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Flood Vulnerability Analysis in the Down Stream of Shiroro Dam and its Environs

Sanusi Ummulkhair, Caleb Odiji, Hamza Dorcas, Sadiya Baba, Nwadike Blessing and Salman Salis
[1] *Department of Strategic Space Application, National Space Research and Development Agency, Airport Road, P.M.B. 437, Abuja, Nigeria*

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Corresponding Author:
Ummulsanusi@gmail.com

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A B S T R A C T

Flooding is one of the most frequent and widespread of all environmental hazards and of various types and magnitudes, occurs in most terrestrial portions of the globe. The downstream of Shiroro dam has been experiencing recurrent floods resulting in the destruction of properties and loss of lives. Consequently, the study aims at mapping flood risk and vulnerability areas downstream of shiroro dam. Topographic maps, soil maps, geology maps, demographic data, and digital elevation models (DEM) were used. These data were analyzed using pair-wise evaluation techniques for decisive weighted-overlay investigation of each factor in flood vulnerability assessment. The result shows that 6.4% of the study area was highly vulnerable, 64.02% was moderate and 29.58% was low. The study highlights the application of GIS in modeling flood risk in the Down Stream of Shiroro Dam and its Environs. Vulnerability assessment critical because it provides an organization with details on any weaknesses in its environment.

Introduction

Flooding is considered to be the most destructive natural disaster, is one of the major environmental crises one has to contend with globally. Flooding may occur as an overflow of water from water bodies such as a river, lake, or ocean in which the water overtops or breaks levees resulting in some of that water escaping its usual boundaries (Yoade *et al*,2020).

Flooding attributes to about one-third of losses worldwide (Olujimi, 2007). Several countries such as India, Poland, and Germany in the past decade have been seriously affected by disastrous floods (Mirza *et al,* 2003). The occurrence of a flood depends on the metrology, topography change, land use, soil type, and antecedent moisture conditions (Funk 2006; Youssef *et al,* 2016; Agbola *et al,* 2012). According to a report by the intergovernmental panel on climate change (IPCC) 2007, which warns of the possibility of an increase in the frequency and intensity of catastrophic weather events such as temperature, extremes, and consistent rain and windstorms, for instance in many African cities floods and droughts are regarded as the most common of all hazards (Van Nicker & Wisner 2014).

In Nigeria it was reported that excessive rainfall is characterized by the period, frequency, trend, intensity, and fluctuation are related to the frequency of flood events occurrence (Ologunorisa and Diego, 2005). Flooding in various parts of the country has forced millions of people from their homes, destroyed Businesses, polluted water resources, and increased the risk of diseases (Yoade *et al,* 2020). According to the report by the national emergency management agency (NEMA) in 2012, it discloses that

256 local government councils out of the 774 local government councils were badly affected by floods in 2012 with Kogi and Adamawa states having the maximum casualty figures. In a study by Yoade et al (2020) it reported that residents opined that heavy rainfall is the highest cause of flooding in Ibadan Eleyele and Apete buildings precisely and it accounted for 40.9% while Terrain of the area is the least cause of flooding in the area and it accounted for 2.8%. Also, Bahago et al 2019 stated that the flood event downstream of shiroro Reservoir at Gurmana in Niger State took a total of 20.368km2 of lands, farmlands, and transportation routes that were severely affected with about 50 members of the households in the area being displaced. The shiroro reservoir has a total installed capacity of 600MW, with four Francis turbines of 150 MW each (NEPA, 1984). In a study by Musa et al, (2016), it was reported that since the construction of the Shiroro Dam reservoir, flooding incidence has been recurrent and perennial with maximum destruction in 1985, 1988, and 2012, hence, villages such as Gunugu, Jiko, Kami, and Manta at the downstream of the Dam have witnessed several flood disasters due to overflow of the Dam. However, these communities have declined government interference at relocating them to a safer place due to the social-economic benefit they derived from the Dam. It is feared that the entire Shiroro Dam Community is likely to submerge if an extreme and extensive rainfall occurs. However, the effect of waters released from dams in Nigeria during flood events has contributed towards aiding the destruction of most downstream communities. Therefore, the current research work intends to fill the gap by identifying and delineate the Shiroro Dam area; assess the areas at risk; and possible suggestions on how to mitigate the impact of seasonal flood disasters on the downstream communities. Given this, the research aims towards mapping out flood risk and vulnerability areas downstream of the Shiriro Dam in Niger state, Nigeria. Furthermore, map and delineate the Shiroro dam flood plain; and also to generate a flood vulnerability map using multi-criteria analysis. This research is likely to lessen the effect of seasonal flood disaster on the downstream communities of the Shiroro Dam reservoir. Furthermore, it would help identify the communities located at potential flood risk zones and thus tends to help the authorities and the victim communities with a contingency plan on how to balance their socio-economic benefits and risk to flooding.

Study Area

The study area covers the communities downstream of Shiroro dam in shiroro local government area of Niger state. The selected villages are Kami, Jiko, Gunugu, and Manta which lies between latitudes 10°19'3.13" and 9°42'29.76" North and longitudes 6°10'45.19" and 7°11'40.53" East (see fig 1). The area is characterized by wet and dry seasons with rainfall occurring in the rainy season months of May to October. Temperature is high in the period of the dry season and less in full wet raining season between 27°C and 35°C [Suleiman et. al., 2015]. According to NPC (2010), the population of Shiroro local government area was reported to be 235,665 people. The study area terrain is generally low lying with some conspicuous hills. Its area has a tropical climate with distinct rainy and dry seasons with annual maximum rainfall varying between 1100mm to 1600mm while the annual minimum precipitation ranged from 400mm to 600mm of the area. The geology of the study is typically and the basement complex rocks with prominent outcrops composing largely of granite. The topography is highly undulating and varying in height, while isolated hills of over 600m are common, the valley in between can be as low as 400m. The hills are made up of granite rocks and the lower terrain is dominated by schist and gneiss. The vegetation of the area is of savannah type with covers of few woodlands mainly trees with little shrubs and grasses.

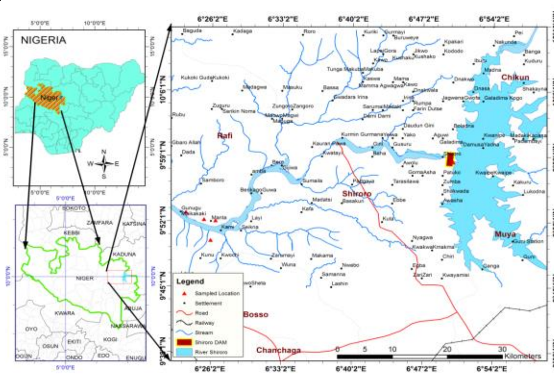

Figure 1. Study Area Map

Materials and Methods

The dataset used for this study was secondary data which contains spatial and non-spatial attributes as shown in Table 1.

Table 1: Data types and sources

Data list		Data type	Data	Data source	Resolution
1.	Landsat 7	Secondary	Satellite imagery	Earth explorer	15m
2.	SRTM (DEM)	Secondary	Slope Flood vulnerable areas	USGS Earth explorer	30m
3.	Soil map	Secondary	The soil of the study area	Nigerian Geological Survey Agency (NGSA)	
4.	Topographic map	Secondary	The topography of the area, contour, drainage network, settlements, utilities, and road.	Nigeria Federal Surveys Topographic Map Gazette	
5.	Geology map	Secondary	Geology of the area	Nigerian Geological Survey Agency (NGSA)	

To identify and map the areas that are vulnerable to flood

Six contributing factors were delineated and examined, geology, slope, soil types, land cover/land use, drainage, and geomorphology, their results are discussed intensively as follows:

Soil

Soil textures exert a great influence on flood vulnerability as far as water infiltration or percolation is a concern. Water infiltrates much faster on sandy soil than clay soil but clay soil is less porous and holds water longer to the point where it becomes runoff. Surface runoff of any area is linked to the soil texture and this can influence flood risk in an area (Ndabula et al., 2012). The figure shows that the study area is characterized majorly by the soil of luvisols type (Figure 2a).

Geology and Lithology

Variation in the geological structure of an can influence flood. The study area is characterized by different types of rocks, which include Type Basement Complex Meta-Sediments Older Granite, which is ranked based on the level of flood vulnerability in the study area (see figure 2b).

Slope

Areal differentiation is a contributory factor to the risk of flood in an area. An area where the slope gentle is highly prone to flood when compare to an where the slope is very steep and rugged. Slope length and steepness influence the rate at which water flows. The slope of the area are measured in percentage Unit: (%) <0 - 1.5, 1.6 - 3.6, 3.7 - 7.37, 4 – 14, and >15 – 36 (see figure 2c).

Elevation

The height of an area relative to the sea level is a factor that is worth considering for flood vulnerability. An area less than 100 meters above sea level is naturally predisposed to flood when compared to an area with high elevation. The figure shows the elevation of the study area(Figure 2d).

Landuse/Landcover of the Area

Land covers are causative factors that can influence flood occurrence due to runoff. For example, areas with less vegetation have high flood vulnerability, while where there is thick vegetation that has less flood vulnerability (Ndabula et al., 2012). Figure 2e

Flow Accumulation

The Flow Accumulation tool calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. The flow accumulation of the study's area the flow accumulation map shows the direction in the slope of the study area, with values ranging from 0-27.55 indicated with shades of colors from blue to red. The red color depicts the region of low elevation which signifies that the flow of water accumulates towards the downstream of the dam see figure 4f.

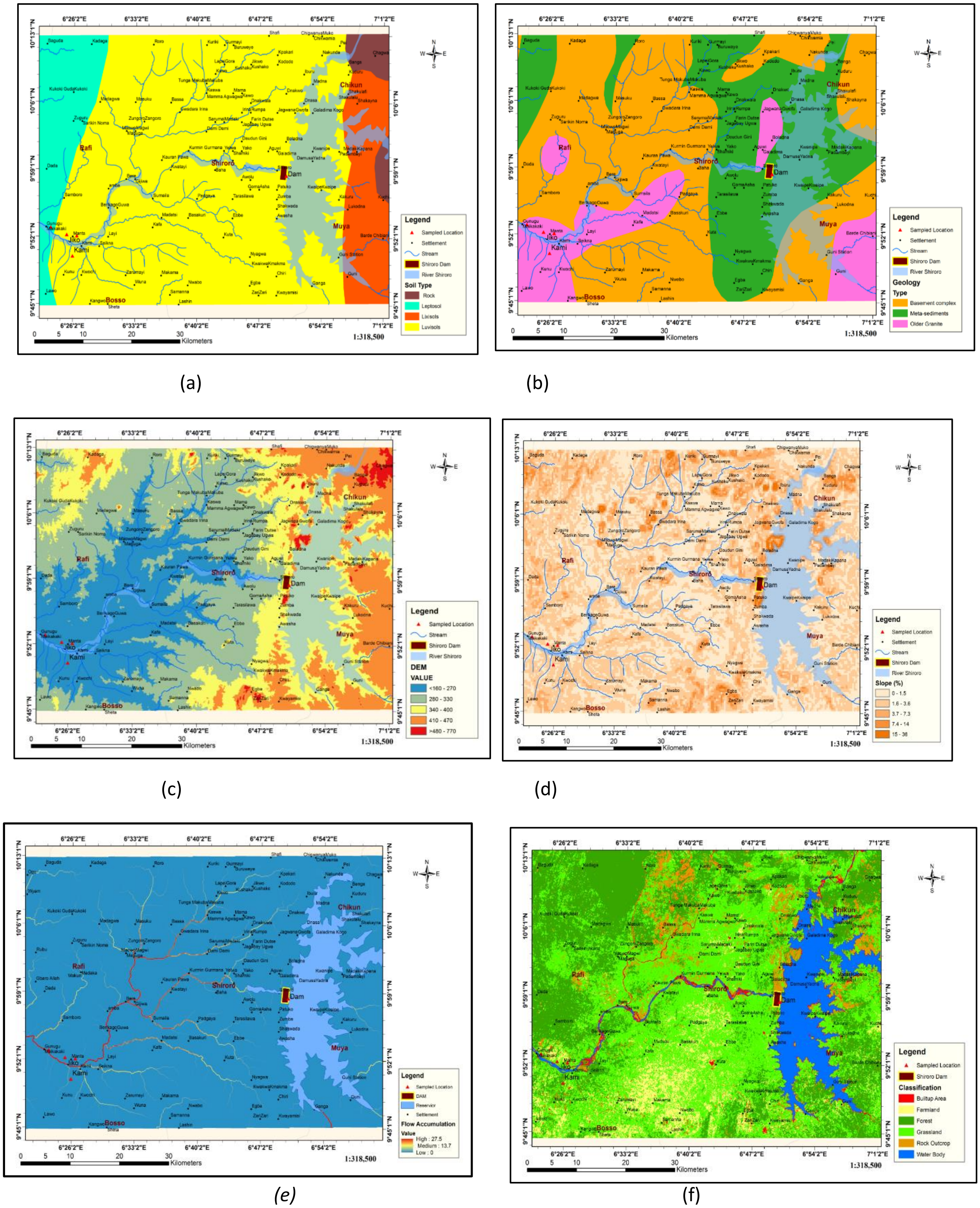

Figure 2 (a) soil texture (b) geology (c) elevation (d) slope (e) flow accumulation (f) land use

Weighed Overlay Analysis Model Result

As with all weighted overlay for multi-criteria analysis, Shiroro Dam Area Flood vulnerability was defined as the problem, the model was broken into sub-models, and input layers were identified as shown in figure 3 and Table 3.

The input criteria layers were indifferent numbering systems with different ranges, to combine them in a single analysis, there were changed to grid raster, each cell for each criterion was reclassified into a common preference scale between 1 to 6, with 6 being the most Flooding causative factor. An assigned preference on the common scale implies the phenomenon's preference for the criterion. The preference values are on a relative scale. That is, a preference of 6 is twice as flooding contributory as a preference of 5.

The preference values were not only allocated relative to each other within the layer but also had similar meaning between the layers see. If a range or factor for one criterion is assigned a preference of 5, it will have the same influence on the phenomenon as a 5 in a second criterion for example for slope the elevation range between <156m - 277.8m was assigned 5. Each criterion was reclassified and weighted and ranked using the Analytical Hierarchical Process (AHP).

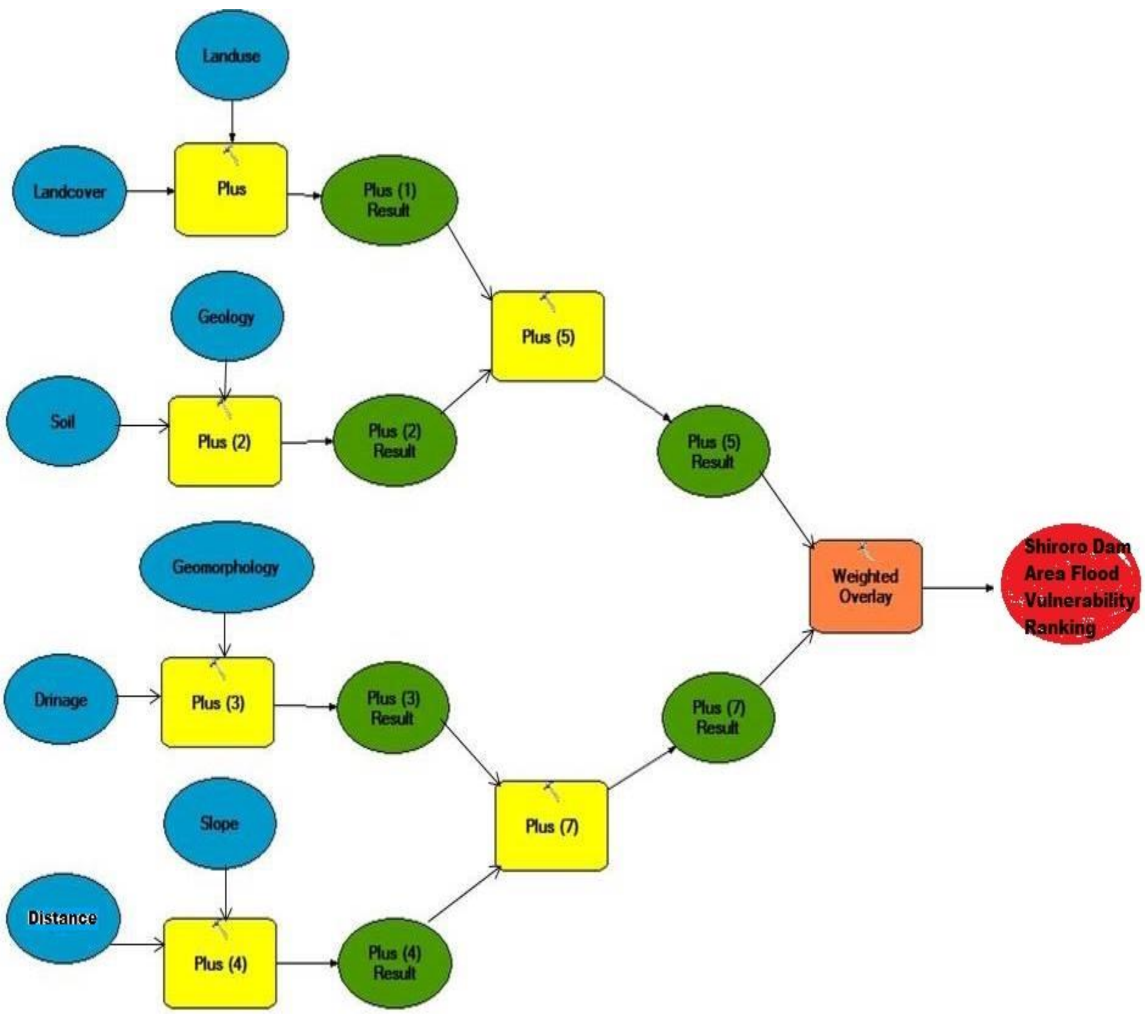

Figure 3. Analysis Model

Table 3: Weighted Ranking of Flooding Factors

Feature	Weight (%)	Factors	Rank
Geology	9	Type	3
		Basement complex	2
		Meta-sediments	1
		Older Granite	
Slope	25	Unit: (%)	
		<0 - 1.5	5
		1.6 - 3.6	4
		3.7 - 7.3	3
		7.4 – 14	2
		>15 – 36	1
Drainage	24	Order (km)	
		>5^{th}	5
		4^{th}	4
		3^{rd}	3
		2^{nd}	2
		<=1^{st}	1
Soil	10	Type	
		Luvisols	4
		Leptosol	3
		Lixisols	2
		Rocks	1
Landuse/landcover	11	Type	
		Waterbody	6
		Builtup Area	5
		Farmland	4
		Grassland	3
		Forest	2
		Rock Outcrop	1
Elevation	20	(m)	
		<156 - 277.8	1
		277.8 - 399.6	2
		399.6 - 521.4	3
		521.4 - 643.2	4
		>643.2 – 765	5
	100		

Result and Discussion

All six factors were combined to create the flood vulnerability map as shown in the figure 4. The areas with high vulnerability are concentrated in the center and south especially around the main river and its tributaries. The high vulnerability class occupies an area of 282 km^2 representing 6.41% of the study area. The moderate level of vulnerability is spread across the vast area of the study area occupying 2818 km^2 representing 64.02% of the study area. The low vulnerability level makes up 29.58% occupying an area of 1302 km^2 of the study area (Table 4). The most influencing for areas having high vulnerability include drainage density, slope, and low elevation while the most impactful factor for areas have low vulnerability are; steep slope and high elevation It is worth mentioning that thousands of people live downstream and within the region of high vulnerability. The nature of the area exposes the people and livelihood to flood witnessed almost every year. Field investigations in the study area revealed that the study area is in a flood plain which already by natural default is a flood hazard and also the study area lack a proper drainage system. It was observed activities of the people like erecting the residential structure on waterways impede the flow of runoff. This map should be used by the government and planners to adopt a mitigative measures (Figure 4).

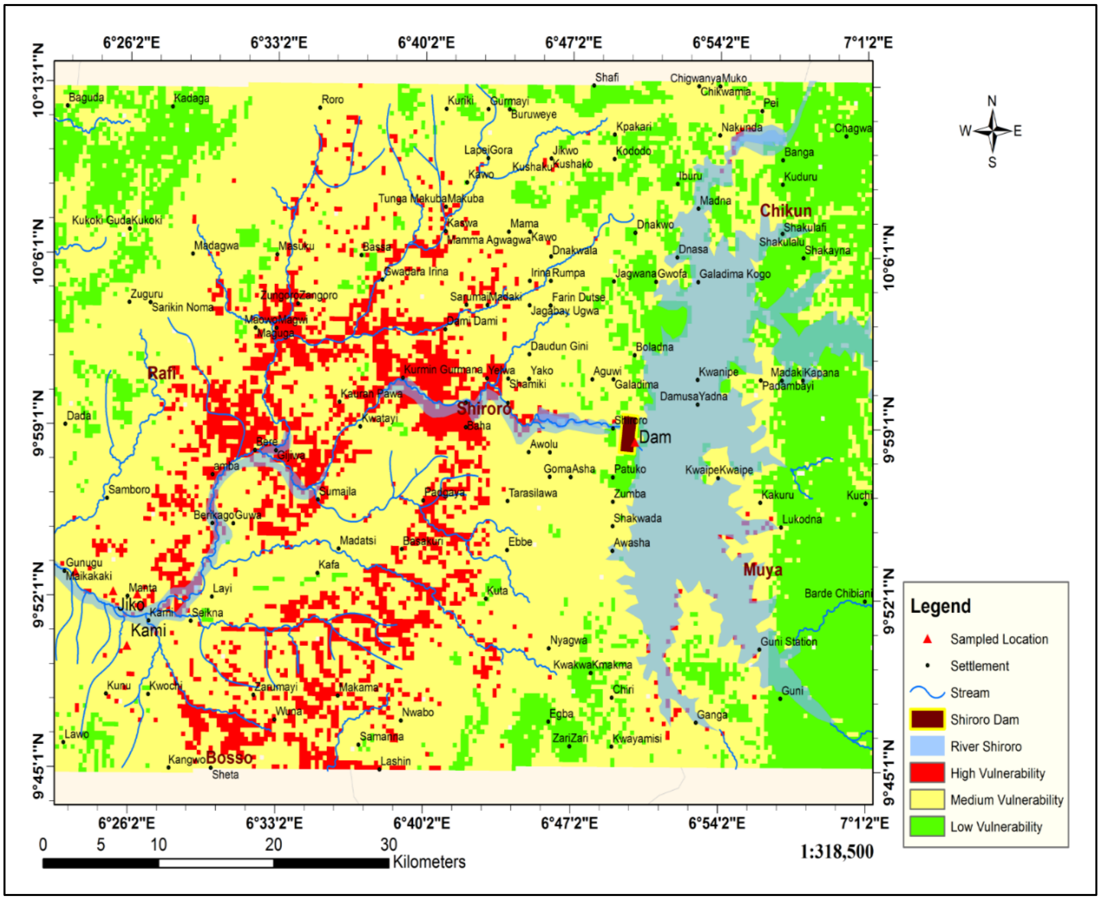

Figure 4.

Table 4. Vulnerability distribution

S/N	Ranking	Area (Km^2)	%
1	High	282.00	6.41
2	Moderate	2818.00	64.02
3	Low	1302.00	29.58
	Total	4402.00	100.00

Conclusion

The study presented the impact of the released water from the Shiroro Dam reservoir on the downstream communities whereby several villages are severely flooded leaving people homeless, destroyed properties, agricultural lands, posing a health risk to the inhabitants. The combination of spatial data sets and multi-criteria analysis with geospatial application software to arrive at results such as land use landcover map, geology map, soil type map, buffer map, and vulnerability map. This makes the methodology employed in this study very flexible to be utilized in any region provided that specified local factors are taken into account.

From the geospatial analysis, the result revealed that 4 communities are vulnerable to flooding due to their proximity to the river. However, 3 communities (Gunugu, Manta, and Jiko) are located within the highly vulnerable zone, while the 4th community (Kami) is less vulnerable compared to the aforementioned communities putting the inhabitants of these communities at higher risk to flooding from released water from the Dam. Hence, future flood occurrences can be averted through effective management, proper mitigation measures, continuous education with sufficient information to residence, and prospective developers. This spatial analytical capacity utilized in this study will not only mitigate the impact of flooding, rather it can be used as a decision support system for planning, preparedness, prevention, mitigation, response, recovery for the possible occurrence of flood activities in the Shiroro Dam environs.

It is, however, recommended that the Shiroro Dam should be properly harnessed to effectively utilize available water upstream without the need to spill excess water to downstream communities. Proper education on the effect of the building near the riverbank should be conveyed to inhabitants. Similarly, the relevant authorities should engage the communities and local authorities in making them aware of the flood risk given the climate variability. Also, a flood early warning and signals should be put in place especially during excessive rainfall. Furthermore, community-initiated mitigation measures should be promoted to build community resilience by delineating the non-flood areas and flood areas, in which the non-flood areas can serve as a impermanent housing for the settlements during flooding.

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Conflits of Intrest

The authors declare no conflict of interest.

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