RESILIENT WATERS PROGRAM

REVISED REPORT

NOT TO BE QUOTED

THE IMPACTS OF CYCLONE IDAI IN THE BUPUSA TRANSBOUNDARY BASINS IN MOZAMBIQUE AND ZIMBABWE

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for Resilient Waters Program

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Executive Summary

Chapter 1

This report focuses on the impacts of Cyclone Idai on Mozambique and Zimbabwe, in particular on the transboundary river basins Buzi, Pungwe and Save (BuPuSa). To assess the impacts, we need to understand of the countries' socio-economic situation and local livelihoods. This report focuses on the impacts of Cyclone Idai in reference to livelihood strategies, which are the core of household and community resilience. Geospatial assessments and socio-economic assessments were undertaken (section 5.1 and 5.2 resp.) before an integrated analysis was made (chapter 6).

Mitigation strategies, covering most of the four Sendai priority areas as well as SADC's abilities to boost resilience, and lessons learnt are the subject of a forthcoming report (July 2020).

Chapter 2

The BuPuSa River basin area is around 166,000 km in size. The Save basin is the largest and the longest river (640 km) with the highest mean annual run-off. The BuPuSa population is around 5.7 million.

The Buzi basin is flood prone, and floods are particularly damaging when the Buzi estuary joins the flood plain of the Pungwe. Almost 90% is located in Mozambique. The Basin Agreement permits a maximum of 766.7 Mm^3 of water abstraction per annum, mostly for irrigation (615 Mm^3). Each country is allocated around half of the total abstractions. Countries may shift sectoral allocations within their overall water allocations. The Pungwe basin is also flood prone and 94% of the basin is in Mozambique. Total permissible annual water abstractions are 809 Mm^3 which is slightly higher than from the Buzi. Mozambique has the largest quota (578 Mm^3); Zimbabwe may abstract 231 Mm^3. The river has one large dam in Zimbabwe (sugar estate) and is underutilized. Plans for further dam developments exist for irrigation and water supply systems. The Save basin is mostly located in Zimbabwe (78%). It is heavily utilized and runs dry in the lower parts. The river is heavily dammed for irrigation. A draft WRM strategy and dam operation guidelines have been developed to manage the river more actively. No bilateral agreement for the river's management exist, but the Save will be included in the three -basins agreement that is currently being developed. The total abstracted amount of water from the three rivers is unknown.

Chapter 3

The profiles of both countries show that Mozambique is roughly twice as big as Zimbabwe is, but the size of the economies is similar. Mozambique's population was 29.7 million in 2017 and is almost double that of Zimbabwe (16.5 million in 2017). Economic growth is below the population growth in both countries, hence per capita income is not increasing. The incidence of poverty is high, particularly in Zimbabwe. Unemployment is high in Mozambique. The figure for Zimbabwe is low as most rural people are reportedly engaged in subsistence farming and not unemployed. The Adjusted Net Savings Index (ANSI) is negative in both countries, because of the consumption of fixed capital in both countries. This indicates lack of maintenance and is unsustainable.

Both countries are high risk countries and vulnerable, as reflected in the Global Risk Index (GRI). This index ranks Mozambique as the 19th highest risk country and Zimbabwe as 47th out of 190 countries. In both countries, vulnerability and inadequate coping capacity are considered the main contributors to the overall high risk. Natural risks present a greater risk than human risks. Droughts are the highest risk in both countries. Floods, tsunami (Mozambique) and epidemics are also common natural risks.

The risk of tropical cyclones is high in Mozambique but low in Zimbabwe due to the latter's inland location.

Both countries are low-income countries and have relatively low levels of human development. Both countries have budgetary constraints and foreign debts are high. Therefore, countries depend on external financial assistance. Because of drought conditions, food insecurity was already high before Cyclone Idai struck; however, Idai worsened the situation dramatically. Both countries share political and governance challenges. In Mozambique, preparation for the October 2019 election were on-going with tension between the main political parties and funding challenges. Conflicts have also arisen in the oil and gas rich province of Cabo-Delgado. In Zimbabwe, government is struggling to stimulate economic growth, stabilize its currency and increase foreign reserves to meet import requirements. Fortunately, both countries have well established disaster management structures in place, but funding and capacity constraints limit full implementation. Climate change is expected to have profound negative impacts in both countries. Natural hazards, particularly droughts and in Mozambique cyclones are expected to increase in numbers and intensity. Given the funding and capacity constraints, integration of climate change adaptation (CCA) and disaster risk management (DRM) therefore seems appropriate.

While the project focuses on the three-basins area (Buzi, Pungwe and Save River basins; BuPuSa), Cyclone Idai affected a much larger area, particularly in Mozambique. An estimated 84 % of the BuPuSa area was affected by the cyclone; 63% of this was in Mozambique and 27% in Zimbabwe. Almost the entire Mozambican part of the three basins was affected compared to around two-thirds in Zimbabwe. The cyclone affected almost the same size of area outside the BuPuSa, of which over three quarters was in Mozambique. Outside the BuPuSa area, Zambezia Province and to a lesser extent Tete Province were affected. Inside the BuPuSa area, the most heavily affected provinces were Sofala and Manica Provinces in Mozambique and Manicaland Province, especially Chimanimani and Chipinge Districts, and Masvingo Province in Zimbabwe. This explains why the Mozambican assessment (PDNA) focused on these four provinces. Our geospatial assessment focused on the BuPuSa area while the socio-economic assessment addressed the entire affected area in each country and focused on the BuPuSa portion.

Chapter 4

In mid-March 2019, Southern Africa was by the extremely powerful Cyclone Idai. This storm devasted parts of southern/central Mozambique, and south east Zimbabwe, even reaching as far as southern Malawi[1]. The transboundary river basins of the BuPuSa basins were hard hit with high winds, heavy rainfall, resulting in storm-surges in coastal regions, flooding and landslides inland in Zimbabwe and Mozambique. Approximately a month later, the devastation was compounded by a second cyclone, Kenneth, which affected Mozambique, Malawi and Tanzania. Tropical storms from the Indian Ocean are a fact of life in Indian Ocean Island States and East Africa; however, the past twenty years have been marked with several significantly intense events, including Eline in 2000, Dineo in 2016, Idai and Kenneth in 2019. The devastating impact of these events, resulting in loss of life, destruction of infrastructure and property, and widespread disruption of livelihoods for already vulnerable populations underlines the need for building resilience. This is especially true in the context of climate change which may see increased intensity of such events as we move into the future.

[1] As the project focuses on the BuPuSa area, the impacts of Idai on Malawi are not considered in this project. Furthermore, the impacts of Kenneth have not been considered.

Chapter 5

The impact assessment comprised two key elements: a geospatial assessment utilizing medium and high-resolution satellite imagery and limited existing spatial data; and a socio-economic assessment informed by extensive research of key sources (see references) and data analysis. While these activities were largely successful, they were constrained by lack or currency of available data, lack of data consistent across countries and different spatial levels (transboundary, national, district and local), and substantial data gaps. While these are common issues across the region, these circumstances highlight the role that lack of data access plays in institutional vulnerability.

<u>Geospatial assessment</u>

The geospatial assessment focused on provision of detailed topographic maps, and three analytical outputs – detailed community-level damage assessments and flood and landslide analysis (Chimanimani and Beira), and basin-scale landcover change analysis. These activities also supported the socio-economic assessment through the provision of additional ’local’ information that in the case of the landcover change data was used to either validate or analyze information sourced from literature, and fill gaps where no data existed; and in the case of the high-resolution imagery analysis provided community level inputs and context where limited information was available. While the high-resolution analyses described below were insightful, they were limited to two demonstration focal areas due to cost constraints.

The damage assessment utilized 0.5-meter resolution WorldView-2 multispectral imagery from before and after the event for two focused study areas. While limited in scope and size, these data provided an insight into how high-resolution imagery could be utilized to augment or replace field work to assess community level damage. While the team was only able to analyze these two examples, the results provided insights into the damaged caused by Cyclone Idai in both communities. The categorization of damaged houses enabled the development of damage heat maps, which revealed differing damage patterns in each location.

ESA Sentinel-1A Synthetic Aperture Radar (SAR) imagery captured during the event was used to identify flooded areas for both focused study areas, and bare earth landcover identified by classifying the high-resolution imagery enabled the detailed mapping of landslides in Chimanimani, which were integrated into the flood analysis map. Analyzing the results of this data and the damage assessment revealed patterns of damage. While flooding was extensive in both areas, the settlements in Beira were largely spared mass flooding, and Chimanimani was more significantly impacted by landslides, with severe damage concentrated around the landslide paths which cut right through several densely populated parts of the village, devastating housing and roads. Furthermore, damage patterns in Beira were varied and seemed to be driven more by selected building materials used, and level of exposure (lack of shelter from wind caused by removal of trees) than flooding *per se*.

Sentinel-2 medium-resolution (10-meter) multispectral imagery was used to create unsupervised image classification layers before and after the cyclone event. The lack of field-validation data to supervise the refinement of the classification and identify specific crop types meant that the analysis was constraint to broad, unvalidated landcover classes – sparse vegetation, grassland/pasture, dense vegetation, cultivated (dryland and irrigated) agriculture, water and urban areas. These data were summarized at a provincial level, recognizing that the *before* conditions were relatively dry – seasonally, and following a lengthy period of drought.

The before and after outputs were combined in a change detection process, illustrating provincial-level changes in landcover. While several interesting observations were made using these data, they are observed against the background of seasonal regrowth and regeneration associated with increased availability of water at the end of the dry season. These results and the cultivated land extents and change were further quantified in terms of exposure to the cyclone. Exposure was calculated using satellite derived cumulative rainfall data obtained from the European Space Agency, landcover change and exposure confirmed that Sofala and Manica Provinces in Mozambique, and Manicaland and Masvingo Provinces in Zimbabwe were the most substantially affected by heavy rain during and in the weeks after the cyclone event.

As detailed district-level information was available for Chimanimani and Chipinge in the Rapid Integrated Needs Assessment (RINA) document for Zimbabwe, the same analysis was conducted at district level for these two provinces, assisting with the validation of a range of data contained within this document.

Socioeconomic assessment

In terms of magnitude the socio-economic impacts were largest in Mozambique because a larger area and more people were affected, including areas outside BuPuSa (e.g. Zambezia and Tete Provinces). The impacts included income and production losses, damages to and destruction of assets (private and public) and social and environmental impacts.

The impacts have been largest on human resources and well-being, buildings and houses, infrastructure (incl. water, sanitation and hygiene WASH) and agriculture (dryland farming and irrigation). Unfortunately, no detailed socio-economic breakdown of the agricultural impacts is available (e.g. impacts on small farmers vis-à-vis large commercial farmers). The impacts on the livestock sector has been limited. Social and environmental impacts occurred but have not or only partly been quantified. In Zimbabwe, the extent and intensity of the impact on forests and Protected Areas has been correlated to the amount and distribution of rainfall. This led to the conclusion that large parts of forests and Protected Areas (PAs) may have been damaged.

Based on the Post Disaster Needs Assessment PDNA (Mozambique) and RINA (Zimbabwe) assessments, 250,000 to 260,000 houses were affected: around 130-140,000 damaged and around 120,000 destroyed. This means that more than 70% of the affected households had their houses damaged or destroyed. In Zimbabwe, the damage was concentrated in three areas in Chimanimani and Chipinge Districts associated with landslide as the geospatial assessment showed. The intensity of damage was high, i.e. houses were mostly destroyed). In Mozambique, most damage occurred in two areas of Beira and was caused by strong winds and flooding. The impacts were more widespread than in Zimbabwe, but the intensity of the damage was lower; two areas were mostly affected in Beira: an area close to the ocean and an area just north of Beira along the railway line. Parts of Beira with a rehabilitated water drainage system was less affected.

Particularly in Mozambique, large areas were flooded both in settlements and farmland. The flooded dry farmland is estimated at around 1-1.5 million ha. In Mozambique 44% of the flooded area of around 750,000 ha could be in BuPuSa; Sofala and Zambezia were most affected. In total 433,000 households suffered from flooded farmland, possibly 200,000 in BuPuSa area, with an average flooded area of 1.6 ha/household. Floods occurred much less in Zimbabwe and was localized so the incidence has been lower there. In Zimbabwe, production losses were estimated at 580,000 MT, mostly subsistence crops but also cash crops for exports. In Mozambique, the production losses are estimated at 2.2 million MT. These losses strongly affected rural livelihoods and increased pre- Cyclone Idai food insecurity even more.

The irrigation sector was adversely affected in both countries. In Mozambique, the PDNA report estimates that 4,300 ha was damaged or destroyed, mostly of small-scale farmers with an average farm size of 0.6 ha. The RINA does not estimate the total affected irrigated area in Zimbabwe. It only has details for 18 specific irrigation schemes in Chimanimani and Chipinge. These schemes cover 2,300 ha and have 5,000 farmers. No figures exist for the estimated production damage to the irrigation sector.

The cyclone damaged or destroyed many water sources and water reticulation systems in both countries as well as sanitary facilities of households, schools and health facilities. Boreholes, wells, and springs are the most common rural water sources, and most were affected and/or contaminated. A number were not yet repaired or replaced by December 2019. In urban areas, water reticulation systems are most important, and many were temporarily affected. In brief, Idai affected access to safe potable water of most people. Sanitary facilities experienced a similar situation. A significant number was damaged or destroyed. This worsened access to sanitary facilities, increased open defecation in the bush and the associated health hazards.

Most public facilities and infrastructure were affected by the cyclone. This includes educational and health facilities, roads, harbor and airport (Beira), pipeline from Beira to Zimbabwe, and electricity distribution systems. Generally, the number of damaged facilities was highest in Mozambique due to the larger area that was affected.

Damaged facilities and infrastructure have had several impacts on households and the private sector:

1. Interruption of education affecting many students;
2. Interruption of and reduced access to health facilities. This adversely affected people with illnesses, pregnant women, family planning etc. and
3. Increased distance to the nearest public facility exposed women and children to risks of harassment and rape.

The cyclone has caused a wide range of social impacts in both countries. The magnitude of the impact is bigger in Mozambique because of the larger number of affected people but the nature of the impacts is similar:

a. Disruption of community and family relationships;
b. Displacement, temporary relocations into shelters and camps;
c. Resettlement from destroyed or high-risk areas to lower risk areas;
d. Losses of breadwinners;
e. Losses of jobs, particularly in the informal sector, the private sector and in agriculture. Public sector employment was maintained;
f. Increased hardships due to income losses and losses of family assets. This may have led to Gender-based violence and conflicts between and within families; and
g. People may also suffer from post-traumatic disorders in areas where the impacts of the cyclone were most severe.

Generally, extreme events affect vulnerable groups disproportionally as these groups are most exposed to risks and have limited adaptation options. They live in low, flood-prone areas, have poor houses and/or live in informal settlements with limited access to public services. The same vulnerable groups have been identified in both countries (PDNA and RINA): children, the elderly, people with disabilities, people living with HIV, internally displaced persons, and women. Their numbers are significant, but not all receive adequate attention in relief and rebuilding efforts.

Idai has had multiple environmental impacts, including landslides and associated land degradation-destruction, destruction of water points and water contamination, destruction of coastal ecosystems and defense line, possible soil pollution associated with flooding, forest destruction and degradation, damage protected ecosystems in Protected Areas, damaged mangroves. Furthermore, increased poverty and reduced access to services and facilities is likely to have increased pressure on 'free' natural resources in forests, rangelands and possibly Protected Areas. In addition, it may have led to littering, uncontrolled waste disposal and pollution. In Mozambique, the risks of asbestos exposure from damaged houses was cited as an example in the DNA report. The livelihood impacts of environmental degradation caused by Idai are significant and qualitatively described in Mozambique. In Zimbabwe, the damage to forest and PAs was explored quantitively. Assuming that the damage is positively related to the rainfall amount, around 4,900 km^2 of forests and 1,050 km^2 of Protected Areas could be seriously damaged (with high rainfall of over 100 mm); mostly in Chimanimani and Chipinge Districts. The possibility to extend this 'rainfall-damage intensity correlation' approach will be further investigated for to agricultural land, livelihoods and population in BuPuSa. In terms of the ecosystem services, Cyclone Idai is likely to have seriously affected all services: production function (crops, animals, fish, water and timber/wood), support services (damaged soil and nutrient formation and damage to the fish breeding/ nursery role of mangroves); regulatory services: pollution and disease control; and cultural services (loss of tourism, cultural and religious services of damaged ecosystems).

The above impacts had profound negative impacts on people's livelihoods. However, no study quantified the livelihood impacts of Cyclone Idai. The starting point is that poverty levels were high and livelihood security is poor. Households use different livelihood sources for a living. In rural areas of Mozambique and Zimbabwe, agriculture is the main livelihood sources: agriculture produce is consumed in the household and/or sold to meet cash needs. Other sources of livelihood are formal and informal employment, gathering of free natural resources, petty or informal trade and illegal gold mining. In Zimbabwe, around two thirds of the rural households cannot adopt a coping strategy to hazards like Idai. The remaining one third adopt different coping measures, which affect their livelihood security and sustainability: Stress measures: Borrowing, reducing savings and selling of assets; Crisis measures: Selling of productive assets, withdrawing children from school and cutting non-food expenditures; and Emergency measures: Selling land and breeding stock as well as begging. These measures erode the asset base of households (e.g. savings, land, animals, lower education and poorer health) and limit future livelihood opportunities. The incidence of poverty was expected to increase by 15%. The situation in rural Mozambique is expected to be similar. Urban areas have better job opportunities and therefore self-employment is often the main source of livelihood (40 % of the urban households). In Beira, Chimoio, Tete and other towns formal employment in the public and private sectors is important too. Self- employment in agriculture and the informal sector, and formal employment in the private sector have been seriously affected while public servants' salaries were maintained. The severity of the impact of Idai on household livelihoods can be seen from the estimates that in Mozambique per capita damage and losses are estimated to exceed the average p.c. annual income. In Zimbabwe, the Idai losses per household are estimated to exceed the average household income in 2017. Households lost valuable income and assets.

Chapter 6

The combination of the geospatial and socio-economic assessments demonstrated the high vulnerability prior and after Cyclone Idai of the countries and communities involved. Community resilience depends on secure and adequate livelihoods, intra community relationships (e.g. between households based on community institutions and processes) and effective support from provincial and national government authorities. As shown above, livelihoods were greatly affected, and it will be challenging to develop better, more diverse and more sustainable livelihoods in future. This applied in particular to vulnerable groups that lived in the most exposed areas and have few, if any, options to adapt. Less information is available about community relationships, but the picture that emerges is mixed. Households have lost breadwinners and the number of orphans has increased. A number of people were injured, possibly permanently, and other had reduced access to health facilities to the detriment of their own and family health. Many households were displaced and found temporary shelter elsewhere. Where households lived in high-risk areas, the intention is to relocate them permanently to lower risk areas. So, communities may be disrupted, facing many new challenges. Moreover, social problems have been reported such as increased gender-based violence (GBV), rape and child abuse. On the other hand, households and communities showed a degree of resilience and support to each other. Most displaced persons were accommodated by other households. Furthermore, households assisted each other to cope and repair some of the damages. The village DRM committees in Mozambique implemented evacuation plans and had shelters available for evacuees.

The assessment identified factors that made the impact worse and other that ameliorated the impact of Cyclone Idai. These are listed in chapter 6 and are not repeated here. In terms of mitigation measures, the factors that made the impacts worse need to be resolved and the ameliorating factors need to be strengthened and expanded, among other based on lessons from other cyclones.

It has been worthwhile to have both the geospatial and socioeconomic assessment combined as they provided complementary results, and their joint analysis probed each assessment deeper. For example, the rainfall-damage correlation approach applied in Zimbabwe to forests and Protected Areas is expanded to affected agriculture, population and livelihoods. The irrigation sector will be further analyzed to better understand the extent and nature of the damage. The geospatial assessment suggests much more exposure of irrigated areas than the irrigation damage from the socio-economic assessment (based on PDNA and RINA data). The geospatial assessment enriched the socioeconomic assessment with more local or sub district findings (e.g. Chimanimani and Beira). Finally, the combination of both assessments provided a strong and new focus on the BuPuSa River basins, while recognizing that the impacts of Cyclone Idai went beyond the three basins and included Zambezia Province. In contrast, the PDNA and RINA assessments were national in nature. Limitations of each assessment were also evident. Ideally, some of the findings of the geospatial assessment could be ‘firmed up’ with ground truthing (beyond the ToR of the project). Lack of village livelihood and Cyclone Idai impact studies necessitated inferences of aggregate PDNA and RINA data based on available statistics in Zimbabwe and largely qualitative livelihood strategy descriptions in Mozambique.

Acknowledgements

TO FOLLOW

Abbreviations

ANSI	Adjusted Net Savings Index
ARA	Administração Regional de Águas (Regional water administration Mozambique)
BRB	Buzi River Basin
BuPuSa	Buzi, Pungwe and Save river basins
CAR	Center for Applied Research
CCA	Climate Change Adaptation
CCGC	Council of key Ministers (Mozambique)
CENOE	Emergency Operation Centers
CPO	Civil Protection Organization
CRG	Core Response Group
CRIDF	Climate Resilient Infrastructure Development Facility
DCP	Department of Civil Protection (Zimbabwe)
DFID	Department for International Development
DMF	Disaster Management Fund
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EMA	Environmental Management Agency
ESA	European Space Agency
GACOR	Reconstruction Coordination Office (Mozambique)
GDP	Gross Domestic Product
GEE	Google Earth Engine
GEF	Global Environmental Facility
GIS	Geographical Information System
GNI	Gross National Income
GNP	Gorongosa National Park
GoM	Government of Mozmabique
GoZ	Government of Zimbabwe
GRD	Ground Range Detection
GRI	Global Risk Index
GRIP	Global Risk Identification Program
GWP	Global Water Partnership
Ha	Hectare
HCA	Hatfield Consultants Africa
HDI	Human Development Index
HOT	Humanitarian OpenStreetMap Team
ICP	International Cooperation Partner
INFORM	Index for Risk Management
INGC	National Institute for Disaster Management
KM	Kilometer
LIMCOM	Limpopo Watercourse Commission
MAE	Ministry of State Administration
MAR	Mean Annual Runoff
MASL	Meters above sea level
MICOA	Ministry of Environment (Mozambique)
MPD	Ministry of Planning and Development (Zimbabwe)
MT	Metric Ton
NCPC	National Civil Protection Committee (Zimbabwe)
NDP	National Development Plan
NDWA	Normalised Differential Water Index

NGO	Non-Government Organization
NP	National Park
NPA	National Plan of Action
OKACOM	Permanent Okavango River Basin Commission
PA	Protected Area
P.c.	Per capita
PDNA	Post Disaster Needs Assessment
PDRRD	DRR Master Plan
PIES	Poverty, Income and Expenditure Survey (Zimbabwe)
PPCR	Pilot Program on Climate Resilience
PRB	Pungwe River Basin
RDC	Rural Development Council
RIASCO	Regional Inter-agency Standing Committee
RINA	Rapid Integrated Needs Assessment
RS	Remote Sensing
RWP	Resilient Waters Project
SADC	Southern African Development Community
SAR	Synthetic Aperture Radar
SD	Sustainable Development
SRB	Save River Basin
ToR	Terms of Reference
TFCA	Transfrontier Conservation Area
UN	United Nations
UN-ECA	UN Economic Commission for Africa
UN- ECE	UN Economic Commission for Europe
UNIDRR	United Nations Institute for Disaster Risk Reduction
USAID	United States Agency for International Development
VH	Vertical/Horizontal
WA	Water Allocation
ZINWA	Zimbabwe National Water Authority

1 Introduction

1.1 Background to the report

This report assesses and analyses the impacts of Cyclone Idai in Mozambique and Zimbabwe, with particular focus on the three transboundary river basins of the Buzi, Pungwe and Save (BuPuSa). The report is part of a project, initiated by Resilient Waters Program (RWP). This program, implemented by Chemonics for the United States Agency for International Development (USAID), has contracted the Centre for Applied Research (CAR) , Botswana, to carry out an assessment of the impacts of Cyclone Idai on communities in Mozambique and Zimbabwe[2] and to identify lessons for the strengthening of communities in resilience against cyclones. CAR with Hatfield Consultants Africa (HCA) undertook a geospatial and socio-economic impact assessment to understand the cyclone's impact and mitigation measures and to develop a plan for follow-up activities, particularly at the community level. The anticipated follow-ups will be a separate RWP project in 2021.

This report focuses on the impacts of the Cyclone Idai in Mozambique and Zimbabwe. The mitigation report is due by the end of July. The Buzi, Pungwe and Save Transboundary River Basins (BuPuSa) are shown in Figure 1.

1.2 Project methodology

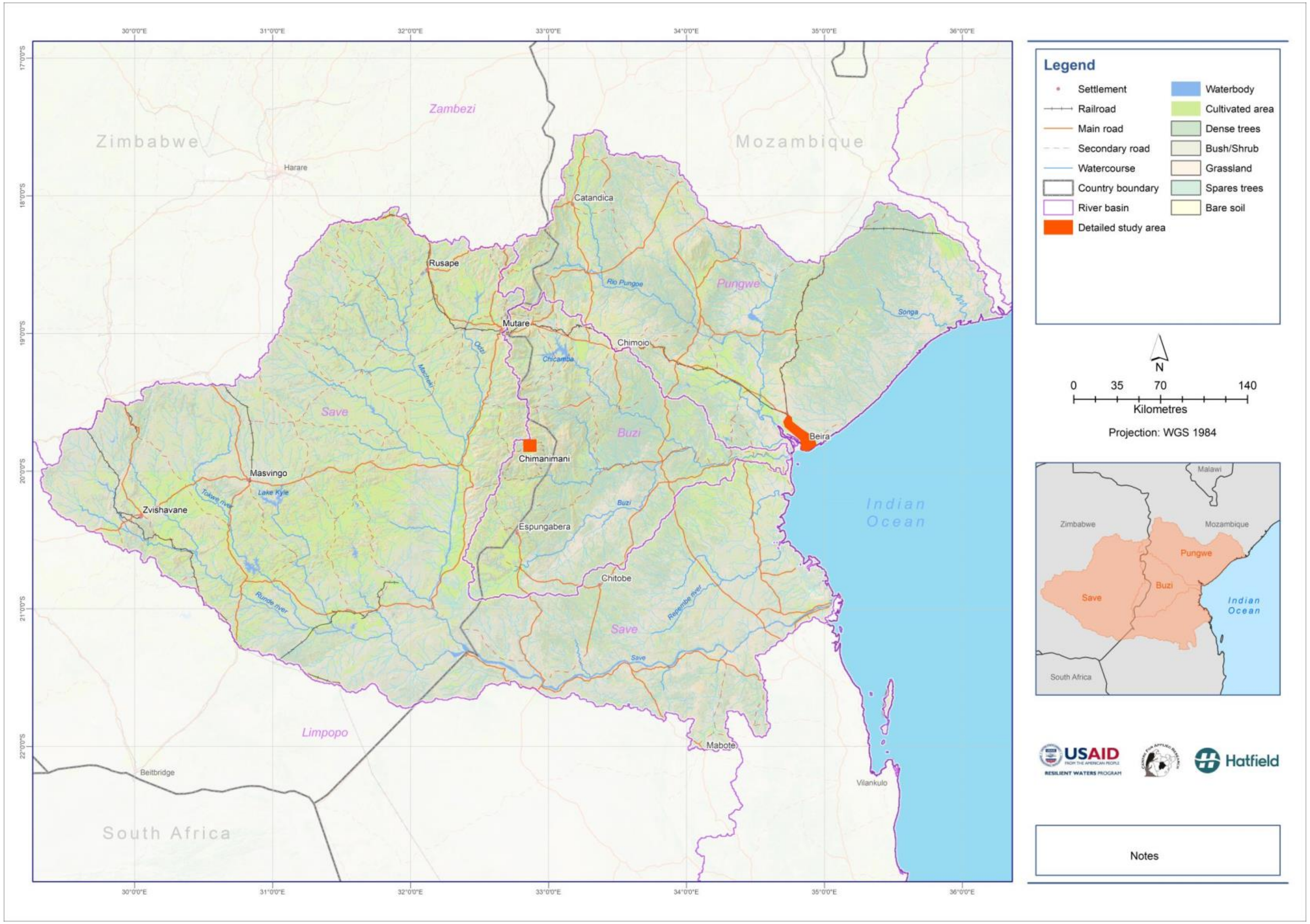
1.2.1 General framework

The project methodology is based on a combination of the Sendai framework (United Nations, 2015), the Southern African Development Community (SADC) Regional Resilience Strategy (2019) and sustainable development and livelihoods, summarized in Figure 2 (page 3). The Sendai framework aims to "to substantially reduce disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries. It has four priority areas: 1. understanding disaster risks; 2. strengthening of disaster risk governance to manage disaster risks; 3. investing in disaster risk reduction (DRR) for resilience; and 4. enhancing disaster preparedness for effective responses, recovery, rehabilitation, and reconstruction.

The SADC Regional Resilience Strategy (SADC, 2019) argues that the focus of resilience should be people and the systems they depend upon. People need to be able to exist in dynamic environments with uncertainties and unexpected events. Two aspects are considered critical. First, the ability to adapt and change before the shocks or disasters occur. Second, people should be at the center of resilience building. Resilience is built on strengthening of different types of capital; human, social, economic, physical, natural and political/ governance. The strategic framework distinguishes four key abilities to boost resilience: 1. anticipative ability: the ability to anticipate and be prepared for shocks prior to their occurrence; 2. absorptive ability: the ability to absorb the adverse impacts and rebuild livelihoods; 3. adaptive ability: the ability to adapt to shocks and mitigate their impacts; and 4. transformative ability: the ability to adjust the governance structures to better handle future shocks.

[2] Idai's impacts on Malawi and the impacts of Cyclone Kenneth are not covered by the project.

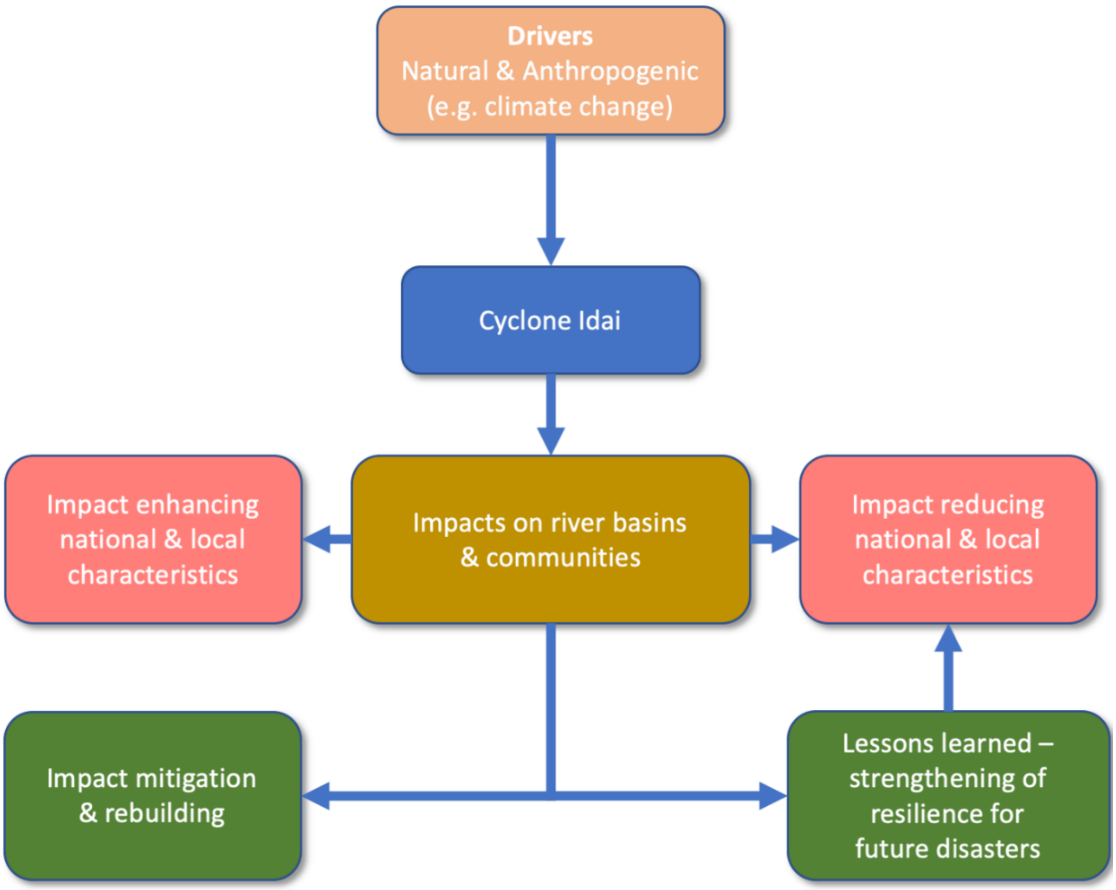
Figure 1: The Buzi, Pungwe and Save River basins (BuPuSa) in Mozambique and Zimbabwe.



Sustainable development (SD) distinguishes four pillars, i.e. environmental, social, economic and institutional/ governance. Sustainable livelihoods are a key part of SD. Generally, people seek to secure and improve their livelihoods (Ellis, 2001). It is therefore important to understand the livelihood strategies in communities, their goals, their sources as well as opportunities and challenges. Most households seek to sustain and improve livelihoods based on agricultural activities, formal and informal employment, and external support (e.g. remittances from family members or government support). Livelihoods are determined by, among others: a. available capital sources and assets, which provide the foundation for production and income generation (e.g. natural capital); b. access to capital assets as determined by household characteristics, institutional arrangements and by organizations (e.g. community or individual assets); c. contextual trends and exogenous shocks that influence household strategies; and d. livelihood sources, diversity and security.

The role of ecosystems in the provision of livelihoods (e.g. food and water) is widely recognized. However, ecosystems also perform other services such as support services (e.g. soil formation, nutrient and water cycling), regulatory (e.g. disease control and pollution absorption) and cultural services (i.e. non-material benefits to communities; Millennium Ecosystem Assessment). Regulatory services provide ‘free’ natural services to society (e.g. pollution absorption) while cultural services include tourism, cultural and spiritual/religious services.

Figure 2: Framework for the assessment of Idai’s community impacts and resilience building.



1.2.2 Geospatial assessment methodology

The geospatial assessment methodology focused on data capture, processing, and analysis to understand three key issues:

1. Community-level damage: assessing damage to residential, commercial and public buildings for one location in Mozambique (Beira) and another location in Zimbabwe (Chimanimani) using high-resolution satellite imagery. These two sites were selected as significantly impacted settlements[3]. Only two sites were selected due to the high costs of high-resolution imagery. The limited use of high-resolution imagery is intended to demonstrate the potential of focused analysis for future work;

2. Extent and nature of floods and landslides at community level: using combined optical and radar satellite image data sources to identify the areas most impacted by the large physical damage phenomena. These analyses were only conducted for the focused study areas. The landslides were mapped using the high-resolution imagery, and the source data for the flood inundation data was not available for the entire basin area; and

3. Basin and provincial scale landcover dynamics focusing on five broad landcover classes and two agricultural categories.

These analyses provide a different and complementary perspective to some of the data identified from Mozambique's Post Disaster Needs Assessment PDNA report (GoM, 2019) and Zimbabwe's Rapid Integrated Needs Assessment RINA report (GoZ *et.al*.,2010), whilst also supporting the socio-economic assessment at community and provincial/national levels with independent data capture and analysis. The approach and results of these analyses are presented below; explanations of data acquisition and pre-processing steps are elaborated in Appendix 9.2.

The following limitations were encountered in the execution of the geospatial assessment:

a. Although substantial data sources were identified during preceding phases of the project, specifically on the HDX platform, all layers obtained required substantial curation prior to use in analysis and cartography;

b. Some data, specifically Sentinel 1A SAR satellite imagery, was not available for the entire basin, preventing the team from performing wider scale flooded area analysis; and

c. Post disaster high-resolution satellite imagery was not available for the Chimanimani focused study area. While a great deal of imagery resides in archives, and imagery is routinely captured for all countries, there are frequently gaps that need to be filled with tasked imagery collections. Hence the acquisition of the *after* image was completed nine months after the cyclone event – when the contract was awarded, and the imagery was purchased. Unfortunately, this introduces a level of uncertainty into the damage assessment results.

1.2.3 Socioeconomic assessment

The socio-economic assessment was undertaken in two stages:

1. Inventory of socio-economic impacts at the country and community level; and

2. Impact analysis, particularly in terms of livelihoods and resilience of communities and countries.

The socio-economic impact inventory has been primarily based on a review of literature and statistics. A detailed internet search was conducted, and key informants assisted to identify important literature and share their views. The project had planned consultative country visits in March and April 2020,

[3] Rationale for these sites is provided in the Inception Report of this project.

but these were cancelled because of the COVID-19 pandemic and the associated travel and work/social distancing restrictions. The countries, RWP and the consultants agreed to replace the country visits with video conferencing with a Core Response Group (CRG) in each country, augmented by an email survey-questionnaire to a Broad Respondent Group (BRG). These consultations started 25th May and are expected to be completed in June, depending on the lockdown and travel conditions in Mozambique, Zimbabwe and Botswana), and the ability/level of response from participants. Consequently, the results of the consultations cannot be incorporated into this report; with the plan being to include the consultation findings in the Mitigation Report.

Core impact assessment documents have been the earlier mentioned PDNA report in Mozambique and the RINA report in Zimbabwe. In addition, an Oxfam report for Zimbabwe (Chatiza, 2019) and reports and data from UNOCHA, UNICEF, IOM- DTM, FAO, UN and World Bank were used. In addition, statistics were used from national statistics offices, and international agencies such as various United Nation agencies and the World Bank. Exploration of data and reports will continue and be included in subsequent stages of the project.

The following limitations were encountered in the execution of the socio-economic assessment:

a. Limited data and information on the impact of Cyclone Idai at the level of individual villages (e.g. village- based studies);

b. Limited baseline data available for the area. Where possible, provincial or national statistics have been used to estimate the impact for the affected areas; such data were better available in Zimbabwe;

c. Limited information about livelihood strategies in urban and rural areas, particularly in Mozambique. In Zimbabwe, the Rural Livelihood Assessment (RLA) survey provided useful data at the provincial and districts levels; and

d. Consultations and contact with institutions and resource persons were hampered by COVID-19 restrictions due to office closure and internet limitations at home.

2 BuPuSa river basins

2.1 Introduction to the basins

The Buzi, Pungwe and Save River (BuPuSa) basins are shared by Mozambique and Zimbabwe. Separate transboundary agreements exist for the Buzi (2019) and Pungwe (2017), with the countries currently developing a three-basin agreement for co-management of water resources and cooperation. The three rivers all originate in Zimbabwe and end in the Indian ocean in Mozambique (Figure 1).

Table 1 provides brief profiles of each basin. An estimated 5.7 million people live in the BuPuSa basins, which cover an area of 166,400 km^2. The average population density is 34.2 persons/km^2, with the highest density in the Buzi River basin (41.6 persons/km^2). The Save is the longest river with the largest basin and the highest mean annual run-off (MAR). Nonetheless, the Save River is said to have dried up in parts of the basin due to heavy development and abstractions upstream. The Buzi and Pungwe Rivers are mostly in Mozambique. In contrast with the Save, the Pungwe River has the potential for further development in Mozambique.

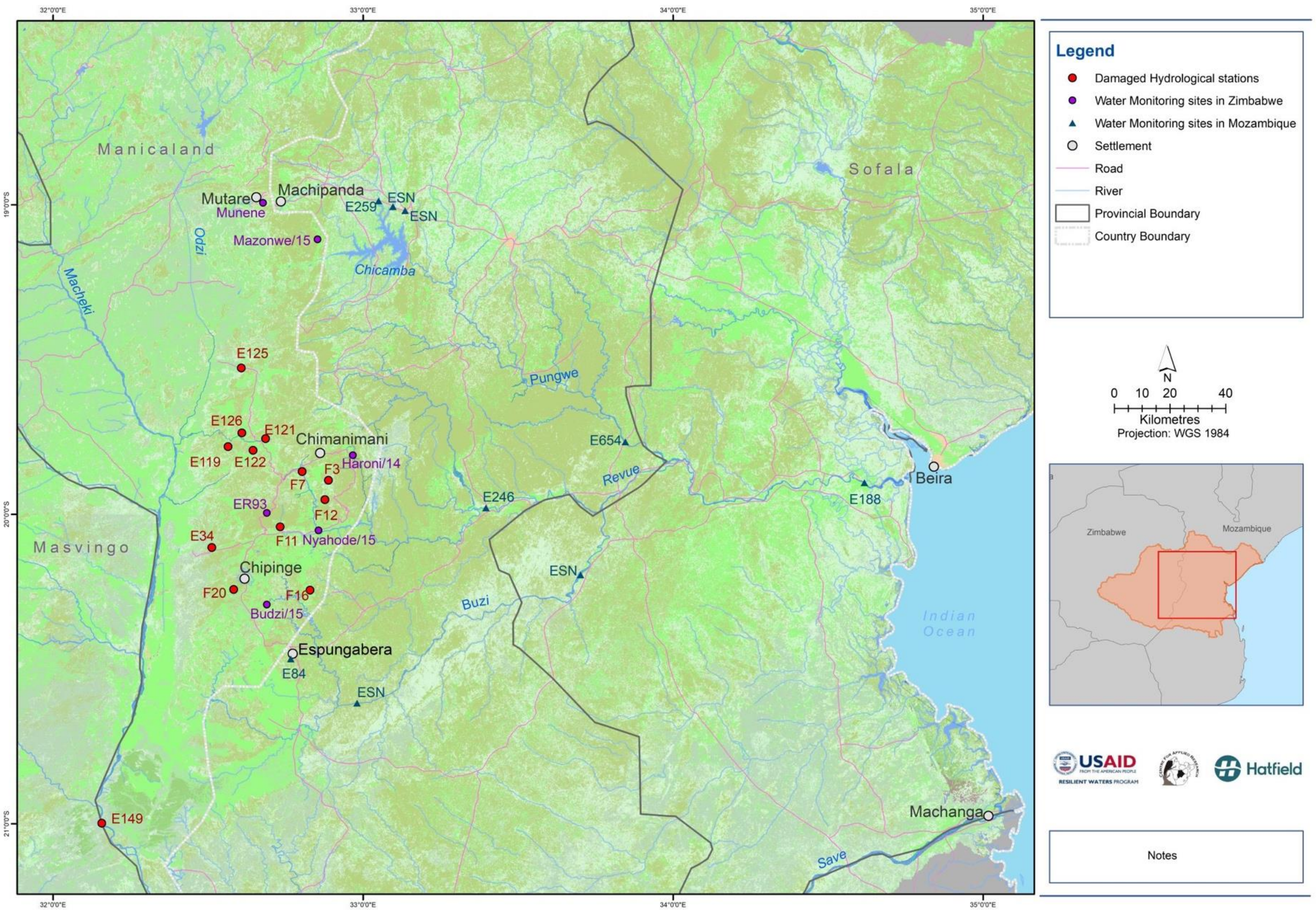
Table 1: Key parameters of the BuPuSa River basins.

River Basin	Area (km^2)	Length (km)	MAR (Mm^3/annum	MAR (m^3/s)	Human Population	Pop. density
Buzi	28,870	250	250-288 at lower Buzi	79.1	1,200,000	41.6
Pungwe	31,150	400		120-133	1,200,000	38.5
Save	106,420	640	7,000	221	3,300,000	31.0
BuPuSa	166,440	1,290		0	5,700,000	34.2

Sources: Climate Resilient Infrastructure Development Facility CRIDF, Wikipedia and 2018 Global Environmental Facility (GEF) project proposal.

Monitoring flows is currently difficult as numerous hydrological monitoring stations along the Save River in Chimanimani and Chipinge districts were either damaged or completely washed away during the Cyclone Idai event. The damaged stations along the Buzi River and district are listed in Table 2, and illustrated in Figure 3.

Figure 3: Hydrological monitoring stations damaged during Cyclone Idai.



Data source: BuPuSa

Table 2: Damaged monitoring stations in the BuPuSa basin.

Station	River	District
E125 Umvumvumvu	Umvumvumvu	Chimanimani
F7 Nyahode	Nyahode	Chimanimani
F3 and F4 Chisengu	Chisengu	Chimanimani
E126 Shinja	Shinja	Chimanimani
E121 Nyanyadzi	Nyanyadzi	Chimanimani
E120 Biriri	Biriri	Chimanimani
E122 Mhakwe	Mhakwe	Chimanimani
F16 Chipudzana	Chipudzana	Chipinge
E34 Tanganda	Tanganda	Chipinge
F19 Chisuka	Chisuka	Chipinge
E119 Nyanyadzi D/S	Nyanyadzi	Chimanimani
F12 and F13 Lower Chisengu	Chisengu	Chimanimani
E149 Save Causeway	Save	Chipinge
F11 Rusitu	Rusitu	Chimanimani
F20 Bangazaan U/S	Budzi	Chipinge

2.2 The Buzi River Basin (BRB)

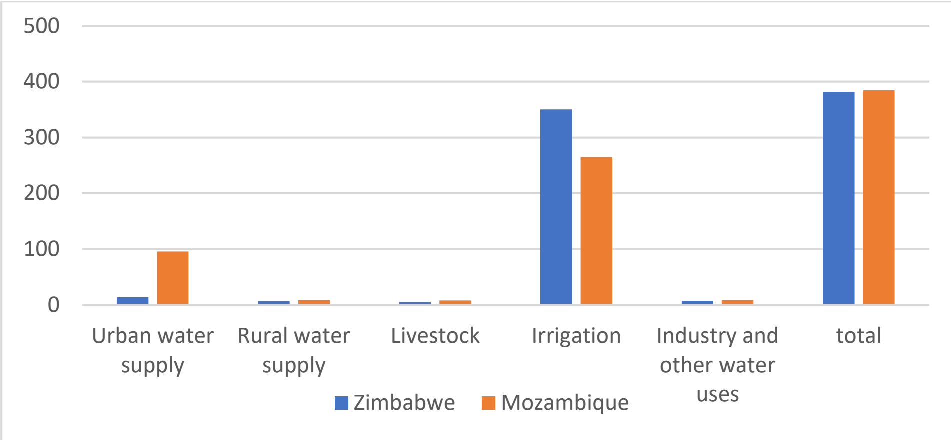
The Buzi River originates in the eastern highlands of Zimbabwe south of Mutare town. It has two tributaries, i.e. the Revue River from the north and the Lucite River from the west. Only 20 km of the river is in Zimbabwe. The river in the Eastern Highlands flows at around 1,200 to 1,500 meter above sea level (m.a.s.l), experiencing around 1,300 mm per annum of rainfall. The basin has three large towns in Mozambique: Buzi, Manica, and Chimoio (capital of Manica Province), with the major port of Beira located just 25 km north of the mouth of the Buzi River.

The basin's population is growing rapidly, but poverty is widespread. In Zimbabwe alone, rural poverty increased from 40% to 60% of the population between 1995 and 2003 (SWECO *et.al,* 2011). Agriculture is the main activity in the basin. Maize is the most commonly grown staple crop, with yields below 1 ton/ha; and cash crops such as bananas, tea, vegetables and forest products also grown commercially. Two dams generate hydropower on the upper Revue River tributary; and many small dams have been developed across the basin for irrigation (SWECO *et*.al., 2011). Agriculture contributes most to the livelihoods of 68 % of the active population, followed by commerce (21%) & other services (10%). Alluvial gold mining is also an informal source of livelihood. The situation is similar in Mozambique: 85 % in agriculture, 10 % in commerce and services and 5 % in industry.

The basin is flood prone, and floods are particularly damaging where the Buzi estuary joins the flood plain of the Pungwe. In terms of management, water planning is done by the Zimbabwe National Water Authority (ZINWA) on the Zimbabwe side, and in Mozambique by ARA-Centro as the regional water administrator (also for the Pungwe and Save).

The Basin Agreement specifies the agreed water abstractions by country and sector (GoM & GoZ, 2019). Total agreed water abstractions are 766.7 Mm^3 per annum, mostly for irrigation (615 Mm^3) followed by urban water supply (109 Mm^3; Figure 4). Reservations for other uses are small; countries may shift allocations between sectors within the amount allocated to the country. This gives the countries and the BuPuSa management flexibility to respond to changing conditions and development priorities. The actual annually abstracted amounts of water are not known.

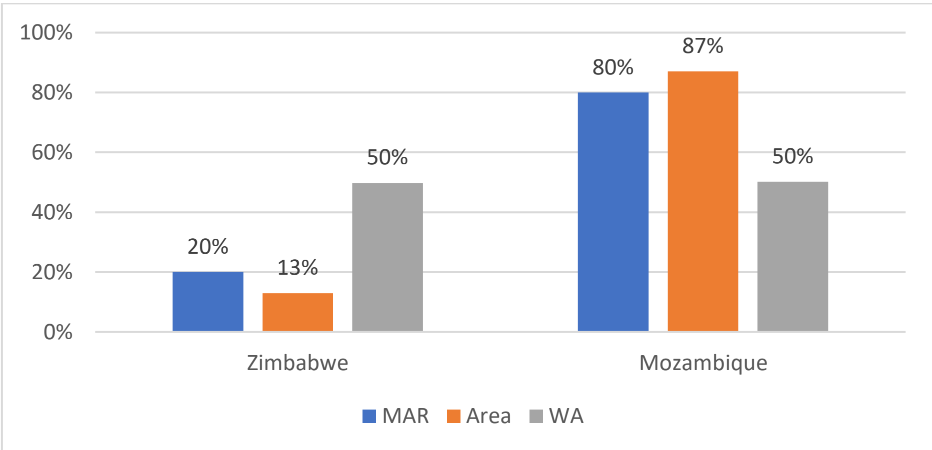
Figure 4: Agreed water abstractions by sector and country in the Buzi River Basin (Mm³).



Source: GoM & GoZ, 2019.

Figure 5 shows the percentage of permitted water abstractions by country, the contribution to the MAR and the basin area.

Figure 5: Agreed water abstraction, contribution to MAR and basin area by country in the BRB (as % of total).



Source: GoM and GoZ, 2019.

2.3 The Pungwe River Basin (PRB)

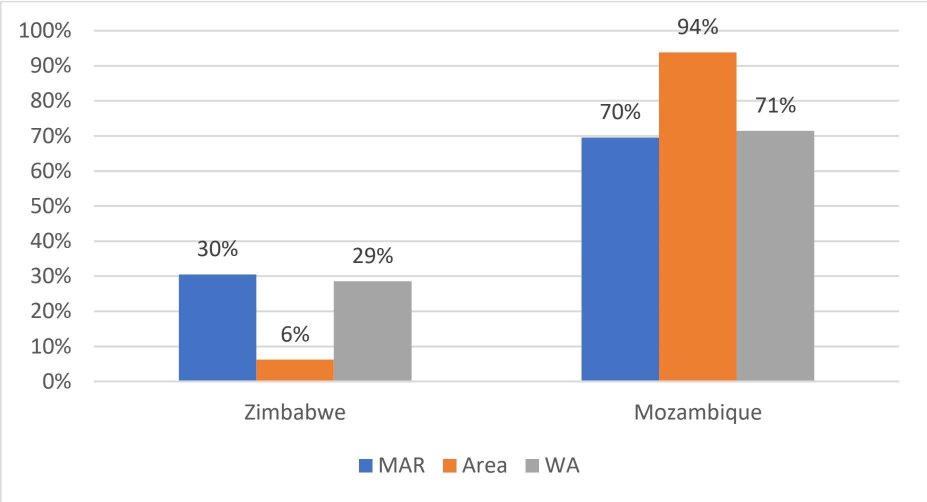
The Pungwe River originates in the Eastern Highlands of Zimbabwe, north of Mutare and ends after 400 km in the Indian ocean in the Mozambique Channel at Beira. It forms a large estuary there, where it is joined by the Urema River; both have large seasonal wetlands or flood plains. Less than 5 % (1,932 km²) of the basin is in Zimbabwe. The river has one major dam in Zimbabwe on the Nyawamba River, owned by a tea company and with a capacity of 17 Mm³, with 19 small dams in Mozambique.

The PRB covers a large part of Mutasa District in Zimbabwe and parts of Sofala and Manica Provinces in Mozambique. In terms of land use, the Zimbabwe portion of the PRB comprises a National Park, exotic forest plantations, and mixed agriculture in the lower parts, along with some alluvial gold mining. In Mozambique, land is mostly mixed subsistence farming, bordering Gorongosa National Park (GNP), with the lower parts of the basin considered flood prone. Over half of the rural population live in poverty, with the most important economic activity being farming; both subsistence dryland farming and irrigated crop farming.

The river water can be considered under-utilized, with less than 20 % of the available water is being actively utilized (GoM & GoZ, 2006). Future development could be based on the fertile soils, ecotourism in GNP and dam developments for water supply systems (GoM & GoZ, 2006).

The agreed maximum annual water abstraction amounts to 809.6 Mm^3, mostly for Mozambique. This figure excludes the expected water flow reduction of 257.3 Mm^3, associated with large scale afforestation plans: 18,000 ha in Zimbabwe and 80,000 ha. In Mozambique (GoM & GoZ, 2016). Figure 6 shows the countries' shares in MAR, basin area and water abstractions.

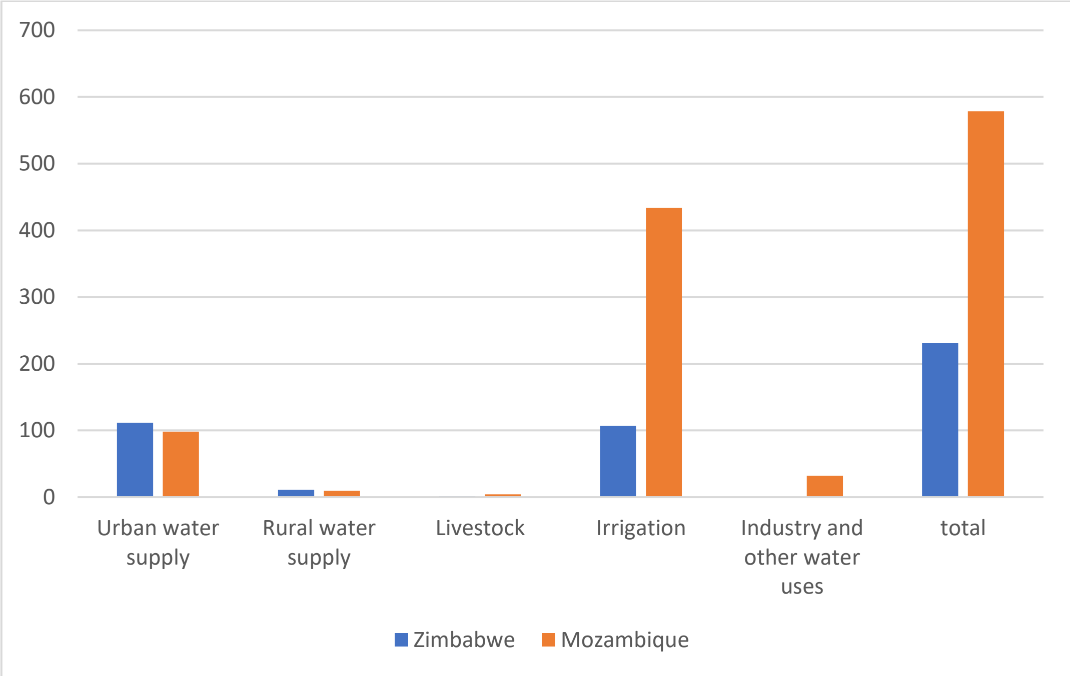
Figure 6: Agreed water abstraction, contribution to MAR and basin area by country in the PRB (as % of total).



Source: GoM & GoZ, 2016.

Figure 7 shows the agreed allocations by sector in the BRB, with irrigation receiving the largest share (541 Mm^3) followed by urban water supplies for Mutare, Dondo and Beira (201 Mm^3). Countries may shift sectoral allocations within 'their' quota, and actual water abstraction volumes being unknown.

Figure 7: Agreed water allocations by sector in the PRB.



Source: GoM & GoZ, 2016.

2.4 The Save River Basin (SRB)

The Save River originates around 80 km south of Harare, heading eastwards before linking with the Odzi River and the Rundu River at the Mozambican border, ending in the Indian Ocean south of Beira. Unlike the Buzi and Pungwe, the basin is mostly located in Zimbabwe. The Save delta has mangrove forest along 100 km of coastline, but due to significant upstream water resource development schemes, the river is almost permanently dry in some lower parts except during periods of seasonally high flows.

Poverty in the basin is among the highest in Zimbabwe, with most households in the basin dependent on mixed subsistence farming prone to high risk of crop failure. The basin is vulnerable to climate change, which is expected to lead to lower rainfall and longer dry periods. The largest water use is irrigation in the Rundu area with a system of large dams and distribution canals. There are many dams on the Save River and its development potential has almost been reached (CRIDF, 2019). The construction of more dams could lead to over utilization if not carefully managed. Nonetheless, the SRB Water Resource Management Strategy (GoM & GoZ, 2013) envisages the development of more dams but this would need to be combined with dam operation guidelines (CRIDF, 2019), environmental flow requirement assessment, and climate resilience strategy as well as community-based irrigation projects[4]. The draft dam operating rules aim to ensure fairly and equitable access to river water and efficient allocation of the available water resources during wet and dry periods.

[4] In Zimbabwe, two communities have been chosen as demonstration sites by the Climate Resilient Infrastructure Development Facility (CRIDF, 2019), which has prepared 50 community-based management projects for Green Fund funding. CRIDF supports a similar initiative in Mozambique with 3,000 ha for community-based management projects.

3 The BuPuSa countries and disaster risk management

3.1 Introduction

Mozambique and Zimbabwe are low-income countries with a modest ranking for human development index: low for Mozambique and medium for Zimbabwe, respectively ranked 180 and 150 out of 189 countries. Mozambique has a long coastline (2,700 km) and is vulnerable to cyclones and sea level rise. Zimbabwe is landlocked and depends on ports in neighboring countries for international trade - Beira in Mozambique and Durban and Richards Bay in South Africa. Apart from the Buzi, Pungwe and Save, several other major southern African rivers also flow into the Indian Ocean in Mozambique (Zambezi, the Limpopo and Nkomati).

Table 3 summarizes a selection of socio-economic characteristics of the countries. Mozambique is roughly twice as big as Zimbabwe, but the size of their economies is similar. Economic growth is below the population growth in both countries, hence per capita income is not increasing. The level of poverty is high, particularly in Zimbabwe; and unemployment is high in Mozambique. The reported unemployment figure for Zimbabwe is low as most rural people are engaged in subsistence farming and not considered unemployed. The Adjusted Net Savings Index (ANSI) is negative in both countries, which is an indicator of unsustainable development, driven by high consumption of fixed capital in both countries, which is generally considered to be indicative of lack of maintenance: countries are consuming their physical capital.

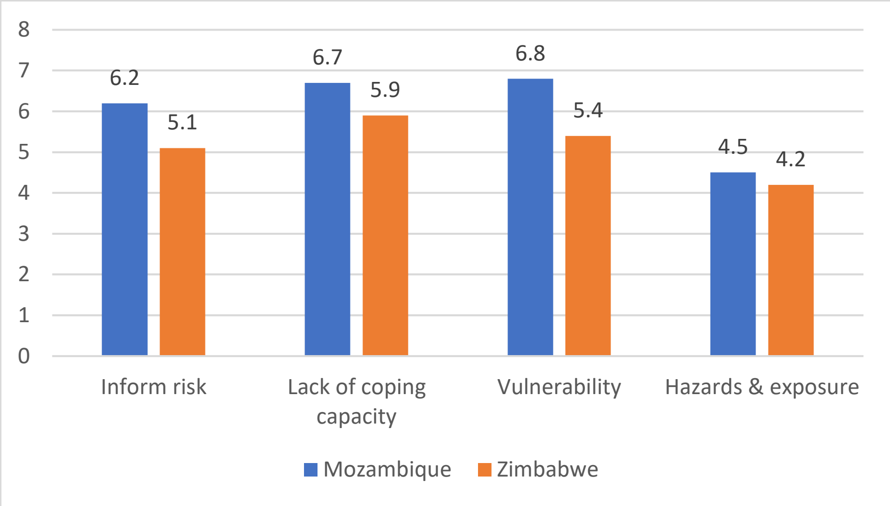
Table 3: Socio-economic profiles of Mozambique and Zimbabwe.

Indicator	Mozambique	Zimbabwe
Population Size	29.7 million (2017)	16.5 million (2017)
Annual population growth rate	1.7% (2005-2010)	2.9% (2005-2010)
Urban population (as % of total)	32	32.5
Land area	799 380 km^2	390 757 km^2
Gross Domestic Product (GDP)	US$ 14.8 billion	US$14.4 billion
Gross National Product per capita	US$590	US$860
GDP annual growth rate	0.8%	1.1%
Gross Savings	10.3% of GNI (Gross National Income)	1% of GNI
Adjusted Net Savings Index	-5.1% of GNI	-16.1 of GNI
Human Development Index (HDI)	Low human development: 0.446 rank 180 out of 189	Medium human development: 0.563 rank 150 out of 189
Population living below nat. poverty datum line	46.1% (2011)	72.3% (2015)
Unemployment as % of labor force	25% (2017)	5.2% (2017)

Sources: HDI 2018 data up-date, HDR 2019 and Little Green Book 2017.

The high vulnerability and low resilience of both countries is reflected in the Global Risk Index (GRI). Mozambique is ranked 19th highest risk country out of 190 countries with an overall score of 6.2 (range 0-10) and Zimbabwe is ranked 47th (overall score 5.1). The GRI has three multidisciplinary components: 1. lack of coping capacity: (institutional and infrastructure; 2. vulnerability: socio-economic & vulnerable groups; and 3. hazard & exposure (natural and human). In both countries, vulnerability and inadequate coping capacity are considered the main contributors to the overall risk (Figure 8).

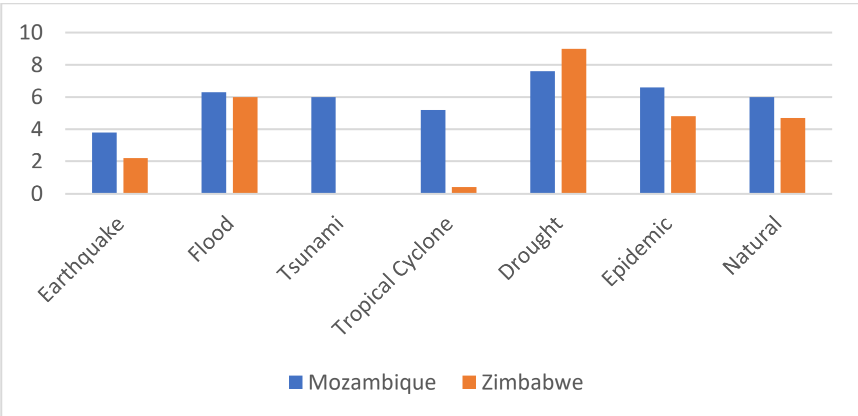
Figure 8: Global Risk Index (INFORM[5]) for Mozambique and Zimbabwe (2020).



Source: INFORM data on https://ec.europa.eu/jrc/en/publication/index-risk-management-inform.

A further breakdown of the GRI component "hazards and exposure" shows that in both countries natural risks represent a greater risk than human risks: for Mozambique 6.0 and 4.7 respectively and for Zimbabwe 4.6 and 3.6 respectively - Figure 9. In terms of natural risks, both countries face multiple natural risks, in particular Mozambique. Droughts are the highest risk in both countries, with floods, tsunami (Mozambique) and epidemics also considered common natural risks. The risk of tropical cyclones is high in Mozambique due to its long coastline, but small in Zimbabwe as it is located inland.

Figure 9: GRI scores for natural risks for Mozambique and Zimbabwe (scale 0-10).



Source: INFORM data on https://ec.europa.eu/jrc/en/publication/index-risk-management-inform

The population distribution in the BuPuSa area is shown in Figure 10, and country specific details are highlighted below.

3.2 Delineation of the BuPuSa area

The project focuses on the BuPuSa river basins area, as agreed during the inception phase. The path of Cyclone Idai (Figure 15 in Chapter 4) intersects directly with the BuPuSa basins, but the increased

[5] INFORM is Index for Risk Management.

rainfall events associated with the cyclone were felt over a much larger area (Figure 11). For this reason, the key impact and needs assessment reports in both countries (PDNA and RINA) cover a larger area than BuPuSa (GoM, 2019; GoZ *et.al.*,2019).

Using aggregated rainfall data from the European Space Agency (ESA), and sourced from the Humanitarian OpenStreetMap Team (HOT) project, a high intensity rainfall exposure zone was delineated, illustrating the overall estimated rainfall impact during and for the two weeks following the event. As can be seen in Figure 11, the zone of exposure extends substantially to the north of the BuPuSa basins, also impacting Tete and Zambezia Provinces of Mozambique, as well as small portions of Mashonaland Central and Mashonaland South in Zimbabwe.

The portions of the various provinces of Mozambique and Zimbabwe included in the BuPuSa basins analysis extent are summarized in Table 4, also identifying the portions of the affected area not considered extensively in the geospatial assessment. This information is also presented in map form in Figure 12. The provinces and sub-ordinate districts of Mozambique and Zimbabwe within the BuPuSa basins are listed in the Appendices (Chapter 9).

Table 4: Portion of provinces inside BuPuSa area.

Country	Province	Total Area (ha)	Area in study (ha)	%	Area of province affected by Idai	Area of province affected by Idai in study area
Mozambique	Gaza	7,551,163	192,281	3	219,765	150,675
	Inhambane	6,887,945	765,498	11	1,183,201	598,213
	Manica	6,280,823	4,594,768	73	6,280,823	4,594,768
	Sofala	6,761,923	5,115,153	76	6,761,865	5,115,113
	Tete	10,092,234	-	-	4,385,972	-
	Zambezia	10,320,618	-	-	10,311,493	-
Zimbabwe	Manicaland	3,575,425	2,760,897	77	3,575,425	2,760,897
	Mashonaland East	2,818,859	477,865	17	1,703,271	467,540
	Mashonaland Central	2,766,633	-		262,235	-
	Masvingo	5,535,209	4,114,936	74	2,594,654	2,590,976
	Matebeleland South	5,440,018	226,975	4	-	-
	Midlands	5,617,081	1,424,328	25	489,084	334,662

Figure 10: Population of major towns and settlements across the BuPuSa basins.

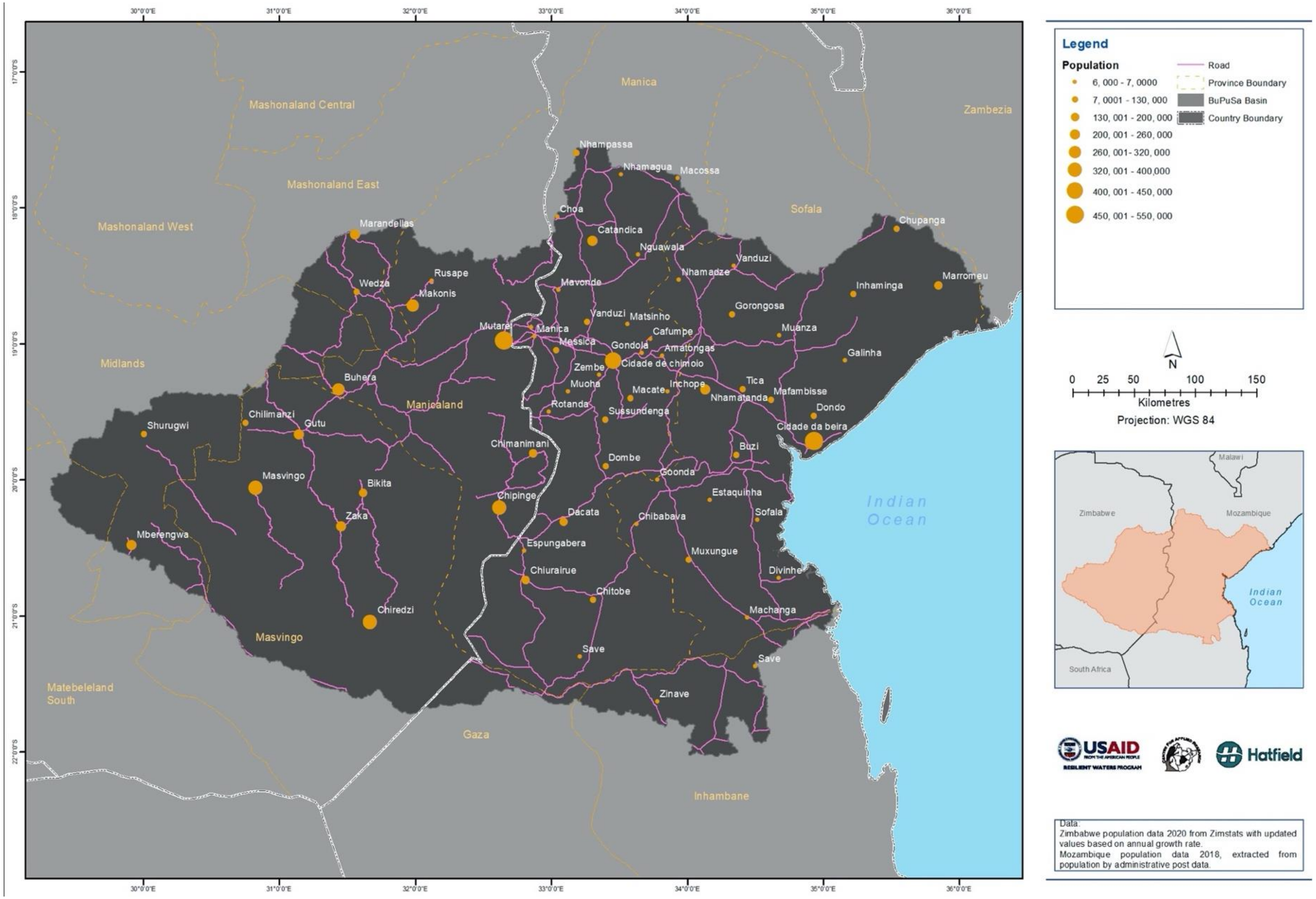


Figure 11: Cyclone Idai zone of influence based cumulative rainfall.

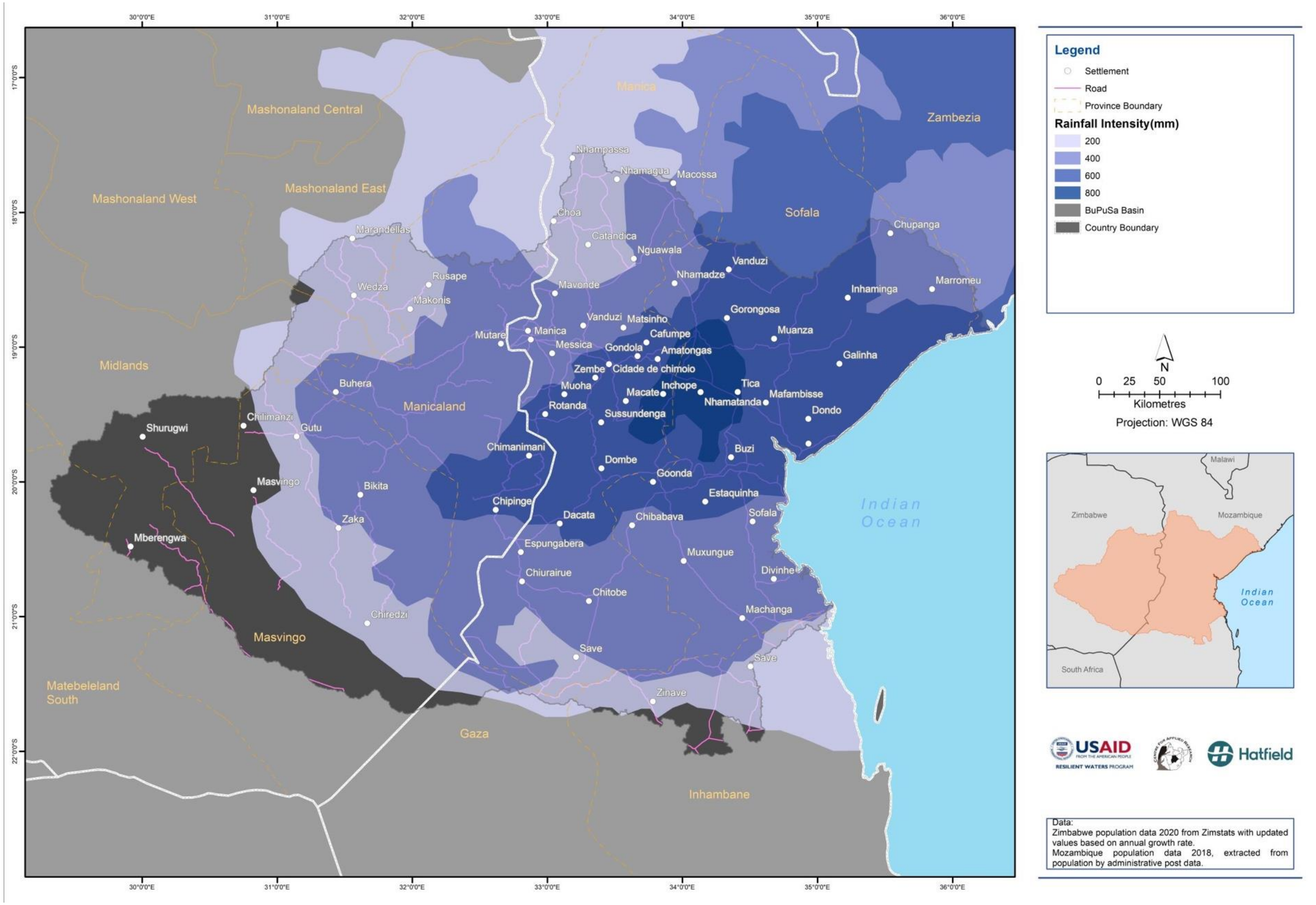
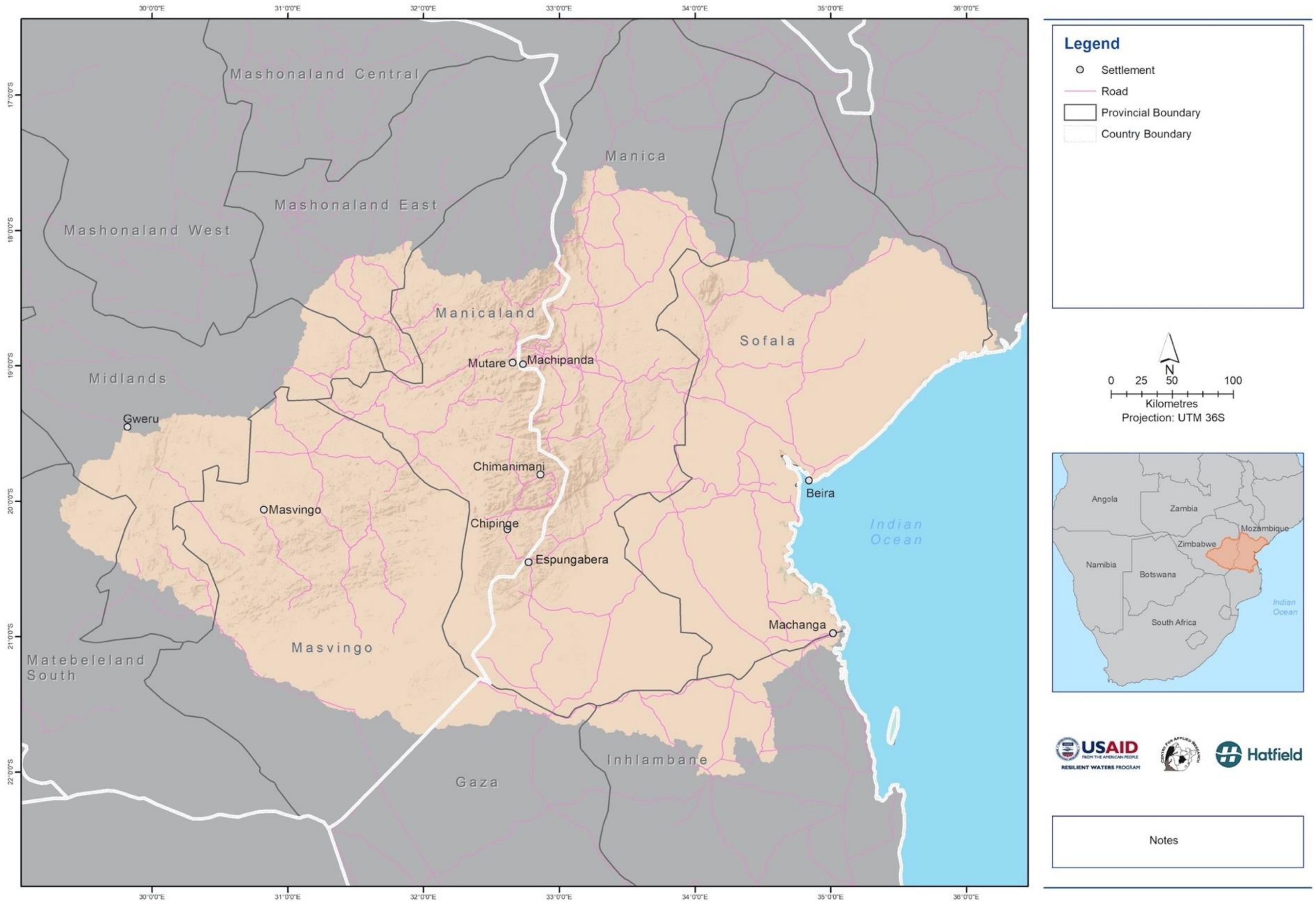


Figure 12: Map of provinces intersecting with BuPuSa basins.



3.3 Mozambique

Cyclone Idai struck the country at a sensitive time when the country was preparing for its October 2019 general election; a period characterized by tensions between the major political parties Frelimo and Renamo. The discovery of oil and gas reserves in Cabo Delgado in combination with the high level of poverty and Cyclone Kenneth has destabilized that province in recent years, with several armed incidences and attacks occurring, exacerbated by a severe drought prior to Cyclone Idai, leading to a high levels of food insecurity prior. However, the country is generally considered self-sufficient for most cereals except wheat and rice (FAO, 2016), and it exports cash crops such as sugar cane and fruits).

At the time of the cyclone, Mozambique was achieving moderate economic growth, but the government was experiencing financial difficulties: it had a budget deficit of 4.6 % in 2018, and a considerable gap in the 2019 planned government budget, resulting in a funding shortage for the elections. The IMF halted loans in 2016 after financial accountability issues arose and government debts amount to 113 % of the Gross Domestic Product (GDP).

Overall, poverty has declined, but remains high at 46 % in 2014, and income inequality is also high at 0.54 in 2014[6].

The four provinces most affected by Cyclone Idai have a total population of 13.5 million people (2018) and an urban population of 8.4 million with an average urbanization rate of 62% (Table 5). Zambezia is the most urbanized province (73 %), while Manica has the lowest urbanization rate (43 %). The average population size per settlement is 92,942, with the largest settlement being Beira (over 500,000).

Table 5: Population by the most affected provinces in Mozambique.

Province	Population 2018	Urban population	% of urban population	Average settlement size
Sofala	2,514,067	1,570,668	62%	83,802
Manica	2,553,353	1,089,491	43%	72,953
Zambezia	5,204,535	3,792,877	73%	121,036
Tete	3,195,256	1,904,916	60%	93,978
Total provinces	13,467,211	8,357,952	62%	92,942

Note: Urban population: population living in settlement of 100,000+ inhabitants. Tete is outside the BuPuSa area and only Chinde area of Zambezia is inside BuPuSa. Inhambane are left out because of minimal damage due to Idai.

The average population density is 35.8 persons/km^2 for the four provinces. Zambezia has the highest population density with 49.2 persons/km^2; Sofala Province has 33.2 persons/km^2. The country's infrastructure is poorly developed, and as shown by the negative ANSI poorly maintained, particularly in rural areas.

The country is vulnerable to climate change and over 60% of the population lives in low lying coastal areas (ATLAS/USAID, 2018). According to the INGC (2009), the frequency and intensity of cyclones is

[6] The Gini ratio measures income (in)equality and is a figure between 0 and 1. The higher the figure, the more unequal the income distribution is. The closer to 0, the more equal the distribution is.

expected to increase[7]. There is indeed an indication that both frequency and intensity of cyclones are increasing. In the period 1957-2008 62 major disasters struck the country, i.e. on average more than 1 per year (INGC & UNDP, 2011).

Mozambique has a well-developed institutional infrastructure for disaster response management[8]. The National Institute for Disaster Management (INGC) is the key institution responsible for disaster risk reduction (DRR), guided by a Council of key Ministers (CCGC) chaired by the Prime Minister (Figure 13). Since 1999 the INGC under the Ministry of State Administration (MAE) coordinates DRR activities centered on four key areas: Disaster prevention and mitigation actions; development of arid and semi-arid zones; emergency actions; and post-disaster reconstruction actions.

The INGC hosts the Reconstruction Coordination Office (GACOR), which handles the resettlement of displaced persons. In 2007, INGC established four regional emergency operation centers (CENOE) in Southern, Central and Northern Mozambique coordinating disaster related issues and emergency operations. At the local level, INCG operates through local disaster risk management (DRM) committees. The INGC manages the Disaster Management Fund (DMF), which was established in 2017, with funds sourced from an annual allocation that should be at least 0.1% of the State budget; this would be US$ 6 million in 2019 (based on an annual state budget of US$6 billion[9]). In addition to the DMF, DRR activities are also included in sectoral budgets. Each sector and district integrate DRR and climate change adaptation (CCA) in their planning and budgeting (UN-ECA, 2015). Funds are, however, limited and sector and district teams are overburdened with cross-sectoral issues such as DRR and CCA. The Ministry of Environment (MICOA) is responsible for climate change adaptation[10] and the Ministry of Planning and Development (MPD) also play a key role in disaster risk management (UN-ECA, 2015 see also Figure 13). The country has a National Strategy for Climate Change Adaptation and Mitigation (2013-2025; GoM, 2012). The GoM further implements a Pilot Program on Climate Resilience (PPCR; UN-ECA, 2015) under the MICOA and the Ministry of Planning and Development (MPD). The aim of the program is to create resilience in areas such as road infrastructure, agriculture, coastal areas and water management.

DRR has also been mainstreamed into the National Development Plan (NDP), the National Agenda 2025 and budgeting systems in various sectors. Other DRR organizations include NGOs, private sector, faith-based organization, ICPs and volunteers. The PDRRD 2017-2030 (PDRRD[11]), is the overall framework for Disaster Risk Management (DRM) in Mozambique. The program aims to reduce risks, reduce impacts of disasters, and avoid the emergence of new risks. PDRRD's objectives are aligned with the priorities of the Sendai Framework for Disaster Risk Reduction 2015 – 2030. The PDRRD program's strategic objectives are as follows:

1. Improve the understanding of disaster risks at all levels;
2. Strengthen governance and public private participation in disaster risk reduction;

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[7] These trends are not statistically significant (due to short timer series). trends on. There could be an overall tendency toward decreasing frequency of tropical cyclones but increasing cyclone intensity in the Indian Ocean (Emanual, 2008; quoted in INGC, 2009).

[8] Mozambique has been proposed as a model for disaster response strategies for other countries (Foley, 2007 quoted in UN-ECA, 2015, p. 33).

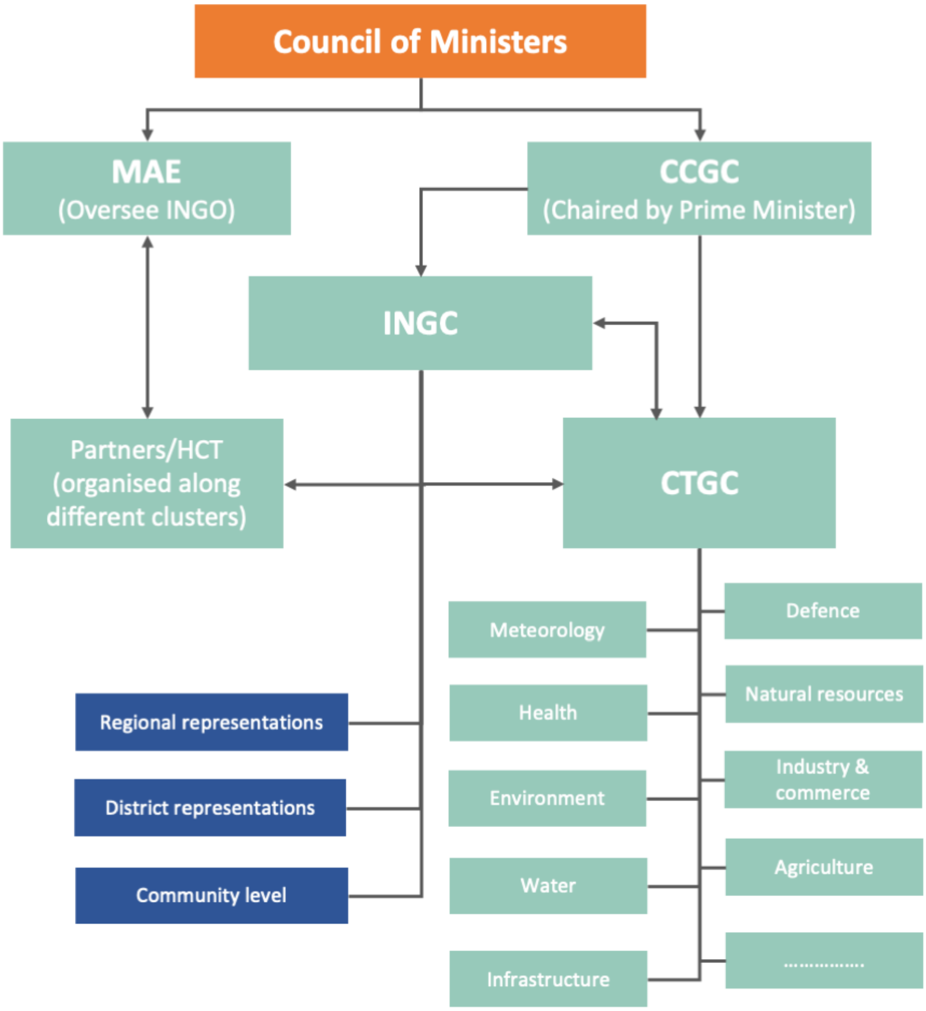
[9] A forecasted shortfall of US$1.5 billion expected to be covered by grants and soft loans.

[10] Key areas identified with respect to climate change (CC) are: coastal protection, early warning system (EWS) and preparedness, prepared cities, resilience in the private sector, water demand management and efficiency, food security, preparing people, dealing with extremes, and DRR strategy (UN-ECA, 2015).

[11] This plan succeeded the 2006 DRR Master Plan, which did not cover climate change and human induced disasters (UN-ECA, 2015).

3. Mainstream DRM in public investment and territorial planning and consolidating financial protection against disaster;
4. Strengthen capacity for disaster preparedness, response and rapid recovery; and
5. Build partnerships and international cooperation.

Figure 13: DRR management structure in Mozambique.



Source: UN-ECA, 2015.

3.4 Zimbabwe

Cyclone Idai struck Zimbabwe during an already fragile political and economic situation (RINA, p.67). Drought had already increased rural poverty and food insecurity. Economically, the local currency was weak[12], and inflation was high (76 % in April 2019). The government deficit was 7.1 % of GDP and foreign reserves covered only one month of imports. Economic problems were compounded by international sanctions, and the country hosted over 20,000 asylum seekers and refugees from neighboring countries adding to the burden of Internal Displaced Persons (IDPs) after the event. As a result of the economic difficulties, maintenance of public infrastructure was poor. Disease outbreaks were also recorded prior to the cyclone (e.g. cholera).

[12] The local currency depreciated by over 100% in 2018.

Cyclone Idai affected the provinces of Manicaland, Masvingo, Mashonaland East and Midlands in the BuPuSa area and a small part of Matebeleland East. In 2017, around 6.3 million people were living in the affected provinces with an average population density of 6.1 persons//km^2 and an urbanization rate of 17% (Table ***6***). In Manicaland 322,000 were affected by Idai (around 19%; RINA).

Table 6: Population by the most affected provinces in Zimbabwe (2017).

Provinces	Population	Urban population	Urban Population as % of total	Population Density (persons/km^2)
Manicaland	1,861,755	286,576	15.4	7.9
Mashonaland East	1,366,522	152,997	11.2	4.7
Masvingo	1,553,145	146,676	9.4	2.6
Midlands	1,514,325	482,365	31.9	9.8
Total population	**6,295,747**	**1,068,614**	**17.0**	**6.1**

Note: Urban areas are i. designated urban areas and ii. places with the following characteristics: over2,500 inhabitants, a compact settlement plan and more than 50% of the employed persons engaged in non-agricultural occupations.

Source: ZimStats & UNFPA, 2017.

In terms of disaster risk management and reduction, the Department of Civil Protection (DCP, Ministry of Local Government, Public Works and National Housing) is the lead institution (Figure 14). It is backed by legislation (Civil Protection Act, Chapter 10:06 of 1989[13]) and has a National Civil Protection Fund, which finance its DRR activities. The DCP acts at the national, provincial and district level and has Civil Protection Units at each point. The National Civil Protection Committee (NCPC) coordinates DRM and is made up of relevant stakeholders from within and outside government. The Civil Protection Act states that 1% of the national budget should be reserved for DRR activities[14]. DRR is led by the 2012 National DRM Strategy and the National Climate Change Response[15].

In terms of water resources, the Department of Water Resources, ZINWA (Central and in provinces) and catchment councils are key institutions. The Zimbabwe National Water Authority (ZINWA) is the key liaison institution for BuPuSa (Buzi, Pungwe and Save Basin institution) and has offices in Mutare.

Other relevant (semi-) government institutions include the following:

1. The Environmental Management Agency (EMA) provides environmental oversight for Zimbabwe, including adherence to environmental quality standards;
2. Rural District Councils (under the Rural District Council Act) are the custodians of natural resources, and may make by-laws to conserve natural resources, including implementing measures to control bush fires, regulate farming and pollution. The Councils are also a key player in the Communal Area Management Program for Indigenous Resources (CAMPFIRE); and
3. The Forestry Commission administers, controls and manages state forests. It also oversees the protection of private forests, trees and forest produce and regulates and control the burning of vegetation.

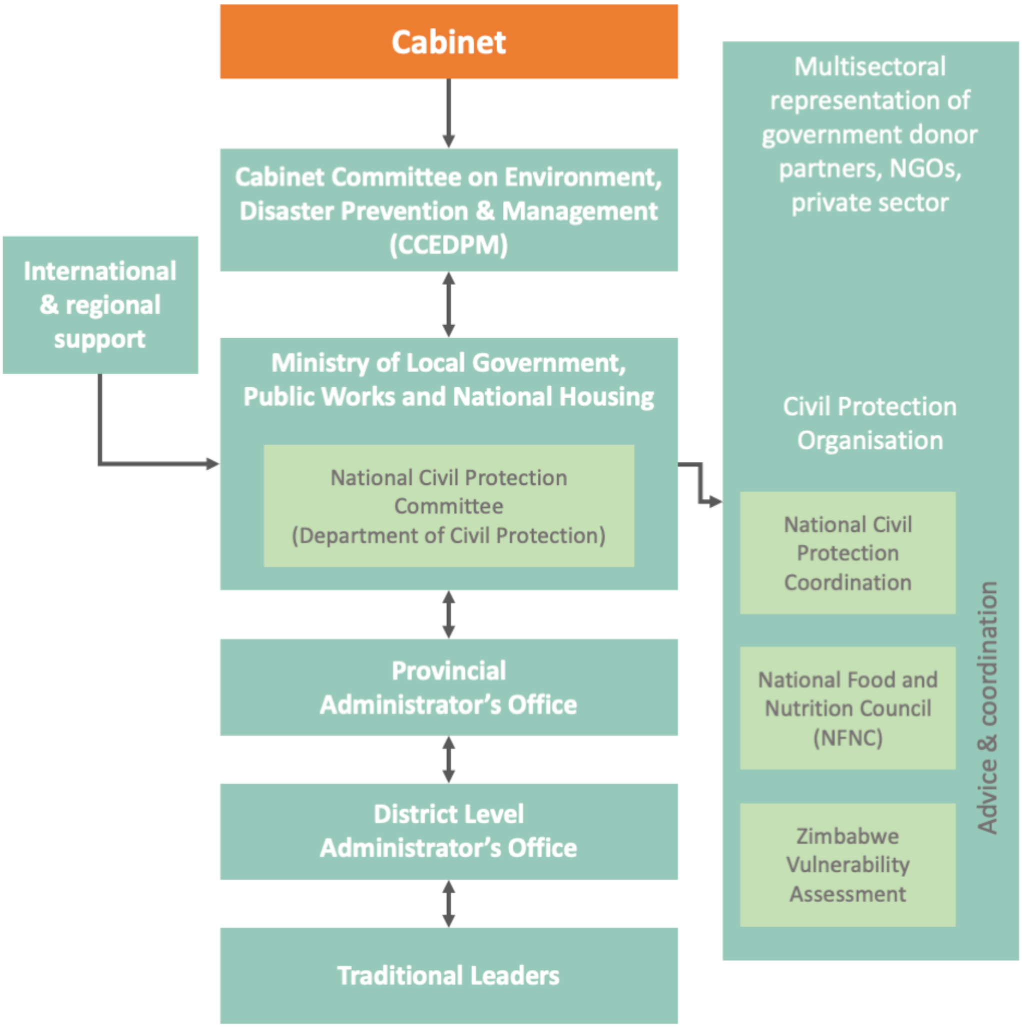
[13] A draft 2015 DRM bill has not yet been finalized. The earlier Act (1989) is reviewed by Machura)2016) in terms of 1) the existence of DRR institutional mechanisms (national platforms) with designated responsibilities, (2) decentralization of responsibilities and resources, (3) availability of dedicated and adequate resources to implement DRR and (4) community participation in DRR.

[14] This would be US$77.7 million in 2019.

[15] A good practice is to integrate DRR and CCA (OECD, 2020). Namibia has done so by adopting “The National Strategy for Mainstreaming Disaster Risk Reduction and climate change adaptation into Development Planning in Namibia 2017-2021” (UNDRR, 2019).

Communities, the private sector and non-government organizations (NGO) as well as International Cooperating Partners (ICP) are key players in DRR and represented in the Civil Protection Platform, and every citizen is obliged to be involved in efforts to avoid disasters. For Cyclone Idai, Provincial Administrator Manicaland led relief efforts, supported by Chimanimani & Chipinge District coordinators. Thirteen technical subcommittees were established at provincial level.

Figure 14: Zimbabwe's DRM institutional framework.

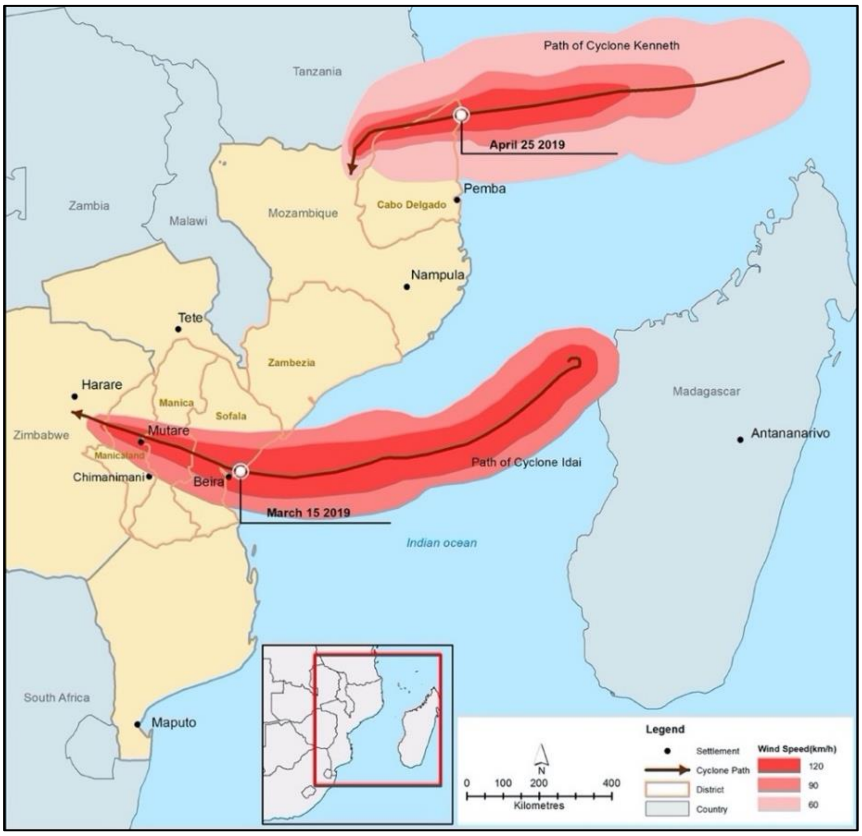


Source: Chatiza, 2019.

4 Cyclone Idai

During mid-March 2019, southern Africa was hit by an extremely powerful cyclone named Idai, with high winds and intense rainfall devastating parts of Mozambique, Zimbabwe and Malawi[16], and the transboundary river basins of the Buzi, Pungwe and Save (BuPuSa) were hard hit in both riparian states. Cyclone Idai brought heavy winds and rainfall leading to flooding and landslides, and considerable physical damage. The paths and points of landfall for Cyclones Idai and Kenneth are shown in Figure 15. Cyclone Kenneth followed a month later, striking Mozambique, Malawi and Tanzania. Global support for Idai relief and recovery has been forthcoming but has not yet been sufficient, making regional and national resilience even more important. Post Disaster Needs Assessments were conducted in both countries soon after the event, with these interventions establishing in general terms the main impacts on agriculture, fisheries, livelihoods, water and sanitation, energy, transport, housing, education, health and culture sectors. The assessments did not go into details for the agricultural sectors, livelihoods and community impacts. Each of these affected areas require substantial investments to reconstruct and planning to improve the resilience of the impacted sectors and communities.

Figure 15: Paths of cyclones Idai and Kenneth.



Source: Adapted from GoM, 2019.

Cyclones are not a new phenomenon in southern Africa as Eline in 2000 and Dineo in 2016 demonstrated, and therefore building resilience to such extreme events is a vital component of sustainable development.

[16] As the project focuses on the BuPuSa area, the impacts of Idai on Malawi are not considered in this project. Furthermore, the impacts of Kenneth have not been considered.

5 Impacts of Cyclone Idai

This chapter discusses the results of the geospatial assessment (5.1) and the socio-economic assessment (5.2).

5.1 Geospatial assessment

The geospatial assessment provides independent analysis and augments the socio-economic assessment. The approach is discussed in section 5.1.1 and the results in section 5.1.2. Methodologies are presented in summary form and are elaborated in more detail in Appendix 9.2, where deemed necessary. Landcover analysis was conducted with medium-resolution imagery at basin-scale, broken down by province and district for Chimanimani and Chipinge in Zimbabwe. The damage assessment and flood/landslide analysis were conducted for the two focused study areas (Chimanimani and Beira), providing examples of detailed analysis possible with high-resolution imagery[17]. Topographic mapping was conducted at basin scale and for focused study areas. The geospatial assessment took cues from remote sensing analysis conducted during the Zimbabwe RINA process, but included additional analysis, such as landcover mapping, and applied them across the entire basin. While rainfall intensity data were utilized, the damage assessment was conducted at building-level in both settlements, to attempt to take the previous method a step further. And, with respect to landcover mapping, entirely new landcover data were developed before and after the event, rather than relying on existing data. Both assessments are complimentary, and clear recommendations about sustainable and operational geospatial approaches will be provided in the following Mitigation Report.

5.1.1 Approach

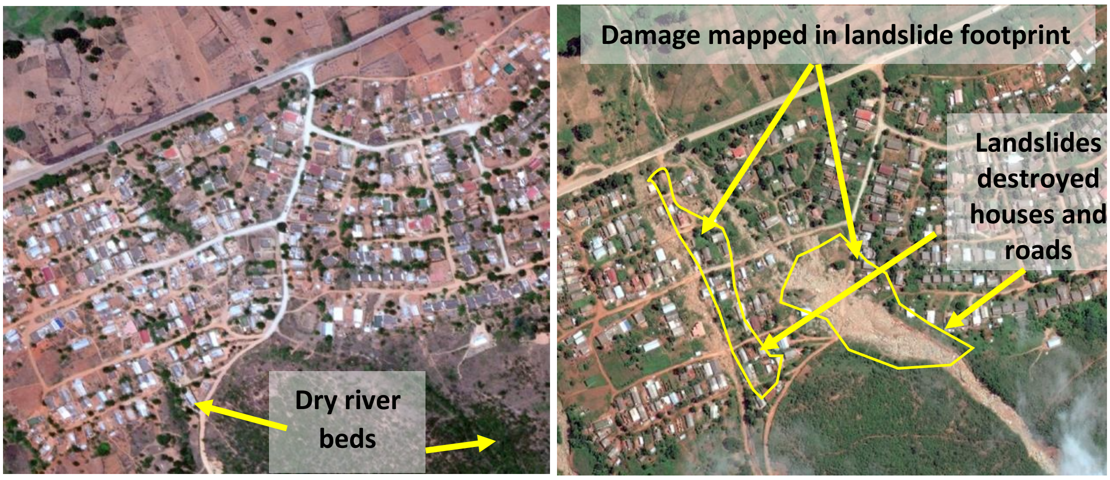
The approaches for the damage assessment, flood and landslide analysis and the landcover change activities are briefly introduced below.

Damage assessment

The damage assessment approach utilized a combination of on-screen, heads-up digitizing data capture from high-resolution satellite imagery, and the geostatistical analysis to develop damage density heat-maps. GIS operators placed a point feature on all buildings in the defined focused study areas in the before high resolution WorldView-2 satellite image, then using the *after* imagery, they categorized the building type (residential, commercial or public), and then assessed the scale of damage, utilizing the following classes for each building (no damage, possible damage, moderate damage, severe damage removed and new building). An example of *before* and *after* imagery for Chimanimani, Zimbabwe is shown in Figure 16.

[17] As stated earlier, these areas were agreed upon during the Inception Phase of this project.

Figure 16: Before (left) and after (right) images for Chimanimani, Zimbabwe.



The full results of the damage assessment for Chimanimani are presented in Figure 19, and Beira in Figure ***20***.

The damage assessment analyses conducted in the focused study areas cover a small fraction of provincial and district land area – Beira 180 km^2 and Chimanimani 100 km^2 - and are not compared with other areas; however, these results show the potential for utilizing high resolution for damage assessment processes in two different contexts – inland and coastal. The locations of these focused study areas are indicated in Figure 1.

Flood and landslide analysis

Flooded area extent estimates were extracted from Sentinel-1 SAR Ground Range Detection (GRD) imagery using a change detection approach comparing GRD imagery products for the before (2019-03-01/2019-03-10) and after the flood event (2019-03-10/2019-03-25). The *before* flood time frame was set to images collected between 1st and 10th March 2019, and the *after* flood time frame was set to images collected between 10th and 26th March 2019. VH (vertical/horizontal) polarisation was selected with a descending mode overpass direction. This multi-polarisation SAR analysis differentiated between existing water and water bodies (farm dams, reservoirs, river channels, etc) and standing water following the extreme rainfall events that caused flooding events.

Landcover mapping

Unsupervised landcover classification was conducted in Google Earth Engine (GEE), using two Sentinel 2A medium-resolution imagery mosaics collected *before* the 20th of February 2019 and *after* the 20th of March 2019. Image analysis was restricted to parts of each province that falls within the BuPuSa basin as explained in Table 4 (page 14). The date ranges for imagery used for before and after imagery analysis were as follows:

- **Before**: 2018-10-20 to 2019-02-20; and
- **After**: 2019-03-20 to 2019-08-31.

These date ranges attempted to capture the situation in the BuPuSa basins as close as possible either side of the cyclone event, and support seasonal congruence and consistent vegetation cover, i.e. not showing mixed conditions, which could provide misleading results. However, there is some variation due to image archive availability and periodic cloud cover. The before image mosaic is provided in Figure 40 in the appendices.

The purpose of this analysis was to show basin-scale landcover before and after the cyclone event, and utilising these data and change detection analysis, the difference between the two periods. As ground-truth validation data collection was not possible, the land cover classification was conducted as an unsupervised, unvalidated basin-wide assessment, utilizing a simplified set of classes with larger urban areas are also delineated where relevant:

1. Dense vegetation: forest, woodland and dense thicket and bush;
2. Grassland/pasture: savanna, grassland landscapes and bare soil;
3. Sparse vegetation: sparsely vegetated bush and scrubland, including senescent bush and thicket;
4. Agriculture: irrigated and dryland cultivation; and
5. Water: open water bodies, standing water, lagoons, dams, reservoirs and estuaries.

While the classification remains unsupervised utilizing broad landcover classes, the changes presented herein show basin- and provincial-scale changes in landcover that indicate landscape-level shifts in cover that correspond with a substantial influx of moisture from rainfall. Furthermore, it must be acknowledged that the period prior to the cyclone was characterized by a long drought across the region, particularly impacting Mozambique and Zimbabwe. Hence, changes in landcover could be simply due to 'greening' of the basin due to increased rainfall[18], as well as regular cyclical season changes anticipated at this time of year. Therefore, without additional year-on-year time series analysis it is not possible to pin-point the causal link between landcover changes and the cyclone event within the budget and timeframe of this project. However, the results of the following analysis contribute useful findings to the overall study by presenting the landcover before and after the event and identifying the extent of dryland and irrigated agriculture in the basin.

As the socio-economic assessment shows that agriculture is the most important rural livelihood source and has been heavily impacted by Cyclone Idai, it is important to note here that crops and crop-calendar information have not be factored into the analysis, meaning that the result of this analysis is primarily a *general landcover and agriculture baseline and change assessment.* The extent of landcover changes are summarised in Table 9 (page 38) and exposure of agriculture is presented in Table 10 (page 38).

The results of the landcover mapping demonstrate landcover status at a basin-scale *before* and *after* the cyclone events, and inform landcover change, which provides an assessment of landscape level change during and immediately after the cyclone, focusing on primary landcover classes. It is important to note that changes in landcover may not be directly linked to direct 'negative' impacts of the cyclone, such as physical damage or removal due to the adverse meteorological conditions, but also due to indirect effects such as substantial increase of available surface water and groundwater, and subsequent large-scale regeneration of vegetation communities and revitalisation of ecosystems.

Furthermore, as the BuPuSa basins are home to widespread agricultural activity, especially Manicaland, Masvingo and Midlands Provinces in Zimbabwe, it is not possible without field validation data to ascertain damage to agricultural crops with remote sensing techniques alone. Hence, the team utilised the cyclone exposure footprint (Figure 11 on page 16) to establish the portion of the study area where the effects of the storm were felt. This therefore presents an estimate of *exposure of*

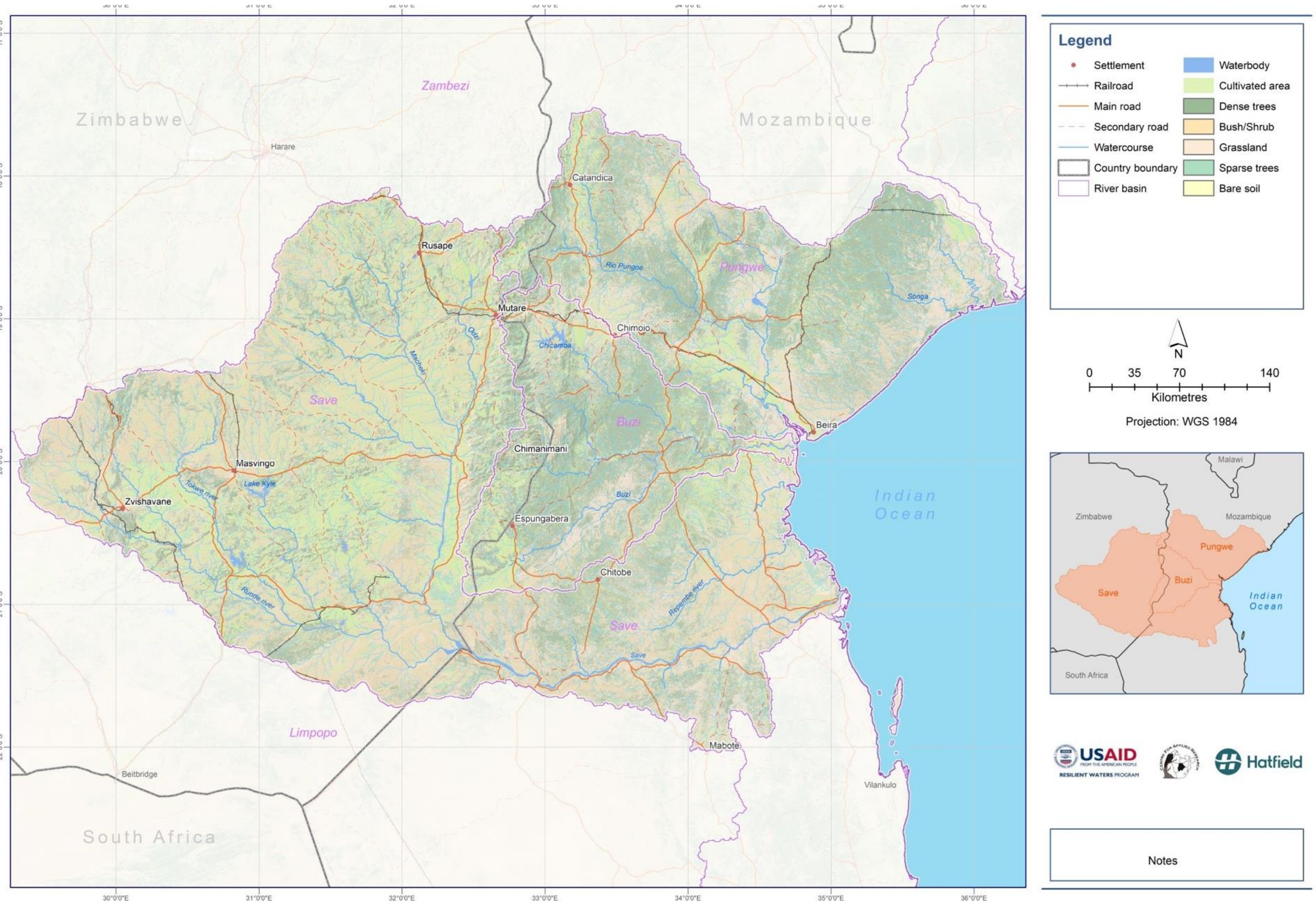
[18] Initially some expected the impact of Idai to be at least partly positive in Zimbabwe due to the increased rainfall and associated growth of vegetation and crops (Zurich Flood Resilience Alliance, 2020).

agriculture. Later in the project, the team will attempt to compare rainfall intensity with agricultural exposure

The following key points relating to landcover, and agriculture baseline/exposure are illustrated in Figure 18.

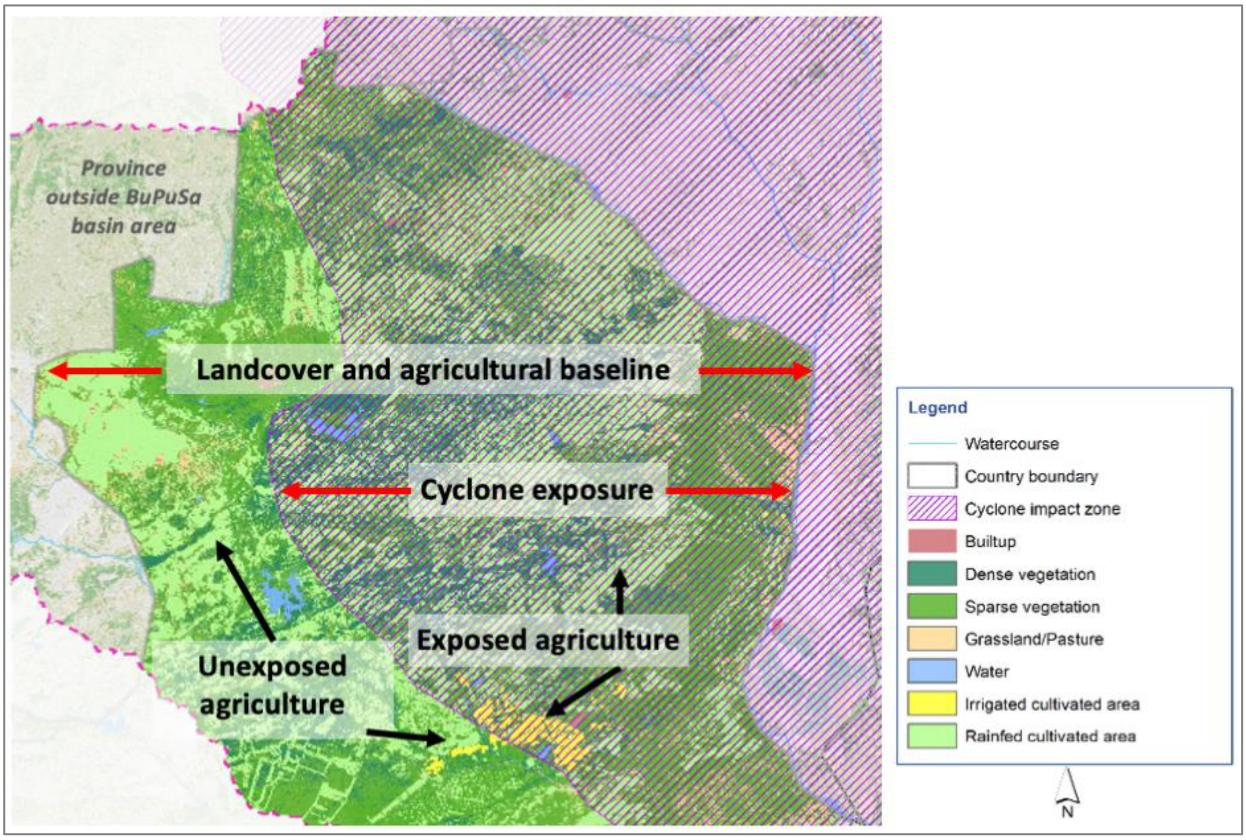
1. The landcover and agricultural baseline is the portion of the basin inside Masvingo Province;
2. The portion of the province outside the basin is greyed out – to the west;
3. The portion of the province inside the basin, and exposed to Cyclone Idai is hatched; and
4. Irrigated (yellow) and dryland (pale green) cultivated land are present inside and outside of the Cyclone impact zone area.

Figure 17: Landcover classification (before Idai) with intersecting provinces.



It is noted there may be value in aligning these data with the national and provincial land use plans for both countries. However, the project team has not yet been able to locate such plans or documents.

Figure 18: Visual explanation of the agriculture baseline and cyclone exposure concept.



The total area is the agriculture baseline, and the area inside the hatching is the exposed agriculture.

Again, it is important to emphasise that exposure does not equate to damage, but rather exposure to increased rainfall, higher winds and the associated physical damage these factors may cause.

5.1.2 Results

The following results focus on the following areas:

- Damage assessment and flood/landslide analysis for the two focused study areas covered by the high-resolution imagery of Beira, Mozambique and Chimanimani, Zimbabwe; and
- The landcover mapping and change analysis for the main provinces affected by the cyclone (as identified in Chapter 3), plus, the two hardest-hit districts in Zimbabwe (Chimanimani and Chipinge).

Again, for reference, the location and extent of the focused study areas covered in the detailed analysis are shown in Figure 1.

5.1.2.1 Damage assessment

Building damage for residential, commercial and public/civic structures for the Chimanimani focused study area are summarised in Table 7, which shows that approximately 8 % of residential buildings were impacted, most of which were completely destroyed/removed, 9 % of commercial buildings, and 4 % of public or civic buildings. However, it should be highlighted that the Chimanimani imagery was captured nine months after the event, providing time for reconstruction and rehabilitation to occur. These data are also summarized in Figure 19.

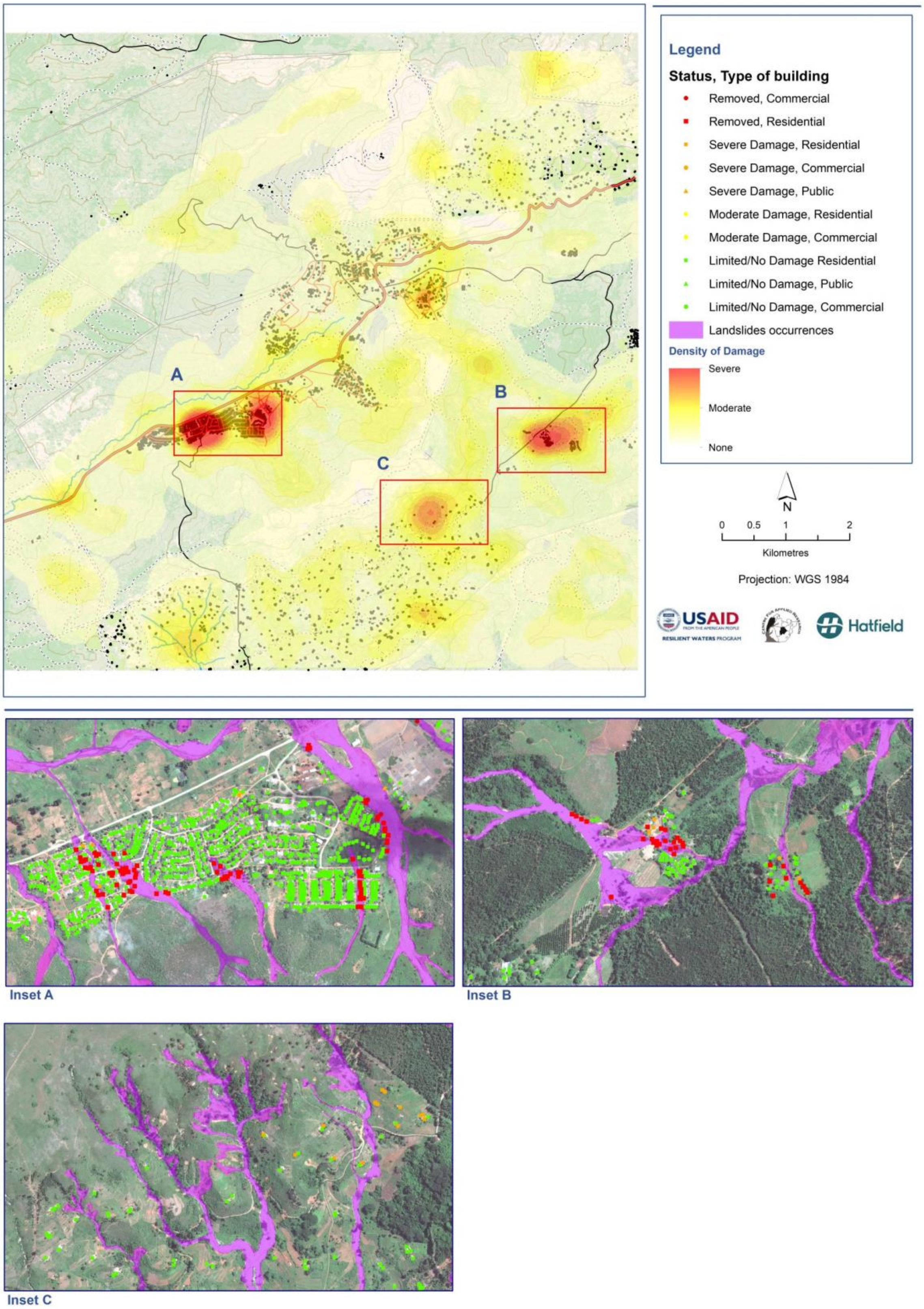
Table 7: Chimanimani building damage assessment (numbers and as %).

	Residential		Commercial		Public		Total
Limited/no damage	3,098	92%	97	92%	26	96%	3,221
Moderate damage	10	0%	1	1%		0%	11
Severe damage	58	2%	1	1%	1	4%	60
Removed	199	6%	7	7%		0%	206
Total	**3,365**		**106**		**27**		**3,498**

Note: The limited/no damage class is presented as a single category, as it was found that change between two images was subjective. Limited damage was difficult to discern from no damage, especially in Chimanimani where the image was captured a significant amount of time after the event.

The area included in Figure 19 is the entire 100 km^2 Chimanimani focused study area (following page). This figure shows the damage density assessment for Chimanimani, which includes the extent of damage to two neighbourhoods heavily impacted by a landslide and subsequent mass slope failure and mudslide are shown in Inset A and Inset B; damage to streets and houses is clearly visible. Complete destruction damage is clustered in four primary locations, with severe damage in a fifth location and severe to moderate damage emanating out from each of these areas. Most damage is localized in lower lying clusters of buildings, close to stream channels running down from the ridges where landslides moved rapidly downslope, destroying buildings and infrastructure in their paths. Damaged road infrastructure is not localized in a single area, with patterns largely matching that of building damage, with most of these areas featuring some form of road infrastructure loss. Interestingly, as shown in the lower inset map, there is some severe damage to residential properties higher up-slopes that are separated from channels and landslides. Without further contextual or validation information, it is assumed that these properties were damaged by high overland flow/runoff.

Figure 19: Building and road infrastructure damage density, Chimanimani.



In Beira, approximately 15 % of residential buildings were damaged, with 18 % of commercial buildings and 27 % of public/civic buildings sustaining some form of damage (Table 8).

Table 8: Beira building damage assessment (numbers and %).

	Residential		Commercial		Public		Total
Limited/no damage	110,606	85%	8,641	81%	1,050	73%	120,297
Moderate damage	6041	5%	899	8%	144	10%	7,084
Severe damage	8053	6%	853	8%	221	15%	9,127
Removed	5345	4%	211	2%	24	2%	5,580
Total	**130,045**		**10,604**		**1,439**		**142,088**

Figure 20 presents the damage density heat map for Beira, Mozambique, with the inset images showing the distribution of damage caused by high winds and heavy rainfall on coastal dwellings. As can be seen, damage is clustered in two main locations, with insets A and B in the north, in-land section, and C and D in the town of Beira itself, at the river mouth.

Within the focused study area, damage appears to be concentrated in two main areas – one in the residential area close to the ocean shore, which would typically be impacted by high winds, heavy rain, and storm surge effects, and a second further north, and approximately eight kilometres from the riverbank, heading inland along the railway line.

With over 5,435 residential properties destroyed, 8,053 severely damaged, 6,041 with moderate damage, and 110,606, the entire Beira area was badly hit. This means that approximately 15 % of residential buildings were damaged in some way. Commercial and civic/public buildings fared slightly worse, with 19 % and 27 % respectively damaged, but with considerably less destroyed buildings. The area closer to the ocean shore was more broadly impacted, but to a lower intensity, with damage spread over a much larger area, possibly due to densely constructed buildings and poor planning.

The area to the north suffered more intense damage, especially in the area to the west of the railway line, but with damage focused in a smaller area. While it is not immediately obvious why the area to the north experienced more intense damage, despite the fact it was less populated, and was further from the shore, analysts proposed that the intensity was caused by less dense building patterns, exposure due to removal of trees for cultivation, and the area being on a slight slope, facing the ocean;

Building materials may have also contributed to the increased amount of damage in these areas, with most roofs constructed from corrugated iron sheets rather than tile or slate, which would be less susceptible to damage. Indeed, analysts noted that buildings with larger roofs were the worst hit, as the roof area is easier to damage in higher winds. Isolated buildings and outer buildings where clustered together were the most severely damaged, with complete destruction, or removal of roof and wall damage, more likely due to exposure. Commercial and civic buildings appear to have been better constructed and have been less severely hit. Areas that had retained more tree cover experienced less damage, as the trees shielded buildings from the wind. However, many of the trees were missing in the after images. They could have been blown down or chopped down to for fuel.

Figure 20: Building damage density, Beira.

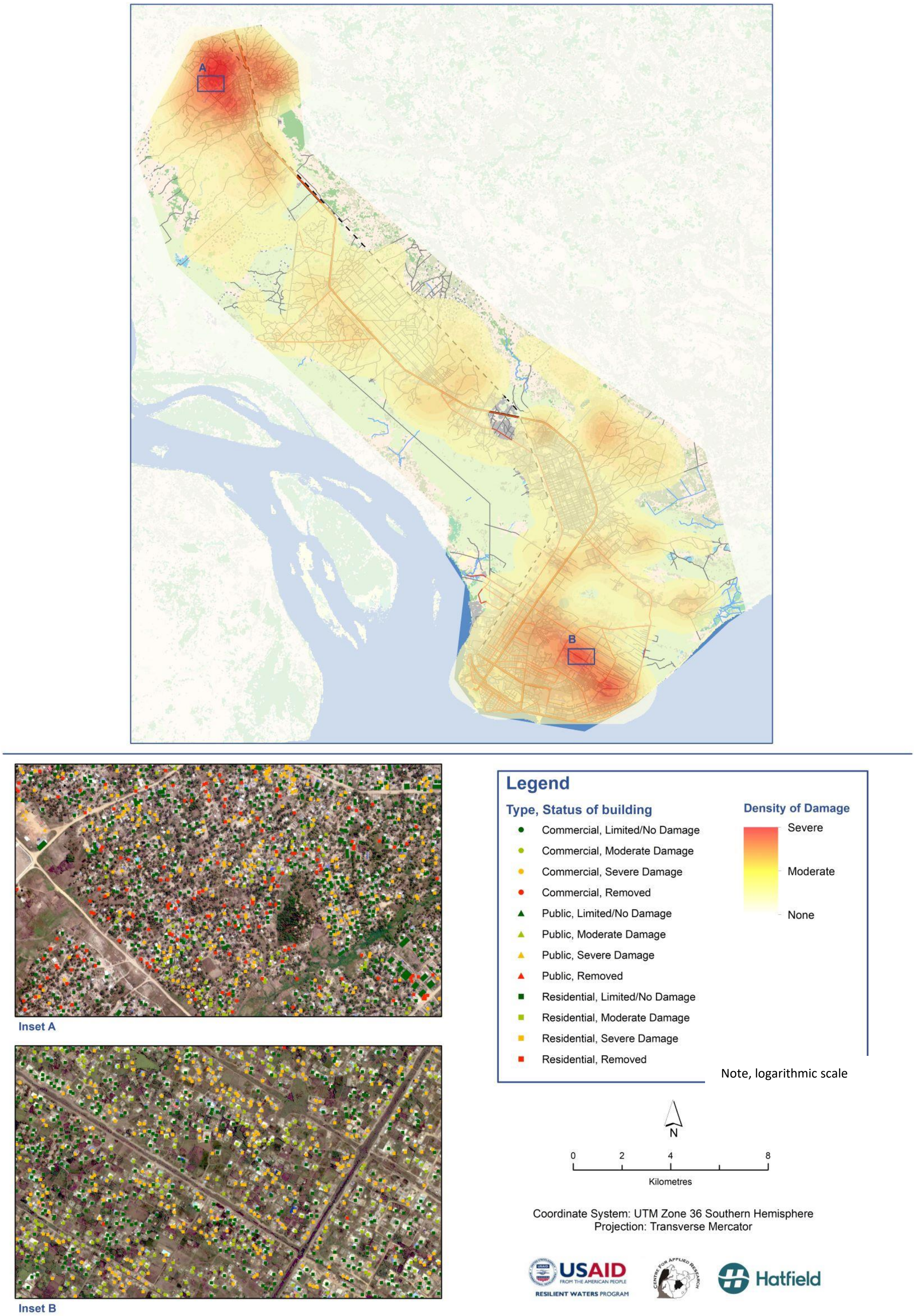


Figure 21, a photograph of Beira taken from low altitude in an aircraft in March 2019, shows the variety of damage sustained across a neighbourhood in the town, with some building sustaining minor damage such as broken windows to removal of roofs and walls.

Figure 21: Homes in Beira damaged by Cyclone Idai, March 2019.

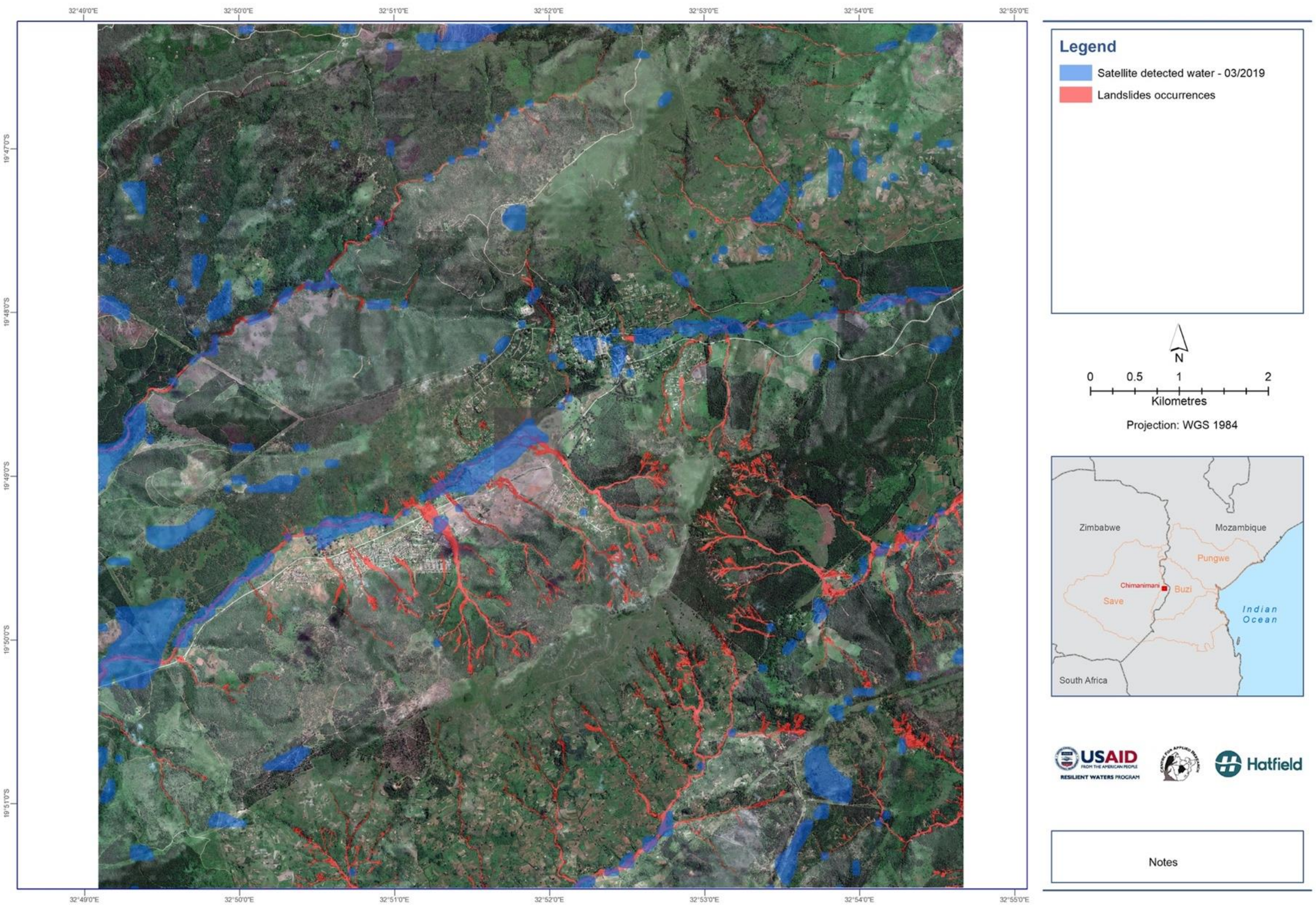
Source: Christopher Jepsen 2019.

The comparison of the damage assessments in both areas shows that the damage patterns are substantially different. Damage in Chimanimani was localized around the devastating landslide paths, and to a lesser extent flooding in low-lying areas and general damage to small-holdings likely due to heavy rain and associated winds. The impacts in Beira were more widely distributed, likely driven by factors such as exposure to the elements, exacerbated by removal of sheltering trees, building density, and building materials.

5.1.2.2 Flood and landslide analysis

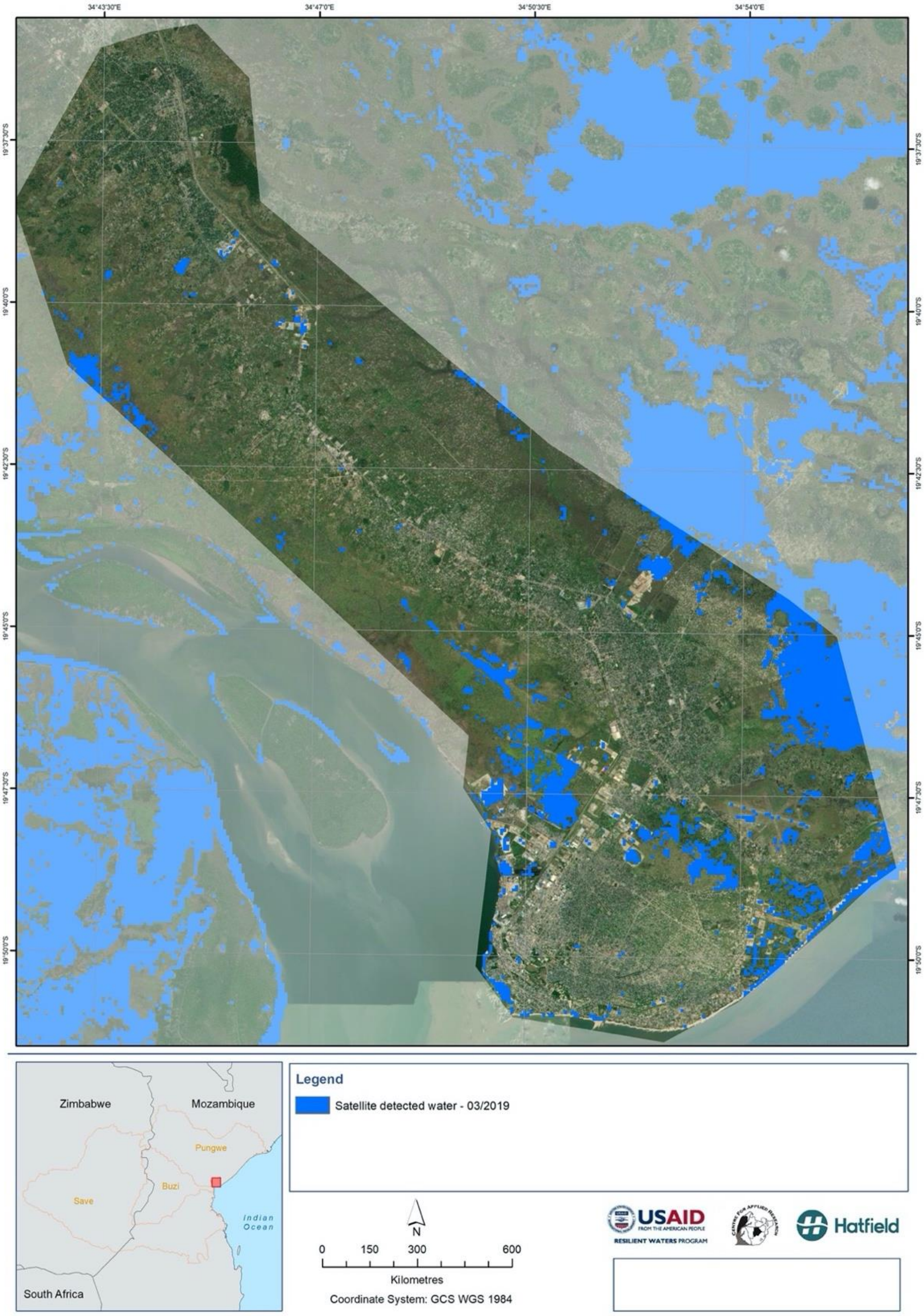
The flood and landslide analysis results for flooded area extents for Chimanimani are shown in Figure 22. Landslide presence was extracted from the high-resolution image classification, with this analysis only performed for the Chimanimani focused study area as no landslides were recorded in Beira. The landslides generally followed stream channels from higher ground, often merging to form larger landslides, moving large amounts of sediment, soil and uprooted vegetation downslope. In many cases the landslides in Chimanimani terminated in flooded river areas. Flooding in Chimanimani was localized on river flood plains and in low-lying areas. Comparing with Figure 22 with Figure 19 (page 31), it can be seen that the majority of the more densely populated areas of Chimanimani village on the south bank of the river are set-back from the river bank and were not inundated; however, there appears to be some limited flood exposure of small-holder farms on the northern bank located closer to the river than the residential areas.

Figure 22: Flooded area and landslide analysis – Chimanimani, Zimbabwe.



The results of the SAR-based flooded area analysis for Beira, Mozambique, created using Sentinel-1A data from March 2019 are shown in Figure 24. As can be seen in this map of Beira, most flooding took place in the unpopulated areas to the north of the main coastal residential district, to the east and further north-east, with limited flooding occurring in the main settlement itself.

Figure 23: Flooded area analysis – Beira, Mozambique.



5.1.2.3 Landcover change

A post classification comparison was conducted on the *before* and *after* landcover data, which provided a “from” and “to” class change description over the window of October 2018/February 2019 (before) and March/August 2019 (after). This enabled a high-level assessment of the amount of landcover change per province. The results of this landcover change analysis are summarized in Table 9, showing *before*, *after,* and change in area: positive change indicates an increase and negative a reduction. Overall, with the exception of Gaza Province in Mozambique, all provinces experienced increases in dense vegetation, and reduction in sparse vegetation, and four of the nine provinces experienced increases in grassland/pasture. Most of these changes in landcover are characterized by the seasonal regeneration and densification of senescent vegetation driven by increased moisture availability across the basins. The dense vegetation includes forest, woodland and remaining denser bushland/thicket, which likely present most of the existing dense vegetation in the *before* assessment. Note, a separate Tree Loss change detection estimate was performed with this assessment, and these data are presented per province in Section 5.2.7.

One of the smaller portions of the BuPuSa area, Gaza Province in Mozambique saw a modest (11 %) decrease in dense vegetation, which changed primarily to sparse vegetation, particularly in the south of the province, close to the edge of the estimated zone of influence of the cyclone. Inhambane Province experienced an increase (16 %) in Grassland/pasture is also evident, likely driven by the seasonal growth and regrowth of grasses from sparse vegetation. With the exception of water coverage increasing by 15 %, likely due to accumulation of standing water, only nominal changes in land cover are noted after the cyclone. Manica Province experienced moderate losses of sparse vegetation (18 %) and substantial (46 %) losses in grassland/pasture, with these landcovers migrating to dense vegetation, which increased by 31 %. Covering the largest area in the entire BuPuSa basin, Sofala Province experienced widespread increases in dense vegetation (41 %) due to seasonal regeneration and regrowth, and commensurate decreases in the sparse vegetation (-40 %) and grassland/pasture (-60 %). It is interesting to note that water cover has increased significantly (32 %), over 25,000 ha more than before the cyclone event.

Manicaland Province in Zimbabwe witnessed a similar pattern to Sofala Province, with a 26 % increase in dense vegetation mirroring the losses of sparse vegetation (-20 %) and grassland/pasture (-26 %). Mashonaland East Province, Zimbabwe saw an overall decrease in sparse vegetation (- 31 %), and an increase in dense vegetation (28 %) and grassland/pasture (37 %). Masvingo Province witnessed an overall significant (-65 %) decrease in grassland/pasture, which appears to have migrated to dense vegetation (18 %), likely due to new growth and regeneration of vegetation communities. Matabeleland South experienced a 66 % loss in sparse vegetation, which shifted to grassland/pasture, particularly in the west of the province. Midlands Province showed losses of approximately 100,000 ha (-21 %) of sparse vegetation, which appears to have contributed to 20 to 25 % increases in grassland/pasture and dense vegetation.

The observations summarized above are illustrated more fully in Section 9.1 (Appendix), where provincial level change dynamics are presented in map form, showing patterns of increases and decreases.

Table 9: Landcover change assessment results.

Country	Province	BEFORE Dense Vegetation	BEFORE Sparse Vegetation	BEFORE Grassland/ Pasture	BEFORE Water	Total area	AFTER Dense Vegetation	AFTER Sparse Vegetation	AFTER Grassland/ Pasture	AFTER Water	CHANGE Dense Vegetation	CHANGE Sparse Vegetation	CHANGE Grassland/ Pasture	CHANGE Water
Zimbabwe	Manicaland	496,126	706,291	232,370	27,961	1,462,748	667,635	586,255	180,854	28,005	171,509	-120,036	-51,516	44
	Mashonaland East	72,050	225,846	43,562	3,395	344,853	100,149	172,461	68,848	3,395	28,099	-53,385	25,286	0
	Masvingo	623,557	1,939,287	265,608	23,616	2,852,068	761,331	1,906,957	160,633	23,147	137,774	-32,330	-104,975	-469
	Matebeleland South	40,198	123,903	31,923	1,590	197,614	41,002	74,775	80,275	1,563	804	-49,128	48,352	-27
	Midlands	296,978	603,860	69,697	6,490	977,025	375,141	501,939	93,454	6,490	78,163	-101,921	23,757	0
Mozambique	Gaza	53,919	130,702	2,527	4,773	191,921	48,689	135,454	3,008	4,771	-5,230	4,752	481	-2
	Inhambane	255,371	436,629	32,760	12,605	737,365	260,368	428,482	33,678	14,837	4,997	-8,147	918	2,232
	Manica	989,346	2,332,683	278,795	58,781	3,659,605	1,436,481	1,973,283	191,059	58,781	447,135	-359,400	-87,736	0
	Sofala	1,345,690	2,752,435	474,109	55,377	4,627,611	2,286,020	1,963,359	297,236	80,995	940,330	-789,076	-176,873	25,618

Table 10: Satellite-based estimates of exposed agricultural land in the BuPuSa area.

Country	Province	Irrigated	Exposed Irrigated Agriculture	Dryland Agriculture	Exposed Dryland Agriculture	Total Agricultural Area	Total Agriculture in exposed area	% Agriculture Exposed	Total Area	% Agriculture	Total Exposed Area	Total Exposed Agriculture	Total Exposed Area in BuPuSa
Zimbabwe	Manicaland	46,298	46,298	1,252,445	1,252,445	1,298,743	1,298,743	100%	3,575,425	36%	3,575,425	36.3%	2,760,897
	Mashonaland East	11,771	11,771	121,376	120,992	133,147	132,763	100%	2,818,859	5%	1,703,271	7.8%	467,540
	Masvingo	35,644	31,178	1,230,688	830,782	1,266,332	861,960	68%	5,535,209	23%	2,594,654	33.2%	2,590,976
	Matebeleland South	13	0	29,460	0	29,473	0	0%	5,440,018	1%	0	0.0%	0
	Midlands	104	0	447,649	115,015	447,753	115,015	26%	5,617,081	8%	489,084	23.5%	334,662
Mozambique	Gaza	0	0	742	742	742	742	100%	7,551,163	0%	219,765	0.3%	150,675
	Inhambane	3,397	3,397	25,639	12,107	29,036	15,504	53%	6,887,945	0%	1,183,201	1.3%	598,213
	Manica	41,531	41,531	894,399	894,399	935,930	935,930	100%	6,280,823	15%	6,280,823	14.9%	4,594,768
	Sofala	21,359	21,359	466,993	466,993	488,352	488,352	100%	6,761,923	7%	6,761,865	7.2%	5,115,113

For each province, the cultivated areas were extracted from the landcover and further classified into rainfed/dryland agricultural land, which consists mostly of small holding and subsistence farming practices, and irrigated agricultural land – focusing primarily on larger irrigation schemes. The total hectarage of land under agriculture was computed, then using GIS spatial analysis, the amount of cultivated land inside the cyclone exposure zone was identified. This area was then used to calculate the portion irrigated and rainfed agriculture within the BuPuSa basins and within in each province that was exposed to the cyclone. The exposure is used here to establish an increased risk of damage from the impacts of the cyclone.

As will be further elaborated in the socio-economic assessment, the majority of the larger irrigation schemes, and smaller-scale irrigated agriculture are Manica and Sofala Provinces in Mozambique, Manicaland and Masvingo Provinces in Zimbabwe. 100 % of dryland cultivation in Manica, Sofala, and Manicaland was exposed, with 68 % in Masvingo Province. A summary of agricultural exposure within the BuPuSa area is provided in Table 10.

All agriculture in the provinces within the BuPuSa basins was exposed to some extent. However, the portion of the provinces under cultivation of some kind varies greatly, from nominal amounts in Gaza and Inhambane Provinces in Mozambique to 36 % in Manicaland Province in Zimbabwe (% Agriculture column in Table 10 above). Furthermore, while the larger irrigation schemes within several of the provinces of the basin may cultivate crops on an industrial scale and employ large numbers of people, irrigated agriculture is a small fraction of the cultivated area within the basin; 4 % in total. Dryland agriculture is prevalent across the basin, primarily in the context of subsistence farming, providing food for the household or contributing to community food security.

Mozambique Agriculture

As the first province within the BuPuSa basins hit by Cyclone Idai, agriculture in Sofala Province was highly exposed to its impacts. Agricultural land equates to approximately 0.5 million ha. in Sofala Province, with 4 % irrigated agriculture, and the remainder rainfed/dryland agriculture. 100 % of agricultural areas within Manica Province – irrigated and dryland - were exposed to the impacts of Cyclone Idai, including irrigated agricultural areas directly to the west of the town of Manica; close to the border with Zimbabwe west of Sussendenga; areas around Bandula on the N6 road, directly south of Sussendenga on the N260; and directly east of Dombe on the south bank of the Buzi River. Dryland/rainfed agriculture is present across the central portion of the province within the study area, with further presence along a corridor to the north, and a third zone in the south close to the border with Zimbabwe. While no irrigated agriculture in Gaza Province was exposed to the cyclone event, all rainfed agriculture was within the cyclone exposure zone. In Inhambane Province, all irrigated agriculture and approximately half of the rainfed agriculture were exposed, including irrigated areas between Mazumba and Macassa, and further west between Lago Chitende and Lago Chissamba, both on the south bank of the Save River, close to the river mouth.

Zimbabwe Agriculture

All agricultural land in the portion of Manicaland Province within the BuPuSa basins was exposed to the cyclone, with irrigated areas located in and around Chipinge, Chimanimani, and Chisumbanje in the south of the province, and to a slightly lesser extent to the north-west of Mutare in the north of the province. The plantations at Chisumbanje are primarily sugarcane, connected with an ethanol green fuel plant, and the plantations near Mutare are tea and sugarcane. Coffee is also grown in this area. Equally, almost all agricultural land in Mashonaland East Province inside the BuPuSa basins was exposed to the impacts of the cyclone event. The exposed irrigated areas are located between Wedza and Marondera, and the area around Macheke and Murehwa. Results of the agriculture exposure analysis showed a significant amount of irrigated agriculture was exposed during the cyclone event, specifically the Tongaat Hulett's Triangle Estate and Hippo Valley Estate plantations directly to the north of Chiredzi. These are two of the largest sugarcane plantations in Zimbabwe, providing employment for over 5,000 people. With just under half a million hectares of dryland agricultural land inside Midlands Province (and only 104 ha of irrigated land), approximately 25 % of the dryland agriculture was exposed to the cyclone event, and none of the irrigated area.

5.1.2.3.3 Specific districts

The landcover change and agricultural exposure analysis conducted at provincial level (above) was also scaled down to district level for Chimanimani and Chipinge Districts in Zimbabwe as these were the most affected districts in Manicaland Province.

Chimanimani District

The landcover change at district level in Chimanimani District followed a similar pattern to that at provincial level in Manicaland, with sparse vegetation reducing significantly, and grassland/pasture reducing to a lesser extent, and dense vegetation increasing. These changes are quantified in Table ***11***.

Table 11: Chimanimani District landcover change.

Landcover class	Before cyclone (ha)	After cyclone (ha)	% change
Dense vegetation	123,086	157,402	22
Sparse vegetation	95,139	63,933	-49
Grassland/pasture	18,882	15,663	-21
Water	2,052	2,160	5

All agriculture in the district (200 ha of irrigated and 99,703 ha of dryland) was exposed to the effects of the storm, with the entire district falling into the second-highest 600 mm rainfall exposure zone[19]. The change in landcover described above is illustrated in Figure 24.

Chipinge District

Landcover change is similar to the pattern in Chimanimani District, with increased dense vegetation and reduced sparse vegetation and grassland/pasture, likely due to regeneration and recovery of woodland, thicket and dense bushland, as listed in Table 12 and illustrated in Figure 25.

Table 12: Chipinge District landcover change.

Landcover class	Before cyclone (ha)	After cyclone (ha)	% change
Dense vegetation	116,382	134,612	14
Sparse vegetation	142,124	129,013	-10
Grassland/pasture	45,869	40,750	-13
Water	7,095	7,095	0

Chipinge District contains substantially more irrigated agriculture (32,331 ha; mostly in sugar plantations) and almost double the dryland agriculture of Chimanimani District. All agricultural land in Chipinge District was also exposed to the second highest exposure level of the cyclone.

[19] As described above on page 34, cyclone exposure is estimated based on proximity to the zone of increased precipitation measured during and for two weeks after the cyclone, with rainfall peaking at 800 mm over this period.

Figure 24: Landcover change for Chimanimani District.

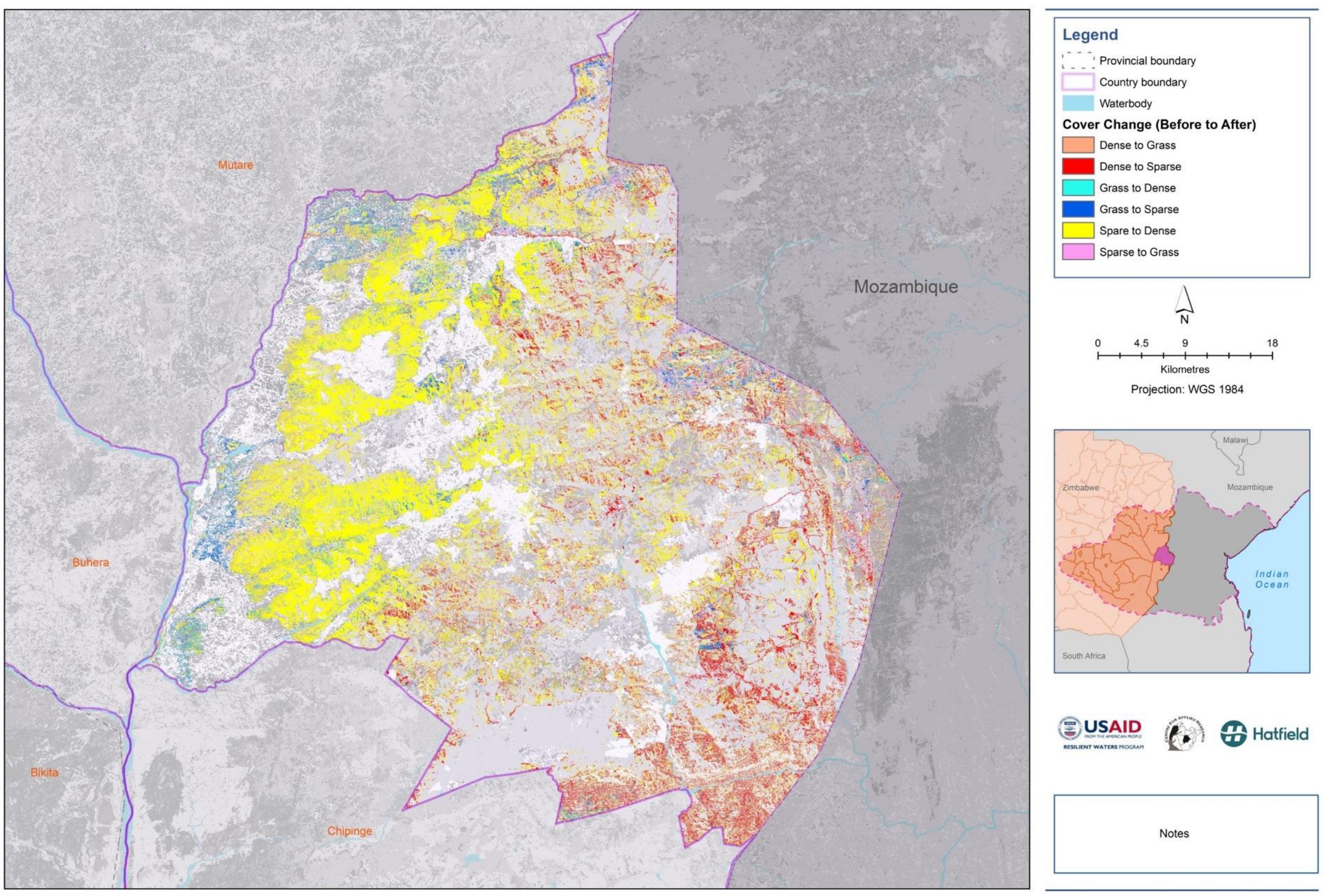
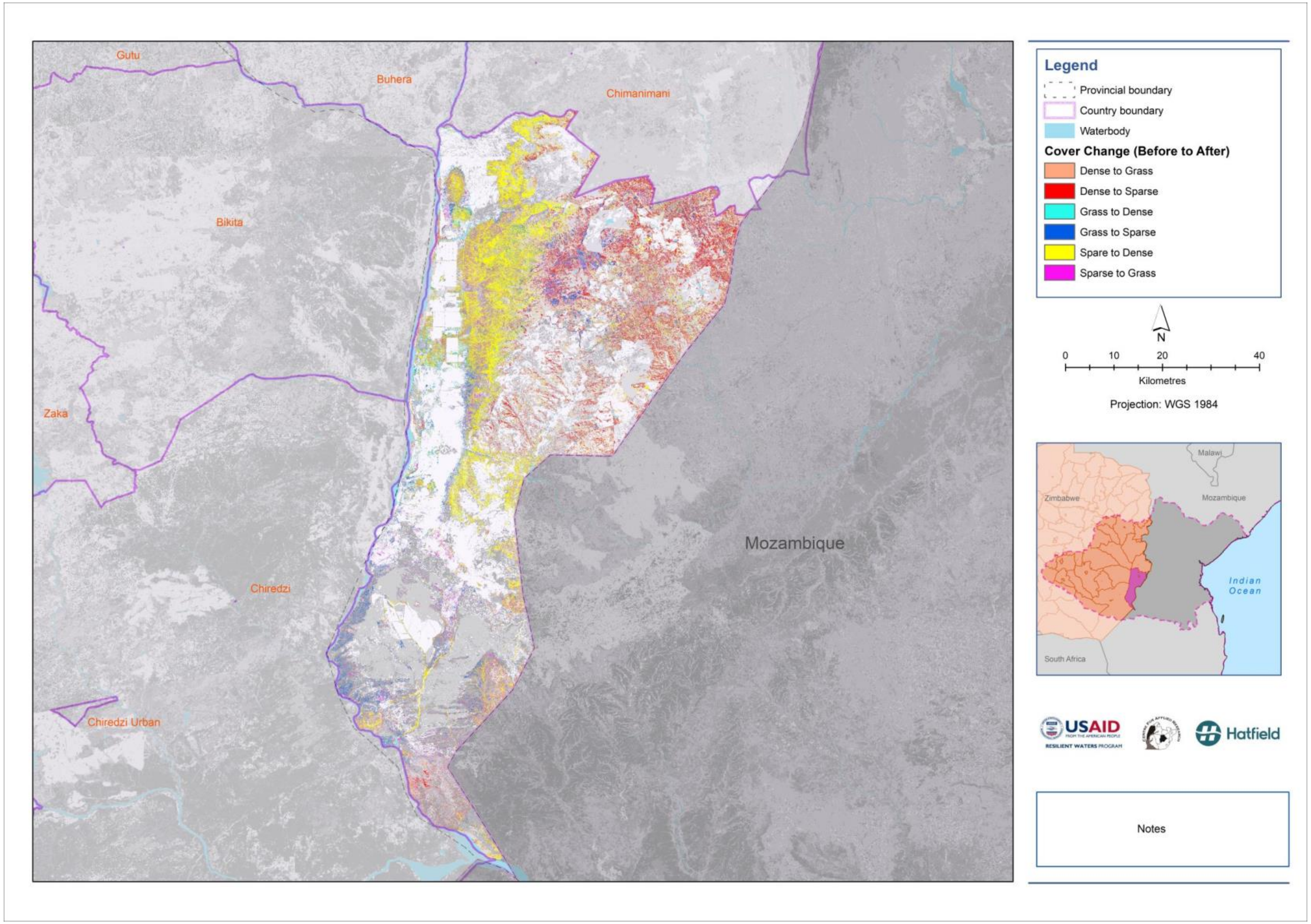


Figure 25: Landcover change for Chipinge District.



5.2 Socio-economic assessment

Cyclone Idai has had major impacts on the countries' people, livelihoods, economies and public infrastructure as well as the private sector. The impacts have been largest in Mozambique; in Zimbabwe, Chimanimani and Chipinge Districts were hardest hit (see section 5.1). Most of the BuPuSa area was affected, but the impacts extended beyond the three basins, in Tete and Zambezia Provinces in Mozambique and in Mashonaland Central in Zimbabwe[20]. While the geospatial assessment focused on the BuPuSa area, the socio-economic assessment went beyond these basins and included the provinces that were covered in the Post Disaster Needs Assessment (PDNA; GoM, 2019) in Mozambique (Sofala, Manica, Zambezia and Tete[21]) and the Rapid Integrated Needs Assessment (RINA: GoZ *et.al.*, 2019) in Zimbabwe (Manicaland, Masvingo East, Mashonaland and Midlands).

5.2.1 Impacts on people

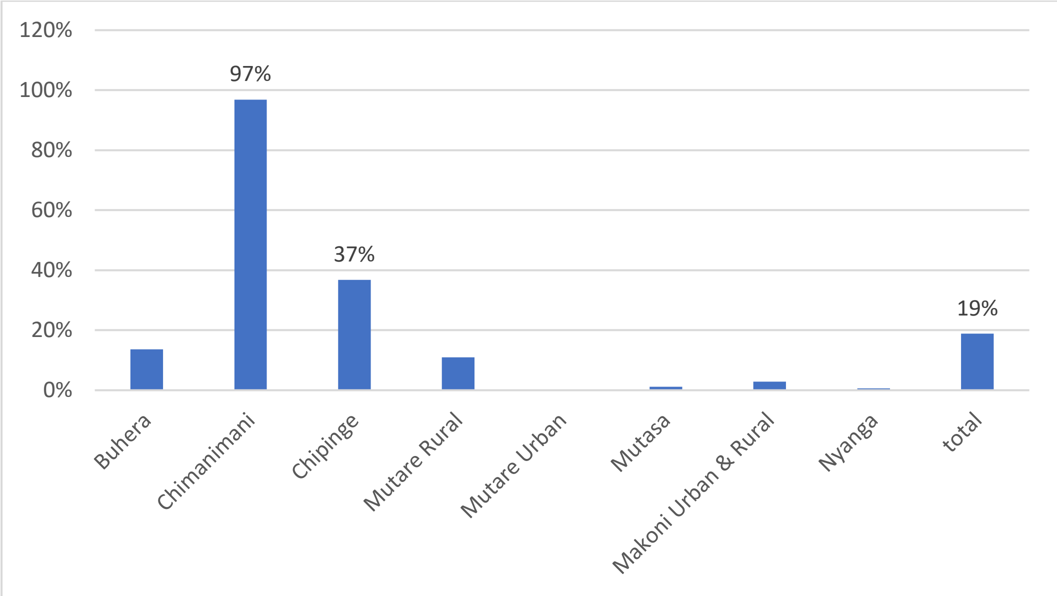
Cyclone Idai had a substantial impact on the human population in different ways, with lives lost and people injured and displaced. Moreover, people's health was affected as well as their access to water and sanitary facilities.

Overall, 1.8 million people were directly affected or around 354,000 households (GoM, 2019: GoZ *et.al.*, 2019). The same reports mention that almost 140,000 people were displaced, 3,200 injured and around 1,000 people lost their lives. Around 250 people went missing in Zimbabwe, and it is unclear whether these have been ever accounted for. In Zimbabwe 270,000 people were affected (54,000 households), mostly in Chimanimani and Chipinge districts (131,650 and 119,600 resp. or 97% and 37% of the district's population resp; GoZ *et.al.*, 2019[22]; Figure ***26***). Some displaced persons were housed in temporary camps and shelters; most stayed with other families. The International Organization for Migration (IOM[23]) estimated that in December 2019, 43,352 persons were still displaced due to Cyclone Idai, most of them living with host communities (IOM-DTM, 2020). This is 72 % of the people initially displaced by the cyclone (60,000). Idai added to the pressure on Zimbabwe's system of refugees and asylum seekers from other African countries.

The most affected population was located in the high rainfall area in Mozambique (Sofala), in flooded areas (Sofala) and in areas with landslides (Chimanimani; Figure 28). In Sofala Province, 53 % of the population was affected (GoM, 2019).

[20] A small part of Matabeleland South is part of BuPuSa but it was not affected by Idai.
[21] A quick assessment of Inhambane Province was done in Annex 3 of the PDNA report (GoM, 2019). Only 110 households were affected in this province
[22] Figures differ slightly between reports (e.g. Chatiza, 2019).
[23] Using its Displaced Tracking Matrix (DTM).

Figure 26: Affected population in Manicaland province Zimbabwe (as % of total population in district).



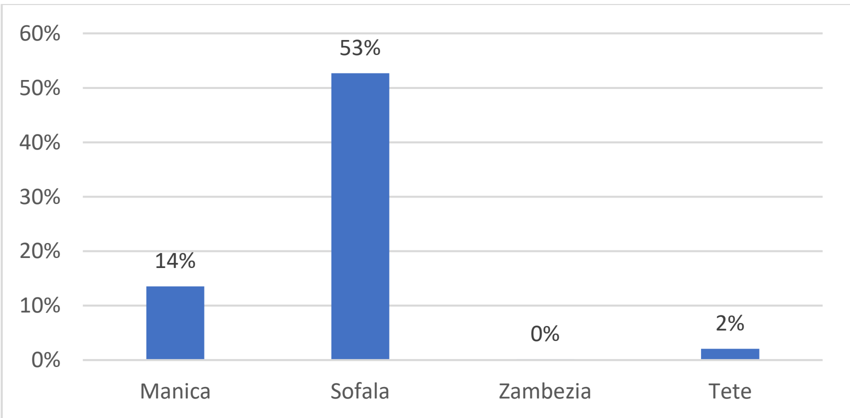
Source: IOM-DTM, 2020.

In Mozambique, over 1.5 million people were affected or around 300,000 households. Sofala Province was hardest hit with 1.2 million affected people; Manica Province had 262,000 affected people. Some 79,000 people were displaced; 73,000 lived in accommodation centers in Manica, Sofala and a few in Tete and Zambezia. Figure 27 shows the percentage of affected people by province. As earlier established (Table 5 and Table 6) the population density is highest in Mozambique (36 persons/km^2) compared to for Zimbabwe's affected provinces (6 persons/km^2).

Figure 28 shows the exposure of settlements to Idai in relation to rainfall amounts, with the majority of the hardest hit settlements in terms of cumulative rainfall being in Sofala and Manica provinces in Mozambique and Manicaland, and to a lesser extent Masvingo in Zimbabwe.

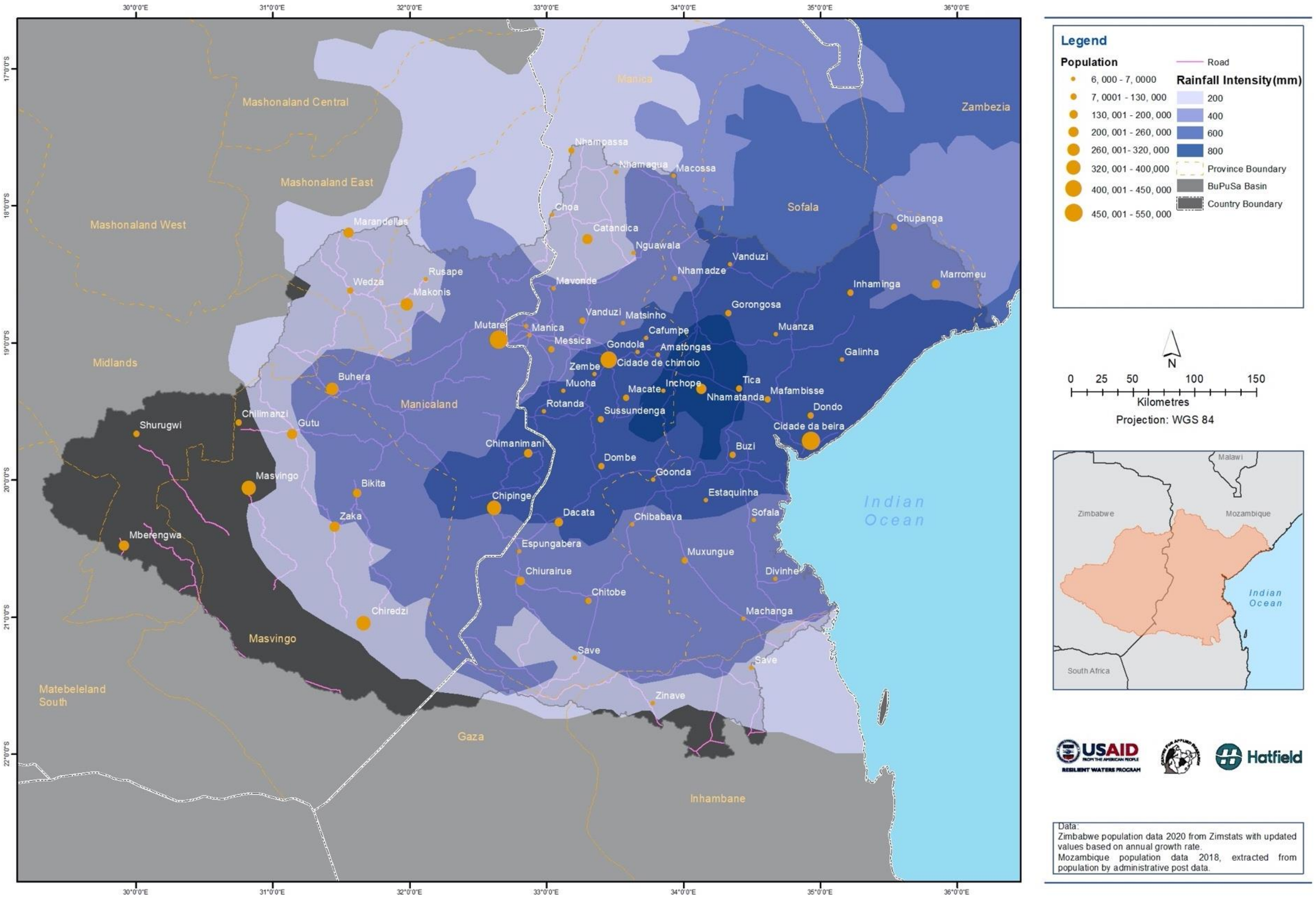
Following Cyclone Idai, outbreaks of cholera and malaria occurred in Mozambique involving 6,000 and 15,000 cases, respectively. In Zimbabwe, some cases of malaria, dysentery and diarrhea were reported; as per end of April 2019, but no cases of cholera, typhoid, measles, and rubella.

Figure 27: Idai affected persons by Province Mozambique (as % of population)



Note: Zambezia and Tete Provinces are outside the BuPuSa area.
Source: GoM, 2019.

Figure 28: Distribution of cumulative rainfall estimates in relation to major settlements.



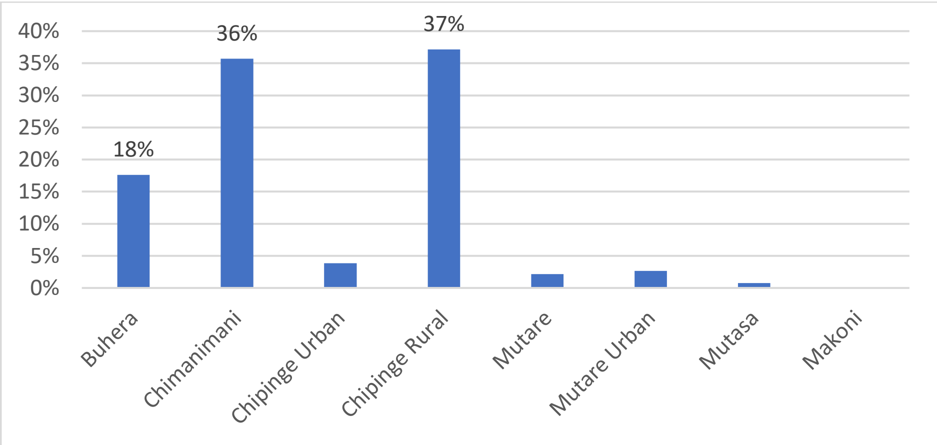
5.2.2 Impact on private buildings

5.2.2.1 Houses

Many houses were damaged or destroyed but estimates vary from 250,000 to 300,000 residential buildings affected. Assuming an average household size of 5 persons, 1.3 to 1.5 million people have thus been affected. In Mozambique, 110 000 houses were completely destroyed and 130,000 partly destroyed. Sixty percent were in urban areas and in low-lying areas close to rivers. The PDNA (GoM, 2019) indicates that most urban households run small businesses from home, which have been also negatively affected.

In Zimbabwe, at least 10,000 houses were destroyed, while government estimates the number of damaged houses at 17,715, roughly one third in Chimanimani and one third in Chipinge Districts (RINA; Figure ***29***). A remote sensing (RS) assessment for RINA puts the figure much lower at 10,730, two-thirds of which in Chimanimani[24].

Figure 29: Damaged houses (as % of total houses in affected districts in Zimbabwe).



Source: Adapted from RINA

5.2.2.2 Business buildings

Limited information is available in the literature for damage to private sector buildings.

In Zimbabwe, wind and rain from Cyclone Idai damaged irrigation infrastructure, plantations of tea, sugar cane, fruit trees and forest plantations. In Mozambique, an estimated 429 private companies were affected, of which 311 were in Sofala Province employing 15,517 people[25]. Most impacts were manifest in damaged warehouses and suspended production[26]. The service and commerce sector were most affected in terms of number of companies (Table 13). However, industry and agribusiness experienced the highest damage. due to losses. Large businesses (over 100 employees) were most affected (two-third of the estimated losses). While small businesses (10 employees or less) suffered modest total damage (US$5.9 million damage, the PDNA concludes that these are most in need of financial assistance to recover.

[24] A recent IOM-DTM estimate puts the number of damage houses at close to 50,000: partial damaged 37,483 and destroyed 10,097. Only 3,047 households have received assistance as per December 2019.
[25] Excluding backyard informal businesses. Assuming each employee was a breadwinner, around 100,000 households may be affected.
[26] Six days in Sofala Province.

Table 13: Affected business buildings in Sofala Province by sector (Mozambique)

Sector	Number of businesses	Employees	Loss value in US$ million
1. Industry	28	2,745	31.2
2. Agro-business	17	735	28.5
3. Commerce	53	2,397	17.2
4. Transport & Logistics	35	2,560	14.3
5. Services	64	2,152	9.9
6. Construction	36	1,590	6.3
7. Fishery	6	2,314	6.3
8. Hotels and Restaurants	29	589	4.6
9. Poultry	35	143	0.8
10. Planning	8	292	0.1
Total	**311**	**15,517**	**119.3**

Source: PDNA, 2019.

The private sector also incurred some damage to private educational and health facilities. The private sector incurred around 3 % of the damage to educational facilities. Table 14 summarizes the damage to commercial properties as assessed in the geospatial analysis. Clearly, Cyclone Idai had negative impacts on private sector buildings. The damage in Beira is more frequent, but the damage in Chimanimani is 'complete destruction'.

Table 14: Damage assessment for commercial properties in Chimanimani and Beira.

Damage category	Commercial Chimanimani		Commercial Beira	
Limited/no damage	97	92%	8,641	81%
Moderate damage	1	1%	899	8%
Severe damage	1	1%	853	8%
Removed	7	7%	211	2%
Total	**106**		**10,604**	

Source: geospatial assessment, this project.

The data tabulated above, derived from remote sensing analysis, demonstrate how such data can be used to fill data gaps. In terms of large-scale data capture and change moving forward, companies such as Ecopia, a partner of Maxar, have recently developed machine learning algorithms to automatically extract building footprints and locations. While too expensive for this project context, such data will in future enable rapid analysis of damage, with regular updates removing the need for manual digitizing. Equally, these technologies could be used to monitor change in state – such as damage. Specific private sector damage assessment (e.g. through a rapid survey) can also fill the observed data gaps.

5.2.3 Impacts on public sector infrastructure

5.2.3.1 Education

According to the PDNA report (GoM, 2019), close to 1,900 education facilities were damaged by Idai in the two countries, most of these in Mozambique. In that country, 1,380 educational facilities were damaged or destroyed: 31 preschools, 1,306 primary schools, 26 secondary schools, 11 technical schools, 3 universities and 3 teacher training institutes. A total of 4,222 classrooms[27] were damaged impacting on more than 330,000 students[28] and 9,616 teachers. Sofala Province was most affected. Public schools accrued 97% of the damage; private school had limited damage (possibly because there were few in the affected area).

The RINA (GoZ *et.al*., 2019) does not provide figures for affected educational facilities in Zimbabwe. Damage was, however, considered significant with collapsed buildings, blow-off roofs, destroyed teaching material and equipment as well as destroyed water and sanitary facilities. The IOM-DTM (2020) assessment estimated that 460 schools were still damaged in December 2019 in Manicaland and Masvingo province, 85 of which were in Chipinge and 38 in Chimanimani. It is not known how many schools have been repaired in 2020.

5.2.3.2 Health facilities

Between 200 and 300 health facilities were damaged by Cyclone Idai. In Mozambique, 94 health units were affected, four of which were destroyed (GoM, 2019), representing around 14% of the health facilities, mostly in Sofala Province. Reduced access to health services led to outbreaks of communicable diseases (cholera, diarrhea, fever and malaria). OCHA (2019) reports that cholera cases remained relatively low, but over 30,000 malaria cases were reported. According to the ECDC (2019) as of 30 March 2019, Mozambique has reported 276 cases of malaria in the areas affected by the cyclone. Beira had 200 to 300 confirmed cases per 1 000 population, while the remainder of Sofala Province, and Manica and Inhambane Provinces had more than 300 confirmed cases per 1 000 population. In Zambezia Province, the malaria incidence varies from 50 to more than 300 cases per 1 000 population. Overall, the cholera outbreak involved 6,727 cases and 8 fatalities[29], and the risk of malnutrition rose significantly.

Zimbabwe's health facilities were also affected. Out of the 315 health facilities in the affected areas, 182 had 'possible flood damage' (24th March 2019) and 145 'moderate or probable rainfall damage' (RINA, p.37). Hospitals (131) and rural health centers (27) were most affected by floods and rainfall damage. Later assessments by WHO (30th of April 2019) and the Ministry of Health and Child Care (MHCC) provide much lower numbers (12 and 28 hospitals and health centers respectively). The IOM-DTM assessment (2020) showed that in December 2019 70 clinics were still damaged, 19 of which were in Chipinge, 16 in Masvingo and 3 in Chimanimani. The damage to the buildings also affected the stored drugs[30] and this was further aggravated by the transport disruptions due to damaged road infrastructure.

5.3.3 Transport and road Infrastructure

Road infrastructure has also been seriously affected. Over 5,000 km of roads were affected, in Zimbabwe mostly regional and local roads and in Mozambique also national roads. In Mozambique, 4,613 km of roads became impassable because of destruction of roads, culverts, bridges, and drifts:

[27] OCHA (2019) provides slightly different figures: 3,582 rooms damaged, and 7,830 teachers affected.

[28] The number of educational facilities in these provinces is unknown. However, it is calculated that 6.4% of the total enrolled students in the four provinces have been affected (based on GoM, 2019, p. 104). It is possible that around 5-10 % of the educational facilities have been damaged.

[29] Earlier figures are lower. ECDCP (2019) OCHA is quoted to report 3 577 cholera cases. Among these cases, six deaths were reported. The main affected areas in Mozambique are Beira, Nhamatanda, and Dondo (8th April 2019).

[30] A shortage of drugs already existed prior to Idai.

24% of the regional network's transit ability was affected and 6.5 % of the national network (Table *15*). Beira harbor and airport were adversely affected disrupting cargo and personnel travels. The major (national) road network for the Mozambican part of the BuPuSa basins is shown in Figure 30.

Table 15: Damage to transport infrastructure by province (Mozambique).

Province	Culverts damaged (No.)	Bridges damaged (No.)	Drifts damaged (No.)	Roads affected (km)	Roads damaged (km)
Sofala	55	1	0	1,450	1,011
Manica	8	5	4	667	69
Tete	10	4	8	1,003	89
Zambezia	17	5	12	1,493	793
Total	**90**	**15**	**24**	**4,613**	**1,962**

Source: PDNA.

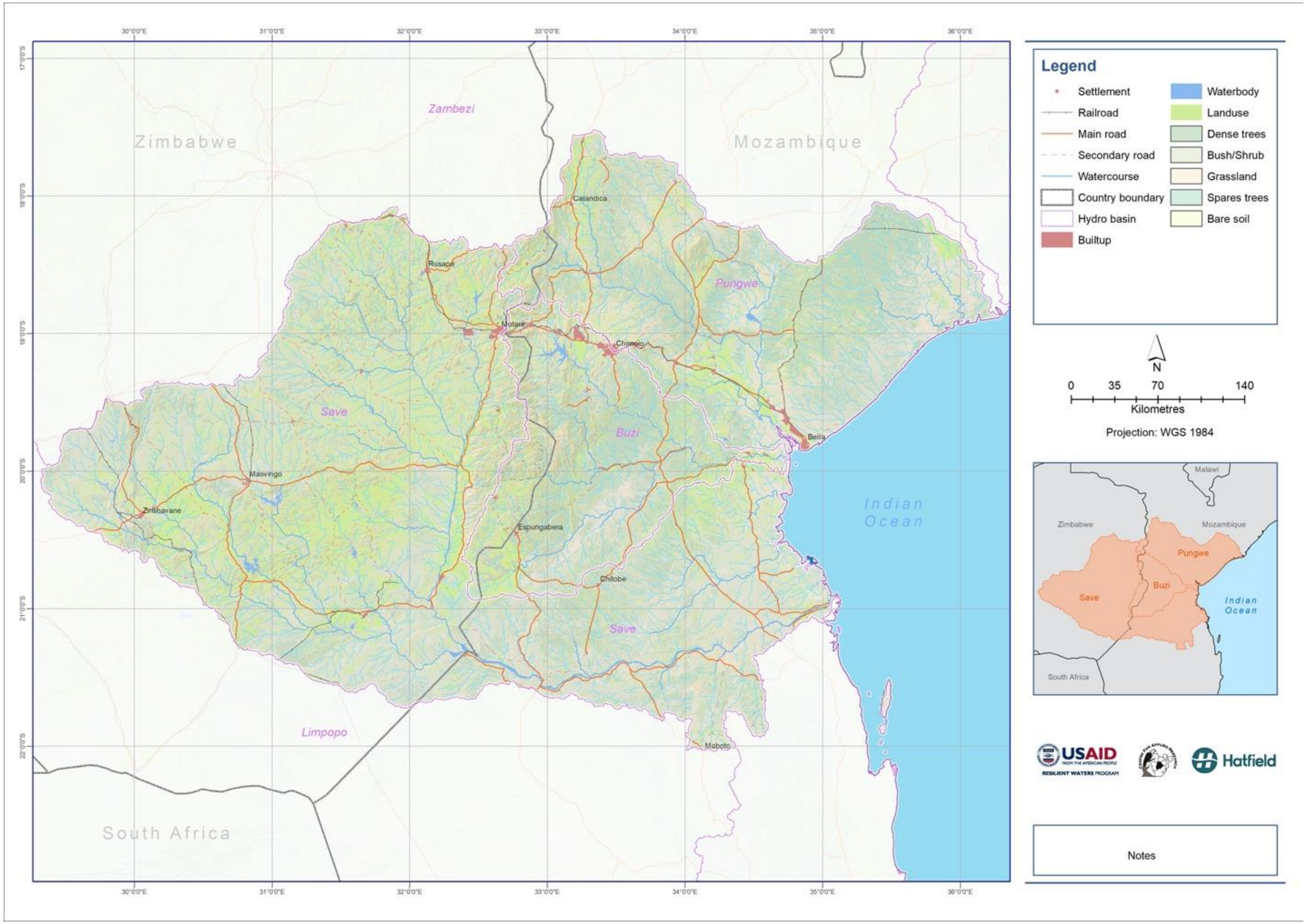
In Zimbabwe, 865 km of roads were damaged, mostly tertiary roads (482 km), making local travel more difficult or impossible. The damage has taken different forms such as roads washed away, erosion of road shoulders and lanes, blocked roads by landslides, clogged drainage systems, as well as damaged/ destroyed bridges, drifts etc. The damage was concentrated in Chimanimani and Chipinge Districts, also due to their mountainous nature and the landslides that occurred. Access to Mutare by road was seriously affected. As can be seen in the high-resolution damage density heat maps in the section on page 30, specifically Chimanimani, the main road passing through the community remained relatively intact, but numerous minor side roads were badly damaged, especially those in the paths of landslides. This would be due to the massive physical force of the landslides.

5.2.3.4 Electricity network

In Mozambique, fewer than a third of the households have electricity, mostly in towns and cities. The BuPuSa basins are served by a government-owned company EDM. Another company (HCB) runs the Cahore Bassa hydropower dam in Tete Province in combination with a powerline to South Africa. In addition, there are mini hydropower and solar PV schemes for rural settlements. The electricity infrastructure was seriously damaged, especially in Beira, Chimoio, Quelemane and Tete.

In Zimbabwe, power generation infrastructure was not badly affected by Cyclone Idai. Some transmission and distribution infrastructure were, however, affected, including 40 secondary substations. The number of households with power outages due to Idai is not known, but it is assumed that the cyclone had an adverse impact on households with electricity as well as public services and the private sector. Furthermore, the fuel pipeline from Beira to Harare was damaged and temporarily closed in Zimbabwe but fuel transport by road avoided severe fuel shortages in other parts of the country.

Figure 30: Road networks within the BuPuSa basins.



5.2.4 Impact on water and sanitation infrastructure

Water and sanitation infrastructure extend to private (households and businesses) as well as public infrastructure (e.g. dams and distribution networks). Both are combined in this section.

The PDNA report (GoM, 2019) states that In Mozambique around half of the population has access to safe drinking water, but only 37 % in rural areas (compared to 83 % in urban areas); fewer have access to sanitary facilities: in urban areas 58 % but in rural areas only 13 %[31].

Urban water supply systems were mostly affected by energy supply interruptions. For example, the Beira/Dondo system was disrupted for ten days, affecting some 340,000 people. In rural areas households had to buy bottled water after their waterpoints got damaged or polluted. Table 16 shows the damaged waterpoints and sanitary facilities in rural and urban areas.

Table 16: Affected water sources and sanitary facilities in Mozambique.

Water/sanitation facility type	Number facilities affected	People affected
Wells and borehole (rural)	705	211,500
Secondary water supply systems (urban)	42	462,000
Main water supply system (urban)	5	1,177,244
Latrines and septic tank (urban)	118,604	593,020
Latrines and septic tank (rural)	71,349	356,745

Source: GoM, 2019.

The water supply of the entire affected population appears to have been affected, and almost one million people had their sanitary facilities affected. Virtually all rural latrines were destroyed, with the population reporting open defecation increasing from 23 % to 46 % in the 14 hardest hit districts (GoM, 2019). Fortunately, significant progress has been made with WASH relief efforts.

In Zimbabwe, households use a variety of water points, including boreholes, dams, rivers, wells and springs. Boreholes and wells are the dominant rural water sources; piped water is the dominant source in urban areas. Boreholes, deep wells and springs were most affected. Based on RINA data, we estimate that over 70,000 households and over 300,000 people had their water sources affected. The damage to springs has the largest impacts on households and people. The IOM-DTM assessment (2019) indicates that in December 2019 299 boreholes and 44 water springs were still damaged.

In term of sanitation, over one third of the rural households have no facility. Pit latrines and 'Blair toilets' are most common in rural areas, flush toilets in urban areas. The RINA report estimates that around 7,400 pit latrines were damaged and 32 toilets at schools and health facilities. Almost 80 % of the damaged pit latrines were in communities; the balance at schools and health facilities. So just over 10 % of the affected households had their sanitary facilities damaged, necessitating use of neighbor facilities or unhygienic use of the bush with its associated health risks.

5.2.5 Impact on the agricultural sector

The agricultural sector is the main source of rural livelihoods in both countries. It is dominated by subsistence dryland farming and animal rearing. However, both countries have a modest commercial, sub-sector which includes irrigation schemes (e.g. sugar cane, tea and fruits) as well as forest

[31] In the affected provinces, access to safe drinking water (42.5%) is slightly below the national average, but improved sanitation (32.4%) is slightly above the national average.

plantations. Mozambique has 3.2 million smallholder farmers and 400 commercial farmers, producing 95 % and 5 % of the sector's output respectively (http://www.fao.org/mozambique/fao-in-mozambique/mozambique-at-a-glance/en). The cyclone's impact on the livestock subsector has been modest. Dryland farming and irrigation were hardest hit.

5.2.5.1 The livestock sector

Livestock mortality was low. The cyclone killed around 6,000 cattle, 2,000 goats and sheep and over 3,000 pigs (GoM, 2019)[32]. Around 400,000 chickens died. Most deaths occurred in Mozambique, particularly in Sofala Province (8,696, excl. chicken) and to a lesser extent Manica Province (1,302). The PDNA report (GoM, 2019) argues that a much larger number of animals (possibly 500,000, excl. chicken) may be affected by Idai because of poorer forage conditions, limited access to water and increased disease risks. It could not be established how many livestock farmers were affected. Fewer than half of the households own livestock (CGAP, 2016). This may even be lower in the BuPuSa area as more livestock is kept in southern Mozambique.

In Zimbabwe, animal losses were smaller and mostly confined to Chimanimani district, with over 90 % of the losses (cattle, goats, sheep and poultry) recorded in this area, presumably due to landslides. A total of 1,421 cattle died, 561 sheep, 49 goats and 13,443 chicken (GoZ *et.al*., 2019). Given the average number of cattle and goats per household in Manicaland of 3.2 and 4 respectively, around 500 households could have been affected. Many households lost chickens, i.e. a regular source of nourishment and/or source of cash.

5.2.5.2 Dryland farming

Cyclone Idai led to significant flooding of drylands. The floods were most widespread in Mozambique (GoM, 2019): an estimated 715,378 ha of cultivated land were flooded by Idai, affecting 433,056 households or 16 % of the households in the affected provinces. On average 1.6 ha of cultivated land was flooded per household. Sofala Province was worst affected: over 400,000 ha of 254,450 households or close to 60 % of the province's households. Production losses have been high. The PDNA report estimated the losses at 2.2 million MT, roughly a quarter of which was corn and cassava. Assuming all households cultivate corn and cassava, each household lost 2,472 kg of corn and cassava. Roughly a quarter of the losses were incurred in Sofala Province. Losses of fruits, vegetables and rice were also high. In addition to production losses, support infrastructure was damaged and or destroyed.

RS estimates for Zimbabwe show that out of the total 1.4 million ha of dryland farming land, 46 % had possible flooding damage (GoZ *et.al.,* 2019, p.19). Maize and millet were the most affected food crops; both important staple crops for rural livelihoods, with production losses estimated around 580,000 MT. Considerable losses of fruit trees also occurred. GoZ *et.al.* (2019) estimates that 1,626 ha of fruit trees were affected, 88 % of which were banana plantations. The remainder was pineapples, mangos and macadamia nuts. Fruits trees are grown mostly for commercial but also for subsistence/ livelihood purposes.

5.2.5.3 Irrigation sector

The impact on the irrigation sector has been smaller than that on dryland farming, probably because of the smaller size of the irrigation sector.

[32] This is 0.1 to 0.2% of the national number of animals (FAO 2018 data base).

In Mozambique, an estimated 4,309 ha of irrigated land and associated infrastructure was damaged or destroyed. This involved mostly small and medium farms. The average irrigation farm size is 1.3 ha, but half of that size in Sofala Province (Table 17).

Table 17: Affected irrigated land and number of farmers (Mozambique).

Province	Total area affected of irrigation (ha)	Farmers
Manica	1,407	828
Sofala	920	1,541
Tete	120	30
Zambezia	1,862	992
total	4,309	3,391

Source: PDNA, 2019.

For Zimbabwe, the impacts on the irrigation sector appear to have been larger. Over 1,500 irrigation schemes may have washed away or were damaged (RINA, p.33). Detailed information for 18 schemes in Chimanimani and Chipinge shows that some 2,300 ha of irrigated land was damaged affecting over 5,000 farmers. Farmers cultivate on average 0.45 ha, but double that in Chimanimani. The schemes vary significantly in size and number of farmers. Using the detailed info, for the estimated 1,500 affected irrigation schemes suggests that the damaged area of irrigation could be as high as 200,000 ha[33] and affect over 400,000 farmers. The difference with the estimates of the geospatial assessment will be further analyzed.

5.2.5.4 Forestry

Forestry is important for commercial production (timber) and for subsistence livelihoods (timber and non-timber products); however, the literature has few details about the impact on the forestry sector. In Mozambique, forest resources are known to be important for rural livelihoods and communities. In addition, there are 177 privately managed forest concessions for timber production. The impact of the cyclone on these plantations is, however, not documented.

The basin-wide geospatial assessment filled in some of the gaps through an independent analysis of tree loss, utilizing Sentinel 2A medium resolution satellite imagery *before* and *after* the event. The estimated tree losses at a provincial and national level are presented in

Table ***18***, and illustrated in Figure 31. This tree loss estimate was developed during the landcover classification by extracting vegetation that appeared dense or clustered (a collection of tall trees), as well as sparse vegetation (a mixture of tall trees and bush). A change detection was then conducted to show, among other things, movement from dense vegetation to sparse vegetation, or dense vegetation to grassland or sparse vegetation to grassland. The combination of these three changes is what is recorded as tree loss as they represent dense forest that has been cut down, removed, or wash-away.

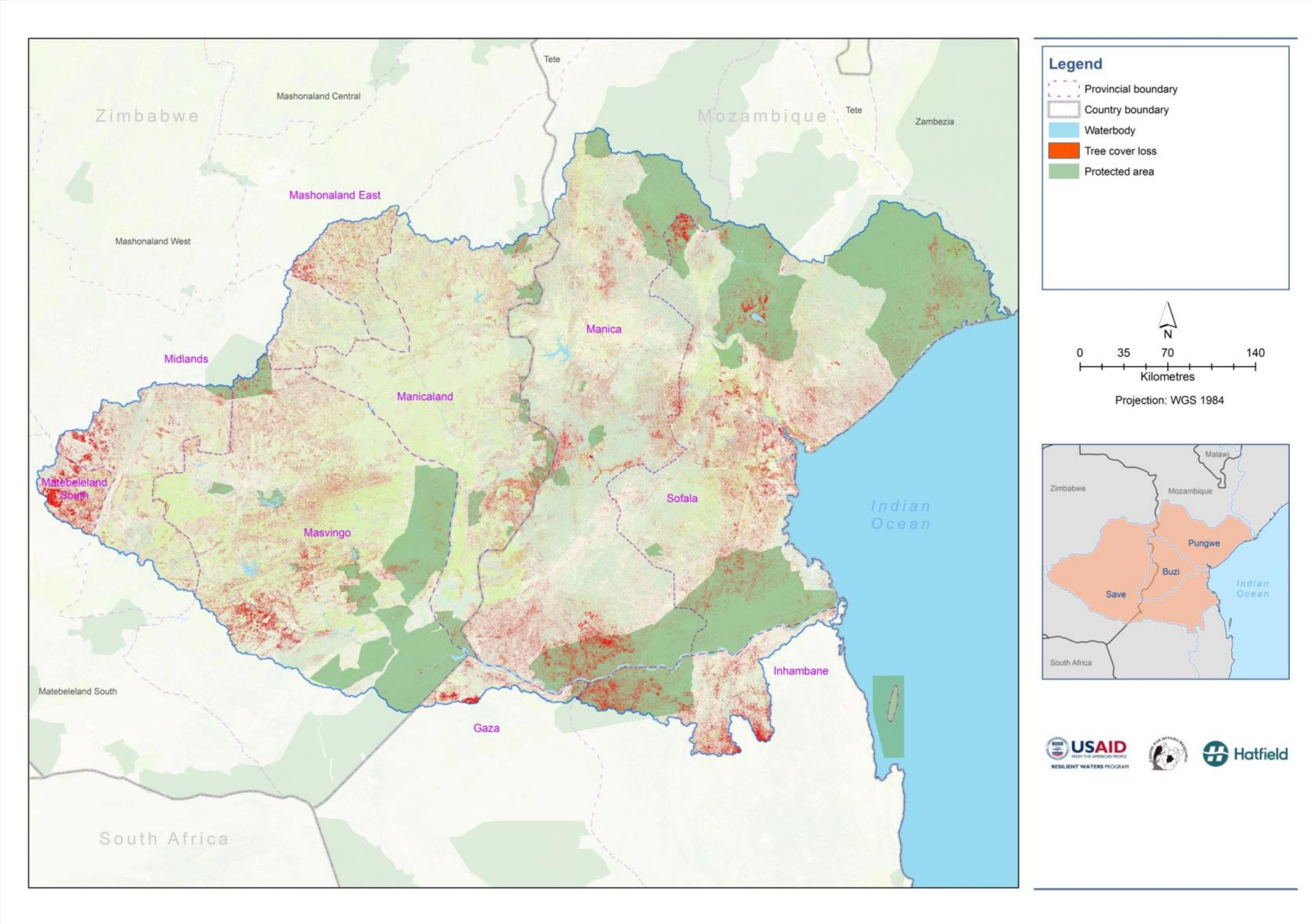
[33] The average size of the 18 schemes is 127 ha/scheme and the average scheme has 280 farmers.

Table 18: Satellite-based estimated tree cover loss (in km^2).

Country	Province	Estimated loss (km^2)
Mozambique	Gaza	236
	Inhambane	1,129
	Manica	3,103
	Sofala	3,520
Mozambique Total		**7,988**
Zimbabwe	Manicaland	1,307
	Mashonaland East	500
	Masvingo	2,550
	Midlands	975
	Matebeleland South	578
Zimbabwe Total		**5,910**
Grand total		**13,898**

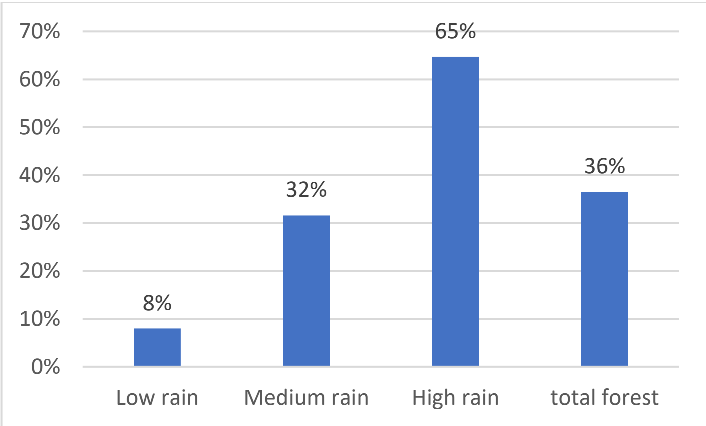
Losses were most extensive in Mozambique, with a total tree cover loss estimate of 7,988 km^2, with lower losses seen in Zimbabwe (5,910 km^2), possibly due to reduced windspeeds as the cyclone moved further inland and weakened. Hardest hit were Sofala and Manica Provinces in Mozambique, with extensive losses seen in northern Sofala, as can be see and illustrated in Figure 31.

Figure 31: Estimated tree loss across the BuPuSa basins during and immediately following Cyclone Idai.



The RINA report concludes that in Zimbabwe, the cyclone's impact on forests has been most severe in Chipinge and Chimanimani Districts. The total affected forest area is estimated at around 12,000 km^2, which is 4 % of the area of affected provinces. The exact damage has not been quantified but the RINA report assumes that the damage increases with the amount of rainfall: low rainfall (25-50 mm): 4,423 km^2 (37.7%); medium rainfall (50-100 mm): 2,412 km^2 (20.6%) and high rainfall (over 100 mm): 4,889 km^2 (41.7%). Over 40% of the forests experienced high rainfall. Chimanimani and Chipinge Districts accounted for over a third of the rainfall affected forests and for almost two third of the high rainfall affected forest (Figure 32). Clearly, these districts were hard hit together with Mutare and Mutasa Districts (GoZ *et.al.*, 2019, p.63).

Figure 32: Share of Chimanimani and &Chipinge Districts in rain affected forest by intensity (as % of total; Zimbabwe).



Source: GoZ *et.al.*, 2019.

An estimated 251 ha of commercial forest plantation was destroyed; however, the total size of the forest plantations is not known.

5.2.5.5 Fisheries sector

The fisheries sector is important in Mozambique within the BuPuSa area, consisting of fisher(wo)men in the Indian Ocean, as well as aquaculture. The sector was hard hit by the cyclone, especially in Sofala Province. In fishing settlements, over 2,100 boats were damaged of an estimated 2,774 fishermen and affecting 10,000 to 15,000 people. Lost fish production in Sofala Province was estimated at 5,210 tons; no figures are available for other provinces.

Aquaculture was also hard hit as it is practiced close to rivers and in low-sea areas. Almost 600 aquaponds with just under 900 small aquaculture farmers were affected. The production loss was estimated at 375 MT. Most of the sector's support infrastructure[34] was located in Sofala Province and badly damaged.

5.2.6 Social impacts

Cyclone Idai caused a wide range of social impacts, including disruption of community and family relationships, displacement, resettlements, losses of breadwinners and jobs and increased hardships due to livelihood losses and losses of family assets. This may have led to gender-based violence (GBV) and conflicts between and within families. People in the worst affected areas may also suffer from

[34] Such as hatcheries, buildings and tanks.

post-traumatic disorders. Generally, extreme events affect vulnerable groups disproportionally as these usually most exposed to risks and have limited adaptation options. They live in low, flood prone areas, have poor houses and/or live in informal settlements with limited access to public services.

In Mozambique, the PDNA (GoM, 2019) discussed the plight of 6 vulnerable groups: children, the elderly, people with disabilities, people living with HIV, internally displaced persons (IDP) and women. We assume below that the population affected by the cyclone has the same percentages of vulnerable groups as the entire country. Children constitute half of Mozambique's population, so around 750,000 children could be affected by Cyclone Idai; the number of orphans and vulnerable children would be around 100,000. Around half of the children are poor. Loss of family income and being orphaned by Cyclone Idai are likely to have increased child labor[35] and abuse of children, including sexual abuse. The elderly[36] tend to be food insecure and depend on family and friends to meet their basic needs. The PDNA report estimates that around 75 % of the elderly in the four provinces needed urgent assistance after the cyclone. Approximately 110 000 people with disabilities are estimated to be directly affected by Cyclone Idai. People with disabilities are at greater risk of violence, exploitation and abuse. The health of people living with HIV depends on access to health facilities, ARVs, Prevention of Mother to Child Transmission (PMTCT) programs and other medicines. Disrupted access to health facilities led to a drop in HIV consultations and possible increased infection rates, especially of newborn babies. Livelihood losses can lead to increase in sex work and associated risks of increased exposure to STIs and HIV. Around 161 000 IDP were accommodated in 164 temporary shelters in April 2019 across Sofala, Manica, Zambezia and Tete provinces. Resettlement is a government policy strategy to move people away from high-risk areas, but it poses socio-economic challenges. Lack of access to land or livelihood sources in new areas can lead to impoverishment and households also feeling a sense of loss of place returning to their old, high risk, areas. This issue will be further addressed in the mitigation report. Women tend to often possess less land, are more often illiterate and marry young. The PDNA report observes an increased risk of GBV. OCHA Situation Report 22 mentions 44 GBV cases from mid-March to mid-May 2019, while the PDNA report (2019) mentions that at least 7,000 women were at higher risk of being raped because of less safe access to water, sanitation and health facilities. In addition, the delivery risks of pregnant women increased due to limited access to safe maternity services.

In Zimbabwe, the social impacts occur mostly in Chimanimani and Chipinge Districts due to the high number of affected households. As in Mozambique, vulnerable groups were most seriously affected, including the poor, children, people with disabilities[37], displaced persons and women. Some GBV cases and rape were reported, some 710 children were orphaned, and over 50,000 people were displaced[38]. The IOM-DTM system tracks IDPs in 8 districts. Outside Chimanimani and Chipinge only 20 % of the IDPs are due to Cyclone Idai. Only 4 % of IDPs live in camps in and around Chimanimani; the rest live with host communities and families. Tensions can easily arise in host communities, which were already poor and now having to accommodate large number of IDPs; this risk is higher if the recovery process is slow and/or IDPs receive comparatively more humanitarian assistance than the local population. In Manicaland Province, Chipinge and Chimanimani Districts have by far the highest number of IDPs. The issue of camps and relocation will be further explored in the forthcoming mitigation report. IDPs, especially women and children are vulnerable to sexual and gender-based violence (SGBV). Some

[35] Already 22 % nationwide prior to Cyclone Idai.
[36] Estimated at 5% of the total population or 1.3 million; Source: Help Age International-Mozambique.
[37] Around 9 % in Manicaland and Zimbabwe at large.
[38] The affected area hosts pre-Idai asylum seekers and refugees in Tongogara Refugee Camp; most of them in transit to South Africa. The Cyclone Idai destroyed and damaged homes (over 2,000 mostly mud bricked houses), and water and sanitation systems (e.g. 600 pit latrines) in the camp increasing the vulnerability of the inhabitants to diseases.

households have lost their breadwinners; many farming households have lost their crops and some livestock, making them more vulnerable to future shocks (including droughts and epidemics).

5.2.7 Environmental Impacts

No detailed environmental impact assessment of Cyclone Idai has been conducted; however, both country assessments contain a largely qualitative environmental assessment. The BuPuSa region is relatively rich in terrestrial[39] and aquatic biodiversity. In Zimbabwe, it includes mountainous terrain stretching into Mozambique where it ends at the coast with estuaries and mangrove forests.

Protected areas accounted for around 5 % of the area affected by the cyclone. In Mozambique, the Idai affected area has 6 Protected Areas (PAs) covering 27,779 km^2. This includes Marromeu National Park (NP) with rich wildlife resources, Chimanimani Nature Reserve which is part of the Transfrontier Conservation Area (TFCA) with Zimbabwe, Magoe NP around the Cahore Bassa dam and Gorongosa NP, which has been restored after the country's civil war. PAs are important for biodiversity protection, but also for generating income and contributing to livelihoods through ecotourism, hunting and fishing. For example, Gorongosa NP is the largest employer in Sofala province other than government. The BuPuSa area has mangrove forests which provide important ecosystem services. Even though no detailed damage assessment was done, it is believed that mangroves were damaged in the Chiveve River and the Nhangau (GoM, 2019). The forest resources have been discussed earlier.

The PDNA report examines qualitatively the livelihood impacts of environmental damages (Table 19). The cyclone has caused direct and indirect environmental damage. Ecosystems such as mangrove were directly affected. In addition, electricity, sanitation and other supply problems made people to utilize more 'free' natural resources such as fuelwood, mangrove, building material etc.

Table 19: Livelihood impact of environmental damage in Mozambique

Environmental damage	Impact on Livelihoods
Flooding of crop areas	Reduced food production, with risks to food security (which was already precarious prior to Idai)
Loss of forests	Impact on availability of timber, fuel, and medicine for local communities. Reduced environmental goods and services to local communities.
Damage and disruption to Mangrove Ecosystems	Impact on immediate and long-term availability of timber, fuel, and medicine. Risk for mangrove die-back à long-term impacts. Loss of nursery grounds and breeding sites for birds, mammals, fish, crustaceans, shellfish, and reptiles à important to livelihood activities of communities. Disruption of sites for accumulation of sediment, nutrients, and contaminants, which will impact availability of fish
Coastal damages (e.g. degradation of dunes)	Increased risk of future flooding and future adverse livelihood impacts.
Loss of terrestrial habitat	Loss of important sites for birds and other species with negative impacts on communities' livelihoods and indirect ecosystem goods and services.
Uncontrolled waste management	Health risks to local populations including the spread of diseases and infections.
Asbestos exposure	Health risks posed to population from inhaling.

Source: amended from PDNA, p. 155.

[39] The area comprises seven WWF Terrestrial Ecoregions.

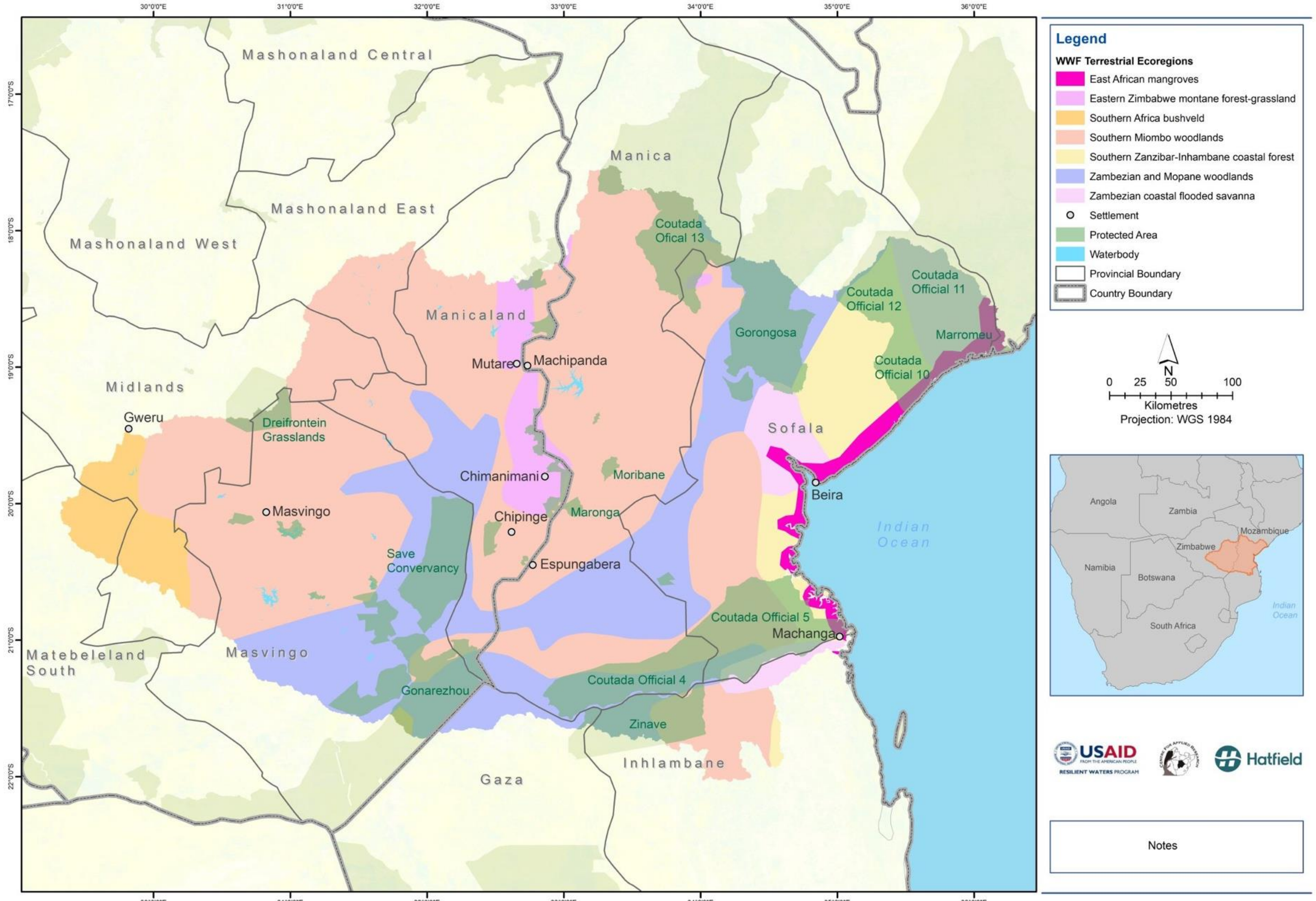
In Zimbabwe, Idai the heavy rainfall associated with the event caused landslides, soil erosion and serious land degradation. Riverbeds were destroyed by boulders coming down from the hills. Currently, some boulders are still unstable and at risk of falling and causing more landslides. Inadequate waste management and dumpsites also contributed to landslides. No remote sensing information was available on soil losses at the time of the RINA report.

The Idai affected areas included 39 Protected Areas with a total size of 4,711 km^2 (1.6% of the area of the affected provinces) The damage in the PAs has not been quantified but the RINA assumed that the damage is heavier in high rainfall parts of the PAs (over 100 mm): low rainfall (25-50 mm): 2,498 km^2 (53.0%); medium rainfall (50-100 mm): 1,167 km^2 (24.8%) and high rainfall (over 100 mm): 1,046 km^2 (22.2%). Chipinge and Chimanimani PAs were most exposed to high rainfall and therefore are expected to have more severe damage, especially the mountainous parts. Figure 33 shows the distribution of protected areas in the BuPuSa basins.

The primary seven ecosystems present in the basin – as defined by the WWF Terrestrial Ecoregions - are also shown in Figure 33. The coastal area consists of East African mangroves, Southern Zanzibar-Inhambane coastal forest mosaic and Zambesian coastal flooded savanna. Inland ecosystems shift to the Southern Miombo woodlands, Zambesian and Mopane woodlands, and Eastern Zimbabwe montane forest-grassland mosaic, with Southern Africa bushveld further inland covering the western-most portion of the basins.

Cyclone Idai destroyed all hydrological stations in the Buzi River, depriving Zimbabwe and Mozambique of vital data about the flows of this river and early warning options of future floods. This adversely impacts on the water resource management and flood predictions in the BuPuSa region.

Figure 33: WWF ecoregions present within the BuPuSa basins.



5.2.8 Livelihood impacts

Secure and adequate livelihoods are essential for community resilience. It is therefore necessary to understand livelihood strategies and explore the livelihood impacts of Idai. In the BuPuSa area, agriculture dominates rural livelihood strategies while households in urban areas have more diverse strategies based on different livelihood options (e.g. employment). Below, the strategies are described and the impacts of Idai.

In Mozambique, only a few village livelihood studies were found. Unlike in Zimbabwe, national statistics on livelihoods, poverty etc. could not be found. The Mozambique livelihood assessment below is therefore general in nature and largely qualitative.

Tomo *et.al*. (2010) and Osbahr *et.al.,* (2008) conducted livelihood studies in 4 villages in Gaza and Nhambane provinces. Their results in terms of livelihood were similar. Dryland farming was the most important livelihood source, but yields were low and post-harvest losses high. Additional sources of livelihood included selling casual labor, wood crafting, traditional beer and healing, charcoal production and selling, fishing, game and other 'wild resources. Remittances were another livelihood source; some benefited from salaries and pensions. Government support programs helped households to cope with droughts. Locally, people coped with droughts by diversification and collective land use management. In short, rural households depend primarily on agriculture but have additional sources to augment their income. Poorer households are worst affected by disasters because of their limited coping options and lack of resilience. Tomo *et.al.* (2010) recommended to pursue livelihood diversification through off-farm activities as the most sustainable option.

Due to Ida, households lost multiple livelihood sources: food, income from crops, lost income from fishing for fishing communities, lost employment opportunities, some reduced contributions from livestock. Moreover, multiple household assets have been damaged or destroyed (e.g. water points, animals, sanitary facilities, and opportunities to engage in informal business from home). As livelihood sources and assets were lost, it can be concluded that poverty and livelihood insecurity must have increased due to the cyclone. Poverty levels were high at 56% for rural areas in BuPuSa and a national average of 46% (GoM, 2019). In the affected provinces, poverty incidence was expected to increase from 64% before Idai to 79% (GoM, 2019).

In urban areas, self-employment is the main source of livelihood of 40% of the urban households (GoM, 2019, p.54). In Beira, Chimoio, Tete and the district capitals formal employment in the public and private sectors is important too. Self- employment in agriculture and the informal sector, and formal employment in the private sector have been seriously affected while public servants' salaries were maintained (GoM, 2019). The self-employed and private sector workers were thus most adversely affected, already coping with poor living conditions prior to Idai.

In rural areas, 80 % of income and food (e.g. cassava and maize) is derived from agriculture (PDNA, p.54). Losses of agricultural wage labor also reduced rural livelihoods. In addition, seeds and stored grain were lost. Livestock losses have been modest but adversely affected livelihoods too. Particularly, the loss of poultry deprived households of a ready cash and food source, while loss of small ruminants affected annual payments and loss of cattle long-term savings. Informal trade opportunities and alluvial gold mining also offer local livelihood opportunities, both of which have been affected by the cyclone. Some households lost breadwinners and therefore their livelihood was severely affected. Many rural households have become dependent on external aid and assistance. Food availability has diminished because of a combination of factors: destroyed crops, damaged local markets and shops and difficulties accessing further away markets because of damaged roads. In brief, food insecurity prevails with poor sanitation and generally poor living conditions. It is estimated that consumption of staple food decreased by over 50%. A total of 1.4 million people required emergency food assistance.

Figure 34 shows the main rural livelihood sources and strategies in the four provinces of Mozambique (circa 2014). While the map distinguishes broad livelihood zones and strategies, it clearly demonstrates the importance of agriculture in the entire BuPuSa region. Fishing and commercial crops such as sugar cane, cotton and cashew nuts and tobacco offer commercial opportunities and wage employment. Fishing is important in coastal areas and near the main rivers.

Figure 35 shows the main livelihood strategies of in Zimbabwe's part of BuPuSa. The strategies are largely agriculture and land-use based. While Figure 34 was produced for a USAID project, Figure 35 has been constructed by this project. Efforts will still be made to harmonize the livelihood strategies in the BuPuSa area.

Zimbabwe has more quantitative data on rural livelihoods and poverty than Mozambique. The Rural Livelihood Assessment (RLA) (ZIMVAC, 2020) documents rural livelihoods at the national and provincial level. The RLA found that 53% of the country's rural households[40] experienced serious livelihood constraints in 2019, i.e. they were under stress, in crisis or under emergency conditions. The situation was worst in Manicaland (Figure 36). Because of the poor livelihood conditions, households reduced their expenditures on agriculture and education in favor of food and health (ZIMVAC, 2020).

Almost two thirds of the rural households (65%) were unable to adopt any coping strategy, and therefore were very vulnerable to shocks like Idai[41]. Insecurity was further enhanced as households encountered multiple shocks in 2018-19. Even households that adopted coping strategies did that at great current and future costs as follows:

1. Stress measures: Borrowing, reducing savings and selling of assets;
2. Crisis measures: Selling of productive assets, withdrawing children from school, and cutting non-food expenditures; and
3. Emergency measures: Selling land and breeding stock as well as begging.

For example, households had to sell animals and reduced their cereal stock (by two thirds for rural Zimbabwe), leaving only 35 kg of cereal stock/ household. Therefore, most rural households depend on external support mostly from government and relatives/remittances, but also from NGOs, UN and churches.

[40]). This was better than in 2018, when 63% of the country's rural households could not cope.

[41] Only 3% of the households had experienced floods in 2018-19. Cash shortages increased cereal prices and drought were most common and experienced by over 75% of the rural households. This percentage was much higher than in earlier years, showing the livelihood stress that most households experienced.

Figure 34: Mozambique livelihood zones within the BuPuSa basins.

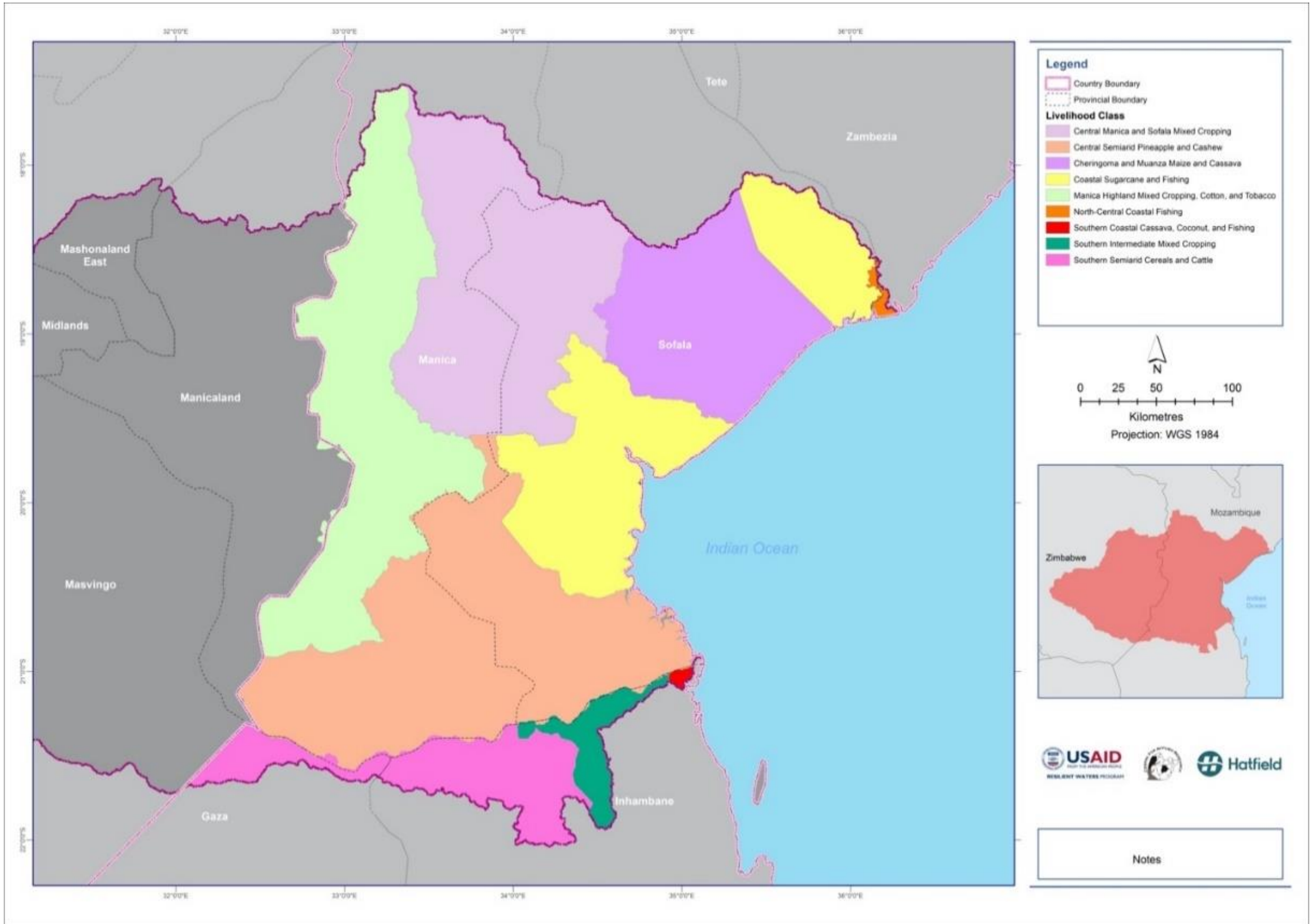


Figure 35: Zimbabwe livelihood zones within the BuPuSa basins.

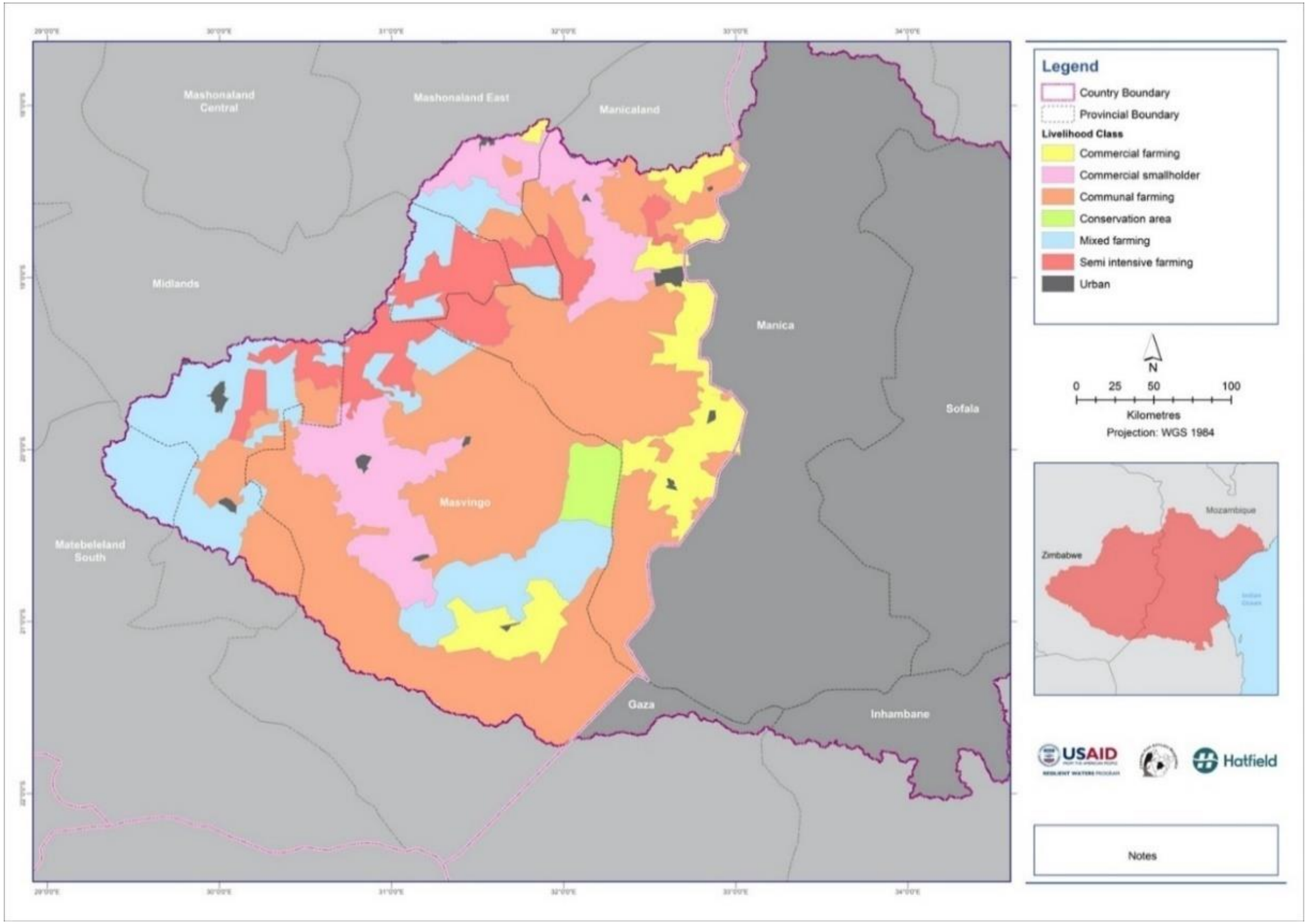
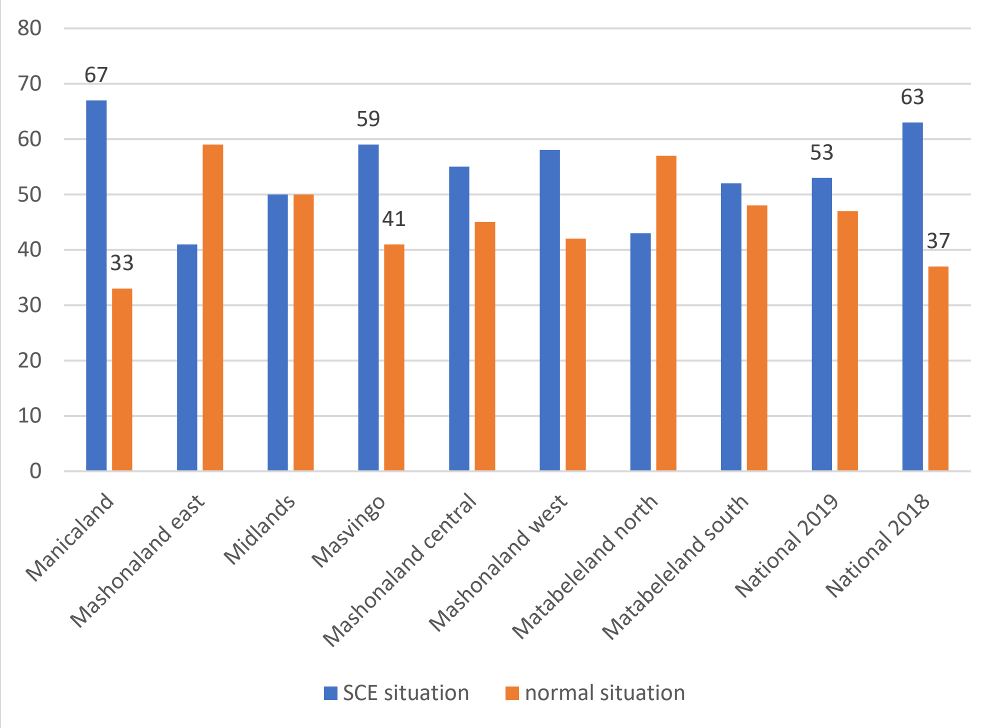


Figure 36: Rural livelihood conditions (as % of households)



Note: SCE = stress, crisis and emergency livelihood situation.

Source: ZIMVAC, 2020.

The Zimbabwe Poverty, Income and Expenditure Survey PIES (2017) shows the pre-Idai situation with respect to employment, income and expenditures. The average income in rural and urban areas is shown in Table 20[42]. The income gap between urban and rural areas is threefold. In-kind income constitutes 34 % of rural income and 17 % in urban areas. The average income in communal land is close to the rural average, while that in commercial farms and resettlement areas is higher. Interestingly, small-scale commercial farmers have a higher income than large-scale commercial farmers. The net cash income of female-headed households is 74 % of the male-headed households.

Table 20: Average annual household income in US$ (2017)

	CL	SSCF	LSCF	RA	Rural	Urban	Total
Net cash income	1,206	1,919	1,703	1,587	1,337	5,345	2,712
In kind income	715	803	557	618	685	1,114	832
Total income	1,921	2,722	2,261	2,205	2,022	6,459	3,544

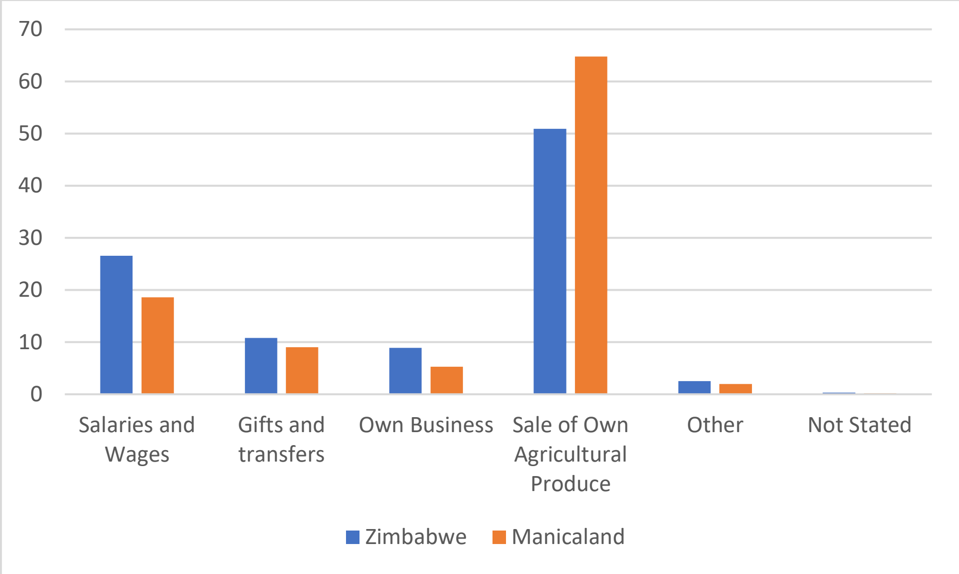
Note: CL= communal land; SSCF= small-scale commercial farming; LSCF= large scale commercial farming; RA= resettlement area.

Source: Zimstats (2019)

Consistent with the RLA. households strongly depend on the sales of agricultural produce (Figure 37). Therefore, the agricultural damage caused by the cyclone has had a profound negative impact on livelihoods, particularly in Manicaland. This in turn has had an adverse effect on expenditure items such as food expenditures and housing costs and water expenditures.

[42] These annual figures are higher than the April figures of the RLA suggest. The RLA estimates the average rural household income for April 2017 and 2018 respectively at US$74 and US$68. If April is the same as other month, the 2017 average income would be US$888/ household.

Figure 37: Household main income sources (adults 18+; as %)



Source: Zimstats (2019)

Households actually drew down on their assets prior to Idai, reflecting the hardships already existing prior to the cyclone (ZimStats, 2019).

In terms of employment, 3.9 million jobs exist and agriculture accounts for 91 % of formal rural employment. Over 80 % of the economically active rural population are farmers. This is 58 % at the national level and highest for female-headed households (67 % compared to 50 % for male-headed households. The overall unemployment rate is 7.7 %, with considerable differences between urban and rural areas. In rural areas unemployment is 1.3 % (as persons are engaged in subsistence farming) while it is 23.3 % in urban areas (ZimStats, 2018). Once more, the impacts of the cyclone must have significantly increased rural unemployment as agriculture (subsistence and commercial) was seriously affected.

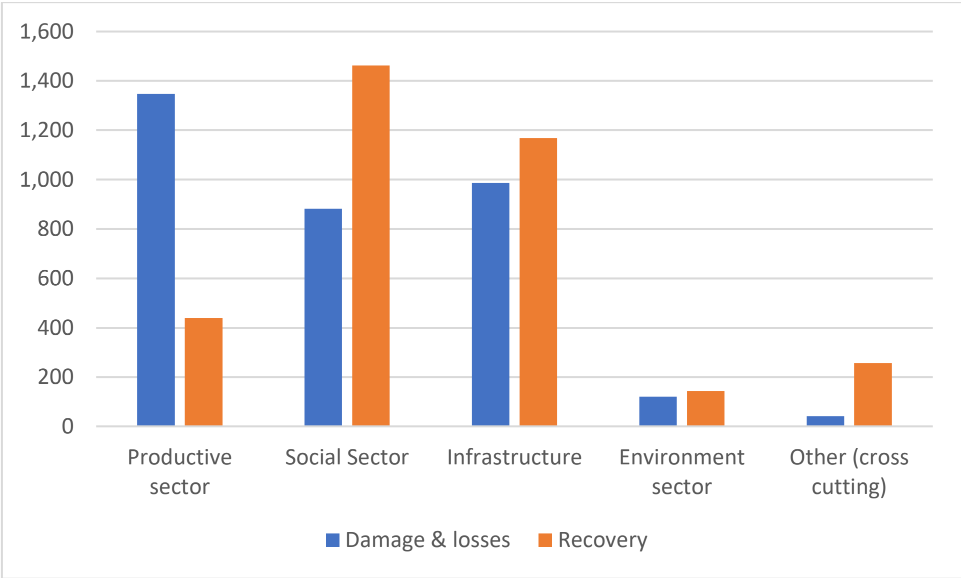
An attempt was made to estimate the impact of Idai on household income. Assuming the low range of housing damage costs and further assuming that 75 % of the agricultural production losses are incurred by households, this together would amount to a loss of US$4,592 per household. This is more than the average annual household income in 2017, and more than double the average rural household income in the same year. Clearly, the livelihood losses are huge and as we saw above the insecurity has further increased due to a decrease in household assets (cereal stock, some loss of livestock and damaged accommodation). It becomes furthermore clear that most households become dependent on external assistance and/or will not recover for years.

5.2.9 Economic costs and the distribution thereof

The estimated damages and losses due to Idai total as much as US$3.4 billion in the two countries together (GoM, 2019 and GoZ, *et.al.,* 2019). The costs for Mozambique are estimated to be US$2.8 billion or 18.9 % of GDP; the costs for Zimbabwe are US$0.6 billion or 3.6 % of GDP. The costs in Zimbabwe are 17.6 % of the total estimated damages and losses. The estimated recovery costs are similar as the damages and losses at US$3.5 billion in total (GoM, 2019; GoZ *et.al.*, 2019); for Mozambique US$3 billion and for Zimbabwe US$0.5 billion. Details of the distribution of the costs of damages and losses as well as recovery by sector are provided in Appendix 9.2.

The damage and losses are highest in the productive sectors, mostly agriculture, infrastructure and the social sector, mostly housing (Figure 38).

Figure 38: Estimated damage and losses due to Cyclone Idai (US$ million).



Sources: based on PDNA and RINA.

The severity of the impact of Cyclone Idai on households can be seen from the comparison of the per capita private damage and losses and the average per capita income for Mozambique. Per capita damage and losses are estimated to be around US$ 840[43], as compared to the average per capita income of US$ 590. Unfortunately, the RINA report does not distinguish private and public sector damage[44]. Half of the damage occurred in Chimanimani and Chipinge Districts (GoZ *et.al.*, 2019). Assuming that only the damages in the productive and social sectors are private, the per capita costs would be US$ 1,275 compared to a per capita income of US$ 860, also more than the average per capita annual income.

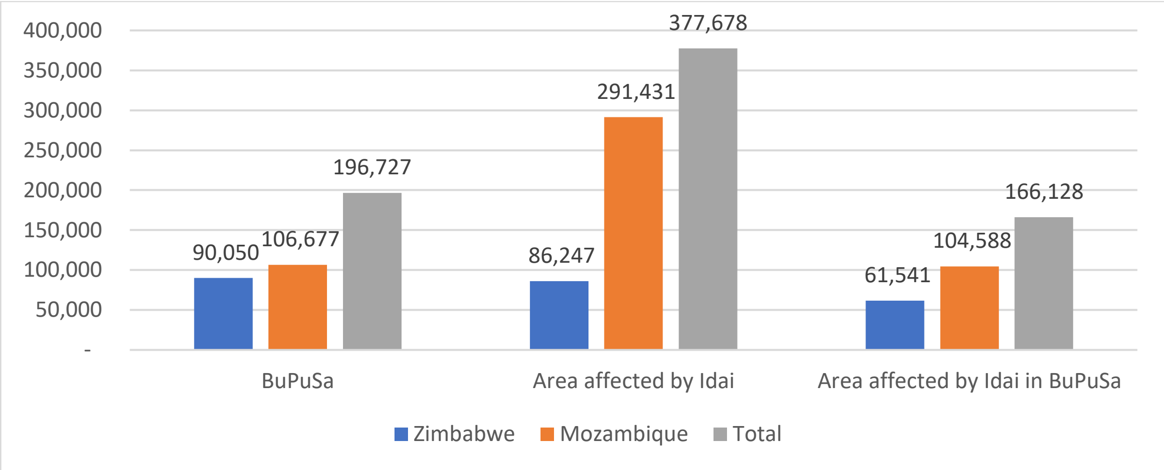
[43] This excludes the private costs and dame to the commerce and industry sector.
[44] RINA also does not differentiate between damage costs and costs of losses.

6 Integrated Impact assessment

This chapter combines and analyzes the different impacts assessed in Chapter 5, guided by assessment framework in Figure 2.

An estimated 84 % of the BuPuSa area was affected by the cyclone; 63 % of this was in Mozambique and 27 % in Zimbabwe. Almost the entire Mozambican portion of the three basins was affected compared to around two-thirds in Zimbabwe. It is important to realize that Cyclone Idai affected almost the same area outside the BuPuSa alone, of which over three quarters was in Mozambique (Figure 39). Outside the BuPuSa area, Zambezia and to a lesser extent Tete Provinces were heavily affected. Inside the BuPuSa area, the most heavily affected provinces were Sofala and Manica Provinces in Mozambique and Manicaland and Masvingo Provinces in Zimbabwe.

Figure 39: BuPuSa and Idai affected areas in Mozambique and Zimbabwe (km²).



Both countries are vulnerable to extreme events and hazards. Drought is most prevalent of natural hazards in both countries. In Zimbabwe, the risk of cyclones is low; but, in Mozambique it is high due to its long coastline, and often in the path of the tropical depressions regularly arising in the Indian Ocean. The INFORM shows that both countries score poorer on lack of coping mechanisms and vulnerability (economically and vulnerable groups) than natural hazards and exposure. In other words, their resilience and ability to favorable respond to disasters is limited. In other words, the socio-economic and governance context are significant challenges for DRR and DRM.

Both countries are low-income countries and have relatively low levels of human development. Both countries have a negative ANSI, primarily because of the inability to maintain physical capital and infrastructure. Poverty is high in both countries but is particularly high in rural Zimbabwe (around 75 % as compared to 46 % in Mozambique). Both countries have serious budgetary constraints, i.e. government deficits and foreign debts are high, and countries depend on external financial assistance. Food insecurity was high prior to Cyclone Idai, among others due to drought. Both countries share political and governance challenges. In Mozambique, elections were held in October 2019, half a year after the cyclone, with tension between the main political parties. In addition, conflicts have arisen in the oil and gas rich province of Cabo-Delgado, which was also hit by Cyclone Kenneth in April 2019. In Zimbabwe, government is struggling to stimulate economic growth, stabilize its currency and increase foreign reserves to meet import requirements.

To their credit, both countries have well-established disaster management structures in place, but the associated funds are inadequate and limited capacity inhibits full implementation. Climate change is expected to have profound negative impacts in both countries. Natural hazards, particularly droughts and in Mozambique cyclones are expected to increase in numbers and intensity. For this reason, the full integration of disaster risk management and climate change adaptation institutional structures appears sensible (OECD, 2020). This will be further elaborated in the forthcoming mitigation report.

No comprehensive socio-economic baseline data (i.e. prior to Cyclone Idai) existed, particularly at the local or district level; where possible the documented impacts have been put in a broader context, mostly using statistics. The combination of the geospatial and socioeconomic assessments also assisted the integrated analysis.

Cyclone Idai affected many people and households: around 1.8 million people in Mozambique (1.5 million) and Zimbabwe (0.3 million) and some 350,000 households. While figures differ, at least 140,000 persons have been displaced by the cyclone, 3 to 4,000 were injured and around 1,000 lost their lives. Assuming an even population distribution, 44 % of these figures apply to the BuPuSa area. Clearly, the scale of the disaster would pose enormous challenges for any country but in this case exceeded the capacity of vulnerable countries like Mozambique and Zimbabwe. This is confirmed by the estimated costs and recovery needs that are a high percentage of GDP (19 % and 4 % of GDP in Mozambique and Zimbabwe resp.)

The largest and most widespread impacts have occurred in Mozambique, Sofala and Manica Provinces and in Zambezia (outside BuPuSa), but the intensity of the impacts in Zimbabwe has been high in Chimanimani and Chipinge Districts.

The specific impacts have been largest on buildings, in particular houses, infrastructure (incl. WASH) and agriculture (dryland farming and irrigation). No detailed socio-economic breakdowns of the agricultural impacts are available (e.g. impacts on small farmers *vis-à-vis* large commercial farmers). The impacts on the livestock sector has been limited. Social and environmental impacts have also occurred but have not been quantified. In Zimbabwe, the extent and intensity of the impact on forests and Protected Areas has been correlated to the amount and distribution of rainfall. The project is extending this 'rainfall intensity-damage' approach to the impacts on dryland farming, irrigation and livelihoods, but the results are not yet available.

Based on the PDNA and RINA assessments, 250,000 to 260,000 houses were damaged. This 'hit' more than 70 % of the affected households. In Zimbabwe, the damage was concentrated in Chimanimani and Chipinge Districts. The geospatial assessment shows that the damage was concentrated in three areas with landslides. The intensity of damage was high: houses were mostly destroyed. In Mozambique, most damage occurred in Beira and was caused by strong winds and flooding. The impacts were more widespread than in Zimbabwe, but the intensity of the damage was less; two areas were mostly affected in Beira: an area close to the ocean and an area just north of Beira along the railway line. The second area also experienced widespread flooding. The geospatial assessment shows that areas with more trees incurred less damage (trees as windbreaks?); the socio-economic assessment found that parts of Beira with a rehabilitated water drainage system was less affected.

Particularly in Mozambique, large areas were flooded both in settlements and farmland. The geospatial assessment shows that in Sofala Province the area under water one month after the cyclone struck was still 46% larger than before Idai (810 km^2 as compared to 554 km^2 before Idai). Obviously, flooding caused significant damage to residential houses, other buildings, farmland and infrastructure.

The flooded dry farmland is estimated to be around 1-1.5 million ha. In Mozambique 44 % of the flooded area of around 750,000 ha could be in BuPuSa; Sofala and Zambezia were most affected. In total 433,000 households suffered from flooded farmland (around 200,000 in BuPuSa?) with an average flooded area of 1.6 ha/household. This suggests that virtually all BuPuSa households in Mozambique had their farmland flooded. Floods occurred much less in Zimbabwe so the incidence must have been lower there. The geospatial assessment (section 5.1) shows that around 3.7 million ha of dryland farming was exposed to Cyclone Idai. Most exposed land was in Zimbabwe (2.3 million ha) compared to 1.4 million ha in Mozambique. As Zimbabwe had minor and localized floods, the exposed drylands were probably mostly exposed to strong winds. The estimate for Mozambique from the geospatial assessment is in the same order as figures mentioned in the PDNA report. In Zimbabwe, production losses were estimated at 580,000 MT, mostly subsistence crops but also cash crops for exports. In Mozambique, the production losses are estimated at 2.2 million MT. These losses strongly affected rural livelihoods and increased pre-Idai food insecurity even more.

The irrigation sector has also been adversely affected in both countries. In Mozambique, the PDNA estimates that 4,300 ha was damaged or destroyed (of which 2,300 in BuPuSa area). This affected mostly small-scale farmers (around 3,300 in BuPuSa with an average farm size of 0.6 ha). The RINA does not provide figures for the overall affected irrigated area in Zimbabwe. It only has details for 18 irrigation schemes in Chimanimani and Chipinge. These schemes cover 2,300 ha and have 5,000 farmers. Upscaling these results to the alleged 1,500 affected irrigation schemes (also in RINA) suggests that as much as 200,000 ha may have been damaged or destroyed. The geospatial assessment found that a total of 155,000 ha of irrigated land was exposed to the cyclone: 89,000 ha in Zimbabwe and 66,000 ha in Mozambique. No figures exist for the estimated production damage to the irrigation sector. Further work will be done to expand the RINA approach of linking rainfall intensity with expected levels of damage in forest and protected areas to agriculture (both dryland farming and irrigation). To do this, the team needs to source additional precipitation data to align the analysis with that of the RINA.

The cyclone damaged or destroyed water sources and water reticulation systems as well as sanitary facilities of households, schools and health facilities. Boreholes, wells and springs are the dominant rural water sources, and most were affected and/or contaminated. In urban areas, water reticulation systems are most important, and many were also temporarily affected. Idai affected access to safe potable water of most people.

The same applied to sanitary facilities. One third of the rural population in Zimbabwe does not have access to sanitary facilities. Pit latrines are common in rural areas; flush toilets in urban areas. While access to sanitary facilities was already low before the cyclone, it worsened afterwards. This led to an increase in open defecation in the bush and associated health hazards.

Most public facilities and infrastructure were affected by the cyclone. This includes educational and health facilities, roads, harbor and airport (Beira), pipeline from Beira to Zimbabwe, and electricity distribution systems. Generally, the number of damaged facilities was highest in Mozambique due to the larger area that was affected. Damaged facilities and infrastructure have had major impacts on households and the private sector:

1. Interruption of education affecting a large number of students;
2. Interruption of and reduced access to health facilities. This adversely affected people with illnesses in need of consultations and treatment (e.g. HIV/AIDS), pregnant women, family planning etc.; and
3. Increased distances to the nearest public facility exposed women and children to risks of harassment and rape.

The cyclone has caused a wide range of social impacts in both countries. The magnitude is bigger in Mozambique because of the larger number of affected people but the nature of the impacts is similar:

a. Disruption of community and family relationships;

b. Displacement, temporary relocations into shelters and camps;

c. Resettlement from destroyed or high-risk areas to lower risk areas;

d. Losses of breadwinners;

e. Losses of jobs, particularly in the informal sector, the private sector and in agriculture. Public sector employment was maintained;

f. Increased hardships due to income losses and losses of family assets. This may have led to Gender-based violence and conflicts between and within families; and

g. People may also suffer from post-traumatic disorders in the most severely affected areas.

Generally, extreme events affect vulnerable groups disproportionally as these groups are most exposed to risks and have limited adaptation options. They live in low, flood-prone areas, have poor houses and/or live in informal settlements with limited access to public services. The same vulnerable groups have been identified in both countries (PDNA and RINA): children, the elderly, people with disabilities, people living with HIV, internally displaced persons, and women. Their numbers are significant, but not all receive adequate attention in relief and rebuilding efforts.

The BuPuSa area has 7 terrestrial WWF ecoregions ranging from coastal zones, semi-arid drylands to upstream mountainous regions) as well as aquatic ecosystems, estuaries, riverine ecosystems, to dryland and ultimately mountainous ecosystems. The ecosystems cover a wide range of natural resources, including aquatic species, low-land and high-land flora and fauna, including wildlife species such as buffalo in Marromeu NP in Mozambique. The Protected areas include a RAMSAR site (Marromeu NP) and the TransFrontier Conservation Area (TFCA) Chimanimani Nature Reserve. The Gorongosa NP in Mozambique (Sofala Province) protects biodiversity and generates income and employment through tourism. Finally, the area has extended forests, which offer a range of services and products to local communities and the country at large. The environment is important for local livelihoods and for commercial operations (timber and tourism in PAs) as well as for the national economies. Idai has had multiple environmental impacts, including landslides and associated land degradation-destruction, destruction of water points and water contamination, destruction of coastal ecosystems and defense line, possible soil pollution associated with flooding, forest destruction and degradation, damage protected ecosystems in Protected Areas, damaged mangroves. Furthermore, increased poverty and reduced access to services and facilities is likely to have increased pressure on ‘free’ natural resources in forests, rangelands and possibly Protected Areas. In addition, it may have led to littering, uncontrolled waste disposal and pollution. In Mozambique, the risks of asbestos exposure from damaged houses can be cited as an example. The Idai affected area has 45 PAs with a total area of 32.5 km^2, most of which is in Mozambique 27.8 km^2 (7 % of the Idai affected provinces is Protected Area). Idai has had significant negative livelihood impacts in Mozambique, but these are described in qualitative terms only (PDNA report). The RINA report for Zimbabwe focuses on damage to Protected Areas and forests. The intensity of damage is assumed to be positively related to the amount of rainfall during Idai. This seems justified as three quarters of the PAs with high rainfall is found in Chimanimani and Chipinge Districts. Around 4,900 km^2 of forests and 1,050 km^2 of Protected Areas could be seriously damaged (with high rainfall of over 100 mm); around 2,400 km^2 of forests and 1,150 km^2 of PA could be moderately damaged while 4,400 km^2 of forests and 2,500 km^2 of PA would not be damaged or have light damage. The possibility to extend this 'rainfall intensity-damage' approach to agricultural land, livelihoods and population will be further investigated.

In terms of the ecosystem services, Idai is likely to have seriously affected all services:

1. Production function: crops, animals, fish, and water; the increase in dead trees and wood may offer a temporary benefit to local communities;
2. Support services: soil and nutrient formation and damage to the fish breeding/ nursery role of mangroves;
3. Regulatory services: pollution and disease control; and
4. Cultural services: loss of tourism, cultural and religious services of damaged ecosystems.

No attempts have been made to quantify the loss of such services (other than the one earlier discussed in this report).

The above impacts had profound negative impacts on people's livelihoods. However, no study quantified the livelihood impacts of Cyclone Idai. We therefore had to infer the livelihood impacts based on the existing livelihood strategies and the impacts of Idai on livelihood sources and assets. The starting point is that poverty levels were high and livelihood security poor. Households use different livelihood sources for a living. In rural areas of Mozambique and Zimbabwe, agriculture is the main livelihood sources: agriculture produce is consumed in the household and/or sold to meet cash needs. The crop losses have been huge; livestock losses were modest. On the livestock side, chicken is an interesting example. A total of 125,000 chicken died in Mozambique and over 13,000 in Zimbabwe, depriving many households of an immediate livelihood source. Other sources of livelihood are formal and informal employment, gathering of free natural resources, petty or informal trade and illegal gold mining. Given the level of poverty and livelihood constraints, reliance on external support is particularly important in Zimbabwe. This is mostly from government and relatives. In Zimbabwe, around two thirds of the rural households cannot adopt a coping strategy to hazards like Idai. The remaining one third adopt different coping measures, which affect their livelihood security and sustainability:

a. Stress measures: Borrowing, reducing savings and selling of assets;

b. Crisis measures: Selling of productive assets, withdrawing children from school and cutting non-food expenditures; and

c. Emergency measures: Selling land and breeding stock as well as begging.

These measures erode the asset base of households (e.g. savings, land, animals, lower education and poorer health) and limit future livelihood opportunities. Idai thus enhances the poverty trap and justifies the prediction that the incidence of poverty could increase by a staggering 15 % in Mozambique. Not much detail about rural livelihoods in Mozambique were found, but the general situation is thought to be similar.

Urban areas have better job opportunities and therefore self-employment is often the main source of livelihood (40 % of the urban households). In Beira, Chimoio, Tete and other towns formal employment in the public and private sectors is important too. Self- employment in agriculture and the informal sector, and formal employment in the private sector have been seriously affected while public servants' salaries were maintained. The self-employed and private sector workers were thus most adversely affected,

The severity of the impact of Idai on household livelihoods can be seen from the comparison of the private damage and losses due to Idai and the average annual income:

1. Mozambique: per capita damage and losses are estimated to be around US$840[45], compared to the per capita average income of US$ 600, i.e. the damage and losses exceed the p.c. annual income; and
2. Zimbabwe: the Idai losses are estimated[46] at US$4,592 per household. This exceeds the average household income in 2017, and more than double the average rural household income in the same year.

In brief, households lost more than the average annual income and in addition, they lost valuable assets.

To some extent, both countries were in the same position as most households. Countries were vulnerable prior to Ida, and the impacts of Idai were so big that they exceeded the financial capabilities of the governments. Although both countries have disaster management funds, these were inadequate to meet the immediate requirements. Following Idai, Mozambique and Zimbabwe almost doubled their appeal for humanitarian aid from US$520 to US$ 995 million; less than half of the revised appeal was funded (US$424 million; Zurich Flood Resilience Alliance (2020). Moreover, even though DRR structures were in place, the scale of the disaster simply exceeded the capacity of the DRR institutions. Idai has suppressed short term economic growth. In Mozambique, economic growth forecasts were reduced from 4.7 % to 2.5 % per year. In Zimbabwe, economic contraction was expected to increase from -2.1 % to -3.6 (RINA, p.15). The estimated damages and losses amount to 24 % of Mozambique's GDP and the recovery need for 21 %. Relief and recovery thus amount to 45% of GDP. The corresponding figures for Zimbabwe are 4 % each. Clearly, the economic burden of Idai weighs much heavier on Mozambique than on Zimbabwe.

It is important to understand factors that may have aggravated and ameliorated the impacts of the cyclone. The currently identified factors are tabulated below together with the expected consequences for observed impacts.

Impact ameliorating factors.

	Ameliorating factor	Consequence for impact
	No springtide during Idai landfall	Flooding would have been far worse in Beira, Sofala and Zambezia
	Presence of trees in residential areas	Trees seem to have worked as a wind breaker and reduced damage to houses and building in Beira
	Partial rehabilitation of Beira's drainage system	Flooding was limited in the parts of Beira with a rehabilitated drainage system
	Both countries have existing DRR structures and procedures. Mozambique is sometimes hailed as a model country, has village DRR committees with evacuation plans and designated shelters	useful for immediate relief and limiting casualties and injuries
	Both countries have early warning systems.	EWS down to the community level is essential but not enough. There is evidence that households do not necessarily use EWS information.

[45] This excludes the private costs and dame to the commerce and industry sector.
[46] This uses the low range of housing damage costs and assumes that 75% of the agricultural production losses are incurred by households.

Impact aggravating factors

	Aggravating factors	Consequence for impact
	Pre- existing food insecurity due to droughts in both countries	This increased the household vulnerability and made many dependent on food aid
	pre-Idai refugees and asylum seekers (Zimbabwe)	Put extra pressure on humanitarian relief, including shelters and camps
	Poor development and maintenance of public infrastructure	Poorly maintained coastal defense structure worsened the cyclone's impacts in Beira. Increased damage to public facilities and infrastructure Too much pressure on local services
	High incidence of poverty, especially in Zimbabwe	Increased the size of vulnerable groups and limited their coping options
	Rural livelihood dependency on agriculture and lack of diversification	Increase livelihood vulnerability to droughts and cyclones
	People living in high risk areas, low areas and informal settlements	This worsened the impacts of on people and households. This factor is linked to poverty and vulnerable groups.
	Budgetary constraints of governments	Underfunding of DRM Funds and dependency on foreign assistance May have slowed down the immediate relief response
	High incidence of HIV-AIDS	High opportunity costs for government and households Increases vulnerability to hazards
	Limited implementation capacity of DRR structures implementation in national and community-based development organisations	Slows down and limits relief & recovery efforts
	Poor macro-economic conditions (Zimbabwe)	"The poor performance of the economy and devastating effects of Cyclone Idai negatively affected the livelihoods of both rural and urban households". (RLA, 2020, p.15)
	International sanctions (Zimbabwe) and no access to IMF loans (Mozambique)	Increased macro-economic problems and limiting growth opportunities as well as Idai recovery.
	Reactive DRR orientation (Zimbabwe)	This aggravates the impacts rather preventing them from happening.
	Climate change	The frequency and intensity of cyclones is expected to increase in Mozambique Mozambique and Zimbabwe are expected to experience more frequent and severe droughts (already the most important natural hazard)

7 Concluding remarks

This report discusses the impacts of Cyclone Idai in Mozmabique and Zimbabwe, in particular in the transboundary Buzi, Pungwe and Save River basins (BuPuSa). The basins have different characteristics in terms of the level of water abstraction (e.g. the Save is heavily used and the Pungwe is underutilized) and exposure to flooding (e.g. the Buzi and the Pungwe are flood prone). Both countries have agreements (Buzi and Pungwe) and/or strategies (Save) for individual basins but are currently developing a combined tri-basin agreement to manage the basins as one entity.

Cyclones are common to Mozambique, but not to Zimbabwe. Drought is the most common disaster in both countries. Globally both countries score relatively low on their ability to manage risks of disasters. In both countries, vulnerability and inadequate coping capacity are considered more important contributors to the overall risk than hazards and exposure (natural and human). Governments' financial, capacity and governance constraints make it difficult to rapidly adequate relief and recovery activities; despite the fact that both countries have clear disaster risk management structures and procedures in place.

Using geospatial assessment (section 5.1) and socioeconomic assessment (5.2), the report discusses the type and severity of the cyclone's impacts on households and communities, the private sector and public infrastructure and sector. In addition, environmental impacts are assessed (section 5.2), supported by quantitative land cover changes and analysis of landslide and tree cover losses (section 5.1). Generally, the impacts have been particularly serious on houses, agriculture (other than livestock) and infrastructure, including WASH. The impacts are largest and most widespread in Mozambique (Sofala Province) but more localized and intense in Zimbabwe, where Chimanimani and Chipinge Districts were hardest hit.

The scale and costs of the impacts are enormous in comparison to the size of the countries' economies (5.2.9 and Section 6) and people's livelihoods. In rural areas, agriculture is the main livelihood source, and consequently livelihoods have been hard hit by lost production, damages to agricultural land, storage facilities, etc. Moreover, agriculture was the most important source of rural employment, which was also greatly reduced. Only employment in the public sector was unaffected. The informal sector in rural and urban areas was affected (e.g. backyard businesses in Beira). Livelihoods were already insecure prior to Cyclone. Not surprisingly, livelihood became even more insecure and poverty increased significantly, making many households dependent on external support and food aid.

The integrated analysis (Section 6) brought the findings of the geospatial and socioeconomic assessments together. It demonstrated the high vulnerability prior and after Idai of the countries and communities involved. Community resilience depends on secure and adequate livelihoods and on intra community relationships (e.g. between households based on community institutions and processes). As we saw, livelihoods were greatly affected, and it will be a major future challenge to develop better and more sustainable livelihoods in future (e.g. through livelihood diversification). This applies particularly to vulnerable groups that lived in the most exposed areas and have few, if any, options to adapt. Less information is available about community relationships, but the picture that emerges is mixed. Households have lost breadwinners and the number of orphans has increased. A number of people were injured, possibly permanently, and other had reduced access to health facilities. Many households were displaced and found temporary shelter elsewhere. Where households lived in high-risk areas, the intention is to relocate them permanently to lower risk areas. This is another major future challenge. A range of social problems have been reported such as increased GBV, rape and child abuse. On the other hand, households and communities showed a degree of resilience and support to each other. Most displaced persons were accommodated by other households. Furthermore, households assisted each other to cope and repair some of the damages. The village DRM committees in Mozambique implemented evacuation plans and had shelters available for evacuees.

The assessment identified factors that made the impact worse and other that ameliorated the impact of Cyclone Idai. These are listed in chapter 6 and are not repeated here. In terms of mitigation measures, the factors that made the impacts worse need to be resolved and the ameliorating factors need to be strengthened and expanded, among other based on lessons from other cyclones.

It has been worthwhile to have both the geospatial and socioeconomic assessments as they provided complementary findings, and each added to the integrated analysis (Chapter 6). For example, the rainfall-damage correlation approach applied in Zimbabwe to forests and Protected Areas is expanded to affected agriculture, population and livelihoods. The irrigation sector will be further analyzed to better understand the extent and nature of the damage. The geospatial assessment suggests much more exposure of irrigated areas than the irrigation damage from the socio-economic assessment (based on PDNA and RINA data). The geospatial assessment enriched the socioeconomic assessment with more local or sub district findings (e.g. Chimanimani and Beira). Finally, the combination of both assessments provided a strong and new focus on the BuPuSa River basins, while recognizing that the impacts of Idai went well beyond the three basins. In contrast, the PDNA and RINA assessments were national in nature. Limitations of each assessment were also evident. Ideally, some of the findings of the geospatial assessment should be 'firmed up' with ground truthing (beyond the ToR of the project). In future PDNAs, there is need for more detailed work on the impact on the private sector, a more detailed assessment of the agricultural sector and of local communities and livelihoods. Ideally, the impacts should be assessed against a proper baseline situation.

Looking ahead, the following activities are planned for the project:

1. Country consultations in June through a survey, video meetings and interviews (June);
2. Further work on a few outstanding 'impact' issues raised above (June-July);
3. Rapid review of other cyclones (May-June);
4. Mitigation and lessons learned analysis and report (due end of July)
5. Project workshops to present and discuss the project results and discuss follow-up activities; and
6. Final reporting (end of November).

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9 Appendices

9.1 Project information

The project involves the following activities:

1. Geospatial assessment of the extent of the impacts of Cyclone Idai in Mozambique and Zimbabwe in terms of areas and the nature of the damage in the affected communities and population;
2. Desk top assessment of the impacts of Cyclone Idai and the level of support offered to the affected population and communities and where possible site visits;
3. Desk top study of the impacts of and adaptations to other cyclones (e.g. Eline and Dineo) on local communities;
4. Identify opportunities to improve community resilience, including the identification and comparison of the national and international adaptive support environment of Mozambique and Zimbabwe;
5. Prepare follow-up community-focused activities/plans to enhance local community preparedness in the face of extreme weather events;
6. Facilitate a regional workshop about the impacts, mitigation measures and possible follow-ups;
7. Make recommendations for the Permanent Okavango River Basin Commission (OKACOM) and the Limpopo Watercourse Commission (LIMCOM) to incorporate the study's findings into disaster planning documents, specifically LIMCOM's River Basin Disaster Risk Management Strategy.

The project started in December 2019 and will end in November 2020. The Inception report was prepared in December 2019 and approved early January 2020. A progress report was produced at the end of March 2020.

9.2 Geospatial assessment details

Below further methodological details are provided (9.1.1) and additional maps are shown (9.1.2).

9.2.1 Methodology

Once pre-processing steps were complete, the satellite imagery layers were ready for processing and analysis, analytics, and integration with the socio-economic assessment.

- Image classification;
- Damage assessment;
- Topographic mapping;
- Flooded area and landslide analysis; and
- Additional building and infrastructure data capture.
-

Image classification
A key initial processing step in preparation for the analysis stages of the assessment is image classification. Satellite and aerial image classification utilise the digital and multi-spectral nature of the imagery, in combination with established algorithms, and domain expertise and landscape knowledge

to group image pixels into predefined and/or statistical groups – or classes. The classification approach utilised depends on the application (what a project or activity is trying to extract from the imagery or focus upon), imagery type (spectral and spatial resolution), and the experience and knowledge of the specialist/expert operator.

Classification was conducted for the high-resolution (50 cm) imagery for the two study areas, and medium-resolution (10-metre) imagery for the entire basin as described below. The medium-resolution imagery mosaic is included below - Figure 40.

High-resolution classification

High-resolution image classification was conducted using e-Cognition object-oriented classification, which accommodates the significant increase in spatial and spectral detail in high-resolution imagery. Object-oriented classification combines the spectral data in the imagery, with the physical shapes of land cover class clusters in the imagery, potentially providing a highly accurate representation of a landscape. This approach is often needed for high-resolution imagery as the information content of a high-resolution is often too 'dense' for traditional methods.

Image classification was used to create the land cover classes used in the backdrop of the topographic maps (Section 9.1.2), and to extract landslide areas (bare soil) at large scale. High-resolution image classification results for Beira and Chimanimani are shown in Figure 41 and Figure 42

Medium-resolution classification

The landcover classification was conducted in Google Earth Engine (GEE), using two sentinel mosaics of imagery collected before the 20th of February 2019 and imagery collected after the 20th of March 2019. Image analysis was restricted to parts of each province that falls within the BuPuSa basin as shown in Figure 17. Using supervised classification, five classes were defined: Dense vegetation, Sparse vegetation, Agriculture, Grassland/Pasture and Water. This resulted in before and after landcover maps for the portions of Manica, Sofala, Gaza and Inhambane in Mozambique; and shown in Manicaland, Masvingo. Midlands, Mashonaland East and Matebeleland in Zimbabwe, shown in Table 21.

Table 21: Portion of provinces inside BuPuSa study area[47].

Country	Province	Total Area (ha)	Area in study (ha)	%	Area of province affected by Idai	Area of province affected by Idai in study area
Mozambique	Gaza	7,551,163	192,281	3	219,765	150,675
	Inhambane	6,887,945	765,498	11	1,183,201	598,213
	Manica	6,280,823	4,594,768	73	6,280,823	4,594,768
	Sofala	6,761,923	5,115,153	76	6,761,865	5,115,113
	Tete	10,092,234	-	-	4,385,972	-
	Zambezia	10,320,618	-	-	10311493	-
Zimbabwe	Manicaland	3,575,425	2,760,897	77	3,575,425	2,760,897
	Mashonaland East	2,818,859	477,865	17	1,703,271	467,540
	Mashonaland Central	2,766,633	-		262,235	-
	Masvingo	5,535,209	4,114,936	74	2,594,654	2,590,976
	Matebeleland South	5,440,018	226,975	4	-	-

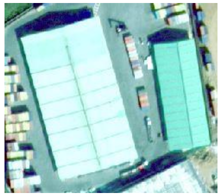
[47] While the study area was established during Inception, it was later observed that the provinces of Tete and Zambezia in Mozambique and Mashonaland Central – areas also impacted by the cyclone - were not covered by the BuPuSa basins area being used for analysis.

Country	Province	Total Area (ha)	Area in study (ha)	%	Area of province affected by Idai	Area of province affected by Idai in study area
	Midlands	5,617,081	1,424,328	25	489,084	334,662

The detailed results of the landcover process discussed in the body of the document are presented in Section 9.1.2 Additional detailed results.

Damage assessment

The damage assessment is described fully in the main document – Section 5.1.2.

		Imagery Examples -Beira		Imagery Examples- Chimanimani	
Category	**Description**	**Before**	**After**	**Before**	**After**
No damage/ limited damage	▪ Building intact ▪ The walls remain standing ▪ The roof is virtually undamaged.				
Moderate damage	▪ Roof remains largely intact but partial damage is present				
Severe Damage	▪ Removed/ Total collapse of the roof ▪ Damage to walls ▪ Building structure not distinguishable				
Removed	▪ Building destroyed ▪ Complete collapse of entire structure ▪ No evidence of building				

Topographic maps

Topographic data was collected from a number of sources – HDX platform, on-screen digitising and image classification - for the focused study areas, and the BuPuSa basins area of interest. These data were then used to compiled topographic maps for all three areas – two focused and one basin-wide. These maps were created anew, showing the situation on the ground immediately prior to the cyclone events. Using existing topographic maps, which would likely be years to decades out of date would not have provided an accurate base for situational analysis, visualisation and/or interpretation.

The topographic maps for Beira and Chimanimani focused study areas are shown in Section 9.1.2 (Figure 43 and Figure 44 below, and the basin-wide topographic map is shown in Figure 45).

Flooded area analysis and landslide presence

The process for flooded area analysis process is covered within the main document – Section 5.1.2.

Additional data capture

Additional data captured from the imagery sources comprised ancillary data to assist with medium-resolution processing and imagery analysis, and additional topographic and damage assessment data for the focused study areas for use in the topographic maps and damage density maps.

- Ancillary data - the medium-resolution Sentinel-2A imagery was used to extract a series of base data sets: road centrelines, hydrographic network and open water, cultivated areas, settlements, mangroves and wetlands, mines, plantations, and rock outcrops. These data were used within the processing and classification routines for the medium-resolution imagery over the BuPuSa basin study area;
- Topographic data - a series of base datasets were extracted from high- and medium-resolution imagery using on-screen digitising: roads, cut-lines and fire-breaks, watercourses and waterbodies, building footprints (for large commercial and public buildings) and built-up areas. These data were used to create smaller scale topographic maps for the entire BuPuSa basin study area, and large-scale topographic maps for Chimanimani and Beira; and
- Building and infrastructure data - in addition to the topographic data captured from the before high-resolution imagery, the project team created a building location dataset, placing a point feature on top of each building in both focused study areas in the before images. Roads, bridges and other infrastructure were also captured using linear and polygon features.

9.2.2 Additional maps

Following are detailed results and map outputs from the main document and the above sections.

Figure 40: Sentinel 2 image mosaic (before Cyclone Idai).

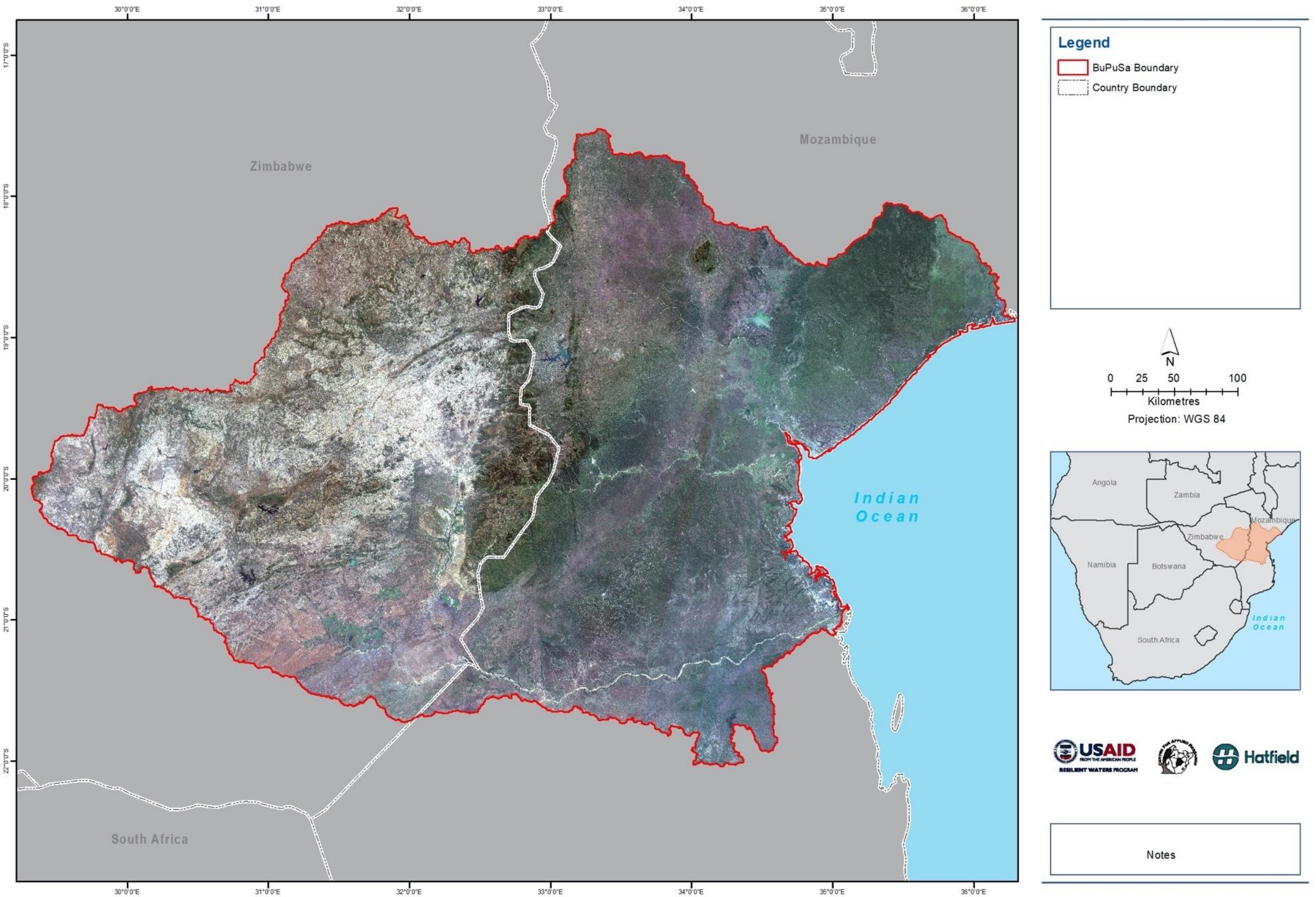


Figure 41: Beira high-resolution image classification.

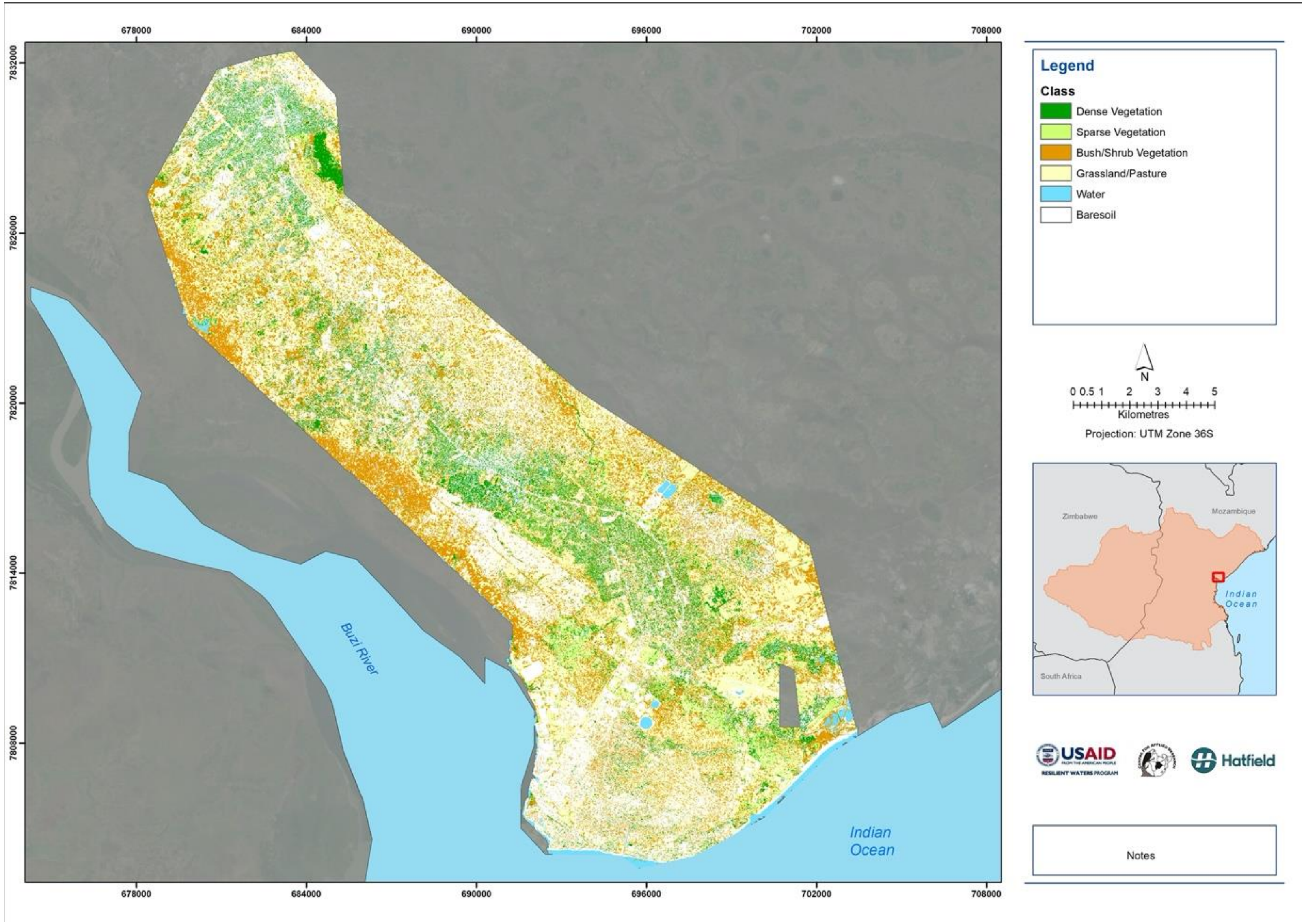


Figure 42: Chimanimani high-resolution image classification.

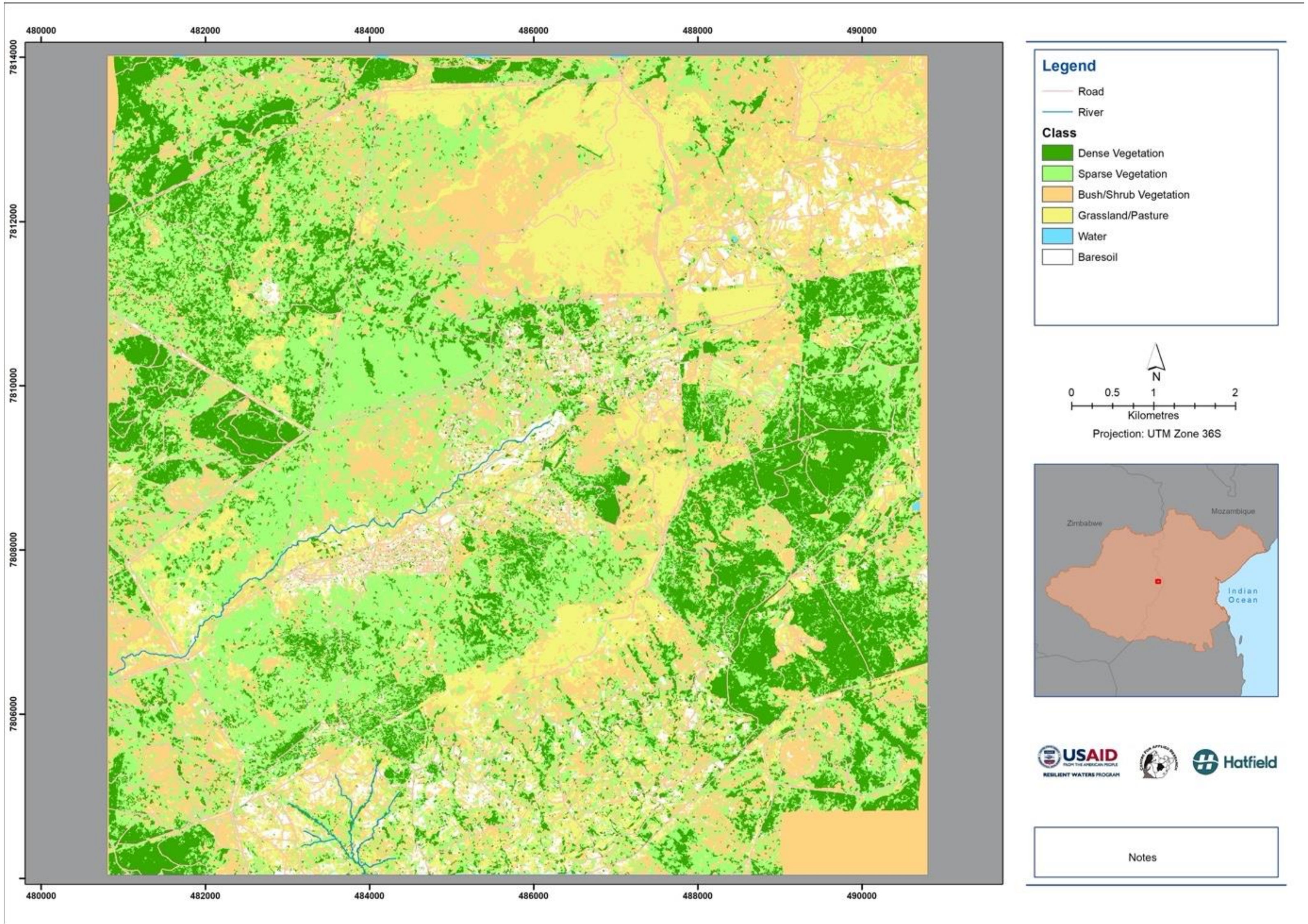


Figure 43: Beira topographic map.

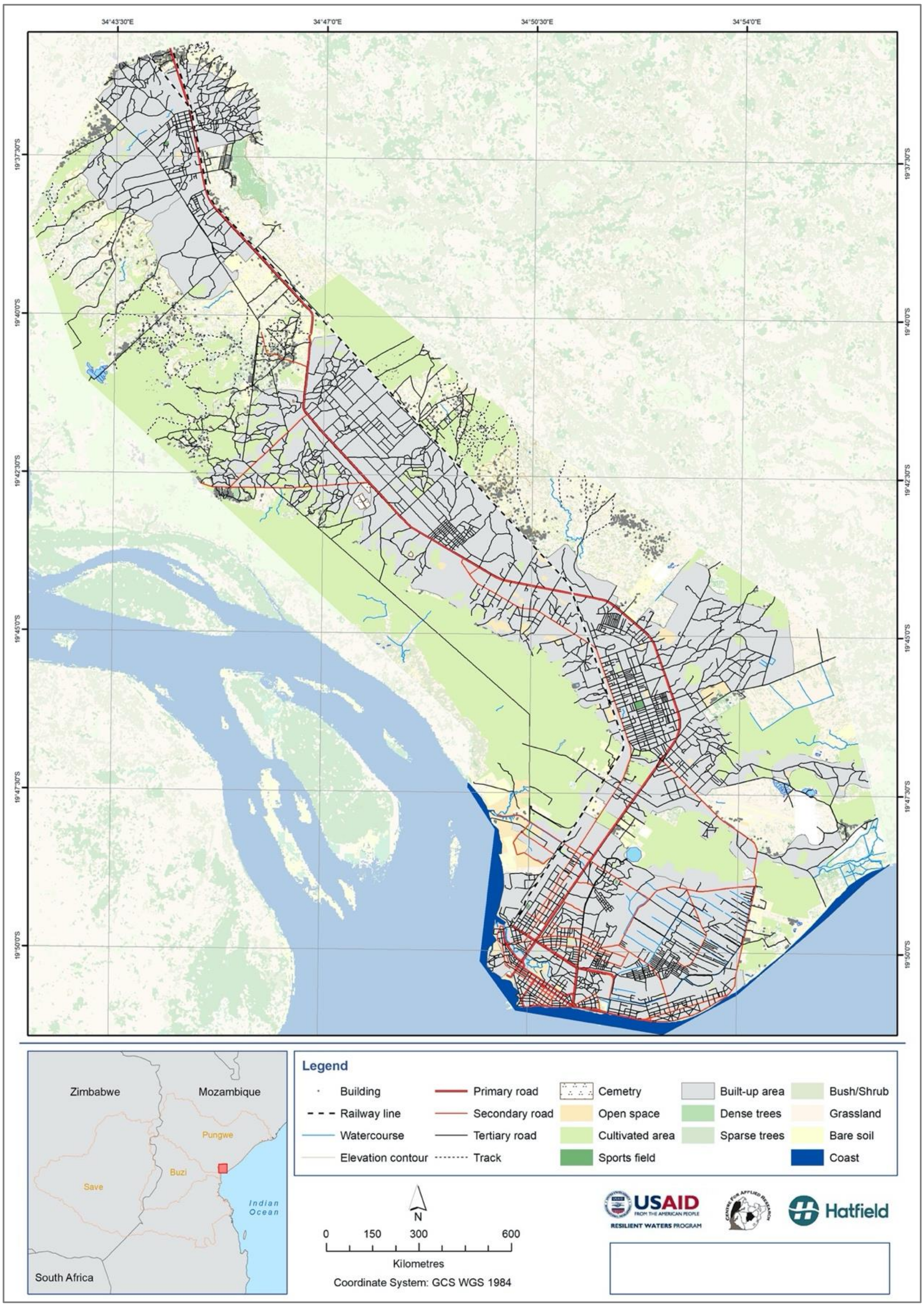


Figure 44: Chimanimani topographic map.

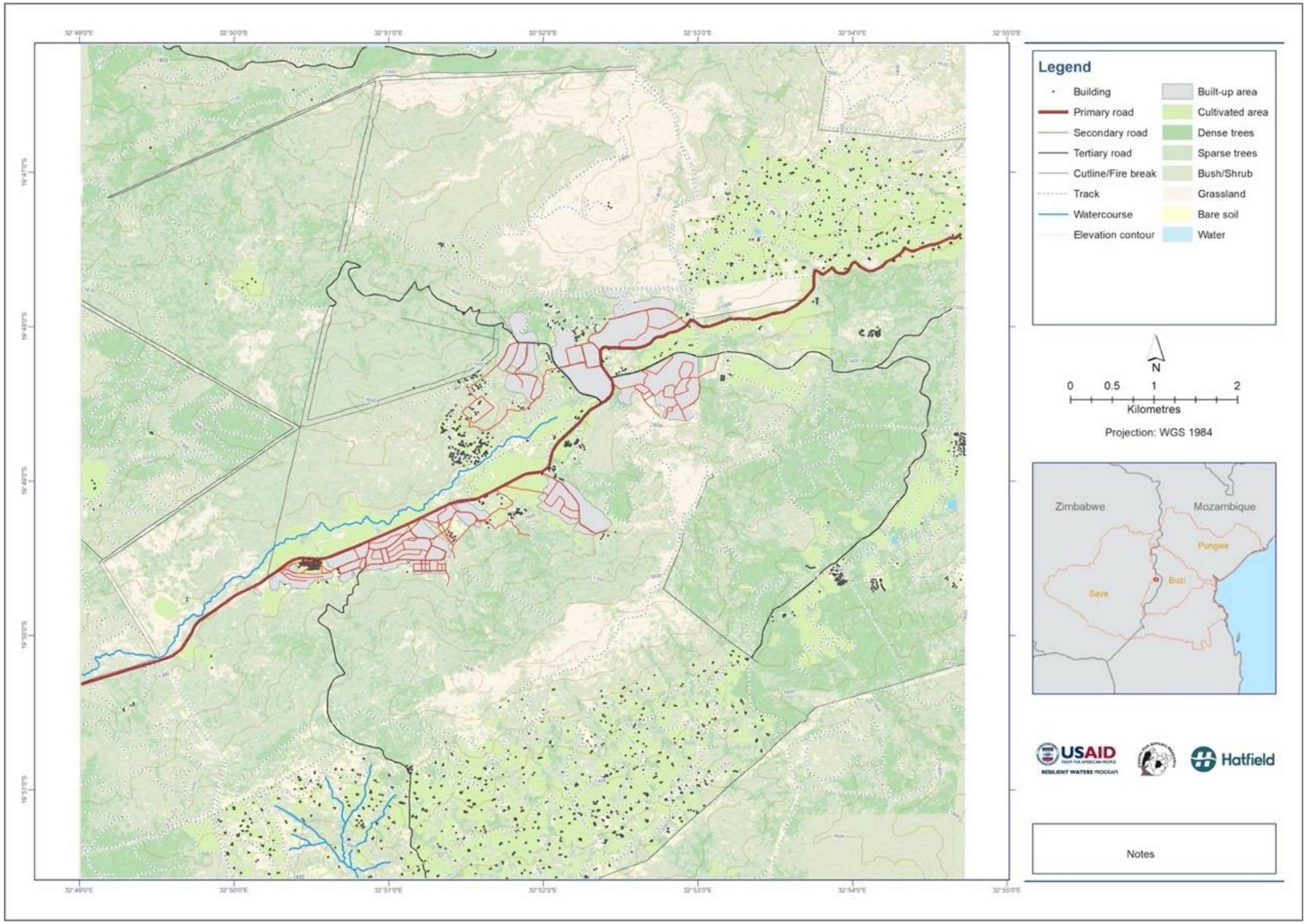


Figure 45: BuPuSa River basins topographic map.

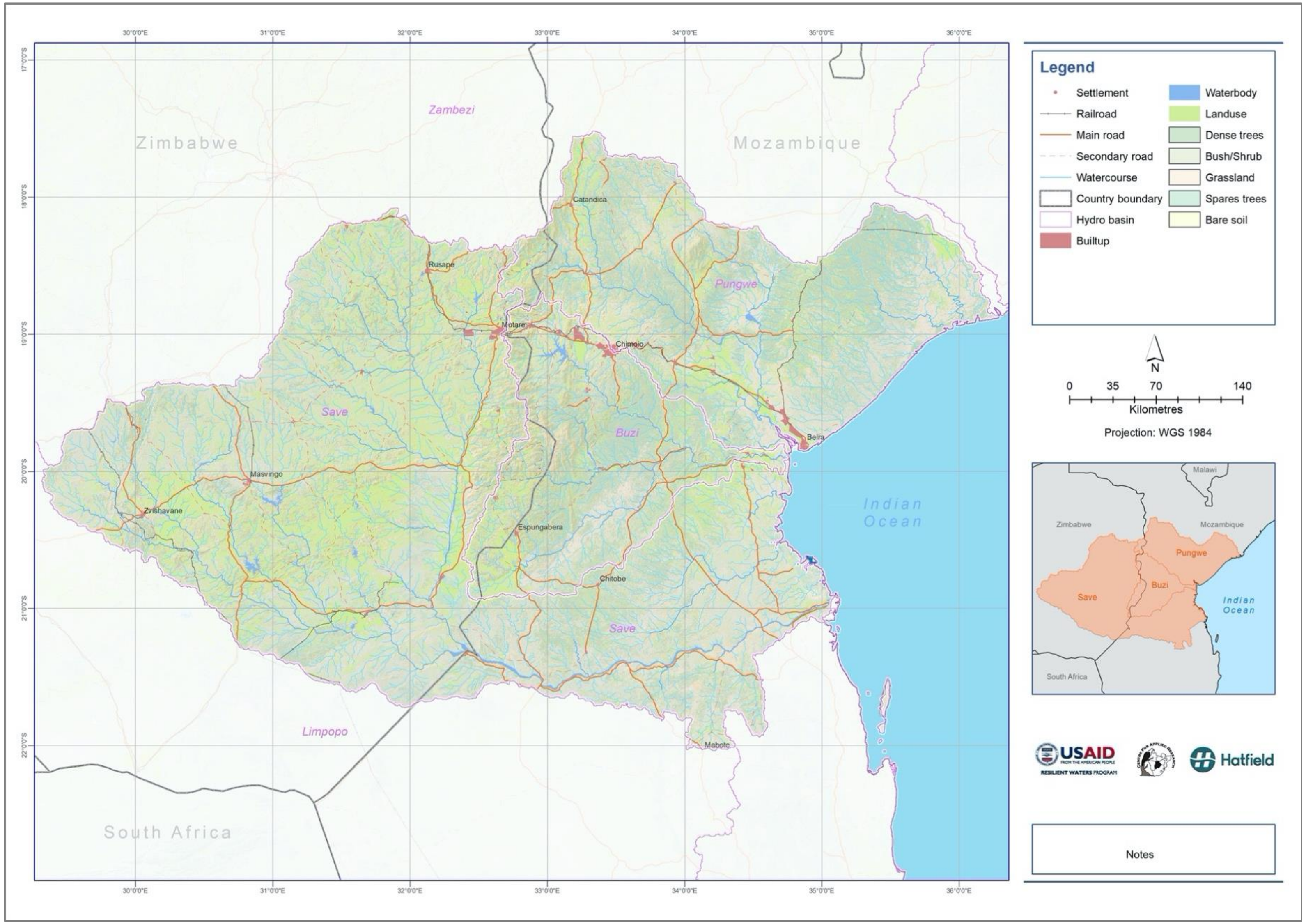
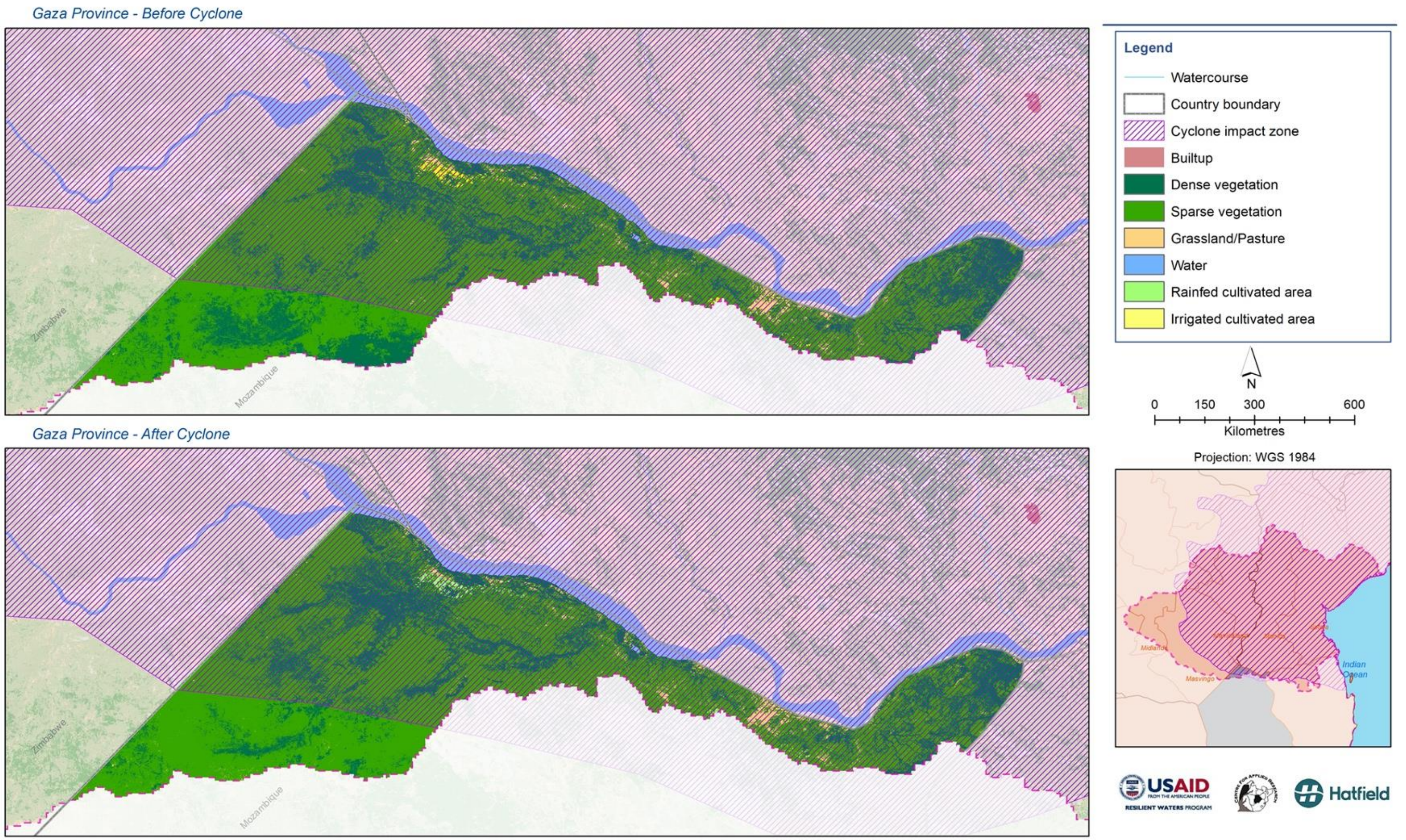


Figure 46: Landcover change analysis for Gaza Province.



	Before Cyclone	After Cyclone	% Change
Dense Vegetation	53,919	48,689	-11
Sparse Vegetation	130,702	135,454	4
Grassland/Pasture	2,527	3,008	16
Water	4,773	4,771	0

* Areas are in Ha

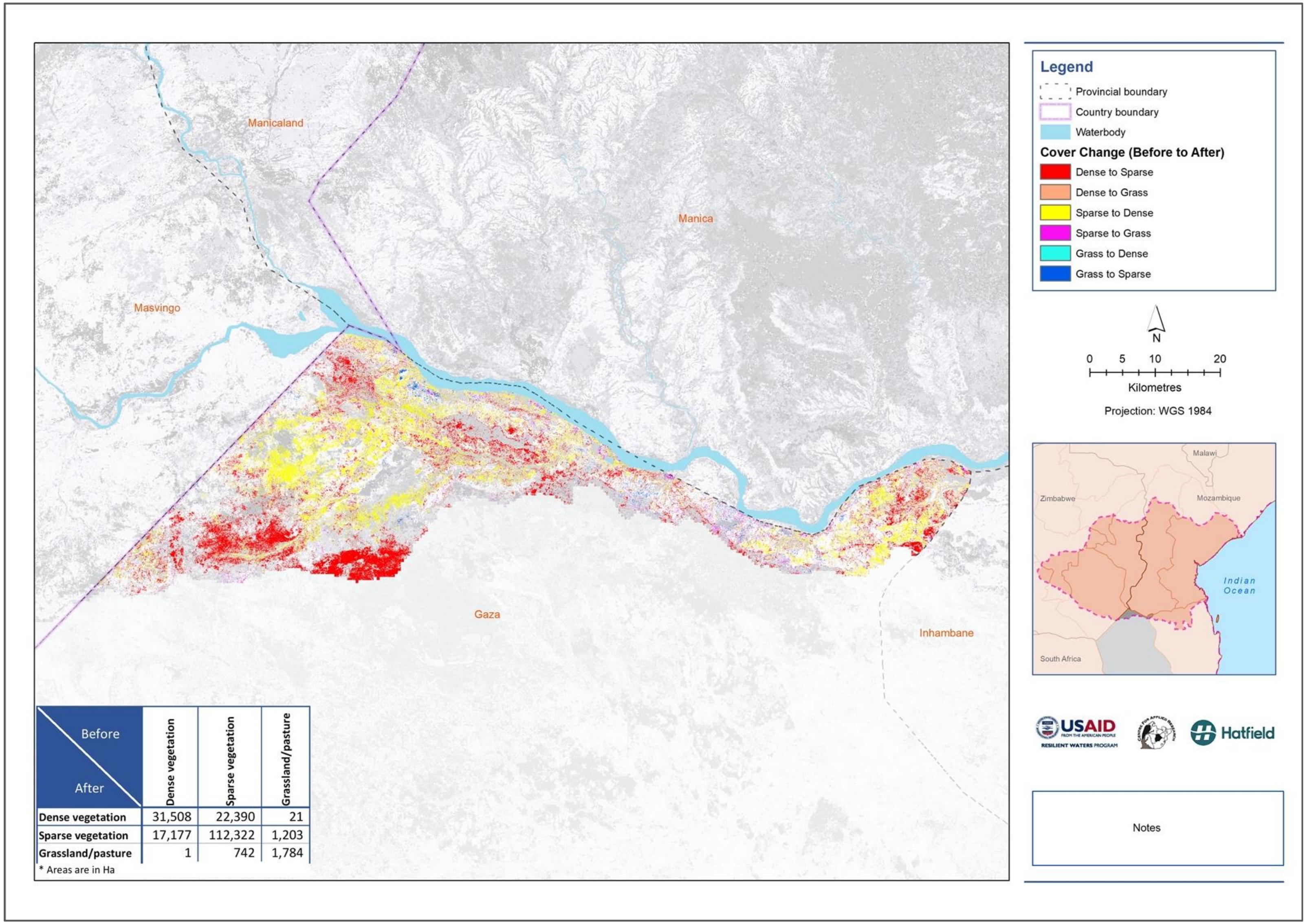
Analysis result of cultivated land that were directly affected by the cyclone

	Total area	Affected by Cyclone	% Affected
Irrigated	-	-	0
Rainfed	742	742	100

* Areas are in Ha

Notes

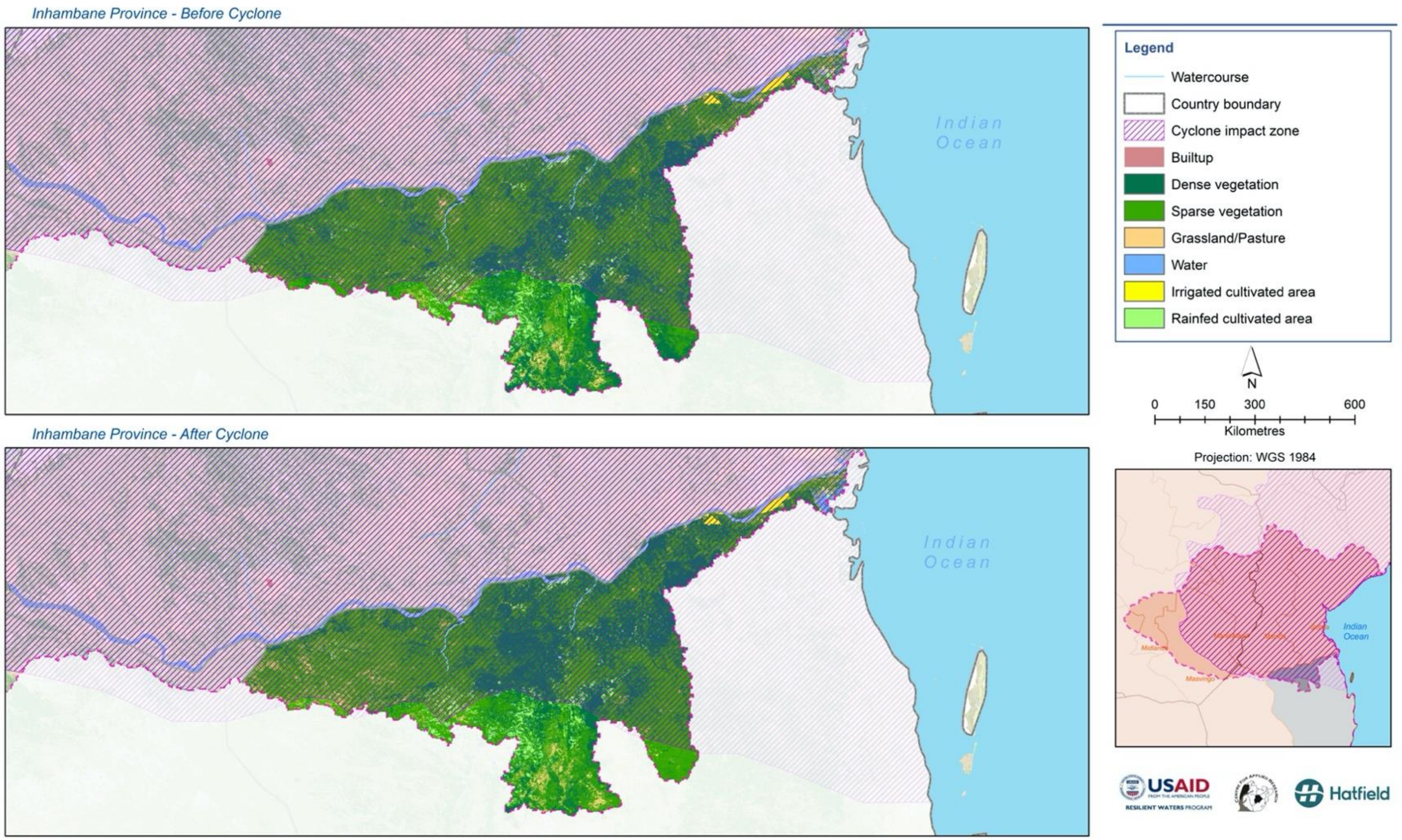
Figure 47: Landcover change dynamics analysis for Gaza Province.



Before / After	Dense vegetation	Sparse vegetation	Grassland/pasture
Dense vegetation	31,508	22,390	21
Sparse vegetation	17,177	112,322	1,203
Grassland/pasture	1	742	1,784

* Areas are in Ha

Figure 48: Landcover change analysis for Inhambane Province.



	Before Cyclone	After Cyclone	% Change
Dense Vegetation	255,371	260,368	2
Sparse Vegetation	436,629	428,482	-2
Grassland/Pasture	32,760	33,678	3
Water	12,605	14,837	15

* Areas are in Ha

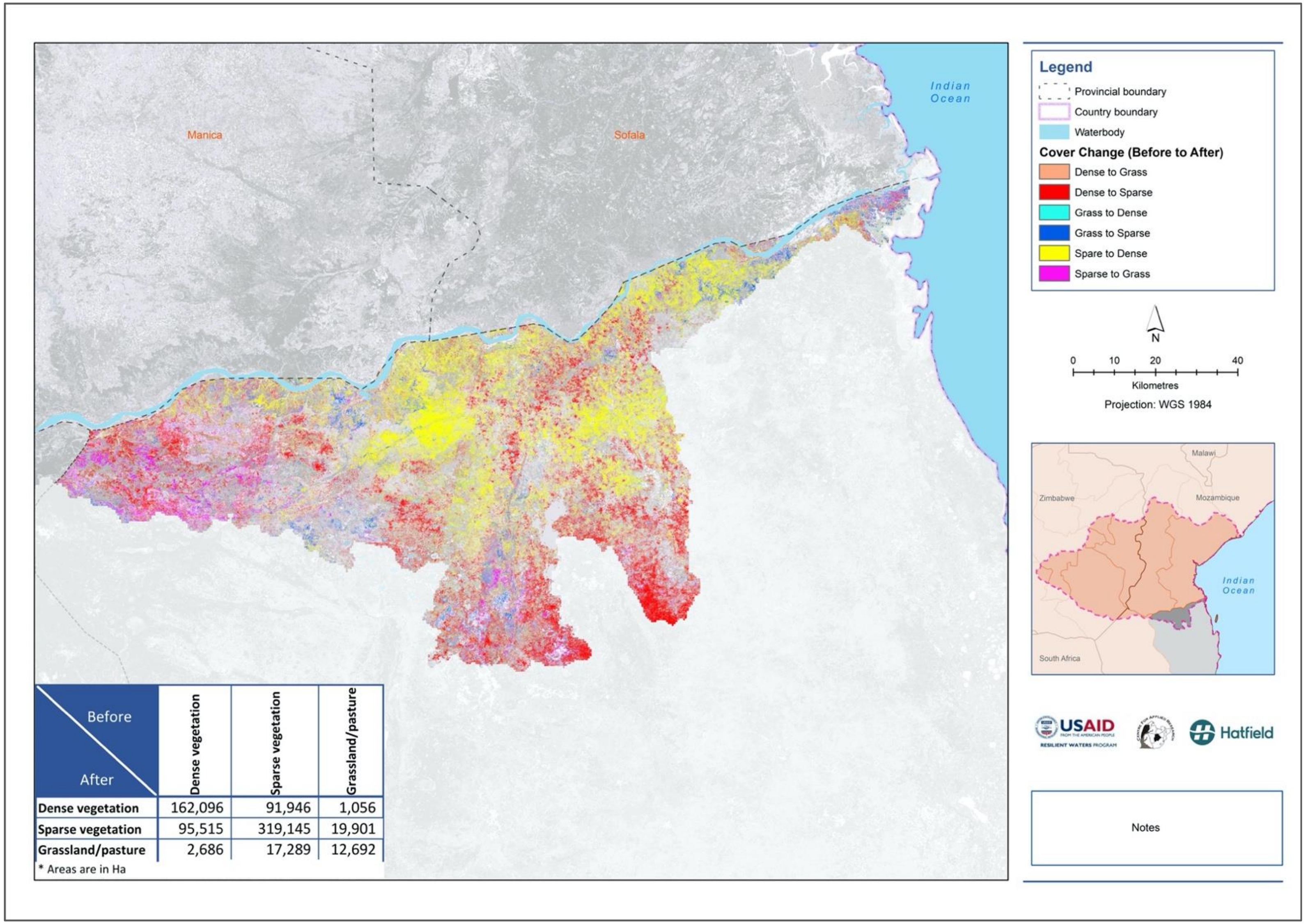
Analysis result of cultivated land that were directly affected by the cyclone

	Total area	Affected by Cyclone	% Affected
Irrigated	3,397	3,397	100.0
Rainfed	25,639	12,107	47.2

* Areas are in Ha

Notes

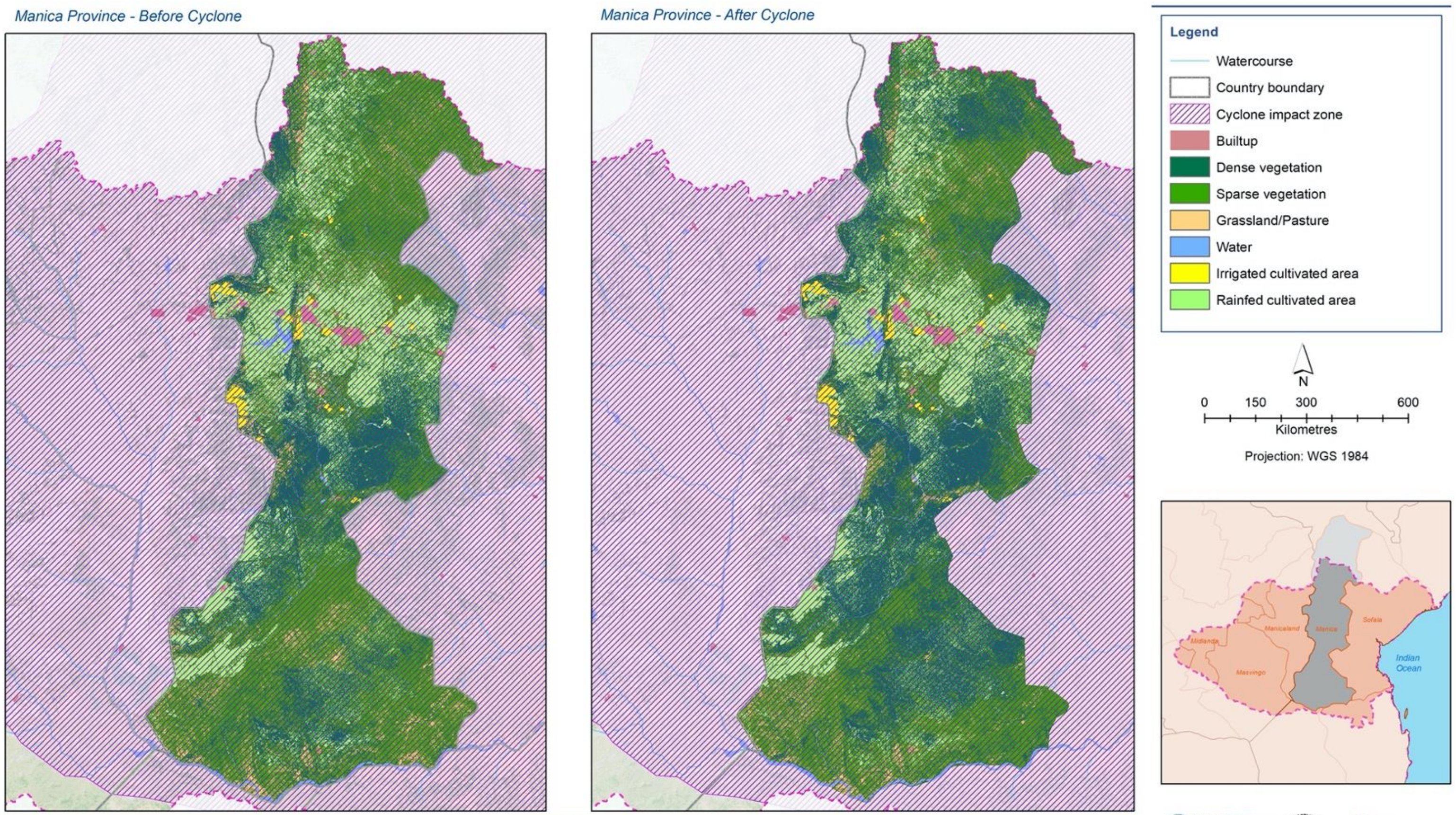
Figure 49: Landcover change dynamics analysis for Inhambane Province.



After \ Before	Dense vegetation	Sparse vegetation	Grassland/pasture
Dense vegetation	162,096	91,946	1,056
Sparse vegetation	95,515	319,145	19,901
Grassland/pasture	2,686	17,289	12,692

* Areas are in Ha

Figure 50: Landcover change analysis for Manica Province.



	Before Cyclone	After Cyclone	% Change
Dense Vegetation	989,346	1,436,481	31
Sparse Vegetation	2,332,683	1,973,283	-18
Grassland/Pasture	278,795	191,059	-46
Water	58,781	58,781	0

* Areas are in Ha

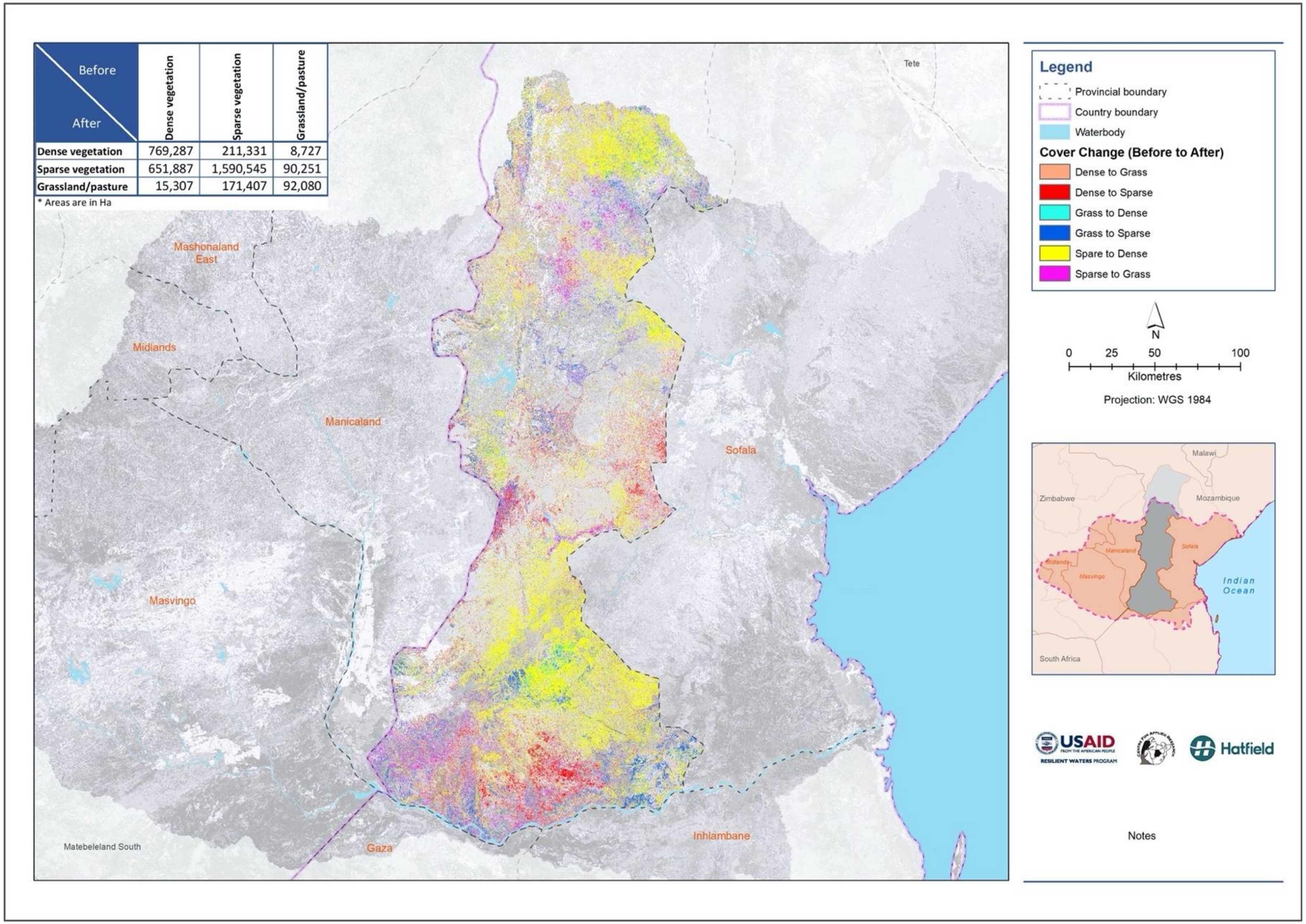
Analysis result of cultivated land that were directly affected by the cyclone

	Total area	Affected by Cyclone	% Affected
Irrigated	41,531	41,531	100
Rainfed	894,399	894,399	100

* Areas are in Ha

Notes

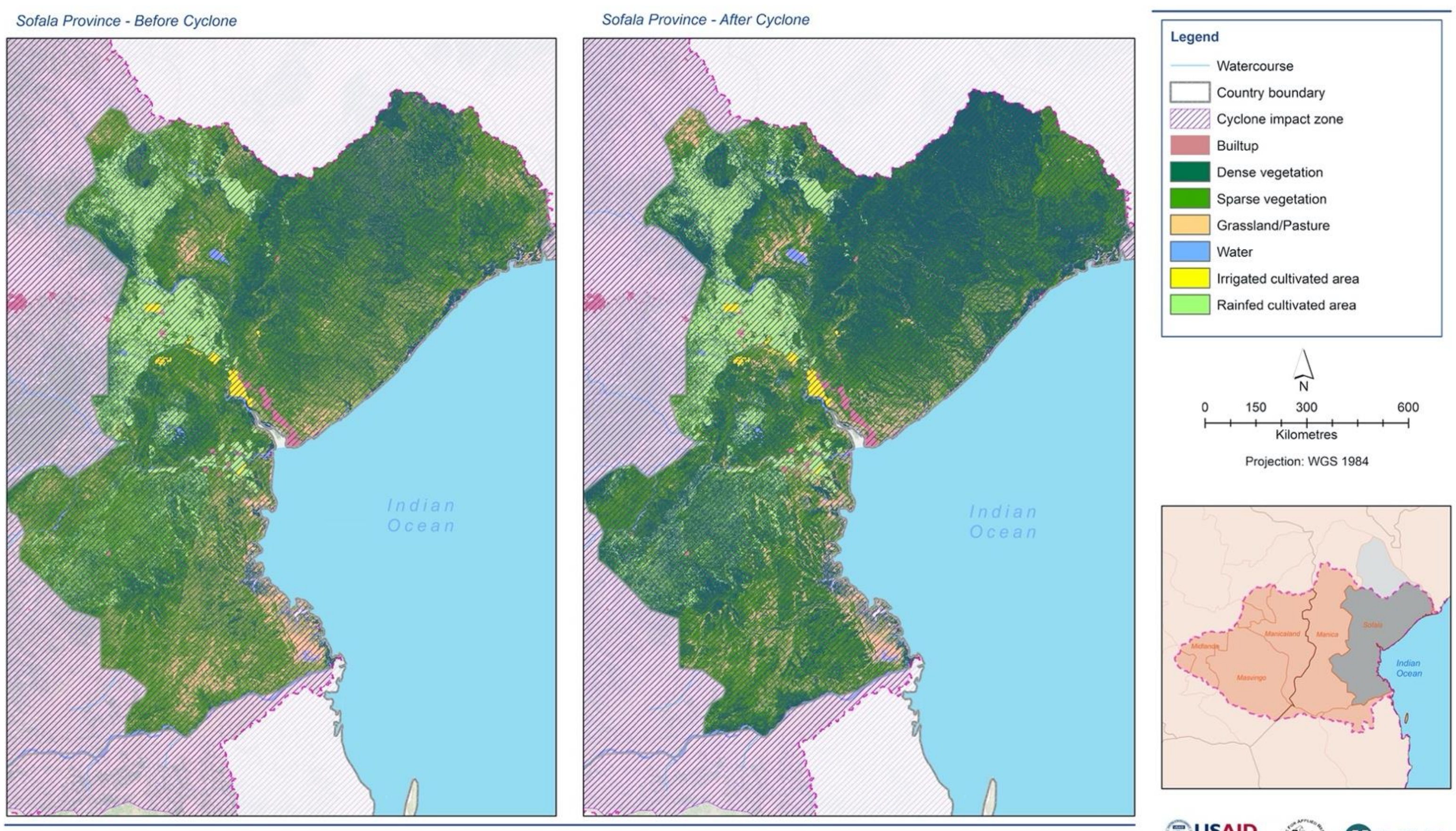
Figure 51: Landcover change dynamics analysis for Manica Province.



Before \ After	Dense vegetation	Sparse vegetation	Grassland/pasture
Dense vegetation	769,287	211,331	8,727
Sparse vegetation	651,887	1,590,545	90,251
Grassland/pasture	15,307	171,407	92,080

* Areas are in Ha

Figure 52: Landcover change analysis for Sofala Province.



	Before Cyclone	After Cyclone	% Change
Dense Vegetation	1,345,690	2,286,020	41
Sparse Vegetation	2,752,435	1,963,359	-40
Grassland/Pasture	474,109	297,236	-60
Water	55,377	80,995	32

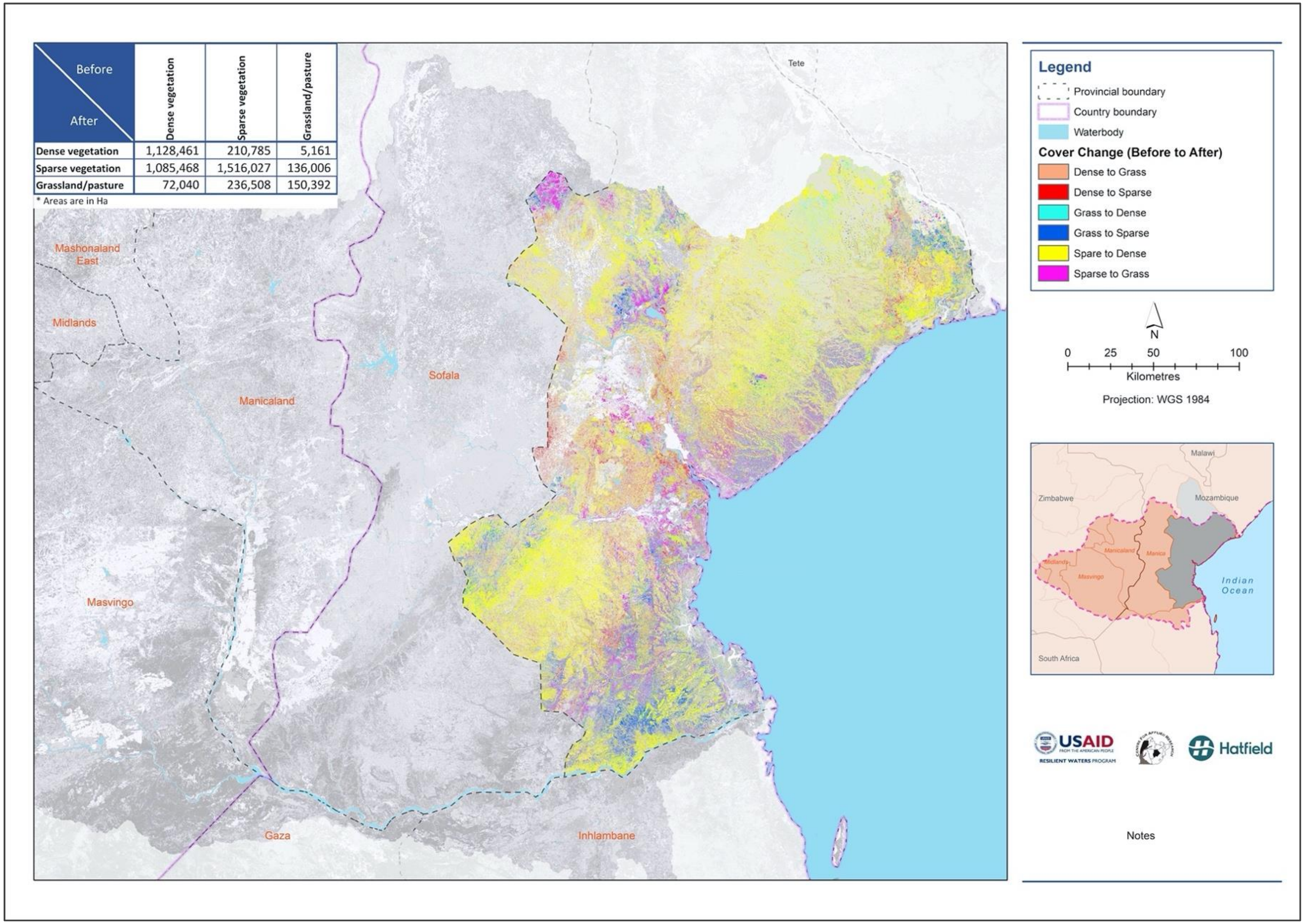
* Areas are in Ha

Analysis result of cultivated land that were directly affected by the cyclone

	Total area	Affected by Cyclone	% Affected
Irrigated	21,359	21,359	100.0
Rainfed	466,993	466,993	100.0

* Areas are in Ha

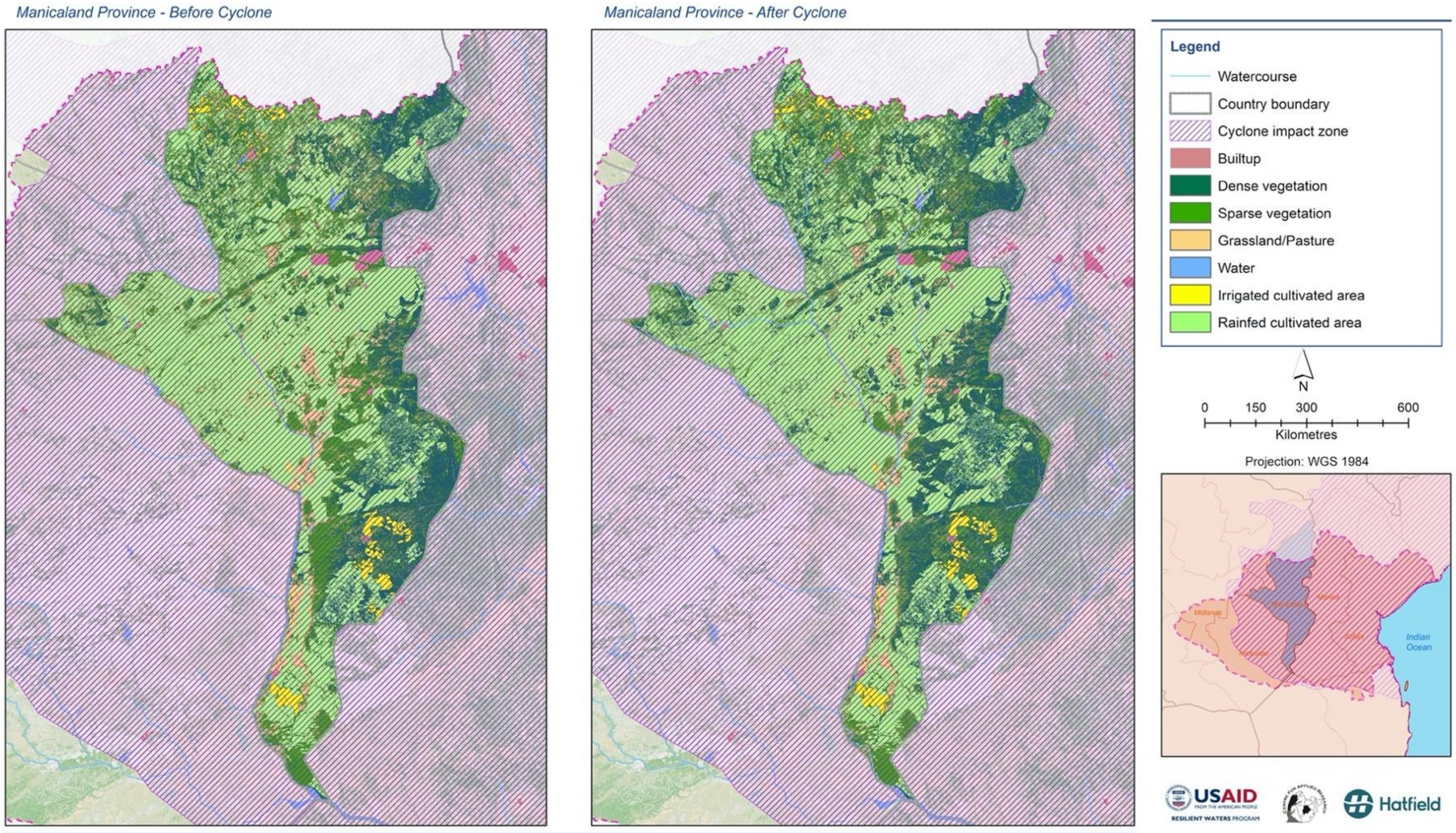
Figure 53: Landcover change dynamics analysis for Sofala Province.



Before / After	Dense vegetation	Sparse vegetation	Grassland/pasture
Dense vegetation	1,128,461	210,785	5,161
Sparse vegetation	1,085,468	1,516,027	136,006
Grassland/pasture	72,040	236,508	150,392

* Areas are in Ha

Figure 54: Landcover change analysis for Manicaland Province.



	Before Cyclone	After Cyclone	% Change
Dense Vegetation	496,126	667,635	26
Sparse Vegetation	706,291	586,255	-20
Grassland/Pasture	232,370	180,854	-28
Water	27,961	28,005	0

* Areas are in Ha

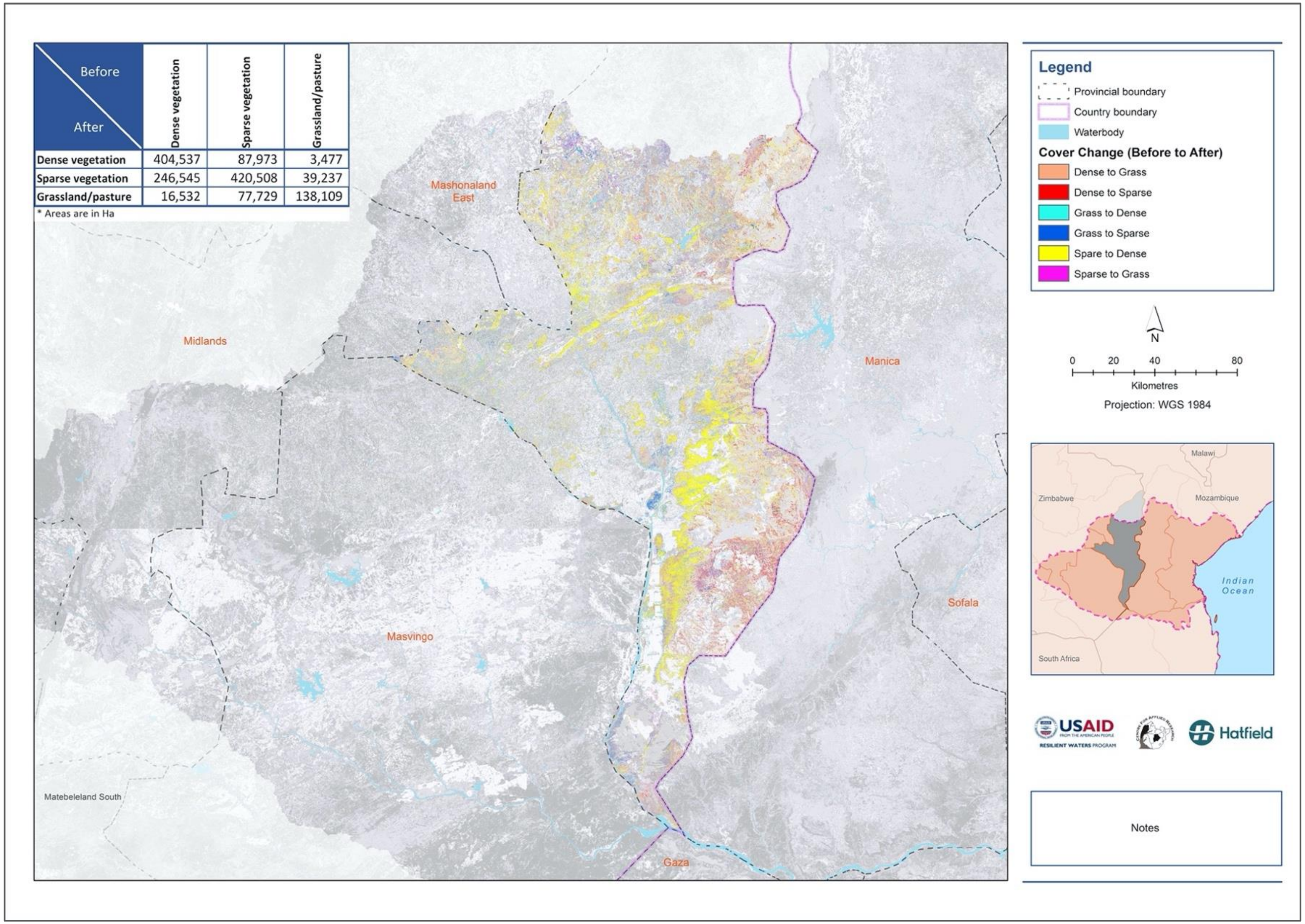
Analysis result of cultivated land that were directly affected by the cyclone

	Total area	Affected by Cyclone	% Affected
Irrigated	46,298	46,298	100.0
Rainfed	1,252,445	1,252,445	100.0

* Areas are in Ha

Notes

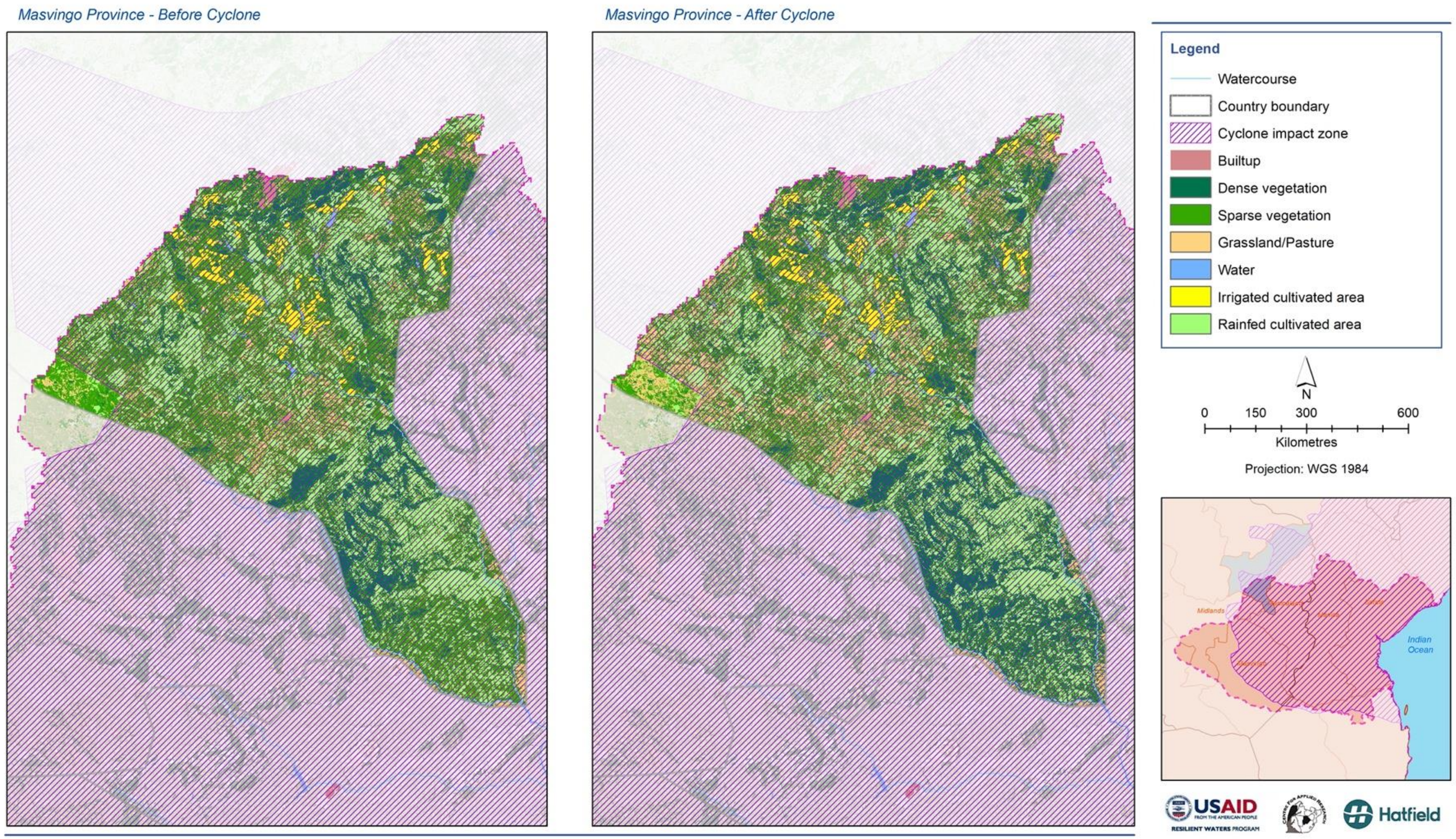
Figure 55: Landcover change dynamics analysis for Manicaland Province.



After \ Before	Dense vegetation	Sparse vegetation	Grassland/pasture
Dense vegetation	404,537	87,973	3,477
Sparse vegetation	246,545	420,508	39,237
Grassland/pasture	16,532	77,729	138,109

* Areas are in Ha

Figure 56: Landcover change analysis for Mashonaland East Province.



	Before Cyclone	After Cyclone	% Change
Dense Vegetation	72,050	100,149	28
Sparse Vegetation	225,846	172,461	-31
Grassland/Pasture	43,562	68,848	37
Water	3,395	3,395	0

* Areas are in Ha

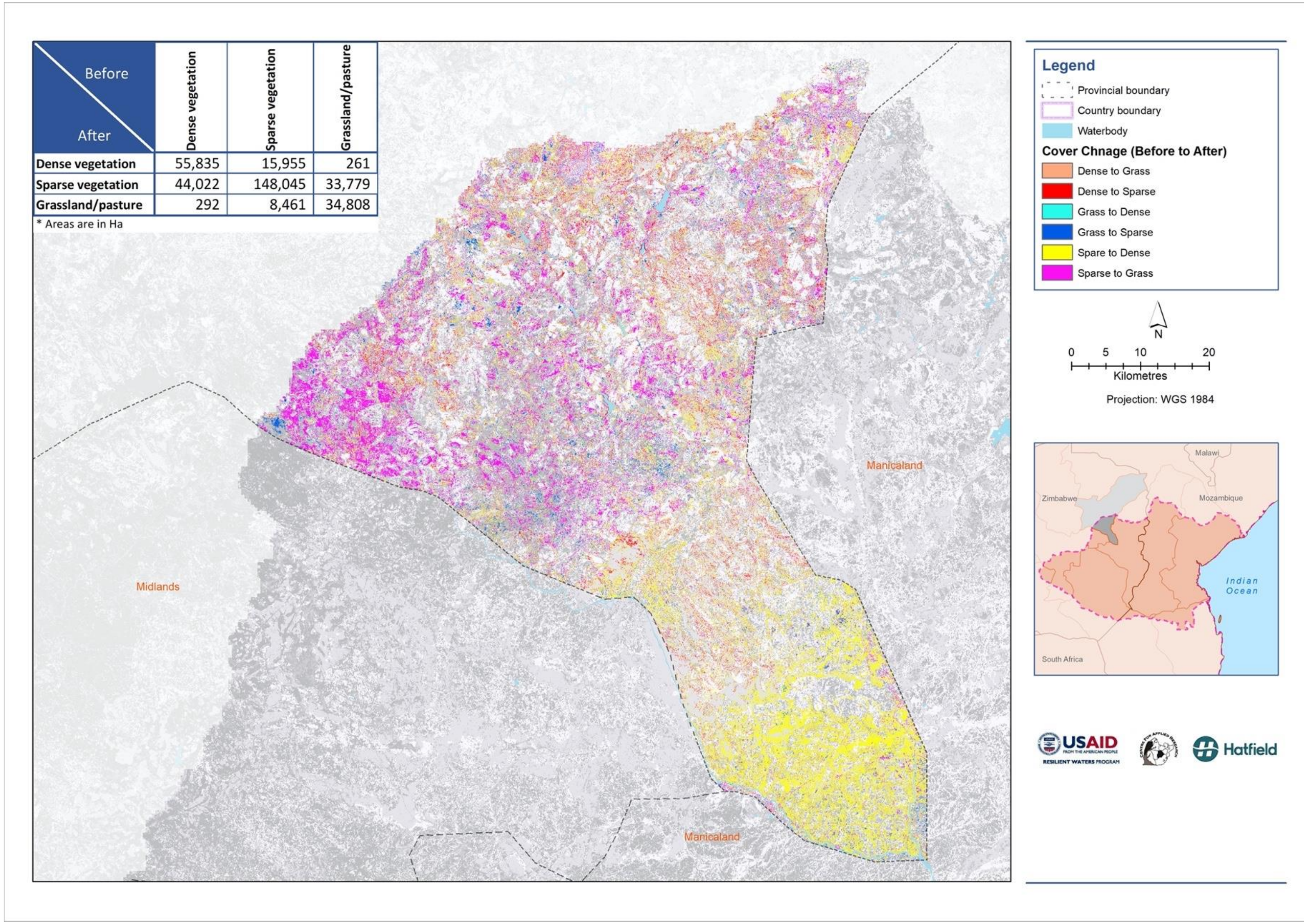
Analysis result of cultivated land that were directly affected by the cyclone

	Total area	Affected by Cyclone	% Affected
Irrigated	11,771	11,771	100.0
Rainfed	121,376	120,992	99.7

* Areas are in Ha

Notes

Figure 57: Landcover change dynamics analysis for Mashonaland East Province.



After \ Before	Dense vegetation	Sparse vegetation	Grassland/pasture
Dense vegetation	55,835	15,955	261
Sparse vegetation	44,022	148,045	33,779
Grassland/pasture	292	8,461	34,808

* Areas are in Ha

Figure 58: Landcover change analysis for Masvingo Province.

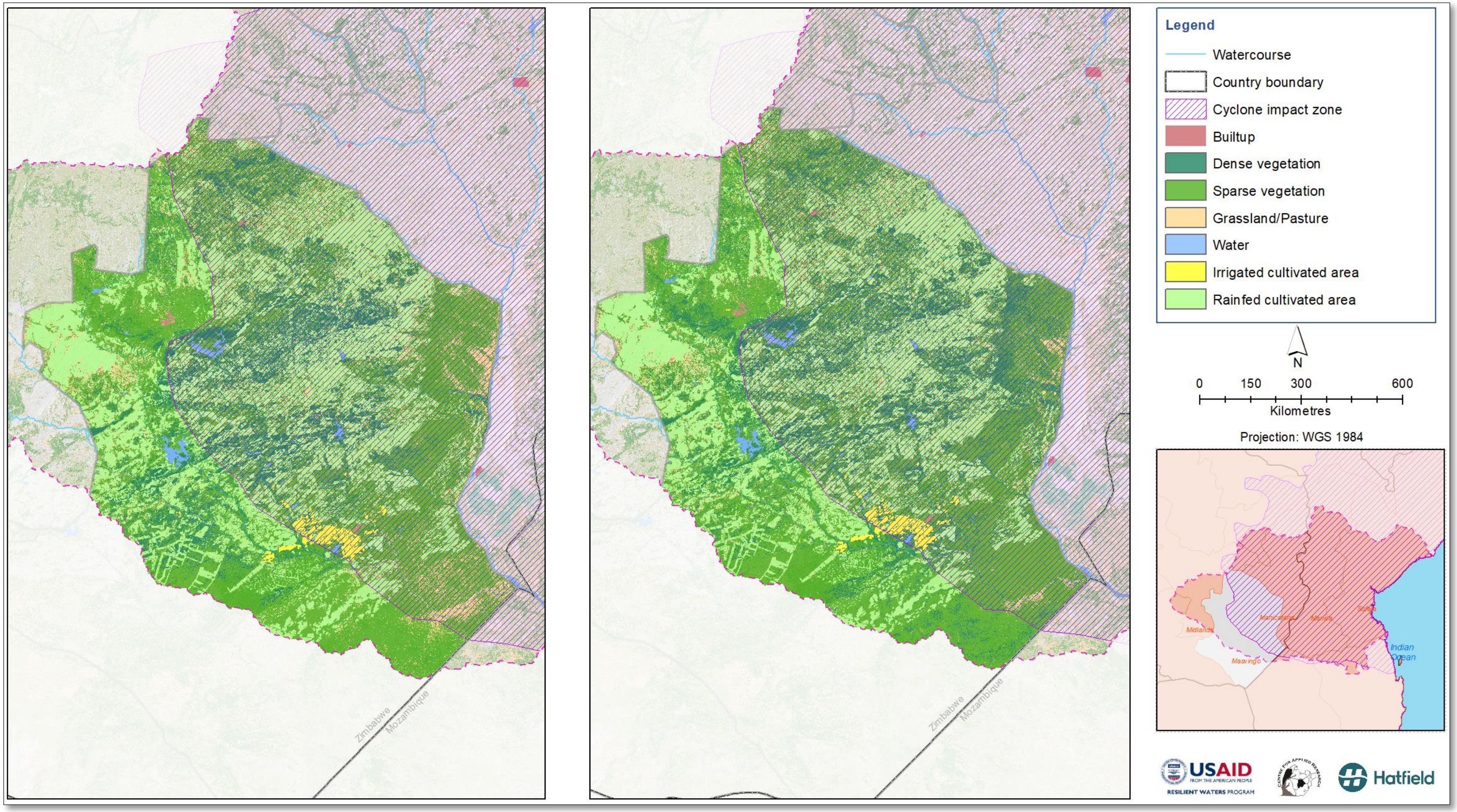
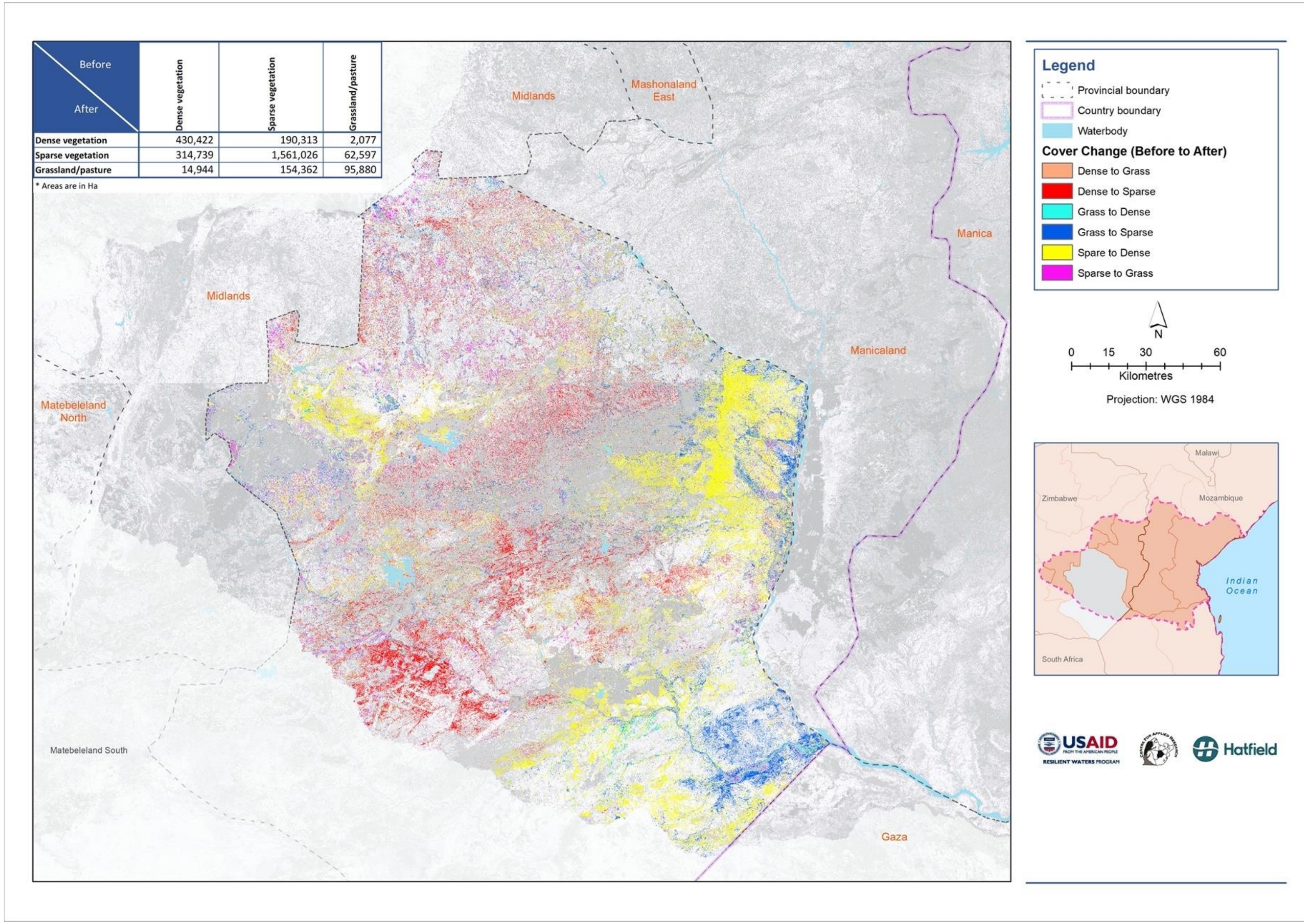


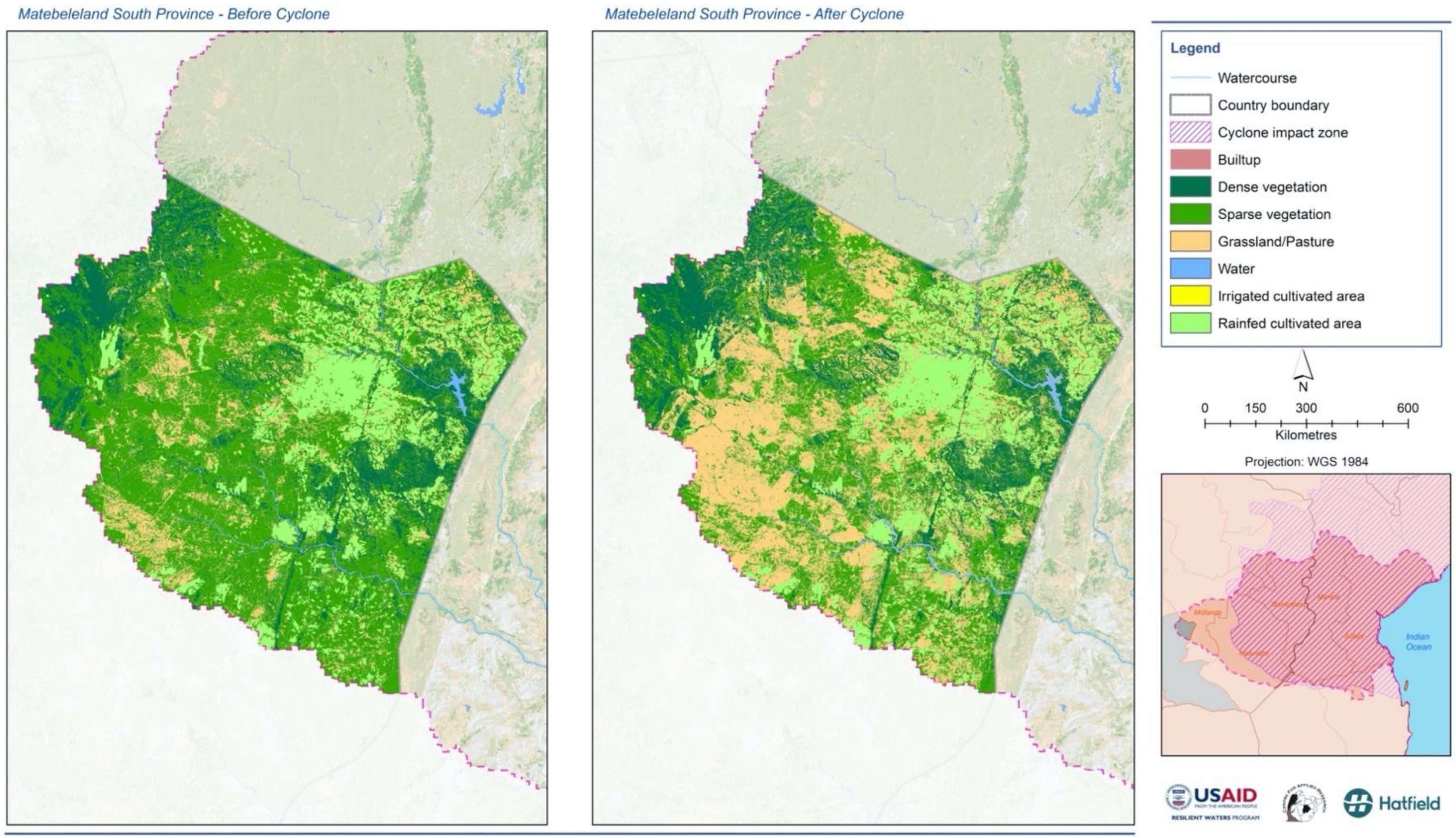
Figure 59: Landcover change dynamics analysis for Masvingo Province.



After \ Before	Dense vegetation	Sparse vegetation	Grassland/pasture
Dense vegetation	430,422	190,313	2,077
Sparse vegetation	314,739	1,561,026	62,597
Grassland/pasture	14,944	154,362	95,880

* Areas are in Ha

Figure 60: Landcover change analysis for Matebeleland South Province.



	Before Cyclone	After Cyclone	% Change
Dense Vegetation	40,198	41,002	2
Sparse Vegetation	123,903	74,775	-66
Grassland/Pasture	31,923	80,275	60
Water	1,590	1,563	-2

* Areas are in Ha

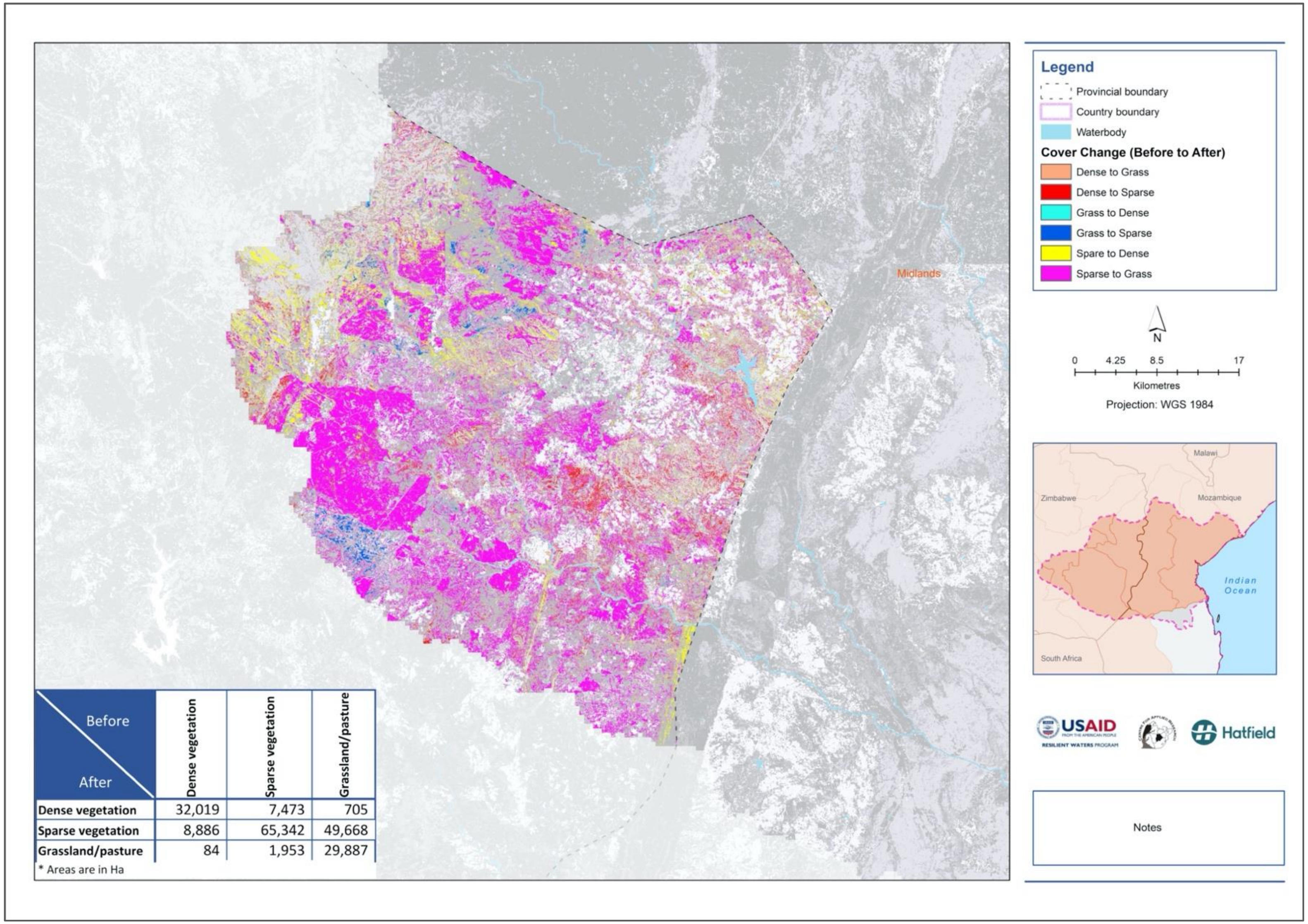
Analysis result of cultivated land that were directly affected by the cyclone

	Total area	Affected by Cyclone	% Affected
Irrigated	13	-	0.0
Rainfed	29,460	-	0.0

* Areas are in Ha

Notes

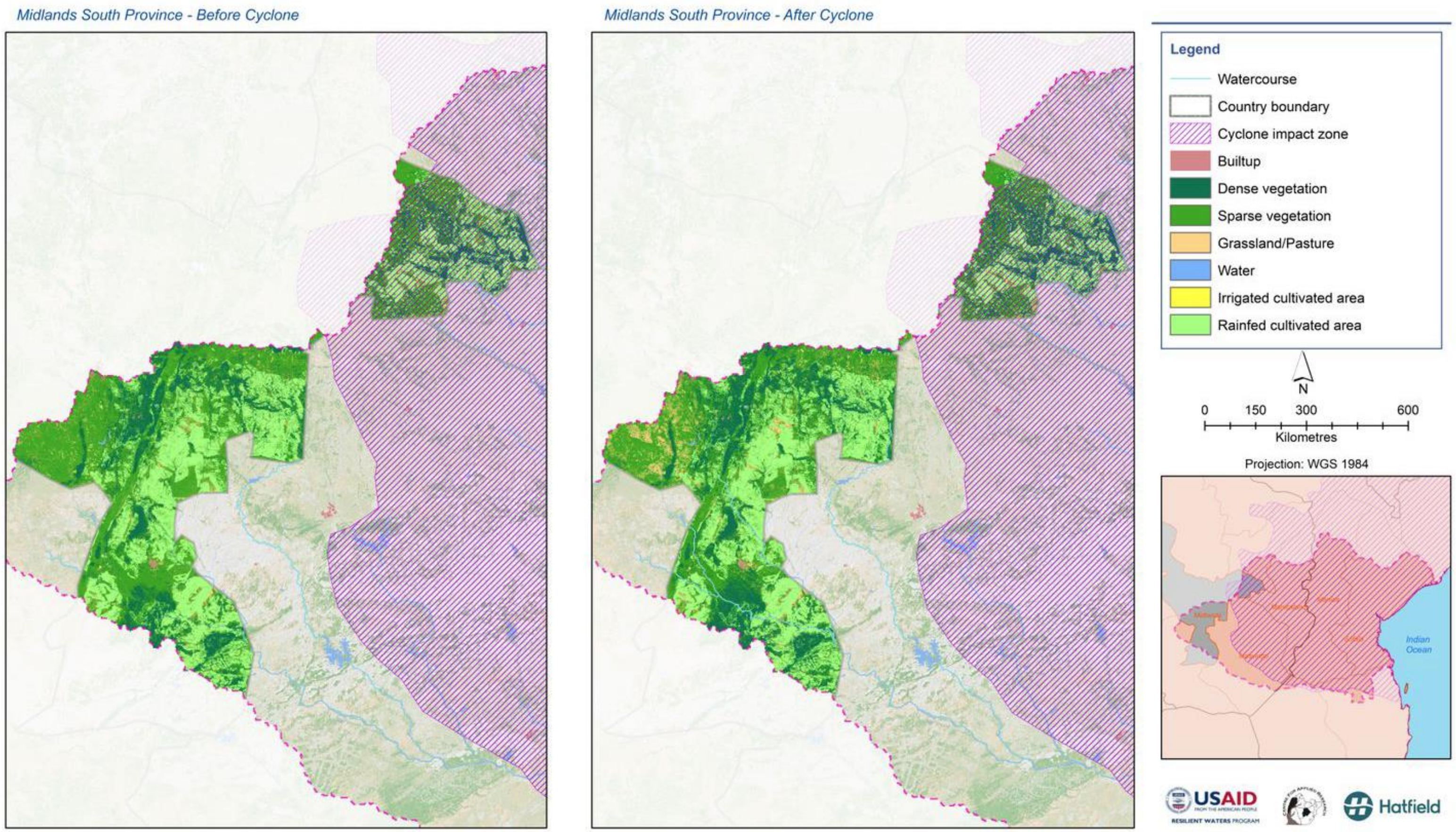
Figure 61: Landcover change dynamics analysis for Matebeleland South Province.



Before / After	Dense vegetation	Sparse vegetation	Grassland/pasture
Dense vegetation	32,019	7,473	705
Sparse vegetation	8,886	65,342	49,668
Grassland/pasture	84	1,953	29,887

* Areas are in Ha

Figure 62: Landcover change analysis for Midlands Province.



	Before Cyclone	After Cyclone	% Change
Dense Vegetation	296,978	375,141	21
Sparse Vegetation	603,860	501,939	-20
Grassland/Pasture	69,697	93,454	25
Water	6,490	6,490	0

* Areas are in Ha

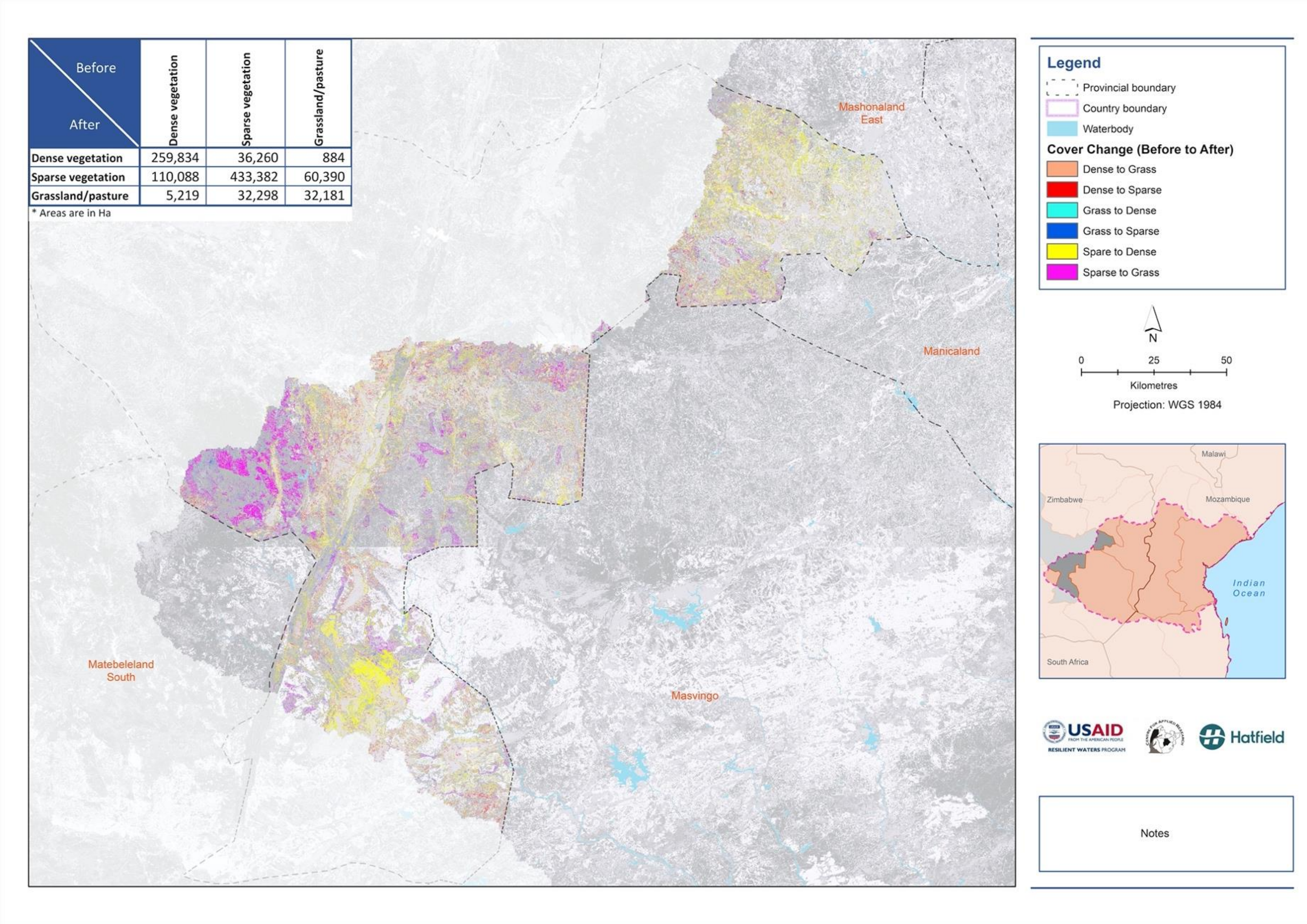
Analysis result of cultivated land that were directly affected by the cyclone

	Total area	Affected by Cyclone	% Affected
Irrigated	104	-	0.0
Rainfed	447,649	115,015	25.7

* Areas are in Ha

Notes

Figure 63: Landcover change dynamics analysis for Midlands Province.



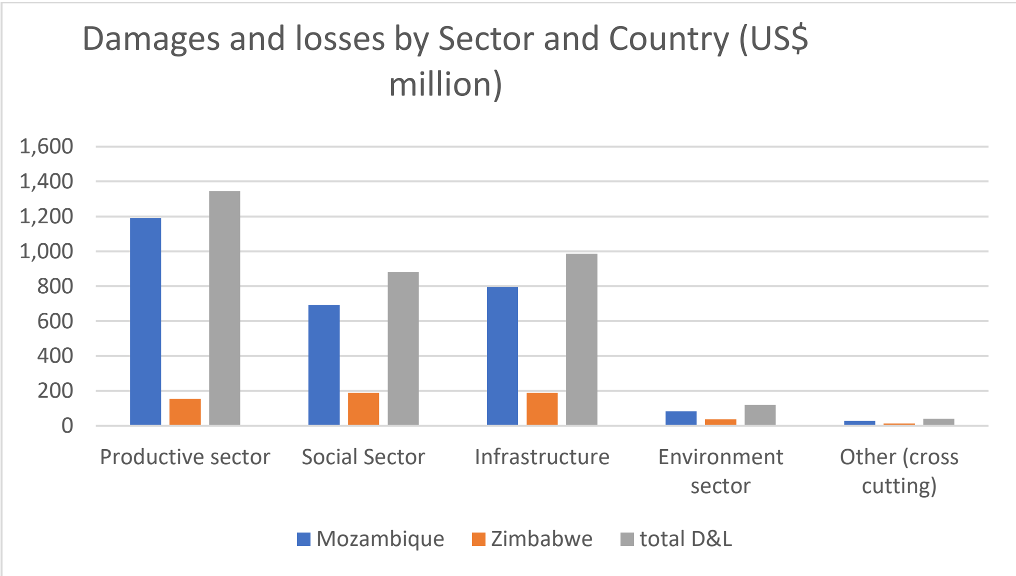
After \ Before	Dense vegetation	Sparse vegetation	Grassland/pasture
Dense vegetation	259,834	36,260	884
Sparse vegetation	110,088	433,382	60,390
Grassland/pasture	5,219	32,298	32,181

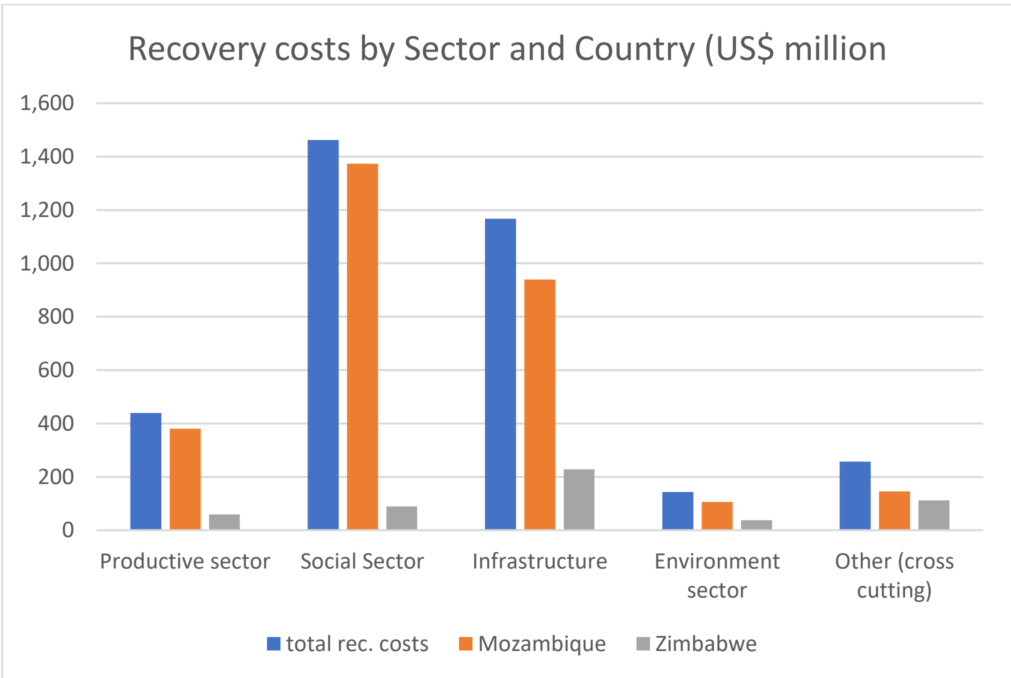
* Areas are in Ha

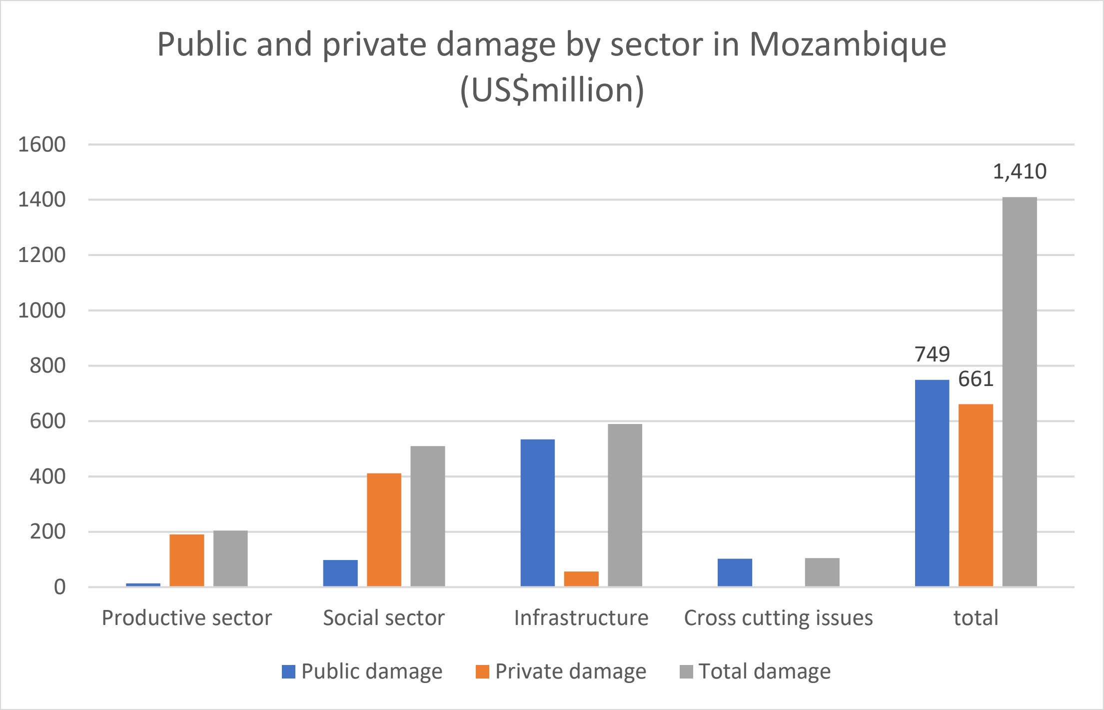
9.3 Socio-economic assessment details

9.3.1 Economic costs of Cyclone Idai and recovery needs

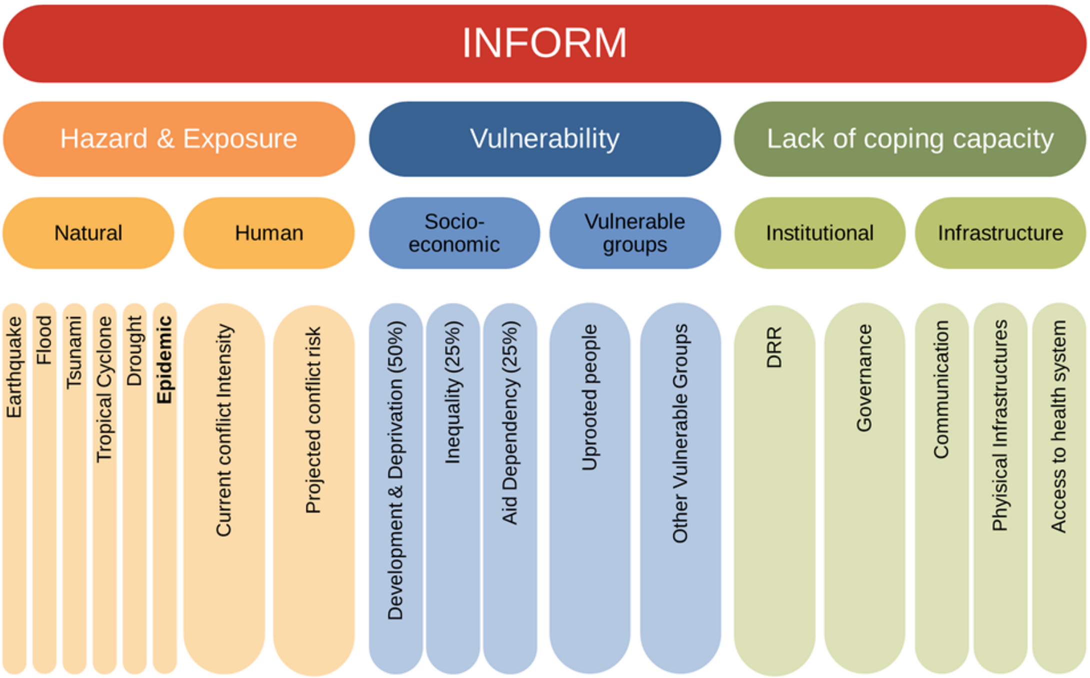
Source: based on PDNA and RINA






Public and private damage by sector in Mozambique (US$million)
1600
1400
1200
1000
800
600
400
200
0
1,410
749
661
Productive sector
Social sector
Infrastructure
Cross cutting issues
total
Public damage
Private damage
Total damage

9.2.2 Composition of Index for Risk Management



Source: https://ec.europa.eu/jrc/en/publication/index-risk-management-inform