Flood Monitoring Using Remote Sensing And Gis Techniques : A Case Study Of Kampala District, Uganda

Dr. Nazar Hammam[1], Abdulwahab. K [2] , and Dr. Anwar Sidahmed Mohamed[3]
[1] Assistant Professor , University of Medical Sciences and Technology (UMST) Khartoum Sudan
[2] Department of geographical information system, university of medical science and technology (UMST) Khartoum Sudan.
[3] Assistant Professor , Remote Sensing and Seismology Authority-National Center for Research- Sudan.
*Corresponding Author:hammamn@gmail.com

***Abstract*—Disasters like floods, earthquakes, wild fires and landslides have become an issue of major concern all over the world. They have become an annual phenomena that have devastating effect on the infrastructure, property and in most cases result in to loss of human life. Amongst the most prevalent natural disasters are the floods, with their frequency of occurrence, extent and cost of damage have escalated around the globe. Kampala, the capital city of Uganda experiences the occurrence of flooding events annually with dire consequences. Previous studies have shown that remote sensing and geographic information systems have been an effective tool in the flood risk management and assessment. This paper seeks to demarcate areas that are susceptible to flooding in Kampala using remote sensing and geographic information systems. The SRTM DEM is used to create the elevation, slope and stream network raster maps. The flood map created from the overlay of the polygon land cover and polygon DEM flood predictability with embedded towns indicates that Kampala is moderately at a high risk of flooding due to its low gradient and slope with the built up areas cover type experiencing high levels of floods especially for the areas that are constructed in the previously occurring drainage channels. The maps created can be useful to the decision makers to identify the flood risk zones, planning drainage systems incorporated with the already existing residential areas. The information can also be helpful to the town planners to mitigate, relocate and manage the victims that have lost their property.**

Keywords—Remote sensing, GIS, floods, DEM, Kampala

1. Introduction

Floods are natural hazards when the water overwhelms lands that are usually dry. Kampala is largely affected by flash floods which are defined by their fast speed occurrence after a heavy and high intensity localized rainfall.[1, 2] , [3] pointed out that the heavy and high intensity rainfall lead to a sudden and quick rise of water levels causing a threat to lives and property of inhabitants. Floods are part of an area of study in the field of hydrology since they are a big concern to agriculture, civil engineering and public health. Human activities like deforestation, wetland removal in order to construct places of settlement or even industries in the case of Kampala city are one of the main causes that triggers flooding since they tend to change the nature of the environment. Land use and floods are closely related, therefore any changes in the land use, such as urbanization across the catchment's area, may trigger a sequence of flood occurrences and more economic losses [4].Several studies including [5], Bronstert [6] indicate that land use changes could be behind this recent frequent and erratic floods. Floods are also largely due to climate changes and rise in the sea levels.

Floods are associated with primary effects such as loss of lives and property, damage of infrastructures, ecosystems, cultural values, roads and bridges [3]. Floods are difficult to control but the impact can be minimized. Advancement in computer knowledge, modelling, remote sensing and Geographic information systems (GIS) have been handy in flood management[7]. In the age of modern technology, integration of information extracted through GIS and remote sensing with other data sets provides tremendous potential for identification, monitoring and assessing flood disasters[8] .Management of data helping to monitor the generated high floods largely relies on the functional facilities supplied by the GIS systems combined with satellite images and hydrological models .

2. Objectives

The study aims to show how GIS can be used as a tool for predicting and monitoring susceptible areas to flood damage and also planning for the relocation of the people in the places most likely to be affected. The study also aims to ascertain the damages caused by floods on to the residential areas, agricultural areas, hence showing the relation between land use and floods. This information will be helpful in the future for flood management .It also shows how GIS provides the basis to develop strategies that combat the people and areas affected by floods.

3. Study Area

Kampala is located in Uganda, East Africa and lies along the following coordinates: 0°18′ 49″ N, 32° 34′ 52″ E. The City borders Lake Victoria, Africa's largest lake in the East and surrounded by Wakiso District in the West and North. Kampala is the Capital City and Seat of Government-with the assorted arms of central government. [9]. Kampala is developed on hills linked by valleys of wetlands and river channels that flow into Lake Victoria. [10]

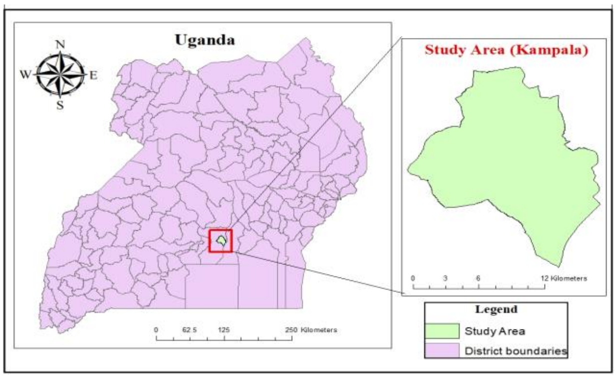

Figure 1 location of the study Area in Uganda

About 23% of Kampala's area is fully urbanized, a significant portion of 60% issemi-urbanized and the rest considered as rural settlements. It covers a total of 189.3 km^2 of land and water, with a population estimated to around 1,650,800 according to the census of 2019. [9].Since Uganda lies along the equator, the climate of Kampala therefore lies in the equatorial region characterized with two annual wet seasons of March to May and September to December. Climate change is placing further strains on the city's ability to manage the urban environment. Increasing levels of rainfall from climate change contribute to storm runoff levels that exceed the capacity of the city's infrastructure, causing flooding and the spread of pollution. [10]

4. Data used and Methods

With the help of the Uganda Bureau of Statistics website, topographic maps were obtained which were later on used to extract the Kampala District administrative boundary .There are no open source sites to download geospatial data on the land use, average water levels above mean sea level, actual rainfall data etc. The open data that was available was used to download the Landsat-8 images and SRTM DEM from USGS website. For this study, a time frame from June to August for the year 2020 which represents the non-flooding season was considered as regards to the Landsat images. Upon acquiring all the required datasets, different processing steps were performed on to the Landsat 8 images like creating composite bands 1 to 8, clipping the study area using the district boundary as well as carrying out supervised classification to show the different land cover types that exist in the area. Spatial data pre-processing was also performed on the DEM like creating the stream Network, slope and elevation.

The processing of the Landsat data for evaluation has the following major components:

1) Mapping of Kampala area before floods usingLandsat-8 OLI images.
2) Determining the percentage of land cover and sum of the area of each land cover type.

A supervised classification was carried out to classify the larger extent of heterogeneous landscapes with the intention of generating three major land cover classes (i.e. urban area, Vegetation and water Body).

For the SRTM DEM, the image is clipped to extract the elevation of the study area. It is then reclassified to create a map of areas prone to flooding. The created raster is then converted to a polygon. The towns' layer is added and clipped with the district boundary to identify the most likely affected zones. The land cover classified map is converted into a polygon map and overlaid to the DEM created for flood prediction to ascertain the extent of the damage predicted to happen to the different land cover types.

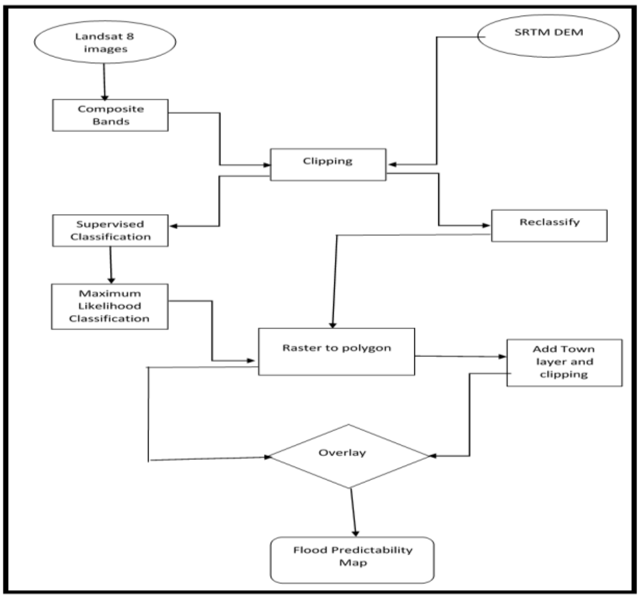

Figure 2 Conceptual framework adopted for the generation of flood predictability map

5. Results

5.1. Land Cover

The land cover map is useful as it reflects the current use of the land and gives an indication of the ability of soil infiltration. About 8% of the study area is water of Lake Victoria, 16.67% vegetation and the largest portion being built-up areas taking a percentage of 75.32%. The vegetation cover slows down the amount of surface runoff and therefore floods are predicted to happen moderately. The built-up areas are characterized by impermeable surfaces and increase the surface runoff hence the increase in the probability of flooding.

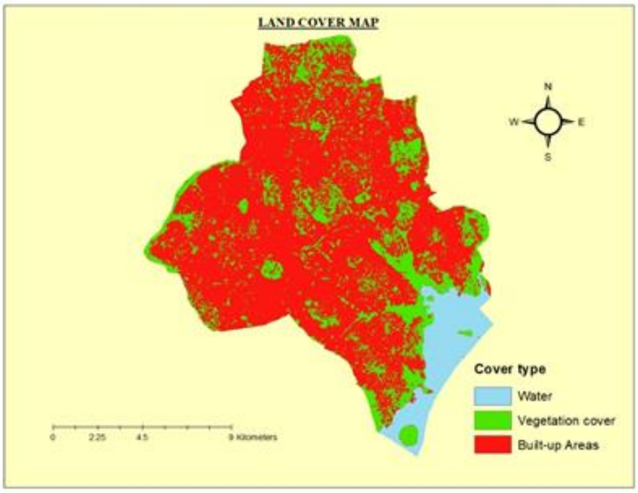

Figure 3Land cover map of Kampala District

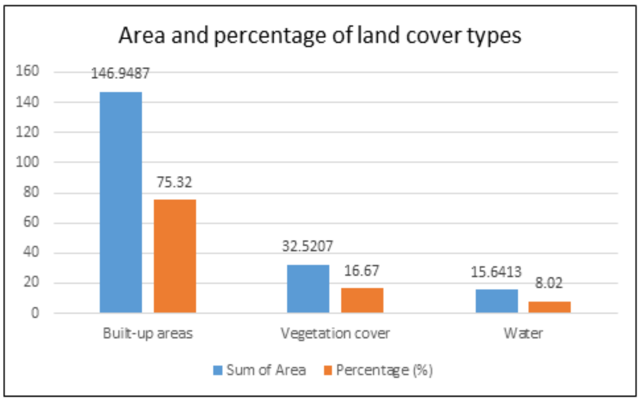

Figure 4 Percentages and area of land cover types

5.2. Drainage extraction

With the help of the GIS software, a series of automatic extraction techniques ranging from flow direction through flow accumulation to the generation of the final stream network, based on the direction of flow of each cell was done using the DEM image.

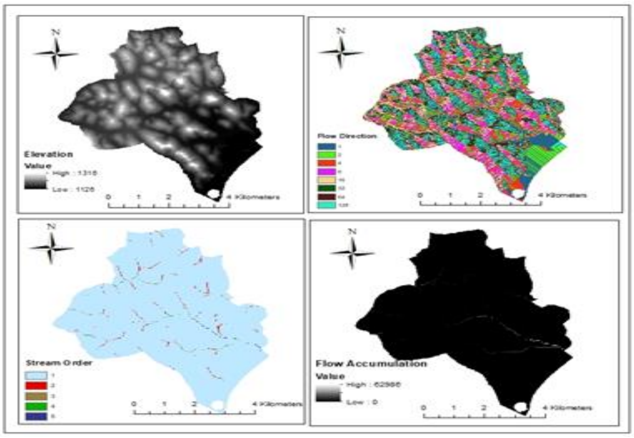

Figure 5 Steps of extraction of stream network

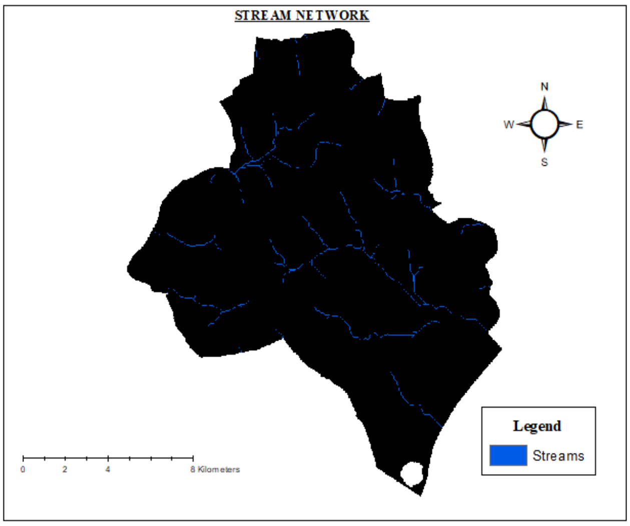

Figure 6 Map of the extracted stream network

The above figure 5, shows the stream network that was extracted from the SRTM DEM. The reclassified stream network is shown below in figure 7 has different colors which represent the different flow accumulation.

Flow accumulation between 0 and 1077m imply very low, between 1077 and 4753 represent low, between 4753 and 11313 show moderate flow, between 11313 and 26403 show high flow accumulation very high flow is shown between 26403 and 62986.

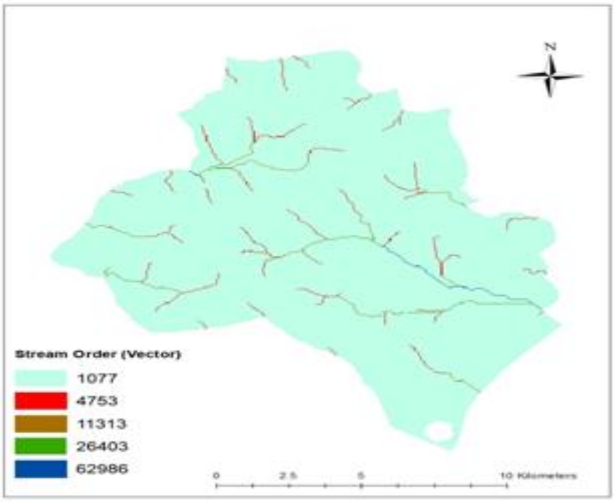

Figure7 Map of reclassified stream network showing stream orders

5.3. Slope and Elevation.

The slope and elevation maps are represented in figures 8 and 9 respectively. Slope and elevation maps are important in showing the flood vulnerability of the area's terrain. The slope has an effect on the surface runoff, infiltration and the direction of flow with low gradient slopes being extremely susceptible to the flood occurrences. Using the natural breaks, the slope was classified and it can be seen that most of the study area is sloppy surrounded by low lying areas. The flat nature of the low lying areas which are coupled with high clay soil content, leads to the rapid accumulation of the rain water leading to floods.

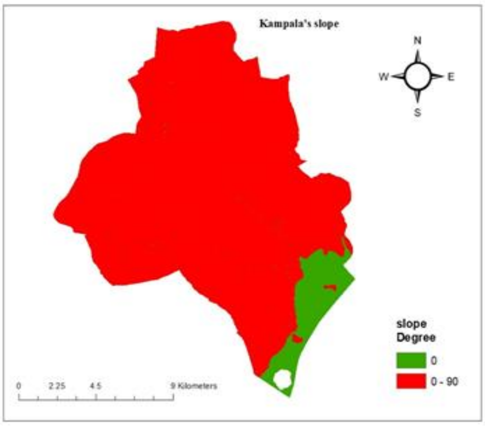

Figure 8 The slope map of Kampala District

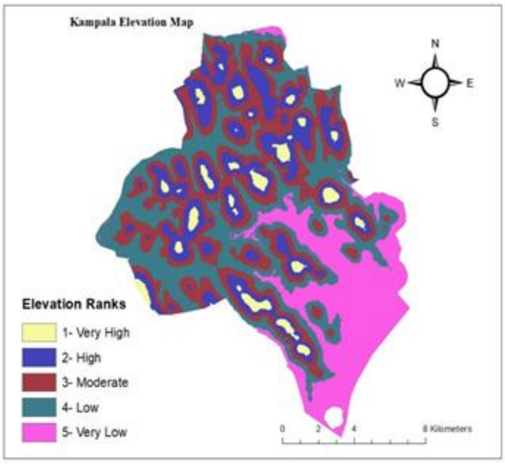

Figure9 Classified elevation of Kampala District

Table1 showing elevation of Kampala district

Elevation (in meters)	Ranking
1126-1154	Very low
1154-1180	Low
1180-1205	Moderate
1205-1238	High
1238-1316	Very High

5.4. Flood prediction

Using a DEM raster, figures 10 and 11 represent a map showing the areas and towns prone to flooding was developed. As seen from the map and comparison made with the elevation map above (figure 9), the low lying regions in the study area were highly predicted to flooding, followed by the moderately low regions. Flooding in the low elevated areas is highly linked to a lot of settlements constructed which increase on the impervious surfaces and obstruction of the water flow in to the natural courses, hence flooding and damaging people's property as well.

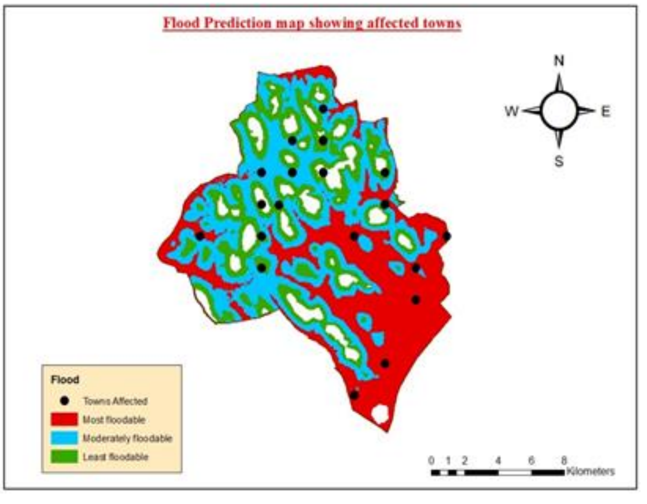

Figure 10 Map of the flood prediction in Kampala District

The flood map that was created from the overlay of the towns, land cover, flood prediction map shows the extent of the damage caused by the floods in the study area. Generally, most of the places susceptible to the flooding are likely to be moderately to highly affected depending on the location. This could be due to the increased built up areas (i.e. residential, commercial and infrastructure developments), which increase in the impervious surfaces which results in an increase in the storm water runoff. The built up areas especially in the wetland regions obstructs the flow of the water across the natural courses which leads to flooding.

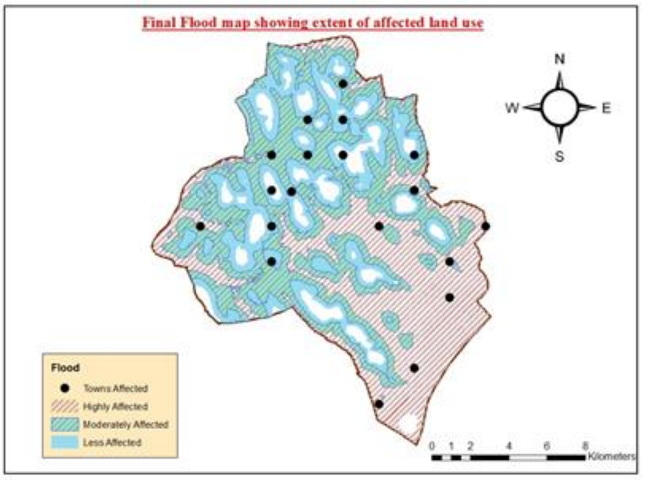

Figure 11Map of predicted flood and extent of the damage on the land cover types

6. Discussion

From the flood predictability map, the study area is generally hilly and surrounded by valleys. The areas with moderate, high or even very high floods are built up areas that are densely populated with residential, commercial and industrial structures. In the occurrence of flooding, a lot of property is damaged and even sometimes lives are lost. The method of relocating victims affected by the floods is not applicable here since a very large population exists in this area. Also since there are two rainy seasons with in the year, relocation would be unrealistic. Some other methods can be used to combat the floods and they include;

1. Better engineering procedures of planning and construction of new drainage systems in Kampala that remove any deficiencies of the existing drainage channels to favor the surface runoff during the heavy downpours.
2. Land use control with the help of NEMA to critically survey any new sites to make sure that the buildings going to be erected don't lie within the wetlands or don't encroach on the main waterways and stream channels.

7. Conclusion

Flood monitoring and control using satellite data showed the effectiveness of getting quick and precise data to predict the areas that are most likely to be affected by flooding. In the study, different geospatial approaches were used to determine and predict the flood prone areas using Landsat 8 images. Despite the absence of the ground reference data, the use of the Landsat image and SRTM DEM proved reliable for identifying the flood prone areas in Kampala. With its low gradient and slope, Kampala district is at a moderately high risk of floods and most of the damage likely to happen in the built up areas.The advancement of RS and GIS techniques coupled with computer modelling have been very useful in answering the questions as regards to the prediction, monitoring and control of the floods. Specifically remote sensing techniques provide a faster option of accessing spatial data of the flood occurrence even when the areas are inaccessible while GIS on the other hand enables the processing, analysis, querying and representation of information in a simplified format.

8. Recommendation

Since there was a problem of cloud cover, Landsat images during the rainy season were not successfully obtained and limited in number for all different satellites and therefore I recommend that remotely sensed data should be always be updated whenever flood monitoring map of an area is to be generated in order to prove the study more valid and accurate.

Adaptation of the research in identification of flood prone areas in Uganda as one of the solutions to combat the effects of flooding and be able to relocate people as well as identifying suitable relocation settlements on time.

References

1. **Berz, G., et al., *World map of natural hazards–a global view of the distribution and intensity of significant exposures.* Natural hazards, 2001. 23(2): p. 443-465.**
2. **Younis, J., S. Anquetin, and J. Thielen, *The benefit of high-resolution operational weather forecasts for flash flood warning.* Hydrology and Earth System Sciences, 2008. 12(4): p. 1039-1051.**
3. **Jonkman, S.N., *Global perspectives on loss of human life caused by floods.* Natural hazards, 2005. 34(2): p. 151-175.**
4. **Alexakis, D., et al., *GIS and remote sensing techniques for the assessment of land use change impact on flood hydrology: the case study of Yialias basin in Cyprus.* Natural Hazards and Earth System Sciences, 2014. 14(2): p. 413-426.**
5. **Milly, P.C.D., et al., *Increasing risk of great floods in a changing climate.* Nature, 2002. 415(6871): p. 514-517.**
6. **Bronstert, A., *Floods and climate change: interactions and impacts.* Risk Analysis: An International Journal, 2003. 23(3): p. 545-557.**
7. **Opolot, E., *Application of remote sensing and geographical information systems in flood management: a review.* Research journal of applied sciences engineering and technology, 2013. 6(10): p. 1884-1894.**
8. **Pradhan, B., M.** Shafiee**, and S. Pirasteh, *Maximum flood prone area mapping using RADARSAT images and GIS: Kelantan river basin.* International Journal of Geoinformatics, 2009. 5(2).**
9. **Statistics, U.B.O., *Statistical abstract.* Kampala: Uganda Bureau of Statistics, 2013.**
10. **Profile, U.E., *Promoting Green Urban Development in African Cities*, 2015, KAMPALA, UGANDA.**