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Original Article

The Impact of Flooding on the Community: A Case of Gweta and Zoroga Villages, Botswana

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ABSTRACT

Floods continue to cause devastating impacts on society, the economy, and the environment. In Botswana, the semi-arid climate makes the country more vulnerable to the effects of hydro-meteorological hazards. The villages of Gweta and Zoroga, located in the Central Tutume district in northeast Botswana have been experiencing flood events almost yearly during the rainy season, with the 2016/2017 being the most severe. The aim of this study was to assess the socio-economic impacts of these floods in the two villages and to map areas susceptible to flooding. A semi-structured questionnaire and a key informant guide were used to collect data from the heads of households. Participatory Geographical Information System was used to map areas vulnerable to flooding. The causes of flooding were increased rainfall intensities, coupled with a lack of flood control structures along the Maun-Nata highway. The devastating 2016/2017 floods caused damage to houses and other property and losses amounting to BWP18 482.58 (1US$=13.24 BWP) worth of cattle, BWP11 282.84 worth of goats and BWP1 314.22 worth of chicken.

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INTRODUCTION

Natural disasters are a common phenomenon throughout the world today as evidenced by their increased frequencies and intensities (Cavallo & Noy, 2010; White & Rorick, 2010; UN, 2002). According to Hay and Mimura (2010), extreme weather and climate events have increased in frequency, intensity, and severity, particularly due to climate change. To date, an increasing number of flood events and flood-related impacts have been reported (Aich et al., 2015; Descroix et al., 2012; Kundzewicz et al., 2013; Tarchiani et al., 2020; Nka et al., 2015). Floods have catastrophic consequences for the population, infrastructure, environment, and economy (WHO, 2002). Bensen and Clay (2004) define a natural disaster as 'the occurrence of an abnormal or infrequent hazard that affects vulnerable communities or geographic areas, causing substantial damage, disruption and perhaps casualties and leaving the affected communities unable to function normally'. Natural disasters are either hydro-meteorological or geophysical. Hydro-meteorological disasters include floods, wave surges, storms, droughts, landslides, and avalanches, while geophysical disasters include earthquakes, tsunamis, and volcanic eruptions; and biological, covering epidemics and insect infestations (Cavallo & Noy, 2010). A natural hazard, on the other hand, is a geophysical, atmospheric, or hydrological event with the potential to cause harm or loss (Bensen & Clay, 2004).

The world over, disasters continue to cause significant social, economic, and environmental damage (Hallegatte & Przyluski, 2010; Mata-Lima et al., 2013). In Australia, for instance, between 1967 and 1999, natural disasters caused damages worth US$37.8 billion (1999 prices) including human deaths and injuries (Gentle et al., 2001). Disaster-related damages have long and short-term social, economic, and environmental consequences (McKenzie et al., 2005; Mertz et al., 2010). The damages caused by disasters are often categorised as either direct or indirect (Department of International Development, 2005). Direct damages refer to physical destruction, while indirect damages are the consequences or secondary effects of direct impacts (Kousky, 2012; Environmental Resources Management, 2005). According to Mertz et al. (2010), direct damages occur due to physical contact of the hazard with humans, property, or other objects, while indirect damages are induced by the direct impacts and occur over space and time.

Direct losses or damages can also be categorised into direct market losses and direct non-market losses (Hallegatte & Przyluski, 2010). Direct market losses are losses for goods and services that are traded in the market (i.e., with observable market prices), such as buildings and cars. Direct non-market losses are negative impacts that cannot easily be valued using market prices because markets for such goods or services do not exist (McKenzie et al., 2005), such as loss of human life. Indirect flood losses are the losses resulting from the consequences of a disaster or hazard, such as output losses occurring due to affected businesses (Hallegatte & Przyluski, 2010).

The impacts of disasters have been significant on poor rural people found mostly in developing countries (Ignaciuk & Mason-D'Croz, 2014; Mata-Lima et al., 2013) who lack social and economic endowments, network of relationships and access to resources and power (Agrawal & Perrin, 2008). Floods and droughts account for 80% of loss of life and 70% of economic losses that are linked to natural hazards in Sub-Saharan Africa (Vincente-Serrano et al., 2012; The World Bank, 2010; Moalafhi et al., 2017). According to Environment Resource Management (2005), low-income countries bear the heaviest burden of these

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costs in terms of average annual damage relative to Gross Domestic Product.

As natural disasters continue to exert negative effects on social, economic, and environmental systems, individuals and communities have responded to the impacts through coping and adaptation.

The key disasters that affect Botswana include droughts, floods, wildfires, diseases epidemics and pest infestations (Government of Botswana, 1996). To a large extent, the semi-arid climate makes the country vulnerable to the effects of hydro-meteorological hazards (Government of Botswana, 2013). The Government of Botswana has a disaster management policy in place that deals with disaster mitigation, preparedness, response and recovery and development (Government of Botswana, 1996). However, there appears to be a dearth of information on the socio-economic impacts of disasters and physical/geographic vulnerability, especially in areas prone to flooding. Knowledge of vulnerability is crucial for identifying appropriate risk reduction measures, such as developing emergency plans and undertaking emergency exercises (Mertz et al., 2010; Karmakar et al., 2010). The need to estimate the economic cost of disaster damage cannot be overemphasised, as disaster-prone countries are faced with challenges in developing policies and strategies for disaster management (Mertz et al., 2010; Logar & van den Bergh, 2013; Balbi et al., 2013).

The aim of the study was to assess the socio-economic impacts of the 2016/2017 floods on the communities of Gweta and Zoroga and the responses of the communities to the floods. Specifically, the research assessed documented flood community experiences in the two villages, estimated the monetary value of direct (tangible) and indirect (intangible) damages of flooding on households in Gweta and Zoroga and investigated the adaptive responses to flooding.

METHODS

Study Areas

The study was undertaken in Gweta and Zoroga villages in the Central Tutume (*Figure 1*). The two villages were purposively selected as study sites as they were devastatingly affected by the floods in 2016. Zoroga is a smaller village with a population of 1592 in 2022 (Statistics Botswana, 2022) and located about 40 km west of Nata along the Maun-Nata Road. It is located on latitude 20^{0} 9’ 52” S, and longitude 25^{0}49’ 35¨ E. Gweta village is located some 205 km from Maun and about 100 km from Nata. It had a population of 5548 (Statistics Botswana, 2022) in 2022. As the gateway to the Makgadikagdi pans, the village also has some tourist attractions.

As for the whole of the country, the Gweta and Zoroga area is a semi-arid climate with an annual climate ranging from months of dry temperate weather during winter to humid subtropical weather interspersed with drier periods of hot weather during summer. Rainfall usually comes between the summer months of October to March, with the remaining part of the year usually dry. During summer, temperatures can reach as high as 34 °C. In winter, which lasts from April to September, the temperature can reach 7 °C. Annual rainfall, mostly brought by warm and moist winds from across the Indian Ocean via the Mozambiquan channel, averages 450 mm over the area, representing almost average quantities across the whole country, which ranges from 250 mm around the extreme southwestern to 650 around the Kasane area in the north. Annual rainfall for the study area is at its highest of around 650 mm per annum at Tutume in the east and reducing to reach about 450 mm per annum at Gweta and Zoroga.

The main economic activities in the two villages include arable and livestock farming, collection and sale of veld products, formal and informal employment, and government welfare support programme. Both arable and livestock farming activities are considered the most important livelihoods.

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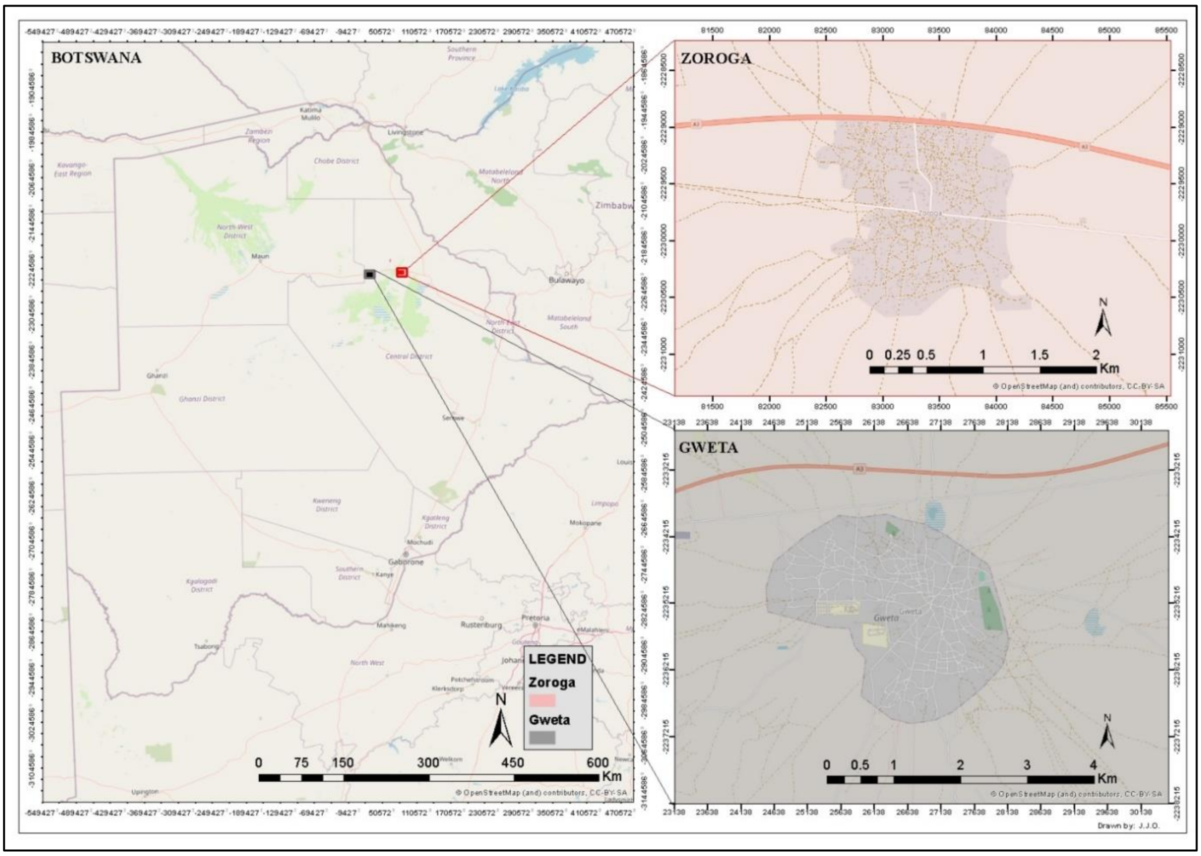
Figure 1: Map of the study area



Data Collection and Sampling

Data collection was preceded by a reconnaissance survey of Gweta and Zoroga villages, the purpose of which was to appreciate the physical environment and explain the objectives and the expected benefits of the study to the communities of the two villages. Meetings were held with community leaders and the Office of the District Commissioner during the survey. Important information, such as maps of the study area, was also collected during the survey. The survey team also piloted the semi-structured questionnaire reconnaissance survey at a small settlement called Tsokatshaa, which was also affected by the floods.

Sampling and Data Collection

For purposes of sampling households, detailed layout maps (physical map paper) showing plot numbers in Zoroga village were obtained from the Office of Nata Sub-Landboard. The total number of plots in Zoroga was 353. The Yamane formula was used to determine the sample size. The formula is expressed as follows: $n = N/[1+Ne^2]$, where: n = estimated sample size, N= population size, and e = margin of error (0.05). Using this formula, a total of 187 plots were selected in Zoroga village.

For Gweta village, a digital GIS shapefile containing plot boundaries of the village was obtained from the Nata Sub-Landboard office and processed within ArcGIS ArcMap Desktop 10.7. The Create Random Points (Data Management) was used to generate random values for all plots, which were about 1381 in total. A dbf file containing plot numbers was then extracted from shapefile and imported into Microsoft Excel, where every 4th plot was selected for the household survey and correspondingly highlighted for easy identification by enumerators on printed maps. PDF files were also created for the enumerators to load on their mobile digital devices.

In both research sites, non-residential plots were excluded after the selection process. These were mainly yards occupied by government employees.

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Also, some of the selected yards were deserted. Subsequently, a total of 164 heads of households in Zoroga and 321 heads of households in Gweta were interviewed. Thus, the combined sample size was 485 households.

The data was collected by well-trained research assistants who administered a semi-structured questionnaire to the selected households in the two villages. The detailed semi-structured questionnaire comprised four main sections: previous flood experience, early warning information, direct and indirect flood impacts, and demographic information of the respondents. The interview was directed to heads of households who were at least 18 years old. In the absence of the head of the household, an elderly member of the household was interviewed. Selected household heads were presented with a consent form prior to the interview. The consent form essentially stated the purpose and the expected benefits of the study and gave them an opportunity to decide their participation in the study.

Data was also collected by conducting key informants' interviews using an interview guide. The key informants or stakeholders in both villages included the District Commissioner based in Tutume Sub-district, the chief representative and ward headmen of the two villages, the district police officer, the nursing superintendent, community development officer (CDO), chairpersons of the various village committees, such as Red Cross, Farmers Association, Village Development Committee (VDC), Village Extension Team (VHT), Village Health Committees (VHC). Issues in the interview included flood origin, frequency, impacts and severity, involvement of community leaders in dissemination of early warning information, probability of the event of flooding, community empowerment to respond to the impacts of flooding and whether the impacts of disasters were adequately budgeted for.

Data Analysis

Socio-Economic Assessment of the Impacts

Socio-economic data was subjected to descriptive analysis (e.g., frequencies, percentages and measures of central tendency and dispersion) and inferential statistics (e.g., T-test and Chi-square). T-test was used to determine any significant differences between means of variables, while Chi-square was used to measure the association between categorical variables such as gender and implementation of flood preventative measures. Information collected from key informants was used to validate or confirm some of the findings from the household survey.

The costs associated with reducing the risk or impacts of flooding (avoided costs) were estimated using the opportunity cost of labour time. This method estimates the opportunity cost of engaging in the implementation of these measures that include the construction of structures such as earth embankments, water diversion channels and retrofitting of houses. In most cases, family labour was used in undertaking these activities. Respondents were asked to estimate the total labour hours used in undertaking preventative measures. The number of hours expended in implementing flood prevention measures was multiplied by the minimum wage of P1000/hour in the agricultural sector (Government of Botswana, 2019).

Estimates were also done for direct damage to or losses of houses and other property such as cars, generators, sowing machines, tuckshops, furniture, groceries, and kitchen utensils. For these estimates, respondents were first asked to state whether the damage experienced was partial or complete. The estimated values were done using the market prices of replacement and repair costs. The replacement cost method is based on the assumption that if a household incurs costs to replace an asset, then that asset must be worth at least what the household paid to replace the lost or original asset (McKenzie et al., 2005). This method may lead to over and undervaluation. The repair cost method is used to estimate the value of

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an asset that has not been totally damaged. According to McKenzie et al. (2005), the ideal estimate of direct damage of a partially damaged asset should reflect its remaining life, which takes into account the value of depreciation. However, respondents could not recall the market price of replacement and repair costs of most of the items or properties affected in this study and were only able to state an overall estimate of the costs of replacement or repair.

The study also attempted to estimate the direct losses of livestock (cattle, goats, sheep, and chickens using market prices. The data for estimating the average prices for different stocks was sourced from Statistics Botswana (2017). For these livestock, the average price was obtained from data on their sales and revenue by various buyers in Tutume central district for the year 2017. The nominal values were also converted to real values (2019 prices).

It is important to note, however, that the use of market prices may underestimate the use value of livestock. For instance, the value of cattle as a source of draft power, milk, manure and social or cultural significance is clearly not captured by market prices. Furthermore, the value of livestock is commonly based on the age of the particular animal (FAO, 2012), and in this study, farmers could not provide information on the age of different livestock lost during the flood.

Direct non-market impacts were not valued but only identified. These included human injuries, disruption of daily household activities, reduction in the frequency of cooking and water contamination. The costs associated with human injuries are often estimated using the resulting losses in earnings and the costs of treatment (McKenzie et al., 2005). However, the few respondents that were injured were unemployed and received free medical treatment in local clinics or hospitals.

To map areas susceptible to flooding in the villages, Participatory Geographical Information Systems (PGIS) was used. This was done to get views of residents of the villages who experience flooding first-hand. Residents of the villages were represented by members of Village Extension Teams (VET), Village Development Committees (VDCs, Farmers Committees, Disaster Management Teams and village leadership including chiefs. For Gweta, which is the larger of the two villages, participants were divided into two groups, after which the groups' sketches were consolidated under each of the three categories. For Zoroga, the participants were just organised into one group since they were few.

Fresh base maps showing residential plots layout of the individual villages and tracing paper were used in each group interview to allow marking directly on the map of areas susceptible to flooding in terms of categories of flood damage, depth, and strength through giving 3 to 4 levels of risk under each category.

Sketch maps from PGIS data were scanned, georeferenced and marked information on base maps was digitised. As the participants gave spatial reference objects and relations during the interview, they were digitised. Narrative analysis also helped validate the sketch maps whereby the sketch maps were described, that is, by looking at the sketch maps and making conclusions.

RESULTS AND DISCUSSION

Profile of Respondents

The respondent's ages ranged from 19 to 89 years, and the mean for male respondents was 48 years (SD = 16.7 years), while that for females was 45 years (SD = 17.8 years). In terms of education, the highest number of respondents (33%) was for those with junior secondary education, followed by those with no formal education (29%). As is a common trend in rural areas, a small percentage of respondents had access to tertiary education (*Table 1*) due to a number of factors, such as a lack of appreciation of the value of education or the lack of finance to pursue education.

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Table 1: Education level and gender of the respondents

Gender	Education					
	No formal education	**Primary education**	**Junior secondary education**	**Senior secondary education**	**Tertiary education**	**Total**
Female	117	83	123	28	19	370
Male	22	27	35	18	13	115
Total	139	110	158	46	32	485

Respondents in the study areas pursue diverse livelihoods that include formal employment, self-employment, arable and livestock farming, drought relief programme, sale of veld products and old age pension. Livestock farming, arable farming and drought relief were ranked as the most important activities by 43%, 30% and 5% of the respondents, respectively. The average monthly income of the respondents was estimated at P1794.76 (US$I38.19).

The majority of the respondents (69%) were born and raised in the two villages, followed by those who have lived in the villages for more than 10 years (*Table 2*). Consequently, respondents who were born and raised in the study area or who have stayed much longer in the study are more likely to have experienced more flood events. A high percentage of respondents (94%) reported having experienced a flood before 2016/2017 which was the period of the worst flood in the flood history of the area (*Table 2*).

Table 2: Respondents' experience of flooding (%) and length of stay in the area

Length of stay in the study area	Experience flooding in the area		
	Yes	**No**	**Total**
Born and raised in the village	63.7	4.5	68.5
0-5 years	3.29	0	3.3
5-10 years	2.68	0	2.7
>10 years	24.54	1.03	25.6
Total	94.4	5.6	100

Discussions held with some of the key informants, such as the chief of Zoroga and the chairperson of the Flood Disaster Committee, revealed that flooding was experienced as far back as 1968, although with less severe impacts than those of the 2016/2017 floods that destroyed people's homes and other assets. In Gweta village, the chief reported that floods occurred as far back as 1955 and 1978, with the latter forcing many of the farmers to abandon ploughing and return to the village.

Causes of the 2016/2017 Floods

During the interviews, the origin or source of floods in Gweta and Zoroga villages was not clearly known to the residents of the two villages; however, the villagers had different views on the causes of these floods. The views on the causes of these floods are shown in *Figure 2*. Generally, people are aware of the signs or indications of climate change. In this study, the majority of people cited climate change-related effects (44%), which include heavy rains, strong winds and land degradation. A small number of respondents (2%) cited poor construction of the Maun-Nata Road (that bypasses the two villages) due to the absence or lack of culverts. This results in a considerable amount of water that crosses the road into the villages.

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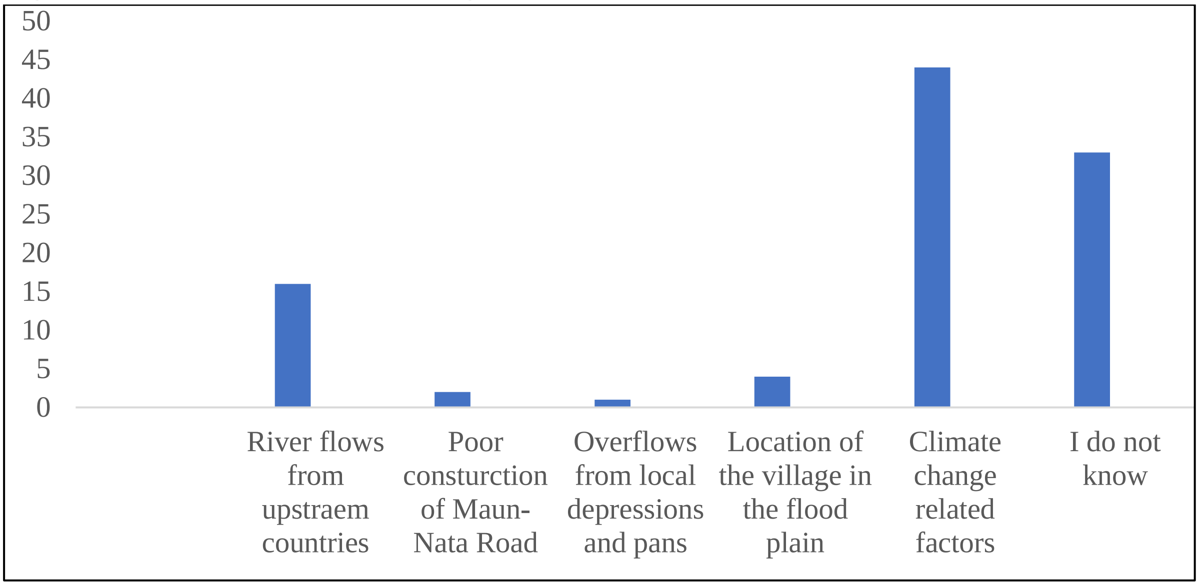
Figure 2: Perceived causes of flooding



Discussions with the chief of Gweta village, the chairperson of the flood disaster committee and the District Commissioner revealed that floods originated from within the catchment of the two villages, as there were no indications of water originating from outside the catchment. According to the chairperson of the Disaster Committee, as the village of Gweta expanded over time, people settled in lower-lying areas that are highly vulnerable to flooding. The majority of those that settled in these areas are possibly younger people who had no previous experience of flooding, while the few elderlies residing in these areas are those who thought that the frequency and intensities of rains to cause any flooding had reduced over time. The discussions also revealed that the village catchment is surrounded by pans that fill up and overflow during heavy rains, though it never resulted in severe flooding in the past. According to the key informants, the likely main cause of the flooding is the lack of culverts or storm drainage systems on Maun-Nata Road. Without these structures, the flow of water is unrestricted, leading to severe flooding. Furthermore, severe flooding is exacerbated by the growth of the built-up environment, especially in Gweta village. According to one of the key informants, attempts to divert water away from the village during 2016/2017 in Gweta resulted in the diverted water causing serious damage to farmers' fields.

Awareness and Perception of Flooding Severity

Respondents were asked about their awareness of the possibility of flooding in the villages. *Table 3* shows the results. Most of them were aware and very aware (87%). The majority of the respondents that were aware were those that were born and raised in both villages. This is expected as these people have a longer experience of flooding that affects them.

Table 3: Respondents' awareness of flooding (%) and length of stay.

Length of stay	Level of awareness of flooding possibility			
	Not aware	Aware	Very aware	Total
Born and raised here	6.8	29.48	32.16	68.45
0-5 years	0.62	2.27	0.82	3.30
5-10 years	0.82	1.24	0.62	2.68
>10 years	4.74	9.90	10.93	25.57
Total	12.58	42.89	44.54	100

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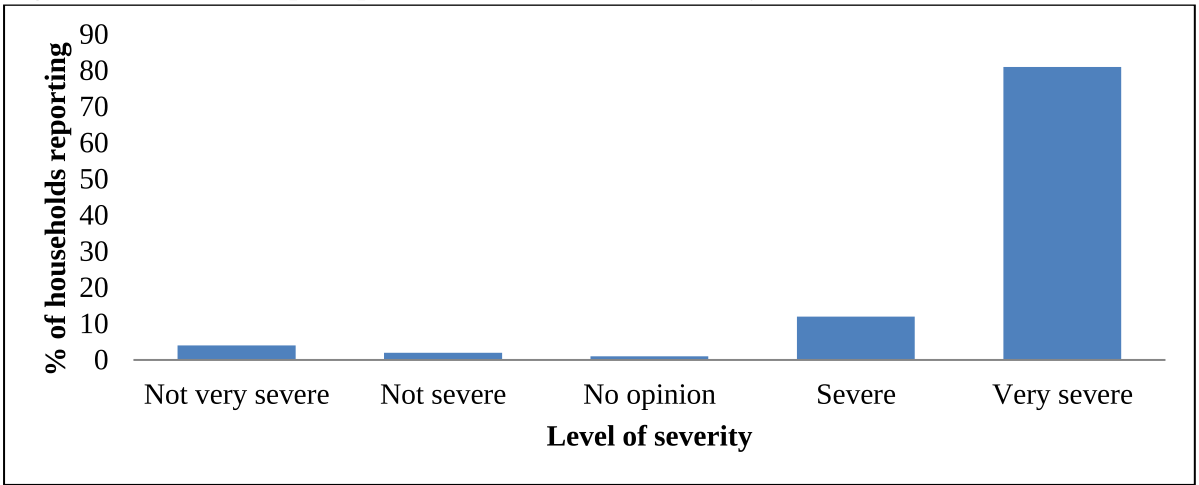
The probability of a home being flooded during the rainy season is determined by various factors such as the physical location of the yard. Homes situated in low-lying areas or depressions, or areas devoid of vegetation, are more likely to be flooded than those located in elevated areas. In this survey, 57% of the respondents indicated that their yard was located in a flood-prone area. The 2016/2017 flood was regarded as the most severe flood in the history of flooding in the area. This was perceived by 81% of the respondents (*Figure 3*). The severity of flood in this context is related to the extent of damage caused by the floods. Respondents who are well-endowed with resources are better placed to cope with or adapt to the impacts of flooding and would therefore perceive flood to be less severe than those who are not well-endowed with resources.

Figure 3: Household's perception of 2016/2017 flood severity



Compared to other previous floods in the area, the 2016/2017 flood was regarded by respondents as most severe (61%), less severe (28%), and not different from other previous floods (9%).

The duration for which the houses were flooded or inundated and the extent to which other households' daily activities or livelihoods were negatively affected by the flood could also give an indication of the severity of the flood. A few respondents (11%) reported that their houses were flooded for a period of less than a week, while a significant number of respondents (73%) reported that their houses were flooded for at least a week. Longer flood inundation implies that activities such as cooking, movement of people and undertaking income-generating activities will be curtailed, leading to negative welfare impacts on households if no relief measures are taken. In Can Tho City in Vietnam, Danh (2017) reported flood inundation of 77 days during the month of September, 121 days during the month of October and 93 days during the month of November that, resulted in total estimated annual losses of US$642 per household.

Respondents in both villages were asked about the frequency of flooding, where a majority (66.4%) perceived the frequency of floods to be increasing in the area (*Table 4*). Most of these respondents were those who were born and raised in the two villages. A Chi-square test was performed to evaluate if there was any significant association between having stayed longer in the village and the perception that flood frequency was increasing. The test showed that there was a significant association between these variables [$X^2 (1, 105) = 3.984, p = 0.046$].

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Table 4: Number of respondents (%) perceiving the frequency of flooding and length of stay

Period of stay	Frequency of flooding				
	Increasing	**Decreasing**	**No change**	**Do not know**	**Total**
Born and raised in the village	48.25	7.42	6.6	6.19	68.45
0-5 years	1.24	1.03	0.41	0.62	3.30
5-10 yrs	1.24	1.03	0	0.41	2.68
>10 years	15.67	3.71	2.27	3.92	25.27
TOTAL	66.39	13.20	9.28	11.13	100

Implementation of preventative measures

While most people had experienced floods in the past, including that of 2016/2017, and were aware and very aware of the possibility of flooding during the rainy season, they had not implemented any flood protection measures. A Chi-square test was performed to evaluate if there was any significant association between previous experience with flooding and the implementation of protective measures. The test showed that there was no association [X^2 *(1, 438) =1.939, p =0.164*] between previous flooding experience and implementation of flood preventative measures. The main factors reported for the lack of implementation of any flood preventative measures are i) the overwhelming force with which the flood water moves, which most traditional structures would not withstand (41%), ii) no knowledge of preventative measures to implement and iii) limited resources (24%). The lack of implementation of flood protection measures is common in rural areas affected by flooding. For instance, in the Limpopo River Basin, South Africa, Gbetibouo (2009) found that a large number of farmers were aware of climate change with 67% of them without adapting to these changes due to barriers to adaption such as lack of access to credit, poverty and lack of saving.

Similarly, in two settlements in Bursa, Turkey, Taş et al. (2013) found a high proportion of respondents that had no mitigation or flood prevention measures in place despite awareness of and previous experience with floods. Contrary to these findings, Mohammad-pajoo and Aziz (2014) found that residents in Kuala Lumpur, Malaysia, who were aware of the risk posed by flooding in their area had a higher level of preparedness than those who were not. In Can Tho City, Vietnam, Danh (2017) found a statistically significant association between flood predictions and the probability of preparedness in terms of implementing measures such as building a barrier, buying a water pumping machine, installing sandbags, and elevating the base of the house, after receiving flood warning information.

In this study, 34% of the respondents had implemented flood prevention measures that included retrofitting traditional houses/huts, constructing cement and brick-made houses, constructing high stoops around the house to prevent water entrance into the yard, constructing trenches to divert the water, piling up bunds of soils around the yard to prevent water entrance. An independent T-test showed a significant difference ($P < 0.05$) in the reported mean cost of materials used for these measures between the Zoroga and Gweta villages. Comparatively, Gweta village is more developed than Zoroga, and its residents are better (more) endowed with resources to implement flood protection measures. Notwithstanding these results, the flood preventive measures implemented by these communities are mostly small-scale in nature, suggesting that most people are constrained by resources to implement such measures. In other countries where the scale and intensity of the floods are larger, the respective governments have taken the responsibility of protecting people against such floods. For instance, in Nepal and Bangladesh, such measures include the construction of embankments, drainage channels and flood shelters for evacuation during flooding (Dewan, 2015).

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Costs of Flooding

Avoided Cost of Flooding

A very small proportion of respondents in both villages implemented flood-related preventive measures. Some of the measures are labour-intensive, and the opportunity cost of labour was used to estimate the costs associated with the implementation of these measures. On average, it took nine (9) days for a respondent to implement these measures (*Table 5*). None of the implementers of these measures required any specialised skills, and almost all the labour involved in the implementation of these measures was unskilled. Since there is an abundance of unskilled labour in Botswana, its shadow price was estimated at 50% of the value of skilled labour (Governments of Botswana,1996). Using the minimum wage rate of P1000/hour in the agricultural sector opportunity) (Government of Botswana, 2019) and assuming that the respondents were engaged for 8 hours a day, the value of labour was estimated to be P36 000.00. In the city of Can Tho in Vietnam, Danh (2014) estimated labour costs (comprising labour itself, lost income, and health) costs to contribute 59% of the total indirect costs of flooding. This indicates that while households may be investing in fixed and durable materials to reduce the impacts of flooding before, during and after the floods, the opportunity cost of flooding presents itself in the form of investing a significant amount of time in undertaking various risk reduction-related activities.

Table 5: Implemented Flood preventative measures

Flood preventative measure	No. of respondents	Time taken (Days)	Proportion of total time (%)
Pouring sand around houses	1	14	13.7
Retrofitting of houses	8	60	58.8
Construction of water diversion trenches	1	14	13.7
Constructing stoops around the house	1	14	13.7
TOTAL	11	102	100

Direct Market Cost of Flooding

Houses and Other Property

The 2016/2017 flood-affected residents of the two villages in many direct ways, including damage to property (e.g., houses, vehicles, and other household items) and crops, death of livestock and increased infestation of mosquitoes with a high potential to cause malaria. Thirty-nine per cent (39%, n = 174) of the respondents reported that their houses were completely damaged, while 14% (n = 67) indicated that their houses were partially damaged by the flood (*Figure 4*). Most of the damages were reported on traditional houses as these mud-constructed structures could not withstand the flood. Other property damage included valuable items such as cars, generators, sowing machines, tuckshops, furniture, groceries, and kitchen utensils.

The total cost of the repair was estimated at BWP33,345 (n =28), which translates into an average household repair cost of BWP1190.89. A total of 87 households estimated the total replacement cost to the value of BWP533, 150.00. The estimated values ranged from BWP160 to BWP50 000. Based on these reported values, the average household replacement values were estimated at BWP6128.16 (n = 87). While these are reported estimates only, they give an indication of the value of damage to property. As expected, the cost of repair is much lower than the cost of replacement. According to these estimates, the cost of replacement of property for a household is five times more than that of repair.

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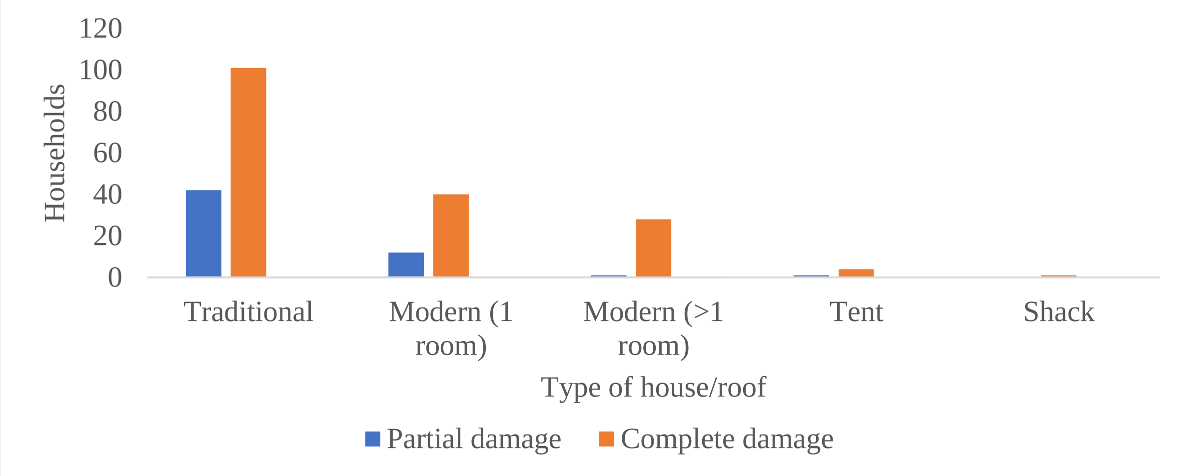
Figure 4: Number of households reporting damage to houses



Livestock Losses

The 2016/2017 flood killed farmers' livestock. The estimated market value of cattle, goats, sheep, and chickens lost is shown in *Table 6*. Chickens were affected in large numbers due to their small size. The total estimated market value of the loss was P1 838 286.00. Market prices, however may grossly underestimate the values of livestock to households. For example, cattle are a source of draft power, milk, meat, and a store of wealth on which households can fall during difficult economic times. Similarly, the small stock is important as a source of meat, milk and cash income and particularly yields quick returns to the farmer compared to other larger livestock. All these values could potentially be underestimated when the market value of the animal is estimated.

According to these results, goats comprised the highest loss of 66%. Based on the households that reported a loss, an average household suffered a loss of P18482.58 worth of cattle, P11282.84 worth of goats and P1314.22 worth of chickens. In terms of 2019 prices, the value of the loss is estimated at P1 835 185.05, which indicates that the price increases/decreases of the different livestock between 2017 and 2019 were very small. The loss of livestock impacts negatively on households as livestock plays significant and multiple roles in the lives of rural people.

Table 6: Number of livestock lost and estimated value of loss (BPW) by village

Livestock	No livestock killed			Average no of livestock lost/household		Livestock Price (BWP)	Total lost value (BWP)	Value in 2019 prices (BWP)
	Zoroga	Gweta	Total	Zoroga	Gweta			
Cattle	122	7	129	7	6	4155.00	535 995	535,995.00
Goats	450	767	1217	10	12	992.00	1 207 264	1,205,937.47
Sheep	14	2	16	7	2	968.00	15 488	15,480.26
Chicken	536	471	1007	18	16	77.00	77 539	77,772.32
Total							1 836 286	1,835 185.05

Reported Crop Losses

Actual monetary crop losses were not estimated due to a lack of data on individual crop stands or the expected yield for that season. Respondents reported that they experienced both partial and complete crop damage due to the flood**.** Complete and partial crop damage was reported on sorghum, maise, millet, and beans. Table 7 shows the number of households reporting partial and complete damage to various crops. The total estimated hectarage of crop losses reported by the farmers was 842.1 ha. For all crops planted, most households reported a complete loss of their crops. Considering crop production as an important economic activity in rural communities,

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the loss of crops has an impact on meeting the nutritional, food security and income generation needs of these households. Furthermore, this loss reduces the livelihood options for most households, increasing their vulnerability to the effects of disasters. The impacts of floods on livelihoods have also been reported by other studies such as Mwape (2009), as high as 94% of the households suffered damage due to flooding in the Kazungula district of Zambia.

Table 7: Number of households reporting partial and complete crop damage by village

Crop	Damage	Village		Total household reporting	%
		Zoroga	Gweta		
Sorghum	Partial	1	3	4	0.8
	Complete	89	119	208	43
Maise	Partial	2	5	7	1
	Complete	95	129	224	46
Beans	Partial	0	5	5	1
	Complete	84	118	202	42
Millet	Partial	0	1	1	0.2
	Complete	15	39	54	11
Pumpkins	Partial	0	0	0	0
	Complete	22	23	45	9
Sweet reed	Partial	0	3	3	0.6
	Complete	39	53	92	19

Direct Non-Market Costs

Some of the impacts of floods not easily evaluated in monetary terms included human injuries and indirect impacts such as a reduction in the frequency of cooking and water contamination. Other respondents reported flood-related injuries in the form of cuts, fractures and strains caused by moving objects and houses collapsing on people (*Table 8*). A single respondent reported a case of drowning that did not result in the loss of human life.

Table 8: Households reported injuries in the two villages

Village	Type of injury					Total
	A cut from sharp moving objects	Broken limb	Hip and/or knee sprain or strain	Drowned but rescued	Back pain due to house collapsing on people	
Zoroga	2	4	2	0	0	8
Gweta	3	1	1	1	1	8
Total	5	1	3	1	1	16

Respondents also reported related flood sicknesses or ailments that included flu, sores, diarrhoea, malaria, pneumonia, and skin irritations. While injuries are associated with health-related costs such as payment for doctor's visits and the cost of medicine, all the respondents indicated that they received free medical assistance in local hospitals and clinics. In other studies, such as Danh (2014), where the impact of flooding was studied, the health costs in the form of doctor's fees, medical treatment and transport were estimated to comprise 23% of the indirect costs.

Respondents also reported that their children could not go to school because of the flood. Sixty-seven percent (67%) of the respondents and 25% in Gweta reported such impacts during the 2016/2017 flood. In countries that frequently experience floods, such as Mozambique, damage caused to school infrastructure by floods often leads to the closure of schools for an extended period of time (World Bank, 2000), leading to children losing several days of schooling.

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Mapped of Areas Susceptible to Flooding

Gweta

Consolidated Participatory Geographical Information System (PGIS) sketches from the two (2) Gweta groups show that there are two (2) flooding lobes, both stretching from the area along the highway at the Filling station (*Figures 5-7*). The first lobe stretches along the Maun-Nata highway for about 2 km in the north-westerly direction before it branches into a south-westerly sub-lobe when it expands four times into a width of about 400 m towards the clinic and narrows down as it curves inwards towards the cemetery. The second lobe stretches from the east of the filling station and moves in a southerly direction at about 200 m in width, reaching the fringes of the northeastern parts of the village. These are the areas more vulnerable to flooding. These lobes are similar in terms of flood damage, depth, and strength. Under the categories of flood damage and strength, the north-westerly moving lobe along the highway has the least risk despite having the largest risk of water depths. The lower risk for damage and strength for this is not surprising as the area is mostly not occupied. This is where large volumes of water accumulate against the road barrier before they cross over into the village.

Figure 5: Flood damage susceptibility in Gweta consolidated from two PGIS groups

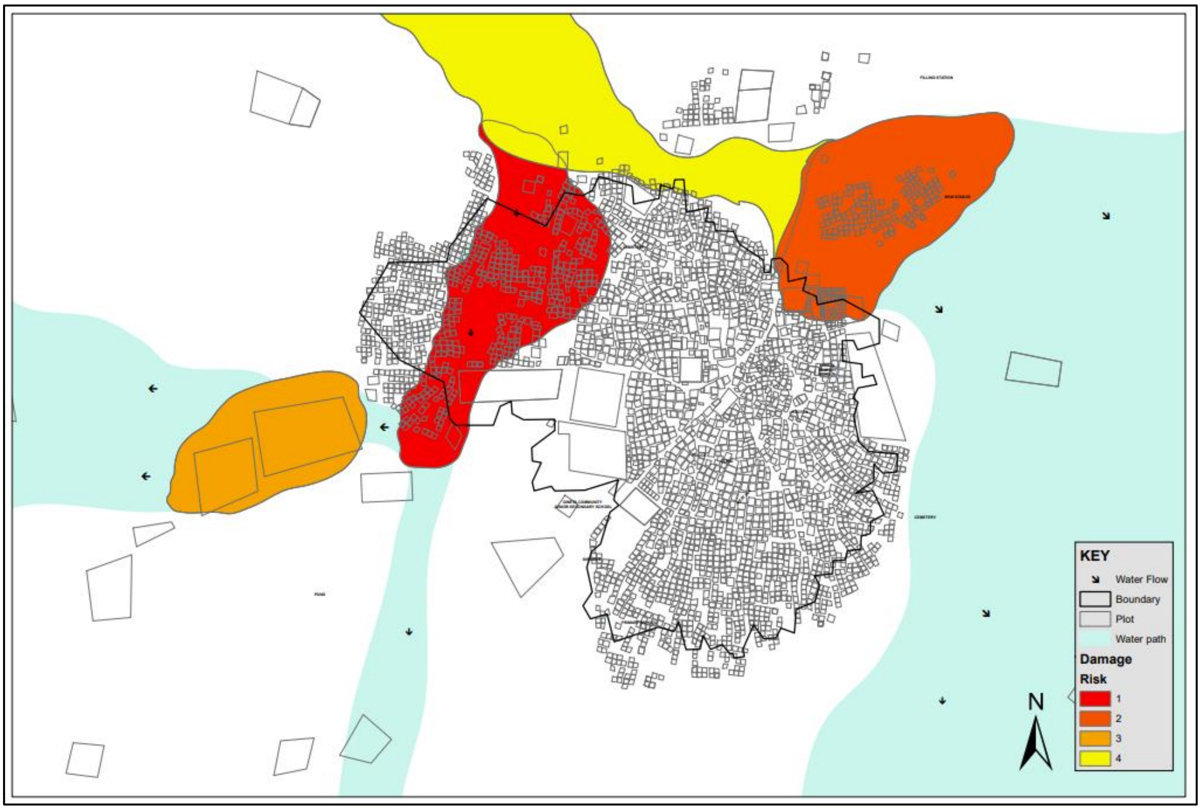

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Figure 6: Flood depth susceptibility in Gweta consolidated from two PGIS groups

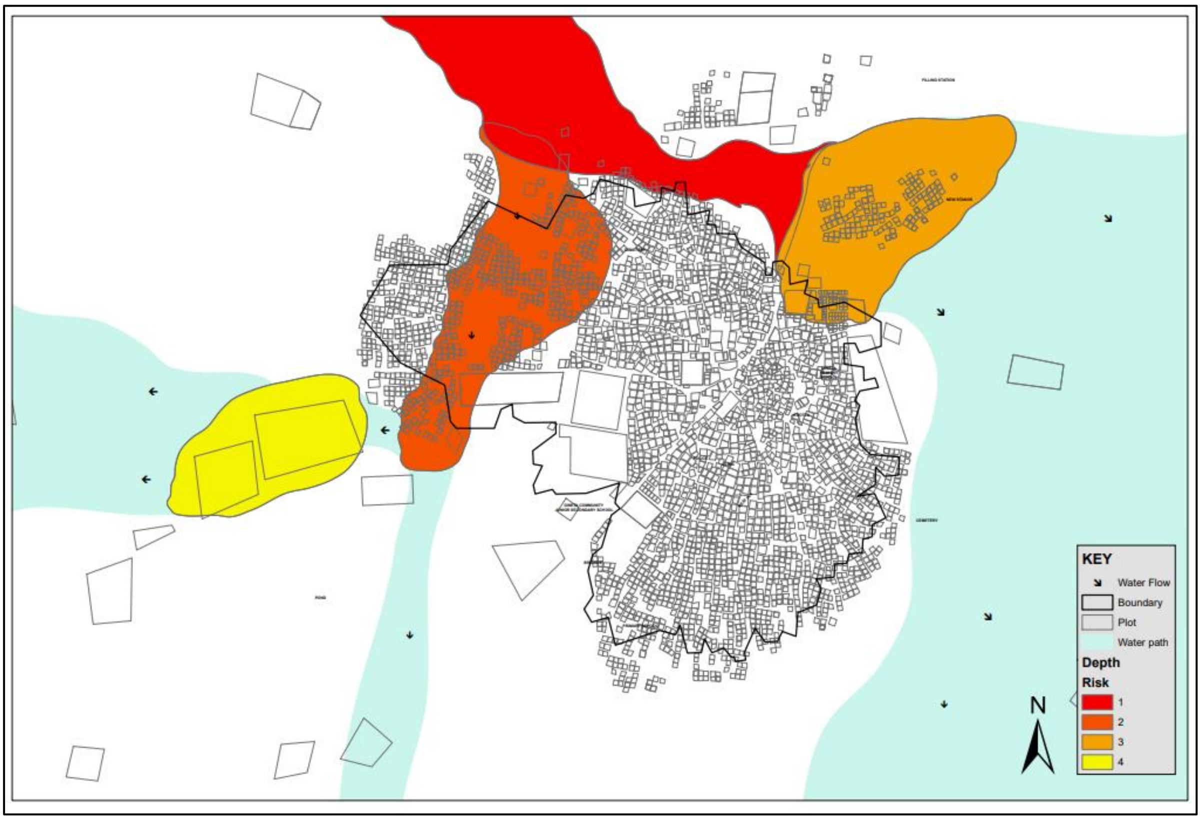
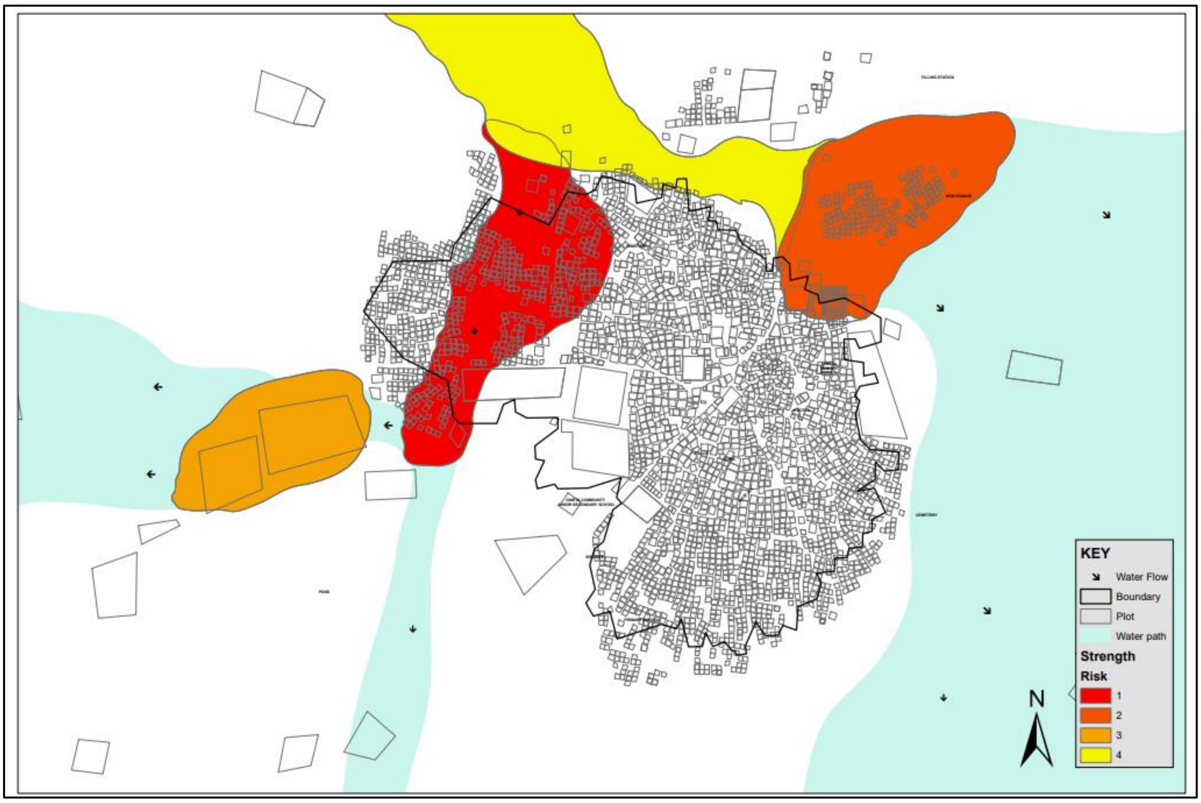


Figure 7: Flood Strength susceptibility in Gweta consolidated from two PGIS groups



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Zoroga

Participants of the PGIS were few (9) and thus only formed one PGIS group. From the group, flood damage risk is made of two lobes. There is the south-westerly moving lobe that starts from the centre of the village and the lobe that enters from the east of the village that branches into a northerly and south-westerly moving sub-lobes at the centre of the village (*Figure 8-10*). Flood depth, damage and strength are similar for the village. The elevated risk of flood damage is more pronounced through the south-westerly moving lobe that starts from the centre of the village, while the largest flood depth is evident through the east-entering lobe. This east-entering lobe has the highest risk of flood strength, followed by the south-westerly moving lobe.

Figure 8: Flood Damage susceptibility in Zoroga based on the PGIS group

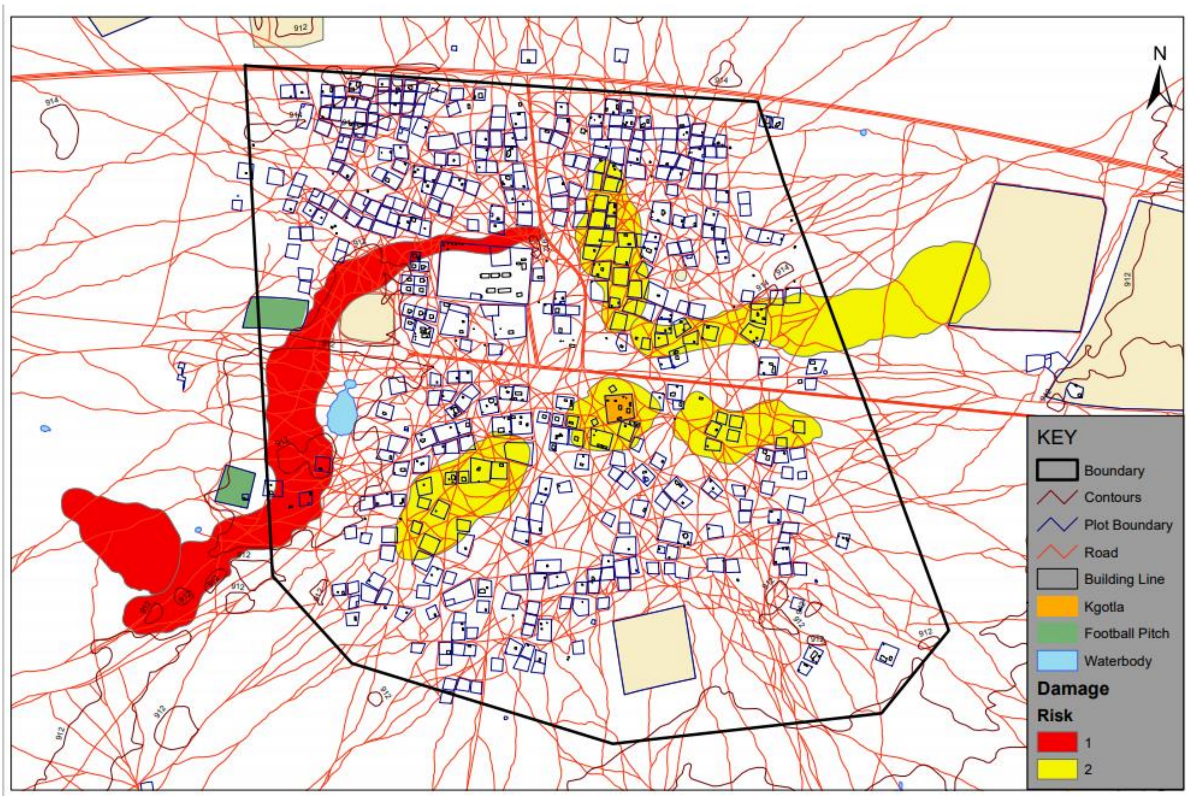

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Figure 9: Flood depth susceptibility in Zoroga based on the PGIS group

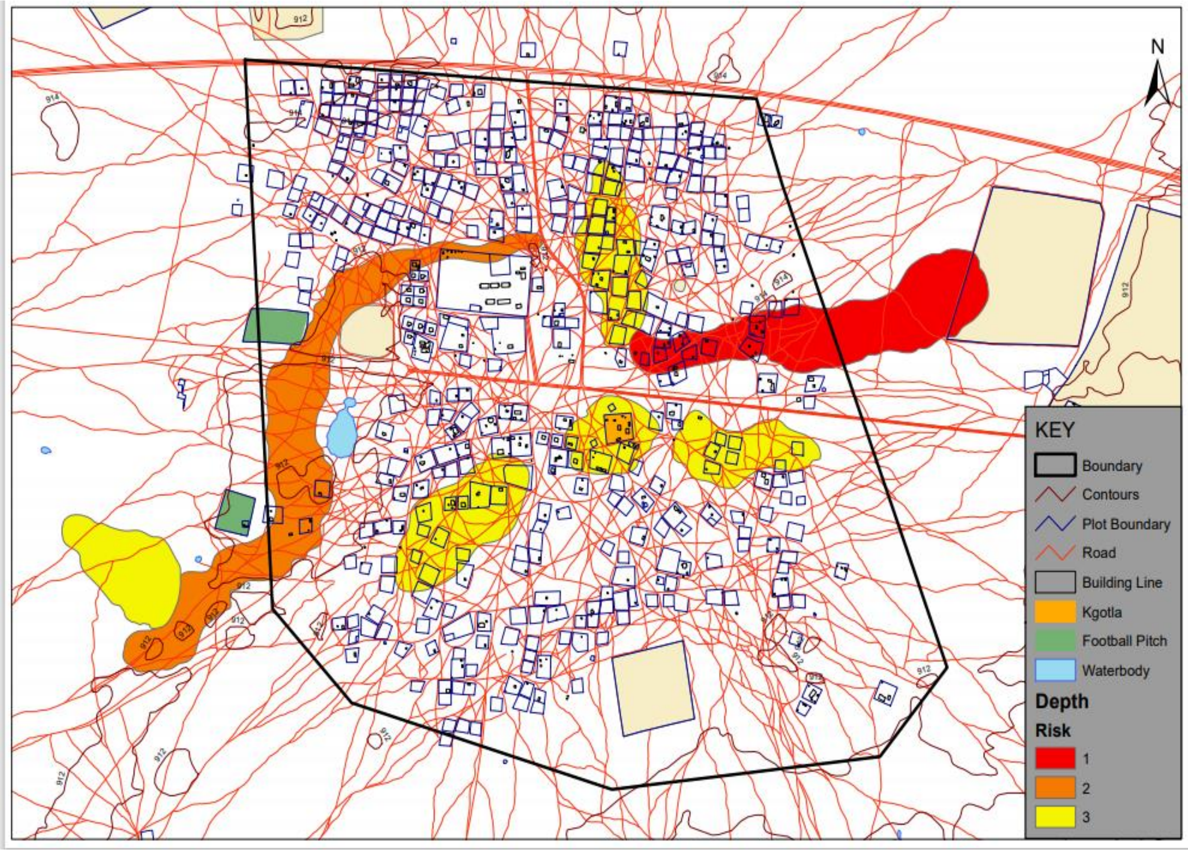
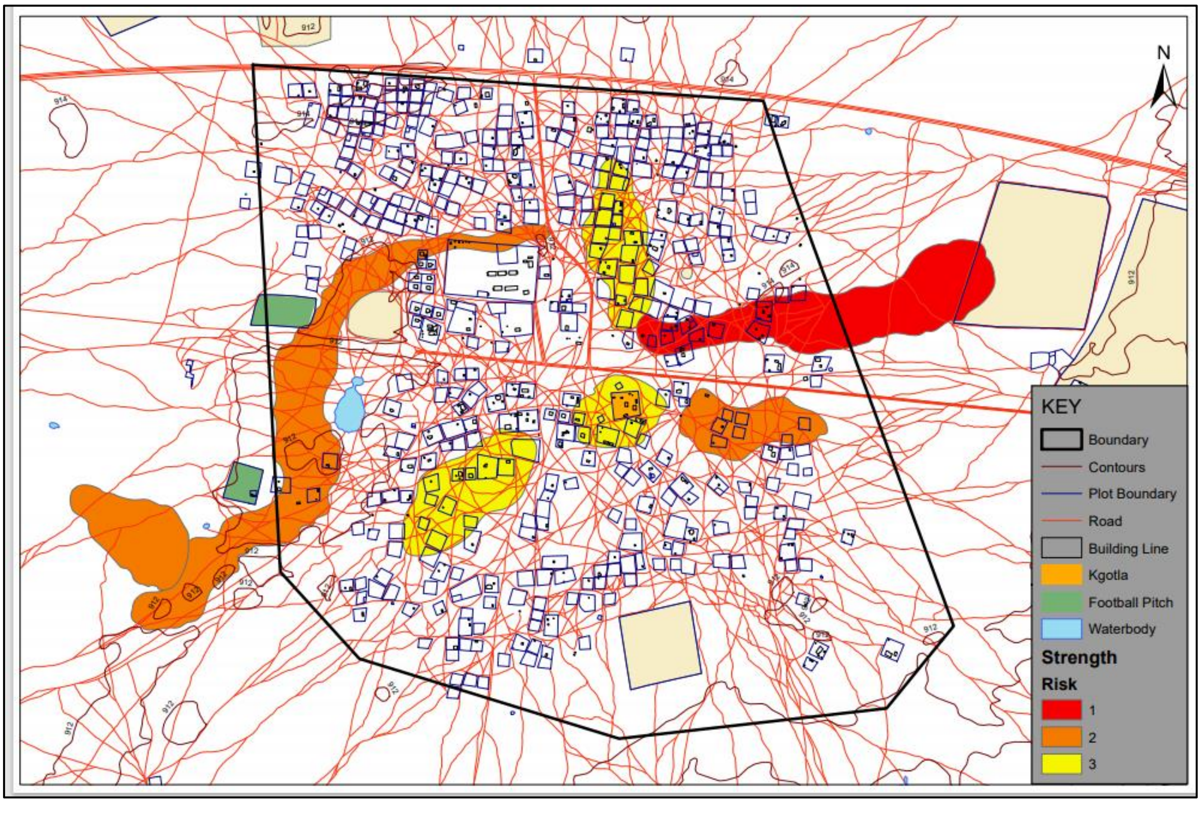


Figure 10: Flood strength susceptibility in Zoroga based on the PGIS group



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CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The villages of Gweta and Zoroga are vulnerable to flooding, which has had devastating impacts on the residents. The areas are low-lying and along the natural paths of water to Makgadikgadi pans. PGIS mapping showed that areas susceptible to flooding in Gweta village start from the Filling station at the junction from the highway into the village from the direction of Nata village; there is the north-west lobe along the highway towards the direction of Maun (that ultimately changes direction into a south-westerly moving sub-lobe) and the southerly moving lobe along the eastern part of the village. For Zoroga village, the flood-vulnerable areas are the south-westerly lobe moving from around the centre of the village and the east-west moving lobe that branches into two sub-lobes at the centre of the village (north moving and south-westerly moving). The lobes depicting flood vulnerability are natural paths of water that have been impeded by different land use activities that modify the drainage systems. One notable example is the highway that impounds water to the north, especially in Gweta, in addition to land use activities and allocations that might not be fully taking into consideration flood vulnerability. It is likely that the villages do not have flood buffer zones for the natural water paths which have been taken up by the villages. This lack of land zoning with developed flood buffer zones is not unique to Gweta and Zoroga but is a challenge for the whole country of Botswana. Water accumulates along the highway and once it over-tops the road, it becomes very forceful, dangerous and sweeps across wide areas compared to when water quantities are spread over time and moving naturally, especially for Gweta. From consultations with the village leadership in Gweta, the highway was constructed not long ago, and during its construction, the road was raised leading to impoundments of water that would naturally flow to the south. Serious flooding situations were not there in the past when the old road, which is gravel, was used. This gravel road to Maun is some 5 kilometres north of the village. Flooding is also exacerbated by increasing rainfall intensities, and this has become an increasing challenge across the whole country. Historically, floods were experienced as far back as the 1930s in the area, but their severity and impacts were not as devastating as the 2016 floods. Compared to other floods, the 2016/17 floods had the most devastating impacts in terms of damage to property, livestock, and crops, as well as in displacing people and disrupting their day-to-day social activities.

The majority of respondents in the two villages are aware of the possibility of flooding during the rainy season. Most of these respondents were those born and raised in the two villages. Residents of the two villages had varied perceptions of the origin of floods. As much as the issue of flooding will always be there, most people perceive the floods to originate from the northern parts of the Maun-Nata highway. This needs to be investigated further with the addition of geophysical analysis to look at all the flood conditioning factors combining both geospatial analysis and geophysical analysis over an expansive area and not only concentrated on the individual villages themselves, as was the case with this study.

In terms of costs, the opportunity cost of labour for implementing various flood preventative measures was estimated at BWP36 000.00/household. The direct damages of flooding to houses and other properties, as estimated by repair and replacement cost techniques, were BWP1 190.89 and BWP6 128.16 per household, respectively. In terms of livestock losses, an average household suffered BWP18 482.58 worth of cattle, BWP11 282.84 worth of goats and BWP1314.22 worth of chickens.

Recommendations

Based on the findings of the study, the following recommendations are made:

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Reassessment of Land Use Activities

The residents of the two villages noted that as the village population increased (especially Gweta), people were allocated new plots in low-lying areas, which hitherto were the pathways or channels of flooding water. Land allocation authorities (Land boards) should therefore consider re-assessing land use activities and/or allocations in line with flood vulnerability. In view of the findings of this study, some of the residents might need to be relocated. This could need the commissioning of a study on developing flood buffer zones and vulnerability maps for the villages.

Establish Household Vulnerability Data

It appears that the frequency of flooding in the villages of Gweta and Zoroga is increasing over time. There is therefore need to establish a scientific basis for predicting flood occurrences in these areas. It is also important to establish baseline data on community vulnerability in areas where flooding is frequent with a view to attending effectively or timely to those in need of assistance during flood events.

Response Capability

Poorly resourced residents must be assisted accordingly to respond adequately before and during the hazard. It should be noted that flood protection works or structures could be very expensive to construct and maintain. Where possible, assistance should be sort from local councils to construct flood diversion structures.

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