting and storage capacities and mechanisms |
| **Livelihoods**<br>-Majority of the residents in Hela and SHP rely on subsistence farming and agriculture-related livelihoods such as selling and trading vegetables, livestock, and cooked meals. A small percentage are employed in mining, education, health and services sectors.<br>-Many rely on financial assistance from relatives during difficult times, including when food and resources are scarce. | -Poverty is prevalent in Hela and SHP. The majority maintain small food gardens for household consumption and for selling anything in excess. These small farms and food gardens are typically rainfed, and therefore very vulnerable to drought, in addition to heavy rainfall, floods and landslides.<br>-There are very few, if any, programs that support subsistence farming, or alternative livelihoods and income sources for families and communities. |
| **Access to Infrastructure and Services**<br>-Most residents in Hela and SHP have limited access to infrastructure and services. Majority are not connected to the power grid (i.e., PNG Power). Only a few establishments have generators and solar power for lighting and charging of mobile phones.<br>-Access to critical facilities like roads, health and schools is likewise limited with only very few health centers and secondary schools in both provinces.<br>-Although mobile phone usage is high with most households owning 1 to 2 phones, mobile phone communications, and in particular, mobile data remains unreliable in remote areas, and too expensive for the majority of the population. | - Alternative sources of power include solar for lighting and wood fire for heating during cold weather<br>-Access to transport is only for those who can afford, while access to roads and other services (health, education, communication, early warning) is limited, especially for those living in remote locations. In particular, women (head of household, pregnant, lactating) and children are affected by the limited availability of, and access to, health and education facilities.<br>-During heavy rain events, river levels increase with strong currents threatening the safety of people, especially school children, damaging walkways and bridges, and cutting off access to important facilities and services. |
| **Low Adaptive Capacity**<br>-Literacy rates in both Hela and SHP are relatively low. | -Young men face a lack of available jobs and business opportunities coupled with heightened expectations and pressure to contribute to the family, clan and |

| Context | Remarks |
| --- | --- |
| -Both provinces have large youth population under the age of 18. This group comprise about 63% and 68% in SHP and in HP, respectively.<br>-There is increasing population in some wards due to polygamy and teenage marriage. | tribe. The limited educational and employment opportunities for the youth, in general, lead to severe disenfranchisement and are also contributing factors to the hostility and violence within and outside communal groups. In conflicts that lead to fighting, women and children often become collateral damage.<br>-Although women are the primary providers of care, food, and water, and take on the men's household leadership role during times of conflicts and fighting, they are culturally excluded from decision-making and do not have access to information or communication facilities. |
| **Weak Governance**<br>-In both provinces, autonomous tribes consider their tribe or clan leader as the sole authority that can give orders on tribe-related issues. Tribe leaders are considered "big men" capable of leading the tribe with (perceived) wisdom and experience.<br>-There is a prevailing system in tribes, called wantok-ism which is a system of social kinship, welfare and mutual obligation through exchange of social capital (i.e., food, money, shelter, security, access to services, adoption, and employment). Tribal leaders are expected to extend their power to support their wantoks.<br>-The concept of ward members and councilors were recognized only upon its introduction in 1995. Ward members and councilors became well respected within local communities, where they work closely with traditional leaders to resolve issues and make decisions concerning tribes and clans. | -Wantok-ism functions as the social safety net that protects members of a tribe, however, it is also a source of conflict of interest and blurring the lines between individual professional/public obligations from tribal obligations, such as in cultural exchanges and compensation obligations. Oftentimes, opportunities related to education, professional development, work, etc., are handed over to people with close relationship or ties with the tribal leader rather than to those who are better qualified or with greater potential or need.<br>-Local governance in Hela and SHP is weak. Government services to address tensions in many communities are limited and further threatened by the increased proliferation of factory-made firearms. There are many areas where there is no visible government presence nor service provision. The government's low capacity to deliver services including implementing the rule of law, providing equitable justice, stopping crimes, and mitigating conflicts, emboldens tribal autonomy and further undermines the government's legitimacy and recognition as the holder of power. |
| **Conflict and Gender**<br>-Hela and SHP provinces are characterized by long history of conflicts between and within groups due to resource and land disputes as well as by raskolism[17] and politically-driven violence. Tribal fighting re-emerged in Tari in the 1980s together with a rise in violence, criminality and a general breakdown in law and order. Interpersonal violence at the household and wider family level is also endemic and there are particular concerns for women and children in such circumstances. In most cases, law enforcers are outnumbered and outgunned by fighting tribes and can only intervene at significant personal risk.<br>-Women often have limited participation in decision-making processes, but are usually on the receiving end of sexual and gender-based violence, human | -In times of conflicts, women take on more roles such as preparing food gardens, providing protection, shelter, firewood and water for the family in addition to their traditional roles as caregivers and caretakers of food gardens.<br>-Movement of women is limited, often dangerous, during conflict situations. In their search for food and water, many women and children were physically or sexually assaulted and/or killed. A few young women were arranged for marriages in exchange for land, and in some cases, in exchange for firearms. Indeed, families who are displaced either by conflict or disasters were sometimes compelled to "exchange" their daughters to land owners for a space to establish their homes and food gardens. |

[17] Raskolism – juvenile gang crime

| Context | Remarks |
|---|---|
| trafficking and exploitation, displacement, and poverty during conflicts and disasters | |

Subsistence farming is often in the form of small home gardens grown by women. Water is manually sourced from rivers or streams without proper filtration, also mostly by women, girls, and children. Majority of residents in both provinces are not connected to the power grid and there are only a few establishments with generators and solar power for lighting and mobile phone charging. Critical facilities like roads, health and schools are likewise difficult to access. The burgeoning population of youth, particularly men, struggle with the limited availability of job and business opportunities coupled with expectations and pressures to contribute to the family. This opens young men up to drug use and violence, heightened by the proliferation of factory-made firearms, leading to *raskolism* or juvenile gang crimes. These circumstances contribute to the prevailing intra-/inter-communal conflicts, and the consequent violence against women and children due to conflicts at the interpersonal, household, and wider family level, as well as the general break down of law and order. Unfortunately, women suffer the brunt of taking over all household responsibilities when the men are focused on fights, where women, girls, and children are also often the collateral damage. The government is incapable of providing effective interventions and services to address tensions, prevent crimes, mitigate conflicts and/or enforce rule of law and access to justice. This further emboldens tribal autonomy and undermines the government's legitimacy and authority. Although there is a system of kinship, welfare, and mutual obligation in tribes that should serve as a social safety net that protects its members, it likewise becomes a vehicle for corruption and perpetuation of gender inequalities when self-interest is prioritized over communal interest and wellbeing.

It is evident that in these pre-existing conditions, women are already marginalized in terms of roles and empowerment in the household and the community. Although they take on a lot of responsibilities including growing food, fetching water, taking care of children, managing household chores, as well as taking over the men's responsibilities during intra-/inter-communal conflicts, they are still culturally excluded from decision-making and dialogues. Moreover, women and children are traditionally subject to neglect (as some men are polygamous, taking on as many as 20 wives), abuse and violence within the family and community, and also suffer the psychological and socio-economic impacts of conflicts, tribal/clan/gang fights, and criminality.

Extreme weather events and climate variability exacerbate the fragilities and pre-existing vulnerabilities of communities dependent on subsistence livelihoods, further increasing the burden on women and girls whose traditional roles are related to natural resource management and provision. These communities have limited capacity to mitigate and prepare for current risks, much less for future climate threats. Indeed, the climate risk assessment indicates potential increase in rainfall, maximum and minimum temperatures, and extreme events that could enhance the likelihood of landslides, floods, and drought (and possibly frost) events in Hela and SHP. These hazards have relevant impacts on the pilot provinces' food and water security, livelihoods and conflict situations. Table 6-2 summarizes the projected hazard scenarios, and potential implications.

**Table 6-2. Hazard scenarios and their implications**

| Hazard Scenario | Implications |
|---|---|
| **Precipitation**<br>-Rainfall is expected to increase by up to 26% in Hela, 22.57% in SHP in 2100<br>**Flood and Extreme Events**<br>-Maximum flood depth is projected to increase by up to 3.04m in 2100 from a baseline of 1.66m for 100-year return flood event in Hela; Similar increase by up to 2.02m is projected in SHP in | **Precipitation**<br>-Heavy rainfall causes crop damage, soil erosion and soil nutrient depletion; and degrades water quality. Stormwater runoff, which may include pollutants like heavy metals and pesticides, can end up in rivers, lakes, and bays endangering human health and aquatic ecosystems. |

| Hazard Scenario | Implications |
|---|---|
| 2100 from a baseline of 1.19m for 100-year return flood event.<br>- Five consecutive days rainfall (RX5day) to increase by up to 56.09% in Hela, and up to 54.95% in SHP in 2100;<br>- Number of extremely wet days (R99p) is expected to increase in 2100 by another 68 to 266mm from a baseline of 92mm in Hela, and another 1 to 238mm from a baseline of 168mm in SHP<br>- Maximum one-day rainfall (Rx1day) is projected to increase in 2100 by up to 35.58% from a baseline of 49.49mm in Hela, and by up to 44.79% from a baseline of 71.04mm<br>- Consecutive wet days (CWD) is expected to increase in 2100 by another 3 to 5 days from a baseline of 35 days in Hela, and by another 38 to 40 days from a baseline of 35 days in SHP | - Heavy rain can cause pooling, overflowing rivers and runoffs, landslide and flooding.<br>- Increased rainfall supports moisture-reliant pathogens. Many weeds, pests, and fungi thrive under warmer temperatures, wetter climates.<br>**Flood**<br>- Flooding destroys crops and causes livestock loss. It also causes injuries, casualties, evacuations, power outages, supply shortages, traffic obstructions and road closures, infrastructure/property damage and debris.<br>- Flooding brings health risks due to water contamination and waterborne diseases. |
| **Temperature**<br>- Daily maximum temperatures in Hela are expected to increase by up to 2.37°C in 2100 from a baseline of 19.79°C; Similar increase by up to 2.45°C is projected in SHP in 2100 from a baseline of 21.64°C.<br>- Daily minimum temperatures are expected to increase by up to 2.10°C in 2100 from baseline of 15.98°C for Hela; Similar increase by up to 1.96°C is projected in 2100 from baseline of 18.29°C for SHP | - Temperature rise increases evaporation, causes soils to become drier, and reduces water outflows. It also causes water temperatures to increase, hence increasing water pollution problems that affect aquatic habitats.<br>- Warming may benefit certain types of crops, or allow farmers to shift to crops grown in warmer areas. If temperature exceeds a crop's optimal level, crop production quantity and quality will decline. Reduced forage quality also reduces the ability of pasture and rangeland to support grazing livestock.<br>- Rising temperature causes heat stress, which increases the animals' vulnerability to disease, reduces fertility, and reduces milk production.<br>- Temperature rise induces new conditions that will affect insect populations, incidence of pathogens, and the geographic distribution of pests, weeds and diseases. Many weeds, pests, and fungi thrive under warmer temperatures, wetter climates.<br>- A rise in temperature increases the likelihood of heat waves that cause illnesses like heat cramps, heat strokes, and even death. In the case of Hela and SHP, the rise in maximum and minimum temperature may not be very disadvantageous. The increase in nighttime temperature might even be beneficial for residents who do not have access to heating. Additionally, this might help reduce the incidence of frost in high altitude areas. |
| **Drought**<br>- Intensity of drought is projected to increase; when drought occurs, it is more intense in terms of the deficit in precipitation although the overall impact is projected to be less<br>- The probability of occurrence of drought is inconclusive but the number of consecutive dry days (CDD) is expected to increase in 2100 by another 6 days from a baseline of 7 days in Hela, and by another 7 to 10 days from a baseline of 10 days in SHP | **Drought**<br>- Drought causes declines in surface and groundwater supplies, affecting water availability and increasing costs to access water for industrial use, household consumption, crop irrigation and livestock production. It increases the rate of erosion, loss of forest cover, runoff of nutrients into water bodies, among other impacts.<br>- The short- and long-term impacts of drought include crop death from insufficient water; crop damage from disease and ungulates; increased incidence of wildfires; increased erosion and impacts downstream; decreased growth and |

| Hazard Scenario | Implications |
|---|---|
| **Frost**<br>-The occurrence of frost is closely linked with incidence of El Niño. Extreme El Niño and La Niña events may increase in frequency from about one every 20 years, to one every 10 years by 2100 | crop/livestock production in terms of quality and quantity; impacts to seed and soil conditions; reduced farm viability; inconsistent supply of products; reduced availability of food; increased dependence on imports; higher commodity prices; and degraded agricultural sector.<br>-Drought also causes land subsidence, seawater intrusion, and damage to ecosystems.<br>**Frost**<br>-Frost causes crop damage, crop quality reduction, and overall poor crop yield. |
| **Landslide**<br>-About 45% of Hela's mountainous areas considered as high to very high landslide-prone | -Landslides cause injuries, loss of life, evacuations, power outages, supply shortages, traffic obstructions and road closures, infrastructure/property damage, loss of natural resources, and damage to land. Landslide debris can block rivers and increase the risk of floods.<br>-Landslides also destroy crops and causes livestock loss. |

The above-mentioned hazards – floods, drought and frost, landslides – are important in terms of impact in both Hela and SHP. For instance, heavy rainfall and floods in September 2012 resulted in the destruction of roads and bridges, displacement of the population, and cut-off of vital government and private sector services in Hela and the eastern part of SHP. About 200,000 people were affected and the damage was estimated at six million dollars (USD 6 million) in SHP. Similarly, the 1997-1998 as well as the 2015-2016 drought and frost caused widespread devastation with many agricultural communities in the Highlands left without food and very limited access to safe drinking water. Finally, the rainfall-induced landslide in November 2016 completely covered two (2) villages in SHP and killed over 40 people, while the earthquake-induced landslides in Hela and SHP in February 2018 killed more 67 people and injured almost 300. Despite the magnitude of the impacts, there is still no mechanism or process established for authorities and residents to better prepare for, manage, and respond.

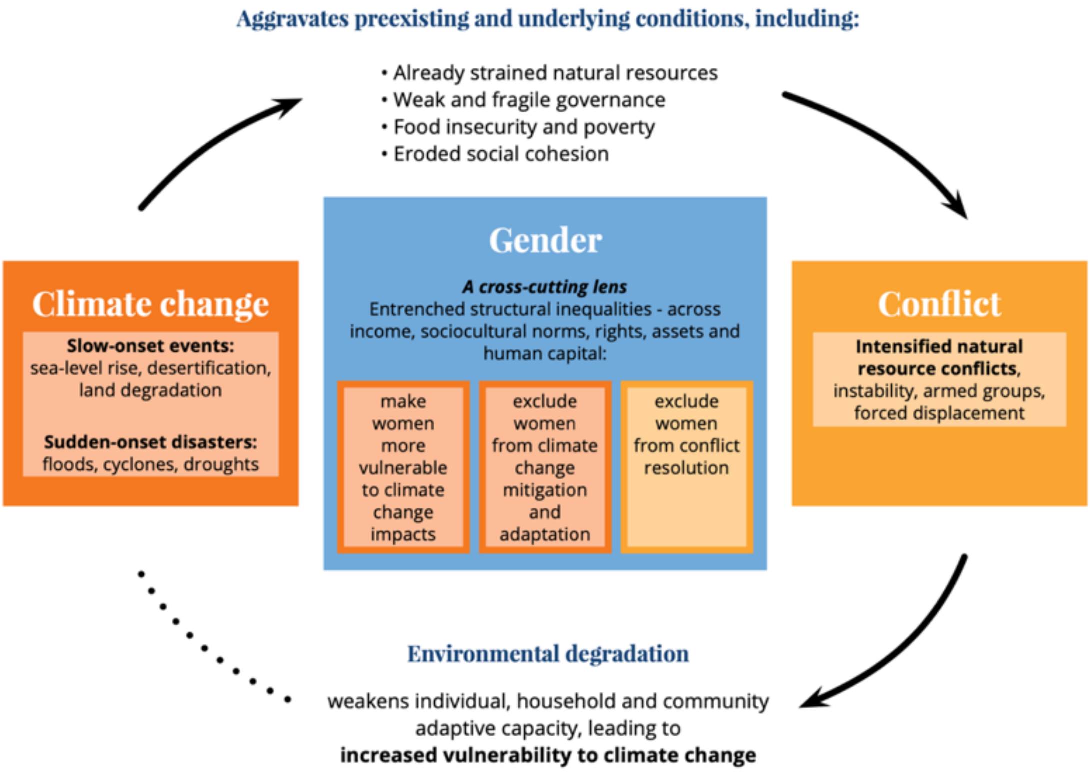



Figure 6-1. Climate-gender-conflict nexus

Figure 6-1 shows the linkages of the contexts and gaps with respect to the results and implications of the climate risk assessment. Without effective mitigation and adaptation measures, climate change can undermine livelihoods particularly those that are agriculture-related, exacerbate poverty, and cause displacements. In fragile contexts like Hela and SHP, it will aggravate underlying political, social, and economic conditions that can increase or renew conflicts and cause communities to be stuck in a vicious cycle of low human development, poverty, and conflict.

# 7 Recommendations

The climate risk assessment results indicate the potential for increased rainfall, maximum and minimum temperature, and extreme events that would enhance the likelihood of landslide, flood, drought (and possibly frost) events in both provinces. These hazards are expected to adversely impact the already strained natural resources, cause food and water insecurity and push people further into poverty. In the absence of established rules and implementation processes for land registration/ownership and development, and within the context of relatively weak governance and support mechanisms, the possibility is high for displacement, instability and conflicts to arise. Unfortunately, the conflicts further push communities, particularly women and children, to even greater levels of vulnerability to climate change and its impacts. In order to address the impacts of climate change risks, the following recommendations are proposed.

### Food and Water Security

- Scale-up the seedbank project by NARI, FAO, Provincial DAL
- Provide agro-met advisory for small-scale subsistence farmers
- Install water harvesting mechanisms in critical facilities/communal areas (schools, health centers, churches)

### Livelihood

- Promote the development of climate-resilient livelihoods (e.g., driver, mechanic, sales, construction, etc.) that are inclusive of both genders, fostering economic independence and reducing vulnerabilities
- Support community-based livestock, poultry or inland fishery breeding and rearing programs, and provide vocational-technical trainings on alternative livelihoods
- Establish and/or support the growth of local (agriculture-based) industries like coffee, tea, etc.

### Law Enforcement

- Strengthen the implementation of laws on land registration and land ownership
- Improve enforcement of regulations and raise awareness against SARV, GBV, etc.

### Disaster Risk Reduction

- Improve the availability of and access to early warning information from national to provincial levels, and then from provincial to district, LLG, ward and household levels
- Support the integration of hazard and risk information in DRM and the development plans or activities of the province, district and LLGs

### Infrastructure and Services

- Enhance availability and access of communities to critical facilities like roads, health centers and schools – rebuild facilities damaged during conflicts and/or construct new facilities in crucial sites

### Community Development

- Ensure women inclusion in household and community decision-making, especially on issues that affect them, their families and livelihoods
- Support community-based initiatives that actively involve women in decision-making, resource management and resilience planning
- Support/scale-up community-based programs and initiatives like the seedbanks, CPDP, CBDRM, SARV Awareness Program, etc. of local and international NGOs
- Implement measures to address gender-based violence including SARV, particularly in situations of displacement and migration caused by climate change impacts.

### Land Use

- Develop land use plans and zoning regulations (at province and LLG levels), indicating suitable sites for establishing settlements, industries, agriculture production (crop and livestock), etc. that integrate current and future hazards and risks

### Policy and Strategy

- Integrate gender perspectives into policies and strategies that would sufficiently and effectively consider the needs, requirements and inputs of men and women
- Enhance women and girls' access to education, resources, and decision-making processes to improve their resilience against climate and disaster risks
- Raise awareness of the gendered impacts of climate change and disaster risks, and the need for gender-sensitive policies at the national and local levels.

### Information and Research

- Update and improve the country's information databases and knowledge sharing mechanisms
- Conduct further research on the intersections among climate, conflict and gender in fragile contexts, and develop sound policies and strategies to mitigate, prepare for and address the disproportionate impacts of climate change and conflicts on women and girls

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## Appendix 1. Participants to the National Inception Meeting and Provincial Workshops

| | Title | First Name | Surname | Position | Organization |
|---|---|---|---|---|---|
| National Inception Meeting, 6 February 2023 | | | | | |
| 1 | Mr. | Raymond | Yamai | Acting Director | Department of Mineral Policy & Geohazards Management (DMPGM) |
| 2 | Mr. | Mathew | Moihi | Acting Assistant Director | Port Moresby Geophysical Observatory, DMPGM |
| 3 | Ms. | Elizabeth | Michael | Acting Assistant Director | Engineering Geology, DMPGM |
| 4 | Mr. | Walimu | Apaka | Principal Scientist | Hydrological Services, Conservation and Environment Protection Authority (CEPA) |
| 5 | Mr. | John | Ari | Senior Hydrographer | Conservation and Environment Protection Authority (CEPA) |
| 6 | Ms. | Anna | Kiman | Food Security Officer | Department of Agriculture and Livestock (DAL) |
| 7 | Ms. | Theresa | Wambon | Science and Technology Officer | Department of Agriculture and Livestock (DAL) |
| 8 | Mr. | Simon | Makip | Cartographer | National Mapping Bureau (NMB) |
| 9 | Ms. | Lilimod | Orari | Cartographer | National Mapping Bureau (NMB) |
| 10 | Mr. | Julius | Wandi | | Department of Works and Highways (DoWH) |
| 11 | Mr. | Jobias | Asinimbu | | Department of Works and Highways (DoWH) |
| 12 | Ms. | Stacy | Manda | | Department of Works and Highways (DoWH) |
| 13 | Mr. | Erick | Sarut | | Climate Change and Development Authority (CCDA) |
| 14 | Ms. | Jacinta | Kull | NC Officer | Climate Change and Development Authority (CCDA) |
| 15 | Ms. | Jason | Paniu | | Climate Change and Development Authority (CCDA) |
| 16 | Mr. | Kupson | Siga | | National Disaster Center (NDC) |
| 17 | Mr. | Christopher | Bazzy | | Department of Mineral Policy & Geohazards Management (DMPGM) |
| SHP Provincial Consultation Workshop, 9 February 2023 | | | | | |
| 1 | Ms. | Jacintah | Yani | Project Coordinator | World Vision |
| 2 | Ms. | Mapera | Angu | Project Officer | World Vision |
| 3 | Ms. | Anna | Emeck | Advisor Com/Dev | SHPA |
| 4 | Ms. | Barbara | Pinpin | Nutrition Manager | SHPHA |
| 5 | Mr. | Francis | Yasi | Com. Dev. Officer | SHPA |
| 6 | Mr. | Peter W. | Wan | PDC | SHPA |
| 7 | Mr. | Sebastian | Hurcoli | Field Coordinator | IOM |
| 8 | Mr. | Peter | John | Crops Manager | SHP-DAL |
| 9 | Mr. | Roderick | Irgo | Caritas PNG | Mendi Diocese Catholic |
| Hela Provincial Consultation Workshop, 16 February 2023 | | | | | |
| 1 | Mr. | Mathias | Hamaia | Manager C & D | Hela Administration |
| 2 | Ms. | Marilyn | Tabagua | Program Coordinator | RWDFI |
| 3 | Mr. | Fred | Lialu | Manager Com/De | Hela Administration |
| 4 | Mr. | Geoffrey | W | Director, Economics | Hela Province |
| 5 | Mr. | James | Komengi | DRR+R Officer | United Church |
| 6 | Mr. | David | Kuna | Team Leader | IOM |
| 7 | Mr. | Eric | Yuguli | Manager | Hela Administration |
| 8 | Ms. | Mary | Miarad | Health Educator | PHA |
| 9 | Ms. | Tai | Lawe | DPA | HPA |

| | Title | First Name | Surname | Position | Organization |
|---|---|---|---|---|---|
| 10 | Ms. | Alice | Bibe | Bus Dep Officer | |
| 11 | Ms. | Janet | Koriama | President | Hela PCDW |
| 12 | Mr. | Richard | Arawi | LLG Manager | Tari Port |
| 13 | Mr. | James | Pokaja | Peace and Governance Chairman | |
| **14** | Ms. | Morgen | Mokai | Councilor | Tebi LLG |
| **15** | Mr. | Daniel | Tumbari | Director | Law & Justice - HPG |

## APPENDIX 2. PARTICIPANTS TO THE NATIONAL AND PROVINCIAL VALIDATION WORKSHOPS

| | Title | First Name | Surname | Position | Organization |
|---|---|---|---|---|---|
| SHP Provincial Validation Workshop, 17 May 2023 | | | | | |
| 1 | Mr. | Henry | Hapen | Deputy Provincial Administrator | SHP Administration |
| 2 | Ms. | Anna | Emeck | Community Development Advisor | SHP Administration |
| 3 | Mr. | John | Kink | Disaster Coordination Advisor | SHP Administration |
| 4 | Mr. | Rim | Kanea | Policy Planning Advisor | SHP Administration |
| 5 | Mr. | Jeffery | Lekep | Law and Justice Advisor | SHP Administration |
| 6 | Mr. | Pore | Suri | Natural Resources Advisor | SHP Administration |
| 7 | Mr. | Thomas | Kuru | District and Local Level Government Officer | SHP Administration |
| 8 | Mr. | Ludwig | Orapawa | Representative | Kagua-Erave District Administration |
| 9 | Mr. | Bruce | Kamuge | Representative | Imbonggu District Administration |
| 10 | Mr. | John | Kiniwi | Representative | Nipa-Kutubu District Administration |
| 11 | Mr. | Brian | Pim | LLG Advisor | SHP Administration |
| 12 | Mr. | John | Anda | Senior Court Inspector | SHP Administration |
| 13 | Mr. | Jackson | Epat | Senior Liaison Officer - Law and Justice Sector | SHP Administration |
| 14 | Mr. | Jack | Kopunye | Peacebuilding Project Officer | World Vision International |
| 15 | Mr. | Cainny | Kewa | Peacebuilding Project Officer | World Vision International |
| 16 | Mr. | Roderick | Irepo | Diocesan Caritas Coordinator - Mendi Diocese | Caritas Papua New Guinea |
| 17 | Ms. | Consuelo | Fernandez | GYPI Project Manager | United Nations Development Programme |
| 18 | Ms | Mary | Konobo | GYPI Project Officer | United Nations Development Programme |
| 19 | Mr. | Michael | Bausas | Consultant | RIMES |
| 20 | Mr. | Peter | Khalil Ferrer | Consultant | RIMES |
| 21 | Ms. | Mary | Wapi | Participant of the CC, DRR, Do No Harm | Mapata 1 |
| 22 | Mr. | Rockins | Rero | Participant of the CC, DRR, Do No Harm | Pira 1 |
| 23 | Mr. | Karabus | Andasua | Participant of the CC, DRR, Do No Harm | Pira 2 |
| 24 | Ms. | Rose | Lax | Participant of the CC, DRR, Do No Harm | Mapata 2 |
| Hela Provincial Validation Workshop, 19 May 2023 | | | | | |
| 1 | Mr. | Tai | Lawe | Deputy Provincial Administrator | Hela Provincial Administration |
| 2 | Mr. | Thomas | Hengebe | Executive Officer | Hela Provincial Administration |
| 3 | Mr. | Andagi Eric | Yuguli | Manager - Climate Change | Hela Provincial Administration |
| 4 | Mr. | Eky | Perebugo | DPA Policy, Planning & Administration | Hela Provincial Administration |
| 5 | Ms. | Joane | Puname | Director - Policy, Planning, & Administration | Hela Provincial Administration |
| 6 | Mr. | Geffery | Walapi | Director - Economic Advancement | Hela Provincial Administration |
| 7 | Mr. | Daniel | Tumbiari | Director - Community Development | Hela Provincial Administration |
| 8 | Mr. | Johnson | Tiki | Director - LLG and District Affairs | Hela Provincial Administration |
| 9 | Mr. | Joseph | Tondop | Provincial Police Commander | Royal Police Constabulary PNG |
| 10 | Mr. | Wesley | Yope | Hawa CIS Commander | Hawa CSI |
| 11 | Mr. | Stanley | Kotange | District Administrator - Koroba District Administration | Koroba District Administration |
| 12 | Mr. | Willy | Kare | District Administrator - Tari-Pori District | Tari-Pori Administration |

| | Title | First Name | Surname | Position | Organization |
|---|---|---|---|---|---|
| 13 | Mr. | Wilson | Pole | District Administrator - Komo-Hulia District | Komo-Hulia District Administration |
| 14 | Mr. | Mark | Mendai | District Administrator - Magarima District | Magarima District Administration |
| 15 | Mr. | Michael | Pani | Councillor LLG Representative | Hides Special Purpose |
| 16 | Mr. | David | Kuna | Hela Field Coordinator | International Organisation for Migration |
| 17 | Ms. | Consuelo | Fernandez | GYPI Project Manager | United Nations Development Programme |
| 18 | Ms. | Mary | Konobo | GYPI Project Officer | United Nations Development Programme |
| 19 | Mr. | Michael | Bausas | Consultant | RIMES |
| 20 | Mr. | Peter | Kahlill Ferrer | Consultant | RIMES |
| 21 | Ms. | Marilyn | Tabagua | Leader | NGO RWAFI |
| 22 | Mr. | Mathias | Hamaga | Chairman | Hela Council of Churches |
| 23 | Mr. | James | Komengi | Church Advocate for Peace | United Church Hela |
| 24 | Mr. | Rex | Kalari | Ward Councillor | Tengo Ward/Margarima District |
| 25 | Ms. | Anna | Palus | Coordinator | Tengo Ward/Margarima District |
| 26 | Mr. | Henry | Tendele | Coordinator | Paipeli |
| 27 | Ms. | Joy | Angai | Coordinator | Paipeli |
| 28 | Mr. | Andrew | Hawa | Church Elder | Idawi Ward |
| 29 | Ms. | Rose | Tambiri | Local Leader | Idawi |
| National Validation Workshop, 23 May 2023 | | | | | |
| 1 | Ms. | Jacinta | Kull | NC Officer | Climate Change Development Authority |
| 2 | Ms. | Priscilla | Pep | NC Officer | Climate Change Development Authority |
| 3 | Ms. | Elizabeth | Michael | Acting Assistant Director - EGB | Department of Mineral Policy and Geohazard |
| 4 | Mr. | Morris | Popone | Researcher | National Statistical Office |
| 5 | Mr. | Desmond | Sow | GIS Officer | National Statistical Office |
| 6 | Mr. | Carter | Guri | Climate Officer | National Weather Service |
| 7 | Mr. | Kasis | Inape | Assistant Director | National Weather Service |
| 8 | Mr. | Christopher | Bazzy | Senior Engineering Geo | Department of Mineral Policy and Geohazard |
| 9 | Ms. | Consuelo | Fernandez | GYPI Project Manager | United Nations Development Programme |
| 10 | Ms. | Mary | Konobo | GYPI Project Officer | United Nations Development Programme |
| 11 | Mr. | Michael | Bausas | Consultant | RIMES |
| 12 | Mr. | Peter | Kahlill Ferrer | Consultant | RIMES |
| 13 | Ms. | Carlyne | Yu | Consultant | RIMES |

# Appendix 3. Factor-Specific Maps and Pairwise Comparisons

**Table 0-1. Pairwise comparison of geological parameters**

| Item Number | Item Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Item Description | Sandstone | Alluvium | Volcanic Rock | Limestone | Shale | Siltstone and Mudstone | Colluvium | Glacial Sediment | Pyroclastic Rock | Granite | Schist | Quartzite |
| 1 | Sandstone | 1.00 | 3.00 | 0.50 | 0.50 | 2.00 | 0.50 | 3.00 | 2.00 | 4.00 | 1.00 | 0.33 | 4.00 |
| 2 | Alluvium | 0.33 | 1.00 | 0.20 | 0.20 | 0.33 | 0.20 | 1.00 | 0.33 | 0.33 | 0.25 | 0.20 | 0.50 |
| 3 | Volcanic Rock | 2.00 | 5.00 | 1.00 | 1.00 | 3.00 | 1.00 | 4.00 | 3.00 | 5.00 | 2.00 | 0.50 | 5.00 |
| 4 | Limestone | 2.00 | 5.00 | 1.00 | 1.00 | 3.00 | 1.00 | 4.00 | 3.00 | 5.00 | 2.00 | 0.50 | 5.00 |
| 5 | Shale | 0.50 | 3.00 | 0.33 | 0.33 | 1.00 | 0.50 | 2.00 | 0.33 | 1.00 | 0.33 | 0.50 | 2.00 |
| 6 | Siltstone and Mudstone | 2.00 | 5.00 | 1.00 | 1.00 | 2.00 | 1.00 | 3.00 | 2.00 | 3.00 | 1.00 | 0.50 | 2.00 |
| 7 | Colluvium | 0.33 | 1.00 | 0.25 | 0.25 | 0.50 | 0.33 | 1.00 | 0.33 | 0.50 | 0.20 | 0.20 | 0.50 |
| 8 | Glacial Sediment | 0.50 | 3.00 | 0.33 | 0.33 | 3.00 | 0.50 | 2.00 | 1.00 | 3.00 | 0.50 | 0.50 | 2.00 |
| 9 | Pyroclastic Rock | 0.25 | 3.00 | 0.20 | 0.20 | 1.00 | 0.33 | 2.00 | 0.33 | 1.00 | 1.00 | 0.20 | 1.00 |
| 10 | Granite | 1.00 | 4.00 | 0.50 | 0.50 | 3.00 | 1.00 | 5.00 | 2.00 | 1.00 | 1.00 | 0.33 | 2.00 |
| 11 | Schist | 3.00 | 5.00 | 2.00 | 2.00 | 2.00 | 2.00 | 5.00 | 2.00 | 5.00 | 3.00 | 1.00 | 4.00 |
| 12 | Quartzite | 0.25 | 2.00 | 0.20 | 0.20 | 0.50 | 0.50 | 2.00 | 0.50 | 1.00 | 0.50 | 0.25 | 1.00 |

**Table 0-2. Pairwise comparison of NDVI values**

| Item Number | Item Number | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | Item Description | -0.1 to 0.2 | 0.2 to 0.4 | 0.4 to 0.6 | 0.6 to 0.8 | 0.8 to 1.0 |
| 1 | -0.1 to 0.2 | 1.00 | 3.00000 | 5 | 6 | 7 |
| 2 | 0.2 to 0.4 | 0.33 | 1.00 | 3 | 4 | 5 |
| 3 | 0.4 to 0.6 | 0.20 | 0.33 | 1.00 | 2 | 3 |
| 4 | 0.6 to 0.8 | 0.17 | 0.25 | 0.50 | 1.00 | 2 |
| 5 | 0.8 to 1.0 | 0.14 | 0.20 | 0.33 | 0.50 | 1.00 |

**Table 0-3. Pairwise comparison of altitude values**

| Item Number | Item Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| | Item Description | <700 | 700-1300 | 1300-1900 | 1900-2500 | 2500-3100 | 3100-3700 | >3700 |
| 1 | <700 | 1.00 | 0.50 | 0.33 | 0.25 | 0.20 | 0.14 | 0.11 |
| 2 | 700-1300 | 2.00 | 1.00 | 0.50 | 0.33 | 0.25 | 0.17 | 0.13 |
| 3 | 1300-1900 | 3.00 | 2.00 | 1.00 | 0.50 | 0.33 | 0.20 | 0.14 |
| 4 | 1900-2500 | 4.00 | 3.00 | 2.00 | 1.00 | 0.50 | 0.25 | 0.17 |
| 5 | 2500-3100 | 5.00 | 4.00 | 3.00 | 2.00 | 1.00 | 0.33 | 0.20 |
| 6 | 3100-3700 | 7.00 | 6.00 | 5.00 | 4.00 | 3.00 | 1.00 | 0.33 |
| 7 | >3700 | 9.00 | 8.00 | 7.00 | 6.00 | 5.00 | 3.00 | 1.00 |

**Table 0-4. Pairwise comparison of lineament values**

| Item Number | Item Number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | Item Description | <1000 | 1000-2000 | 2000-4000 | 4000-6000 | 6000-8000 | >8000 |
| 1 | <1000 | 1.00 | 1.00 | 2.00 | 3.00 | 4.00 | 4.00 |
| 2 | 1000-2000 | 1.00 | 1.00 | 2.00 | 3.00 | 4.00 | 4.00 |
| 3 | 2000-4000 | 0.50 | 0.50 | 1.00 | 2.00 | 3.00 | 3.00 |
| 4 | 4000-6000 | 0.33 | 0.33 | 0.50 | 1.00 | 2.00 | 2.00 |
| 5 | 6000-8000 | 0.25 | 0.25 | 0.33 | 0.50 | 1.00 | 1.00 |
| 6 | >8000 | 0.25 | 0.25 | 0.33 | 0.50 | 1.00 | 1.00 |

**Table 0-5. Pairwise comparison of distance to river values**

| Item Number | Item Number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | Item Description | <500 | 500-1000 | 1000-1500 | 1500-2000 | 2000-2500 | >2500 |
| 1 | <500 | 1.00 | 3.00 | 5.00 | 7.00 | 8.00 | 9.00 |
| 2 | 500-1000 | 0.33 | 1.00 | 3.00 | 5.00 | 6.00 | 7.00 |
| 3 | 1000-1500 | 0.20 | 0.33 | 1.00 | 3.00 | 4.00 | 5.00 |
| 4 | 1500-2000 | 0.14 | 0.20 | 0.33 | 1.00 | 2.00 | 3.00 |
| 5 | 2000-2500 | 0.13 | 0.17 | 0.25 | 0.50 | 1.00 | 2.00 |
| 6 | >2500 | 0.11 | 0.14 | 0.20 | 0.33 | 0.50 | 1.00 |

**Table 0-6. Pairwise comparison of distance to road values**

| Item Number | Item Number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | Item Description | <500 | 500-1000 | 1000-1500 | 1500-2000 | 2000-2500 | >2500 |
| 1 | <500 | 1.00 | 3.00 | 5.00 | 7.00 | 8.00 | 9.00 |
| 2 | 500-1000 | 0.33 | 1.00 | 3.00 | 5.00 | 6.00 | 7.00 |
| 3 | 1000-1500 | 0.20 | 0.33 | 1.00 | 3.00 | 4.00 | 5.00 |
| 4 | 1500-2000 | 0.14 | 0.20 | 0.33 | 1.00 | 2.00 | 3.00 |
| 5 | 2000-2500 | 0.13 | 0.17 | 0.25 | 0.50 | 1.00 | 2.00 |
| 6 | >2500 | 0.11 | 0.14 | 0.20 | 0.33 | 0.50 | 1.00 |

**Table 0-7. Pairwise comparison of precipitation values**

| Item Number | Item Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| | Item Description | <3000 | 3000-3300 | 3300-3600 | 3600-3900 | 3900-4300 | 4300-4600 | >4600 |
| 1 | <3000 | 1.00 | 0.50 | 0.33 | 0.20 | 0.17 | 0.13 | 0.11 |
| 2 | 3000-3300 | 2.00 | 1.00 | 0.50 | 0.25 | 0.20 | 0.14 | 0.13 |
| 3 | 3300-3600 | 3.00 | 2.00 | 1.00 | 0.33 | 0.25 | 0.17 | 0.14 |
| 4 | 3600-3900 | 5.00 | 4.00 | 3.00 | 1.00 | 0.50 | 0.25 | 0.20 |
| 5 | 3900-4300 | 6.00 | 5.00 | 4.00 | 2.00 | 1.00 | 0.33 | 0.25 |
| 6 | 4300-4600 | 8.00 | 7.00 | 6.00 | 4.00 | 3.00 | 1.00 | 0.50 |
| 7 | >4600 | 9.00 | 8.00 | 7.00 | 5.00 | 4.00 | 2.00 | 1.00 |

**Table 0-8. Pairwise comparison of slope values**

| Item Number | Item Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| | Item Description | 0-5 | 5-10 | 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | >35 |
| 1 | 0-5 | 1.00 | 0.50 | 0.33 | 0.25 | 0.20 | 0.17 | 0.14 | 0.11 |
| 2 | 5-10 | 2.00 | 1.00 | 0.50 | 0.33 | 0.25 | 0.20 | 0.17 | 0.13 |
| 3 | 10-15 | 3.00 | 2.00 | 1.00 | 0.50 | 0.33 | 0.25 | 0.20 | 0.14 |
| 4 | 15-20 | 4.00 | 3.00 | 2.00 | 1.00 | 0.50 | 0.33 | 0.25 | 0.17 |
| 5 | 20-25 | 5.00 | 4.00 | 3.00 | 2.00 | 1.00 | 0.50 | 0.33 | 0.20 |
| 6 | 25-30 | 6.00 | 5.00 | 4.00 | 3.00 | 2.00 | 1.00 | 0.50 | 0.25 |
| 7 | 30-35 | 7.00 | 6.00 | 5.00 | 4.00 | 3.00 | 2.00 | 1.00 | 0.33 |
| 8 | >35 | 9.00 | 8.00 | 7.00 | 6.00 | 5.00 | 0.50 | 2.00 | 1.00 |

**Table 0-9. Pairwise comparison of landform parameters**

| Item Numb | Item Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Item Description | Limestone | Dissected v | Polygonal ka | Hilly terrai | Karst plains | Strike ridge | Volcanic co | Undifferen | Homoclina | Little disse | Little disse | Mountains and | Volcano-all | Structural | Lake | Composite |
| 1 | Limestone plateau with narrow karst corridors | 1.00 | 0.50 | 0.50 | 0.50 | 1.00 | 2.00 | 0.50 | 1.00 | 1.00 | 0.50 | 1.00 | 0.14 | 1.00 | 1.00 | 9.00 | 2.00 |
| 2 | Dissected volcanic footslopes and volcano-alluvial fans | 2.00 | 1.00 | 0.50 | 0.50 | 1.00 | 2.00 | 0.33 | 1.00 | 1.00 | 0.50 | 1.00 | 0.17 | 1.00 | 1.00 | 9.00 | 2.00 |
| 3 | Polygonal karst: plateaux or broad ridges on limestone covered with numerous rugged hills | 2.00 | 2.00 | 1.00 | 0.50 | 2.00 | 3.00 | 1.00 | 3.00 | 1.00 | 1.00 | 2.00 | 0.20 | 1.00 | 2.00 | 9.00 | 3.00 |
| 4 | Hilly terrain with weak or no structural control | 2.00 | 2.00 | 2.00 | 1.00 | 2.00 | 4.00 | 2.00 | 3.00 | 3.00 | 2.00 | 3.00 | 0.33 | 2.00 | 3.00 | 9.00 | 4.00 |
| 5 | Karst plains | 1.00 | 1.00 | 0.50 | 0.50 | 1.00 | 0.33 | 0.33 | 1.00 | 0.50 | 0.33 | 1.00 | 0.14 | 0.33 | 0.50 | 9.00 | 0.50 |
| 6 | Strike ridges and hogback ridges: steep, sharp crested structurally controlled ridges | 0.50 | 0.50 | 0.33 | 0.25 | 3.00 | 1.00 | 1.00 | 3.00 | 3.00 | 2.00 | 3.00 | 0.33 | 1.00 | 3.00 | 9.00 | 3.00 |
| 7 | Volcanic cones and domes | 2.00 | 3.00 | 1.00 | 0.50 | 3.00 | 1.00 | 1.00 | 3.00 | 3.00 | 2.00 | 3.00 | 0.33 | 1.00 | 3.00 | 9.00 | 3.00 |
| 8 | Undifferentiated swamps | 1.00 | 1.00 | 0.33 | 0.33 | 1.00 | 0.50 | 2.00 | 1.00 | 2.00 | 0.50 | 1.00 | 0.17 | 0.33 | 0.50 | 9.00 | 2.00 |
| 9 | Homoclinal ridges and cuestas: inclined asymmetrical structurally controlled ridges | 1.00 | 1.00 | 1.00 | 0.33 | 2.00 | 0.33 | 0.33 | 0.50 | 1.00 | 2.00 | 2.00 | 0.17 | 0.20 | 1.00 | 9.00 | 2.00 |
| 10 | Little dissected volcanic footslopes and volcano-alluvial fans | 2.00 | 2.00 | 1.00 | 0.50 | 3.00 | 0.50 | 0.50 | 2.00 | 0.50 | 1.00 | 3.00 | 0.14 | 1.00 | 2.00 | 9.00 | 3.00 |
| 11 | Little dissected or undissected relict alluvial, colluvial mudflow or fans | 1.00 | 1.00 | 0.50 | 0.33 | 1.00 | 0.33 | 0.33 | 1.00 | 0.50 | 0.33 | 1.00 | 0.14 | 0.33 | 0.50 | 9.00 | 1.00 |
| 12 | Mountains and hills with weak or no structural control | 7.00 | 6.00 | 5.00 | 3.00 | 7.00 | 3.00 | 3.00 | 6.00 | 6.00 | 7.00 | 7.00 | 1.00 | 3.00 | 4.00 | 9.00 | 7.00 |
| 13 | Volcano-alluvial plains | 1.00 | 1.00 | 1.00 | 0.50 | 3.00 | 1.00 | 1.00 | 3.00 | 5.00 | 1.00 | 3.00 | 0.33 | 1.00 | 3.00 | 9.00 | 4.00 |
| 14 | Structural plateaux | 1.00 | 1.00 | 0.50 | 0.33 | 2.00 | 0.33 | 0.33 | 2.00 | 1.00 | 0.50 | 2.00 | 0.25 | 0.33 | 1.00 | 9.00 | 2.00 |
| 15 | Lake | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 1.00 | 0.33 |
| 16 | Composite alluvial plains | 0.50 | 0.50 | 0.33 | 0.25 | 2.00 | 0.33 | 0.33 | 0.50 | 0.50 | 0.33 | 1.00 | 0.14 | 0.25 | 0.50 | 3.00 | 1.00 |

**Table 0-10. Pairwise comparison of PGA parameters**

| Item Number | Item Number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | Item Description | <0.2 | 0.2-0.3 | 0.3-0.4 | 0.4-0.5 | 0.5-0.6 | >0.6 |
| 1 | <0.2 | 1.00 | 0.50 | 0.33 | 0.20 | 0.17 | 0.13 |
| 2 | 0.2-0.3 | 2.00 | 1.00 | 0.50 | 0.25 | 0.20 | 0.14 |
| 3 | 0.3-0.4 | 3.00 | 2.00 | 1.00 | 0.33 | 0.25 | 0.17 |
| 4 | 0.4-0.5 | 5.00 | 4.00 | 3.00 | 1.00 | 0.50 | 0.25 |
| 5 | 0.5-0.6 | 6.00 | 5.00 | 4.00 | 2.00 | 1.00 | 0.33 |
| 6 | >0.6 | 8.00 | 7.00 | 6.00 | 4.00 | 3.00 | 1.00 |

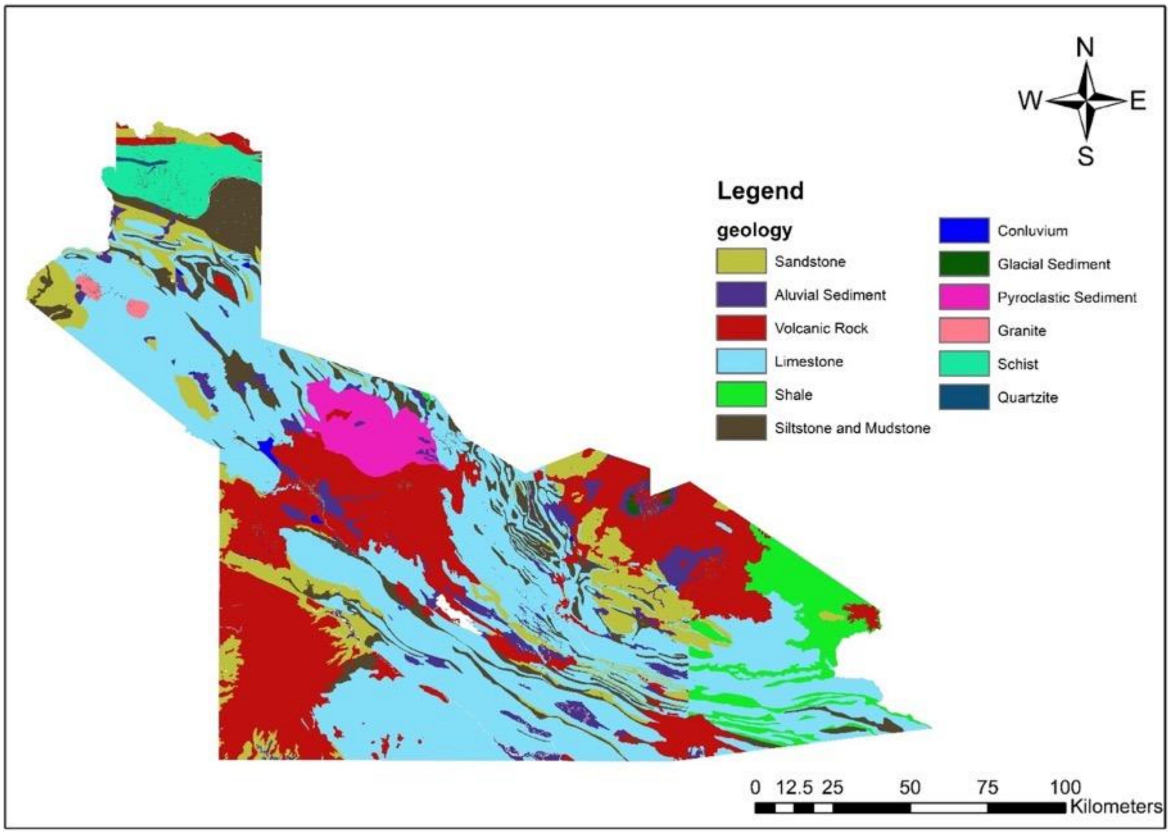



**Figure 0-1. Hela and SHP geology map**

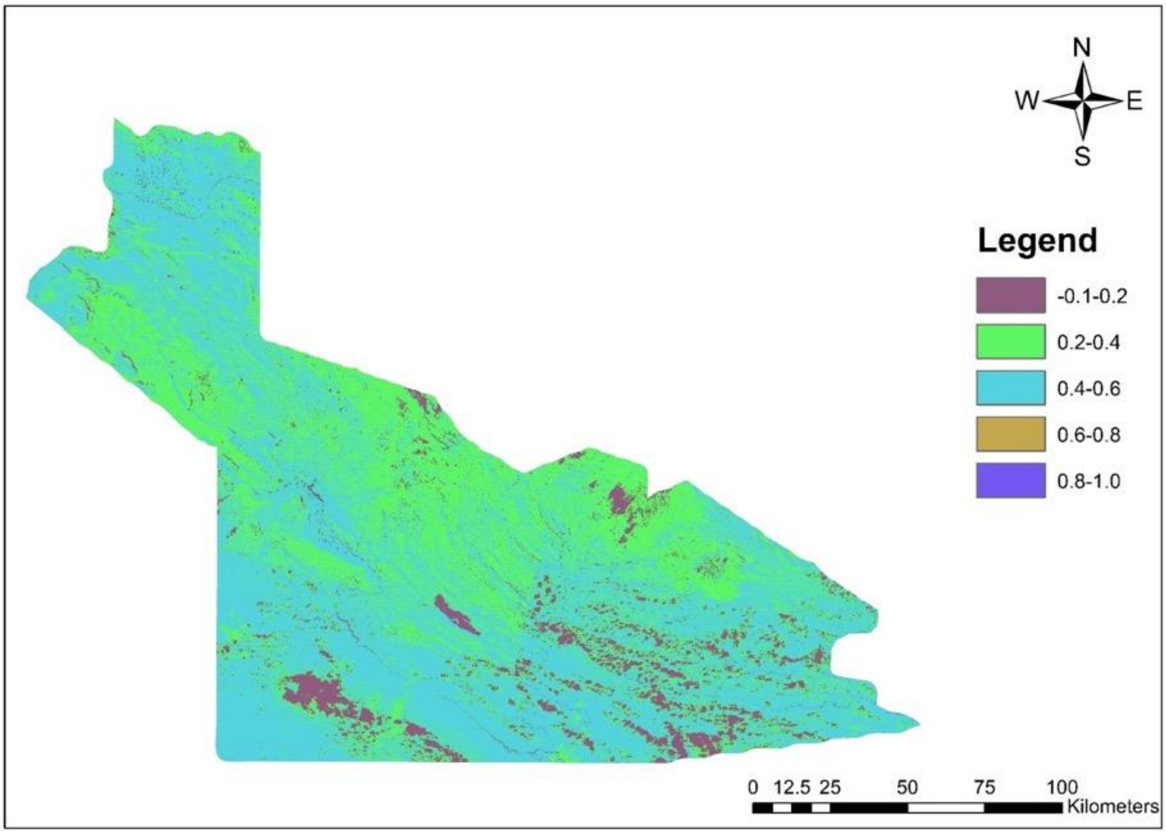



**Figure 0-2. Hela and SHP NDVI map**

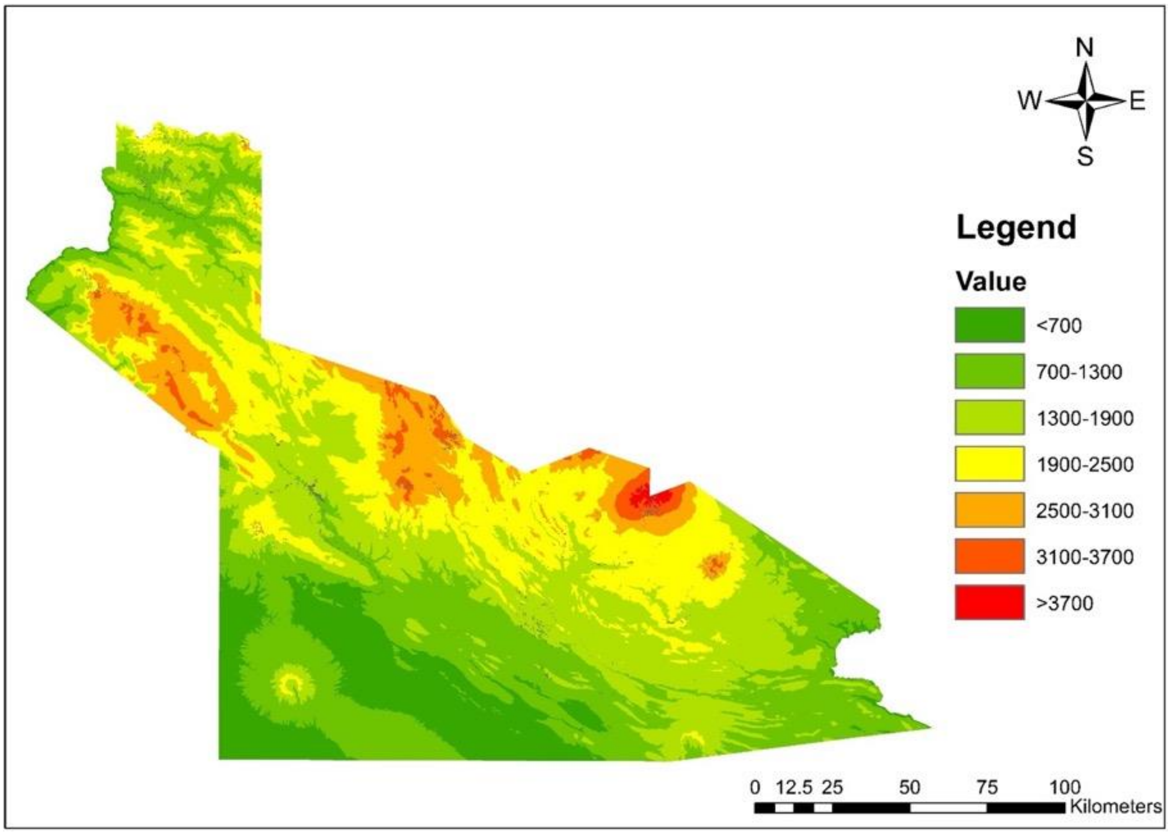


Figure 0-3. Hela and SHP altitude map

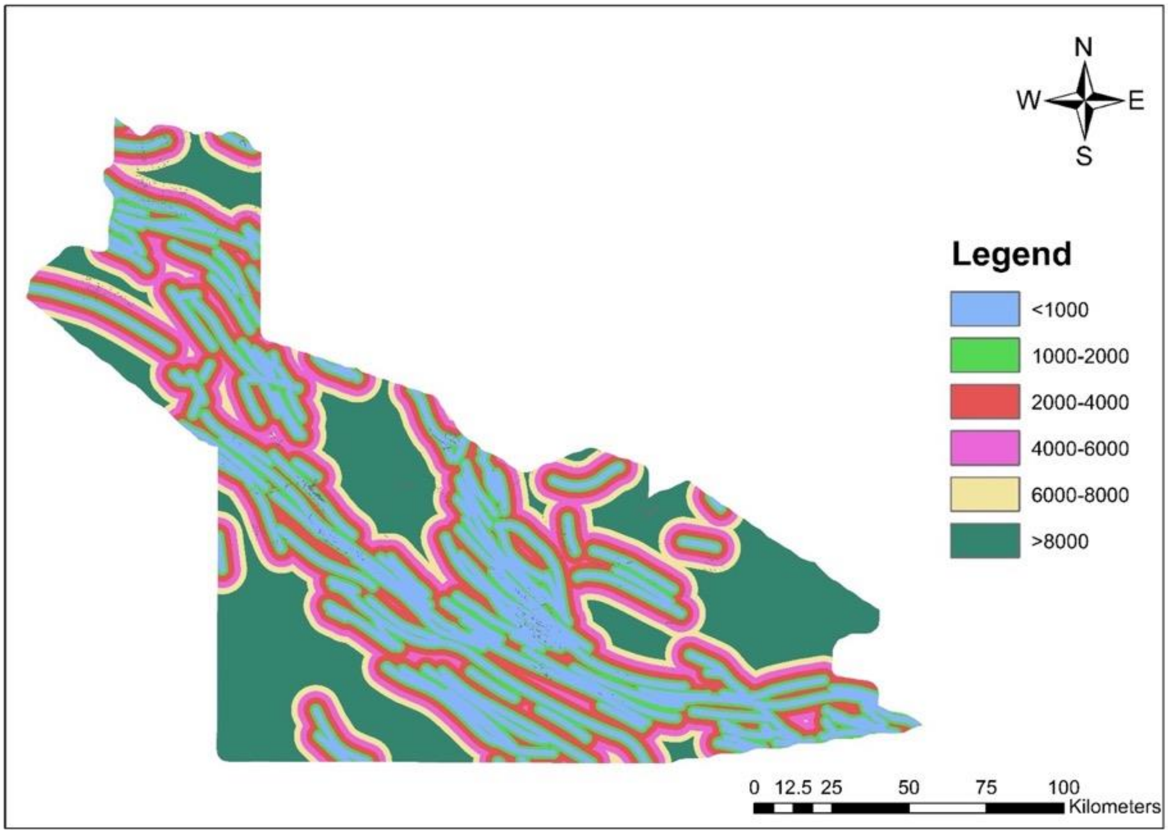


Figure 0-4. Hela and SHP distance to lineament map

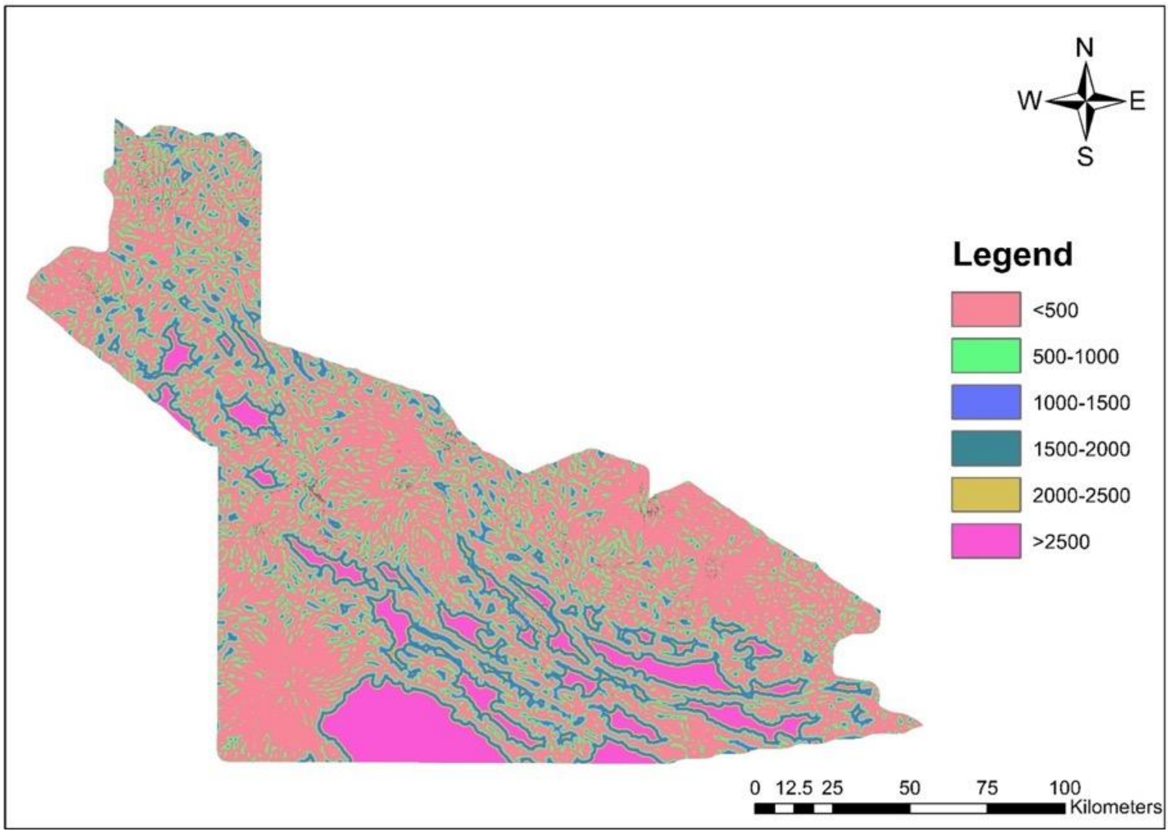


**Figure 0-5. Hela and SHP distance to river map**

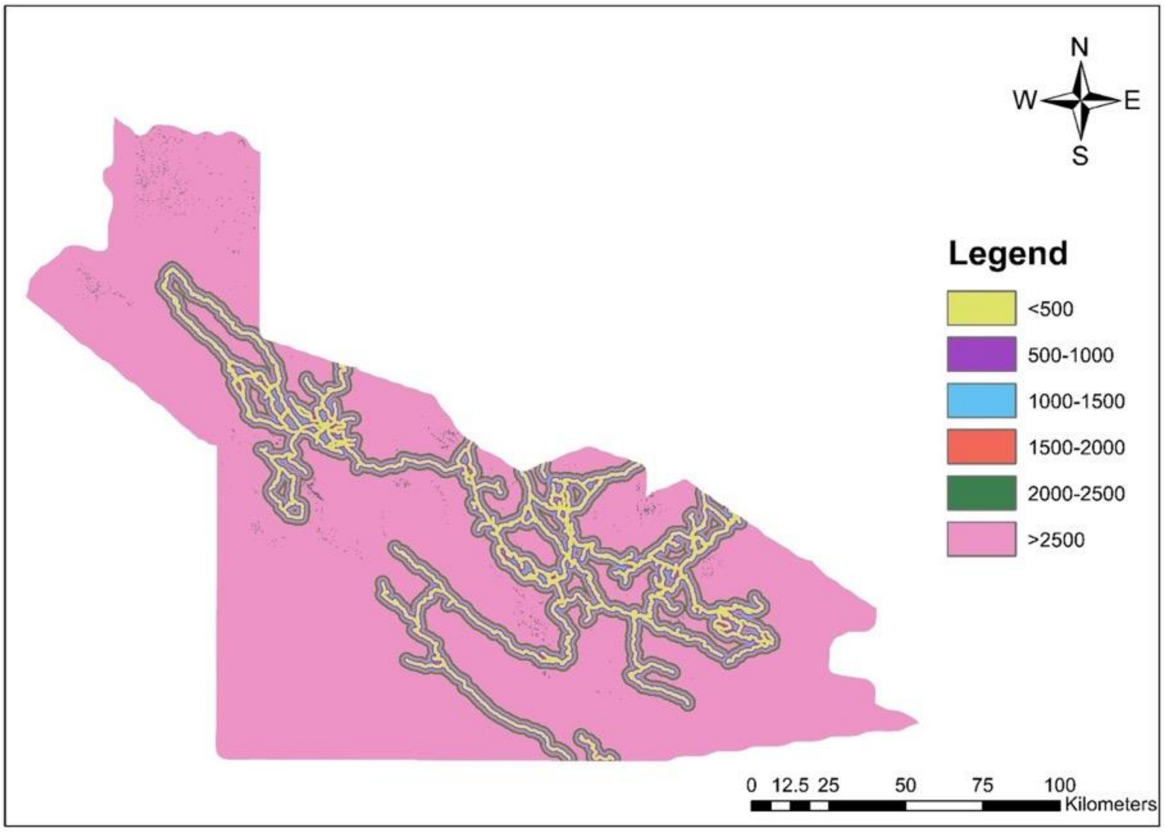


**Figure 0-6. Hela and SHP distance to road map**

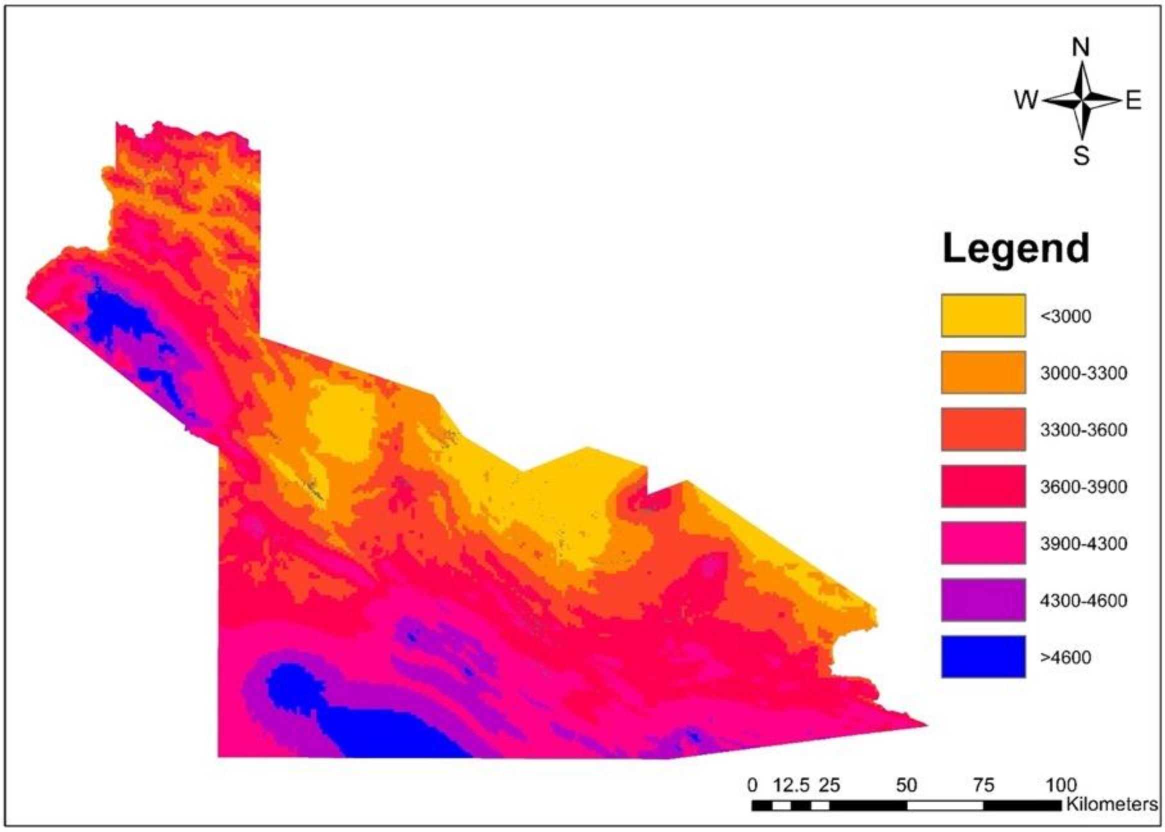



**Figure 0-7. Hela and SHP precipitation map**

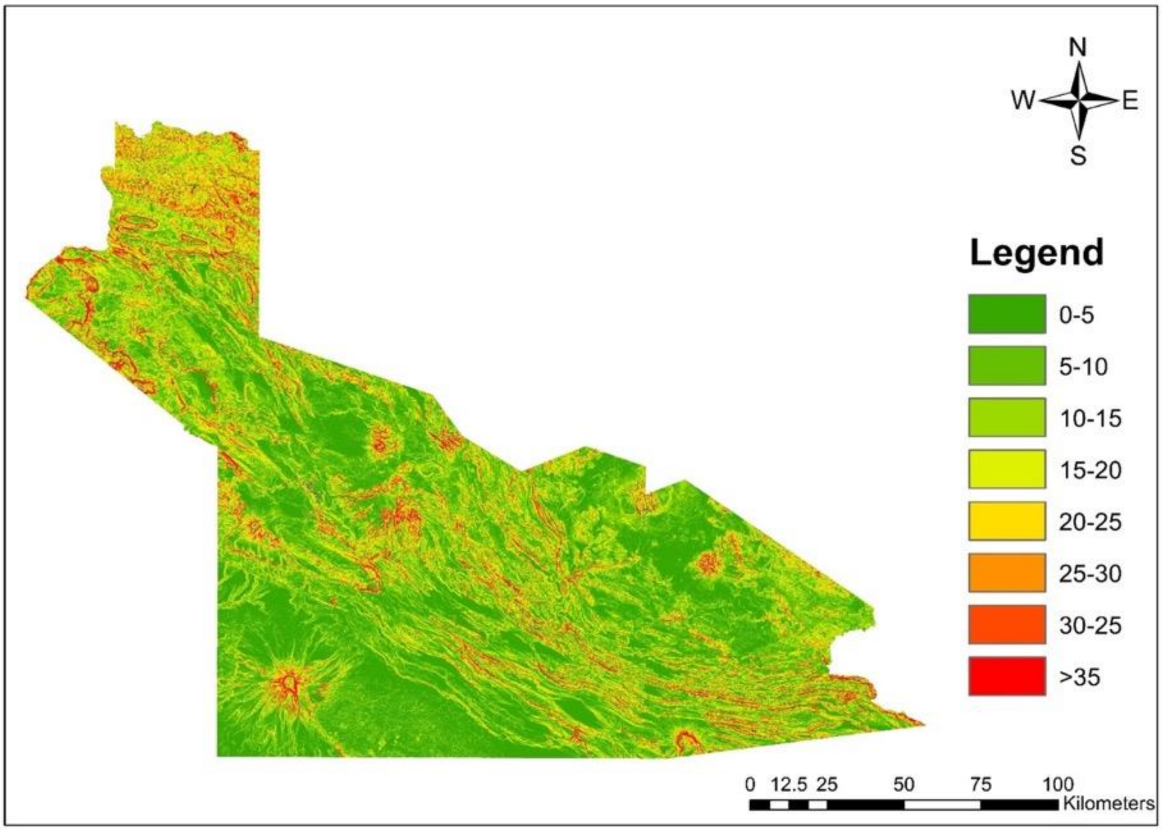



**Figure 0-8. Hela and SHP slope angle map**

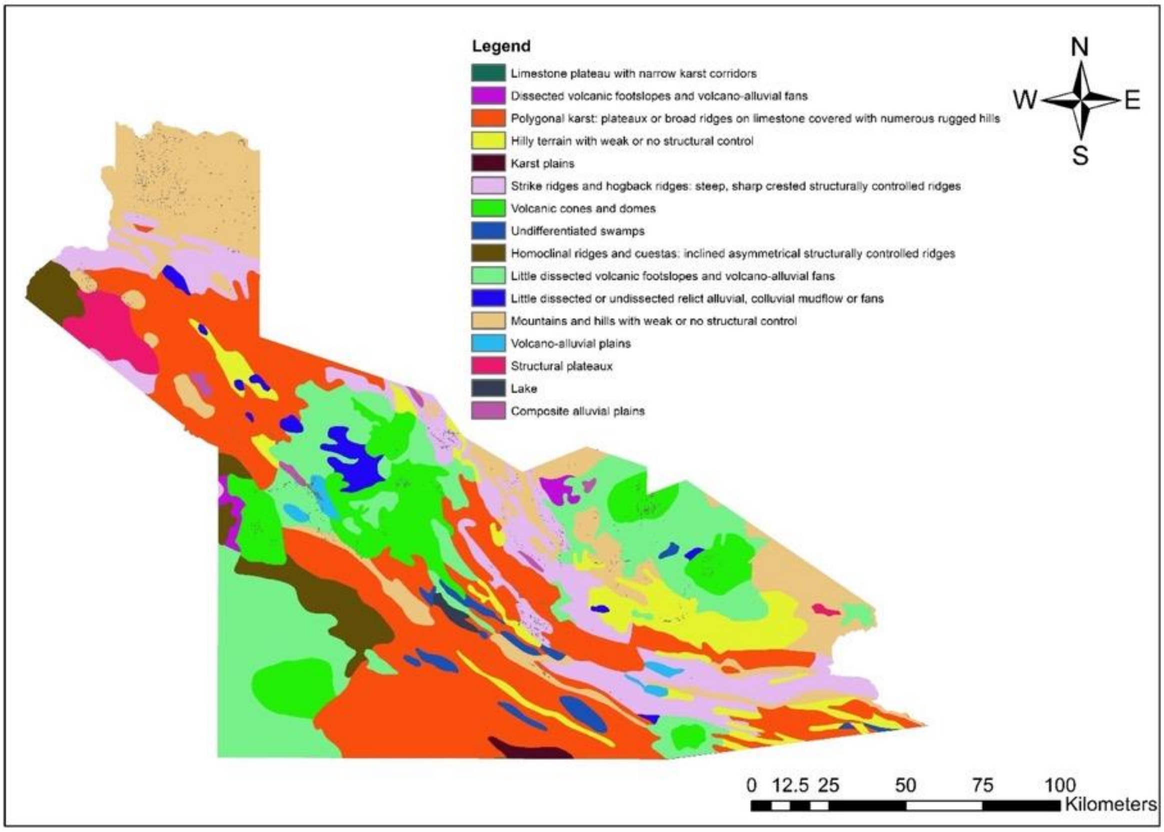



**Figure 0-9. Hela and SHP landform map**

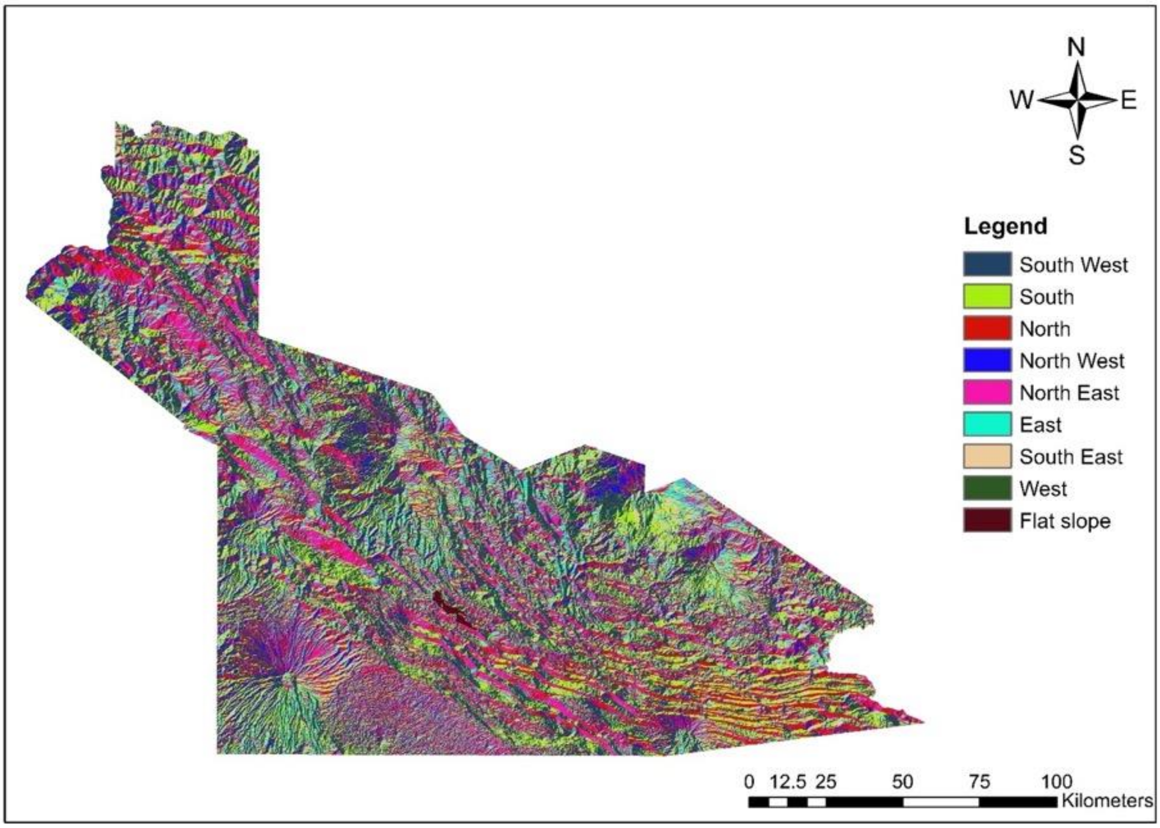



**Figure 0-10. Hela and SHP aspect map**

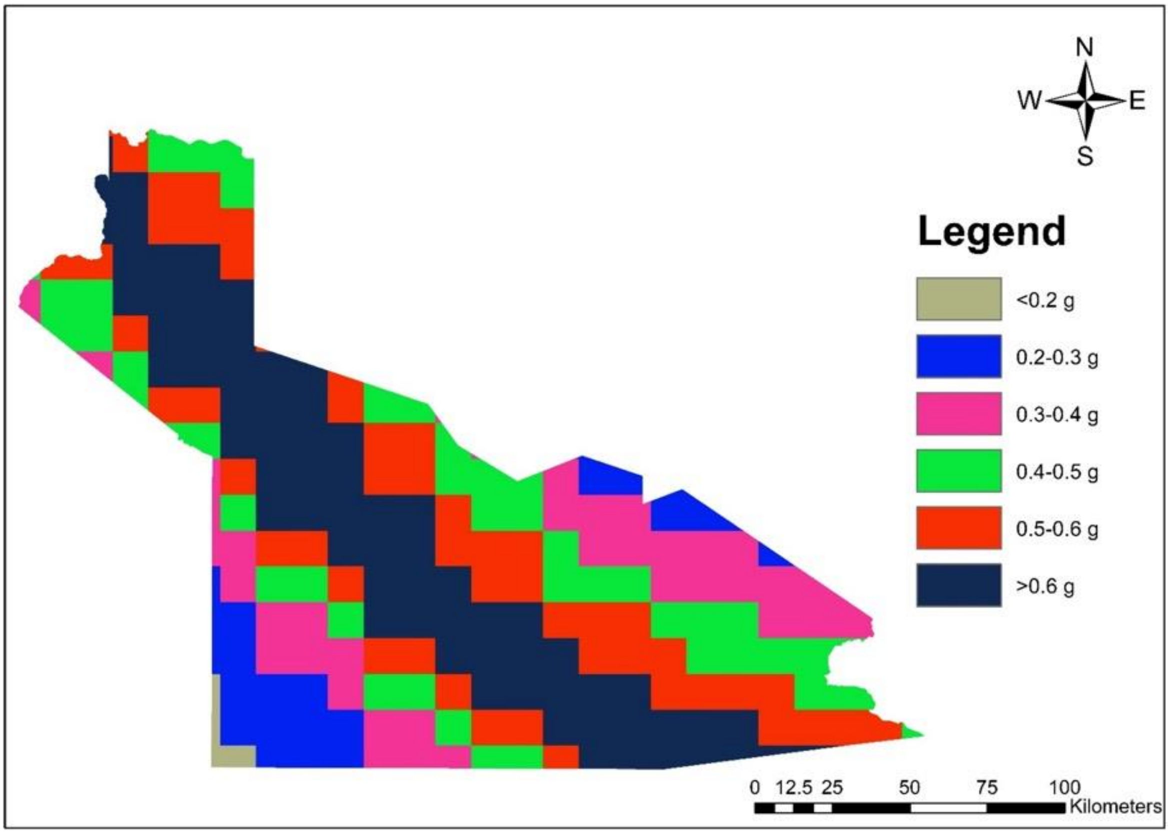
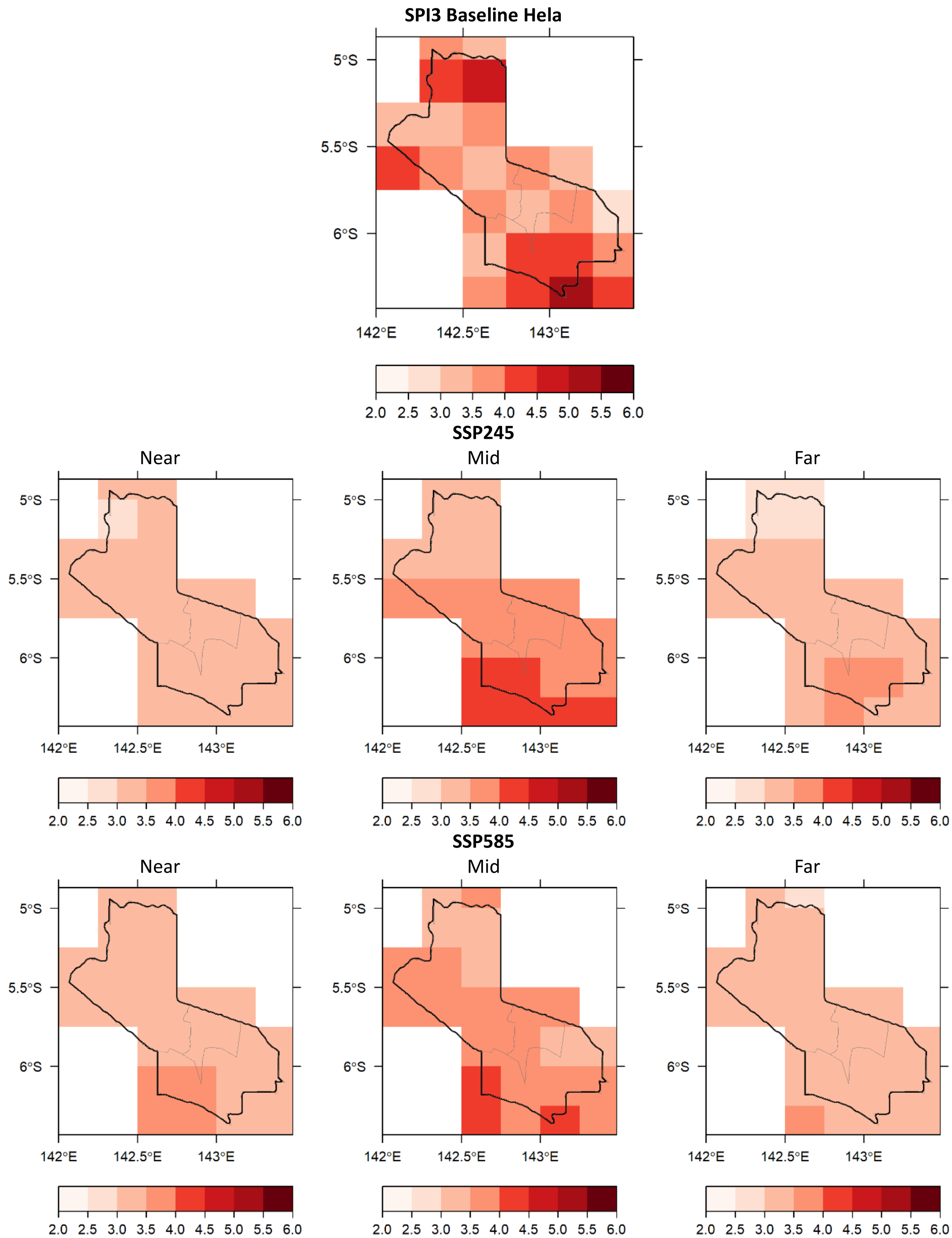
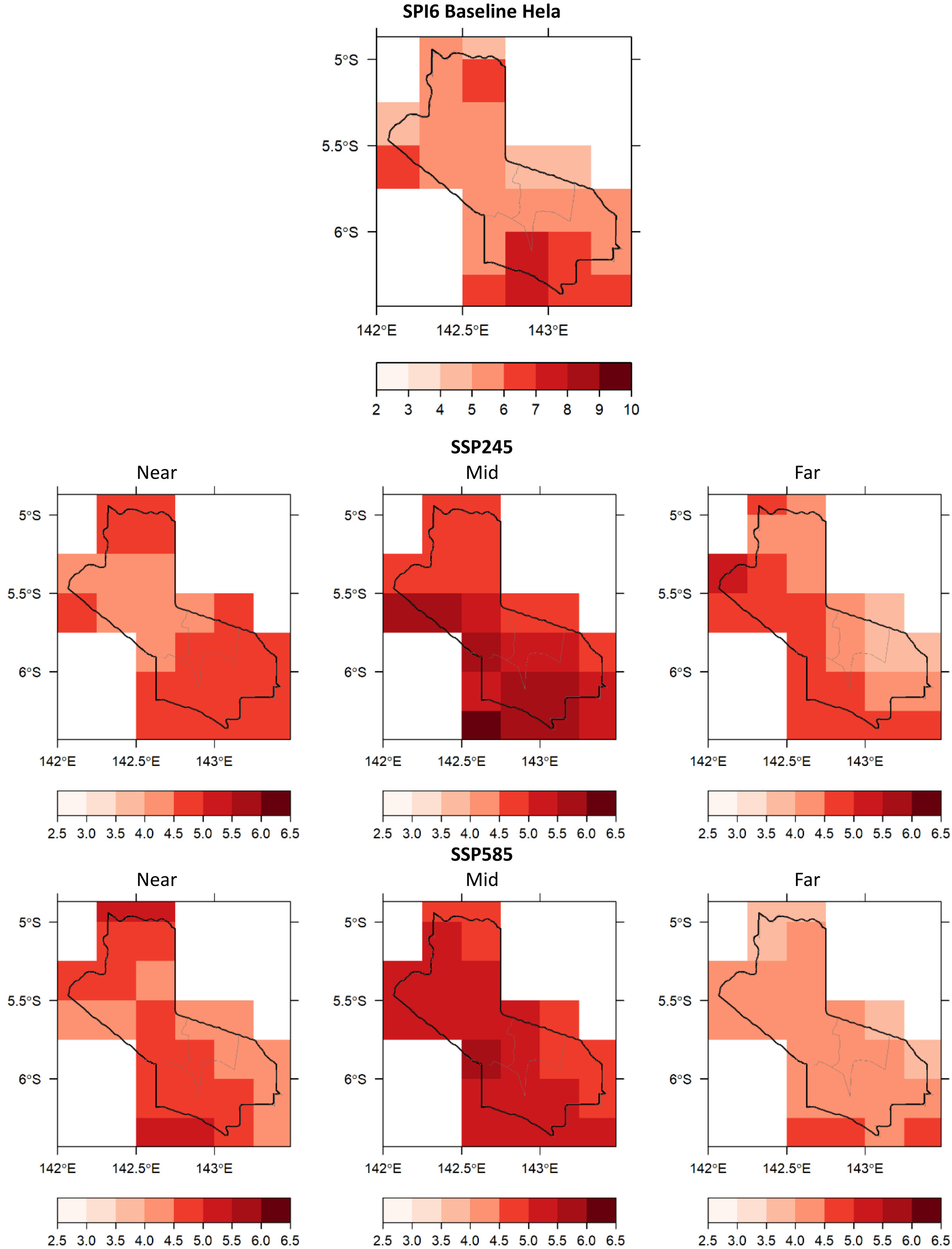
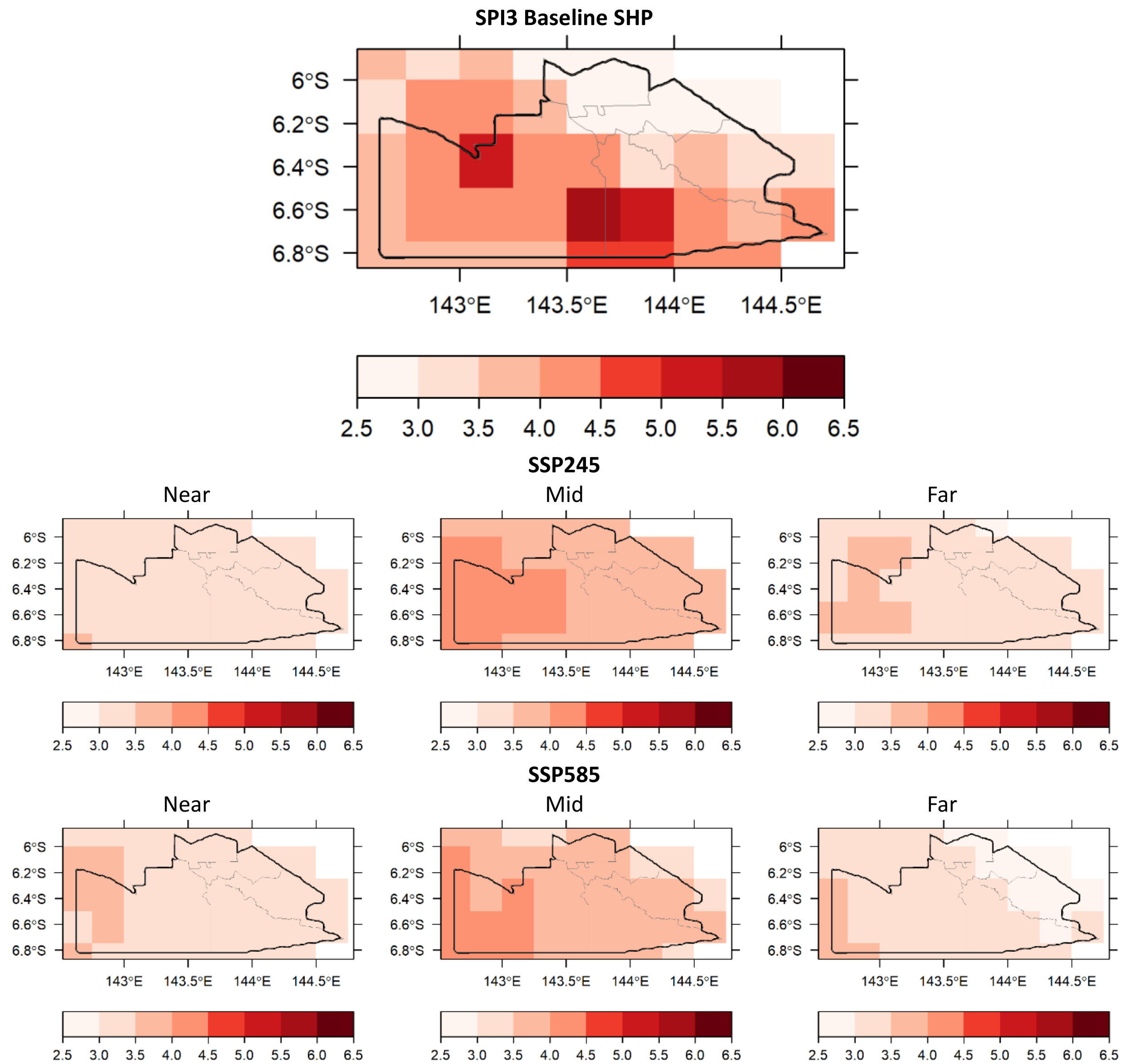


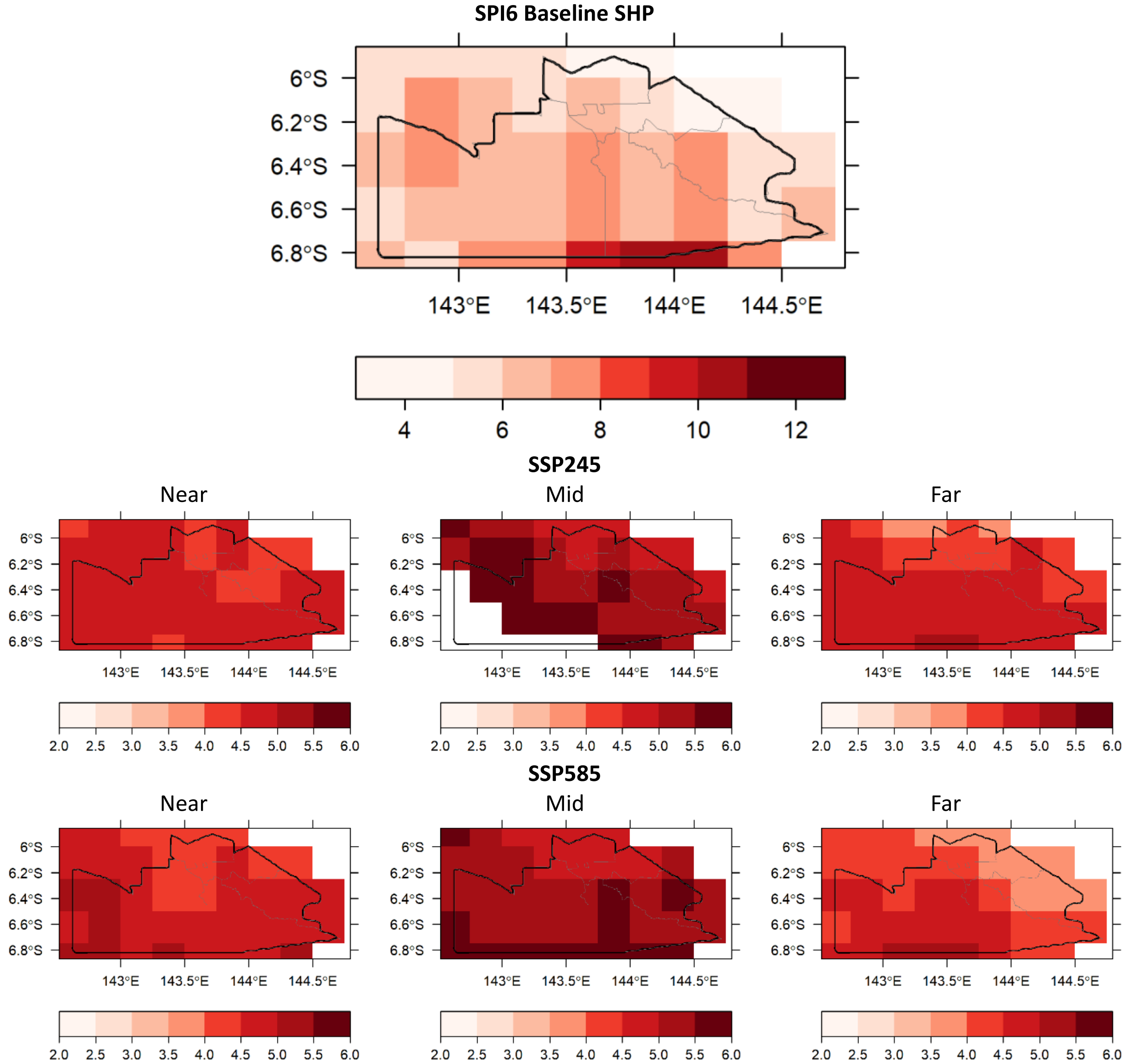

**Figure 0-11. Hela and SHP PGA map, 475-year return period**

# Appendix 4. Results of Drought Duration Analysis for Hela and SHP Using SPI

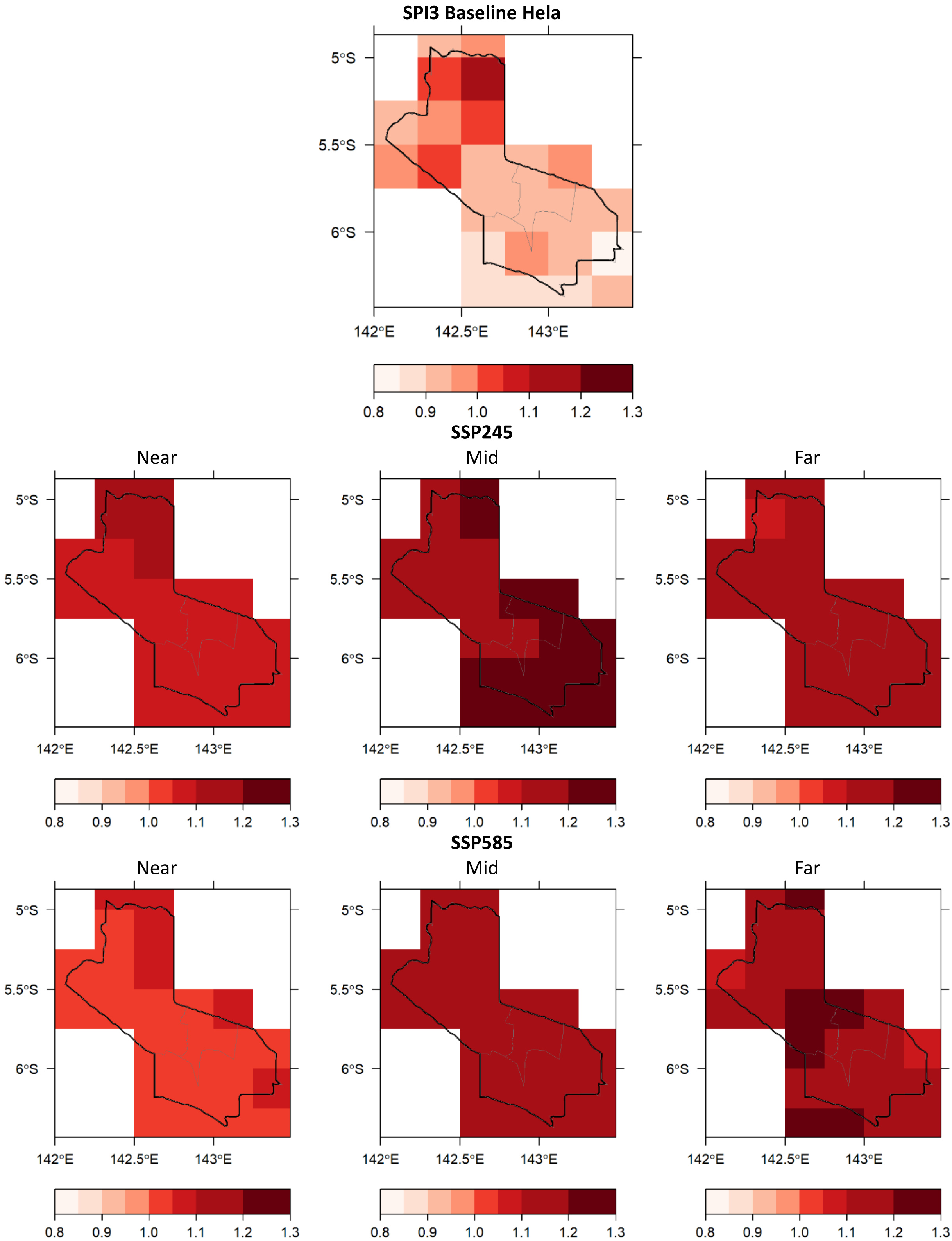


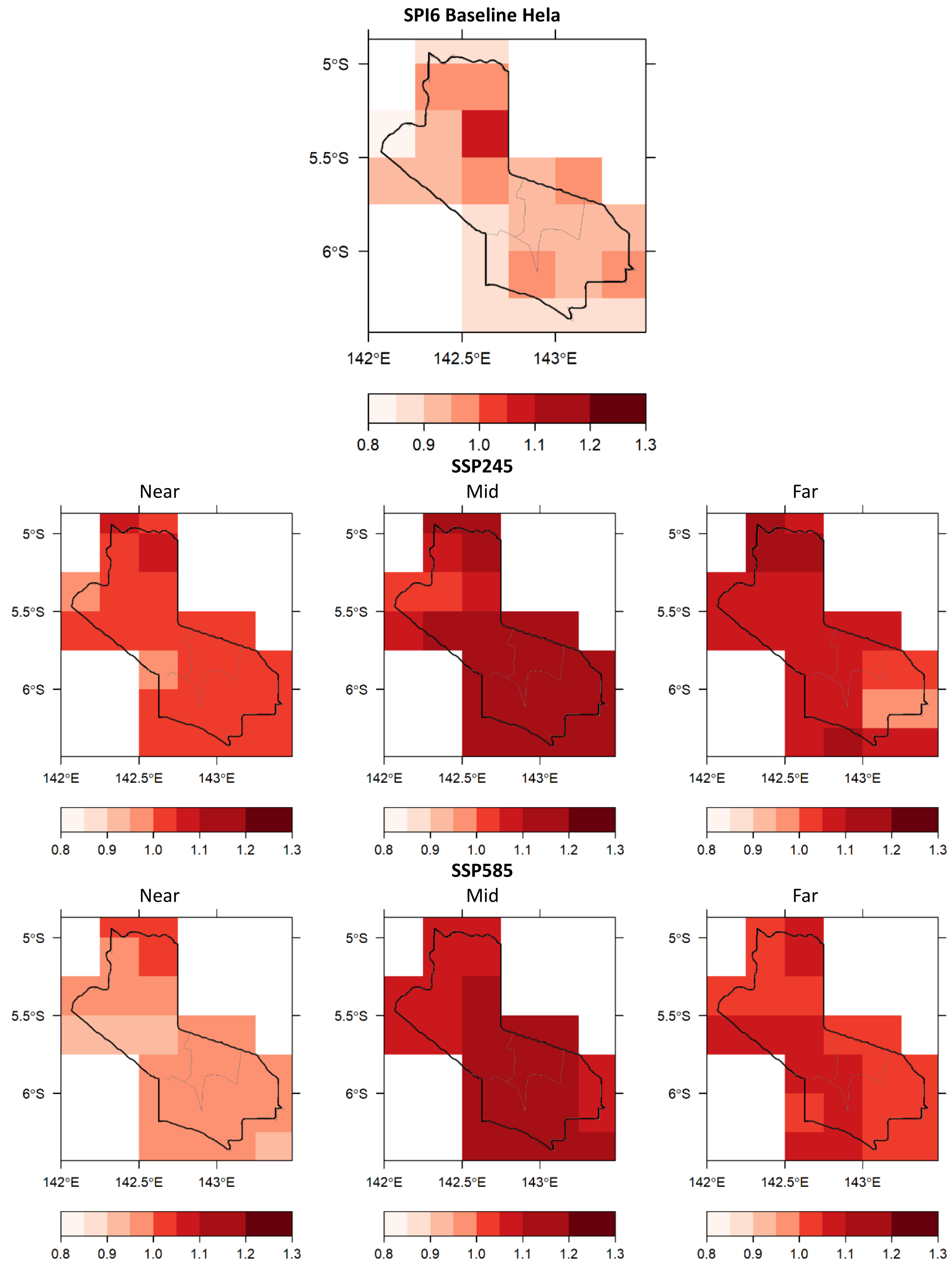

SPI6 Baseline Hela
5°S
5.5°S
6°S
142°E
142.5°E
143°E
2 3 4 5 6 7 8 9 10
SSP245
Near
Mid
Far
2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5
SSP585
Near
Mid
Far
2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5

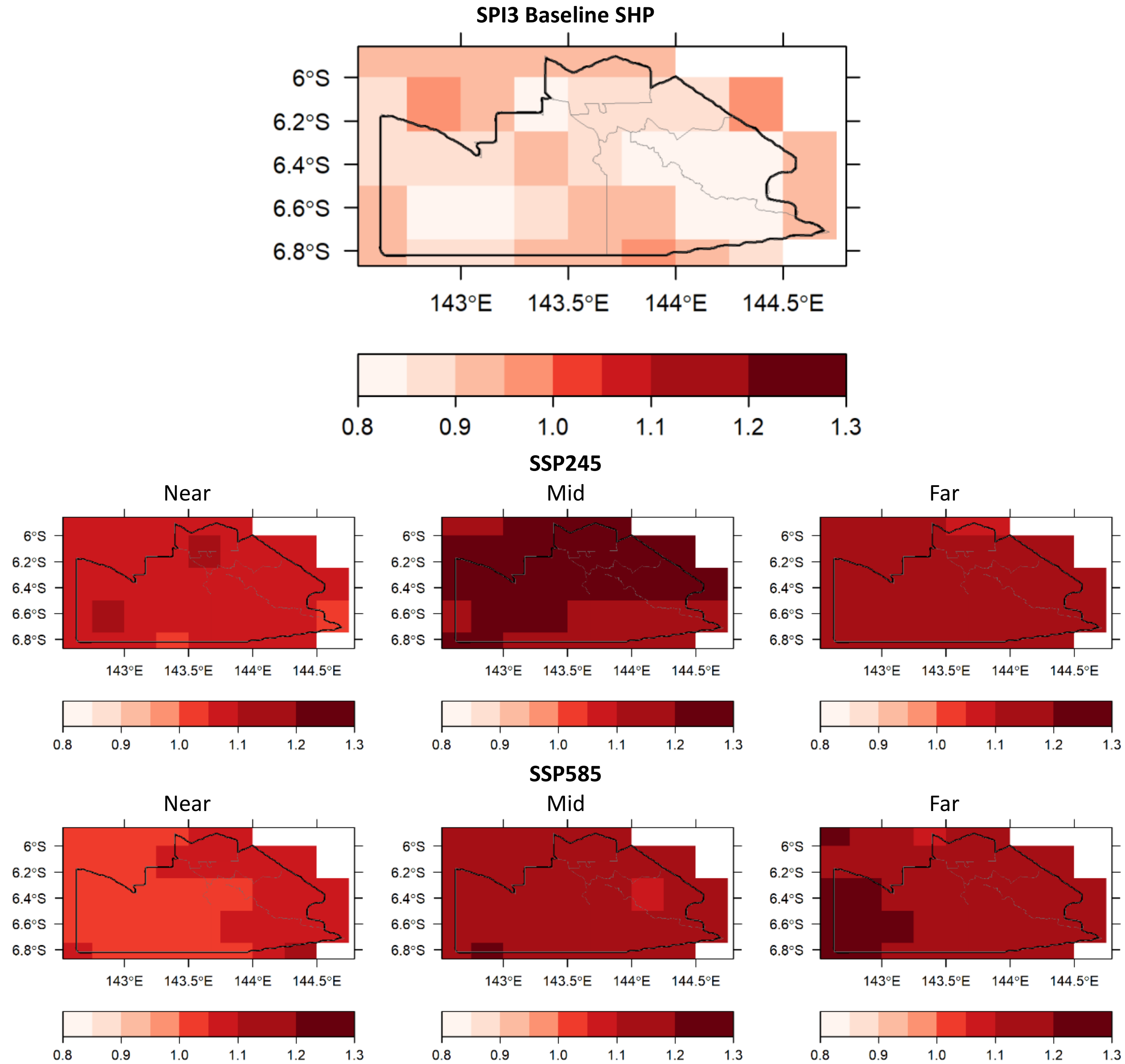

SPI3 Baseline SHP
6°S
6.2°S
6.4°S
6.6°S
6.8°S
143°E
143.5°E
144°E
144.5°E
2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5
SSP245
Near
Mid
Far
SSP585
Near
Mid
Far

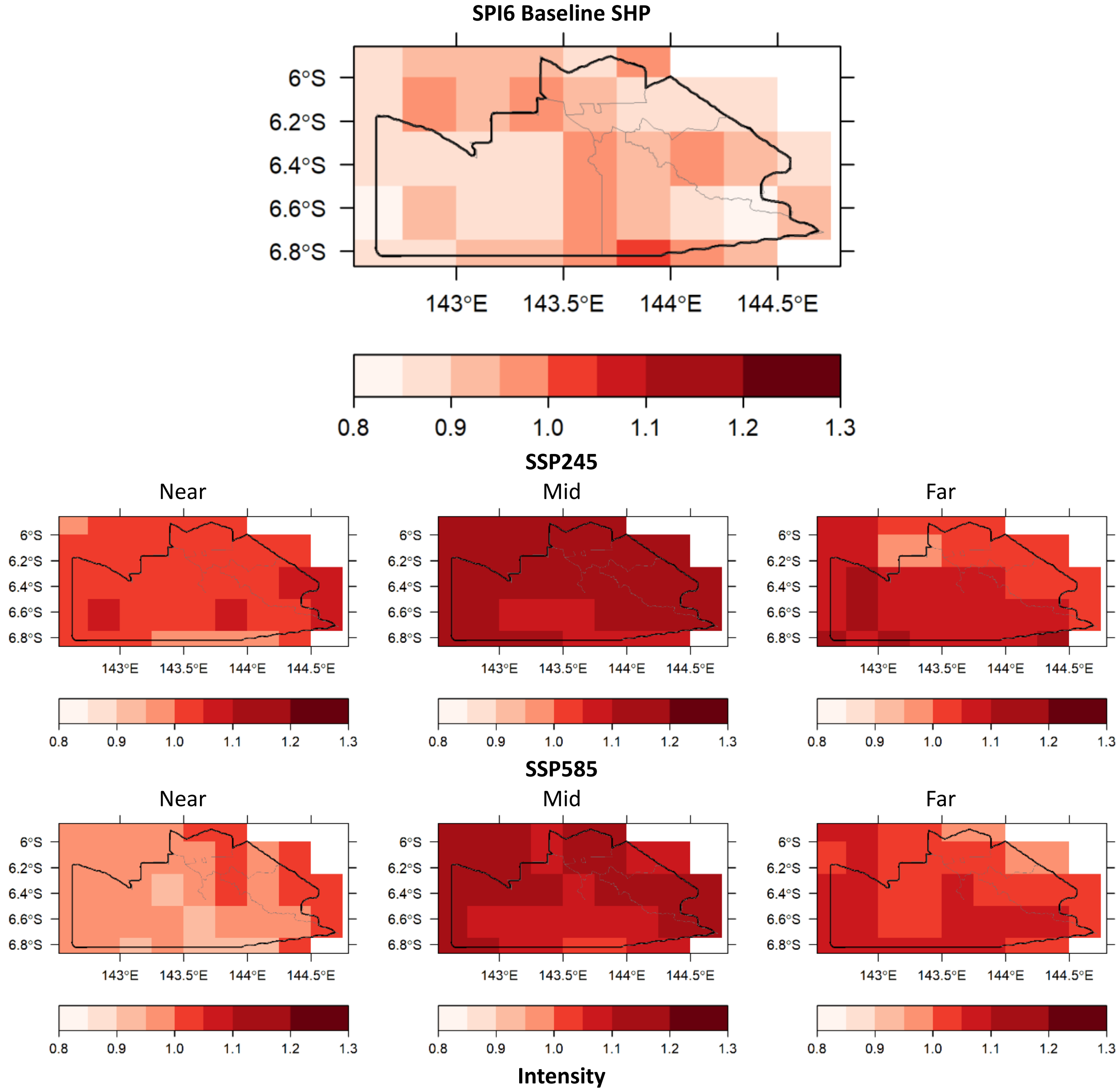

SPI6 Baseline SHP
6°S
6.2°S
6.4°S
6.6°S
6.8°S
143°E
143.5°E
144°E
144.5°E
4
6
8
10
12
SSP245
Near
Mid
Far
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
SSP585
Near
Mid
Far

# Appendix 5. Results of Drought Intensity Analysis for Hela and SHP Using SPI



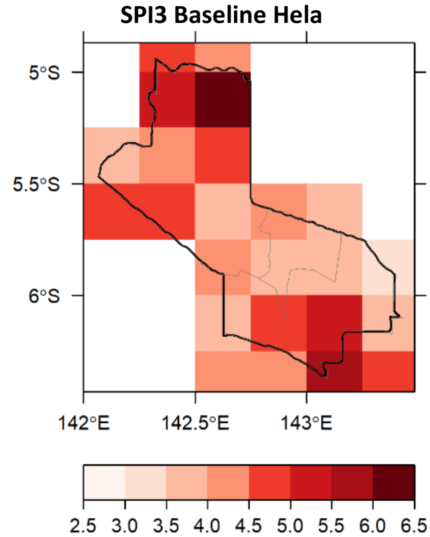

SPI6 Baseline Hela
5°S
5.5°S
6°S
142°E
142.5°E
143°E
0.8
0.9
1.0
1.1
1.2
1.3
SSP245
Near
Mid
Far
SSP585
Near
Mid
Far


SPI3 Baseline SHP
6°S
6.2°S
6.4°S
6.6°S
6.8°S
143°E
143.5°E
144°E
144.5°E
0.8
0.9
1.0
1.1
1.2
1.3
SSP245
Near
Mid
Far
SSP585
Near
Mid
Far

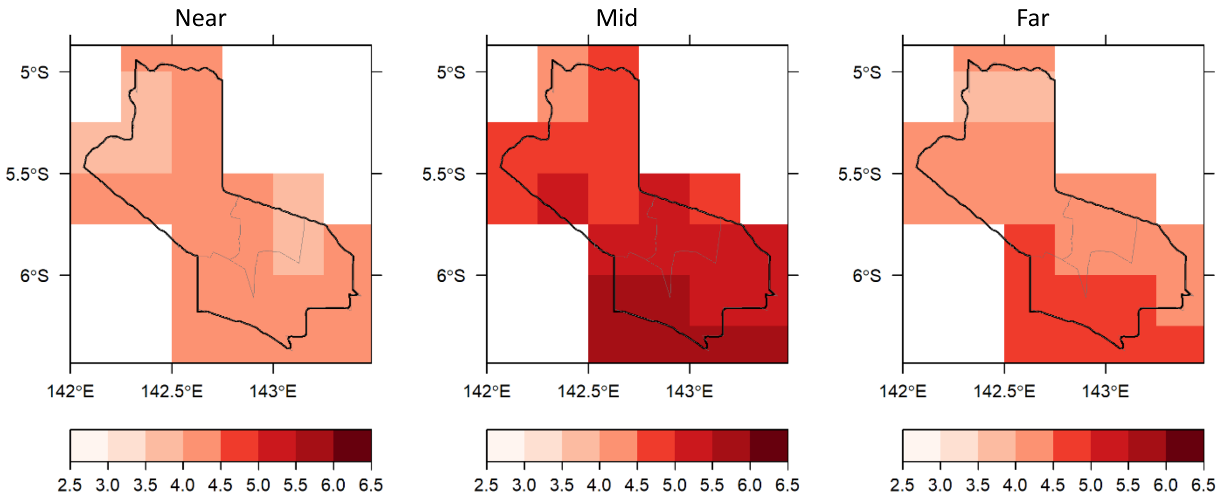


SPI6 Baseline SHP
6°S
6.2°S
6.4°S
6.6°S
6.8°S
143°E
143.5°E
144°E
144.5°E
0.8
0.9
1.0
1.1
1.2
1.3
SSP245
Near
Mid
Far
SSP585
Near
Mid
Far
Intensity

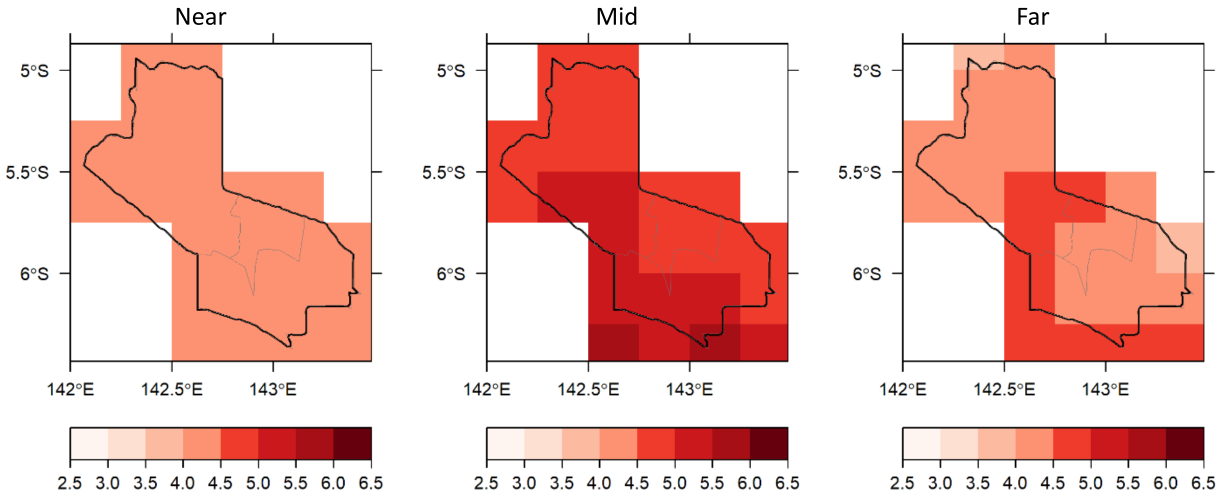
# APPENDIX 6. RESULTS OF DROUGHT SEVERITY ANALYSIS FOR HELA AND SHP USING SPI

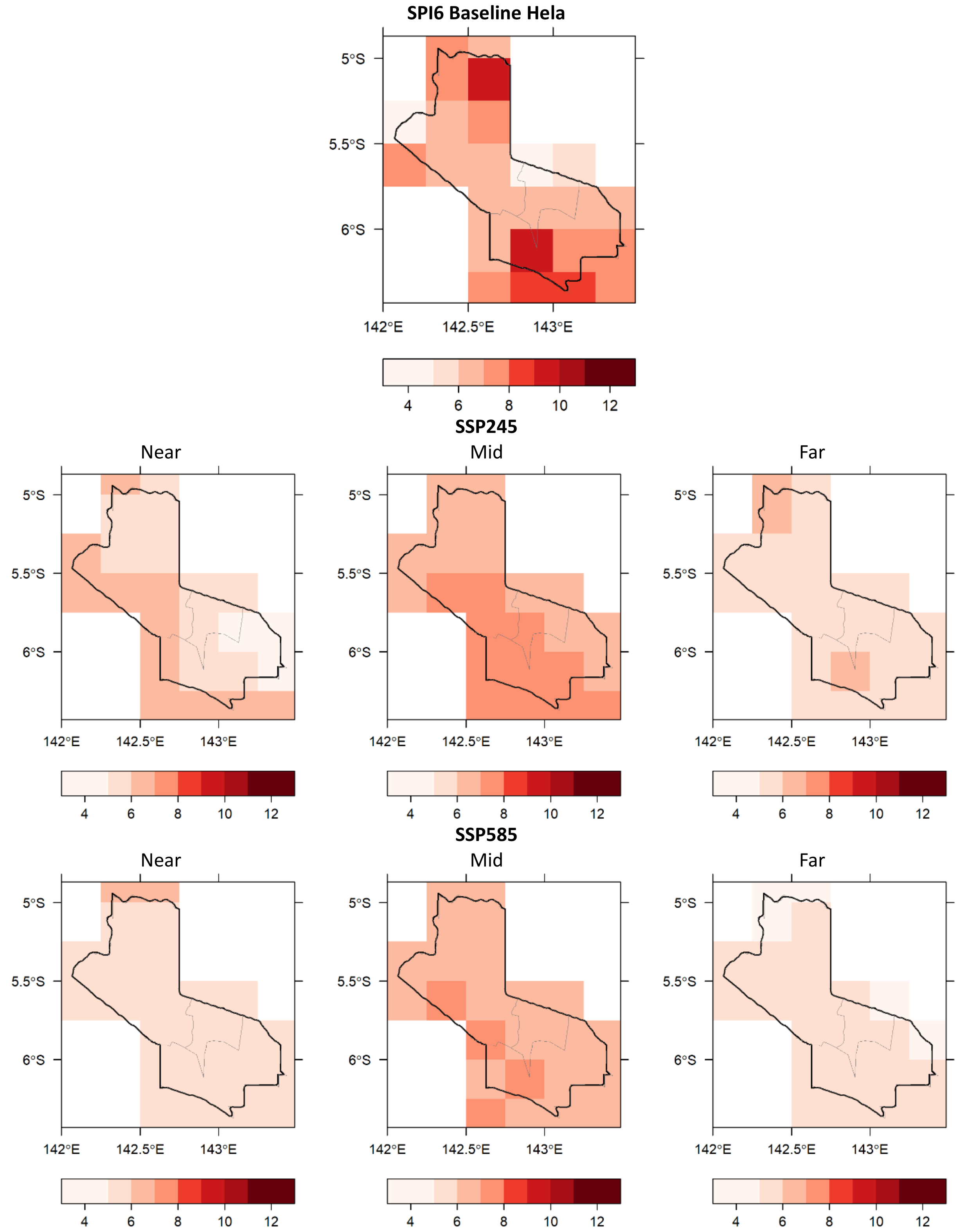


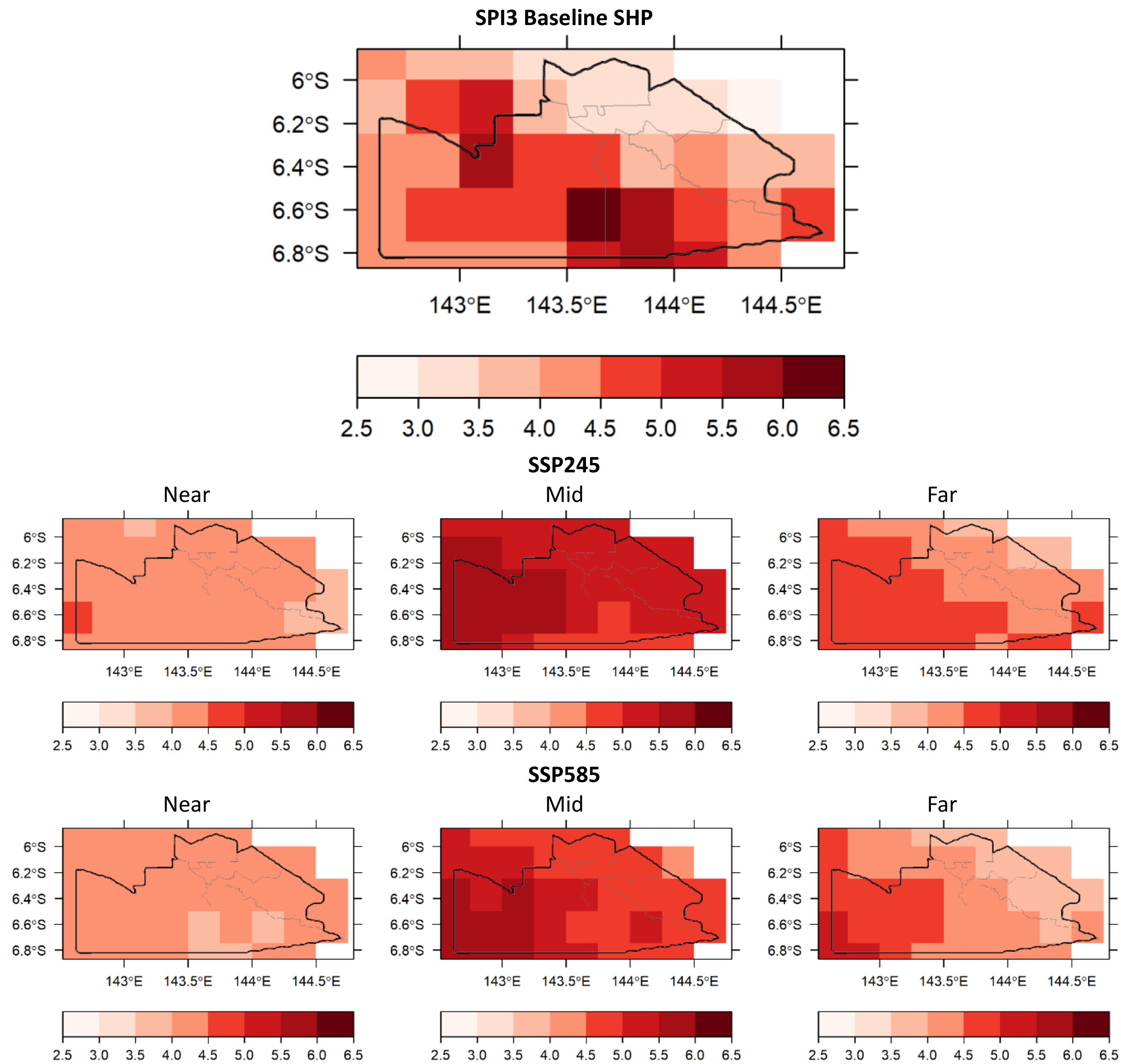

**SSP245**

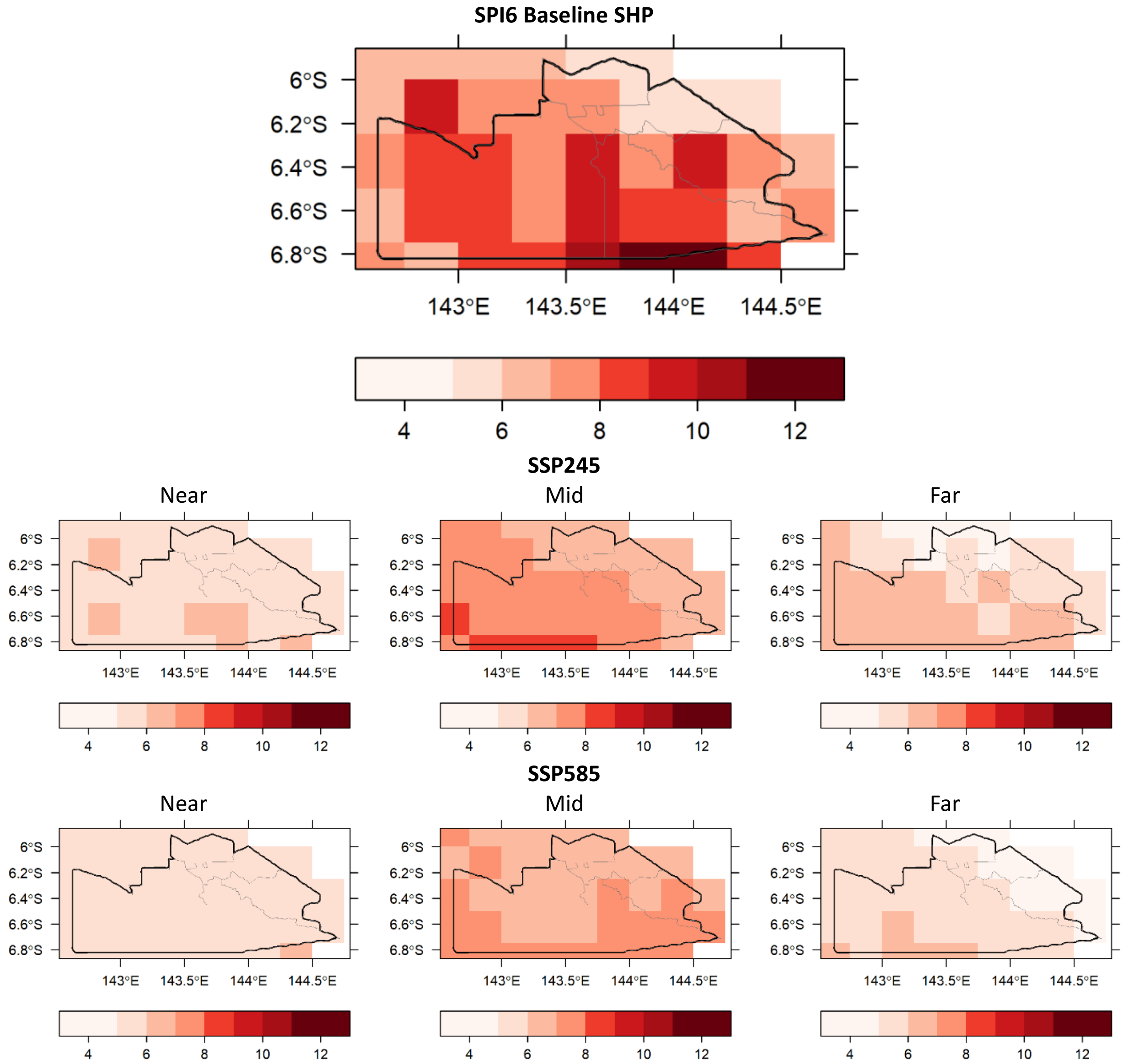



**SSP585**




SPI6 Baseline Hela
5°S
5.5°S
6°S
142°E
142.5°E
143°E
4
6
8
10
12
SSP245
Near
Mid
Far
SSP585
Near
Mid
Far


SPI3 Baseline SHP
6°S
6.2°S
6.4°S
6.6°S
6.8°S
143°E
143.5°E
144°E
144.5°E
2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5
SSP245
Near
Mid
Far
SSP585
Near
Mid
Far


SPI6 Baseline SHP
6°S
6.2°S
6.4°S
6.6°S
6.8°S
143°E
143.5°E
144°E
144.5°E
4
6
8
10
12
SSP245
Near
Mid
Far
SSP585
Near
Mid
Far