Risks Profile of

NATURAL HAZARDS

and Selected Diseases
in Namibia

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ACRONYMS

AIDS	Acquired immunodeficiency syndrome
ALOS	Advanced Land Observing Satellite
AW3D30	ALOS World 3D - 30m
CHIRPS	Climate Hazards Group Infrared Precipitation with Stations
COVID-19	Coronavirus disease of 2019
CPC	Climate Prediction Centre
DEM	Digital Elevation Model
EA	Enumeration Area
ERA5	European Centre for Medium-Range Weather Forecasts Atmospheric Reanalysis of the Global Climate Version 5
GRN	Government of the Republic of Namibia
HIV	Human immunodeficiency virus
IDW	Inverse Distance Weighting
IPD	Indoor Patient Department
MODIS	Moderate Resolution Imaging Spectroradiometer
MoHSS	Ministry of Health and Social Services
NOAA	National Oceanic and Atmospheric Administration
OPD	Outpatient Department
PSL	Physical Sciences Laboratory
RD	Rainfall Departure
TB	Tuberculosis
UN	United Nations
UNAM	University of Namibia
WGLC	Global Lightning Climatology
WWLLN	World Wide Lightning Location Network

FOREWORD

Namibia is faced with frequent occurrences of natural disasters and infectious diseases, with some causing huge environmental and socio-economic damages and losses. For example, the 2009 and 2011 floods, the COVID-19 pandemic, and the unforgiving drought of 2019, are some of the disasters the country has faced in recent years.

The occurrence and the impacts of natural disasters in Namibia are multi-faceted and spatially differentiated; which speaks to the differentiated exposure, sensitivity and adaptive capacity of the society.

The costs involved in managing natural disasters and supporting recovery efforts in Namibia have been immensely high, signalling that the practice of disaster management is socially and economically unsustainable. The recurrence of some hazards also signals the need to shift from disaster management to risk management.

Socio-economic costs of natural disasters can be minimized by building resilient communities and infrastructures. Resilience-building involves enhancing adaptive capacity and reducing exposure and sensitivity of the communities and infrastructures to natural hazards. Shifting from disaster management to risk management through resilience-building efforts is in conformity with the Sendai Framework for Disaster Risk Reduction 2015 - 2030, to which Namibia is a signatory.

Reducing and managing risks rather than disaster requires understanding of the risks. Risk profiling is therefore the first step towards understanding the disaster. This risks profile has thus established the baseline information necessary for disaster risk reduction in accordance with the Sendai Framework.

It, therefore, gives me a great pleasure to present to you the National Risk Profile, and I would like to call upon Offices, Ministries, and Agencies to prioritize disaster and integrate disaster risk maps in the planning processes at all levels of government and across all sectors to reduce the impacts of natural hazards on the society.

Rt. Honourable Dr. Saara Kuugongelwa-Amadhila, MP
Prime Minister

PREFACE

Namibia, situated in sub-Saharan Africa, is known for its disaster-prone arid climate that increases the frequency of natural hazards. In recent years, the country has faced an escalation in both the frequency and intensity of these calamities. While hazards themselves do not pose a significant threat without human involvement, the interaction between hazards and humans raises valid concerns.

Given Namibia's status as a developing nation in a constant state of progress, it is crucial to acknowledge potential risks that could impede sustainable development and take proactive steps to address them.

Namibia has committed to the Sendai Framework for Disaster Risk Reduction 2015-2030, which prioritizes the comprehensive understanding of disaster risk encompassing vulnerability, capacity, exposure, hazard characteristics, and the environment. The initial focus of the framework is on grasping the essence of disaster risk. In response to this, the Government of the Republic of Namibia, with support from the University of Namibia, has initiated the development of National Risk Profiles of Natural Hazards and selected diseases. These profiles aim to provide a thorough understanding of 14 hazards, including drought, flood, heatwave, wildfire, and others, delving into aspects such as exposure, vulnerability, and coping capacity.

The information gathered through these profiles can be utilized for emergency preparedness, prevention, mitigation, response, and reconstruction efforts. Additionally, this data will aid decision-makers and practitioners in disaster risk reduction to make well-informed decisions and heighten risk awareness across Namibian communities, particularly among the most vulnerable. Furthermore, this study will play a pivotal role in shaping community-centered disaster risk reduction strategies and lay the groundwork for sustainable development planning at all governmental levels, fostering the creation of National Resilience Building.

Appreciation is extended to Prof. Martin Hipondoka, Dr. Eliakim Hamunyela, and their team for their outstanding work, as well as to the United Nations Organizations, Namibia Statistics Agency, and various government bodies for their valuable contributions to the study's finalization. Gratitude is also expressed to the Government of the Republic of Namibia for sponsoring this comprehensive study.

I-Ben Natangwe Nashandi
Executive Director

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We received overwhelming support from many individuals, government ministries, agencies and departments, and organisations. The Office of the Prime Minister skilfully steered the unfolding of the project and provided valuable support in the data collection and stakeholder consultations.

In particular, the unsurpassed support and leadership of Mr I-Ben Nashandi, Executive Director, and Ms Hellen Likando, Director of Disasters Risk Management, were instrumental in the realisation of this risk profile, which is regarded as the first of its kind in the country. The tireless efforts towards data collection, patience, and diplomacy of Ms Anna Dumeni are applauded with appreciation. Mr Paulus Ashili and Ms Mercy Mahoto furthered the objectives of the project to completion.

Invaluable data was received from the Namibia Statistics Agency, Ministry of Health and Social Services, Ministry of Mines and Energy, Namibia Meteorological Service, and Ministry of Agriculture, Water and Land Reform. We also received warm welcomes from the regional councils, several constituency councillors, village councils, traditional authorities, and insightful members of the public. Incredible satellite data and voluminous by-products are generated for free by many individuals that we have not met. We particularly acknowledge the use of data or services from Google Earth, Google Earth Engine, National Aeronautics and Space Administration, European Space Agency, Japan Aerospace Exploration Agency, Climate Hazards Center at UC Santa Barbara, World Wide Lightning Location Network, and European Centre for Medium-Range Weather Forecasts.

Ray Amukwaya, Elias Andima, Sirrka Augustus, Philemon Deloven, Milika Dineinge, Jafet Haindongo, Vistolina Ingashipola, Nicole Moller, Katukula Namongwe, Tjamana Muukua, Tangeni Nakapipi, and Mandema A. Rozitha went beyond the call of duty by spending innumerable hours doing visual satellite image interpretation, and enduring heat and mosquitoes during the extended period of field verification. Eric Kemanya and Ndeyapo Gideon at UNAM provided invaluable logistical support.

During the course of this risk profile, we interacted with and gained insights from many individuals including: Aini Shapaka, Albert Liyali, Alex Mudabeti, Amalia Muhongo, Amanzi Trails, Amon Nghifikwa, Anastacia Amunyela, Anastasia Johannes, Anatolia E. Ashipala, Anna David, Anna Dumeni, Anna Nguno, Anna Richter, Anna-Maria Niipare, Anseline Beukes, Assegid Tassew Mengistu, Austin Simasiku, Axab Skrywer, Ayaka Handa, Benita T. Elago, Bernadette Shalumbu, Bufelo Lushetile, Christiana Manziana van Neel, Christopher Likando, Connie Brendell, David N. Sheehamandje, Dinelao Gabriel, Dorothy Maloboka, D. W. D. Basson, Edward Hamutoko, Elias Andima, Elieser Kariseb, Elise Mbadeka, Emmy-Else Ndevaetela, Enrico Bezuidenhout, Eric N. Kemanya, Erwin Kamati, Erwin Nakafingo, Ester Shifotoka, Eugenia Kaundinge, Evelina Iileka, Fabian Hiskia, Fariedah Shikongo, Fillemon N. Shikongo, Freddy Muyamba, Frederika Shigwedha, Frieda Katenda, Gabriel Namagumbo, Geofrey M. Salyani, George Seister, Georgina Katjiuongua, Geraldine Diergaardt, Gereld Alwin Eiseb, Gerrier R. van Wyk, Gerrit A. Witbooi, Gibson Kamuaruuma, Gideon Mulenga, Gift Kamupingene, Gloria Kamwi, Glynis Harrison, Hellen Likando, Helvi Shilongo,

Hesham A. ELSherif, Hilarous Shilomboleni, Hileni T. W. Heita, I-Ben N. Nashandi, Ileni Simon, Ivan Vries, Iyaloo Mwaningange, Jafet Haindongo, Jimmy Simataa, Johanna Ambata, Johanna D. M. Nekaro, Johanna Mushelenga, John Hausiku, Jona M. Kangumbe, Jonas Kapenda, Josephat Katuahupira, Josephine Tjizu, Karinamuinjo C. Katjiteo, Katukula Namongwe, Kristofina Amakali, Lesley Shikomba, Linea Elago, Lusia Amutenya, M. Skrywer, Mako Sitali, Manelia Shakela, Maria Helao, Maria Nanyemba, Matheus H. Hantoka, Matheus Iipinge, Matheus Ndjodhi, Matheus Singambwe, Mathilde Kooper, Mberii Kapuku, Mandema A Rozitha, Mercy Mahoto, Mesag Mulunga, Michael Kalumba, Michael Otsub, Milika Dineinge, Mose Bonaventure Gariseb, Mwaka Silishebo, Naemi N. Shoopala, Nangula Shivute, Ndapewa Mwenyo, Ndapunikwa Hamunyela, Ndelitungilwa J Mutota, Ndeuhala Hangala, Ndeyapo Gideon, Nicholus Mutenda, Nicole Moller, Nicoletta Mokhatu, Olimpio Nhuleipo, Paulus Ashili, Paulus Shikongo, Petrus Kosmas, Peyavali Mushelenga, Phelemon Deloven, Philemena Ochurus, Ray Amukwaya, Raymond I. Jossop, Reagan Chunga, Robert T. Nandjila, Russel Titus, Sakeus Ihemba, Salome M. K. Tuahuku, Sandra Nakale, Sarafia Ashipala, Senovia Leukes, Sharon Goagoses, Simon A Dirkse, Sirrka Augustus, Samuel Kangootui, Sonnia N. Iiyambo, Stanley Awa-Eiseb, Stefanus Amuulo, Stefanus Sanda, Tangeni Nakapipi, Tjamana Muukua, Uazamo Kaura, Vernel Thomas, Veronika Immanuel, Victorina Shimanda, Vistolina Ingashipola, V. T. Karumendu, and Wilbard Nashandi.

EXECUTIVE SUMMARY

Namibia experiences frequent occurrences of natural disasters, including infectious diseases, with some causing huge environmental and socio-economic damages and losses. In recent years, the country has encountered several disasters, such as the floods in 2009 and 2011, the COVID-19 pandemic, and the relentless drought of 2019. At the time of writing, the country is bracing for the 2023/2024 drought.

The occurrence and effects of natural disasters and infectious diseases in Namibia are diverse and vary in different areas, indicating the varying levels of exposure, sensitivity, and adaptability within the Namibian society. The diverse and pervasive occurrence of these disasters are costly to the country when dealt with in a non-holistic manner. Consequently, Namibia promulgated a disaster risk management law, the Disaster Risk Management Act 10 of 2012, to provide a legal framework for managing disaster risks in the country. This legal instrument provided the necessary framework for facilitating the nation's transition from disaster management to risk management and focus on resilience-building, which aligns with the Sendai Framework for Disaster Risk Reduction 2015–2030. However, a comprehensive understanding of disaster risk for various hazards in the country was lacking.

The Government of the Republic of Namibia, through the Office of the Prime Minister, commissioned this study to profile the disaster risks of pertinent natural hazards and selected diseases countrywide at the level of Population Enumeration Area, the lowest possible spatial scale in the country. The study profiled the vulnerability and risk of nine natural hazards (drought, flood, heatwave, wildfire, sea level rise, frost, earthquakes, windstorms and lightning) and five diseases (malaria, HIV/AIDS, COVID-19, foot and mouth disease and diarrhoea).

As the profile shows, there is not a single place in Namibia which is risk-free from all 14 hazards analysed in this profile. There are, however, areas that are free from some risks such as malaria, wildfire, foot and mouth disease, and sea level rise. At the same time, there is not a single place in Namibia which is at high risk of all 14 hazards. The profiled risks are spatially differentiated. Nevertheless, there are areas with high or very high-risk levels for multiple disaster risks. In the Zambezi Region, for example, there are areas compounded with a high or very high risk of floods, malaria, diarrhoea, and foot and mouth disease. The south-eastern part of the //Kharas Region is concurrently under high or very high risk of heatwaves, frost and earthquakes. This speaks to the need for resilience-building efforts to be risk-holistic and area-specific, to reduce vulnerability and disaster risk of the communities and infrastructure. Thus, this profile has established the baseline information necessary for Namibia to move from managing natural disasters and leverage the mechanism for disaster risk reduction in accordance with the Sendai Framework. However, there is a need to integrate disaster risk maps in the planning processes at all levels of government and across all sectors to reduce the impacts of natural hazards on society. For this integration to be effective, it is imperative to develop an integrated and spatially-enabled data management system for storing data on hazards, risks, vulnerabilities, impacts and interventions to support resilience-building efforts. This data management system should be accompanied by mandatory and standardised annual reporting of all hazards and their impacts to ensure that resilience-building efforts are evidence-based.

01

INTRODUCTION

INTRODUCTION

Natural disasters are ravaging many parts of the globe, inflicting immense socio-economic pains on communities (United Nations Office for Disaster Risk Reduction [UNDRR], 2022). Namibia is not exempted from this ravage. For example, in 2008, 2009 and 2011, Namibia experienced devastating floods which killed over 300 people and caused immense economic damage (Government of Namibia, 2009; Mendelsohn et al., 2013). Since 1990, Namibia also declared six national emergencies in 1992/3, 1995/6, 2012/13, 2013/14, 2015/16, and 2018/19 due to extreme drought events (Hipondoka, et al., 2021).

Natural disasters are caused by natural hazards. A natural hazard is “a natural process or phenomenon 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” (United Nations International Strategy for Disaster Reduction [UNISDR], 2009). In recent years, the frequency and intensity of many natural hazards have increased, particularly climate-related hazards, as a result of climate change (Rahmstorf & Coumou, 2011; Seneviratne et al., 2012). At the same time, many people are increasingly settling in risky areas (Mazzoleni et al., 2021; Mendelsohn et al., 2013; Tellman et al., 2021), making them even more vulnerable to natural hazards. Often, people settled in risky areas are less informed about their risk to natural hazards, primarily due to a lack of or inadequate risk profiling. In some areas, people only become aware of their risk after a natural disaster has occurred, which leads to disaster management rather than risk management.

Managing disasters is economically and socially more costly and disruptive than managing risk. For example, more than 670,000 people were directly affected by the 2009 flood in the Cuvelai Basin, of which 21,000 were displaced (Government of Namibia, 2009). More than 900 small and medium business enterprises were also closed and about 45,000 ha of cropland were destroyed (Government of Namibia, 2009), thus affecting the livelihood of the people. The 2009 flood further led to a temporary closure of 135 schools, and severely damaged more than 20 roads, affecting accessibility to 12 health centres (Government of Namibia, 2009). Overall, the economic damages caused by the 2009 floods in the Cuvelai Basin were estimated at N$ 772, 784, 800 million (Government of Namibia, 2009) which is equivalent to U$40 880 000 million based on the exchange rate of April 2024. This amount does not include the response and recovery cost. While the communities were recovering from the 2009 flood, the country suffered yet another flood disaster in 2011, a disaster which claimed 110 lives and caused massive economic damages and losses (Government of Namibia, 2011). The total cost of the response to the 2011 floods was N$30 million (Government of Namibia, 2011).

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135 schools

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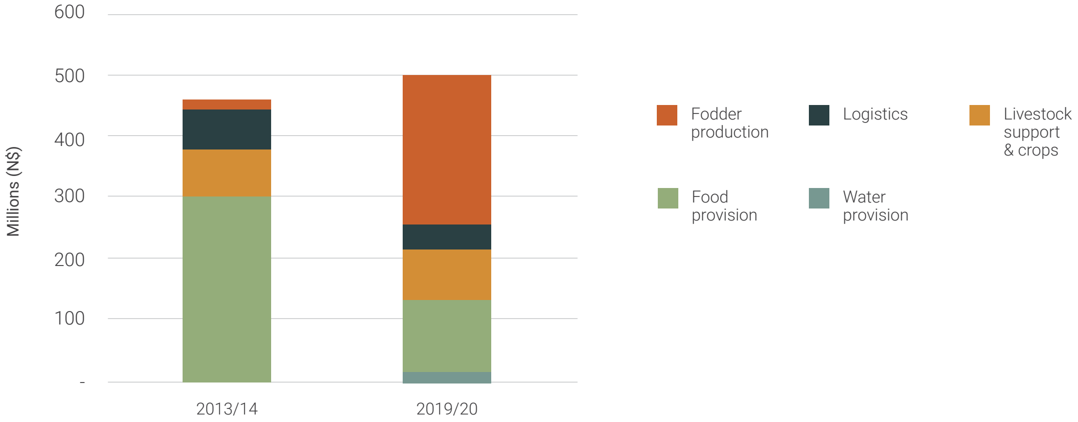


Figure 1: Government expenditure on drought in 2013/2014 and 2019/2020 (data source: Office of the Prime Minister, Namibia)

In Namibia, farming is the main source of income for 23% of rural households (Namibia Statistics Agency, 2016), but it is vulnerable to drought hazards. In 2018/2019, for example, a total of 97,854 livestock perished due to drought (Office of the Prime Minister, 2020). This livestock loss was preceded by two consecutive losses in 2012/13 and 2013/14 also due to drought. The combined cost of the 2013/14 and 2018/19 droughts was nearly N$1 billion (Figure 1; Office of the Prime Minister, 2014; 2020). Certainly, the impact of past natural disasters on society is huge, and managing the impacts arising from those natural disasters has been costly to the Government. Some of the damages and losses caused by past natural disasters could have been avoided through proper risk management mechanisms such as anticipatory planning and disaster preparedness.

To prevent and manage risks rather than disasters, the international community adopted the Sendai Framework in 2015 as a mechanism for disaster risk reduction (United Nations, 2015). Namibia is a signatory to the Sendai Framework for Disaster Risk Reduction 2015–2030 and has promulgated a disaster risk management law (Disaster Risk Management Act 10 of 2012). This law aims to, amongst others, "provide for an integrated and coordinated disaster management approach that focuses on preventing or reducing the risk of disasters, mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post-disaster recovery". As a first step, reducing and managing risks rather than disasters requires understanding the risk. Under the Sendai Framework, understanding disaster risk is the first priority for action to ensure that "policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment". On this basis, risk profiling is required to understand disaster risk. Disaster risk profiling entails the quantification and mapping of disaster risks.

A risk is a combination of the probability of an event and its negative consequences (UNISDR, 2009). The negative consequences could be injuries, property damage, death, loss of livelihood, disruption of economic activities or environmental damage, and these negative consequences result from the interactions between natural or human-induced hazards and vulnerable conditions of the individuals or communities (UNISDR, 2009).

The risk level is a function of the magnitude of the prevailing hazard and the vulnerability of the community, whereas community vulnerability depends on the exposure, sensitivity to a hazard, and the adaptive capacity of the community (Figure 2).

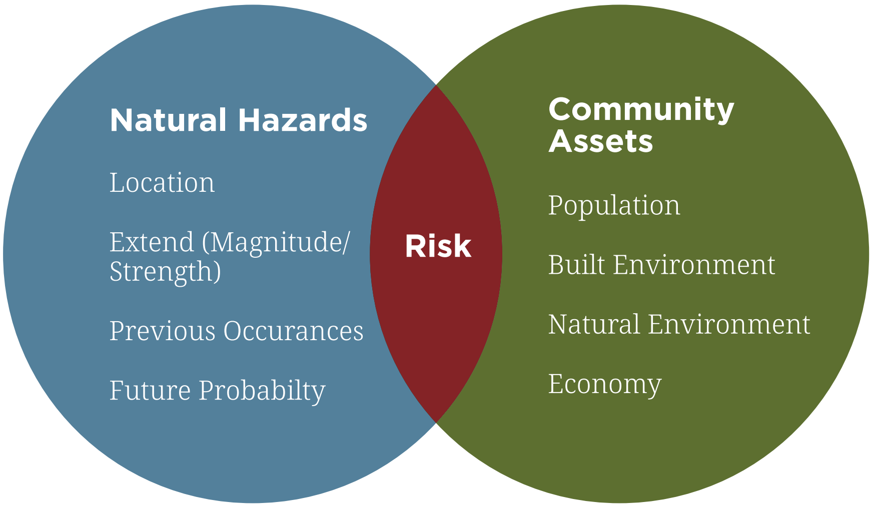


Figure 2: Conceptual interaction of natural hazard and assets to result in risk (Source: Colorado Planning for Hazard, 2020)

According to the United Nations (2016), exposure refers to the "situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas". Exposure can therefore be measured based, for example, on the number of people or type of assets in the area where the hazard can occur. Being exposed to a hazard is not a sufficient determinant of vulnerability. The sensitivity to the hazard is equally critical. Sensitivity is the degree to which people or assets exposed to a hazard could be harmed. People or assets with high sensitivity to a hazard are more vulnerable than those with low sensitivity. Vulnerability can, however, be offset by the adaptive capacity of the exposed people or assets. Adaptive capacity is "the combination of all the strengths, attributes and resources available within an organisation, community or society to manage and reduce disaster risks and strengthen resilience" (United Nations, 2016).

To understand the risks of natural disasters that affect the country, Namibia has undertaken to profile these risks. The most pertinent natural hazards for Namibia are drought, flood, heatwave, wildfire, frost, diseases - inclusive of zoonotic diseases, sea level rise, earthquakes, windstorms, and lightning. Disaster risk for some of these hazards has been profiled in the past, either at a local, regional, or national level. However, previous risk profiles were either limited in scope or scale of analysis. For example, the disaster risks have been profiled for the City of Windhoek (City of Windhoek, 2019), but such local-level profiling was not extended to the rest of the urban areas in Namibia. In 2018, the disaster risks for drought and floods were profiled for the whole country (UNDRR & Centro Internazionale in Monitoraggio Ambientale [CIMA], 2019), but the scale of analysis was at the regional level, making the profile less useful for local-level planning. Therefore, past disaster risk profiling efforts in Namibia were inadequate to inform "policies and practices for disaster risk management" as required by the Sendai Framework.

To address the aforementioned limitations, the Government of the Republic of Namibia, through the Office of the Prime Minister, commissioned this study to profile the disaster risks of the pertinent natural hazards and selected diseases countrywide at the lowest possible spatial scale. This risk profile presents the findings of the study.

The general methodological approach employed to profile the disaster risks is presented in Chapter 2. The specific analyses and findings for each hazard risk assessment are presented in Chapters 3 to 12. The composite risk is presented in Chapter 13, whereas Chapter 14 covers the main conclusion and recommendations. Overall, this study represents the first most detailed and elaborate analysis of disaster risks in Namibia and can better inform the implementation of integrated measures for reducing and managing the disaster risks at local, regional and national levels in Namibia. Figure 3 shows the Namibian regions and their capitals.

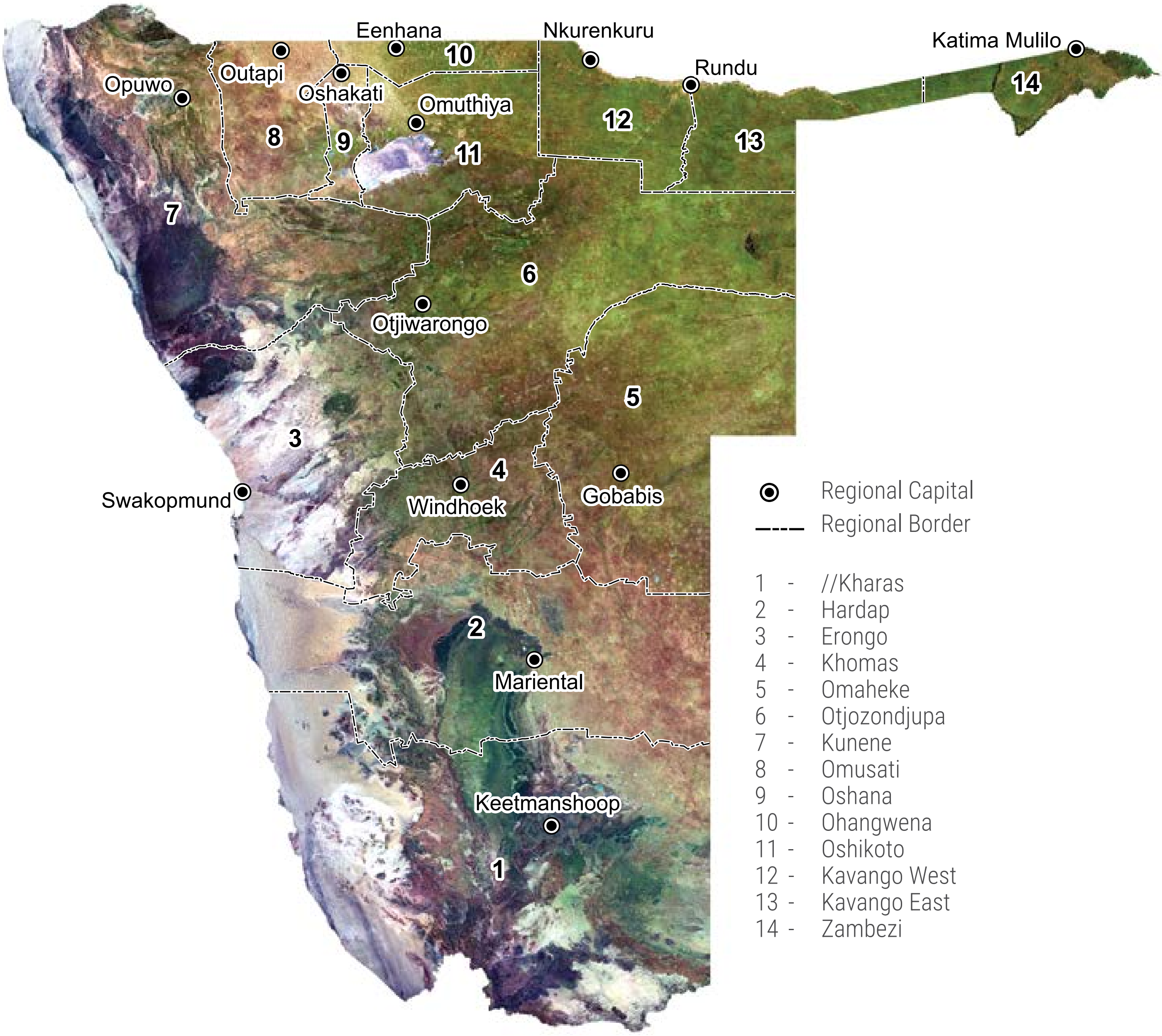


Figure 3: Namibia as seen from space, overlaid with regional capitals and political regions. Background image from Landsat, 2021.

02

METHODOLOGICAL APPROACH

METHODOLOGICAL APPROACH

In the literature, there are several approaches for risk assessment, namely the quantitative risk assessment approach, event-tree approach, risk matrix approach and indicator-based approach (Van Westen & Greiving, 2017). In this profile, the indicator-based approach was used for risk mapping because Namibia has limited data, and this approach allows for cross-comparison of different areas while accounting for several other components of vulnerability. With an indicator-based approach (Figure 4), the risk assessment process is divided into several components, namely the hazard, exposure to the hazard, vulnerability to the hazard and capacity to adapt (Van Westen & Greiving, 2017).

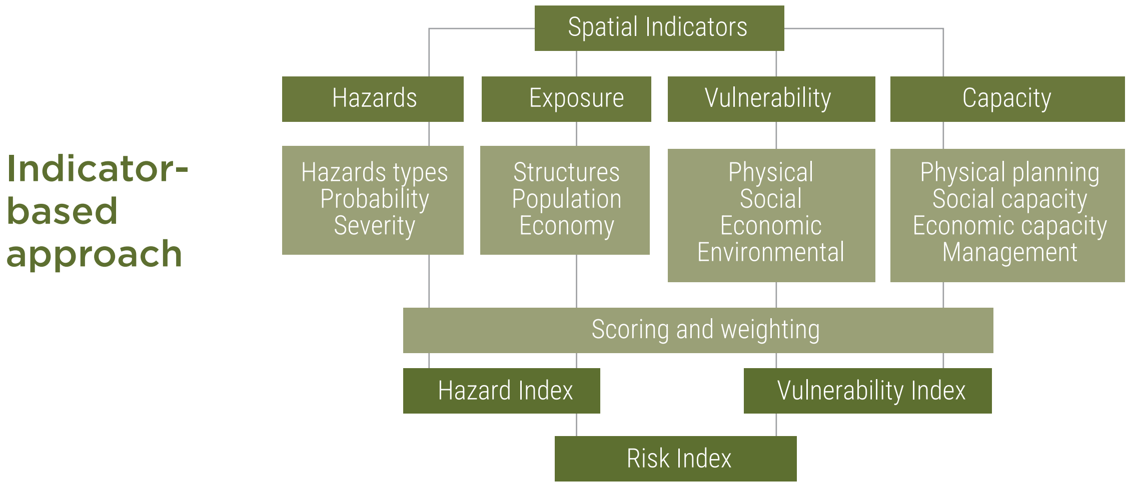


Figure 4: Conceptual setup of the Indicator-based approach (source: Van Westen & Greiving, 2017)

Components of the disaster risk were quantified spatially. Each indicator was first standardised or reclassified to range from zero to one, and sub-indicators were subsequently weighted and combined before calculating the vulnerability and risk. After standardisation, the resulting values for exposure, sensitivity, adaptive capacity, and hazard were scaled between zero and one. Vulnerability and risk were then calculated as follows:

Vulnerability = Exposure + Sensitivity - Adaptive Capacity

Risk = Hazard x Vulnerability

As a result of standardisation, the values for vulnerability and risk also ranged from zero to one, with one representing the highest vulnerability or risk. The risk level can be zero if at least the hazard or vulnerability value is zero. Essentially, standardisation of data allows for the comparison of indicators for the various administrative units and provides flexibility for upscaling of vulnerability and risk.

Unlike previous profiles of disaster risk in Namibia, this profile mapped the disaster risks at the Enumeration Area. This is a unique approach because an Enumeration Area is the lowest spatial scale in Namibia at which official demographic data from the Population and Housing Census are disaggregated (see Figure 5), thus allowing for the provision of detailed information regarding the vulnerability and disaster risk of communities. In this way, areas with high vulnerability and high risk can be unmasked more accurately at the micro-level, which can allow for targeted intervention to build the resilience of affected communities.

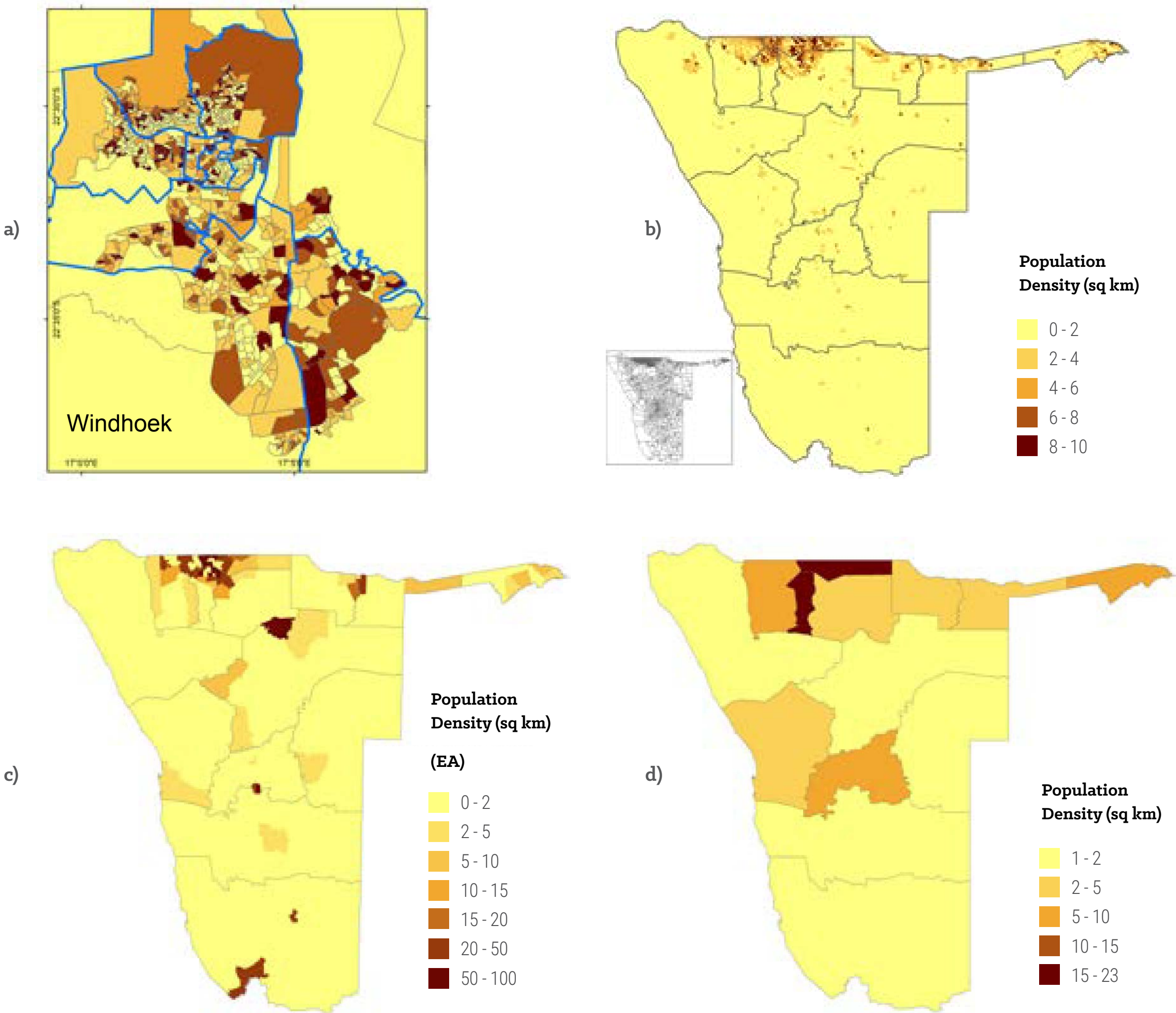


Figure 5: The benefit of assessing the risk profile at the level of the Enumeration Area (a) and (b), which helps to unmask variations within regions (d), constituencies (c), or local authorities. The population density was used here to illustrate the benefit.

Analysis of vulnerability at the level of the Enumeration Area is also advantageous because, in the case of Namibia, upscaling from Enumeration Area to town and settlement, constituency and regional levels is possible and straightforward. For example, Windhoek comprises 10 constituencies, which are subdivided into 756 Enumeration areas. Collectively, the country is parcelled into 5490 Enumeration areas averaging 16,000 ha in size, and the results of this profile are produced at this unprecedented level of detail. This is not the case with approaches used to produce previous disaster risk profiles for Namibia.

03

DROUGHT VULNERABILITY AND RISK ASSESSMENT

DROUGHT VULNERABILITY AND RISK ASSESSMENT

3.1 DROUGHT HAZARD

Drought is one of the most widespread natural hazards, often with dire consequences for many communities across the globe, especially those who are highly dependent on subsistence agriculture. Namibia, the most arid country in sub-Saharan Africa, experienced devastating droughts in recent years, with the 2019 drought being the worst in the last 90 years (Liu & Zhou, 2021; Shikangalah, 2020). Recent drought events, such as the 2019 drought, did not only result in livestock mortality, but wild animals as well (see Figure 6).

In this profile, the drought hazard was mapped following the Percent of Normal Precipitation Rainfall Departure (RD) methodology adopted by Hipondoka et. al (2021). The RD method uses the formula of Kraus (1977), x_{ij}=((r_{ii} - $\bar{r}_i$)/$\bar{r}_i$)*100, where, r_{ij} is annual rainfall at pixel *i* during year *j* and $\bar{r}i$ is mean annual rainfall at pixel *i* for the period 1981/82 – 2021/22. Essentially, the drought hazard was spatially characterised by computing deviations from the long-term average using a hybrid wall-to-wall rainfall data with a 5.3 km spatial resolution from the Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) dataset of 1990 to 2022 (Funk et al., 2014).

A negative deviation of 10% or more from a long-term mean of annual rainfall represents a drought event. The threshold set for rainfall departure from the long-term mean varies from country to country. For example, South Africa, with a mean annual rainfall ranging from 100 mm to 1200 mm, set a threshold of -30% (Bruwer, 1993). India, with an mean annual rainfall of 300–650 mm, has a threshold of -20% (Samra, 2004). Zucchini and Adamson (1984) assert that "drought occurs when there is less water available than is needed and not when there is less than expected." In that context, setting a high threshold value for Namibia would not accommodate the needed water for rural communities making a living in marginal areas with low (e.g. 100 mm) mean annual rainfall. We subsequently lowered the threshold of RD to -10% for Namibia.

a) b)

Figure 6: Some drought events affected both livestock and wild animals. Image (a) cattle and (b) wildebeest.

Drought frequency, which is the number of years in which a drought event was detected, was computed for each 5.3 x 5.3 km pixel of CHIRPS and subsequently used as a measure of drought hazard (Figure 7). Some areas experienced more than 16 drought events between 1990 and 2022. These areas are mostly in the western upland of the Erongo, Kunene and Hardap regions. Six droughts were declared as national disasters between 1990 and 2022. Drought is most frequent in western uplands along the escarpment which transcends the Erongo, Hardap, and Kunene regions, as well as in the Oshana and Omusati regions. The intensity and spatial extent of drought events were different during the 1990-2022 period, with some droughts being more intense and widespread. For example, the 2018/19 drought was the most intense and widespread, with almost the whole country experiencing a negative rainfall deviation of 50% and less (Figure 8).

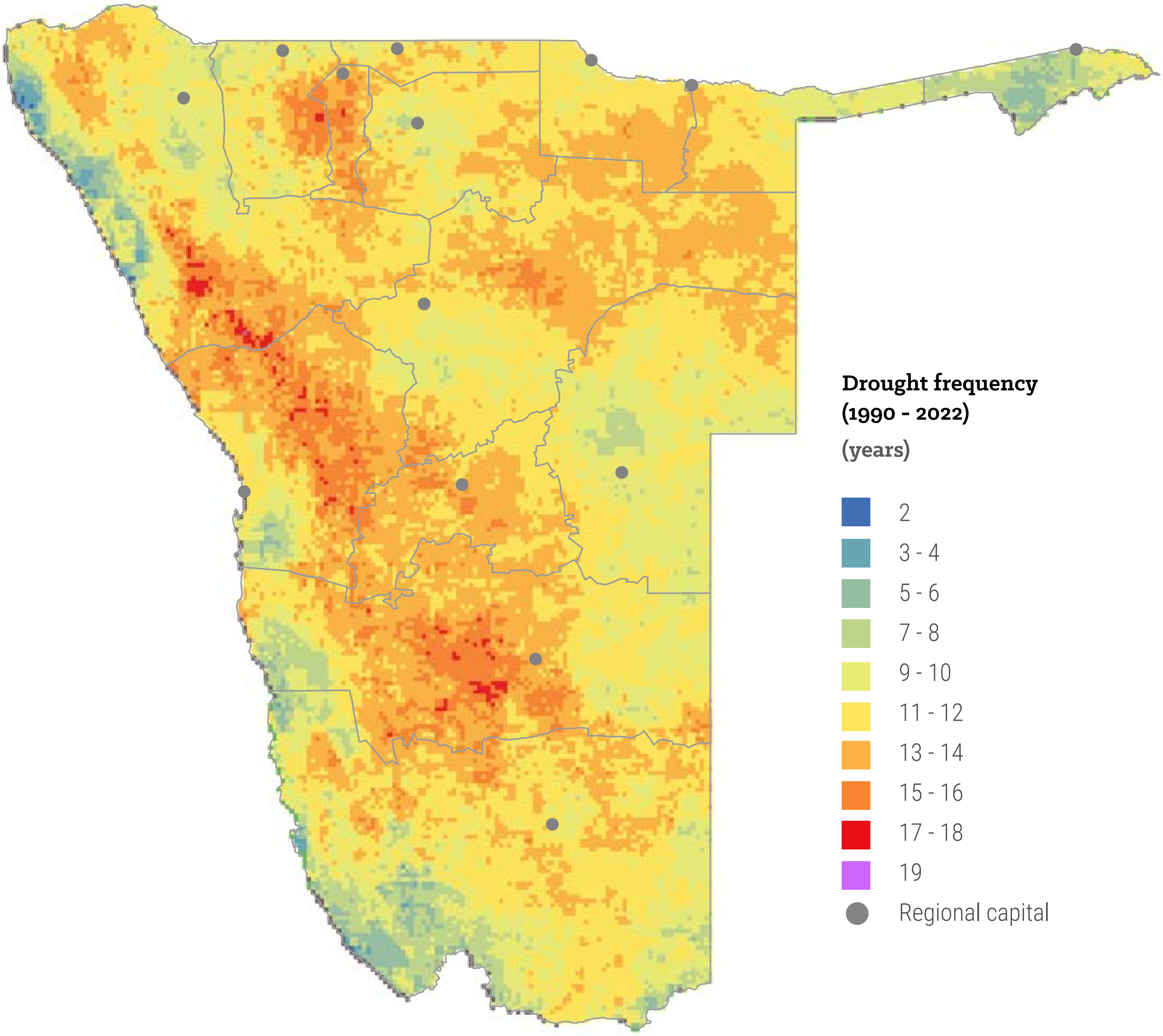


Figure 7: Drought frequency between 1990 and 2022 based on CHIRPS rainfall data

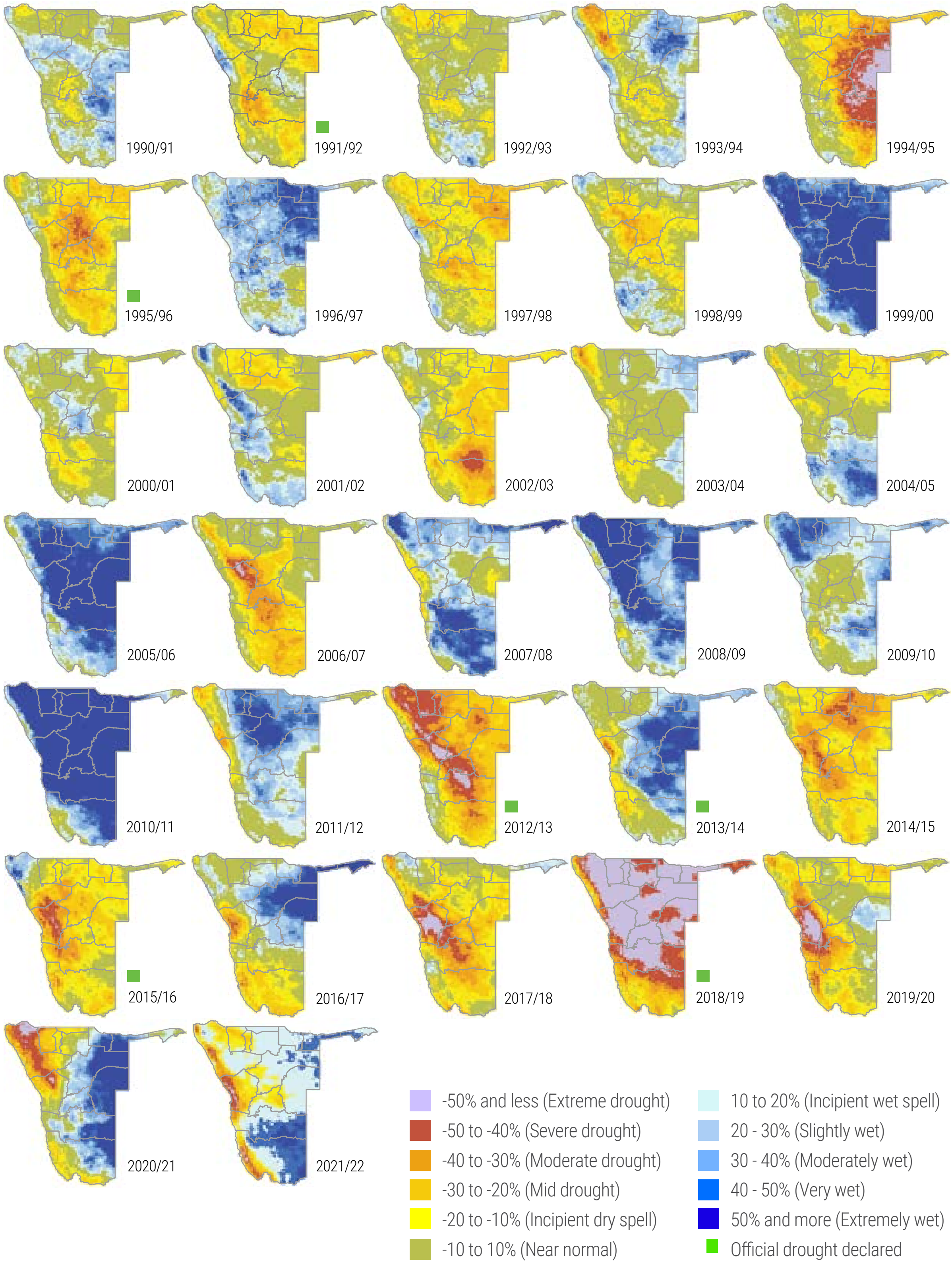


Figure 8: Deviation of rainfall from long-term mean from 1990 to 2022

3.2 EXPOSURE TO DROUGHT

Drought affects and damages the livelihood of the people because livestock dies, drinking water becomes scarce, crops fail, and some people eventually starve. Areas with a high density of people can be viewed as having the highest exposure. In Namibia, areas with a high density of people are predominantly in the northern regions and the urban areas. A large part of Namibia has a population density of less than two people per square km (Figure 9). The number of households per area is also a relevant metric for quantifying exposure to drought. Therefore, population density (Figure 9) and proportion of households (Figure 10) were combined, with equal weight, to create an exposure dataset. The combined exposure dataset was then standardised to range from zero to one (Figure 11).

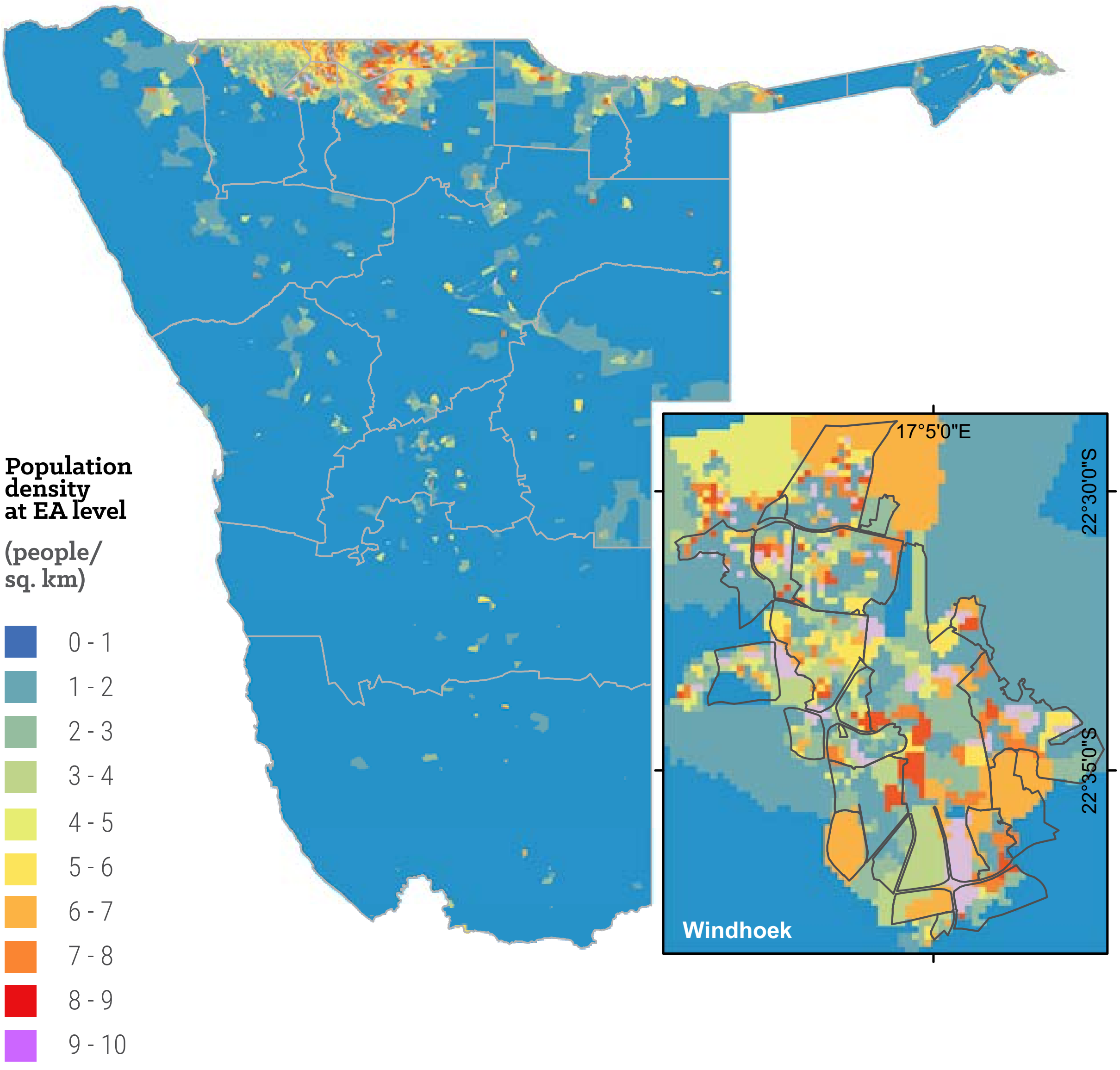


Figure 9: Population density at the level of Enumeration Area

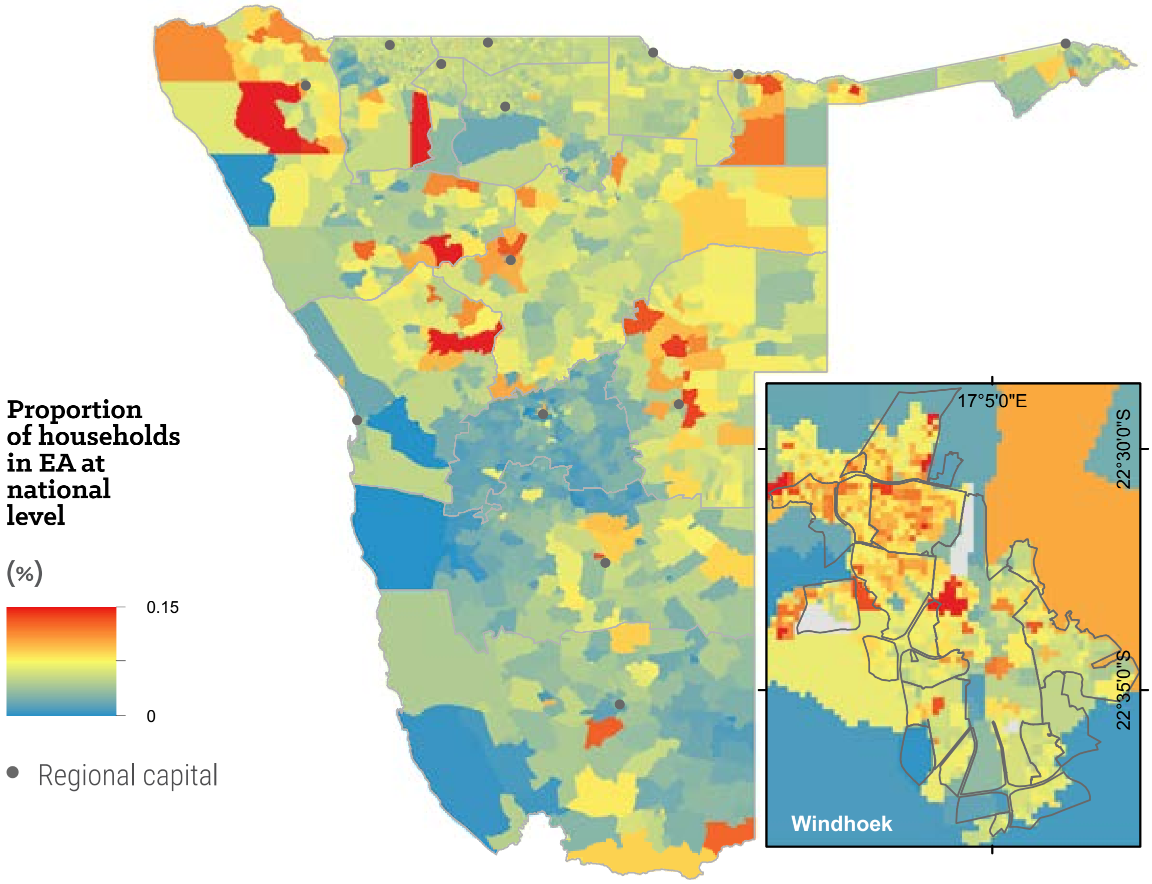


Figure 10: Proportion of households in Enumeration areas relative to national population based on the 2011 national census data

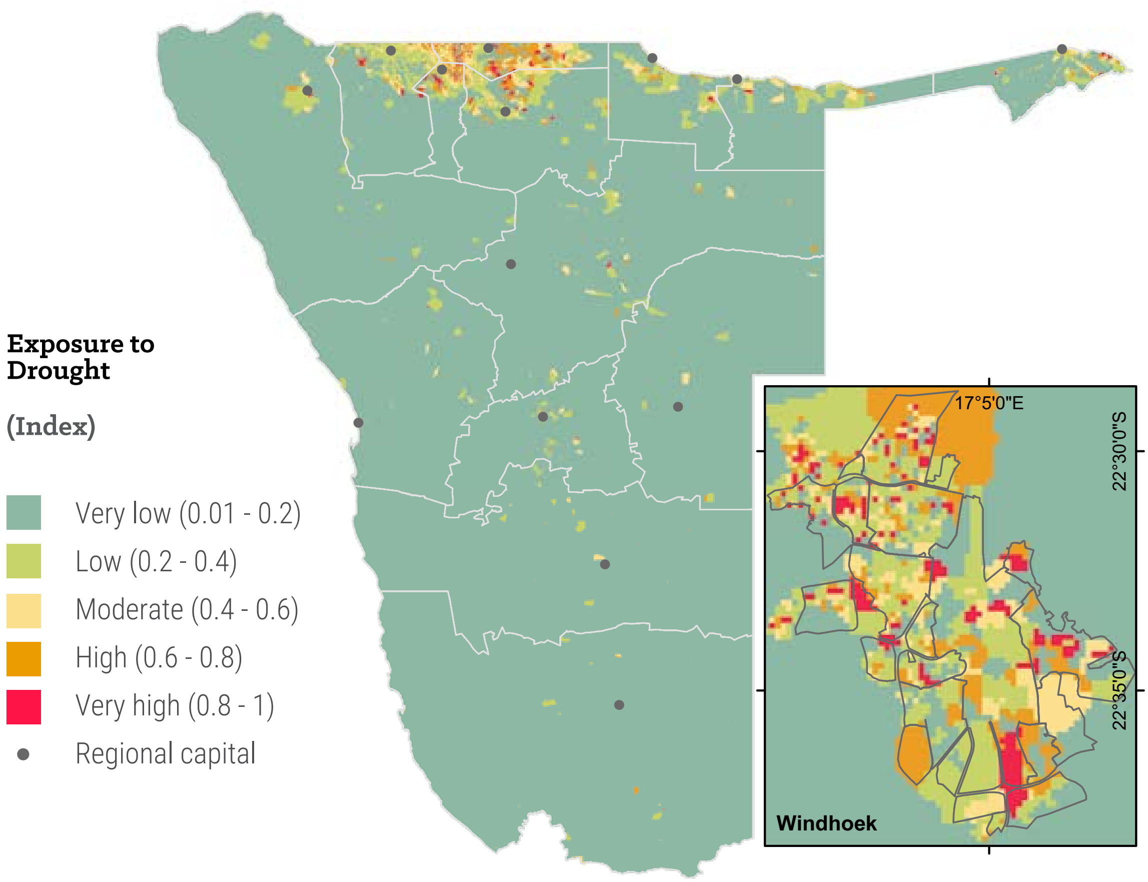


Figure 11: Exposure of human population to drought

3.3 SENSITIVITY TO DROUGHT

The sensitivity of people to drought varies depending on their assets and livelihood. It is logical, for example, for people who depend on subsistence farming to be highly sensitive to drought. This is because drought reduces the availability of freshwater and negatively affects crops and livestock. People with no or little assets, especially financial and other assets, can also be considered more sensitive to drought. In this profile, a dataset for dominant livelihood (Figure 12) was used to represent sensitivity to drought, with areas dominated by agro-pastoral communal and pastoral communal livelihood as the most sensitive to drought.

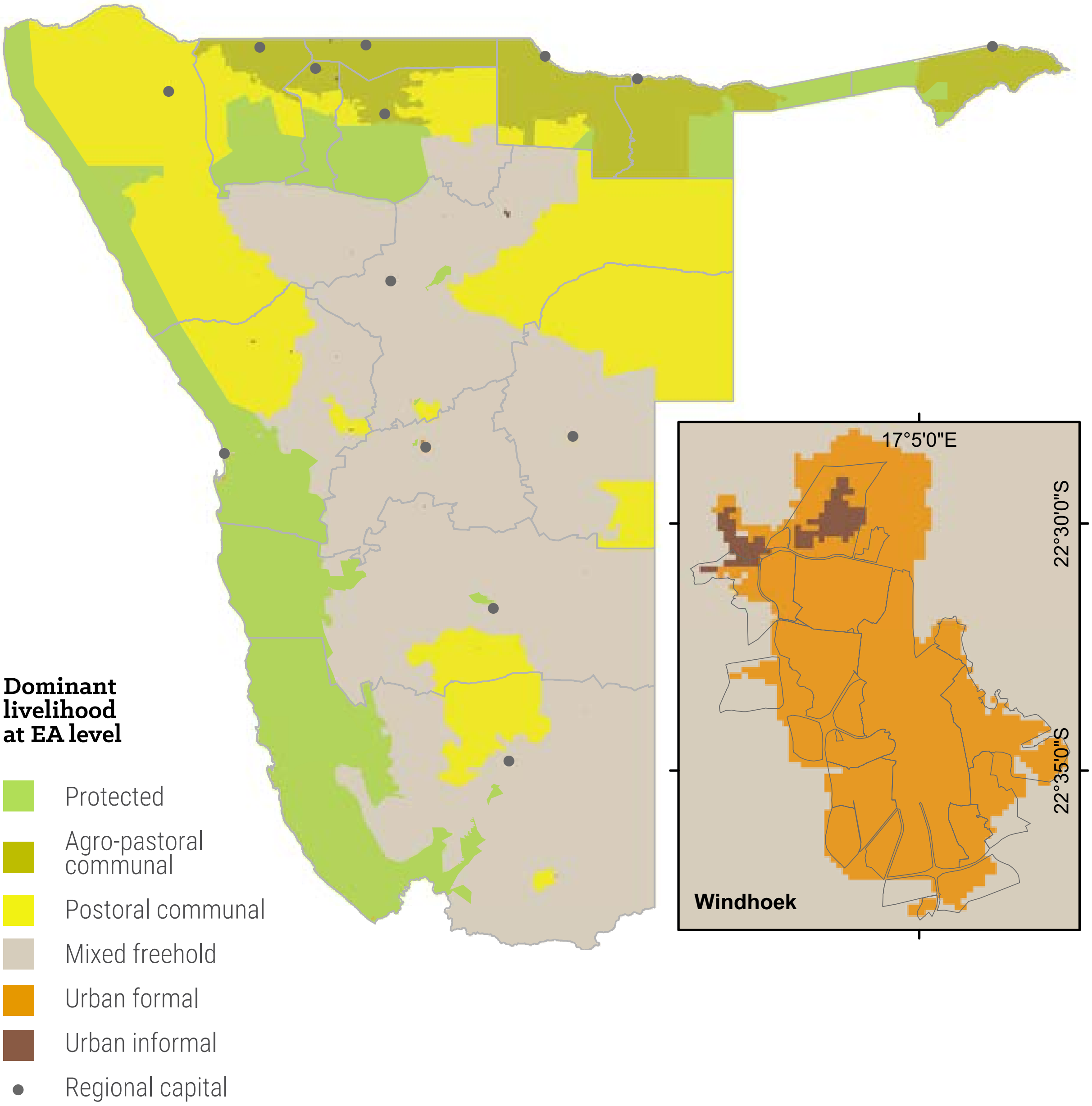


Figure 12: Dominant livelihood at Enumeration Area (EA) level (data source: Atlas of Namibia Team, 2022)

3.4 ADAPTIVE CAPACITY TO DROUGHT

Although drought often has devastating consequences, people with the capacity to modify their situations can adapt to drought. For example, people living in drought-prone areas but having financial means to buy or produce fodder can be viewed as having high adaptive capacity for drought. Therefore, at the local level, the median income per capita is a reasonable metric to represent adaptive capacity (Figure 13). In this context, areas with high median income per capita could be viewed as having higher adaptive capacity to drought. The median income per capita ranged from N$500 to more than N$5000; the national average is N$ 2000. Across Namibia, the median income per capita was highest (N$33,000) in freehold lands (locally known as commercial farms) and in urban areas. However, urban areas presented a diverse median income per capita, with some areas having a median income per capita as low as N$500. However, it should be noted that summary metrics such as median value can hide disparities in an area. While the inclusion of metrics that capture variation in income per capita would enhance the measure of adaptive capacity, data on income variation is currently lacking in Namibia at an appropriate spatial scale.

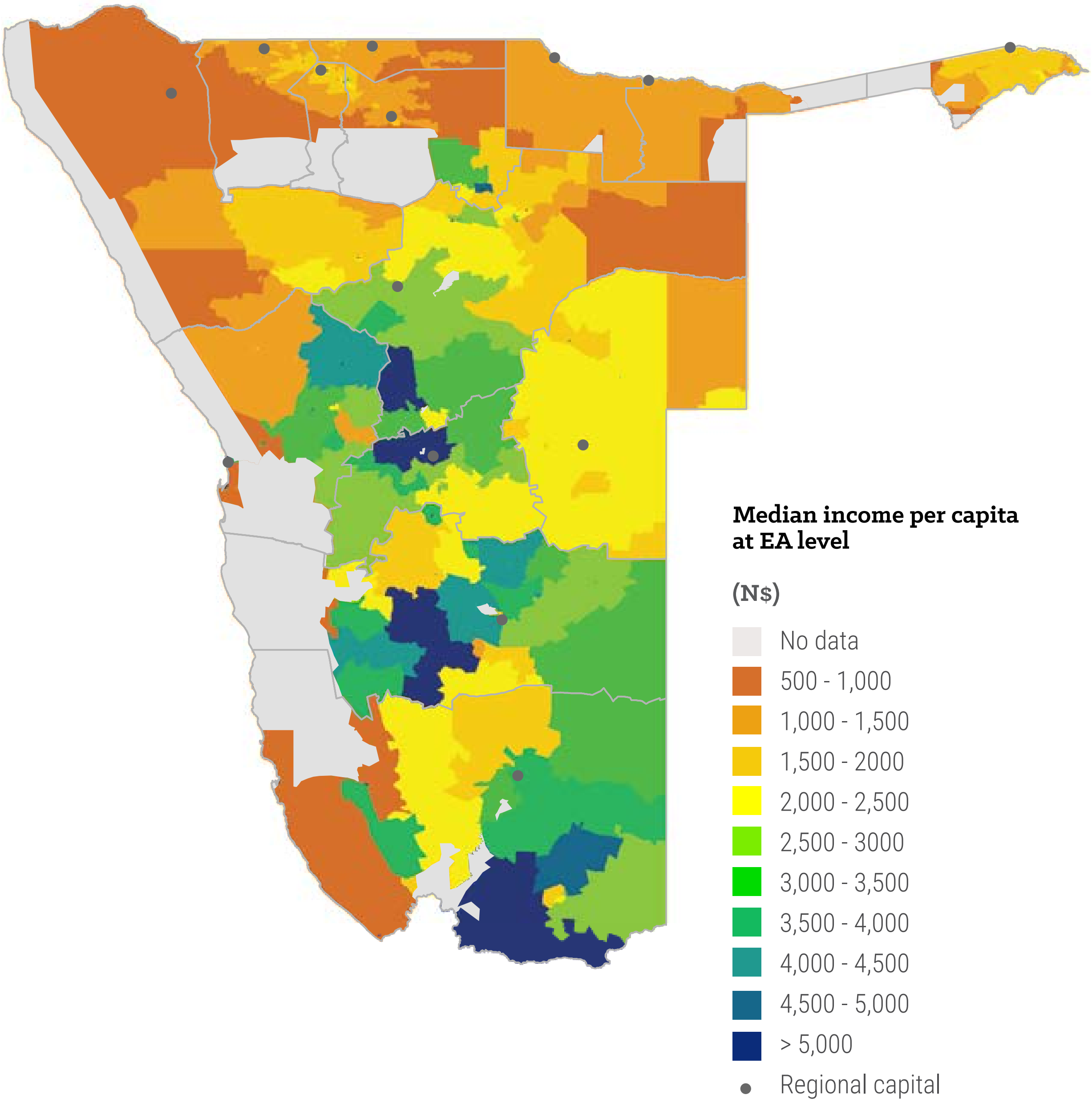


Figure 13: Median income per capita at EA level adjusted to 2021 condition (data source: Atlas of Namibia Team, 2022)

3.5 VULNERABILITY TO DROUGHT

In general, vulnerability to drought is higher in communal areas (Figure 14). This spatial pattern is not surprising, because communal areas in Namibia have largely a high density of people and households, which translates into high exposure. At the same time, communal areas are highly sensitive to drought because the livelihood of most people in communal areas is centred around subsistence farming (livestock and/or rainfed crops). Yet, per capita income is low across the communal areas (Figure 13). Therefore, when an area has a combination of high drought exposure and sensitivity, and low adaptive capacity, the vulnerability would be predictably high. Areas with the highest vulnerability to drought are found mainly in the Ohangwena, Oshana and Oshikoto regions. Based on the 2011 Population and Housing Census, a total of 929, 730 people are residing in areas with high to very high vulnerability to drought (Table 1).

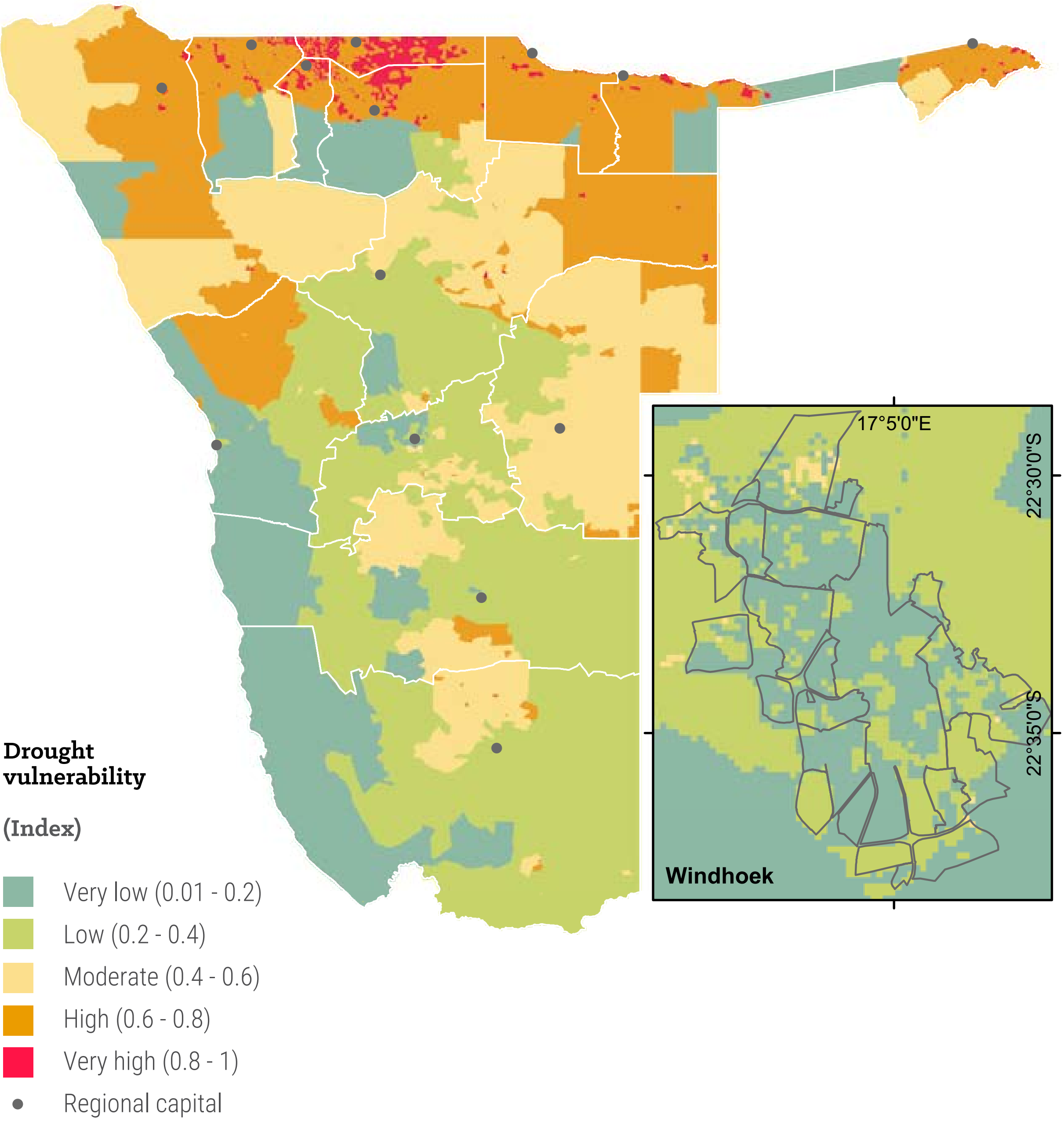


Figure 14: Spatial distribution of the vulnerability of the human population to drought

Table 1: Distribution of population by drought vulnerability level in each region of Namibia

Drought vulnerability level	Erongo	Hardap	Khomas	Kunene	Kavango East	Kavango West	Ohangwena	Omaheke	Omusati	Oshana	Oshikoto	Otjozondjupa	Zambezi	//Kharas
Very low	79213	29112	175797	5183	9278	619	2032	6581	6488	24308	6586	19313	14271	25926
Low	41473	35056	131078	10551	22422	3	6094	18418	2377	21436	12469	37941	5402	34145
Moderate	7725	24711	33861	19906	17354	252	1607	31887	3812	8696	8952	39272	8180	8779
High	7782	2638	488	31662	54974	60247	93665	6975	169835	53137	104061	23165	37211	2901
Very high	573	122	0	2789	17485	19363	118313	0	38989	45182	23624	2170	11969	983

Ohangwena region Distribution of population by drought vulnerability level

VERY LOW	MODERATE	VERY HIGH
2032	1607	118 313

Understanding the proper context of vulnerability metrics is important when analysing vulnerability maps and prioritising areas for drought resilience building. The Kunene Region, for example, is highly sensitive to drought and has low adaptive capacity, but the exposure is relatively low because the density of people and households is relatively low. So, when addressing the drought vulnerability of an area, it is important to properly understand in which dimensions of vulnerability (exposure, sensitivity, and adaptive capacity) an area is lagging.

3.6 DROUGHT RISK

The analysis shows that only a few areas have high to very high drought risk across the country (Figure 15). Most areas have either moderate or low drought risk. Drought risk in the communal areas is primarily moderate to very high, whereas freehold areas have low risk. This pronounced variation between communal and freehold areas is mainly because communal areas have high vulnerability and low adaptive capacity (median income per capita). Protected areas have low drought risk, largely because of low vulnerability due to low exposure and sensitivity to drought. A total of 205,946 people are residing in areas with high to very high drought risk (Table 2).

Table 2: Distribution of population by drought risk level in each region of Namibia

Drought risk level	Erongo	Hardap	Khomas	Kunene	Kavango East	Kavango West	Ohangwena	Omaheke	Omusati	Oshana	Oshikoto	Otjozondjupa	Zambezi	//Kharas
Very low	103086	40097	244553	13290	26661	3216	8980	17244	9818	31466	18254	41991	49125	55096
Low	23511	41660	93133	42948	48937	15291	76845	42260	102683	20456	64483	50013	25491	9908
Moderate	8016	8446	3497	12923	40605	52469	111335	4176	85273	38108	63092	25309	2417	7381
High	2719	1436	41	930	4734	9508	23858	181	22989	57015	69863	4548	0	349
Very high	0	0	0	0	576	0	747	0	738	5714	0	0	0	0

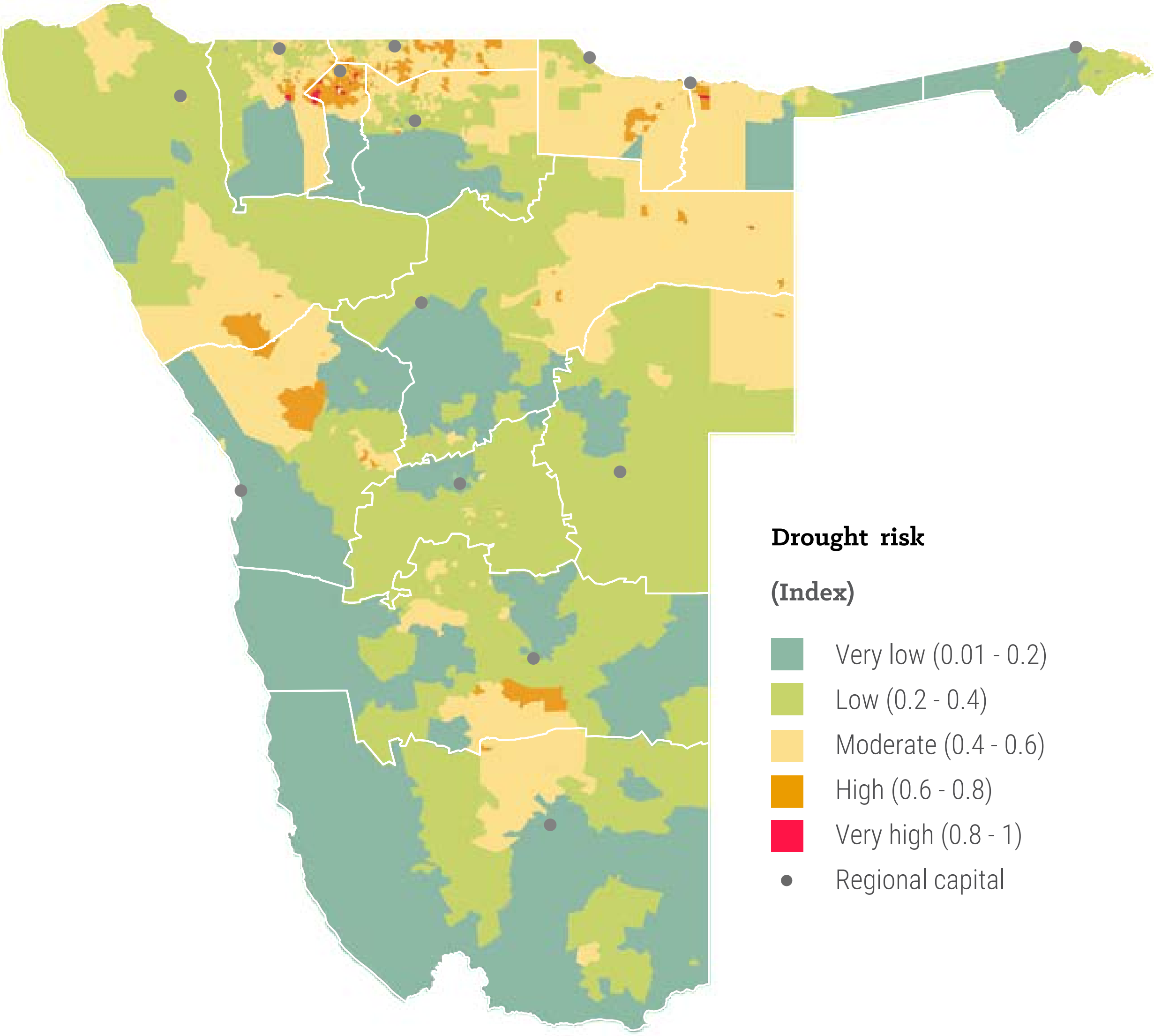


Figure 15: Spatial distribution of the risk for the human population to drought

04

FLOOD VULNERABILITY AND RISK ASSESSMENT

FLOOD VULNERABILITY AND RISK ASSESSMENT

4.1 FLOOD HAZARD

Floods are one of the natural hazards that have caused natural disasters in Namibia in recent years. Yet, elaborate and spatially explicit information on flood-prone areas does not exist. To quantify flood hazards in Namibia, detection and mapping of surface water occurrence and frequency were carried out across the country. Surface water occurrence and frequency were mapped from Landsat imagery at a 30 m spatial resolution, covering a period of three decades (1990-2021), using machine learning.

Training of machine learning models and the assessment of their performance was done using human-interpreted samples. A total of 35, 500 sample pixels were interpreted through visual analysis of multispectral Landsat images (Figure 16). Water occurrence was mapped for each year. This long-overdue critical dataset of surface water forms the basis of flood hazards. Flood plains in the Zambezi Region and the Iishana sub-basin in the Cuvelai Basin (Figure 17) are some of the areas where the large extents of surface water occurrence and high frequency of occurrence (Figure 18) were recorded during the study period.

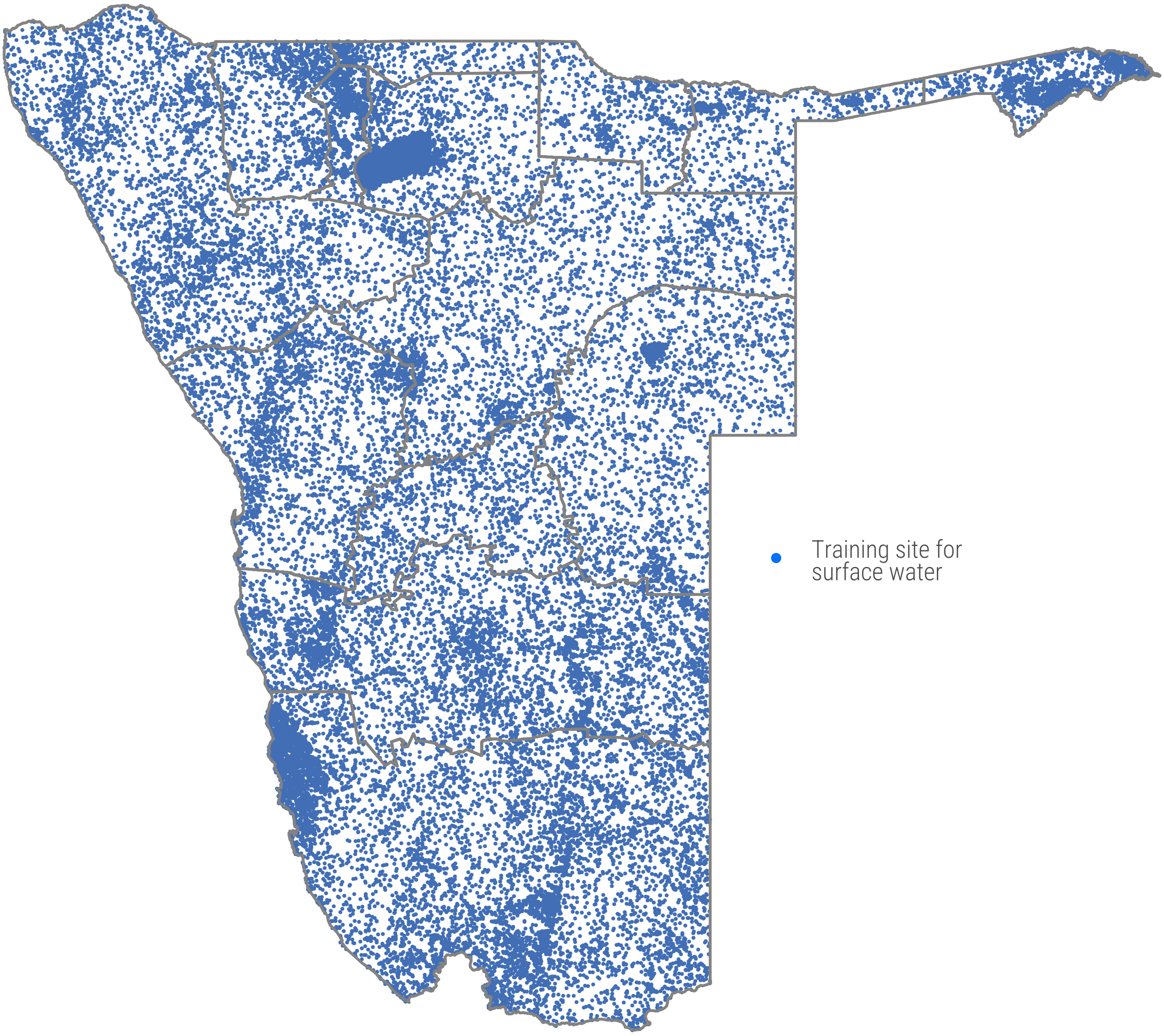


Figure 16: Training sites for generating surface water occurrence in Namibia using Landsat images and machine learning

The surface water frequency of occurrence was aggregated at the level of the Enumeration Area, by computing the average and maximum water frequency (Figure 19). The average and maximum water frequency were used to represent flood hazards.

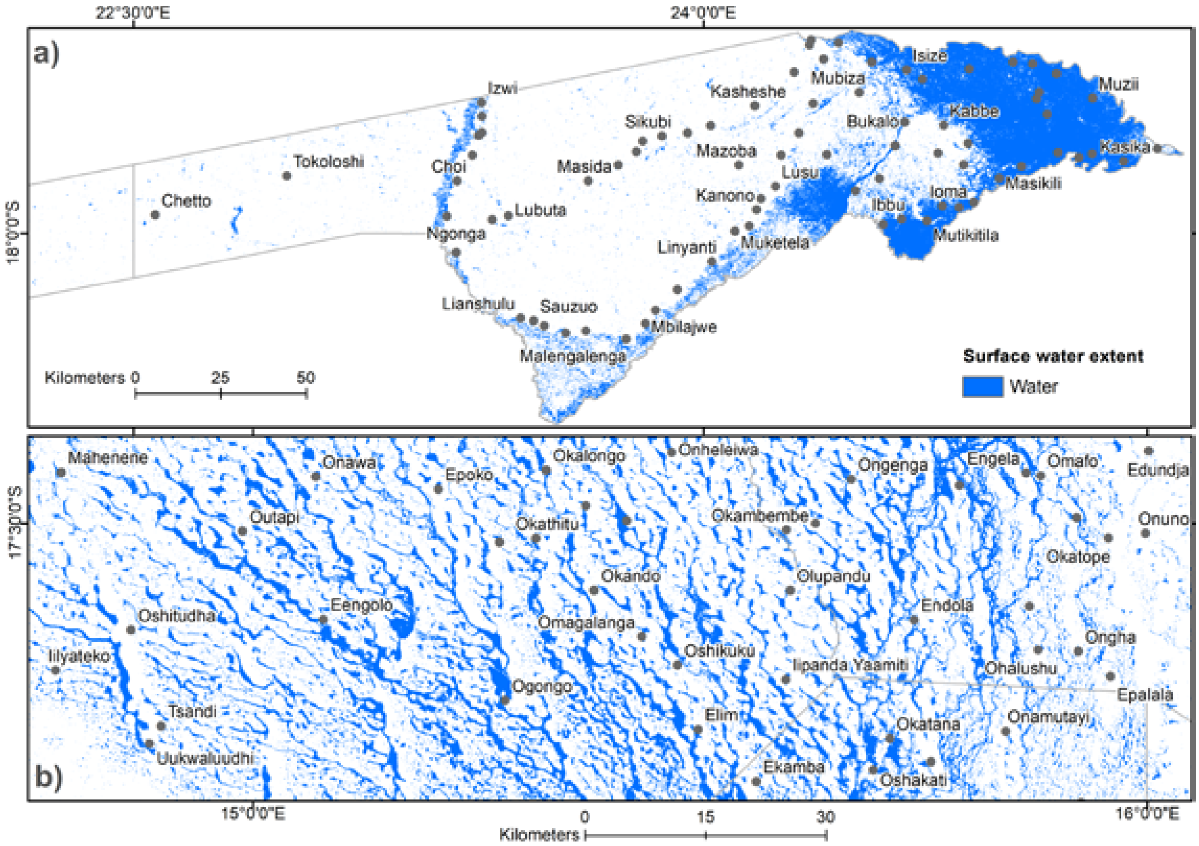


Figure 17: Extent of surface water (1990-2021) in part of the Cuvelai Basin (a) and the Zambezi Region (b)

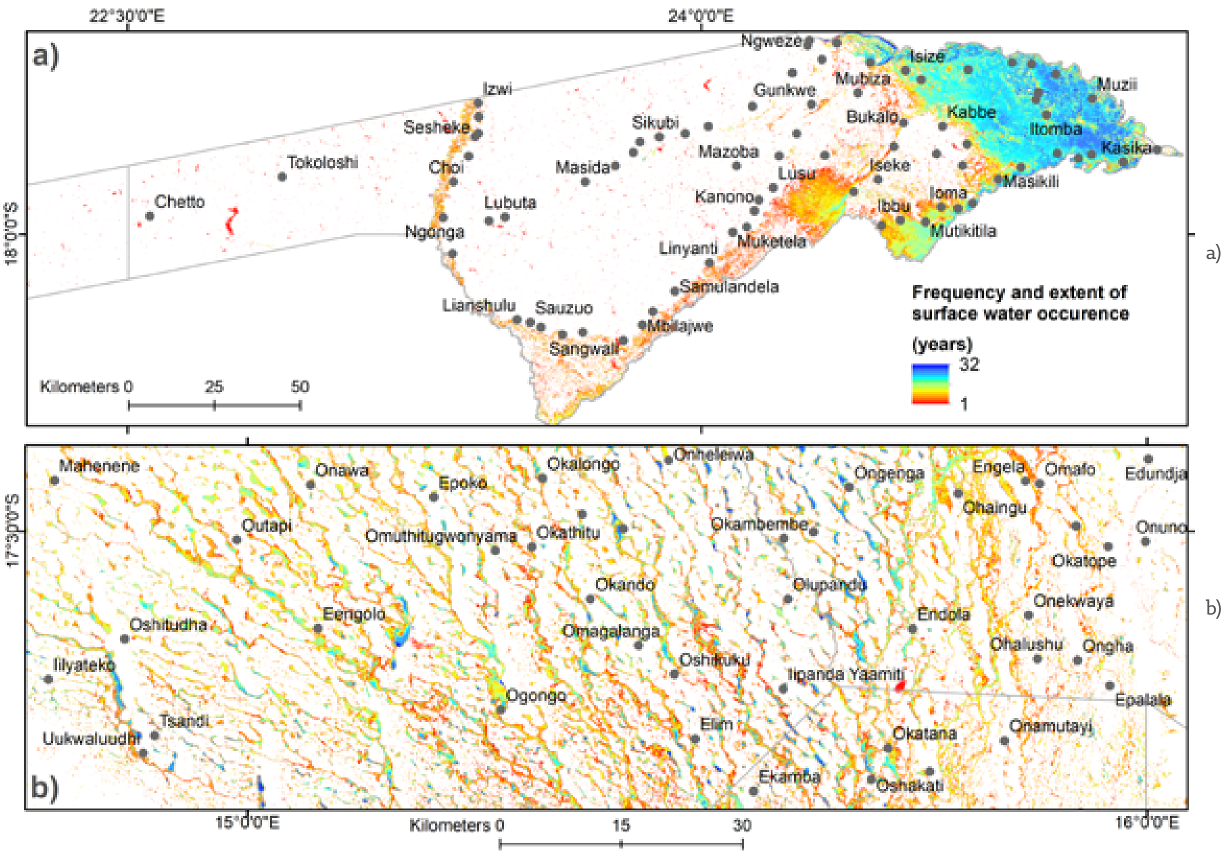
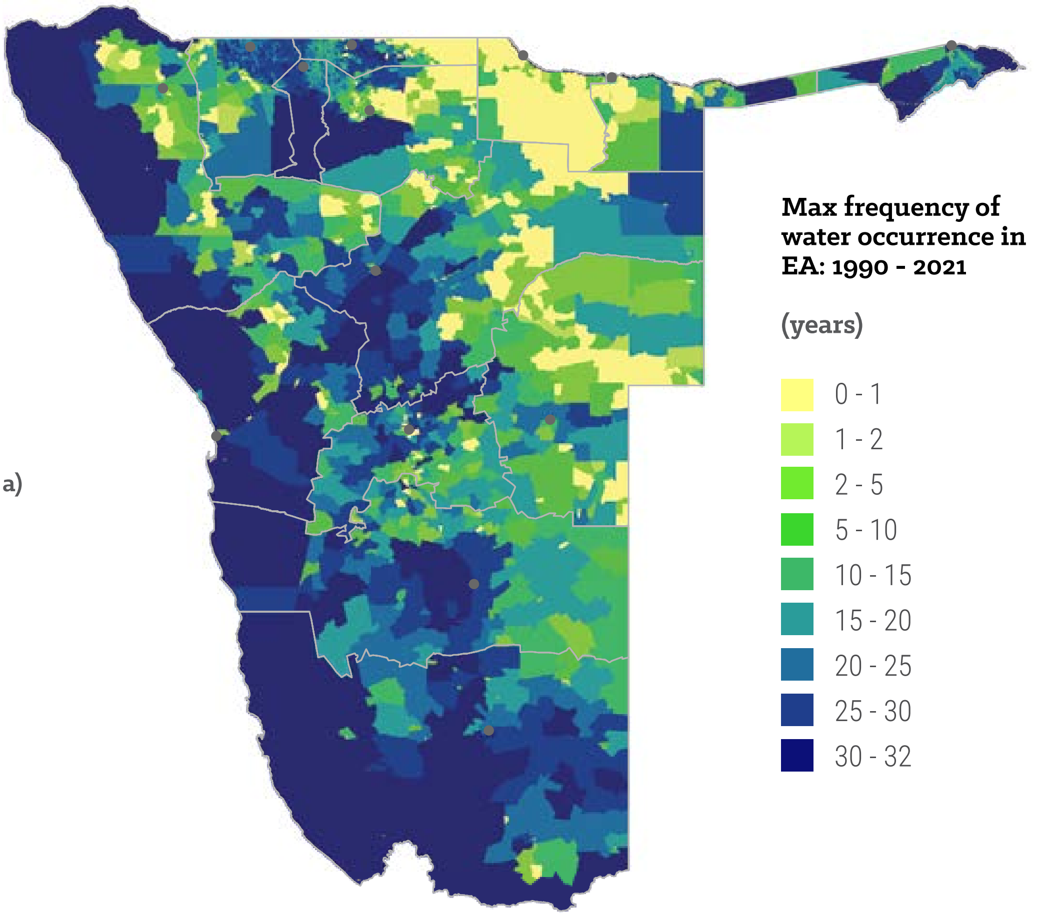


Figure 18: Frequency of surface water (1990-2021) in part of the Cuvelai Basin (a) and the Zambezi Region (b)

a)



b)

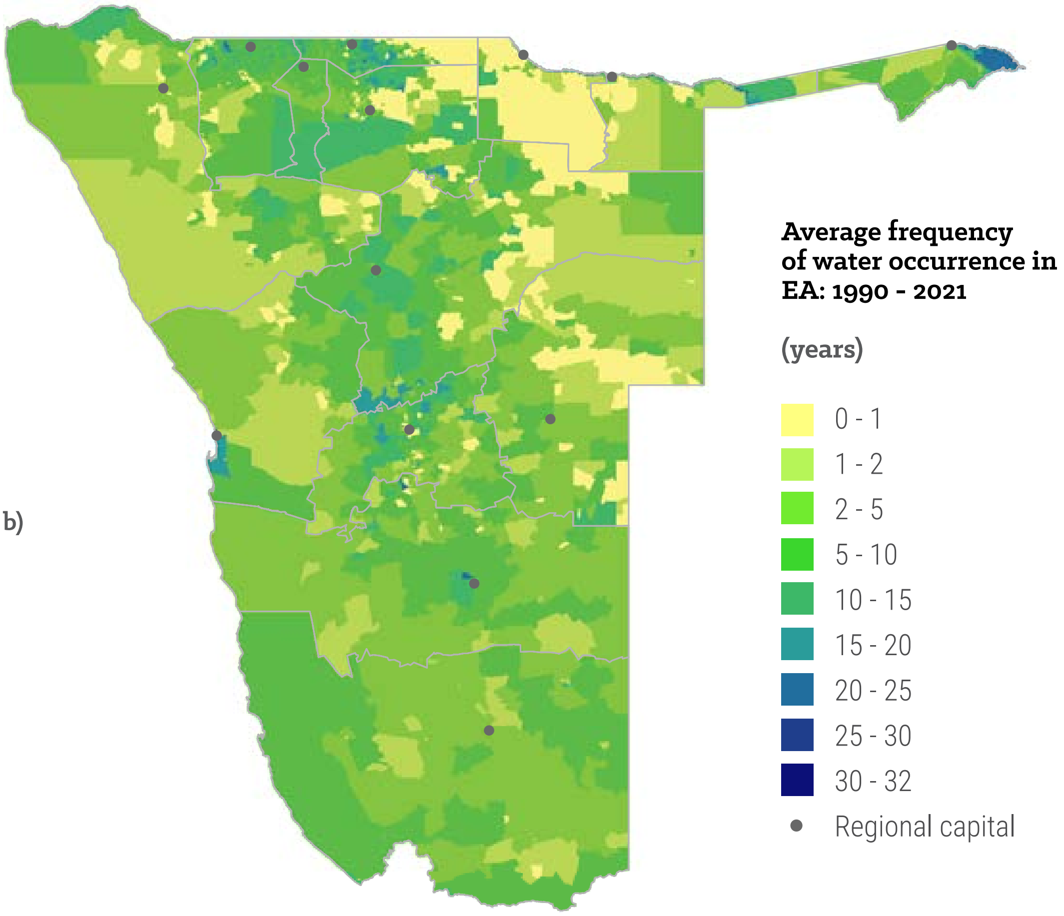


Figure 19: a) Maximum and b) average frequency of years at the level of Enumeration Area from 1990 to 2021

Between 1990 and 2021, the largest extents of surface water were mapped in 2008, 2009, and 2011 (Figure 20). These were the years in which flood disasters ravaged Namibia the most since independence. Figure 21 shows the flood levels around the Orange River during 2010, 2011, 2021 and 2022.

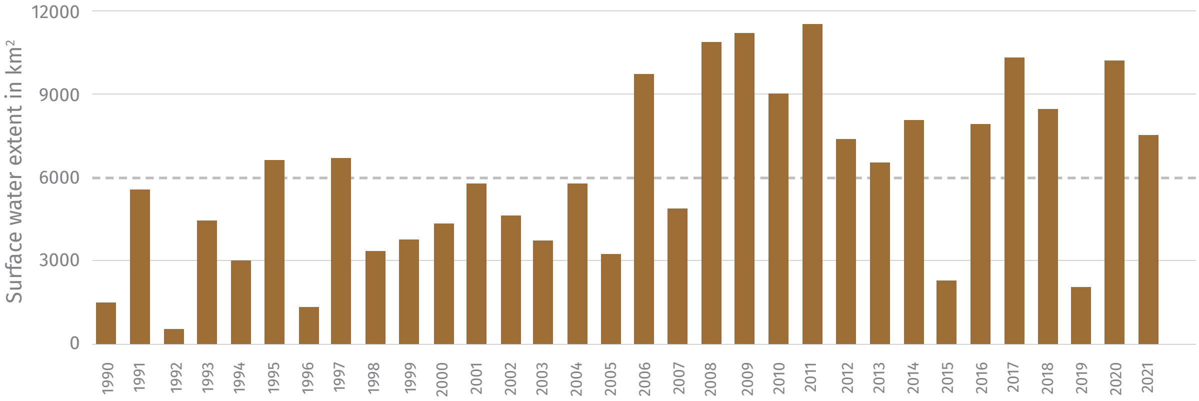


Figure 20: Surface area covered with water during the 1990-2021 period in Namibia as detected from satellite images

Figure 21: A signboard showing the levels of historical floods since 2010 on the bank of the Orange River, with a vehicle used for scale. In this instance, the property is built with a calculated risk since it is below the floodline.

4.2 EXPOSURE TO FLOODING

With the flood hazard mapped at a high spatial resolution (30 m), exposure was made at two levels: human population (Figure 9) and building footprints (Figure 22). This is because floods affect people and damage buildings. There are many ways flood affects people. For example, floods can kill people and limit access to schools (Figure 23) and health facilities by surrounding the area where the facility is.

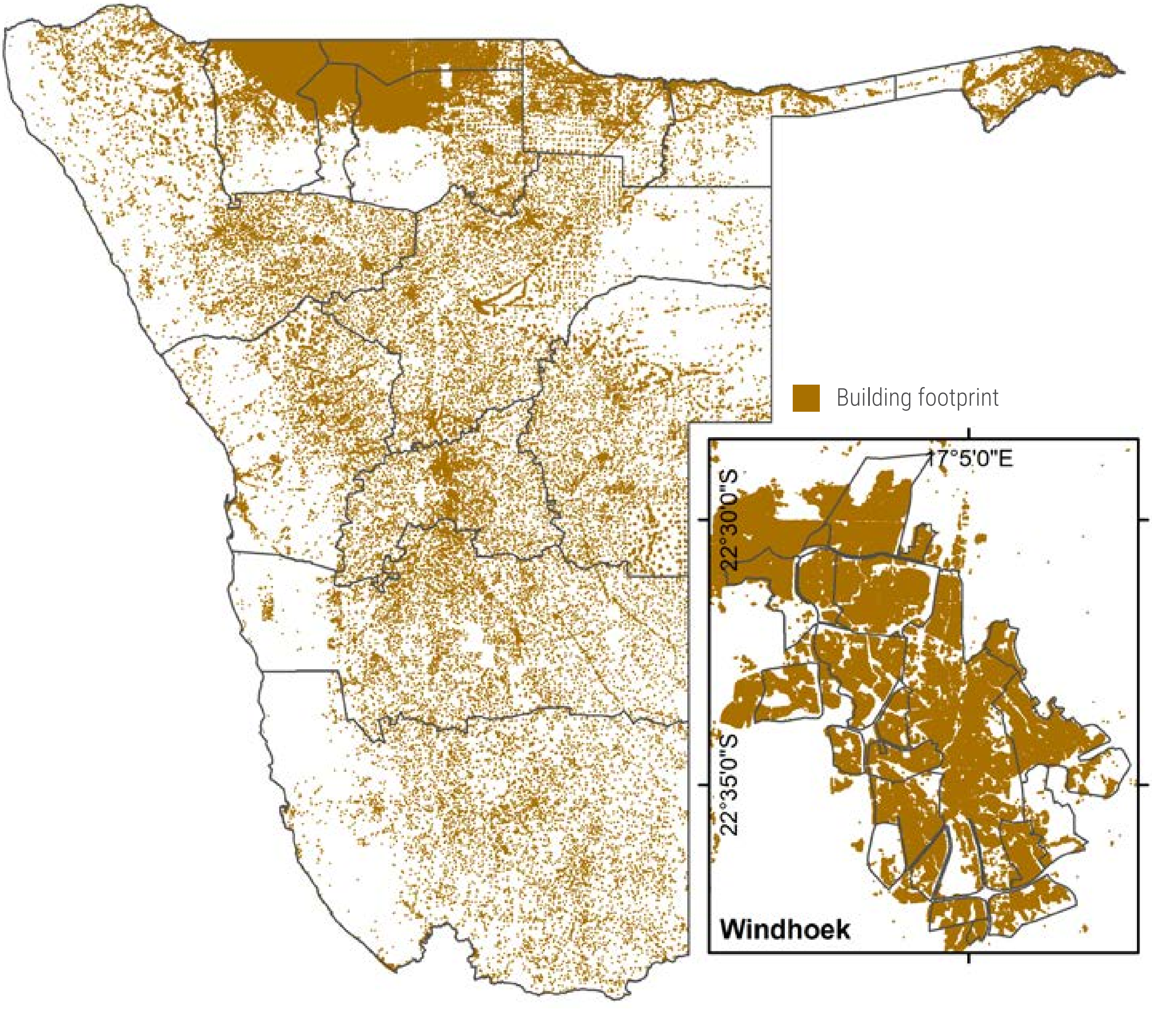


Figure 22: Building footprints in Namibia and Windhoek (insert map) based on a Google dataset (Sirko et al., 2021)

Figure 23: An example of a public facility surrounded by flood water. Onghala Combined School was inaccessible due to the flooded access-road during the 2023 flood. The school is located in the southeastern portion of the 'island' in the middle of the image. The school was closed for weeks in 2023 due to flooding.

The relative proportion of the human population and buildings per Enumeration Area were used as indicators of exposure to flooding (Figure 24) . The higher the proportions the greater the exposure.

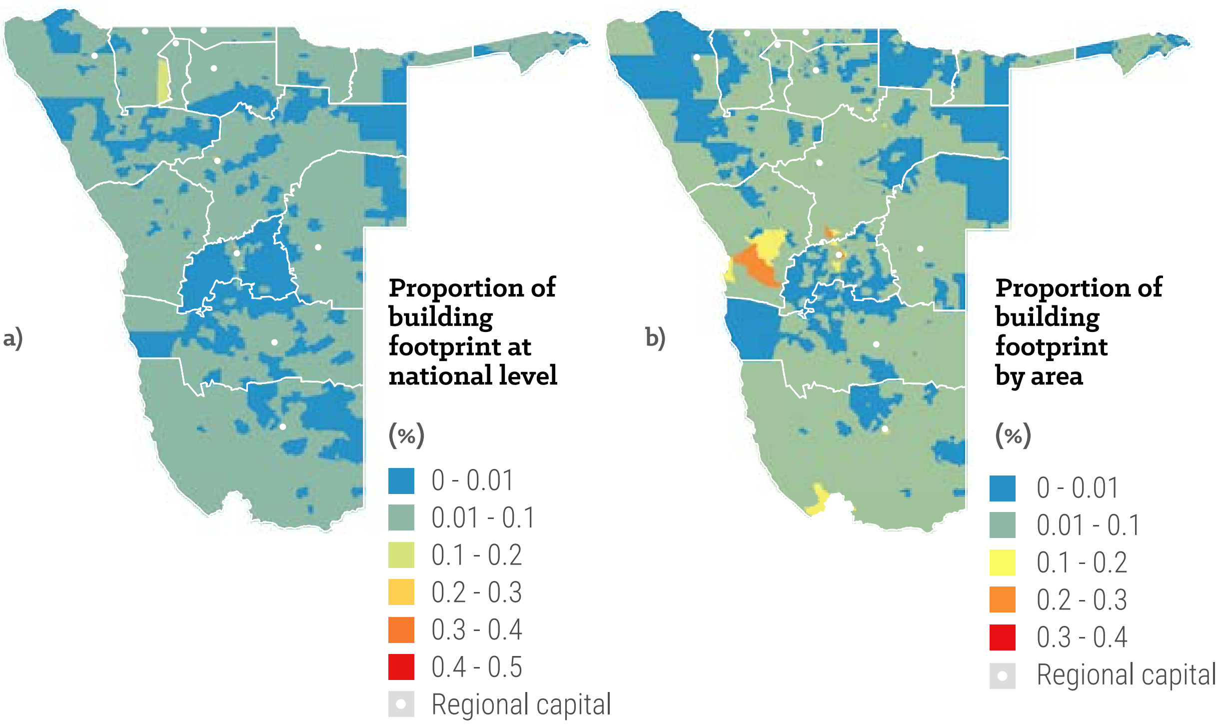


Figure 24: Proportion of national (a) number and (b) extent of building footprints per Population Enumeration Area

By September 2022, the number of national building footprints stood at about 2,951,000. Just under 29,000 (0.98%) of the building footprints were in areas where surface water has been detected between 1990 and 2021. About 62% of building footprints within the 1990-2021 surface water occurrence (Figure 19) were in the Oshana, Zambezi, Ohangwena, Oshikoto and Omusati regions. Another 31% of building footprints within the surface water coverage were in the //Kharas and Erongo regions. In these regions, flash flooding occurred due to a lack of culverts and a stormwater drainage system. Figure 25 shows the location of buildings, in parts of the Zambezi floodplains and Cuvelai Basin/Inland delta, in relation to the surface water occurrence. A high number of buildings within the surface water coverage shows that buildings were constructed in flood-prone areas (Figure 26). In some cases, flooding of buildings might have been induced by infrastructure development such as roads (Figure 27). While some buildings may have been erected on the fringes of seasonal water courses without much precautionary measures (Figure 26), other builders appear to have knowingly taken a risk. In Figure 28a, the building was already flooded while the construction was ongoing, which implies that the owner was aware of the risk. In Figure 28b, the foundation of the building was raised to a "safe" limit from flooding.

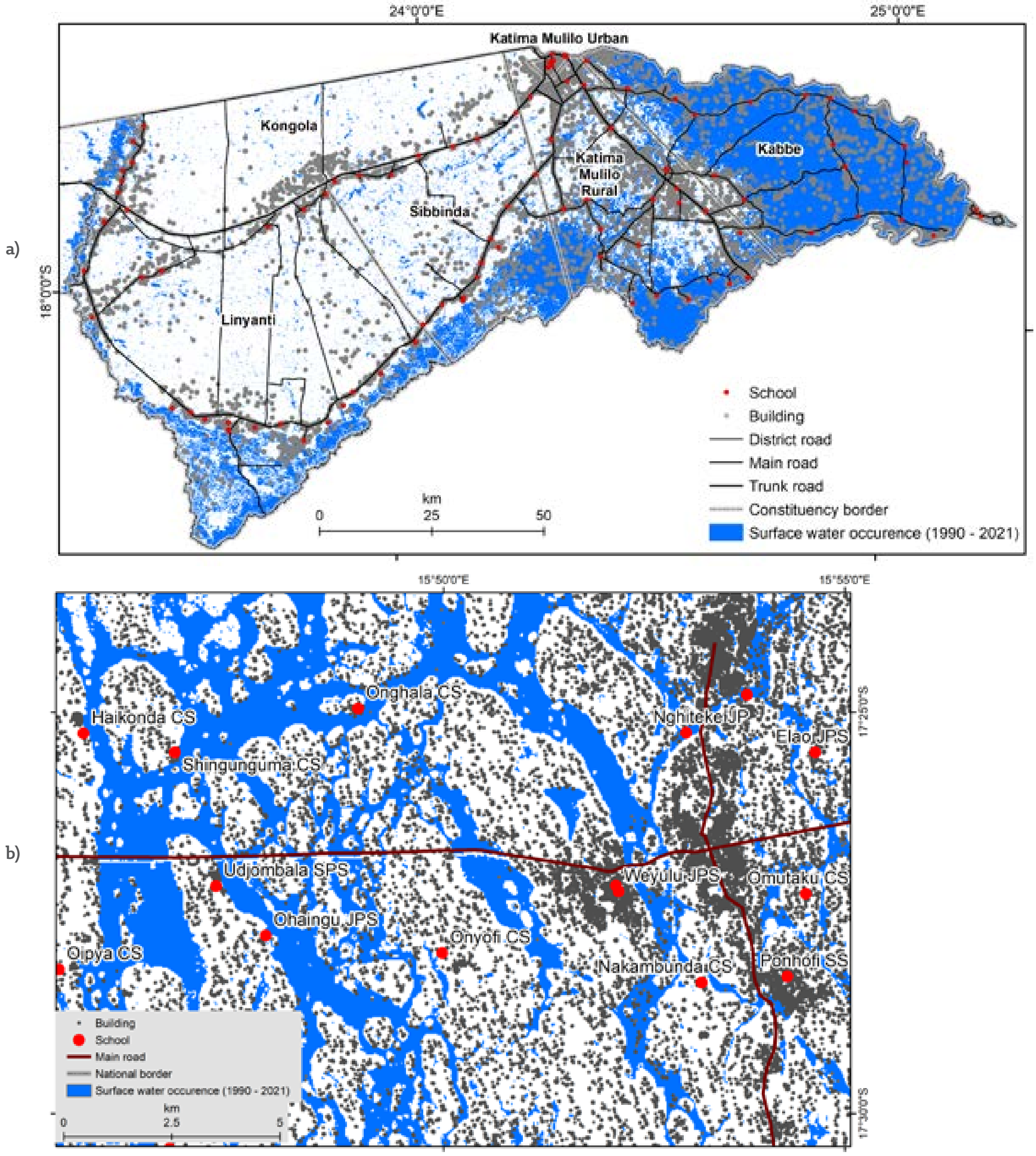


Figure 25: Extent of surface water in parts of the (a) Zambezi floodplains and (b) Cuvelai Basin/Inland delta in relation to the location of schools and other buildings (e.g. homesteads)

a)

b)

Figure 26: An example of flooded buildings which were constructed in seasonal watercourses (a) and near seasonal water courses with dyke roads blocking the water flow in the Cuvelai Basin (b)

Figure 27: An example of a homestead damaged by flooding induced by the newly developed road near-by the homestead in the Cuvelai Basin. Note the water marks on the inner wall of the homestead.

a)

b)

Figure 28: An example of buildings constructed knowingly or lack of awareness at flood-prone sites. In (a), the building was flooded before the construction was completed, whereas in (b), the foundation of the building was raised above the level of the current flooding. Note the water lilies known for growing in iishana, depressions, or pans where rainwater collects and the lilies only bloom with about 30 cm of water depth.

4.3 SENSITIVITY TO FLOODING

Since water hardly accumulates on steep slopes, human beings and buildings on steep slopes are less sensitive to flooding. Therefore, slope steepness was used as the measure of sensitivity (Figure 29). The slope steepness was derived from the ALOS DEM at 30 m resolution. Average slope steepness was then computed per Enumeration Area. A large part of Namibia has average slope steepness below 10% (Figure 29).

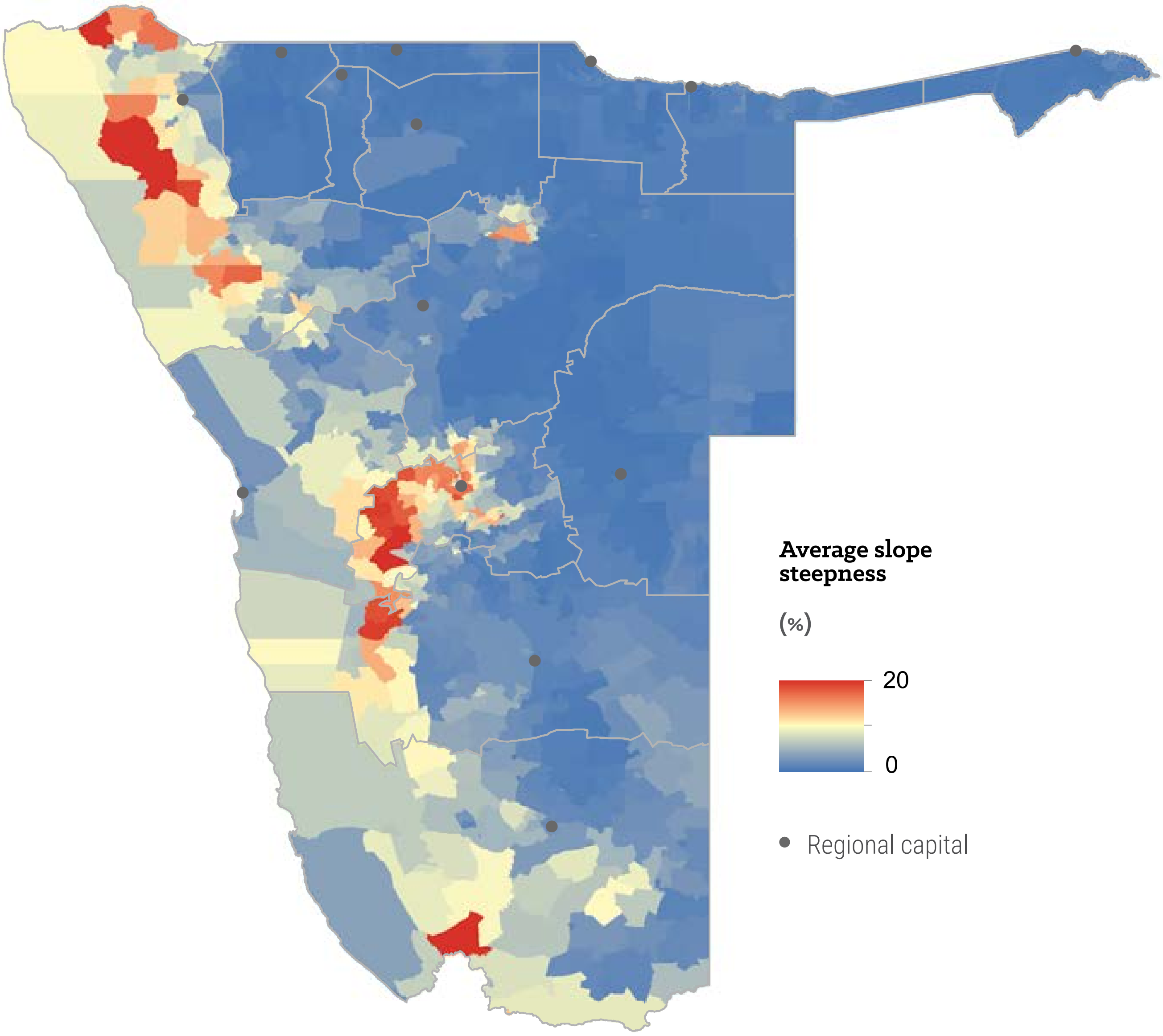


Figure 29: Average slope steepness per Enumeration Area

4.4 ADAPTIVE CAPACITY TO FLOODING

Persons with financial means can develop resilience against flooding in several ways. For example, they can modify their surroundings and invest in resilient infrastructure to adapt to flood hazards. In some cases, the modification of the surroundings to cope with floods can rely on rudimentary methods and materials (see Figure 30). In this profile, the average median income per person was considered an appropriate indicator for adaptive capacity to floods (Figure 13). Areas with a high average median income per person are expected to have a high adaptive capacity to floods.

Figure 30: An example of modification of the surroundings to cope with flooding. In this case, old tyres and crates were used to facilitate access to the buildings during the flooding. The effectiveness of this rudimentary modification in the case of extreme floods is not known.

In the Cuvelai Basin, flooding does not only bring disasters; it also brings along the fish that local people harvest for their own consumption and income generation. Figure 31 shows an example of people catching fish in the Cuvelai Basin/Inland-delta. Floods in this area enhance fish consumption - a major source of protein. Income generated from sales can also be used to offset the negative impact of flooding. In essence, this is a form of adaptive capacity.

Figure 31: An example of fishing in the flooded Cuvelai Basin

4.5 VULNERABILITY TO FLOODING

About 773,840 residents in Namibia live in areas with very high to high vulnerability to flooding (Table 3). The vulnerability is concentrated in northern Namibia, namely in the Cuvelai Basin, along the Kavango River and in the Zambezi floodplains (Figure 32). There are also some isolated Population Enumeration Areas across the country with high vulnerability to flooding.

Table 3: Vulnerability to flooding of the population per region in index categories (see legend in Figure 32)

Flood vulner-ability level	Erongo	Hardap	Kho-mas	Kunene	Ka-vango East	Ka-vango West	Ohang-wena	Oma-heke	Omu-sati	Oshana	Oshi-koto	Otjo-zond-jupa	Zam-bezi	//Kha-ras
Very low	0	65	14073	0	0	0	0	0	0	0	0	0	0	1047
Low	70305	36271	215797	3881	5694	0	410	3890	2744	6353	8030	14690	7903	33073
Moder-ate	51285	35092	101097	21279	12479	622	3274	13959	7631	38524	14820	41155	8890	28469
High	12914	19127	10257	41705	78626	58284	67727	46012	141251	58441	88540	59309	46174	9162
Very high	2204	1084	0	3226	24714	21578	150039	0	69875	49441	44302	6707	13869	983

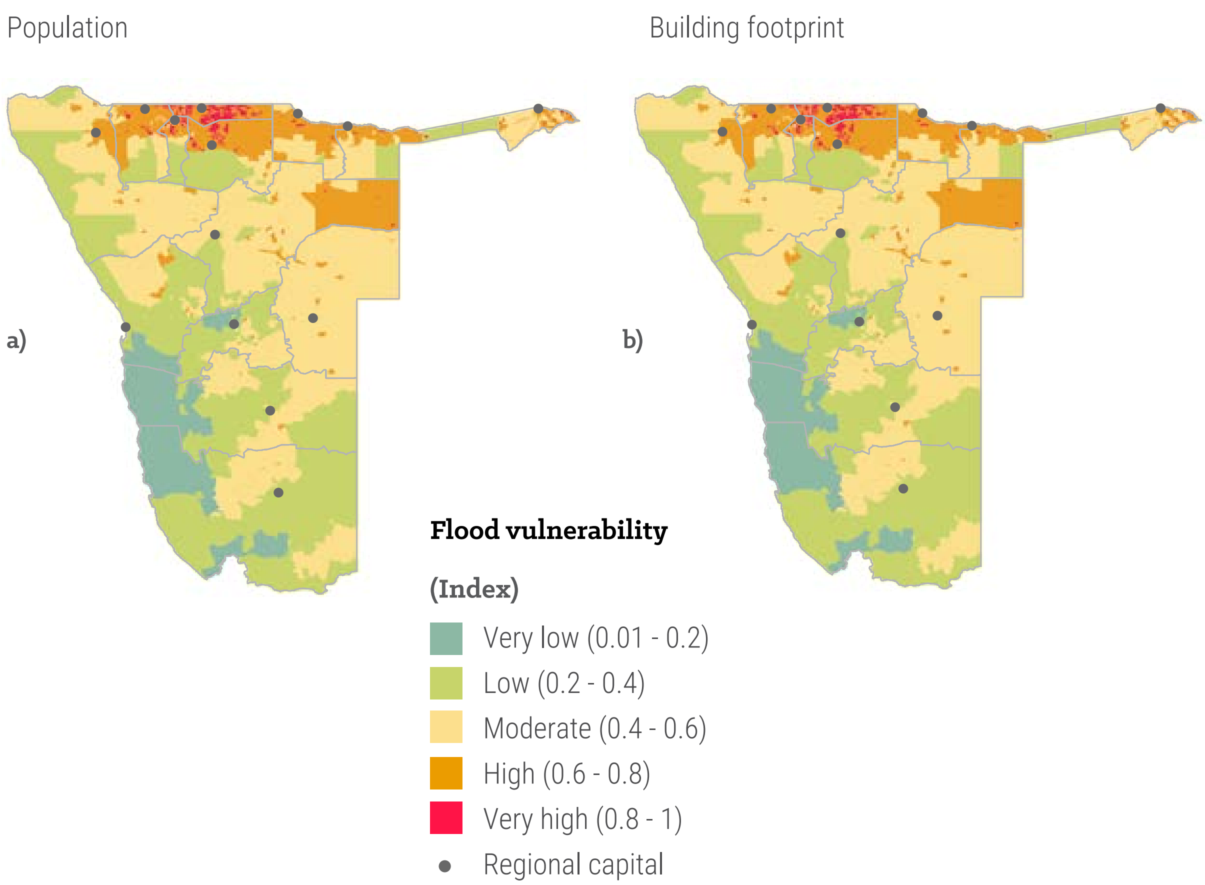


Figure 32: Spatial distribution of the vulnerability to flooding for (a) residents and (b) buildings

4.6 FLOODING RISK

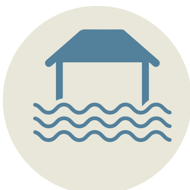
The flooding risk for persons (Figure 33) and buildings (Figure 34) is highest in the Zambezi Region particularly in the floodplains, followed by areas in the Cuvelai Basin in north-central Namibia. These areas have high flooding frequency. The rest of the country has a very low risk of flooding. Flash floods often come unexpectedly and may have a high destructive energy. However, mapping flash floods with satellites is challenging due to their short-lived nature. As a result, areas that experience flash floods might appear to have low flooding risk despite the economic damages flash floods cause.

Based on the 2011 Population and Housing Census data, about 19,200 people were residing in areas with moderate to very high flood risk (Table 4), of which 3,202 were children aged between 0 and 4 years, and 1,506 were elderly people (60+ years old). A total of 49 households headed by minors (people aged less than 18 years) were in areas with moderate to very high flood risk, and 980 were headed by elderly people (see Appendix 2). Figure 35 shows the combined risk for people and buildings.

Table 4: Distribution of population by flooding risk level (column 1) per region

Flood risk level	Erongo	Hardap	Kho-mas	Kunene	Ka-vango East	Ka-vango West	Ohang-wena	Oma-heke	Omu-sati	Oshana	Oshi-koto	Otjo-zond-jupa	Zam-bezi	//Kha-ras
Very low	135806	91639	341224	70091	110397	71162	192985	63861	198516	124177	151134	121861	64001	72542
Low	902	0	0	0	7335	6719	27491	0	22670	27117	4282	0	3507	192
Moder-ate	0	0	0	0	3707	2603	1235	0	315	1465	276	0	4993	0
High	0	0	0	0	74	0	0	0	0	0	0	0	2597	0
Very high	0	0	0	0	0	0	0	0	0	0	0	0	1935	0

ZAMBEZI REGION DISTRIBUTION OF POPULATION BY FLOOD RISK LEVEL



VERY LOW	MODERATE	HIGH
64001	4993	2597

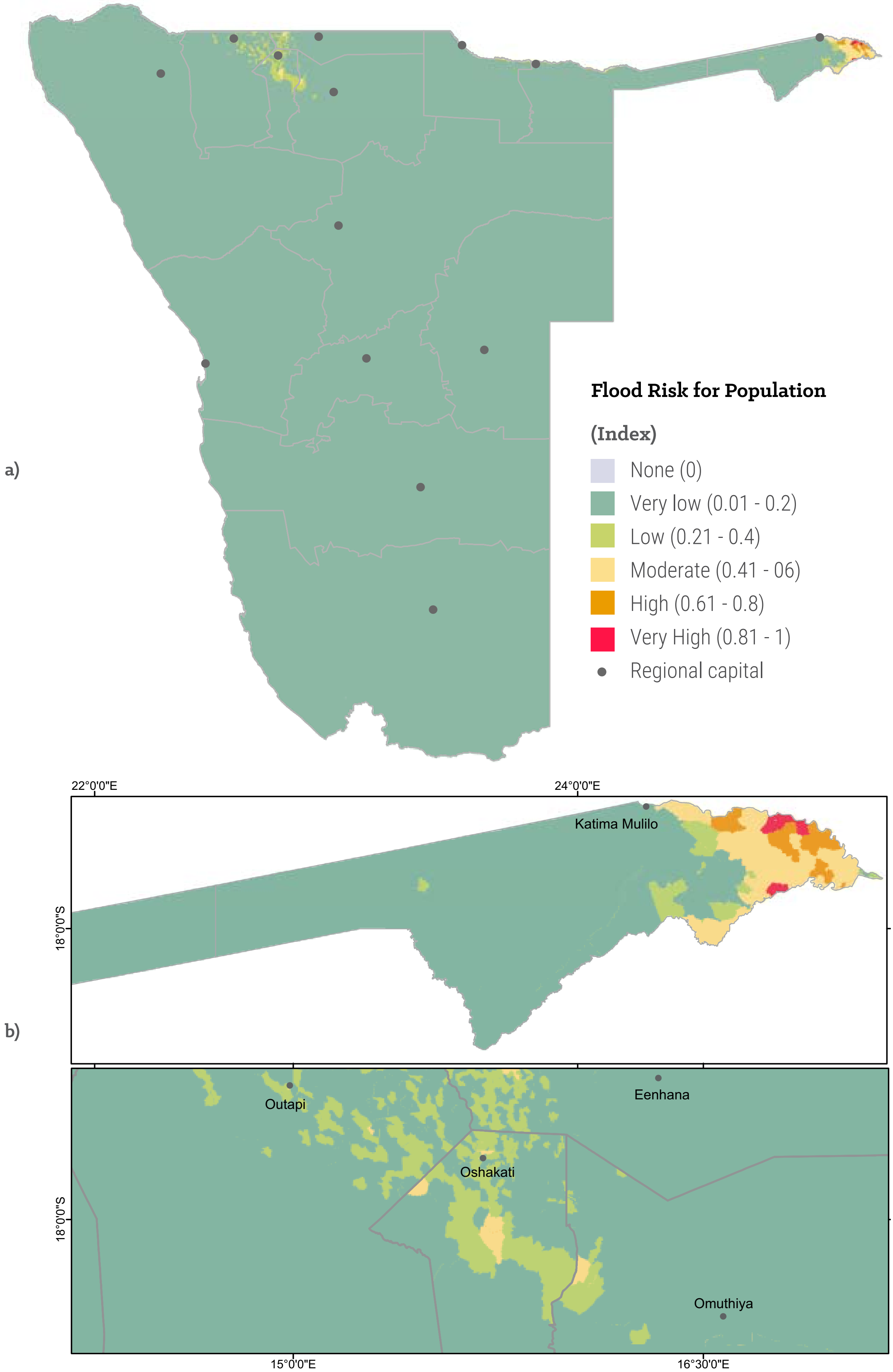


Figure 33: Spatial distribution of the risk of flooding to the population at (a) the national scale, and (b) inserts for the position of the Cuvelai Basin and the Zambezi

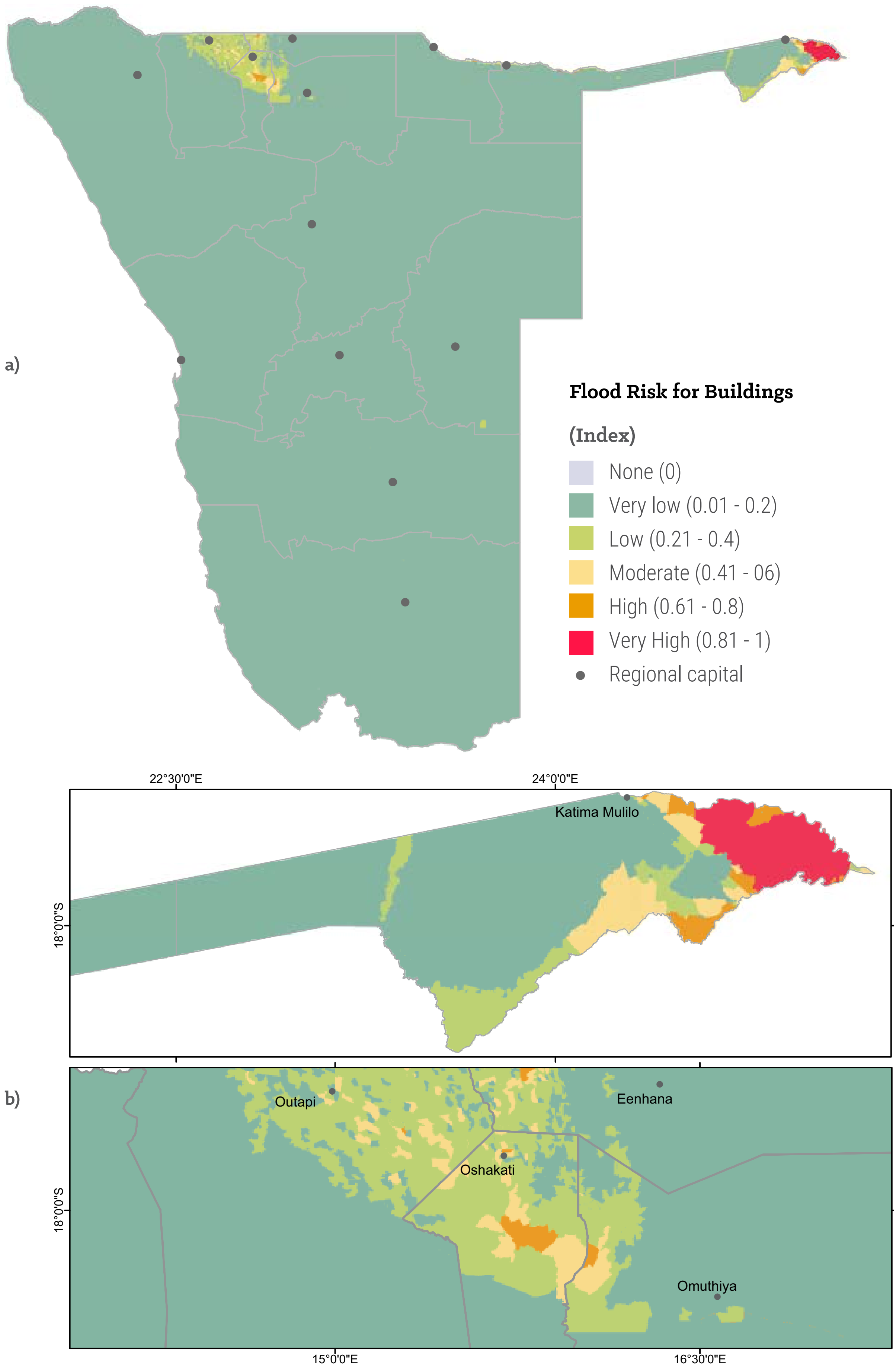


Figure 34: Spatial distribution of the risk of flooding to buildings at (a) the national scale, and (b) inserts at finer scale for the two main high flooding risk zones, namely the Cuvelai Basin and the River Zambezi floodplain

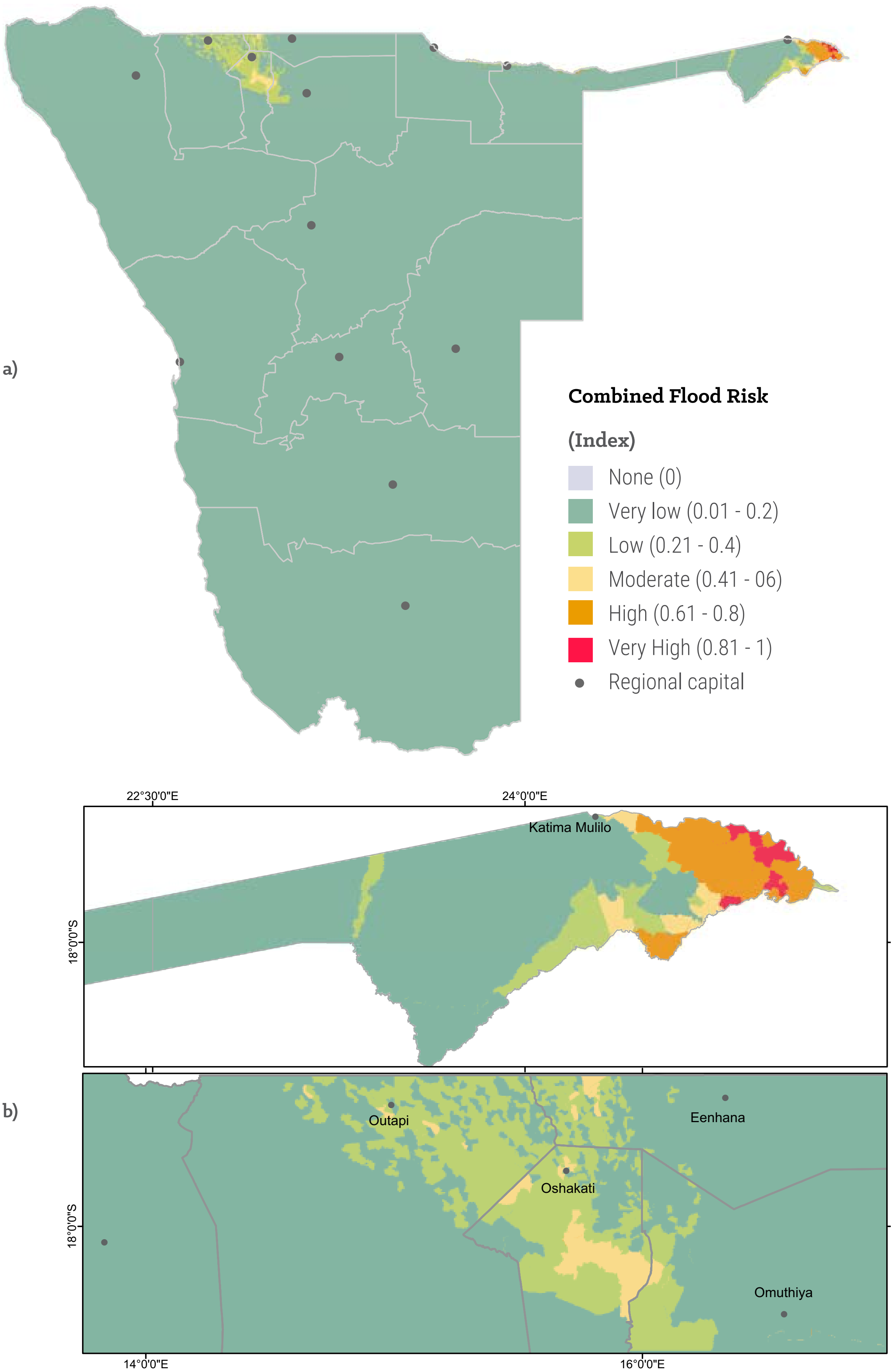


Figure 35: Composite risk of flooding to the population and buildings at (a) the national scale, and (b) inserts at finer scale for the two main flooding risk zones, namely the Cuvelai Basin and the River Zambezi floodplain

05

WILDFIRE VULNERABILITY AND RISK ASSESSMENT

WILDFIRE VULNERABILITY AND RISK ASSESSMENT

5.1 WILDFIRE HAZARD

Wildfire kills people, livestock and wild animals, and destroys assets (e.g. homes) and grazing areas across the globe. In Namibia, wildfire is a common hazard as an integral component of the savanna ecosystems, and it often happens when there is enough fuel load after a good rainy season. Wildfires can be ignited naturally through a lightning strike or by humans.

In this profile, wildfire hazard was quantified spatially using satellite data from Moderate Resolution Imaging Spectroradiometer (MODIS) with a 500 m spatial resolution, covering a period of 22 years (2000-2022). MODIS detects fires daily on the earth's surface at 500 m resolution, providing a reasonably good dataset for wildfire hazard mapping. Wildfire frequency was then calculated as the total number of years the fire was detected at a particular location. Wildfire frequency was used as a measure of wildfire hazard. Areas with a high frequency of wildfire have a high wildfire hazard. The wildfire frequency was standardised for the hazard values to range from 0 to 1.

Wildfires are widespread across the country, but they are mainly common in the Kavango West, Kavango East and Zambezi regions (Figure 36). In these regions, some areas have burned almost every year since 2000. Cumulatively, the largest area (234,682 km^2) burned is in the Kavango East region between 2000 and 2022, followed by the Kavango West region (133,692 km^2). The //Kharas Region recorded the smallest cumulative burned area (1,512 km^2) over the same period. For the entire country, the largest burned area (92, 987 km^2) in a single year was recorded in 2012 (Table 5).

Table 5: Distribution of burned area (km2) by year in each region of Namibia

Year	Erongo	Hardap	Khomas	Kunene	Kavango East	Kavango West	Ohang-wena	Oma-heke	Omusati	Oshana	Oshi-koto	Otjo-zondjupa	Zambezi	//Kha-ras	Total per year
2000	6.8	3.25	194	897	549.8	378.3	64	65	1841	10	1241.5	1600.5	362	2.8	7215.95
2001	648.5	194.8	2204	5151.5	8864.8	2161.5	0	4091.5	4123.3	574	645.5	4196.5	5713	0	38568.9
2002	26.3	50	184	816.3	11210.5	7946	4.5	1444.5	937.3	273.3	300	3990.5	6134.5	12.8	33330.5
2003	0.25	0.25	126	647.5	11131.8	7519.5	386	3624.8	289.3	95.8	130	4230.3	5001.3	2.5	33185.3
2004	16	9	23	435	11868	9103.5	392.5	112.5	3913.8	263.3	2280.8	4433.8	6008.5	6	38865.7
2005	4.5	3.3	403	55.3	12832.8	6655.3	151.5	361.5	3871.8	799.8	1806.3	5789.5	4233.5	0.8	36968.9
2006	2020.8	285	1604.5	6260.8	11906.5	4333	7	261.8	13846.5	1820	1667.3	5750	5325.5	178.5	55267.2
2007	235	67	190.5	45.3	12832.8	9367.8	101.5	7484	512.5	661	409	11004.5	5322.8	26.8	48260.5
2008	34	429.5	226	81.8	11593.8	4568.8	31.5	2286	453	470.3	97.5	4398.3	5418	6	30094.5
2009	26	183.8	581.8	2711.3	13794.8	6309.5	90.5	4990.3	4820	2839.5	2445.8	14222.3	3833.5	0	56849.1
2010	7	123	593	340.3	12435.3	9907.8	19.3	6729	2325.75	378.3	281	13072.5	4196.3	10.8	50419.35
2011	3382.8	891	852.8	1537.3	16703.3	11728.5	56.3	16996.5	6267.5	780	5574	19358.8	5360	18.8	89507.6
2012	1089.3	884.3	954.8	3160.5	14600.5	13035.3	249.3	13159.8	6164.8	3036.8	5659.8	25573.8	5289.8	128.5	92987.3
2013	0	15.8	101.8	16	13244.5	8426.8	141	5433.5	8.8	78.8	444.5	7061	4305.5	8.5	39286.5
2014	1.5	75	364.8	257	9298	6059.3	15.5	338.3	991.3	276.5	272.5	5988.3	3922.3	9.5	27869.8
2015	14.8	57.5	173.8	0.5	8143.3	4785	3.5	1444.3	1644.8	0.25	241.5	4409.5	5294.5	37.8	26251.05
2016	3	0	122.3	10.5	7935.5	5942.8	259.8	770.5	5.8	0	813.5	2715.8	3564.5	2.5	22146.5
2017	0	41	245.5	478.5	11727.3	4198	59.8	268.3	351	149.5	2138	3584	5401.3	0	28642.2
2018	43	5.5	50.5	310	6245.3	2351	0.3	1745.8	4	369.3	376.5	5042.5	4655.5	1	21200.2
2019	0	0	0.25	0	5074.5	822.5	0	59.3	0	6.3	2.5	355	3331.5	0	9651.85
2020	0.25	0	142.8	418	8943	5015.8	232.3	3218.3	1020.5	322.8	5722	6500.3	3047.5	0	34583.55
2021	144.8	456.5	3948.3	6055	5137	1905.5	192.3	1058.8	5309	1360.3	5409.3	6581	4300.5	9.3	41867.6
2022	516	1059.3	526	677.5	8609	1171	0	668.3	2252.3	0.5	129.3	6162.3	3544.3	1048.8	26364.6
Total	**8220.6**	**4834.8**	**13813.45**	**30362.9**	**234682.1**	**133692.5**	**2458.4**	**76612.6**	**60954.05**	**14566.35**	**38088.1**	**166021**	**103566.1**	**1511.7**	**889384.65**

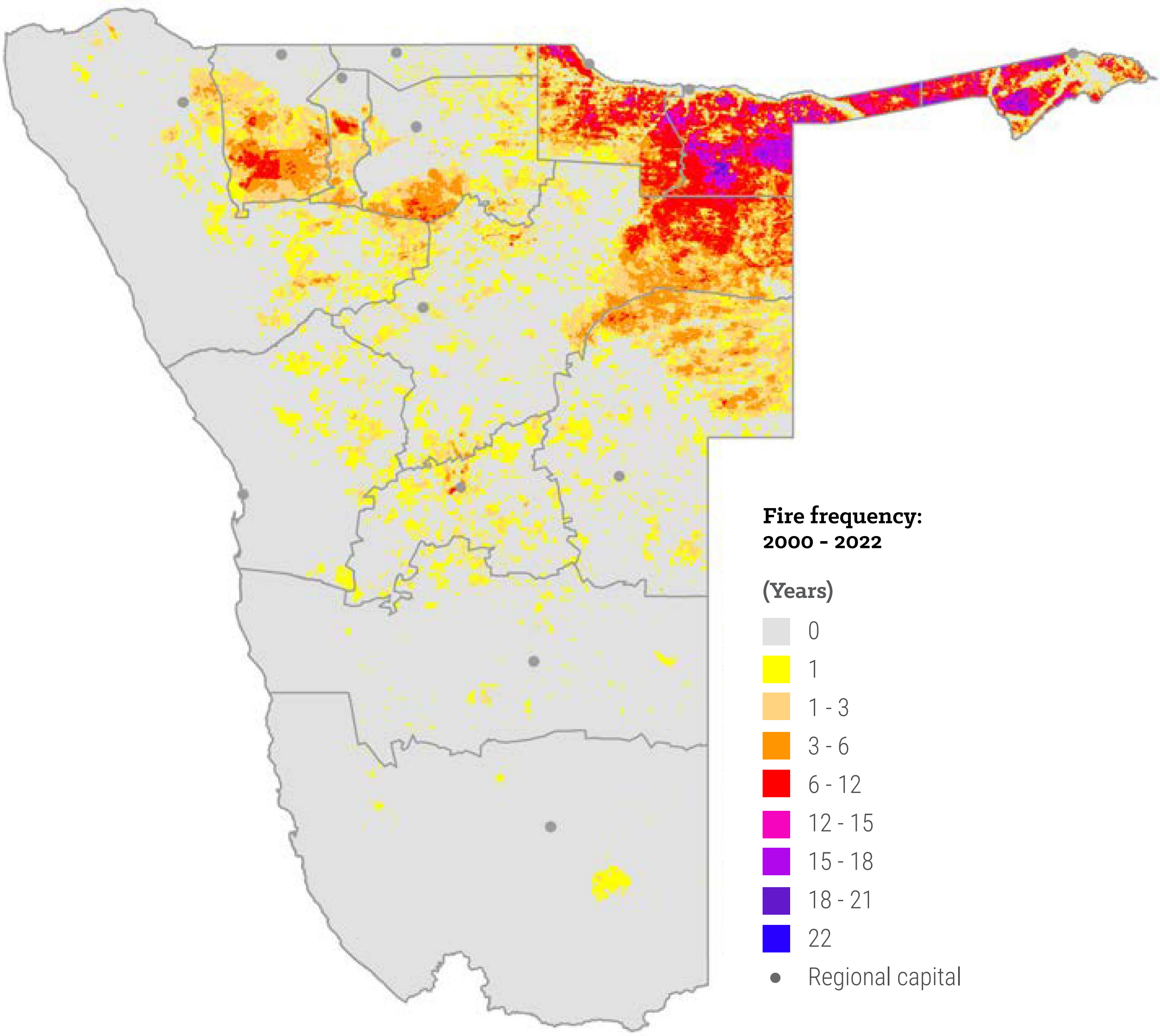


Figure 36: Fire frequency in Namibia from 2000 to 2022 based on MODIS satellite images

5.2 EXPOSURE TO WILDFIRE

Human fatalities and destruction of homes caused by wildfires are generally rare in Namibia. This is probably due to wildfire management strategies (e.g. creation of fire cutlines) put in place both at the local and national levels. What is rather common in Namibia is the fatalities of livestock and wild animals and the burning of rangelands. So, the appropriate measure for exposure to wildfires is the density of livestock and wild herbivores (Figure 37). Livestock density was mainly high in some areas in the Ohangwena, Oshana, Omusati, Kavango West and Zambezi regions, whereas herbivore density was high mainly in national parks. Datasets for livestock and wild herbivore densities were combined and standardised to represent exposure to wildfire.

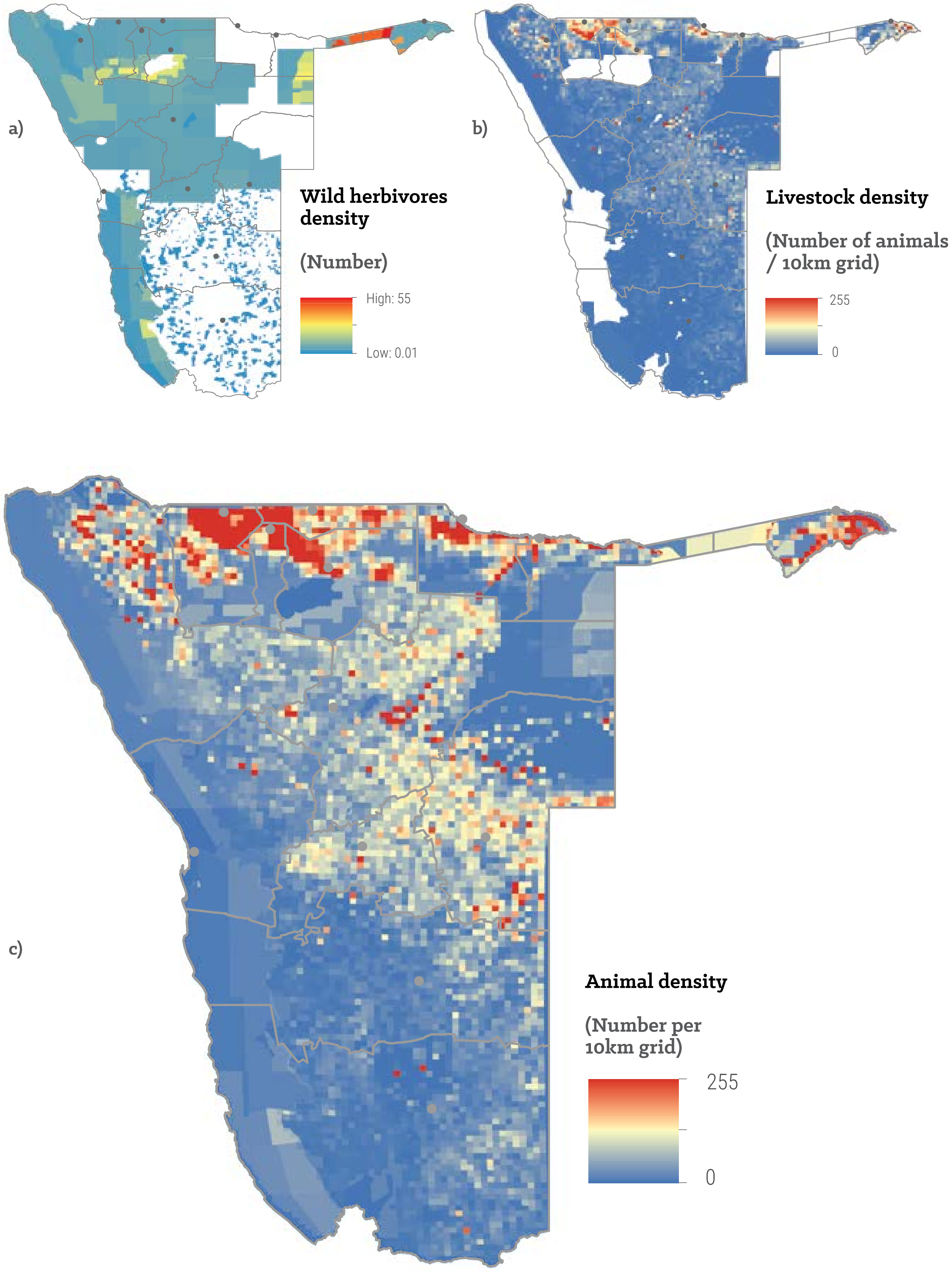


Figure 37: Density of (a) livestock and (b) wild herbivore, as well as (c) the combined density (data source: Mendelsohn et al. 2002)

5.3 SENSITIVITY TO WILDFIRE

With livestock and wild herbivores being the main exposure to wildfire, the appropriate sensitivity measure for wildfire is livelihood. Areas where people are highly dependent on livestock and wild herbivores for their livelihood can be viewed as more sensitive to wildfire. The dominant livelihood dataset (Figure 12) was used as a measure of sensitivity to wildfires. Each dominant livelihood was allocated a score, whereby the most sensitive livelihood was allocated a score of 1, and 0.2 for the least sensitive livelihood. Areas where pastoral communal livelihood was dominant were considered most sensitive (=1) to wildfire because the livelihood is less diverse, followed by agro-pastoral communities (=0.8). Urban areas were allocated the lowest score of sensitivity (0.2) for wildfires.

5.4 ADAPTIVE CAPACITY TO WILDFIRE

Given that wildfire can be ignited both by humans and natural processes, adapting to it is relatively difficult. Implementing management strategies that limit the spread of, and damage by, wildfire can be viewed as the appropriate way to adapt to wildfire. Such fire management strategies require financial resources. Therefore, it is logical to view areas where the median income per capita is relatively high as having a higher adaptive capacity for wildfire than in areas where the median income per capita is low. The dataset for median income per capita (Figure 13) was thus used as a measure of adaptive capacity to wildfire.

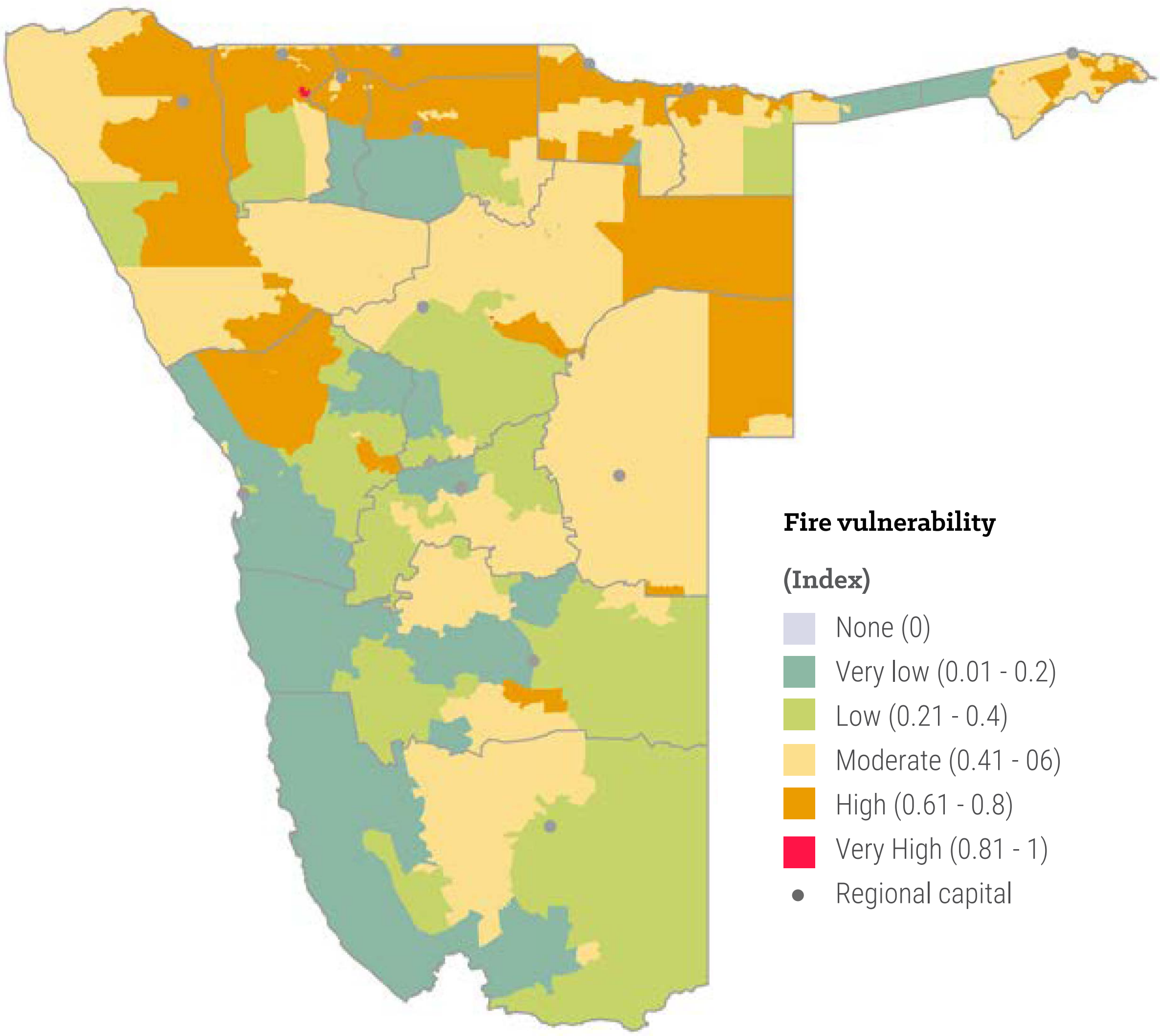


Figure 38: Spatial distribution of the vulnerability to wildfire

5.5 VULNERABILITY TO WILDFIRE

Areas with the highest vulnerability to wildfire were mainly in regions dominated by agro-pastoral and pastoral communal livelihoods. In particular, the Ohangwena, Oshikoto, Kavango West, Kavango East, Oshana, Omusati, Zambezi, Otjozondjupa, Omaheke, Erongo and Kunene regions have most of the areas vulnerable to wildfire (Figure 38). Essentially, more than half of the country has a vulnerability score of moderate to very high. One EA in Omusati has a very high wildfire vulnerability (Figure 38). This EA covers areas where cattle posts are and therefore has a high concentration of cattle.

5.6 WILDFIRE RISK

The wildfire risk is high to very high in areas only in three regions: Kavango East, Kavango West and Zambezi (Figure 39). In these areas, the risk is high because both vulnerability and hazard are high. Although the vulnerability is high in most parts of the country, wildfire hazard is low because fire occurrence is infrequent. More than half of the country has a very low risk for wildfire, and a sizable part of the country has no risk for wildfire. Low wildfire risk in most parts of the country, mostly because of low hazard, might be indicative of the success of wildfire management strategies that have been put in place to limit the spread of wildfire. It might also be due to the limited fuel load on the herbaceous layer because of overgrazing and drought events.

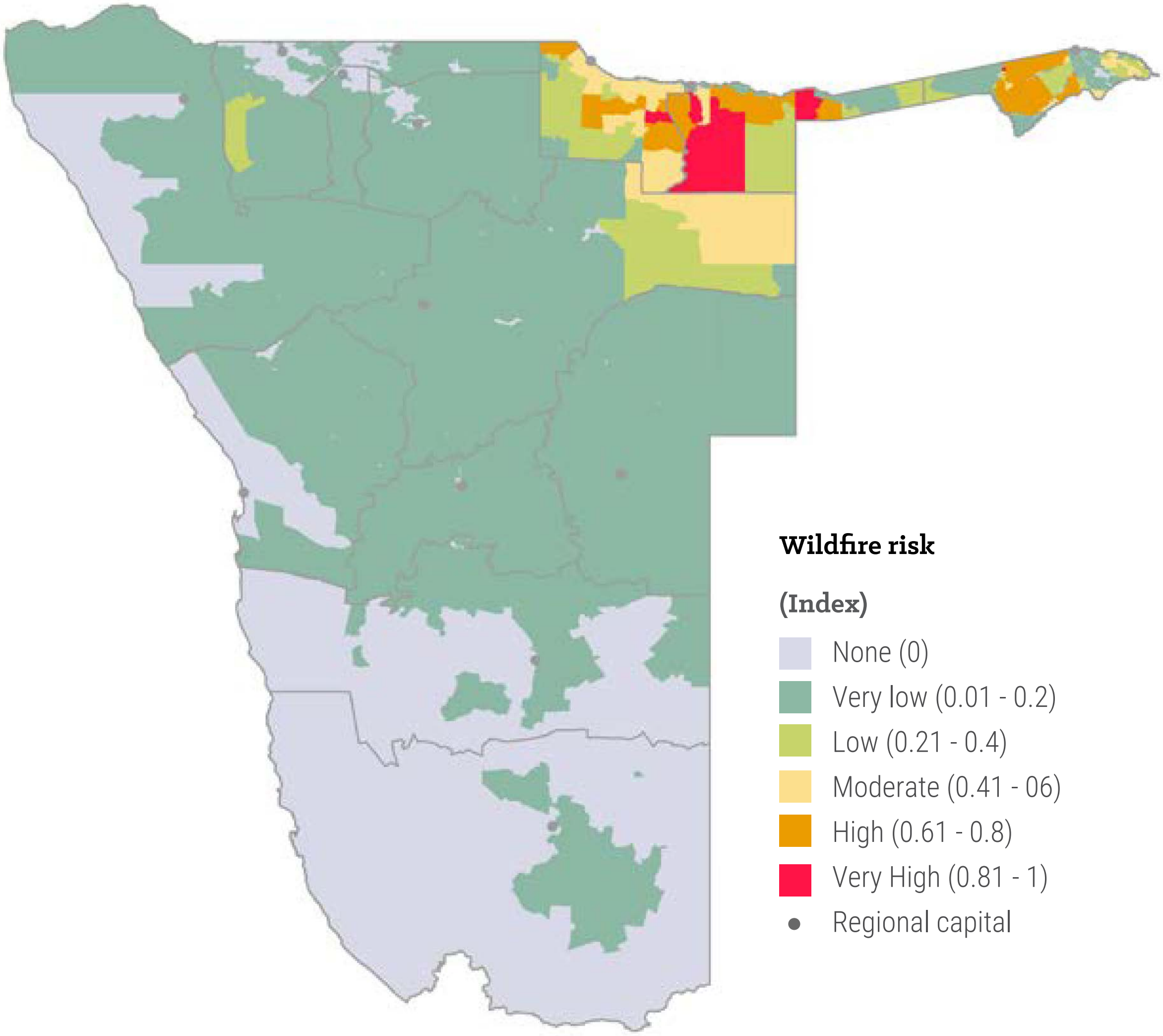


Figure 39: Spatial distribution of the risk to wildfire

06

HEATWAVE VULNERABILITY AND RISK ASSESSMENT

HEATWAVE VULNERABILITY AND RISK ASSESSMENT

6.1 HEATWAVE HAZARD

Heatwaves are detrimental to human health, and they kill people across the globe. With the climate changing, heatwaves are becoming more intense and frequent. In this profile, heatwave hazard was derived from gridded data for the daily maximum surface air temperature covering the 1980-2021 period from CPC Global Unified Temperature data products provided by the United States (US) National Oceanic and Atmospheric Administration (NOAA) Physical Sciences Laboratory (PSL).

A temperature threshold of 40 °C was used for incipient heatwave. The threshold value for heatwave temperature differs from region to region and can be set below 30 °C. Namibia being largely a semi-arid country, the threshold value was based on the firing rate of excitable cells in the human nervous system which begins to fail after reaching 40 °C to 41 °C (Piatadosi, 2003). It should be noted that Xu et al. (2018) reported that two-day-duration heatwaves in Australia were more detrimental than longer-lasting heatwaves when heatwave intensity was not high. Therefore, the heatwave frequencies should be interpreted contextually in that regard. The average number of days per year with a temperature above 40 °C was then computed for each 0.5 x 0.50 degree grid cell. The number of days with temperatures above 40 °C has been increasing over the last four decades, especially in the south and south-eastern parts of Namibia (Figure 40). The year 2021 was the hottest for most parts of Namibia during the 1980-2021 period (Figure 41a). In some areas, the temperature reached almost 50 °C (Figure 41b).

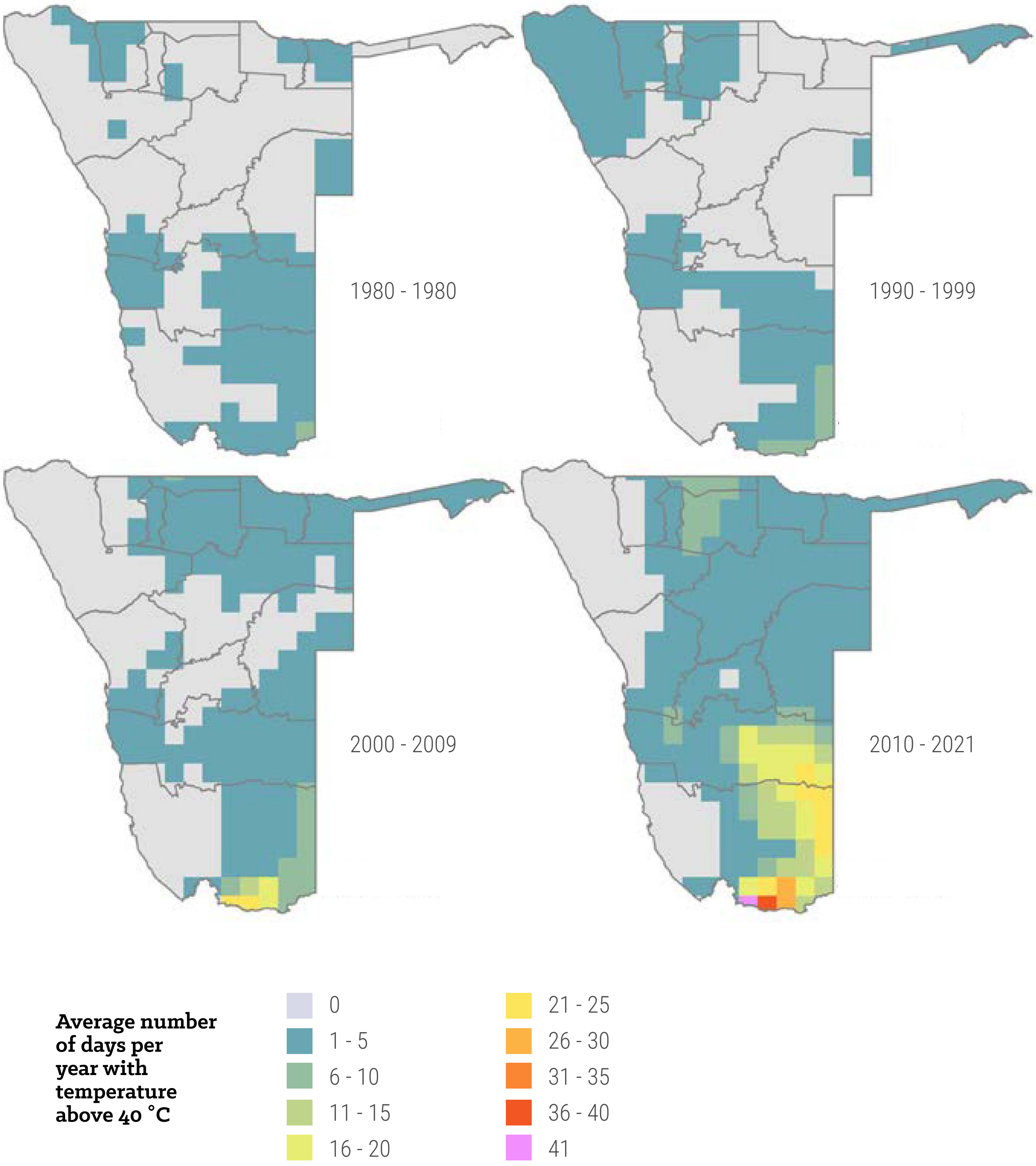


Figure 40: Average number of days/year with temperatures above 40 °C from 1980 to 2021 (data source: NOAA)

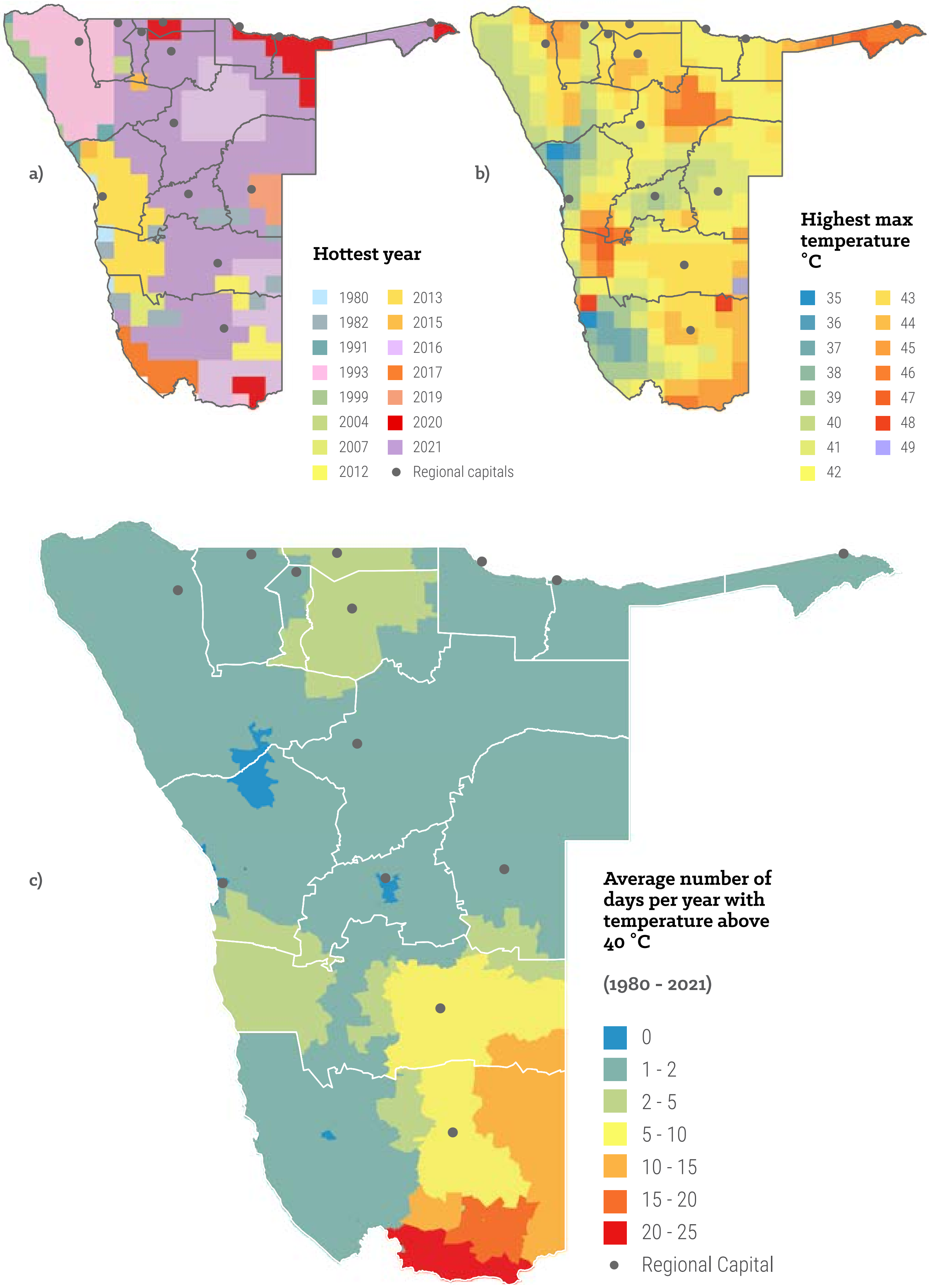


Figure 41: Hottest years (a) and maximum temperature recorded (b) as well as composite of the average number of days/year with a temperature above 40 °C (c) from 1980 to 2021 (data source: NOAA)

6.2 EXPOSURE TO HEATWAVE

For heatwaves, the human population was considered to be exposed to the hazard. The elderly, the young and the impoverished are generally regarded as being more sensitive to heat exposure, with heatstroke being the most severe form of heat illness (Piatadosi, 2003). However, heat stroke is not the primary cause of mortality due to excessive heat exposure. Oahashi et al. (2021) revealed that higher summer temperatures in Japan are linked to increased rates of acute ischaemic heart diseases, cerebral infarction, and pneumonia. Population density data (Figure 9) were used to quantify exposure to heatwave, with densely populated areas having the highest exposure. Heatwave also affects animals, but analysis for animals was not included in this profile.

6.3 SENSITIVITY TO HEATWAVE

Humans ameliorate heatwave effects by staying indoors and in shades and cooling off with water. However, staying in shades and cooling off with water would not apply when someone is sleeping. Staying indoors is only effective if one has installed a cooling system or if the building materials have cooling effects. Therefore, building materials are the most relevant sensitivity variable in Namibia.

Corrugated iron/zinc materials are the most used for roof construction in Namibia, especially in the south and central parts of the country, whereas thatch and wood/stick are widely used in the northern parts of Namibia (Figure 42). For walls, cement bricks and corrugated iron/zinc are common in the south and central parts of the country, whereas wood/sticks are widespread in the northern areas (Figure 42). Figure 43 shows examples of buildings constructed with corrugated iron/zinc and wood/stick.

The insulation capacity of buildings and the buildings heated in the day, which continue to radiate heat, have a bearing on the variation of the population's exposure to heatwave over time. As a result, data on building materials for walls and roofs were collated from the 2011 Population and Housing Census data at each EA to derive the sensitivity map (Figure 44). Between 1991 and 2011, for example, the number of houses constructed with corrugated iron/zinc roofs increased by 22%, from 40% to 62%, whereas the proportion of houses with outer walls constructed using corrugated iron/zinc has increased by 12% during the same period (Namibia Statistics Agency, 2012; National Planning Commission, 1994). Corrugated iron materials were assigned the highest sensitivity score (=1) due to their low capacity to shield people from extremely hot temperatures, whereas thatch and wood/stick were assigned the lowest sensitivity score (=0.2). Sensitivity to heatwaves is mainly high in the southern and central parts of the country (Figure 44).

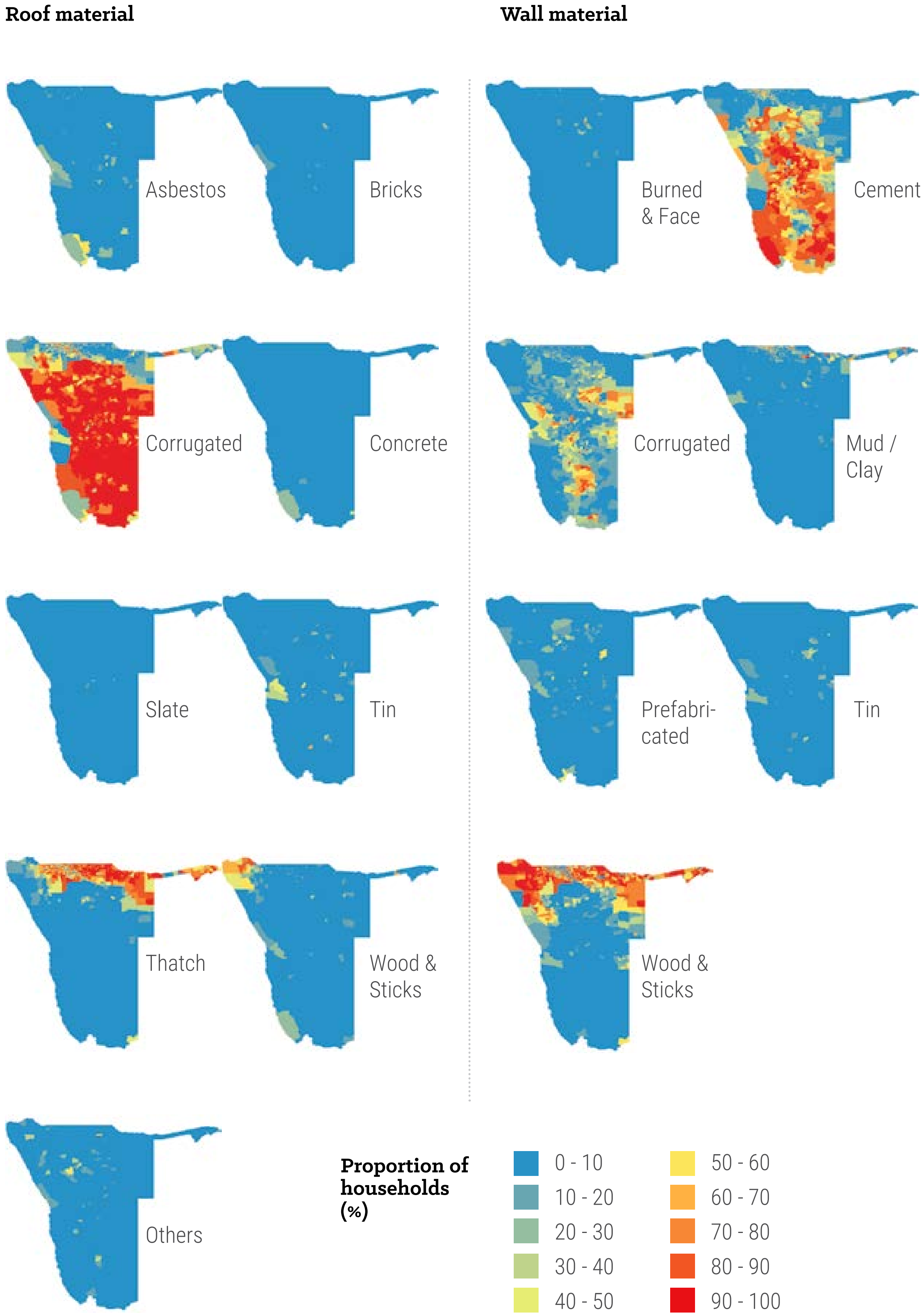


Figure 42: Building materials used for wall and roof construction in Namibia (Data source: NSA)

Figure 43: Examples of buildings constructed with corrugated a) iron/zinc, b) stick and mud and c) wood

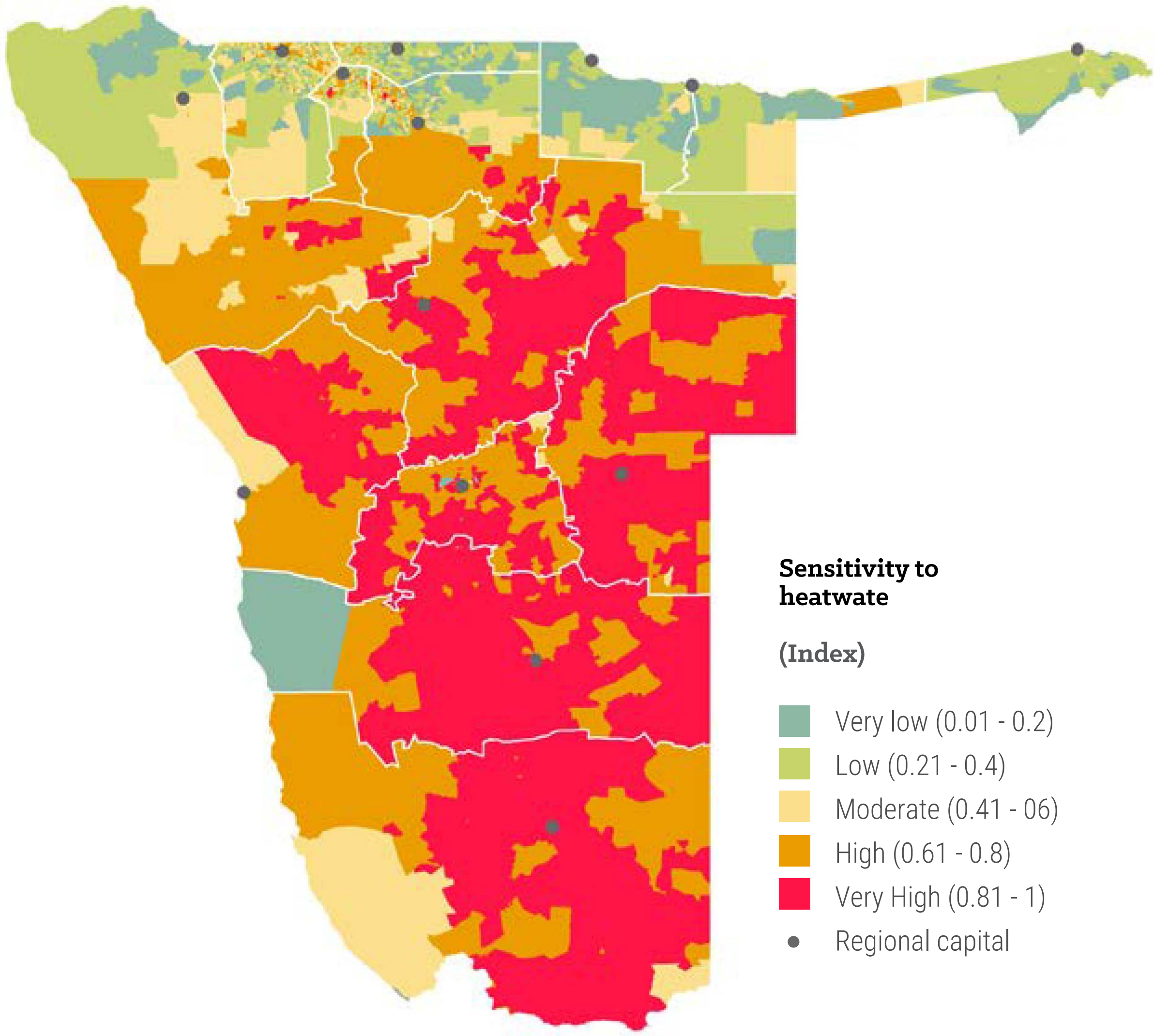


Figure 44: Spatial distribution of the sensitivity to heatwaves

6.4 ADAPTIVE CAPACITY TO HEATWAVE

With a climate changing rapidly resulting in extreme weather conditions, adapting to heatwave is practically challenging. Passive cooling, which entails "cooling buildings without or with minimal energy consumption" (Geetha & Velraj, 2012), is ideal for a sustainable earth, but it is still in its infancy. The use of air conditioning (AC) is commonly regarded as an effective method for mitigating heatwave. Essentially, installing cooling systems in residential buildings can mitigate heatwave effects. Cooling systems require electricity, either from the grid or solar panels coupled with batteries; the latter for nighttime cooling. Further, urban and peri-urban residents have almost no scope to alleviate their exposure to extremely high indoor temperatures because they cannot stay outside or leave their doors/windows open to increase air ventilation due to a high crime rate. Night-time respite for the body to recover during a heatwave is a critical mechanism (Basu & Samet, 2002). Data on access to electricity from the electricity grid as collected during the 2011 Population and Housing Census (Figure 45) was, therefore, used as a proxy for the adaptive capacity to heatwave. The data shows that access to the electricity grid is low in most parts of Namibia (Figure 45). This shows that, currently, many households do not have the capacity to adapt to heatwave by AC. Figure 46 shows an example of the AC system powered by solar panels at a thatched structure in southern Namibia.

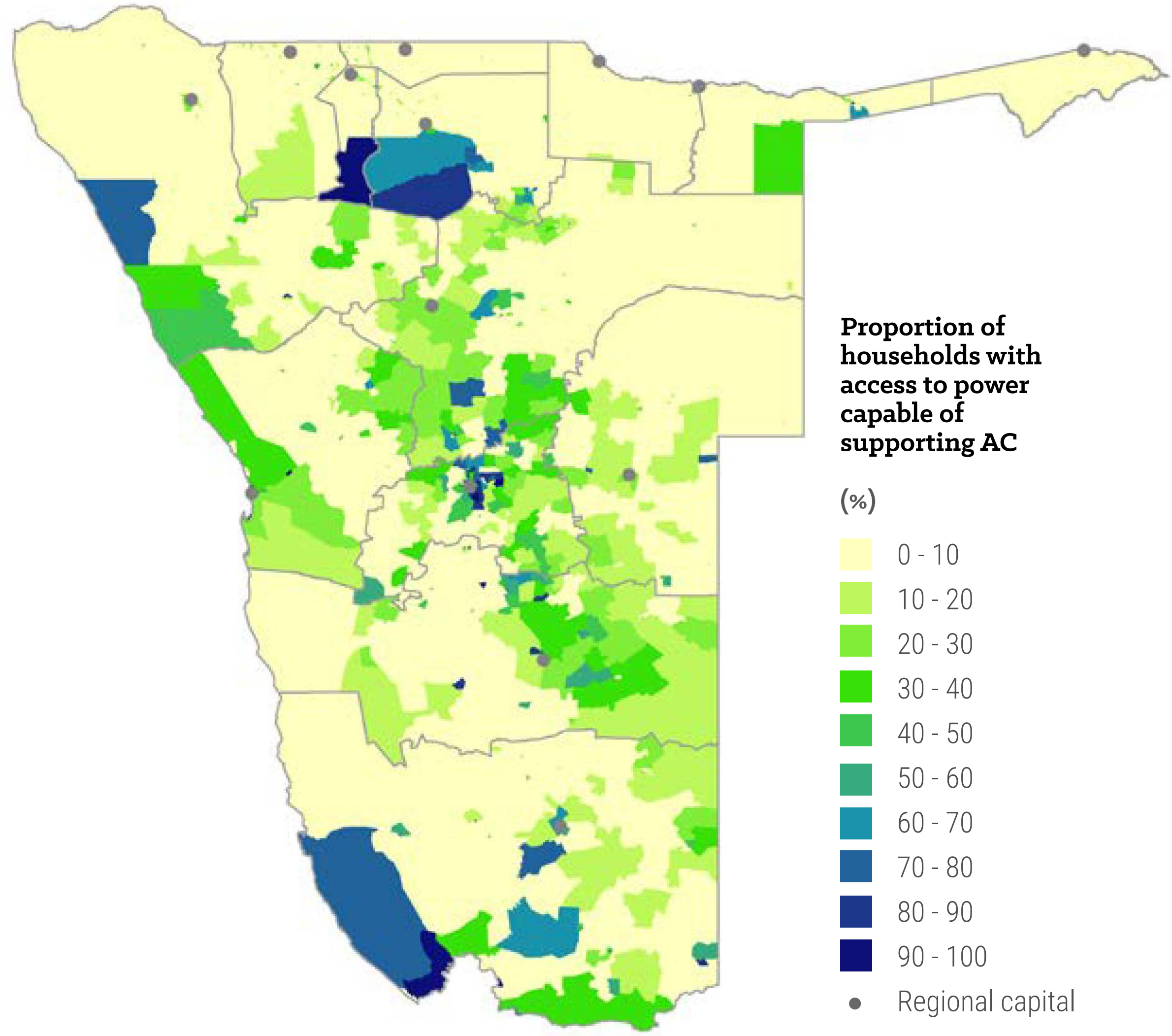


Figure 45: Proportion of households connected to the electrical grid suitable for air conditioning

Figure 46: An example of the air condition system powered by solar panels on a partially thatched structure in southern Namibia

In the south of the country where heatwaves are frequent, people generally remain indoors when temperatures are too high. Staying indoors is, however, a challenge to those who live in corrugated iron structures. The lack of trees in some parts exacerbates the situation as there is no natural shading to shield one from the heat of the day. Dressing up in cotton clothing covering most of the body to trap sweat which creates a cooling effect when winds blow is another method reportedly used commonly in the south of the country to ameliorate the effects of heatwave. Others, especially the elderly, would drink tea in hot weather which encourages sweating, and results in evaporative cooling as well. Some residents build thatched structures or construct cavity walls to minimise indoor temperatures (Figure 47).

a)

b)

c)

d)

Figure 47: An example of building structures used in some parts of the country and adapted to heatwave

Anecdotal accounts suggest that Noordoewer and Aussenkehr used to be the hottest areas in the southern part of the country. The Warmbad area is seemingly getting hotter than Noordoewer and Aussenkehr in recent years. It is theorised that the introduction of vineyards in the Aussenkehr areas (Figure 48) may be a key factor in ameliorating hot temperatures in their immediate surroundings and serving as a form of adaptive capacity.

Figure 48: Vineyards in the Aussenkehr areas

6.5 VULNERABILITY TO HEATWAVE

Vulnerability to heatwave is widespread in Namibia (Figure 49). More than 80% of the country has a vulnerability score of high to very high. EAs with very high vulnerability are mainly concentrated in the Omaheke, Otjozondjupa, Hardap, //Kharas, Erongo regions and to some extent, Kunene Region (Figure 49). Vulnerability is also high in urban areas, especially in informal settlements where the provision of electricity and other services is limited. Over 1, 378, 000 people are residing in areas with high to very high vulnerability (Table 6). The widespread high vulnerability to heatwave is not surprising, however, because most buildings in the country are constructed with materials sensitive to heatwave while the adaptive capacity is low.

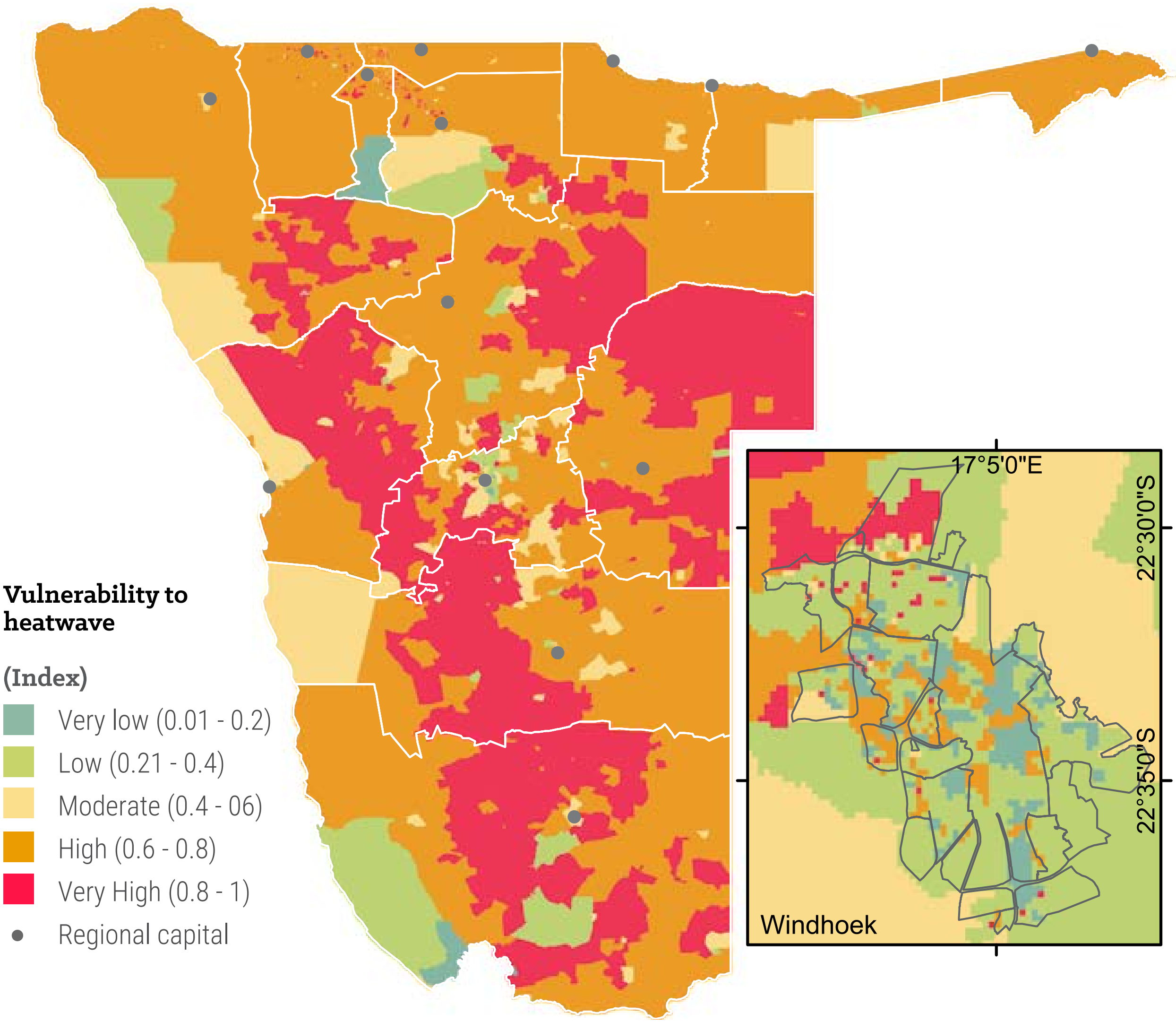


Figure 49: Spatial distribution of the vulnerability to heatwave

Table 6: Distribution of population by heatwave vulnerability level in each region of Namibia

Heat-wave vulner-ability level	Erongo	Hardap	Kho-mas	Kunene	Ka-vango East	Ka-vango West	Ohang-wena	Oma-heke	Omu-sati	Oshana	Oshi-koto	Otjo-zond-jupa	Zam-bezi	//Kha-ras
Very low	70874	6771	32764	28	1951	0	0	0	624	2225	118	1988	829	2808
Low	13708	19441	138138	4793	9634	1170	4309	6457	5587	20388	6491	24440	7270	15526
Moder-ate	6673	13614	22538	7484	7523	8288	9008	5208	5954	16357	12119	14984	7690	15380
High	33899	23946	53039	49342	98343	71026	201505	19419	201313	99407	120382	51044	60460	27261
Very high	12178	27867	94745	8444	4062	0	6943	32777	8023	14382	16582	29405	784	11759

6.6 HEATWAVE RISK

Like vulnerability, heatwave risk is widespread with about 90% of the country having a moderate risk score. In the //Kharas and Hardap regions, however, some areas have high to very high-risk scores (Figure 50). Some areas in the northern regions (Ohangwena, Oshana, Omusati and Oshikoto) also have a high risk of heatwave. About 1, 746, 897 people live in areas with a moderate risk score for heatwave, 172, 986 live in areas with a high risk, while 2, 011 are residing in areas with a very high-risk score for heatwave (Table 7). The heatwave risk score is moderate to very high for most parts of the country, mainly because the vulnerability is high.

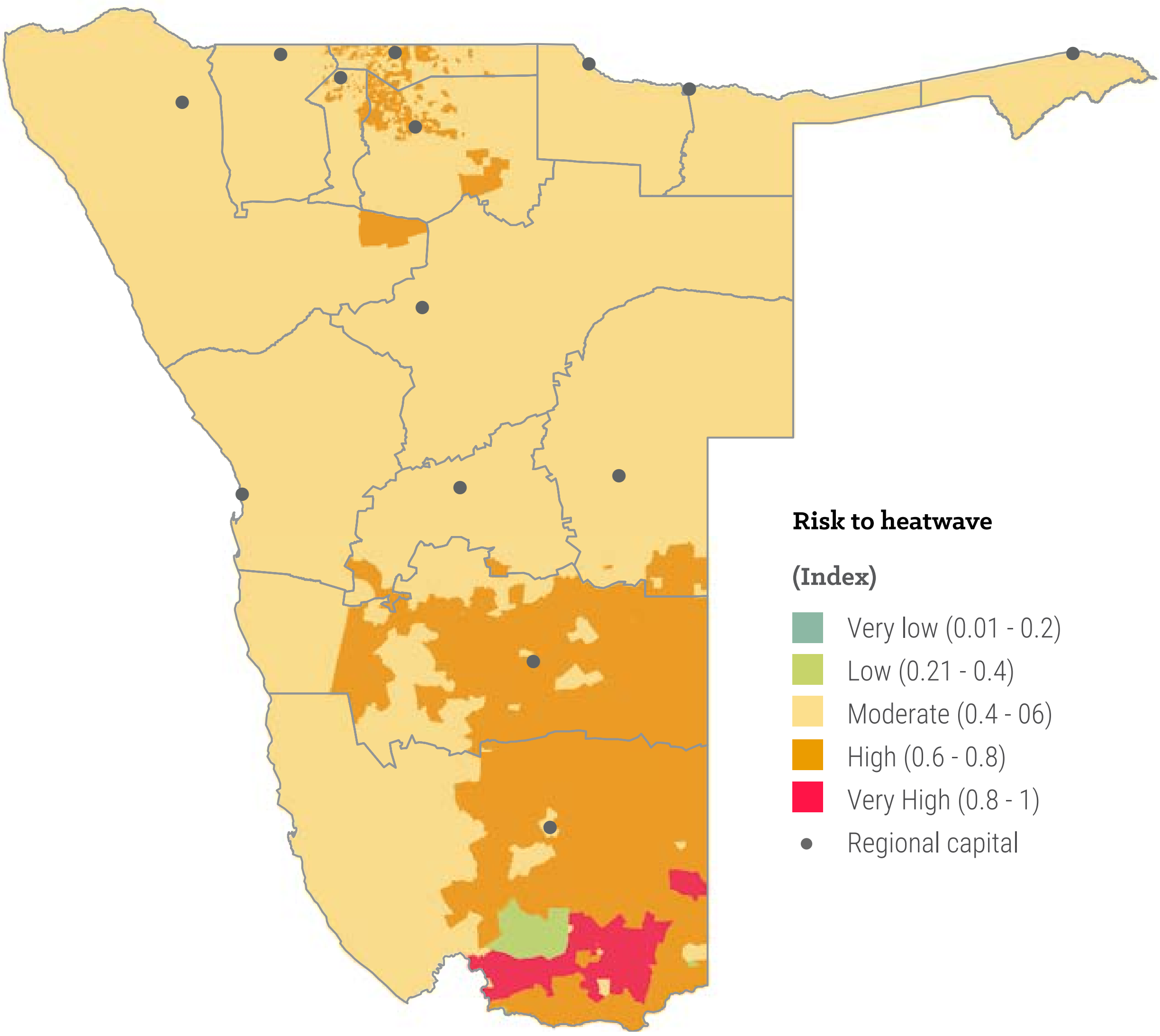


Figure 50: Spatial distribution of the vulnerability to heatwave

Table 7: Distribution of population by heatwave risk level in each region of Namibia

heatwave risk level	Erongo	Hardap	Khomas	Kunene	Kavango East	Kavango West	Ohangwena	Omaheke	Omusati	Oshana	Oshikoto	Otjozondjupa	Zambezi	//Kharas
Very low	0	0	0	0	0	0	0	0	0	0	0	0	0	106
Low	0	4029	0	0	0	0	0	0	0	0	0	0	0	3460
Moderate	137332	67442	340452	68999	121513	80484	175120	61006	220562	140045	88613	121861	77033	46435
High	0	20168	772	1092	0	0	46645	2855	939	12714	67079	0	0	20722
Very high	0	0	0	0	0	0	0	0	0	0	0	0	0	2011

07

FROST VULNERABILITY AND RISK ASSESSMENT

FROST VULNERABILITY AND RISK ASSESSMENT

7.1 FROST HAZARD

Frost hazard was derived from gridded data for the daily minimum surface air temperature covering the 1980-2021 period, also mined from the CPC Global Unified Temperature data products provided by the NOAA PSL. Temperature below 0 °C was considered for forming frost. The average number of days per year with temperatures below 0 °C was computed per 0.5 x 0.5 degree grid cell. Frost is mainly common in the south and south-eastern parts of Namibia (Figure 51). The number of days with frost is largely similar over the last four decades.

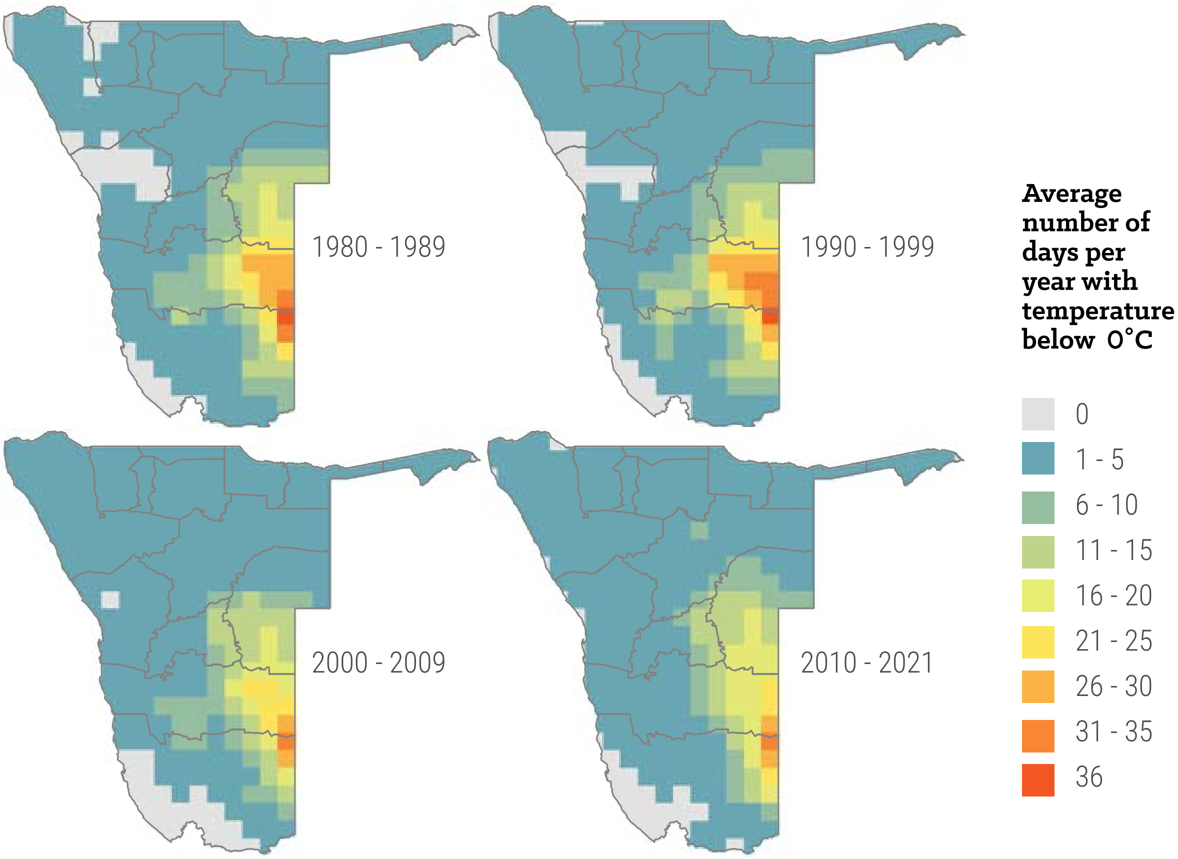


Figure 51: Average number of days per year with temperature below 0 °C from 1980 to 2021 (data source: NOAA)

7.2 EXPOSURE TO FROST

People can be affected by frost negatively, but the effect can be minimised by using warm clothing and heating. Since frost also kills small stock, especially sheep, it is logical to use small stock (sheep and goats) as exposure to frost instead of people. The small stock was thus used as an exposure. Figure 52a shows the spatial distribution of small stocks across Namibia. The number of small stocks is mainly high in the northern regions. However, the northern regions are dominated mainly by goats (Figure 52b), whereas the density of sheep is high in the southern regions (Figure 52c).

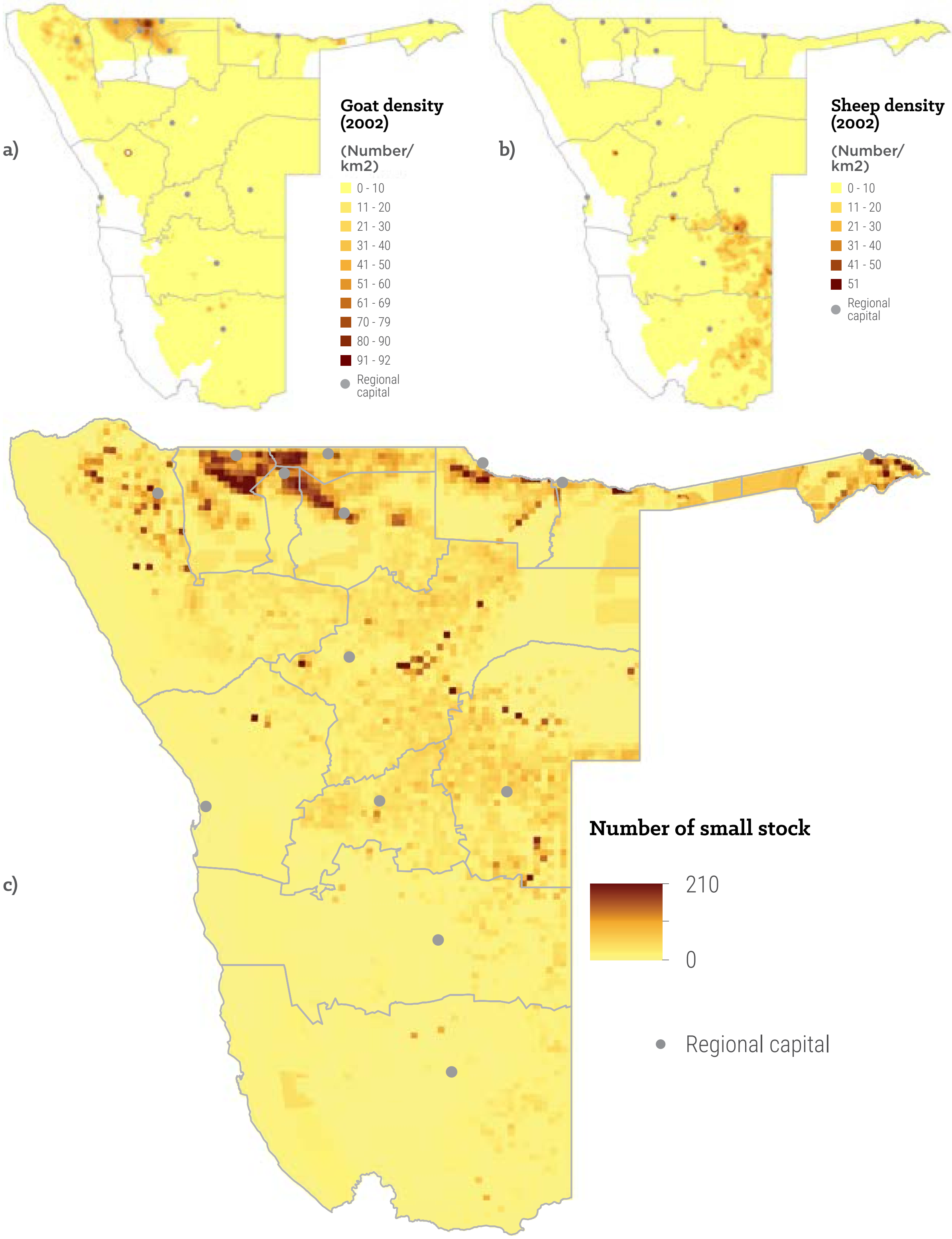


Figure 52: Number and density of small stock in Namibia (data source: Mendelsohn et al. 2002.)

7.3 SENSITIVITY TO FROST

The appropriate sensitivity measure for frost is livelihood because when frost kills the small stock, the livelihood of the people who depend on such small stock is negatively affected. The dominant livelihood dataset (Figure 12) was, therefore, used as a measure of sensitivity to frost. Pastoral communal livelihood was considered the most sensitive to frost (=1), followed by agro-pastoral communities (=0.8).

7.4 ADAPTIVE CAPACITY TO FROST

It is logical to expect that farmers with high incomes are more likely to invest in the infrastructure that protects their small stock from frost than farmers with low incomes. For example, it was revealed during the field visit that some farmers use shade nets and corrugated iron to shield small stock in kraals from cold conditions. Therefore, the median income per capita averaged at EA was used as a measure of adaptive capacity to frost (see Figure 13). Data for the median income per capita were standardised to form an adaptive capacity score, ranging from 0 to 1. Areas with the highest median income per capita were assigned an adaptive capacity score of 1. It should be noted that the adaptive capacity score is relative.

7.5 VULNERABILITY TO FROST

A large part of Namibia has a moderate vulnerability score for frost (Figure 53). However, areas around the central, south and south-eastern parts of the country have a high to very high vulnerability score. Such areas have a high vulnerability score due to high exposure and the sensitivity weight assigned to the livelihood of pastoral communal areas.

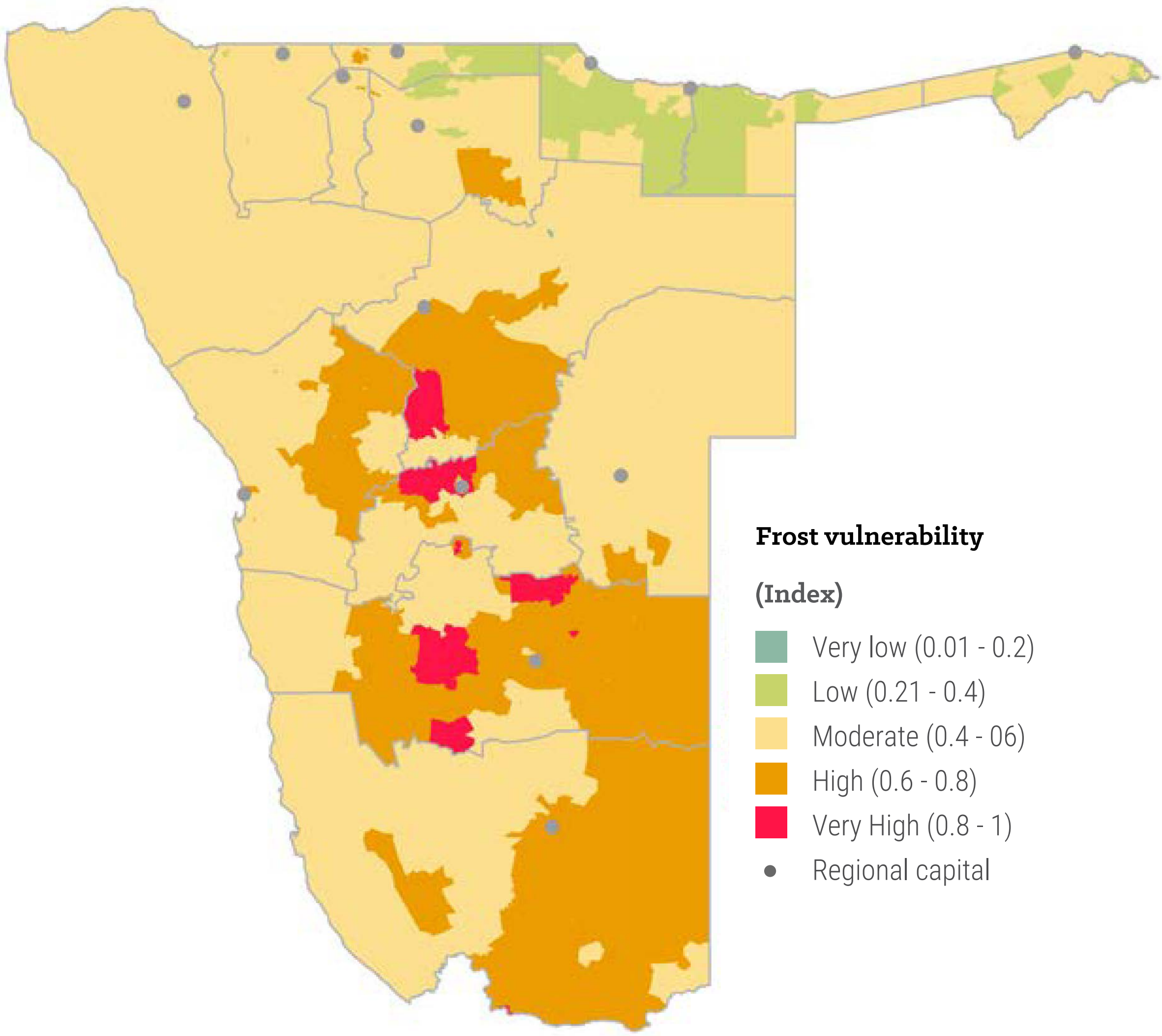


Figure 53: Spatial distribution of the vulnerability to frost

7.6 FROST RISK

Despite vulnerability being moderate to very high in most parts of the country, the risk for frost is only moderate to very high in the southeastern part of the country (Figure 54). Moderate to very high risk is limited to areas around Mariental, Aranos, Koes and Aroab. These are also areas where sheep density is high (Figure 53c). The rest of the country has low to very low frost risk. Spatially limited frost risk is due to frost hazard. Most parts of the country rarely experienced frost conditions during the 1980-2021 period (Figure 54). In the areas around Mariental, Aranos, Koes and Aroab, however, frost conditions are common. Besides sheltering animals to help protect them from freezing temperatures, options are limited for minimising frost hazards and building resilience. Therefore, strategies for building frost resilience should instead focus on reducing vulnerability by increasing the adaptive capacity of small-stock farmers. Promoting the construction of insulated shelters for small stock accompanied by robust and timely weather forecasting could build resilience for small stock farmers against frost. Tackling other dimensions of vulnerability (exposure and sensitivity) might be more challenging.

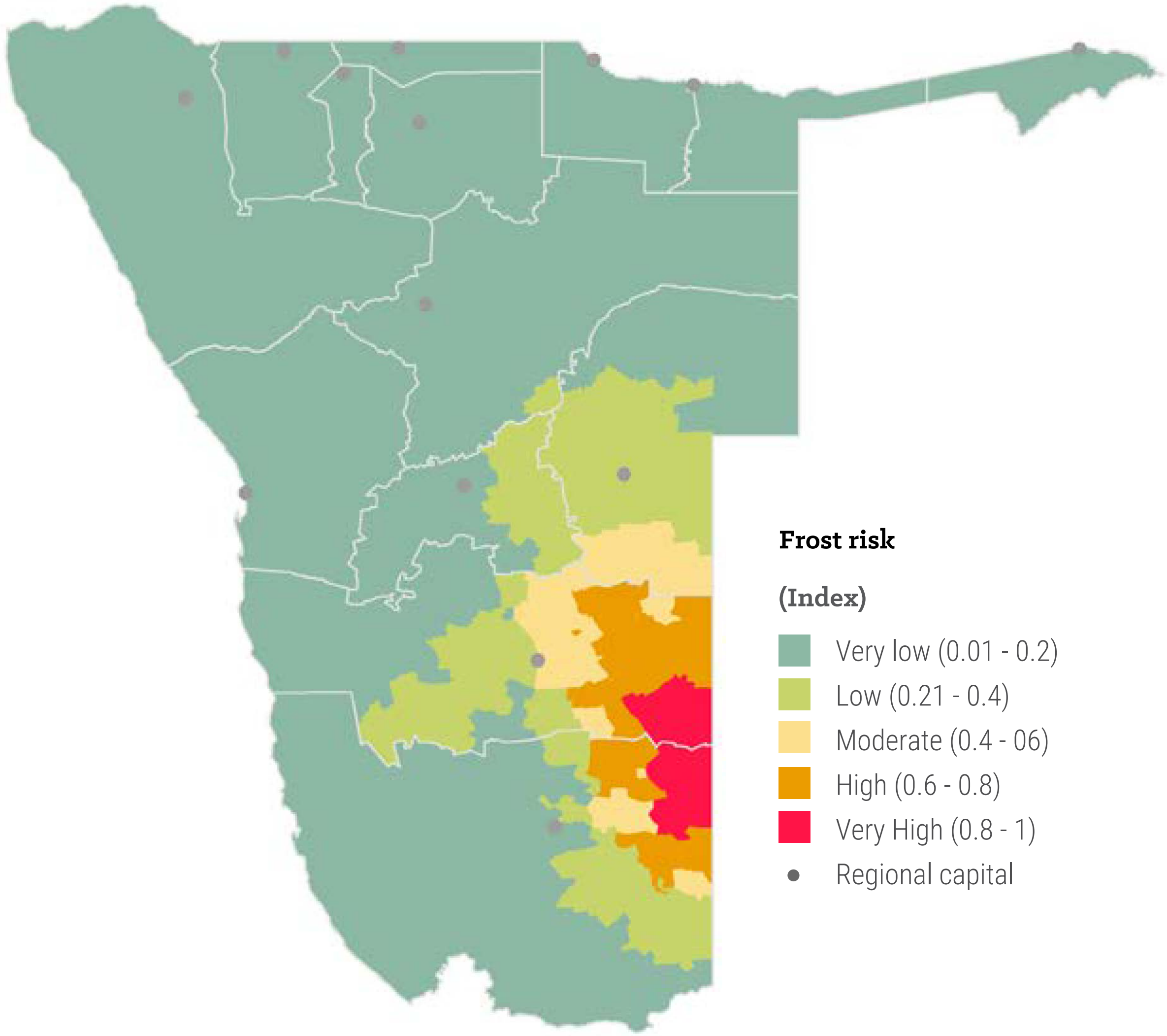


Figure 54: Spatial distribution of the risk to frost

08

WINDSTORM VULNERABILITY AND RISK ASSESSMENT

WINDSTORM VULNERABILITY AND RISK ASSESSMENT

8.1 WINDSTORM HAZARD

Strong winds can damage infrastructure, such as buildings, electrical poles, and trees. Such damages can have a significant impact on the livelihood of affected communities. When the wind is strong enough to cause damage, it is referred to as a windstorm (Kruger et al., 2016). A wind speed of 62 km per hour is considered strong enough to cause damage (Kruger et al., 2016).

However, there is no fixed wind speed threshold for defining a windstorm because the damage that can be caused is relative to the nature and quality of buildings (Kruger et al., 2016). In Namibia, many buildings especially in rural areas and peri-urban are often not built following any certified construction standards. Therefore, they may be damaged by winds with speeds of less than 62 km per hour. A threshold of 40 km per hour was instead used in this profile to define a windstorm. Data for wind speed was derived from the ERA5-Land hourly dataset covering the 1990-2021 period. The data has a spatial resolution of ~11.1 km (Mũnoz-Sabater et al., 2021). The frequency of the windstorm was computed for each grid cell. Windstorms are mainly common in the southern and western parts of Namibia, dominated by windstorms with speeds of 40-49 kmph (Figure 55). Areas along the coast between Nami≠nü (formerly known as Lüderitz) and Oranjemund are the hotspots of windstorms (Figure 55). Figure shows examples of damages caused by windstorms in Namibia.

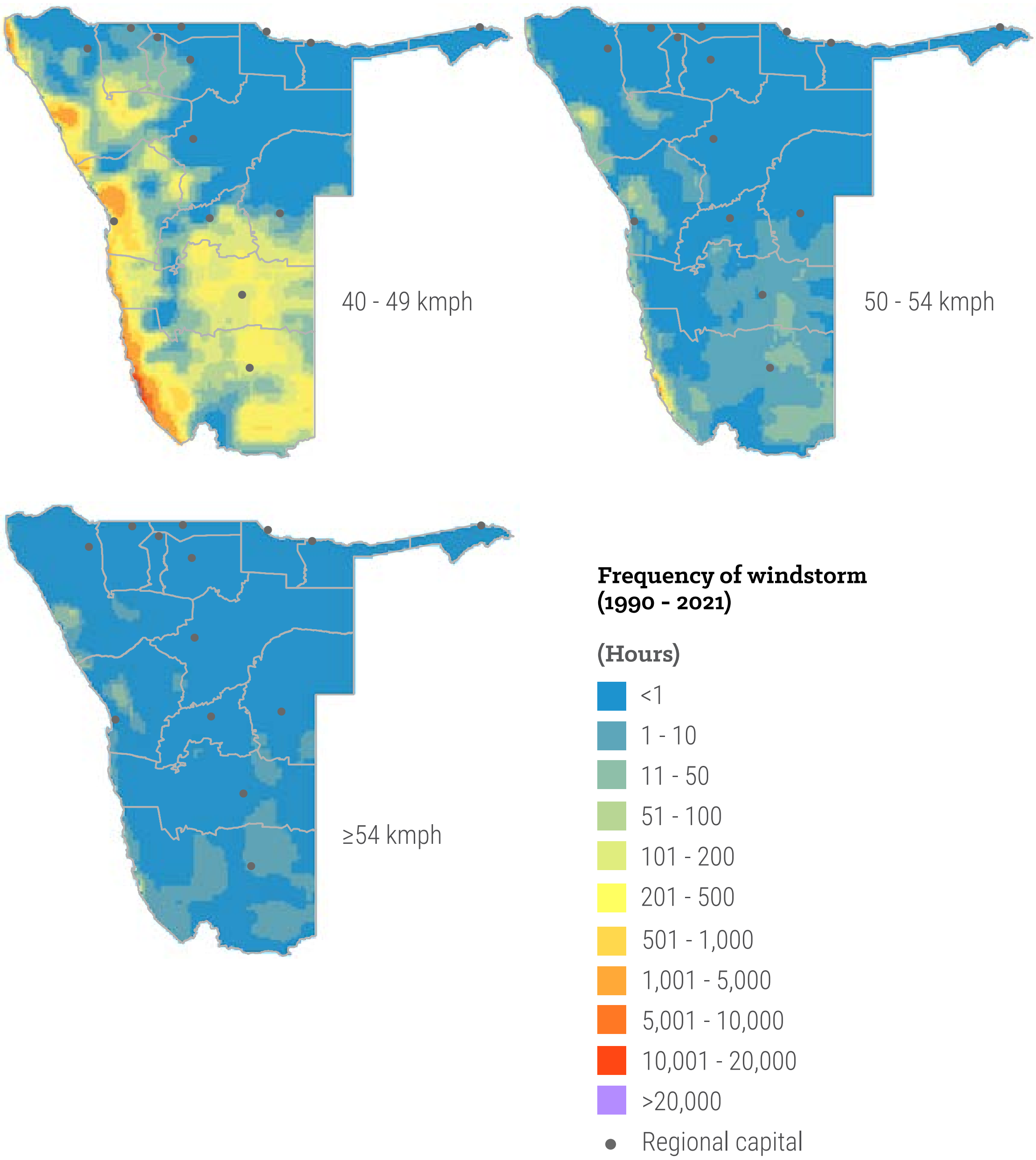


Figure 55: Frequency of sandstorms of various speeds from 1990 to 2021 based on the ERA5-Land hourly dataset

a)

b)

c)

d)

Figure 56: An example of corrugated iron/zinc roofs blown away in Berseba (a and b), and trees uprooted, by the wind in Ohangwena (c) and Berseba (d)

8.2 EXPOSURE TO WINDSTORM

For Namibia, buildings are the main and pertinent exposure to windstorms. The building footprint dataset (Figure 22) was thus used as a measure for windstorm exposure by calculating the proportion of building footprints per EA as a fraction of the total number of building footprints in the country (Figure 57). EAs with a high proportion of building footprints were mainly in Windhoek, Otjiwarongo and a corridor between Okahandja and the coast (Figure 57).

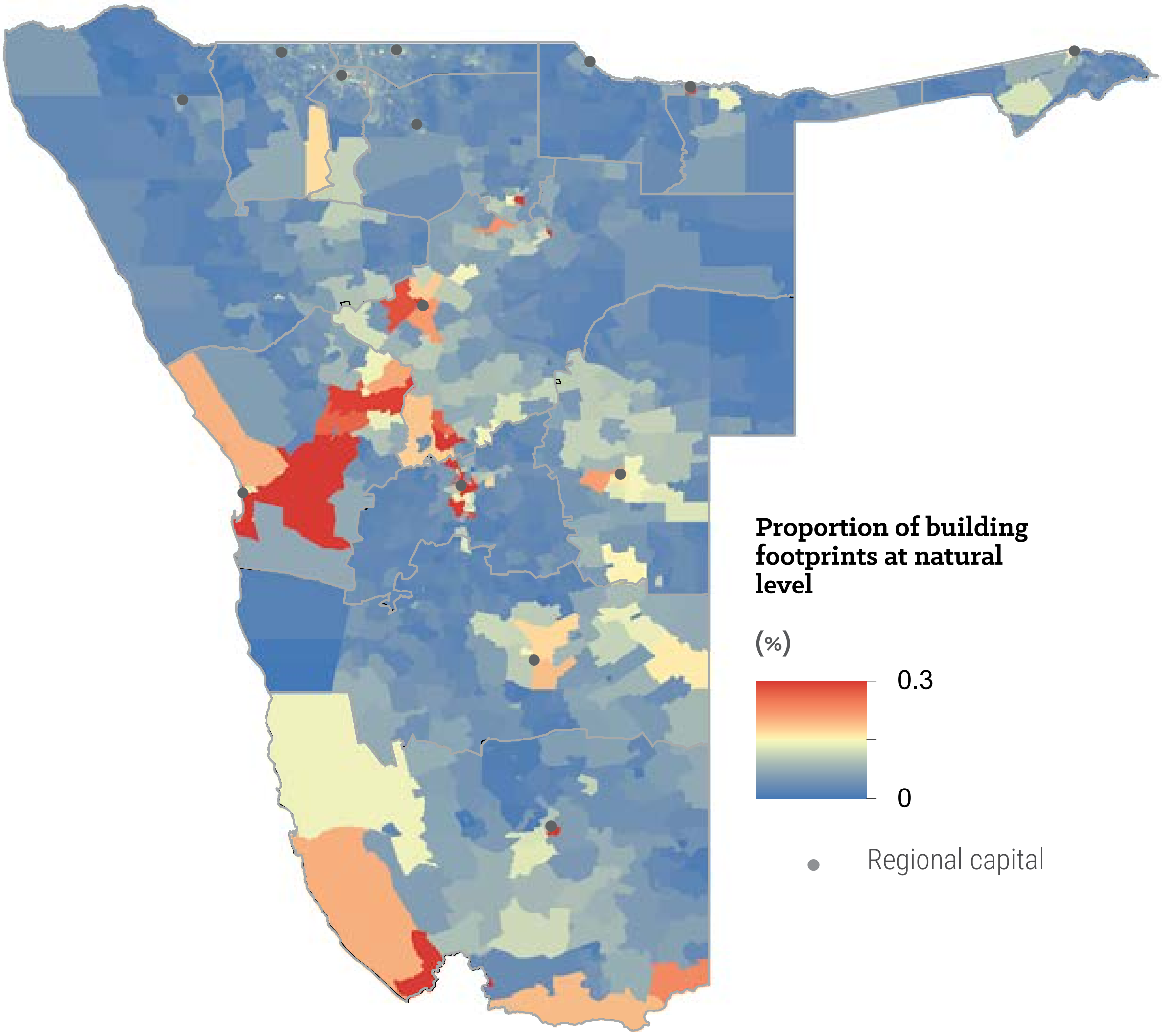


Figure 57: Proportion of building footprints per Enumeration Area

8.3 SENSITIVITY TO WINDSTORM

Blowing off of roofs by stormy wind is one form of damage a windstorm can cause to buildings. Therefore, in this profile, roof materials were used to represent sensitivity to windstorms. Roofs of buildings in Namibia are mainly constructed with asbestos, corrugated iron/zinc, concrete, bricks, thatch, wood/sticks and tin materials (NSA, 2012). Amongst these materials, roofs made with corrugated iron/zinc are particularly sensitive to damage by windstorms. Therefore, the proportion of buildings with corrugated iron/zinc roofs was used as a measure of sensitivity to storms, with areas with high proportions being more sensitive. The proportion of buildings with corrugated iron/zinc roofs was standardised to range from 0 to 1. Data for roof materials were collected during the 2011 Population and Housing Census (NSA, 2012). The use of corrugated iron/zinc roofs is widespread across the country, but it is more popular in the central and southern parts, where 90-100% of buildings have corrugated iron/zinc roofs (Figure 58).

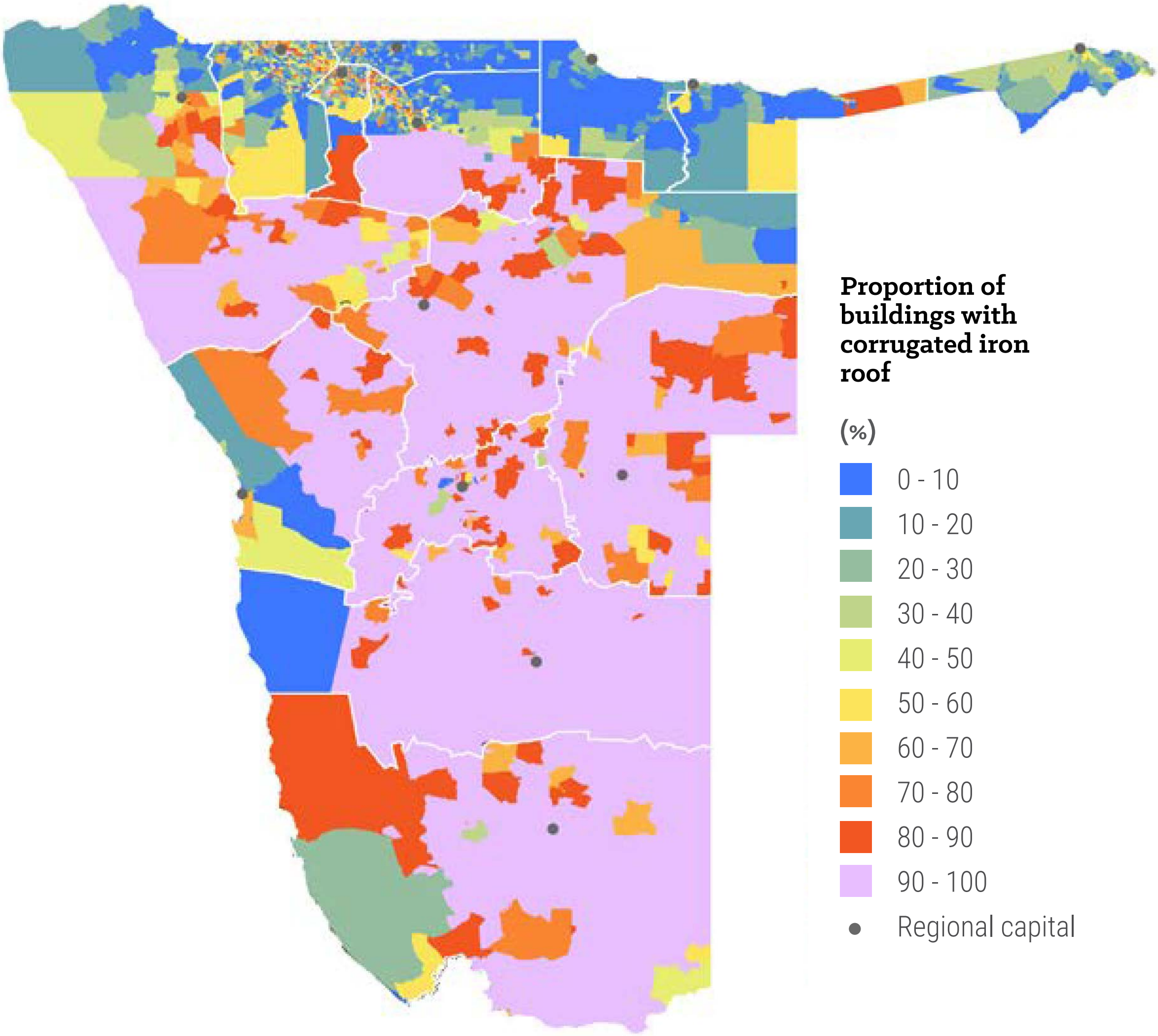


Figure 58: Proportion of buildings with corrugated iron roofs per Enumeration Area

8.4 ADAPTIVE CAPACITY TO WINDSTORM

People with relatively high incomes are likely to use professional builders and quality materials when constructing their structures. Therefore, it is logical that areas with high median income are likely to have buildings of high quality whose roofs are less prone to windstorm damage. The average median income per capita (Figure 13) was thus used to represent the adaptive capacity to windstorm. The averaged median income per capita data were standardised to range from 0 to 1.

8.5 VULNERABILITY TO WINDSTORM

More than 80% of the country has a windstorm vulnerability score of moderate to high (Figure 59). Areas with high vulnerability were mainly in the Omaheke, Otjozondjupa, southern Kunene, northern Erongo, Khomas, Hardap, //Kharas regions and along the Tsumeb-Oshakati-Outapi corridor (Figure 59). Vulnerability is high in these areas because of high sensitivity and exposure. Addressing vulnerability to windstorms is complex, but increasing employment opportunities for people to have better incomes and reinforcing construction standards lead to low vulnerability.

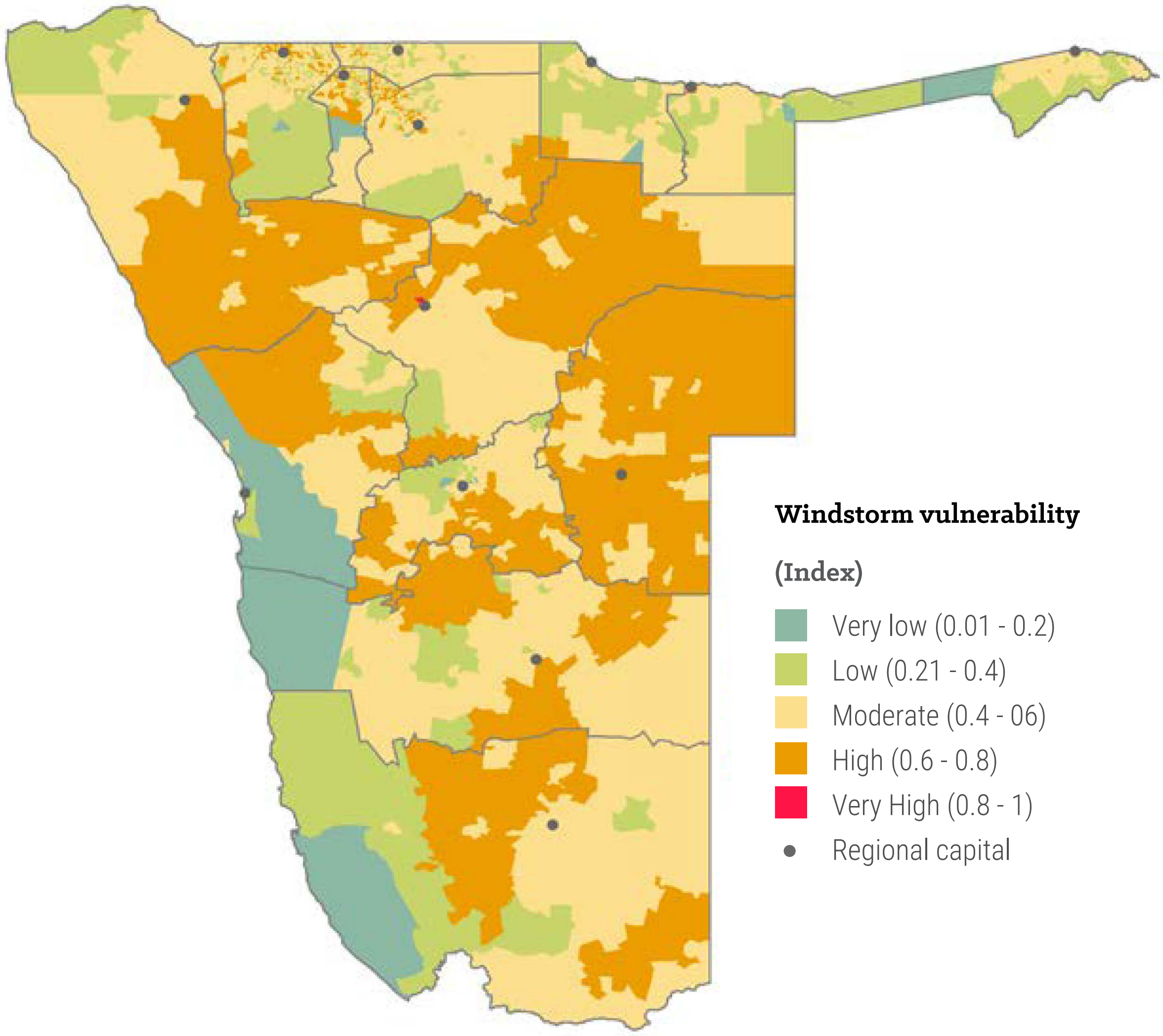


Figure 59: Spatial distribution of the vulnerability to windstorm

8.6 WINDSTORM RISK

High vulnerability to windstorms is widespread but the risk is largely confined to areas around Nami≠nü (Lüderitz) and the coastal areas west of Opuwo in the Kunene Region (Figure 60). The rest of the country has very low risk. The risk is particularly very low for Nami≠nü town itself (Figure 60). Areas around Nami≠nü have very high risk, but their vulnerability is very low. The higher risk is due to disproportionately higher frequencies of windstorms when compared to the rest of the country. The vulnerability is low in the Nami≠nü area due to low sensitivity. In the Nami≠nü area, people rarely use corrugated iron/zinc roofs (Figure 59). Instead, they use asbestos, concrete and wood/sticks. In the coastal areas of Namibia, corrugated iron/zinc materials are prone to rusting due to the high percentage of moisture from the Atlantic Ocean. As long as people continue to be well informed to avoid roof materials sensitive to windstorms, the high risk in the Nami≠nü area is manageable. With climate change, however, if the frequency of windstorm hazards increases in vulnerable areas, the risk of such areas may increase drastically across the country. Resilience-building efforts should focus on reducing vulnerability to windstorms. It should be noted, however, that all types of asbestos are carcinogenic.

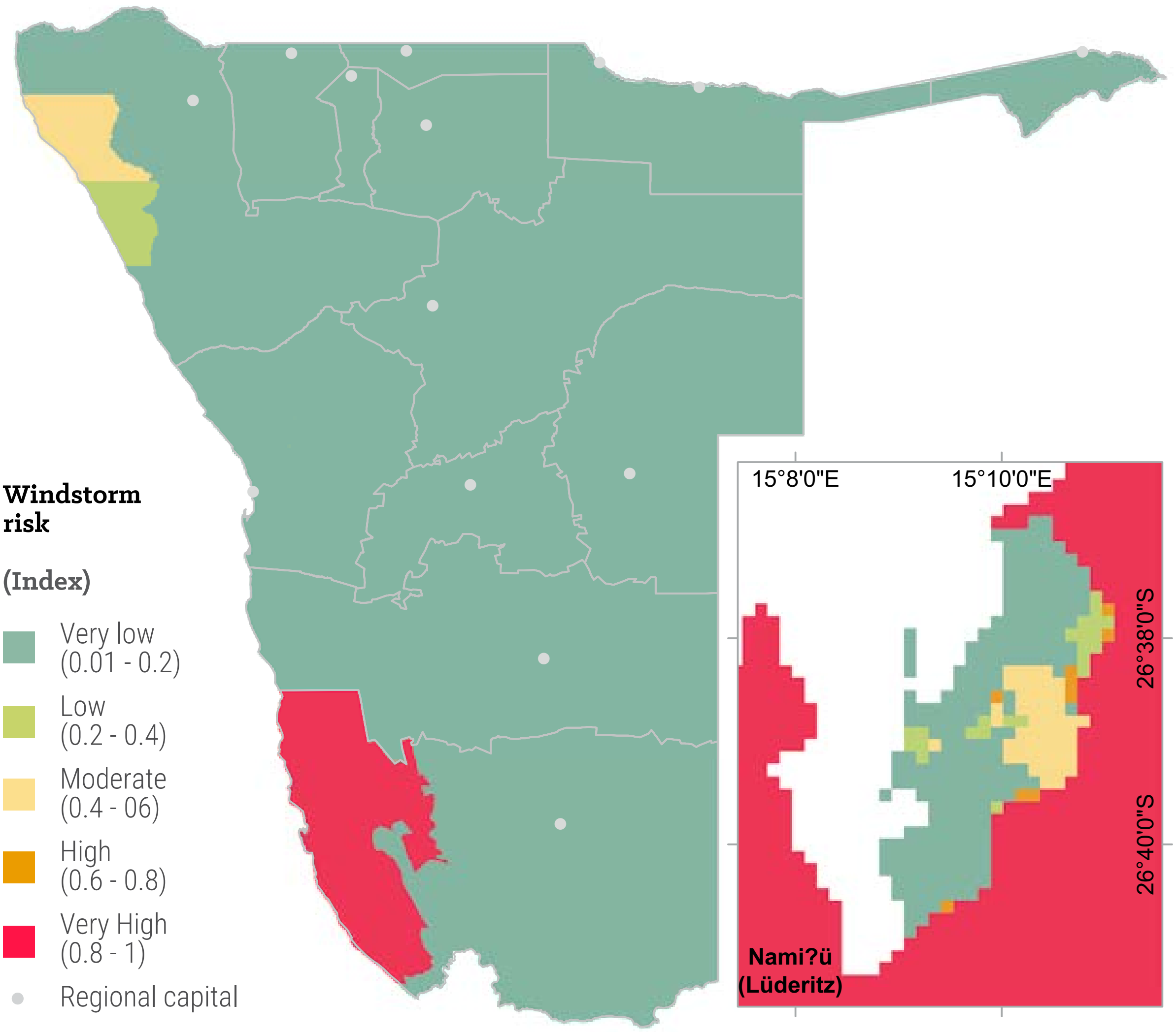


Figure 60: Spatial distribution of the windstorm risk

09

LIGHTNING STRIKE VULNERABILITY AND RISK ASSESSMENT

LIGHTNING VULNERABILITY AND RISK ASSESSMENT

9.1 LIGHTNING STRIKES HAZARD

Lightning strikes kill people and animals and destroy infrastructure. In Namibia, cases of people and/or animals killed by lightning strikes are reported in the media almost every rainy season. However, systematic recording of lightning strikes and fatalities does not exist.

Lightning strikes hazard was quantified using daily gridded time series data from the World Wide Lightning Location Network (WWLLN) Global Lightning Climatology (WGLC) with a spatial resolution of 0.5° by 0.5° (Kaplan & Lau, 2021). This dataset provides daily information on lightning stroke density per grid cell for the period 2010-2020. The annual average lightning stroke density was calculated per grid cell and subsequently used to represent the lightning strike hazard (Figure 61a). Lightning stroke density is high in the Kavango East, Kavango West, Ohangwena and Oshikoto, north of Otjozondjupa and Zambezi regions.

Lightning strikes on humans and animals were collated from the main local newspapers (Namibian Sun, The Namibian, The New Era, and The Republikein). Data were collated by systematically searching news items mentioning lightning strikes. The printed and soft copies of newspapers were made available by respective news media. Lightning strikes were then geocoded using the reported auxiliary information, such as the village or farm name where the lightning strike occurred). Unsurprisingly, the cases of lightning strikes on people and animals are largely concentrated in areas where lightning stroke density is high (Figure 61b).

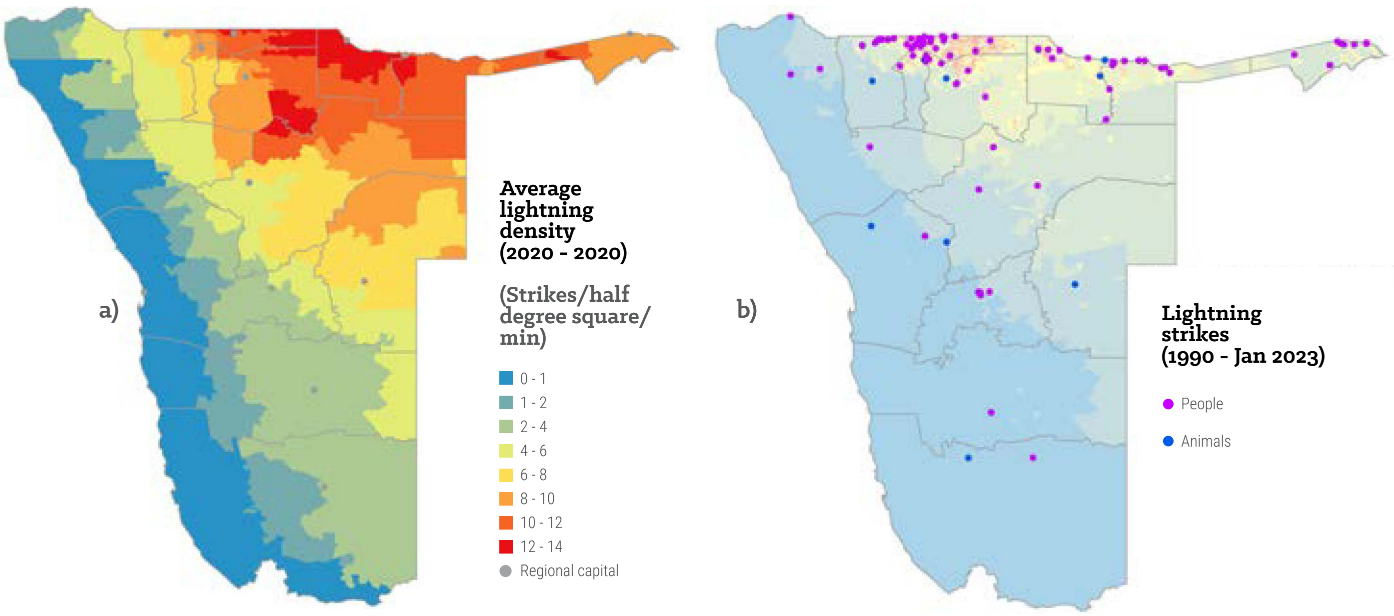


Figure 61: (a) Average lightning density from 2010 to 2020 and (b) lightning strikes on people and animals from 1990 to January 2023. Lightning density data were derived from Location Network (WWLLN) Global Lightning Climatology (WGLC), whereas lightning strikes were collated from newspapers

A total of 150 cases of people struck by lightning in Namibia have been reported in the media between 1990 and January 2023 (Table 8). Of this, 83% were fatalities. The gender of a quarter (n=37) of people who died or were injured is unknown. For the remainder, nearly half (n=70) were male, while a third (n=43) were females. People of all ages were affected, the oldest and youngest persons being 82 years and 9 months old, respectively; the average age is 23 years. The record further shows more than 260 livestock and 13 wild dogs struck by lightning from 17 incidents in the Erongo, //Kharas, Kavango West, Kunene, Ohangwena, Omaheke, Oshana and Oshikoto regions during that period. There was also an aquaculture with more than 2000 fish stock, along with attendant infrastructure, destroyed in 2011 at Uis.

Table 8: Number of human and animal fatalities and injuries by lightning in each region from 1990 to January 2023 in Namibia

Region	People Fatality (n)	People Injured (n)	People Fatality (%)	People Injured (%)	Animal fatalities	Animal fatalities (%)
//Kharas	1	0	0.8	0.0	71	26
Erongo	0	1	0.0	3.8	13	4.8
Hardap	1	3	0.8	11.5	0	0
Kavango East	24	1	19.4	3.8	0	0
Kavango West	11	2	8.9	7.7	37	13.6
Khomas	6	1	4.8	3.8	0	0
Kunene	7	3	5.6	11.5	19	7
Ohangwena	33	5	26.6	19.2	50	18.3
Omaheke	0	0	0.0	0.0	35	12.8
Omusati	10	1	8.1	3.8	9	3.3
Oshana	6	1	4.8	3.8	20	7.3
Oshikoto	5	3	4.0	11.5	19	7
Otjozondjupa	2	1	1.6	3.8	0	0
Zambezi	18	4	14.5	15.4	0	0
Total	124	26	100	100	273	100

9.2 EXPOSURE TO LIGHTNING STRIKES

Lightning strikes can kill people and animals as well as destroy infrastructure such as buildings and powerlines. Therefore, infrastructures, people and animals are exposed to lightning. In this profile, however, the exposure was limited to humans and animals. Human population density (Figure 9) and animal density (Figure 37) datasets were separately used as exposures for lightning strikes. Areas with either high human population density or animal density were allocated a high score of exposure.

9.3 SENSITIVITY TO LIGHTNING STRIKES

Areas where people live in structures not insulated from lightning or are engaged in extensive agriculture are more sensitive to lightning strikes (Michalon, et al., 1999). Therefore, farmers and ranchers are sensitive to lightning strikes. In this profile, the dominant livelihood dataset (Figure 13) was used to allocate lightning sensitivity. Pastoral and agro-pastoral communal areas and rural formal areas where extensive agriculture is a norm were allocated a high sensitivity score (=1) whereas urban areas were allocated a lower score (=0.4).

9.4 ADAPTIVE CAPACITY TO LIGHTNING STRIKES

The availability of lightning-safe structures, using motor vehicles while in the field and engaging less in extensive agriculture are some factors that minimise lightning strikes. When these conditions are present, one can be viewed as having a high adaptive capacity for lightning strikes. Unfortunately, data on lightning-safe structures or the use of motor vehicles when engaging in extensive agriculture is not available. Median income per capita can be an indirect indicator of adaptive capacity. In areas where median income per capita is high, people may build lightning-safe structures. From this perspective, the average median income per capita (Figure 13) was used as a measure of adaptive capacity for lightning strikes.

9.5 VULNERABILITY TO LIGHTNING STRIKES

The results show that people and animals are less vulnerable to lightning strikes in most parts of Namibia (Figure 62). For people, moderate to very high vulnerability is mainly confined to the Ohangwena, Oshana, Kavango West, Omusati, Kavango East and Zambezi regions (Figure 62).

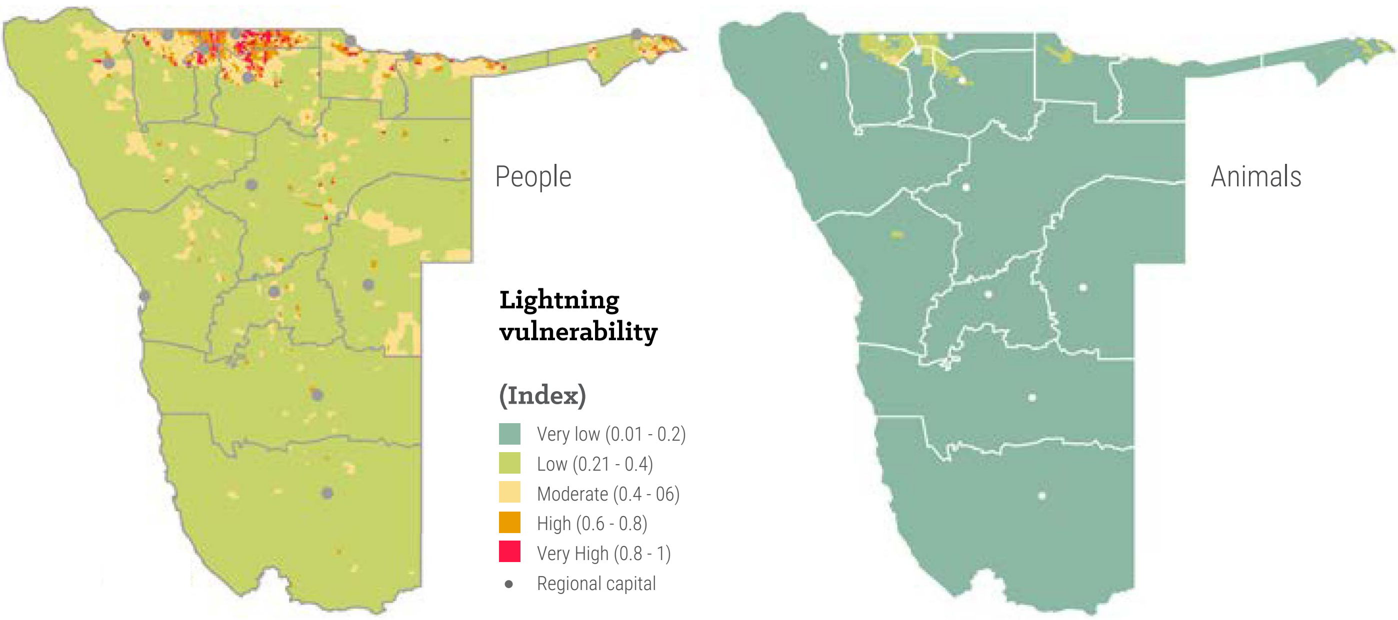


Figure 62: Spatial distribution of the vulnerability of people and animals to lightning strikes

Over 800,000 people reside in areas with moderate to very high vulnerability to lightning strikes (Table 9). The moderate to very high vulnerability in these regions is due to the high human exposure as a result of high population density and high sensitivity because livelihood in these areas is dominated by extensive agriculture. Other regions have isolated pockets of moderate to very high vulnerability. Vulnerability for animals is largely confined to areas in the Cuvelai Basin, in the rest of the northern part of the country, and to the Zambezi floodplains. However, animal vulnerability in those areas is only low to moderate (Figure 62).

Table 9: Distribution of population by lightning vulnerability level in each region of Namibia

Lightning vulnerability level	Erongo	Hardap	Khomas	Kunene	Kavango East	Kavango West	Ohangwena	Omaheke	Omusati	Oshana	Oshikoto	Otjozondjupa	Zambezi	//Kharas
Very low	69119	25891	149607	3427	15064	0	3214	9754	1162	18165	4218	17370	12867	22104
Low	60359	58697	149583	57612	66390	31060	40031	50282	29205	32417	42963	69374	26241	39658
Moderate	6907	6748	40310	8635	32705	35534	80619	3542	148965	49047	79091	29206	28585	10972
High	679	303	1724	417	6918	12264	84555	283	41470	48324	28333	4056	9200	0
Very high	173	0	0	0	436	1626	13346	0	699	4806	1087	1855	140	0

9.6 LIGHTNING STRIKE RISK

The risk for lightning strikes for both humans and animals is very low for most of the country (Figure 63). About 73% of the people live in areas with very low to low risk. Only 27% of the population live in areas with moderate to very high risk (Table 10). Like vulnerability, moderate to very high risk is largely confined to areas in the Ohangwena, Oshana, Kavango West, Omusati, Kavango East and Zambezi regions (Figure 63). In these areas, both vulnerability and hazard were relatively high. The risk for animals is also mainly confined to the Cuvelai Basin in the northern part of the country, in the Kavango West Region, and to the Zambezi floodplains. The large parts of the Omaheke and Otjozondjupa regions have low risk.

Table 10: Distribution of population by lightning risk level in each region of Namibia

Lightning risk level	Erongo	Hardap	Khomas	Kunene	Kavango East	Kavango West	Ohangwena	Omaheke	Omusati	Oshana	Oshikoto	Otjozondjupa	Zambezi	//Kharas
Very low	137237	91345	329995	60755	17524	0	4758	33941	18014	31568	1034	45673	13473	72734
Low	0	294	11229	9336	55506	16019	42291	28729	129664	53978	68956	64017	38169	0
Moderate	0	0	0	0	33565	40286	87878	1191	68752	56210	61924	12005	22224	0
High	0	0	0	0	14005	13389	78804	0	5071	11003	21577	166	3167	0
Very high	0	0	0	0	913	10790	8034	0	0	0	2201	0	0	0

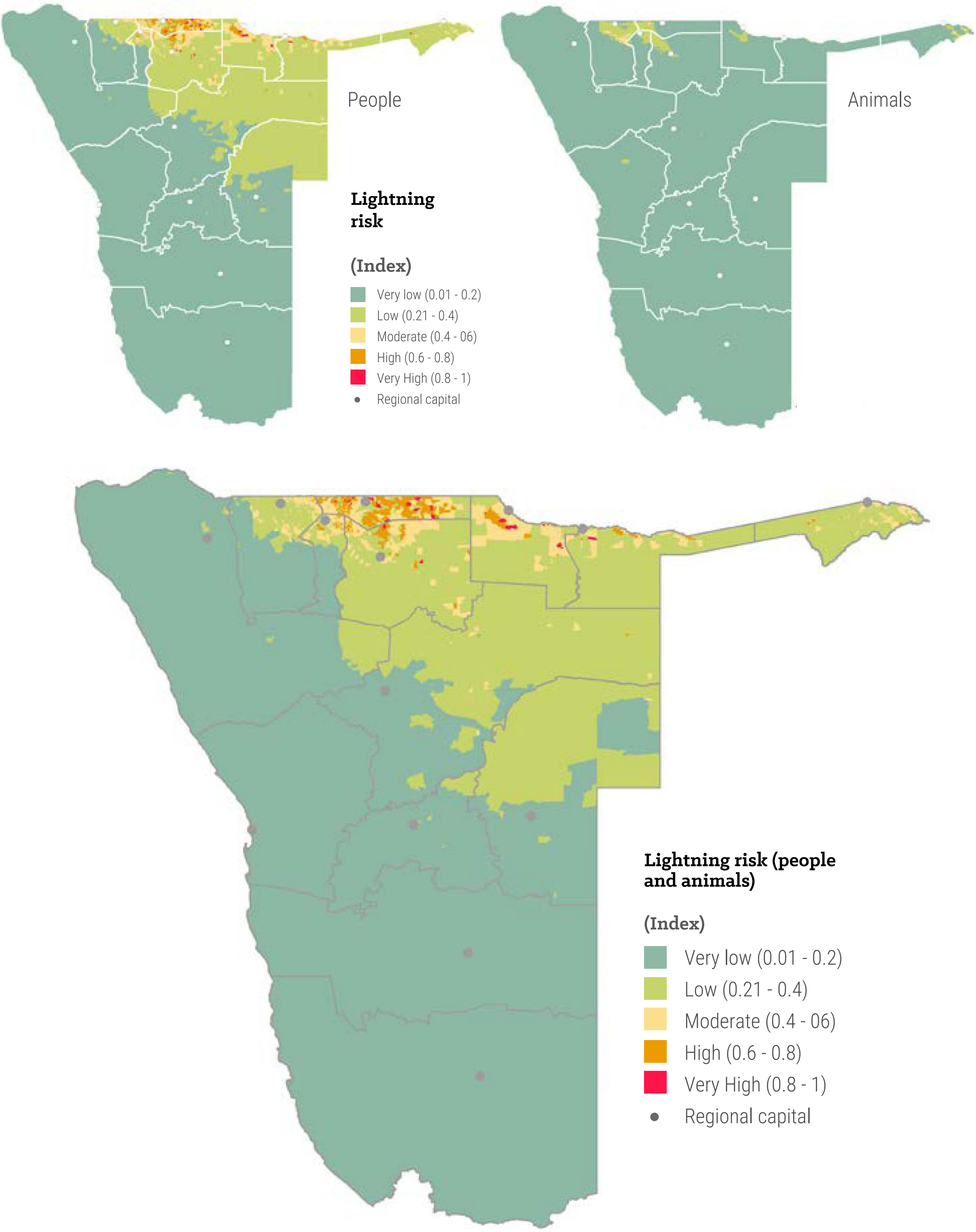


Figure 63: Spatial distribution of the risk of people and animals to lightning strikes

10

SEISMIC (EARTHQUAKE) VULNERABILITY AND RISK ASSESSMENT

SEISMIC (EARTHQUAKE) VULNERABILITY AND RISK ASSESSMENT

10.1 SEISMIC HAZARD

In essence, earthquakes do not kill people. What kills people are buildings and their contents as a result of collapsing material and falling structures caused by earthquakes through ground movement and shaking. As far as we can ascertain, there is no recorded loss of human life in Namibia due to earthquakes.

Although material damage is reported in the country, it may likely have been under-reported at the national level in terms of occurrence and financial cost. Notable examples of building instability in relation to earthquake or fault structure include the Bank of Namibia building in Windhoek (Figure 64; Nakafingo, 2023) and school hostels in Anker (Pienaar, 2018). Some critical national buildings are therefore constructed on fault lines.

The existing record at the Ministry of Mines and Energy for seismic events in Namibia dates to 1910 when the only measure of an earthquake's strength was a subjective assessment of the intensity of shaking observed near the epicentre of the earthquake. The dataset has subsequently recorded the intensity of 22 events that occurred between 1910 and 1947. From 1952, the records show just over 3300 earthquake events occurring in Namibia and an additional 170 within a 100 km buffer from the border or coast (Figure 65a).

These records convey the existence of earthquake threats in Namibia. Buildings constructed of brick masonry or brittle concrete are particularly vulnerable to tremors. Figure 66 shows an example of a building constructed with brick masonry which has been damaged by an earthquake in Anker, Namibia. In general, earthquakes of a magnitude less than 3 happen on a weekly basis, while those of magnitude 3 and above happen monthly in the country. As Figure 65a shows, only a single incident with a magnitude of 6 occurred near Namibia. The event took place in 2015 with an epicentre located 80 km off the coast of Toscanini. The strongest seismic event of 5.6 magnitudes recorded within the country took place in 2021 at Erwee, west of Kamanjab. Before that, the previous record for the strongest event has a magnitude of 5.5 and dates to 1952, occurring at farm Genadendal located 30 km to the northeast of Grunau. The Kamanjab area has a high density of earthquake events but with relatively lower magnitudes. This suggests that energy is released frequently which prevents a build-up of high-intensity events. The more destructive earthquakes typically have magnitudes between 5.5 and 8.9. A magnitude of zero is the limit of human perceptibility.

As Figure 65a shows, earthquakes are widespread across the country, but most earthquakes have magnitudes less than 4. This implies that these are subtle earthquakes. However, the continuous occurrence of subtle earthquakes can cause gradual cracking of walls constructed with brick masonry or brittle concrete. Considering that cracks in building walls are a common phenomenon in Namibia, continuous fixing of subtle and gradual cracking of buildings is one of the major hidden financial burdens of earthquakes in Namibia. The burden is likely to be high in rural areas where, oftentimes, buildings are constructed without adhering to certified construction standards.

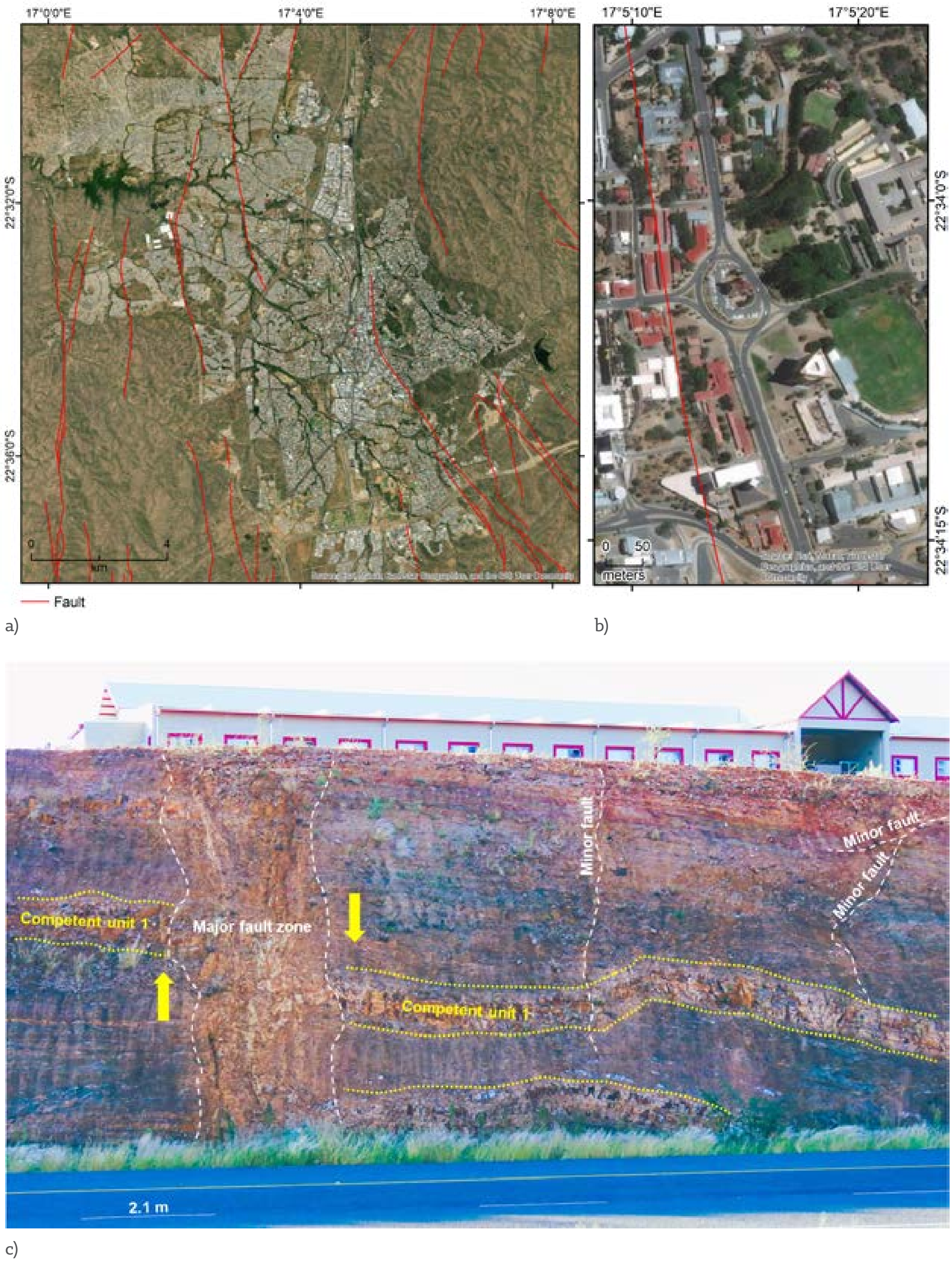


Figure 64: a) Distribution of faults in Windhoek, Namibia, b) location of a fault in relation to Bank of Namibia, c) ground level of one of the mapped faults in Windhoek. This fault lies below a multi-story building projecting out in the background. The arrows point in the direction of block movements. For nominal scale, part of the road marking is labelled. Photo: M Hipondoka; photo annotation: GN Shaanika.

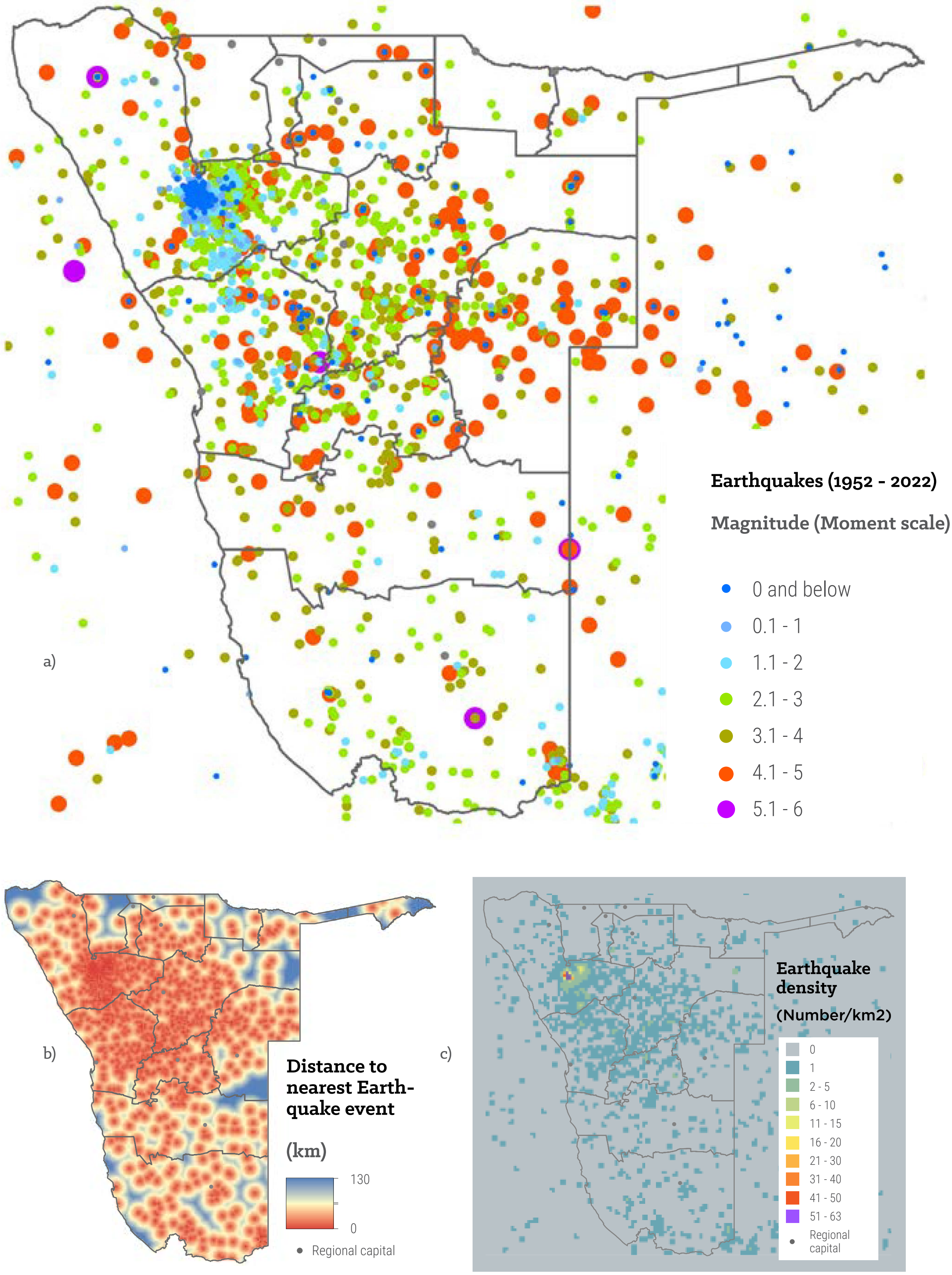
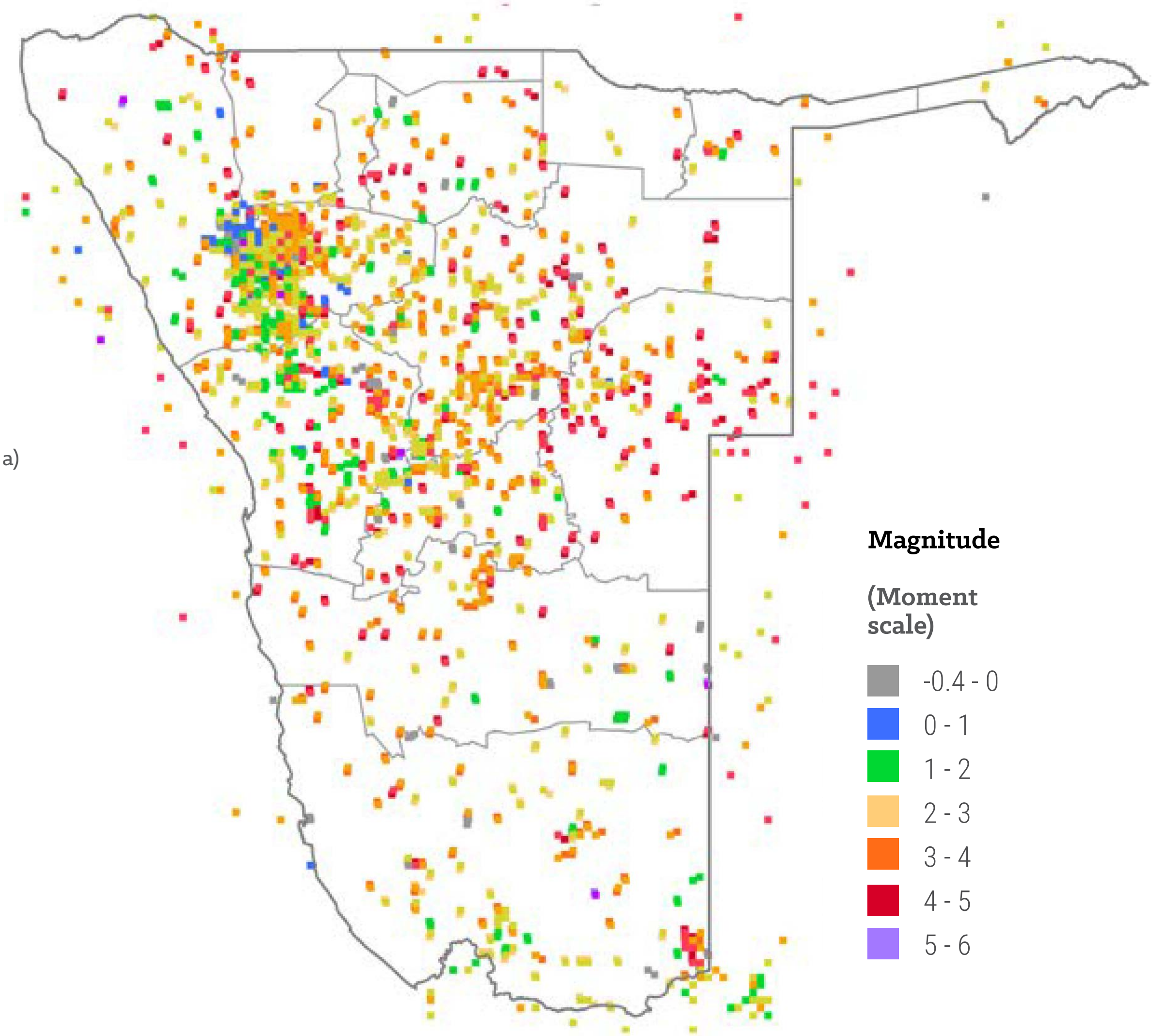


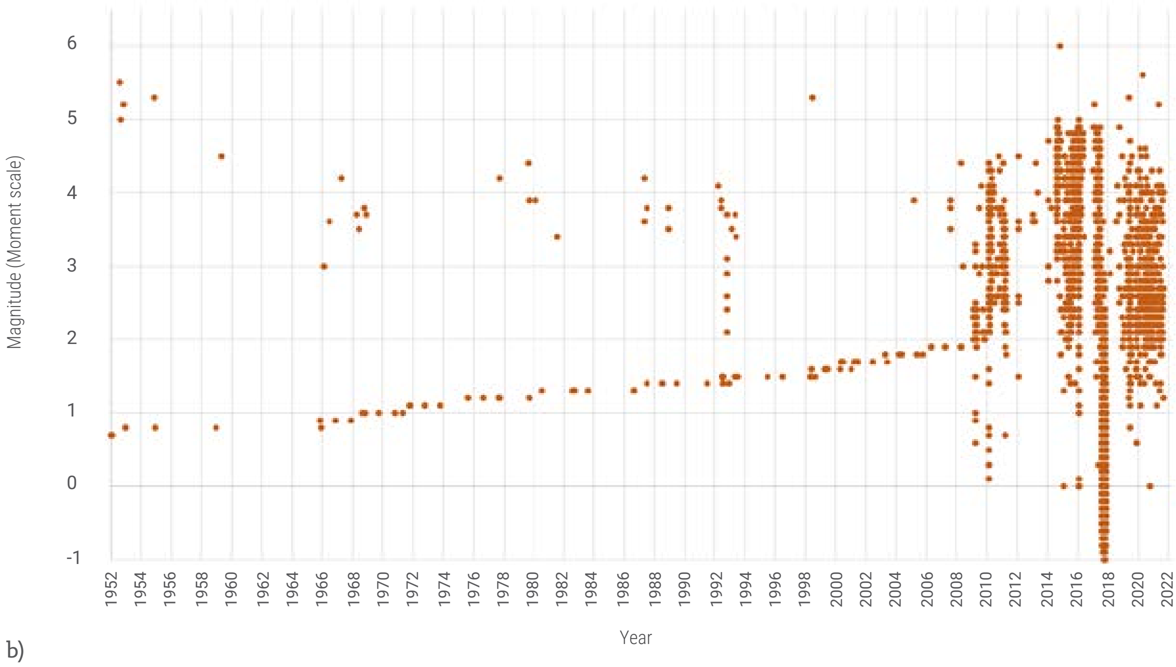
Figure 65: (a) Spatial distribution of earthquakes that happened in and around Namibia from 1952 to 2022, (b) distance to the nearest earthquake event, and (c) earthquake density

Figure 66: The office of the //Gaoio Daman Traditional Authority in Anker, Kunene Region, damaged by earthquake

Earthquake hazard was determined based on earthquake magnitude (Figure 65a), distance to the nearest earthquake location (Figure 65b), and earthquake density (Figure 65c). Each metric was standardised before computing the mean hazard score. Earthquake events were first interpolated to create a continuous map before calculating the mean hazard score. The highest recorded earthquake magnitude per each 10 km by 10 km grid cell was also computed (Figure 67a). Overall, the measurement of earthquake events has improved since 2010, leading to the recording of earthquakes with even smaller magnitudes (Figure 67b).

a)





b)

Figure 67: (a) Highest recorded earthquake magnitude per 10 km x 10 km grid and (b) the time series of earthquake magnitude from 1952 to August 2022

10.2 EXPOSURE TO SEISMIC ACTIVITIES

Exposure to seismic activities was determined based on the number and national proportion of building footprints (Figure 68). Areas with a high number and proportion of building footprints were regarded as having high exposure to seismic activities.

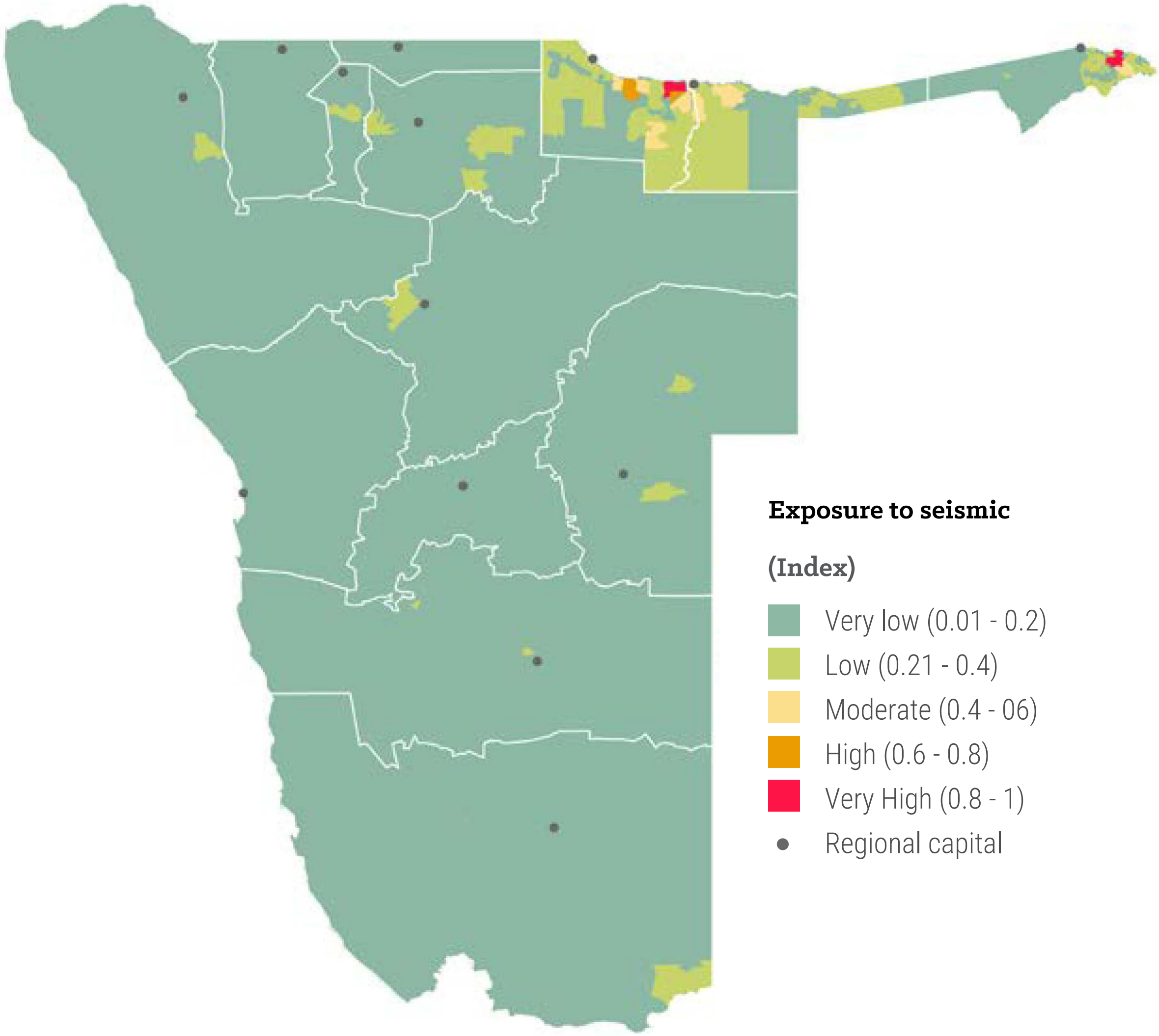


Figure 68: Spatial distribution of exposure to seismic activities

10.3 SENSITIVITY TO SEISMIC ACTIVITIES

Sensitivity to seismic activities was determined based on building materials for walls (Figure 69a), the mapped fault density (Figure 69b), and the distance to the nearest fault line (Figure 69c). Data for building materials were collected during the 2011 Population and Housing Census (NSA, 2012), whereas fault line data were sourced from the Ministry of Mines and Energy.

Areas with a high proportion of buildings with walls constructed using cement, burned bricks, mud and clay were regarded as having high sensitivity to seismic activities. As a result, cement was assigned a sensitivity score of 1, burned bricks was 0.8, prefabricated was 0.5, mud and clay were 0.4, and the rest of the materials were assigned a sensitivity score of 0.2. The mean sensitivity score for wall materials was then computed for each EA.

The density of mapped fault lines (Figure 69b) and the distance to the nearest fault lines (Figure 69c) were computed from the fault lines dataset using the Kernel Density and Inverse Distance Weighting (IDW) approaches, respectively. The density and distance data were then separately standardised to generate sensitivity scores for Faultline density and distance to the nearest fault lines. The scores were subsequently combined with the sensitivity score wall materials to create a mean sensitivity score for seismic activities (Figure 70).

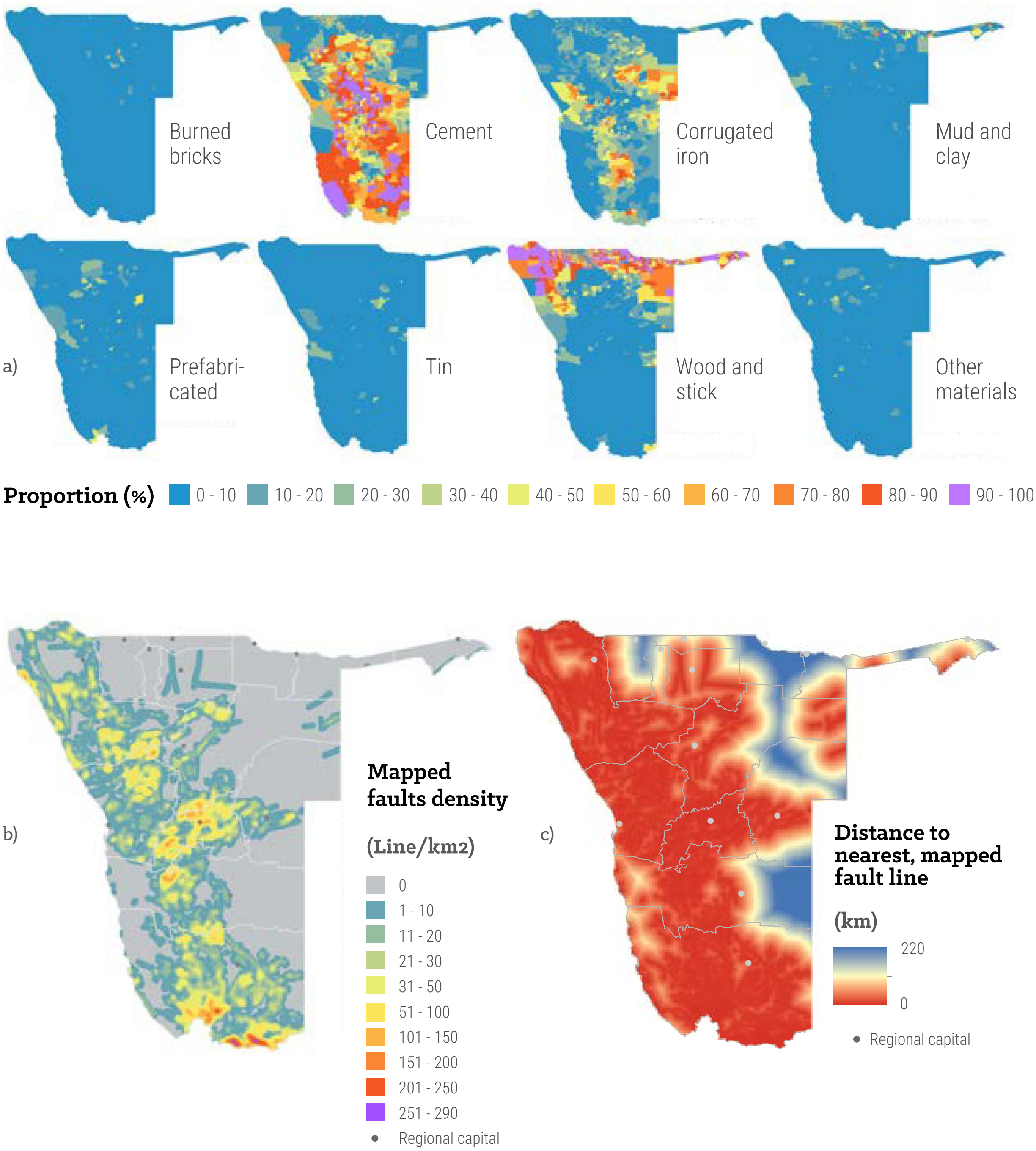


Figure 69: (a) Proportion of the building materials used for wall construction (b) mapped faults density and (c) distance to the nearest mapped fault line

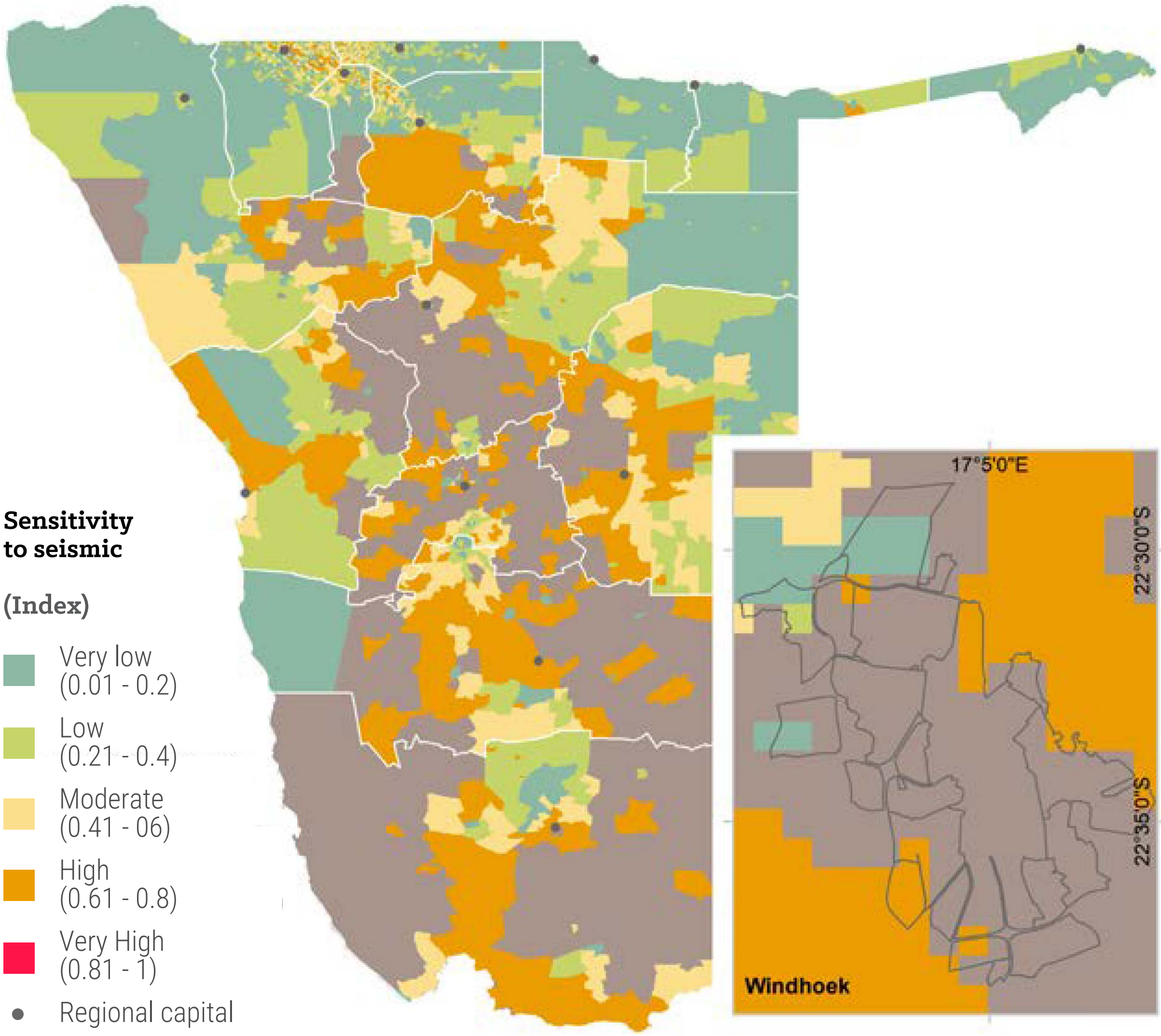


Figure 70: Spatial distribution of the sensitivity to seismic activities

10.4 ADAPTIVE CAPACITY TO SEISMIC ACTIVITIES

Adapting to seismic activities requires building earthquake-resistant structures. Without such buildings, the adaptive capacity for earthquakes is near zero. Earthquake-resistant buildings are rare in Namibia. Two known hostel blocks were constructed recently in Anker for Edward //Garoeb Primary School (see Figure 71). Anker is a few kilometres west of Kamanjab and is in the area with the highest density of seismic activities. Earthquake-resistant buildings were constructed following the damage of the previous cement-brick hostel caused by an earthquake in March 2018. In view of rare earthquake-resistant building structures across the country and the unavailability of requisite data, the adaptive capacity for seismic activities was set to zero. As a result, the vulnerability was basically a summation of exposure and sensitivity.

Figure 71: An earthquake-resistant hostel block constructed recently in Anker for Edward //Garoeb Primary School, Kunene Region

10.5 VULNERABILITY TO SEISMIC ACTIVITIES

Areas with a high vulnerability index for seismic activities are concentrated in the central and southern parts of the country (Figure 72). Some isolated areas have very high vulnerability. Areas with high vulnerability either have a high density of fault lines, and high proportions of buildings, or most building structures are sensitive to earthquakes. The whole of Windhoek has either high or very high vulnerability to seismic activities. Windhoek is in an area with a high density of fault lines. A notable number of north-south running faults also occur west of Mariental.

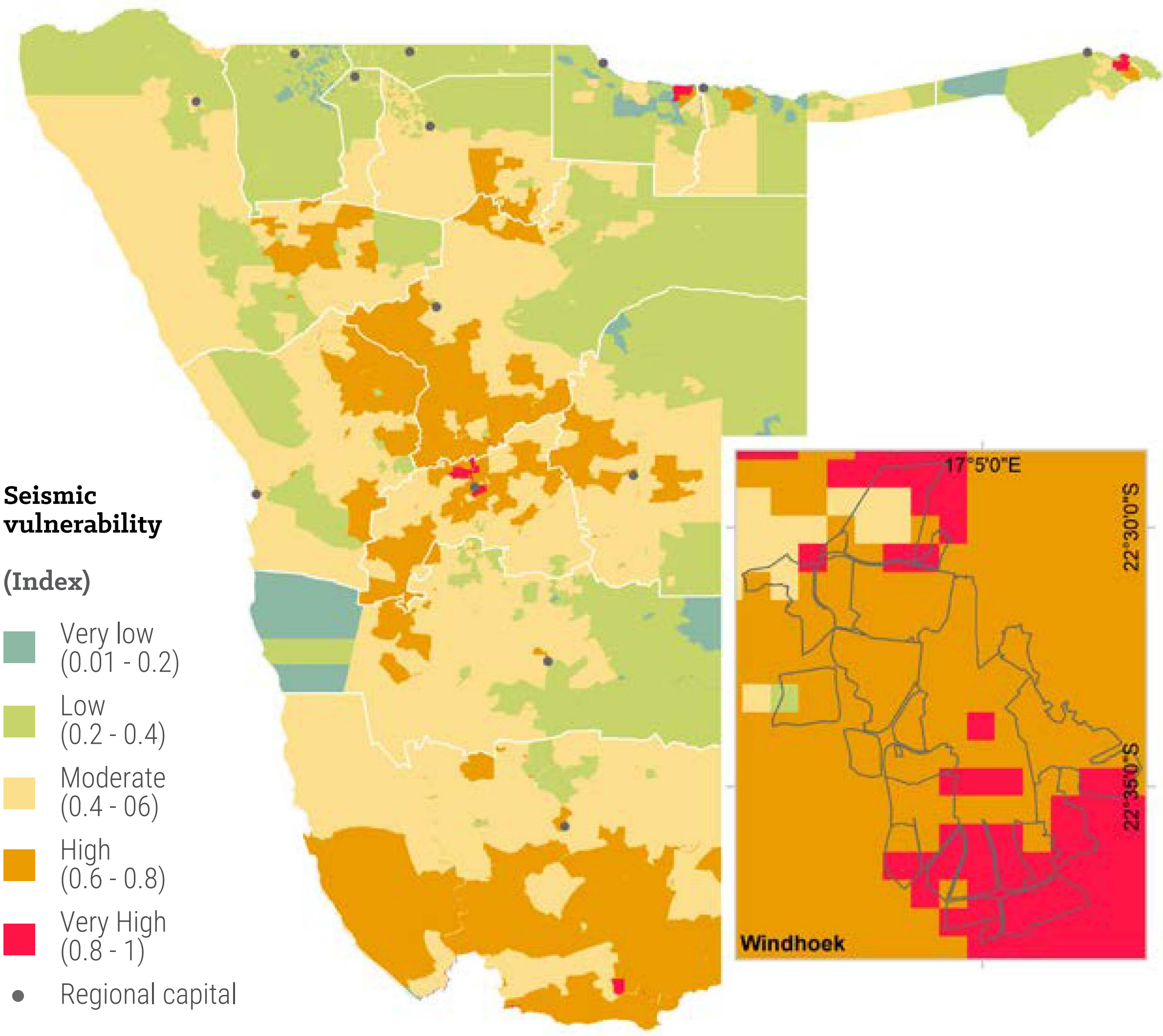


Figure 72: Spatial distribution of the vulnerability to seismic activities

10.6 SEISMIC RISK

High and very high seismic risk is limited to four clusters of EAs (Figure 73). Two clusters are in the //Kharas Region, one cluster is in the area around Windhoek-Okahandja in the Khomas and Otjozondjupa regions, and the other cluster is in the Kamanjab area in the Kunene Region. The EA which covers Anker has the highest seismic risk. The rest of the country has very low to moderate risk.

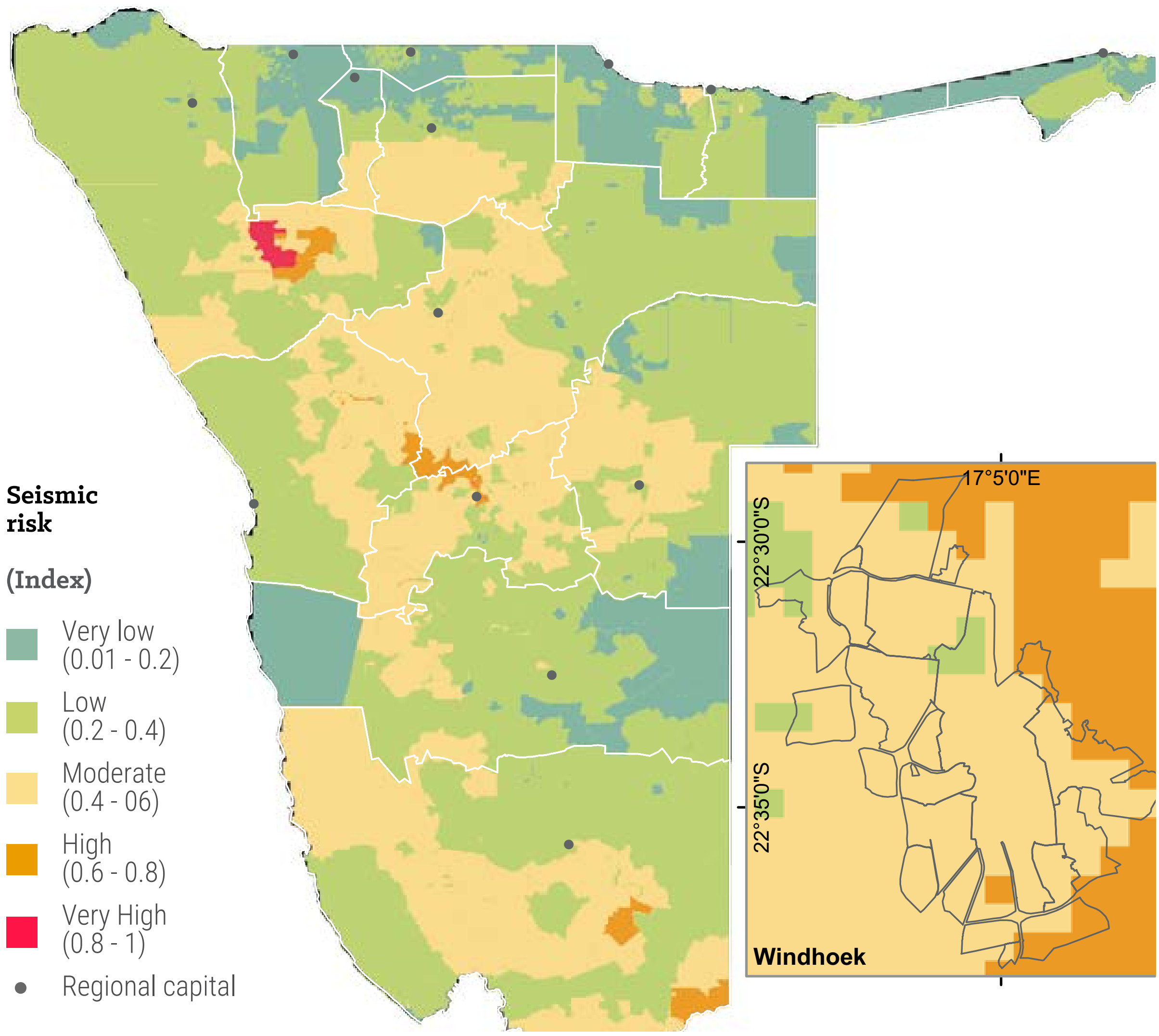


Figure 73: Spatial distribution of the risk to seismic activities

11

SEA LEVEL RISE VULNERABILITY AND RISK ASSESSMENT

SEA LEVEL RISE VULNERABILITY AND RISK ASSESSMENT

11.1 SEA LEVEL RISE HAZARD

Sea level rise, as a result of climate change, threatens coastal regions across the globe. Namibia has a coastline of 1572 km along the Atlantic Ocean, stretching from the Orange River Mouth in the south to the Kunene River Mouth in the north. Human settlements have been established along the coast albeit in a few locations.

Major towns along the coast are Oranjemund, Nami≠nü, Walvis Bay, Swakopmund and Henties Bay. Currently, no noticeable sea level rise has been reported along the Namibian coast. In future, however, climate change could trigger sea level rise on the Namibian coast. In this context, the elevation above sea level was used as the basis for establishing areas under threat from sea level rise in relation to current predictions.

11.2 EXPOSURE TO SEA LEVEL RISE

Buildings are the ones that are directly exposed to a sea level rise. For this reason, the building footprints (Figure 22) were used as exposure to sea level rise in this profile. For each EA along the coastal area of Namibia, the proportion of building footprints (Figure 74) was computed as a fraction of the total number of building footprints in the country. The proportion of building footprints is high in the EAs in Walvis Bay and Swakopmund. EAs with a high proportion of building footprints were considered to have high exposure. Note that other infrastructures like bridges were not considered due to data limitations.

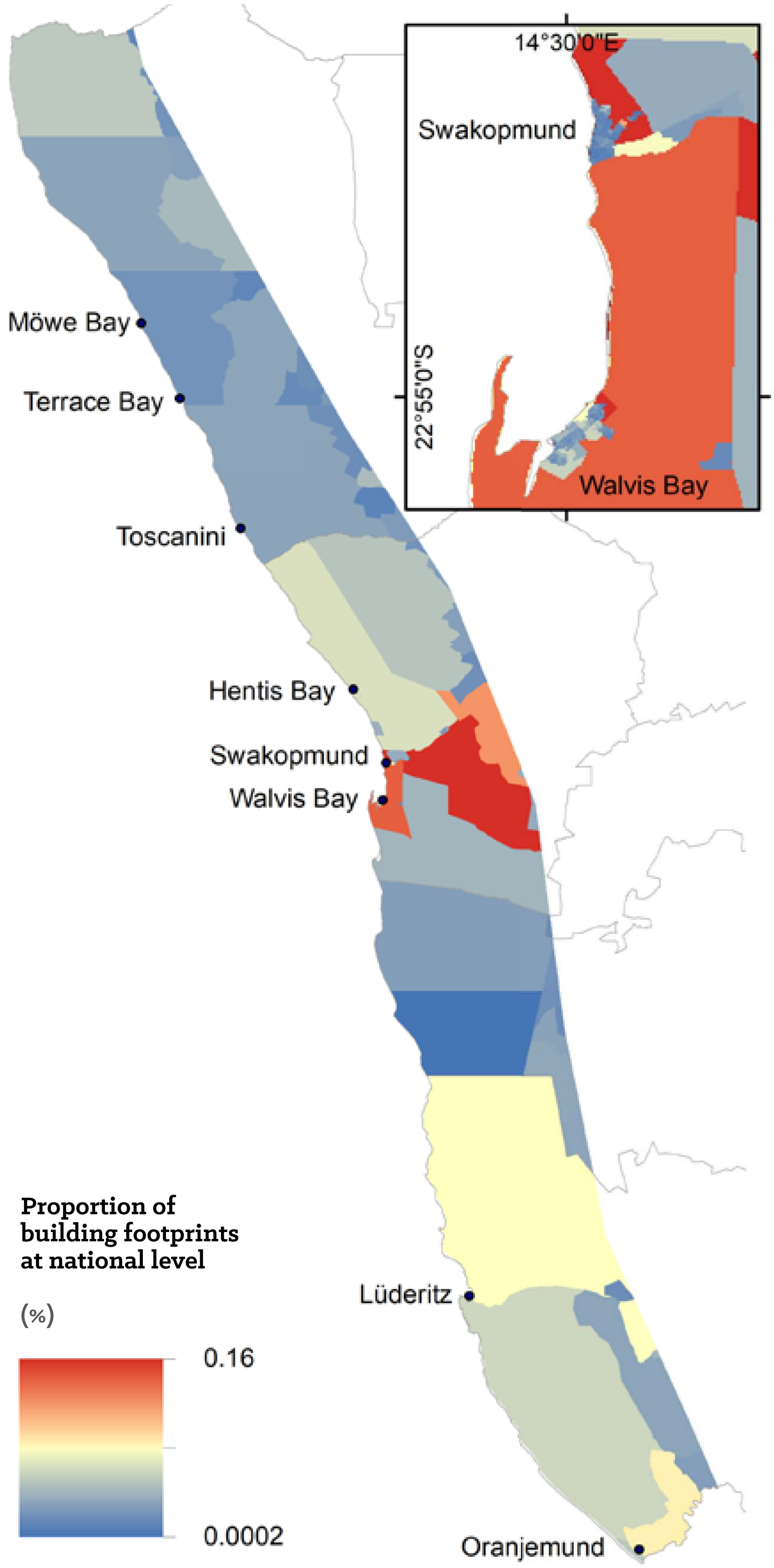


Figure 74: Proportion of building footprints per Enumeration Area along the Namibian coastline

11.3 SENSITIVITY TO SEA LEVEL RISE

Slope steepness was used as a measure of sensitivity to sea level rise (Figure 75). Steep areas along the coast are regarded as less sensitive to sea level rise when compared to flat ones. In the context of sea level rise analysis, a digital surface model with a finer spatial resolution is preferable. However, Namibia does not have a fine-resolution digital surface model covering the entire 1,572 km coastline. The slope steepness was derived from a 30 m resolution Advanced Land Observing Satellite (ALOS) Digital Surface Model (AW3D30). Given the coarser resolution of AW3D30, the accuracy level in identifying areas sensitive to sea level rise is limited.

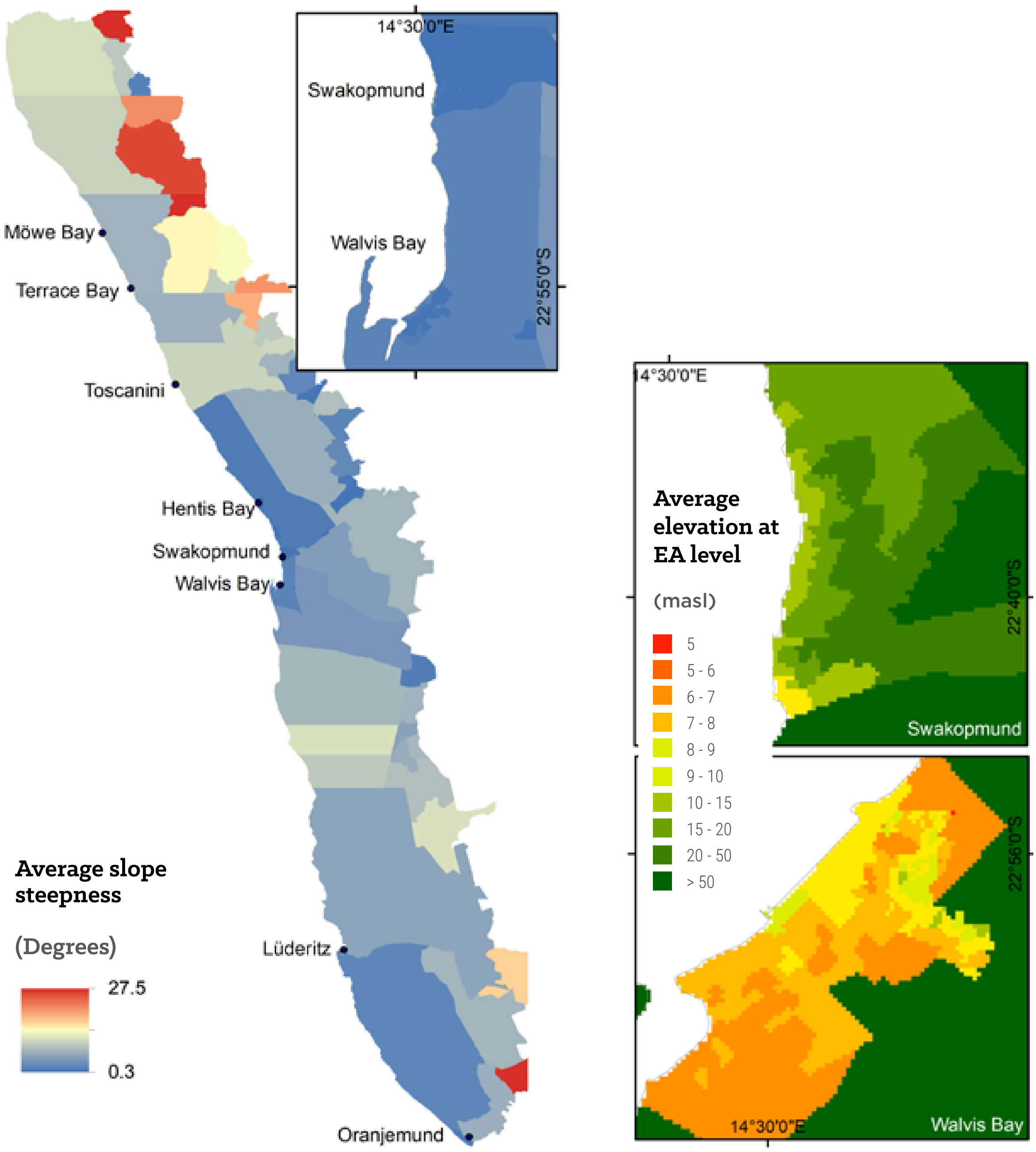


Figure 75: Slope steepness along the coast derived from Advanced Land Observing Satellite (ALOS) Digital Surface Model (AW3D30)

11.4 ADAPTIVE CAPACITY TO SEA LEVEL RISE

Average median income per capita was used as the adaptive capacity for sea level rise based on the premise that people with relatively high incomes are likely to build structures which can cope better with sea level rise. These measures include potential modification to their surroundings to protect or make their building structures more resilient against sea level rise. EAs with high median income per capita were mainly concentrated in Walvis Bay and Swakopmund (Figure 76).

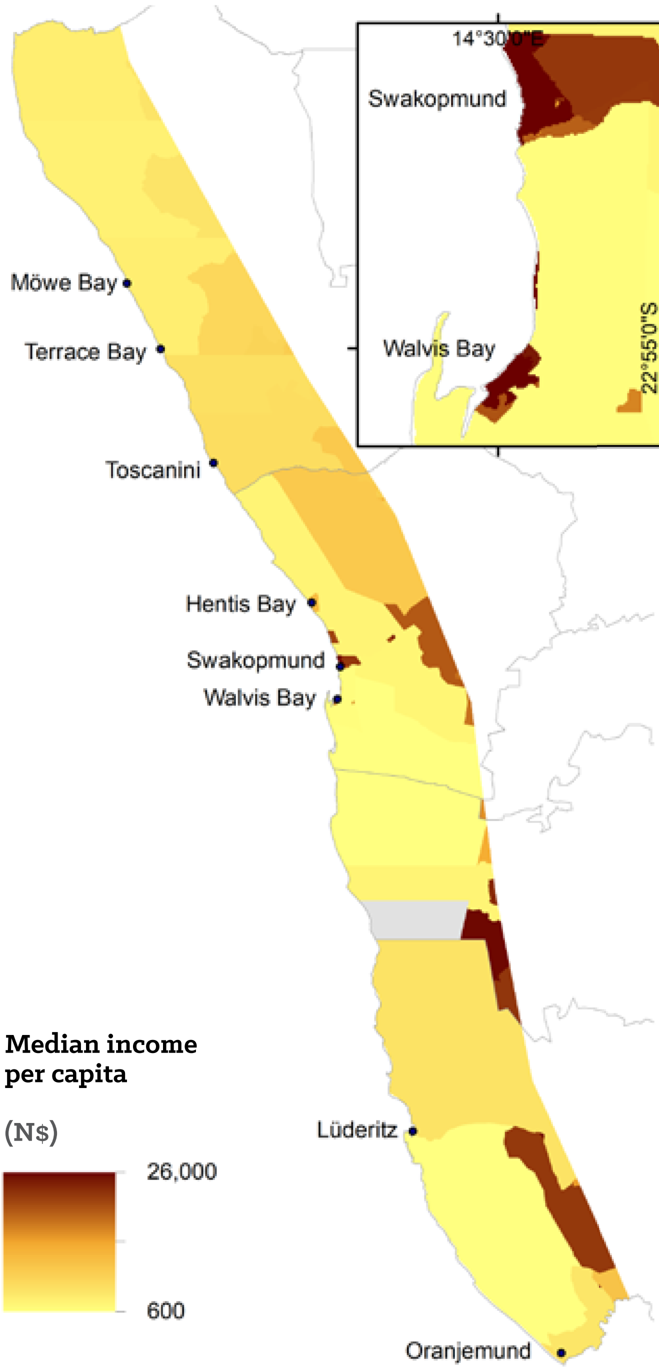


Figure 76: Median income per capita per Enumeration Area along the Namibian coastline

11.5 VULNERABILITY TO SEA LEVEL RISE

EAs with the highest vulnerability to sea level rise were in Swakopmund and Henties Bay (Figure 77). Some EAs in Walvis Bay also have moderate to high vulnerability.

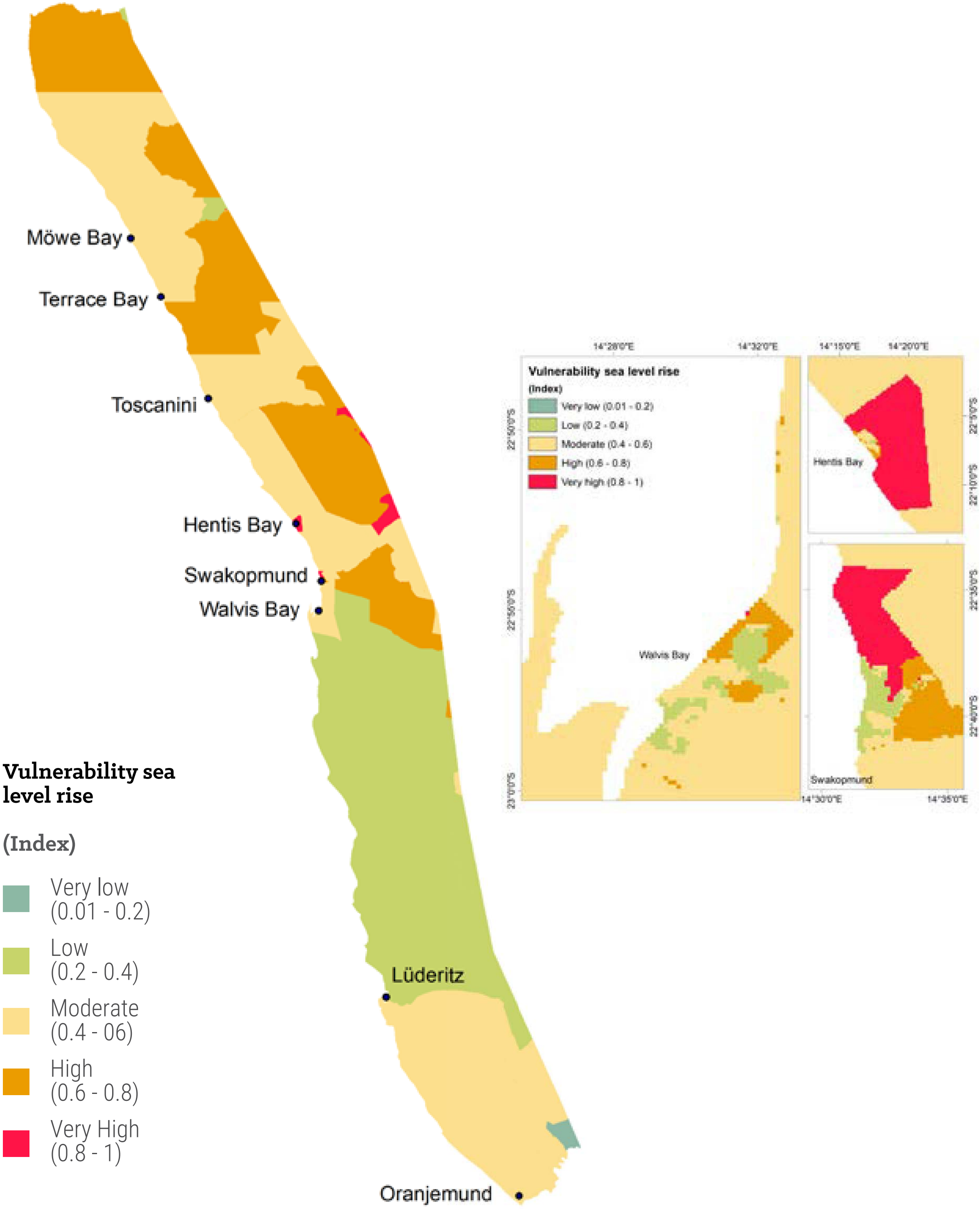


Figure 77: Spatial distribution of the vulnerability to sea level rise along the Namibian coast

11.6 SEA LEVEL RISE RISK

Along the entire 1572 km coastline, Henties Bay and the northern part of Swakopmund have the highest risk for sea level rise (Figure 78). The rest of the coastline has very low to moderate risk. Areas with high to very high risk in Henties Bay and Swakopmund are of great concern because of the density of buildings and limited protection. Resilience-building efforts should, therefore, target these areas to mitigate the risk.

Figure 78: Spatial distribution of the vulnerability to sea level rise along the Namibian coast

12

DISEASE VULNERABILITY AND RISK ASSESSMENT

DISEASE VULNERABILITY AND RISK ASSESSMENT

There are many infectious disease outbreaks or symptoms of infections that may affect a significant human or animal population in a country. This profile singled out malaria, COVID-19, HIV/AIDS and diarrhoea for the human population, while foot and mouth disease is pursued in relation to animals. Tuberculosis is covered rudimentary due to data limitations. The selection of these diseases was guided by their occurrence in the country, the perceived socioeconomic impact, and data availability. These diseases are covered in the next subsections of this chapter, beginning with malaria.

12.1 MALARIA

12.1.1 Malaria hazard

Along with a network of local and international partners, Namibia has been relentless in the fight against malaria. As Figure 79 shows, incidences of malaria dropped from over 500,000 cases per year in the early 2000s to less than 15,000 in the last three years across the country. This translates into a decrease of over 40 folds. Likewise, the number of deaths due to malaria decreased at the same rate from about 1,800 to below 50 over the same period.

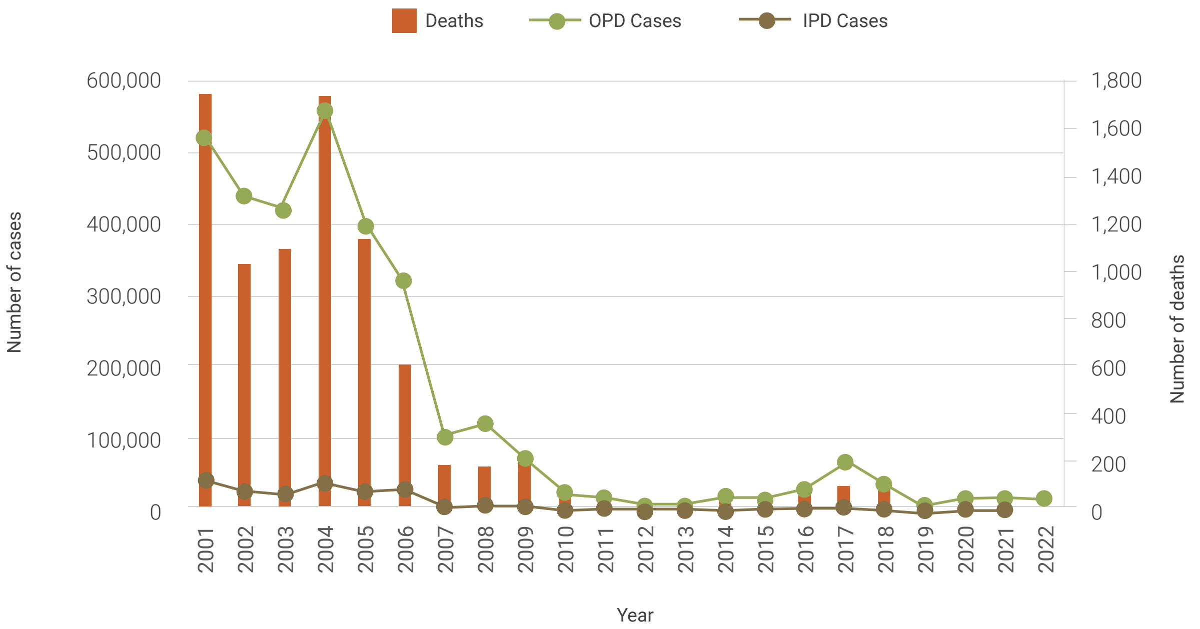


Figure 79: Number of malaria cases and deaths in Namibia from 2001 to 2022. Note: OPD = outpatient department; IPD = indoor patient department

While these cases are reported across the country, local transmission is thought to be limited to areas where climatic conditions are favourable for Anopheles mosquitoes, which transmit malaria. As such, malaria is common in the northern half of Namibia, with the Zambezi, Kavango East, Kavango West, Ohangwena, Oshana and Omusati regions being most affected.

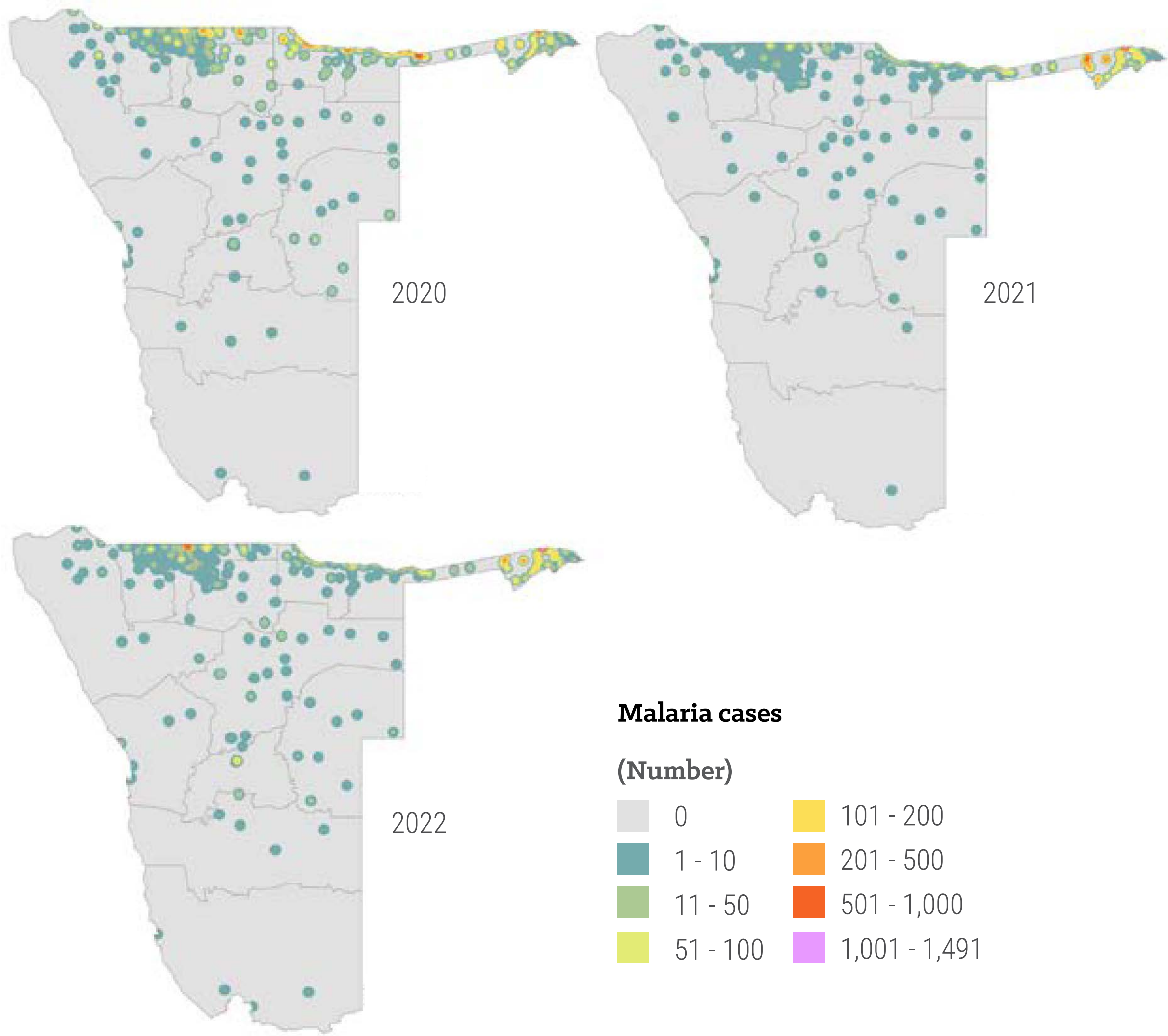


Figure 80: Spatial distribution of malaria cases by health facility in Namibia from 2020 to 2022

In recognising this success in the fight against malaria thus far and to guide targeted intervention, the risk profiling for malaria used data covering the last three years. Health centres that reported significant cases of malaria during the last three years are in the Zambezi, Kavango East, Kavango West, and Ohangwena regions (Figure 80). However, the Zambezi region had about 52% of all malaria cases in 2022, while no region was as dominant in 2020 and 2021. The lopsided figure of the 2022 cases in the Zambezi Region is likely due to the success achieved in other regions. For a representative distribution of malaria, it was deemed necessary to aggregate malaria cases from health centres to the nation's 34 health districts, and subsequently to the EA for generating the malaria hazard.

12.1.2 Exposure to malaria

Although malaria also affects animals, the analysis for the profile limited the exposure to the human population only. As such, we combined the human population density (Figure 9) and proportion of household (Figure 10) datasets to create the exposure index as described in Section 3.2.

12.1.3 Sensitivity to malaria

The sensitivity of people to malaria is linked to the Plasmodium parasites that cause malaria, which in turn depends on the presence of Anopheles mosquitoes for transmission. The temperature of 17 to 33 °C favours the development and survival rate of both the parasite and Anopheles mosquitoes (Beck-Johnson et al. 2013). We, therefore, adopted the malaria belt suggested by Gething et al. (2011) as part of defining the sensitivity of people who are in areas with a favourable climate for Anopheles mosquitoes.

The presence of water is also another critical environmental condition for supporting a thriving population of Anopheles mosquitoes. Surface water frequency (Figure 18), which was derived and described in Section 4.1, was subsequently incorporated in the calculation of the sensitivity index. We also factored distance to surface water (Figure 81) in calculating the sensitivity index because the proximity to stagnant water bears significant exposure to mosquitoes. Since we relied on satellite-derived water masks at 30 m resolution, it is expected that the water mask dataset missed small stagnant water bodies, especially in urban areas where a proper sewage system is lacking or in gardens.

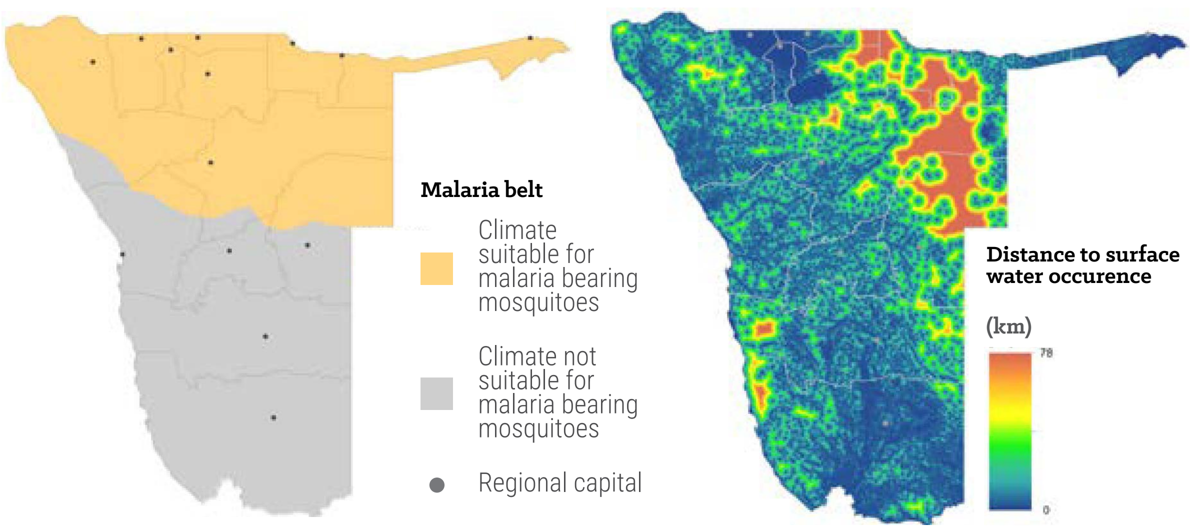


Figure 81: (a) Malaria belt and (b) distance to surface water occurrence

12.1.4 Adaptive capacity to malaria

Relentless efforts mentioned earlier in the fight against malaria are multi-pronged endeavours. At a personal level, people resort to using mosquito bed nets (some of which are impregnated with insecticide), wearing clothes that cover most of the body, and the use of insect repellent on exposed skin. The Namibian government has also established effective indoor residual spraying in malaria-prone zones. Data related to these activities are either non-existent or not collated. The absence of such datasets rendered the adaptive capacity to malaria not factored in the profile.

12.1.5 Vulnerability to malaria

Vulnerability to malaria is most pronounced in the Ohangwena, Oshikoto and Oshana regions (Figure 82) where more than 200,000 people reside in areas with very high vulnerability (Table 11). High vulnerability extends from these regions to include the northern half of Omusati, eastern Kunene, along the Kavango River and eastern Zambezi. Gam in the Otjozondjupa region also stands out as being highly or very highly vulnerable to malaria (Figure 83). The rest of the country falls under nearly equal proportions of low and moderate levels of vulnerability, with clusters of very low or negligible vulnerability scores.

Table 11: Distribution of population by malaria vulnerability level in each region of Namibia

Malaria vulner-ability level	Erongo	Hardap	Kho-mas	Kunene	Ka-vango East	Ka-vango West	Ohang-wena	Oma-heke	Omu-sati	Oshana	Oshi-koto	Otjo-zond-jupa	Zam-bezi	//Kha-ras
None	0	0	0	0	0	0	0	351	0	0	0	0	0	0
Very low	15684	47583	78434	0	0	1483	206	19980	0	0	0	5078	0	25603
Low	81978	31539	169681	2270	2614	12847	2157	27959	0	0	5070	23160	0	29878
Moder-ate	31061	12517	80175	50364	48030	42276	59994	13774	71991	31039	60493	55120	30834	15022
High	7479	0	12934	14491	59094	14737	84125	1191	133362	74504	75082	21195	28995	2231
Very high	729	0	0	2966	11775	9141	75229	606	16148	47216	15047	17308	17204	0

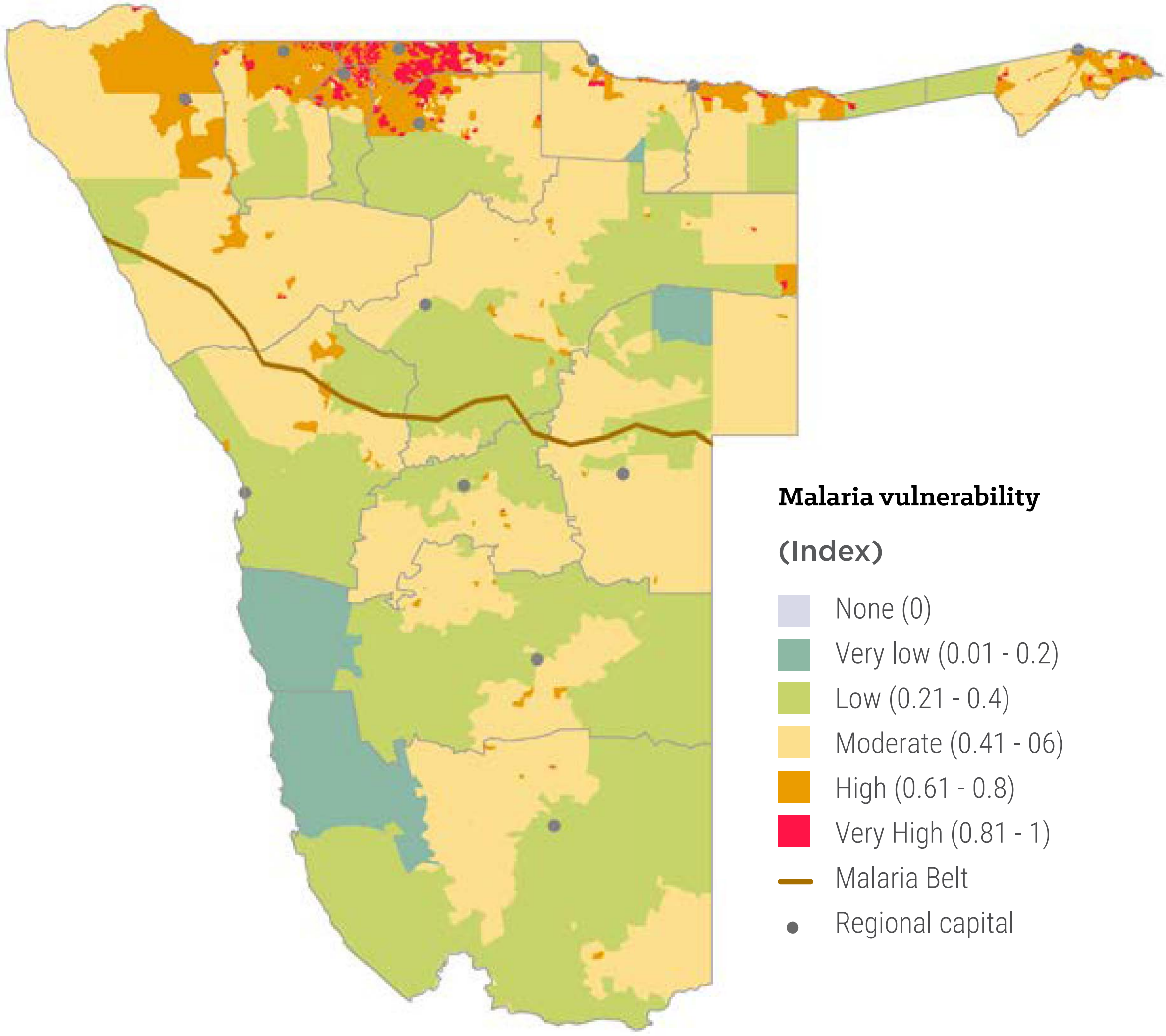


Figure 82: Spatial distribution of the vulnerability to malaria

12.1.6 Malaria risk

The recent trend in the drastic reduction of malaria cases in Namibia resulted in the Zambezi floodplains as the only place in the country with people at a high and very high risk of malaria (Figure 83). The rest of the Zambezi Region falls under moderate or low-risk levels. Over 68,000 people in the Zambezi Region reside in areas with moderate to very high malaria risk (Table 12). A very low-risk level covers more than 90% of the remaining area in the country where the climate is favourable to Anopheles mosquitoes. The Omaheke, Khomas, and portions of the Erongo and Hardap regions are also included in the low-risk zone. The risk of malaria is negligible in a third of the country, with the //Kharas Region being the safest.

Table 12: Distribution of population by malaria risk level in each region of Namibia

Malaria risk level	Erongo	Hardap	Kho-mas	Kunene	Ka-vango East	Ka-vango West	Ohang-wena	Oma-heke	Omu-sati	Oshana	Oshi-koto	Otjo-zond-jupa	Zam-bezi	//Kha-ras
None	136708	91639	238201	30855	0	619	0	41138	69863	1452	24064	118908	0	72402
Very low	0	0	103023	39236	121513	79865	221711	22723	151638	151307	130785	2953	0	0
Low	0	0	0	0	0	0	0	0	0	0	0	0	8804	0
Moder-ate	0	0	0	0	0	0	0	0	0	0	0	0	12623	0
High	0	0	0	0	0	0	0	0	0	0	0	0	41254	0
Very high	0	0	0	0	0	0	0	0	0	0	0	0	14352	0

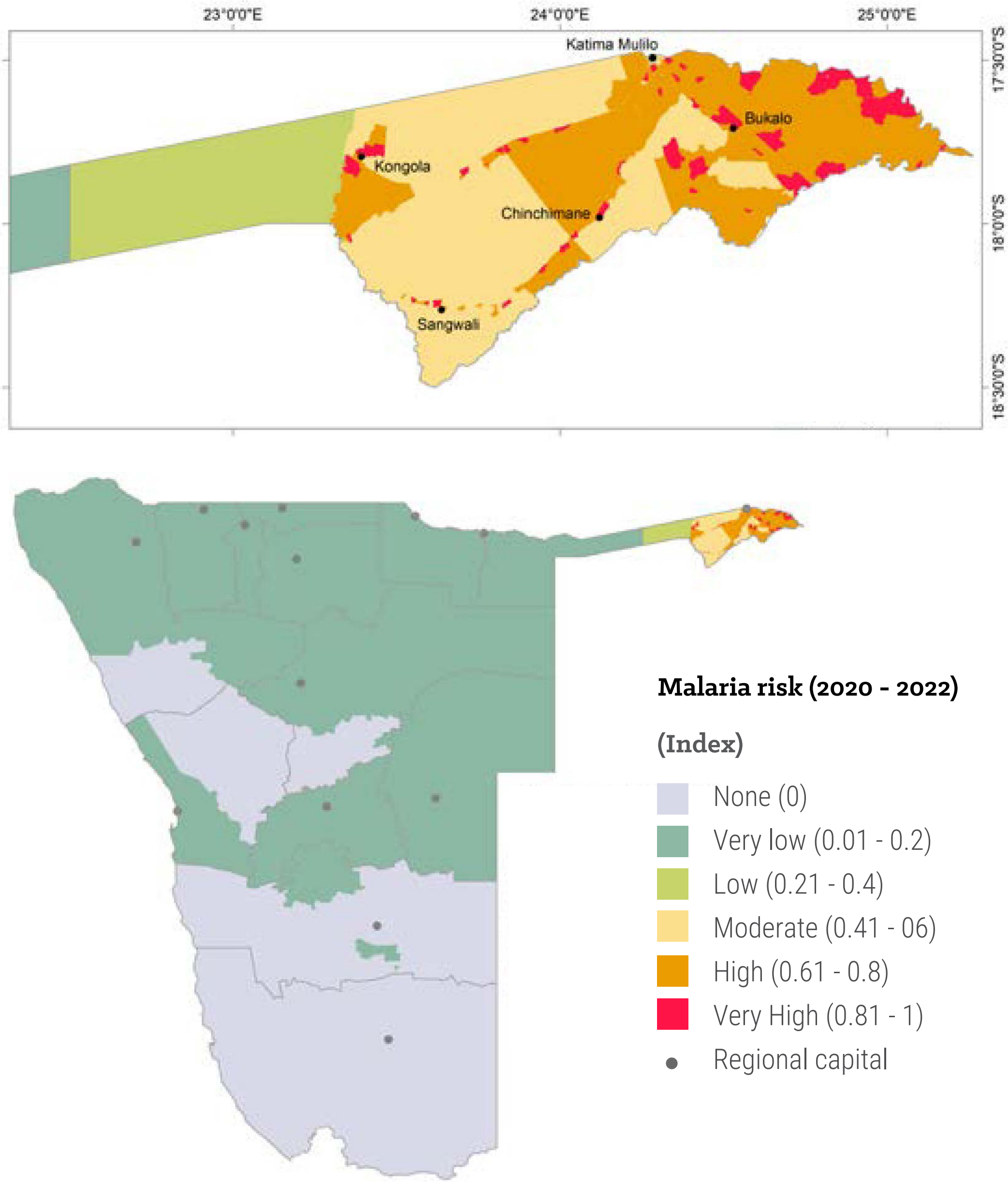


Figure 83: Spatial distribution of the risk to malaria

12.2 COVID-19

12.2.1 COVID-19 hazard

The outbreak of the coronavirus virus or COVID-19, which was first identified in the Chinese city of Wuhan in December 2019, was reported for the first time in Namibia on 13 March 2020. It was imported by a couple from Romania who were in Namibia as tourists. Four days later, President Hage Geingob declared a state of emergency on 17 March 2020, which precipitated the first nationwide lockdown on 28 March 2020.

The availed data for COVID-19 cases (Figure 84) was aggregated at the health district level. Cases of COVID-19 peaked in 2021 when approximately 120,200 people were infected and reported at health centres, while 5,090 people died (Figure 86). The number of cases and deaths dropped drastically in 2022 and remained very low in the first quarter of 2023. Just under half of the COVID-19 cases occurred in the Khomas Region. Walvis Bay (11,500 cases) and Oshakati (10,570) health districts were the next affected areas in the country. Nyangana and Aranos health districts reported cases below 500, the lowest for any district in the country.

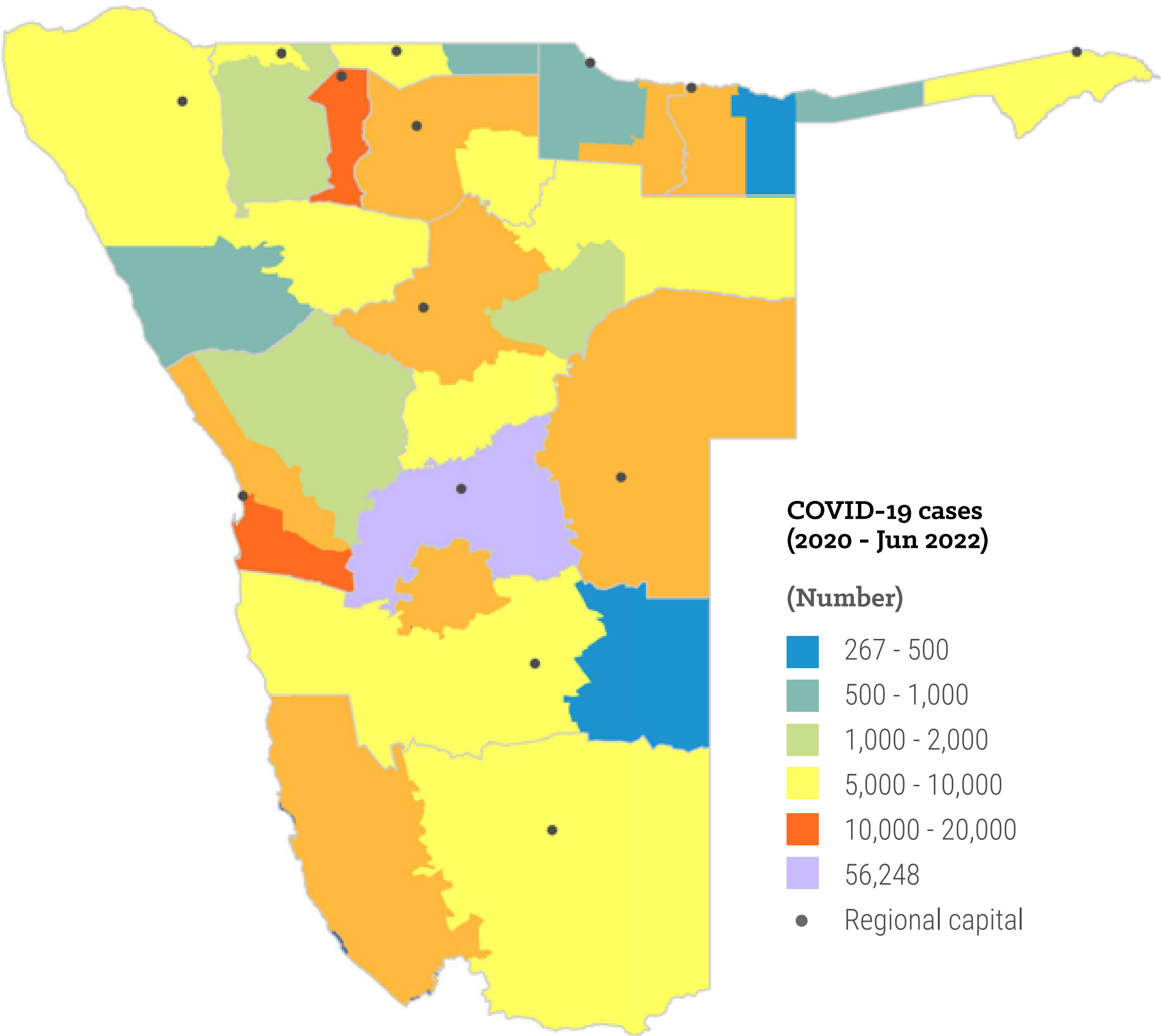


Figure 84: Number of COVID-19 Cases by health district from 2020 to June 2022

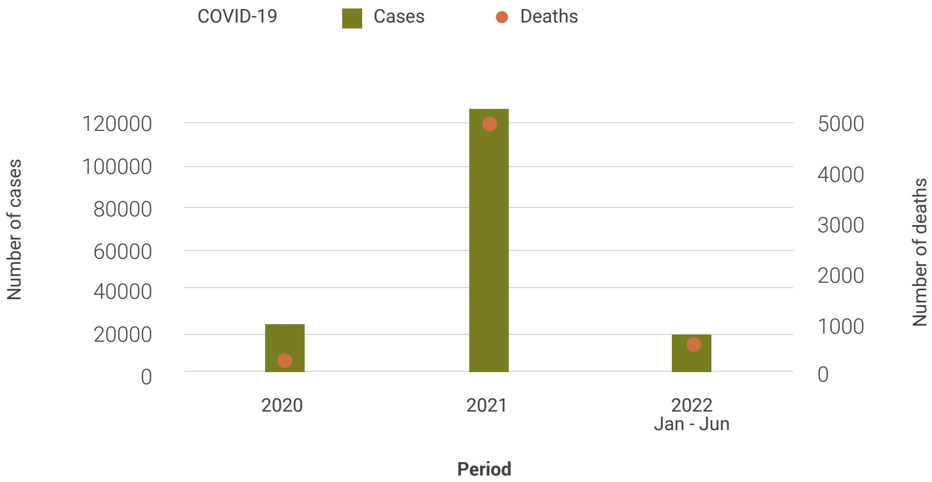


Figure 85: The number of COVID-19 cases and deaths by year from 2020 to June 2022

12.2.2 Exposure to COVID-19

Although the spreading mechanism is not well understood, current information suggests that the coronavirus can also spread from people to animals during close contact (Shi et al., 2020; Sit et al. 2020). For the purpose of this risk profile, only the human population was considered for exposure to the virus. The exposure index was thus determined based on the human population density (Figure 9) combined at an equal weighting with the dataset for the proportion of households (Figure 10).

12.2.3 Sensitivity to COVID-19

COVID-19 affects everyone. However, persons who are older than 60 years or who have health conditions like lung or heart diseases, diabetes or conditions that affect their immune system are more vulnerable to COVID-19 infection. The latest census data of 2011 contains information about the age category of people at the level of the EA. We exploited this dataset to derive two by-products for calculating the sensitivity index based on people aged 60 years and above. The population density of people aged 60 years and above in the EA was then combined at an equal weighting with the national proportion of the same age group at the same level of aggregation (Figure 86), which resulted in the sensitivity index. Data was not available for health conditions (such as those mentioned above) that may exacerbate COVID-19 infection and its impact.

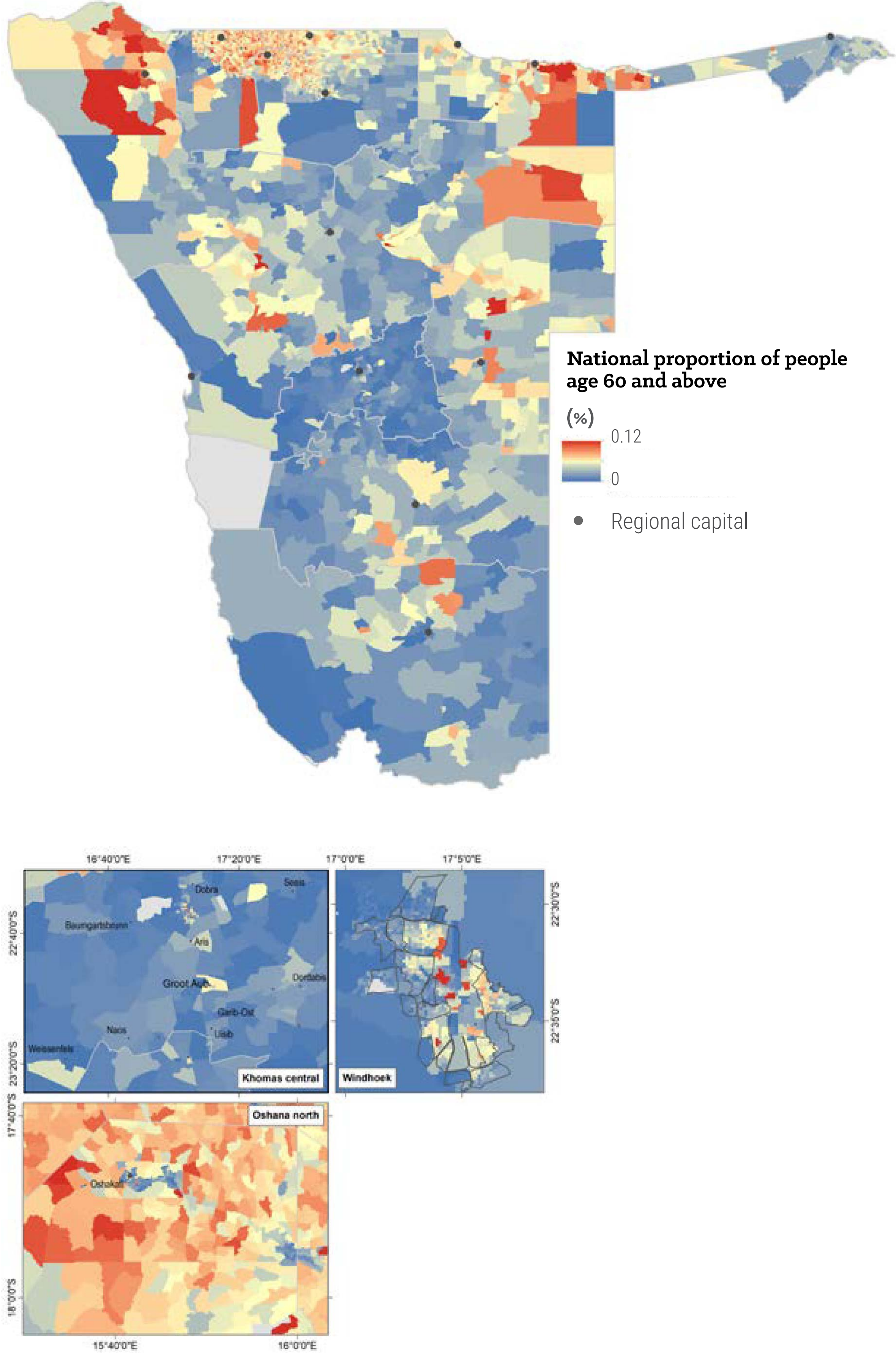


Figure 86: Proportion of persons aged 60 and above per Enumeration Area

12.2.4 Adaptive capacity to COVID-19

The most common forms of adaptive capacity in mitigating COVID-19 infection were a combination of lockdowns, (self) isolations, wearing of masks, immune boosting and COVID-19 vaccination. However, the available information, such as the number of lockdowns or people vaccinated in the country, is not suited for spatial analysis at the adopted level of analysis for the risk profile. Data for other mitigation efforts, such as the scale of isolations, wearing of masks and immune boosting, do not exist. As a result, no adaptive capacity was factored into the calculation of the vulnerability for COVID-19 disease.

12.2.5 Vulnerability to COVID-19

The vulnerability (Figure 87) of people to COVID-19 in Namibia is revealed in both rural settings and urban centres. Over 365,000 people reside in areas with high to very high vulnerability to COVID-19 (Table 13). The high and very high rate of vulnerability is particularly pronounced in core areas in Ohangwena, Oshana and Oshikoto regions. These are predominantly rural communities, as illustrated in Figure 87, centred around Oshakati. The greater part of Oshakati Urban has a very low or low vulnerability index. In contrast, there are significant numbers of EAs in Windhoek where the vulnerability to COVID-19 is high or very high. There are also areas in Kunene, Kavango East and Kavango West with high and very high levels of vulnerability to COVID-19. More than 80% of the country falls into very low or low levels of vulnerability.

Table 13: Distribution of population by COVID-19 vulnerability level in each region of Namibia

COVID-19 risk level	Erongo	Hardap	Khomas	Kunene	Kavango East	Kavango West	Ohangwena	Omaheke	Omusati	Oshana	Oshikoto	Otjozondjupa	Zambezi	//Kharas
Very low	52387	45708	138220	24497	9115	9016	8810	25340	17088	17265	20821	42850	21123	31469
Low	50107	24913	101514	30166	63059	39799	62514	28242	81168	52476	57705	31584	24244	20180
Moderate	24112	13419	51513	10144	32071	14850	51221	4717	87066	28784	58066	24253	19131	12938
High	9823	7599	47128	4098	12495	13369	73574	4866	32085	42626	16561	18934	12166	7339
Very high	903	0	2849	1186	4772	3450	25646	696	4094	11608	2539	4240	369	808

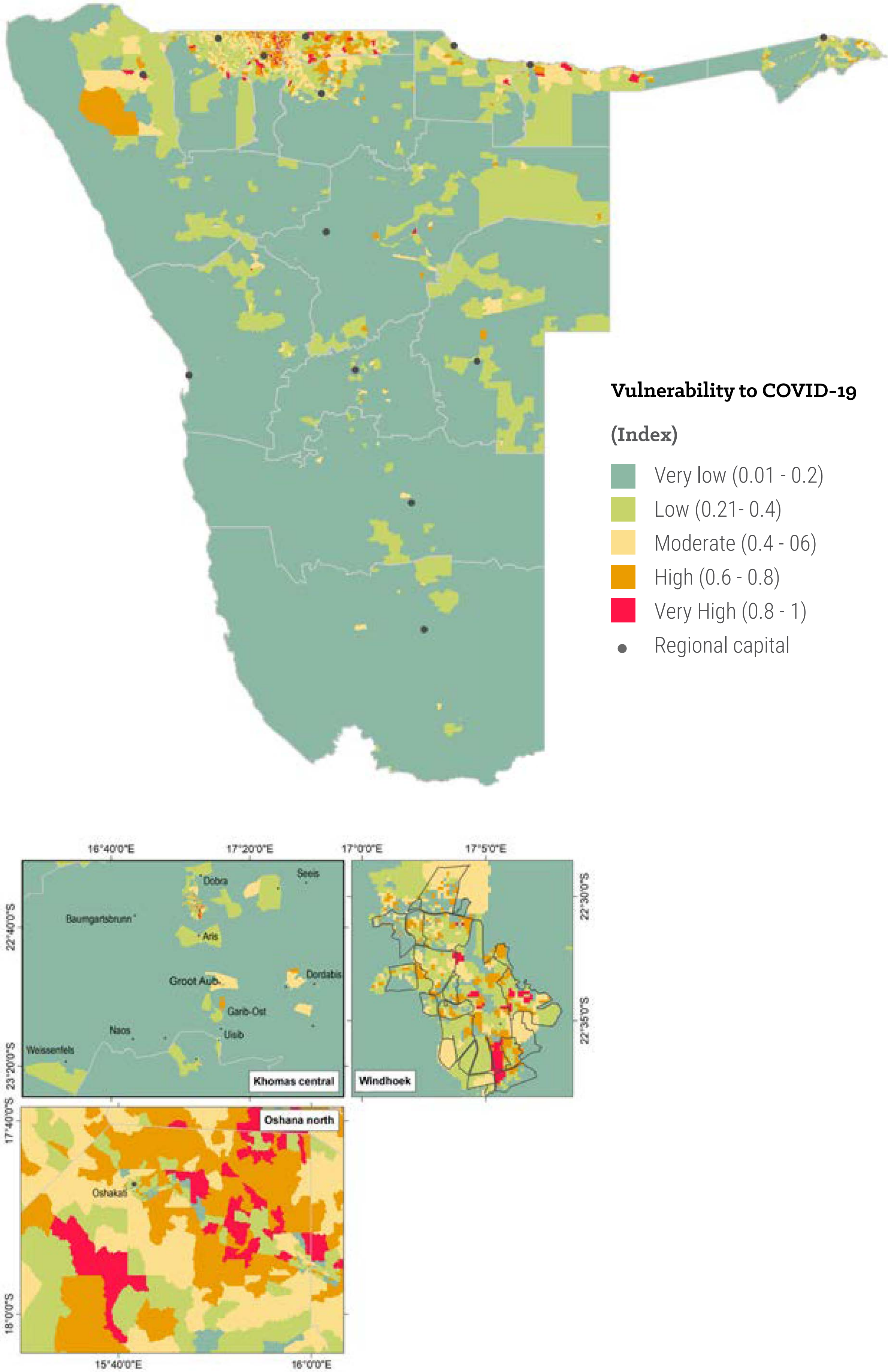


Figure 87: Spatial distribution of the Vulnerability to COVID-19

12.2.6 COVID-19 risk

The risk of COVID-19 in Namibia is highly localised. Significant areas of high and very high risk are in Windhoek and the surroundings (Figure 88). Much of the country is characterised by low and very low levels of risk of COVID-19 infections. Except for the Aranos Health District, areas with negligible levels of risk are in national parks with a small number of residents and even a much lower number of people aged 60 and above.

Table 14: Distribution of population by COVID-19 risk level in each region of Namibia

COVID-19 risk level	Erongo	Hardap	Kho-mas	Kunene	Ka-vango East	Ka-vango West	Ohang-wena	Oma-heke	Omu-sati	Oshana	Oshi-koto	Otjo-zond-jupa	Zam-bezi	//Kha-ras
Very low	137127	91639	126123	70091	121513	80484	221765	63861	221501	150211	155692	121861	76918	72734
Low	205	0	95496	0	0	0	0	0	0	2548	0	0	0	0
Moderate	0	0	49981	0	0	0	0	0	0	0	0	0	0	0
High	0	0	51194	0	0	0	0	0	0	0	0	0	0	0
Very high	0	0	18430	0	0	0	0	0	0	0	0	0	0	0

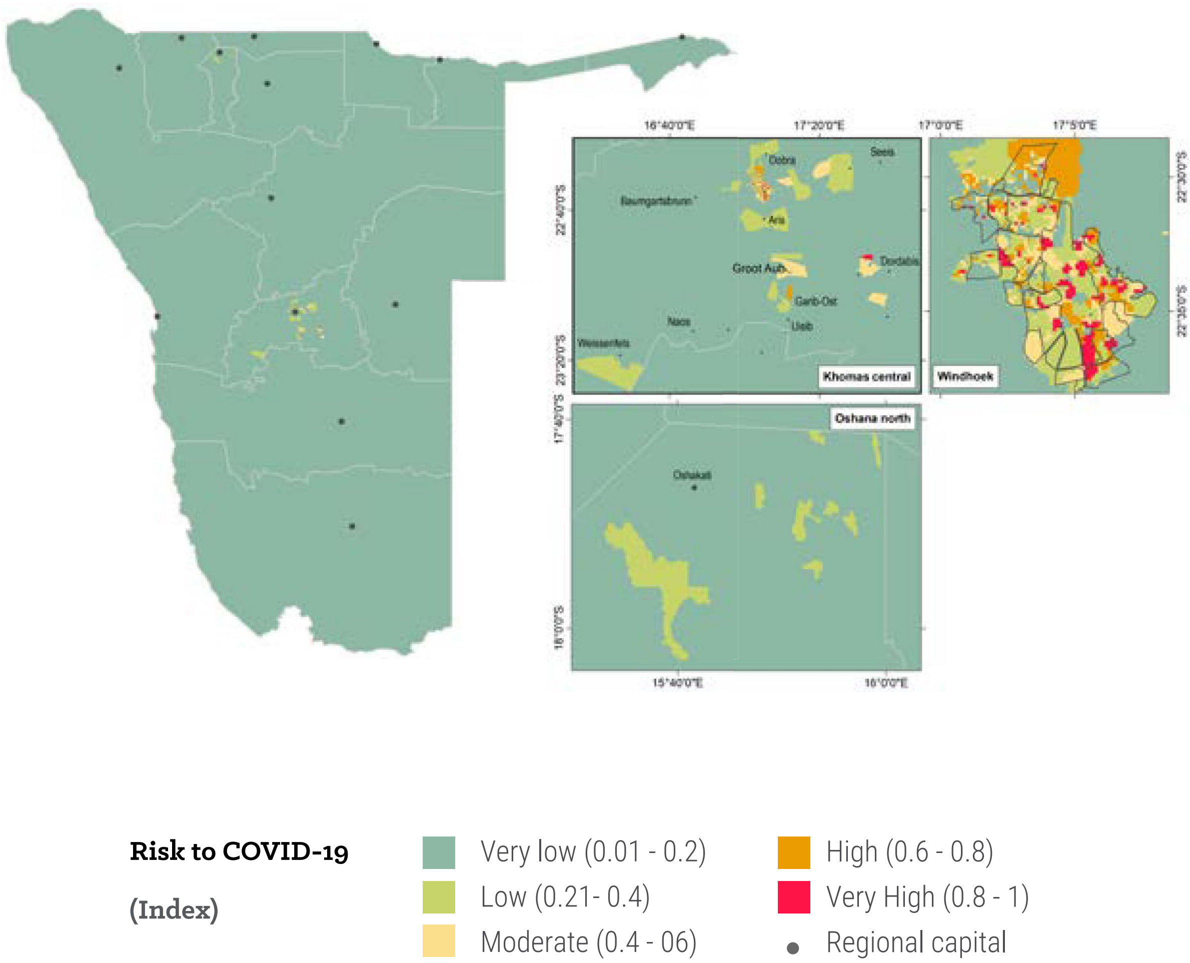


Figure 88: Spatial distribution of the risk of COVID-19

12.3 HIV/AIDS

12.3.1 HIV/AIDS hazard

The first case of the human immunodeficiency virus (HIV) was reported in Namibia in 1986 (Ministry of Health and Social Services [MoHSS], 2015). This virus attacks the body's immune system. If HIV is not treated, it can lead to acquired immunodeficiency syndrome (AIDS). Although this virus is reported in all regions, it predominantly affects the Khomas, Oshana, Ohangwena, Kavango East, and Omusati regions. Both deaths and infections have been on the increase since the early 1990s before starting to decline in 2004 (Figure 89). At its peak around 2002, it killed approximately 11,000 people annually, while the annual infections were estimated at 21,000. The annual infection has now declined to less than 2000 cases in 2022 (Figure 90). Until 2001, females were more infected than males.

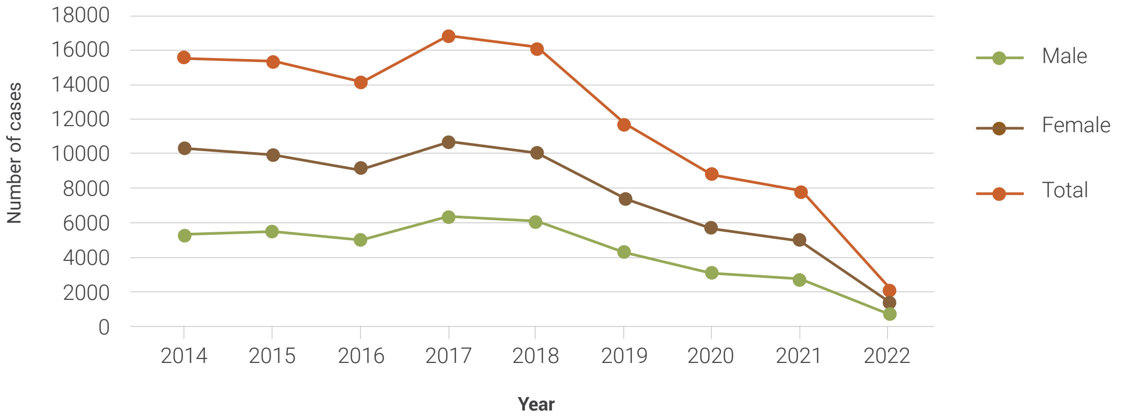


Figure 89: The number of HIV/AIDS-positive cases recorded at health facilities from 2014 to 2022

12.3.2 Exposure to HIV/AIDS

HIV/AIDS infects people of all ages. Most of the new HIV infections are transmitted through unprotected heterosexual sex and mother-to-child transmission. Other infections occur through co-morbidities and opportunism.

12.3.3 Sensitivity to HIV/AIDS

To calculate the sensitivity index, we used the prevalence rate and teenage pregnancies as proxies. The prevalence rate of 2016 (Figure 91; MoHSS, 2016) for each group was employed to estimate the number of people who are more sensitive to HIV infections in each EA (Figure 92). The number of teenage pregnancies at all health centres covers the 2012 - June 2022 period (Figure 93). On average, about 13,000 teenage pregnancies occurred in the country. However, teenage pregnancy increased from the annual average by over 11% in 2020 and 10% in 2021 (Figure 93). This increase could be attributed to the COVID-19 pandemic when school activities were disrupted. By June 2022, a total of 6085 cases of teenage pregnancy were reported countrywide.

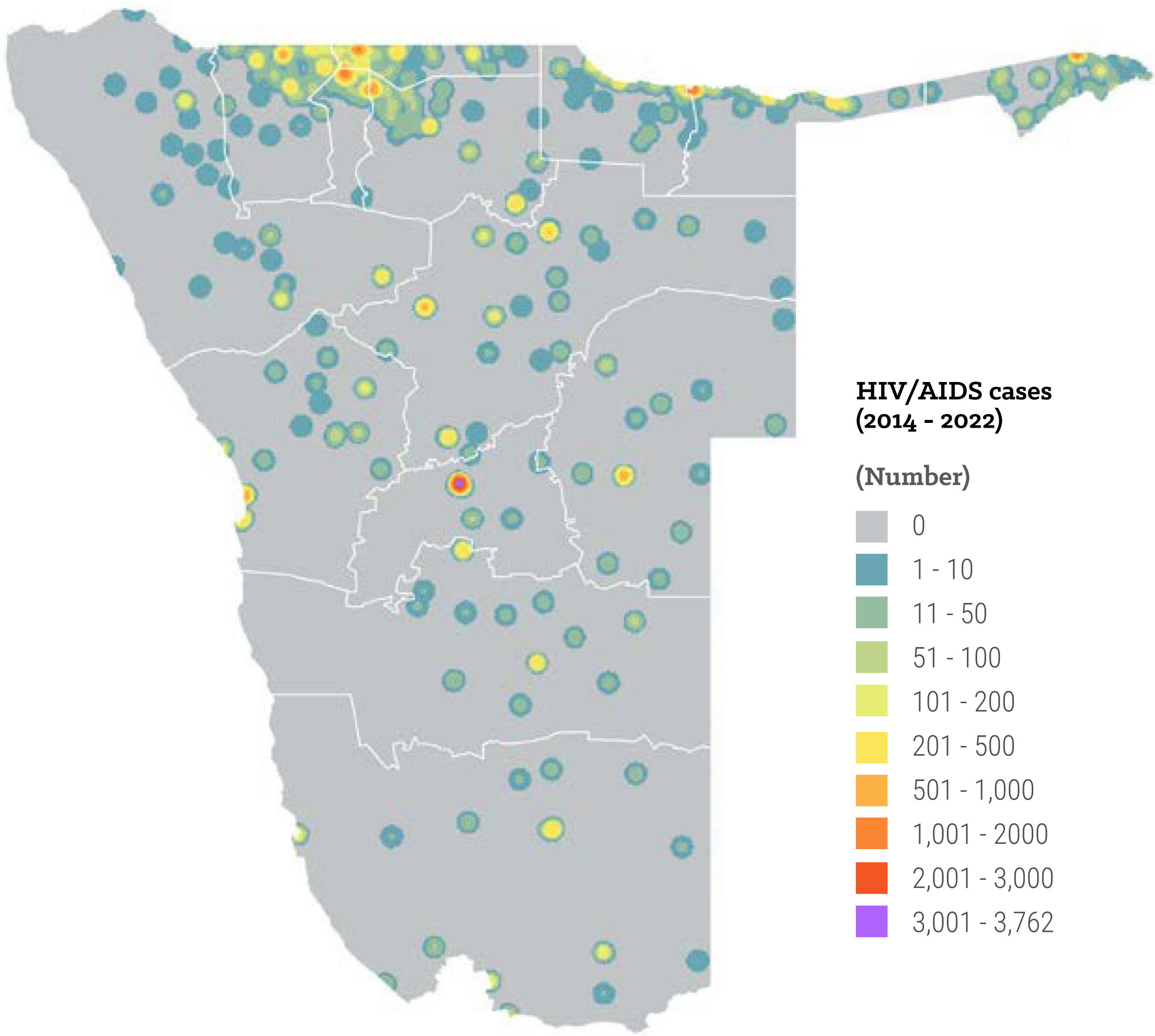


Figure 90: Spatial distribution of HIV/AIDS-positive cases recorded at health facilities between 2014 and 2022

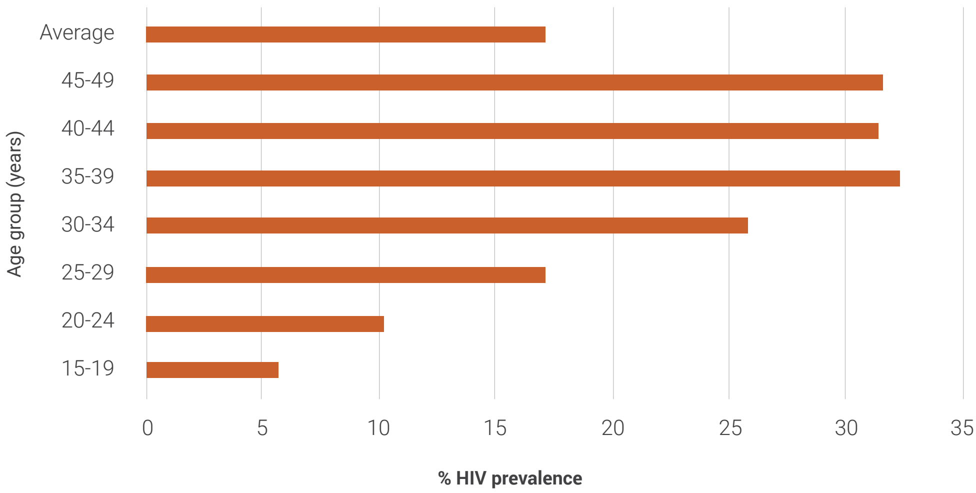


Figure 91: Prevalence of HIV/AIDS by age group in 2016 (MoHSS, 2016)

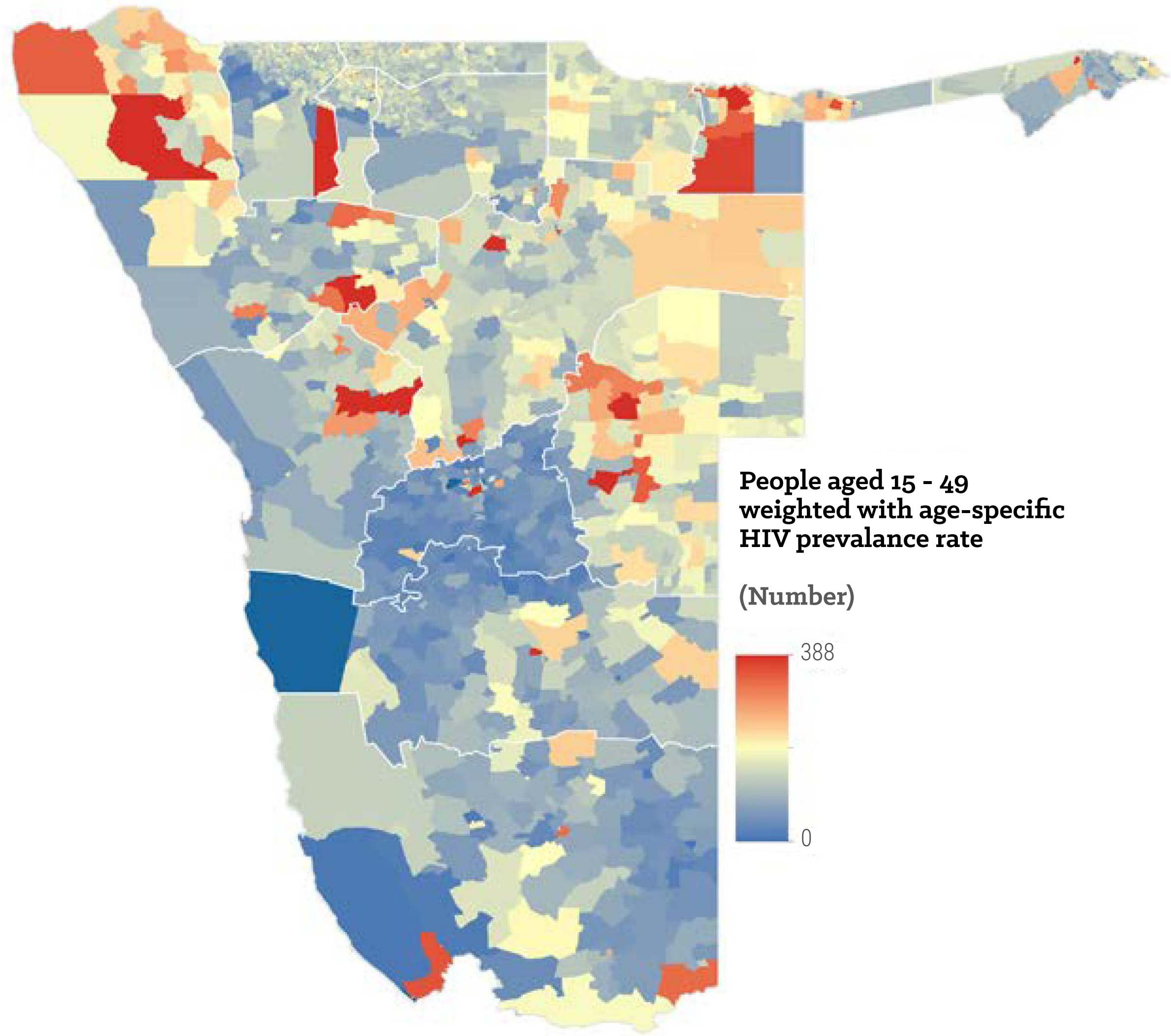


Figure 92: Number of people aged 15-49 weighted with age-specific HIV prevalence rate

12.3.4 Adaptive Capacity to HIV/AIDS

There are several initiatives in Namibia focusing on the fight against AIDS/HIV. These initiatives include scaling up the services pertaining to antiretroviral therapy; male circumcision; prevention of mother-to-child transmission; maintaining the high standard of blood safety for transfusion; promotion and distribution of condoms; and community mobilisation and awareness. However, there is no data available on any of these initiatives. As a result, the study did not factor in any adaptive capacity in the risk assessment for HIV/AIDS.

12.3.5 Vulnerability to HIV/AIDS

Khomas and all the northern regions are vulnerable to HIV infections (Figure 94). Within these regions, there are notable hot spots in the Khomas, Kavango East, Kavango West, Zambezi, Ohangwena, Oshikoto and Oshana. Except for Omaheke where a third of the region falls under a low vulnerability index, the remainder of the country is characterised by a very low vulnerability rating.

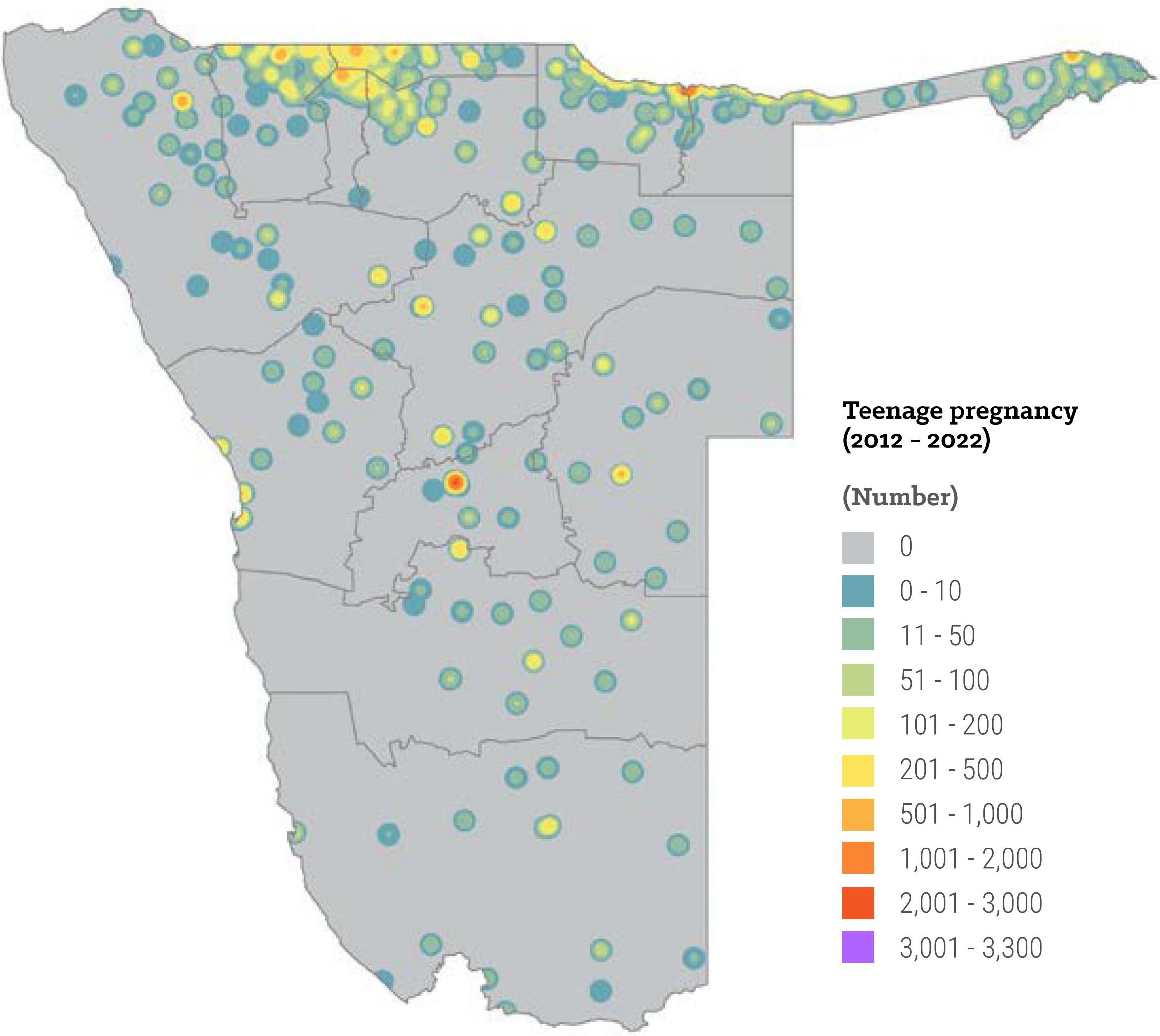


Figure 93: Number and distribution of teenage pregnancies recorded between 2012 and 2021 in Namibia

Table 15: Distribution of population by HIV/AIDS vulnerability level in each region of Namibia

HIV/ AIDS vulner-ability level	Erongo	Hardap	Kho-mas	Kunene	Ka-vango East	Ka-vango West	Ohang-wena	Oma-heke	Omu-sati	Oshana	Oshi-koto	Otjo-zond-jupa	Zam-bezi	//Kha-ras
Very low	47796	60607	0	23579	18864	252	5494	17469	42544	0	10173	56456	0	43630
Low	65009	27430	58422	41221	23697	29838	76105	37431	141957	51692	74583	42560	36531	24672
Moder-ate	23393	3531	192725	4874	31350	34175	93994	8961	37000	88571	64821	22845	30283	4432
High	132	71	88721	417	42566	11578	46118	0	0	12496	6115	0	10178	0
Very high	0	0	1356	0	5036	4641	0	0	0	0	0	0	0	0

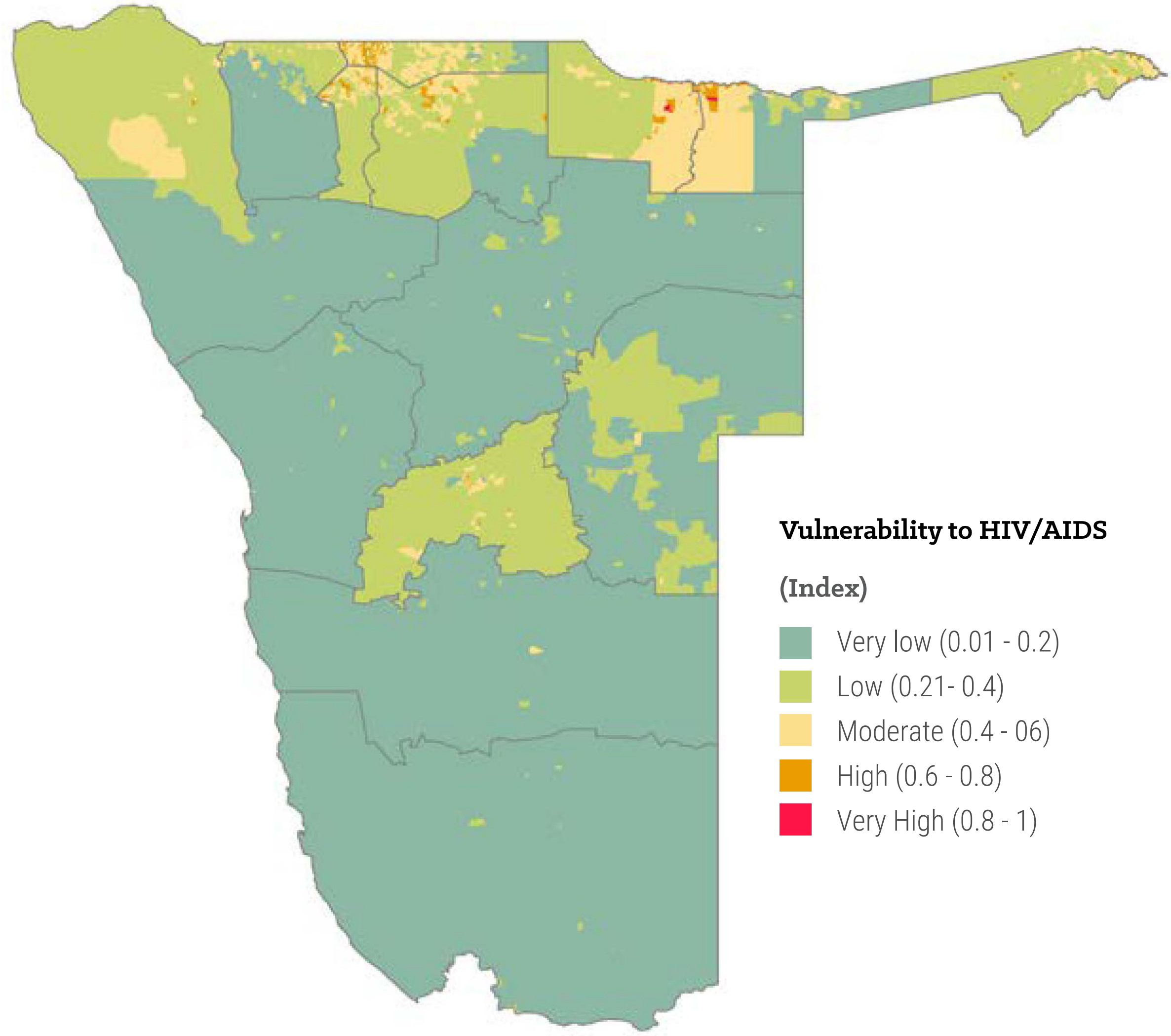


Figure 94: Spatial distribution of the vulnerability to HIV/AIDS

12.3.6 HIV/AIDS risk

Over 310,000 people reside in areas with moderate to very high HIV/AIDS risk (Table 16). The risk of HIV infections is rated highest in the Khomas and Kavango East regions (Figure 95). They are followed by the Oshana, Ohangwena, Oshikoto and Zambezi regions. The rest of the regions have a very low index of HIV risk.

Table 16: Distribution of population by HIV/AIDS risk level in each region of Namibia

HIV/ AIDS risk level	Erongo	Hardap	Kho-mas	Kunene	Ka-vango East	Ka-vango West	Ohang-wena	Oma-heke	Omu-sati	Oshana	Oshi-koto	Otjo-zond-jupa	Zam-bezi	//Kha-ras
Very low	136272	91024	0	70091	46998	42775	107573	63265	221501	37339	128111	121861	52367	72734
Low	0	544	58422	0	54761	29917	114138	242	0	114664	27581	0	24625	0
Moder-ate	0	0	192725	0	19754	7792	0	354	0	756	0	0	0	0
High	0	71	88721	0	0	0	0	0	0	0	0	0	0	0
Very high	0	0	1356	0	0	0	0	0	0	0	0	0	0	0

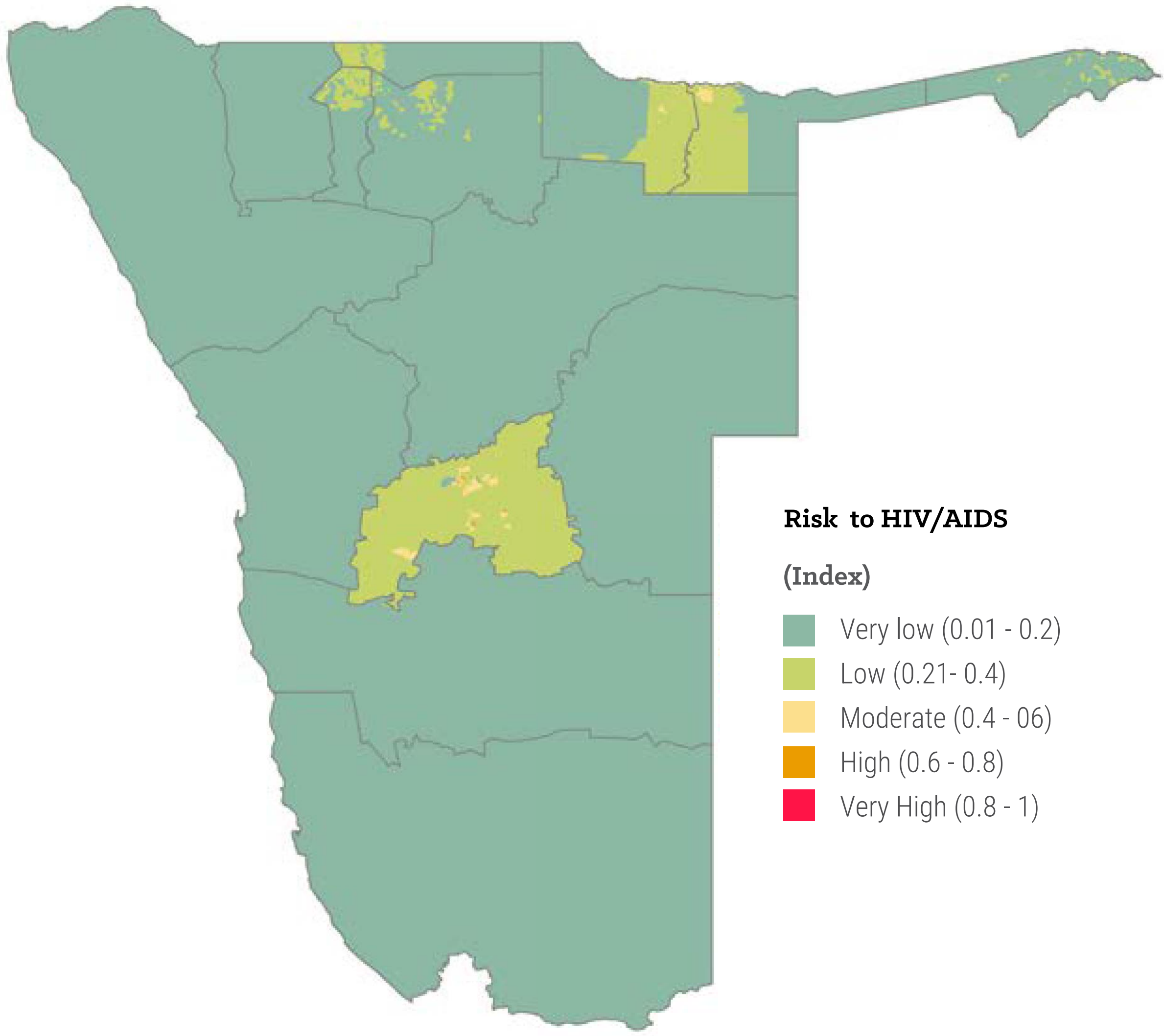


Figure 95: Spatial distribution of the risk of HIV/AIDS

12.4 DIARRHOEA

12.4.1 Diarrhoea hazard

Although there are many causes, diarrhoea is often a symptom of infections caused by bacteria, parasites, or viruses. It manifests itself as loose, watery, and possibly more frequent bowel movements. The stool may also have blood. Bacteria, parasites, and viruses can be spread through contaminated water, such as by faeces. Diarrhoea was thus included in the risk profile as a diagnostic symptom to help reveal the occurrence of bacterial, viral, and parasitic organisms in the environment across the nation.

Cases of diarrhoea with or without blood are recorded separately at health centres in the country. Available data dates to 2008. Diarrhoea without blood is severe in Windhoek, Rundu and Katima Mulilo (Figure 96), which recorded, respectively, an average of 26,000, 20,000 and 15,000 cases annually during the study period. It is also recorded in high numbers with an annual average of 4,000-6,000 cases at Oshakati, Onandjokwe, Eenhana, Outapi and Engela. Cases of diarrhoea without blood with an annual average between 1,000 and 3,000 are also noticeable along the Kavango River and at many health centres in all regions.

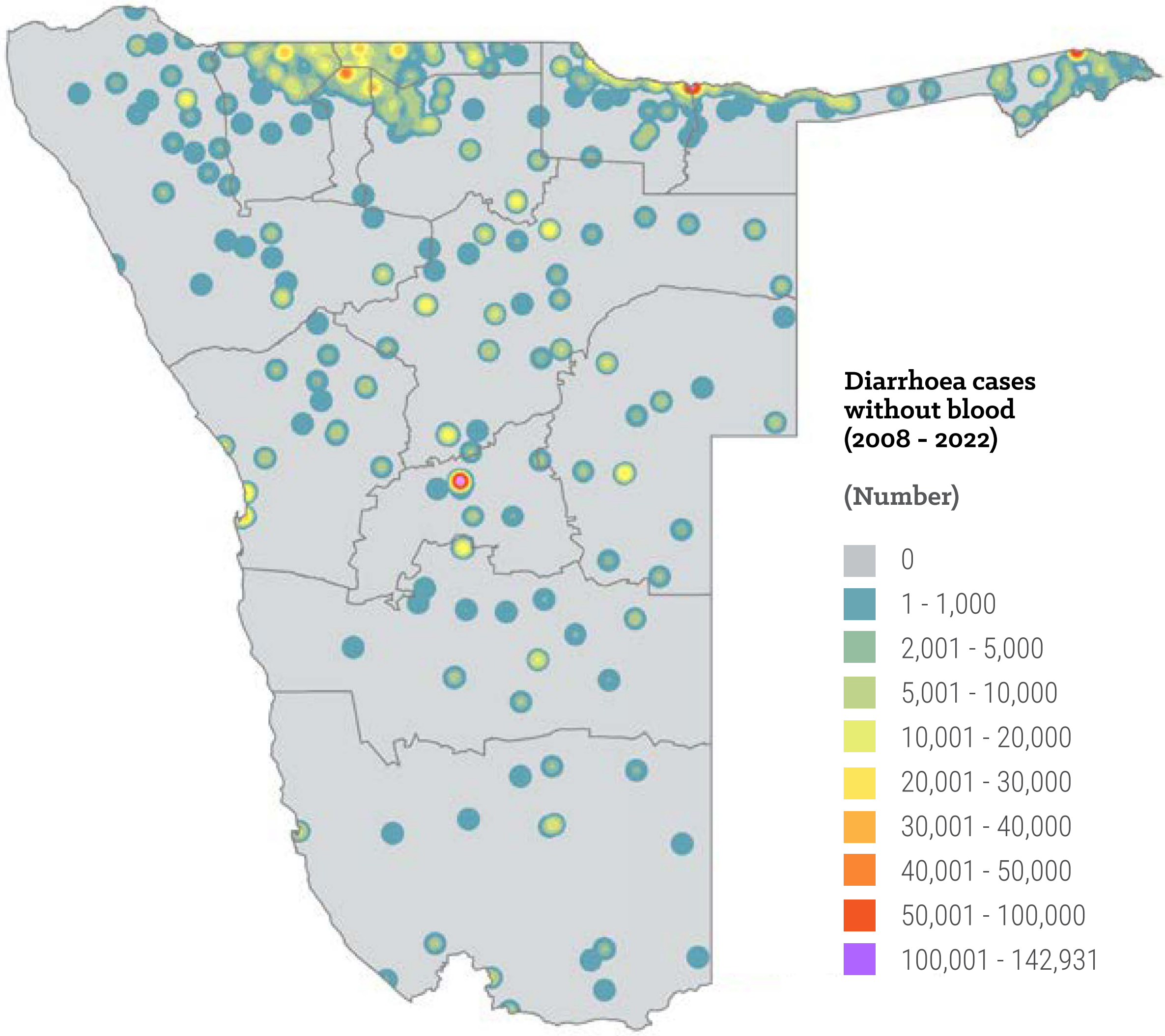


Figure 96: Number and distribution of diarrhoea cases without blood from 2008-2022

While the numbers are lower in comparison to diarrhoea without blood, the pattern for a high number of cases of bloody diarrhoea occurs in Eenhana, Katima Mulilo and Windhoek, where annual averages of 600-800 cases are reported. There are also noticeable cases of bloody diarrhoea in the average range of 200-300 annually that occur along the Kavango River (Figure 97).

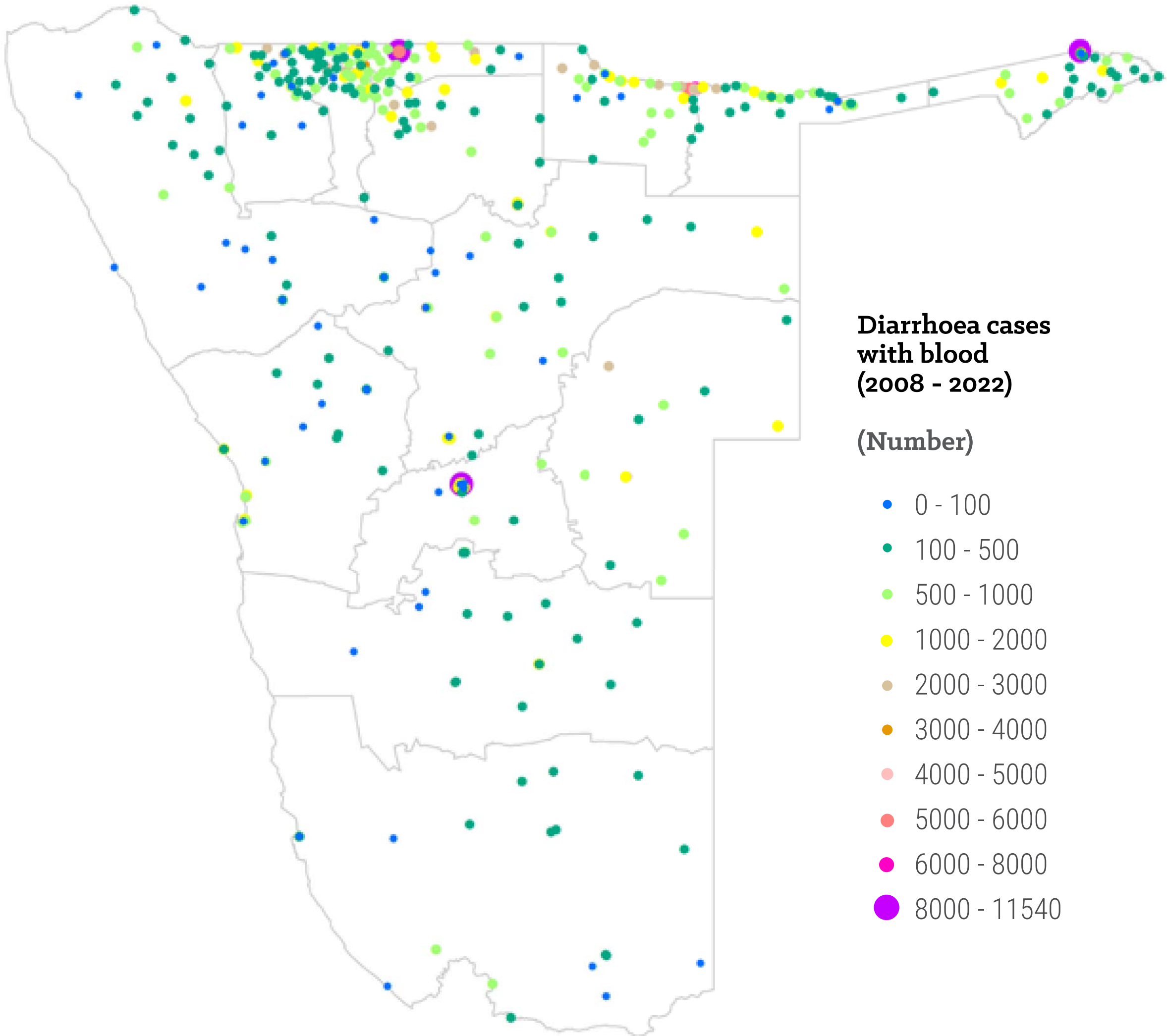


Figure 97: Number and distribution of diarrhoea cases with blood from 2008-2022

12.4.2 Exposure to diarrhoea

Human population was used as exposure for diarrhoea. Because infectious diarrheal diseases are also contagious and thus can be spread from one person to another, the population density (Figure 9) at the EA was factored into the exposure index along with the proportion of the population (Figure 10) in each EA at the national level. The two datasets were weighted equally.

12.4.3 Sensitivity to diarrhoea

Contaminated water for domestic use, as well as poor sanitation and hygienic conditions, are the leading causes of the occurrence and spreading of diarrhoea. The input data for deriving the sensitivity was subsequently generated from the 2011 Census data using the proportion of households with unsafe drinking and cooking water (Figure 98), and the proportion of households without a toilet facility (Figure 99) in each EA. Unsafe water for domestic use includes untreated water sourced from the river, dam, stream, canal, unprotected well or borehole with an open tank.

The highest prevalence of unsafe water for domestic use is in the Zambezi floodplains, the eastern part of Ohangwena, and some EAs in the Omusati, Oshana and Kunene regions (Figure 98). Much of northeastern Kunene is characterised by up to half of the households in the EA without safe drinking water. Some EAs in the northern portion of the Omaheke and Erongo regions also have more than half of the households without access to safe drinking water.

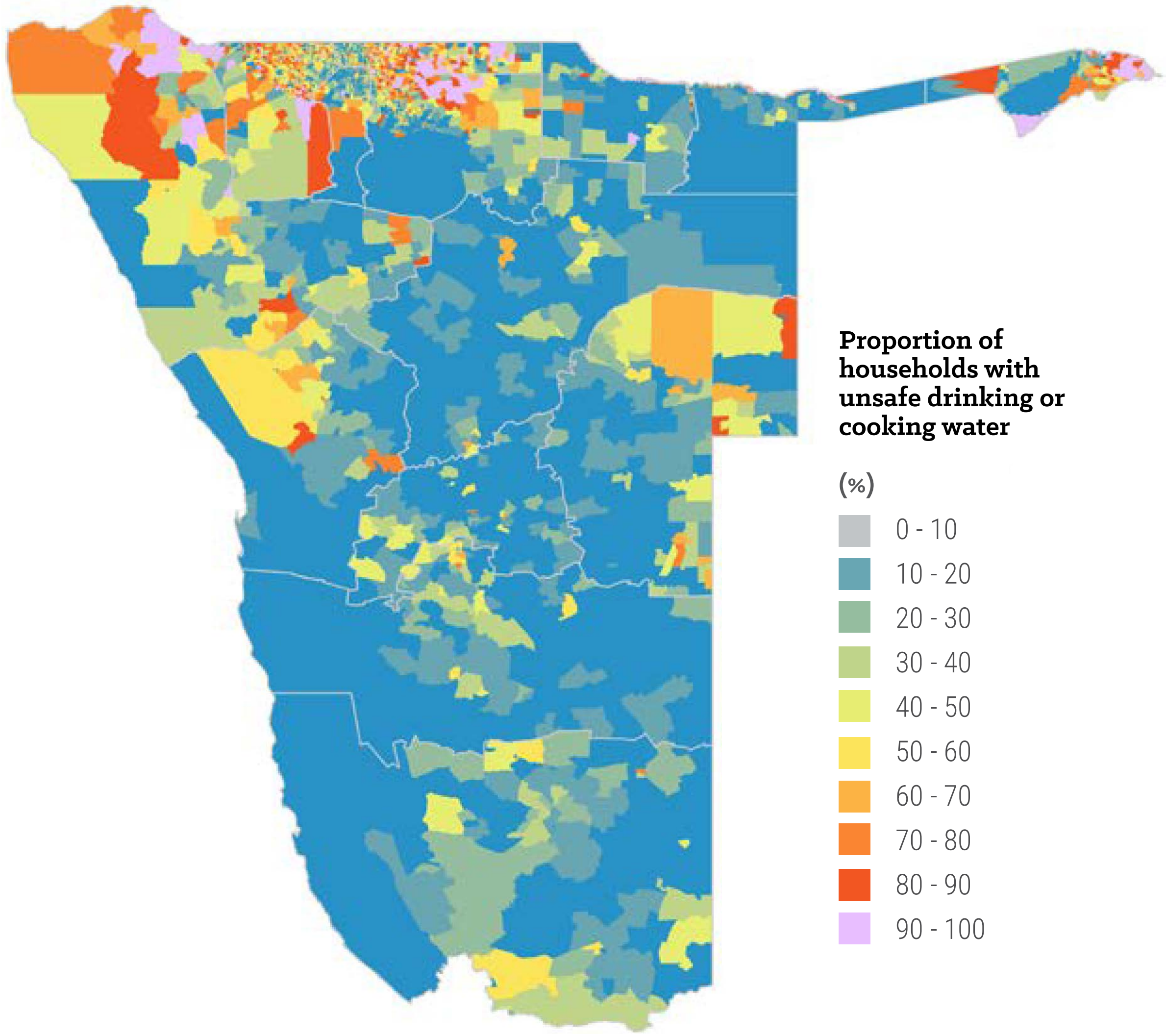


Figure 98: Proportion of households with unsafe drinking and cooking water

Households without toilet facilities are widespread in the northern part of the country, from the Kunene to Zambezi regions (Figure 99). The same trend occurs in the eastern Otjozondjupa and Omaheke regions. Most of these areas have 80-100% of the households in EAs without a toilet facility. In contrast, the Khomas and southern Otjozondjupa regions have a low or very low proportion of households without a toilet facility.

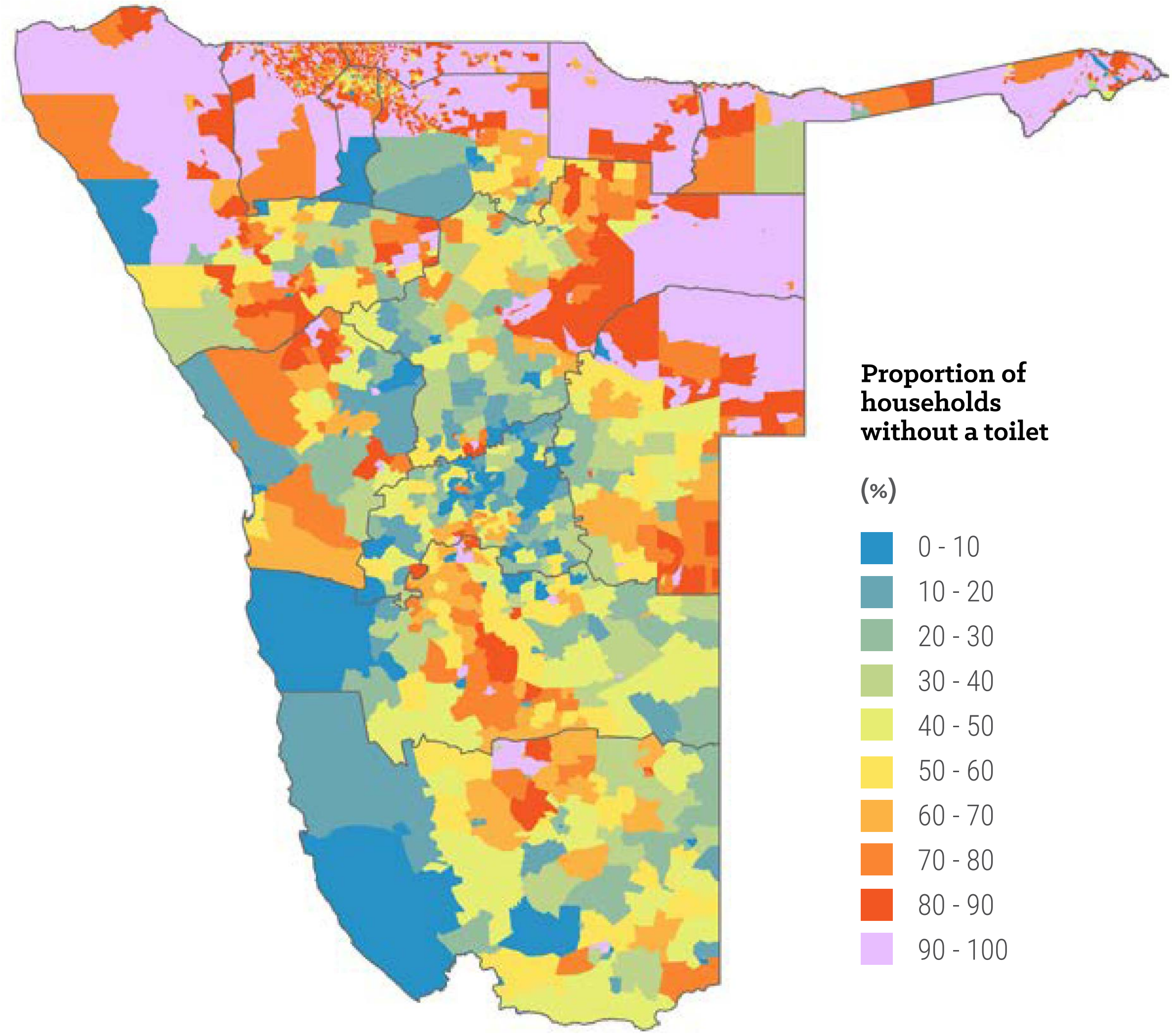


Figure 99: Proportion of households without a toilet

12.4.4 Adaptive capacity to diarrhoea

Mitigation measures to prevent the occurrence and spreading of diarrhoea include but are not limited to access to safe drinking, cooking and washing water, improved sanitation, maintaining good personal and food hygiene, and health education. The absence of safe water for domestic use and lack of toilet facilities were already used above for calculating the sensitivity index. It would thus be inappropriate to recycle the same data in two separate indices, sensitivity, and adaptive capacity in this instance, for the same hazard. There is no data regarding the efforts directed to other measures, such as maintaining good food hygiene. However, it is assumed that the level of income is central to access to safe water for domestic use, improved sanitation, and other mitigation measures for diarrhoea. For this reason, the average median income at the level of the EA was used as a proxy for adaptive capacity to diarrhoea. The less the average median income (Figure 13), the less the capacity to intervene and implement preventative measures for diarrhoea.

12.4.5 Vulnerability to diarrhoea

More than 1,410,000 people reside in areas with moderate to very high vulnerability to diarrhoea (Table 17). Spatially, just over two-thirds of the country is at the threshold of moderate to very high levels of vulnerability to diarrhoea (Figure 100). The area most vulnerable straddles the border between the Ohangwena and Oshikoto regions. The Zambezi floodplains, EAs along the Kavango River, and a few patches in Omusati and Kunene regions have also emerged with a very high vulnerability index (Figure100).

Table 17: Distribution of population by diarrhoea vulnerability level in each region of Namibia

Diarrhoea vulnerability level	Erongo	Hardap	Khomas	Kunene	Kavango East	Kavango West	Ohangwena	Omaheke	Omusati	Oshana	Oshikoto	Otjozondjupa	Zambezi	//Kharas
Very low	11965	0	35884	0	1120	0	242	0	0	1137	0	479	0	3058
Low	75763	42295	178062	9660	9440	685	3700	11362	5729	25291	12930	33365	9638	35422
Moderate	43520	43674	103974	33970	59450	32063	39180	44862	46204	58258	57784	68483	26677	30569
High	4238	5670	22449	24598	40339	36294	127565	7637	155575	61435	77182	18387	34945	3685
Very high	0	0	0	1863	11155	11442	51024	0	13993	6638	7796	333	5773	0

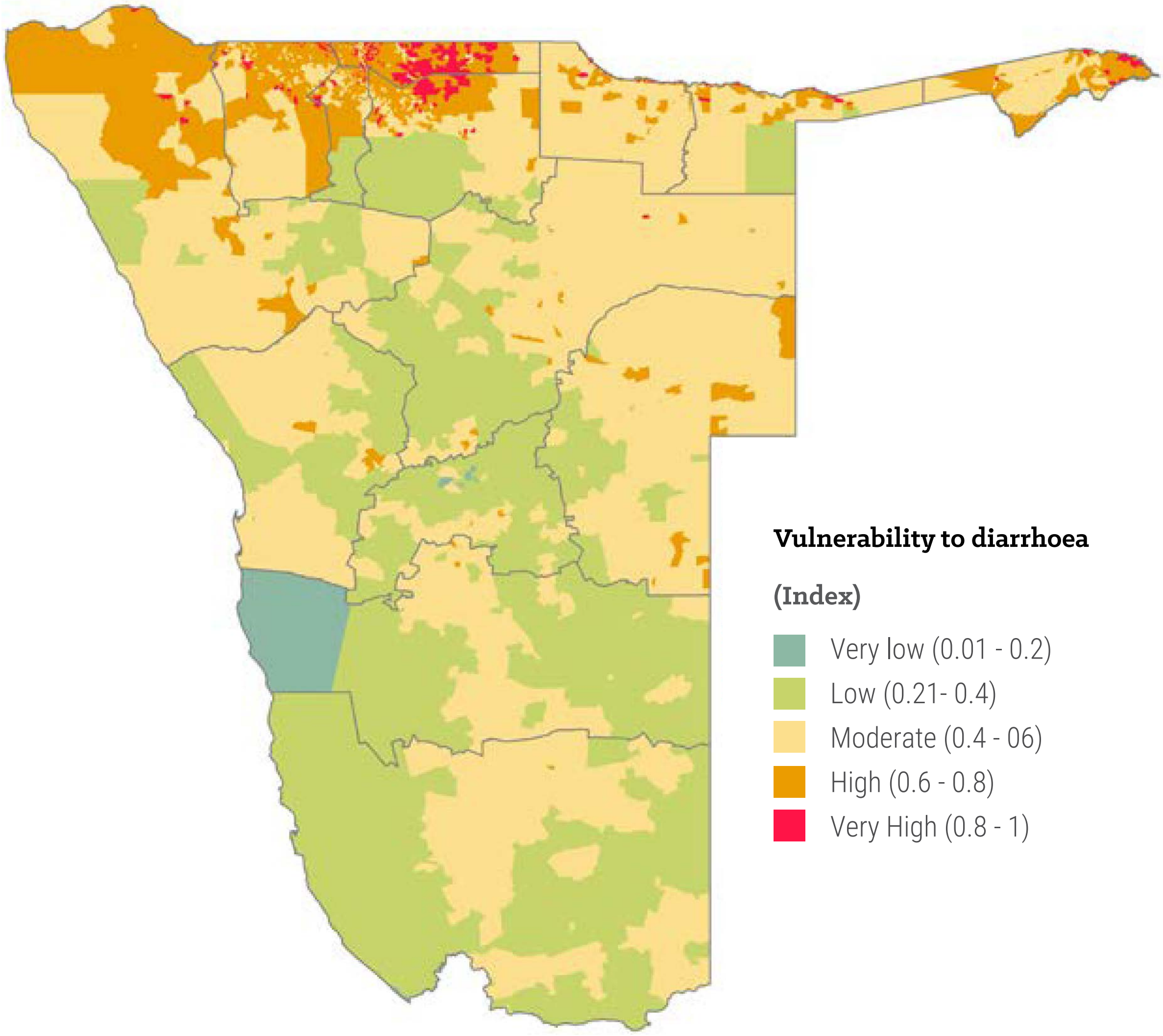


Figure 100: Spatial distribution of the vulnerability to diarrhoea

12.4.6 Diarrhoea risk

The risk for diarrhoea without blood has a larger footprint than diarrhoea with blood. The risk for diarrhoea without blood is high in the Zambezi Region, especially in the floodplains where the risk is very high (Figure 101a). A similar level of risk is also in the Kavango East and Kavango West regions. Approximately 80% of the country has a very low risk of bloodless diarrhoea.

The EAs with a very high risk of diarrhoea without blood in the Kavango East and Kavango West regions also have a very high risk of diarrhoea with blood (Figure 101b). This is the only part of the country where a high risk of both types of diarrhoea is compounded. A total of 7,685 people (Table 18) from 1282 households reside in areas with a very high risk of diarrhoea. Of these households, 629 (49%) are female-headed, 431 (34%) are headed by elderly persons, and 12 (1%) by minors (see Appendix 8). The combined total of these three groups amounts to 84% of the households in the discussion. The EAs in the Aranos Health District have the least risk of both types of diarrhoea. Khomas is the only region in the central part of the country where low and moderate levels of risk are dominant. The rest of the regions south of Oshikoto are dominated by a very low risk of diarrhoea (Figure 101c).

Table 18: Distribution of population by diarrhoea risk level in each region of Namibia

Diarrhoea risk level	Erongo	Hardap	Khomas	Kunene	Kavango East	Kavango West	Ohangwena	Omaheke	Omusati	Oshana	Oshikoto	Otjozondjupa	Zambezi	//Kharas
Very low	11965	0	35884	0	1120	0	242	0	0	1137	0	479	0	3058
Low	75763	42295	178062	9660	9440	685	3700	11362	5729	25291	12930	33365	9638	35422
Moderate	43520	43674	103974	33970	59450	32063	39180	44862	46204	58258	57784	68483	26677	30569
High	4238	5670	22449	24598	40339	36294	127565	7637	155575	61435	77182	18387	34945	3685
Very high	0	0	0	1863	11155	11442	51024	0	13993	6638	7796	333	5773	0

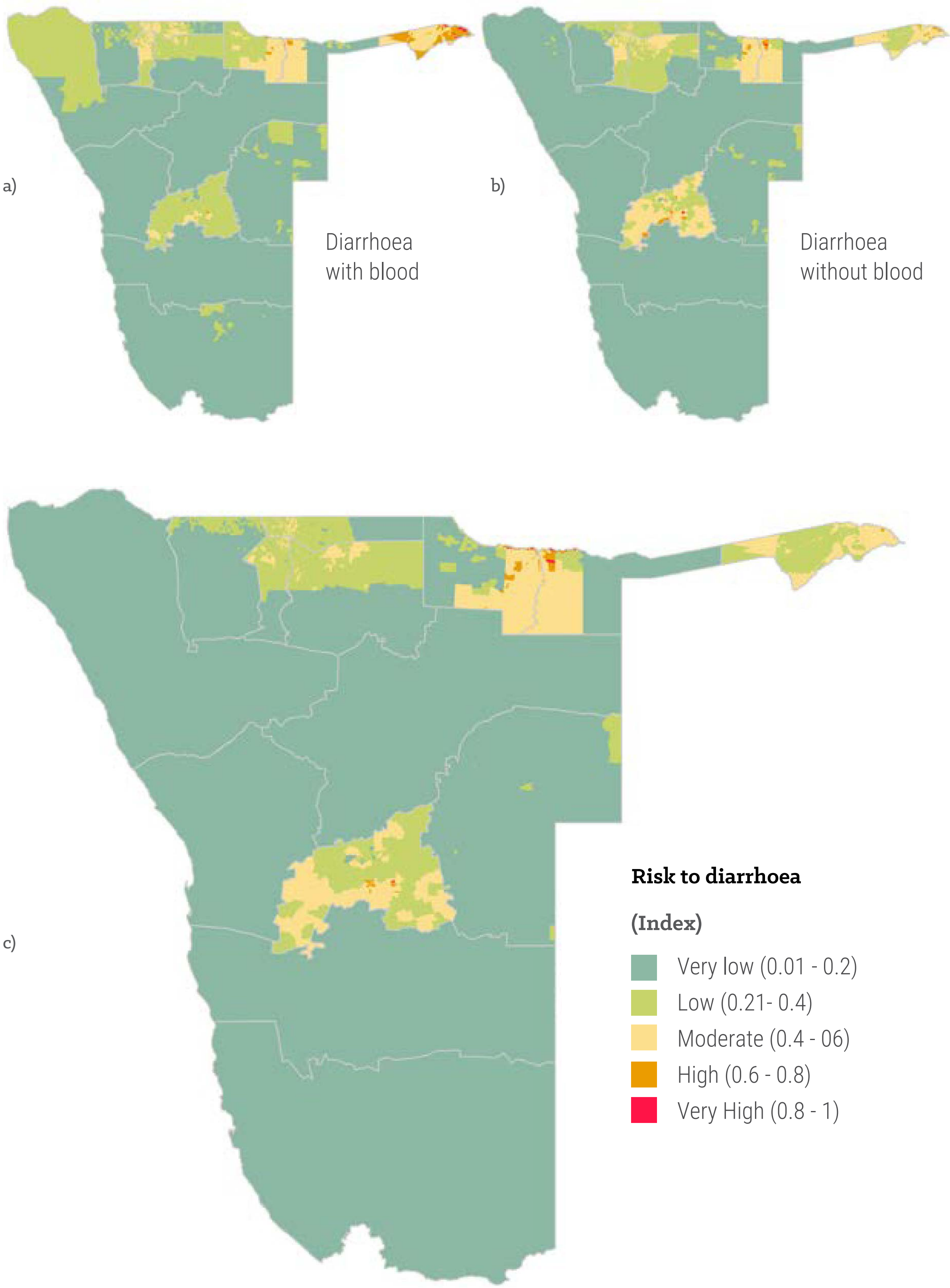


Figure 101: Spatial distribution of the risk of diarrhoea (a) diarrhoea with blood (b) diarrhoea without blood and (c) a combination of both diarrhoeas

12.5 TUBERCULOSIS (TB)

Tuberculosis (TB) is a disease caused by a bacteria known as Mycobacterium tuberculosis, which has affected humans for centuries. Although it is treatable, it occurs regularly in Namibia and spreads more commonly through minute droplets released when a person with this bacterium in the lungs or throat coughs, sneezes, laughs, speaks or sings.

Two major concerns in Namibia about TB are TB/HIV coinfection and the increase in drug-resistant TB in the country since 2007 (Chipare et al. 2020; Ricks et al., 2012). As such, approximately 60% of TB patients in Namibia are HIV positive. The co-infection was particularly pronounced in the 1990s when TB cases increased from 322 per 100,000 persons in 1990 to a peak of 817 per 100,000 persons in 2004 (Rick et al. 2012). The 2004 peak just lagged the peak of HIV discussed in Section 12.3.

The data covering the 2010-2021 period reveals a reduction by half of TB incidences from more than 10,000 to about 5,000 (Figure 102). Similarly, the death rate decreased from 1,040 people in 2010 to 470 people in 2021. The available data were aggregated at the national level and thus did not allow analysis at the requisite scale for this study.

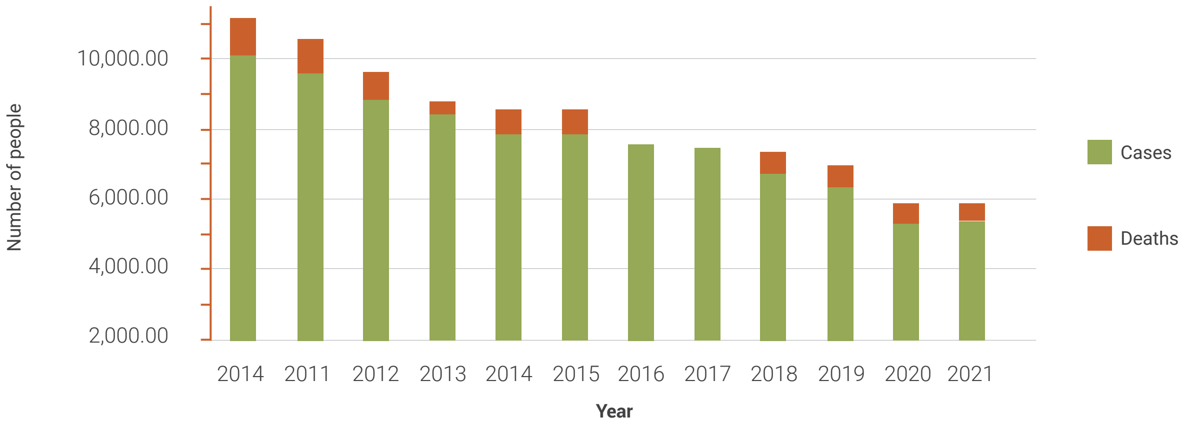


Figure 102: Number of people infected by and who died of Tuberculosis from 2010 to 2021 in Namibia. Note: there is no data for deaths in 2016 and 2017.

12.6 FOOT AND MOUTH DISEASE

12.6.1 Foot and mouth hazard

Lung sickness, rinderpest, and foot and mouth diseases are the three most historic animal diseases that have far-reaching implications on the socio-economic development in Namibia. All these diseases were imported into Namibia, beginning with lung sickness in 1856 from Holland via South Africa, followed by rinderpest in 1897 from South Africa, and lastly foot and mouth disease in 1934, presumably through Botswana as it was first reported in the Gobabis district (Schneider, 2012). Although eliminated in much of Namibia, the outbreak of lung sickness still occurs sporadically in the Omusati, Oshana, Ohangwena, Oshikoto, Kavango West, and Kavango East regions. Rinderpest has been eliminated successfully. The last outbreak of foot and mouth in commercial areas was reported in 1964 (Schneider, 2012). However, the disease continues to break out in all northern regions from Kunene to Zambezi. Therefore, foot and mouth disease was included in this study due to its persistence in the country and socio-economic impact.

Foot and mouth disease is a severe, highly contagious viral disease which affects cattle, swine, sheep, goats, and other cloven-hoofed ruminants, including wildlife. Available data for incidences of foot and mouth cases cover the 2011-2021 period (Figure 103). The cases also include two cases of caprine (goat) species and one case of buffalo; the rest are for bovine species (cattle). The cases are mainly concentrated in eastern Zambezi and the northern parts of the Ohangwena and Kavango West regions. The highest level of occurrence at an annual average of 15 cases per annum is in the Masikili-Ihaha area (Zambezi), near the borders with Botswana. In the Kunene Region, a lone incursion occurred in 2018 at Oromauwa.

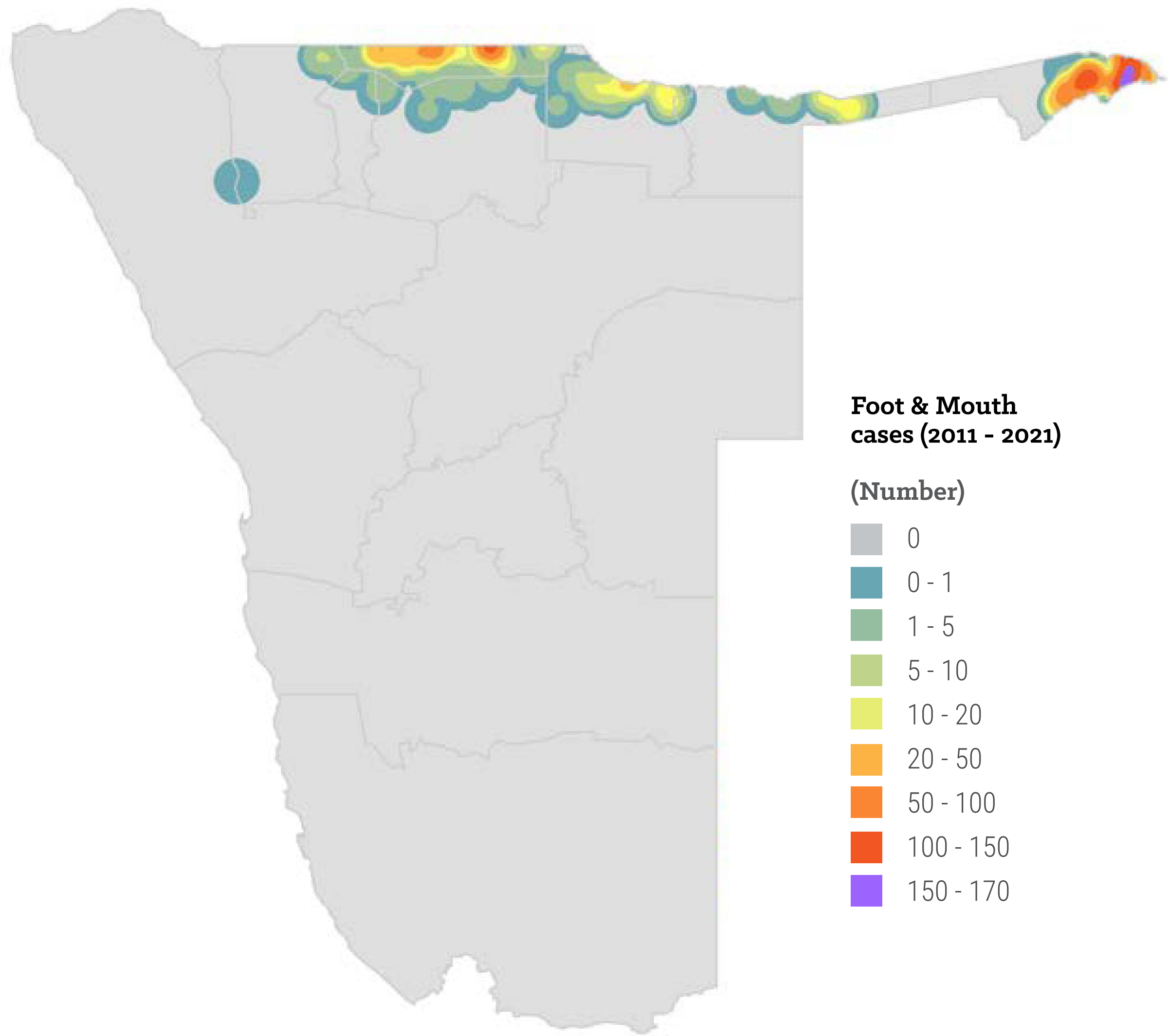


Figure 103: The number and distribution of foot and mouth cases

12.6.2 Exposure to foot and mouth disease

Both livestock and wildlife were included at an equal weight in the exposure data set. The processing of data and distribution of the animals are described in Section 9.2.

12.6.3 Sensitivity to foot and mouth disease

Foot and mouth disease is a transboundary animal disease. This implies that animals are more susceptible to foot and mouth infection in areas where animals roam freely due to the limited ability to control their movement. Free-roaming animals in Namibia is a norm in communal areas and national parks. However, the socioeconomic impact of foot and mouth outbreaks is much more devastating to farmers in communal areas than to the state. Additionally, Schneider (2012) asserts that all foot and mouth outbreaks in Namibia are regarded as due to the transboundary movement of animals from Angola, Zambia, or Botswana. The recent detection in Namibia of a new serotype O, which has a 99.5% nucleotide identity to foot and mouth viruses collected since 2018 in Zambia (Banda, 2022), points to this non-endemic status of foot and mouth disease in Namibia. The proximity to porous international borders aggravates the sensitivity of northern communal areas to foot and mouth infection.

In essence, the livelihood dataset mirrors the free-roaming areas in the country. It also indirectly exposes sensitive livelihoods that are subjected to porous international borders. These two factors made it fitting to use the livelihood dataset described in Section 3.3 as a basis for computing the sensitivity index to foot and mouth disease. An index score of 1 was assigned to agro-pastoral and pastoral communal areas where animals roam freely. The limited impact of porous international borders on areas in the interior where animals roam freely is embedded in and addressed through the adaptive capacity index described in Section 12.3.4. Protected and rural formal areas were assigned an intermediate index score of 0.6 and 0.5, respectively. Urban formal and urban informal areas were given the lowest index scores of 0.1 and 0.2, respectively.

12.6.4 Adaptive Capacity to foot and mouth disease

Effective control measures against foot and mouth disease include quarantine, disinfection, vaccination and controlling animal movement. These measures are implemented in Namibia. A virtual cordon line, with control posts at Epukiro, Waterberg, Otjituuo, Tsintsabis, Namutoni, Rietfontein, Okaukuejo, Cauas-Okawa, Huab, Tsawisis and Sesfontein, was introduced in Namibia in 1897 (Miescher, 2012) and divided the northern communal areas from the rest of the country. Ironically, the cordon line was aimed to protect farms in the south of the country from the outbreak of rinderpest, which was reported in South Africa at the time. The major epidemic of foot and mouth disease of 1961 in Namibia precipitated the erection of game-proof fences along parts of the earlier virtual cordon line and resulted in formalising the current veterinary cordon fence (Figure 104; Scheider, 2012).

Figure 104: A portion of the veterinary cordon fence (known as the redline) in the Etosha region, Namibia

This veterinary cordon fence plays a critical role in preventing the spread of the disease from the northern communal areas to southern regions. The spatially explicit nature of this fence, the relentless effort invested in maintaining it, and the strict control against animal and meat movement from the north to the south of Namibia qualify it by default as an input for generating the adaptive capacity index (Figure 105). Areas north of the cordon veterinary fence are assigned an index score of 1, while areas in the south are assigned an index score of 0.2. It is assumed that data for centralised vaccination campaigns exist but were not secured for risk profiling.

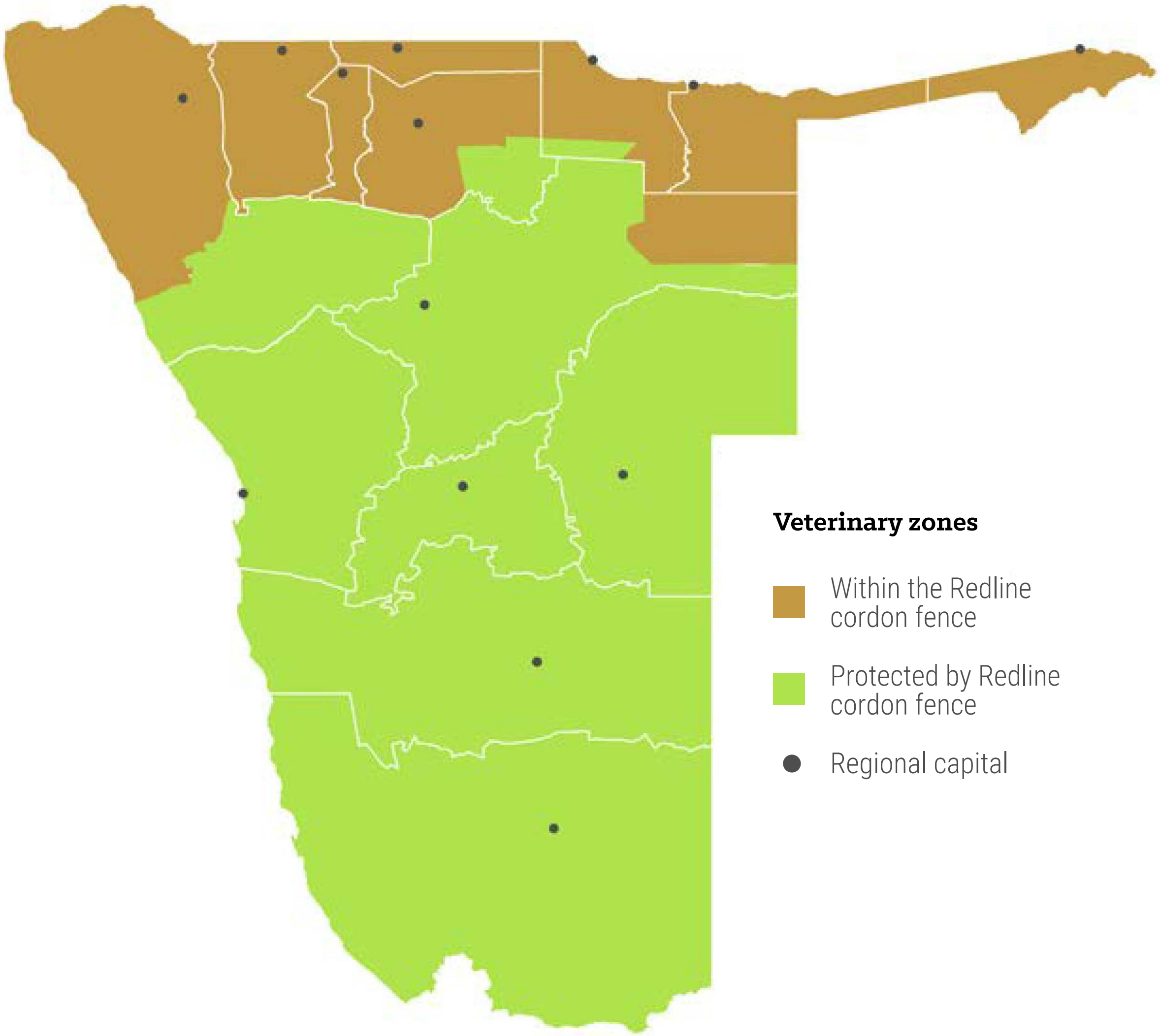


Figure 105: The adaptive capacity for Foot and Mouth Disease

12.6.5 Vulnerability to foot and mouth disease

Communal areas north of the veterinary cordon fence have a very high vulnerability index score (Figure 106). Similarly, a high vulnerability score is dominating in protected areas north of the cordon veterinary fence. The rest of the rural areas in the country fall into the moderate and low index, while urban areas are mainly characterised by very low to negligible levels of vulnerability to foot and mouth disease.

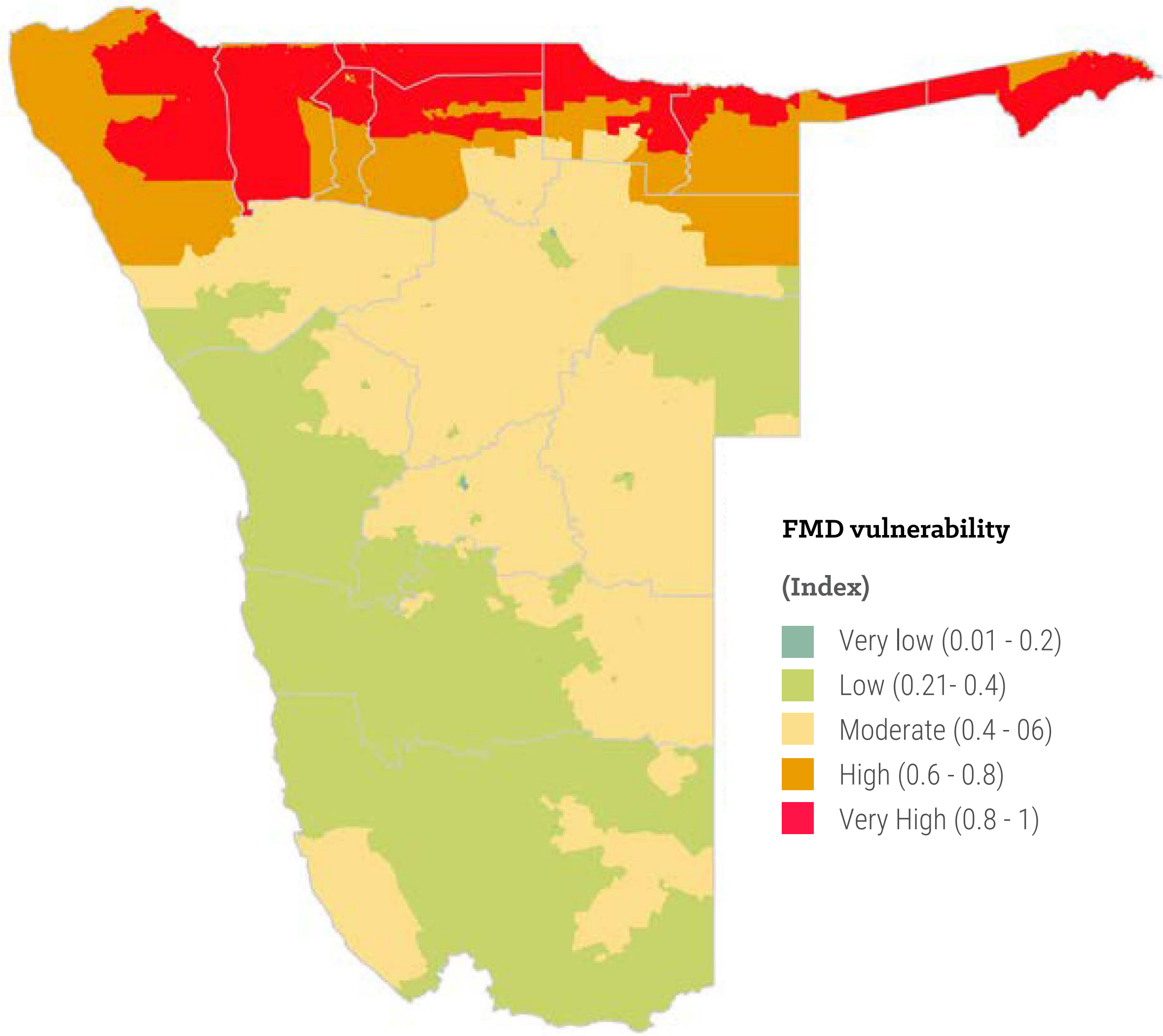


Figure 106: The vulnerability to foot and mouth disease

12.6.6 Foot and mouth risk

The Zambezi floodplains emerged as the zone with the highest level of risk of foot and mouth disease (Figure 107). The moderate to high levels of risk are also limited to the Zambezi Region. Segments of the communal area from the central-eastern Kunene to western Zambezi regions are characterised by a very low level of risk, while the northern Ohangwena, bordering the Kunene Province in Angola, has a low-risk level. The risk of foot and mouth disease is negligible for the rest of the country.

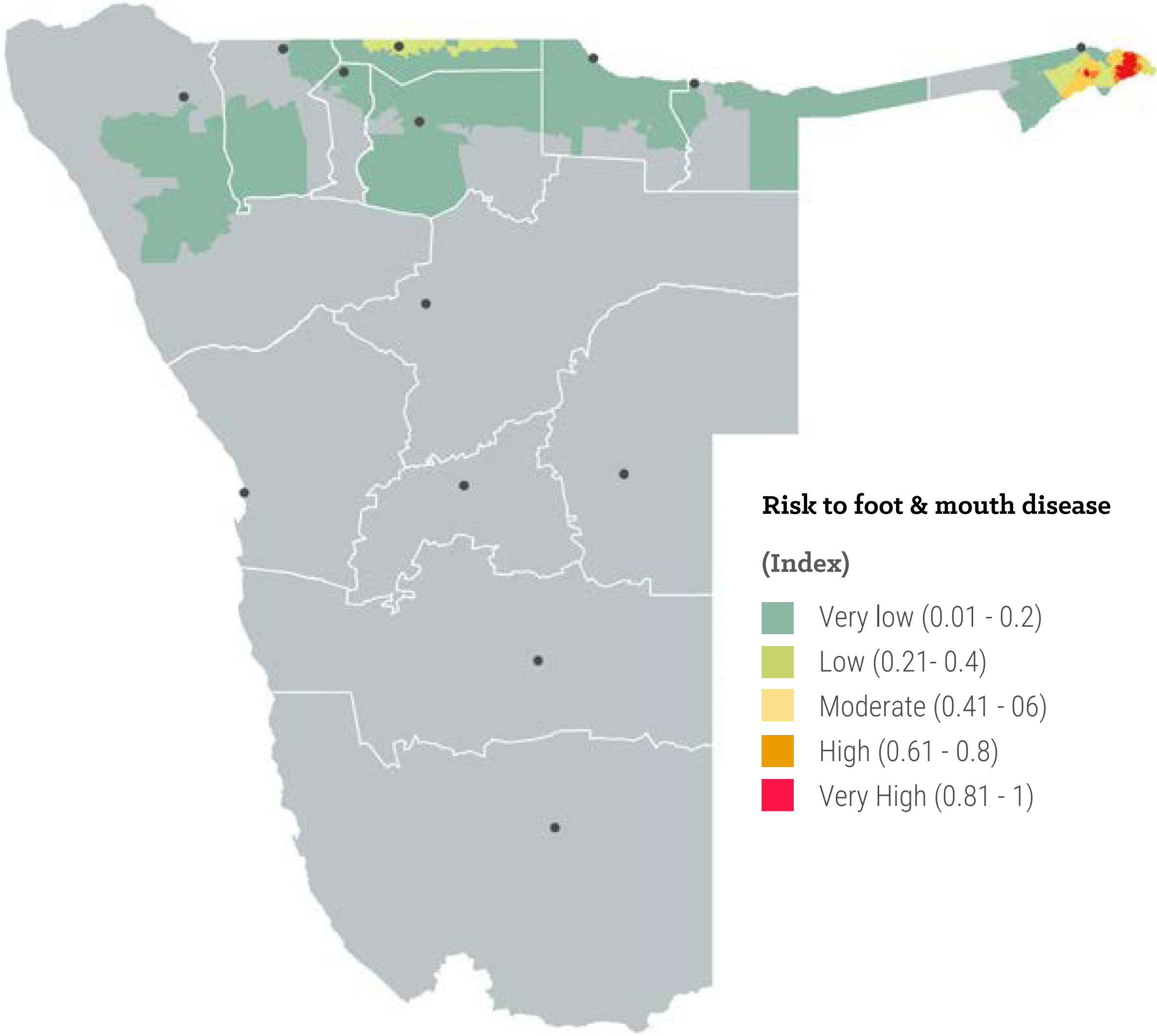


Figure 107: The risk of foot and mouth disease

13

OVERALL VULNERABILITY AND RISK ASSESSMENT

OVERALL VULNERABILITY AND RISK ASSESSMENT

Arguably, any unmitigated disaster has far-reaching negative socio-economic implications for society. For example, without taking preventative measures, the outbreaks of foot and mouth disease may be as devastating as the drought of 2019 in Namibia. The perceived impact of some of the disasters may also be imperceptible or fall into oblivion due to several factors, such as time lapsed since a disaster occurred, slow onset, normalisation, or lack of awareness.

Earthquakes may serve as a classic example of the time-lapse and the lack of awareness, while slow onset pertains to drought. Similarly, heatwave and diarrhoea are prime contenders for normalisation in Namibia. Additionally, some natural disasters are compounded, cyclic or intertwined with others (Figure 108). A devastating drought, for example, may be followed by an above-normal rainfall year, which results in a good grazing potential for the animals. But the above-normal rainfall can also cause various diseases, such as lumpy skin, that may further ravage the remnants of livestock that survived the preceding drought. With limited livestock in the area, the good rangeland for grazing becomes a fuel load for wildfires. In short, the ranking and weighting of multiple disasters and their severity or impact is largely subjective due to the interplay of socio-economic and environmental factors, compounded with perceptions and information deficit.

Figure 108: An example of a house faced with multi-hazards. In this case, the house is flooded and at the same time rooms are built with corrugated iron/zinc materials which expose inhabitants to heatwave.

To ease the process of ranking and weighting the vulnerability and risk of natural disasters, each participant in the Validation Workshop of this study was requested to independently rank each hazard in terms of importance to Namibia. The workshop took place in February 2023 and was co-organised by the Office of the Prime Minister and the University of Namibia. Participants comprise government officials from relevant ministries and government agencies such as agriculture, health, local government and housing, national planning, statistic agency, safety and security, environment, meteorology, mines and energy, local authorities, and regional councils from all 14 regions. Additionally, some participants were from non-governmental and world bodies, including the Namibia Red Cross, World Health Organisation, Food and Agriculture Organisation, United Nations Population Fund, and local institutions of higher learning. More than 80 participants attended the workshop.

Each participant was provided with a scoresheet with pre-listed hazards. Only hazards whose data were available and analysed prior to the workshop were pre-listed on the scoresheet. However, participants were informed that they were free to add and rank any other natural hazard not listed on the scoresheet that they thought was critical for Namibia. The possible score ranged from 1 to 10, with 10 representing high importance. An average score was then calculated for each hazard.

Seventy-two participants completed the survey at the beginning of the workshop and 63 at the end of the workshop. The ranking was done at the beginning and the end of the workshop to profile the views of participants immediately before and after the discussions held during the workshop.

Table 19 shows the ranking of pre-listed hazards and those that were added by workshop participants. Drought and flood were ranked equally in the first round as the most critical natural hazards in Namibia. However, flood was ranked second in the last round (Table 19). COVID-19 was ranked third after wildfire in the first round, and the two hazards switched positions in the last round. Lightning was ranked lowly (at position 10) during the first round of ranking, but its ranks changed to the 6th position in the last round. In contrast, heatwave was ranked 7th in the first round, and 10th in the last round. Along with the drought mentioned earlier, foot and mouth disease was the only other hazard covered during the workshop that maintained the same position (5th) in both rounds. Frost was ranked last, followed by sea level rise in the first round. These two disasters also switched positions in the last round.

Nine additional hazards were added to the list by participants. Pest outbreak was added to the list by 22 participants in the first round of ranking and by 15 in the last round. Unfortunately, none of these additional hazards could be added to this profile due to data limitations, except TB which was subsequently covered at a rudimental level as the available data was aggregated at the country level (Section 12.5).

Table 19: The ranking of natural hazards in terms of importance to Namibia by participants during the Validation Workshop for the risk profile

Hazard	First score	Last score	Average score	First ranking	Last ranking	Average ranking	First score index	Last score index	Average score index
Drought	9.1	8.7	8.9	1	1	1	1.00	1.00	1.00
Flood	9.1	7.5	8.3	1	2	2	1.00	0.87	0.93
COVID-19	8.7	6.6	7.6	3	4	3	0.96	0.76	0.86
Wildfire	7.9	7.4	7.6	4	3	4	0.86	0.86	0.86
Foot and mouth disease	6.7	6.4	6.6	5	5	5	0.74	0.74	0.74
Windstorm	6.2	5.9	6.1	6	7	6	0.68	0.69	0.68
Lightning	5.1	6.1	5.6	10	6	7	0.56	0.71	0.63
Malaria	5.2	5.8	5.5	9	8	8	0.57	0.67	0.62
Earthquake	5.3	5.4	5.3	8	9	9	0.58	0.62	0.60
Heatwave	5.5	5.1	5.3	7	10	10	0.60	0.59	0.59
Rabies	4.3	5.0	4.6	11	11	11	0.47	0.58	0.52
Frost	3.6	4.3	3.9	13	12	12	0.40	0.49	0.44
Sea level rise	3.8	4.0	3.9	12	13	13	0.42	0.46	0.44
Added by workshop participants									
Pest outbreak	2.4	1.9	2.1	14	14	14	0.27	0.21	0.24
Landslide	0.4	0.4	0.4	17	15	15	0.05	0.04	0.05
Human wildlife conflict	0.5	0.2	0.4	15	16	16	0.06	0.03	0.04
Cold	0.5	0.1	0.3	16	18	17	0.05	0.01	0.03
Hailstorm	0.1	0.2	0.2	19	17	18	0.02	0.02	0.02
Scabies	0.2	0.0	0.1	18	19	19	0.02	0.00	0.01
Bush encroachment	0.1	0.0	0.0	20	20	20	0.01	0.00	0.00
TB	0.0	0.0	0.0	21	21	21	0.00	0.00	0.00

Essentially, the results of this survey were used as a basis for determining the weighting of the ranked natural disasters and calculating the composite vulnerability and risk. The overall vulnerability and risk were generated using the weighting based on the scores from the first and last rounds of ranking as well as the average of the two. For comparison, overall vulnerability and risk were also generated based on the equal weighting of hazards. Diarrhoea and HIV/AIDS, which were not included in the survey, were only factored in one of the equal-weighted assessments.

13.1 VULNERABILITY

The assemblage of vulnerabilities for all 14 hazards that were spatially mapped in this study revealed a checkered pattern between the northern and southern regions. The southern regions are dominated by heatwave, frost, earthquakes, and windstorms (Figure 109). These vulnerabilities are not as pronounced in the northern regions, which are more vulnerable to foot and mouth disease, flood, drought, diarrhoea, and malaria (Figure 109).

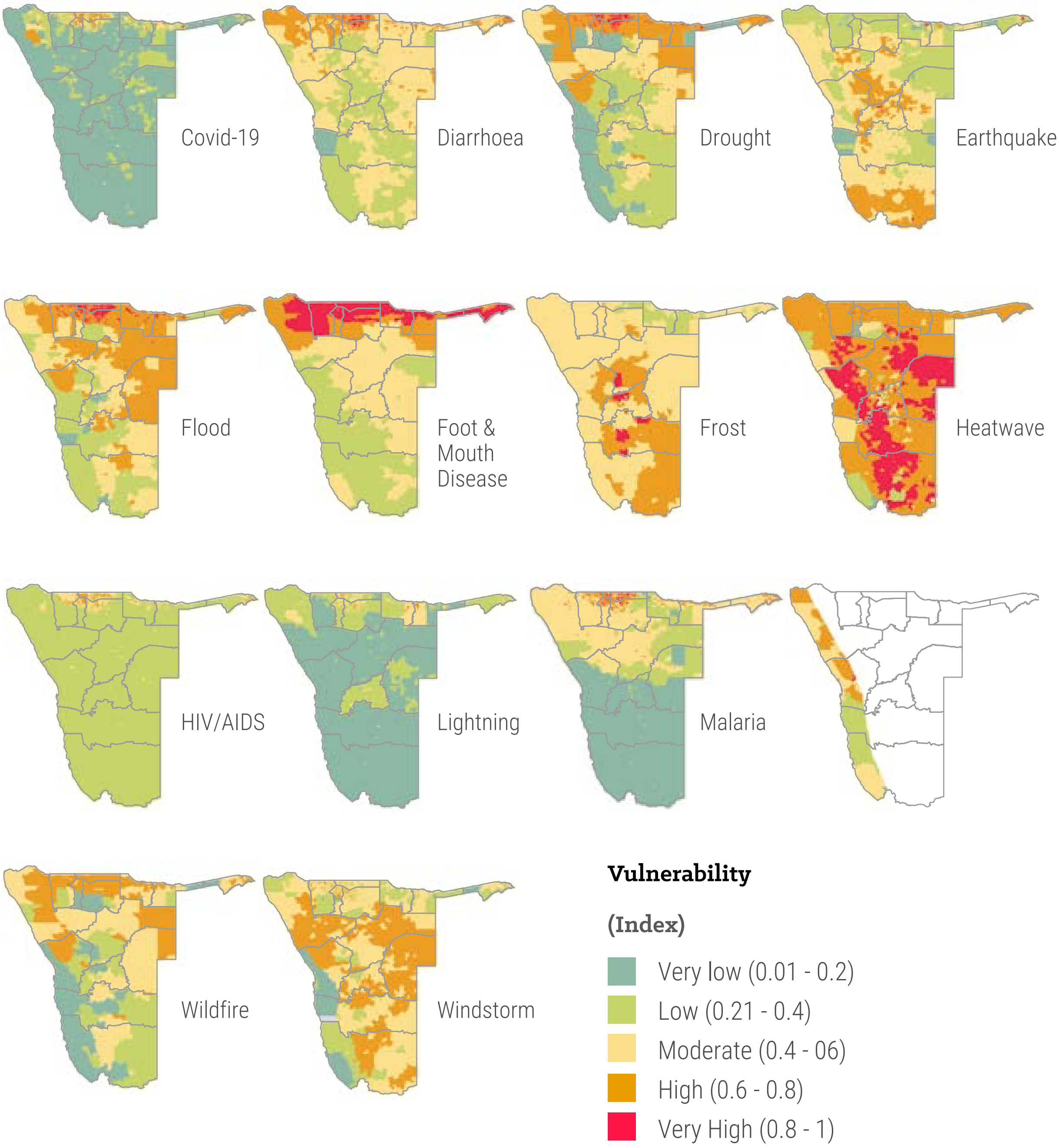


Figure 109: Spatial distribution of the vulnerability to natural hazards covered in this study

Surprisingly, the ranking of stakeholders yielded no major spatial differences in overall vulnerability when computed using the results of the first and last rounds of the survey and the average of the two (Figure 110). Even more surprising is that there are no pronounced spatial differences in the distribution of the overall vulnerabilities when weighted using stakeholder ranking and equal weighting (Figure 111).

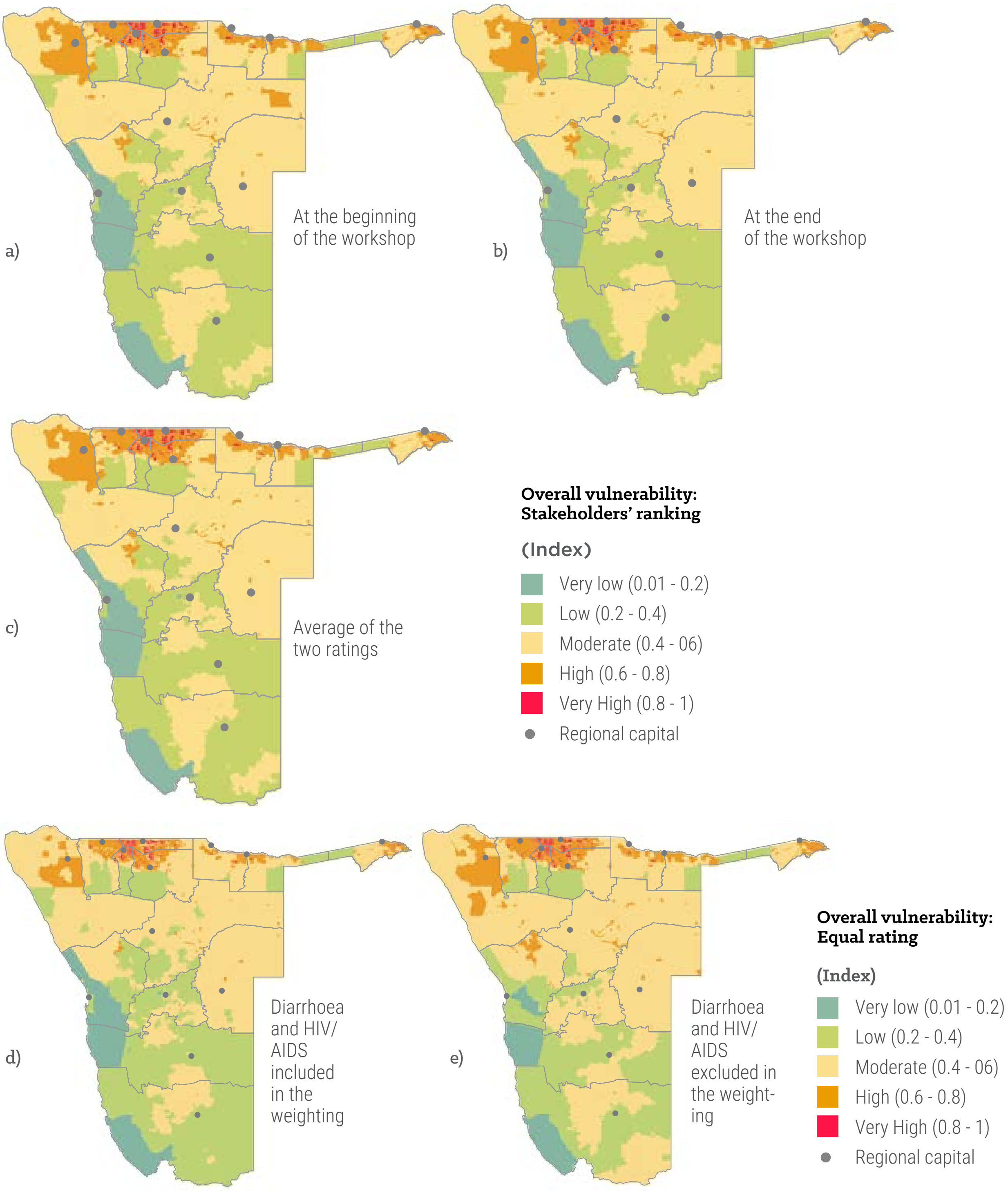


Figure 110: Overall vulnerability of hazards covered in this study and computed based on weights from stakeholder ranking and equal weighting

The influence of diarrhoea and HIV/AIDS on the overall vulnerability surfaced only in the northeastern Kunene region where a high vulnerability class decreased in zones previously falling under high vulnerability. A portion of northern Erongo and Omusati have also followed a similar pattern.

13.2 RISK

Heatwave is the most pervasive risk across the country, followed by drought and earthquakes (Figure 111). Interestingly, the earthquake is lowly ranked by stakeholders at the workshop. Because of the imperceptible impact of the earthquake in Namibia, its pervasiveness in the country may not receive significant attention. However, there is a severe, hidden economic cost that earthquakes may be causing in Namibia. Key amongst others is the widespread cracking of buildings and roads that cost billions of dollars annually in repairs. It is likely that the multitude of tremors that the country experiences each year contributes to this hidden cost that goes unreported. With limited information at our disposal, such cost may be erroneously attributed to poor workmanship or perceived poor or inappropriate building materials.

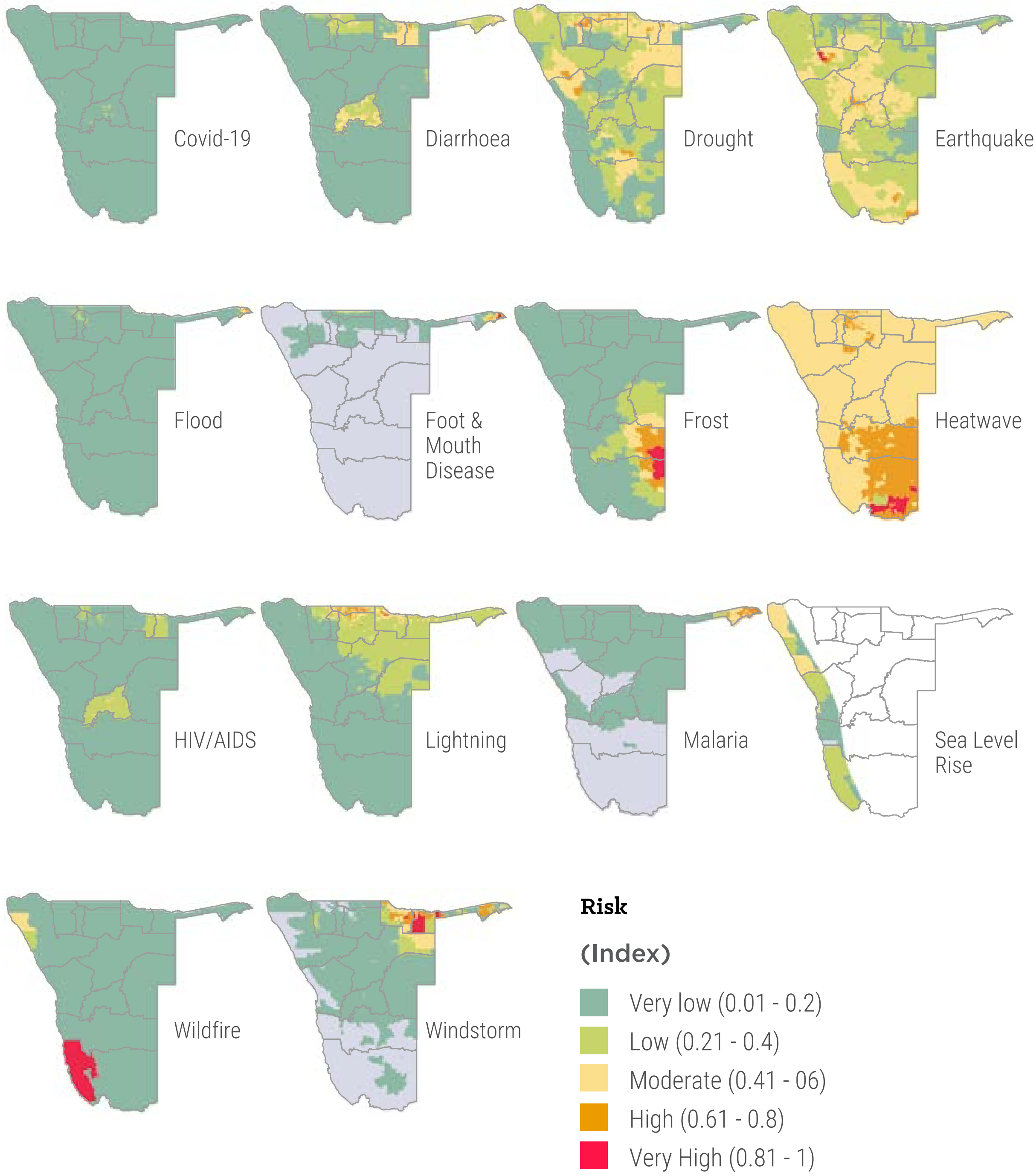


Figure 111: Spatial distribution of the risks to natural hazards covered in this study

Another example of unaccounted cost due to the impact of natural disasters in the country is the 2006 floods in Mariental that triggered a long-term knock-on effect on the property market in the area. In its aftermath, many insurance companies resolved not to cover the area's flood-related claims. This adds further strain to the property development and market in the area already beset with costly wall cracks (Figure 112). While these cracks are anecdotally attributed to the clayey soil in the subsurface, they may as well be aggravated by an unrecognised structural problem.

Figure 112: A house in Mariental with wall cracks, a phenomenon common in the town and affecting the property market in the area

Figure 113: The remnant of Mukorob today, reminiscing the loss of revenue from tourism in the area. Its collapse in December 1988 is associated with a distant earthquake in Armenia which highlights that the impact of some natural hazards may originate beyond the immediate surroundings of the area. Its status as a national monument remains in force today.

Further, the nostalgic Mukorob or Finger of God (Figure 113) is one of Namibia's geological attractions some 80 km south of Mariental that collapsed on 7 December 1988. The timing of its collapse is associated with a 6.8 magnitude earthquake whose waves registered heavily that day at the seismological station of the Geological Survey of Namibia in Windhoek, although the epicentre was some 7,500 km in Armenia (Schneider, 2004). The collapse of this geological attraction has essentially contributed to unaccounted economic loss through tourism, and such long-term effects are hardly considered in the impact of natural hazards.

It should, therefore, be noted that Mariental and its surroundings may be vulnerable to distant earthquakes. Hence, the role of tremors in its risks may not be ruled out as some natural hazard events need not occur in the immediate surroundings of affected assets or people. A holistic assessment of overall natural hazards for any area is therefore imperative.

The overall risk maps computed based on weights from stakeholder ranking of hazards before and after the validation workshop were largely similar, implying that the overall map was not sensitive to the weighting of individual maps even though the ranking of some of the hazards by stakeholders was different from the initial ranking (Figure 114).

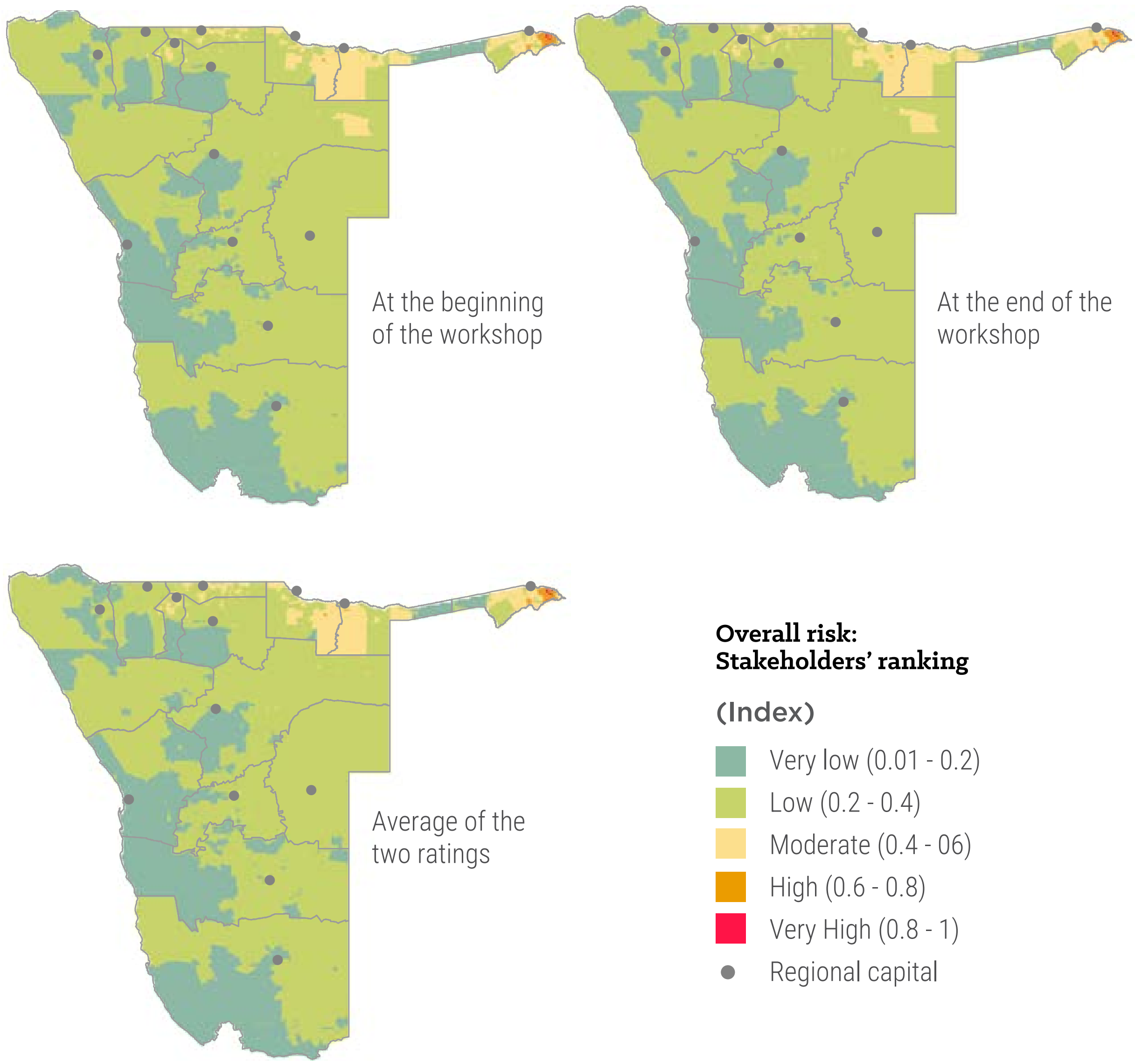


Figure 114: Overall risk computed based on weights from stakeholder ranking of hazards before and after the validation workshop, as well as the average of the two ratings

The spatial distribution of the overall risk was also not sensitive to the weighting approach of the individual risk maps. Essentially, the overall risk computed using specific weights derived from the ranking of hazards by stakeholders and the equal weighting approach yielded a similar pattern of risk distribution across the country (Figure 115). The Zambezi floodplains have the highest overall risk in Namibia, followed by the Kavango East, Kavango West, Ohangwena and Oshana regions (Figure 115).

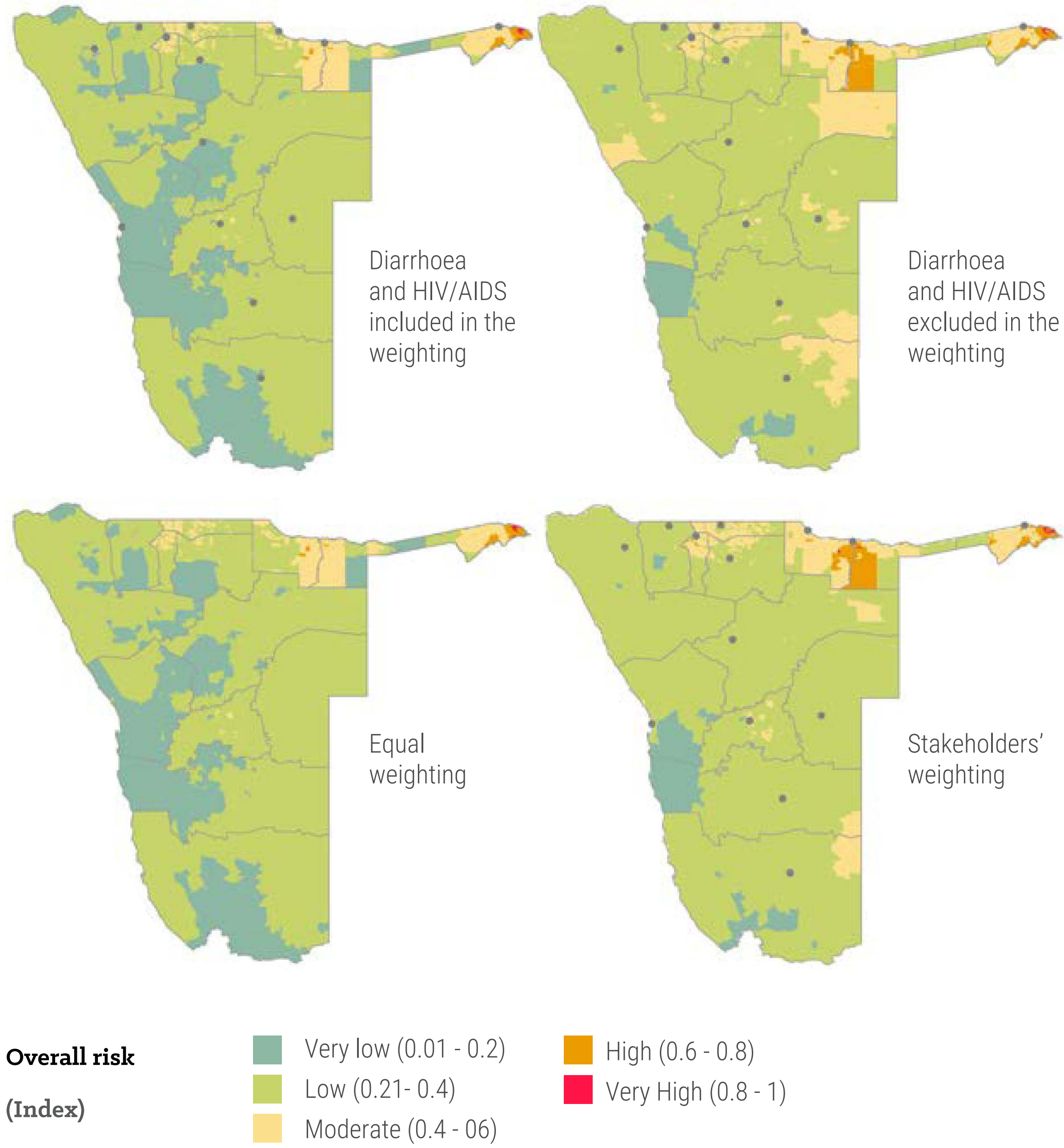


Figure 115: Overall risk computed based on weights from stakeholder ranking of hazards and equal weighting

14

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

The relative vulnerability and disaster risk of 14 hazards were assessed and mapped across Namibia at an EA level, which allowed for the unmasking of vulnerabilities and risks at unprecedented levels of detail. Since the analyses were done at the enumeration area (eg. Fig 49 and 68), the risk and vulnerability maps are thus useful for the development of resilience strategies for natural disaster risks at the local, regional, and national levels.

There is not a single place in Namibia which is risk-free from all 14 hazards analysed in this profile. There are, however, areas free from some risks such as malaria, wildfire, foot and mouth disease, and sea level rise. At the same time, there is not a single place in Namibia which is at high risk of all 14 hazards. That is, risks are spatially differentiated, but there are areas with high or very high-risk levels for multiple disaster risks. In the Zambezi Region, for example, there are areas concurrently with a high or very high risk of floods, malaria, diarrhoea and foot and mouth disease. The south-eastern part of the //Kharas Region is concurrently under high or very high risk of heatwaves, frost and earthquakes. For the overall risk (combined risks), areas with the highest risk are mainly in the Zambezi, Kavango West, Kavango East, Oshana and Ohangwena regions.

It should be noted, however, that vulnerability and disaster risk levels at each location are relative to the whole country. Relative vulnerability and risk allow for comparability across the country. Therefore, vulnerability and disaster risk levels should be interpreted in the context of them being relative to the whole country. It is also imperative to mention that the results of this study can be rescaled from the risk and vulnerability relative to the national level to the levels relative to a local authority, constituency, or region. In other words, the product of this profile can be reproduced and rescaled relative to a specific local authority, constituency, or region.

This profile relied on some data which were collected more than 10 years ago, especially data related to population number, housing characteristics and livestock. This fact should be considered, especially when interpreting vulnerability maps. Furthermore, the impact of past resilience-building efforts has not been factored into the analysis of vulnerability and disaster risk due to a lack of appropriate data. It is, therefore, possible that the vulnerability of some areas has significantly changed. Based on the findings of this profile, the following is recommended:

I. Targeted and area-specific resilience-building efforts are needed to reduce disaster risk for natural hazards.

II. For climate-related risks, resilience-building efforts should be streamlined to reduce vulnerability.

III. For diseases, resilience-building efforts should target both vulnerability and hazard. The reduction in malaria cases over the years is an excellent case study of how targeting the hazard can reduce the risk. The increase in malaria cases in areas where malaria was near elimination during the years with floods, however, points to the need to also reduce the vulnerability.

IV. Implementing resilience-building efforts in a piecemeal fashion should be avoided.

V. Given that disaster management is an expensive exercise, for some disaster risks (e.g. floods), resilience-building efforts should include reviewing and amending existing laws or promulgating new laws as a mechanism to reduce vulnerability. For example, in the case of floods, a significant number of buildings are constructed in flood-prone areas without implementing appropriate mitigation measures. Such practice should be discouraged.

VI. Spatial planning processes should be streamlined at national, regional, district, and local levels, including in rural areas to account for disaster risks.

VII. Disaster risk maps need to be integrated into the development of towns, settlements, and villages to ensure the safe allocation of land for settlement purposes.

VIII. In future, it should be ensured that the location and the impact of each implemented resilience-building activity are mapped to enable the monitoring of vulnerability.

IX. There is a need to develop an integrated and spatially enabled data management system for storing data on hazards, risks, vulnerability, impacts, and interventions to support resilience-building efforts.

X. There is a need for the creation of awareness across all sectors on the importance of the systematic collection of data on hazards and the impact of disasters.

XI. There is a need to implement a mandatory and standardised annual reporting of the occurrence of all hazards and their impacts to close the current data gaps to ensure that resilience-building efforts are evidence-based.

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APPENDICES

Appendix 1: Distribution of population and households by drought risk level in each region of Namibia, based on 2011 Population and Housing Census data.

Region	Drought risk level	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Fe-male-Head-ed House-holds	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly Peo-ple (60+)
//Kharas	Very low	55096	6357	2777	16087	6121	9966	112	1540
	Low	9908	1158	914	2557	812	1745	17	484
	Moderate	7381	1089	1002	2053	748	1305	28	643
	High	349	62	56	123	62	61	0	40
Erongo	Very low	103086	11158	5751	33150	11173	21977	218	3356
	Low	23511	3168	1168	7416	2675	4741	55	727
	Moderate	8016	1518	1085	2685	945	1740	24	736
	High	2719	475	376	865	391	474	8	238
Hardap	Very low	40097	4065	2919	8533	3230	5303	57	1647
	Low	41660	3883	2048	7736	2634	5102	53	1201
	Moderate	8446	1282	927	2495	953	1542	29	582
	High	1436	262	288	543	209	334	4	182
Kavango East	Very low	26661	4348	1344	5242	2219	3023	51	729
	Low	48937	8334	3443	9278	4216	5062	94	2041
	Moderate	40605	7163	3772	7462	3376	4086	74	2371
	High	4734	964	524	974	443	531	6	330
	Very high	576	97	43	94	36	58	2	26
Kavango West	Very low	3216	604	273	613	269	344	8	188
	Low	15291	2751	1158	2525	1054	1471	28	701cg
	Moderate	52469	9624	4121	8872	3455	5417	103	2584
	High	9508	1660	825	1681	694	987	21	540
Khomas	Very low	244553	27724	9872	68603	27355	41248	506	5222
	Low	93133	8680	2306	20012	7000	13012	126	1315
	Moderate	3497	438	247	796	317	479	5	160
	High	41	18	14	27	11	16	0	8
Kunene	Very low	13290	1837	951	3365	1712	1653	38	515
	Low	42948	9647	3746	11249	4133	7116	254	2103
	Moderate	12923	2680	1245	3576	1366	2210	59	758
	High	930	195	68	305	134	171	6	42
Ohangwena	Very low	8980	1209	237	3344	1624	1720	25	125
	Low	76845	12799	7778	14853	8725	6128	257	5573
	Moderate	111335	19817	11885	20906	11837	9069	482	8714
	High	23858	4243	2621	4556	2492	2064	98	1886
	Very high	747	115	91	139	83	56	2	68
Omaheke	Very low	17244	2250	986	4533	1819	2714	50	525
	Low	42260	7499	3469	10600	3316	7284	158	2226
	Moderate	4176	884	365	980	276	704	14	247
	High	181	55	5	61	30	31	1	5

Region	Drought risk level	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Fe-male-Head-ed House-holds	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly Peo-ple (60+)
Omusati	Very low	9818	1272	452	3085	1505	1580	44	256
	Low	102683	15826	10980	20468	11317	9151	326	7924
	Moderate	85273	13145	11194	18015	9967	8048	246	8147
	High	22989	3399	3341	4860	2861	1999	42	2405
	Very high	738	128	77	195	104	91	3	53
Oshana	Very low	31466	3997	918	9561	4868	4693	87	479
	Low	20456	2727	811	5881	2963	2918	47	512
	Moderate	38108	5704	3824	8637	4771	3866	109	2667
	High	57015	8345	6982	11975	6710	5265	149	5055
	Very high	5714	887	767	1230	702	528	15	572
Oshikoto	Very low	18254	2524	1122	5161	2197	2964	57	677
	Low	64483	11167	6204	15729	7614	8115	276	4427
	Moderate	63092	10499	7141	14233	7225	7008	206	5207
	High	9863	1501	978	2277	1159	1118	24	675
Otjozond-jupa	Very low	41991	6575	2879	12177	5054	7123	134	1620
	Low	50013	8049	3064	13560	4549	9011	125	1838
	Moderate	25309	4876	1986	6334	2129	4205	86	1229
	High	4548	887	371	1121	428	693	14	220
Zambezi	Very low	49125	8175	3128	13951	6232	7719	150	2143
	Low	25491	4383	2205	6712	2944	3768	65	1657
	Moderate	2417	459	145	583	209	374	10	105

Appendix 2: Distribution of population and households by flood risk level in each region of Namibia, based on 2011 Population and Housing Census data.

Region	Flood risk level	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Female Headed Households	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly Peo-ple (60+)
//Kharas	None	527	87	0	94	10	84	2	0
	Very low	72015	8555	4749	20610	7653	12957	155	2707
	Low	192	24	0	116	80	36	0	0
Erongo	Very low	135806	16157	7905	43318	14936	28382	297	4780
	Low	902	105	364	509	175	334	6	217
Hardap	Very low	91639	9492	6182	19307	7026	12281	143	3612
Kavango East	Very low	110397	19162	8181	21198	9424	11774	218	4960
	Low	7335	1088	648	1213	595	618	5	385
	Moderate	3707	634	279	609	257	352	4	151
	High	74	22	18	30	14	16	0	1
Kavango West	Very low	71162	13116	5663	12201	4760	7441	148	3545
	Low	6719	1096	517	1054	494	560	8	332
	Moderate	2603	427	197	436	218	218	4	136
Khomas	Very low	341224	36860	12439	89438	34683	54755	637	6705
Kunene	Very low	70091	14359	6010	18495	7345	11150	357	3418
Ohangwena	Very low	192985	33372	19171	38068	21319	16749	765	13877

Region	Flood risk level	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Female Headed Households	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly People (60+)
	Low	27491	4589	3286	5459	3281	2178	93	2376
	Moderate	1235	218	151	230	137	93	5	112
Omaheke	Very low	63861	10688	4825	16174	5441	10733	223	3003
Omusati	Very low	198516	30275	23186	41726	22917	18809	582	16671
	Low	22670	3437	2852	4686	2727	1959	79	2111
	Moderate	315	58	6	211	110	101	0	3
Oshana	Very low	124177	17457	10226	30969	16650	14319	332	7111
	Low	27117	3991	2895	5920	3164	2756	72	2048
	Moderate	1465	212	181	395	200	195	3	126
Oshikoto	Very low	151134	25046	15031	36193	17580	18613	556	10690
	Low	4282	600	388	1144	579	565	7	277
	Moderate	276	45	26	63	36	27	0	19
Otjozondjupa	Very low	121861	20387	8300	33192	12160	21032	359	4907
Zambezi	Very low	64001	10721	4497	17938	8021	9917	180	3194
	Low	3507	710	364	1113	505	608	12	279
	Moderate	4993	864	371	1215	484	731	14	258
	High	2597	476	160	678	273	405	14	118
	Very high	1935	246	86	302	102	200	5	56

Appendix 3: Distribution of population and households by malaria risk level in each region of Namibia, based on 2011 Population and Housing Census data.

Region	Malaria risk level	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Female Headed Households	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly People (60+)
//Kharas	None	72402	8625	4719	20719	7703	13016	157	2692
Erongo	None	136708	16262	8269	43827	15111	28716	303	4997
Hardap	None	91639	9492	6182	19307	7026	12281	143	3612
Kavango East	Very low	121513	20906	9126	23050	10290	12760	227	5497
Kavango West	None	619	102	39	124	41	83	3	25
	Very low	79865	14537	6338	13567	5431	8136	157	3988
Khomas	None	238201	25593	8803	63033	24757	38276	441	4744
	Very low	103023	11267	3636	26405	9926	16479	196	1961
Kunene	None	30855	4791	2566	9404	3393	6011	95	1486
	Very low	39236	9568	3444	9091	3952	5139	262	1932
Ohangwena	Very low	221711	38179	22608	43757	24737	19020	863	16365
Omaheke	None	41138	7228	3169	10245	2970	7275	150	2004
	Very low	22723	3460	1656	5929	2471	3458	73	999
Omusati	None	69863	9845	8492	15635	8123	7512	212	6037
	Very low	151638	23925	17552	30988	17631	13357	449	12748
Oshana	None	1452	150	103	425	149	276	4	43
	Very low	151307	21510	13199	36859	19865	16994	403	9242
Oshana	None	24064	3645	1585	6972	2529	4443	72	879
	Very low	130785	21956	13809	30275	15591	14684	489	10078

Region	Malaria risk level	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Female Headed Households	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly People (60+)
Otjozondjupa	None	118908	19864	8123	32498	11884	20614	353	4817
	Very low	2953	523	177	694	276	418	6	90
Zambezi	Low	8804	1435	320	2279	959	1320	Low	169
	Moderate	12623	2166	707	3599	1561	2038	35	501
	High	41254	7028	3318	11569	5174	6395	131	2389
	Very high	14352	2388	1133	3799	1691	2108	29	846

Appendix 4: Distribution of population and households by heatwave risk level in each region of Namibia, based on 2011 Population and Housing Census data.

Region	Heatwave risk level	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Female Headed Households	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly People (60+)
//Kharas	Low	3566	524	253	1096	464	632	14	149
	Moderate	46435	5611	2629	14542	5657	8885	102	1441
	High	20722	2238	1667	4624	1434	3190	34	989
	Very high	2011	293	200	558	188	370	7	128
Erongo	Moderate	137332	16319	8380	44116	15184	28932	305	5057
Hardap	Low	4029	456	337	1068	456	612	14	167
	Moderate	67442	6431	4219	13084	5169	7915	93	2538
	High	20168	2605	1626	5155	1401	3754	36	907
Kavango East	Moderate	121513	20906	9126	23050	10290	12760	227	5497
Kavango West	Moderate	80484	14639	6377	13691	5472	8219	160	4013
Khomas	Moderate	340452	36836	12422	89380	34675	54705	637	6693
	High	772	24	17	58	8	50	0	12
Kunene	Moderate	68999	14219	5929	18114	7241	10873	354	3373
	High	1092	140	81	381	104	277	3	45
Ohangwena	Moderate	175120	30253	18029	34094	19197	14897	697	13002
	High	46645	7930	4583	9704	5564	4140	167	3364
Omaheke	Moderate	61006	10146	4581	15461	5158	10303	208	2820
	High	2855	542	244	713	283	430	15	183
Omusati	Moderate	220562	33627	25932	46441	25633	20808	658	18697
	High	939	143	112	182	121	61	3	88
Oshana	Moderate	140045	19683	12730	33005	17905	15100	379	8896
	High	12714	1977	572	4279	2109	2170	28	389
Oshikoto	Moderate	88613	15273	7630	22862	10193	12669	361	5248
	High	67079	10418	7815	14538	8002	6536	202	5738
Otjozondjupa	Moderate	121861	20387	8300	33192	12160	21032	359	4907
Zambezi	Moderate	77033	13017	5478	21246	9385	11861	225	3905

Appendix 5: Distribution of population and households by lightning risk level in each region of Namibia, based on 2011 Population and Housing Census data.

Region	Lightning	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Female Headed Households	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly People (60+)
//Kharas	Very low	72734	8666	4749	20820	7743	13077	157	2707
Erongo	Very low	137237	16295	8349	44039	15167	28872	305	5040
Hardap	Very low	91345	9445	6129	19199	6964	12235	141	3579
	Low	294	47	53	108	62	46	2	33
Kavango East	Very low	17524	2847	836	3453	1586	1867	30	455
	Low	55506	9725	3926	10689	4635	6054	111	2329
	Moderate	33565	5783	2996	6243	2818	3425	60	1849
	High	14005	2386	1305	2465	1175	1290	21	820
	Very high	913	165	63	200	76	124	5	44
Kavango West	Low	16019	3097	1241	2815	925	1890	33	757
	Moderate	40286	7368	3337	6930	2875	4055	84	2112
	High	13389	2411	1102	2232	933	1299	26	696
	Very high	10790	1763	697	1714	739	975	17	448
Khomas	Very low	329995	35350	12208	86195	33435	52760	615	6577
	Low	11229	1510	231	3243	1248	1995	22	128
Kunene	Very low	60755	12711	5298	15742	6366	9376	319	3011
	Low	9336	1648	712	2753	979	1774	38	407
Ohangwena	Very low	4758	682	143	1813	848	965	11	94
	Low	42291	6982	3674	8449	4662	3787	138	2618
	Moderate	87878	15134	9394	17447	10042	7405	355	6855
	High	78804	13965	8616	14750	8434	6316	321	6260
	Very high	8034	1420	785	1339	775	564	39	539
Omaheke	Very low	33941	5389	2291	8734	2974	5760	134	1415
	Low	28729	5070	2463	7118	2335	4783	87	1542
	Moderate	1191	229	71	322	132	190	2	46
Omusati	Very low	18014	2075	926	4308	1751	2557	99	613
	Low	129664	20448	15657	27796	15373	12423	358	11356
	Moderate	68752	10503	8888	13621	8114	5507	188	6396
	High	5071	744	573	898	516	382	16	420
Oshana	Very low	31568	3934	905	9604	4910	4694	86	486
	Low	53978	7700	4458	13639	7139	6500	132	3053
	Moderate	56210	8325	6586	11930	6772	5158	159	4795
	High	11003	1701	1353	2111	1193	918	Low	951
Oshikoto	Very low	1034	129	66	297	96	201	5	33
	Low	68956	11546	6561	17188	8013	9175	301	4654
	Moderate	61924	9996	6436	13849	7178	6671	189	4628
	High	21577	3595	2269	5393	2597	2796	63	1603
	Very high	2201	425	113	673	311	362	5	68
Otjozondjupa	Very low	45673	7274	3088	13468	4860	8608	153	1767
	Low	64017	11119	4382	16502	5953	10549	169	2647
	Moderate	12005	1950	803	3177	1338	1839	37	485

Region	Lightning	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Female Headed Households	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly People (60+)
	High	166	44	27	45	9	36	0	8
Zambezi	Very low	13473	2203	341	3654	1599	2055	44	180
	Low	38169	6554	3031	10727	4644	6083	116	2158
	Moderate	22224	3751	1786	5977	2749	3228	60	1332
	High	3167	509	320	888	393	495	5	235

Appendix 6: Distribution of population and households by COVID-19 risk level in each region of Namibia, based on 2011 Population and Housing Census data.

Region	COVID-19	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Female Headed Households	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly People (60+)
//Karas	Very low	72734	8666	4749	20820	7743	13077	157	2707
Erongo	Very low	137127	16300	8344	44035	15171	28864	304	5040
	Low	205	19	36	81	13	68	1	17
Hardap	Very low	91639	9492	6182	19307	7026	12281	143	3612
Kavango East	Very low	121513	20906	9126	23050	10290	12760	227	5497
Kavango West	Very low	80484	14639	6377	13691	5472	8219	160	4013
Khomas	Very low	126123	11294	2156	25902	9577	16325	167	1188
	Low	95496	10855	5151	28028	11122	16906	216	2835
	Moderate	49981	6320	2062	14816	5881	8935	97	1091
	High	51194	6339	1767	15490	5948	9542	115	931
	Very high	18430	2052	1303	5202	2155	3047	42	660
Kunene	Very low	70091	14359	6010	18495	7345	11150	357	3418
Ohangwena	Very low	221765	38183	22612	43798	24761	19037	864	16366
Omaheke	Very low	63861	10688	4825	16174	5441	10733	223	3003
Omusati	Very low	221501	33770	26044	46623	25754	20869	661	18785
Oshana	Very low	150211	21299	12922	36815	19761	17054	404	9024
	Low	2548	361	380	469	253	216	3	261
Oshikoto	Very low	155692	25691	15445	37400	18195	19205	563	10986
Otjozondjupa	Very low	121861	20387	8300	33192	12160	21032	359	4907
Zambezi	Very low	76918	12986	5465	21197	9366	11831	225	3895

Appendix 7: Distribution of population and households by HIV/AIDS risk level in each region of Namibia, based on 2011 Population and Housing Census data.

Region	HIV/AIDS	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Female Headed Households	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly People (60+)
//Kharas	Very low	72734	8666	4749	20820	7743	13077	157	2707
Erongo	Very low	136272	16207	8274	43731	15076	28655	302	4998
Hardap	Very low	91024	9427	6154	19194	6987	12207	142	3594
	Low	544	47	25	75	27	48	1	15
	High	71	18	3	38	12	26	0	3
Kavango East	Very low	46998	8167	4380	8646	3830	4816	93	2740
	Low	54761	9256	3398	10526	4697	5829	102	1994
	Moderate	19754	3483	1348	3878	1763	2115	32	763
Kavango West	Very low	42775	7825	3104	7111	2696	4415	86	1915
	Low	29917	5525	2665	5242	2163	3079	57	1691
	Moderate	7792	1289	608	1338	613	725	17	407
Khomas	Low	58422	2443	1740	6557	1798	4759	53	1034
	Moderate	192725	23292	7495	56187	22433	33754	392	4052
	High	88721	10966	3189	26331	10316	16015	191	1615
	Very high	1356	159	15	363	136	227	1	4
Kunene	Very low	70091	14359	6010	18495	7345	11150	357	3418
Ohangwena	Very low	107573	19156	9851	21248	11423	9825	429	7071
	Low	114138	19023	12757	22509	13314	9195	434	9294
Omaheke	Very low	63265	10586	4764	16024	5356	10668	223	2964
	Low	242	34	27	65	36	29	0	18
	Moderate	354	68	34	85	49	36	0	21
Omusati	Very low	221501	33770	26044	46623	25754	20869	661	18785
Oshana	Very low	37339	5177	2917	9691	5071	4620	105	1982
	Low	114664	16333	10333	27287	14786	12501	299	7272
	Moderate	756	150	52	306	157	149	3	31
Oshikoto	Very low	128111	21268	12589	31007	15029	15978	482	8900
	Low	27581	4423	2856	6393	3166	3227	81	2086
Otjozond-jupa	Very low	121861	20387	8300	33192	12160	21032	359	4907
Zambezi	Very low	52367	9150	4154	14992	6604	8388	160	2995
	Low	24625	3855	1314	6230	2770	3460	65	903

Appendices

Appendix 8: Distribution of population and households by diarrhoea risk level in each region of Namibia, based on 2011 Population and Housing Census data.

Region	Diarrhoea	Population	Children Population (0 -4)	Elderly population (60+)	Number of Households	Female Headed Households	Male Headed Households	Households Headed by Minors (<18)	Households Headed by Elderly People (60+)
//Kharas	Very low	72479	8637	4734	20728	7710	13018	156	2699
Erongo	Very low	135428	16196	8260	43684	15062	28622	302	4992
Hardap	Very low	91639	9492	6182	19307	7026	12281	143	3612
Kavango East	Very low	46596	8044	4244	8695	3855	4840	92	2659
	Low	10803	1836	628	2535	1082	1453	21	329
	Moderate	48833	8238	2790	8946	4014	4932	84	1581
	High	11521	2168	1112	2252	1042	1210	25	710
	Very high	3760	620	352	622	297	325	5	218
Kavango West	Very low	18336	3382	1267	2986	1010	1976	40	736
	Low	24164	4373	1799	4060	1668	2392	45	1157
	Moderate	14240	2659	1224	2607	979	1628	32	782
	High	19819	3575	1784	3378	1483	1895	36	1125
	Very high	3925	650	303	660	332	328	7	213
Khomas	Very low	33830	3127	2999	11689	4049	7640	65	1608
	Low	163557	16807	6264	38891	16348	22543	302	3339
	Moderate	113417	12337	2630	28658	10869	17789	210	1465
	High	27662	4202	499	9398	3164	6234	58	276
	Very high	1903	323	34	642	187	455	1	16
Kunene	Very low	70091	14359	6010	18495	7345	11150	357	3418
Ohangwena	Very low	27838	5034	2055	6143	2748	3395	155	1427
	Low	159426	27190	16640	31271	18073	13198	573	12088
	Moderate	34447	5955	3913	6343	3916	2427	135	2850
Omaheke	Very low	59935	9939	4536	15165	5021	10144	212	2808
	Low	3926	749	289	1009	420	589	11	195
Omusati	Very low	141731	20686	17191	31062	16966	14096	424	12378
	Low	79770	13084	8853	15561	8788	6773	237	6407
Oshikoto	Very low	19827	2471	627	5458	2705	2753	59	309
	Low	115485	16361	10443	28176	15205	12971	290	7386
	Moderate	17447	2828	2232	3650	2104	1546	58	1590
Otjozond-jupa	Very low	26631	4021	1766	7813	2960	4853	81	998
	Low	120104	19867	12892	27701	14408	13293	446	9403
	Moderate	8114	1713	736	1733	752	981	34	556
	Very low	121047	20387	8299	33192	12160	21032	359	4907
Zambezi	Very low	7006	1073	201	1852	804	1048	27	104
	Low	31465	5528	2532	9236	4191	5045	95	1821
	Moderate	38272	6352	2724	10095	4373	5722	103	1965
	High	290	64	21	63	17	46	0	15

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