CLIMATE RISK, VULNERABILITY AND RISK ASSESSMENT IN THE NEW IRELAND PROVINCE IN PAPUA NEW GUINEA

COLOPHON

Project:
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LIST OF ABBREVIATIONS

ANU	Australia National University
CCDA	Climate Change and Development Authority
CDD	Continuous dry days
DRM	Disaster Risk Management
IPA	Investment promotion authority
IPCC	Intergovernmental Panel on Climate Change
LLG	Local Level Government
LULC	Land Use / Land Cover
MASP	Mapping Agricultural Systems of PNG
NSO	National Statistical Office
PCRAFI	Pacific Catastrophe Risk Financing and Insurance Initiative
PIC	Pacific Island Countries
PNG	Papua New Guinea
PNGRIS	PNG Resource Information System
PSI	Physical sensitivity index
RC	Replacement cost
UNDP	United Nations Development Program
UNISDR	United Nations International Strategy for Disaster Reduction
WB	World Bank
WFP	World Food program

0. EXECUTIVE SUMMARY

Background

Papua New Guinea is prone to natural disasters induced by climate change, climate variability, and sea-level rise, including tsunamis, cyclones, inland and coastal flooding, landslides, and droughts.

UNDP is supporting a four year project, implemented by the Climate Change and Development Authority (CCDA), titled “Enhancing Adaptive Capacity of Communities to Climate Change-related Floods in the North Coast and Islands Region of Papua New Guinea,” financed by the Adaptation Fund. The project seeks to build community resilience to coastal and inland flooding through improved awareness, risk management, and institutional capacity to implement appropriate adaptation measures.

Within this context, Antea Group, Hydroc & World Vision have conducted a climate risk, vulnerability and risk assessment in five provinces in Papua New Guinea (East Sepik, Madang, Morobe, Northern, and New Ireland).

Objective

The objective of the study was to identify climate risks, exposure, and vulnerability to principal climate hazards affecting five pilot provinces (East Sepik, Madang, Morobe, Northern, and New Ireland) and to prepare a Composite Risk Atlas and Maps/Indexes for the hazards at the district level.

Methodology

The methodology to identify and map current and future climate hazards, vulnerability and risks has been developed by the project team based on internationally accepted definitions and approaches found in the Disaster Risk Reduction and Climate Change Adaptation literature and customised based on data availability and quality for the five pilot province provinces in Papua New Guinea (East Sepik, Madang, Morobe, Northern, and New Ireland).

Data has been collected from leading institutions in Papua New Guinea and form international sources. Following a careful review and quality check of the available data, hazard maps, vulnerability indices and maps, and risk maps were produced for the following climate hazards:

- Inland flooding
- Coastal flooding
- Drought
- Extreme weather events (tropical cyclones)
- Increase of precipitation intensity and variability

The assessment was done for the current situation and a future situation based on projects climate data. The overall procedure followed involved the following steps:

<u>(i) Data collection and quality control</u>

Data has been collected from leading institutions in Papua New Guinea and international sources.

<u>(ii) Analysis of the existent climate data and climate change projections & hazard maps</u>

The available observation data from weather stations in PNG is too scarce for the purposes of this study. To overcome this issue, the project team took on a significant effort to downscale General Circulation Model (GCM) data and create climate time series that could be used for modelling and mapping the hydro-meteorological hazards for this study.

In order to cope with the limited availability of qualitative historic observation data, the main strategy followed by this study was to reanalyse hindcasted and forecasted outputs from downscaled model data to derive actual and projected patterns for parameters like temperature, precipitation and wind speed. These parameters are subsequently utilized to compute hazard parameters for risk mapping.

All analyses are based on climate model output from the 5th Coupled Model Intercomparison Project (CMIP5) , which informed the Intergovernmental Panel on Climate Change (IPCC) fifth assessment reports (IPCC 2013) .

A simple downscaling correction for spatial variability was applied, which adjusted the rainfall intensity and temperature value but does not affect the variability, including seasonal.

Under low, medium and high emissions scenarios, PNG is projected to get significantly hotter and slightly wetter. No significant change in mean or extreme wind speed is projected.

Increases in rainfall intensity are projected throughout the region. Further work (beyond the scope of this report) may ascertain the potential impact on flash and riverine flood risk.

The risk of seasonal drought is projected to decrease because of the increase in rainfall. However, increases in the lengths of dry spells and increased risk of extreme rainfall may have negative consequences for agriculture.

Based on various analysis as published under IPCC, cyclone frequency is expected to decrease in the southwest Pacific and hence in the waters around PNG, while some indications exist that intensities may increase . This report has used coarse data as available from previous study. For a more detailed assessment of future cyclone risk detailed regional cyclone modelling considering changes to cyclone drivers would need to be conducted.

Sea level rise along PNGs coastline is in line with global developments. To understand coastal flooding a combined analysis of sea level rise, the respective tidal signals, potential storm surges and aspects of increased wave energy resulting from increasing water depth would be required using coastal modelling tools. For the modelling detailed bathymetrical and topographical data, beyond the details that are currently provided by the SRTM data would be needed.

The hazard **(1) Drought** is characterised as a normal, recurrent feature of climate, temporarily deviating from normal climatic conditions for a specific location. In technical settings, a climatic hazard should represent the probability with which climatic events of various intensity are to occur. Drought hazard could therefore be defined as the frequency of abnormal precipitation deficits at some level of intensity in a particular region.

In order to describe the evolution of drought over time in the context of climate change, several metrics were considered relative to mean climate variables (temperature, precipitation and surface wind speed), duration statistics (continuous dry/wet days) and water balance indicators (precipitation minus evapotranspiration). These metrics were computed at a 0.5° grid over the area of interest in current and future climate conditions.

None of these metrics can be interpreted in the probabilistic manner necessary to quantify drought hazard. The most suited indicator selected for drought hazard is the annual maximum dry spell length i.e. the expected maximum number of continuous dry days (CDD) within a year. Using this indicator to quantify the level of drought hazard makes the assumption that regions which experience longer drought events are also the more likely to experience drought in terms of frequency. Also, because the expected duration of drought events is critical to evaluate the related consequences and the associated risk for crop production, this choice is consistent for a risk assessment: higher expected CDD will lead to higher levels of risk.

The hazard **(2) precipitation intensity and variability** is defined in terms of increased rainfall intensity and variability. Rainfall variability as a hazard cannot be easily predicted and is even more difficult to map. We consider the risks associated with rainfall increase relative to (i) agricultural system tolerance to a rainfall regime change, and (ii) communities sensitivity to intense rainfall events, extreme runoff and flash floods in urban areas.

To account for these two components, we consider two hazard indicators: (i) cumulative annual rainfall, and (ii) the total annual rainfall when the daily rainfall exceeds the 95th percentile. The underlying hypothesis is that heavy, intense rainfall is more likely to happen in overall wetter areas.

The mapping of **(3) extreme weather events** around Papua New Guinea, more specifically tropical cyclones, requires the analysis of historic cyclone path databases and damage reports, as well as observed meteocean parameters, like sea surface temperature. A review of past events was undertaken to understand the relation between driving factors, cyclone occurrence and damage potential occurring in the waters around the studied area. A projected future cyclone occurrence map was derived based on compiled data in the IPCC Fifth Assessment Report (AR5 report), summarized and averaged for the southwest Pacific.

Given the lack of hydro-meteorological data, topo-bathymetric data, gauged data, soil type and land use data, a pragmatic approach to develop **(4) inland flood hazard** maps has been customized for the purposes of this study. The method is based on limited available information and GIS routing techniques. Rainfall derived from the climate models were used to compute intensity duration frequency relations (IDF) for the current and the projected situations. The intensities are subsequently transported into run-off by means of the 'rational method'. These steps allow deriving maximum flood discharges at any location within the considered river reach. Combining the discharge with an estimated reach geometry allow to derive water levels and subsequently flood maps.

Potential changes in flood hazard are assessed by comparing the estimated flood maps generated for a specific frequency and intensity of precipitation of current climate data versus maps derived using future climate projections.

The mapping of **(5) Coastal flood** is one of the most important climate change related hazards in this area because most settlements in the North coast and islands of Papua New Guinea are located along its coast. Climate change is expected to lead to global sea level rise that would increase the coastal flooding areas. In order to identify the current coastal flooding extension, hourly tidal levels and wave height data are assessed. The projected sea level rise is extracted from global sea level projections and local oceanographic particularities for PNG. Then, the projected coastal flooding extension is estimated by adding the sea level rise to the total level of the current scenario.

<u>(iii) Developing social, infrastructure and economic vulnerability indices & vulnerability maps</u>

Vulnerability is defined as a 'set of conditions and processes resulting from physical, social and economic factors, which increase the susceptibility of a community to the impact of the hazard'. This includes intrinsic characteristics that predispose the asset or the community to suffer from a hazard, but also the potential loss that can result from it.

The general procedure for producing vulnerability and maps for each hazard follows these main steps:

(1) Identification of elements (sensitive assets) that are potentially exposed to the hazard: Maps showing communities, infrastructure and land use are combined with the hazard maps to identify the elements exposed to each of the hazards.

(2) Sensitivity of the elements potentially damaged by the effect of hazards are assessed using various indicators that are then combined into indices. Three separate indices are constructed to express physical, economic and social sensitivity to each of the hazards considered in this study. Each sensitivity index is derived from a set of indicators reflecting the various constituents of physical, social and economic sensitivity respectively.

(3) Vulnerability is interpreted here as the potential damage of the hazard. Potential damaging effects of a hazard are estimated as the product of the maximum potential loss (exposure) and sensitivity. To this end, sensitivity is expressed as an index (1 to 5) or a percentage (loss fraction). For physical, economic and agricultural vulnerability assessment, the maximum loss associated to the exposed assets is estimated by their replacement cost. In the case of social vulnerability, maximum

loss is the estimated number of exposed people. In order for vulnerability to be mapped and allow visual interpretation, it is scaled into five categories: very low, low, medium, high and extreme.

(iv) Risk mapping

Once the three vulnerability components (physical, economic and social) computed and mapped, risk is calculated as the product of the hazard index and the vulnerability index. A risk matrix allows consistent reclassification of the product operation between hazard and vulnerability.

(v) Composite risk

Finally, in order to map only one risk synthetic value, it was decided to use the maximum value of the three risk components to produce a "composite risk map". Risk maps can also be displayed for each vulnerability component separately for visualising potential damage to population, buildings and crops separately.

Key findings

Climate of Papua New Guinea

Based on observations carried out in Port Moresby since 1950, it can be concluded that a steady warming, averaging ~0.1 °C/decade,[1] is taking place. Over the next decades, **temperature** is projected to continue to increase, with a projected warming of 0.4-1 °C by 2030 under a business-as-usual emissions scenario. By 2050, under such a scenario, a 1.1 – 1.9 °C warming is projected. Over the next 30-50 years, increases in the average temperature will result in more very hot days, with potentially severe impacts on agriculture and human health.

The limited available information on precipitation reveals that there is no clear long-term historical change in rainfall in Port Moresby, although elsewhere there has been a slight decrease. In line with expectations globally, precipitation is projected to increase in response to the warming of the atmosphere. More extreme **rainfall** days are expected, likely contributing to increasing frequency of inland flooding. The regional pattern and magnitude of the increase is, however, highly uncertain.

Overall, trends in both rainfall and temperature are dwarfed by year-to-year variability.

On a global scale, the frequency of **tropical cyclones** is projected to decrease overall, but the frequency of high intensity cyclones is projected to increase. The projections for PNG are consistent with global projections, with fewer but more intense storm events expected.

Sea level rise is a serious consequence of climate change for Papua New Guinea. Under a business-as-usual scenario, by 2030, sea level in PNG is expected to rise[1] by 4-15 cm. Combined with natural variability, such a rise would increase the impact of storm surges and the risks of coastal flooding. It is notable that these projections could be underestimations, due to uncertainties in projections of ice sheet melt.

In addition to changes in climate, changes in land use may affect flood risk, for example through changes to catchment scale runoff and patterns of inundation. Since 1990, there has been a small degree of deforestation (reduction of forests from 31,523 KHa in 1990 to 29,159 KHa in 2007)[2] and an increase in land used for agriculture (877,000 Ha in 1990 to 1,040,000 Ha in 2007). Changes in coastal land use may affect the risk and impacts of tidal flooding.

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[1] Climate Change in the Pacific: Scientific Assessment and New Research | Volume 2: Country Reports; Chapter 11: Papua New Guinea

[2] ITS consulting, 2009, downloaded from www.unredd.net

Conclusions and recommendations

The risks are predictable. Disasters occur through lack of preparedness for likely occurrences. The immediate steps should be to set in place an adequate mechanism to respond to the kinds of emergencies that are likely to occur: principally flooding, landslide, some storm effects, and occasional drought. The disaster response team in Morobe is one of the best we have seen, and could be the model for other provinces like this one: adequately provisioned with boats to access difficult coastal areas, such as Tufi, 4x4 vehicles to reach inland, and standing arrangements with the air force and police, to reach populated areas not served by roads. This needs to be backed up with meteorological and early warning information, and a network that allows this information to reach areas likely to be affected. Emergency preparation, at the district and LLG level is essential, to know in advance how to cope with rescue and care of displaced people. In many places, local level organisation is the only way to ensure some buffer of security.

Invest in risk knowledge. Stakeholders can become more resilient by understanding the current and projected hydro climatological risks. Current initiatives in community-based disaster risk reduction could be enhanced to incorporate customized information related to the present risk mapping.

Incorporate adaptation strategies at various levels (community, district, province and national) to cope with changing climate. This should include institutional, physical, and structural measures. Integrating disaster management into school curriculum would be helpful.

Focus on urban flooding and the damage to infrastructure around major cities. This could imply the maintenance of drainage systems and clean-up of drainage infrastructure, bridges, and culverts before the rainy season begins. These measures should allow that the road network remains operational during the rainy season and that the urban damages are reduced.

Lowland flooding is a recognised feature of the rural ecology in this province that people have experienced for generations. Flooding in upland areas is likely to be exacerbated with greater intensities of rainfall. The practice of terracing could be introduced in the hilly regions of the Province to reduce soil deterioration, erosion and flash floods.

The traditional crop mix is well established to distribute risk, and to cover for most eventualities. As the frequencies of hazards change, the relative importance of one crop may change with respect to others. For example, longer dry spells is likely to increase the importance of cassava.

In rural zones, the focus should be on revising cropping practices and strategies for controlling and managing flash floods and bank erosion within an integrated approach.

Adequate measures for coping with drought risk should be defined. These could include reforestation plans for upper catchments to increase infiltration (positive for ground water recharge and effective reducing surface runoff). Additionally, communities should be trained on digging and maintaining superficial wells to improve their resilience to drought. For urban areas, a master plan on water supply, taking in account population increase and climate change, should be developed.

Papua New Guinea's Agricultural Research Institute considers drought to be the major climatic threat to agriculture in the country and is breeding crops for drought resistance. This research should be tested as quickly as possible at the local level, to give local people the chance to adapt local practices.

Protecting against drought requires the same measures as protecting against flash floods, using land and water management to restrain water and allow it to permeate the soil.

Community based DRR actions should be furtherly developed, especially in the most critical communities. Actions should include shelters and evacuation plans in place and communicated to residents. Early warning systems should be put in place focussing on alerting the population by alerts broadcast on TV and radio and sent by text to cell phones in advance.

Local government officials, hospital staff, the Red Cross, NGOs, and community, school and religious leaders should be further trained in emergency response to disasters. Emergency supplies, clothes, food, medical items, etc. should be procured and stored in strategic locations, ready for rapid distribution by emergency management personnel.

Organization of chapters

The report is organised in four chapters starting with this executive summary. Chapter 1 describes the objectives and methodology in greater detail and provides an overview of the baseline situation in the Northern Province. Chapter 2 describes the hazard assessment for inland flooding, coastal flooding, drought, extreme weather events and increase in precipitation intensity and variability, for the current and future scenario's. In chapter 3 we discuss the selection of exposed assets and their characteristics to compute sensitivity indices and to map social, infrastructure and economic vulnerability for the province. In chapter 4 we present the resulting risk maps and the composite risk map is presented in chapter 5. We conclude with recommendations in chapter 6.

1. INTRODUCTION

Papua New Guinea is prone to natural disasters induced by climate change, climate variability, and sea-level rise, including tsunamis, cyclones, inland and coastal flooding, landslides, and droughts.

UNDP is supporting a four year project, implemented by the Climate Change and Development Authority (CCDA), titled “Enhancing Adaptive Capacity of Communities to Climate Change-related Floods in the North Coast and Islands Region of Papua New Guinea,” financed by the Adaptation Fund. The project seeks to build community resilience to coastal and inland flooding through improved awareness, risk management, and institutional capacity to implement appropriate adaptation measures.

Within this context, Antea Group, Hydroc & World Vision have conducted a climate risk, vulnerability and risk assessment in five provinces in Papua New Guinea (East Sepik, Madang, Morobe, Northern, and New Ireland) .

This report describes the hazard, vulnerability and risk assessment for the New Ireland Province in Papua New Guinea.

1.1. Objectives

The objective of this study is to identify climate risks, exposure, and vulnerability to principal climate hazards affecting five pilot provinces (East Sepik, Madang, Morobe, Northern, and New Ireland) and to prepare Composite risk maps at the province and district level for (i) inland flooding, (ii) coastal flooding, (iii) drought, (iv) extreme weather events, and (v) increase in precipitation intensity and variability.

This requires:

- the assessment and mapping of major climate hazards in each of the 5 provinces in terms of their nature, geographical distribution, severity and frequency. Document the changing patterns induced by projected changes in the future climate.
- the assessment and mapping of physical, social and economic vulnerabilities and prepare district wise vulnerability profiles/maps for climatic hazards.
- the assessment of risks maps for the five hazards and a composite risk map, as a result of hazard and vulnerability assessments.

1.2. Methodology

The methodology to identify and map current and future climate hazards, vulnerability and risks has been developed by the project team based on definitions and approaches found in the Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) literature, and customisation taking into account data availability and quality for the five pilot province provinces in Papua New Guinea (East Sepik, Madang, Morobe, Northern, and New Ireland).

Data has been collected from leading institutions in Papua New Guinea and international sources. Data used and sources are listed in Annex 2. Following a careful review and quality check of the available data, hazard maps, vulnerability indices and maps, and risk maps were produced for the following climate hazards:

- Inland flooding
- Coastal flooding
- Drought

- Extreme weather events (tropical cyclones)
- Increase of precipitation intensity and variability

The assessment was done for the current situation and a future situation based on projects climate data. The overall procedure followed involved the following steps (shown in Figure 1) and explained in the following pages.

Vulnerability and risk maps were made for three sectors:

- Social
- Physical (or infrastructure)
- Economic

The overall process is shown in Figure 1, and is explained in the following sections.

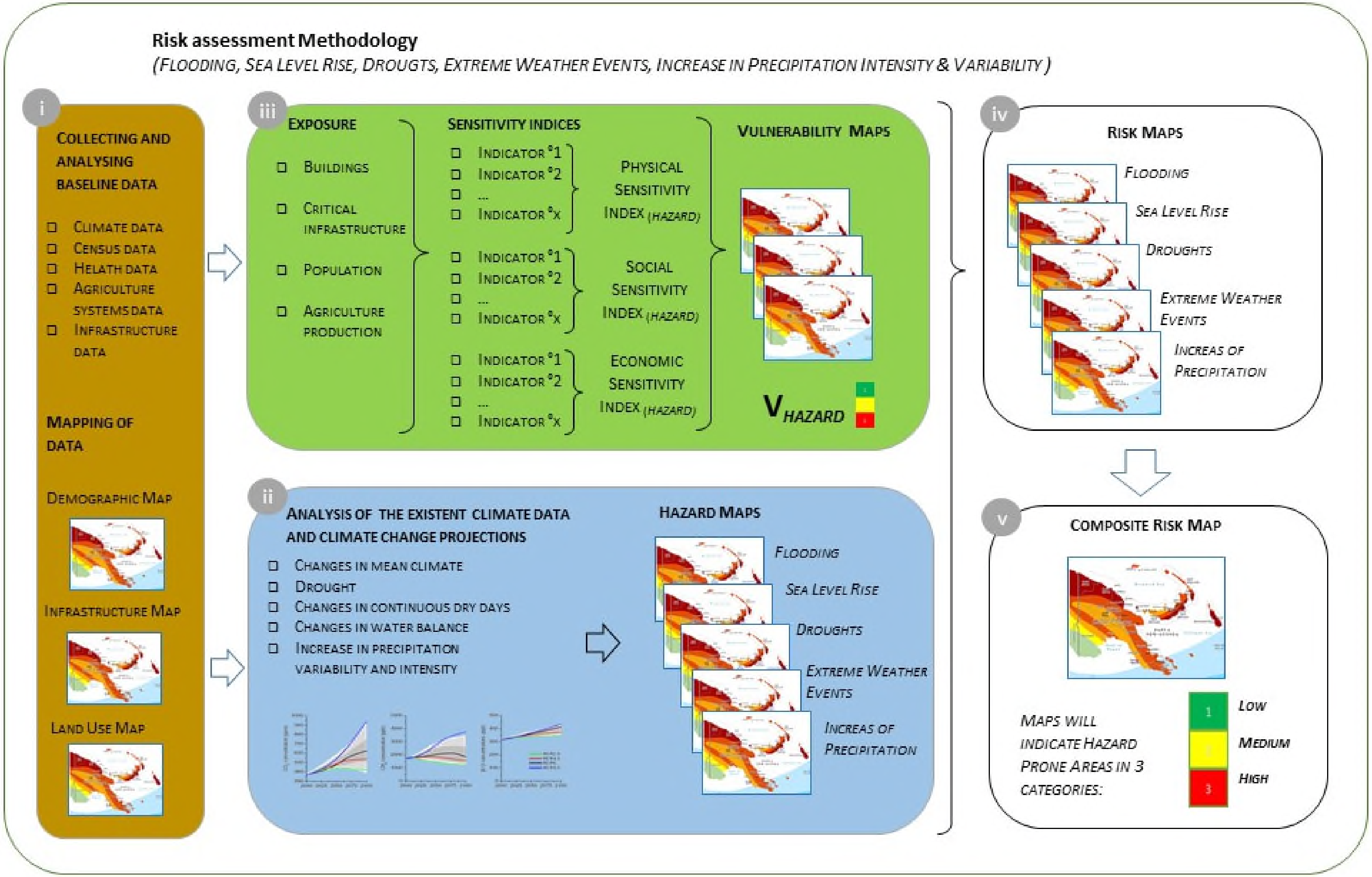

Figure 1. Risk mapping methodology

1.2.1. Hazard assessment

The definition of hazard used throughout this study is consistent with the UNISDR (2009)[3] definition: 'Dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage'.

Moreover, the hydrometeorological hazards, which are the focus of this study, are defined as the "process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage."

In order to produce maps for climate induced hazards, data on current climate and projected climate were collected from national and international sources for analysis of the climate metrics.

The available observation data from weather stations in PNG is too scarce for the purposes of this study.

In order to cope with the limited availability of qualitative historic observation data, the main strategy followed by this study was to reanalyse hindcasted and forecasted outputs from downscaled General Circulation Model (GCM) data to derive actual and projected patterns for parameters like temperature, precipitation and wind speed. These parameters were subsequently utilized to compute hazard parameters for risk mapping.

All analyses are based on climate model output from the 5th Coupled Model Intercomparison Project (CMIP5) , which informed the Intergovernmental Panel on Climate Change (IPCC) fifth assessment reports (IPCC 2013) .

A simple downscaling correction for spatial variability was applied, which adjusted the rainfall intensity and temperature value but does not affect the variability, including seasonal.

Following the analysis of the current and projected climate, a series of maps were produced for the hazards listed above and this under the current climate conditions and the forecasted climate. The result are show in chapter 2 of this report.

1.2.1.1. Drought

Drought is characterised as a normal, recurrent feature of climate, temporarily deviating from normal climatic conditions for a specific location. In technical settings, a climatic hazard should represent the probability with which climatic events of various intensity are to occur. Drought hazard could therefore be defined as the frequency of abnormal precipitation deficits at some level of intensity in a particular region.

In order to describe the evolution of drought over time in the context of climate change, several metrics were considered relative to mean climate variables (temperature, precipitation and surface wind speed), duration statistics (continuous dry/wet days) and water balance indicators (precipitation minus evapotranspiration). These metrics were computed at a 0.5° grid over the area of interest in current and future climate conditions.

None of these metrics can be interpreted in the probabilistic manner necessary to quantify drought hazard. The most suited indicator selected for drought hazard is the annual maximum dry spell length i.e. the expected maximum number of continuous dry days (CDD) within a year. Using this indicator to quantify the level of drought hazard makes the assumption that regions which experience longer drought events are also the more likely to experience drought in terms of frequency. Also, because the expected duration of drought events is critical to evaluate the related consequences and the

[3] UNISDR (2009) Terminology on Disaster Risk Reduction
http://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf

associated risk for crop production, this choice is consistent for a risk assessment: higher expected CDD will lead to higher levels of risk.

CDD was computed for a large extent encompassing Papua New Guinea: 140-160° longitude, -15-0° latitude, with values ranging from 11 to 90 days. Looking exclusively at the provinces under study, CDD ranges from a minimum of 13 days and the maximum values of 28 days. There is a slight, however not dramatic, change between the current and future climate conditions. While drought shows an increasing trend, overall

1.2.1.2. Precipitation intensity and variability

The hazard precipitation intensity and variability is defined in terms of increased rainfall intensity and variability. Rainfall variability as a hazard cannot be easily predicted and is even more difficult to map. We consider the risks associated with rainfall increase relative to (i) agricultural system tolerance to a rainfall regime change, and (ii) communities sensitivity to intense rainfall events, extreme runoff and flash floods in urban areas.

To account for these two components, we consider two hazard indicators: (i) cumulative annual rainfall, and (ii) the total annual rainfall when the daily rainfall exceeds the 95th percentile. The underlying hypothesis is that heavy, intense rainfall is more likely to happen in overall wetter areas.

The indicator of Total Annual Rainfall (pr) was computed for a large extent encompassing Papua New Guinea: 140-160° longitude, -15-0° latitude, with values ranging from 1 100 mm to 3 800 mm. Strictly for the fives provinces under study, classes and contours of 100 mm are shown between a minimum of 2 300 mm and a maximum of 3 800 mm for the study area.

For the indicator of Total Rainfall in Wet Days (r95p), the larger extent of 140-160° longitude, -15-0° latitude includes values from 250 mm to 910 mm. Strictly for the fives provinces under study, classes and contours of 20 mm are shown between a minimum of 430 mm and a maximum of 840 mm.

1.2.1.3. Extreme weather events (cyclones)

The mapping of extreme weather events around Papua New Guinea, more specifically tropical cyclones, requires the analysis of historic cyclone path databases and damage reports, as well as observed meteocean parameters, like sea surface temperature. A review of past events was undertaken to understand the relation between driving factors, cyclone occurrence and damage potential occurring in the waters around the studied area.

Using data acquired from the Bureau Of Meteorology of Australia (BOM), all cyclone tracks that occurred from 1970 until 2016 and that passed within 200 km of Papua New Guinea were analysed. In the absence of measured cyclone width data the assumed average diameter of cyclones with destructive wind speeds is assumed as 2 degrees, based on observations of historic cyclones.

The number of times that a cyclone crossed over each grid of the area of interest was counted and converted into a historic cyclone occurrence map.

A projected future cyclone occurrence map for the southwest Pacific was derived based on compiled data in the IPCC Fifth Assessment Report (AR5 report), summarized and averaged for the southwest Pacific. This analysis resulted in a projected decrease of cyclone intensity of 44%. Therefore, each count per grid in historic cyclone occurrence map is multiplied by a factor of 0.56 in order to obtain the respective projected cyclone occurrence map.

The occurrence maps are re-classified into 5 classes of hazard level, required to later calculate the extreme weather risk maps. Two sets of hazard maps are assessed, one for the current scenario and another for the projected scenario.

1.2.1.4. Inland floods

Papua New Guinea suffers regular flooding events. Changes in flooding patterns in PNG are expected to arise as consequences of meteorological changes resulting from climate change. Specifically, changes in the intensity and frequency of rainfall events may lead to changed runoff patterns. Changes in anthropogenic influence are also expected to play a large role in future flooding, including catchment deterioration through unsustainable development practices as well as river engineering works that alter the hydraulic regime.

The risk of inland flooding can be inferred from changes in the climate and in the daily statistics of the weather. Metrics of particular relevance for assessment of flood risk are: maximum five day cumulative precipitation, total annual rainfall when the daily rainfall exceeds the 95th percentile and the simple precipitation intensity index.

Given the lack of hydro-meteorological data, topo-bathymetric data, gauged data, soil type and land use data, a pragmatic approach to develop inland flood hazard maps has been customized for the purposes of this study. The method is based on limited available information and GIS routing techniques. Rainfall derived from the climate models were used to compute intensity duration frequency relations (IDF) for the current and the projected situations. The intensities are subsequently transported into run-off by means of the ‘rational method’. These steps allow deriving maximum flood discharges at any location within the considered river reach. Combining the discharge with an estimated reach geometry allow to derive water levels and subsequently flood maps.

There is no detailed information on digital terrain models nor river and floodplain for all the province. The flood maps in this report are estimated based in SRTM-3 data. This is the main input that defines the surface slope, and whether there is or not flooding.

Runoff coefficients are estimated from a soil map obtained from the National Mapping Bureau of Papua New Guinea (NMB), land cover map (Globalcover 2009), and a slope map (created using SRTM-3 data).

Runoff coefficients are estimated at pixel level allowing to create a map for runoff coefficients with a resolution of 90x90 meters. This runoff coefficient map is constant for the existing and future flood maps, as it is beyond the scope of this study to estimate future changes due to land use from anthropogenic activities.

The contributing area (the effective surface of a catchment contributing to runoff at the outlet) is derived from the DTM using GIS techniques. The flow accumulation map shows the number of pixels contributing flow to each downstream channel pixel and is derived from a digital elevation model. The stream channel network is derived from the flow accumulation map.

The analysis is carried out at province scale using a resolution of 90x90 m. The accumulated area at each point in a stream network is calculated. This computation indicates how many pixels contributed runoff to a specified location along the stream in km^2. A filtering step is applied to remove any creeks where the contributing watershed area (independent of the runoff coefficient) is less than a specified amount (30 km^2). This is necessary to prevent nearly every pixel being part of the stream network.

The time of concentration Tc is estimated for each pixel in the stream network by using the Kirpich regression equation (described in USDA NRCS 2010).

Potential changes in flood hazard are assessed by comparing the estimated flood maps generated for a specific frequency and intensity of precipitation of current climate data versus maps derived using future climate projections.

The flood elevation along the stream network is interpolated to generate flood elevation surface over the entire watershed. The flood elevation surface is then compared to the digital elevation model to identify where, and how deep, flooding occurs (i.e. where the flood elevation map is higher than the digital elevation model). A natural neighbour interpolation is used (ESRI 2010). This type of interpolation is local, uses only samples surrounding the query point, and interpolated elevations are guaranteed to be within the range of the surrounding samples. It will not produce peaks, ridges, or valleys that do not already exist in the input data. While computationally expensive, this method gives very smooth and reasonable water surface elevation surfaces.

As a last step, areas that are shown to be flooded in the flood map but that are not hydraulically connected to the stream network are removed. The result is a flood depth raster depicting only areas that are hydraulically connected to the stream network.

1.2.1.5. Coastal floods

Coastal flood is one of the most important climate change related hazards in this area because most settlements in the North coast and islands of Papua New Guinea are located along its coast. Climate change is expected to lead to global sea level rise that would increase the coastal flooding areas. In order to identify the current coastal flooding extension, hourly tidal levels and wave height data are assessed. The projected sea level rise is extracted from global sea level projections and local oceanographic particularities for PNG. Then, the projected coastal flooding extension is estimated by adding the sea level rise to the total level of the current scenario.

Sea level rise along PNGs coastline is in line with global developments. To understand coastal flooding a combined analysis of sea level rise, the respective tidal signals, potential storm surges and aspects of increased wave energy resulting from increasing water depth would be required using coastal modelling tools. For the modelling detailed bathymetrical and topographical data, beyond the details that are currently provided by the SRTM data would be needed.

1.2.2. Vulnerability assessment

Vulnerability is defined by the UNISDR as a “set of conditions and processes resulting from physical, social and economic factors, which increase the susceptibility of a community to the impact of the hazard”. This includes intrinsic characteristics that predispose the asset or the community to suffer from a hazard, but also the potential loss that can result from it (UNISDR 2009).

Vulnerability is interpreted in this study as the potential damage (potential negative effects) of the hazard.

The general procedure for producing vulnerability maps for each hazard follows these steps:

1.2.2.1. Exposure

The first step is to identify the elements (sensitive assets) that are potentially exposed to the hazard: maps showing communities, infrastructure and land use are combined with the hazard maps using GIS techniques to identify the elements exposed to each of the hazards.

The ‘elements’ considered in this study are:

- Communities (demographic maps)
- Buildings (infrastructure maps)
- Agricultural land use (land use maps) /agricultural systems (agriculture survey)

1.2.2.2. Sensitivity indices

Where sensitivity refers to “the physical predisposition of human beings, infrastructure , and environment to be affected by a dangerous phenomenon due to lack of resistance and […] intrinsic and context conditions making it plausible that such systems once impacted will collapse or experience major harm and damage” (IPCC 2012).

Sensitivity of the elements potentially damaged by the effect of hazards is assessed using various indicators that are subsequently combined into sensitivity indices. Three separate indices are constructed to express respectively physical, economic and social sensitivity to each of the hazards considered in this study. General steps for the construction of a composite sensitivity index are:

- Inventory of data sources
- Assessment of data quality
- Selection of indicators
- Describing indicators and their relation to physical, social and economic sensitivity for each hazard
- Valuing indicators
- Normalisation of indicators, to allow operations (multiplications…) between them. One step further is standardization, transforming indicators into a consistent ordinal or unit-less scale to make them comparable to one another
- Assigning weights to indicators
- Calculating cumulative scores: the normalized or standardized indicators are averaged or added together to obtain a synthetic sensitivity score
- Defining categories for sensitivity reclassification (normalisation).

An overview of the indicators selected to constitute physical, social and economic sensitivities is given in the following paragraphs.

Social sensitivity

The social sensitivity Index is an aggregate view of a suite of variables that provides a sense of a community's overall sensitivity to climate change induced hazards. An appropriate suite of indicators is chosen based on the literature, taking in account the particularities of PNG and consistently with the available data. This is show in Table 1.

Social sensitivity of a community is assumed to be the same regardless of the hazard at hand. This is to say that a community in poor health or lack of education will increase equally the impact of the damage caused by a potential disaster, whichever it is.

Table 1. Overview of social sensitivity indicators and data

	Sensitivity Indicators (hazard dependent or not)	Geographic data	Format
SOCIAL Sensitivity	- Child and maternal health - Malaria incidence - Population density - Population dependency (age) ratio - Literacy rate	Population spread, according to census and building distribution.	- Health centre points - Census unit points - 2 x 2 km grid

Demographic indicators were calculated based on demographic statistics at census unit level received from the National Statistical Office (Census 2011). Following indicators were used:

- Population density (people/km2)
- Age dependency ratio : population below 15 and above 65 years old, divided by the population between 15 and 65.
- Literacy in at least one language (% of population over 10 years old)

Health indicators are calculated based on health performance data provided by the Department of Health. Data are collected for each health centre and summary statistics of the various health indicators are available at district and provincial level. Following indicators were used:

- Percentage of Children Weighed at Clinics Less than 80% Weight for Age 0 to 4 years old (%)
- Percentage of Facility Births that are Low Birth Weight (<2500 grams) (%)
- Incidence of Diarrhoea in Children under 5 years old (/1000 pop. < 5yr)
- Incidence of Malaria (per 1000 pop.)

The two indicators regarding weight of infants and children were selected because they can serve as sensitive proxy indicators for nutritional status, food availability, variety and intake in a human population.

The two indicators concerning the incidence of disease (childhood diarrhoea and malaria) were selected because they can be considered as sensitive proxy indicators for the general health status of a human population. The incidence of malaria can also serve as a proxy indicator of lost productivity in a population.

Physical sensitivity

To assess the physical sensitivity of infrastructure and buildings, the study focuses on buildings, infrastructure, and critical facilities. Infrastructure includes transport systems (roads, bridges, airports, port facilities, etc.), utilities (water and electricity), and critical facilities (including hospitals and health centres, emergency services, key transport and communications systems, essential services).

Factors influencing physical sensitivity of the exposed elements include both generic factors and hazard-specific factors. The infrastructure sensitivity index is therefore assessed for each of the five hazards separately and expressed as a hazard-dependent sensitivity index.

Table 2. Overview of infrastructure sensitivity indicators and data

	Sensitivity Indicators (hazard dependent or not)	Geographic data	Format
Infrastructure Sensitivity	- Building characteristics - Infrastructure characteristics	Buildings (PCRAFI 2013) Special infrastructure (PCRAFI 2013)	Points (buildings and punctual infrastructure) Lines (roads)

Physical characteristics influencing building resistance to each hazard are first selected as sensitivity indicators. Table 3 below lists building characteristics affecting (decreasing or increasing) the potential impact of each hazard.

Table 3. Indicators influencing building sensitivity

N°	Indicator	Inland flooding	Coastal flooding	Cyclonic wind
1	Building defect	x	x	x
2	Foundation type			
3	Foundation			

	bracing type			
4	Roof shape			x
5	Roof pitch			x
6	Roof material			x
7	Shutter type			x
8	Wall opening type			x
9	Wall material	x	x	x
10	Minimum floor height	x	x	

Temperature changes, drought and annual rainfall variations are considered without significant physical damage on buildings and infrastructure.

Information describing special infrastructure is limited. Only for roads and bridges, secondary modifiers were used that affect sensitivity to flooding and cyclonic wind hazards (Table 4). By default, other infrastructures without descriptive information were considered to have a constant sensitivity to the mentioned hazards, irrespective of their size or other particularities. Sensitivity is considered null for temperature changes, drought and annual rainfall variations.

Table 4 Indicators influencing road and bridge vulnerability

Indicator	Inland flooding	Coastal flooding	Cyclonic wind
Road surface (dirt, gravel, sealed)	x	x	x
Road condition (good, fair, poor)	x	x	x
Bridge type (ford, steel, wooden, concrete…)	x	x	

For building, each indicator is given a score corresponding to the building characteristics. These indicators are valued according to interview/surveys and literature (Table 5). Indicators are then aggregated for each building, taking into consideration its different characteristics.

Table 5 Building sensitivity indicators scores

Attribute name	Description	Value	Legend	Sensitivity Inland Flooding	Sensitivity Coastal Flooding	Sensitivity Cyclonic Wind
Defect	Describes defects in the building structure that may compromise its strength	1	Minor	0	0	0
		2	Major or Uninhabitable/poor construction	1	1	1
		8	None or under construction	2	2	2
WallMat	Material used to clad the walls of the buildings occupied levels	2	timber & masonry/concrete	1	1	1
		7	traditional	2	2	2
		8	none	2	2	2
		9	complex/other	1	1	1
		10	masonry	0	0	0

Attribute name	Description	Value	Legend	Sensitivity Inland Flooding	Sensitivity Coastal Flooding	Sensitivity Cyclonic Wind
		30	plywood sheet	2	2	2
		40	timber board	1	1	1
		50	fibre-cement sheet	2	2	2
		60	metal sheet	1	1	1
		80	concrete	0	0	0
Roof Shape	Roof shape	1	MONOPITCH	-	-	2
		5	ARCH	-	-	0
		20	GABLE	-	-	2
		30	HIP	-	-	1
		40	COMPLEX	-	-	1
Roof Pitch	Angle of the roof	1	FLAT (0§)	-	-	2
		2	LOW (1§-25§)	-	-	2
		3	MODERATE (25§-45§)	-	-	0
		4	STEEP (>45§)	-	-	2
		9	COMPLEX	-	-	1
Roof Mat	Roof material	1	metal	-	-	0
		2	concrete	-	-	0
		7	traditional	-	-	2
		9	complex/other	-	-	1
Shutter	Describes whether the windows have cyclone protection	10	none/partial/unknown	-	-	2
		20	present	-	-	0
		21	grill	-	-	1
Min FloorH	Minimum floor height of the lowest living level above ground (meters)	1	0-0,1m	2	2	-
		2	0,2-0,3m	2	2	-
		3	0,4-1,0m	2	2	-
		4	1,1-3m	1	1	-
		5	>3m	0	0	-
Wall Open	Describes the amount of windows or if the structure is open (wall opening type)	10	<75% of wall is windows	-	-	1
		11	>75% of wall is windows	-	-	2
		20	Open space	-	-	2
		21	No windows	-	-	0

For special infrastructure Indicators are valued for bridges and roads in relation with their characteristics (Table 6 and Table 7).

Table 6 Bridge sensitivity indicators scores

Type	Sensitivity to Flood	Sensitivity to Wind
Causeway	0	0
Concrete	1	0
Culvert	0	0
Ford	0	0
Steel	1	1
Wooden	2	1

Table 7 Road sensitivity indicators scores

Condition	Surface	Sensitivity to Flood	Sensitivity to Wind
Good	Dirt	1	0
Good	Gravel	1	0
Good	Sealed	0	0
Fair	Dirt	2	0
Fair	Gravel	1	0
Fair	Sealed	1	0
Poor	Dirt	2	0
Poor	Gravel	2	0
Poor	Sealed	2	0

For other special infrastructures, we assume maximum sensitivity index by default (=2). We make the assumption that the size of the infrastructures (small, medium or large airport/mine etc) does not influence the sensitivity factor.

However, some infrastructure are intrinsically less sensitive than common buildings. For example, a mine does not lose all value in the event of a flood or a storm, even a strong one. Therefore, a sensitivity index of 2 will not mean a loss fraction of 100%. Also, roads or airstrips are intrinsically less sensitive than buildings, in the sense that, in most scenarios, they do not risk total destruction. This is taken into account when estimating potential damage.

Indicators for the sensitivity of buildings and of special infrastructure where aggregated into a composite physical sensitivity index for each hazard.

The composite building physical sensitivity index (PSI) is calculated as a weighted average that gives more importance to the “defect” indicator, which is assumed to be the most critical secondary modifier to affect the vulnerability to disaster. Physical sensitivity is calculated as the average between the index associated to defect and the average of all other indexes associated to other indicators.

Economic sensitivity

The aim of an economic sensitivity assessment is to unveil the economic consequences associated with natural disasters and the potential extend of damage to economic assets and related aspects in key economic sectors. According to Papua New Guinea investment promotion authority (IPA), the main “economic sectors in Papua New Guinea are agriculture and livestock, forestry, mining and petroleum, tourism and hospitality, fisheries and marine resources, manufacturing, retailing and wholesaling, building and construction, transport and telecommunications, and finance and business trade” (IPA 2017).

The economic sensitivity assessment depends strongly on the availability and refinement of the data. Identifying national databases with economic parameters for the country on provincial level (or lower) has been difficult. Because of this, and because agriculture is the main economic activity and since most of the population rely on their own production for their livelihood, the economic sensitivity analysis focuses on the agricultural sector. Sensitivity of the commercial and the industrial sectors, including mining, are already assessed by the physical sensitivity component and double counting should be avoided. Indirect damage to the different economic sectors is not taken into consideration here, because of the lack information on the disruption or inactivity duration caused by the different hazards. Such indirect damage includes for example economic losses due to transport disruption, market change or destruction of the means of production. Given the fact that duration information is essential for such economic loss calculations, indirect damage cannot be quantified in the framework of this project.

The main crops and agricultural activities in the province were identified. The potential impact of climate change induced hazards on these crops was assessed based on information gathered in the framework of interviews and literature reviews.

Data sources used for this task include land use data (PNG Resource Information System (PNGRIS) and Mapping Agricultural Systems of PNG (MASP). Crop replacement costs are also necessary for the vulnerability assessment and were collected from the PCRAFI study (PCRAFI 2013).

Factors influencing economic sensitivity of the exposed elements include both generic factors and hazard-specific factors. Those sensitivity indexes are therefore assessed for each of the five hazards separately and expressed as a hazard-dependent sensitivity index.

Table 8. Overview of economic sensitivity indicators and data

	Sensitivity Indicators (hazard dependent or not)	Geographic data	Format
ECONOMIC Sensitivity	- Crop tolerance to climatic changes - Plantation tolerance	Agricultural survey (Australian National University) PCRAFI-PacRIS Land Use/Land Cover (agricultural area)	Agricultural system and plantation polygons

Crop information was retrieved for each agricultural system described in the MASP surveys. Some areas were designated as plantations without crop specification. Intersecting with land use information from PNGRIS, these zones were assigned a plantation type (e.g. Palm Oil, Coconut, Banana…). Where those two sources of information did not match, surveyed “plantation” systems (according to MASP) were labelled as forest or open spaces on the land use map. For these areas, no assumptions could be made for a specific crop.

Tolerance of each plant variety to characteristic ranges of climate conditions was evaluated by means of expert knowledge, literature and data review. The selected climate variables corresponding to the hazard understudy are listed in Table 9.

Table 9. Indicators for crop tolerance assessment

Temperature ranges (∘C)	–0 1–10 10–20 20–30 30–40
Inland flood depth (m.) *(without flow)*	<0.5 0.5–5 5–10 >10
Sea level rise (m) *(assumes salinisation of groundwater)*	<0.5 0.5–5 5–10 >10
Annual rainfall (mm.) *(assumes relatively even distribution)*	0–500 500 – 1000 1000 – 3500

	3500 – 5000
Max. Consecutive drought (days)	0–14 14–30 >30
Cyclonic winds (km/hr)	0–60 60–120 >120

In order to simplify the weighing system and the aggregation procedure of crop indicators in each agricultural system, these indicators were reduced to a reduced selection (Table 10).

Table 10. Selection of indicators for crop tolerance assessment

Indicator	Critical range/threshold
Inland flood depth (without flow)	> 0.5 m
Sea level rise (assumes salinization of groundwater)	> 0.5 m
High annual rainfall (mm.)	3500 – 5000
Max. Consecutive drought (days)	14–30
Cyclonic winds (km/hr)	60–120

Crop tolerance was evaluated for the major crops listed in the MASP database, for each hazard, on a scale from 0 to 2 (0 = Tolerant; 1 = Moderately tolerant; 2 = Intolerant). Based on their characteristics, the key crops were attributed low, medium or high tolerance scores taking into account their hazard-dependency and based on available literature.

Table 11 gives the tolerance scores for critical ranges of 8 climate hazards for staple crops. Tolerance of other crops, fruit, vegetable, nut types was also assessed and scored. The complete table of tolerance scores can be found in Annex 3.

Table 11. Tolerance score for staple crops

	INLAND FLOOD DEPTH (m.) ***(without flow)***	**SEA LEVEL RISE (m)** ***(assumes salinisation of groundwater)***	**LOW ANNUAL RAINFALL (mm.)** ***(assumes relatively even distribution)***	**HIGH ANNUAL RAINFALL (mm.)** ***(assumes relatively even distribution)***	**MAX. CONSECUTIVE DROUGHT (days)**	**CYCLO NIC WINDS (km/hr)**
Critical range	*0.5–5*	*0.5–5*	*0–500*	*3500 – 5000*	*14–30*	*60–120*
Banana (Musa cvs)	1	2	2	1	2	2
Cassava (Manihot esculenta)	2	2	0	1	0	2
Chinese taro (Xanthosoma sagittifolium) also Cocoyam/Tannia	2	2	2	1	2	2
Coconut (Cocos nucifera)	2	0	2	1	1	2
Sago (Metroxylon sagu)	1	2	2	1	1	2
Sweet potato (Ipomoea batatas)	2	2	2	1	2	0
Taro (Colocasia esculenta)/	1	2	2	1	2	2

dasheen						
Yam (Dioscorea alata)	2	2	2	0	0	2
Yam (Dioscorea esculenta)	2	2	2	0	0	2

The objective of this step of the methodology was to assign a sensitivity (or tolerance) score to each crop in all agricultural systems. Each crop has a different relative importance inside the system and a different replacement cost. Therefore, sensitivity was not aggregated at grid cell level at this stage. When computing the vulnerability index of each grid cell (see Part 3), vulnerability has to be aggregated for all crops according to (1) their predominance in the system (proportional to the surface area), (2) their replacement cost (value associated to a total loss), (3) in the case of flooding, whether or not they are exposed.

To give a notion of the most represented crops, the relative importance of each staple crop is show in Figure 2 as the proportion of agricultural systems where the crop is present.

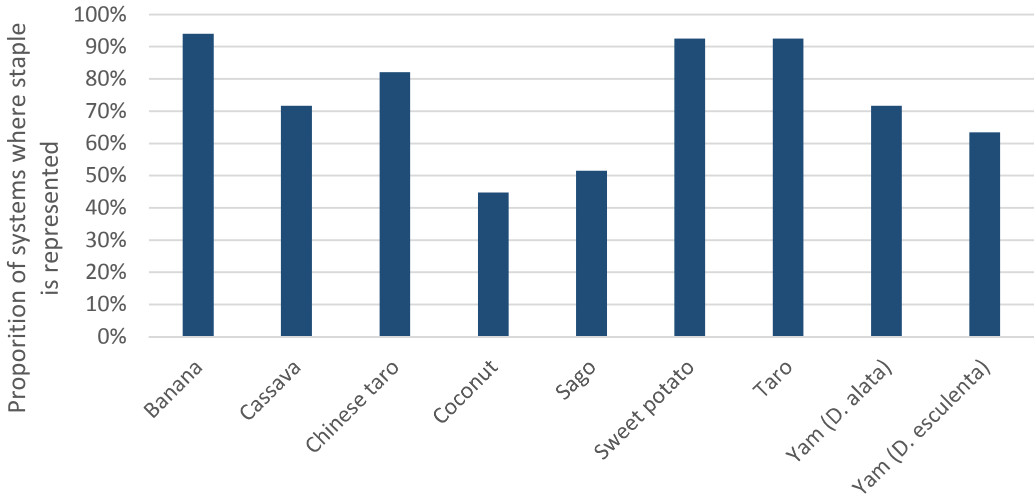

Figure 2. Representativeness of each staple crop across all systems

Some general comments on the chosen indicators are given in Table 12.

Table 12. General comments of crop tolerance scores

Indicator	Comment
Temperature ranges (∘c)	Temperature and altitude are related. In PNG, the temperature difference per 1,000m of altitude is 5.2∘C. The temperature tolerance of crops determines the altitudes at which they can be grown. For most of these crops, except notably coffee, a rise in temperature will extend the area at which they can be grown, as long as the supply of water is adequate..
Inland flood depth (m.)	The effects of flood on crops are functions of depth, the period of inundation and the velocity of flow. Most crops, for example, can withstand a day under 50 cm of water, if it drains away rapidly thereafter. With flowing water, even 10 cm can flatten a crop and remove the soil. Since most inland flood is caused by rivers breaking their banks, the effect of velocity is the most critical, but also the least studied. Trees can withstand deeper floods, but still only for very short periods in most cases.
Sea level rise (m)	Most of the tolerance scores relates to a crop's tolerance to salinity in the soil. Tidal

	surges, due to storms, will have immediate effects similar to river floods (lodging of plants, erosion of soil). They will also leave behind salt residues in the soil, which may last for a considerable time before rain leaches it out. The longer term problem is the effect that mean sea-level rise has on subterranean water reserves. This excludes salt-intolerant crops from being grown on that land for the future. This is a growing problem on the coasts. Certain important crops (e.g. cocoa, papaya, banana) can be adversely affected even by salt born on the wind)
Annual rainfall (mm.)	Average annual rainfall requirement is a very rough measure. Its distribution through the year is important. Most tropical crops benefit from an even distribution of rain throughout the growing season.
Max. Consecutive drought	For annual crops, this vulnerability data relates to the growing season. Many perennials are accustomed to a dry season. Even for annuals, the period at which a drought occurs can determine its resistance. Some crops (e.g. coffee) require a dry spell at certain stages of development (such as flowering); others can tolerate drought except at critical periods in their development (e.g. just after planting).
Cyclonic winds	A wind speed of about 60 km/h seems to be a dividing line between a tolerable wind and a destructive one. Lowe, ground-covering plants, such as sweet potato, are less susceptible to high wind. Trees offer more resistance and are more prone to breaking branches or uprooting. Nonetheless, tall, native coconut palms, which have evolved under cyclonic conditions, are more resistant than recently developed dwarf varieties. Breadfruit may be uprooted but has an outstanding capacity or regenerate. Cyclones are often followed by periods of drought, which can be more damaging to many crops than the storm itself.

Tolerance scores can only take index values of 0, 1 or 2. Normalisation is therefore not needed.

1.2.2.3. Vulnerability maps

Vulnerability is interpreted here as the potential damage of the hazard. Potential damaging effects of a hazard are estimated as the product of the maximum potential loss (exposure) and sensitivity. To this end, sensitivity is expressed as an index (1 to 5) or a percentage (loss fraction).

For physical, economic and agricultural vulnerability assessment, the maximum loss associated to the exposed assets (buildings, crops, …) is estimated by their replacement cost. In the case of social vulnerability, maximum loss is the estimated number of exposed people. In order for vulnerability to be mapped and allow visual interpretation, it is scaled into five categories: very low, low, medium, high and extreme.

Finally, vulnerability should be divided by a factor accounting for the coping capacity (C) of the community at large. For physical and agricultural aspects, vulnerability (V) can be expressed as a function of sensitivity (S) (Equation 1).

$$V_{PHY\ or\ ECO} = \frac{Maximum\ damage \times S_{PHY\ or\ ECO}}{Capacity}$$

Equation 1 Expression of physical/economic vulnerability

Social vulnerability is proportional to exposed population (Equation 2).

$$V_{SOC} = \frac{Number\ of\ exposed\ people\ \times S_{SOC}}{Capacity}$$

Equation 2 Expression of social vulnerability

Capacity was not computed at this stage and vulnerability was mapped with a homogeneous capacity of 1 which could be adjusted in the future when more information becomes available.

For each hazard, a set of maps depict the respective vulnerability index for each relevant components: physical, social and economic. Social vulnerability is assumed not hazard-dependant, so the same social vulnerability map is considered for all hazards. Buildings are considered not vulnerable to drought: drought is primarily relevant for the economic damage caused to crops. Physical and social vulnerabilities were thus not assessed for drought hazard. In the case of intense rainfall, building physical sensitivity and population social sensitivity were not assessed but a single indicator reflecting population density is used to account for the damage caused by heavy rainfall in urban areas ("urban vulnerability"). Conceptually, this indicator should reflect damage to both buildings and human lives.

Table 13. Relevant risk components per hazard

	Physical vulnerability	Social vulnerability	Economic vulnerability
Drought		x	x
Intense rainfall		x	x
Inland flooding	x	x	x
Coastal flooding	x	x	x
Extreme Weather	x	x	x

Social vulnerability

The social component of vulnerability focuses on the exposure of social groups or individuals to stress as a result of environmental change, where stress refers to unexpected changes and disruption to livelihoods. This definition emphasizes the social dimensions of vulnerability following the tradition of analysis of vulnerability to hazards.

Social Sensitivity is associated with the population exposed to hazard, and how the people's characteristics and conditions will affect their resiliency to the hazard. Social sensitivity and vulnerability mapping is therefore based on the distribution of communities and population. Census data is associated to so-called census units. GPS coordinates are available for these census units but they offer poor visualization because they represent communities various sizes (rural vs urban).

In order to map the social sensitivity, the social indicators were linked to the census units located on the map. The 7 social indicators described above are expressed in different units (number of cases per 1000 people, percentage of births, percentage of young children etc.). In order to aggregate them into a single index, they were normalised, though simple ranking.

In order to represent a more realistic spread of the population on the territory, population density was associated with location of buildings and population was subsequently reaggregated per grid cell (2 by 2 kilometres).

The results for each grid cell finally were reclassified into 5 social vulnerability classes for mapping.

Physical vulnerability

To calculate vulnerability, we estimate the potential damage to each building (or building cluster) *b* by multiplying their sensitivity index (S) - ranging from 0 to 2 - by their replacement cost (RC). Sensitivity is hazard specific, and so is the potential damage to each building.

Vulnerability is proportional to the potential damage associated to a certain hazard and is expressed in monetary value as to make it comparable (and additive) with infrastructure vulnerability. Because the sensitivity index is not expressed as a percentage, and because replacement cost is only but a gross estimation of damage loss, this calculated “potential damage” value has little monetary meaning but, scaling the index so, allows us to express building and infrastructure vulnerabilities in the same units.

Vulnerability is computed for exposed buildings only. For cyclones, all buildings are considered exposed, but for flooding, it reduces considerably the number of buildings taken into consideration.

To calculate infrastructure vulnerability, interpreted here as the potential damage to a structure, the sensitivity index of each infrastructure type is multiplied with their value, or replacement cost.

Roads are intrinsically less sensitive than buildings: a maximum sensitivity score of 2 does not mean total loss of the road whereas it can be the case for a building or a minor infrastructure. Therefore, road sensitivity was divided by 4 in order to balance more realistically their influence in the aggregated vulnerability index.

For the computation, linear and punctual infrastructure need be distinguished because the replacement cost of linear infrastructure such as roads is expressed in $/km (Table 14), whereas the replacement costs of punctual infrastructures are absolute values ($)(Table 15, Table 16 and Table 17).

Table 14. Replacement cost for roads

Surface	Replacement cost ($/km)
Dirt	100.000
Gravel	250.000
Sealed	500.000

Table 15. Replacement cost for bridges

Type	Replacement cost ($)
Concrete/Steel	10.000
Steel	10.000
Wooden	1.000
Causeway/Ford/Culvert (insensitive)	-

Table 16. Replacement cost for airstrips

Type	Replacement cost ($)
Airstrip	10.000

Table 17. Replacement cost for special infrastructure

	Maximum loss fraction	Replacement cost ($)	Equivalent PCRAFI
AIRPORT	0,5	100.000	Small airport
CHEMICAL	1	10.000	Storage tank
CROP	0	-	Counted in economic vulnerability
ELECTRICITY - Generator	1	1.000	
ELECTRICITY - Substation	1	500.000	

	Maximum loss fraction	Replacement cost ($)	Equivalent PCRAFI
FUEL	1	20.000	
MINE	0,5	10.000	Small mine
OTHER TRANSPORT	1	30.000	Bus station
PORT	0,5	5.000	Small port
PRODUCE	1	10.000	Storage tank
TELECOMMUNICATION	1	5.000	communication
UNKNOWN	0	-	
WASTE WATER - Treatment ponds	1	2.000.000	Water Treatment
WASTE WATER - Others	1	10.000	Storage tank
WATER - Treatment plant	1	2.000.000	Water Treatment
WATER - Pump station	1	40.000	Water intake
WATER - Others	1	10.000	Storage tank

For visualization, physical vulnerability is finally aggregated at the 2 x 2 km grid cell level, summing up potential damage for all buildings and infrastructures in it.

Since potential damage of a building/infrastructure is the product of sensitivity and replacement cost of this building/infrastructure, we can see this aggregation method as a weighted sum of sensitivity, using replacement costs as weights. Vulnerability depicted in a grid cell will naturally also depend on the number of buildings and infrastructures located in it.

This physical vulnerability index accounts only for the value of physical property and not for societal value or indirect damage that can be caused by the destruction of buildings. In particular, no weight is currently given to the different types of infrastructure other than their sensitivity factors and replacement cost. We might think that damage to some special infrastructure will generate bigger loss than the direct damage to the buildings and installations. More weight could be attributed to schools, aid posts, hospitals and police station that have a societal value that might exceed their replacement cost. This is not accounted for at the moment. Note as well that such buildings are likely to be reported in both the building and the special infrastructure databases.

It should be kept in mind that some infrastructures might overlap with economic indicators (mines, power plants, communications…). To avoid double counting, we assume that their economic sensitivity is approximated by their replacement cost and therefore already accounted for in the physical vulnerability. Economic sensitivity considers agricultural activities only. Doing so, indirect costs associated with the loss of commercial, social, communication and industrial infrastructure are ignored.

To produce an index easy to visualize, we can convert potential damage monetary estimates into an ordinal index. This vulnerability index can be obtained by reclassification, using a certain number of classes, and quantile, natural jenks or other bins.

In agreement with the uncertainty associated with the index and for good visual results, we choose to produce 5 classes (1 to 5).

Physical vulnerability is computed and shown only for a selection of pixels which contain exposed buildings or special infrastructures, or both. Vulnerability for the empty pixels is therefore considered as “no data” and does not appear on the map. Cells containing assets but with vulnerability equal to zero will, however, appear in blue shade (“very low vulnerability”).

To ensure consistency between cyclone and flood risk maps, classification is based on the same bins for flood and cyclone risk, using the flood layer quintiles as baseline.

Economic vulnerability

In order to include potential damage of a hazard to agricultural systems in the vulnerability index, the theoretical value of agricultural activities must be estimated. Replacement cost of each individual crop in the system are estimated based on the results of the PCRAFI study (PCRAFI 2013), using average values. The vulnerability of a crop towards a certain hazard is obtained by combining their value and sensitivity (i.e. tolerance score). The overall average vulnerability of the system is the weighted average of all vulnerabilities of represented crops, according to their relative importance.

For each crop in an agricultural system, vulnerability towards a hazard is described as the potential damage caused by the hazard to the crop, in $/ha.

Replacement costs considered for staple crops, vegetable, fruit, nuts and narcotics in agricultural systems are the estimates for subsistence agriculture. Replacement costs for cash crops in each system and for plantation crops are the estimates for commercial agriculture.

Crop vulnerability has then to be aggregated for each agricultural system, making assumptions on the importance of each crop in the system. The aggregation is additional, using a weighted sum of the represented varieties.

There is some subjectivity in the weights as no precise information about the surface area effectively covered by each crop in the system was available. According to the significance of the “dominant” and “sub-dominant” descriptors, we assume the following hypotheses in order to determine the weights:

- Weights for dominant crops should have a minimum of 0,33 (one third)
- Weights for subdominant crops should have a minimum of 0,1 and maximum of 0,33 (one third)
- Weights for other present crops should be below 0,1

In order to give each system the same total weighting, regardless of the number of varieties represented in it, weights were adjusted as to reach a total of 100 %, with as consequences that:

- Weight for one dominant crop will be higher if it’s the only dominant crop (with other crops being equal)
- Weight for one subdominant crop will be higher if it’s the only subdominant crop
- The sum of weights for all represented crops should be equal to 100%, whenever possible given the other assumptions

Additionally, certain cash crops are mentioned as part of some agricultural systems (Cocoa, Coffee Arabica, Coffee Robusta, Oil Palm, Rubber, Chillies and Coconut), with only qualitative information on their importance: “none”, “minor or insignificant”, “significant”, “very significant”. These cash crops are taken into consideration only for significant and very significant cash crops in the system. When weighting the composite index, significant and very significant are assumed equivalent to subdominant staple crops (in terms of importance), with a weight between 10 and 33 %.

Based on these assumptions, weights are determined for dominant, sub-dominant (and cash crops) and other crops in each system.

Table 18. Weighting of crops in agricultural systems

	Weight dominant crops	Weight subdominant (and cash) crops	Weight other crops
Average (all systems)	0.43	0.15	0.01

Minimum	0.28	0.1	0.003
Maximum	86	0.33	0.023

It is not always possible to fulfil both the conditions of minimum 1/3 weigh for dominant staple crops and 100 % total of weights. Therefore, the weight for dominant crops is sometimes as low as 0.28 (instead of 0.33) in some cases (Table 18).

For the special case of plantations, only one variety is determined based on the Land Use/Land Cover layer, and a unique sensitivity is given for the whole area (w = 100%). Zones designated as plantation in the MASP but where no crop could be associated were ignored.

For drought, high rainfall and extreme weather, risk can be computed based on the vulnerability of each system/plantation as whole. The economic vulnerability of a grid cell is the one associated with the system with the largest surface area, if more than one.

In the case of inland flooding, because the flood zone resolution is much higher than 2km, only the vulnerability of the flooded portion of the agricultural system inside each grid cell is taken into account: MASP systems and plantations are intersected with flood zones to determine exposure of the agricultural areas.

The resulting vulnerability index can be expressed in $/ha but does not represent total potential monetary loss because no information was available about the exact surface area covered by each crop : the surface area of each system/plantation does not mean effective “garden surface area”. The MASP layer is an approximate representation of the zones where the described agricultural systems are the most representative. As a consequence, the vulnerability indexes only have a relative meaning.

The vulnerability value calculated above is expressed in $/h but has no meaningful monetary units because there is not enough information on crop and garden area, rotations etc. It is therefore reclassified into 5 manually-defined categories to allow a contrasting visualization. Categories are the same across all provinces and for all hazards (Table 19).

Table 19. Economic vulnerability reclassification

Potential damage class ($/ha)	**Economic vulnerability**
< 1000	Very low
1000 - 1500	Low
1500 - 2000	Medium
2000 - 3000	High
> 3000	Extreme

Figure 3 shows the distribution of MASP polygons in the five categories. The maximum at 12,037 $/ha in Figure 3 corresponds to the oil palm plantations and appears as considerably more sensitive than other systems because of the high replacement cost of commercial oil palm plantations (in opposition to subsistence replacement cost).

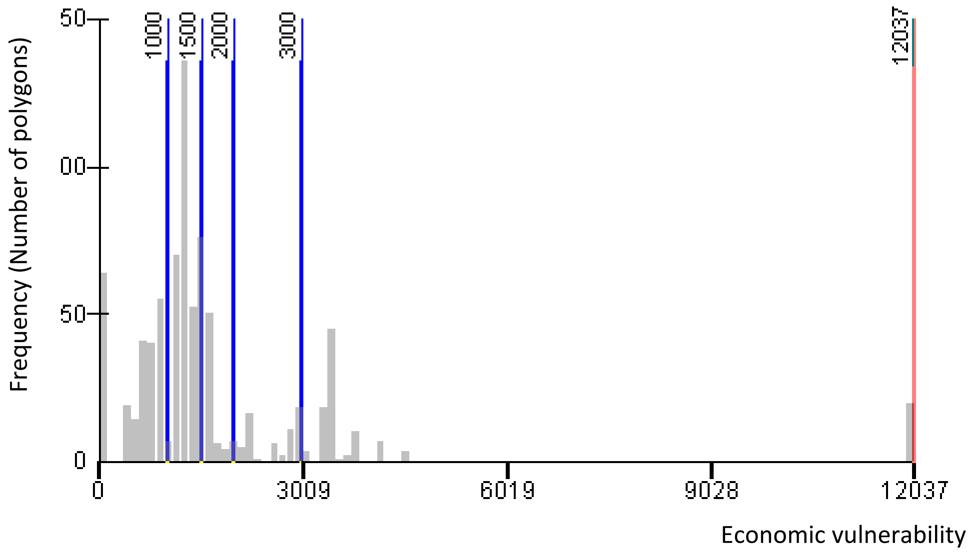

Figure 3. Frequency distribution of agricultural systems (MASP) and plantations vulnerability to extreme weather

This reclassified composite agro-economic vulnerability index can then be mapped based on the agricultural and plantation polygon of the MASP geo-database. Indexes are reclassified the same way for agricultural systems and for plantations in all the provinces, and for all hazards.

Because the polygons are much bigger than 2 x 2 km pixels, it was not deemed necessary to rasterise them at this stage. Agro-economic vulnerability values will however be associated to grid cells in the following steps, in order to compute the total vulnerability index combining physical, social and economic dimensions

Symbology

All mapped indices can be expressed qualitatively in terms of a hazard-dependent index scaled into three or more classes. Vulnerability and risk indices are classified according to 5 categories: very low, low, medium, high and extreme (Figure 4).

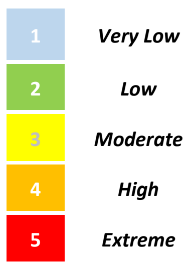

Figure 4. Vulnerability and risk classes

1.2.3. Risk assessment

Risk is defined by the United Nations International Strategy for Disaster Reduction as the combination of the probability of a hazardous event and its negative consequences which result from interactions(s) between natural or man-made hazard(s), vulnerability, exposure and capacity (UNISDR 2009).

Once the three vulnerability components (physical, economic and social) computed and mapped, risk is calculated as the product of the hazard index and the vulnerability index (Equation 3).

$$Risk = Hazard\ x\ Vulnerability$$

Equation 3. Risk calculation

Once the three vulnerability components (physical, economic and social) computed and mapped, risk is calculated as the product of the hazard index and the vulnerability index. A risk matrix allows consistent reclassification of the product operation between hazard and vulnerability.

Continuous hazard indicators are reclassified into five classes whenever possible, for consistency with vulnerability classes, and to smooth a bit more of the spatial variability of hazard levels (using only three classes, all provinces sometimes end up in the same category). The risk matrix becomes thereafter:

Hazard Potential damage	Vulnerability	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Very likely (5)
Insignificant (1)	Very Low	1	2	3	4	5
Minor (2)	Low	2	4	6	8	10
Moderate (3)	Medium	3	6	9	12	15
Major (4)	High	4	8	12	16	20
Severe (5)	Very High	5	10	15	20	25

1.2.4. *Composite risk*

The overall composite risk map for the province has been derived from the risk maps for the respective hazards as presented in the previous chapter.

The map indicated areas that are exposed to multiple risks. To count the number of risks per pixel on the map, risks occurrence with values moderate, high or very high were counted. This results in the following categories. The area that are exposed to some very low of low risks for one or more hazards have received a value ‘0’, areas that are not coloured on the map have not been characterised at risk for any of the considered hazards. All areas with a values 1 to 5 are have been identified as having a moderate (or higher) risk for 1 to 5 hazards. An example is shown in Figure 5.

Note: the maps in this report will be updated to count for coastal risk, at the moment this is not included and the maximum value on the map therefore is 4 and not 5.

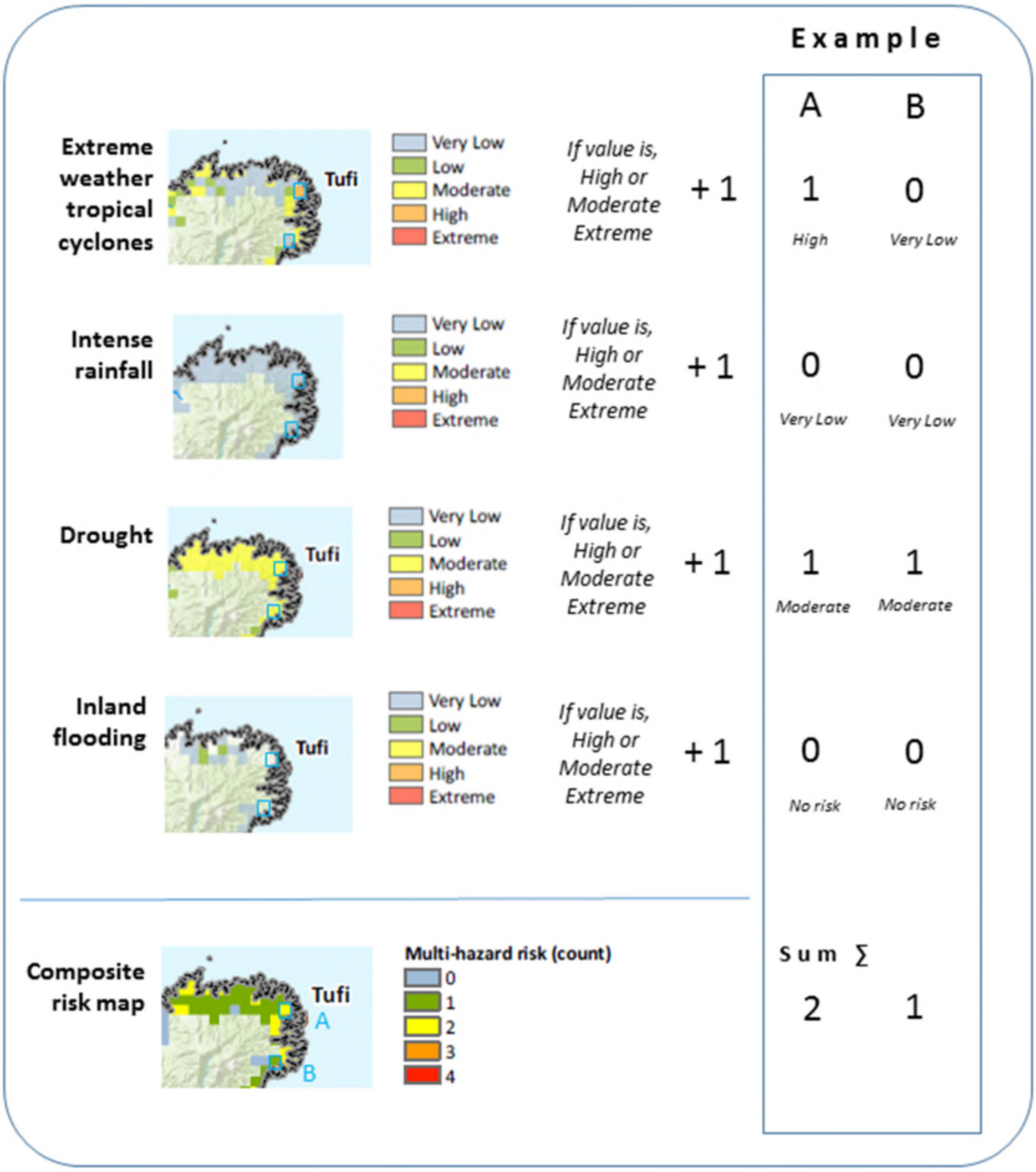

Figure 5. Example calculation of composite risk

1.3. Baseline information of New Ireland Province

1.3.1. Administrative

The New Ireland Province is a set of islands and is the most north eastern province of Papua New Guinea neighbouring the New Britain Island. It has the city of Kavieng as its provincial headquarters. It belongs to the Islands Region and it is composed from a total of two districts: Kavieng District and Namatanai District. Each district is in turn divided into Local-Level Government Areas (LLGs). There are a total of 10 LLGs in New Ireland Province.

Table 20. Number of wards per LLG

District	LLG	Number of wards	
Kavieng District	Murat Rural	6	48
	Lovongai Rural	19	
	Tikana Rural	19	
	Kavieng Urban	4	
Namatanai District	Namatanai Rural	21	90
	Sentral Niu Ailan Rural	22	
	Konoagil Rural	17	
	Tanir Rural	14	
	Nimamar Rural	16	
	Matalai Rural	0	

Figure 6. Administrative map New Ireland province

1.3.2. *Topography*

New Ireland Province is the most north eastern province of Papua New Guinea and it is composed of several islands. As described in the National Research Institute's *Papua New Guinea: District and Provincial Profiles* (2007), the New Ireland Province includes the main island of New Ireland as well as the Saint Matthias and East Islands to the north and the Tabar, Lihir, Tanga and Feni Island groups to the east.

Figure 8 shows the main rivers flowing through New Ireland Province. The most important river systems are Lossuk and Lumis of north-western New Ireland .

Figure 9 show the slope map for New Ireland Province. The slopes map is obtained by classifying the digital elevation model into three classes as presented in Table 21.

Table 21. Slope classes an occurrence in New Ireland Province

Slope (%)	Code
0-5	1
5-10	2
>10	3

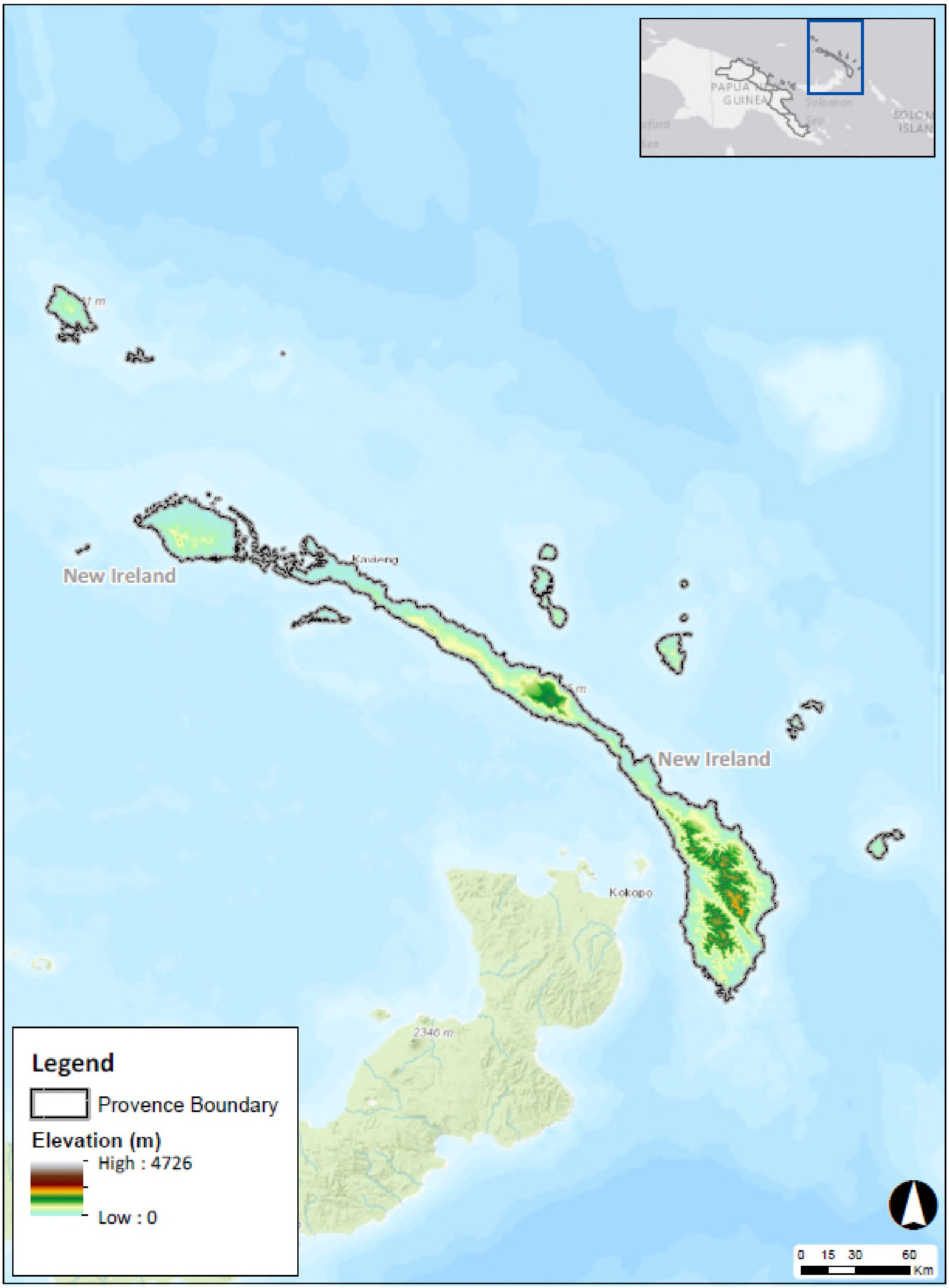

Figure 7. Elevation map of New Ireland Province

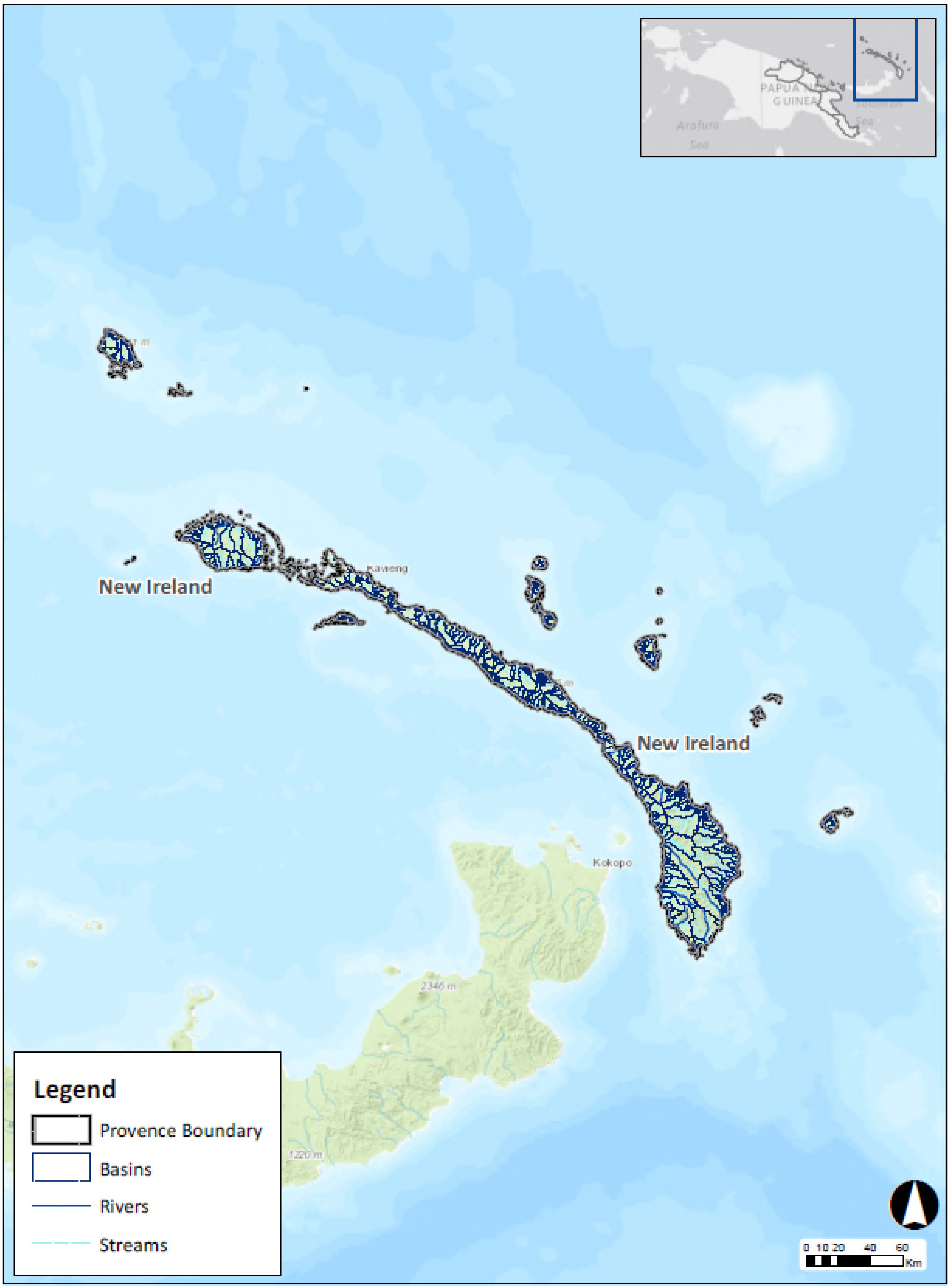

Figure 8. Main rivers found in New Ireland Province

Figure 9. Slopes classification map for New Ireland province (from DTM, from SRTM-3, 90m).

1.3.3. Land use / land cover

Figure 10 show the soil cover map for New Ireland Province. The largest part of the province is classified as 'other' which is mostly forest or other uncultivated land. These parts of the province are very sparsely populated. About 46% of the province is marked as agriculture.

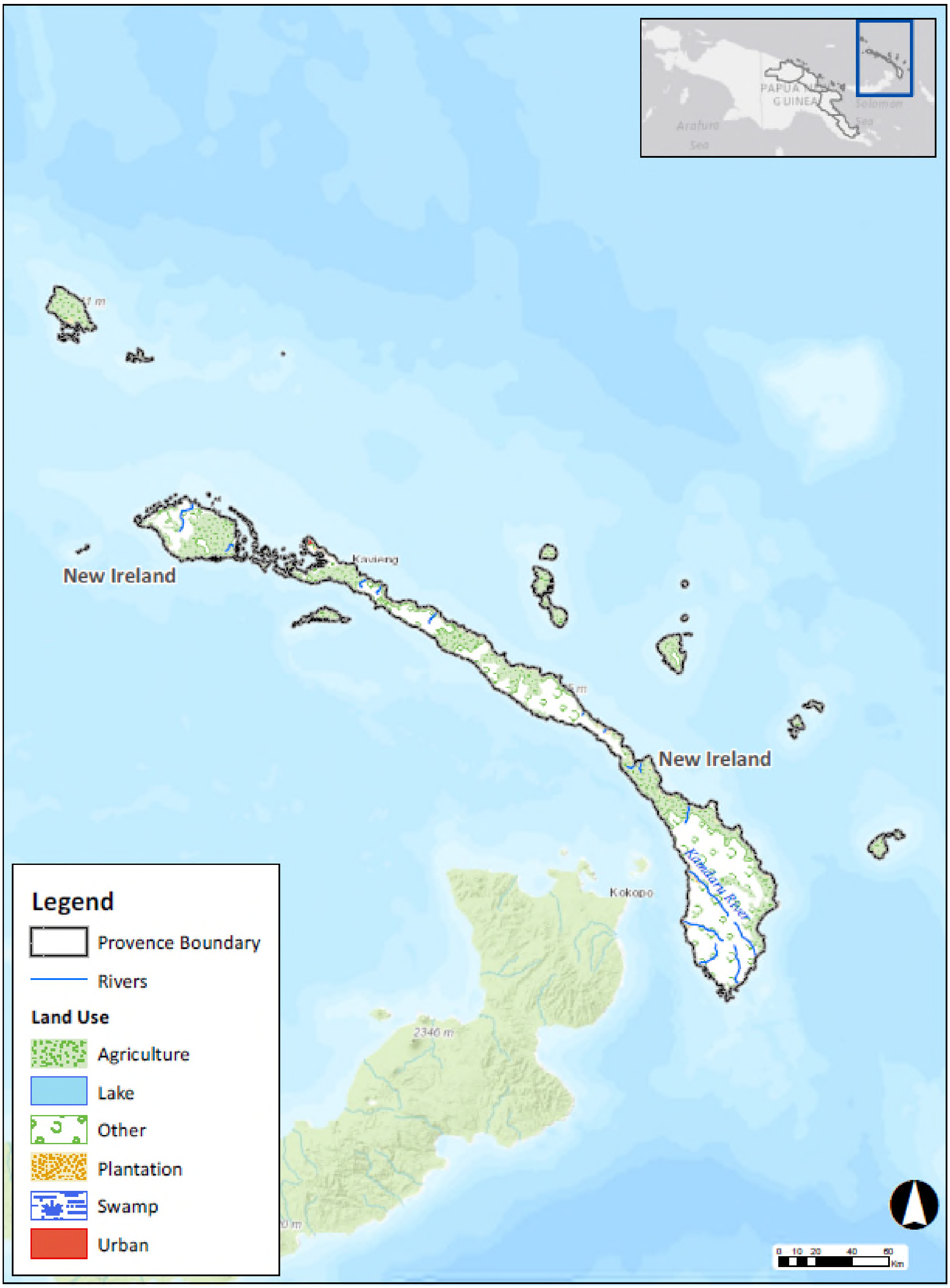

Figure 10. Land Use map New Ireland Province

1.3.4. Population and health

The New Ireland Province has a total of 194,067 inhabitants and 29,634 households according to the 2011 national census. It comprises the 2,7% of PNG's total population and has an annual growth rate of 4,5% for the period 2000-2011. The province consists of two districts, Kavieng and Namatanai. The district with the highest population count is Namatanai with 110.905 inhabitants.

The population density is 13.7 inhabitants per km^2, somewhat higher than the national average of 11. The average household size in the province is 6.5 persons.

Table 22. Population numbers per age group and per district

District	Age Group				
	Age not stated	0 - 4 yr	< 15 Yrs	15-64 yrs	> 65 yrs
Kavieng District	207	11,691	34,799	44,504	2,212
Namatanai District	251	14,982	44,974	59,721	2,505

The more densely populated LLGs are Lae Urban and Wae Bulolo Urban, followed by Ahi Rural which is situated along the coast in the vicinity of Lae. This can be seen in Figure 11.

The adult literacy rate for the province is 77.4%, which is relatively high and significantly higher than the national average of 67.6%.

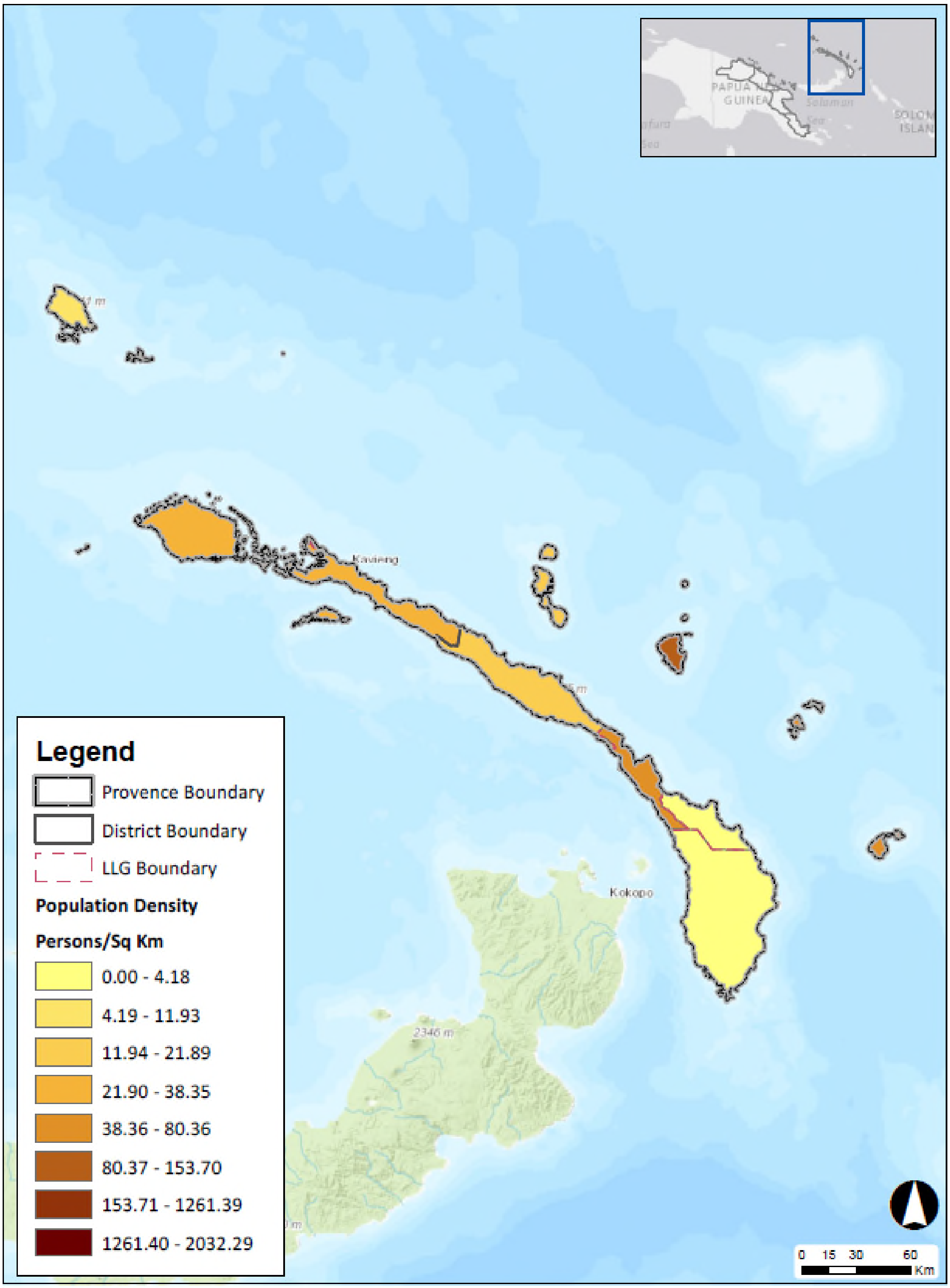

Figure 11. Population density map of New Ireland Province

Selected health indicators taken from the health performance report 2010-2014 for the province and its respective districts are shown in the Table 23, together with the national average.

Table 23. Selected Health Indicators for New Ireland Province (2014)

District	Low Weight for Age < 5 years old (%)	Low Birth Weight (%)	Incidence of Malaria (1,000 pop.)	Incidence of Diarrhoea (<5 years/1,000 pop.)
Kavieng	25	7.3	122	159
Namatanai	24	5.6	156	149
New Ireland	**24**	**6.4**	**141**	**153**
National	**24**	**7.7**	**108**	**291**

Figure 12 shows the locations of health centers and aid posts in the province. There are a total of 35 aid posts and 30 health centres in the province. The percentage of children weighed at clinics is less than 80% of the normal weight for their age in New Ireland Province during the period from 2010-2014.

In 2014, Kavieng District had 7.3% of low birth weight children in New Ireland Province, it's lower than provincial and national averages of 11% and 7.7%. This district had also the highest number of recorded cases of malaria. Namatanai District had the highest reported incidence of diarrhoea in children under 5 years old. So, Kavieng District displays the highest sensitivity on health indicators, but not by a significant margin.

Table 24. Number of Healthcare facilities per District

District	Aid posts	Health centres
Kavieng District	10	13
Namatanai District	25	17

Figure 12. Location of health centers and aid posts in New Ireland Province

1.3.5. Infrastructure

Figure 13 shows the main road network in the province. The main roads classified as highway of national roads are connecting East to West parts of the island. A large part of the province is not easy accessible by road.

Table 25 Kilometers of roads in New Ireland

	Highway	National Road	Provincial road
Km of roads in New Ireland	533.05	261.21	306.76

Table 26 Number of bridges in New Ireland

District	Number of bridges
Kavieng District	3
Namatanai District	0

Table 27 Total of public establishment

District	Aid posts	Health centres	Police stations	Airports	Schools	Religion	Government	Public facility
Kavieng District	10	13	4	2	38	68	103	69
Namatanai District	25	17	4	1	96	100	132	91

Figure 13. Road infrastructure in New Ireland Province

1.3.6. Agriculture and livelihood

Economy in New Ireland Province, similarly to other provinces in Papua New Guinea, is strongly characterized by its agrarian nature. As an agrarian society, 80% of the people in PNG grow the food they eat while also growing cash crops. Most inhabitants of New Ireland Province rely on mature-age coconut plots and cocoa trees although many are also involved in the oil palm industry, particularly in the Kavieng district. Also, Kavieng mud crabs have become a very popular export product along with fish caught in New Ireland's vast Exclusive Economic Zone (EEZ) of about 230.000 square kilometres.

Most people on the main island and from Lavongai can earnhigh incomes from the sale of copra, cocoa, oil palm, fish and food. However, the very south of the island and the island groups off-shore earn lower incomes. Wage-earning opportunities are available in Kavieng while significant incomes are available from wages and royalties from the Lihir Goldmine.

2. PROVINCE RISK PROFILE

2.1. Hazard Assessment

In this chapter we discuss the results of the analysis of climate data and projected climate, and we discuss the hazard maps produced for Norther Province for the five climate hazards considered in this study:

- Inland flooding (as a function of precipitation)
- Coastal flooding due to sea level rise
- Drought (as function of temperature and precipitation)
- Extreme weather events (tropical cyclones)
- Increase of precipitation intensities and variability

Hazard maps for each of the five hazards listed above indicate the areas likely to be affected by the hazard and provide an indication of its relative intensity.

2.1.1. Current and future climate

A brief review on Papua New Guinea's current climate and future prospections is available in the regional overview publication from International Climate Change Adaptation Initiative (ICCAI) (2011)[4]. The content of the publication is the result of a collaborative effort between the Papua New Guinea National Weather Service (NWS) and the Pacific Climate Change Science Program – a component of the Australian Government's International Climate Change Adaptation Initiative.

The key conclusions of the report are:

- Observed air temperatures depict a steady increase; it is expected that they will continue to warm resulting in more very hot days in the future.
- Rainfall observations since 1950 at Port Moresby do not show a clear trend, but observations at Kavieng seem to show a decrease in wet season. Projections on rainfall patterns, show an increase over this century with more extreme rainfall days expected.
- Tropical cyclones are not very frequent in the country; projections depict a further decrease on number of tropical cyclones with a slight increase in their intensities.
- Sea level observations have shown a clear rise in the recent past. This tendency will continue throughout this century.

Furthermore, the analysis of existing climate data and projected climate change reveals the following information:

- Based on observations carried out in Port Moresby since 1950, it can be concluded that a steady warming, averaging ~0.1 °C/decade, is taking place. Over the next decades, temperature is projected to continue to increase, with a projected warming of 0.4-1 °C by 2030 under a business-as-usual emissions scenario. By 2050, under such a scenario, a 1.1 – 1.9 °C warming is projected. Over the next 30-50 years, increases in the average temperature will result in more very hot days, with potentially severe impacts on agriculture and human health.

[4] Climate Change in the Pacific: Scientific Assessment and New Research. Volume 1: Regional Overview. Volume 2: Country Reports. Available from November 2011

- The limited available information on precipitation reveals that there is no clear long-term historical change in rainfall in Port Moresby, although elsewhere there has been a slight decrease. In line with expectations globally, precipitation is projected to increase in response to the warming of the atmosphere. More extreme rainfall days are expected, likely contributing to increasing frequency of inland flooding. The regional pattern and magnitude of the increase is, however, highly uncertain.
- Overall, trends in both rainfall and temperature are dwarfed by year-to-year variability.
- On a global scale, the frequency of tropical cyclones is projected to decrease overall, but the frequency of high intensity cyclones is projected to increase. The projections for PNG are consistent with global projections, with fewer but more intense storm events expected.
- Sea level rise is a serious consequence of climate change for Papua New Guinea. Under a business-as-usual scenario, by 2030, sea level in PNG is expected to rise2 by 4-15 cm. Combined with natural variability, such a rise would increase the impact of storm surges and the risks of coastal flooding. It is notable that these projections could be underestimations, due to uncertainties in projections of ice sheet melt.
- In addition to changes in climate, changes in land use may affect flood risk, for example through changes to catchment scale runoff and patterns of inundation. Since 1990, there has been a small degree of deforestation (reduction of forests from 31,523 KHa in 1990 to 29,159 KHa in 2007) and an increase in land used for agriculture (877,000 Ha in 1990 to 1,040,000 Ha in 2007). Changes in coastal land use may affect the risk and impacts of tidal flooding.

2.1.2. *Inland flooding*

The most relevant flooding features within the province are described in the following paragraphs. The description follows the river systems reaching the coastline from North to South.

The map for inland flooding hazard of the province of New Ireland shows mostly flooding zones with a 5 year return period, but there is also a considerable amount of 10 year return period in the north western half of the province and 50 year return period around Namatanai, around Konos and scattered throughout Kavieng District. (Figure 14)

Projections for the future do not show much change. (Figure 15). The table below gives the flood areas (km²) for current and future climate conditions in the New Ireland province.

Table 28 Flood areas (km²) for current and future climate

New Ireland	HND	H40
T 0-5y	284.7	284.9
T 5-10y	0.1	0.1
T 10-50y	0.3	0.4
Total	285.1	285.4

During the community risk assessment (CRA[5]), 4 communities were visited in the New Ireland Province: Manggai, Patiagaga, Sohun and Kaluan.

[5] All communities are reported to suffer regular inland flooding events in their respective CRAs. While the estimated flood maps reported here are a good indication of their extension, they use a SRTM with resolution too coarse for ensuring the flood extensions at community level.

Flooded areas are observed around the Manggai community, as expected along the banks of the Manggai River, according to what is mentioned in its CRA[6].

Flooded areas are observed around the Patiagaga community, along the banks of the Virung river, according to what is mentioned in its CRA[7].

Flooded areas are observed around the Sohum community, along the banks of the Lang and the Benatu creeks, according to what is mentioned in its CRA[8].

Flooded areas are observed around the Kaluan community, along the banks of the Kaluan river and the road, according to what is mentioned in its CRA[9].

[6] Report Community Risk Assessment, Manggai Village, Tikana LLG, Kavieng District, New Ireland Province, Papua New Guinea

[7] Report Community Risk Assessment, Patiagaga Village, Lovongai LLG, Kavieng District, New Ireland Province, Papua New Guinea

[8] Report Community Risk Assessment, Sohun Village, Namatanai LLG, Namatanai District, New Ireland Province, Papua New Guinea

[9] Report Community Risk Assessment, Kaluan Village, KonosLLG, Namatanai District, New Ireland Province, Papua New Guinea

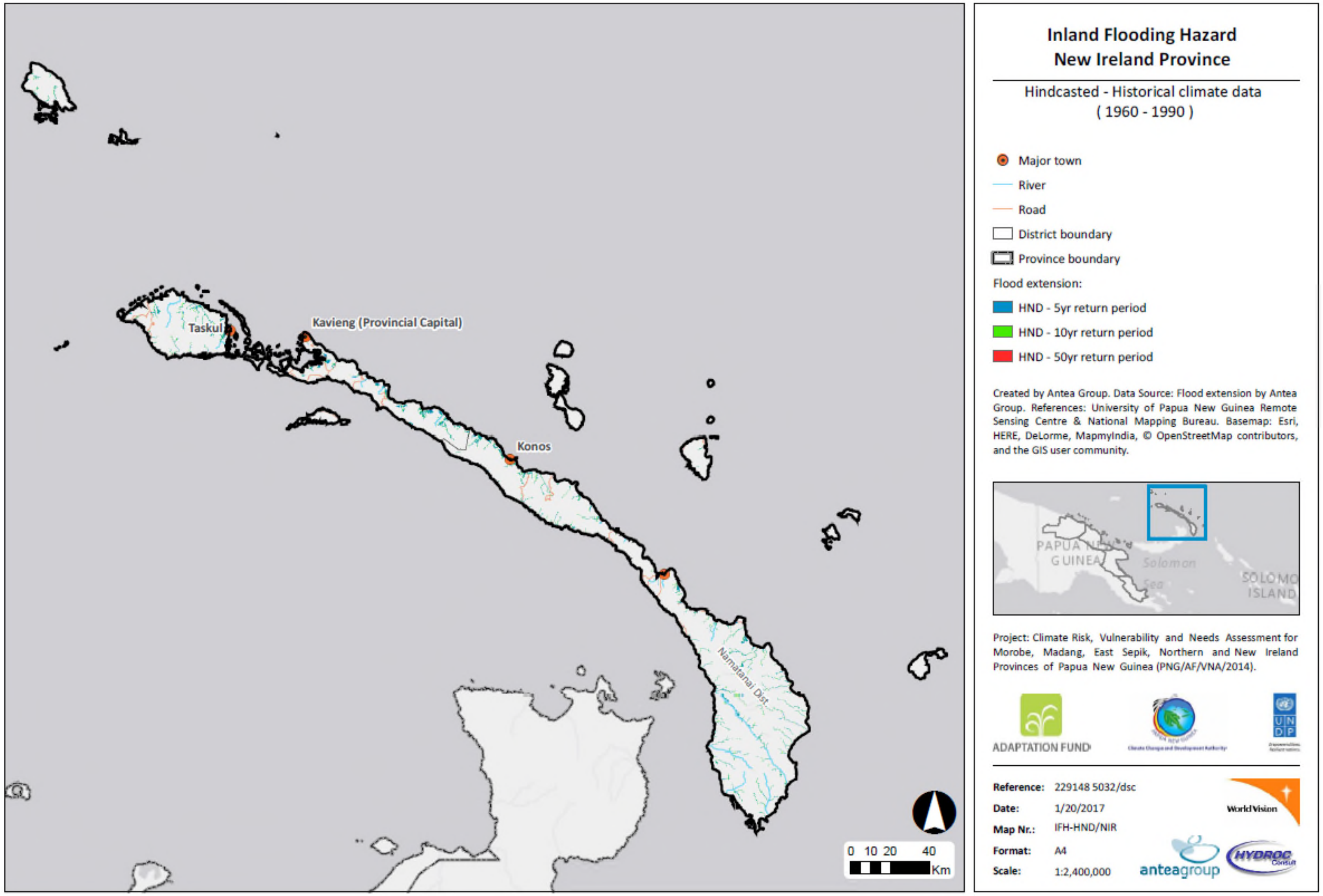

Figure 14. Inland flooding (current climate) ■ flooded

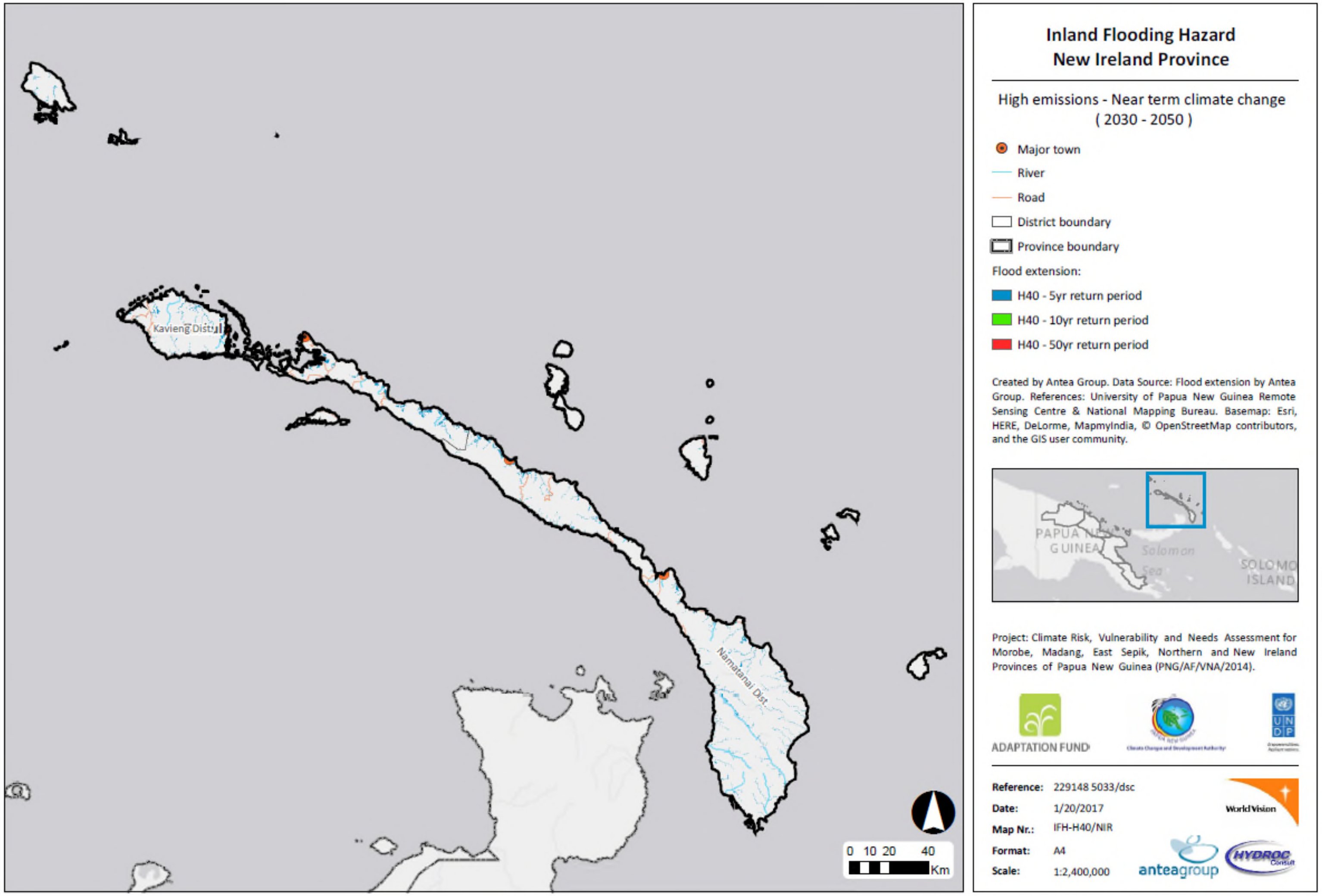

Figure 15 Inland flooding (projected climate) ■ flooded

2.1.3. Coastal flooding

The coastal flooding analysis estimated water levels for different return periods for the existing and projected sea level. The available coarse (20 x 20 m) topographic information (SRTM) did not allow to explicitly map the coastal flooding hazard for the province. In order to asses which coastal areas would be most prone to flooding a detailed survey of the coastal zone (LIDAR) is recommended; the survey would provide a reliable description of the topographical relieve.

Another major limitation is the lack of quality, long-term water level measurements tied to a consistent (known) vertical datum that is the same as the vertical datum of the DEM.

2.1.4. Drought

The map of drought hazard shows that the nothrwestern part of the province is the driest , with 26 continuous dry days in the island of Mussau and it gradually decreases to the south east, reaching the 16 continuous dry days in the southernmost point of Namatanai District. (Figure 16)

Projections show that the province will be less dry in the near future, with values that will range the 22 to 15 continuous dry days in a similar pattern as nowadays. (Figure 17)

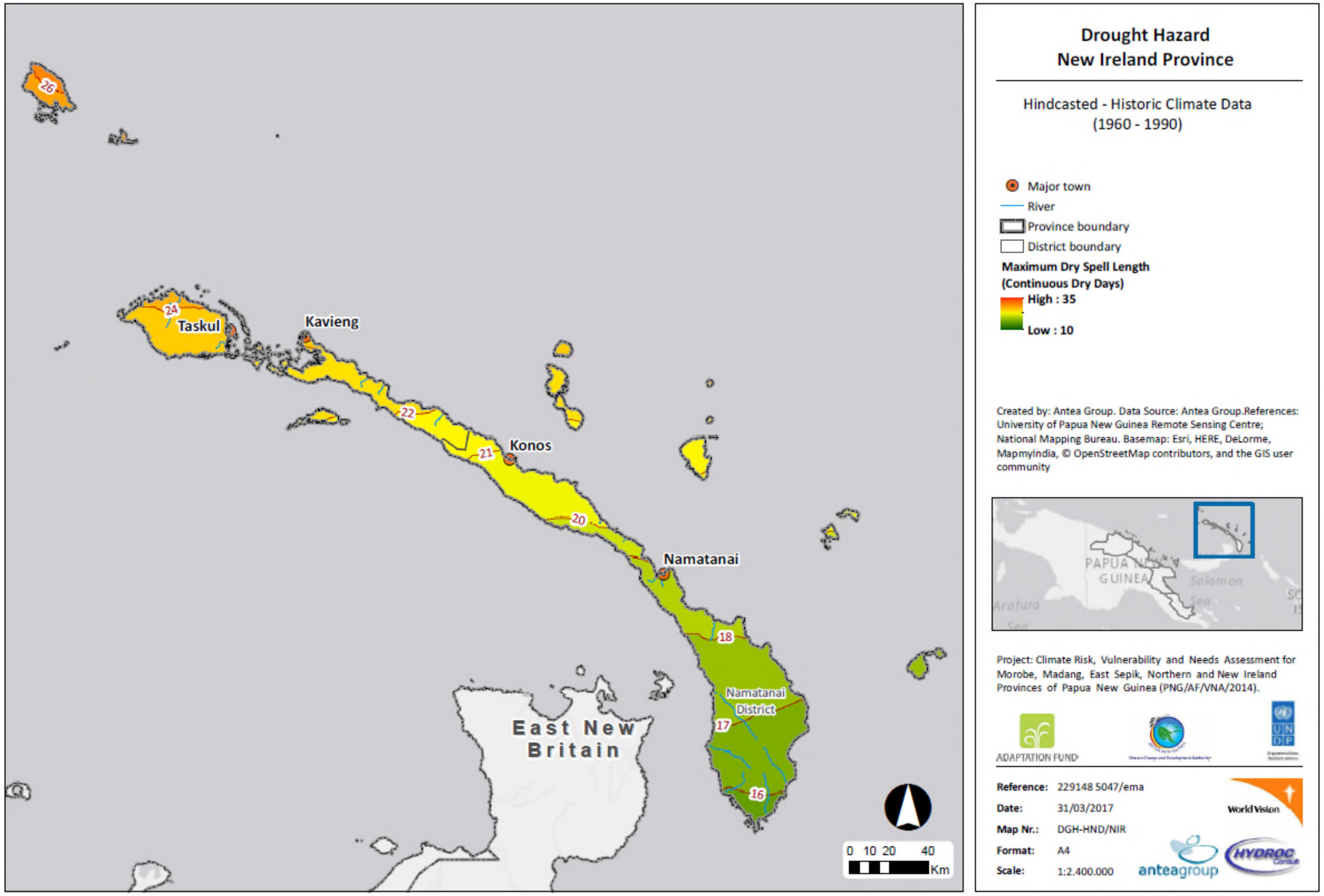

Figure 16. Drought (current climate) expressed as number of continuous dry days 10-16 16-21 21-24 24-29 >29

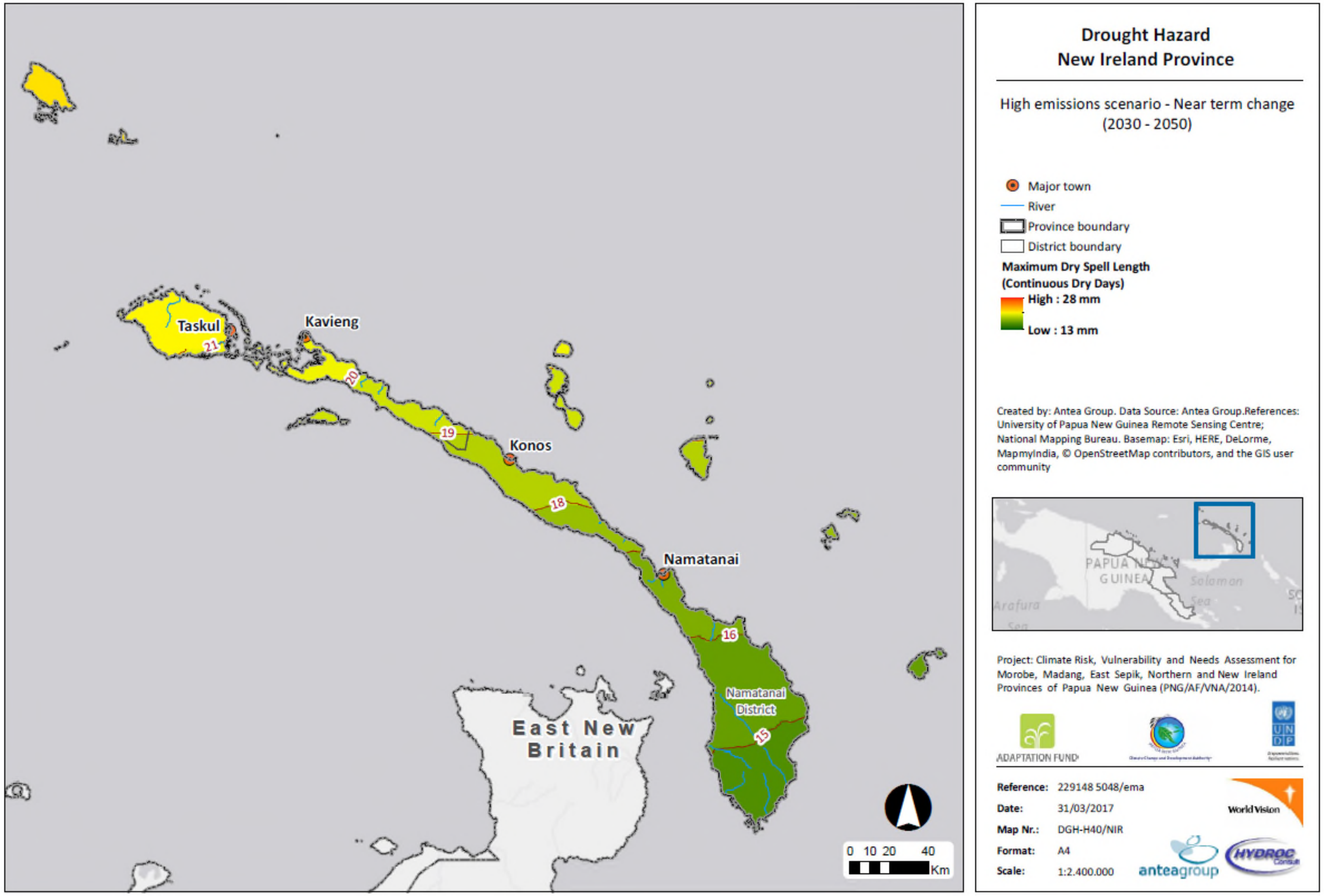

Figure 17. Drought (projected climate) expressed as number of continuous dry days 10-16 16-21 21-24 24-29 >29

2.1.5. *Extreme weather events (tropical cyclones)*

New Ireland Province is not prone to cyclones. This is illustrated in maps on the next pages.

Cyclone hazard is expressed as a number N which is the number of cyclone passes over a grid cell (0.5 degree grids) over a observed historical period 1970-present (the average diameter of cyclones with destructive wind speeds is assumed as 2 degrees).

Under existing climate conditions, there is no registered tropical cyclone event in this province during the observed period (count =0 in Figure 18) and neither is it foresee in the projections for the future scenario (Figure 19).

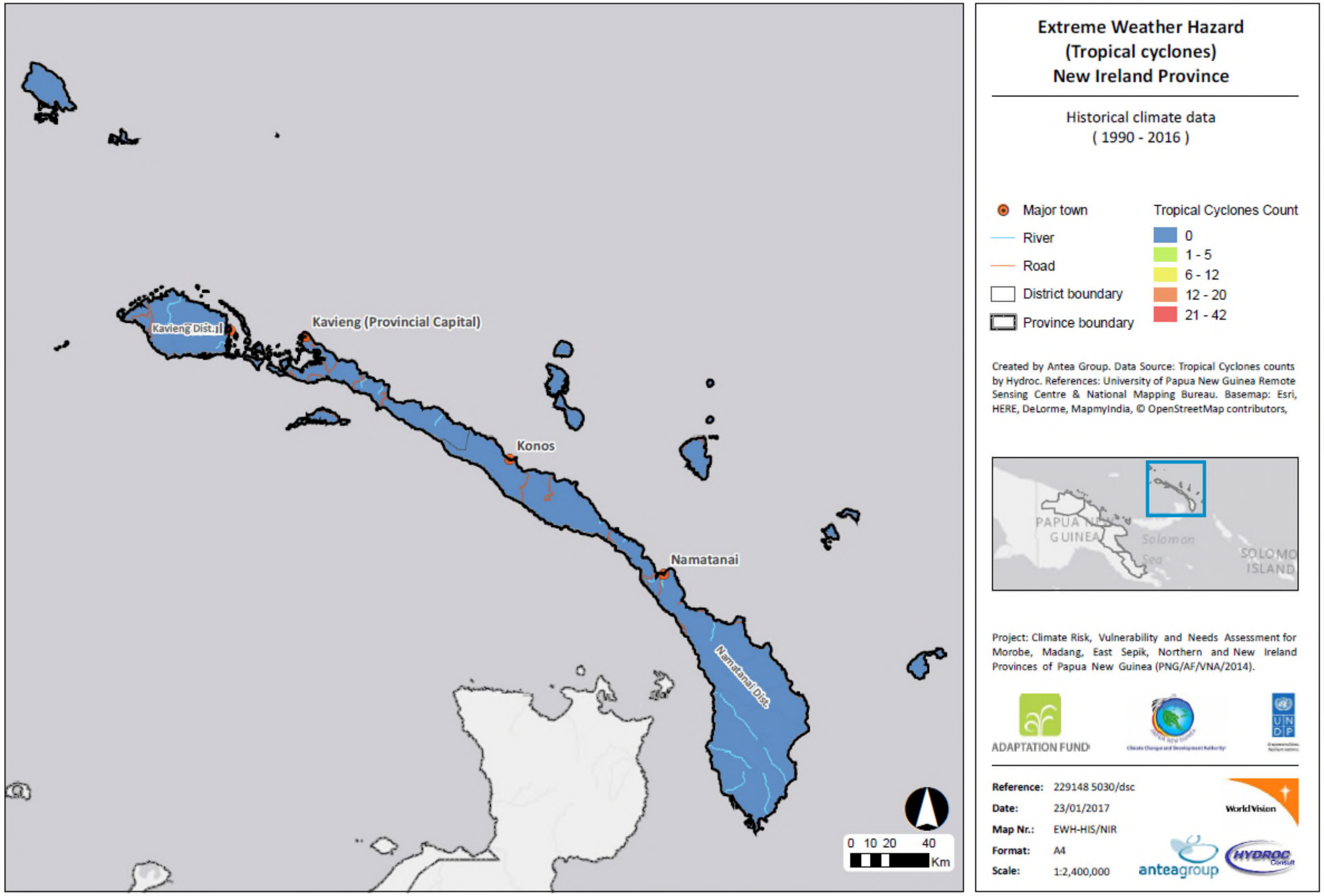

Figure 18. Tropical cyclones (current climate) as number of cyclones ■0 ■1-5 ■6-12 ■12-20 ■>21

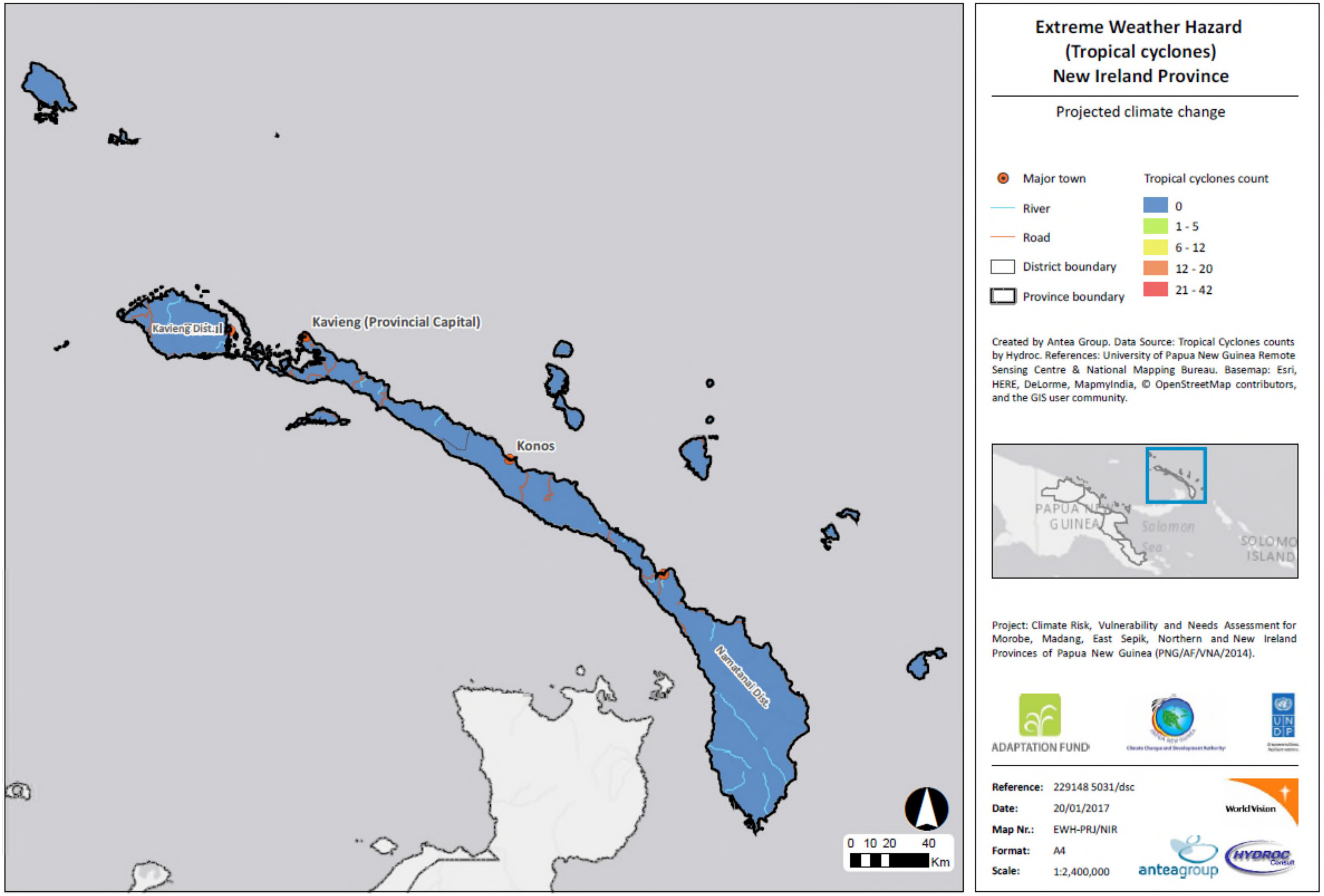

Figure 19. Tropical cyclones (projected climate) as number of cyclones ■0 ■1-5 ■6-12 ■12-20 ■>21

2.1.6. *Increase of precipitation intensity and variability*

The map for intense rainfall hazard for New Ireland shows that the province has low rainfall values to the north west (2600mm) and it gradually increases to the south east, reaching the 3000mm. (Figure 20)

Projections for the future show a slight increase, with values that will range the 2800mm to the north west up to the 3200mm in the south east. (Figure 21)

When it comes to talk about total rainfall on wet days, once more, the values are currently lower to the north west (around 480mm) than the south east (around 620mm). (Figure 22)

Projections show that rainfall intensity will increase in the near future with values that will range 600mm in the north west to 720mm in the south east. (Figure 23)

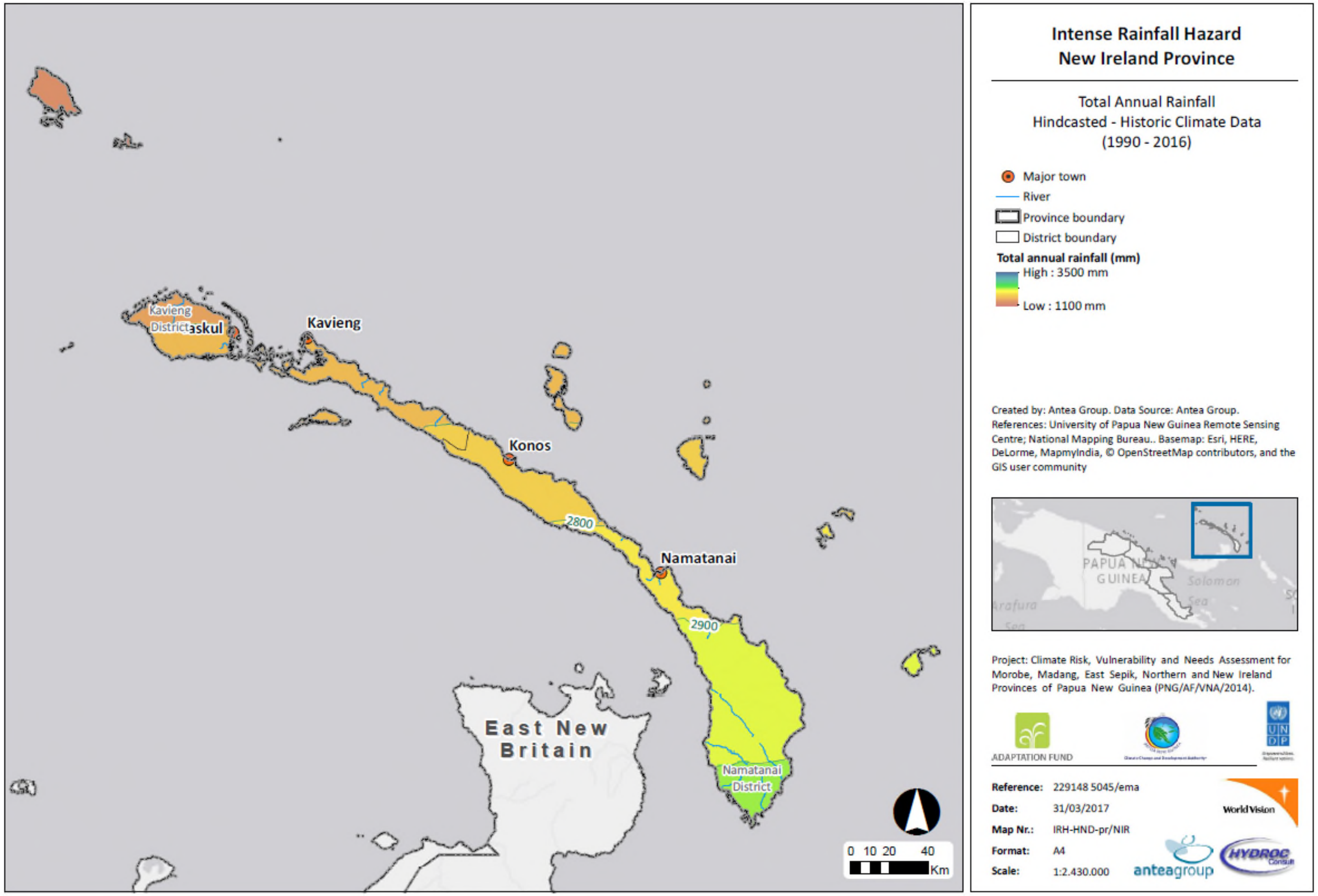

Figure 20. Total annual rainfall in mm (current climate) 1135-2078 2079-2710 2711-2979 2980-3280 3281-3777

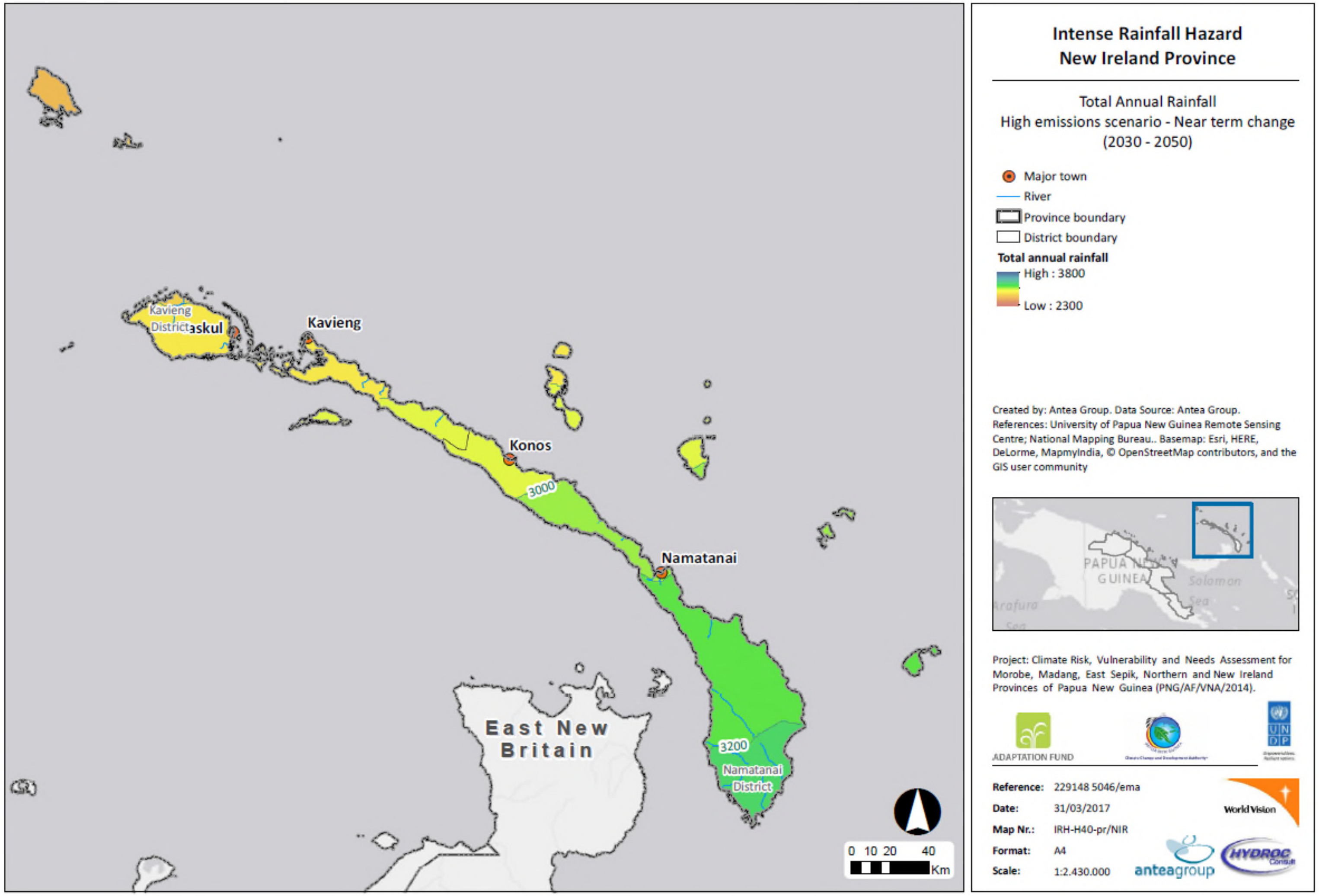

Figure 21. Total annual rainfall in mm (projected climate) 1135-2078 2079-2710 2711-2979 2980-3280 3281-3777

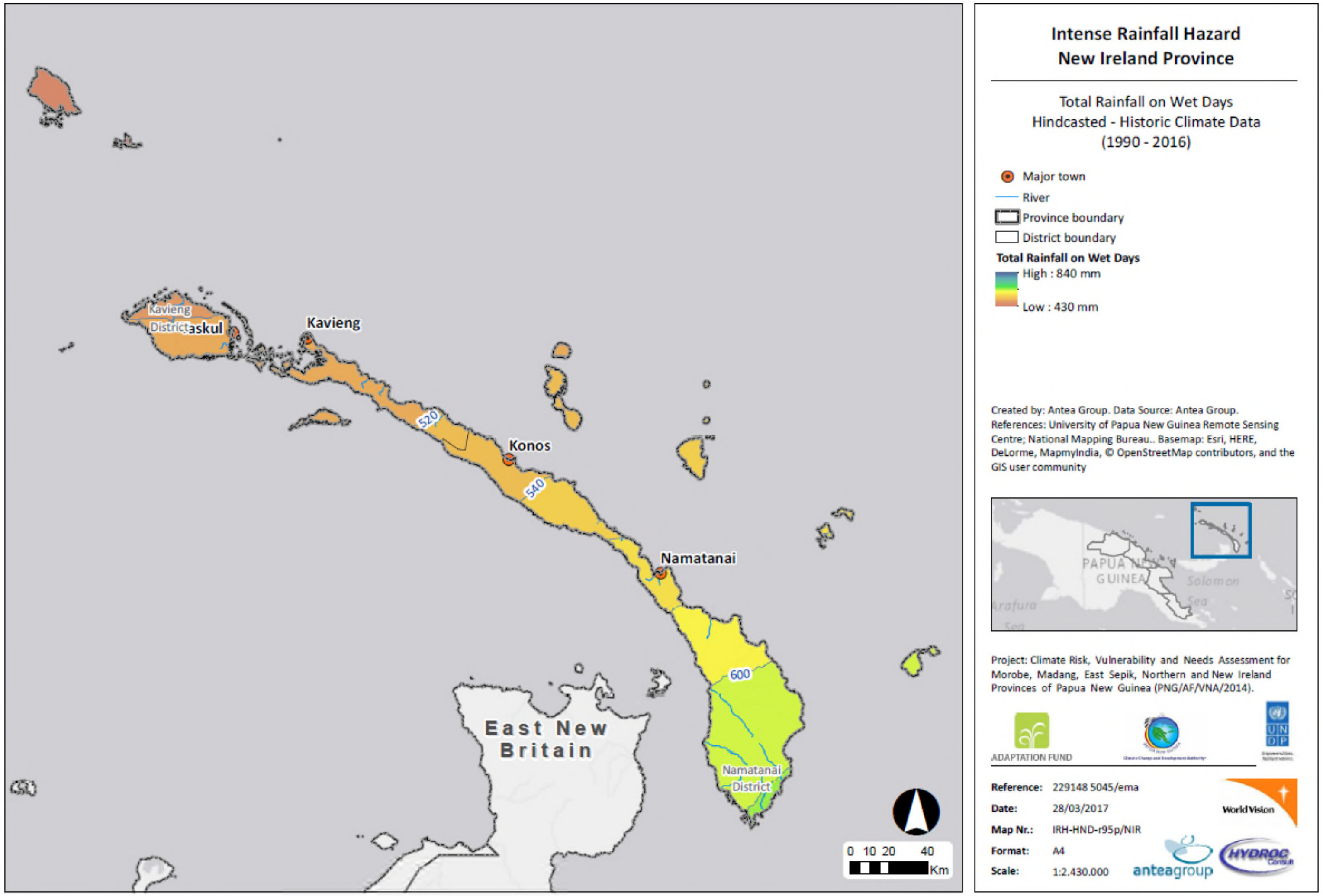

Figure 22. Rainfall on wet days in mm (current climate) 250-500 501-600 601-700 701-800 801-900

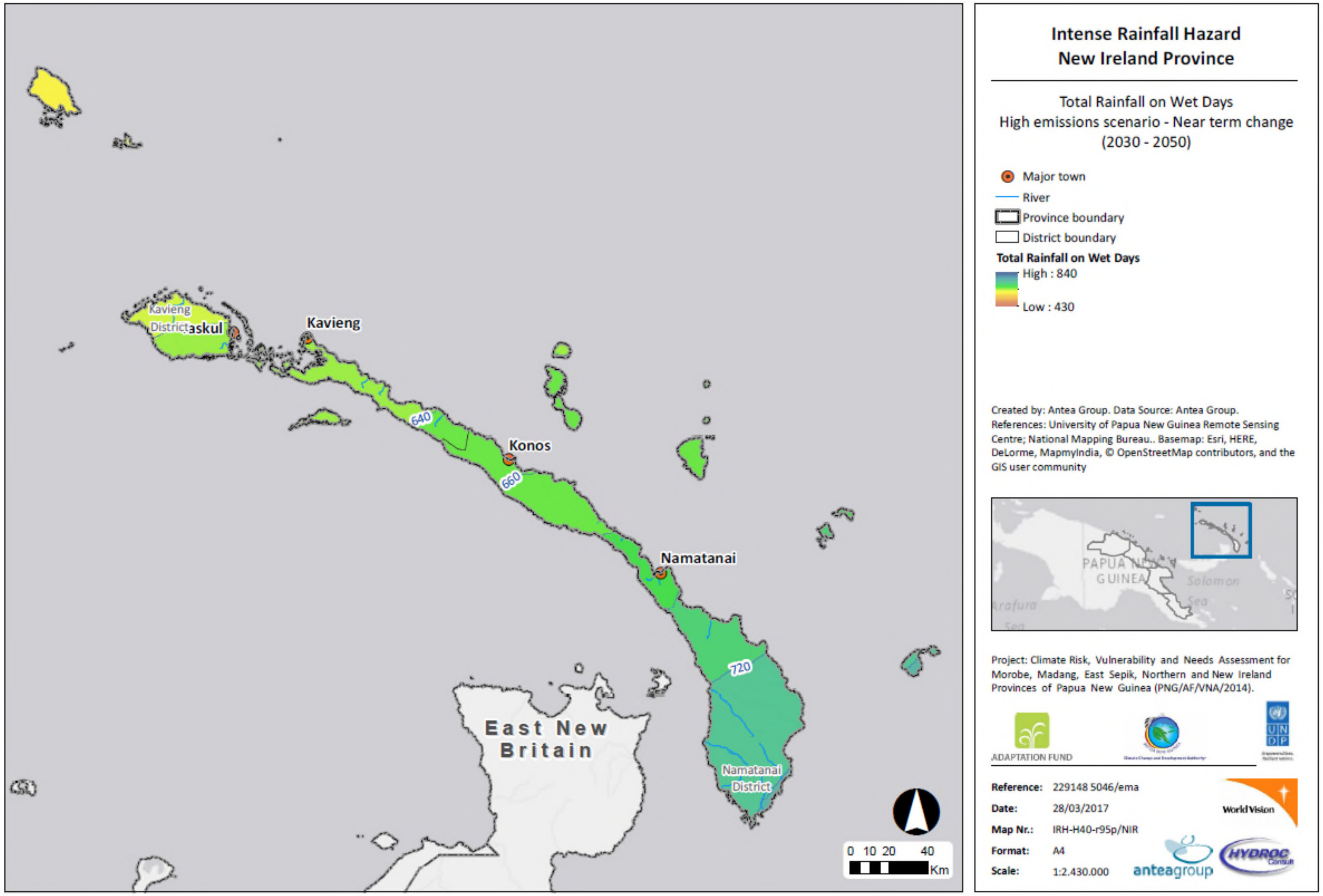

Figure 23. Rainfall on wet days in mm (projected climate) 250-500 501-600 601-700 701-800 801-900

2.2. Vulnerability Assessment

In this chapter we discuss the vulnerability maps for New Ireland Province. The vulnerability assessment for the five climate induced hazards discussed in the previous chapter, was conducted for three of its components:

- Social vulnerability
- Physical vulnerability (infrastructure)
- Economic vulnerability

2.2.1. Vulnerability to inland flooding

Social vulnerability

Social vulnerability to inland flooding is generally low in the province, however there are areas with high social vulnerability to inland flooding in the northern part of Lovongai LLG in Kavieng District and south of Kavieng town in Kavieng Rural LLG. (Figure 24)

Physical vulnerability

The map for inland flooding physical vulnerability shows some scattered hotspots, mostly around Konos and the centre of Kavieng District but the highest concentration is in New Hanover Island. (Figure 25)

Economic vulnerability

Economic vulnerability is generally low in the province, though two hotspots can be seen along the coast of Namatanai District: one around Namatanai Town and the other a little bit further southeast, around Kapsel. (Figure 26)

Composite vulnerability to inland flooding

The combined map for inland flooding vulnerability shows a rather low profile for the province, with the exception of some scattered hotspots, whereas the highest concentration is in the northern stretch of coast in the centre of Kavieng District and in the Island of New Hanover. (Figure 27)

The district that accumulates a slightly higher % of composite vulnerability (3+4+5) is Kavieng, as can be seen in the table below :

Table 29. Distribution of vulnerability classes for inland flooding in New Ireland Province (combined social, economic and physical)

	HAZARD : INLAND FLOODING						
	COMPOSITE VULNERABILITY %						
District	1	2	3	4	5		(3+4+5)
Kavieng District	17,9	5,3	1,1	0,3	5,2	70,3	6,6
Namatanai District	13,7	3,9	1,8	0,8	1,9	77,9	4,5

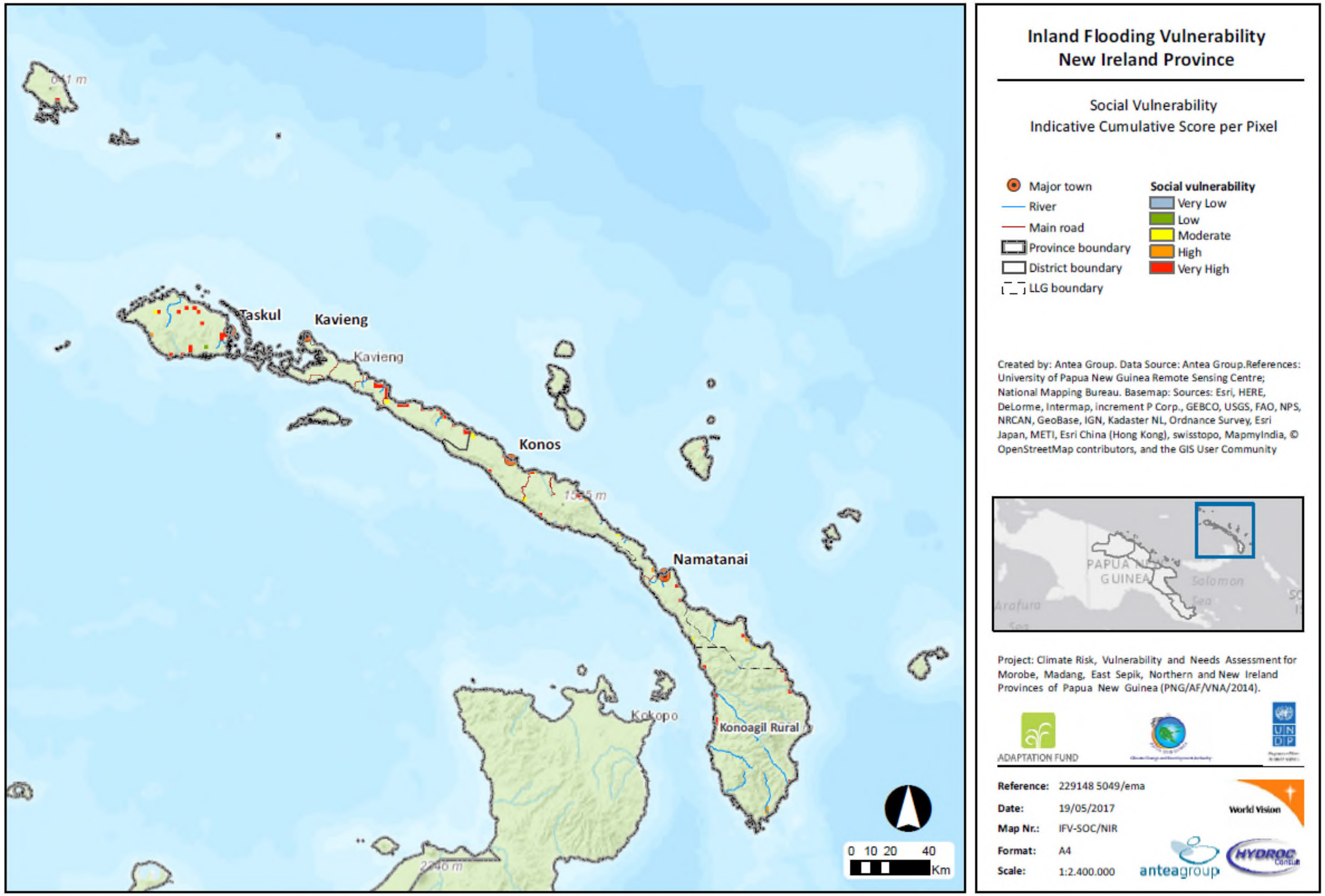

Figure 24. Social vulnerability to inland flooding in New Ireland Province

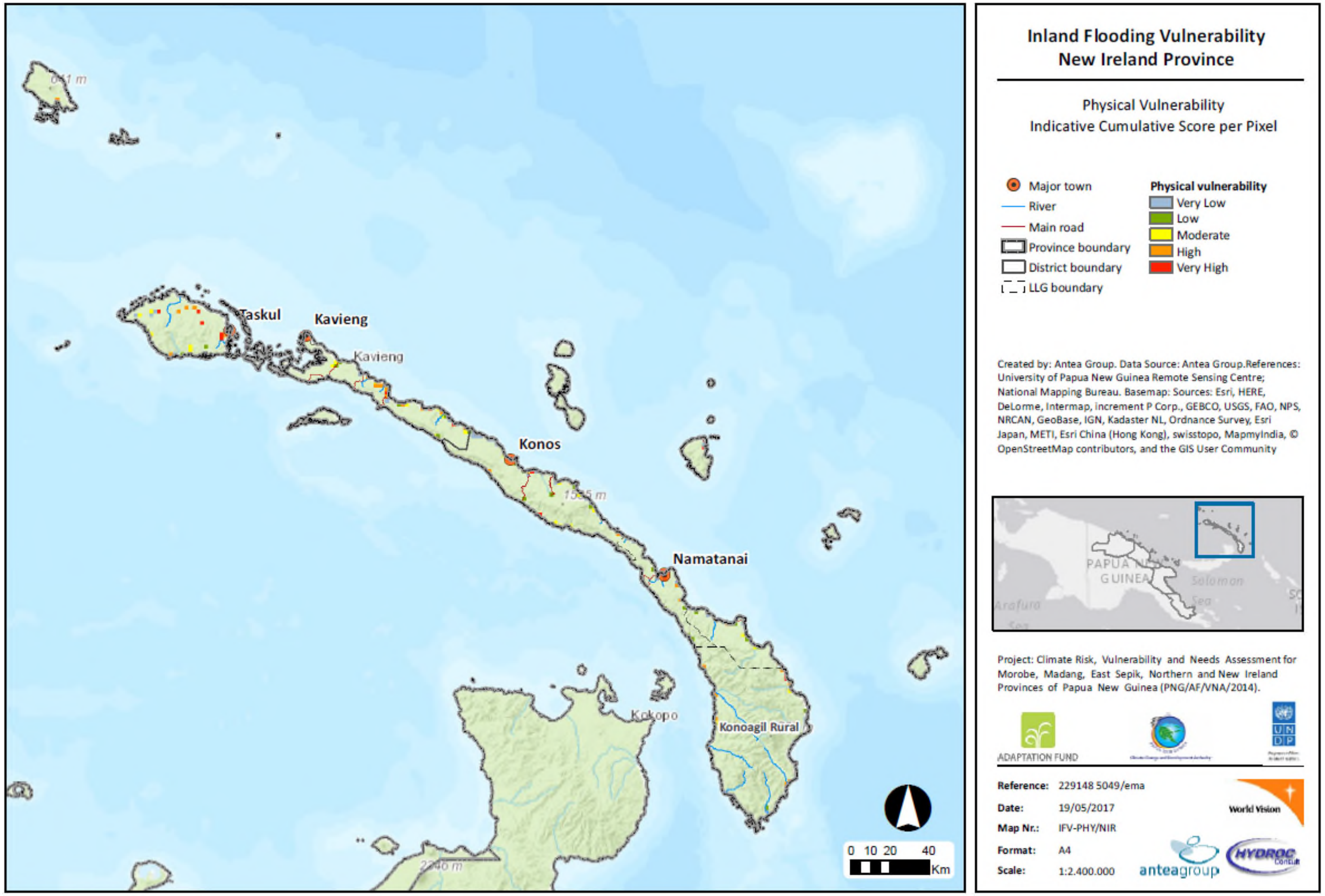

Figure 25. Physical vulnerability to inland flooding in New Ireland Province

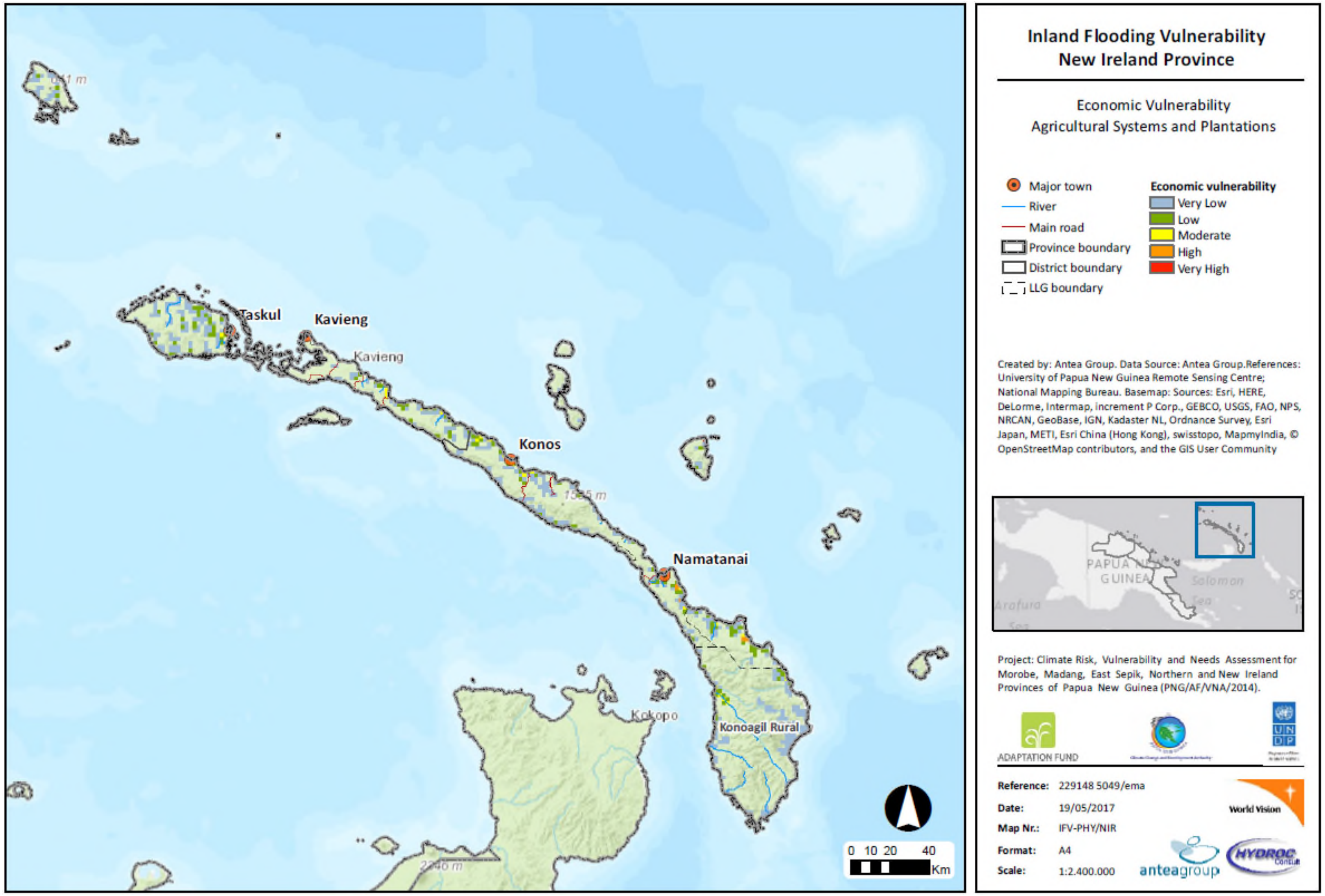

Figure 26. Economic vulnerability to inland flooding in New Ireland Province

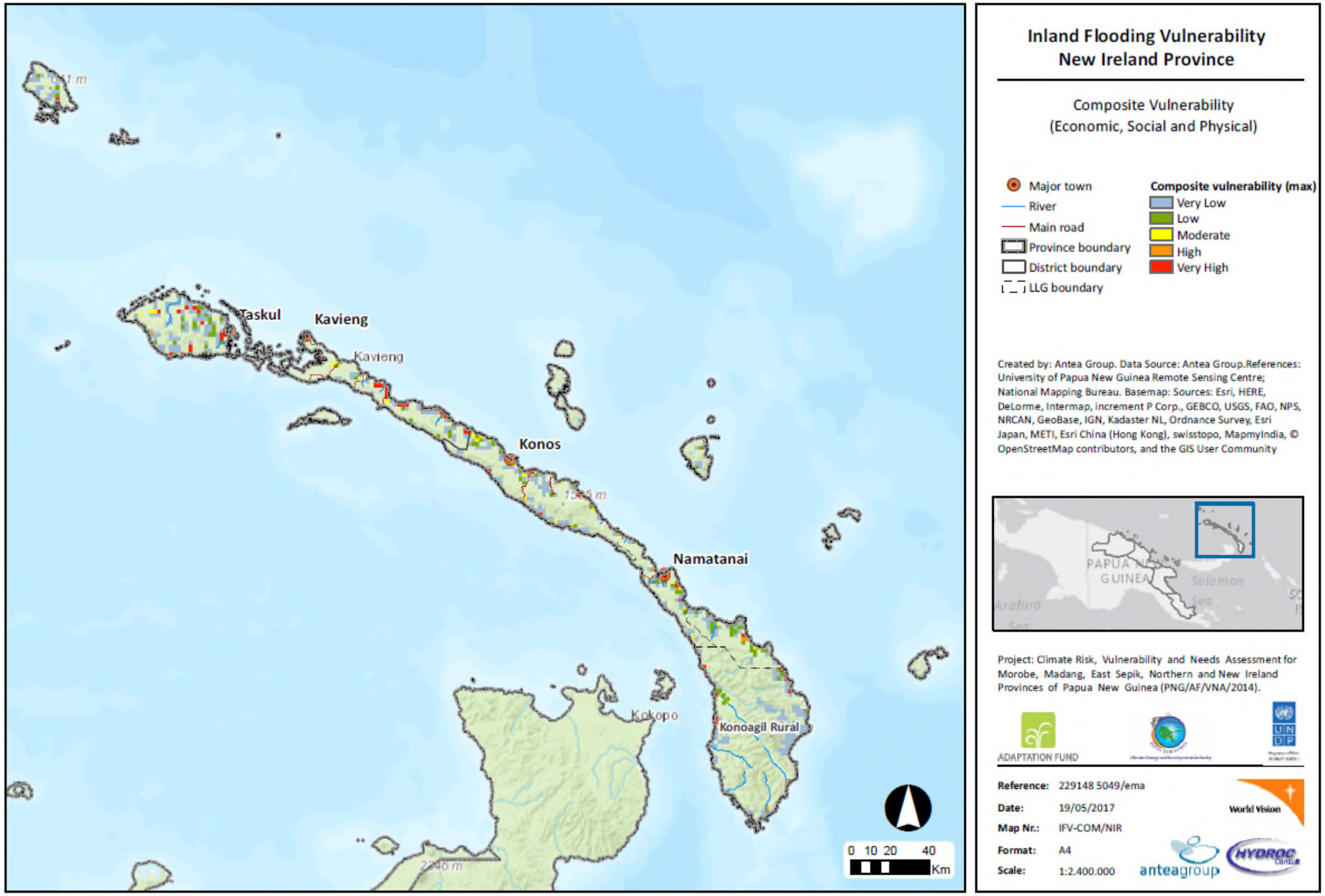

Figure 27. Combined inland flood vulnerability map for New Ireland Province

2.2.2. *Vulnerability to coastal flooding*

<maps not available>

2.2.3. *Vulnerability to drought*

Social vulnerability

There is generally low to moderate social vulnerability to drought in the province. Areas with the highest social vulnerability to drought are found in the northern part of the province in Lovongai LLG in Kavieng District and along the east and west coasts in Namatanai District in Namantani Rural, Matalai and Konoagil Rural LLGs. (Figure 28)

Economic vulnerability

Economic vulnerability to drought is rather low for the whole province with just a couple of moderate hotspots in Namatanai District, in the coast northwest from Namatanai Town and in the south west coast, in the stretch between Kamandaru and Gilingil rivers. (Figure 29)

Combined vulnerability to drought

The combined map for drought vulnerability shows that the province has a low profile, with just some moderate hotspots scattered along New Hanover Island and Namatanai District but the area where the hotspots are higher is in the southern part of Lahir Island. (Figure 30)

The district that accumulates a slightly higher % of composite vulnerability (3+4+5) is Kavieng, as can be seen in the table below :

Table 30. Distribution of vulnerability classes for drought in New Ireland Province (combined social and economic)

	HAZARD : DROUGHT						
	COMPOSITE VULNERABILITY %						
District	1	2	3	4	5		(3+4+5)
Kavieng District	20,3	40,9	6,8	0,0	0,7	31,2	7,5
Namatanai District	10,1	29,9	4,7	0,8	0,4	54,0	5,9

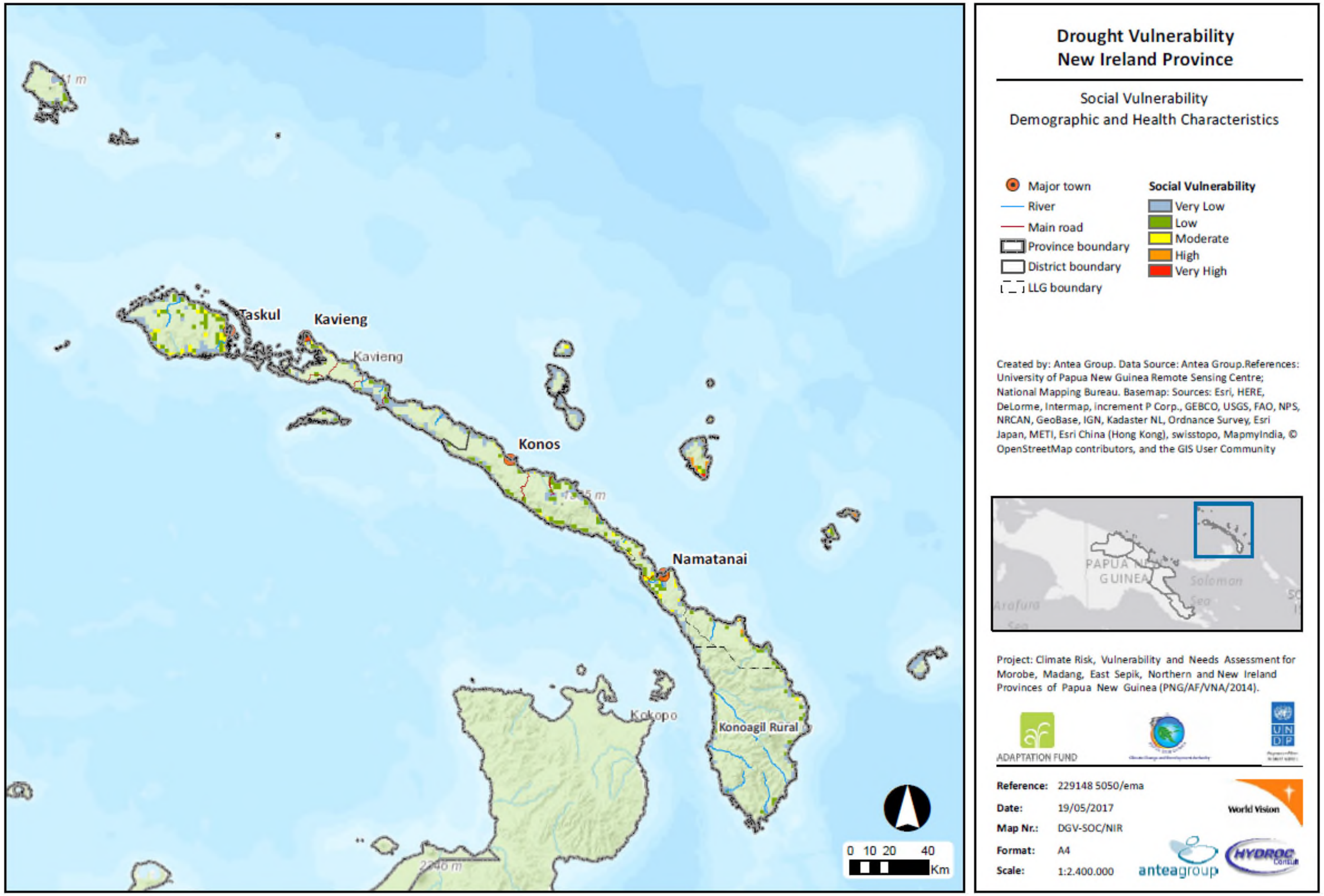

Figure 28. Social vulnerability to drought in New Ireland Province

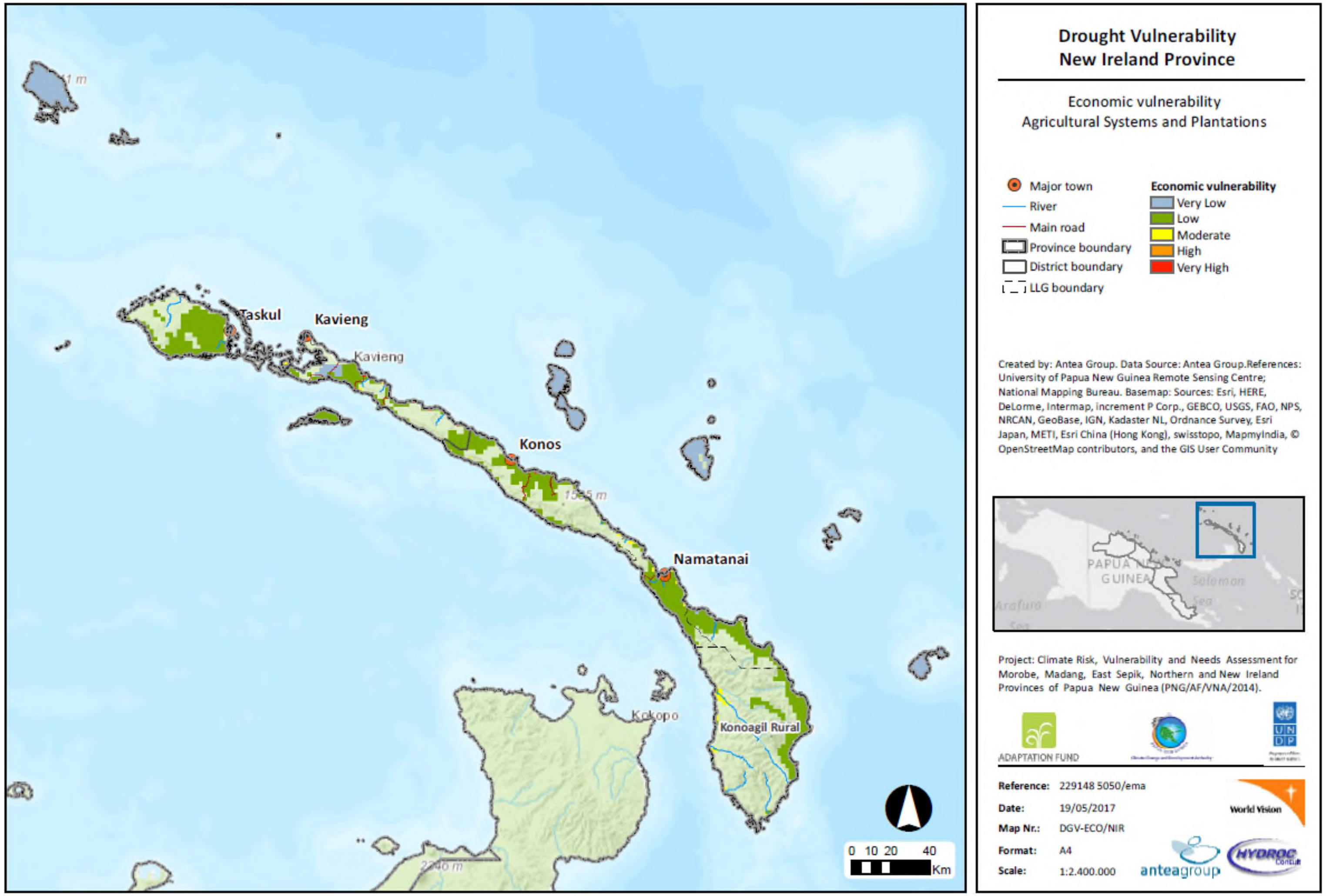

Figure 29. Economic vulnerability to drought in New Ireland Province

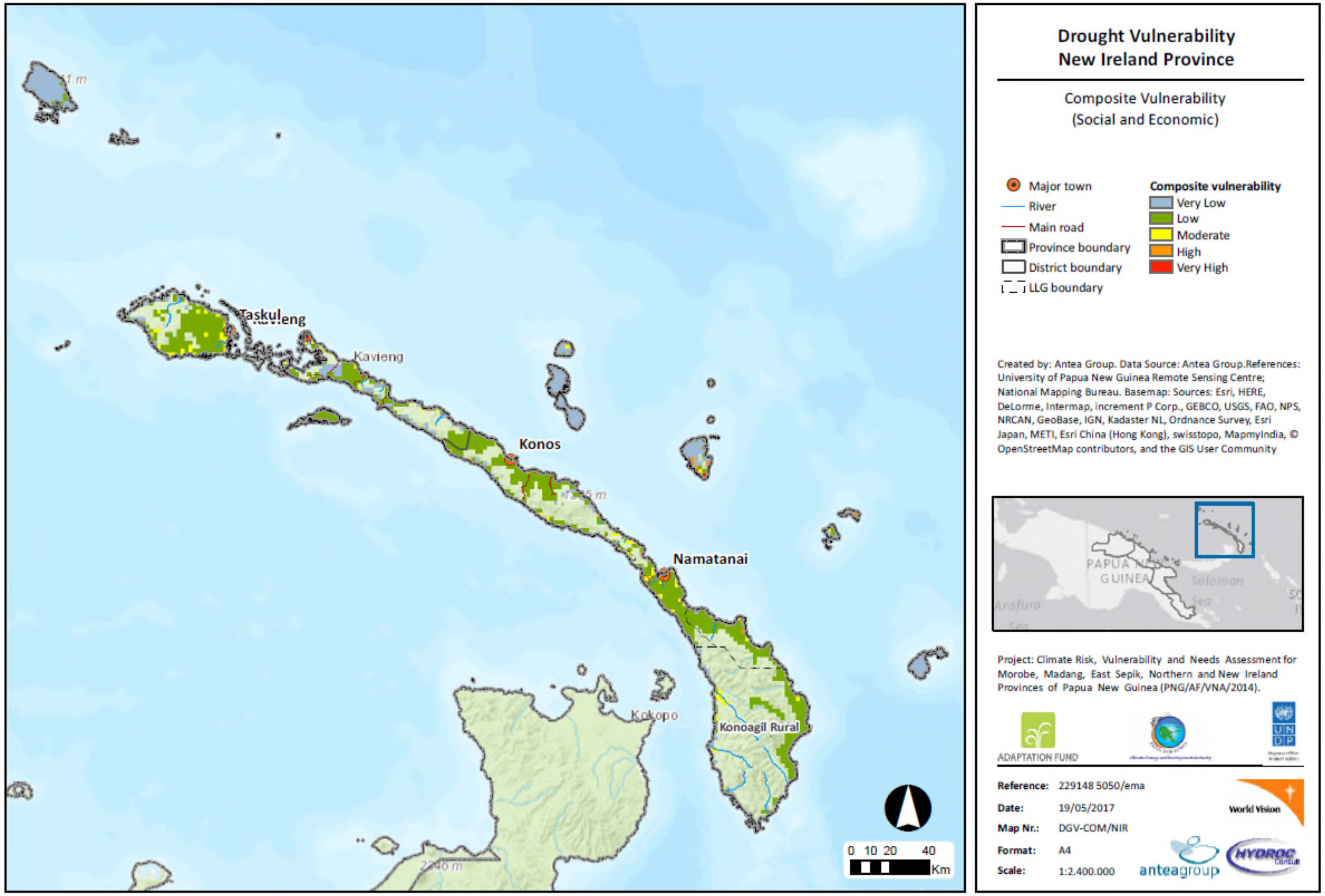

Figure 30. Combined drought vulnerability map for New Ireland Province

2.2.4. *Vulnerability to extreme weather (cyclones)*

Social vulnerability

Social vulnerability to extreme weather is generally low in the province, with a few areas of moderate vulnerability found in the northern part of the province along and near the coast in Lovongai LLG in the northern part of Kavieng District. (Figure 31)

Physical vulnerability

The map for extreme weather physical vulnerability shows some scattered hotspots, especially in the islands of New Hanover and Lahir. Other hotspots are found in the central part of Kavieng District, around Namatanai Town and in the smaller islands: Dyaul, Simberi, Tatau, Malendok and Boang. (Figure 32)

Economic vulnerability

Economic vulnerability to extreme weather is very high in the northern part of Namatanai District and in the region between Kamandaru and Gilingil rivers in Konoagil Rural. Hotspots of high vulnerability are found in the three main Isalnds north of Namatanai District. Additionally, some moderate hotspots can be found around the region of Konos, to the south east of Kavieng Town and in the western part of New Hanover Island. (Figure 33)

Combined vulnerability to extreme weather

The combined map for extreme weather vulnerability shows that the area around Namatanai has a big concentration of hotspots with a very high profile, which extend down the northern coast and to the section between the mouths of the Kamandaru and Gilingil rivers. Additionally, the islands to the north of Namatanai concentrate a high profile, as well as scattered hotspots around New Hanover Island. Finally, some moderate hotspots can be found around the region of Konos, to the south east of Kavieng Town and in the western part of New Hanover Island. (Figure 34)

Both districts accumulate more or less the same % of composite vulnerability (3+4+5), as can be seen in the table below:

Table 31. Distribution of vulnerability classes for extreme weather (cyclones) in New Ireland Province (combined social, economic and physical)

	HAZARD : CYCLONE						
	COMPOSITE VULNERABILITY %						
District	1	2	3	4	5		(3+4+5)
Kavieng District	16,0	22,1	19,3	7,7	7,3	27,5	34,3
Namatanai District	2,0	11,5	10,0	6,5	16,9	53,1	33,4

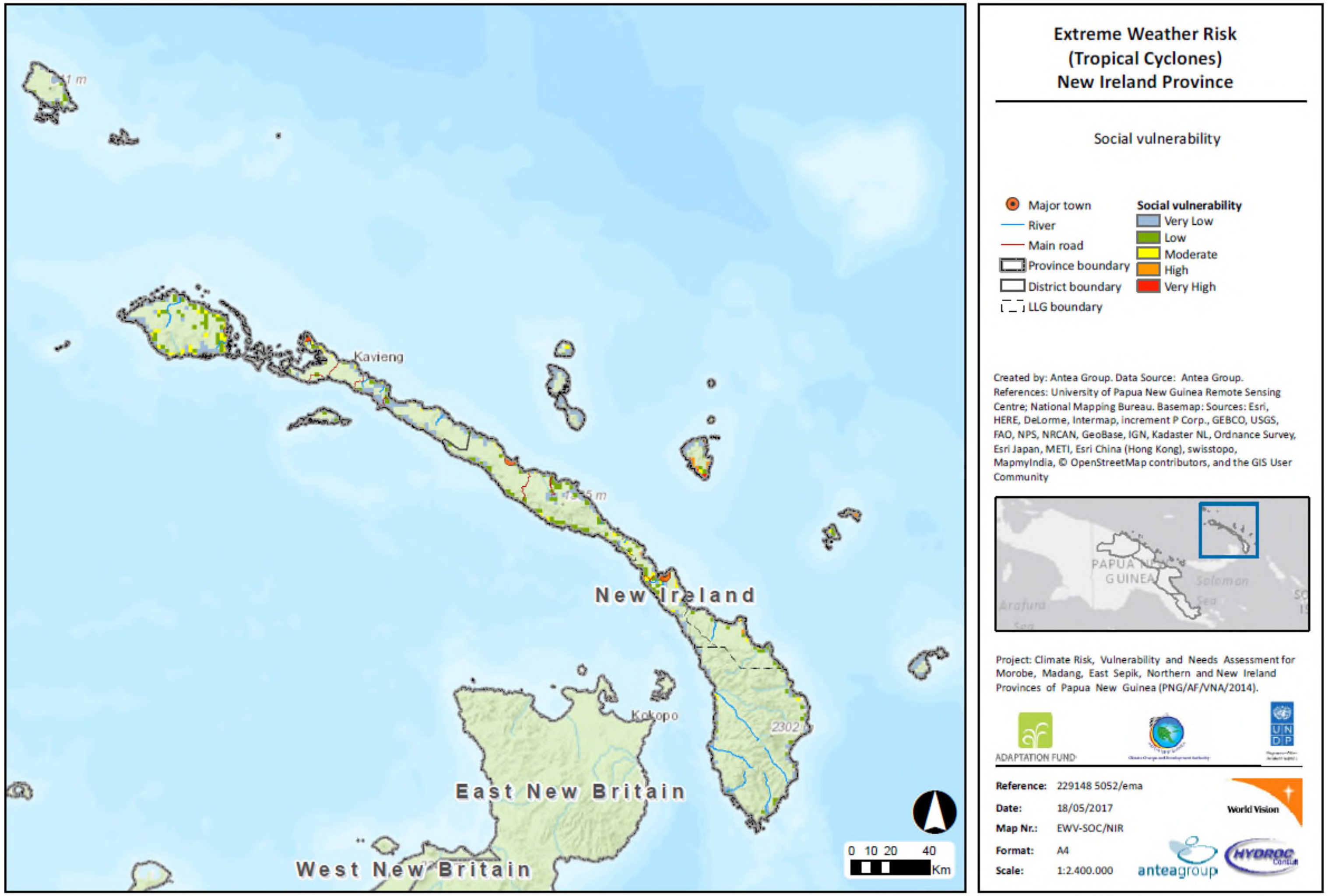

Figure 31. Social vulnerability to cyclones in New Ireland Province

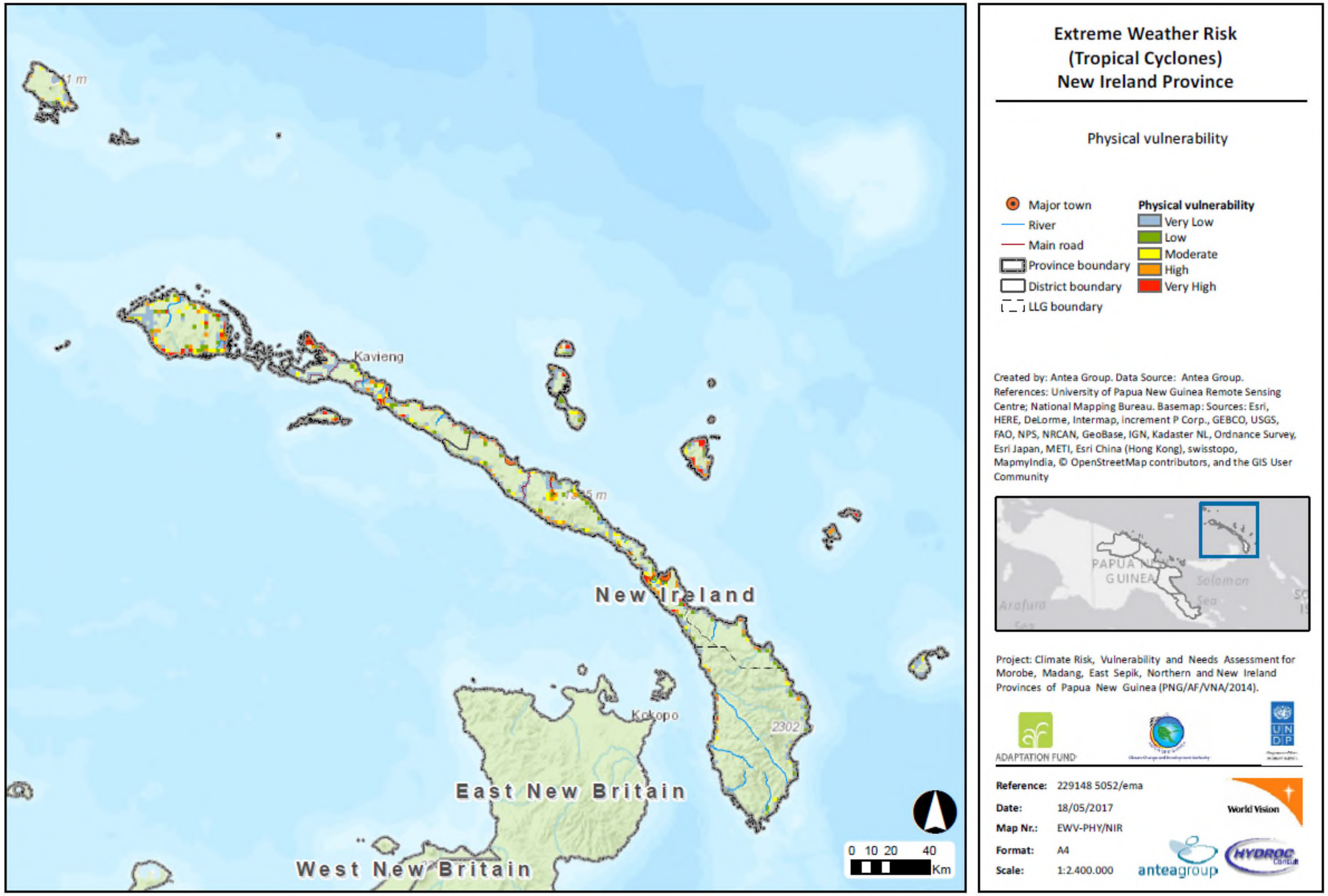

Figure 32. Physical vulnerability to cyclones in New Ireland Province

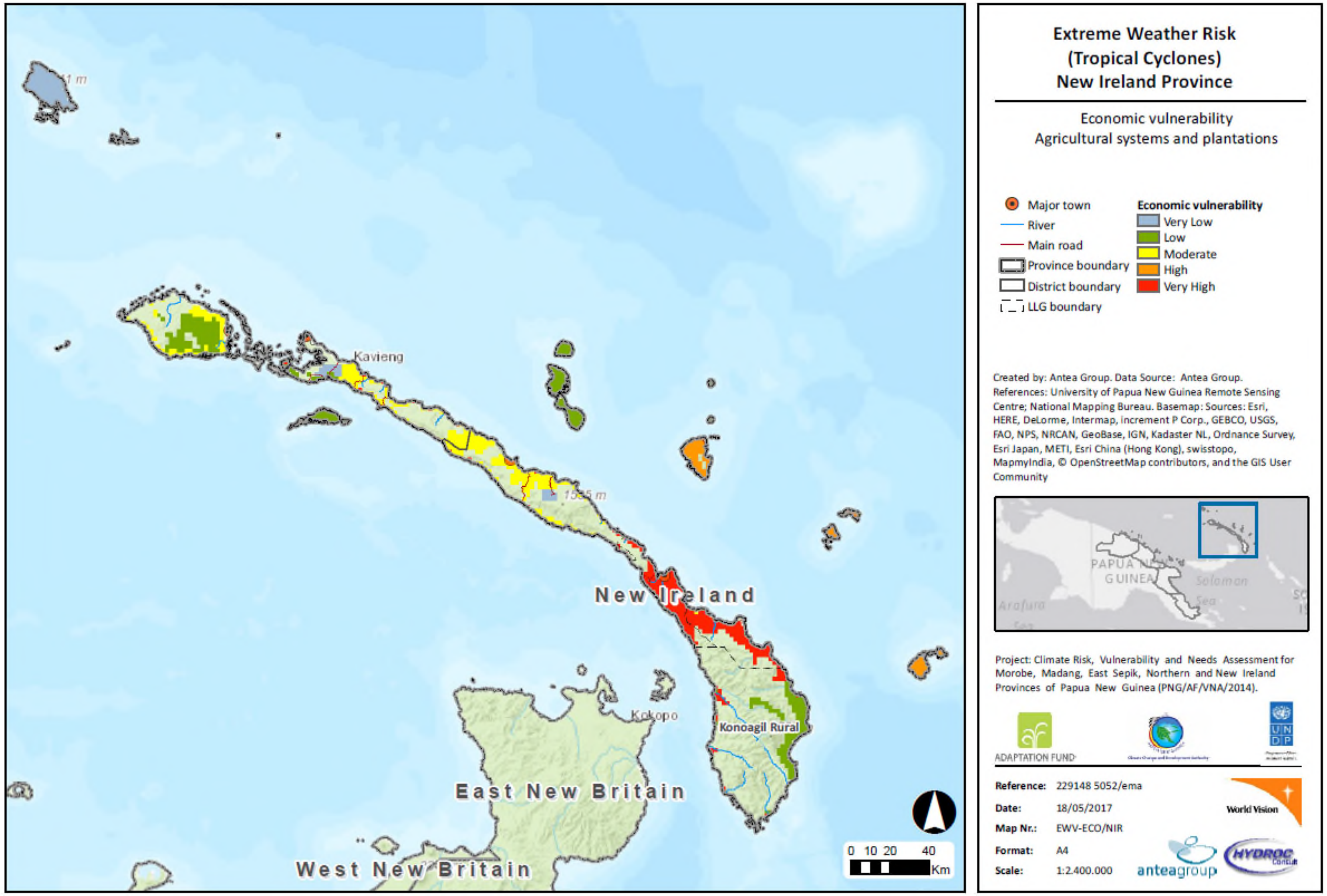

Figure 33. Economic vulnerability to cyclones in New Ireland Province

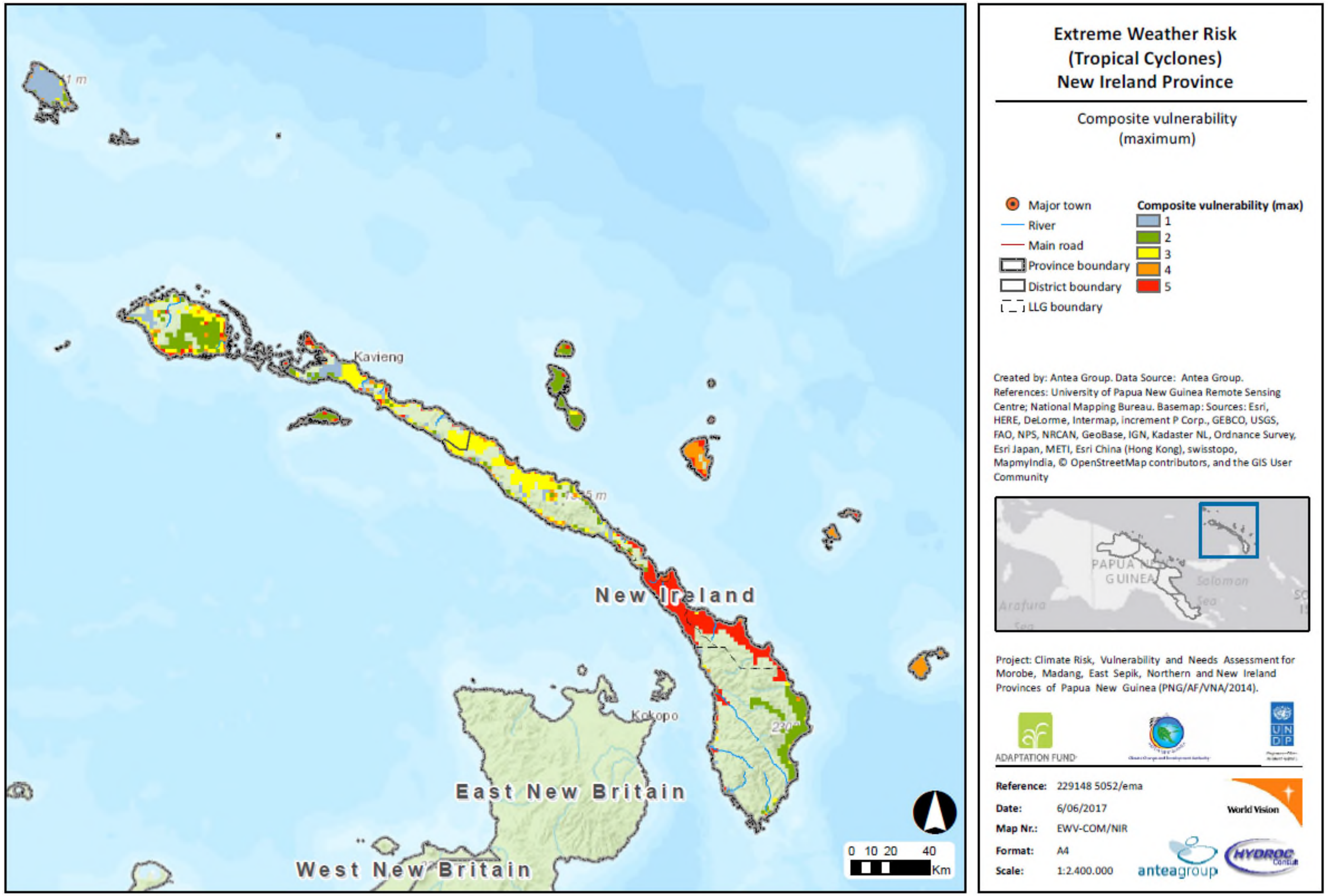

Figure 34. Combined vulnerability to cyclones in New Ireland Province

2.2.5. Vulnerability to precipitation intensity and variability

Social vulnerability

Areas with the highest social vulnerability to precipitation intensity and variability in New Ireland Province are found in the island of Lahir. In a lower degree, in the coastal areas of Lovongai LLG in the northern part of the province in Kavieng District and in the coastal areas in the central part of Namantanai District, mainly in Namatanai Rural, Matalai Rural and Konoagil Rural LLGs. (Figure 35)

Economic vulnerability

The province shows a low to moderate profile, with just a couple of hotspots Namatanai District: along the coast north to Namatanai Town and in the stretch between the mouths of the Kamandaru and Gilingil rivers. (Figure 36)

Combined vulnerability to intense rainfall

The combined map for vulnerability to intense rainfall shows only a few hotspots, the most concentrated ones in the southern part of Lahir Island. Other outstanding are in the coast north to Namatanai Town and in the stretch between the mouths of Kamandaru and Gilingil rivers in Konoagil Rural. Finally, the island of New Hanover concentrates various moderate hotspots. (Figure 37)

The district that accumulates a slightly higher % of composite vulnerability (3+4+5) is Kavieng, as can be seen in the table below:

Table 32. Distribution of vulnerability classes for precipitation intensity and variability in New Ireland Province (combined social, economic)

	HAZARD : PRECIPITATION						
	COMPOSITE VULNERABILITY %						
District	**1**	**2**	**3**	**4**	**5**		(3+4+5)
Kavieng District	39,1	22,8	6,2	0,8	0,2	31,0	7,2
Namatanai District	25,0	14,8	3,1	2,6	0,2	54,3	5,9

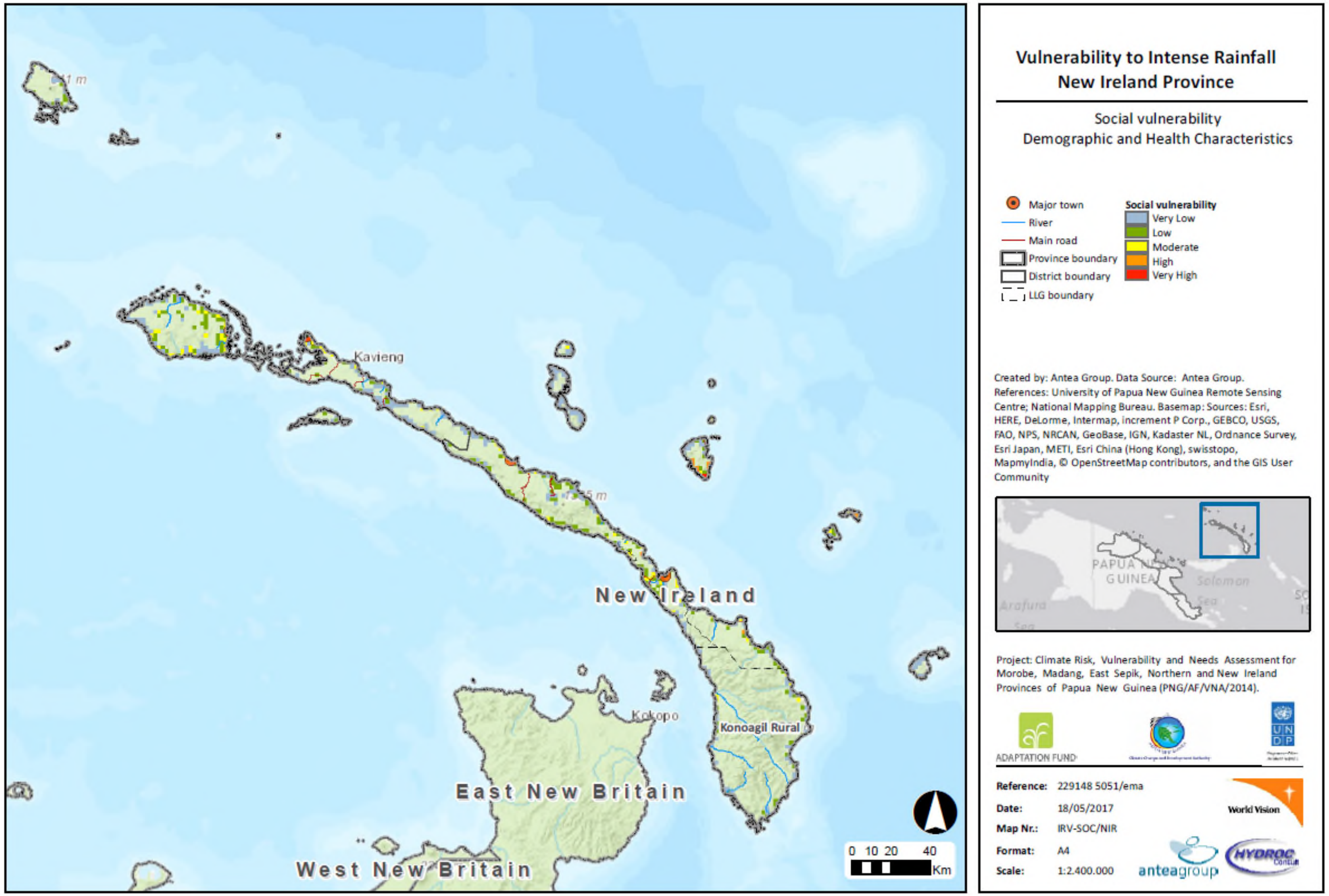

Figure 35. Social vulnerability to precipitation intensity and variability (intense rainfall) in New Ireland Province

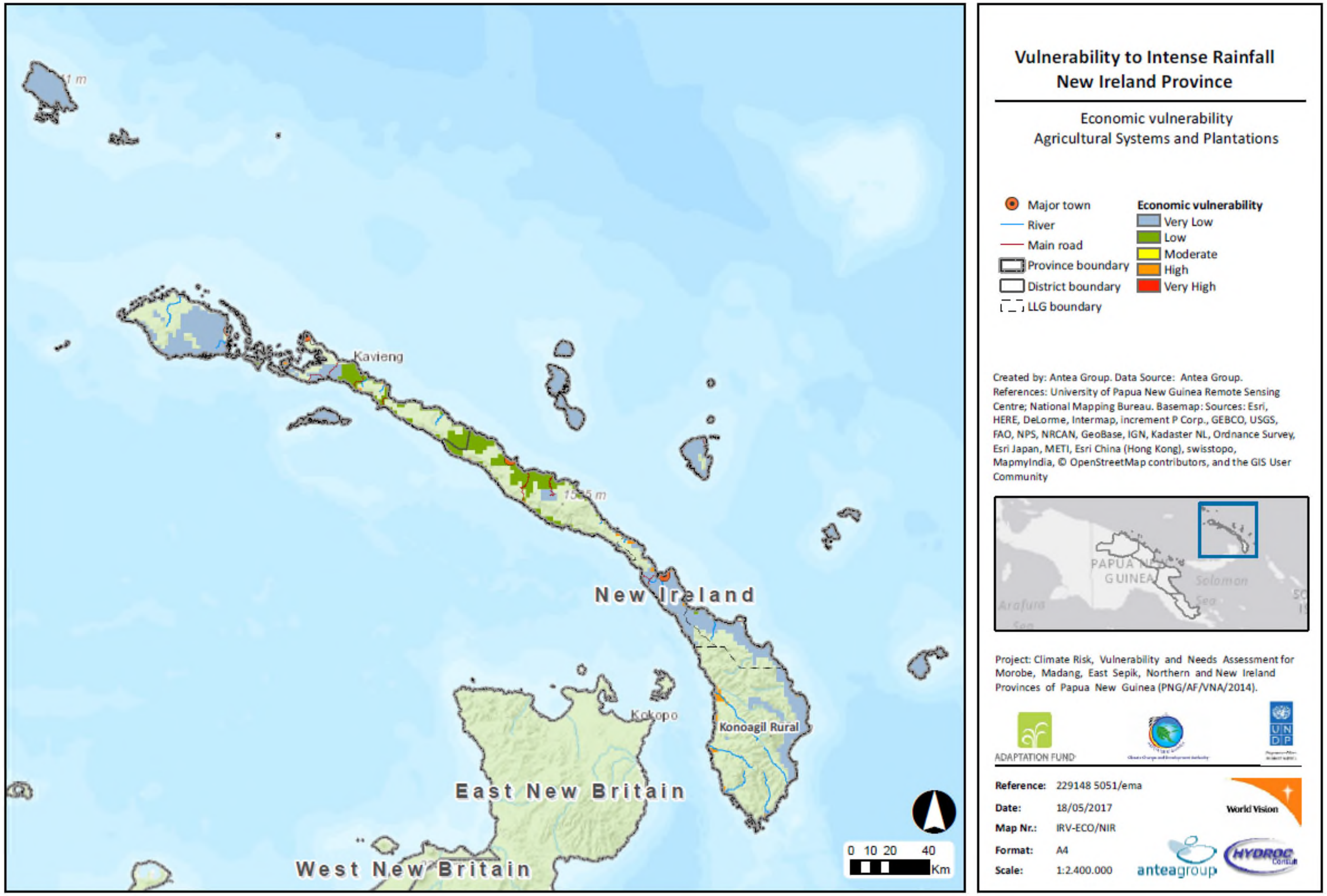

Figure 36. Economic vulnerability to precipitation intensity and variability (intense rainfall) in New Ireland Province

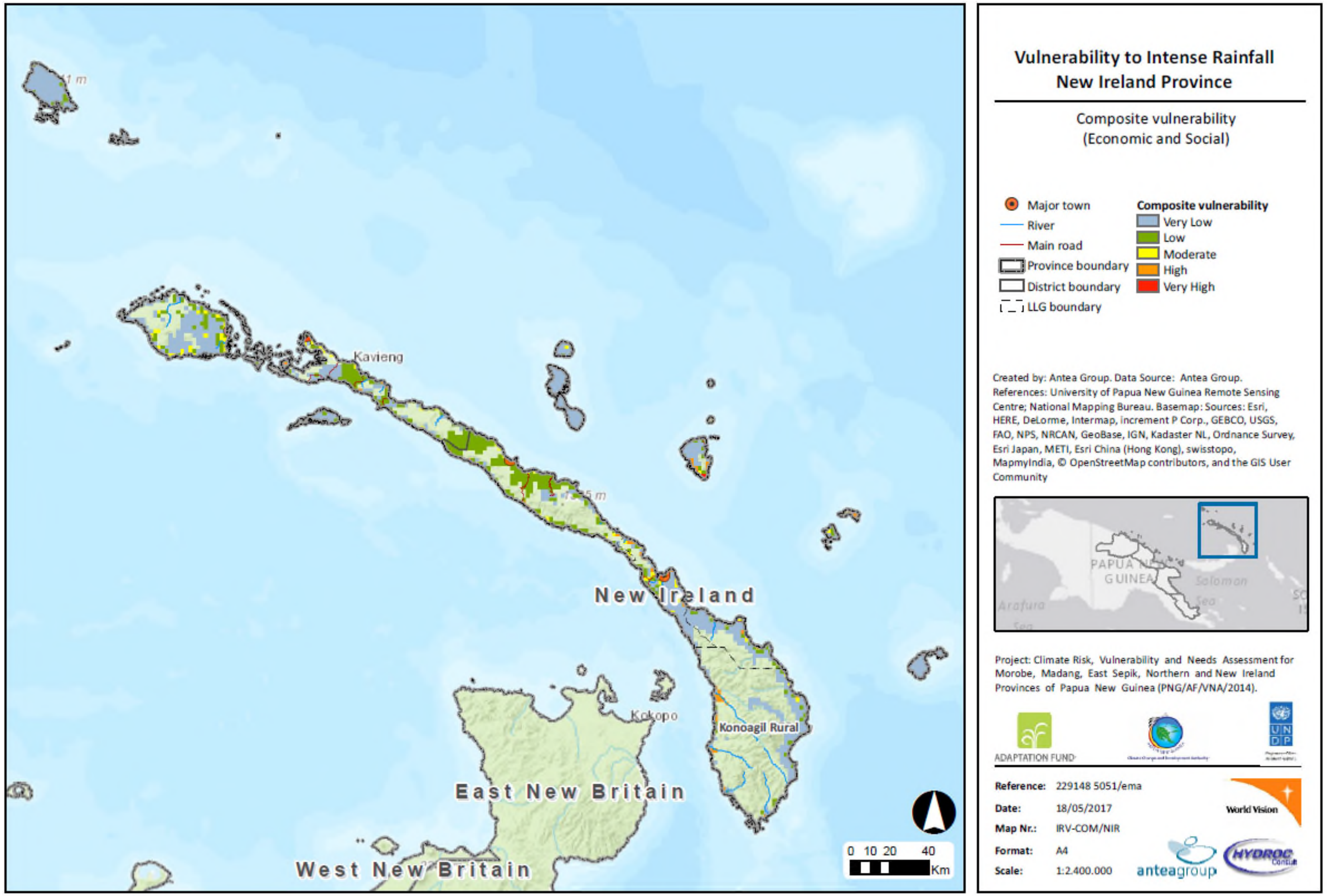

Figure 37. Combined vulnerability to precipitation intensity and variability (intense rainfall) in New Ireland Province

2.3. Risk Assessment

In this chapter we discuss the risk maps produced for New Ireland Province and this for each of the five hazards considered in the study. Risk maps were produced for each of the three components:

- Social vulnerability
- Physical vulnerability (infrastructure)
- Economic vulnerability

More over the risk maps were produced each time under the current climate and under a projected climate scenario.

2.3.1. Inland Flood Risk

The social risk from inland flooding in the province is generally low, with a few small scattered areas of moderate risk located in the northern part of Lovongai LLG in Kavieng District. Projections for the future do not show much change. (Figure 38 and Figure 42)

The map of inland flooding physical risk shows some minor hotspots, mostly around Manggai and the northern part of New Hanover Island. Projections for the future do not show much change. (Figure 39 and Figure 43)

The economic risk for inland flooding of the district is rather low and there are only a couple of minor hotspots in the area around Manggai, to the north west of Konos, in the stretch of coast south of Namatanai Town and in the island of New Hanover. Projections for the future do not show much change. (Figure 40 and Figure 44)

The composite inland flooding risk map of New Ireland shows no major issues, and projections for the future look pretty much the same, as can be seen in the table below:

Table 33. Distribution of inland flood risk classes in New Ireland Province

	HAZARD : INLAND FLOODING													
	RISK 1960-1990 %							RISK 2030-2050 %						
District	**1**	**2**	**3**	**4**	**5**		**(3+4+5)**	**1**	**2**	**3**	**4**	**5**		(3+4+5)
Kavieng District	19,5	6,8	2,1	0,8	0,5	70,3	3,4	19,5	6,8	2,1	0,8	0,5	70,3	3,4
Namatanai District	14,7	4,7	1,9	0,5	0,3	77,9	2,7	14,7	4,7	1,9	0,5	0,3	77,9	2,7

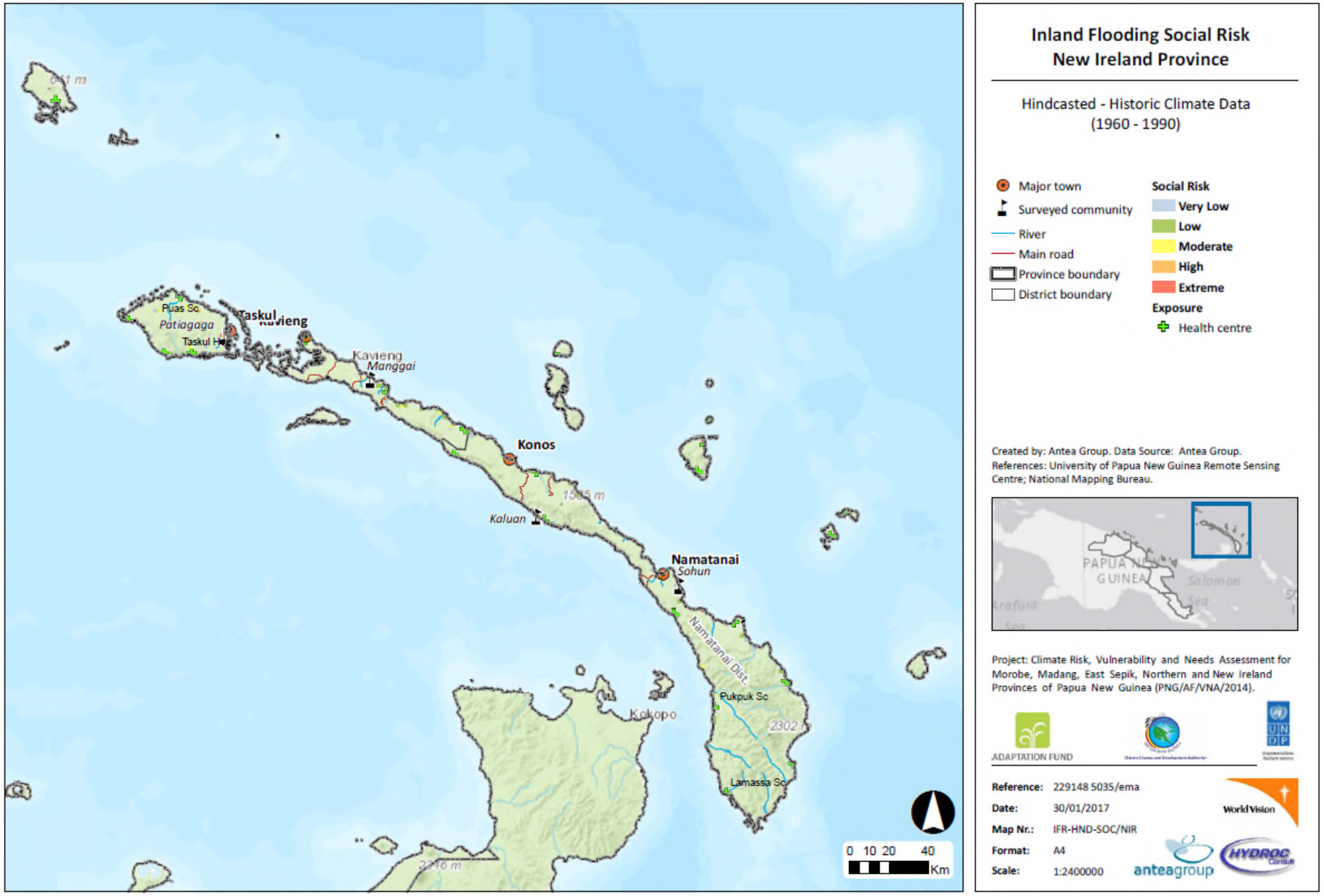

Figure 38. Inland Flooding Social Risk (current climate) Very Low Low Moderate High Extreme

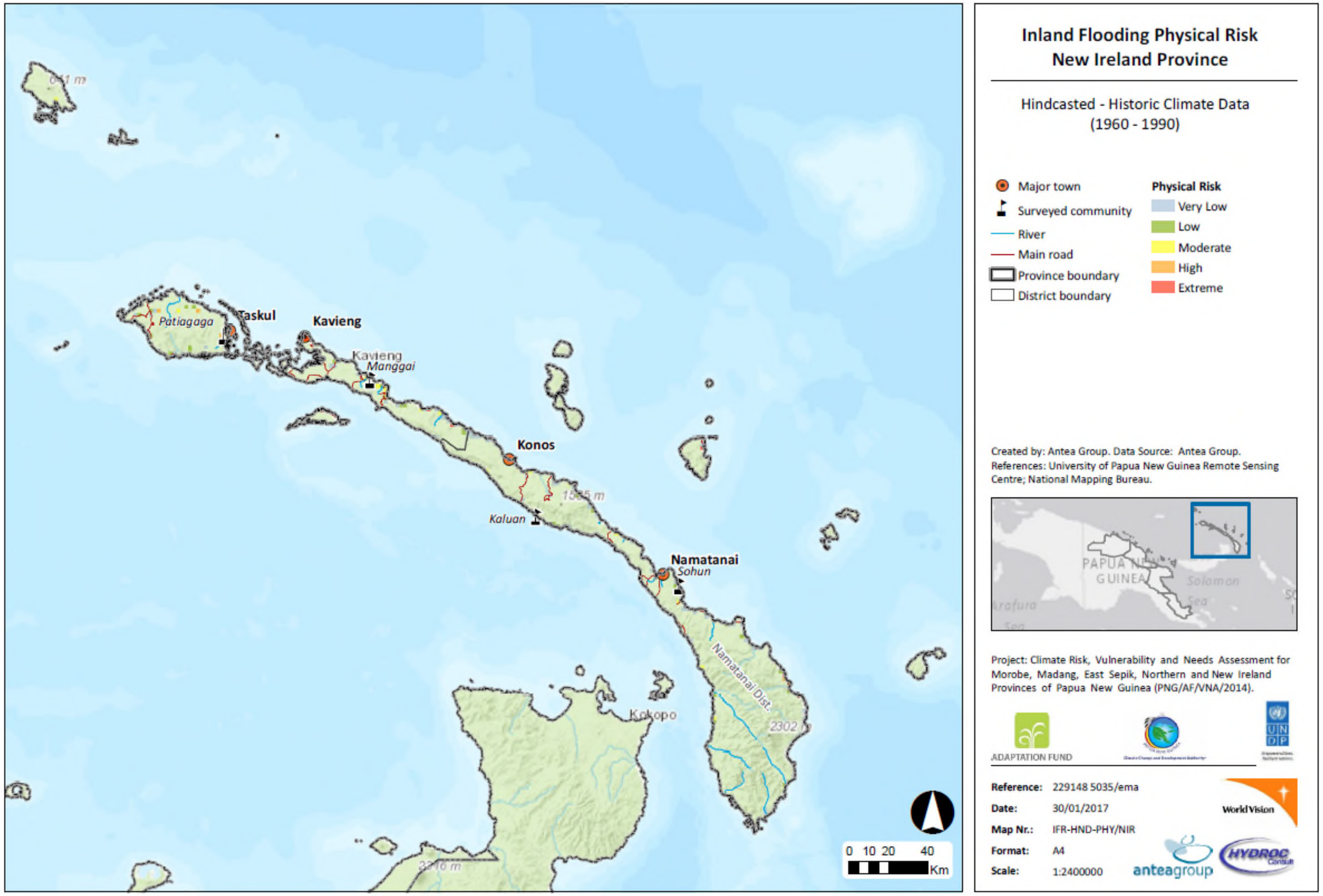

Figure 39. Inland Flooding Infrastructure Risk (current climate) **Very Low** **Low** **Moderate** **High** **Extreme**

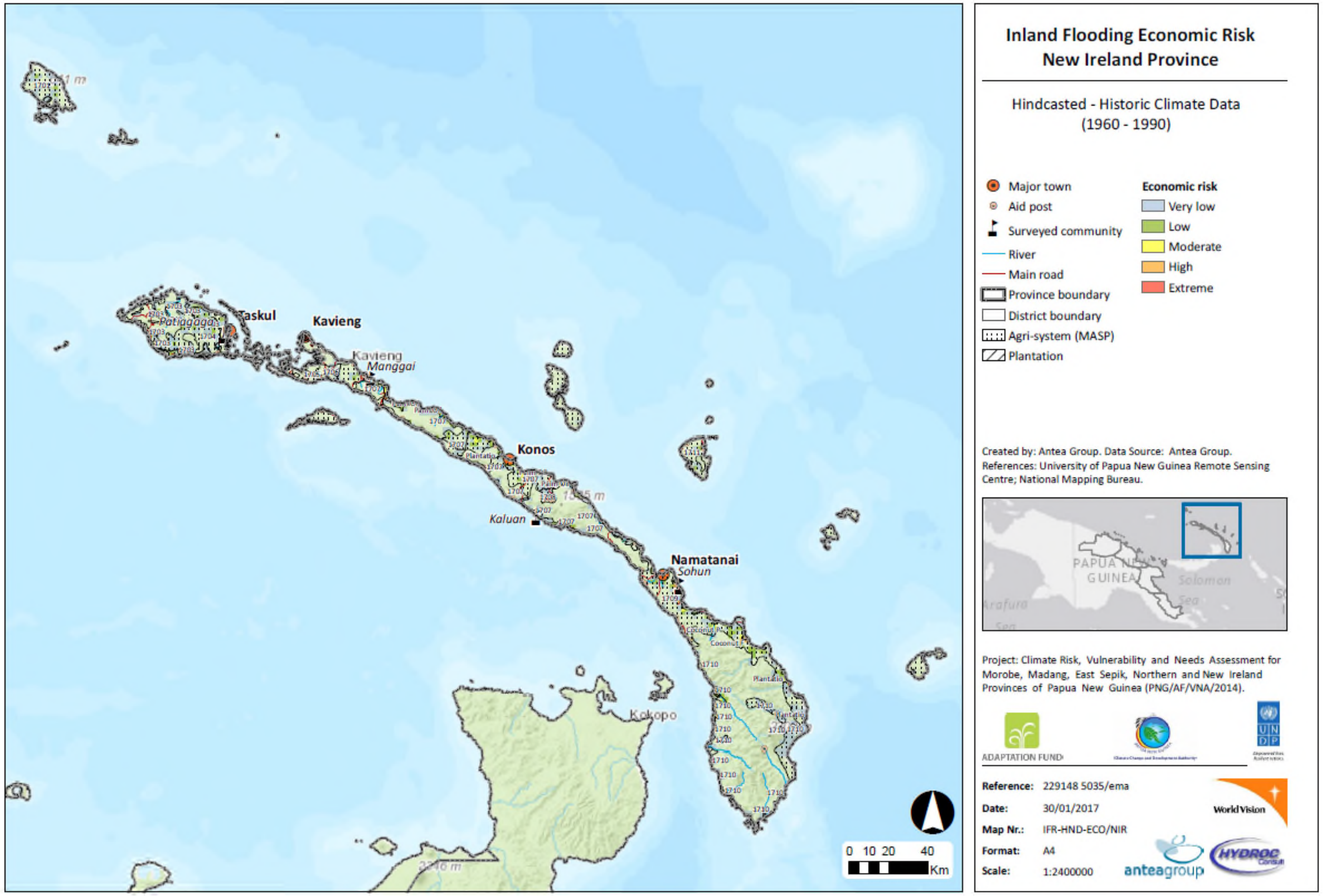

Figure 40. Inland Flooding . (current climate) Very Low Low Moderate High Extreme

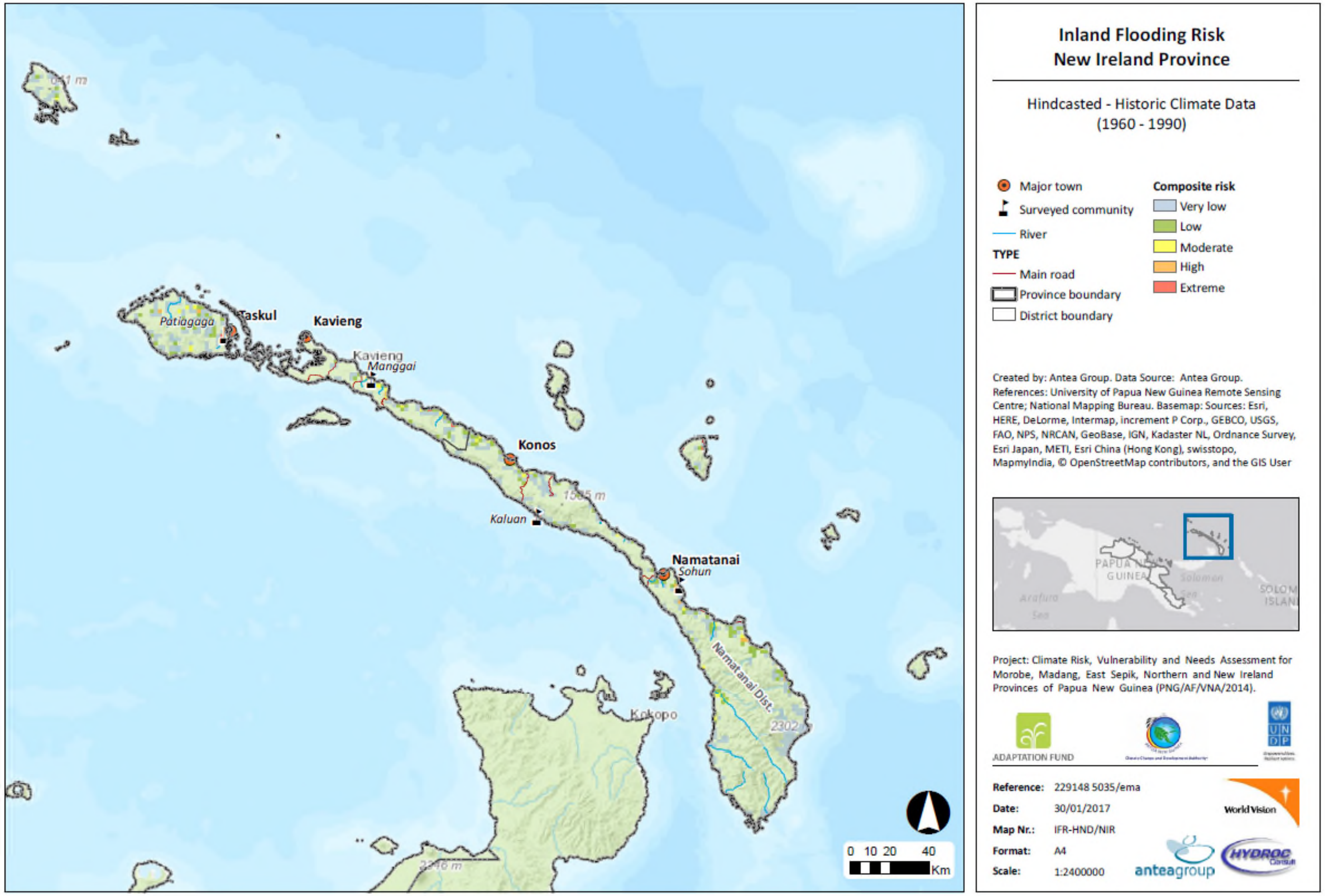

Figure 41. Inland Flooding Composite Risk (current climate) Very Low Low Moderate High Extreme

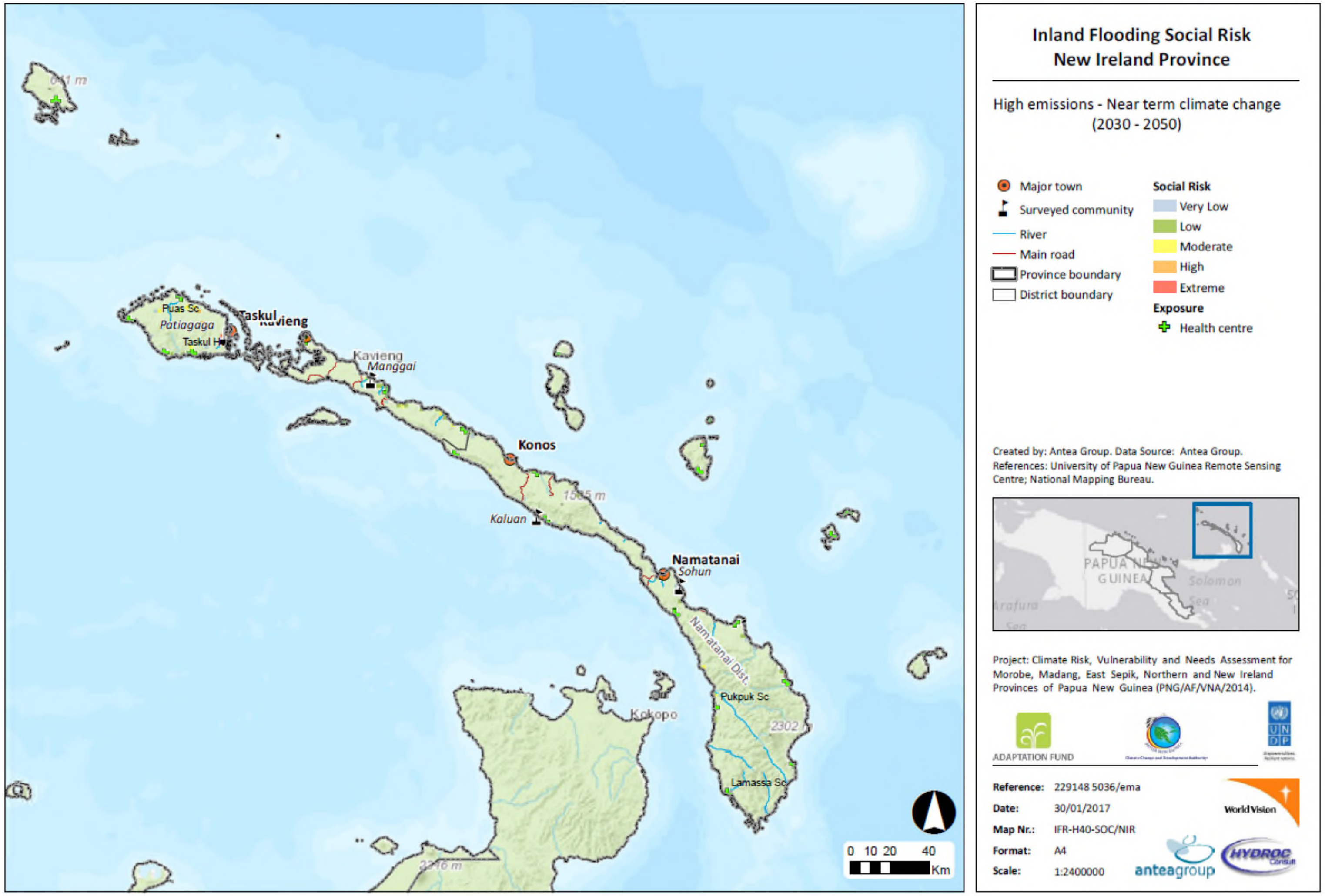

Figure 42. Inland Flooding Social Risk (projected climate) Very Low Low Moderate High Extreme

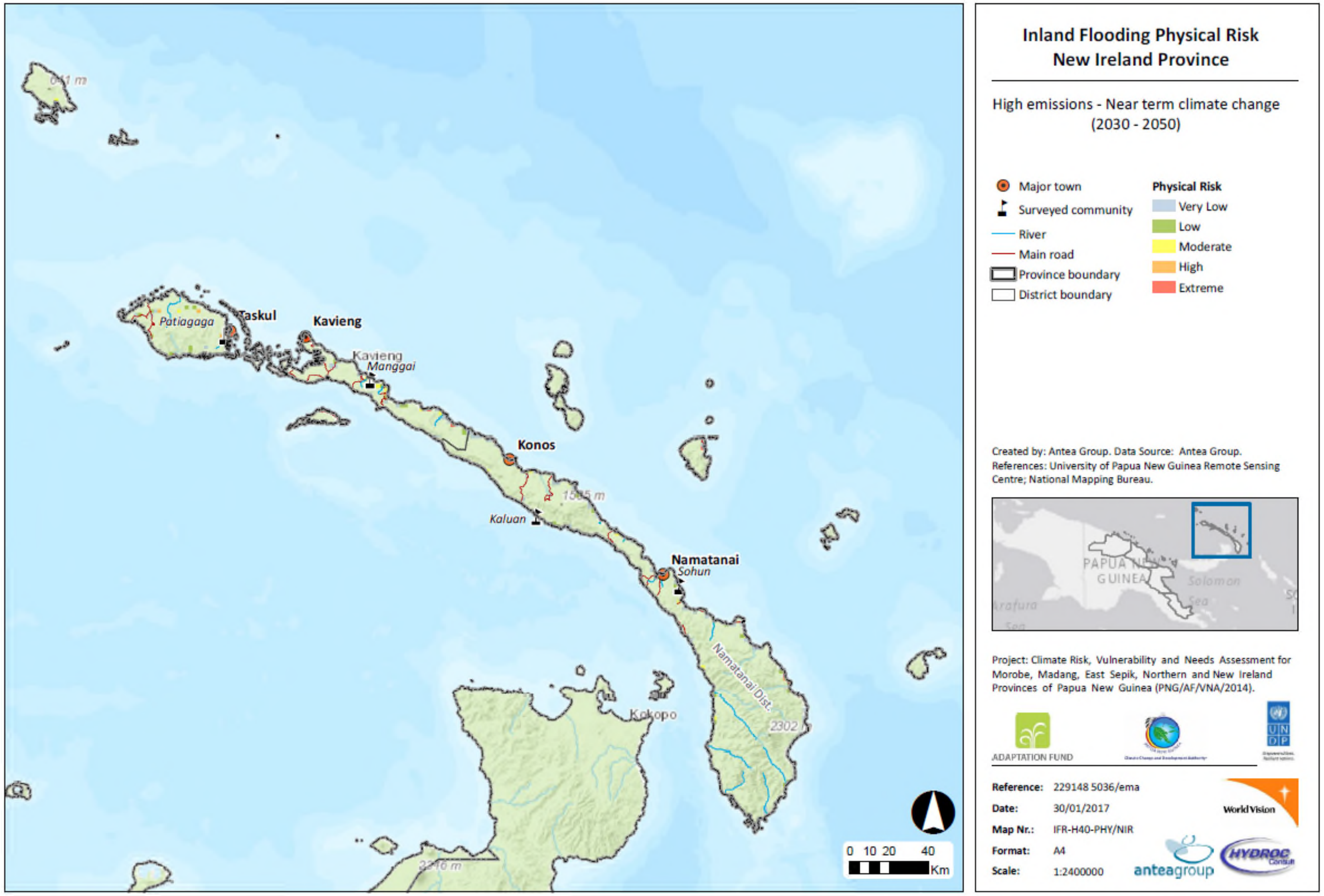

Figure 43. Inland Flooding Physical Risk (projected climate) Very Low Low Moderate High Extreme

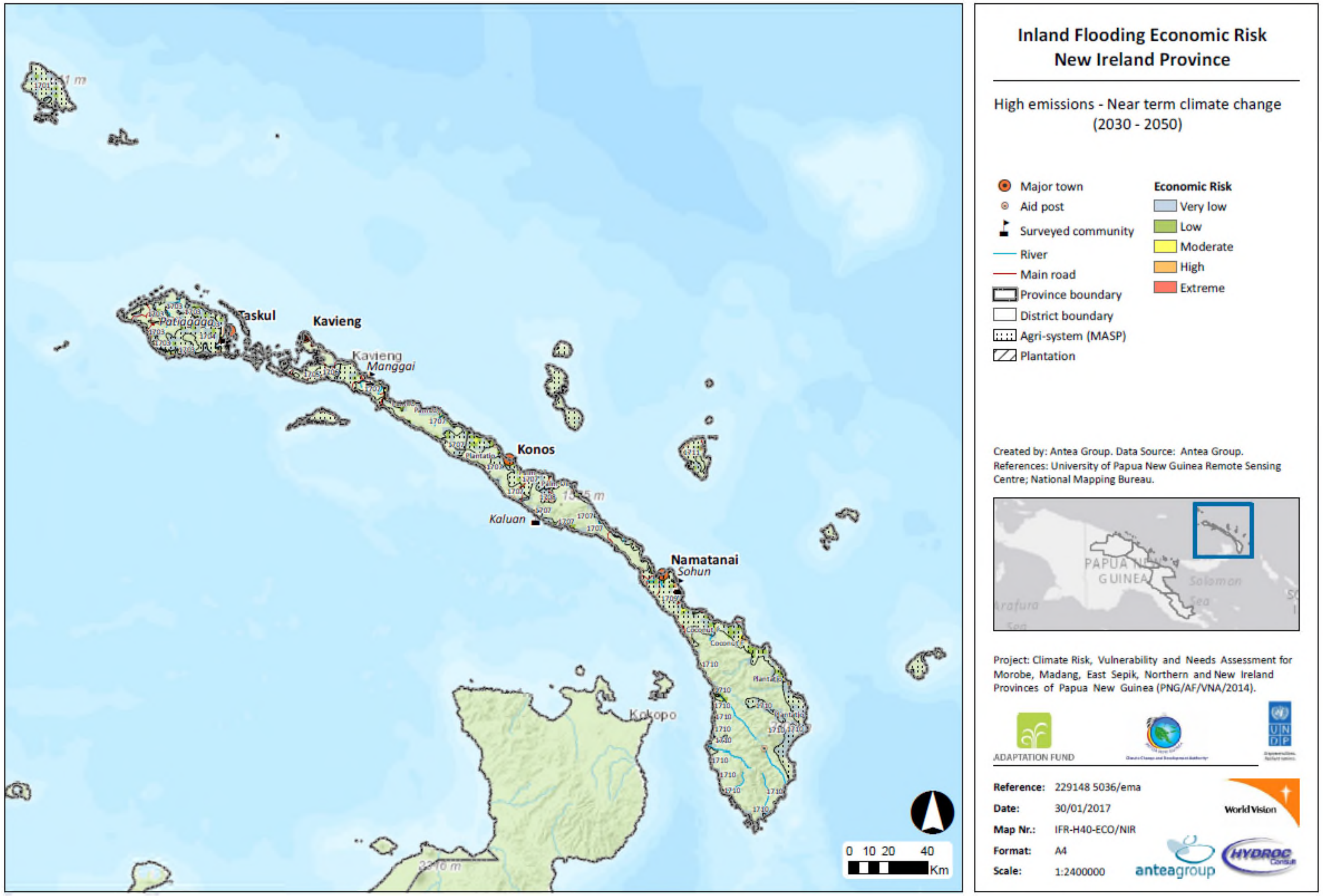

Figure 44. Inland Flooding Economic Risk (projected climate) Very Low Low Moderate High Extreme

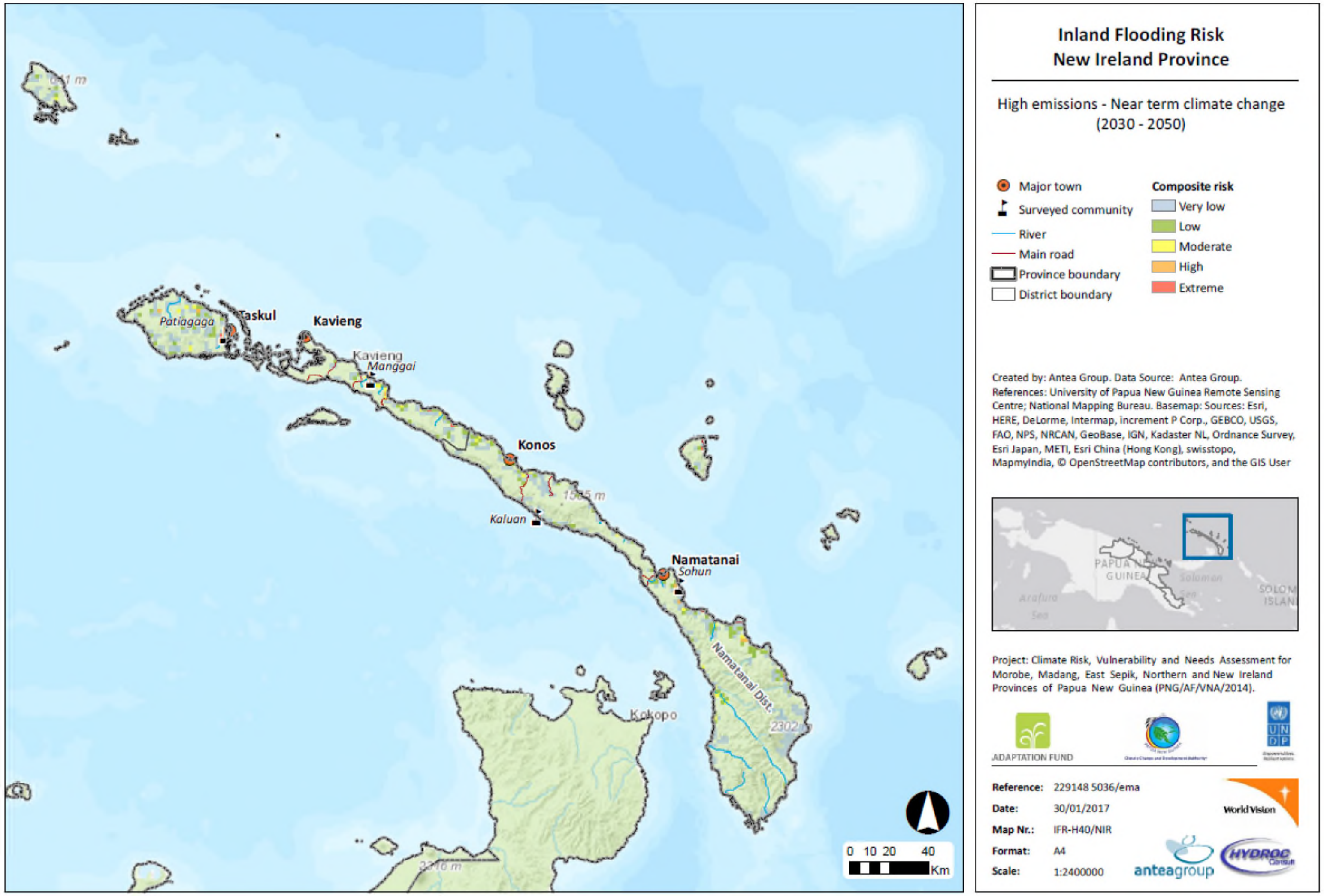

Figure 45. Inland Flooding Composite Risk (projected climate) ■ **Very Low** ■ **Low** ■ **Moderate** ■ **High** ■ **Extreme**

2.3.2. Coastal Flood Risk

The lack of available topographic information prevented mapping coastal flood risk for the province.

2.3.3. *Drought Risk*

The social risk from drought in the province is generally low to moderate, with the highest social risk from droughts in the northern part of Kavieng District, around Manggai in central Kavieng District and along the coast north of Namatanai town. Projections for the future tend to decrease slightly. (Figure 46 and Figure 49)

The Community Risk Assessments carried out during the study provide additional details of how climate-related events impact communities. Following is a description of how droughts have affected one community, Manggai in Ward 7, Tikana LLG, in Kavieng District.

Drought has occurred at least four times (1937, 1979, 1997 and 2015) in Manggai based on the disaster timeline developed by the community. The most severe droughts were the 1997 and 2015 extreme dry spells. In both instances, the village sources of drinking water dried up. Water levels in the Manggai River significantly dropped and even stopped flowing. People had to depend on this water, which got contaminated, leading to an outbreak of water-borne diseases.

Food crops were also badly affected as most of them were wiped out during the droughts. The drying up of water sources affected the yields of food and cash crops including cocoa and coconut. The soil became hard and dry and thus difficult to plant new crops. There was a shortage of seedlings and suckers, not only in the village but also in nearby areas.

Bushfires also worsened the situation, as many of the existing crops were burned affecting both food and cash crops. With most people not getting enough food from their gardens and production of cash crops severely affected, they relied on wild foods to survive. Sago, which is abundant in the community, was the source of food for families during the drought periods in the past.

The people of Manggai have experienced extreme weather events from 2009-2014, including heavy precipitation over a long period of time, long dry periods, and short period of extreme rainfall. These events have created havoc on people’s normal lives because it impacts their usual daily routine and livelihood activities. As a result, their overall productivity, food security and incomes were affected.

Current economic risk to drought is moderate in three hotspots: the eastern half of New Hanover Island, the area around Manggai and the area north west of Konos. Projections for the future tend to decrease, whereas only the eastern half of New Hanover Island will remain moderate. (Figure 47 and Figure 50)

The composite map for drought risk for New Ireland shows that the province has a low to moderate profile, with the most prominent hotspots around the island of New Hanover, the central part of Kavieng District and the area in the boundary between the district of Kavieng and the district of Namatanai. (Figure 48 and Figure 51)

Projections for the future show that the province will suffer less drought episodes in the near future, and only the area of New Hanover remains with a moderate risk. The order of magnitude can be seen in the table below:

Table 34. Distribution of drought risk classes in New Ireland Province

	HAZARD : DROUGHT													
	RISK 1960-1990 %							RISK 2030-2050 %						
District	**1**	**2**	**3**	**4**	**5**		**(3+4+5)**	**1**	**2**	**3**	**4**	**5**		**(3+4+5)**
Kavieng District	0,0	20,3	47,8	0,0	0,7	31,2	48,5	6,9	34,0	27,1	0,7	0,0	31,2	27,8
Namatanai District	5,0	32,2	8,2	0,6	0,1	54,0	8,9	19,9	21,6	3,9	0,4	0,0	54,1	4,3

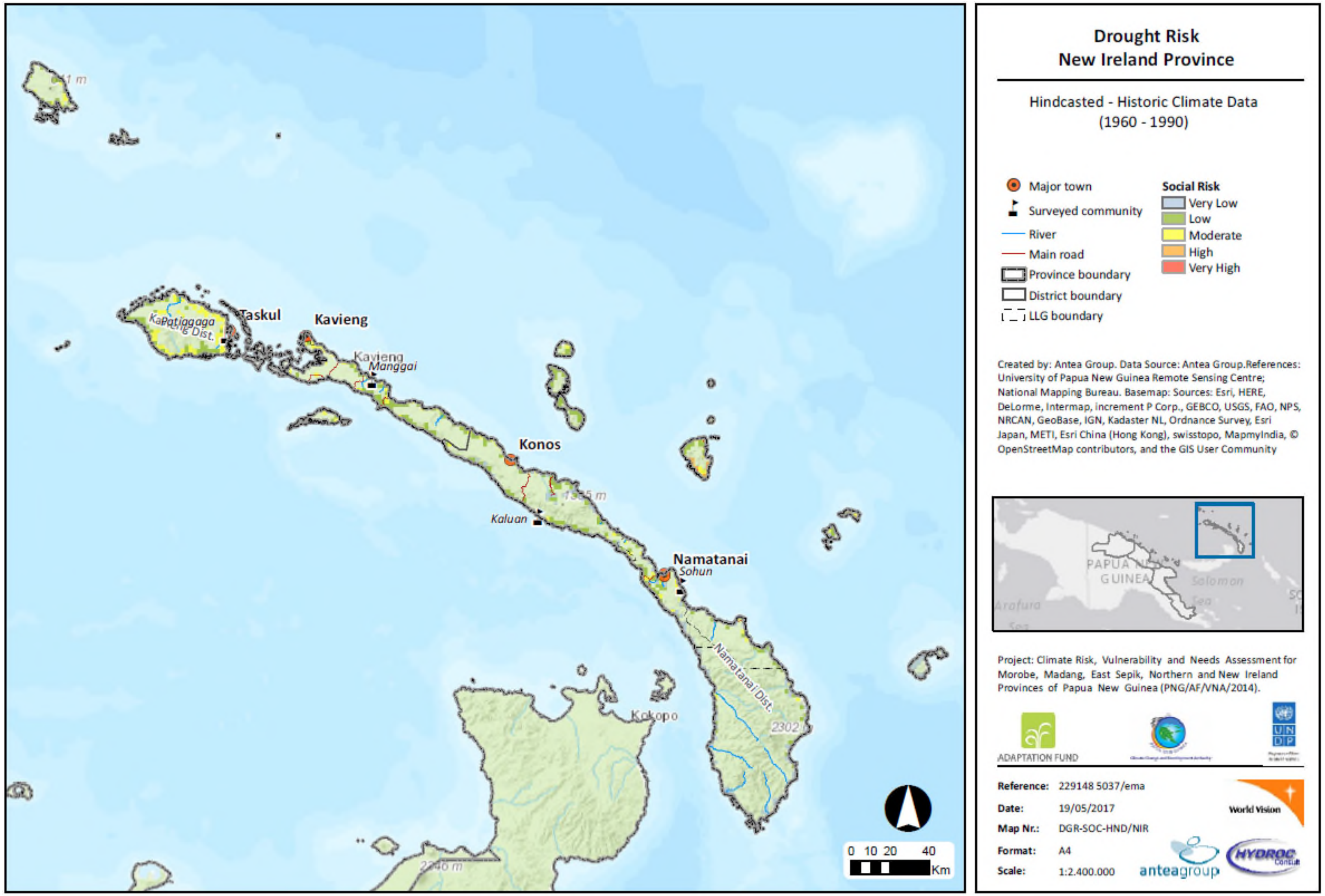

Figure 46. Drought Social Risk (current climate) ■Very Low ■Low ■Moderate ■High ■Extreme

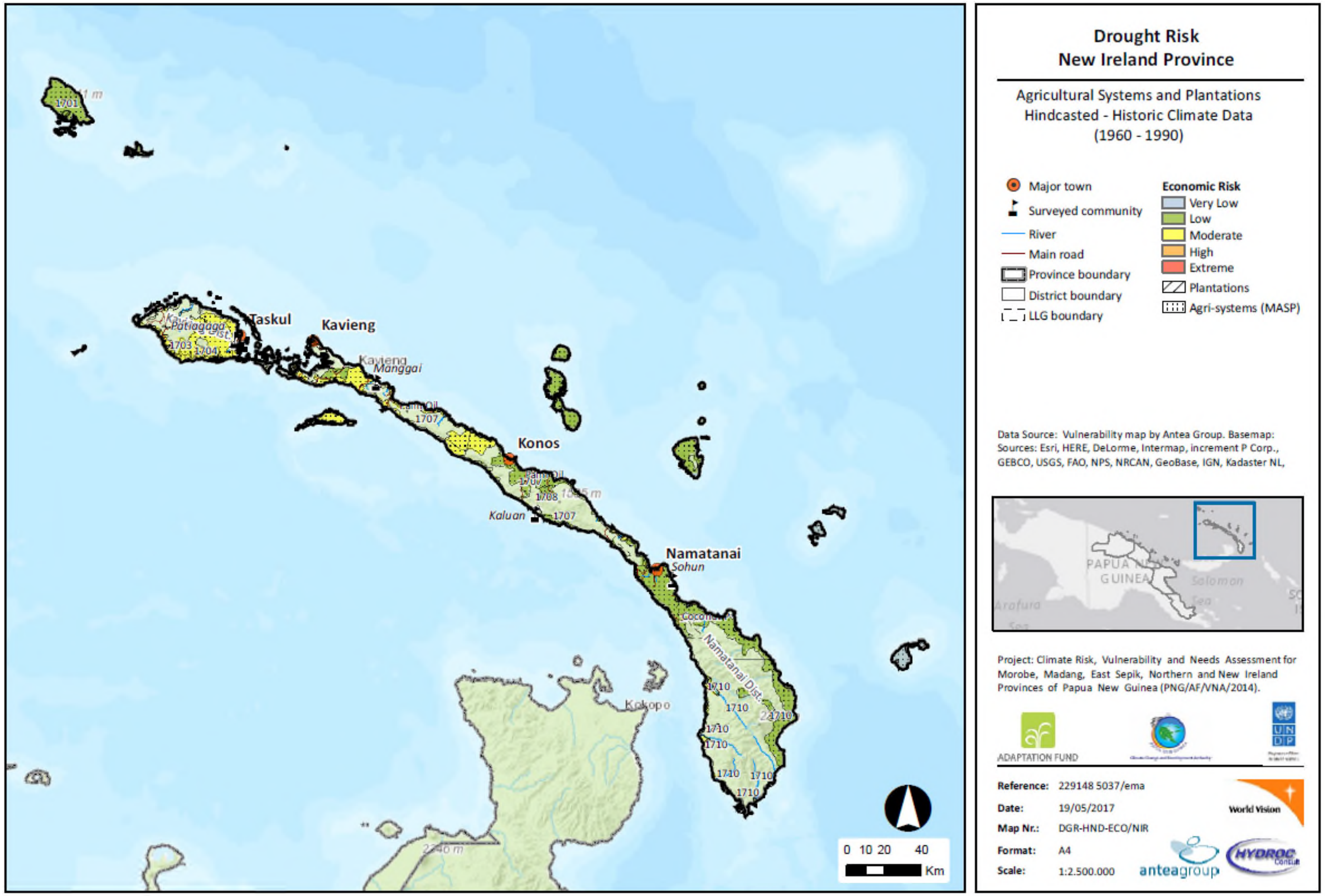

Figure 47. Drought Economic Risk (current climate) **Very Low** **Low** **Moderate** **High** **Extreme**

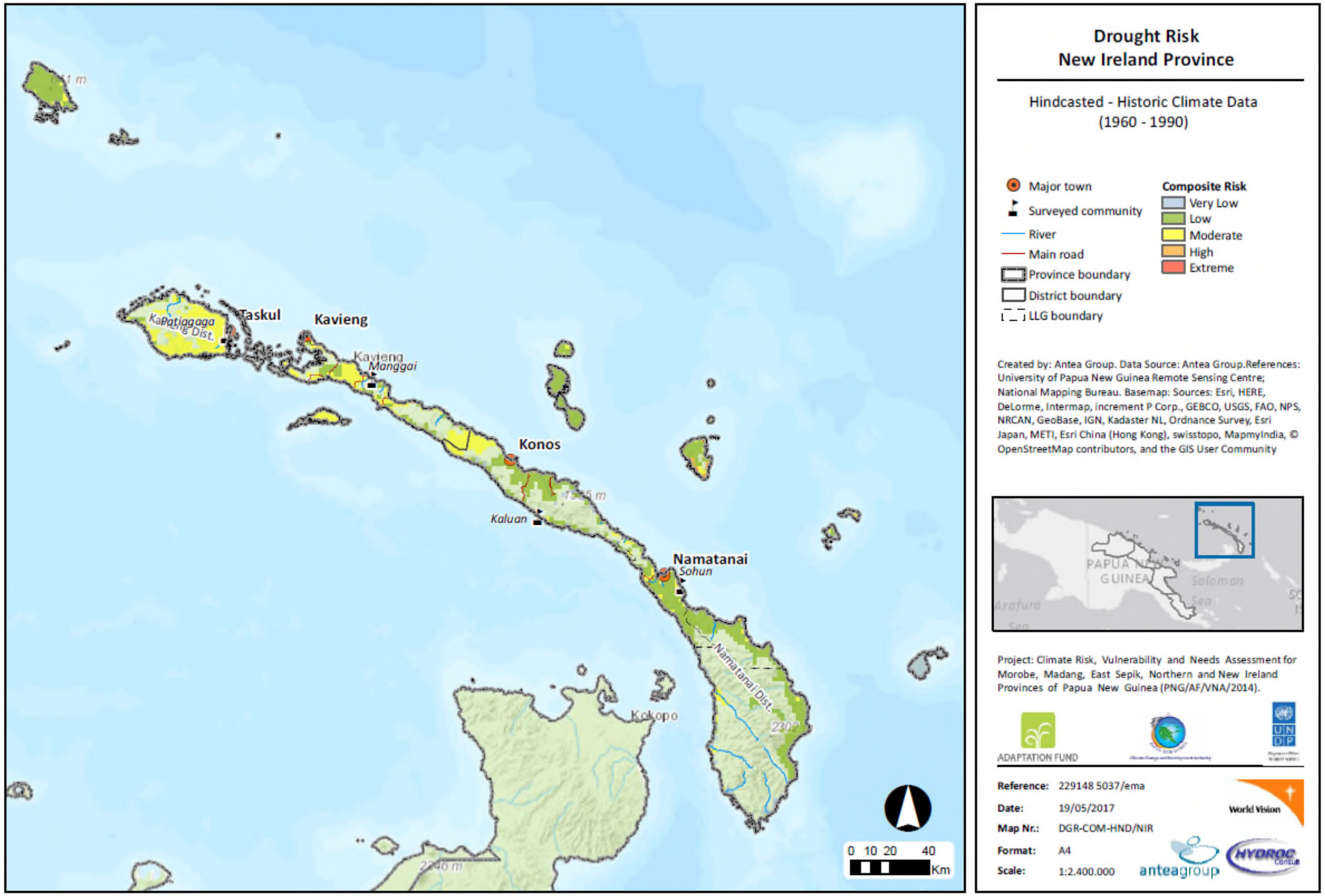

Figure 48. Combined Drought Risk (current climate) Very Low Low Moderate High Extreme

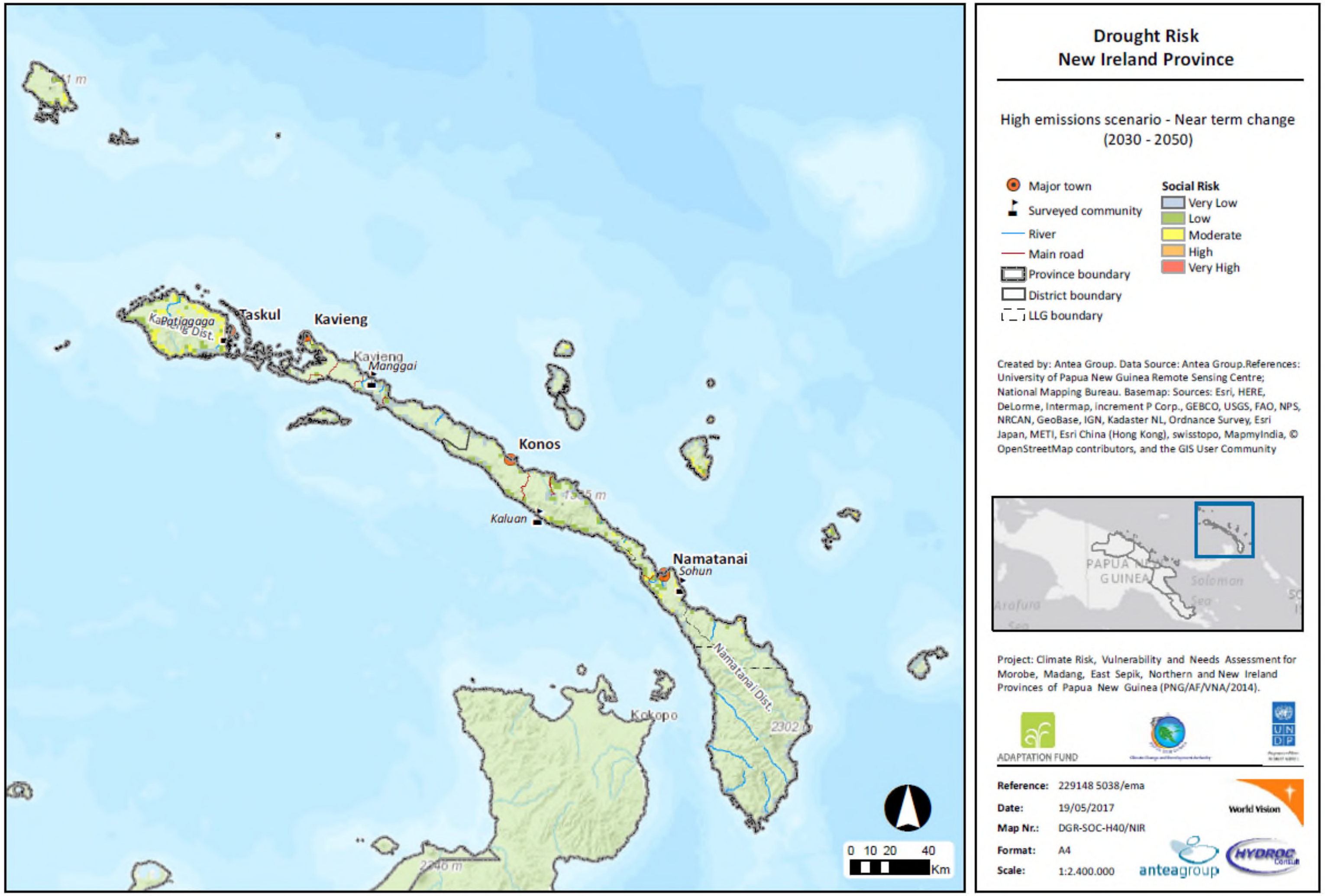

Figure 49. Drought Social Risk (projected climate) Very Low Low Moderate High Extreme

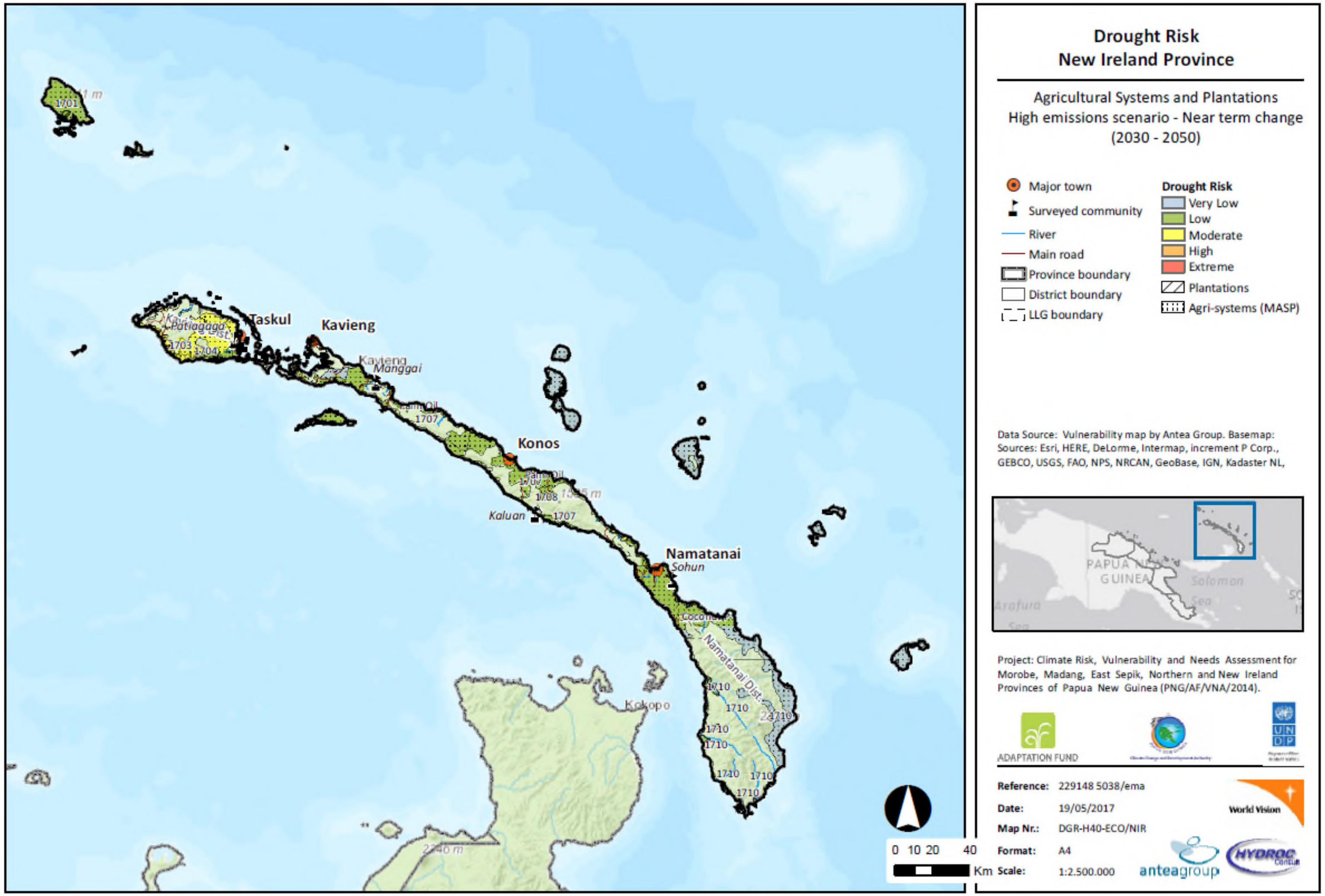

Figure 50. Drought Economic Risk (projected climate) **Very Low** **Low** **Moderate** **High** **Extreme**

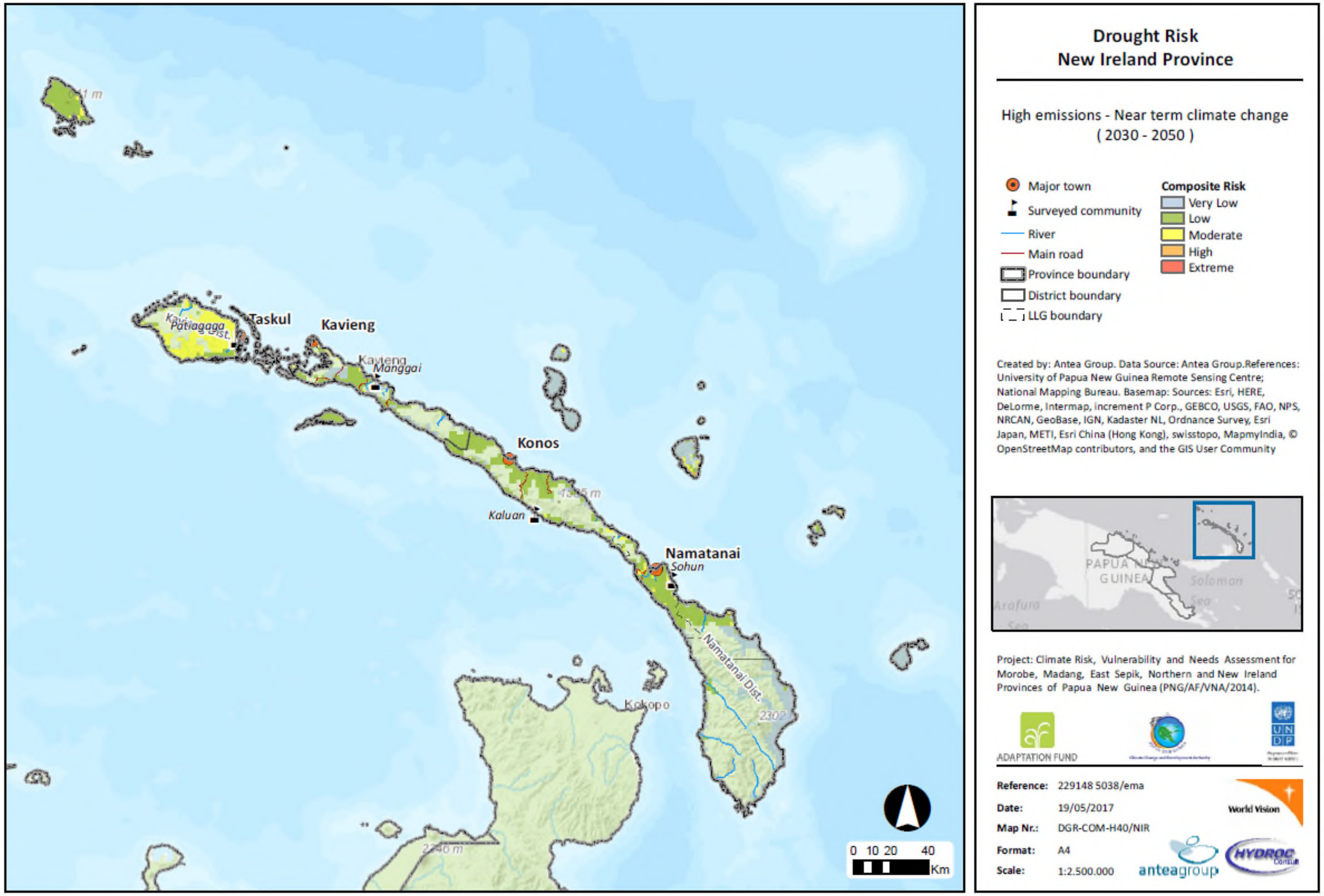

Figure 51. Combined Drought Risk (projected climate) Very Low Low Moderate High Extreme

2.3.4. *Extreme weather (tropical cyclone) Risk*

The social risks from extreme weather in the province are generally low, with the highest risk being found along the coast of Lovongai Rural LLG in the northern part of Kavieng District and along the coast of the offshore islands off the east coast of the province. Projections for the future do not show much change. (Figure 52 and Figure 56)

The map for extreme weather physical risk does not show any major issues and projections for the future remain the same. (Figure 53 and Figure 57)

Current economic risk to extreme weather is low to very low for the whole province, and projections for the future show the same tendency. (Figure 54 and Figure 58)

The composite map for extreme weather risk for New Ireland shows that the province has a low to very low profile, with no major issues to mention, and projections for the future do not show much change. (Figure 55 and Figure 59)

Table 35. Distribution of extreme weather (cyclones) risk classes in New Ireland Province

	HAZARD : CYCLONE											
	RISK 1960-1990 %						RISK 2030-2050 %					
District	1	2	3	4	5		1	2	3	4	5	
Kavieng District	38,1	34,3	0,0	0,0	0,0	27,5	38,1	34,3	0,0	0,0	0,0	27,5
Namatanai District	13,5	33,4	0,0	0,0	0,0	53,1	13,5	33,4	0,0	0,0	0,0	53,1

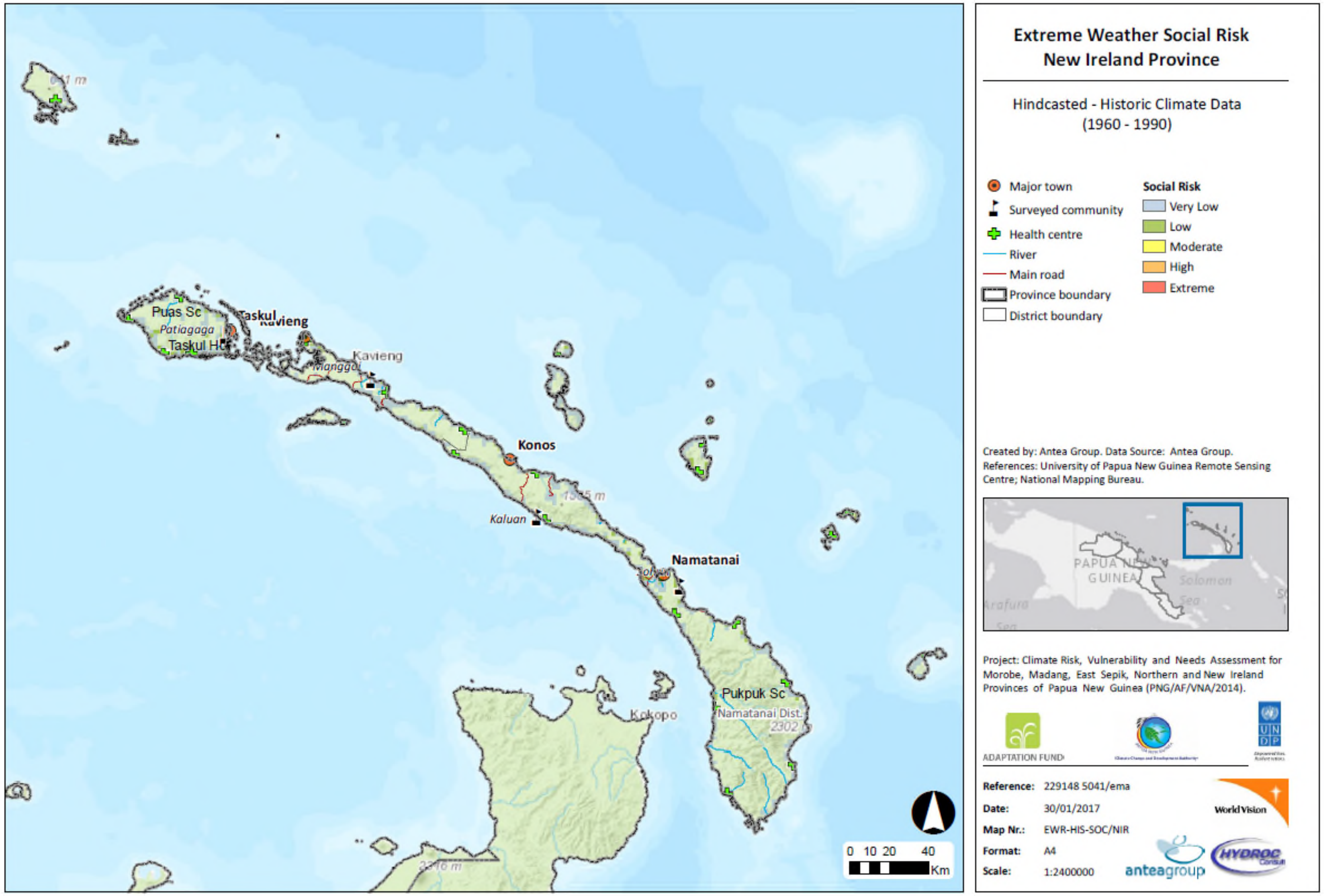

Figure 52. Tropical cyclones Social Risk (current climate) ■Very Low ■Low ■Moderate ■High ■Extreme

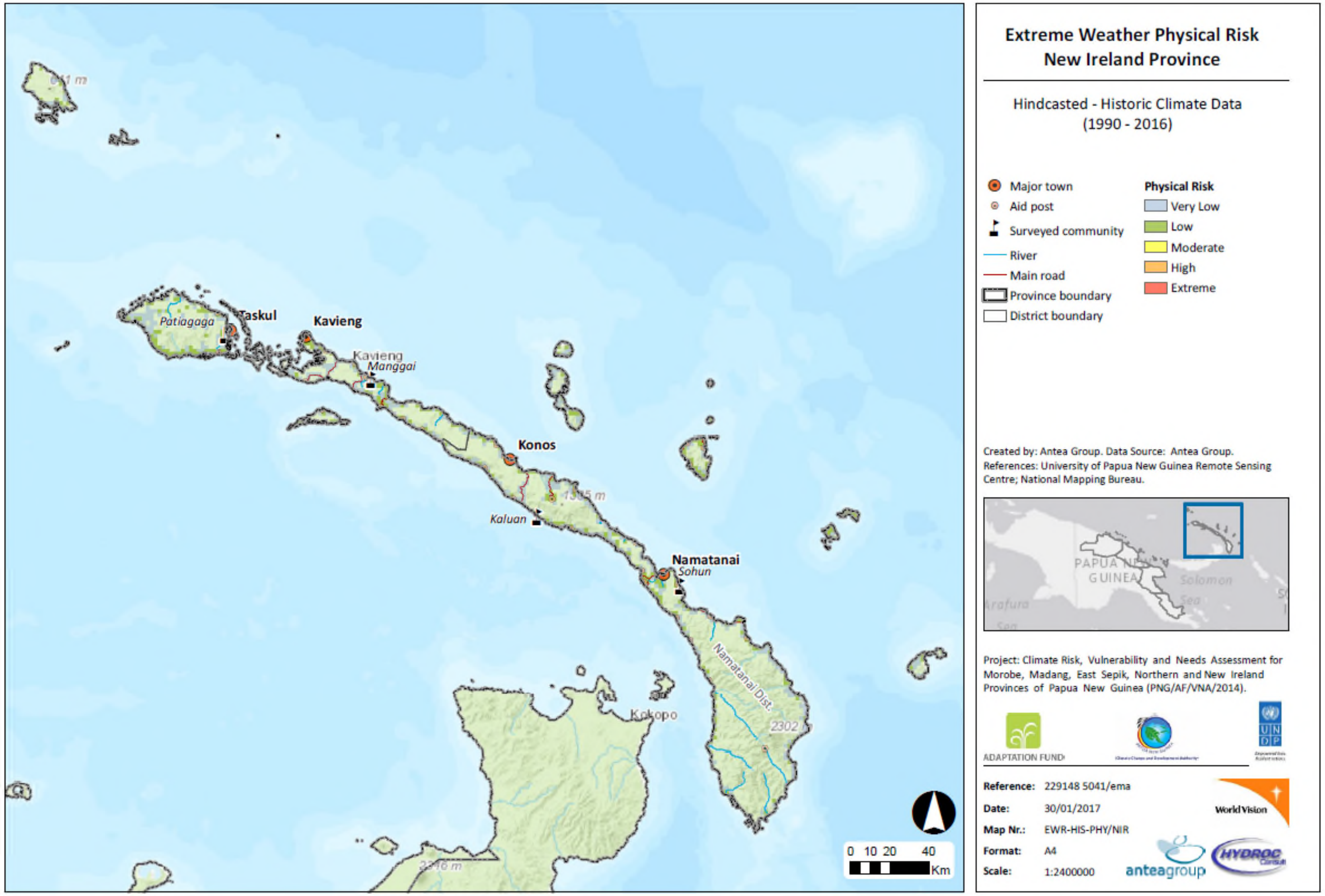

Figure 53. Tropical cyclones Physical Risk (current climate) ■**Very Low** ■**Low** ■**Moderate** ■**High** ■**Extreme**

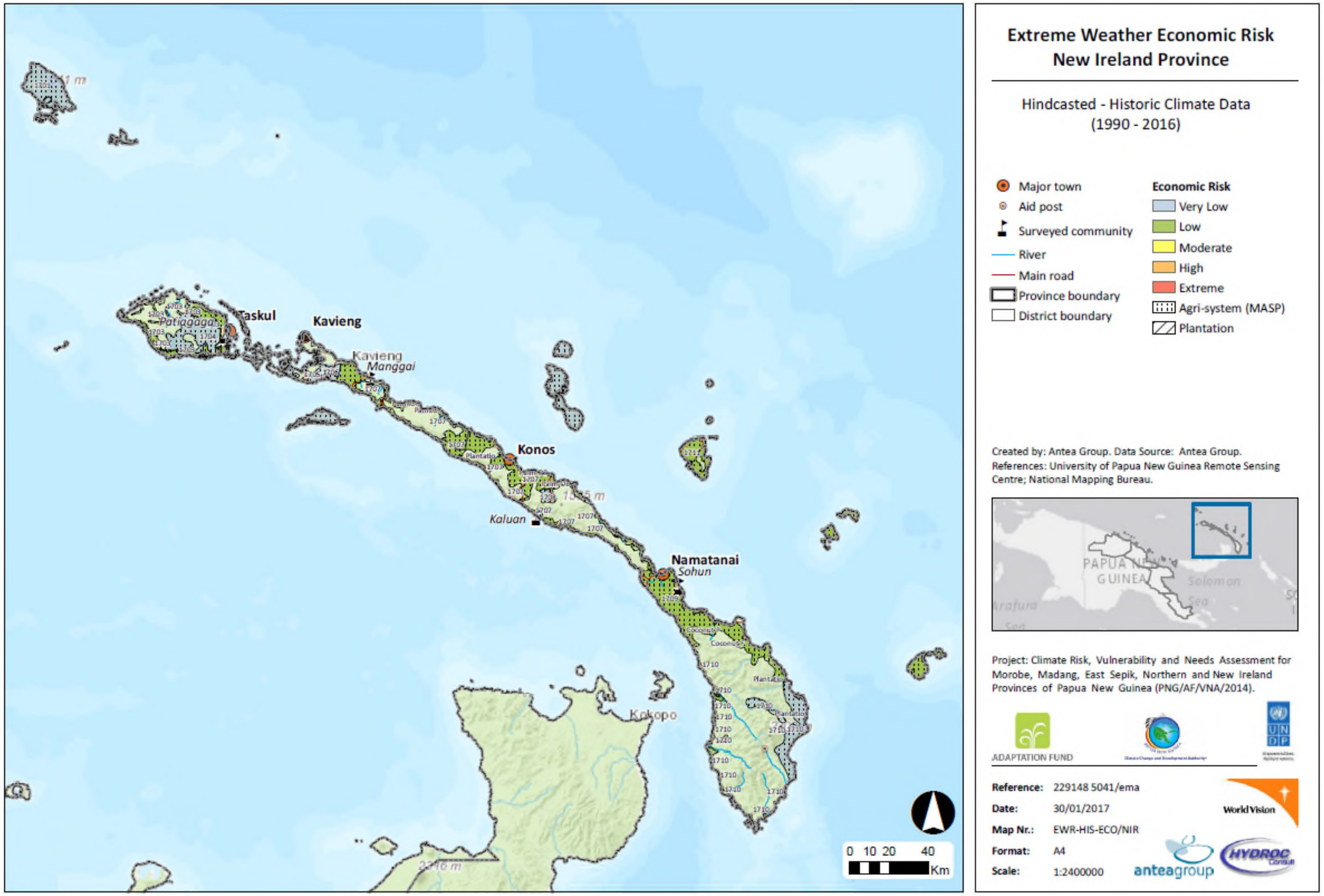

Figure 54. Tropical cyclones Economic Risk (current climate) ■ **Very Low** ■ **Low** ■ **Moderate** ■ **High** ■ **Extreme**

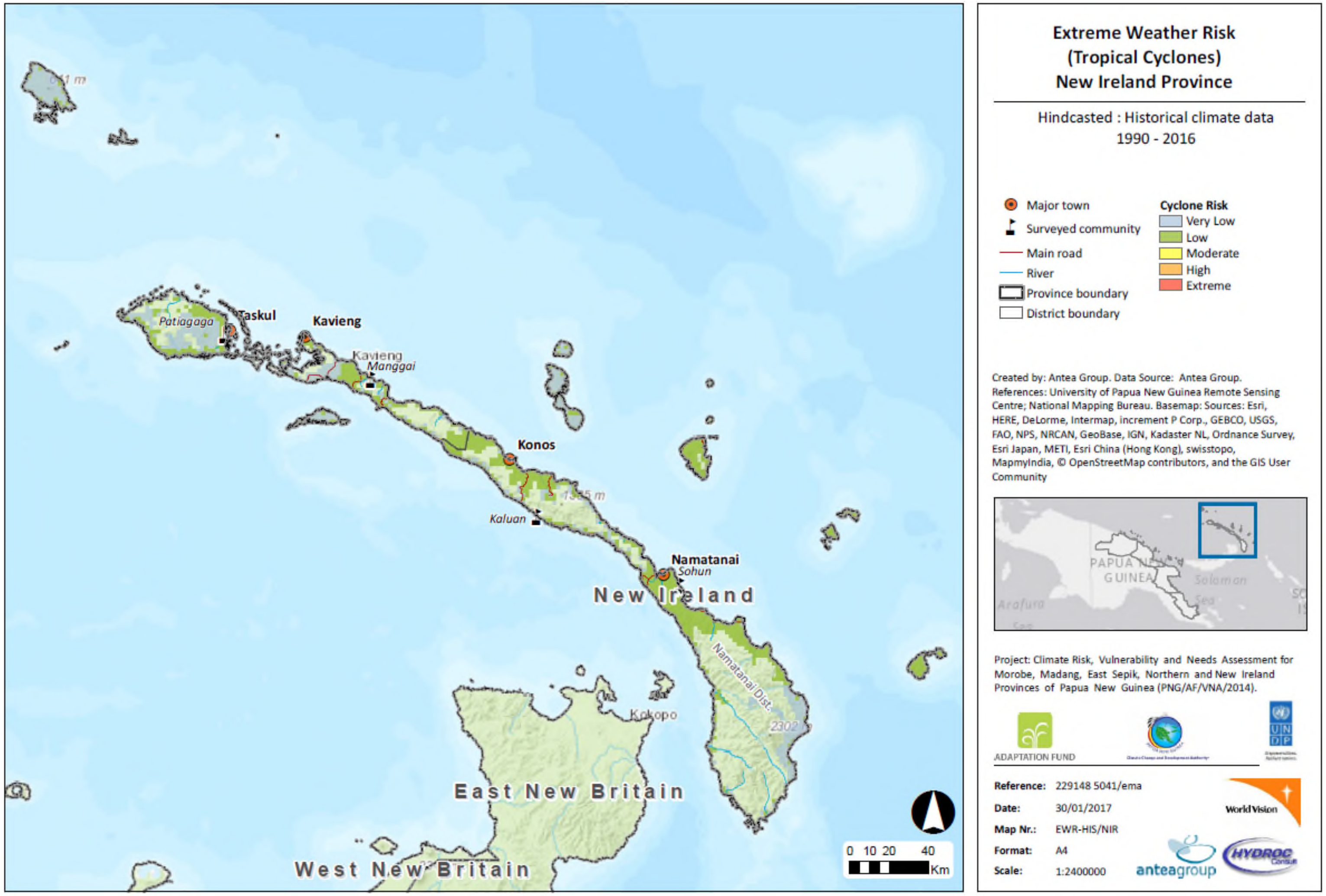

Figure 55. Tropical cyclones Composite Risk (current climate) **Very Low** **Low** **Moderate** **High** **Extreme**

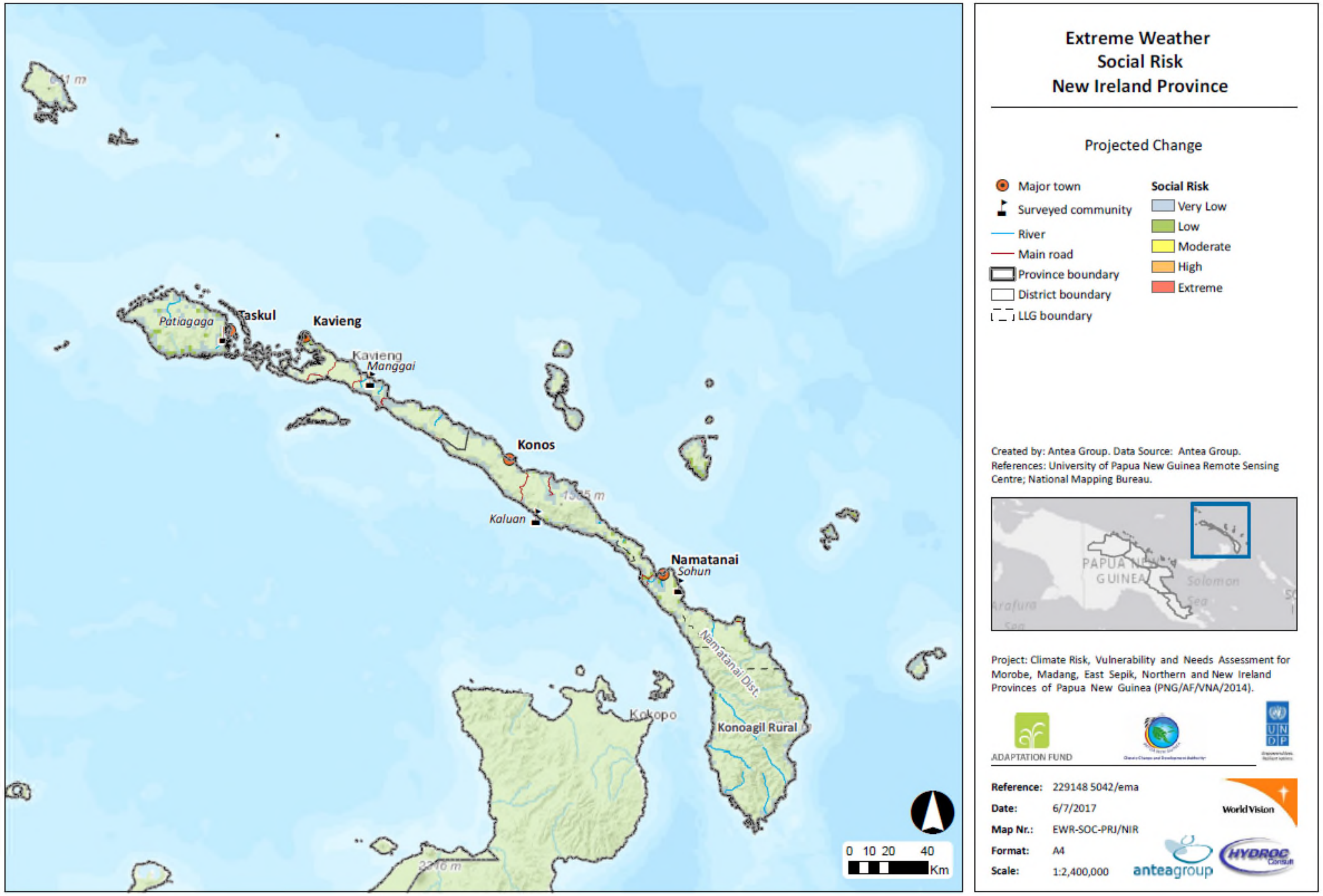

Figure 56. tropical cyclones Social Risk (projected climate) Very Low Low Moderate High Extreme

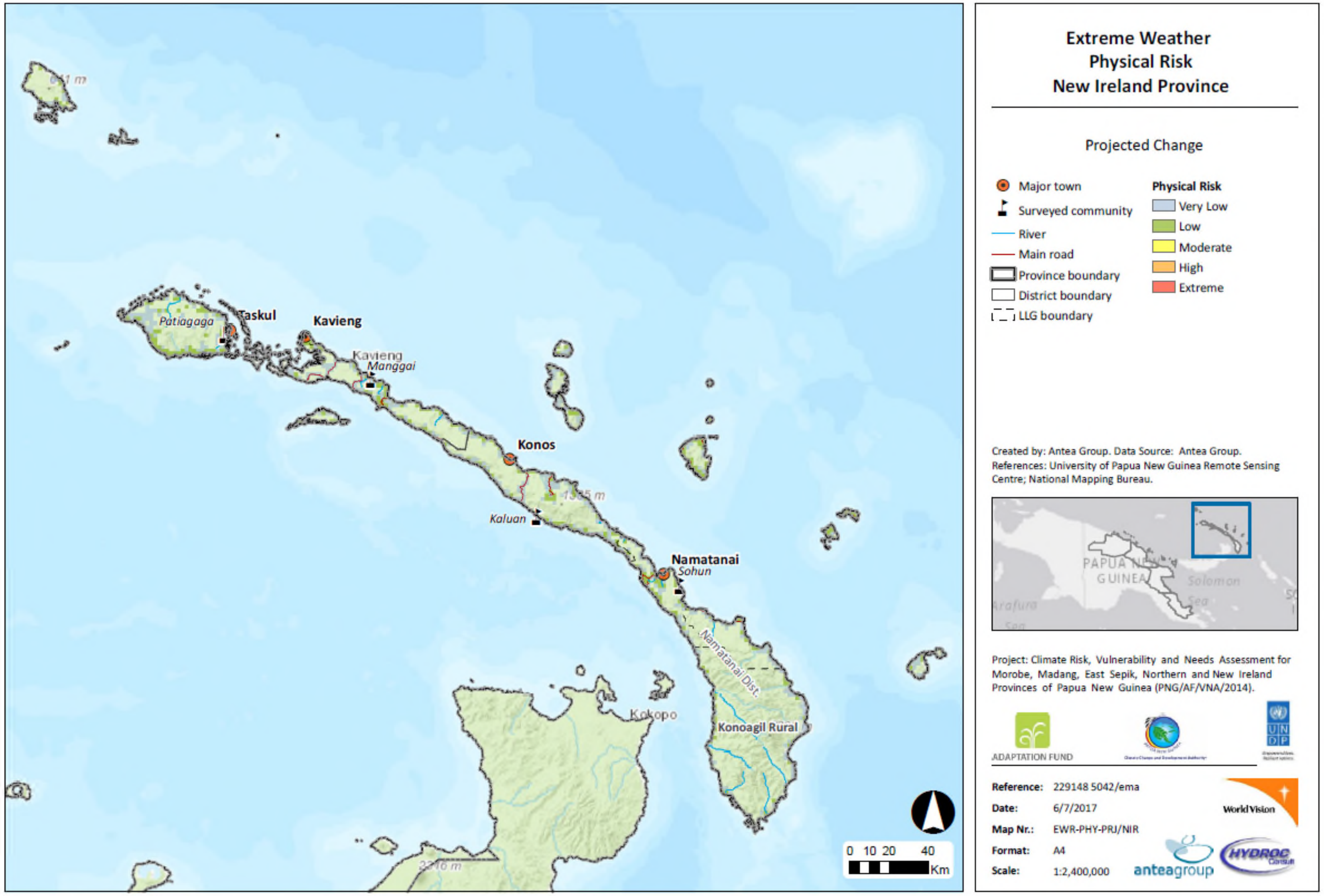

Figure 57. Tropical cyclones Physical Risk (projected climate) Very Low Low Moderate High Extreme

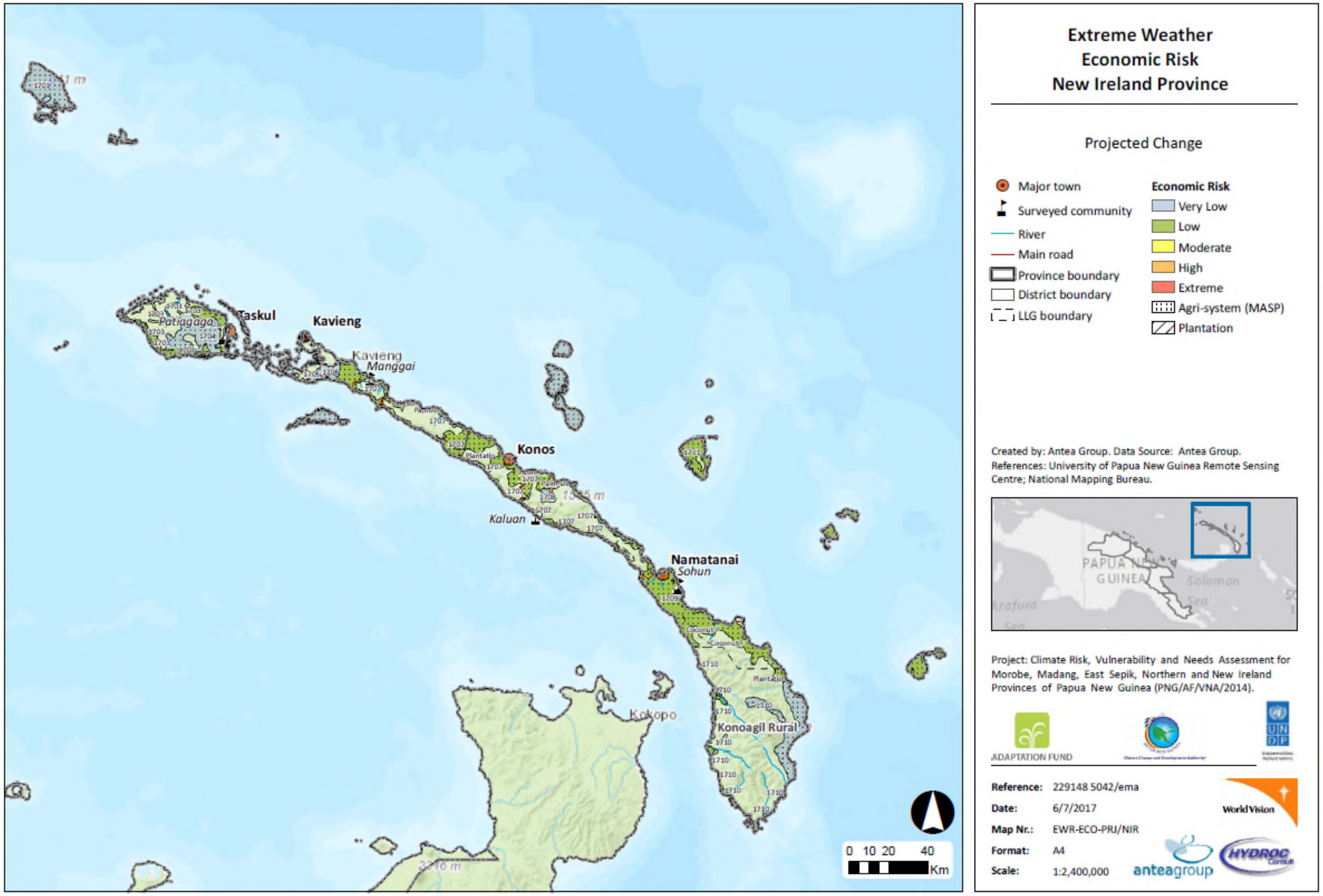

Figure 58. tropical cyclones Economic Risk (projected climate) ■**Very Low** ■**Low** ■**Moderate** ■**High** ■**Extreme**

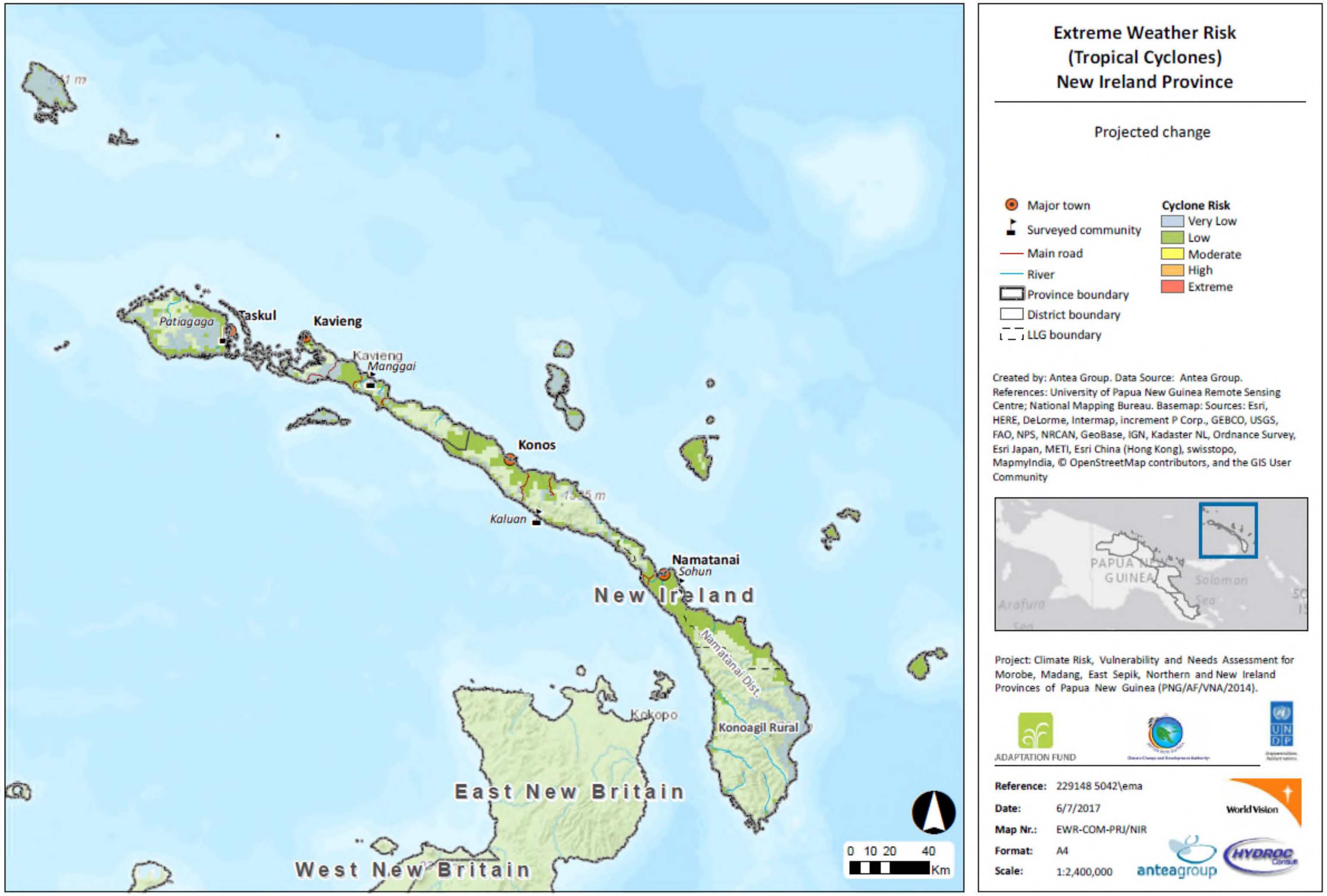

Figure 59. Tropical cyclones Composite Risk (projected climate) Very Low Low Moderate High Extreme

2.3.5. *Increase of precipitation intensities and variability*

The highest risk from high rainfall is found in Lovongai Rural LLG in the northern part of Kavieng district and along the east coast of the district south of Kavieng town, including the Manggai area. There is high risk from high rainfall along the southern coast of the islands off the east coast of Namatanai District. Additionally, there are areas of high to moderate risk along the entire east coast of Namatanai District. Projections for the future show a slight increase in the risk, in the areas mentioned before, especially, in Lahir Island. (Figure 60 and Figure 63)

Current economic risk to rainfall intensity is very low for all the province, and only a bit higher in the area around Konos and the south of Namatai District. Projections for the future indicate a slight increase throughout the province in the near future. (Figure 61 and Figure 64)

The composite map for intense rainfall risk for New Ireland shows that the province has a very low profile and just the area around Konos is slightly higher. (Figure 62 and Figure 65)

Projections for the future show that the province will have an incipient risk in the near future, around the area of New Hanover, the central part of the province and around the area of Namatanai. The order of magnitude can be seen in the table below:

Table 36. Distribution of precipitation intensity and variability risk classes in New Ireland Province

	HAZARD : PRECIPITATION													
	RISK 1960-1990 %							RISK 2030-2050 %						
District	**1**	**2**	**3**	**4**	**5**		**(3+4+5)**	**1**	**2**	**3**	**4**	**5**		(3+4+5)
Kavieng District	61,9	7,2	0,0	0,0	0,0	31,0	0,0	31,2	22,7	15,0	0,0	0,2	31,0	15,2
Namatanai District	30,2	12,0	3,3	0,1	0,0	54,4	3,4	2,4	27,6	8,8	5,4	1,5	54,3	15,7

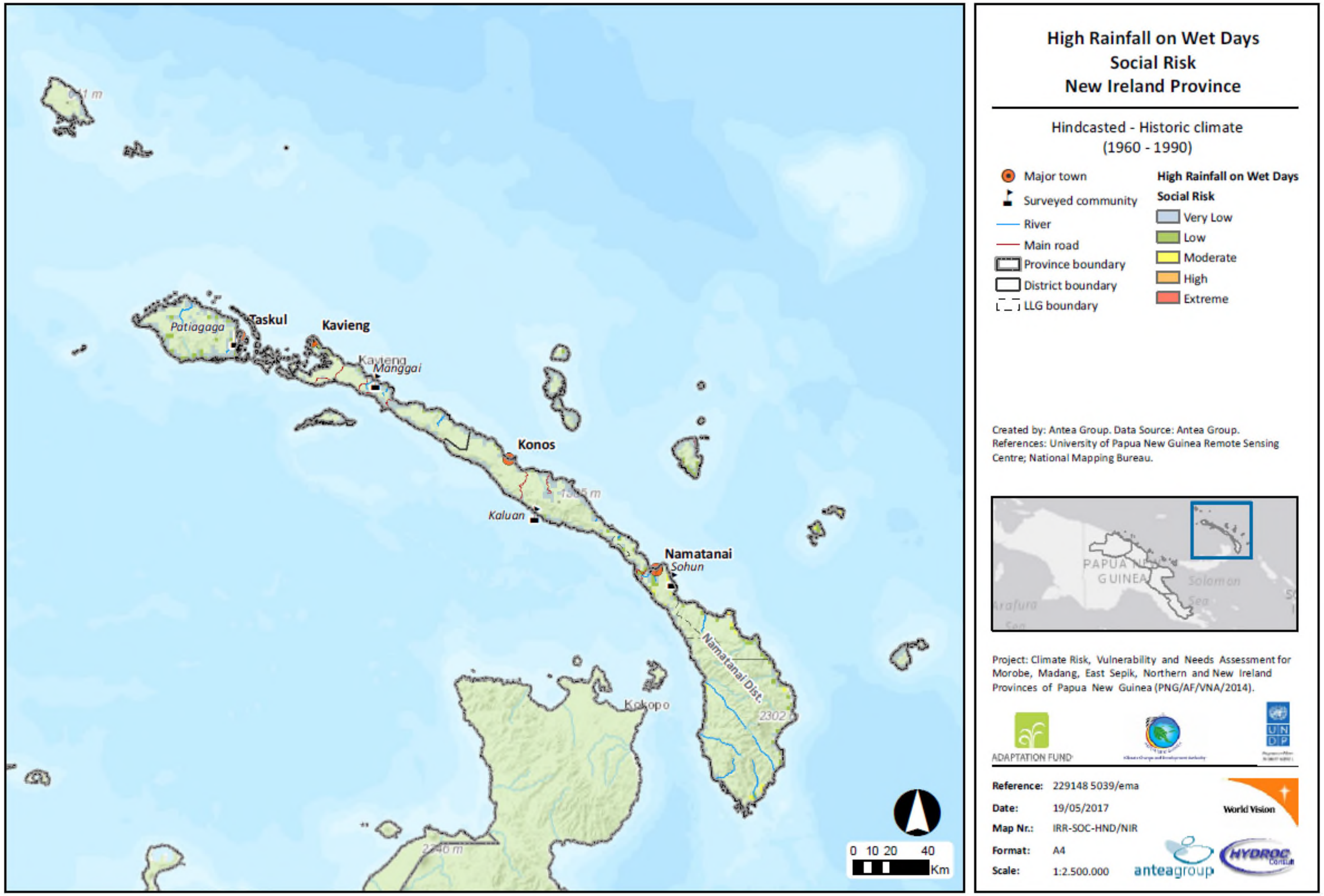

Figure 60. Precipitation intensities and variability social risk (current climate) Very Low Low Moderate High Extreme

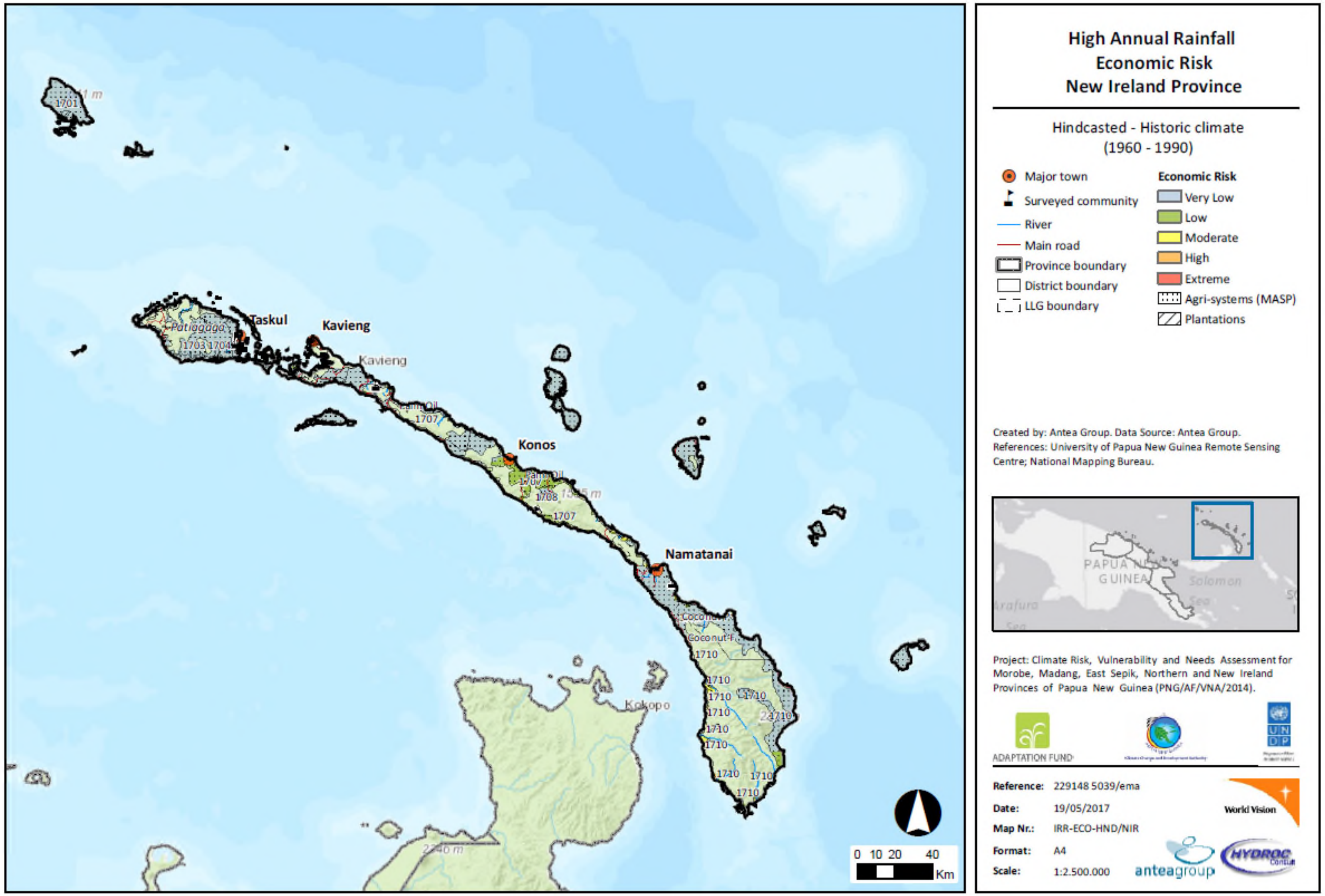

Figure 61. Precipitation intensities and variability Economic Risk (current climate) Very Low Low Moderate High Extreme

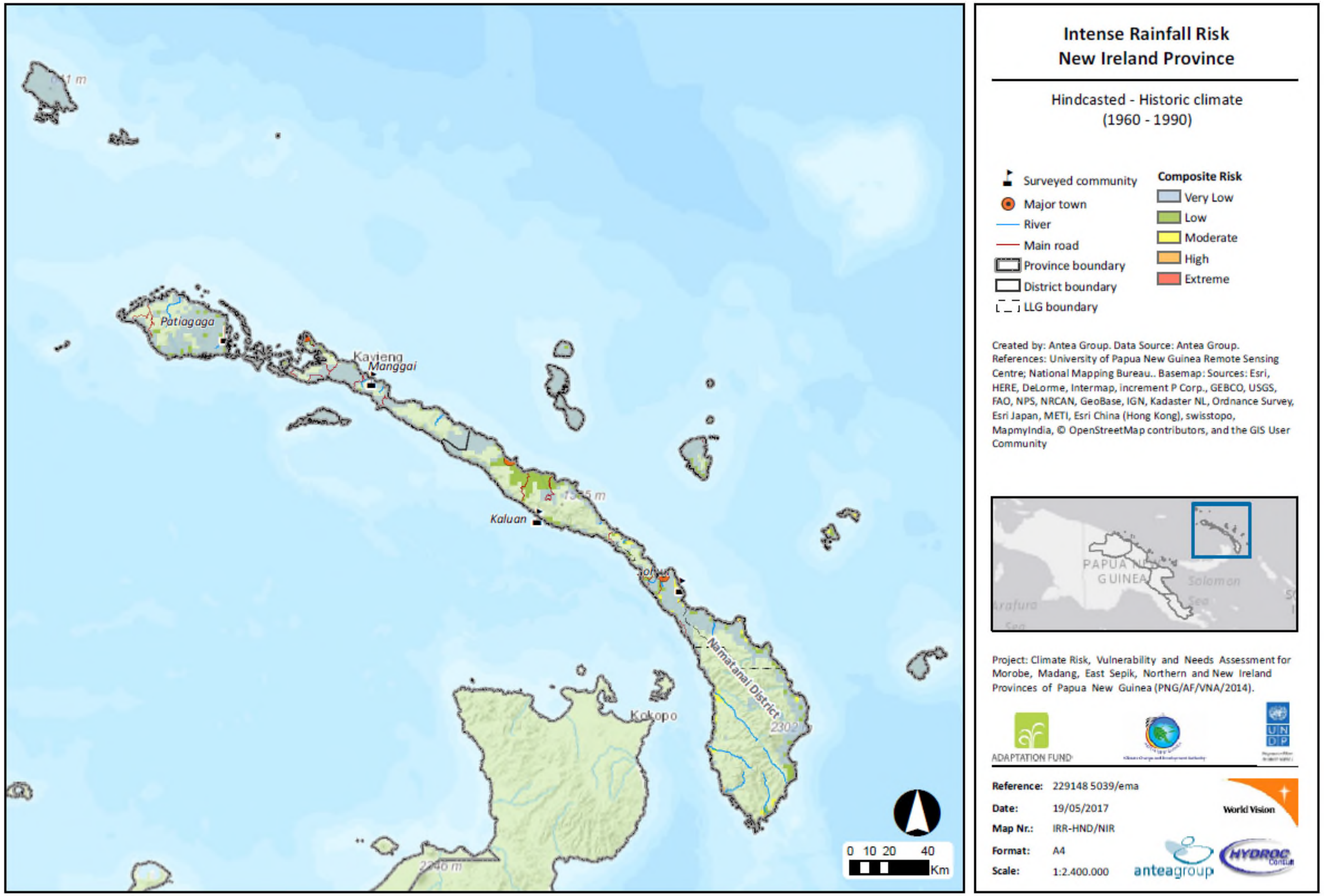

Figure 62. Precipitation intensities and variability composite Risk (current climate) Very Low Low Moderate High Extreme

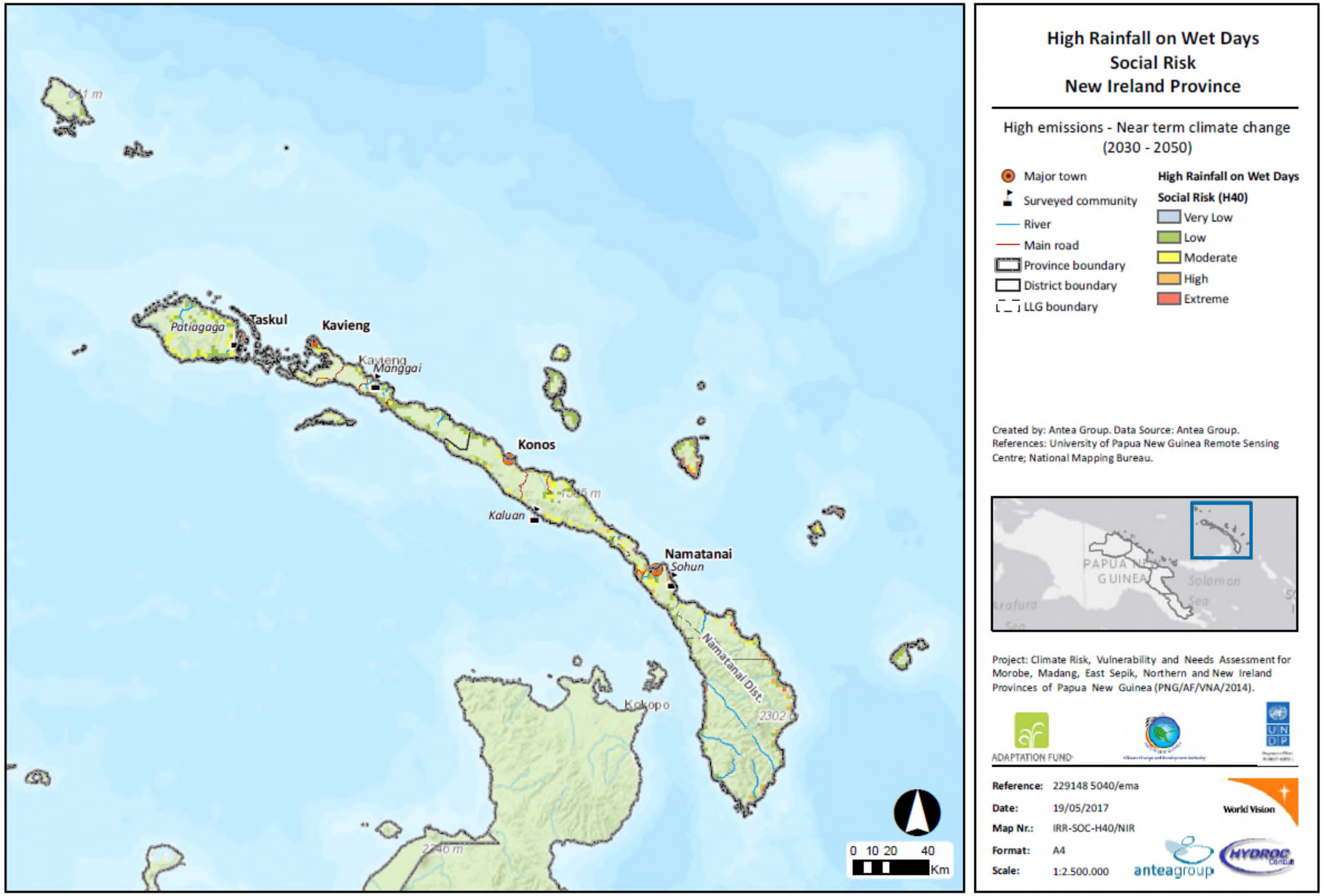

Figure 63. Precipitation intensities and variability Social Risk (projected climate) ■**Very Low** ■**Low** ■**Moderate** ■**High** ■**Extreme**

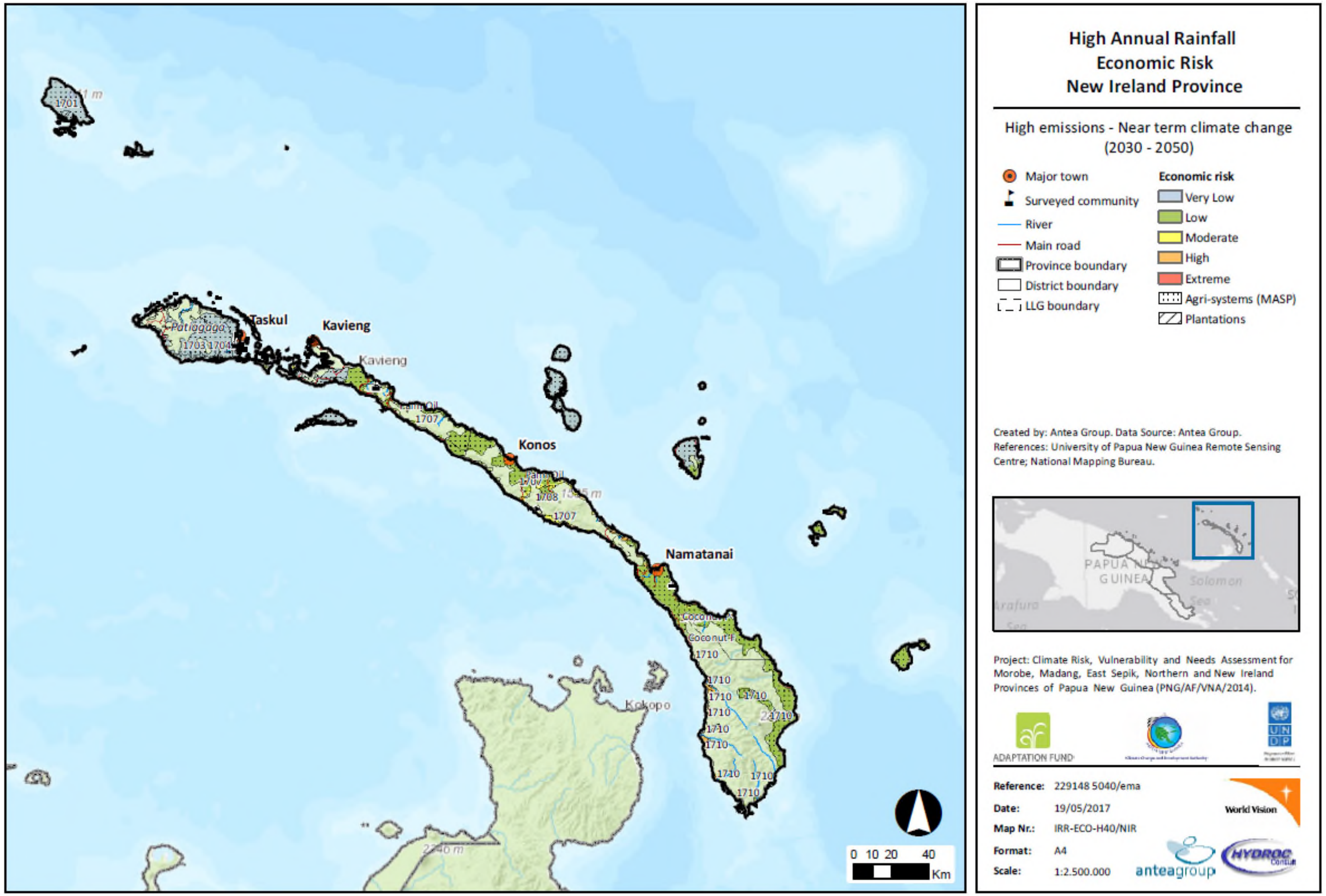

Figure 64. Precipitation intensities and variability Economic Risk (projected climate) Very Low Low Moderate High Extreme

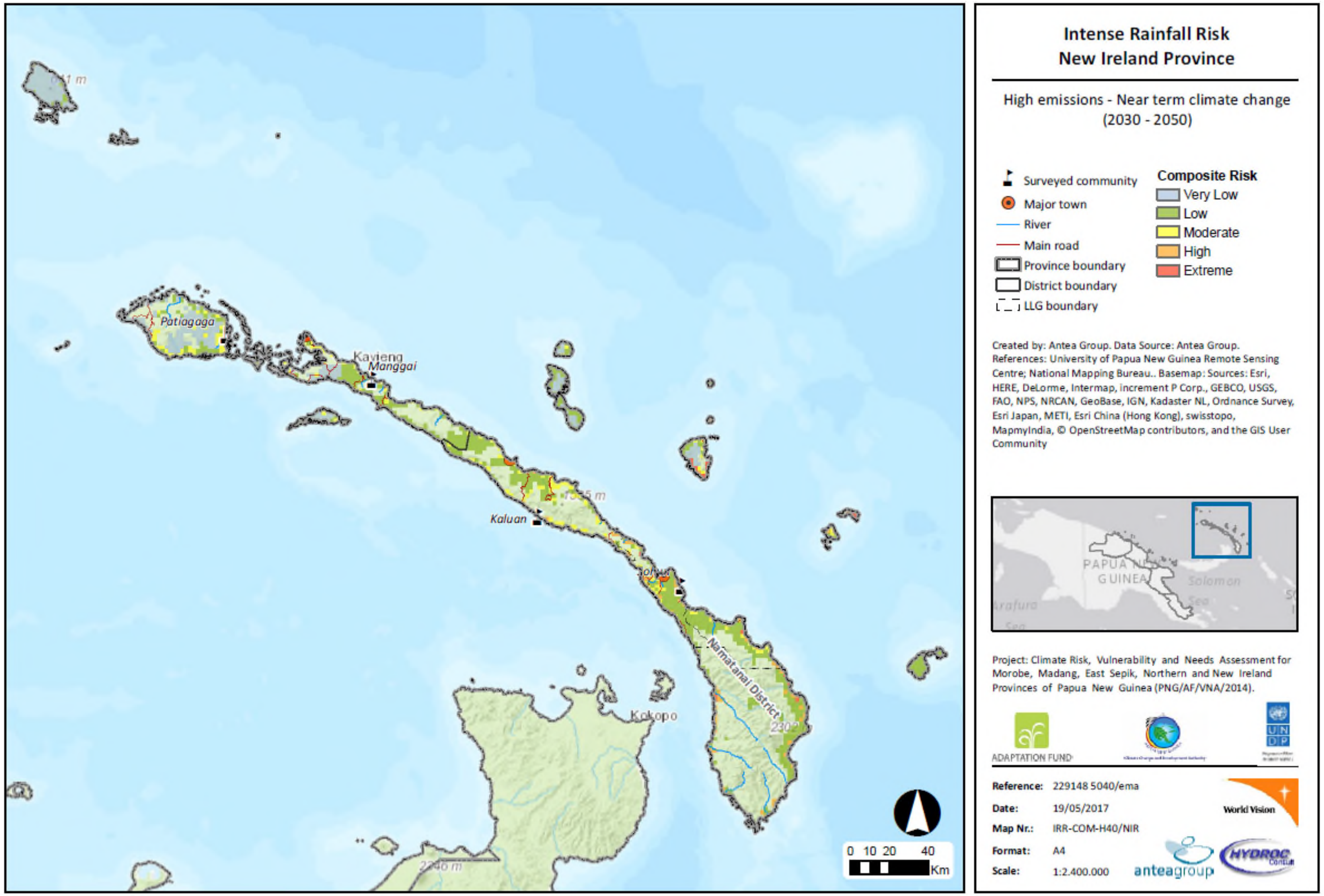

Figure 65. Precipitation intensities and variability Composite Risk (projected climate) **Very Low** **Low** **Moderate** **High** **Extreme**

2.4. Composite Risk

The overall composite risk map for the province has been derived from the risk maps for the respective hazards as presented in the previous chapter.

The map indicated areas that are exposed to multiple risks. To count the number of risks per pixel on the map, risks occurrence with values moderate, high or very high were counted. This results in the following categories. The area that are exposed to some very low of low risks for one or more hazards have received a value ‘0’, areas that are not coloured on the map have not been characterised at risk for any of the considered hazards. All areas with a values 1 to 5 are have been identified as having a moderate (or higher) risk for 1 to 5 hazards. (Figure 66 and Figure 67)

Table 37 shows the percentage distribution of composite risk classes in the province for the current and projected climate. This table shows which % of the province is prone to some risks.

Note: the map needs to be updated to count coastal risk, for the moment this is not included and the maximum value on the map therefore is 4 and not 5.

Table 37. Distribution of composite risk classes

	HAZARDS													
	RISK 1960-1990 %						RISK 2030-2050 %							
District	**0**	**1**	**2**	**3**	**4**	**5**		**0**	**1**	**2**	**3**	**4**	**5**	
Kavieng District	27,5	46,4	2,8	0,0	0,0		23,3	42,3	23,9	8,9	1,6	0,0		23,3
Namatanai District	39,1	7,3	2,5	0,9	0,0		50,2	33,2	10,9	5,3	0,5	0,0		50,2

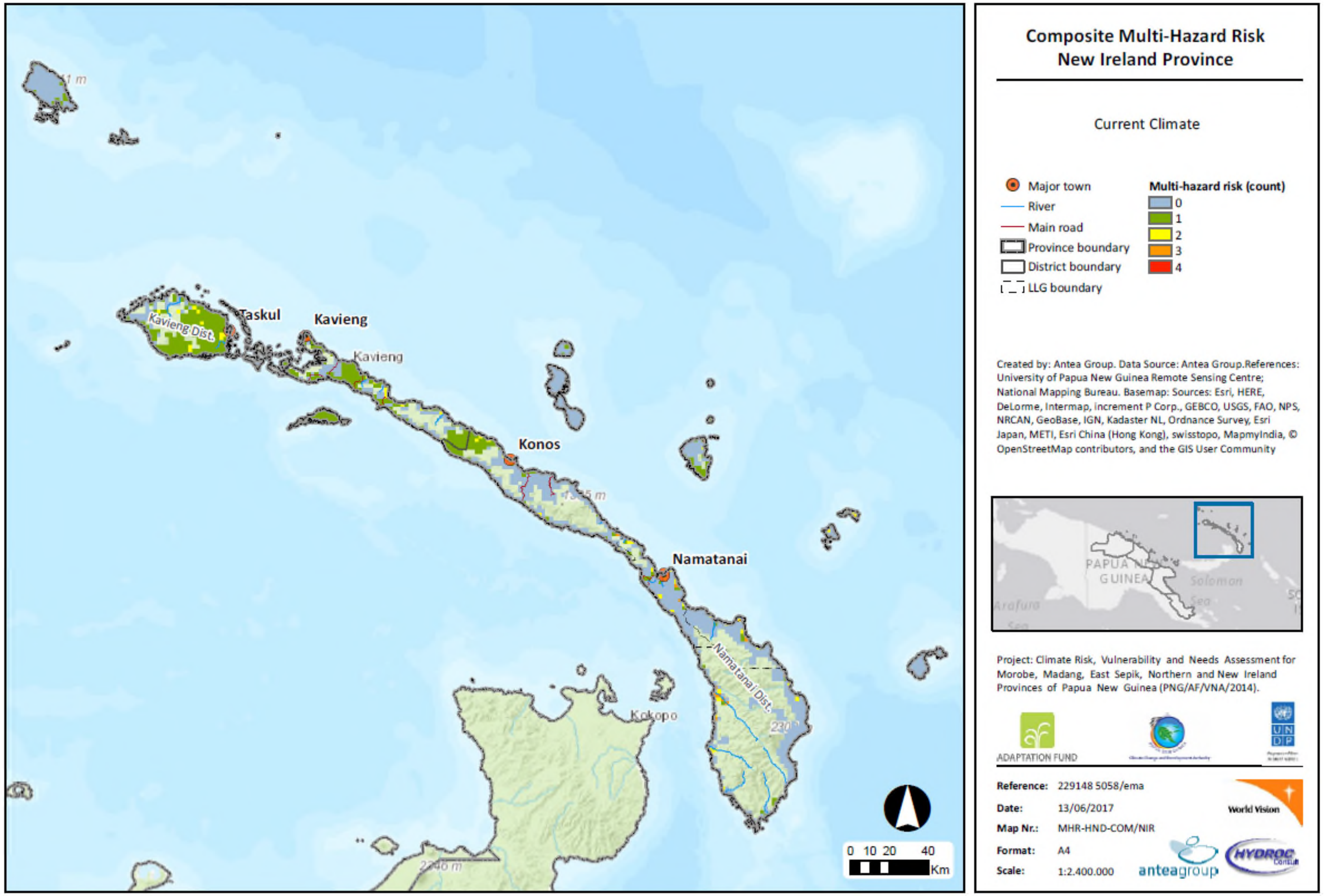

Figure 66. Composite Multi-Risk Map New Ireland Province (current)

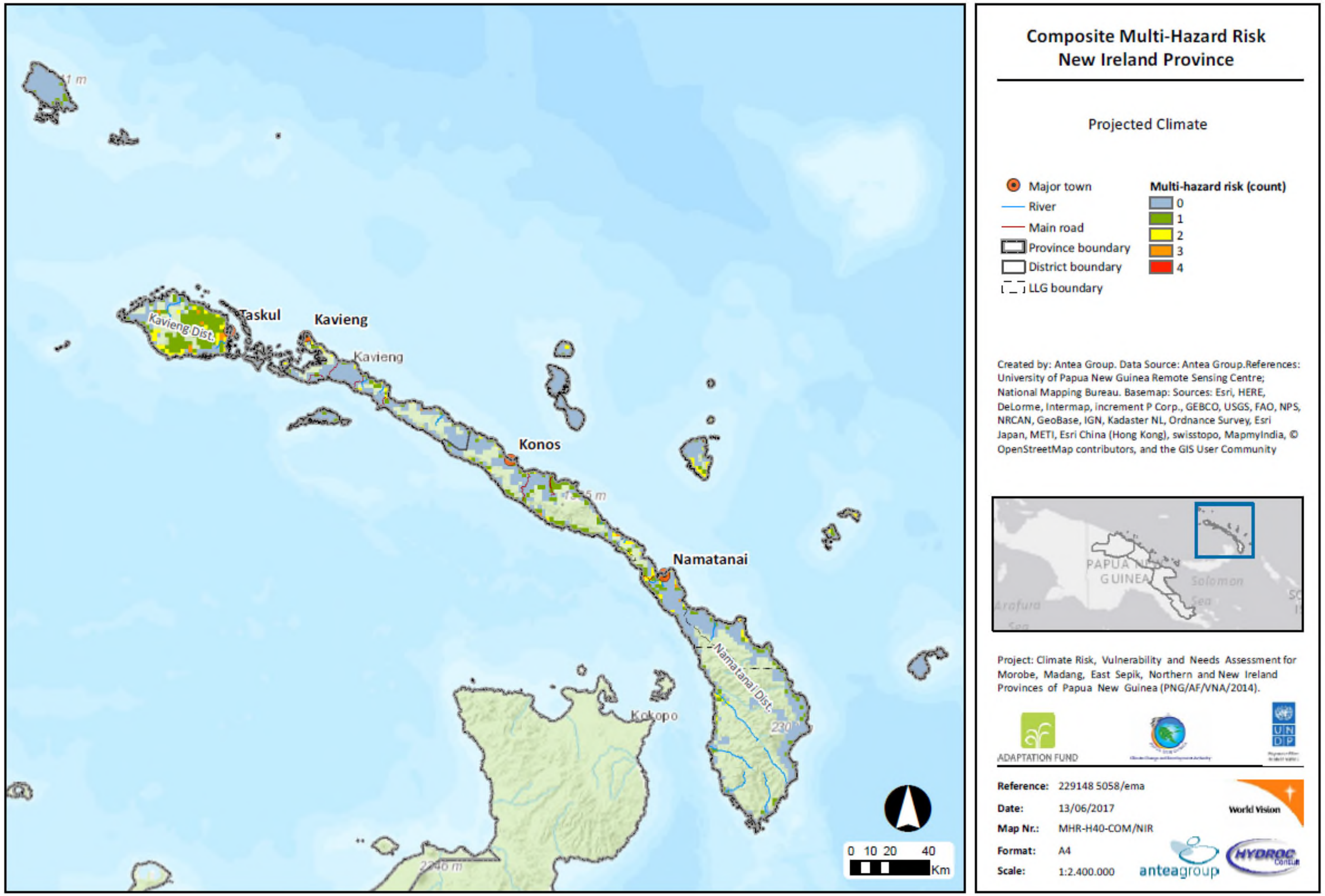

Figure 67. Composite Multi-Risk Map New Ireland Province (future)

3. DISTRICT RISK PROFILES

3.1. *Kavieng Risk Profile*

3.1.1. *General description*

Kavieng District includes the northern end of New Ireland as well as the St. Matthias Group of Islands and Lavongai and Tingwon Islands. Moderate to high incomes can be earned from the sale of copra, cocoa, betel nut, fish and food across this district, with some potential to expand copra and cocoa production. The district headquarters is located in Kavieng. There are 4 Local Level Governments in this district: Murat Rural, Lavongai Rural, Tikana Rural and Kavieng Urban. Number of wards assigned to this district is 48.

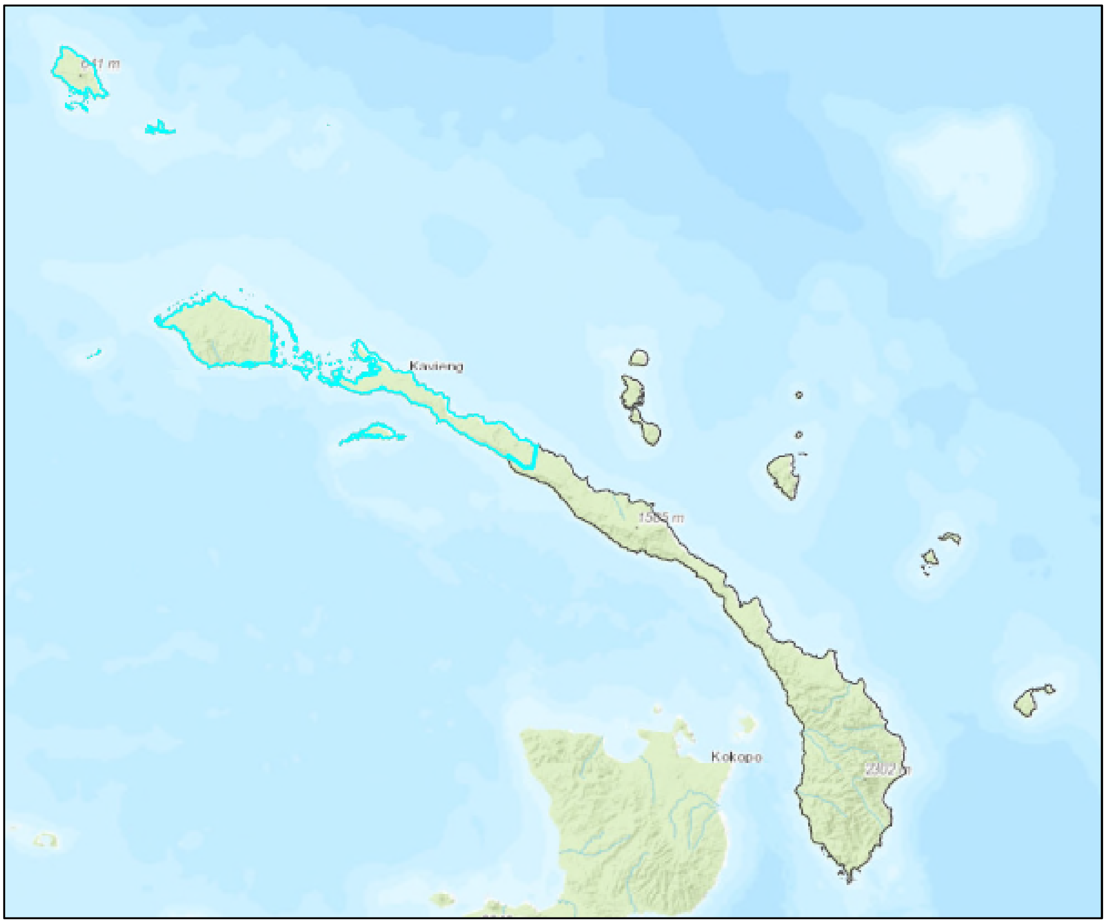

Figure 68. Kavieng District

Kavieng District has a population of 83,162[10]. The average population density is relatively low, 17.9 inhabitants per km^2. The highest population densities are found on the East Islands and Tingwon Island with 162 persons/km2. The coastal plains of Lavongai Island have moderate population densities, while New Ireland and Dyaul Island have lower densities. The Saint Matthias Islands have lower population densities, while the interior of Lavongai Island has less than 10 persons/km^2. The Kaut hills and coastal

[10] National Population and Housing Census, 2011, National Statistical Office, 2013.

plains, southeast of Kavieng, have significant in-migration. The population of the Tigak and East Coast Kara Nalik areas has increased by an average of 8 % per year in recent decades, which is very high.

The most disadvantaged people in the district are the population living on Mussau Island, Lavongai Island and on the west coast of New Ireland who generally live in areas with low agricultural potential.. People in the East Islands and on Tingwon Island are also at a disadvantage due to very high population densities, which result in pressure on land and land shortages. As a result, people become vulnerable to food and water shortages during periods of drought. Overall, people in Kavieng District are slightly disadvantaged relative to people in other districts of PNG. There is no agricultural pressure, land potential is moderate, access to services is good and cash incomes are relatively high.

People in the coastal areas of Lavongai Island and on Tingwon and Dyaul islands require less than four hours' travel to reach Kavieng, while people in the Saint Matthias Islands and those in the interior of Lavongai Island require 4–8 hours' travel. There are good roads in the coastal areas of New Ireland and minor roads on Lavangai, Dyaul and Mussau islands. Outboard motor boat and canoe travel are used along the coast and between the islands**.**

Table 38. Selected Health Indicators for Kavieng District (2014)

Low Weight for Age < 5 years old (%)	Low Birth Weight (%)	Incidence of Malaria (1,000 pop.)	Incidence of Diarrhoea (<5 years/1,000 pop.)
25	7.3	122	159

Kavieng District has an adult literacy rate of 76.9%, with a significant disparity in literacy rates between males (78.8%) and females (74.4%).

3.1.2. Hazards

Hazard maps can be found in the province description (refer to Section 1) and the annex.

Kavieng District is not prone to tropical cyclones and projections for the future show the same tendency.

The map for current inland flood hazard shows some flooding zones, mostly 5 year return, but also some 50 year return as in the east of New Hanover or to the southeast of Kavieng. Projections for the future show similar patterns.

The map for current total annual rainfall shows that the district has a low to moderate precipitation profile, with values that range from 2079 to 2710mm for most of the district, except a little corner in the south east, where values are a little bit higher. Projections for the future show an increase for the whole district to values ranging the 2711 to 2979, except in Murat Rural, where they will remain a bit lower.

The map for total rainfall on wet days shows that Murat Rural and the northern part of New Hanover Island have values that range 250 to 500mm, and the rest of the district, from 501 to 600mm. Projections for the future show a slight increase in rainfall intensity, where Murat Rural will remain between 501 to 600mm but the rest of the district will have values of 601 to 700mm.

Finally, drought hazard is moderate to high in the district, with values that range from 24,1 to 29 continuous dry days in Murat Rural and the northern part of New Hanover Island and 21,1 to 24 continuous dry days for the rest of the district. Projections for the near future show a slight decrease in the dryness of the district, where Mural Rural and the island of new Hanover will be moderate (21,1 to 24 continuous dry days), and the rest of the district, low (16,1 to 21 continuous dry days).

3.1.3. *Risk*

In Figure 69, we can see that the risks associated with inland flooding, coastal flooding, drought and extreme weather hazards. The composite risk is predominantly low to very low. However, there are a few moderate risk hotspots. They are located in the neighborhoods of ....

Figure 70 also presents the composite risks but in a future climate projection. The composite risk is changing. There are many moderate risk areas, mostly on the coast, and there are some high risk areas located around ....

In this district, the social risks are generally low to moderate, with the highest social risk from inland flooding, drought, and high rainfall being found in Lovongai Rural LLG in the northern part of the district and along the east coast of the district south of Kavieng town, including the Manggai area. Projections for the future do not show much change for social risks.

The economic risk in Kavieng District is mostly low or very low. Current economic risk to drought is moderate in three hotspots: the eastern half of New Hanover Island, the area around Manggai and the area north west of Konos. The various agricultural systems like food crops and palm oil plantations represent areas of moderate to high risk (Table 29). Projections for the future do not show much change for economic risk.

Table 39. Top agricultural activities of citizen households in Kavieng[11]

Activities	% engaged	% engaged for cash
Coconut	67,6	55,5
Food crops	71,2	11,5
Betel nut	57,9	27,9
Cocoa	31,8	30,9
Fishing	47,0	10,3

The physical risk to inland flooding is represented in a couple of minor hotspots along the north coast, and projections for the near future follow the same pattern. Conversely, the physical risk to extreme weather is low to very low, and projections for the future do not show much change.

According to the previous section, the most important hazards are inland flood with mostly 5 year return, drought and high rainfall. In future projections, the drought risk is decreasing and the composite risk increases. So, inland flood and high rainfall hazards will be closely monitor in the Kavieng district. The risks management must be establish. To reduce the social risk, communication actions can be organized. Then, protection systems can be put in place to limit the economic and physical risk.

	HAZARD : CYCLONE					
	COMPOSITE VULNERABILITY %					
LLG	**1**	**2**	**3**	**4**	**5**	
Murat Rural	67,3	9,2	10,2	5,1	1,0	7,2
Lovongai Rural	5,7	33,7	16,7	8,5	7,3	28,1
Tikana Rural	10,9	15,2	24,9	7,9	7,6	33,5

[11] National Research Institute (2010), 'Papua New Guinea District and Provincial Profiles)

Kavieng Urban	0,0	0,0	0,0	0,0	100,0	0,0

	HAZARD : DROUGHT					
	COMPOSITE VULNERABILITY %					
LLG	**1**	**2**	**3**	**4**	**5**	
Murat Rural	83,7	9,2	0,0	0,0	0,0	7,2
Lovongai Rural	6,0	51,1	10,1	0,0	0,0	32,8
Tikana Rural	15,5	41,3	4,6	0,0	1,2	37,4
Kavieng Urban	0,0	0,0	74,9	0,0	26,4	0,0

	HAZARD : INLAND FLOODING					
	COMPOSITE VULNERABILITY %					
LLG	**1**	**2**	**3**	**4**	**5**	
Murat Rural	21,4	3,1	0,0	0,0	1,0	74,5
Lovongai Rural	26,5	7,3	1,3	0,3	4,7	60,0
Tikana Rural	8,8	4,3	1,2	0,3	6,7	78,7
Kavieng Urban	0,0	0,0	0,0	0,0	17,6	82,4

	HAZARD : PRECIPITATION					
	COMPOSITE VULNERABILITY %					
LLG	**1**	**2**	**3**	**4**	**5**	
Murat Rural	83,7	9,2	0,0	0,0	0,0	7,2
Lovongai Rural	39,7	17,0	9,5	0,6	0,0	33,2
Tikana Rural	25,8	32,8	3,6	1,2	0,0	36,5
Kavieng Urban	0,0	0,0	74,9	0,0	26,4	0,0

	HAZARD : CYCLONE											
	RISK 1960-1990 %						RISK 2030-2050 %					
LLG	**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**	
Murat Rural	76,5	16,3	0,0	0,0	0,0	7,2	76,5	16,3	0,0	0,0	0,0	7,2
Lovongai Rural	39,4	32,5	0,0	0,0	0,0	28,1	39,4	32,5	0,0	0,0	0,0	28,1
Tikana Rural	26,1	40,4	0,0	0,0	0,0	33,5	26,1	40,4	0,0	0,0	0,0	33,5
Kavieng Urban	0,0	100,0	0,0	0,0	0,0	0,0	0,0	100,0	0,0	0,0	0,0	0,0

	HAZARD : DROUGHT											
	RISK 1960-1990 %						RISK 2030-2050 %					
LLG	**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**	
Murat Rural	0,0	83,7	9,2	0,0	0,0	7,2	0,0	83,7	9,2	0,0	0,0	7,2
Lovongai Rural	0,0	6,0	61,2	0,0	0,0	32,8	0,3	11,7	55,2	0,0	0,0	32,8
Tikana Rural	0,0	15,5	45,9	0,0	1,2	37,4	15,5	41,3	4,6	1,2	0,0	37,4
Kavieng Urban	0,0	0,0	74,9	0,0	26,4	0,0	0,0	0,0	74,9	26,4	0,0	0,0

	HAZARD : INLAND FLOODING											
	RISK 1960-1990 %						RISK 2030-2050 %					
LLG	**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**	
Murat Rural	21,4	3,1	1,0	0,0	0,0	74,5	21,4	3,1	1,0	0,0	0,0	74,5
Lovongai Rural	28,4	7,9	1,9	1,6	0,3	60,0	28,4	7,9	1,9	1,6	0,3	60,0
Tikana Rural	10,6	7,0	2,7	0,3	0,6	78,7	10,6	7,0	2,7	0,3	0,6	78,7
Kavieng Urban	0,0	0,0	0,0	0,0	17,6	82,4	0,0	0,0	0,0	0,0	17,6	82,4

	HAZARD : PRECIPITATION											
	RISK 1960-1990 %						RISK 2030-2050 %					
LLG	**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**	
Murat Rural	92,8	0,0	0,0	0,0	0,0	7,2	83,7	9,2	0,0	0,0	0,0	7,2
Lovongai Rural	56,8	10,1	0,0	0,0	0,0	33,2	34,7	13,2	18,9	0,0	0,0	33,2
Tikana Rural	58,6	4,9	0,0	0,0	0,0	36,5	12,8	36,1	14,6	0,0	0,0	36,5
Kavieng Urban	0,0	100,0	0,0	0,0	0,0	0,0	0,0	0,0	74,9	0,0	26,4	0,0

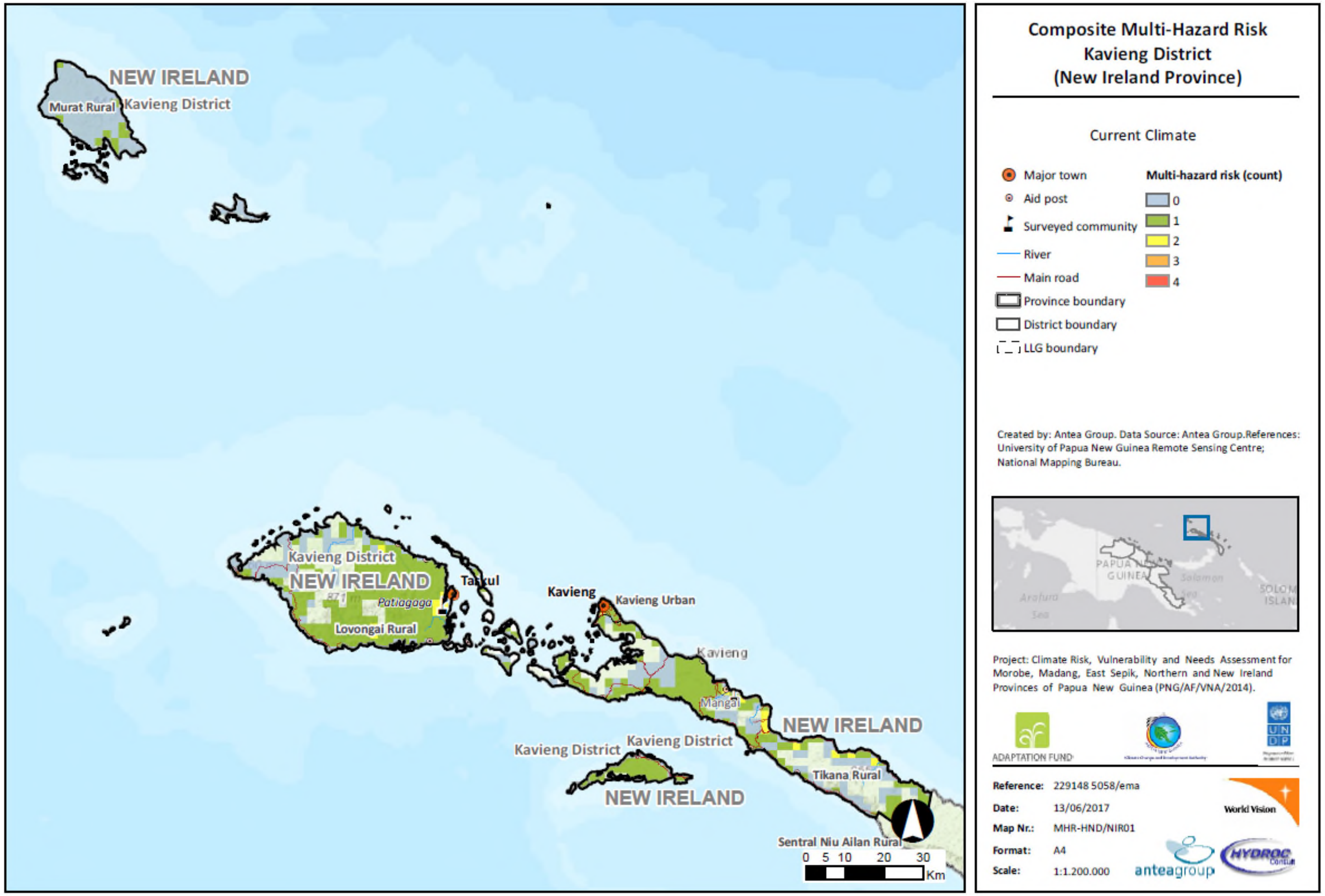

Figure 69. Composite risk map for Kavieng District (current climate)

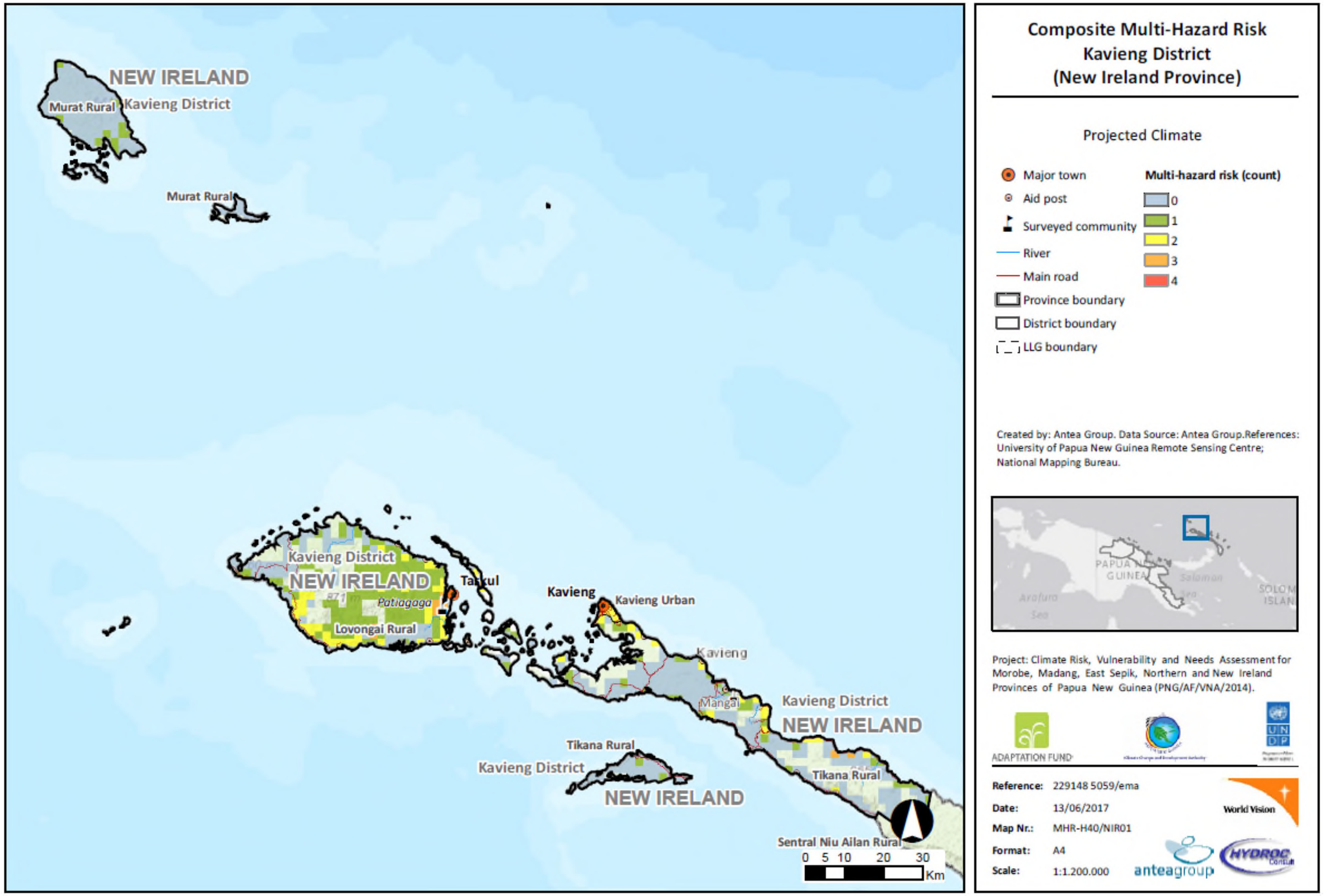

Figure 70. Composite risk map for Kavieng District (future climate)

3.2. Namatanai Risk Profile

3.2.1. General description

Namatanai District occupies the south of New Ireland as well as the Tabar, Lihir, Tanga and Anir Island Groups. The Shleinitz Range is in the north of New Ireland with Verron and Hans Mayer Ranges in the south. Moderate to high incomes can be earned from the sale of copra, cocoa, betel nut, fish and food across this district. Cash incomes are also earned from some plantation activities and wages and royalties from the goldmine are available to communities on Lihir Island. The district headquarters is located in Namanatai. There are 5 Local-Level Governments in Namanatai District: Namanatai Rural, Sentral Niu Ailan Rural, Konoagil Rural, Tanir Riral and Nimamar Rural. Number of assigned wards to this district is 90.

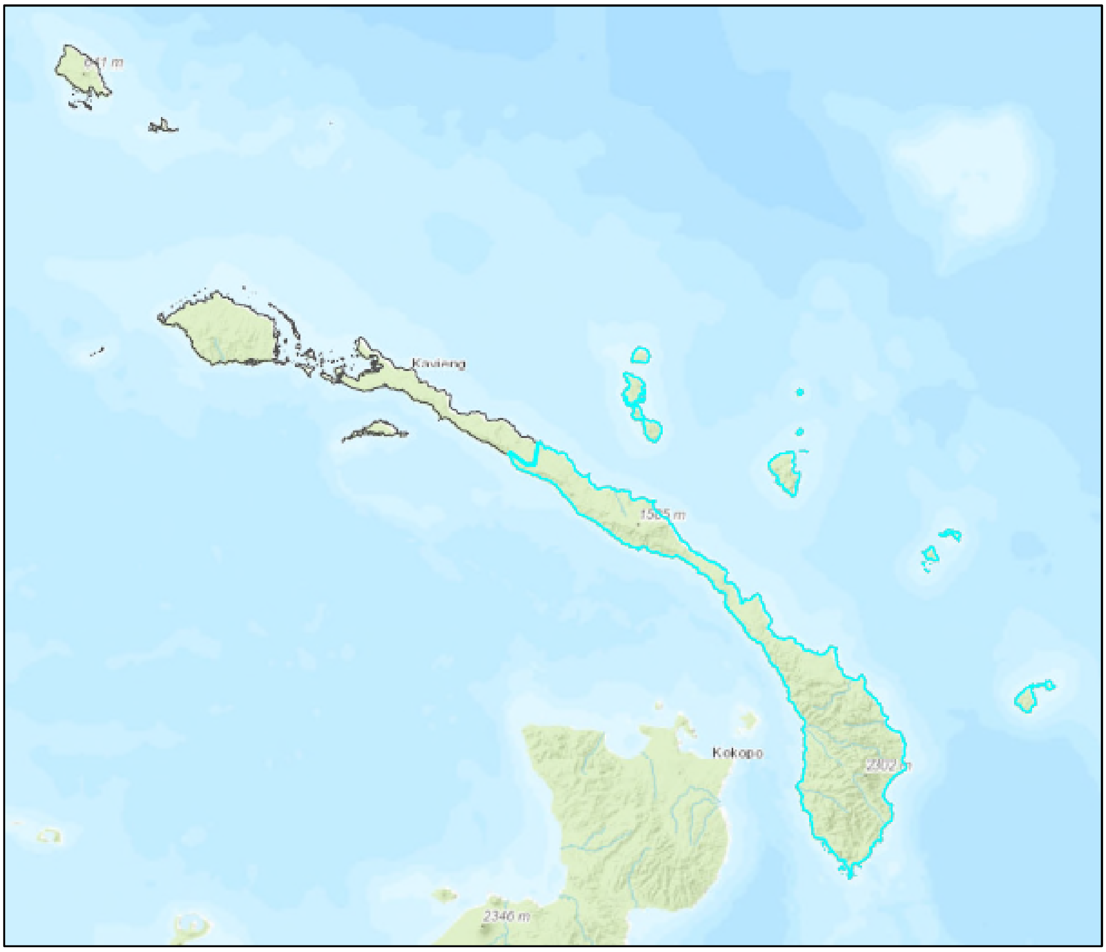

Figure 71. Namatanai District

Namatanai District has a population of 110,905[12]. The average population density is relatively low, 9.9 inhabitants per km². The highest population densities are found on Mali, Mahur and Masahet islands in the Lihir Group, and on Boang Island in the Tanga Group, with over 200 persons/km². The coastal plains of Lihir and Malendok islands and the Anir Islands have moderate densities of over 50 persons/km², while the central part of New Ireland has lower population densities.

[12] National Population and Housing Census, 2011, National Statistical Office, 2013.

The far south of New Ireland and the Tabar Islands have the lowest population densities in the district. The southeast coast around Namatanai has experienced significant in-migration in recent years. The population of the East Coast Namatanai area has increased by 5.1 per cent per year in recent decades.

The most disadvantaged groups in the district are those in the moderate agricultural pressure areas

around Namatanai and on Boang Island. These people are vulnerable to land degradation and declining crop yields. Large numbers of people in central New Ireland and on Lihir Island are constrained by low potential environments, while people on Mali, Masahet and Mahur islands, in the Lihir Group, have very low incomes. Overall, people in Namatanai District are slightly disadvantaged relative to people in other districts of PNG. There is some agricultural pressure, land potential is moderate, access to services is moderate and cash incomes are relatively high.

Cash incomes on New Ireland north of Manga are high and are mainly derived from sales of copra, cocoa, oil palm, betel nut, fish and fresh food. In the south of New Ireland and on the island groups, people earn low incomes from sales of cocoa, copra, fish, fresh food and betel nut. Small numbers of people on the southeast coast of New Ireland receive cash wages from work in cocoa and oil palm plantations. People on Lihir Island receive cash wages and royalties from gold mining operations.

People in New Ireland north of Namatanai town require less than four hours' travel to reach Namatanai or Kavieng, while those south of Namatanai and in the island groups require 4–8 hours' travel. The Bulominski Highway connects Kavieng to Namatanai along the east coast. There are minor roads in most coastal areas of New Ireland and in the island groups, but many are in poor condition. Outboard motor boat and canoe travel are common along the coast and between the islands.

Table 40. Selected Health Indicators for Namatanai District (2014)

Low Weight for Age < 5 years old (%)	Low Birth Weight (%)	Incidence of Malaria (1,000 pop.)	Incidence of Diarrhoea (<5 years/1,000 pop.)
24	5.6	156	149

Namatanai District has an adult literacy rate of 77.9%, with a significant disparity in literacy rates between males (78.9%) and females (76.7%).

3.2.2. *Hazards*

Hazard maps can be found in the province description (refer to Section 1) and the annex.

Namatanai District is not prone to tropical cyclones and projections for the future show the same tendency.

The map for current inland flood hazard shows some flooding zones, mostly 5 year return (for example, in Kamdaru River in the south of the district) but also some 50 year return as around Namatanai Urban , Lenkamin or Ugana. Projections for the future show similar patterns.

The map for current total annual rainfall shows that the district presents three different ranges of values: from 2079 to 2710mm in the islands to the north west of the district; 2744 to 2979mm in most of the mainland until Veitin; and from 2980 to 3280 to the south of Veitin. Projections for the future show an increase for the whole district to values ranging the 2980 to 3280mm, except everything above the parallel of Konos, that will remain a bit lower (2711 to 2979 mm).

The map for total rainfall on wet days shows that Konoagil Rural has an average 601 to 700mm, while the rest of the district has slightly lower values (501 to 600mm). Projections for the future show a general increase in rainfall intensity, where everything to the south of Ratubu will range values from 701 to 800mm and everything to the north from 601 to 700mm.

Finally, drought hazard is low (16,1 to 21 continuous dry days) , except everything above the parallel of Konos, which is moderate (21,1 to 24 continuous dry days) and the southernmost part of the district, where values are lower (10,7 to 16 continuous dry days). Projections for the near future show a slight decrease in the dryness of the district, where everything beloxw the parallel of Palabong will range values between 10,7 to 16, and everything above of 16,1 to 21 continuous dry days.

3.2.3. Risk

In Figure 69, we can see that the risks associated with inland flooding, coastal flooding, drought and extreme weather hazards. The composite risk is predominantly low to very low. However, there are a few moderate risk hotspots. They are located around Namatanai city and around rivers of Konoagil Rural.

Figure 70 also presents the composite risks but in a future climate projection. The composite risk is changing. There are many moderate risk areas, mostly on the coast, around Namatanai city and in the small east Islands. Also, there are some small high risk areas.

In this district, The social risks from hazards in Namatanai District are generally low to moderate, except for high risk from high rainfall along the southern coast of islands off the east coast of the district. There are also areas of high to moderate risks from high rainfall along the entire east coast of the district. Projections for the future do not show much change for social risk.

Economic risk is lower in the Namatanai district. Areas of economic risk are mainly on the east coast and around major cities. Plantations with coconuts and oil palm, represent moderate to high risk areas. However, in this district the risk is essentially low. Projections for the future do not show much change.

Table 41. Top agricultural activities of citizen households in Namatanai[13]

Activities	% engaged	% engaged for cash
Coconut	74,5	54,8
Food crops	78,7	13,3
Betel nut	75,2	25,9
Livestock	47,7	19,6
Fishing	50,9	4,9

The physical risk to inland flooding is represented in a couple of minor hotspots along the north coast, and projections for the near future follow the same pattern. Conversely, the physical risk to extreme weather is low to very low, and projections for the future do not show much change.

The map for inland flooding physical risk shows barely any hotspots, and projections for the future follow the same pattern.

The map for extreme weather physical risk shows a low to very low profile for the district, and projections for the near future do not show much change.

According to the previous section, the most important hazards are inland flood with mostly 5 year return and high rainfall. In future projections, the composite risk increases slightly. So, inland flood and high rainfall hazards will be closely monitor in the Namatanai district. To reduce the social risk, communication actions can be organized where it is necessary. Then, protection systems can be put in place to limit the economic and physical risk, especially around Namatanai city and on the islands.

[13] National Research Institute (2010), ‘Papua New Guinea District and Provincial Profiles)

	HAZARD : CYCLONE COMPOSITE VULNERABILITY %					
LLG	1	2	3	4	5	
Namatanai Rural	0,7	2,7	2,0	2,0	74,2	18,4
Sentral Niu Ailan Rural	4,8	18,2	30,5	6,1	4,6	35,8
Konoagil Rural	1,1	12,9	2,0	0,9	3,7	79,4
Tanir Rural	0,0	0,0	2,3	84,0	13,7	0,0
Nimamar Rural	0,0	3,6	3,6	52,8	38,2	1,7
Matalai Rural	0,6	0,6	2,4	2,4	55,8	38,1

	HAZARD : DROUGHT COMPOSITE VULNERABILITY %					
LLG	1	2	3	4	5	
Namatanai Rural	0,0	64,8	14,0	1,3	0,7	19,1
Sentral Niu Ailan Rural	19,1	36,8	4,4	0,0	0,7	39,1
Konoagil Rural	1,8	15,9	2,8	0,0	0,0	79,5
Tanir Rural	75,3	11,4	6,8	8,0	0,0	0,0
Nimamar Rural	51,0	20,0	9,1	12,7	5,5	1,7
Matalai Rural	3,0	54,0	4,2	0,6	0,0	38,1

	HAZARD : INLAND FLOODING COMPOSITE VULNERABILITY %					
LLG	1	2	3	4	5	
Namatanai Rural	14,0	8,0	2,0	2,0	2,0	71,9
Sentral Niu Ailan Rural	18,0	3,5	3,9	0,9	2,4	71,3
Konoagil Rural	11,6	1,5	0,5	0,5	1,4	84,5
Tanir Rural	4,6	0,0	0,0	0,0	0,0	95,4
Nimamar Rural	9,1	3,6	0,0	0,0	1,8	85,4
Matalai Rural	15,8	13,9	2,4	1,2	3,0	63,6

	HAZARD : PRECIPITATION COMPOSITE VULNERABILITY %					
LLG	1	2	3	4	5	
Namatanai Rural	47,5	16,7	10,7	4,7	0,7	19,8
Sentral Niu Ailan Rural	20,6	35,3	3,5	1,5	0,0	39,1

Konoagil Rural	14,8	2,9	0,5	2,2	0,0	79,6
Tanir Rural	75,3	11,4	6,8	8,0	0,0	0,0
Nimamar Rural	49,1	20,0	9,1	12,7	5,5	3,5
Matalai Rural	43,7	12,1	4,2	0,6	0,0	39,3

	HAZARD : CYCLONE											
	RISK 1960-1990 %						RISK 2030-2050 %					
LLG	1	2	3	4	5		1	2	3	4	5	
Namatanai Rural	3,3	78,2	0,0	0,0	0,0	18,4	3,3	78,2	0,0	0,0	0,0	18,4
Sentral Niu Ailan Rural	23,0	41,2	0,0	0,0	0,0	35,8	23,0	41,2	0,0	0,0	0,0	35,8
Konoagil Rural	14,0	6,6	0,0	0,0	0,0	79,4	14,0	6,6	0,0	0,0	0,0	79,4
Tanir Rural	0,0	100,0	0,0	0,0	0,0	0,0	0,0	100,0	0,0	0,0	0,0	0,0
Nimamar Rural	3,6	94,6	0,0	0,0	0,0	1,7	3,6	94,6	0,0	0,0	0,0	1,7
Matalai Rural	1,2	60,7	0,0	0,0	0,0	38,1	1,2	60,7	0,0	0,0	0,0	38,1

	HAZARD : DROUGHT											
	RISK 1960-1990 %						RISK 2030-2050 %					
LLG	1	2	3	4	5		1	2	3	4	5	
Namatanai Rural	0,0	64,8	15,4	0,7	0,0	19,1	1,3	63,5	15,4	0,7	0,0	19,1
Sentral Niu Ailan Rural	3,5	43,6	13,1	0,7	0,0	39,1	19,1	36,8	4,4	0,7	0,0	39,1
Konoagil Rural	3,3	14,5	2,7	0,0	0,0	79,5	17,7	2,8	0,0	0,0	0,0	79,5
Tanir Rural	75,3	11,4	13,7	0,0	0,0	0,0	75,3	11,4	13,7	0,0	0,0	0,0
Nimamar Rural	0,0	52,8	30,9	10,9	3,6	1,7	51,0	20,0	21,8	5,5	0,0	1,7
Matalai Rural	4,2	54,0	4,9	0,0	0,0	36,9	24,9	34,6	2,4	0,0	0,0	38,1

	HAZARD : INLAND FLOODING											
	RISK 1960-1990 %						RISK 2030-2050 %					
LLG	1	2	3	4	5		1	2	3	4	5	
Namatanai Rural	14,7	9,4	1,3	2,7	0,0	71,9	14,7	9,4	1,3	2,7	0,0	71,9
Sentral Niu Ailan Rural	19,9	5,0	3,3	0,2	0,2	71,3	19,9	5,0	3,3	0,2	0,2	71,3
Konoagil Rural	12,2	1,9	1,0	0,1	0,3	84,5	12,2	1,9	1,0	0,1	0,3	84,5
Tanir Rural	4,6	0,0	0,0	0,0	0,0	95,4	4,6	0,0	0,0	0,0	0,0	95,4
Nimamar Rural	9,1	3,6	0,0	0,0	1,8	85,4	9,1	3,6	0,0	0,0	1,8	85,4

Matalai Rural	16,4	14,6	3,6	1,2	0,6	63,6	16,4	14,6	3,6	1,2	0,6	63,6

	HAZARD : PRECIPITATION											
	RISK 1960-1990 %						RISK 2030-2050 %					
LLG	**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**	
Namatanai Rural	58,8	13,4	8,0	0,0	0,0	19,8	0,0	47,5	16,7	14,0	2,0	19,8
Sentral Niu Ailan Rural	36,8	23,0	1,1	0,0	0,0	39,1	5,3	33,5	18,6	3,5	0,0	39,1
Konoagil Rural	12,9	4,1	3,2	0,3	0,0	79,6	0,0	14,8	0,1	4,7	0,8	79,6
Tanir Rural	75,3	13,7	11,4	0,0	0,0	0,0	0,0	75,3	11,4	8,0	9,1	0,0
Nimamar Rural	69,2	27,3	0,0	0,0	0,0	3,5	27,3	21,8	21,8	7,3	18,2	3,5
Matalai Rural	43,7	12,1	4,9	0,0	0,0	39,3	0,0	43,7	10,9	4,9	1,2	39,3

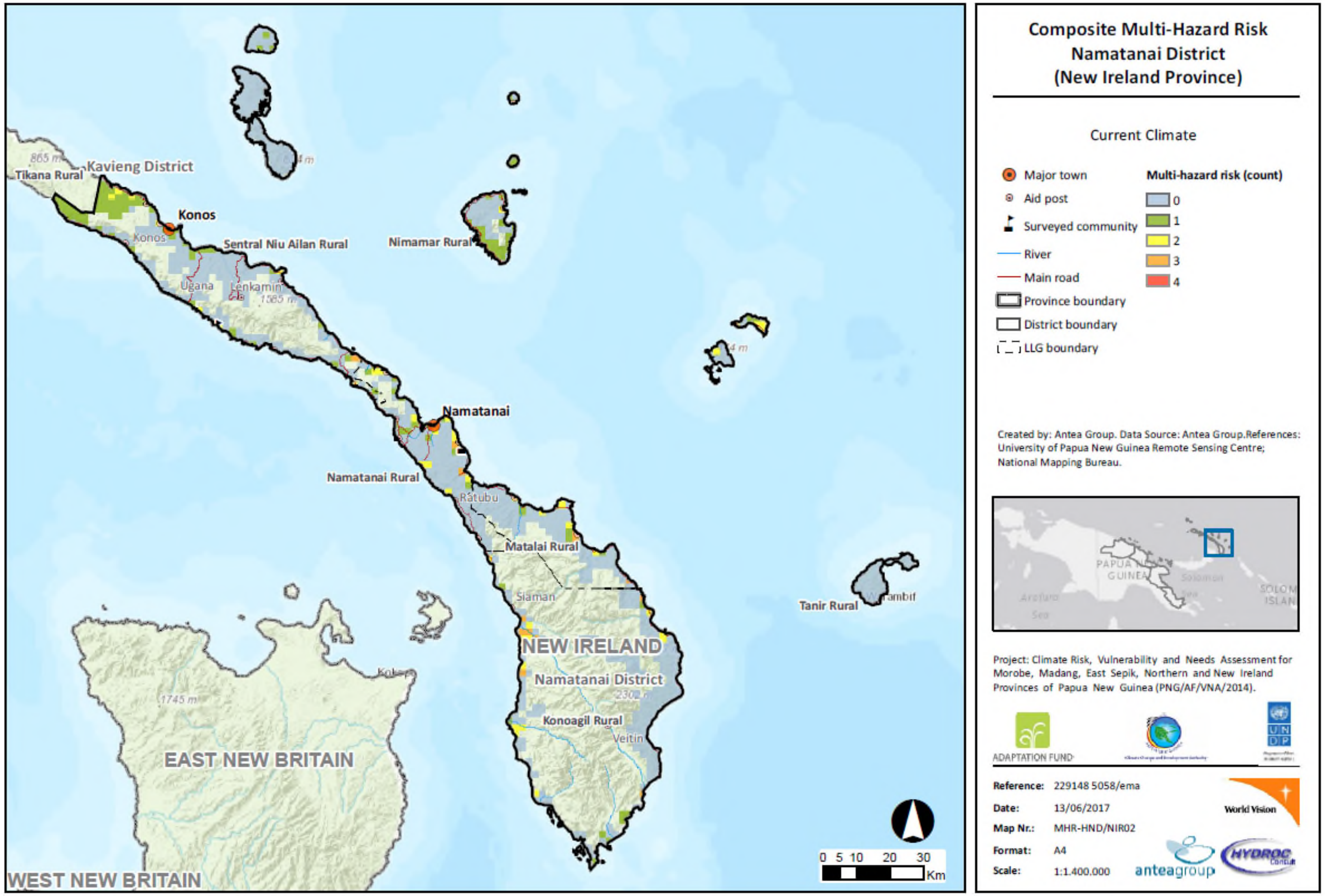

Figure 72. Composite risk map for Namatanai District (current climate)

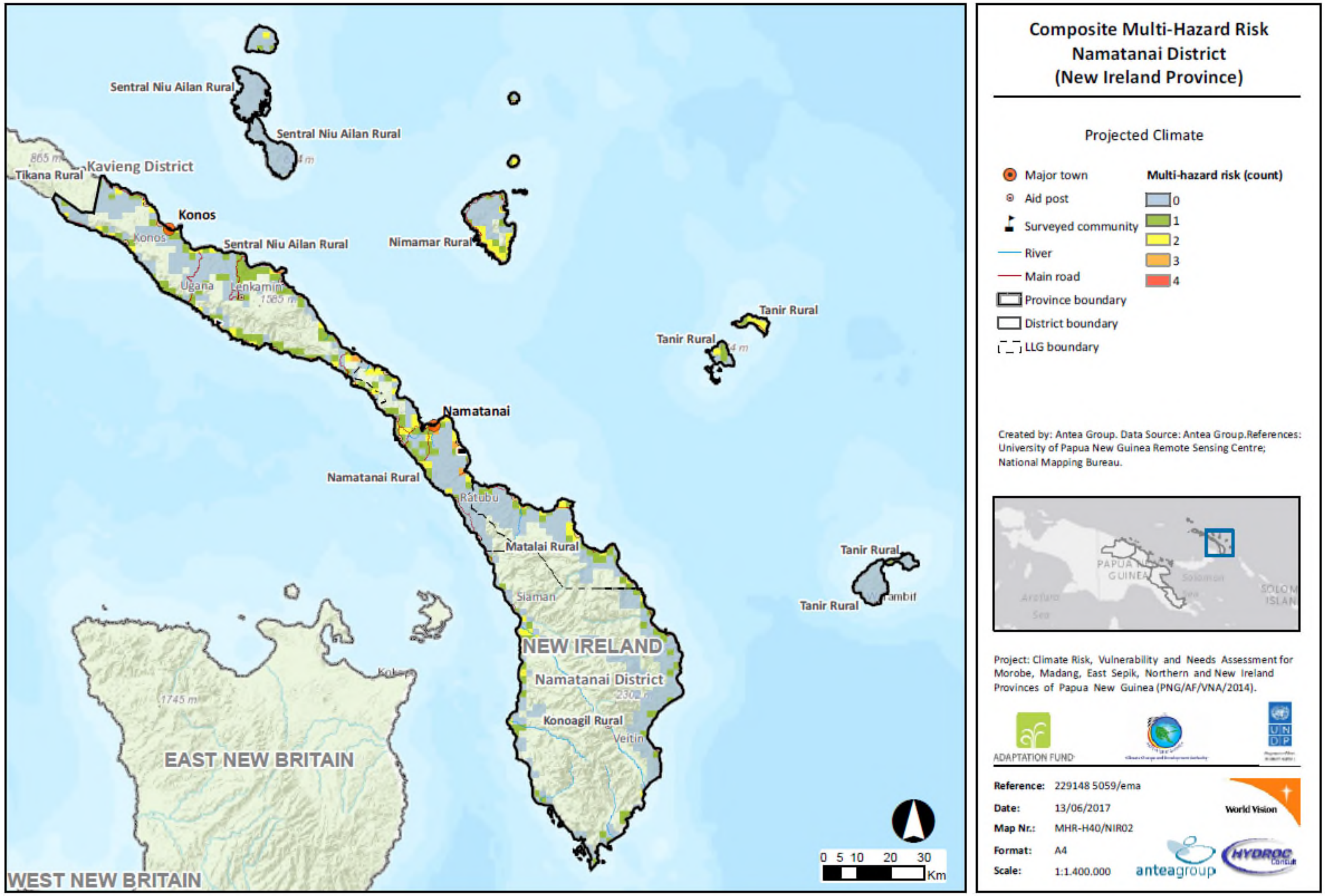

Figure 73. Composite risk map for Namatanai District (future climate)

4. RECOMMENDATIONS

This section focuses on the needs, priorities, and opportunities for reducing the impact of the major climate change hazards within the province. These recommendations are derived from the risk mapping and profiling carried out in the previous sections.

Based on these outcomes, 'a way forward for reducing the impacts and vulnerabilities to climate change hazards' is sketched at a high level, focusing on achievable solutions for the major issues identified during the hazards, vulnerability, and risk assessments.

4.1. Needs and priorities

The hydro meteorological hazard mapping carried out for the province shows that inland flooding, increase on precipitation intensities and drought are hazards affecting the province up to some extent. There is no evidence of the province being within a cyclone prone region. The existing situation will be exacerbated slightly in the future. Although the hazard patterns will remain as the ones produced by the current climate; it is expected that the intensity of their impacts would slightly increase.

Services like water supply, urban drainage and irrigation will be increasingly important in the future as problems like flash floods, bank erosion, landslides, drought, wild fires increase.

Projected hazards over the next 50 years are not remarkably more severe than over the past 50 years. Rather, increasing human activities and development may result in greater risk. In more remote areas, pressure grows to extend gardens further up steeper hillsides, increasing the risk of erosion and landslides. At the same time, populations density has increased, due to the introduction of the oil palm blocks, and due to the increasing attraction of urban areas. In certain areas, rural livelihood systems are becoming increasingly concentrated and dependent on cash incomes from a single source. Oil palm in smallholder blocks spreads wealth, but still creates large areas of monoculture which increases risk (from weather, disease, etc.).

The crop assortment is likely to remain similar. Subsistence crops will remain the same, but their relative importance may change in response to changes in climate.

4.2. Opportunities

Development opportunities were identified based on a previous study on the feasibility of EWS23 and missions for the present study.

The Provincial Disaster Committee is aware that more collaboration with private partners for disaster response would be recommended; private instances are often better equipped and Public Private Partnerships could be effective. Disaster plans, which are not currently based on vulnerability or risk maps, should be updated based on the results of this assessment.

The provincial government has several organisations and networks representing women, youth, or ethnic groups. These groups can be further involved in disaster preparedness. Although the PDC has some training materials, more would be needed to support a broader education campaign.

As in other provinces, this province intends to continue decentralisation towards districts and the LLG to improve service delivery. District Development Authorities are being established for this purpose. Districts are funded by the province but also by national government (See District Development Authority Act 2014). This opportunity would allow districts focusing on implementation plans customized for their regions.

The International Organisation for Migration (IOM) runs a community-based programme to develop disaster management plans at the community level. This work on awareness is certainly needed and can be further developed in synergy with the outcomes of the present study.

NGOs like World Vision, ADRA, and others are active in the province implementing projects on DRR; the risk assessment from this study can enrich the work of these NGOs.

4.3. Way forward

The way forward for New Ireland Province should comprise updating current provincial plans including following key elements:

The risks are predictable. Disasters occur through lack of preparedness for likely occurrences. The immediate steps should be to set in place an adequate mechanism to respond to the kinds of emergencies that are likely to occur: principally flooding, landslide, some storm effects, and occasional drought. The disaster response team in Morobe is one of the best we have seen in the studied area, and could be the model for other provinces like this one: adequately provisioned with boats to access difficult coastal areas, such as Tufi, 4x4 vehicles to reach inland, and standing arrangements with the air force and police, to reach populated areas not served by roads. This needs to be backed up with meteorological and early warning information, and a network that allows this information to reach areas likely to be affected. Emergency preparation, at the district and LLG level is essential, to know in advance how to cope with rescue and care of displaced people. In many places, local level organisation is the only way to ensure some buffer of security.

Invest in risk knowledge. Stakeholders can become more resilient by understanding the current and projected hydro climatological risks. Current initiatives in community-based disaster risk reduction could be enhanced to incorporate customized information related to the present risk mapping.

Incorporate adaptation strategies at various levels (community, district, province and national) to cope with changing climate. This should include institutional, physical, and structural measures. Integrating disaster management into school curriculum would be helpful.

Focus on urban flooding and the damage to infrastructure around major cities. This could imply the maintenance of drainage systems and clean-up of drainage infrastructure, bridges, and culverts before the rainy season begins. These measures should allow that the road network remains operational during the rainy season and that the urban damages are reduced.

Lowland flooding is a recognised feature of the rural ecology in this province that people have experienced for generations. Flooding in upland areas is likely to be exacerbated with greater intensities of rainfall. The practice of terracing could be introduced in the hilly regions of the province to reduce soil deterioration, erosion and flash floods.

The traditional crop mix is well established to distribute risk, and to cover for most eventualities. As the frequencies of hazards change, the relative importance of one crop may change with respect to others. For example, longer dry spells is likely to increase the importance of cassava.

In rural zones, the focus should be on revising cropping practices and strategies for controlling and managing flash floods and bank erosion within an integrated approach.

Adequate measures for coping with drought risk should be defined. These could include reforestation plans for upper catchments to increase infiltration (positive for ground water recharge and effective reducing surface runoff). Additionally, communities should be trained on digging and maintaining superficial wells to improve their resilience to drought. For urban areas, a master plan on water supply, taking in account population increase and climate change, should be developed.

Papua New Guinea's Agricultural Research Institute considers drought to be the major climatic threat to agriculture in the country and is breeding crops for drought resistance. This research should be tested as quickly as possible at the local level, to give local people the chance to adapt local practices.

Protecting against drought requires the same measures as protecting against flash floods, using land and water management to restrain water and allow it to permeate the soil.

Community based DRR actions should be furtherly developed, especially in the most critical communities. Actions should include shelters and evacuation plans in place and communicated to residents. Early warning systems should be put in place focussing on alerting the population by alerts broadcast on TV and radio and sent by text to cell phones in advance.

Local government officials, hospital staff, the Red Cross, NGOs, and community, school and religious leaders should be further trained in emergency response to disasters. Emergency supplies, clothes, food, medical items, etc. should be procured and stored in strategic locations, ready for rapid distribution by emergency management personnel.

ANNEXES

ANNEX 1 DEFINITIONS

ANNEX 2 DATA SOURCES USED

ANNEX 3 CROP TOLERANCE SCORES

Annex 1 Definitions

Sensitivity

Sensitivity refers to "the physical predisposition of human beings, infrastructure , and environment to be affected by a dangerous phenomenon due to lack of resistance and […] intrinsic and context conditions making it plausible that such systems once impacted will collapse or experience major harm and damage" (IPCC 2012).

Capacity

Capacity is "the combination of all the strengths, attributes and resources available within a community, society or organisation that can be used to achieve agreed goals, in this context : to cope with disasters (UNISDR 2009).

Vulnerability

Vulnerability is defined by the UNISDR as a "set of conditions and processes resulting from physical, social and economic factors, which increase the susceptibility of a community to the impact of the hazard". This includes intrinsic characteristics that predispose the asset or the community to suffer from a hazard, but also the potential loss that can result from it (UNISDR 2009).

Vulnerability is interpreted in this methodology as the potential damage (potential negative effects) of the hazard, divided by a factor accounting for the coping capacity of the community at large:

$$Vulnerability = \frac{Potential\ damage}{Capacity}$$

Equation 4 Definition of vulnerability

Furthermore, vulnerability can be broken down in several components of the system, such as:

- Physical vulnerability
- Social vulnerability
- Economic vulnerability
- Environmental vulnerability (not considered in the present study)

Hazard

Hydrometeorological hazards are processes or phenomena of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Hazards studied in this project are inland flooding, coastal flooding, extreme weather events i.e. cyclones, increase in rainfall intensity and variability, and drought.

Risk

Risk is defined by the United Nations International Strategy for Disaster Reduction as the combination of the probability of a hazardous event and its negative consequences which result from interactions(s) between natural or man-made hazard(s), vulnerability, exposure and capacity (UNISDR 2009).

Conventionally, risk is expressed by the notation **Risk = Hazard x Vulnerability**. Some disciplines also include the concept of exposure to refer particularly to the physical aspects of vulnerability.

Annex 2 Data sources used

Climate metrics

National Weather Service (NWS) is responsible for monitoring and forecasting weather in Papua New Guinea[14]. Secretariat of the Pacific Community (SPC, formerly SOPAC) observed that, in general, National Meteorological Services and National Geological Surveys in the Pacific are professionally staffed, well-supported, and well-trained in comparison to National Hydrological Services. This is also observed in Papua New Guinea, where hydrological services are part of the Conservation & Environment Protection Authority (CEPA, formerly the Department of Environment and Conservation).

Until the 80s and early 90s, at least 95 stream gauging stations were operational. An assessment by HYCOS of the PNG hydrological archive indicated a total of 357 sites (water level and/or gauging stations) that operated for varying periods, some of which were at mining sites. This data amounts to perhaps hundreds of station years of data. Between 2000 and 2010, the river monitoring was reduced from 130 stations to less than 10. The database compiled from historic records is available at CEPA, but were not made available to the consultant. It has been reported that PNG currently has no functional hydrological monitoring network.

The National Weather Service maintains a network of 13 weather stations (Figure 74) including 3 automatic and 10 manual stations.[15] The following variables are recorded daily at the manual stations and hourly at the automatic stations: Rainfall, Air temperature, Wind, Pressure, and Humidity.

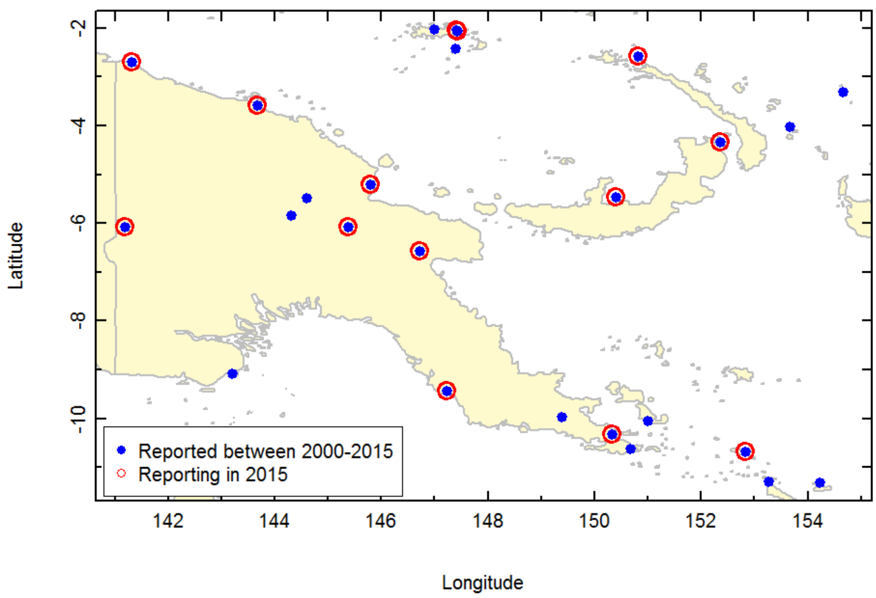

Figure 74. Location of Global Surface Summary of the Day (GSOD) weather stations across Papua New Guinea.

[14] UNDP (2016) 'Assessment of early warning systems (ews) for inland and coastal flooding in papua new guinea - Final report - review, analysis, and recommendations', carried out by Antea Group.
[15] This information was obtained during interviews. Other sources report 14 manned National Weather Service stations, 7 automatic stations.

The applicability of the observed measurements for model calibration and disaster risk assessments is limited. Further, there are many gaps at the manual stations. This is primarily due to failure of the observers to report measurements. In addition, there is a significant delay in reporting (up to serval days).

The observational data, as described above, is managed within the NWS using the Australian Bureau of Meteorology's CliDE[16] system. CliDE incorporates a quality control (QC) module and has the ability to store both metadata and sub-daily observations. Data that fails the QC checks are flagged, but not discarded.

Additional data sources seem to be available country wide but they were not accessible to the consultant. For instance, following national regulations, mine companies are expected to monitor the environmental performance of each mine. They produce annual summary reports including tables of gauged data. However; the data is not stored in a central repository and is therefore only available as a hard copy.

Due to the limited availability and quality of historic hydro-meteorological datasets, time series data was downscaled for the area of interest from all applicable sources; 5th Coupled Model Intercomparison Project (CMIP5) and General Circulation Models (GCMs). The scale of the GCM data is too coarse for the analysis under this project, hence the data was downscaled to a common 0.5° grid and spatio-temporal data stored in netCDF files. A simple spatial correction, based on the ERA-Interim reanalysis was used for the downscaling (http://www.ecmwf.int/en/research/climate-reanalysis/era-interim).

There are several studies related to estimation of climate change projections in the pacific region and Papua New Guinea[17][18]. The Pacific Climate Change Portal[19] provides a helpful entrance to documentation, data and projects related to climate (projections) for the country.

Social vulnerability

Census units data

A shapefile with georeferenced census unit points was provided by the National Statistical Office. Geographic coordinates of each census unit was given with variable reliability. Additionally to census unit location, the attribute table contains information on the province, the district, the LLG, the Ward, the reliability of the GPS coordinates, the number of households, the number of people (male and female) and the average household size (in number of people per household).

From the National Statistical Office database, we can also retrieve information at census unit level such as literacy statistics and age distribution.

Health performance data

From the PCRAFI shapefiles provided by UNDP, we dispose of the geographic coordinates for most health centres on the territory.

The Health Information System / Department of Health provided Health Sector Performance data per health centre. Indicators are available regarding maternal health, child health and number of patients with some major diseases. Performance indicators are available per Health centre (2015), but also aggregated at district level in the annual sector review per district (2011 to 2014).

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[16] CliDE – Climate Data for the Environment; http://www.bom.gov.au/climate/pacific/about-clide.shtml

[17] Asian Development Bank (2013), 'The economics of climate change in the Pacific Mandaluyong City, Philippines'

[18] Australian Bureau of Meteorology and CSIRO (2011), ' Climate Change in the Pacific: Scientific Assessment and New Research. Volume 1; Regional Overview. Volume 2: Country Reports. 288 pp.

[19] https://www.pacificclimatechange.net/

Infrastructure vulnerability

Infrastructure database

The infrastructure database was assembled using similar techniques to those used for buildings (see 1.1.1). It comprises a detailed and extensive inventory of major assets such as airstrips, major roads, and bridges. Other types of infrastructure are (non-exhaustively) geolocated: bus stations, communications, dams, docks, generators, helipads, mines, oil and gas infrastructure, ports, power plants, water intakes, storage tanks, water treatments etc.

Replacement costs for buildings and infrastructure

The economic losses from damage to buildings are directly related to the replacement cost (or value) of each building. The PCRAFI building database includes a replacement cost for each building/building cluster. The total value of a building is calculated as the product of the replacement cost for the building occupancy type (residential, commercial, industrial etc), floor area and number of stories. Replacement cost values for different types of buildings and occupancy types were collected from a variety of sources (PCRAFI 2012). On average in PNG, residential buildings a have replacement cost of $ 76,943 in urban and $ 5,510 in rural areas. Non-residential building have a replacement cost of $ 278,459 and $ 75,689 in urban and rural areas respectively.

The geodatabase with roads and other infrastructure does not c ontain location-specific replacement cost values, but the replacement cost of each piece of infrastructure can be estimated based on their characteristics (Table 42).

Replacement costs will be used for asset quantification in vulnerability computations.

Table 42. Unit replacement costs of infrastructure in PIC (Source: PCRAFI 2013)

Type	Cost (US$)	Metric
Large Airport	518	per linear foot of runway
Medium Airport	366	per linear foot of runway
Helipad	88,000	per unit (40 12.5'-by-20' slabs)
Airstrip	10,000	per unit
Small Airport	100,000	per unit
Dam	100,000,000	per unit
Large Scale Mine	500,000,000	per unit
Medium Scale Mine	100,000,000	per unit
Small Scale Mine	10,000,000	per unit
Steel/Concrete Bridge	10,000	per linear meter of span
Non-Steel/Concrete Bridge	1,000	per linear meter of span
Roads	500,000	per linear kilometer
Railroads	100,000	per linear kilometer
Dock	100,000	per unit
Water Treatment	2,000,000	per unit
Storage Tanks	10,000	per unit
Water Intake	40,000	per unit
Bus Station	30,000	per unit
Communications	5,000	per unit
Oil & Gas Facility	20,000,000	per unit
Power Plant - Very Large	40,000,000	per unit
Power Plant - Large	10,000,000	per unit
Power Plant - Medium	5,000,000	per unit
Power Plant - Small	1,000,000	per unit
Power Plant - Very Small	500,000	per unit
Generator	1,000	per unit
Substation	500,000	per unit
Port - Very Large	100,000,000	per unit
Port - Large	50,000,000	per unit
Port - Medium	10,000,000	per unit
Port - Small	5,000,000	per unit
Port - Very Small	1,000,000	per unit

Economic vulnerability

Buildings database

The exposure database established by PCRAFI (Pacific Catastrophe Risk Financing and Insurance Initiative) includes a comprehensive inventory of residential, commercial, public and industrial buildings. It consists of their location, replacement cost and structural characteristics which affect their vulnerability to the effects of natural disasters. The locations of the buildings (Figure 75) were determined using four different levels of building extraction methodologies: (i) manually digitized from high-resolution satellite imagery and surveyed in the field; (ii) manually digitized from high-resolution satellite imagery but not field verified; (iii) extraction of building clusters and manually counted from moderate to high-resolution satellite imagery; (iv) buildings that are mostly located in rural areas were inferred using image processing techniques from low to moderate resolution satellite imagery and/or census data.

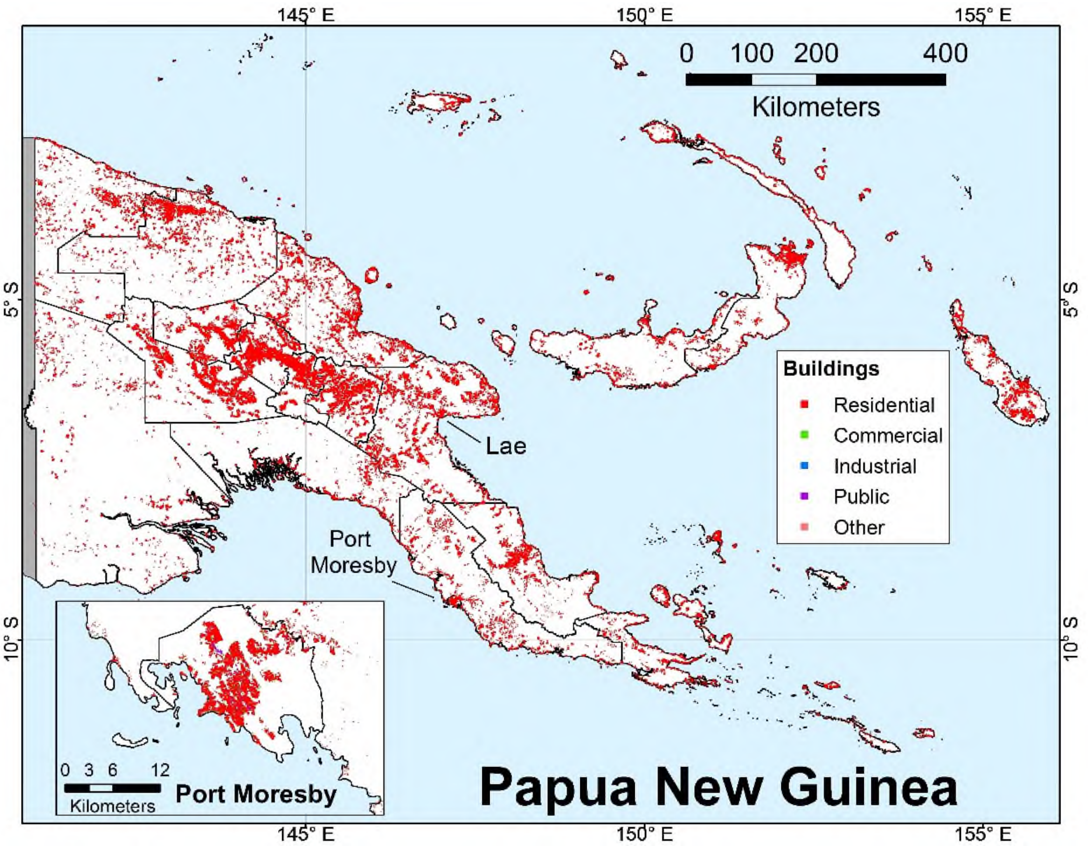

Figure 75. Location of buildings in PNG (Source: PCRAFI)

The building database provides information about occupancy (residential, commercial or other) and secondary characteristics that are relevant to sensitivity to hazard: specific structural details, such as wall type, roof type, foundation type, and presence of defects. There are also global characteristics such as number of stories and floor area.

These secondary modifiers refer to characteristics of the building which tend to increase or decrease the sensitivity with respect to that of the typical building in its respective construction class (residential/non-residential). For example, the presence of window shutters is likely to reduce the vulnerability of wind damage as compared to the vulnerability of a similar building with no shutters. Likewise, a building with a tall, unbraced, stilt-like foundation would be more vulnerable to ground shaking than a similar building with a slab foundation. The effects on the expected losses for buildings that have characteristics related to more than one modifier are cumulative.

Land use/Land cover database

The Land Use / Land Cover (LULC) geo-database in the PNG Resource Information System (PNGRIS) is a comprehensive inventory of major crops and other land use categories (e.g., forests, lakes and rivers, sand, settlements, barren land, and grass land). The LULC maps were generated primarily using remote sensing and were supplemented with various sources (PCRAFI 2013 p26-27). The main systems included in the LULC layer are (agricultural systems are in bold):

1. Open Land Grass Land
2. Forest
3. **Palm Oil** (subclass: Coffee, Coconut)
4. **Coconut Forest**
5. **Coconut Crops**
6. **Coconut Plantation**
7. **Banana** (subclass: Papaya, Taro, Yam, Cassava)
8. **Cultivated Land** (subclass**:** Rice, Vegetables & Fruits, Taro, Corn, Nuts, Peanu)
9. Settlement
10. Water
11. Wet Land

Agricultural systems survey

Reports of the agricultural survey carried out in by the ANU (Autralian University of Australia) were provided by the PNG National Agricultural Research Institute. The following reports on provincial level were analysed during this study: Allen et al. 2002a, Allen et al. 2002b, Allen et al. 2002c, Hide et al 2002 and Bourke et al. 2002. This survey provides detailed description of all the agricultural systems in each province and a shapefile with these agricultural systems and their descriptive attributes.

Subsistence crops, designated as staple crops, tend to divide between sweet potato systems, taro systems and, in places, cassava systems. In addition, some cash crops also influence the sensitivity of agricultural systems. For example, coffee has long been an important export earner, and dominates many highland systems. Rubber is also important in certain areas, as is sugar in the Ramu area.

The ANU agricultural survey describes staple crops in each system as dominant, subdominant or present. According to the methodology, the following definitions apply:

- Dominant staple crop: more than one third of staple garden area, and therefore no more than 3 dominant staples may be identified for a system.
  Exception: sago (palms are not cultivated in gardens)
- Subdominant staple crops: cover more than 10 per cent of the staple garden area; up to six crops may be listed.
  Exception: sago
- All staple crops: up to 10 staple crops including crops classed as dominant and subdominant, as well as other staple crops which occur commonly. (= other crops)

Presence of other products such as fruit, vegetables, nuts and narcotic is indicated as well in the survey data. There is also succinct information on the presence of cash crops such as rubber, tobacco, oil palms, sugar etc. Qualitative descriptors are:

0- None
1- Minor or insignificant
2- Significant
3- Very significant

Replacement costs for key crops

Unit replacement costs of different cash crops in the PICs were derived by PCRAFI (2013) from crop production budgets issued by local governments. **Fout! Verwijzingsbron niet gevonden.** shows the replacement costs per hectare computed for the key crops under production in the PICs. “The average replacement cost estimates are representative of production systems with average production and management practices. These average costs are not representative of subsistence farmers that use fewer inputs and therefore have less production costs, or commercial farmers that use inputs intensively and obtain higher prices when selling their products in the export markets" (PCRAFI 2013).

Replacement costs are note part of the sensitivity index but will be used for asset quantification in vulnerability computations.

Table 43 Replacement costs for key crops under different production systems in the PICs (PCRAFI 2013 p 28)

Crop type	Average replacement cost (US$ per hecatre)	Replacement cost subsistence (US$ per hecatre)	Replacement cost commercial farmer (US$ per hecatre)
Banana	4,065	1,016	6,098
Breadfruit	386	97	579
Cassava	2,468	617	3,702
Cocoa	1,766	442	2,649
Coconut (Copra)	294	74	441
Coconut (Fresh Nut)	504	126	756
Coconut (Mature Nut)	504	126	756
Coffee	1,512	378	2,268
Ginger	7,697	1,924	11,546
Gourd/Squash	1,213	303	1,820
Kava/Yaqona	3,532	883	5,298
Lemon	966	242	1,449
Mango	375	94	563
Nut Tree	1,750	438	2,625
Oil Palm	5,300	1,325	7,950
Papaya	3,039	760	4,559
Pineapple	2,009	502	3,014
Pumpkin	2,999	750	4,499
Rubber Tree	504	126	756
Sago Palm	1,488	372	2,232
Sugarcane	1,234	309	1,851
Sweet Corn/Maize	1,822	456	2,733
Sweet Potato	1,474	369	2,211
Giant Taro/Ta'amu	1,365	341	2,048
Taro	2,993	748	4,490
Tobacco	9,080	2,270	13,620
Vanilla	1,243	311	1,865
Yam	9,843	2,461	14,765

Annex 3 Crop tolerance scores

Scores in red are not directly supported by literature and have a higher degree of uncertainty.

TOLERANCES: 0 = Tolerant; 1 = Moderately tolerant; 2 = Intolerant

		Representativity	Number of systems	INLAND FLOOD DEPTH (m.) *(without flow)*	SEA LEVEL RISE (m) *(assumes salinisation of groundwater)*	LOW ANNUAL RAINFALL (mm.) *(assumes relatively even distribution)*	HIGH ANNUAL RAINFALL (mm.) *(assumes relatively even distribution)*	MAX. CONSECUTIVE DROUGHT (days)	CYCLONIC WINDS (km/hr)
			134	*0.5–5*	*0.5–5*	*0–500*	*3500 – 5000*	*14–30*	*60–120*
STAP	02 Banana (Musa cvs)	94.03%	126	1	2	2	1	2	2
STAP	04 Cassava (Manihot esculenta)	71.64%	96	2	2	0	1	0	2
STAP	05 Chinese taro (Xanthosoma sagittifolium) also Cocoyam/Tannia	82.09%	110	2	2	2	1	2	2
STAP	06 Coconut (Cocos nucifera)	44.78%	60	2	0	2	1	1	2
STAP	08 Potato (Solanum tuberosum)								
STAP	09 Sago (Metroxylon sagu)	51.49%	69	1	2	2	1	1	2
STAP	11 Sweet potato (Ipomoea batatas)	92.54%	124	2	2	2	1	2	0
STAP	13 Taro (Colocasia esculenta)/ dasheen	92.54%	124	1	2	2	1	2	2
STAP	14 Yam (Dioscorea alata)	71.64%	96	2	2	2	0	0	2
STAP	15 Yam (Dioscorea esculenta)	63.43%	85	2	2	2	0	0	2
CASH	Cocoa			2	2	2	1	1	2
CASH	Coffee Arabica			2	2	2	2	1	2
CASH	Coffee Robusta			2	2	2	2	1	2
CASH	Oil Palm			0	2	2	0	1	2
CASH	Rubber			2	2				

		Representativity	Number of systems	**INLAND FLOOD DEPTH (m.)** ***(without flow)***	**SEA LEVEL RISE (m)** ***(assumes salinisation of groundwater)***	**LOW ANNUAL RAINFALL (mm.)** ***(assumes relatively even distribution)***	**HIGH ANNUAL RAINFALL (mm.)** ***(assumes relatively even distribution)***	**MAX. CONSECUTIVE DROUGHT (days)**	**CYCLONIC WINDS (km/hr)**
CASH	Sugar			2	2	2	1	2	1
CASH	Chillies			2	2	2	1	1	1
CASH	Orchids – Vanilla			2	2	2	1	0	2
CASH	Cattle			2	2	2	1	2	2
CASH	Coconut			2	0	2	1	1	2
CASH	Betel			2	2	2	0	2	2
FRUIT	07 Mango (Mangifera indica)	70.15%	94	2	2	1	0	0	0
FRUIT	09 Orange (Citrus sinensis)	27.61%	37	2	2	1	1	0	0
FRUIT	12 Pawpaw (Carica papaya)	75.37%	101	2	2	2	1	2	2
FRUIT	13 Pineapple (Ananas comosus)	69.40%	93	2	2	2	2	0	0
FRUIT	15 Sugar (Saccharum officinarum)	97.76%	131	2	2	2	1	2	1
NARC	2 Betel nut, lowland (Areca catechu)	82.84%	111	2	2	2	0	2	2
NARC	4 Betel pepper, lowland (Piper betle)	81.34%	109	2	2	2	0	2	2
NARC	5 Tobacco (Nicotiana tabacum)	97.76%	131	2	0	2	1	2	2
NUT	01 Breadfruit (Artocarpus altilis)	83.58%	112	2	2	2	1	0	0
VEG	01 Aibika (Abelmoschus manihot)	86.57%	116	2	2	2	1	2	1
VEG	09 Corn (Zea mays)	93.28%	125	2	2	2	2	0	2
VEG	21 Pumpkin tips (Cucurbita moschata)	80.60%	108	2	2	2	1	1	0