Increasing hazard risk knowledge through geotechnology and geospatial modelling in Chipinge and Chimanimani Districts

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1 Abstract

Chimanimani and Chipinge districts, located in Manicaland Province of Zimbabwe are prone to multiple hydrogeological and meteorological hazards that negatively affect the livelihoods of communities living therein. These hazards include landslides, floods, tropical cyclones, droughts and prolonged dry spells. To this end, *Terre des hommes Italia* (TDH-IT) with funding from DG-ECHO working together with the University of Zimbabwe, Department of Geography Geospatial Sciences and Earth Observation, the Zimbabwe National Water Authority (ZINWA), the Meteorological Services Department (MSD) and Department of Civil Protection (DCP) implemented a project titled *Integrated Protection, Education in Emergencies and Disaster Risk Reduction in multi-hazard areas of Chipinge and Chimanimani districts.* The selection of the two districts was based on their susceptibility to multiple hazards based on a review of literature on past disasters that affected the country. The project employed several methods to gather baseline data on natural hazards including desk reviews, focus group discussions, key informant interviews, geospatial modelling, validation and spatial mapping. The results of the project indicated that the two districts are affected by several natural hazards with the most frequently occurring hazards in order of intensity and geographic extent being cyclone induced floods, drought, flash floods, landslides, and strong winds (whirlwind). The impacts of natural hazards on human livelihoods in the district were regarded as severe with cyclone Idai that was experienced in 2019 regarded as the worst disaster ever recorded. The results of landslide susceptibility modelling indicated that Chimanimani district has the largest area that is highly susceptible to landslides while the larger part of Chipinge district has low susceptibility. In this regard the hotspot areas for landslides are mostly in Chimanimani district where the greatest damage to infrastructure and loss of human was greatly felt during cyclone Idai. In addition, droughts were observed to occur frequently in the lower parts of the two districts particularly those falling in agroecological 4 and 5. The results of the study are important to guide landuse planning, development of early warning systems, strengthening community-based disaster risk reduction efforts and community awareness programmes.

2 Introduction

Zimbabwe experiences multiple weather-related hazards ranging from frequent cyclones, periodic droughts, floods, disease epidemics and landslides (Mukwada and Manatsa, 2013; Shackleton et al. 2015). For instance, severe drought episodes affected the country in 1991–1992, 1994–1995, 2002–2003, 2015–2016, 2018–2019 and 2019-2020 (Frischen et al, 2020). From these, the 1991-92 drought is regarded as the worst ever recorded natural hazard to have affected the country. In addition to droughts, riverine and flash floods affect some parts of the country including Manicaland, Masvingo and Matabeleland provinces which are mostly in the Save, Runde and Umzingwane catchment areas (Chanza et. al, 2020). Previous studies indicated that of all the tropical cyclones that form in the southwest Indian Ocean only about 5% make a landfall in Mozambique thereby potentially affecting Zimbabwe. Tropical cyclones may bring dry spells or heavy rains/flooding across the country. Most of the extreme flood events are associated with tropical cyclones, for example, Eline (2000), Dineo (2017), Idai (2019), Chalene (2020-2021), Eloise (2021) and Ana (2022). Several studies from southern Africa have indicated that extreme hydrological events are increasing in frequency and magnitude (Goodess, 2013; Yanda, 2010). For example, the El Niño-Southern Oscillation effect has continued to strengthen in the previous decades (1900-2010) resulting in more severe floods (Manatsa et al., 2011). In recent years, the frequency of droughts and floods has increased owing to several factors such as climate change, deforestation and land-use changes (Davis-Reddy et al. 2017).

The occurrence of cyclones and droughts disrupt the livelihoods of communities living in the affected areas through the destruction of infrastructure, crops and livestock including deaths. For example, in 2019, the eastern parts of the country mostly Chimanimani and Chipinge districts were hit by tropical Cyclone Idai resulting in at least 172 deaths, more than 186 people injured and about 327 reported missing. The cyclone affected over 270,000 people across 9 districts in Zimbabwe with the majority in Chimanimani and Chipinge districts. In Chimanimani and Chipinge districts, 20,002 households (61.5%) or 100,106 people (74.2%) were severely affected by the loss of houses and livelihoods (Chanza et. al, 2020). Cyclone Idai increased environmental risks which made most communities in Chipinge district vulnerable to hazards. In addition to floods induced by cyclones and heavy rains, Chipinge and Chimanimani district were also affected by landslides, particularly in areas characterized by high elevation and steeper slopes. The landfall of cyclone Idai in 2019 resulted in the two districts experiencing landslides leaving a trail of destruction to infrastructure including deaths. The occurrence of hazards is being worsened by climate change, which is increasing the frequency of these extreme events, especially tropical storms and droughts as well as their intensity. These extreme events are worsened by the absence of and insufficient early warning systems in the country resulting in an acute threat to human security.

The University of Zimbabwe Department of Geography Geospatial Sciences and Earth Observation has actively participated in various activities in Chimanimani and Chipinge districts. The department carried out a landscape analysis for Chimanimani by assessing the potential climate change-related projects suitable for the district in a project supported by GEF Small Grants Project Operation Phase 6 under UNDP. Moreso, the department has carried out baseline surveys of climate change Impacts in the Chimanimani district under the Scaling Adaptation with a focus on the Rural Livelihoods Project supported by Oxfam and hence has in-depth knowledge of the area. In the aftermath of the devastating cyclone Idai in March 2019, the department in collaboration with various government departments carried out a GIS and remote sensing-based rapid assessment of the effects of the cyclone using unmanned aerial systems. This involved the use of drone technology to map the affected parts particularly, Ngangu, Rusitu Valley, Peacock and Skyline. On a project commissioned by the International Red Cross Society through the World Wide Fund for Nature (WWF), the department also carried out a spatial multicriteria analysis of suitable sites for the construction of Disaster Preparedness and Rescue centres in the two districts. This involved overlaying various biophysical and socio-economic layers and identifying the most suitable sites. Stakeholder consultations were carried out to validate the results of the GIS-based site suitability assessment as well as to get community buy-in before the final section of sites in the two districts. Thus, the current research extends and builds on previous work carried out in Chipinge and Chimanimani districts by the University of Zimbabwe, Department Of Geography Geospatial Sciences and Earth Observation. In particular, lessons learnt and results from previous projects were integrated with the *IPEED project* (*Integrated Protection, Education in Emergencies and Disaster Risk Reduction in multi-hazard areas of Chipinge and Chimanimani districts) implemented with funding from* DG-ECHO by Terre Des Hommes Italy.

The research was motivated by the observation that disaster risk reduction interventions often fail to produce the intended results and meet set objectives possibly due to a limited understanding of the nature and mechanisms driving natural hazards as well as the extent to which they affect different communities. Therefore, the main objective of the research was to develop knowledge products that contribute to and support national disaster management systems at central and community levels, reinforcing early warning and linking early warning to early action and building local capacities in preparedness and contingency planning The main aim was achieved through a comprehensive risk analysis and modelling to inform Disaster Preparedness and Disaster Recovery in the target areas.

The project had the following specific objectives:

i. Exploring the main hazards in selected wards is crucial to deepening our understanding of the relationship between community resilience and disaster risk perception.
ii. To execute a comprehensive risk analysis and modelling exercise to support hazard zonation;
iii. To determine the percentage reduction in vulnerability contributed by the IPEED project through the modelling of the total population in risk-prone areas.

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3 Materials and Methods

3.1 Study area

Chipinge and Chimanimani Districts are located in the eastern part of Zimbabwe in Manicaland Province. Chimanimani district traverses different agroecological regions from region I which receives the highest amount of rainfall (>1000mm) to agroecological region V which receives less than 450mm of rainfall annually. Based on the 2022 population and housing census report, the district has a population of 153,620 inhabiting an area of 3450.14 km^2 translating to a density of 44. 5/km² (ZIMSTAT, 2022). Of the total population in Chimanimani, 52% were females while 48% were males. Due to the rugged terrain in the district, the greater proportion of the population settles in valleys and steep slopes thereby making them vulnerable to, floods, and landslides. Similarly, Chipinge district traverses different agroecological regions from region I (>1000mm) to V (<450mm). As a result of this climate, the region is suitable for forestry plantations, banana, apples, macadamia nuts, coffee, and tea in addition to intensive livestock production for agriculture Approximately 70% of the population in Chipinge district rely on agriculture as the major source of livelihood which contributes to their food and nutritional security (Chifamba and Mashavira, 2011). The research targeted wards 3; 6;7, 16; 21; and 22 in Chimanimani and wards 5; 6; 8; 16; 20; 22; 23; 25; and 27 in Chipinge district pre-identified as most exposed to (seasonal) hazards droughts, floods and cyclones. The spatial distribution of the target wards is shown in Figure 1.

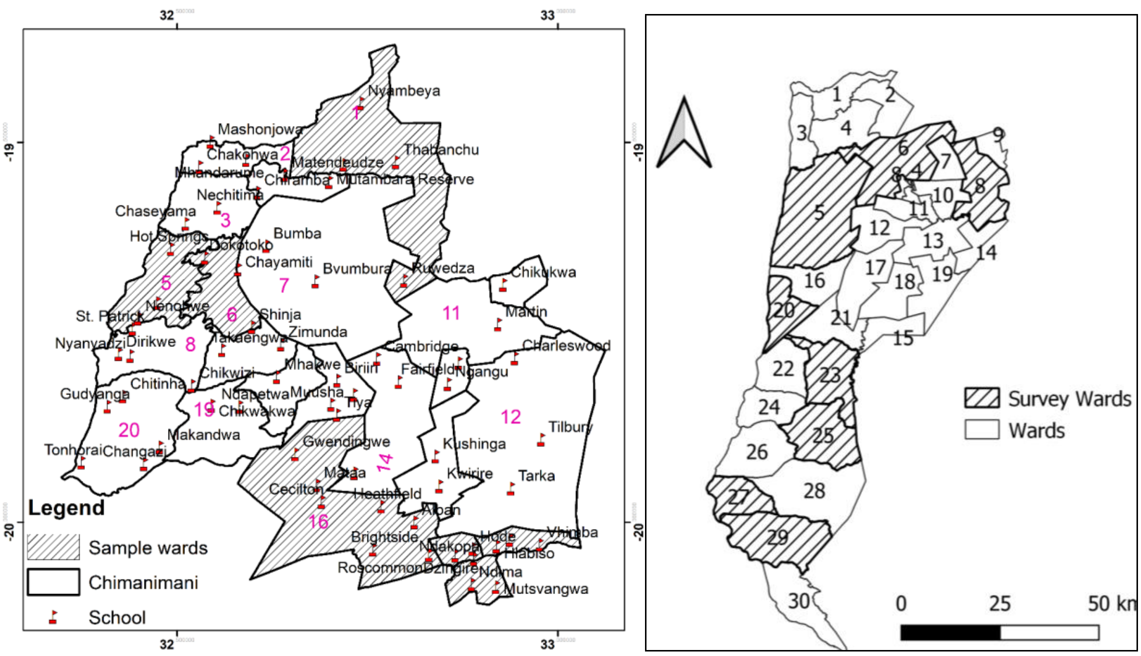

Figure 1: showing the Spatial distribution wards in the target areas where the research was conducted in Chipinge and Chimanimani districts

3.2 Data collection

3.2.1 Perception survey

The community perception surveys were carried out in wards 3; 6;7, 16; 21; and 22 of Chimanimani and wards 5; 6; 8; 16; 20; 22; 23; 25; and 27 in Chipinge (Figure 1) targeting 3000 households. In each ward, three age and gender-sensitive focus group discussions were conducted followed by an all-stakeholder feedback meeting at the district level to collect information on the perception of people towards hazards, the combination of disasters that leads to the highest impact on the target communities and how they cope with them in their respective areas. During the field survey, the following people were part of the discussions: One representative of the District Civil Protection team; RDC represented by the respective ward Councillor for the ward, DRR Focal Person (Teacher from local School), Extension Officer from AGRITEX, Representatives of the lead farmers and representatives of community stakeholders including CCWs and VHWs (See Figure 2). Information from the perception survey was used to identify suitable and effective messaging and means to disseminate early warning. In addition, the perception survey gathered information on optimal messaging of early warning information for influencing human behaviour, taking cognizance of traditional practices, norms and beliefs in these hazard-prone communities.

Figure 2: Some of the participants during focus group discussions for perception surveys.

3.2.2 Drone mapping

The drone mapping exercise started with preparatory work involving desktop studies to establish boundaries of the target areas and appreciation of the terrain to be mapped. After the boundaries of the selected sites were established, mission plans were established to guide the drone mapping exercise. A Real-Time Kinematic (RTK) connection was established between the RTK Base and the drone for improved location accuracy (Figure 3). The actual aerial mapping was then executed in 7 7-day period. The acquired high-resolution imagery completion of the aerial mapping exercise was used for identifying and characterising areas prone to different hazards. Specifically, high-resolution drone imagery was used for fine-scale mapping of flood-prone areas as a preamble to the development of early warning and alert systems.

Figure 3: Preparatory work for setting up an unmanned aerial system for mapping

3.3 Data analysis

Landslide susceptibility modelling

Maximum Entropy modelling (MaxEnt) (Phillips and Dudík 2008), a machine learning algorithm was applied to model landslide susceptibility based on eight conditioning environmental variables and landslide occurrence data collected across the two districts. These included slope, geology, elevation, soil type, distance from the river, landcover and topographic wetness Index. Table 1 provides a summary of the datasets used, sources as well as relevance in landslide modelling.

Table 1: Datasets used in modelling landslide hazard

Dataset	Source
Dem and its derivatives	https://earthexplorer.usgs.gov/
Soil	www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/en/
Geology	Geological Survey of Zimbabwe
Sentinel Data (used to extract locations where landslides occurred)	https://earthexplorer.usgs.gov/

The susceptibility of each mapping unit was defined as a function of conditioning factors and the spatial relationship between these factors and historical landslides. The MaxEnt technique was adapted to estimate landslide-prone areas by correlating observed landslide occurrences to biophysical covariates (Phillips and Dudík 2008). The landslide susceptibility assessment was performed on the assumption that future landslides are more likely to occur under similar conditions where past and present landslides occurred (Mandal and Mondal 2019).

Flood modelling

To understand flood occurrence in the two districts, the HEC-RAS v.6.0 software along with the ArcGIS extension, RasMapper was used for hydraulic simulations. To generate runoff, the Hydrologic Engineering Centre Hydrologic Modelling System (HEC-HMS) model was applied for the subcatchments and subzones as well as critical locations. Flow characteristics from HEC-RAS simulate depth, flow and velocity with time and location. The data required for steady uniform hydraulic modelling is primarily, topography, friction, boundary conditions and validation data. A Triangulated Irregular Network (TIN) was created from the high-resolution (SRTM 30m) DEM. Geometric layers such as the stream centreline, bank lines, flow path centrelines and cross-section cut lines were then created from the TIN and aerial photographs from Google Earth.

3.3.2 Drought modelling

Satellite-derived Vegetation Condition Index (VCI) was used to characterize drought occurrence in the district. VCI was chosen over other drought indices as it is one of the most used remotely sensed indices for drought and crop condition monitoring and has been successfully applied across several agricultural landscapes (Unganai and Kogan, 1998; Kuri et al., 2019; Kuri et al., 2020; Frischen et al., 2020). VCI provides near real-time data across spatial scales and overcomes the problem of a sparse network of meteorological stations that are characteristic of most developing countries such as Zimbabwe (Dhakar et al., 2013). The VCI was derived from 10-day NDVI composites from SPOT VEGETATION 1 and PROBA-V satellite at 1km spatial resolution. SPOT VGT data is available from the 21st of April 1998 up to the 31st of May 2014. PROBA-V Normalized Difference Vegetation Index (NDVI) data were used to fill the gap (1 June 2014 to 31 December 2018). NDVI is a spectral index derived from remote sensing data to estimate vegetation vigour and is closely related to drought conditions (Drisya et al., 2018). The data were accessed from the Flemish Institute for Research website (http://www.vito_eodata.be).

3.3.1 Validation of risk perception by communities

Hazard risk maps generated through geospatial modelling were validated through community perception surveys. The maps were also complemented with data derived from secondary sources such as published literature, and reports by various institutions especially in the aftermath of Cyclone Idai.

4.0 Results and Discussion.

4.1 Natural hazards identified by communities in Chimanimani and Chipinge districts

In Chipinge district, the most frequently occurring hazards in order of intensity and geographic extent are droughts, floods, cyclones, human diseases, landslides and heavy winds (whirlwind winds). In addition, earth tremors, heat waves, fires and human-wildlife conflict were identified as threats to human lives and livestock. For Chimanimani District, the most frequently occurring hazards in order of intensity and geographic extent are droughts, cyclones, floods, landslides, and strong winds (whirlwinds). Other hazards include earthquakes, pests, and human diseases such as malaria, typhoid and Covid-19 (table 2). Despite being confined to a few wards, livestock diseases and human-wildlife conflicts tend to significantly affect human lives and their livelihood.

Table 2 shows Natural hazards identified by communities in Chimanimani district

	Chipinge	**Chimanimani**
Hazard	**Wards affected**	**Wards affected**
Droughts	1, 3, 4,16, 17, 18, 20, 2324, 25, 26, 27, 28, 30,	2,3,4,5,6,7,8,9,12,13,18,20, 22, 23
Floods	3, 5, 16, 20, 21, 22	21,22,13,23,5,16,20,18
Cyclones	3, 4, 6, 19, 27, 24, 26, 15, 10, 14, 21, 22, 12, 9, 16	21,22,16,23,13,12,5,15,20
Human-wildlife conflicts	3, 4, 5, 16, 20, 21,28,29,30	21,22,23
Heavy winds	16,20,21, 22,23,24,25,26,27,28,29,30	13,21,22,6
Landslides	2, 6,7,8,9	23,22,16,21,17,15,13, 12
Fire	9,1,2, 13	15,1,14,11,18,12,13
Disease Epidemics	5,9,12,15,16,19,21,22,23,24,25,26,27,28, 29,30,31	22,21,13,16
Lightning	7,10,22,23	
Pest		21,22,23
Excessive rain		23,22,21
Earth tremors/ Earthquakes		21,22,23

These hazards at times occur singly but in most cases occur in combination hence making much of the district prone to multi-hazard (table 2 and Figure 1&2). The common disease epidemics that occur in the different wards of Chipinge district include malaria, cholera and diarrhoea. In terms of malaria, wards in the lower part of the district which experience high temperatures and low rainfall are most susceptible and hence most people in these areas are severely affected. Cholera and diarrhoea are water-borne diseases associated with floods and cyclones. Strong winds associated with whirlwinds are also common in the area. An emerging challenge that exacerbates the impacts of different hazards such as droughts and floods is human-wildlife conflicts. Most people in the western part of the district are affected by wild animals that come from Chipinge Safari area and Save Conservancy. In Chimanimani districts, respondents indicated that previously, natural hazards such as cyclones, droughts floods, landslides, and strong winds (whirlwinds) used to occur once in five years. Although perceptions on the frequency of occurrence of natural hazards differed among FDGs (1-3 years), there was consensus that droughts, cyclones, floods and wildfires are now occurring annually with the frequency having increased after Cyclone Idai. Similarly, earthquakes were a rare phenomenon in the district, but their frequency has increased to almost 1 in 5 years.

4.2 Temporal pattern of hazards in Chipinge District

In most wards that were visited, hazards are a seasonal phenomenon while wildfires and floods occur once every two years (table 3). A key observation was that human-wildlife conflict was noted as a daily problem because during the rainy season, wildlife destroys people's crops and the main problem animals are elephants, buffaloes, and other antelopes. During the dry season, livestock in the area is affected by lions, and hyenas so the communities are always in danger of these animals.

Table 3: Frequency of occurrence of different hazards in Chipinge District

Hazard	**Occurrence**
HWC	Daily
Floods	Every season
Cyclone	Every season
Heavy winds	Every season
Droughts	Every season
Landslides	Once in 3years
Strong winds	Every season
High temperatures	Every season
Human Diseases	Every season
Wildfire	Once in 2 years
Floods	Once in 2 years
Road accidents	Periodically

4.3 Elements at risk of different hazards and severity of impact:

During the focus group discussions, participants were asked to identify the elements at risk of hazards as well as rank them in terms of severity of being affected. Table 4 shows the elements at risk and the number of times the element was identified as being affected by the hazards. From the discussions, it was observed that droughts negatively affect crops and livestock including water resources. Floods damage roads, bridges, and infrastructure such as schools and health facilities. The problems associated with human-wildlife conflicts include the destruction of crops and the loss of livestock.

Table 4: Elements at risk of different hazards and severity of impact

		Chipinge	**Chimanimani**
Hazard	**Elements at risk**	**Ranking (Frequency of being affected)**	
Droughts			
	Crops	25	48
	Livestock	35	29
	Humans	35	49
	Water resources	7	Undefined

		Chipinge	Chimanimani
Hazard	**Elements at risk**	**Ranking (Frequency of being affected)**	
Floods	Irrigation Infrastructure	5	3
	Roads	7	21
	Houses	17	30
	Schools	18	24
	Cropping land	2	
	Bridges	17	
	Health facilities	10	
HWC	Crops	11	
	Livestock	17	
Cyclones	Transformers	1	
	Mobile network Infrastructure	5	
	Bridges	17	
Heavy Winds	Schools	18	
	Health facilities	10	
	Houses	17	

4.4 Level of preparedness of communities for natural hazards

Chipinge District: Participants were asked to indicate their level of preparedness based on how they responded to previous natural hazards. Results from the survey illustrated that the greater part of the communities (59%) indicated that they were not prepared to deal with natural hazards that occur in the district due to resource constraints. Eight percent (8%) of the FGDs had about 50% and 30% level of preparedness while 25 % indicated that they had a 10% level of preparedness.

Chimanimani District: Participants were asked to indicate their level of preparedness based on how they responded to previous natural hazards. Results of the survey illustrated that 30% of the community was not prepared to deal with natural hazards that occur in the district due to resource constraints. Five percent of the FGDs had about a 5% level of preparedness while 15 % indicated that they had a 10% level of preparedness. Generally, there is a low level of preparedness across the district as indicated by less than 50% preparedness suggesting the need for strengthening community response to disasters. This could be done through awareness and training, and even increasing the revenue streams which provide communities with better coping mechanisms e.g., construction of strong infrastructure or procurement of food during drought periods.

4.5 Drivers of Vulnerability

The study survey also sought to determine the possible reasons why different communities were severely affected by different hazards (Figure 4). The majority of the people cited poor housing structures as a major reason for the collapse of houses during periods of heavy rainfall and floods. This included the material used and putting stones on top of rooftops in the belief this would make the structures stronger. Building houses in low-lying areas was also cited as Houses in low-lying areas also increased the vulnerability to floods.

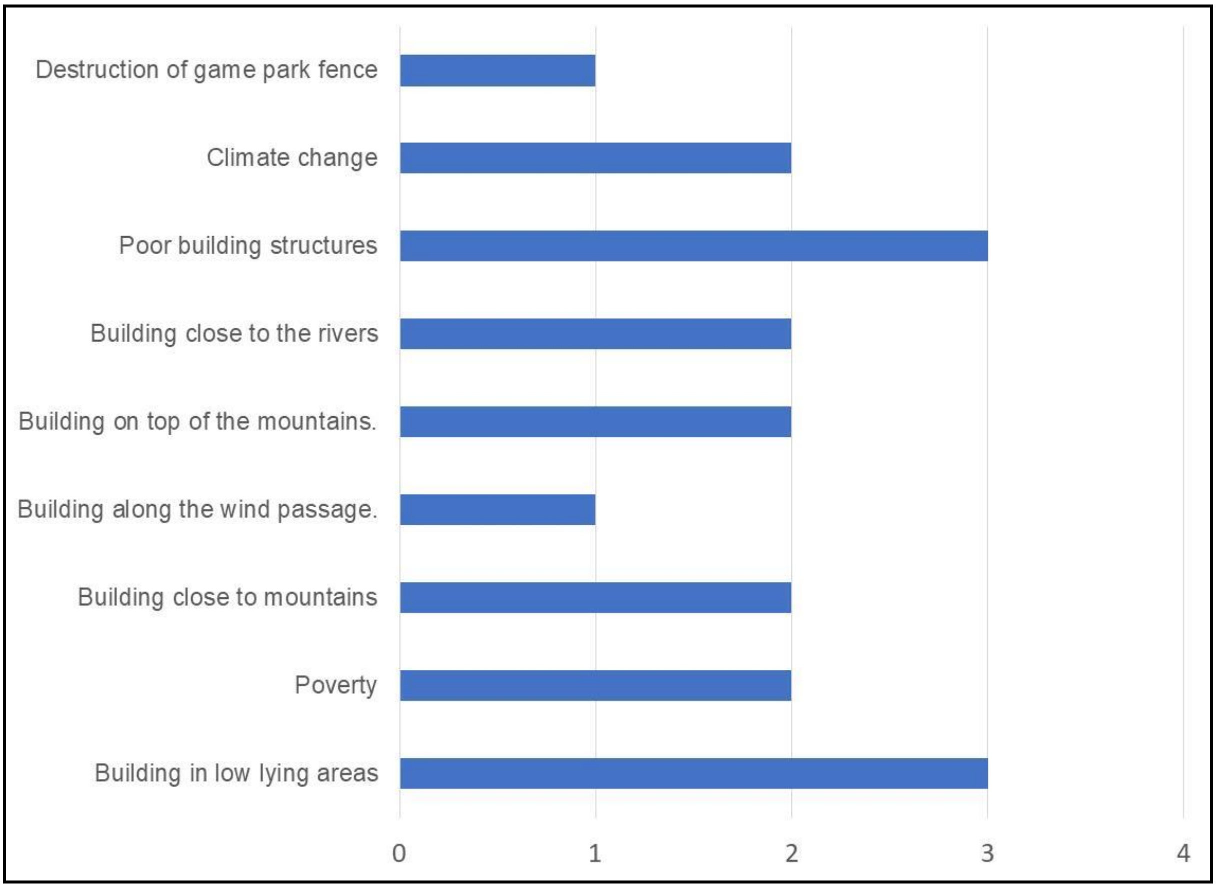

Figure 5: Determinants of Vulnerability to different hazards

4.6 Coping mechanisms

During the FGDs participants were asked to indicate the coping measures which they used to reduce the adverse effects of the different natural hazards. In this case, the objective was to understand the ability to manoeuvre, absorb, accommodate, and recover from natural hazards. It was highlighted that communities adopt several strategies to deal with specific hazards that affect them from time to time (Table 5). During a natural hazard, households in the district adopt multiple coping strategies that include securing roofs with heavy stones when there is a threat of a cyclone and heavy winds. Communities seek casual jobs, rely on donor support, and community support and sell livestock, fruits, and firewood to cope with multiple hazards that occur in their district.

Table 5: Coping strategies adopted by communities to deal with natural hazards

Hazard	Coping strategies
Drought	Piece jobs including, Domestic work in the Tongogara refugee camp Eating bananas and adjusting the number of meals eaten per day Fishing Food aid Casual labour Hunting and gathering Selling fruits Moulding bricks for sale Crossing the border to find employment (South Africa and Mozambique) Basket and mat weaving Eating porridge in the morning to save maize meal Poaching
Cyclone/Flood	Moving away from low-lying areas to higher ground Moving to evacuation centres Construction of strong infrastructure Community support Using shouters to warn people Design roofs that withstand strong winds (Parapet roofs) Donor support
Strong wind (Whirlwind)	planting hedges surrounding homes Place stones on rooftops Construction of parapet houses
Malaria	Filling holes with stagnant water Use of traditional methods to chase mosquitoes away

4.7 Institutional support during disasters

Figure 6 illustrates the proportion of sampled communities who receive assistance from various institutions during disasters. Results showed that most people received assistance from Non-governmental Organisations (46%) and the Government (23%) during disasters. Apart from these institutions, communities also revealed that the local community receive help from local members of parliament. For instance, during cyclone Idai, multiple institutions were involved in assisting cyclone victims through search and rescue operations, searching for and retrieving bodies as well as burying the dead. In addition, several organisations provided shelter, food, emergency health services, water and sanitation, and socio-psycho support among other critical interventions. However, the sampled communities feel that these institutions should do more to support them, for example by training communities to assist themselves through such time.

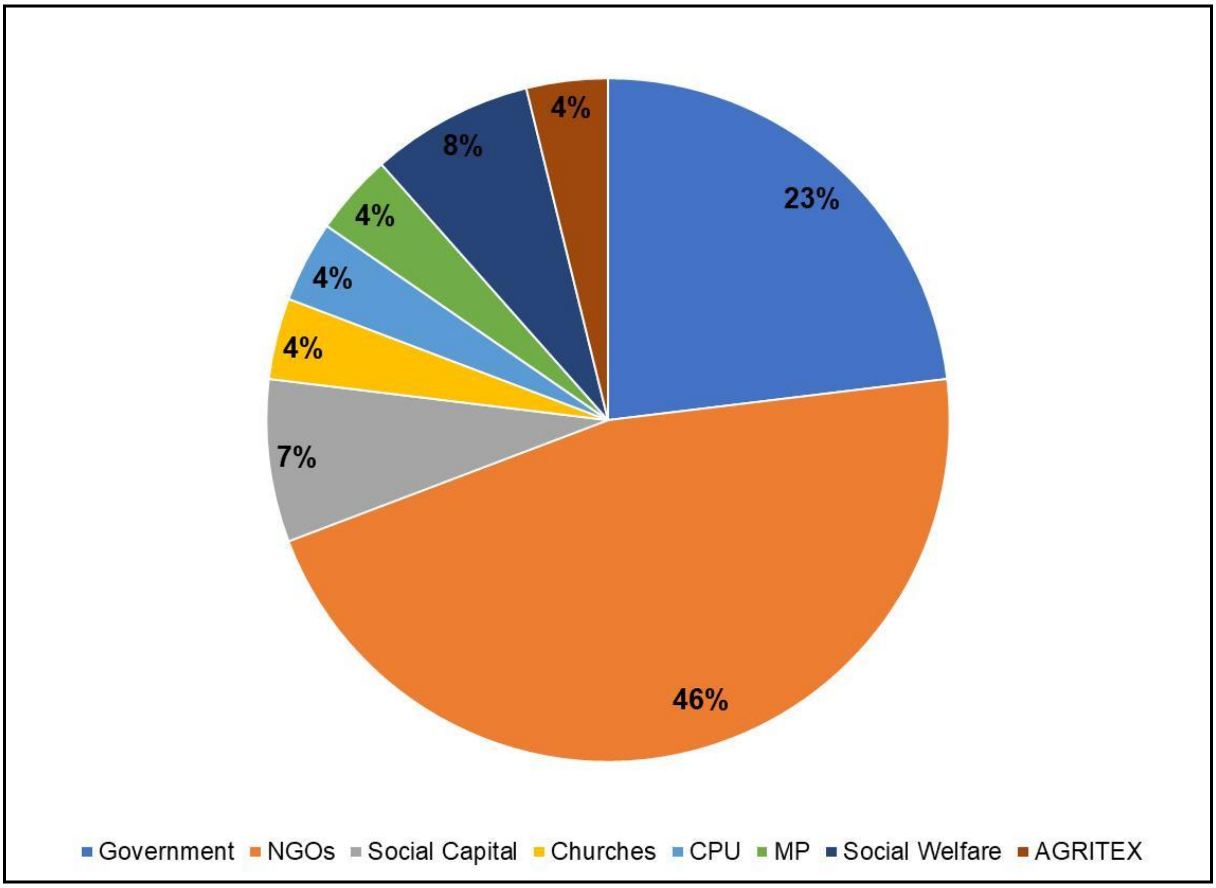

Figure 6: Percentage of the community receiving support from different institutions during disasters

When asked about whether they were satisfied with the different interventions during disasters, communities reported that they were generally not satisfied with interventions made by different players in addressing the negative impacts of natural hazards especially in the aftermath of Cyclone Idai. The communities indicated that they expect to get assistance as they are still recovering from Cyclone Idai. More so the community indicated that the assistance they were getting from NGOs was usually not enough for everyone and also different NGOs would avail aid to the same people because they come with aid specifically meant for certain categories in the community.

4.8 Ways of increasing community resilience to disasters

Participants suggested several ways through which the resilience of different people to disasters can be enhanced. In the drought-prone parts of the district, the construction of additional dams and the drilling of boreholes for irrigation were identified as key interventions for increasing community resilience to drought spells that occur during the growing season. For the existing dams, de-siltation was identified as an important strategy for increasing water storage and supply. In the event of a drought communities insisted that food must be distributed to everyone affected not just a selected few as this is not reducing food insecurity in the district. In addition, AGRITEX could assist farmers in planting traditional grains such as rapoko, millet and sorghum, especially given the unreliable rainfall patterns coupled with an increase in midseason dry spells. Participants indicated that communities are aware of the need to construct strong and durable houses and schools but cannot afford them due to limited sources of money. Thus, they requested the government and its partners to support communities in building better and stronger infrastructure including bridges, clinics, and schools. Given the recurrence nature of cyclones and floods in the district, communities suggested the construction of safe shelters with at least one per ward. It was also noted that the government could help communities establish income-generating projects such as poultry, piggery, and beekeeping to increase revenue streams to support coping and adaptation strategies. The main coping strategies of households include diversifying livelihood strategies, intensifying agriculture and finding off-farm employment. The high population growth rates mean land holdings are shrinking in size and land productivity is decreasing, thereby resulting in increasing poverty and out-migration.

4.9 Mode of communicating warnings

Different modes of communication are used to relay information on anticipated hazards in the districts (Figure 7). Most of the early warning is accessed through radios SMS messages over the phone and also on TV. The same messages are also passed to some members of the community through social media. In addition, there are some community structures e.g., Disaster Risk Reduction Committees, Department of Civil Protection, AGRITEX officers, and local leadership. However, the communities indicated that not every household in the district has a radio, television, or cell phone thereby making it difficult for some members of the community to access the early warning.

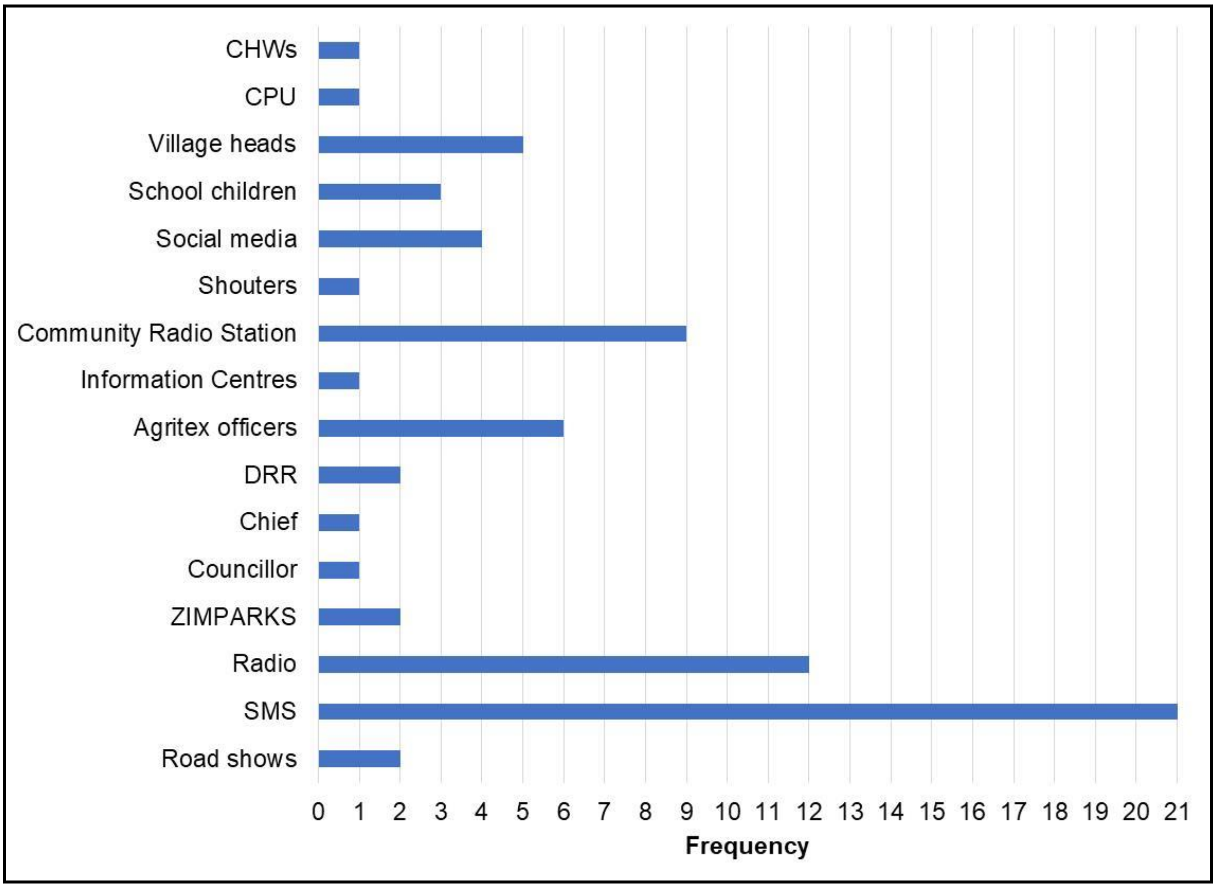

Figure 7: Preferred method of communication of early warning for hazards

In addition, the mobile network coverage is poor and in most cases, the network will not be available for days. Although communities get early warnings through radios, they highlighted that the communication needs to be localised to make it relevant and effective. Furthermore, it was also indicated that communication must be sent out early to communities likely to be affected to provide timely response to warnings. However, there is a need to tailor these warnings by making sure that communities fully understand the implications of the warnings and what they are expected to do in the event of a disaster. Thus, improved access to relevant information related to early warning will likely reduce the vulnerability of communities through providing advice on disaster response strategies, coping and even adaptation strategies

4.11 Priority interventions

During the survey, communities were asked to prioritise interventions in managing natural hazards in the district. The communities identified increasing and improving network coverage, the establishment of community radio stations, reconstruction of destroyed infrastructure as well as food aid as key priority interventions that would help communities recover from recurrent hazards and build back better. Lack of communication network was cited as the key barrier to dealing effectively with hazards. Enhancing early warning systems, increasing awareness campaigns, and provision of piped water were also identified as priority interventions. To ensure that these interventions are effective there is a need to ensure that institutions involved in disaster risk management systems have adequate technical, financial, and logistical capability.

Lessons learnt from the Project

i. **The use of geospatial technology in disaster risk reduction should be enhanced at all levels.**

Unmanned aerial vehicles were successfully used to acquire high-resolution imagery and point clouds that were used to generate high-resolution contour lines of up to 50cm intervals. These were generated along selected segments in the flood plains of Chipinge to guide the installation of gauging stations as well as developing flood alerts. Geospatial modelling was used to characterise flood and drought risk including landslide susceptibility in Chipinge and Chimanimani (Figure 8). The outputs were validated during risk perception surveys and then later developed into land use zonation maps to guide spatial planning.

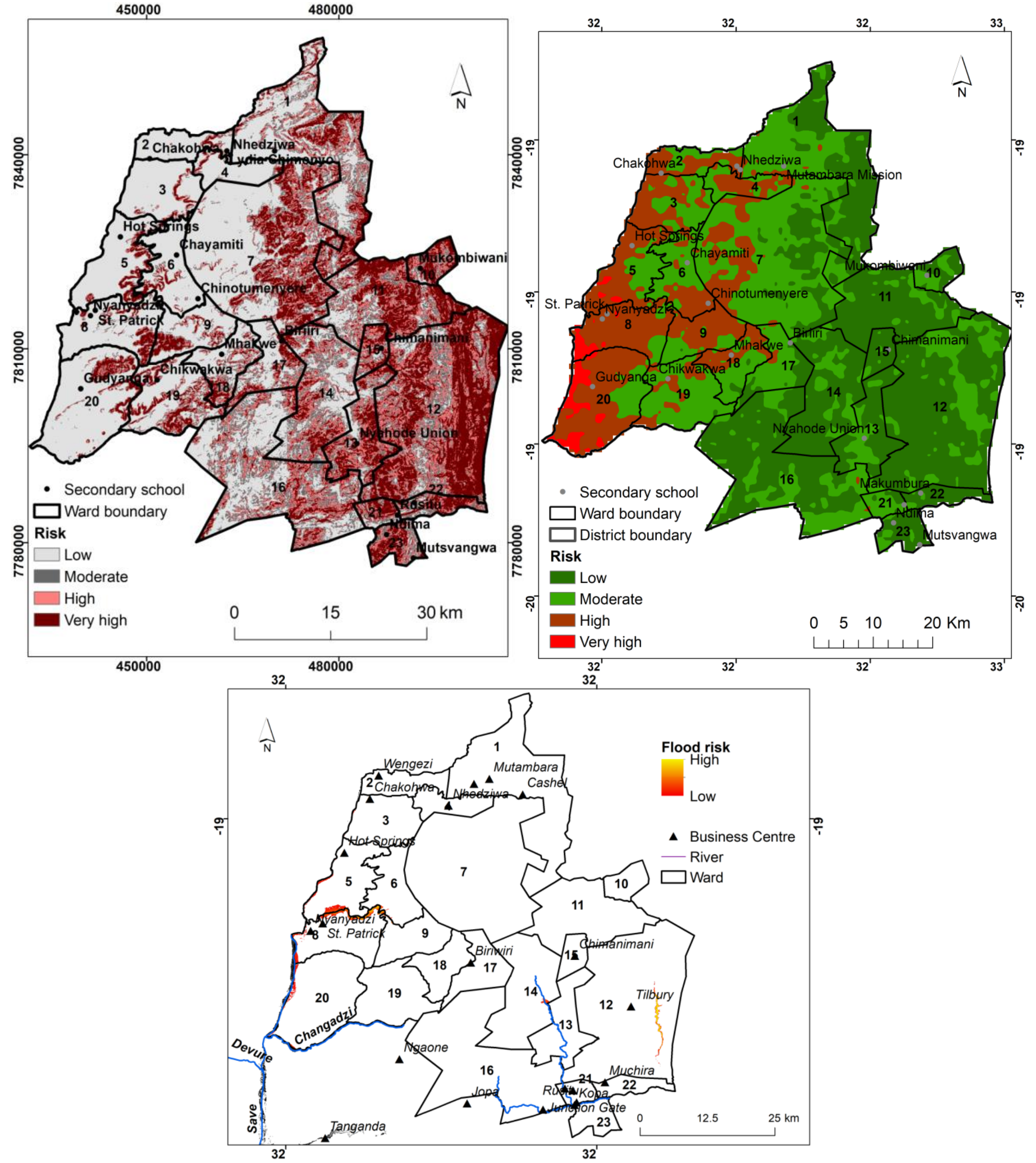

Figure 8: Spatial variation in Landslides (Upper left), Drought (Upper right) and Floods (Bottom) hazard in Chimanimani district

A similar approach was also used in Chipinge district to characterise the susceptibility of the district to drought, landslides and floods (figure 9).

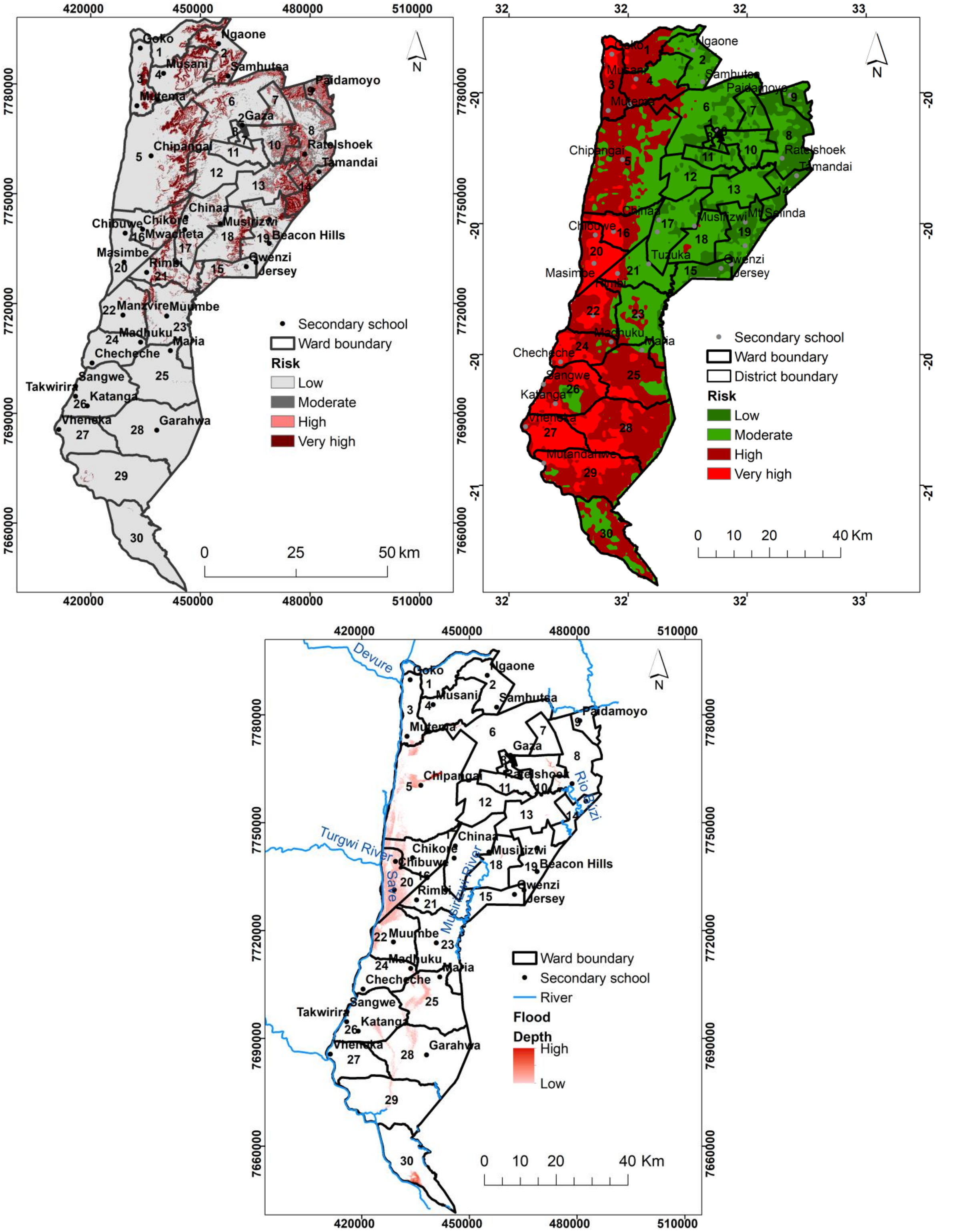

Figure 9: Spatial Distribution of landslide susceptibility (upper left) Drought risk (Upper left) and flood risk (bottom) in Chipinge District

Drought risk and population at risk in Chimanimani District

The results of overlaying the drought risk map and the population likely to be affected are illustrated in Figures 10 and 11. It can be observed that approximately 11% of the households fall in the low drought risk category while 35% of the households are within the moderate hazard category. About 30% and 24% of the households are within the high and very high drought risk category, respectively.

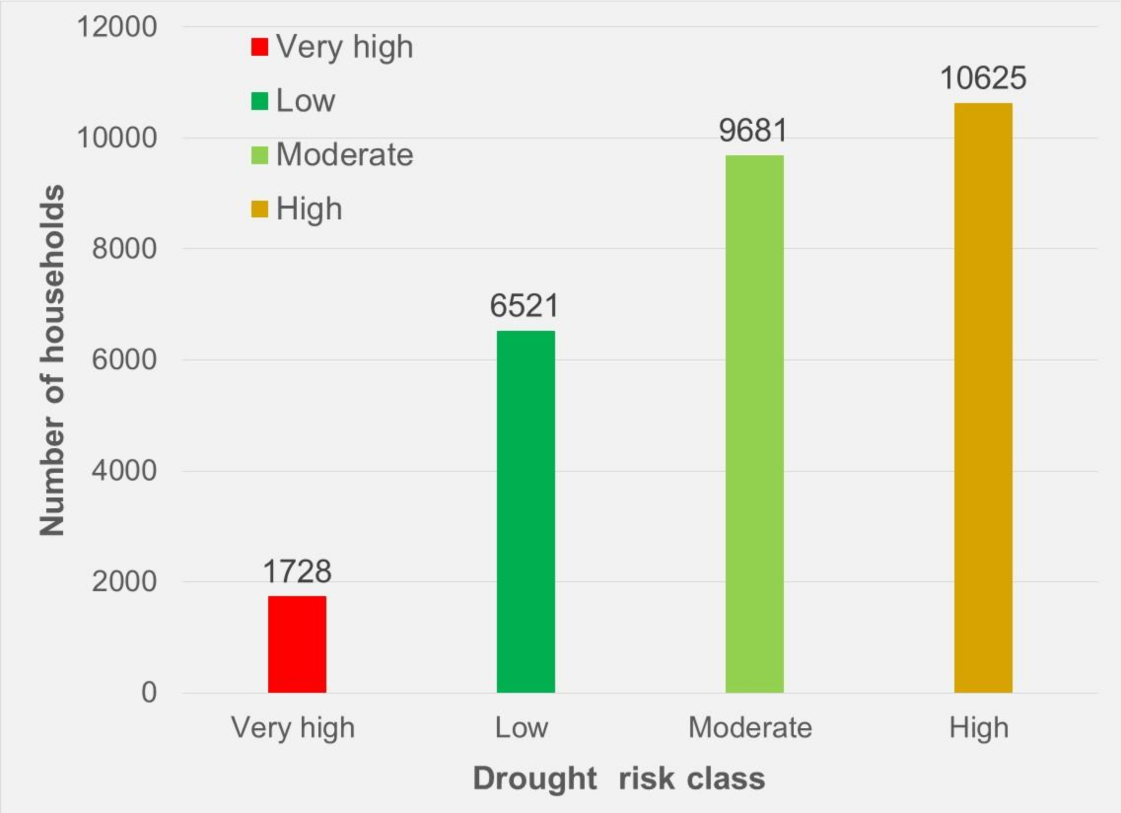

Figure 40: Number of households exposed to different drought categories across Chimanimani District

At the ward level, results of drought risk assessment show that drought risk varies significantly across wards in the district with wards 5, 8 and 20 having a significant proportion falling in the very high-risk category (figure 11). Of these wards, ward 20 seems to be the most affected by severe drought episodes. Unlike the very high drought risk category which is confined to fewer wards, the high risk drought class is widespread covering wards 1 to 9 and 16-20. These high to very high drought-risk areas are mostly confined to the western and southern parts of the district. These areas are mostly in the leeward side which is the rainshadow of the eastern highlands so they are affected by the orographic nature of the rainfall that falls in the area. Rainfall falls on the windward side while hot dry air descends on the leeward side of the mountains resulting in little or no rainfall. The impact of these droughts on local communities has been devastating, especially for small-scale farming and food availability. In contrast, households within the eastern and northern parts of the district are in low-risk areas and are largely in agroecological zones I and II, which are wetter and generally more suitable for farming activities.

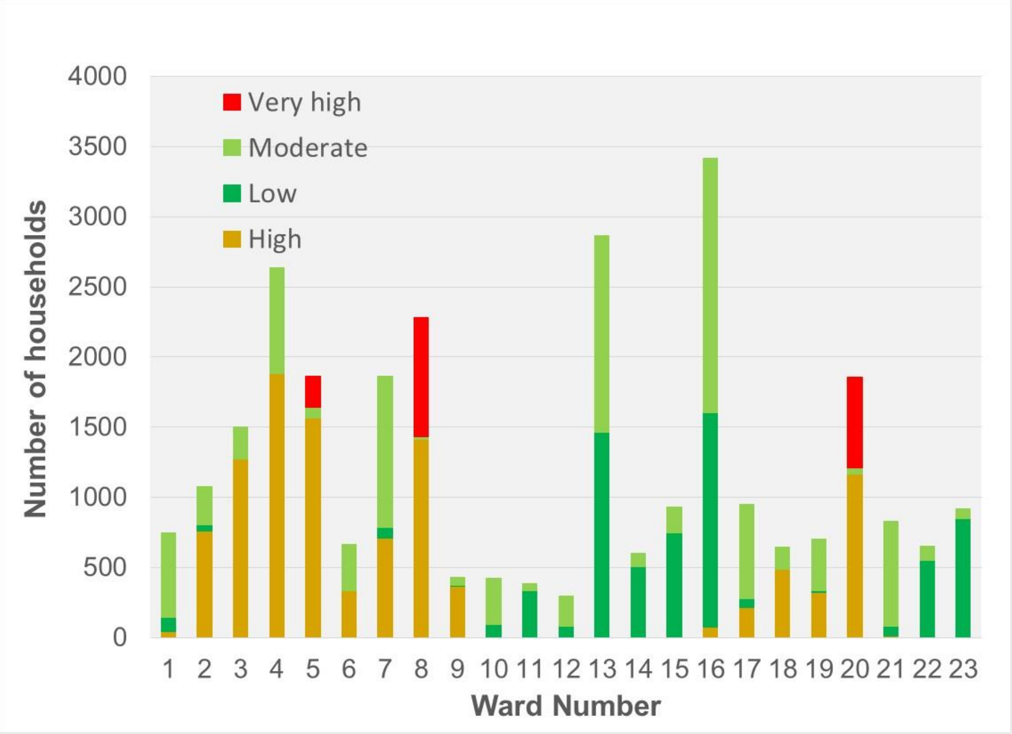

Figure 11: Number of households exposed to different drought risk categories across wards of Chimanimani District

Landslide Susceptibility and population at risk in Chimanimani District

Results of landslide zonation in Chimanimani district indicate that a larger proportion of the population is in the low-risk areas (figure 12). A limited number of households (<5000) are distributed across the moderate, high and very high categories of landslide susceptibility in the district (figure 12).

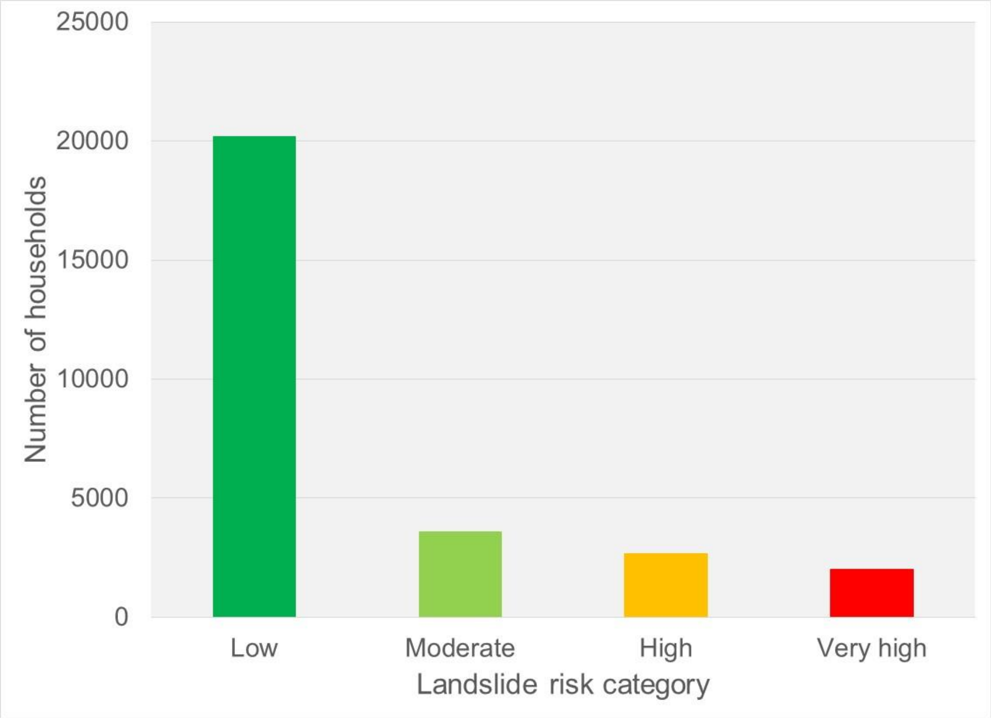

Figure 12: Number of households exposed to different landslide categories across Chimanimani wards

The distribution of households in the different landslide susceptibility categories across the district is shown in Figure 13. It can be observed that a large proportion of the households across the wards in the district lie in the low to moderate category of landslide susceptibility. Specifically wards 1-9, and 16-20 which are dominated by the low-risk category have a large proportion of the population in the low susceptibility category (13). In contrast, wards 13, 15, 16, 21-23 are characterised by all four categories of landslide susceptibility (Figure 13).

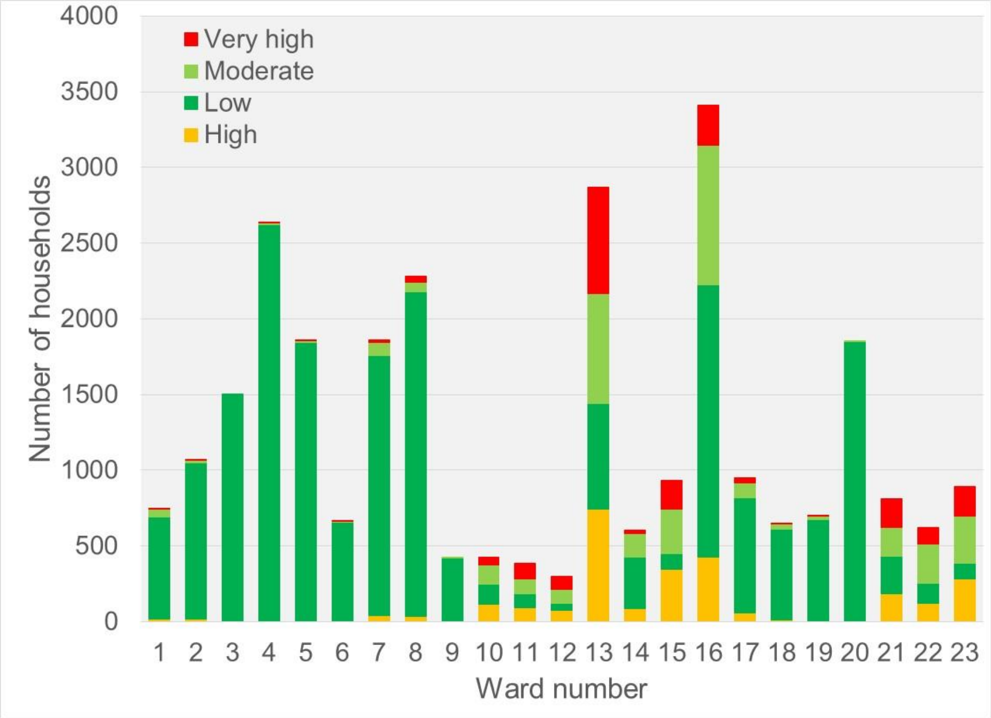

Figure 13: Number of households exposed to different landslide susceptibility categories across wards of Chimanimani district

The results of landslide susceptibility modelling indicated that Chimanimani district has the largest area that is highly susceptible to landslides while the larger part of Chipinge district has low susceptibility.

Chipinge District

Figure 14 shows the drought risk at the district level according to the drought severity classes: low, moderate, high, and very high. The moderate drought risk class is the most prevalent in the district with 35% of the households exposed to this drought risk category. The high to very high risk categories are the next most prevalent drought risk categories affecting 30 and 24% of the households, respectively. Only, 10% of the district falls in the low drought risk category.

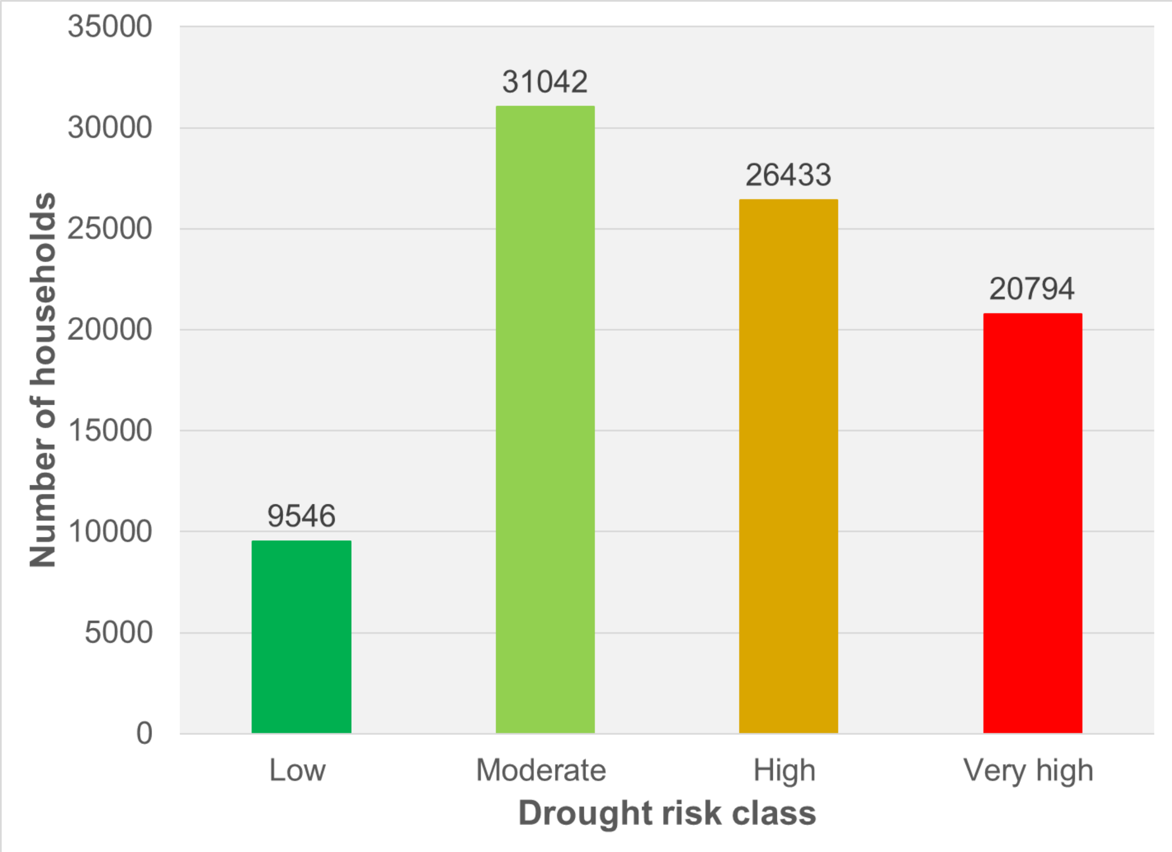

Figure 14: Number of households exposed to different drought categories across wards of Chipinge District

The variations in drought risk at the ward level show marked differences in the households exposed to different drought risk categories. For instance, households in the southern and western parts of the districts are largely within the high to very high risk drought category constituting more than 53% of the households in the district. When the households in the moderate category are combined with those in the moderate drought risk category, it is observed that close to 90% of households are at relatively high risk of drought. This is because the bulk of the district is in the rain shadow area, thereby resulting in little or no rain received in these areas. It is therefore not surprising that the western and southern regions of the district lie wholly in Region V(a) of the revised Agroecological regions. As the district is predominantly dependent on rain-fed agriculture, these results have serious implications for the agriculture sector as well as livelihoods dependent thereon.

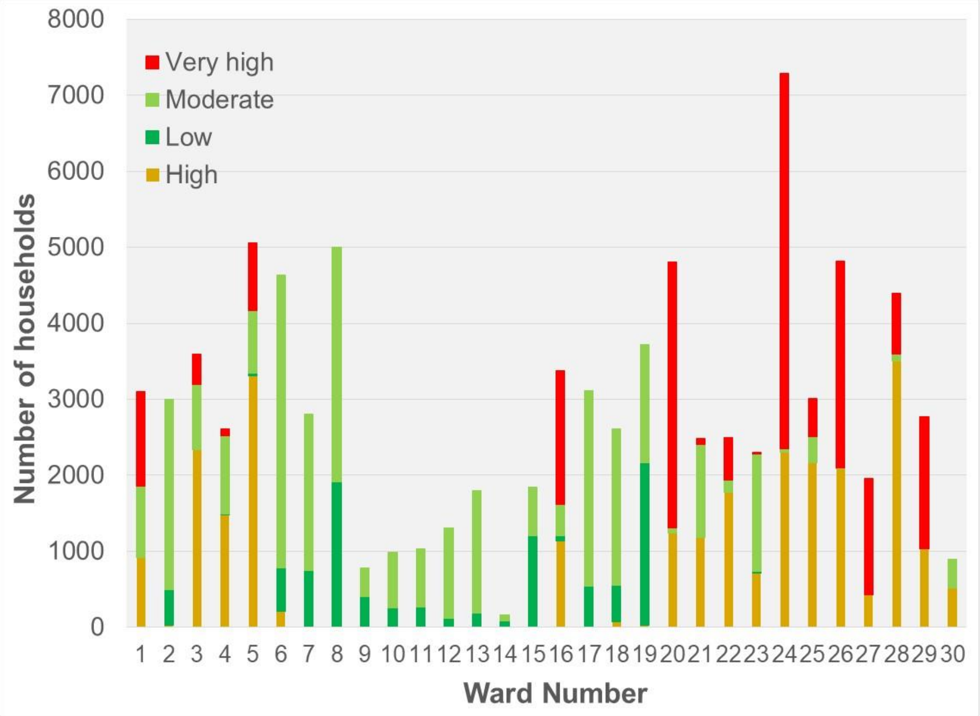

Figure 15: Number of households exposed to different drought risk categories across wards of Chipinge District

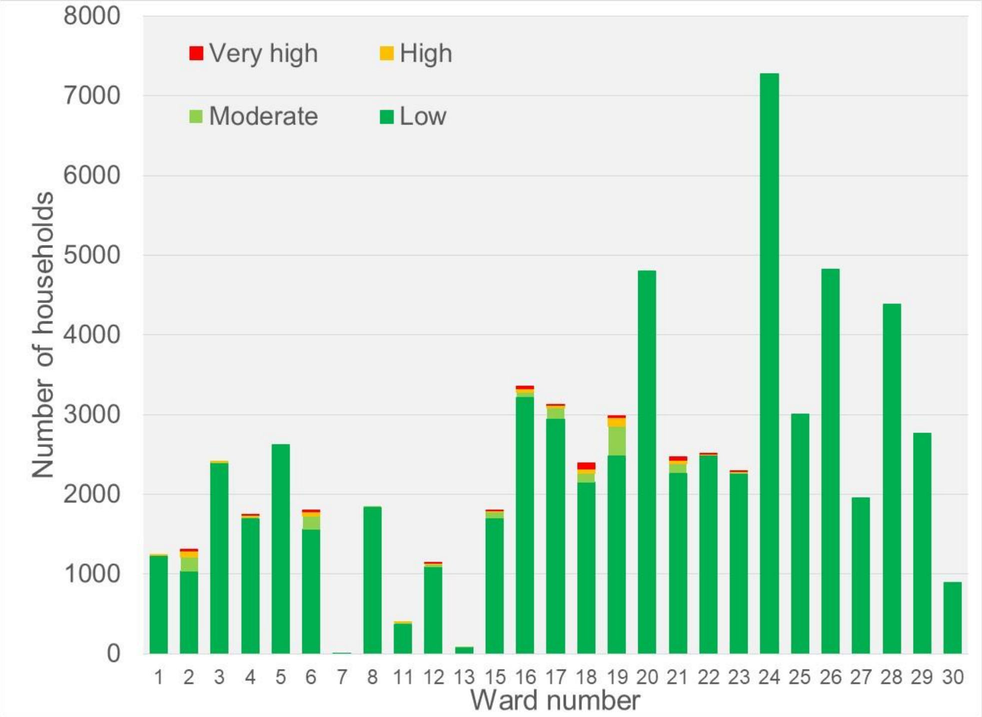

Figure 16: Number of households exposed to different landslide susceptibility categories across wards of Chipinge district

Mitigation measures through project activities

The consortium-initiated interventions aimed at improving and enhancing the capacity of 33 548 (13 889 Males, 19 659 Females) individuals in Chipinge and Chimanimani to be able to deal with shocks and stresses associated with climate-related hazards such as floods. The beneficiaries were targeted as 21 916 (9862 Males, 12054 Females) who included school learners from the 2021-, 2022- and 2023- exam classes selected from the wards targeted by the intervention. There has been an improvement in the knowledge capacity of district-level stakeholders, communities, and school learners due to the capacity-building exercise done in partnership with CARE, ZRCS, and Practical Action, where communities received training and integrated training with indigenous knowledge systems for sustainability. The involvement of communities in the strengthening community-based observatory network, community surge response groups, ward-based DRR communities, and school-based DRR clubs show how communities are now prepared to take a stand against climate-related hazard risks. Information has been amplified to reach communities and schools through telecommunication industries, community-based radio stations (like Ndau FM, Vemuganga FM and Chimanimani FM), community sensitisation campaigns and meetings, school learner engagements through assembly sessions amongst other methodologies that have been utilized by the intervention.

Activities to strengthen early warning systems at the district level have also been done. The consortium

i. Establishing local observatory and forecasting equipment for meteorological indices to improve drought and flood monitoring and early warning through the installation of an Automatic weather station at Mutambara High in Chimanimani and Mt Selinda High in Chipinge District.
ii. Establish a local hydrological observatory network and risk alert systems along the flood-prone Save Valley sub-catchment area. Through the installation of hydro-gauging stations in the form of beacon markers on 3 sites in the low-lying areas along the Save River tributaries (bridges) and data loggers were installed on the following rivers: Tanganda Bridge (E195), Dewure (E118) and Nyautsa Bridge (E194) by ZINWA
iii. The setting of warehouses of 300m^2 capacity at Bumba Ward 7, Chimanimani District and Kondo Ward 16, Chipinge District to improve district-level logistics with partners and the government prepositioning NFIs for emergency response.
iv. Capacitate district and community structures on mainstreaming protection-sensitive disaster preparedness and climate change into development planning, strengthening the Contingency planning and district-level DRR planning.

The support of district-community-school level DRR activities resulted in

- increased disaster risk reduction (DRR) knowledge for district stakeholders, community members, learners and teachers.
- increased participation of community members, learners, and teachers in raising awareness on DRR issues at schools and surrounding communities through evacuation drills, flood awareness campaigns, community radio disaster preparedness sessions
- increased participation of communities in planning and acting against hazards which they are prone to before they become disasters in support of the district endeavours.

4 Development of triggers for emergency response based on the results

TDH and its consortium participated in the development of threshold triggers at the district level. Through the hydro-gauging stations installed by ZINWA, threshold figures for flooding in the target wards have been calibrated on the data loggers. The equipment automatically sends messages to the community representatives and ZINWA whenever the communities downstream are threatened by floods. Similarly, the automated weather stations installed by the Meteorological Services Department (MSD) to increase the network density will assist in providing data used for predicting weather which will improve seasonal forecasts. The overall objective is to have weather alerts generated that will help communities to understand weather patterns. Hazard risk assessments resulted in the ranking of wards in the two districts according to susceptibility to flooding, drought and landslides. An Inter-agency approach facilitated by the DCP has helped incorporate the number of people likely to be affected per each ward along with the infrastructure threatened in the contingency plan. This information is also accessible to all partners in the district and is key to disaster preparedness and emergency response. The district has also calculated the required NFIs required for prepositioning in the district warehouse based on the modelled population at risk allowing partners to contribute toward that capacity. Throughout the project period, yearly contingency and DRR plans have been reviewed regularly to foster a culture in which communities contribute to its development.

6. Conclusion

The results of the study showed that communities in the focal districts are aware of the hazards that affect their areas and the factors that increase their vulnerability to disasters. A key factor that was identified during the perception surveys is the issue of poor housing structures which results in the buildings collapsing when there is excessive rainfall. In this regard, there is a need for local authorities to enforce building standards so that people build back better to increase their resilience to hazards such as floods. Another issue that reduces the effectiveness of early warning systems is the mode of communication. During the perception surveys, short messages and community radio stations were identified as the most preferred and accessible mode of communicating impending threats. Communities have their traditional ways of dealing with disasters hence there is a need to infuse community-based early warning systems with scientific evidence to enhance effectiveness. Primary and secondary school students are negatively affected by disasters hence the need to penetrate these schools with information and capacitate both the teachers and the learners on DP to increase their level of awareness.

Results obtained from this project illustrate the importance of integrating geospatial technologies, indigenous knowledge systems and scientific research in generating practical and strategic information that guides intervention in disaster risk management. Improved understanding and management of hazards across different landscapes is achievable through working partnerships between research institutions and field practitioners. This is critical in ensuring that research is not only relevant to but is usable by the intended communities. There is thus a need to strengthen such partnerships and take advantage of the vast opportunities offered by advances in geospatial technology in disaster management. Lastly, community involvement is key in the development and validation of proposed interventions as it guarantees acceptance and embrace by the local communities and beneficiaries.

7. Recommendations

Strategically, Zimbabwe needs to invest in space systems and technologies to ensure timely response time to disasters to minimize loss of lives and property damage. In the aftermath of Cyclone Idai (2019), several organizations were active in the two districts of Chimanimani and Chipinge with each organisation focusing on their area of interest. The organisations were working in silos and there was minimal sharing of information. To enhance the impact of interventions, there is a need for organizations to work collaboratively in the same area so that the impact of the projects can be felt by communities. It is recommended that the government of Zimbabwe make sure that data is shared among different actors to avoid situations where baseline surveys are carried out in areas where other organisations already have the data.

Future interventions are also recommended to utilize the following findings.

- Disaster risk interventions should be based on field data so that they are tailored to suit local conditions; including infusion of scientific research and indigenous knowledge systems to enhance the effectiveness of disaster risk reduction interventions;

- The use of geospatial technology in disaster risk reduction should be enhanced at all levels;
- Feedback workshops are important for the validation of generated products and for creating a shared understanding of project outputs which prepares local leadership and communities to deal with disasters;
- Considering that, droughts were mentioned, as one of the major hazards in the survey, there is a need to capacitate communities in Chimanimani to prepare for such a yearly hazard. There is therefore need to capacitate communities with income-generating projects and, irrigation schemes to enhance food security and generate income to fight poverty and reduce early child marriages that some villagers are resorting to for survival.
- School-going children were identified as being at the highest risk when disasters like cyclones and floods occur. This is mainly because the road network, bridges and school buildings are destroyed thereby making learning impossible. To this end, there is a need to reduce the distance that students walk to schools as some respondents mentioned distances of up to 8km to get to their learning institutions. Therefore, there is a need to set up more primary and secondary schools in the district preferably each ward should have an additional primary and secondary school.
- Considering that poor housing structures have been mentioned as the key driver of the vulnerability of communities to natural hazards there is a need to come up with model building structures and plans that are resilient to floods, strong winds and cyclones. The villagers will thus need funding to develop and build these resilient structures. The most preferred mode of communication for future hazards is through SMS and over the radio. As such, there is a need to make sure that all the wards in the district have very good network coverage at all times. This is against the background that there is poor network coverage in most of the wards as mentioned by the respondents. To this end, there is a need for the network operators (Econet, Telecel and Netone) or the Postal and Telecommunication Regulatory Authority of Zimbabwe (POTRAZ) through its Universal Fund to finance the construction of resilient base stations in optimal locations that are less prone to these hazards. Moreover, there is a need to increase the number of community radio stations whose radio transmitters are optimally placed to cover the whole district,
- During the hazards, there is a need to develop a resilient communication network for the DRR committees. This can be achieved by setting up a network of ‘walkie-talkies’ and providing whistles for the villagers,
- There is also a need to set up evacuation centres that are equipped with health and education materials as well as a food facility (warehouse). These must be placed in areas that are less susceptible to the hazards but close to affected communities

8. Acknowledgements

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9. References

- Davis-Reddy, C.L. and Vincent, K. 2017: Climate Risk and Vulnerability: A Handbook for Southern Africa (2nd Ed), CSIR, Pretoria, South Africa.
- Frischen, J., Meza, I., Rupp, D., Wietler, K., and Hagenlocher, M.(2020). Drought Risk to Agricultural Systems in Zimbabwe: A Spatial Analysis of Hazard, Exposure, and Vulnerability. Sustainability 2020, 12, 752; doi:10.3390/su12030752.
- Kuri, Farai, et al. "Predicting maize yield in Zimbabwe using dry dekads derived from remotely sensed Vegetation Condition Index." International Journal of Applied Earth Observation and Geoinformation 33 (2014): 39-46.
- Manatsa, D., C. H. Matarira, and G. Mukwada. "Relative impacts of ENSO and Indian Ocean dipole/zonal mode on east SADC rainfall." International Journal of Climatology 31.4 (2011): 558-577.
- Mandal, S., and S. Mondal. 2019. Probabilistic approaches and landslide susceptibility. Pages 145-163 in Geoinformatics and Modelling of Landslide Susceptibility and Risk. Springer.
- Mukwada, Geoffrey, and Desmond Manatsa. "Geospatial and temporal analysis of drought years in Zimbabwe, 1940–1999." Geographia Polonica 86.4 (2013): 313-326.
- Phillips, S. J., and M. Dudík. 2008. Modelling of species distributions with MaxEnt: new extensions and a comprehensive evaluation. Ecography 31:161-175.
- Shackleton, S., Ziervogel, G., Sallu, S., Gill, T. and Tschakert, P., 2015. Why is socially just climate change adaptation in sub-Saharan Africa so challenging? A review of barriers identified from empirical cases. Wiley Interdisciplinary Reviews: Climate Change, 6(3), pp.321-344.
- Unganai, Leonard S., and Felix N. Kogan. "Drought monitoring and corn yield estimation in Southern Africa from AVHRR data." Remote sensing of environment 63.3 (1998): 219-232.

Annexes:

1. https://drive.google.com/drive/folders/1vudujtWKaKM2wtz_gnJsSS6erdR13Rdf?usp=sharing
2. NB Annexes can also be requested from TDH at c.muzite@tdhitaly.org