FLOOD DISASTER VULNERABILITY ASSESSMENT OF PHYSICAL AND ENVIRONMENTAL FACTORS IN RAMOTSWA AND TAUNG VILLAGES, BOTSWANA.

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Abstract
The paper explores the spatial and physical factors that increase communities' vulnerability to flood disasters using Geographic Information Systems (GIS). The paper is derived from a 2013-2015 study which carried out a vulnerability assessment of factors that contribute to flood disasters in Ramotswa and Taung villages in the South East District of Botswana. The study adopted Turner et al (2003) vulnerability framework which uses exposure, sensitivity, and resilience as part of the vulnerability model. The study provided baseline information that could be used to explore and implement new measures to reduce vulnerability and the severity of the effects of floods on urban and peri-urban settlements. Planning interventions that could be undertaken in urban and peri-urban villages to reduce community vulnerability to flood disasters were also highlighted in the study. Botswana, an active member of the United Nations (UN), is committed to sustainable human settlements planning and development. However, the country is faced with constraints; such as inadequate financial, technical and human resources to enable sustainable human settlements' planning and development. One of the adversely affected areas is land use planning which reduces the vulnerability of settlements and communities against flood disasters. Globally there has been a long standing recognition within the UN system of the importance of sustainable human settlements in global environmental change. For instance, in 1975 the UN established the United Nations Centre for Human Settlements. In 1992 Agenda 21 was released by the UN to address human settlements issues which included sustainable land use planning and management of disaster-prone areas. More recently, in 2015 the UN adopted seventeen Sustainable Development Goals (SDGs) for 2016-2030. One of these is SDG 11, which aims to "make cities and human settlements inclusive, safe, resilient and sustainable." This paper contributes to the debate of issues in sustainable human settlements in Botswana.

Key Words*: Floods Disaster; Vulnerability; Planning Intervention.*

1 INTRODUCTION

Globally, there have been concerns of climate variability in some parts of the world (Intergovernmental Panel on Climate Change, 1996; European Environment Agency, 2001; United Nations World Meteorological Organization, 2011). According to the United Nations World Meteorological Organization (UNWMO) (2011), the outcome of this climate variability has resulted in drought and floods in areas not normally prone to these phenomena. The common perception of the increasing frequency of floods and inundation has been often supported by the growing concern of climate change (Domeneghetti *et al*, 2015). In the Southern Africa Development Community (SADC) region, Angola and Namibia were affected by flooding in February and March of 2009 and approximately 100 people drowned. Thousands of people were displaced while roads and bridges were washed away in the affected areas making them inaccessible. Similarly, Botswana has been affected by floods numerous times in different parts of the country causing extensive damage to households. In 2013, heavy rains caused extensive flooding in the Central District of Botswana and destroyed homes (mud huts), roads, flooded dams, fields and destroyed livestock and livelihoods (International Federation of Red Cross (IFRC), 2013). There are many other incidences of flooding recorded in the following districts; Chobe, Ngamiland, Gaborone, North East, South East and Ghanzi (Government of Botswana, [GoB] 2008). Botswana has experienced extensive damage to property and infrastructure such as roads, bridges, railways, power lines, and other public and private assets as a result of flooding (GoB, 2008).

Globally, there has been a long standing recognition within the United Nation (UN) system of the importance of sustainable human settlements in global environmental change. For instance, in 1975 the UN established the United Nations Centre for Human Settlements. In 1992 Agenda 21 was released by the UN to address human settlement issues among other things; among these was sustainable land use planning and management of disaster-prone areas. More recently, in 2015 the UN adopted seventeen Sustainable Development Goals (SDGs) for 2016-2030. One of these is SDG 11, which aims to "*make cities and human settlements inclusive, safe, resilient and sustainable*". In keeping with the UN's Sustainable Development Goals (SDGs) for 2016-2030 with specific reference to SDG 11, there is a growing need for disaster risk reduction and subsequently disaster risk management.

"Disaster risk reduction can be defined as the systematic development and application of policies, strategies and practises to minimise vulnerabilities and disaster risks throughout a society, to avoid (prevent) or to limit (mitigate and prepare) adverse impacts of hazards, within the broader context of sustainable development" (United Nation-Inter-agency Secretariat of the International Strategy for Disaster Reduction (UN-ISDR), 2002:25). Although communities in developing countries are resilient to disasters, they are usually more vulnerable as a result of poverty, high unemployment, distributional inequalities, high population growth and a lack of strong national and local institutions for dealing with disasters (Mechler, 2002). In addition, Marcus (2005) highlights that 98% of people that are affected by flood disasters are from countries of low to medium human development. Wisner *et. al*. (2003) concur that the risks involved with disasters are connected to the vulnerability created by many people through their normal existence. Wisner *et. al* (2003) add that poor people can only afford to live in slum settlements in unsafe ravines and on low lying land within and around the cities where they have to work, therefore, the spatial variety of nature thus provides different types of environmental opportunities and hazards. Disasters should thus be perceived within the broader patterns in societies. Marcus (2005) adds that the main strategy of vulnerability reduction to flood disasters at the household level is to strengthen local capacities as well as their coping mechanisms. Thus, understanding the casual factors of risk and vulnerability to disasters is critical in designing effective risk reduction interventions (Marcus, 2005). The first step to understanding these causal factors is to conduct a vulnerability assessment.

According to the Government of Botswana (GoB) (2009), there is insufficient information on the levels and extent of vulnerability as indicated by the generalised documentation of flood disasters and those affected by them in Botswana. The capacity of national and district institutions charged with managing disasters is low (GOB, 2009) as a result of inadequate information of where and how people are vulnerable. Additionally, there are no comprehensive records on floods in Botswana since the country has historically not been afflicted by the disaster (Toteng and Mogonono, 2010). "Relatively few researchers have used Geographic Information System (GIS) as a tool for understanding both biophysical and social vulnerability" (Cutter *et al.*, 2000: 718). This indicates a clear void in the literature on the spatial analytical approach to vulnerability. There has been no substantial documentation of flooding or vulnerability to flood disasters in Ramotswa and Taung villages despite the fact that these villages have been affected by floods in 2000, 2003 and 2006 (GoB, 2008) as well as in 2011, 2013 and 2017. The main aim of this paper is to discuss the vulnerability assessment on flood disaster in Ramotswa and Taung villages with specific focus on the physical factors namely land use and topography. Specifically, this paper assesses the factors that lead to flood disaster vulnerability in Ramotswa and Taung villages. The paper firstly articulates the vulnerability assessment in the context of exposure, sensitivity, and resilience of the communities with the aid of Turner *et al* (2003) vulnerability framework. This is followed by the analysis of causal factors of vulnerability to flood disasters in the study areas. Lastly, the paper also highlights possible planning interventions that could be used in peri-urban villages to reduce community vulnerability to flood disasters.

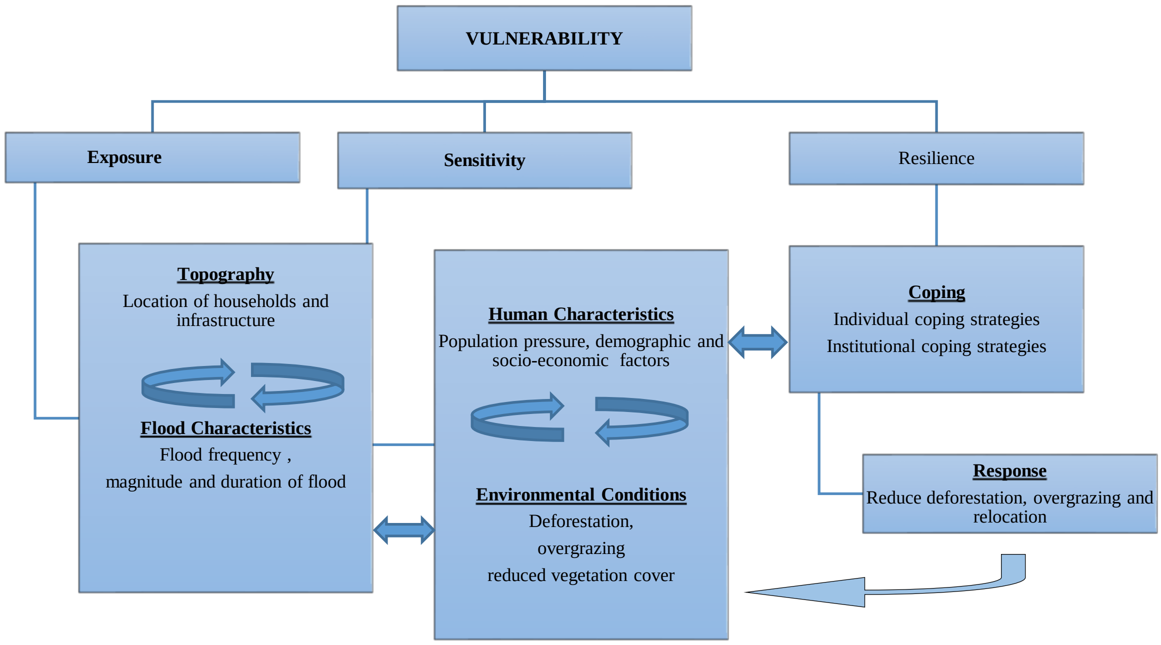
2 VULNERABILITY FRAMEWORK

The Turner *et al* (2003) vulnerability framework couples and examines vulnerability within the broader and closely linked human-environment context. The vulnerability framework (see Figure 1) defines exposure, sensitivity, and resilience (coping response, impact response and adaptation response) explicitly as part of vulnerability (United Nations University-Institute of Environment and Human Security (UNU-EHS), 2002). These elements are interactive and scale dependent, therefore the analysis is affected by the way in which the couple system is conceptualized and bounded for study (Turner *et al.*, 2003). In this framework the human–environment conditions of the system determine its sensitivity to any set of exposures. These conditions include both social and biophysical capital that influence the existing coping mechanisms, which take effect as the impacts of the exposure are experienced, as well as those coping mechanisms adjusted or created because of the experience. For the human subsystem, these mechanisms may be individual or autonomous action and/ or policy-directed changes. Importantly, the social and biophysical responses or coping mechanisms influence and feed back to affect each other, so that a response in the human subsystem could make the biophysical subsystem more or less able to cope, and vice versa.

Vulnerability to natural hazards plays a pivotal role in understanding the true extent of risk. Given that vulnerability is multifaceted, it therefore requires a multi-disciplinary or integrated methodological approach (both quantitative and qualitative) that involves multiple stakeholders hence the selection of this framework which is appropriate for this study. Its flexibility allows for the assessment of vulnerability at different spatial scales although this framework will be applied at a local level. The Turner *et al.* framework has also been selected because it recognizes the human- environment interactions and how these have a direct impact on the vulnerability of communities. This framework also emphasizes how the social and biophysical conditions contribute to vulnerability.

However, for the vulnerability assessment in Ramotswa and Taung the vulnerability framework has been modified. Exposure will refer to the location of the people and infrastructure in relation to the topography. Exposure will also highlight the flood characteristics such as the frequency, magnitude and duration of flood. Sensitivity will be assessed in the context of the human characteristics (population pressure, demographic and socioeconomic) and the environmental conditions (deforestation, overgrazing, reduced vegetation cover and excessive rainfall) thus recognizing the human-environmental interactions. Lastly, resilience will be confined to the coping strategies or response of the individuals in the community and the institutional coping strategies put in place by the government or local community as a whole and how these have been adopted to reduce vulnerability.

Figure 1: Adaptation of Turner *et al.,* Vulnerability Framework



2.1 Conceptualizing Vulnerability

Vulnerability shapes the manner and extent in which different communities are affected by disasters (UN-ISDR, 2007; Birkmann, 2005; Maskrey, 1993; Wisner *et. al.,* 2003). Vulnerability refers to the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards (UN-ISDR, 2004). Reducing vulnerability thus, requires identifying points of intervention in the causal chain between the emergence of a hazard and the human consequences (Clark *et al*, 1998). There are four groups of vulnerability factors that are relevant in disaster reduction, namely: physical, economic, social and environmental. The physical factors describe the exposure of vulnerable elements within a region while the economic factors describe the economic resources of individuals, populations groups, and communities. The social factors describe non-economic factors that determine the well-being of individuals, population groups, and communities, such as the level of education, security, access to basic human rights, and good governance while the environmental factors, describe the state of the environment within a region. All of these factors describe properties of the vulnerable system or community rather than of the external stressors.

2.1.1 Social Vulnerability

Social vulnerability describes those characteristics of the population that influence a community's capacity to prepare for, respond and subsequently recover from hazards and disasters (Cutter *et al.,* 2009). Social vulnerability is a pre-existing condition of a particular community that is independent of the hazard type or the source of the threat. Understanding this social vulnerability highlights or explains why some communities experience hazards and disasters differently even though they have been exposed to the same level of flooding or storm surge inundation. It is important to understand the context in which social vulnerability occurs. Rufat *et al* (2015) assert that context distinguishes the generalized notions of social vulnerability (those reflected in indicator studies) from its manifestations in specific disasters. Deconstructing vulnerability can thus be achieved by understanding the geographical and temporal characteristics which describe the human and environmental conditions and interactions that make individual disasters unique.

2.1.2 Population Pressure

Social vulnerability to floods is affected by a neighborhood's population density, urbanicity and legitimacy of settlements. Informal or uncontrolled neighborhoods and illegal settlements are faced with poor drainage and infrastructure (Tas *et al*, 2013). Population and built environment density are the key drivers of social vulnerability that often correspond with lower income settlements (Rufat *et al*, 2015). Population and built environment density has the potential to increase the risk of disease transmission during and after a flood event and inhibit post-event relief and recovery processes (Dewan, 2013). There are other factors that are drivers of flood-related social vulnerability such as population growth and urban sprawl (Rufat *et al*, 2015). Porio (2011) adds that in developing metropolises, rapid urbanization and population growth are associated with unregulated sprawl, often with informal settlements and weak infrastructural and economic bases. For example, Gaborone already has one of the highest population densities in the country thus the population spills into the catchment areas (Statistics Botswana, 2014:10). Simela and Tembo (2005) concur that in cases where tribal land is in close proximity to urban areas, there is a high demand and pressure for land that is felt as a result of the population within the urban areas growing at a rate faster than that which serviced land can be availed and allocated within the urban area.

Increased population density implies extra demand for social services, land, infrastructure and employment. Furthermore, high population density is often associated with poor sanitation, more especially for people living in poverty (Statistics Botswana, 2014). Furthermore, increased population density poses a challenge of waste water creating a breeding place for disease vectors like mosquitoes and water borne disease given that in most cases drainage systems are not maintained properly.

2.1.3 Land Tenure

Land tenure has a bearing on social vulnerability to flood disasters, although the causal relationship varies across cultures (Steinfuhrer and Kuhlicke, 2002). The level of control that a resident has over the adoption of structural mitigation measures is strongly influenced by property ownership. This results in disparities in flood susceptibility between property owners, renters, squatters and the homeless (Rufat *et al*, 2015). Studies have shown that renters, as compared to homeowners, were associated with higher inundation levels (Brouwer *et al*, 2007), more adverse health impacts (Whittle *et al*, 2010, Rufat *et al*, 2015), higher rates of displacement and job loss (Elliott and Pais, 2006). Additionally, renters, have a lower return rate as compared to home-owners in the aftermath of a flood (Elliott *et al*, 2009) as they are not attached to their homes. On the other hand, landlords were found to be major contributors to post-flood building repairs and social support (Aßheuer, Thiele-Eich and Braun 2013). In addition, homeowners have shown a greater awareness of flood risks, deeper understanding of warnings, taken more immediate action to minimize flood damage and were less likely to seek emergency shelter (Rufat *et al,* 2015).

Home owners have also shown greater reluctance to evacuate which shows a combination of a greater sense of attachment to place among homeowners. Moreover, several studies (Steinfuhrer and Kuhlicke, 2002; Pelling, 1997) have shown that property owners in response to flooding were more likely to make structural improvements to reduce future flood losses. Physically, there are also factors that increase vulnerability to flooding. These are listed below;

i) Building homes on the river bank or on flood plains.
ii) Constructing new housing settlements without improving the existing drainage system, thus overwhelming the drainage system.
iii) The construction of residential or commercial buildings without taking into consideration the current and future flooding impacts which can increase vulnerability to flood disasters.
iv) Living close to the coast can make one vulnerable to storm surges and coastal flooding.
v) Lack of maintenance of drains and waterways.

2.2 Vulnerability Measurement

Cutter and Finch (2007) did a comparative vulnerability study in the United States of America to assess the spatial and temporal patterns in social vulnerability from 1960 to date. Results from the study revealed that the components that consistently increased social vulnerability for all the time periods were population change (extreme depopulation resulting in the loss of the young and actively working population thus increasing reliance on social safety nets) and an increase in population (resulting in a more diverse population requiring more development) in the urban areas. Cutter and Finch (2007) assert that the degree to which a population is vulnerable is not solely dependent upon proximity to the source of the threat of the physical nature of the hazard but that social factors also play a role in determining vulnerability.

Ejenma *et. al* (2014) carried out a study to assess the spatial impact of river Kaduna flooding of Kaduna South in Nigeria. This study used high resolution Satellite Imagery and a Digital Elevation Model (DEM) in ArcGIS to identify flood prone areas along the middle course of the river. The DEM was further used to create a flow accumulation model and subsequently reclassified to capture vulnerability using equal interval separation based on the elevation. The DEM was overlaid on the land use/land cover classification in order to produce a vulnerability map for the area. The vulnerability classification ranged from very highly vulnerable to very lowly vulnerable to river flood disaster and risk. With the use of ground elevation, flood history and proximity to the river channel vulnerability maps were produced.

Frazier *et al.* (2009) and Yarnal (2007) state that using vulnerability maps as planning tools, emergency managers can address the primary causes of vulnerability which is not static and changes from place to place. Vulnerability can be deduced into a single standardized value or score which can then be classified into standard deviations or quartiles and subsequently mapped using a Geographic Information System (GIS) which allows for the ease of data editing, analysis, storage and visualization (DeMers, 2005). In Botswana the National Disaster Management Office commissioned the Hazard Identification, Vulnerability and Risk Assessment (2008) with the aim of conducting a hazard assessment by identifying potential hazards, the probability of their occurrence, intensity and area of impact. Other objectives included a vulnerability and risk assessment and providing profiles (hazards and vulnerabilities, capacities and resources) of the districts assessed. The methodology used was a mathematical calculation of the *Disaster Risk Rating* using a *Hazard Rating (H), Vulnerability Rating (V), Manageability Rating (M)* and a *Capacity Rating (C).* The ratings derived were determined by various factors retrieved from existing reports, statistics or data collected from workshops and consultations. Within the South East District, Ramotswa was identified as a locality that is at high risk of floods and droughts in that study. The study recommended that hazard severity maps should be refined on a smaller scale especially with regard to flood lines amongst other factors. One of the limitations noted in that study was a lack of a structured, integrated communication and awareness strategy and programme throughout the country.

In Botswana, according to Toteng and Mogonono (2010), poor urban planning is a major contributor to flooding problems that have since the 1990s occurred in many settlements including Gaborone during the occasional heavy rains. Toteng and Mogonono (2010) did a case study of Gaborone to examine the prospects for urban planning and technology intervention for urban flood disasters in Botswana. In their study, Toteng and Mogonono (2010) conducted structured households interviews and semi-structured interviews with physical planners. The findings of their study revealed that poor planning, unsatisfactory design of storm water drains could exacerbate floods leaving communities vulnerable to floods. Their study recognized the need for identifying areas that are prone to flooding to determine activities that are less vulnerable to floods.

Heavy rains that are accompanied by tropical storms which are too much for streams and rivers to handle cause flash floods (United Nations Environment Programme (UNEP), 2004). According to Statistics Botswana (2013: 119), a "storm" is defined as a violent disturbance of the atmosphere with strong winds, and usually rain, thunder, lightning, or snow", while flooding usually takes place in a situation where water overflows in a dry place or within existing water bodies. The combination of both storms and floods are common in Botswana and cause widespread damage. There are other factors that influence floods. Masoudian and Theobald (2011) assert that topographical elements such as land surface, slope, the river longitudinal profile and cross section affect every natural flood. Masoudian and Theobald (2011) further add that meteorological elements (temperature, rainfall, evaporation, sunshine, and wind), soil properties (soil type, hydraulic conductivity, and field capacity), land use (agricultural area, settlement area) and land cover are the other elements that influence flooding. In addition, Chow (1966) and Linsley (1997) state that the final element that affects floods is the river network. When flooding poses a threat to humans, livestock or infrastructure they become disasters.

2.3 Disaster mitigation and adaptation strategies

A disaster is a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources (UN-ISDR, 2007). Disasters thus need to be managed through risk reduction. According to the UN-ISDR (2007) this entails reducing vulnerability of people and property as well as their exposure to hazards. Risk reduction further includes the wise management of land and the environment, and improving preparedness for adverse events. According to Birkmann (2006), disasters should be viewed as the complex interaction between possibly damaging events such as floods, fires, droughts, earthquakes and the vulnerability of a society, its infrastructure, economy and environment which are all determined by anthropogenic factors. Additionally, the United Nations (2005) in their final document of the World Conference on Disaster Reduction Hygo Framework for Action 2005 – 2015 emphasized the call for supporting systematic as well as strategic approaches to the reduction of vulnerabilities and risks to hazards. This emphasis suggests that the starting point of reducing disaster risk and thus promoting a culture of resilience to disasters is in understanding the hazards in conjunction with the physical, social, economic and environmental vulnerabilities to disasters that communities face. With reference to the increasing frequency of disasters and continuing environmental degradation, measuring vulnerability is a crucial task if science is to help support the transition to a more sustainable world (Kasperson *et al.,* 2005).

Coping capacity has been deconstructed in terms of preventative or adaptive actions that are undertaken before the onset of the flood, but mainly as a set of reactive strategies adopted in the immediate aftermath (Wisner *et al,* 2003). Rufat *et al* (2015) define 'coping capacity' as the aggregate of resources available to people to contest the negative effects of hazards, and the practice used to deploy them. Rufat *et al* (2015) assert that mitigation measures taken prior to the flood tend to focus on structural measures such as the elevation of structures or household contents. Chatterjee (2010) adds that mitigation measures employed in India include raising foundations, construction of a second floor and the use of a platform that is elevated within the house to store valuables and protect the members of households. Linekamp *et al* (2011) and Pelling (1998) highlight other mitigation measures noted in Guyana and Suriname; namely, raising the level of yards, erection of barriers near doors and cleaning drainage channels. Additionally, Rufat *et al* (2015) highlight the following flood protection and preparedness measures; elevating homes, purchasing flood insurance, stockpiling supplies, and moving building contents to higher ground.

3 DISCUSSION OF MAIN FINDINGS AND RESULTS

3.1 Background

This study was carried out in the South East District of Botswana in Ramotswa and Taung villages. Ramotswa is a village that is located 35km southwest of Gaborone City, while Taung (also known as Ramotswa Station) is adjacent to Ramotswa. The population of Ramotswa and Taung currently stand at 28,952 and 3,360 respectively (Statistics Botswana, 2014). Due to their close proximity to Gaborone City, Ramotswa and Taung villages have been growing faster than other villages in Botswana in the past few years (GoB, 2009). The study settlements consist of plains that are generally undulating with outcrops such as the Rankepa, Sepitswane, Tsokwane, Ditsotwane, Bojanje, Mmapeloeng and other hills. In this region the topography is fairly hilly in nature with an altitude ranging from 1068m to 1189m above sea level (Vogel and Staudt, 2003). There are ephemeral rivers in this area namely the Ngotwane and Taung Rivers (Taung is a tributary of Ngotwane river) and these rivers are part of the Gaborone Dam catchment area and the Limpopo river system (GoB, 2009).

Most of the rain water seeps into the ground and is stored in the water bearing rocks underlying the area. Floods occur when large volumes of runoff flow quickly into streams and rivers while the peak discharge of a flood is influenced by topography amongst other factors (Konrad, 2014). Thus, the hilly nature of Ramotswa and Taung villages promotes an increase in runoff which leads to flooding in the event of excessive rainfall over a short period of time. According to Wischmeier (1966) in FAO (1996), runoff usually increases with the slope on small plots, but that increase is also a function of the soil surface roughness and water retention capacity of the type of crop as well as the saturation level before the rain.

3.2 Disaster Management structures in Botswana

According to the 2015 Natural Disaster Digest (Statistics Botswana, 2016), the Government of Botswana has put mechanisms in place in an effort to improve disaster preparedness. These include the National Committee on Disaster Preparedness (NCPD) in 1993, the National Policy on Disaster Management in 1996. Furthermore, in 2013 the Botswana Government implemented the National Disaster Risk Reduction Strategy of 2013 - 2018 after realizing that the frequency and magnitude of disasters are on the rise. The National Policy on Disaster Management provides a comprehensive disaster management programme that is aimed at reducing vulnerability as well as the impact of future disasters. This policy outlines that disaster management relates to the needs of Botswana and should thus be integrated in development. As such, development projects and programmes are evaluated in the context of disaster impact and whether or not strategies for reducing vulnerability of populations to various disaster risks have been taken into consideration.

The South East District Development Plan 7 (SEDDP7, 2009) emphasizes some proposed strategies that are to be effected to ensure preparedness for disaster occurrences. SEDDP7 proposed that preparedness committees will be formed and operationalized in each of the villages in the districts for disaster incidents. The outcome and effectiveness of these committees can only be ascertained once the progress made in SEDDP7 is reviewed. Several challenges toward disaster preparedness have been mentioned in the SEDDP7. These are:

i) Inadequate resources and unwillingness of communities to voluntarily participate in disaster mitigation.
ii) Coordination of disaster mitigation and management is centralized.
iii) South East is prone to floods due to hilly terrain along Gaborone dam catchment area.
iv) The district has a poor storm water drainage system which also compounds the flooding problem.

3.3 Methodology of Vulnerability Assessment

Methodological approaches to vulnerability are highly varied (Cutter, 1996). Given the varied definitions of vulnerability, it is difficult to operationalize the concept using specific variables or indicators. The analytical approaches range from historical narratives (Colten, 1991), contextual analyses (Mitchell *et al.,* 1989), case studies (Liverman, 1990b), to statistical analyses, GIS and mapping techniques (Parrish *et al.,* 1993; Hepner and Finco, 1995). There has been a shift from more qualitative work that is centered on conceptual models and frameworks to more quantitative measures of vulnerability (Cutter et al, 2009).

In order to assess how the topography of Ramotswa and Taung villages promotes flooding and thus increasing the community’s vulnerability to flood disasters some techniques in ArcGIS were used. A 1:50 000 1986 map showing Ramotswa and Taung was scanned and geo referenced in ArcMap. Thereafter X, Y coordinates and the corresponding Z (elevation) values were extracted from the map and populated on an excel sheet. The excel sheet was loaded into ArcMap and converted into a points shape file in order to perform surface interpolation. This procedure was done using the IDW function under Raster interpolation in the 3D analyst tools from ARC Tool box and produced an image. The image created was loaded into ArcScene and automatically converted to a Digital Elevation Model (DEM).

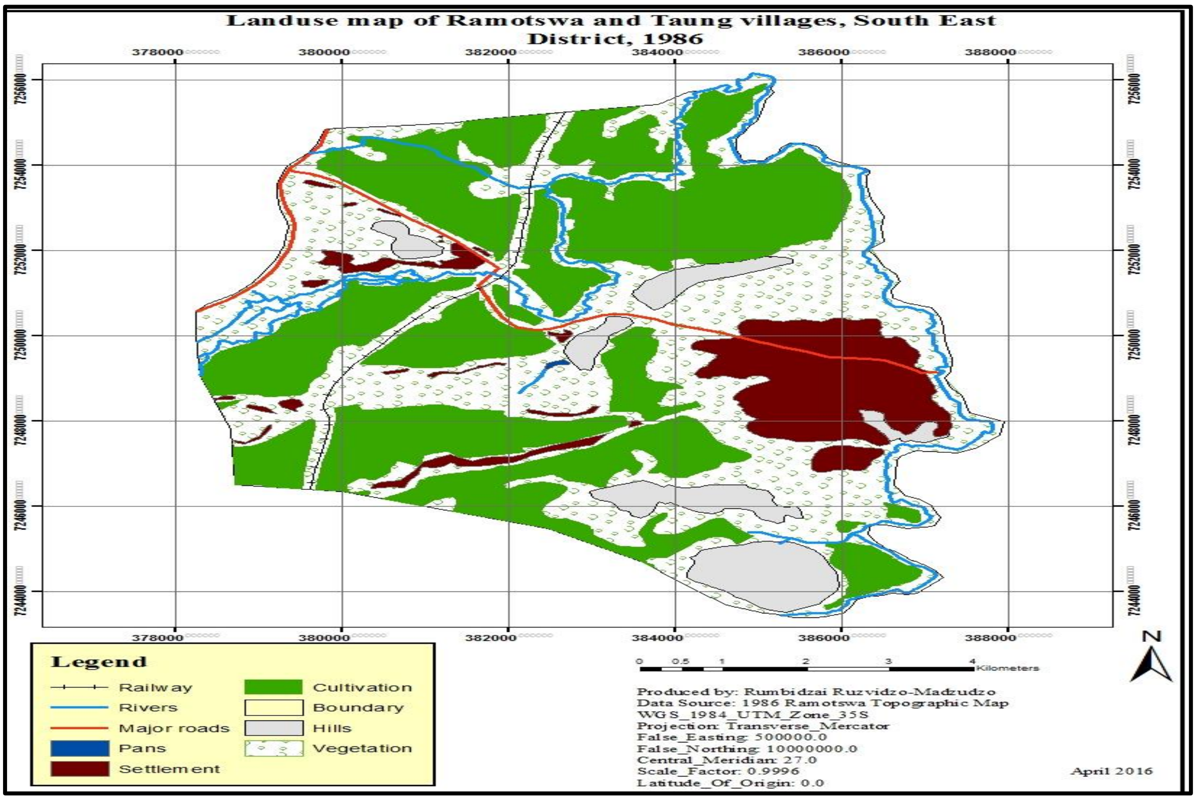
Land uses from 1986 map of Ramotswa and 2015 Google Earth Image of Ramotswa and Taung Villages were identified and digitized in order to perform land use change detection and to also assess the location of infrastructure in relation to the topography of Ramotswa. The digitized layers of roads, railway line, rivers and built-up area for 1986 and 2015 were overlaid and displayed on the DEM of the Ramotswa and Taung villages. A comparison of the land uses from both periods yielded changes in land uses and were analysed and presented using tables.

3.4 Environmental factors contributing to flood disaster vulnerability

3.4.1 Land use and land cover change

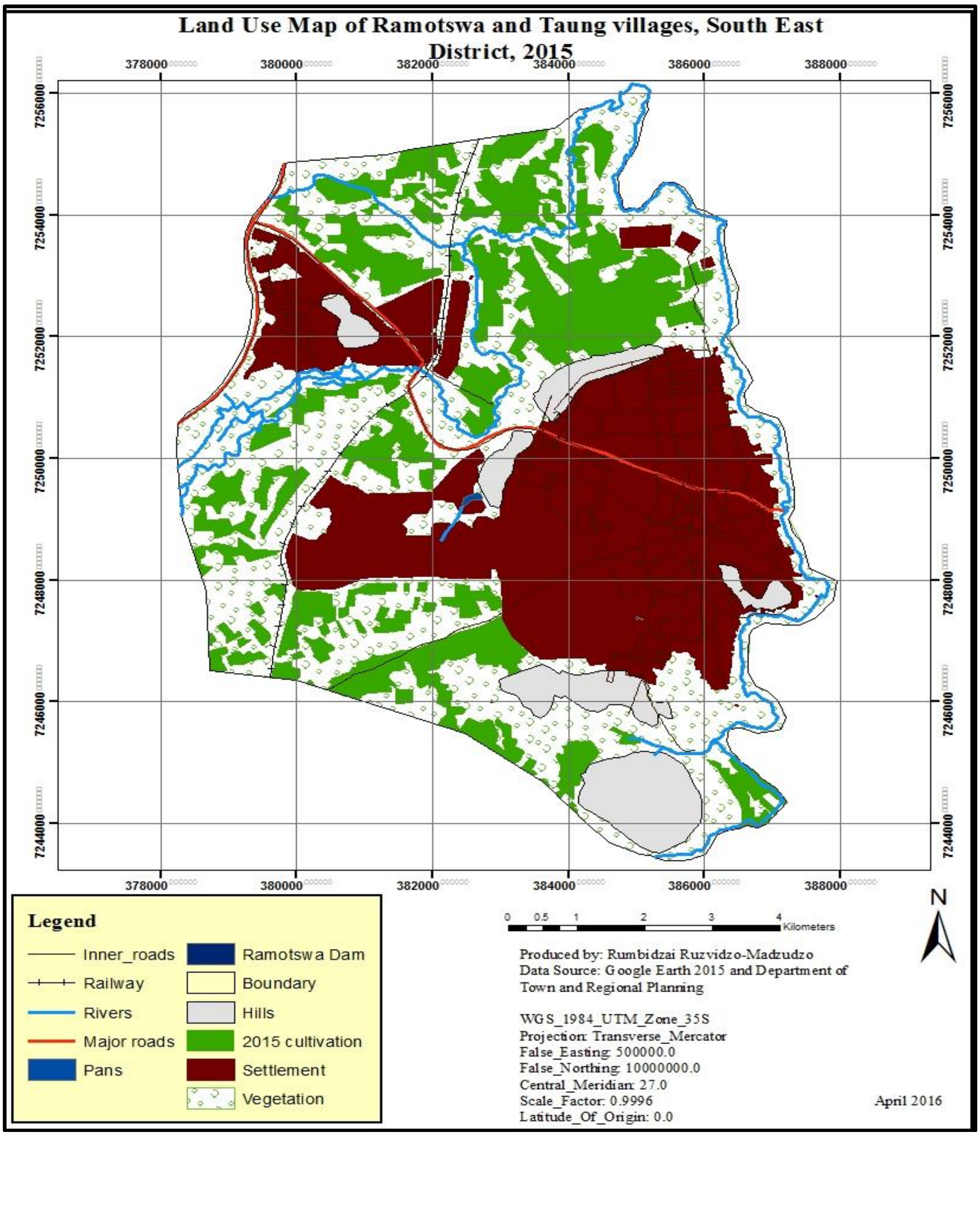
There are a number of environmental factors that have contributed to the increase of vulnerability of the study settlements. Ramotswa and Taung settlements have experienced significant land use changes between the year 1986 and 2015. Figure 2 and Figure 3 illustrate the spatial landscape of Ramotswa and Taung Villages in 1986 and 2015 respectively. The rapid growth of the settlements has led to land use change and land use conversions. Figure 2 shows that in 1986 almost half (49%) of the study area was covered by vegetation, while the cultivation and settlement area accounted for 41% and 10% respectively.

Figure 2: Land use map of Ramotswa and Taung Villages in 1986



An analysis of Figure 3, which illustrates the spatial landscape of the study settlements in 2015, shows significant changes with regard to the land use and land cover. With reference to the land use, vegetation cover showed a slight decline accounting for 45% of the study area. Contrary to the base period of 1986, the cultivation area and settlement areas show substantial changes where the settlement has grown exponentially and accounts for 33% of the study area. Figure 3 further depicts that the cultivation area has considerably reduced to about 22%. In addition to this reduction the cultivation area now consists of smaller portions of fragmented pieces of land signifying a shift in the agricultural practices from low intensive farming over vast pieces of land to high intensive farming over smaller portions of land. This shift in itself has the potential to exert pressure on the environment.

Figure 3: Land use map of Ramotswa and Taung Villages in 2015



Further analysis of the land use changes observed in Ramotswa and Taung settlements was undertaken and is illustrated in Table 1. Table 1 shows a comparison of the changes observed between the study periods. Regarding vegetation cover, there was a negative growth of 7% (2,940,141m²) between the periods of 1986 and 2015. The reduction in vegetation in this study can be attributed to deforestation that has partially accommodated the vast expansion of the settlements and other developments. According to Furbish and Rice (1983) changes in the land cover and land use emanating from human activities like deforestation, forest logging, road construction, fire, drought and cultivation on steep slopes can have tremendous effect on hazards. This assertion is consistent with the findings of the study area where deforestation, road construction and construction of house on slopes have a bearing on the effects of floods. Additionally, the conversion of vegetated areas (land cover change) to facilitate the expansion of the settlement increases the sensitivity of the environment given that the settlement is a high intensity land use. This subsequently increases the vulnerability of the environment to the effects of flooding.

Table 1: Land use/ cover change between 1986 and 2015

Land use/cover	1986		2015		Growth rate
	Area (m²)	**%**	**Area (m²)**	**%**	
Vegetation	39,356,925	49	36,416,784	45	(7)
Settlement	8,080,635	10	26,372,773	33	226
Cultivation	32,926,455	41	17,571,610	22	(47)
Ramotswa Dam	-	-	2,849	0	-
Total area	**80,364,016**	100	**80,364,016**	100	-

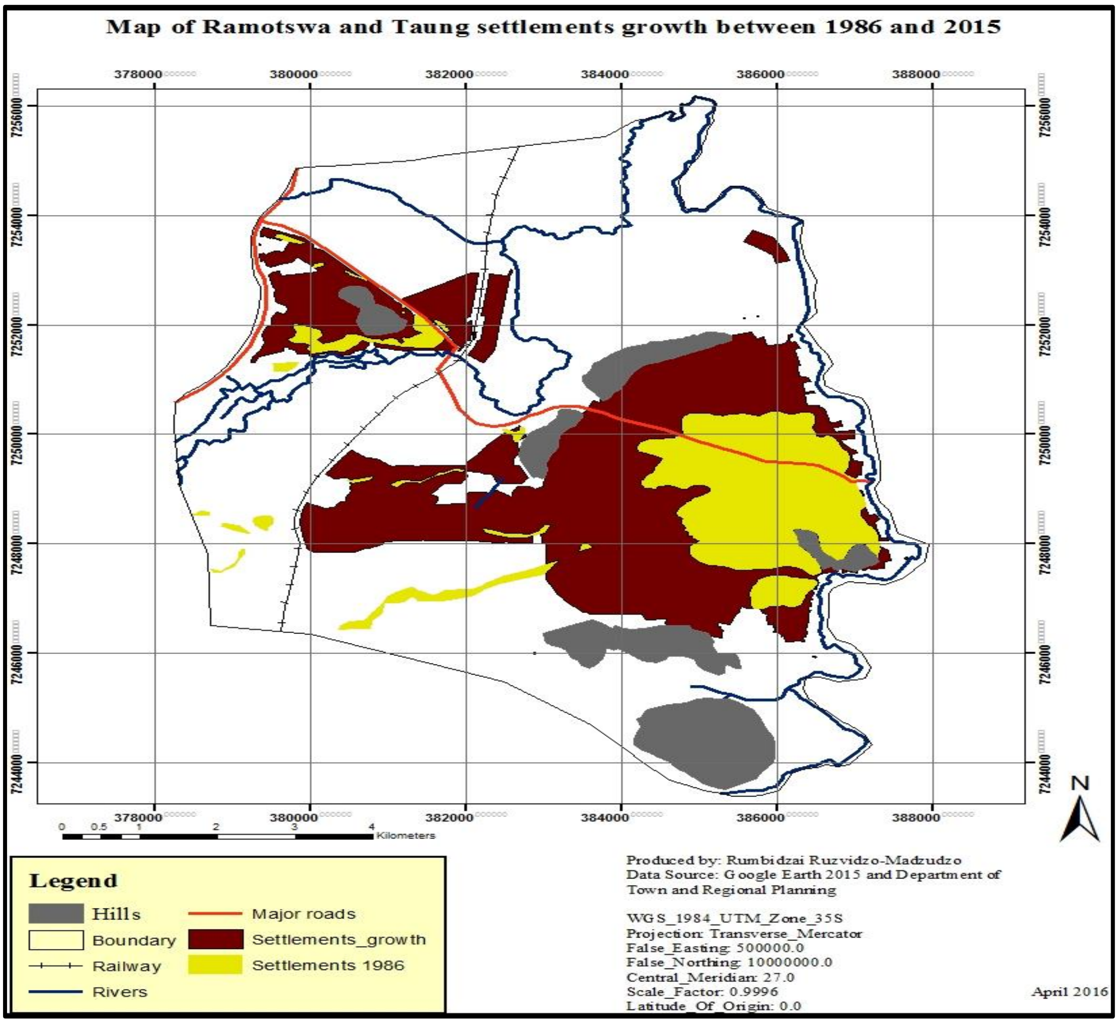
Source: Author's Survey (2015)

A similar trend was observed with reference to the cultivation area as shown in Table 1. There was a marked reduction of about 47% of the cultivation are between 1986 and 2015. The reduction of agricultural land can be attributed to the growth of the settlement and the shift in sources of livelihoods strategies from being purely agriculture to small business ownership, formal and informal employment. While this shift reduces the heavy dependence on agriculture, it also in a way reduces the food resources accumulated from subsistence farming.

In contrast, the settlement area grew exponentially. As depicted in Table 1, the settlement grew significantly by 226% between the periods of 1986 and 2015. This growth has been a direct result of the population growth in Ramotswa and Taung resulting in a rapid increase in demand for resources and land. The growth of the settlements can be partially attributed to their location which has been instrumental in attracting people to the area. The settlements lie between the capital city Gaborone and Lobatse, therefore; the study settlements have become an alternative target for accommodation that is within close proximity of Gaborone. This pattern is consistent with Simela and Tembo (2005) who assert that tribal land that lies adjacent to urban areas experiences high demand.

Figure 4 shows the spatial illustration of the settlement growth. The growth of the settlements has been facilitated by land use conversions over the study periods. About 5,288,457m² which constitutes 13.4% of the cultivation area in 1986 was converted from agricultural use for residential purposes in the settlement.

Figure 4: Growth of study settlements



Source: Author (2016)

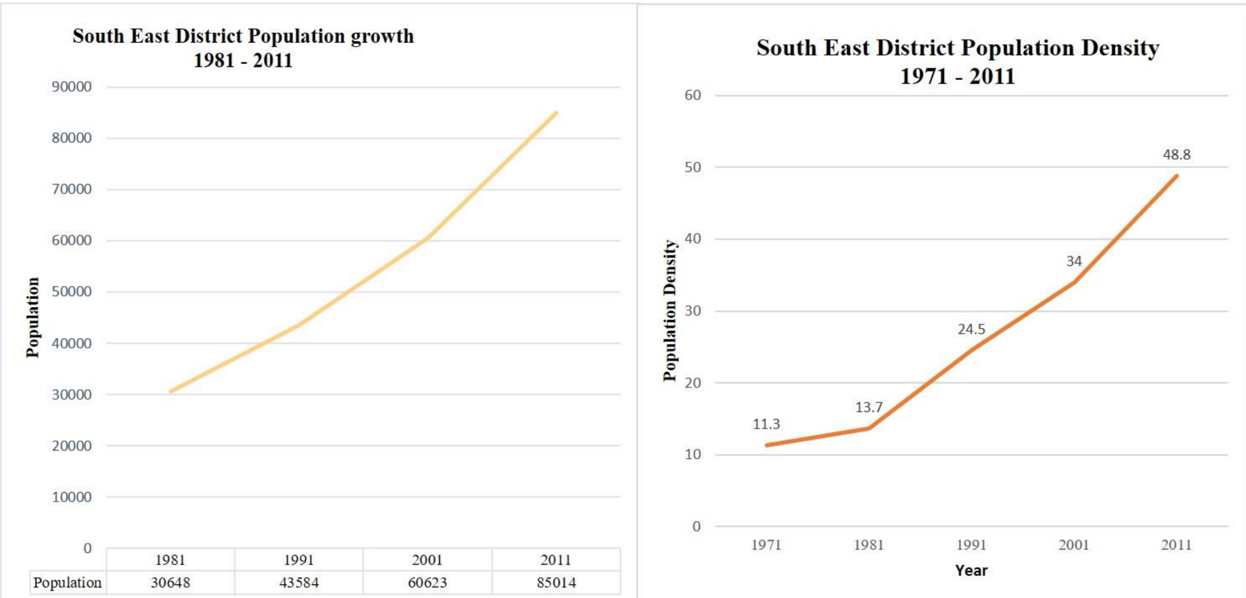
3.4.2 Rapid development of road network

With regard to the road network, in 1986 there were mainly tracks that served the purpose of linking the settlements with their fields. The only main road that existed in 1986 was the road from Boatle Junction which links Taung and Ramotswa settlements. In 1986 the presence of the railway line passing through Taung village is observed. According to the 1986 land use and land cover map from the Department of Surveys and Mapping (then Department of Surveys and Lands) there is no visible sign of development along the railway line in Taung. Comparatively, the road network in the 2015 land use and land cover map showed a more intricate network of inner roads. Some factors that could be advanced to explain the increase in the density of inner roads include: the expansion of Ramotswa and Taung settlements and increased development necessitating better connectivity and transportation of people, goods and services. Over the years, the railway line that passes through Taung has resulted in the emergence of an industrial site around it. According to the SEDDP7 (2009), the railway line provides opportunities for minimized production and labour costs of goods and services as well as costs of the supply and delivery of goods. Examples of these industries include manufacturing of textiles and leather products, steel, fencing materials and building materials.

3.4.3 Pressure on the environment

As previously noted, rapid population growth has resulted in the exponential growth of the settlements. This phenomena increases social vulnerability to flood disasters (Cutter *et al.*, 2009). In the case of the study area, rapid population growth has resulted in the demarcation of more plots in areas such as steeper plots that are susceptible to flooding. Additionally, according to the South East District Development Plan 7 (2009-2016), the South East District has experienced widespread land degradation and soil erosion in areas of intensive land use. This can mainly be attributed to the high population density in the district. Further to this, the small size of the district coupled by the increasing number of livestock exerts a lot of pressure on the available grazing land around the settlements. In addition, Figure 5 illustratively shows that the South East District has generally experienced a rapid increase in district density despite 'being one of the smallest districts in Botswana' (SEDDP7, 2009).

Figure 5: South East District Population Growth and Density



Source: Statistics Botswana (2011)

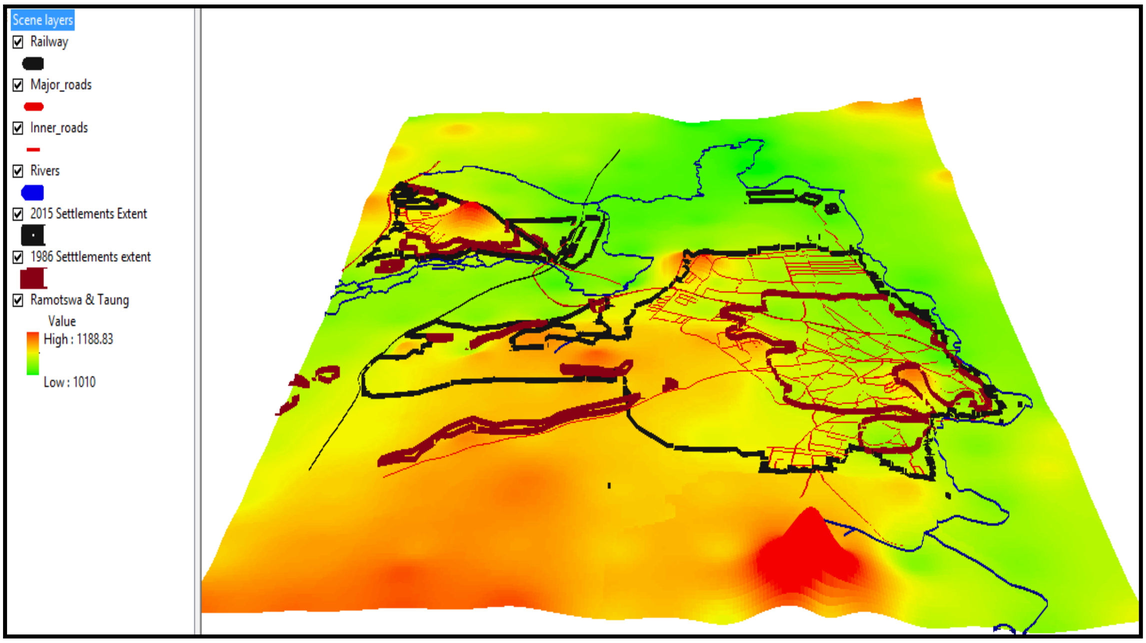
According to Toteng and Mogonono (2010:4), the creation of highly impermeable surfaces in urban areas such as roofs, roads and paved surface areas inhibit infiltration so that a high proportion of storm rainfall appears as runoff. This is also confirmed by Paul and Meyer (2001) who assert that an increase in imperviousness directly results in an increase in runoff at the expense of infiltration. Also, Konrad (2014) states that the removal of vegetation, soil and depressions from the land surface through the construction of roads and buildings replaces permeable soils with impermeable surfaces such as roads, roofs, parking lots which store little water and reduces infiltration. Konrad (2014) further adds that vegetation removal and the creation of impermeable surfaces accelerates runoff to ditches and streams. Although Ramotswa and Taung are villages, they have experienced the increase of built –up areas and roads. This was observed in the spatial analysis. This factor alone coupled with the unmatched drainage system has undoubtedly played a part in increasing the vulnerability of the settlements to flooding.

3.5 Physical factors contributing to flood disaster vulnerability

3.5.1 Topography

With specific reference to the topography of Ramotswa and Taung villages, there are several hills that are found in the settlements namely Bojanje located in Taung and Sepitswane Hills, Kamkana and Mmapeloeng hills, Tsokwane Hills and Ditsotswane hills in and around Ramotswa. The presence of these hills has influenced the location of the settlements to the low lying areas. The highest point in the study area is 1209m while the lowest is 1010m with a mean of 1046m and a standard deviation of 18.36. Figure 6 shows a Digital elevation model of the study area which depicts the location of the settlements in 1986 and in 2015 in relation to the topography of the area. Figure 6 further illustrates the location of the roads, rivers and railway line in relation to the topography of the area. The growth of the settlement has encroached on the hilly landscape of the area thus introducing an increased level of vulnerability through an intensification of run-off during the rainy season. This in itself increases vulnerability to the effects of floods especially for developments located downhill.

Figure 6: Topography map of Ramotswa and Taung Villages

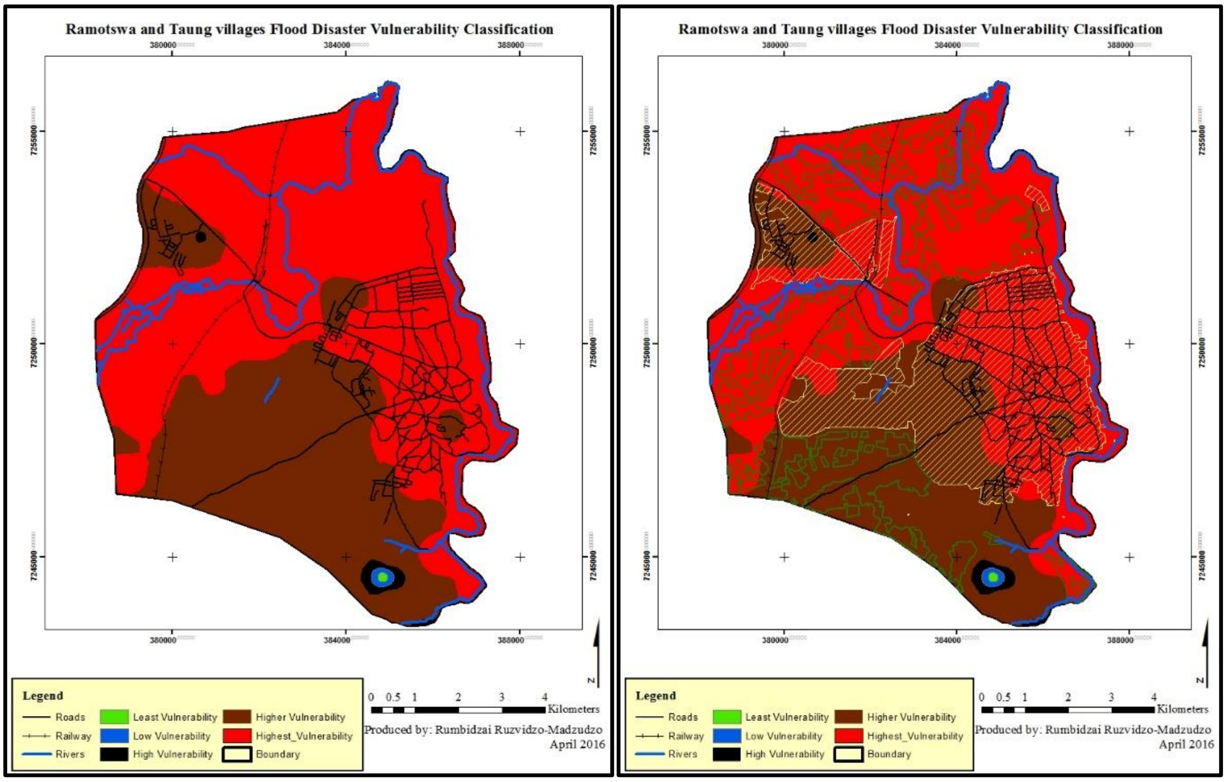


Source: Author's construct. 2016

3.5.2 Vulnerability Classification of Ramotswa and Taung villages

The study sought to determine the level of vulnerability of Ramotswa and Taung villages in relation to the location of the settlements and elevation with the use a DEM model. Elevation (Z values) was used to classify the study settlement into five (5) vulnerability levels, namely; Highest, Higher, High, Low and Least Vulnerability using equal intervals of the elevation. As depicted in Figure 7 a significant portion of the study area is classified under highest vulnerability to high interval vulnerability. An assessment of the classified DEM which was over laid with critical infrastructure such as roads, the railway line and the settlement, as (Figure 7) showed that a significant proportion of the settlements fall within the highest vulnerability zone. In addition, it is useful to note that the Taung industrial area near the village falls within the highest vulnerability zone. This finding is pivotal in the formulation of sound mitigation measures that cushion the stakeholders from loss due to damage of property and disruption of productivity in a flooding occasion.

Figure 7: Vulnerability Classification in Ramotswa and Taung Villages



Source: Author's construct, 2016

4 CONCLUSION

The key finding was that the study settlements had undergone exponential spatial and population growth since 1986. This growth resulted in land use and land cover change. For instance, land that was previously used for agricultural purposes has over time been partially converted to residential use while there has also been a reduction of the vegetation cover. Moreover, overgrazing has intensified in the area thus placing increased pressure on the biophysical environment. Pressure on the ecosystem reduces the ability of the environment to withstand the extreme impacts of flooding and highly increases its sensitivity.

As regards the topography, it was found that the study area is generally hilly in nature with rivers in the low lying areas. This is where the settlements are mainly located although in recent times, there has been a rising trend of residential structures located on the slopes, particularly in the Taung area. The study has provided empirical evidence of the vulnerability of Ramotswa and Taung villages given that the two sites have been repeatedly hit by floods. In all the incidences there was little information documented beyond anecdotal newspaper articles in terms of recording the extent, severity, magnitude, loss of property and life incurred in the past.

The incorporation of the spatial or land use element has highlighted how human interactions with their biophysical environment in the form of different land uses have exacerbated the effects of floods thus increasing the community's vulnerability. The temporal review of land use changes has adequately illustrated the physical growth and expansion of the settlement which is consistent with population statistics.

Conceptually, vulnerability was viewed through the Turner *et al* (2003) framework which was adapted and applied on a local scale. This framework captured vulnerability in the context of **Exposure** (topography and flood characteristics), **Sensitivity** (human characteristics and environmental conditions) and **Resilience** (coping and response). With regard to **exposure**, the topography of the study area was found to play a significant influence on the location of the settlements. Due to the hilly nature of the area, the settlements are located in the low lying areas, which coincide with the intersection of rivers and streams in the area. With the expansion of the settlements there has been allocation of plots on the slopes of the hills which disturbs the normal downhill flow of water when there is rainfall. It must therefore be recognized that the mere location of the settlements in low lying areas near the rivers predisposes them to the risk of flood disasters. Pertaining to **sensitivity** to flood disasters, the population pressure, deforestation, overgrazing, reduced vegetation cover and land use change to intensive land uses was highlighted as factors that increase the sensitivity of the environment. As humans interact with their biophysical environment through the above factors, sensitivity of the environment is increased which is the case with the study settlements. This increase in sensitivity has been a result of the human interactions in terms of changes in land use and land cover in Ramotswa and Taung settlements. Lastly, in terms of **resilience**, there are insufficient proactive mechanisms in place to mitigate and actively increase the community's capacity to cope with the effects of flood disasters. Additionally, there was no evidence to suggest the existence of programs geared towards reducing the social vulnerability of the communities.

4.1 Implications for planning

4.1.1 Increase of community's resilience to flood disasters

There is a need to conduct further research on the households that are located in the areas that have been identified as being most vulnerable in order to identity and find ways of reducing social vulnerability and to increase their resilience to disasters. In addition, there should be an assessment of the infrastructure and development that is found on the flood plain in order to adequately plan for mitigation measures that will reduce the severity of floods in the area.

4.1.2 Hydrological Modeling

There is need for hydrological experts to be engaged to perform flood risk modeling based on forecasted rainfall especially in areas that have been known to flood such as in the area where the train de-railed as a result of damage to the railway line during the rainy season. This will ensure that adequate precautions are taken to avoid a repeat of such incidents especially since the passenger train is now in operation and passes through the railway line in Taung.

4.1.3 Documentation of effects of Flood Disasters

Surveying should be carried out after each flooding occasion in order to maintain clear documentation of the severity and frequency of flooding. Currently there is insufficient documentation of floods that have occurred in the past.

4.1.4 Public Awareness

The communities should be educated on practices that exacerbate the effects of flood disaster such as clearing of vegetation, over stocking of livestock resulting in overgrazing. Further to this, they should be taught about the dangers of their actions and be advised on sustainable practices in cattle rearing.

4.1.5 Importance of Land Cover

Since overgrazing, reduced vegetation and deforestation has been observed in the area, there should be programs that are geared towards encouraging afforestation and control of stocking rates in the settlements.

4.1.6 Community Capacity Building for Flood Disaster Mitigation

Given that the South East District Council does not have staff that is dedicated to disaster management there is need to mobilize the community through directed capacity building using community based programs that have been proven to work in other communities.

4.1.7 Enforcement of Development Control

There is need for the South East District Council to regulate the construction of perimeter walls in order for the design to allow water to flow from one plot to another. This could be done through the use of bye-laws. This will help to reduce the obstruction of the flow of water from one individual plot to another which will reduce water ponding in lower lying plots.

4.1.8 Expansion of Drainage Infrastructure

The planned expansion of the drainage system in Ramotswa and Taung should be accelerated to avert further flooding and loss of property on plots and in households.

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