Geospatial Approach for Determining Drainage Network Patterns and Causes of Flood in Garin Lamido, Yobe State, Nigeria

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Abstract

Flooding is an inevitable worldwide natural phenomenon occurring from time to time, especially in flood prone localities, which can directly harms animals, destroy the environment they live and wreak havoc on humanity. This study has presented a state of the art approach for determining drainage network patterns and causes of floods issues in the study area. The study made use of Shuttle Radar Topographic Mission (SRTM) and Satellite imagery datasets. These images were used to produce the drainage network patterns map, base map, overlaid map of the drainage network patterns and base maps as well as to extract terrain parameters of the study area. Three (3) simple methods of soil types test were used to ascertain soil types of the study area, namely; the squeeze, ribbon and Jar test methods. Therefore, the research findings have provide snapshots spatial relationships between the drainage network patterns and existing features in the study area. The study has also reveals major causes of flooding in the study area, namely; drainage network patterns, terrain parameters, soil types, and human activities such as deforestation, mining, constructions among others. The slope analysis has reveals that most parts of the study area, which is about 184.5ha (72.361%) of the total land-cover are characterized by a flat terrain. An analysis of the results of soil types tests reveal that most parts of the study area, which is about 239.85ha (94.069%) of the total land-cover (254.97ha) are mainly made up of loamy soils, which has very low rate of water absorption. Hence, the surface runoff water finds it difficult to infiltrate into the soil, and thus often floods over most parts of the study area. It important to note that the results of this study can serve as a model through which the excess surface runoff water can be properly drained into channels leading into nearby streams or ponds, which can further be harnessed for purposes such as irrigation, ranching among others.

Keywords: *Geospatial, Drainage Network Patterns, Terrain Parameters, Floods, and Soil Types*

Introduction

Among the several types of natural disasters, flooding is an inevitable worldwide natural phenomenon occurring from time to time especially in a flood prone localities, such as riverine places which have very poor drainage systems (Koons et al., 2012; He et al., 2016). It is pertinent to note that lack of effective and efficient drainage system in a given geographic location normally gives room for natural drain to follow wrong path and thus damages the environment (Gallant et al., 2000).

Other factors which can caused flooding are the climate change (environmental degradation), topography (slope), type of soil and human activities such as deforestation, intensified land use, increase in populace and poor zoning of land-use (Delgado et al., 2011; Li et al., 2012).

Flooding, which is one of the global environmental issue, can directly harm animals, destroy the environment they live and wreak havoc on humanity (Hutchinson and Gallant, 2000). Flooding causes considerable damage to highway, settlement, farmland and natural resources (Cohen, 2017; Musa et al., 2017). Floods not only damage lives, properties, natural resource and environment, they can also have a negative effect on socio-economic activities and other areas of human means of living in the affected places (Musa et al., 2018a). The downturn of public hygiene is one more negative effect of flooding due to the upsurge in water-borne diseases and unsanitary conditions (Liang, 2017). This makes inhabitants of such places exposed to diseases and infections from mosquitoes and other insects. Consequently, this global environmental issue must be tackled using state of the art techniques.

Garin Lamido is one of the most rapidly developed areas in Gashua town of Bade LGA of Yobe State, Nigeria. However, these developments are limited to properties like residential buildings, schools, markets, etc., with little or no infrastructure developments, such as roads, drainage system and dams among others (Zhang et al., 2012).

It is common to see streets in the study area flooded with litters everywhere after a short period of rainfall because the available drainage network normally cannot effectively channeled the redundant (excess) runoff water into the natural system (Zhang and Guilbert, 2012; Wu et al., 2012). The stagnant water usually flows into homes and farmlands, which in turn pollutes the environment and makes it susceptible to air and water borne diseases thereby causing health issues, deaths and damages to properties (Anozonwu et al., 2010). Situations such as this normally leads to a very unhygienic atmosphere for dwellers of this neighborhood and it also contributes to the environmental degradation (Scott et al., 2016).

Even worse, there are visible manifestations of the substantial depletion of the land due to erosion (Igwe, 2012; Kumar and Mishra, 2015). This is because the up risen water levels in the natural drainage system caused severe turbulence and backflow to the drainage system (Liu and Zhang, 2010), thereby causing erosion problems in the study area (Ezemonye, 2012).

The aim of this paper is to determine the drainage network patterns and causes of flood related issues in the study area using geospatial based approach. Five (5) objectives were identified, namely; creation of drainage network patterns, creation of base map, determination of spatial relationships between the drainage network patterns and existing features, extraction of terrain parameters and determination of soil types of the study area. The paper presents a robust approach for analysing terrain characteristics with respect to surface runoff with a view to providing means for designing effective and efficient drainage system in the study area (Gao, et al. 2016; Parmenter and Melcher, 2012). Hence, the research findings can serve as a model through which the surface runoff can be properly drained into channels leading into a nearby streams, ponds or reservoirs, which can be further harnessed for other purposes such as irrigation, ranching, etc.

The research findings will furnish policy makers and other environmental stakeholders with a means to better understand the effects of flood related issues on current and future developments in the study area (Li et al., 2004) so as to improve flood protection measures and administration which will in turn curb the recurring annual flooding using geospatial (Geographic Information System and Remote Sensing) approach.

Study Area

Garin Lamido is a settlement in Sabon Gari ward of Gashua town, Bade Local Government Area, Yobe State, Nigeria. It is spatially located at North of the Equator between Latitudes $12^0\ 54'\ 16''$ and $12^0\ 54'\ 21''$ and East of the Greenwich meridian between Longitudes $11^0\ 01'\ 13''$ and $11^0\ 02'$

54*”*. The terrain of the study area is roughly flat and partially undulating, which is mainly formed by sands. It is made up of two different types of soil, namely; loamy and partially sandy soils. The inhabitants of the area are mostly engaged in economic activities such as farming, fishing and trading (Aji, 2017). Figure 1 depicts the map of the study area.

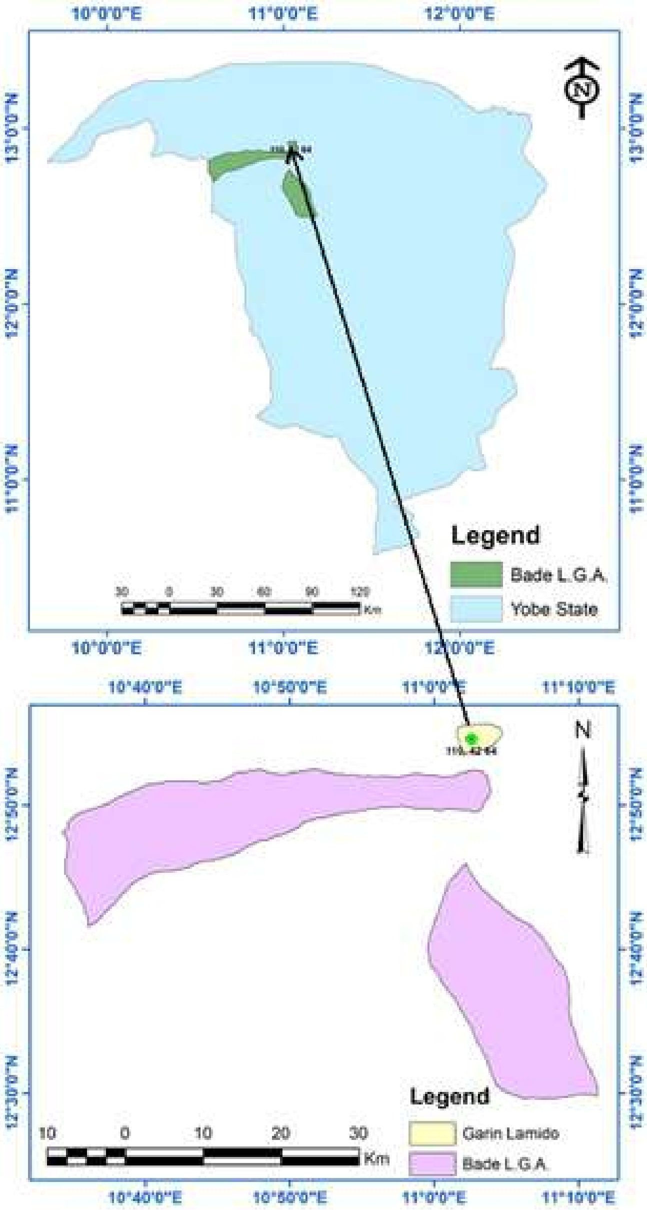

Figure 1: The study area (Nigerian shapefiles obtained from the Office of the Surveyor General of the Federation (OSGOF))

Materials and Methods

Materials

Shuttle Radar Topographic Mission (SRTM) and satellite imagery were the datasets utilized in this study. The SRTM, which is commonly known as Digital Elevation Model (DEM), was acquired from the Earth Resources Observation System (EROS), Data Centre of the United States Geological Survey (USGS) and the Satellite imagery from the Google Earth Pro. Table 1 shows more details about the spatial information of these datasets. ArcGIS 10.3 was the software package used in the study.

Table 1: Spatial information of the datasets used

Data	Type	Source	Resolution	Band	Date
Landsat 8 SRTM, (DEM)	Primary (Raster)	United State Geological Survey www.earth explorer.usgs.gov	30m	Red 4 Green 3 Blue 2	2018
Google Earth Image	Primary (Raster)	Google Earth Pro.	15m		2018

Methods

The methods employed in this study entails determining the drainage network patterns and causes of floods in the study area using geospatial based approach. Consequently, for the fulfillment of the above task, the research work is divided into six (6) main parts, namely; image pre-processing, creation of drainage network patterns map, base map creation, determination of spatial relationships between the drainage network patterns and existing features, extraction of terrain parameters and determination of soil types of the study area. The sequence of execution of these tasks is in accordance with the research objectives as illustrated in Figure 2.

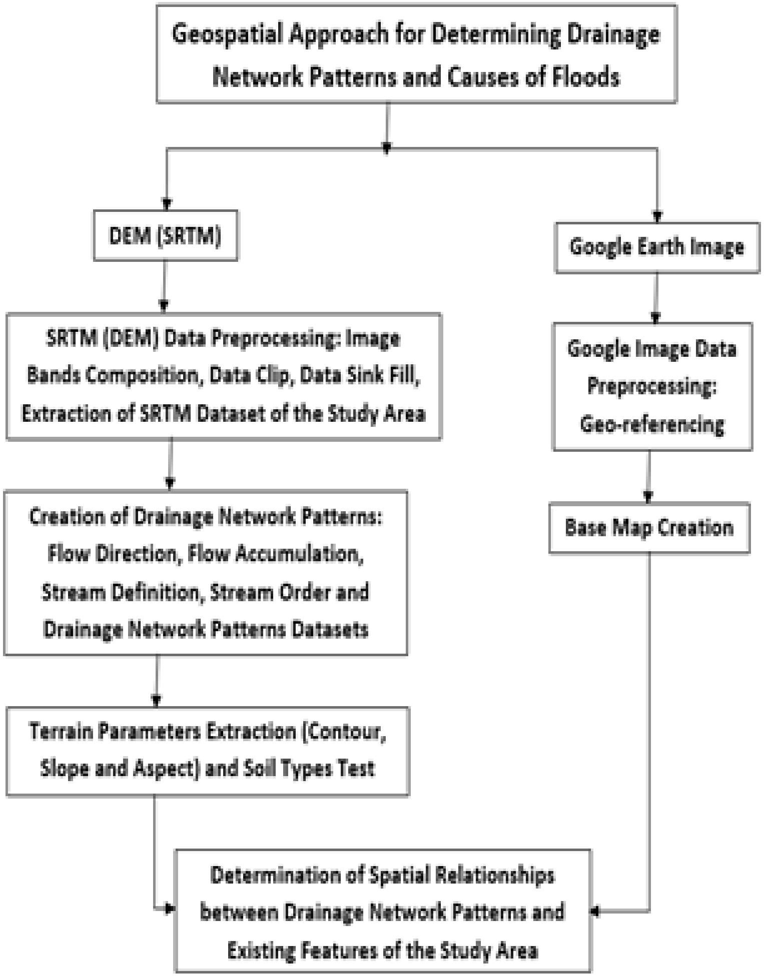

Figure 2: The methodology flow chart

Image/SRTM Preprocessing

It is necessary to perform image preprocessing so as to minimize the noises and distortions introduced to the image at the imagine time (Musa et al., 2018). The input image datasets were resampled to a cell size of 30m × 30m resolution, after which the google image was atmospherically and geometrically rectified and then transformed to local mapping coordinates system to ensure better and efficient GIS based analysis and mapping of drainage network. Table 2, shows the local mapping coordinates system used for image geometric restitution.

Table 2: Coordinates System used for Image Restitution

Point	Northing (m)	Easting (m)	Projection	Zone	System
A	1424614.28	718916.83	WGS84	32	UTM
B	1424704.61	723287.18			
C	1427288.25	723171.92			
D	1426989.10	718910.91			

After restitution, a single visual compelling image of the SRTM was formed by composing the multiple image bands together. Afterwards, the composed SRTM layer was clipped by separating image with maximum unwanted background, which permits easier image editing at post processing stage.

For appropriate depiction of valleys, gullies, basins and/or streams, the SRTM data was sink filled to round up heights or elevation values to the nearest whole number and eliminate inaccuracies from clarity and sharpness (resolution) of the data. Then, the interested portion was also extracted from the filled data to show extents of the study area.

Creation of Drainage Network Patterns

This is necessary for an effective drainage system which makes it possible for all the excess runoff water (waste water and sewage) to be properly removed, by channeling it to the disposal sites. As such the environment becomes well drained and get rid of wastewater without causing inconveniences to inhabitants of the area (Liu and Zhang, 2010). Therefore, in order to achieve this task the methodologies adopted by Hom et al., (2012); and Malaperdas and Panagiotidis, (2018) were followed, namely; creation of flow direction, flow accumulation, stream definition, stream order, as well as drainage network patterns datasets of the study area.

Flow Direction Dataset

Standard D-8 algorithm embedded in Arc-hydro Tool of ArcGIS software was employed to determine information regarding water flow direction for each and every central pixel of the data input arrays of 3 by 3 pixels. This algorithm compares the value of central pixel each time to the value of figures of it 8 neighboring pixels. The method of steepest slope was employed to determine the downhill steepest slope for a central pixel. Hence, the directions of out flows (flow direction) for each and every cell of the filled DEM data was generated as a raster dataset. This dataset shows eight (8) different flow directions in the study area, namely;

i. The northern direction
ii. The northeastern direction
iii. The northwestern direction
iv. The southern direction
v. The southeastern direction
vi. The southwestern direction
vii. The eastern direction and
viii. The western direction

Flow Accumulation Dataset

The flow directions dataset was used as an input in order to generate the flow accumulation dataset of the study area. This helps to determine the total value of hydrologic flow that represents the amount of input pixels which chip in any amount of water to each and every single outlet.

Stream Definition Dataset

The flow accumulation dataset was used as an input for generating the stream definition data of the study area. This provides a means to determine network of cells that define areas in which streams can be created.

Stream Order Dataset

The stream definition and flow direction raster datasets were used as input to create stream order data of the study area. At this stage, pixels of the output dataset were ranked into numerical order according to number of the tributaries and relative size of the stream, namely:

i. First order stream, which belongs to drainages of very low capacity;
ii. Second order stream, which belongs to drainages of low capacity;
iii. Third order stream, which belongs to drainages of medium capacity; and
iv. Fourth order stream, which belongs to drainages of high capacity.

Drainage Network Patterns Dataset

The flow direction and stream order raster datasets were used as input to create the network of drainage patterns of the study area. This entails finding the points at which two or more streams come together as well as assigning a distinctive ID to each and every stream in between these points and also to the streams which have only a single node.

Base Map Creation

This task was achieved by digitizing all the prominent details from the rectified image dataset so as to depict surrounding reference information which may include; contours, streets, prominent features, and political boundaries, after which additional thematic data can be added to it. It can also be employed for location references since it provides both the foundation and initial building blocks for creating map which in turn provides users with geographical and visual context for the data (Dempsey et al., 2011).

Determination of Spatial Relationships between the Drainage Network Patterns and Existing Features of the Study Area

It is important to note that the location of features is commonly remained unchanged in any map overlay analysis, such that other variables can be analyzed simultaneously (Avery and Berlin, 1985; Vimal et al., 2012). Therefore, the drainage network patterns and base maps were superimposed with the aid of ArcGIS software.

This is to show the spatial relationship between the patterns of the drainage network and all existing features across the study area. Thus, helps to appreciate where very low, low, medium and high capacity drainages are located as well as their spatial relationships with various existing features across the study area. Hence, it provides visual context information that helps to understand effects of floods related problems on current and future developments across study area.

Extraction of Terrain Parameters

The terrain parameters of the study area, which includes; contour, slope and aspect datasets were extracted from rectified DEM data (Hutchinson et al., 2000). The contours often help to provide an insight about the terrain pattern (topography) of the study area. Whereas, the slope data helps to show degree of steepness of various points of interest (prominent features) across the study area.

To generate the slope data, a slope for each point is calculated as the highest degree of change of height (elevation) between that point and its abutting points. So also, the aspect map provides values that indicate the directions which the slopes face, with 0^0 facing toward north direction, 90^0 facing toward east direction, 180^0 facing toward south direction, and 270^0 facing toward west direction. It was made such that orientations of slopes are measured clockwise in degrees from 0^0 to 360^0. As in the work of Malaperdas and Panagiotidis (2018), the contour, slope and aspect data were expressed as digital values.

Soil Types and Soil Types Testing Methods

Soil is usually made up of different particles like sand, silt and clay. The major types of soils viz-a-viz: sandy, loamy and clay soils have distinct characteristics that make them unique. Information about soil types often helps to determine its strengths and weaknesses (Ahukaemere, C.M., 2012; www. madhavuniversity.edu.in; www.nrcs.usda.gov). Hence, the essentials, patterns and components of the least sized soil types, namely; sand, silt, clay and loam as shown in Figure 3, 4, 5 and 6 respectively are as follows:.

1 Sand

The sandy soil as shown in Figure 3, is made up of tiny pieces (particles) of rocks and hard minerals, like silicon dioxide. They are the biggest form of soil particles, in which every single soil bit is often seen by a naked eye. The particle size of rough sandy soil varies from 2 – 4.75mm, medium sandy soil varies from 0.425 – 2mm and fine sandy soil varies from 0.075 – 0.425mm. The texture of a sandy could either be rough, smooth, or polished.

The rougher or grander particle size of the sandy soil often makes wet or dry sandy soil to have a coarser texture when squeezed with fingers and thus, the soil becomes lighter and falls apart easily when tried to stick together using hand. Sandy soil could have either angular, sub angular, rounded, flat or elongated shape or outline (Ahukaemere, 2012; www. madhavuniversity. edu.in).

Figure 3: Sandy soil (www. madhavuniversity.edu.in).

2 Silt

The silt soil as shown in Figure 4, is a non-stiff or low flexile material due to its smoothness. Silt is a type of soil which sinks slowly and settles to form sediment at the bottom of a liquid. Silt soil particles are moderate in size which normally blend in between sandy and clay soils. The particles of a silt soil often varies in size between 0.002 and 0.06mm. Due to its texture intricacy or fineness, when dampen (slightly wet) it turn out to becomes a soft and smooth mud that can readily be made into balls or other shapes and when it has a lot of moisture (very wet), it blends perfectly with water to form smooth and soft puddles of mud (Ahukaemere, 2012; www. madhavuniversity.edu.in).

Figure 4: Silt soil in wet condition (www.Madhav university.edu.in)

3 Clay

The particles of a clay soils as shown in Figure 5, are the smoothest among all the soil types. Its particle size is estimated to be less than 0.002mm. It is made up of very tiny (microscopic and sub-microscopic) particles, which often come into being as a result of degeneration (chemical decomposition) of rocks. Clay is a smooth as well as fine-grained, sticky or cohesive soil. They stick together easily and usually become a sticky or gummy texture when they are in moisture or dry condition. Clay soil consist of over 25% clay, silicates, iron, mica, aluminum hydrous-oxides, quartz and carbonates. Due to the spaces found in between clay soil particles, it used to withhold a significant quantity of water. It is important to note that, clay soil normally expands when mixed with water and shrink when it get dried. In comparison to sandy soil particles, which are typically round in shape, the particles of clay soil are mostly thin, flat and bonded with tiny plates (Ahukaemere, 2012; www.Madhav university.edu.in).

Figure 5: Clay soil when mixed with water

4 Loam

The loamy soil as shown in Figure 6, is made up of clay, sand and silt soils and thus, reaps benefits from the qualities and textures of these 3 different soil types. Subject to predominant composition of these three (3) different types of soil, it can be regarded as either sandy or clay loam. The way and manner (proportions) the particles of these soils blend in the loamy soil usually makes the loam. For example, if a loamy soil is made up of 30% clay soil, 50% sandy soil and 20% silt soil, then it is usually referred to as a sandy clay loam, with the nomenclature of the soil types listed before the "loam" in the order in which their particles are most dominant in the loam. That is to say the labels "clay loam," "silt loam" and "sandy loam" are used to refer to soils that are made predominantly from those types of soil particles (Ahukaemere, 2012; www. madhavuniversity.edu.in).

Figure 6: Loam soil (www. madhavuniversity.edu.in).

It is important to note that there are different methods (from simple to more complex) which can be used to get a general idea of soil types of a given geographical location. Therefore, three (3) simple methods of soil types test adopted from Ahukaemere, (2012) and www.nrcs.usda.gov, were used to ascertain the soil types of the study area, namely; the squeeze test, the ribbon test and the Jar test.

1 The Squeeze Test

In order to perform this method of soil test, a handful of soil samples obtained from different parts of the study area were mixed together in a container. Thus, the methodologies adopted from Ahukaemere, (2012); www.nrcs.usda.gov; and www.harwichwater.com, were employed to ascertain the soil types of the study area as follows:

I. By scooping up the mixed soil samples and the spreads it on a platform.
ii. It was left to get dry out until it becomes powdery or crispy.
iii. Stones, roots, or other forms of wastes were removed from it.
iv. By grabbing a small handful of less wet (i.e. non-dried or muddy) ball of the soil sample using hand and then squeezes it between thumb and pointer fingers. The soil types of the study area was being able to be determined based on soil texture and other features of the three (3) major types of soil, namely; clay, loamy and sandy soils as follows:

a. Clay soil has a smooth, slick, slimy and sticky texture. It usually get formed into ribbons shape when molded using fingers
b. Loamy soil often has a smooth, slick, partially sandy, and sticky texture. It can also get formed into a ball shape that falls apart easily.
c. Sandy soil usually has a very loose and gritty texture. To form a ball shape using this soil type is almost not possible.

2 The Ribbon Test

By taking a few quantity of less wet soil sample and then forms a ribbon shape using hands. Thus, the methodologies adopted from Ahukaemere, (2012); www.nrcs.usda.gov; and www.harwichwater.com, were followed to determine the soil types of the study area, based on properties of the three (3) major types of soil, namely; sandy, clay, and loamy soils as follows:

I. If the ribbon is being held vertically without breaking, then it is mostly a clay soil.
ii. If the ribbon breaks off when it is being held in an upright position, then it is a

loamy soil which perhaps has approximately about 25% to 50% clay particles in the soil.

iii. In a situation where a ribbon cannot be formed at all, then it is a sandy soil.

3 The Jar Test

The jar is comparatively more accurate than the remaining methods of soil type tests. To perform this method of soil test, the procedures adopted from Ahukaemere, (2012); www.nrcs.usda.gov; and www.harwichwater.com, were followed to determine the soil types of the study area, based on properties of the three (3) major types of soil, namely; sandy, clay, and loamy soils as follows:

I. Soil samples obtained from a number of different places across the study area were mixed together inside a container.

ii. By scooping up a can or small bowl of the mixed soil samples and spread it on a platform.

iii. It was left to dried out up to the time it becomes powdery or crispy.

iv. Stones, rootstocks, or any other forms of waste were removed and then crushed it into powder using a mortar.

v. About 1-inch-depth layer of the soil sample was placed inside a quart-sized transparent glass jug and then filled 2/3 of the glass jar with water.

vi. A pinch of salt was added to it in order to help the soil particles separate. It is important to note that 1 teaspoon of liquid dish detergent can also be used instead of salt.

vii. The solution was shake vigorously and then it was allowed to settled down into three (3) layers of the major soil types, say; clay, loamy and sandy soils as follows:

a. The sand settled very fast (within a very short period of time) to constitute the bottom layer.

b. Some few hours afterwards, the silt also get settled.

c. The clay soil takes some days in order to settle down (i.e. 3-5 days).

d. Hence, a clear visual differences of the larger, smaller and very fine particles of the sandy, silt and clay soils, respectively were observed from the solution inside the glass jar.

viii. The total amount of the sample soil was measured from quart-sized clear glass jar. Hence, the ratios of each layer of the three (3) soil types were measured by applying some little math as follows.

a. For instance, if the total quantity of the soil is one-inch in depth and the sand layer at the base of the jar is ¼-inch-thick, then the soil can be said to be 25% sandy soil.

b. If the adjoining layer which is silt is also ¼-inch in depth, then the soil is said to be 25% silt.
c. Similarly, as the remaining next layer which is clay is 1/2-inch deep, then the soil is 50% clay.
d. Based on ratios of each layer of the three (3) soil types (i.e. 50% clay, 25% sand and 25% silt), the soil type can be said to be clay sandy loamy soil (Ahukaemere, 2012; www. madhavuniversity.edu.in).

By comparing and evaluating the results obtained from each of the above three methods, the soil types of the study area were being able to be determined.

Results and Discussion

Creation of Drainage Network Pattern

The drainage network patterns dataset of the study area was created using a geospatial based techniques, as in Hom et al., (2012) and Cho, (2019). These include determination of the following datasets, namely; flow direction, flow accumulation, stream definition, stream order and drainage network patterns maps.

Flow Direction Dataset

The flow direction is a raster dataset which reveals the directions in which the excess surface rain water flows. As shown in Figure 7, the excess rain water of the study area often flows into eight (8) different directions namely; the northern, northeastern, northwestern, southern, southeastern, southwestern, eastern and western directions.

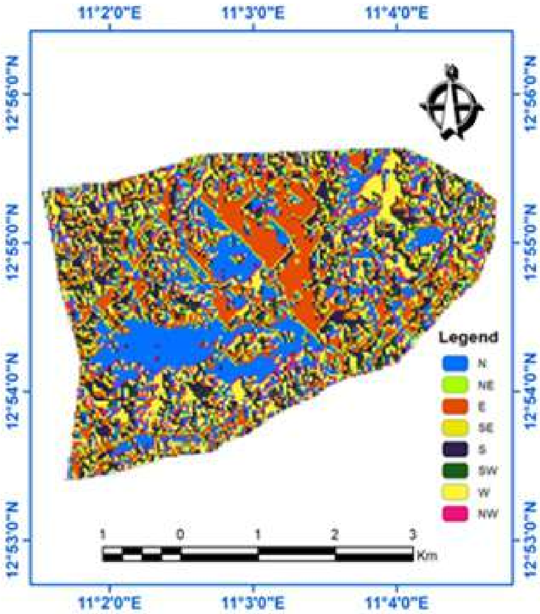

Figure 7: The study area flow direction map

From the flow direction data of the study area as shown in Table 3, the northern, eastern, southern and western directions have the highest out-flow of water and land mass coverage.

They have a total land mass of 58.431ha (22.017%), 52.389ha (20.547%), 43.536ha (17.075%) and 39.923ha (15.658%) of the total land cover (i.e. 254.97ha), respectively. Thus, the highest volume of the overflowing rain water will drain to these directions. Whereas, the northeastern, northwestern, southeastern and southwestern directions have the least out-flow of water and land mass coverage. They have a total land mass of 16.349ha (6.412%), 15.923ha (6.245%), 14.296ha (5.607%) and 14.123ha (5.539%) of the total land cover (i.e. 254.97ha), respectively.

Table 3: Flow direction data of the study area

Flow Direction	Land-cover Percentages (%)	Area (ha)
North (N)	22.917	58.431
North-East (NE)	6.412	16.349
East (E)	20.547	52.389
South-East (SE)	5.607	14.296
South (S)	17.075	43.536
South-West (SW)	5.539	14.123
West (W)	15.658	39.923
North-West (NW)	6.245	15.923
Total	**100**	**254.97**

Flow Accumulation Dataset

As shown in Figure 8, this dataset shows the cumulative values of water flow. It represents the numbers of pixels, which serve as an input that chips in any amount of the surface rain water to each and every outlet in the study area. It also reveals the variation of cumulative hydrologic flow values from as low as 0 to as high as 8913 pixel values.

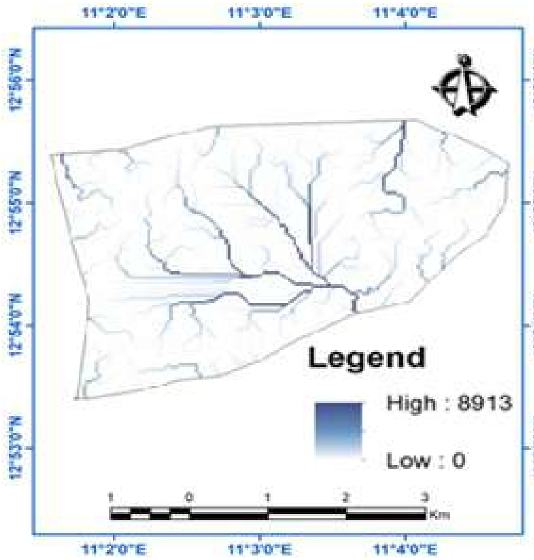

Figure 8: Flow accumulations map of the study area

Stream Definition Dataset

The stream definition dataset as shown in Figure 9, provides a network of cells that define areas in which streams are located in the study area. These were further used to define capacities of various streams across the study area into some varying categories.

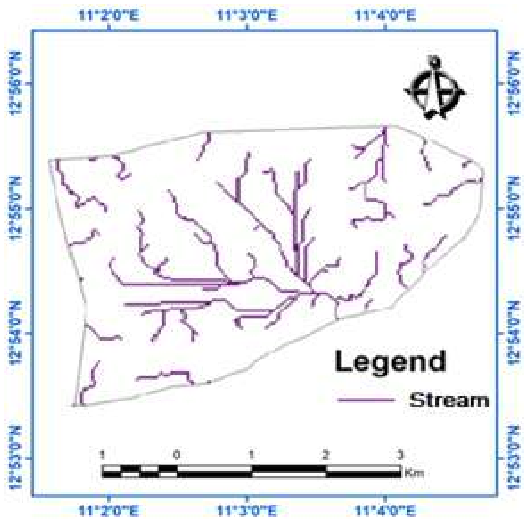

Figure 9: Stream definition map of the study area

Stream Order Dataset

The stream order dataset as shown in Figure 10, classifies the various streams in the study area based on their number of tributaries. It ranks pixels of the output dataset into numerical order according to numbers and relative size of the various streams across the study area.

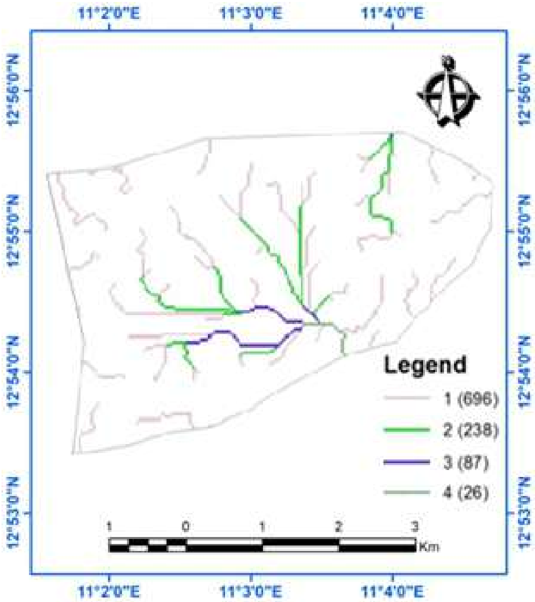

Figure 10: Stream order map of the study area

Therefore, the stream order dataset ranks the streams in the study area into four different numerical orders (streams capacities) with their respective number of streams as follows:

I. 1st order stream, which belongs to streams with very low capacity has 696 streams.

ii. 2nd order stream, which belongs to streams with low capacity has 238 streams.

iii. 3rd order stream, which belongs to streams with medium capacity has 87 streams.

iv. 4th order stream, which belongs to streams with high capacity has 26 streams.

Drainage Network Patterns Dataset

The drainage network patterns as shown in Figure 11, is a vector dataset which shows layout of the drainage network across the study area. It presents the drainage network ordering, where a unique ID is assigned to each and every streams within the drainage network of the study area.

In other words, it shows points at which two or more tributaries (streams) meets, as well as allocating a distinctive ID to each and every tributaries in between these points (nodes) and also to the tributaries which have only a single node. More so, it also shows the ranking of various drainages across the study area into four varying numerical orders with their respective drainage capacities, namely:

i.. 1st order drainages, which has high drainage capacity;

ii. 2nd order drainages, which has medium drainage capacity;

iii.3rd order drainages, which has low

drainage capacity; and

iv. 4th order drainages, which has very low drainage capacity.

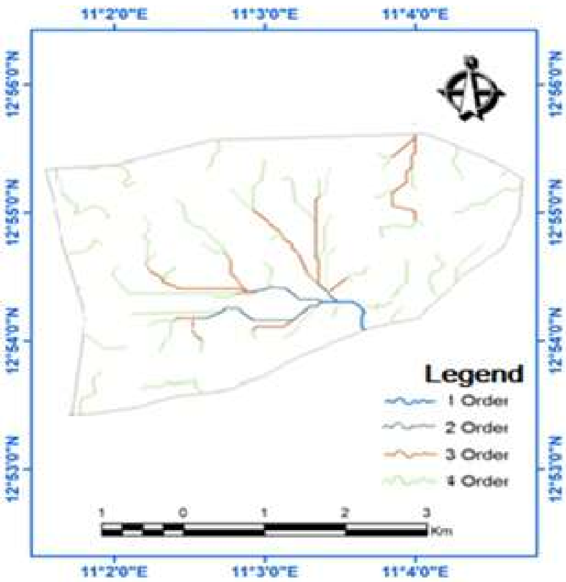

Figure 11: Drainage network patterns of the study area

Base Map Creation

The base map provides background reference information necessary to orient location of the map upon which addition of new thematic information can be done seamlessly. It also adds to the aesthetic appeal of the new created map. As shown in Figure 12, it depicts respective positions of both natural and man-made features across the study area. These may include; water bodies, residences, market places, schools, health centers, worship centers, roads, and so on.

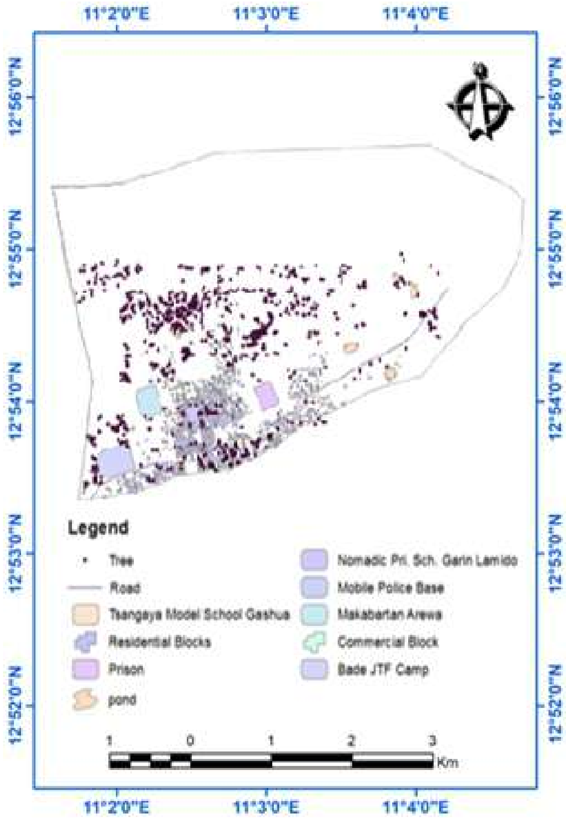

Figure 12: Base map of the study area

Determination of Spatial Relationships between the Drainage Network Patterns and Existing Features of the Study Area

The overlaying analysis was employed to establish spatial relationships between the drainage network patterns and existing features across the length and breadth of the study area. As shown in Figure 13, this helps to identify where high, medium, low and very low capacity drainages are located as well as establishing their spatial relationships with the existing features. The relationships also help in providing terrain information necessary for understanding issues related to floods on current and future developments in the study area.

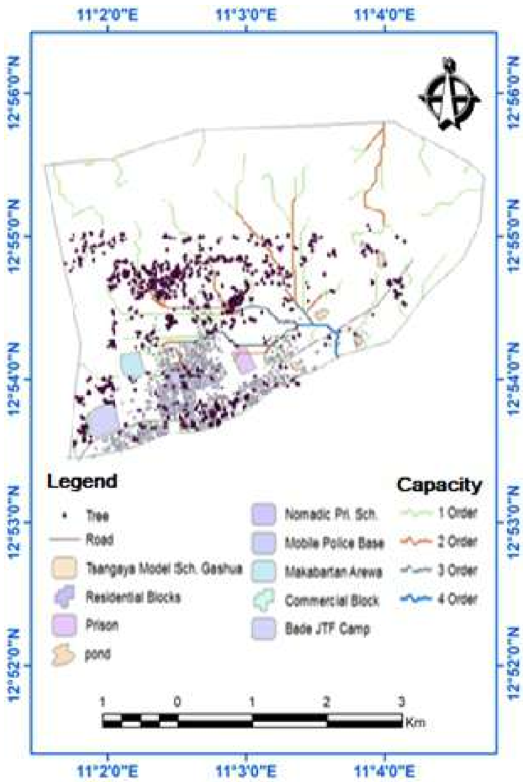

Figure 13: Overlay of drainage network patterns and base maps of the study area

Extraction of Terrain Parameters

Terrain parameters namely; contour, slope and aspect datasets were extracted from the rectified DEM data. As in the work of Malaperdas and Panagiotidis (2018), the contour, slope and aspect data were expressed in the form of digital values. The contour map as shown in Figure 14, provides an insight about the elevation or depth (topography) of various points of interest across the study area. It also reveals that the terrain of the study area is relatively flat, with minimum and maximum contour values of 335 and 341 meters above mean sea level, respectively. This informed the use of a contour interval of 0.5m. Whereas, the slope map as shown in Figure 15, shows the degree of steepness of prominent features across the study area. So also, as can be seen in Figure 16, the slope map was further classified into five classes, namely;

I. The areas with a flat terrain
ii. The areas with a gentle slope terrain
iii. The areas with a sloppy terrain
iv. The areas with a steep slope terrain and
v. The areas with an extreme slope terrain. to be expressed in the form of digital values respectively.

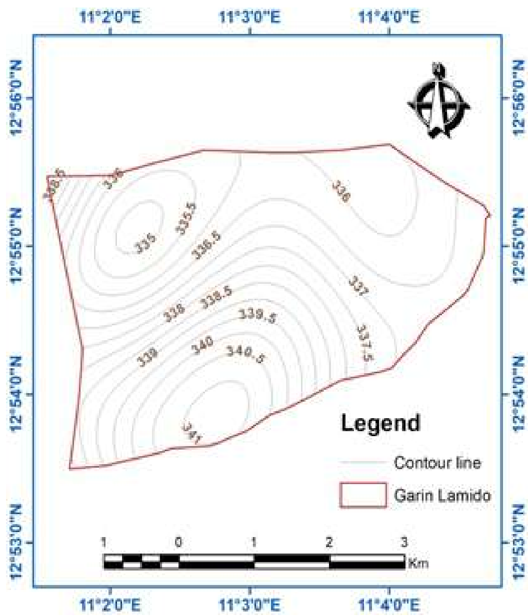

Figure 14: The study area contour map

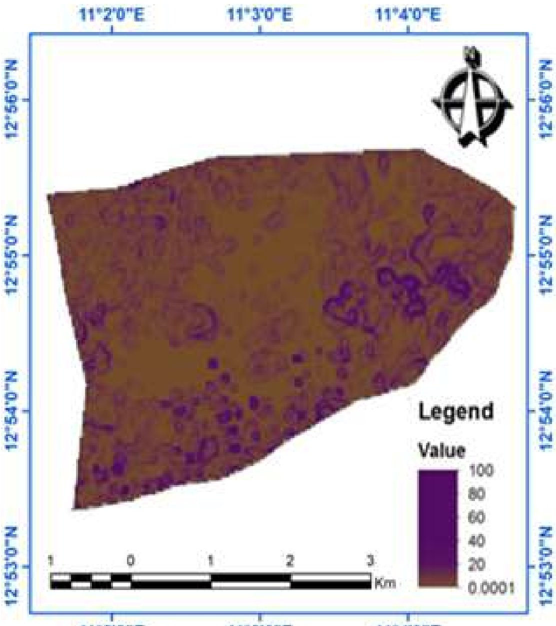

Figure 15: The study area slope map

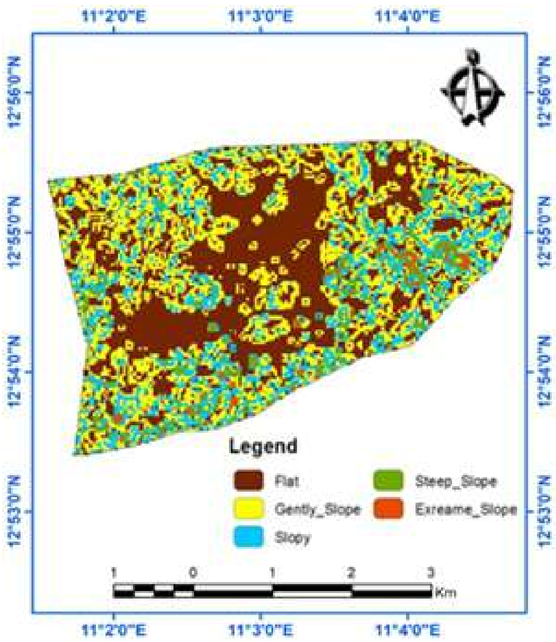

Figure 16: The study area classified slope map

The classified slope data as shown in Table 4, reveals that the largest portion of the area is characterized by a flat terrain covering a total land mass of about 184.5ha (72.361%) of the total land-cover (i.e. 254.97ha). The second largest portion of the area is characterized by an extreme slope terrain. It has a total land mass of about 19.98ha (7.836%) of the total land-cover (i.e. 254.97ha).

The third largest part of the area is characterized by a sloppy terrain. It has a total land mass of about18.450ha (7.236%) of the total land-cover (i.e. 254.97ha). So also, the fourth largest portion of the area is characterized by a steep slope terrain. It covers a total land mass of about 16.920ha (6.636%) of the total land cover (i.e. 254.97ha). Whereas, the smallest part of the area is characterized by a gentle slope terrain. It covers a total land mass of about 15.120ha (5.931%) of the total land cover (i.e. 254.97ha).

Table 4: The study area classified slope data

Slope Type	**Land -Cover Percentage (%)**	**Area (ha)**
Flat	72.361	184.50
Gentle Slope	5.931	15.12
Slopy	7.236	18.45
Steep Slope	6.636	16.92
Extreme Slope	7.836	19.98
Total	**100**	**254.97**

The aspect map as shown in Figure 17, was made such that orientations of slopes are measured clockwise in degrees from 0^0 to 360^0. It contains aspect values that are used to indicate the directions which the slope face, namely:

i. Flat-northern direction
ii. Northern direction
iii. Northeastern direction
iv. Eastern direction
v. Southeastern direction
vi. Southern direction
vii. Southwestern direction
viii. Western direction and
ix. Northwestern direction

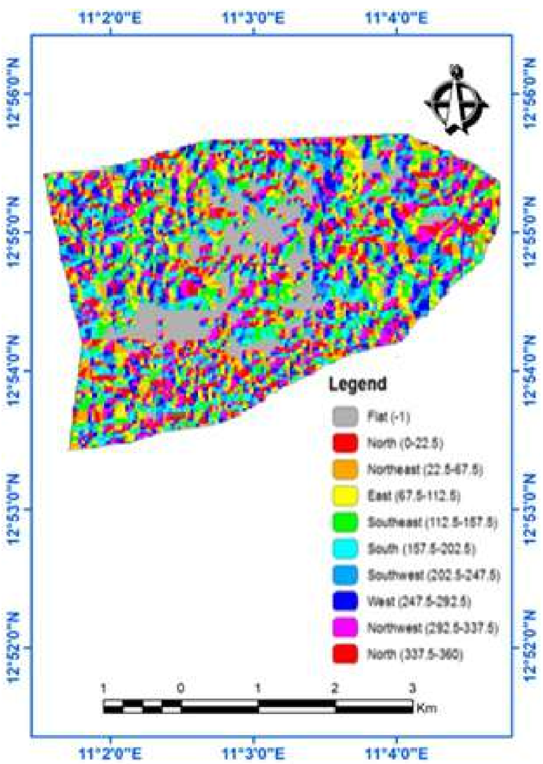

Figure 17: The study area aspect map

As shown in Figure 18, the aspect dataset was further classified into nine distinct directions at 40^0 intervals.

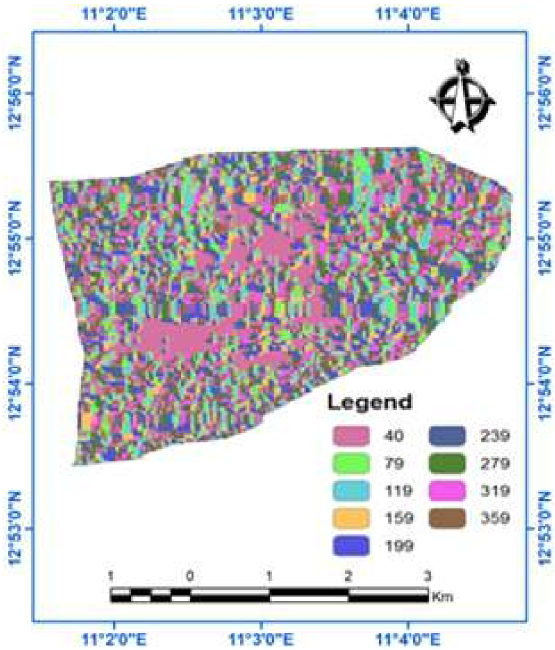

Figure 18: The study area classified aspect map

The classified aspect data as shown in Table 5, reveals that the largest portion of the study area is characterized by flat terrain covering a total land mass of about 139.783ha (54.823%) of the total land-cover (i.e. 254.97ha). It has an aspect value of 40^0, which means that most of the rains water often remains stagnated all over the flat terrain while very little amount of it drains slightly towards the northern direction. The second largest portion of the area, covers a total land mass of 15.957ha (6.258%) of the total land-cover (i.e. 254.97ha). It has an aspect value of 319^0, which means that the excess rains water drains towards the western direction. The third largest portion of the area, covers a total land mass of 15.246ha (5.980%) of the total land-cover (i.e. 254.97ha). It has an aspect value of 159^0, which means that the rains water drain towards the eastern direction. The fourth largest portion of the area, covers a total land mass of 14.688ha (5.761%) of the total land-cover (i.e. 254.97ha). It has an aspect value of 79^0, which means that the rain water drains towards the northern direction.

So also, the fifth largest portion of the area, covers a total land mass of 14.571ha (5.715%) of the total land-cover (i.e. 254.97ha). It has an aspect value of 119^0, which means that the rain water drains towards the north-eastern direction. Similarly, the sixth largest portion of the area, covers a total land mass of 14.328ha (5.619%) of the total land cover (i.e. 254.97ha). It has an aspect value of 279^0, which means that the rain water drains towards the southwestern direction.

So also, the seventh largest part of the area, covers a total land mass of 13.950ha (5.471%) of the total land-cover (i.e. 254.97ha). It has an aspect value of 199^0, which means that the rain water drains towards the southeastern direction. The eight largest part of the area, covers a total land mass of 13.644ha (5.351%) of the total land-cover (i.e. 254.97ha). It has an aspect value of 359^0, which means that the rain water drains towards the northwestern direction.

And finally, the smallest part of the area, covers a total land mass of 13.491ha (5.291%) of the total land-cover (i.e. 254.97ha). It has an aspect value of 239^o, which means that the rain water drains towards the southern direction.

Table 5: The Study Area Classified Aspect Data

Aspect Face or Direction	Area (ha)	Land-Cover Percentages (%)	Aspect in Degrees
Flat-Northern	139.783	54.823	40
Northern	14.688	5.761	79
North-eastern	14.571	5.715	119
Eastern	15.246	5.980	159
South-eastern	13.950	5.471	199
Southern	13.491	5.291	239
South-western	14.328	5.619	279
Western	15.957	6.258	319
North-western	13.644	5.351	359
Total	**254.97**	**100**	**359**

It is important to note that the aspect data, reveals that the excess run-off water in most of parts of the study area often remains stagnant all over the flat terrain while very little amount of it drains slightly towards the northern direction. In consequence, the directions of water out-flows from all the slope faces with minimum land coverage often drained to the directions which have the maximum land cover.

Hence, this provides a clue upon which all water discharge from the north, northeast, east and west directions (i.e. directions with maximum coverage) can be linked up to further drain the rains water to the rivers, ponds or reservoirs that are located within the area.

Soil Types and Methods of Soil Types Test

Three simple methods of soil type test, were used to ascertain the soil types of the study area, namely;

1. The squeeze test
2. The ribbon test and
3. The Jar test.

The Squeeze Test

By squeezing a small handful of damp, but not soaking wet soil between thumb and pointer fingers, the soil type of the study area was determined based on the soil textures and some other physical characteristics of the three (3) major types of soil, visa viz; clay soil, loamy soil and sandy soil as follows:

a. Clay soil has a smooth, slick, slimy and sticky texture. It usually get formed into ribbons shape when molded using fingers
b. Loamy soil often has a smooth, slick, partially sandy, and sticky texture. It can also get formed into a ball shape that falls apart easily.
c. Sandy soil usually has a very loose and gritty texture. To form a ball shape using this soil type is almost not possible.

Hence, the result obtained from this test corresponds to physical features of a loamy soil as the soil sample is a little bit fine, slicky, sticky and partially sandy. It also used to make a ball shape which falls apart easily.

The Ribbon Test

By taking a handful of a little bit wet soil and then molded it into a ribbon shape using hands. Thus, the soil types of the study area was determined based on some physical characteristics of the three (3) major types of soil, visa viz; clay soil, loamy soil and sandy soil as follows:

a. If the ribbon is being held vertically without breaking, then it is mostly a clay soil.
b. If the ribbon breaks off when it is being held in an upright position, then it is a loamy soil which perhaps has approximately about 25% to 50% clay particles in the soil.
i. In a situation where the ribbon shape cannot be formed at all, then it is a sandy soil.

Similarly, as in the squeeze test method, the result obtained from this test corresponds to some physical attributes of a loamy soil as the ribbon often tends to breaks off when held vertically.

The Jar Test

The jar is comparatively more accurate than the remaining methods of soil type tests. The following procedures were followed to determine the soil types of the study area, based on properties of the three (3) major types of soil, namely; sandy, clay, and loamy soils:

i. By placing about 1-inch depth stones and other waste stock free mixture of soil samples, obtained from different parts of the study area inside a quart-sized transparent glass jug and then filled 2/3 of the glass jar with water.
ii. After a pinch of salt was added to enables the soil particles to separate, the solution was shake vigorously and then it was allowed to settled down into three (3) layers of the major soil types, say; clay, loamy and sandy soils as follows:
a. The sand settled very fast (within a very short period of time) to constitute the bottom layer.
b. Some few hours afterwards, the silt also get settled. A visual differences were seen between the larger particles of the sandy soil and the smaller particles of the silt soil.
c. The clay soil takes some days to settle down (i.e. 3-5 days).
d. Hence, a clear visual differences of the larger, smaller and very fine particles of the sandy, silt and clay soils, respectively were observed from the solution inside the glass jar.
iii. The total amount of the sample soil was measured from quart-sized clear glass jar. Hence, the ratios of each layer of the three (3) soil types were measured by applying some little math as follows.
a. For instance, as the total quantity of the soil inside the glass jar is one-inch in depth and the sand layer at the base of

the jar is ¼-inch-thick, then the soil can be said to be 25% sandy soil.

b. As the next adjoining layer, which is silt soil is also ¼-inch in depth, then the soil is said to be 25% silt.

c. As the remaining next and the last layer, which is clay soil, is 1/2-inch deep, then the soil is 50 percent clay soil.

d. Based on ratios of each layer of the three (3) soil types (i.e. 50% clay, 25% sand and 25% silt), as seen from the solution inside the glass jar, the soil type can be said to be a clay sandy loamy soil (Ahukaemere, 2012; www, madhav university. edu.in).

By comparing the results obtained from each of the above three (3) methods, it is important to note that the study area is mainly composed of loamy and partially sandy soil. The loamy soil (partly clay and sandy soil) which has very low rate of water absorption covers most part of the study area. It covers a total land mass of about 239.85ha (94.069%) of the total land-cover (i.e. 254.97ha). Whereas, the areas with sandy soils cover a total land mass of about 15.12ha (5.931%) of the total land-cover (i.e. 254.97ha). In consequence, the surface rains water finds it difficult to infiltrate into the soil and thus, it often over-floods most places in the study area.

As shown in Table 6, it is sufficed to say that combinations of two spatial characteristics of the study area, namely; slope and soil types have contributed significantly to the annual recurrences of floods issues in the study area.

Table 6: Slope Data and Soil Type of the Study Area

Slope Type	Land-cover Percentages (%)	Area (ha)	Soil Type
Flat	72.361	184.50	Loamy
Gentle Slope	5.931	15.12	Partially Sandy
Slopy	7.236	18.45	Loamy
Steep Slope	6.636	16.92	Loamy
Extreme Slope	7.836	19.98	Loamy
Total	**100**	**254.97**	

Conclusion and Recommendations

This paper has presented a workflow for determining drainage network patterns and causes of floods issues in the study area using a geospatial based approach. Therefore, the following conclusions have been made in accordance with the achieved objectives as stipulated in this paper:

The drainage network patterns map has reveals ranking of various streams in the study area into four different numerical orders with their respective drainage capacities, namely:

1. 1st order stream, which has high capacity drainages
2. 2nd order stream, which has medium capacity drainages
3. 3rd order stream and which has low capacity drainages
4. 4th order stream, which has very low capacity drainages

Furthermore, the overlaying of the drainage network patterns and base map of the study area has provides snapshots of all the terrain information as well as the spatial relationships between the drainage network patterns and all existing features across the study area. This will in turn help to furnish policy makers and other environmental stakeholders with a means to better understand effects of flood related issues on current and future developments in the study area.

More so, critical analysis of the contour, slope and aspect data reveal that most parts of the study area are characterized by a flat terrain. These areas have a total land mass of about 184.5ha (72.361%) of the total land-cover and are mostly associated with stagnant rain water, as the excess rain water cannot or often find it difficult to be properly discharged.

The research findings also reveals that the study area is mainly made up of loamy and partially sandy soil. The loamy soil (partly clay and sandy soil) which has very low rate of water absorption covers most part of the study area with a total land mass of about 239.85ha (94.069%) of the total land-cover (i.e. 254.97ha). Consequently, the surface rain water finds it difficult to infiltrate into the soil and thus, over-floods the area.

In conclusion, the research findings have demonstrated the capabilities of geospatial based approach in determining the drainage network patterns as well as the root causes of flood related issues in the study area. Hence, it is sufficed to say that the combined effects of the spatial characteristics of the study area, namely; drainage network patterns, terrain parameters information (i.e. contours, slope conditions and aspect faces), soil types as well as other human activities such as deforestation, mining, construction, etc., have significantly contributed to the annual recurrences of floods related issues in the study area. Consequently, the following recommendations were put forth;

i. Government should provide efficient and effective drainage network system such that all the excess rains water can be removed or channeled neatly to disposal points without causing inconveniences to inhabitants of the study area. This will in turn helps to ensure that the environment always remains well drained and free of waste during raining seasons. And thereby, curbs the annual recurrence of floods related problems.

ii. Environmental planners and other stakeholders responsible for land-use zoning and/or allocation should often utilize DEM capabilities to improve on floods protection measures and administrations. This is necessary, as an accurate analyses of terrain and hydrological characteristics of a given geographic location using DEM will aid to avoid allocating flood prone areas for uses such as residential, commercial, educational, recreational, industrial, etc.

iii. The study is limited to semi-urban area which has less structural complexity Therefore, further study should be carried out in a complete urban setting which has complex spatial characteristics in order to ascertain the suitability as well as robustness of the approach.

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