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# MITIGATING THE EFFECT OF EROSION THROUGH WATERSHED ANALYSIS AND WATER CHANNELING: A CASE STUDY OF GOMBE LOCAL GOVERNMENT AREA, GOMBE STATE, NIGERIA

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**Abstract:** Soil erosion refers to the wearing away of a field's topsoil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage. Historical documents had shown how erosion has been threatening and inflicting havoc on human being and his environment, starting from ancient records to date. Gombe Local Government Area of Gombe State is one of such areas affected by this disaster. The study was aimed to employ the technique of watershed analysis in mitigating the effect of erosion in Gombe Local Government Area. GIS and Remote Sensing method was used to acquire information from satellite images and Shuttle Radar Topographic Mission (SRTM) data to produce water channel map along the study area. The Satellite imagery was downloaded from USGS website. Landsat 8 imagery was used to classify the study area into built-up area, vegetation, water body and bare surface. While the SRTM data was used to generate slope map, flow direction map, flow accumulation map, fill sink map and stream pattern map, from which the watershed map was produced. The aim of the research has been achieved by producing a watershed map of the study area, revealing the areas that are prone to erosion in addition with the proposed water channel that will effectively discharge water into a major dam in Gombe state so as to mitigate the effect of erosion in Gombe L.G.A. Hence the research recommends the implementation of proper water discharge into Dadin Kowa dam. Some measures that will help in mitigating the effect of erosion includes structural measures, infiltration measures, afforestation and effective land planning.

**Keywords**: Mitigate, Erosion, Watershed Analysis and Water Channeling.

## 1. Introduction

Historical documents had shown how erosion has been threatening and inflicting havoc on human being and his environment, starting from ancient records to date from the mid-twentieth century and numerous literatures review how soil erosion has been perceived previously by scholars, land surveyors, farmers, land owners, researchers, and policy makers. Gombe L.G.A. is fast becoming hazardous for human habitation. Hundreds of people are directly affected every year and have to be relocated. Large areas of agricultural land are becoming unsuitable for cultivation as erosion destroys farmlands and lowers agricultural productivity and human settlement.Soil erosion is an environmental problem that degrades

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land, threatens agricultural productivity and hydrologic systems in the watersheds. It is caused by extensive human-environment interactions through agricultural practices, urbanization, construction and deforestation. These activities impact on soil characteristics and reduce the land-cover that provides stability to the soil. Climate, topography, vegetation cover, land-use pattern and soil characteristics are biophysical factors aiding soil erosion processes, [1]. The disaster of erosion in Gombe is growing at an alarming rate. Formation of gullies has become one of the greatest environmental disasters facing Gombe state, most especially Gombe L.G.A.

The increase in extreme weather events predicted with climate change that will magnify the existing water and wind erosion situations and may create new areas of concern is also a major factor. Farmlands must be protected as much as possible, with special attention to higher risk situations that will leave the soil vulnerable to erosion. This has encouraged both National and International bodies to involve in the prevention and response in order to minimize the damage caused by accidents involving erosion. But with the persistent occurrence of this phenomenon, the success of the struggle against this cankerworm has not yielded any lasting result. From the indigenous approach of controlling soil erosion among farmers, it was observed that farmers have more often than not practiced these control measures for intensions that are primarily different from controlling erosion, their practices coincidentally assist in averting soil erosion to considerable degree. This draws attention to the fact that more respective attention to local knowledge and practices are necessary basis for effective and appropriate environmental policies, particularly in developing countries, [2]. Various measures and works are being carried out to mitigate and prevent the direct and indirect effects of erosion. However, these actions often cannot be implemented in a whole region prone to erosion due to limited financial or human resources, [3]. Surface cover is a necessary element for controlling erosion losses following a skidding disturbance, particularly on steep slopes. Therefore, identifying the area that requires particular attention for conservation is necessary, [4]. Watershed analysis is known as a method of dividing a landscape into different watershed classes on the basis of selected topographic features. Watershed can be defined as the total area of water flowing to a given outlet point or more often known as pour point. The boundary between two adjacent watersheds is the drainage line. The name refers metaphorically to a geological watershed, or drainage divide, which separates adjacent drainage basins. In the study of image processing, a watershed is a transformation defined on a grayscale image. The name refers metaphorically to a geological *watershed*, or drainage divide, which separates adjacent drainage basins. The watershed transformation treats the image it operates upon like a topographic map, with the brightness of each point representing its height, and finds the lines that run along the tops of ridges. It describes the potential topographic soil erosion risks of a landscape on the basis of its physical and / or environmental features. Most of the study in hydrology field takes a watershed as a basic unit for better understanding. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimensions of its landforms. Watershed analysis provides the process of formulation and carrying out of a course of action involving modification of the natural system of watershed to achieve specified objectives and this can be integrated into a GIS environment for better and faster results,[5].

### 1.1 Statement of the Problems

Land is an imperative resource that should be protected in all ramifications. The negative impact of erosion is obvious in Gombe state. The dwellers have experienced adequate damage of properties such as houses, farmlands and roads as a result of erosion. Despite the increased in population, the useful lands are reducing. Gully erosion is causing functional and structural damage to infrastructural facilities such as culvert outlets and roads within the stream channels as well as other public and private structures along the channel, [6]. It is against this background that this study attempts to derive ways of mitigating the effect of erosion in Gombe L.G.A. through the use of watershed analysis.

### 1.2 Limitation of the study

This study is limited to Gombe Local Government Area in Gombe state, Nigeria. On the other hand, the study was not able to carry out thorough comparison between the present condition of gully sites and their condition in the past few years in order to be ascertain on their rate of expansion.

## 2. Methodology

The GPS coordinate data was acquired with the use of Hand-held GPS was used for ground truthing. Land Sat 8 imagery covering the study area was downloaded from USGS website. Land Sat 8 is an American Earth Observation Satellite launched on February 11, 2013 with the collaboration between NASA and USGS. Land Sat 8 has a medium resolution of 30-meter spatial resolution, multispectral image data affording seasonal coverage of the global landmasses ensuring the geometry calibration, coverage characteristics, spectral characteristics, output product, quality and data availability to permit studies of land cover and land use change over time. It has output format Geo-TIFF with pixel size of 15meters/30meters/100 meters (panchromatic/ multispectral/thermal) and WGS 84 datum.

The SRTM data were also obtained. SRTM is a digital elevation models on a near-global scale from $56^0$S to $60^0$N, generating high resolution digital topographic database of the Earth. SRTM consists of a specially modified radar system that flew on board the space shuttle mission in February 2000 with a resolution of one arc second (30m), but this has only been released over united states territory and one arc second dataset covering Australia was made available in November, 2011; the rest of the World, only three arc second (90m) data are available. Each one arc second tile has 3,601 rows, each consisting of 3,601 16 bit cells. The dimension of the three arc second tiles is 1201 x 1201.

### 2.1 Data Reliability and Accuracy

The reliability of data used for a particular finding is determined by the validity and quality of such data. How experienced an observer is may be a very good way to judge the reliability of such data. The validity of the data is determined by the precision of the instrument used and hence the precision of the set of data, [6]. Statistically, the precision is described as the degree of closeness of set of repeated measurement to one another. The reliability of the data is measured based on the accuracy of such data while accuracy refers to the degree of closeness of the data to other sites called the true values, often referred to as “Gold Standard Data”[6]. Therefore, the data used for this research were observed by observed by an experienced person and were tested to be precise and accurate.

### 2.2 Data Processing

#### 2.2.1 Clipping the research area from the STRM contour

The contour was extracted from the STRM data by selecting clip from extracted tool in spatial analyst to extract contour of Gombe L.G.A. This was then used as input to create DEM from the extract of points using Surfer.

#### 2.2.2 Digital elevation model creation

DEM was created by extracting X, Y, and Z parameters from the STRM data, clipping that of Gombe L.G.A. and interpolating the point data using Spline or Kriging from the spatial analyst tool in the Arc GIS. Digital Elevation Model (DEM) is an operation that was used to describe the behavior of the operation as input raster for the Flow direction operation.

#### 2.2.3 Creation of a slope map

The slope map was created using ArcGIS tool Using DEM as an input raster. Express as a percentage, it was identified as the rates of change in z-values from each cell. The Slope is most frequently run on an elevation dataset, to identify sharp changes in Z value. Steeper were shaded blue on the output slope raster. The Z-values of the input surface were multiplied by the Z-factor when calculating the final output surface. Mathematically it is presented by

$$Percetage\ rise = \left(\frac{Rise}{Run/distance}\right) \times 100$$

Where rise: is the variation in z-values of cells

Run/distance: is the horizontal equivalent of the rise.

**2.2.4 Creation of stream network**

Stream network was created from flow accumulation raster to show path of streams in the study area. The operation involves reclassification of flow accumulation results using reclassification tools in spatial analyst tool. The stream order was classified using strahler method in ArcGIS. Strahler method is a method of accumulating water from small different tributaries into a larger tributary and from that to another tributary larger than the latter.

**2.2.5 Production of watershed map**

Watershed map that was produced from spatial analysis tool theme was categorized by showing different tributaries that are flowing into an outlet.

**2.3 Presentation of result**

The classified image shown in figure 1 below is the result of various land uses within Gombe Local Government Area. The land uses include; built-up area having the highest total area, accounting for 42.250% and water body having the least of them which is equivalent to 7.810% as shown in table 1. Figure 2 is the resultof the Digital Elevation Model (DEM) thatwas produced to describe the behavior of the terrain. The slope map shown in figure 3 shows areas that are relatively flat and those that are hilly.

The stream network that shows basic drainage network and pattern in the study area is shown in figure 4. While figure 5 depicts the stream order and their linkage with Dadin Kowa dam.

The watershed map produced for the study area are categorized into five, with each scale showing the number of tributary flowing into a particular outlet as it is shown in figure 6.

The suggested water channel map was produced from the result of the overlay between the major stream networks in Gombe state and the network pattern of the study area. This can be seen in figure 7. While its linkage or connection with Dadin Kowa dam can be seen in figure 8.

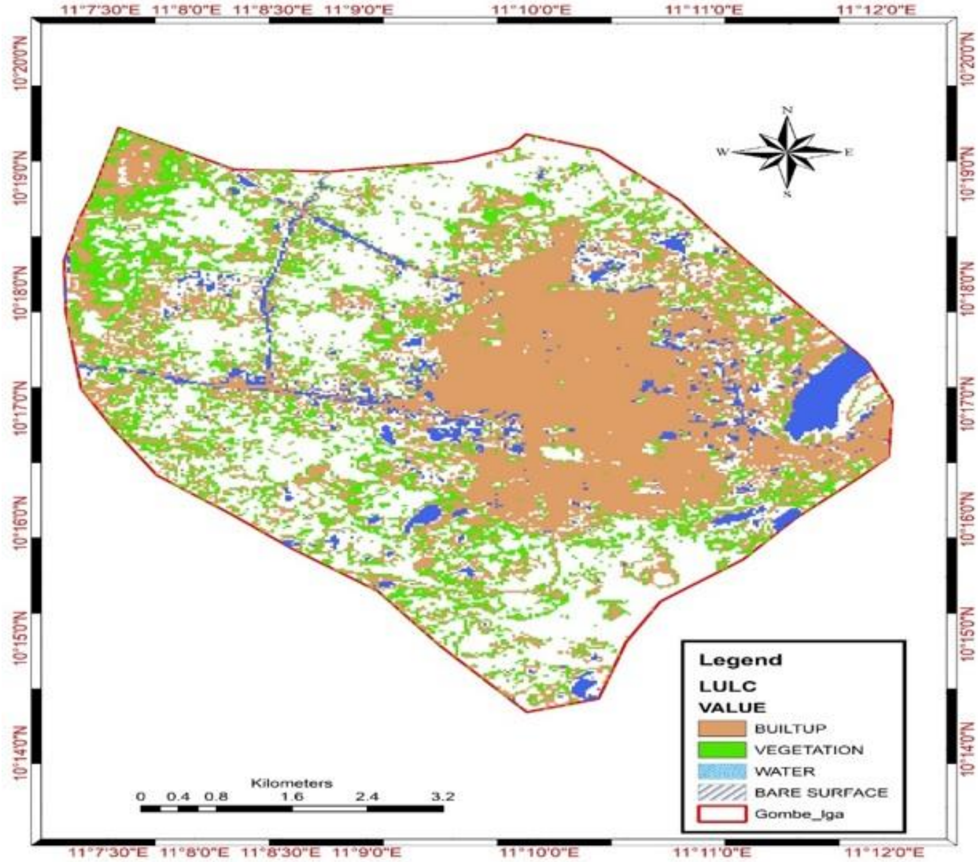


Figure 1: Land Use Land Cover Classification map

Table 1: Land Use Land Cover Classes

| S/N | Land Use Land Cover Classes | Area {M2} | Percentage |
|---|---|---|---|
| 1 | Built up area | 1347124.55 | 42.250 |
| 2 | Vegetation | 690833.85 | 21.725 |
| 3 | Water | 224520.94 | 7.810 |
| 4 | Bare surface | 910219.30 | 28.215 |

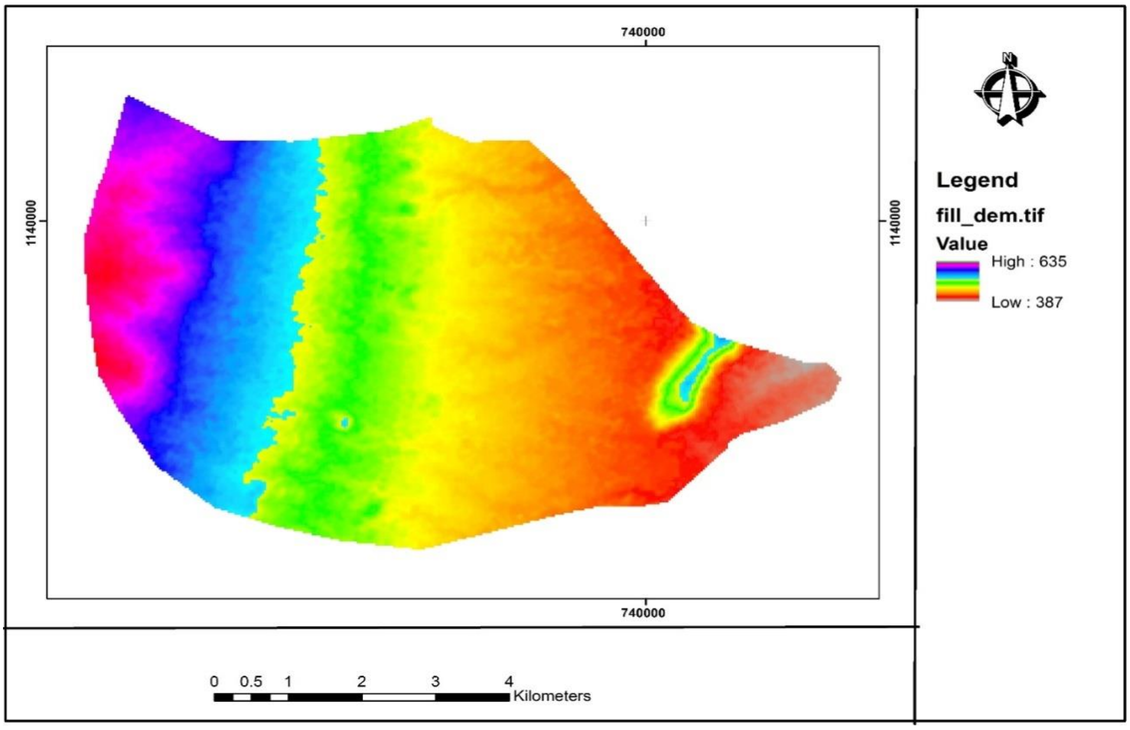


Figure 2: Digital Elevation Model of the study area

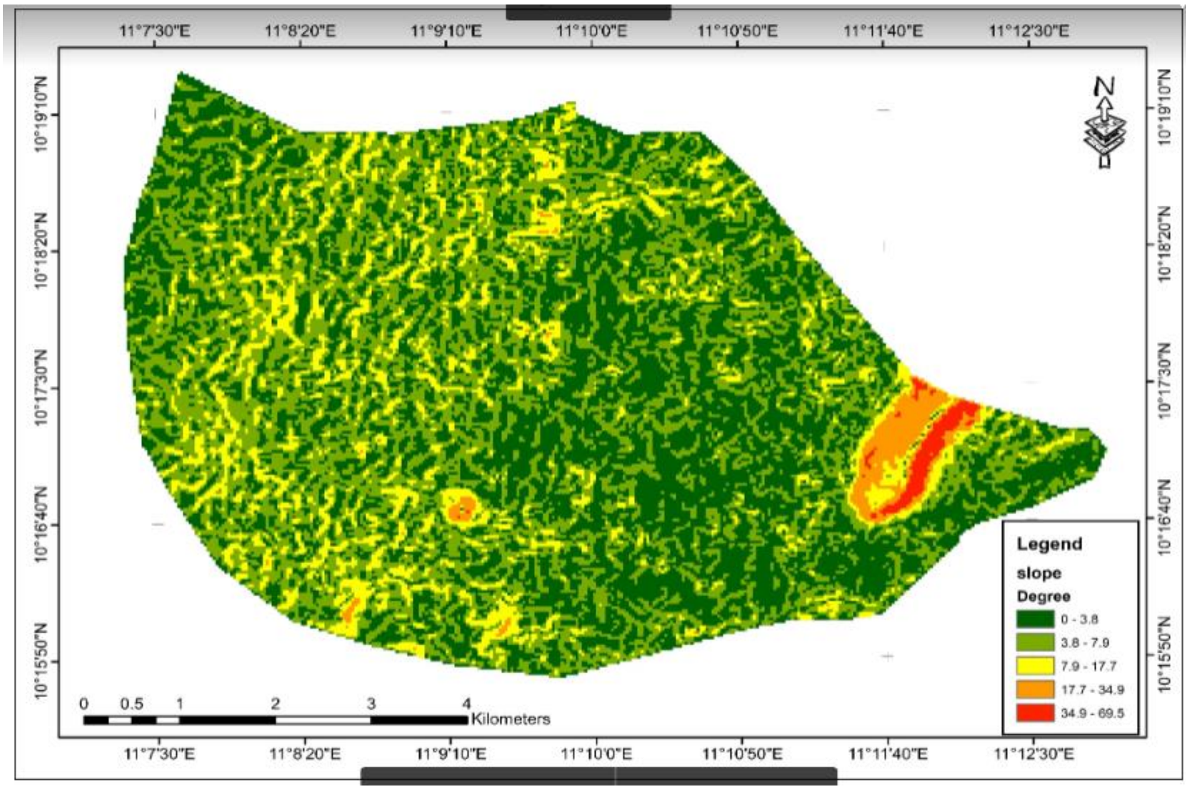


Figure 3: Slope map of the study area

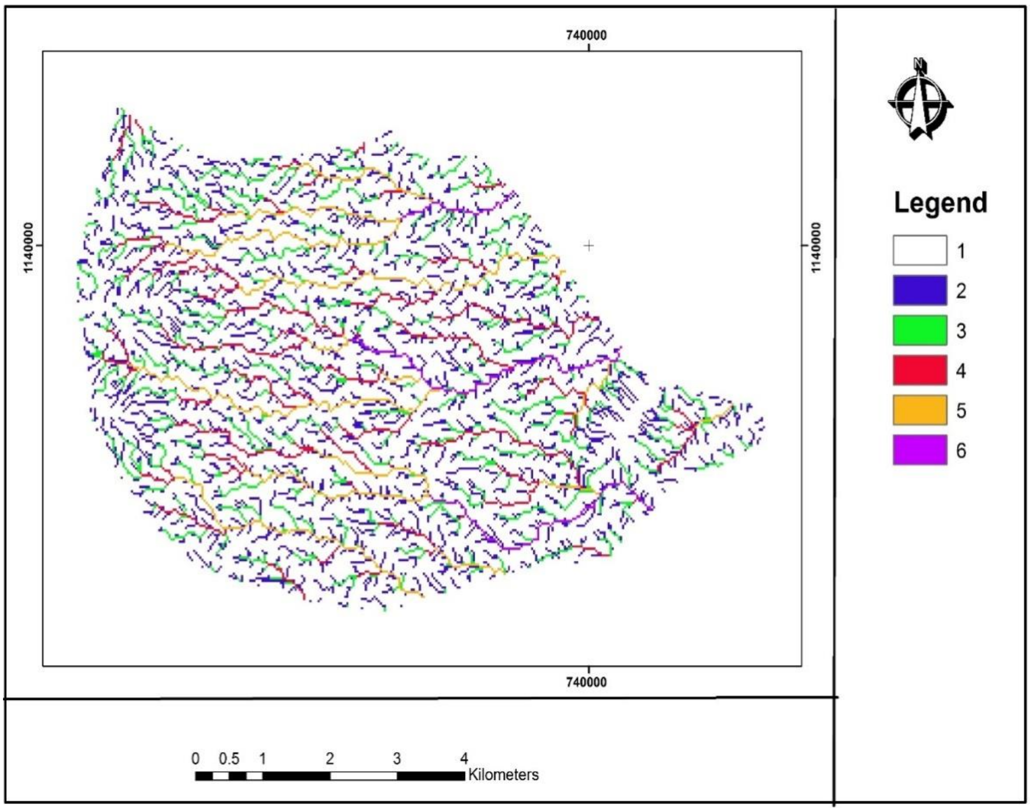


Figure 4: Stream network of the study area

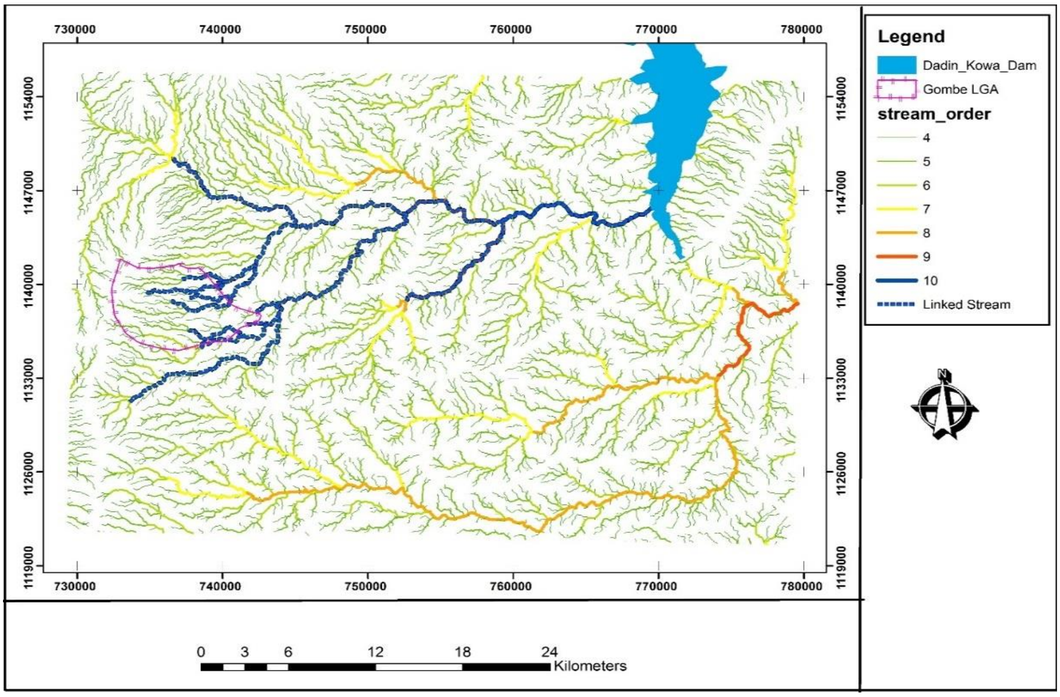


Figure 5: Stream linkage map

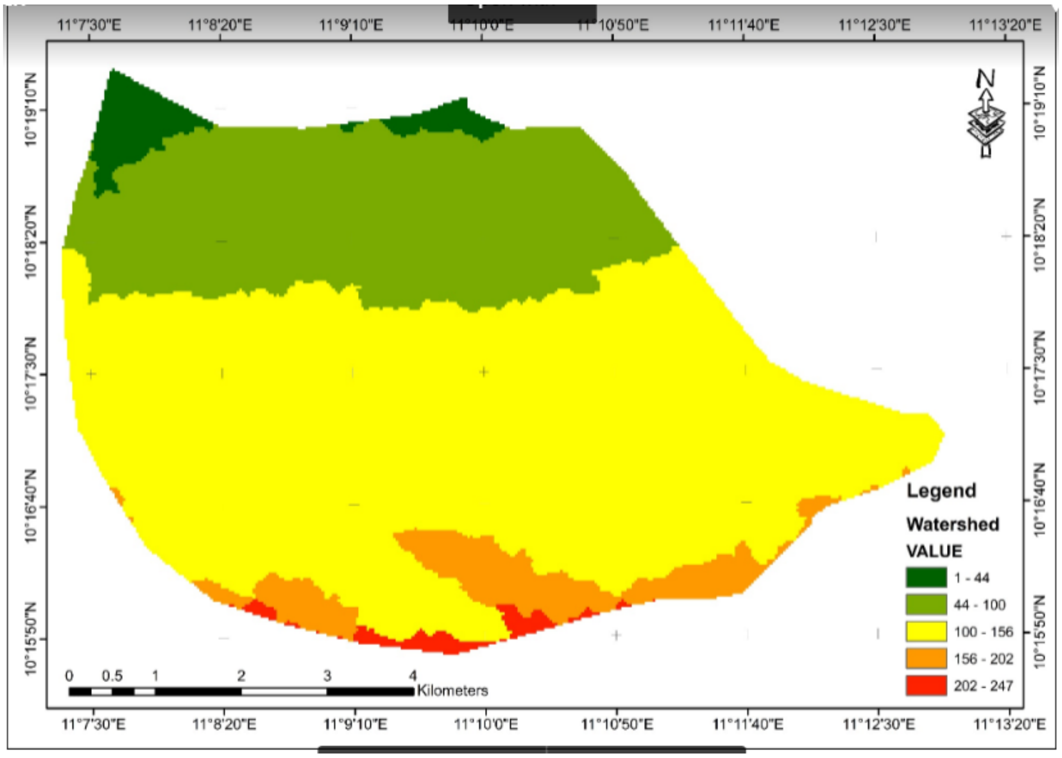


Figure 6: Watershed Map of the study area

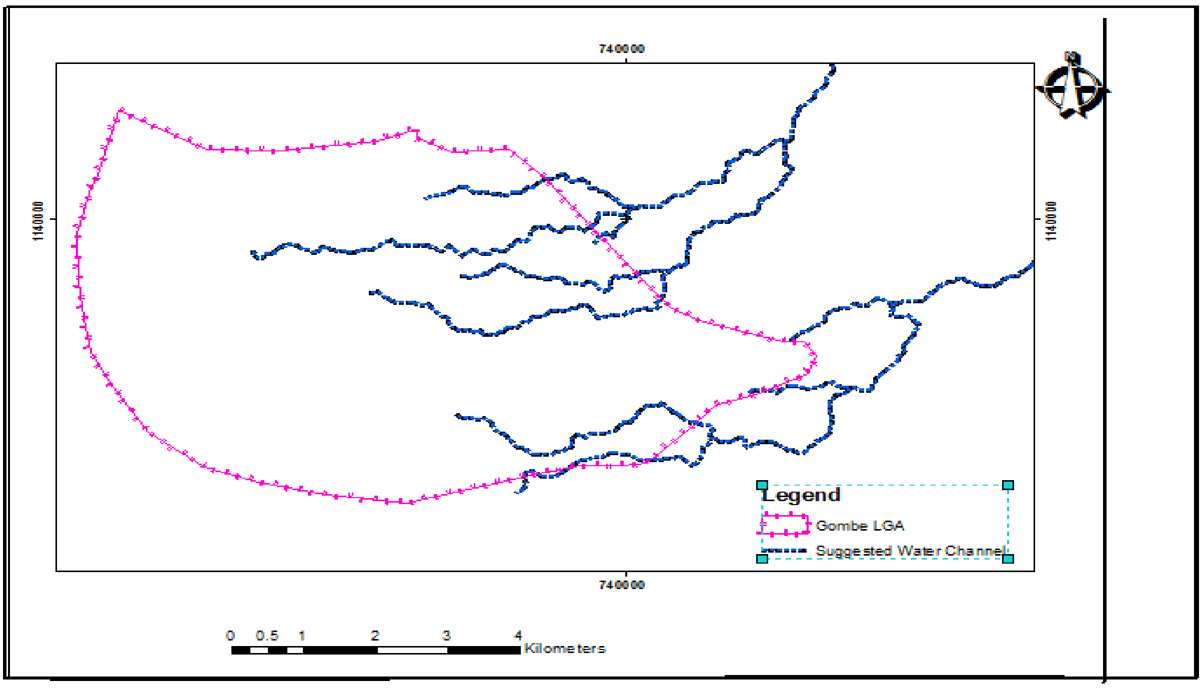


Figure 7: Suggested water channel in the study area

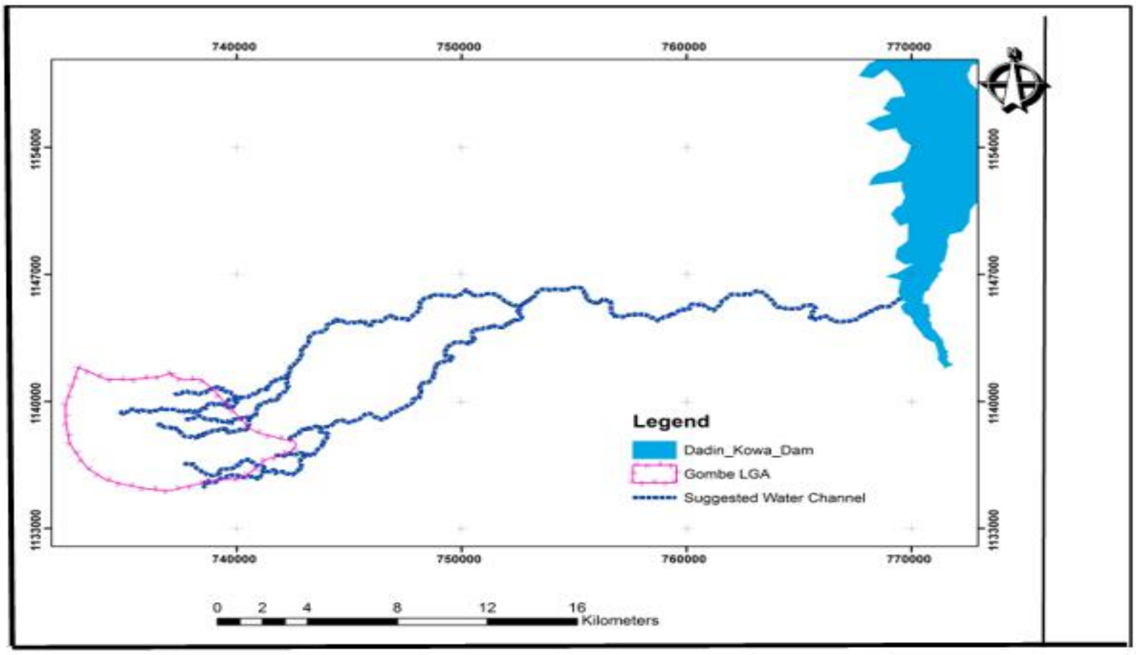


Figure 8: Suggested Water channel linked with a major dam (Dadin Kowa dam)

### 2.3.1 Discussion of Result

From the classified image, shown in figure 1, various land uses within the study area were shown with built-up area having the highest total area, accounting for 42.250% and water body having the least of them which is equivalent to 7.810% as in the table 2. According to change detection carried out for 1990, 1999 and 2009. The physical growth of Gombe L.G.A. can be traced to early 1990s when the settlement covered just about 14 percent. In 1999, built up area reached about 23.21 percent and in 2009 the state capital (Built-up Area) reached 32.67 percent while in 2019, the built-up area had accounted for 42.250 percent. The period between early 1990s and 2019 therefore, has witnessed rapid increase in built up area. This high increase could be attributed to influx of civil servants and other migrants when Gombe town became the State capital in 1996 or it may be due to tarred roads and streets that has witnessed great improvement over the years. The implication of this growth, and consequent outward expansion, as well as deforestation of the savanna woodland of Gombe state catchment areas, has increase area of impervious surfaces which generated high runoff than infiltration during rainfall events, consequently accelerated gullies. Figure 2 is the result of Digital Elevation Model (DEM) that is used to describe the behavior of terrain with elevation parameter. It is a digital model or three-dimensional (3D) representation of a terrain's surface as shown in figure 2. This can be altitude of terrain surface which is also known as Digital Terrain Model, or altitude of soil layers. Digital Elevation Model can be generated from spot heights, contour lines, aerial photographs or satellite imageries. In a DEM, each cell of raster GIS layer has a value corresponding to its elevation (z-values at regularly spaced intervals). DEM data files contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the “Bare Earth”.

Figure 3 is the result of the Slope map. Slope is the measure of steepness or the degree of inclination of the terrain relative to the horizontal plane. Slope express the percentage, an angle, or a ratio of the average rise or depression of the terrain. Slope map measure surface features such as knolls, dips benches, cliffs, etc. Slope features are very imperative in the field of studies like geomorphology, avalanches and decision making. Depending on the nature of terrain inclination and size of the feature, slope map describes the average topography of the terrain with greater percentage values at the steeper slopes. The slope map in figure 3 shows that most of the areas in Gombe L.G.A. lies in relatively flat areas which are represented in green colour and the areas in red and orange colours are signifying the hilly part.

Figure 4 and 5 are the results of the stream network maps that show basic drainage network in the study area and their patterns. The stream network uses flow accumulation as an input raster map and brings out raster map containing cumulative drainage count. It automatically fills possible gaps between extracted drainage line and the superfluous streams which might have come up within the flow accumulation extraction. Limited number of streams were produced by the processes which reduce the drainage network ordering, this gives only external streams with a length greater than certain value to remain in the output drainage network as shown in figure 4. The streams with lower order meet at a point to form a stream of higher order. The higher order streams later accumulate to form a stream network that is higher in order than the latter.

Figure 6 is the resultof Watershed map of the study area that was produced with five different scales. Each outlet is showing the total number of tributaries flowing into it. The higher the number of tributary flowing into a given outlet, the more the area will be prone to erosion. The area with an outlet where water is flowing from thirty-nine (39) tributaries will be more prone to erosion than an area where we have an outlet with no water flowing into it. During the creation of watershed map, it is necessary to first create pour point raster simply because, the pourpoint map serves as a required and compulsory input for successful creation of watershed map.

The proposed water channel shown in figure 7 was produced from the result of the overlay of different stream networks in the entire state and the stream network of the study area. The proposed channel network was designed in order to transport water from the higher order streams in the study area to closest and major dam in Gombe state which is known as Dadin Kowa dam. The higher order streams and other water networks in the study area are flowing in the North-East direction to link up with Dadin Kowa dam. The proposed water channel is a long capacity channel drainage of three (3) meters width that will effectively transport water from the higher order streams within the study area to Dadin Kowa dam in Deba Local Government Area of Gombe State as it can be seen in figure 8. The channel drainage is suggested to be three meters wide within the study area, but it is proposed to be ten meters wide as from Dumbe village to Dadin Kowa dam. This expansion is due to the fact that more streams that are higher in order than the highest order we have within the study area are meeting at Dumbe. Streams of order nine (9) or order ten (10) within the study area would become streams of order six (6) or seven (7) when they meet with streams from other Local Government Areas in the state.

**2.4 Conclusions and Recommendations**

The aim of this research has been achieved by establishing a channel network for effective transportation of water and the generation of watershed map in part of Gombe Local Government Area showing different number of tributaries that are flowing into the outlet. This has provided a way for the mitigation of erosion menace, so as to safeguard the lives and properties of the inhabitants area. Establishment of long capacity drainage will limit the frequency of occurrence of erosion disaster within the area through the proper collection and discharge of water into the main dam. With this fact, appropriate and early solution could be implemented and can increase public awareness regarding erosion effect. If erosion is not controlled, further increase in runoff and gully erosion on slopping ground of that area will ultimately destroy the productive value of the land.

Since it is a known fact that effective land use planning can play a vital role in mitigating the effect of erosion. It is therefore recommended to adopt an appropriate land use planning in the erosion prone areas. Also, the removal of sand and clay for construction purposes should be regulated. This is because constant removal of sand and clay for commercial purposes tends to increase the gully length, deepen the button of gully and widen the gully scarp head which can result to land degradation and increase the rate of gully erosion. It is also recommended that such study should be carried out in other Local Government Areas in Gombe state so as to mitigation the effect of erosion in the entire state.

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