Global Scientific JOURNALS
GSJ: Volume 11, Issue 7, July 2023, Online: ISSN 2320-9186
www.globalscientificjournal.com

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM IN MAPPING FLOOD AREAS IN THE ASHAIMAN MUNICIPALITY, GHANA

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Abstract
Flooding is a serious, common, and costly hazard that many countries face over the years. Flooding due to excessive rainfall in a short period of time is a frequent hazard in the Ashaiman Municipality. In this study, we seek to map flood-prone areas in Ashaiman Municipality, using Geographical Information System (GIS). Identification and mapping of flood-prone areas are valuable for risk reduction. We then mapped flood areas in the municipality using the Boolean Approach in GIS. The result reveals that floodable areas covered approximately an area of 3 km² out of the overall total land size of 45 km². This shows that areas prone to floods cover a quarter of the whole municipality. It is also interesting to note that 846 acres of land were covered by floods in the municipality. Areas liable to flooding were grouped into “most liable to flood” which covered about 375 acres of the land, “less liable to flood” which covered 471 acres of the land, and “not liable to flood” covering the widest acres of land (10,273 acres). The flood-prone zones should be viewed with special attention and given utmost importance. It is recommended that the results obtained can thus be utilized as baseline information for policy-making to combat flood-induced disasters.

1.0 Background

With rapid urbanization and ever-increasing population growth, improving the quality of life of the world’s population has been the core concern of countries across the globe (Islam and Karim, 2019). With this, urban flooding is one of the world’s problems in recent times because of its frequent occurrence, which results in loss of lives and property. This is particularly notable in the developing world, where the pursuit of development has frequently sparked haphazard urban spatial planning that poses serious environmental challenges, aggravating the myriad issues that already plague these nations (Maskrey and Lavell, 2023). Following this, it is no doubt that one type of natural disaster that occurs frequently and recognises no boundaries is flooding. Since it occurs naturally, it cannot be stopped and may result in fatal consequences including human displacement and damage to properties and the environment. Statistical data from 1990 to 2013 shows that floods caused over 7 million fatalities and more than US $ 600 billion in losses worldwide (Osei et al., 2021).

Specifically in Africa, over 82 million people were affected by floods between 1950 and 2019, resulting in the deaths of 27,702 persons with the entire cost of flood increasing significantly after the year, 2000 (Tramblay et al., 2020). The United Nations has reported that the impact of flooding in Africa has led to the spread of diseases, displacement of people and deaths in countries such as Niger, Central African Republic, Guinea, and Ghana (Opoku et al., 2021).

In Ghana's major cities and low-lying communities, flooding has turned into a year-round problem and naturally, low-lying areas have been proven to be susceptible to floods (Attipoe 2014; Dekongmen et al., 2021). Again flooding in the country is mostly a recurring issue that occurs every year during the rainy season, which lasts from April to October, and gets worse during the months of August and September in the northern part of the country and May and June in the southern part of the country (Owusu and Agbozo, 2019) including the Ashaiman Municipality.

Owning to the topographical characteristics of the Ashaiman Municipality, the area is generally low-lying, pointing to the flood-prone nature of the municipality (Ampadu, 2020). In this regard, studies on the Ashaiman Municipality have been on urban water stress and poor sanitation (Ablo and Yekple, 2018), use of aphrodisiacs among adult male residents (Manortey et al., 2018), farming within a dual legal land system (Boamah et al., 2020), and waste management practices (Yin et al., 2021). The occurrence of floods is a very complex phenomenon such that researchers from different parts of the world are interested to understand and explore mechanisms for better management and prevention of floods. That is why in recent decades, multi-criteria decision models have been used to undertake hazard management and geospatial mapping using remote sensing and geographic information systems (Das, 2018). However, to the best of our knowledge, no studies have applied Geographic Information System (GIS) in mapping flood-prone areas in the Ashaiman Municipality. It is with this that this study seeks to map flood-prone areas in the Ashaiman Municipality using GIS.

2.0 Materials and methods

2.1 Study area

Ashaiman Municipal Assembly covers a total land area of about forty-five (45) square kilometers. It was carved out of the then Tema Municipality, now Tema Metropolitan Authority, as one of the newly created Districts in 2008 by LI 1889 and Local Government Act of 1993 (Act 462). Ashaiman Municipality is located about 4km to the North of Tema and about 30km from Accra, the capital of Ghana. Whiles Tema is situated on the Greenwich Meridian on Longitude 00, Ashaiman falls within Latitude 5° 42' North and Longitude 0° 01'west. Ashaiman shares boundaries to the North and East with Kpone-Katamanso District and to the South and West with Tema Metropolis. Ashaiman covers a total land area of 45km2. Its proximity to Tema and Accra makes it easy for community members to have access to high-level social facilities and infrastructure such as good roads, water, Hospitals, and electricity. It also serves as a dormitory town for workers in most industries in the Tema Township.

The population of Ashaiman Municipality, according to the 2010 Population and Housing Census, is 190,972 representing 4.8 percent of the region's total population. Males constitute 49.1 percent and females represent 50.9 percent. The municipality is considered urban and has a sex ratio of 94.1. About a third (31.9%) of the population of the municipality is youthful (0-14 years) depicting a broad base population pyramid which tapers off with a small number of elderly persons (2.4%). The total age dependency ratio for the municipality is 52.1, and the same for both males and females. The Total Fertility Rate for the municipality is 2.6 with a

General Fertility Rate of 77.5 births per 1000 women aged 15-49 years which is above the region's rate of 75.7. The Crude Birth Rate (CBR) is 23.7 per 1000 population. The crude death rate for the municipality is 3.9 per 1000.

Precambrian rocks of the Dahomeyan formation underlie the area: metamorphic rocks mainly consisting of granite, gneiss, and schist probably derived from sedimentary layers. These rocky formations are weathered or decomposed at the surface with a thickness (of the weather component) not exceeding 12m in the area. The soils are mostly sandy clays that are suitable for the cultivation of vegetables: okra, peppers, cabbage, and cucumber are major vegetables produced in urban gardens. The relief of the area is generally flat and forms part of the Accra-Togo plains. However, there are isolated hills in the general area but even these barely reach 65m high. The relief makes it easy for the construction of roads and drains.

Ashaiman lies within the Accra-Togo plains and therefore experiences a climatic condition that extends from the east coast of Ghana into Togo. Rainfall in this area ranges from 730mm to 790mm. The rainy season starts from April to July (the major season) and September to November (the minor season). Temperatures are high throughout the year. Humidity varies with the seasons with a height of 60-80% in the wet season and less than 30% in the dry periods. The vegetation consists of savannah grasses and shrubs due to the low rainfall regime. However, because of human activities, the natural vegetation no longer exists.

Ashaiman has well-engineered drains along major roads in the township. Drainage within the residential units is, however, very poor as there is no well-engineered drainage system, creating problems of liquid waste disposal within these units. This situation compounds the already existing problem of sanitation in the Municipality. Most of the drains along the major routes are also choked.

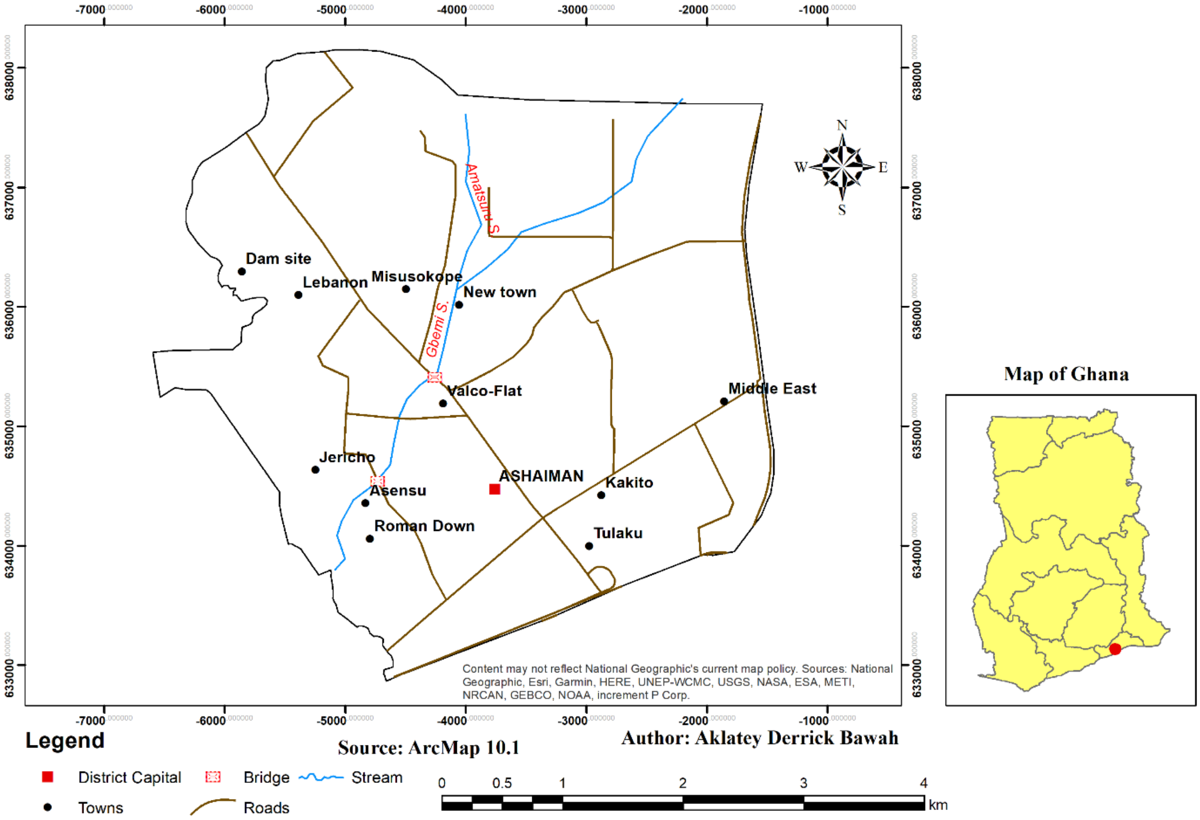

Figure 1: Geographical location of the study area

2.2 Requisite dataset and source

The objective of the study was to use GIS to map flood areas in the Ashaiman Municipality. In line with this objective, we used two types of approaches in the multi-criteria analysis thus, the Boolean Operation and the weighted overlay method. We used the Boolean logic approach in a GIS environment to map flood areas. This is because unlike weighted overlay, which applies a common measurement scale of values to varied and dissimilar inputs to produce an integrated result, the Boolean operation is probably the simplest and best-known type of GIS for suitability analysis (Hussaini et al., 2022). For Boolean operation, all criteria are assessed using thresholds of suitability in other to produce a Boolean map, which is then combined by logical operations such as intersection ("AND") and union ("OR"). Only one or zero values are assigned to each unit area, specifying whether it is suitable or unsuitable.

Data to be used for this study were sought from two main sources namely, primary sources and secondary sources. The data collected from the primary source included, Ghana highway data and Ghana water dater all downloaded from Mapcruzin.com, some data like the digital elevation layer (DEM) was also downloaded from geocommunity.com and the stream dataset was not available thus the researcher digitized the layer from ESRI base map. Obtaining primary data involved field survey and group discussions, measurements, information related to flood identification and topographic map interpretations and satellite/photographic images. Data from secondary sources were obtained from published information on flood generation factors such as rainfall, discharge of the various rivers or water bodies and human activities, land use planning (industrial estate, settlement zones, flood-prone areas, government buildings, business centres, etc.) of the study area are compiled and used by specialized organizations such as Meteorological Services, Ministry of Works and Housing. Factors considered in mapping out flood areas in the municipality included soil type, elevation, rivers, settlement, land use and land cover and rainfall. For the purpose of the study, we considered two factors thus Elevation and Soil type but the whole community is characterised by one type of soil, Elevation was considered the most important factor, which we chose among several others in mapping flood areas in the municipality.

Data preparation

This study is going to show how data are going to be edited and organized under the ArcGIS environment using ArcGIS ModelBuilder. This advanced GIS technique of using ArcGIS in preparing data in the ArcGIS environment can be categorised into two (2) thus: Geo-processing tool and the ModelBuilder. ArcGIS, developed by ESRI Inc., is the most frequently used software in the GIS field. The powerful GIS software is compatible with many different types of file format, such as Excel, dBASE, Shapefile, and more.

In addition, the shapefile of the study area was selected and the layer was created from the district of Ghana dataset. Town, road, and elevation layers of the district under study were clipped from the entire layer of the country shapefile using the clip tool and with the help of ArcCatalog 10.1. The elevation for Ashaiman municipality ranges between 9m to 62m as the lowest and highest elevation respectively. Here, we reclassified elevation data and values were assigned to areas with elevation heights of 9m -17m. This was assigned to most floodable areas whereas 17m – 22m was assigned to less floodable areas and "NoData" was assigned to areas that were not prone to flooding. Areas with heights 9m -17m which were liable to flood were assigned one (1), areas with height 17m – 22m was assigned two (2) whereas areas with height above 22m were not floodable and were assigned "NoData" as shown in table 1.

Table 1: Reclassifying elevation layers to flood risk values.

Elevation	**Reclassified Values**
9m – 17m	1
17m – 22m	2
22m and above	NoData

Source: Field Workbook, 2018

After the reclassification process, the reclassified elevation layer which was in raster format was then converted back to vector layer using the raster to polygon tool in the conversion toolbox. As the initial stage for input data for processing with the GIS, a set of map layers were defined according to the expected criteria which have to be introduced into ArcGIS 10.1. The Boolean operation, however, was adopted since it was the best method for the study. The modelbuilder was also used in the study to make the work efficient, fast and make it easy. The modelbuilder is the component that includes all the selection criteria and the algorithms that execute the mapping of areas prone to flood. The modelbuilder below shows the methods used in our study. Therefore, the development process consists of several main steps as:

- Selecting the geographical area to map floodable areas.
- All layers were clipped by analysis tool, except the elevation layer which was clipped by the data management tool in Arc Toolbox.
- The elevation layer reclassified under flood risk.
- The reclassified elevation was then converted from raster to polygon to produce flood risk map, showing areas liable to flooding.
- Affected towns were located with the help of the "Select layer by location" tool in the Arc Toolbox.

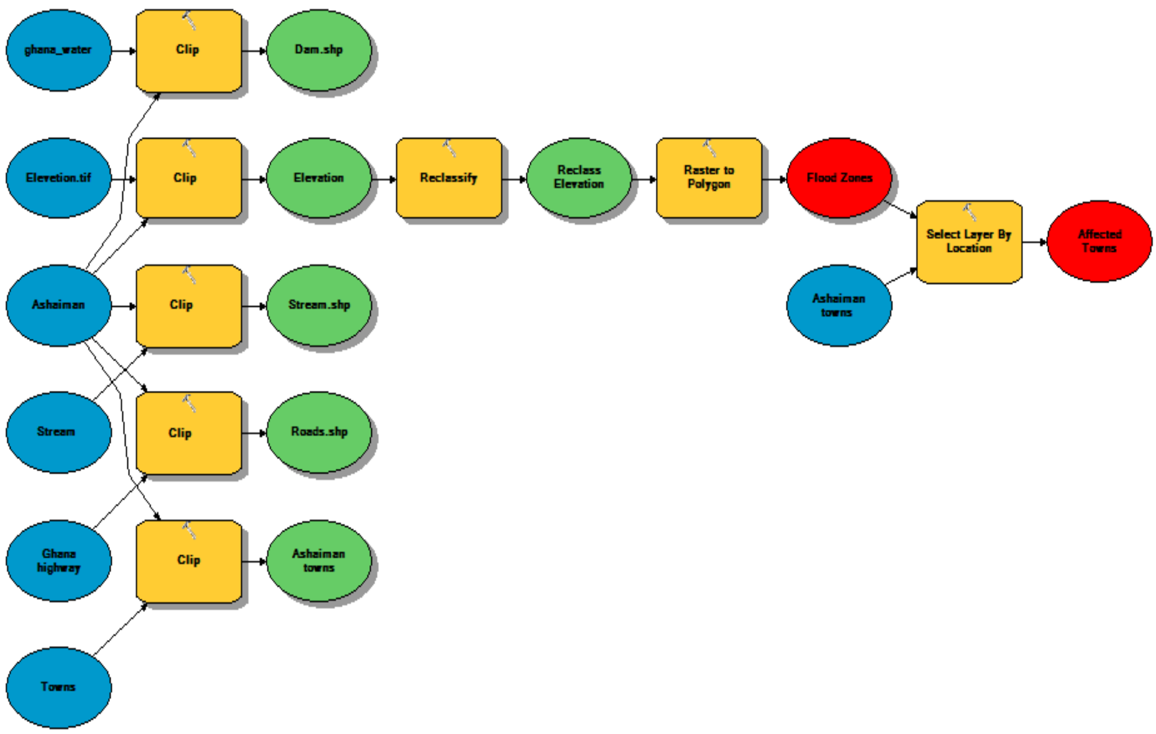

Figure 2: ModleBuilder representing the processes involved in mapping flood prone areas in Ashaiman Municipal.

Source: ArcMap 10.1

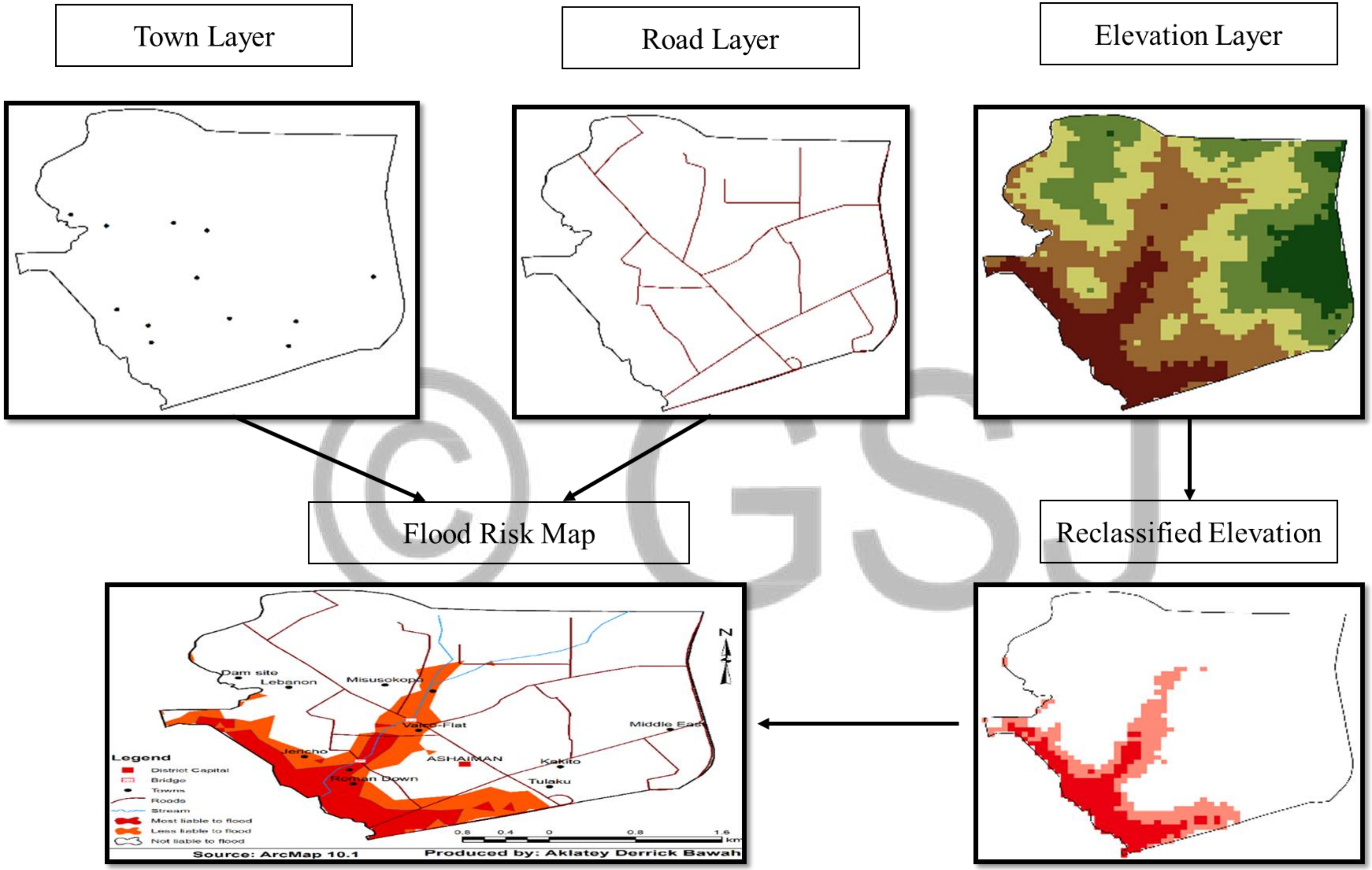

Figure 3: A flow diagram showing data preparation of flood map

3.0 Results and Discussion

3.1 Flood Risk Mapping

To help municipalities in identifying potential hazards for flooding we decided to undertake a flood risk mapping. Flood risk is generally accepted to be a combination of the likelihood or probability of flooding and the potential consequences arising. Flood risk maps have played important roles in flood management and control. This is because the consequences of flooding in urban areas can be lessened by mapping urban flood risk and anticipating the location of flood-prone areas using flood hazard maps (Eini et al., 2020). The frequent flooding of Ashaiman in recent times has become one of the Municipal's problems during the rainfall season, especially in June and July. The occurrences of the flooding could not be prevented but the impacts of the flooding can be minimized. With this flood risk map, areas that are most liable to the occurrence of flooding can be identified and other preventive measures can be taken before the flooding happens. The flood-prone map in Figure 5 shows the areas within Ashaiman and their possibilities of flood occurrences.

The flood map in Figure 4 further reveals that floodable areas covered approximately an area of 3 km² out of the overall total land size of 45 km². This shows that areas prone to floods cover a quarter of the whole municipality. Table 2 shows areas covered by floods in square kilometres and acres, so interestingly 846 acres of land were covered by floods in the municipality. Areas liable to flooding were grouped into most liable to flood which covered about 375 acres of the land, less liable to flood 471 acres of the land and not liable to flood, based on the height of the area.

Table 1: Areas of the land covered by flood.

Level of flooding	Area in Square kilometres (km²)	Area in Acres
Most liable to flood	1	375
Less liable to flood	2	471
Not liable to flood	42	10,273
Total land area	45	11,120

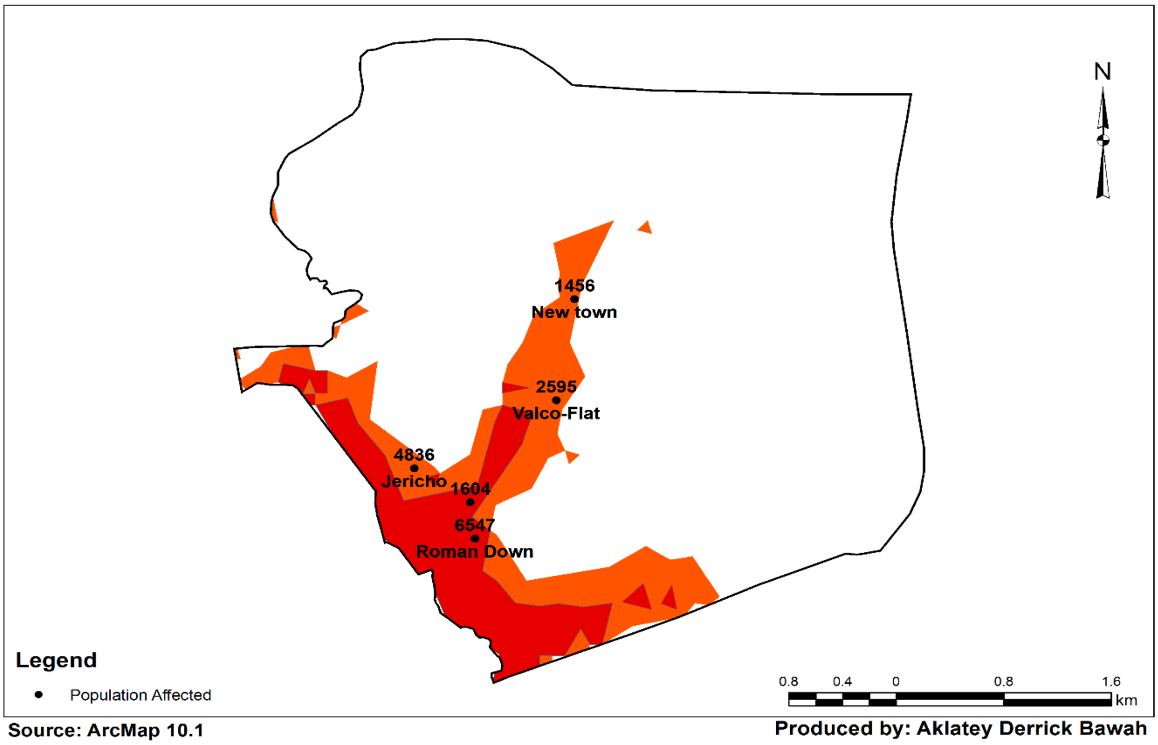

Figure 4: showing the towns and their population likely to be affected by flood

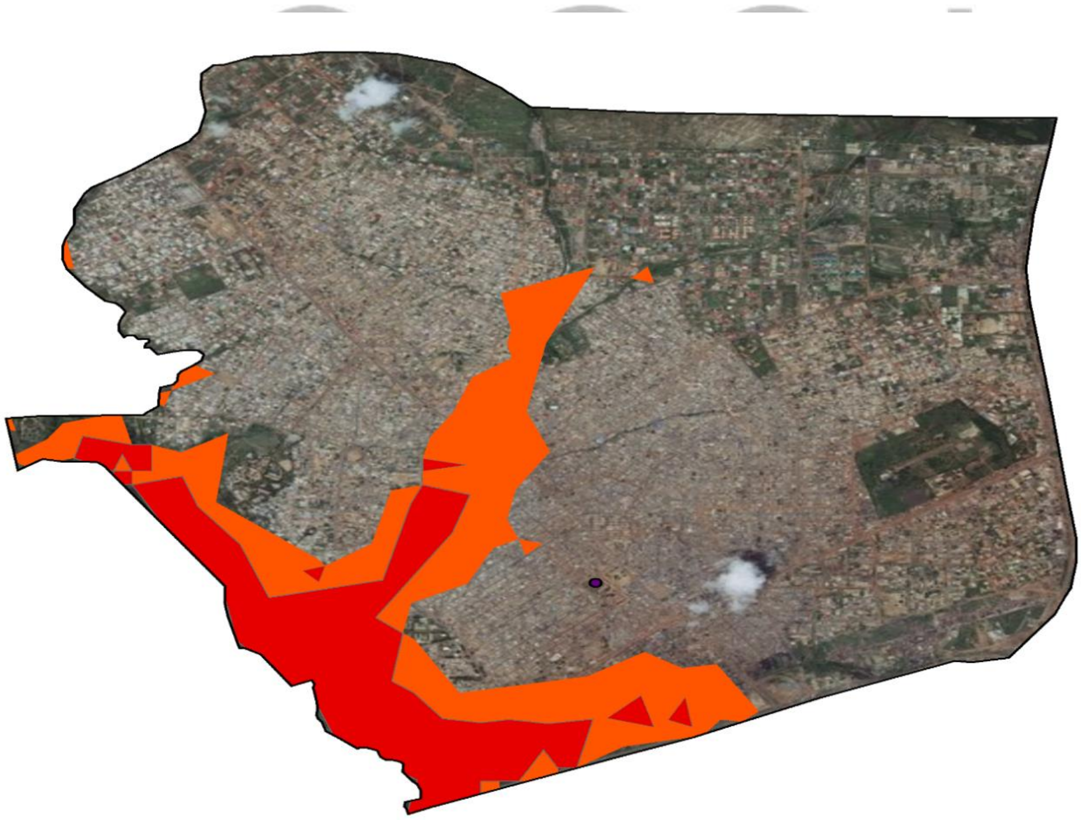

Figure 5: Shows flood risk overlaid on Esri base map from Google Earth.

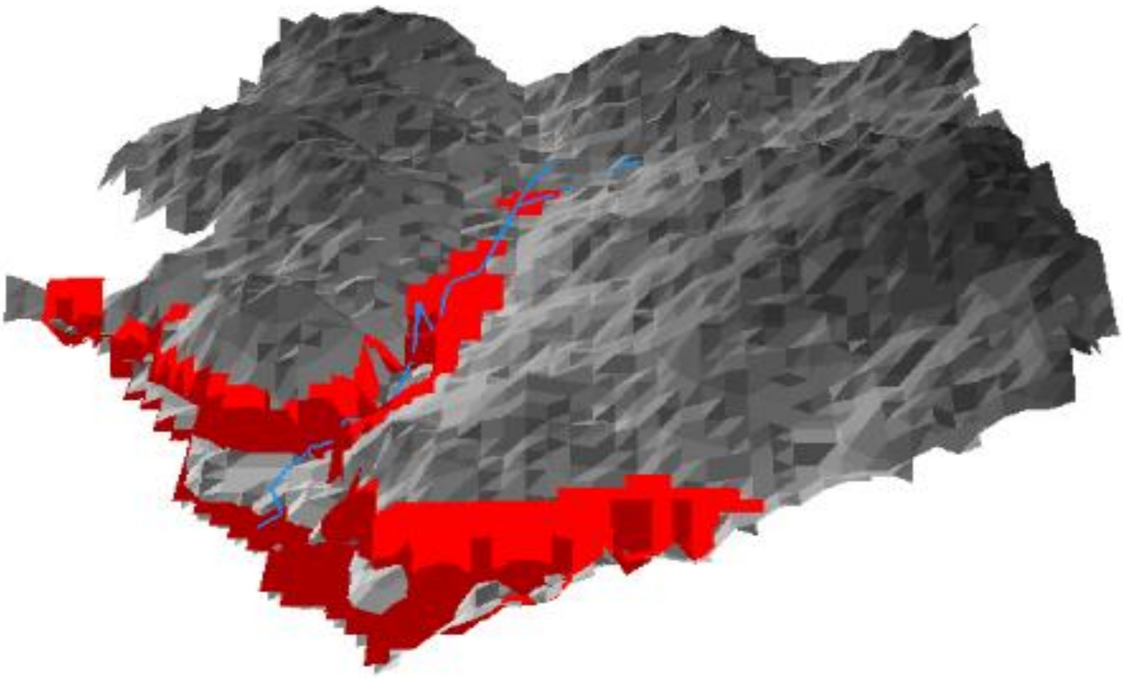

Figure 6: Flood risk map overlaid on a 3D view from ArcScene 10.1.

Conclusion

The study identified flood-prone areas within the Ashaiman Municipality, as flood disaster is recognized to be one of the major obstacles in attaining development goals. This means that disaster reduction should be a major concern for all. The widespread availability of digital geographic data and GIS techniques open new opportunities for using distributed models in mapping out areas liable to flood. The model used elevation data as one of the criteria in a simple way to predict areas that are flood-prone. GIS provides a powerful platform for developing the model and displaying model results in a spatial way so that it becomes possible to capture local complexities of an elevation and compare model results to field measurements. Flood risk mapping was undertaken and identification of potential hazards for flooding was considered to design a flood risk map for the municipality to serve as a quick assessment tool during pre and post-disaster situations and also, the settlement that is likely to be found within flood risk zone. We recommend that the Ashaiman Municipal Assembly working through the Municipal Works, and Physical Planning Departments should monitor and control the construction of buildings or projects in the flood risk zones. These departments should cooperate with decision makers and agencies such as NADMO, in giving out building permits. We also recommend that buildings in the waterways should be demolished and the affected people be relocated or compensated.

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