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Assessment of the impacts of gully erosion on Auchi settlement, Southern Nigeria

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Gully erosion in Auchi has become a serious environmental disaster to the town and its neigbouring villages. It has threatened and even destroyed many of the urban infrastructure, properties, and lives as well as retarding the social and economic growth and development of the town. The research work therefore assesses the impact of gully erosion on Auchi town with the aid of data derived from satellite imageries, Global Positioning System (GPS), base map, as well as direct field observation. The approach involve digitizing the imageries along the gully path on the Arcmap to establish the extent of loss of land due to gully erosion as well as creating contour map, Digital Terrain Model (DTM), slope profile of the study area using the Digital Elevation Model (DEM) of the study on ArcGIS 10.1, Surfer10 and Global mapper softwares. Results obtained from the analysis of the imageries revealed that a total area of 37913m^2 was lost to gully erosion between year 2006 and 2012, and that the gully is expanding at an alarming rate of 6318.8m^2 per annum. By the year 2015, a total area of 15,9407m^2 is expected to be claimed by the disaster if no effective measure is taken to ameliorate the devastating effect. The research therefore, recommends channelling of runoff water to less risk areas, planting of trees and other vegetal cover, and public awareness campaign to enlighten the inhabitants on the need to control gully erosion.

Key words: Environmental disaster, impact of gully erosion, runoff water, urban infrastructure.

INTRODUCTION

Erosion and floods, especially in urban areas are fast becoming the most reoccurring disasters in many towns and cities of the world. Settlements, cities' infrastructure and farmlands are continually being destroyed by these hazards. Soil erosion is a single major process responsible for the lost of vast amount of soils worldwide as seen in the study of Murck et al. (1996).

Hughes et al. (2001) observed that one kilometre of gully would produce 10,000 cubic metres of sediment per Km^2 of land. They further emphasized that if such happens for a gully aged 100 years; the mean annual rate of erosion would be 1.5 tonnes per hectare per year.

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Onyegbule (2010) defined soil erosion as a process whereby the surface layer of the soil is detached and carried by agents of denudation and a lower in the soil is exposed leaving a topographic roughness on the resulting landscape. Jeje (2005) estimated that 531,417.6 and 329,436.5 tones of sediments were removed from gullies in Auchi and Ikpoba slope, Benin City respectively.

Gully erosion within settlements requires peculiar attention because of the threat it poses to buildings and other structures that endanger human lives. The gully in Auchi has posed numerous threats to the inhabitants of the area. Here it has caused many residential buildings and worship centres to collapse, destroying road networks and other infrastructure, and degrading land for commercial and agricultural purposes. It has been observed that more buildings are perching precariously on the edge of the stream channel. The present situation in Auchi despite the basement rock formation that comprises the Kukuruku Hills and other outcrops of rocks in Afemai land deserve urgent attention because of the destruction the gully has caused the people of the area.

Jimah (2006) emphasized that the supply of food and access to suitable farmland devoid of erosion threat is critical to sustaining the teeming population of the town. He further said that due to soil loss and depletion of food, from wind and gully erosion, thereby inducing discernment in agriculture crop productions, food scarcity, malnutrition and poverty. Jeje (2005) also identified gully erosion in Auchi, Efon-Alaye and Benin City and classified the gullies on their bases of physiographic locations such as hillslope, road aligned and valley side gullies. It has also been revealed in other studies that gullies appear to be urban phenomenon and has been occurring at unprecedented rates, creating numerous problems and resulting in huge economic, human and social losses in many cities in Southeast and Southwestern Nigeria.

More so, there are other recent reports on the impact of gully erosion in the area ranging from devastation of roads within the town and major roads linking Edo State to other states. This has attracted both regional and National attention, as they impedes the movement of goods and persons from one region to the other within the country, and further leading to loss of other valuable infrastructure. Other areas that gully erosion has devastated in Nigeria include Abariba (Abia State), Efom Alaye (Ekiti State) Nsukka and Ugwuaba area of Enugu state and Agulu Nanka gully site of Anambra State, NEST (1991). The problem of erosion, therefore, should not be seen in isolation, but likened to a cancerous cell that could become widespread and all pervasive.

Ehiorobo and Izinyon (2012) monitored soil loss to erosion in Edo State. Their work pointed out that gully erosion has been neglected because gully processes are difficult to study and difficult to control. Although gullies are usually striking, their small spatial extent generally renders them undetectable in most generally available topographical maps and low resolution imageries.

Onwuka and Okoye (2009) reported that the gully in Ekwulobia which started from flood water that flows down from Isuofia some hundreds of kilometres from Oko and Ekwulobia in South Eastern Nigeria is estimated to have a mean advance rate of 150 metres every 3 to 5 years. The years with mostly heavy rainfall and slides occurring in late October and early November are rare, but when they occur have devastating effects because they are generally atypical and so unexpected.

Akpokodje and Akaha (2010) reported that the initiation and development of gullies are facilitated by natural processes such as rainfall, topography, soil properties, and texture amongst others. Ogboi and Odeh (2012) in their study on erosion problems in Ika environs observed that erosion problems are more common in cultivated farmland, exposed/bare compounds, on poorly constructed road sites and in places of concentrated buildings and that area plagued by soil erosion has the vegetation cover removed either by cultivation or construction works or bush burning.

Ajaero and Mozie (2011) in their assessment of gully erosion menace in Agulu-Nanka area reported that Agulu-Nanka gully erosion area represents a wide area being eaten away gradually and continuously by landslide cum gully advancement processes covering the entire Aghori basin, which covers many communities in the region. Their work has also shown that, landslide resulted from floods and gully erosion in Nigeria cause death, loss of properties, and population displacement when they occur in densely populated area. Adekalu et al. (2007) and Okpala (1990) in their view, says the formation of gullies has become one of the greatest environmental disasters facing many towns and villages in Southeastern Nigeria. They further emphasized that the region is fast becoming hazardous for human habitation and that hundreds of people are directly affected every year and have to be relocated. Ehiorobo and Izyyon (2012) established that one of the main causes of rill and gully erosion in Edo State includes road construction with an inappropriately terminated drainage network, while damages done by surface runoff to the road may be limited and off site effects can be very severe. They added that the use of GPS to establish 3D control and total station instrument has proven to be effective in the measurement of morphological parameters of gullies.

Some studies have revealed that gully erosion and other forms of land degradations has huge implication on food supply to the affected community. For example, Al-Hassan and Momoh (2006) pointed out that soil erosion has huge impact on the production of food, thereby making it difficult to sustain the growing population of the affected towns brought about by urbanization. Ezezika and Adetola (2011) have indicated that despite the region's susceptibility to gully erosion, it can be prevented through enhanced public awareness programs and better land management practices.

Although the practices are insufficient to resolve the

huge gully erosion sites, and the practices can prevent the occurrence of other ones. They added that it is important for community leaders to organize awareness programmes that provide reliable information to the community on gully erosion mitigation strategies. Anejiounu et al. (2013) pointed out that mapping of areas of soil erosion risk is important in the erosion control measures, and from the foregoing, it has been established that erosion is a major threat to soil and water resource conservation in Southeastern Nigeria. Nwido and Ebinne (2013) further opined that various attempts made at controlling erosion in the region have yet to achieve a significant result.

Given that some information exist on the causes of gully erosion in Auchi, as revealed in the previous studies of Jimah (2006) and Jeje (2005), the study, therefore, assesses the impact of gully erosion on the settlement of Auchi, Estako West local government Area of Edo State, using GIS and Remote Sensing techniques. The specific objectives pursued are:

1. Identify the location of the gully erosion sites.
2. Accurately map the extent of the gully sites.
3. Assess the impact of the gully erosion on the various land uses in the study area between 2006 and 2012,

The study covers part of Auchi where the gully erosion has devastated a large area of land. It focuses on areas that the erosion is noticeable such as Warake road, Inu Umaru Street, Igbeadokhai Street, Hausa quaters, Zango and the plain of River Orle.

Geographical location of the study area

Auchi is located in the northern part of Edo state. It is approximately one hundred and thirty kilometers (130 Kms) away from Benin City, the capital of Edo state. It is located on the intersect of latitude 7°N and longitude 6°E in the tropics. Auchi is the headquarters of Etsako west local government. It is bounded to the north by by Jattu, to the south by Aviele, to the east by Iyakpi, and to the west by Owan local government area. Auchi is the administrative centre of Etsako West local government area and the seat of the Federal Polytechnic Auchi (Figures 1 and 2).

MATERIALS AND METHODS

The data used in this study include political map of Edo State, base map of the study area, digital elevation model of the study area, three satellite imageries of the study area (spot 7) as presented in Figures 3, 4 and 5, global positioning system (GPS) and soil samples of some selected gully sites of the study area.

Some of the approaches employed in the work include the integration of Geographic Information System (GIS) and Remote Sensing with use of Global Position System (GPS), Digital Elevation Model (DEM), direct field observation and oral discussion with the inhabitants to assess the impact of gully erosion on settlement, identifying the gully locations in the study area, establishing the various causes of soil erosion as well as projecting further impact of the gully erosion if nothing is done to mitigate or ameliorate its impact. The softwares used in the work include ArcGIS 10.1, excel sheet, surfer 10 and global mapper. Relevant literature such as published articles, journals as well as unpublished research works were consulted in the course of this work, to reveal an update of issues on gully erosion.

Data processing procedures

The first phase involve the combination of GIS and remote sensing through the use of the satellite imagery to map and assess the extent, impact and the rate of gully expansion between 2006 and 2012. The satellite imageries (spot 7) of 2006, 2009 and 2012 with 1 m resolution were acquired from spot image as shown in Figures 3, 4 and 5, respectively. Three years interval was taken in order to identify a significant increase of the gully between 2006 and 2012. The size of the area devastated by the gully in 2006 was determined by importing the imagery into ArcGIS 10.1 software environment. The area was then calculated by editing and digitizing along the gully edge and path on the satellite imagery using polygon features on the Arctool box and the area lost to the gully was automatically calculated in square meter in the attribute table of the software. Subsequently, the total area lost to the gully erosion between 2009 and 2012 was determined by repeating the same procedure on the ArcGIS 10.1 environment.

RESULTS AND DISCUSSION

Results from data was processed to ascertain the extent of the gully erosion in the study area between 2006 and 2012 as presented in Figure 6 showing the rate of expansion of the gully erosion. It can be seen from the graph that in the year 2006 a total area of 102,537m^2 was lost to the gully; in 2009 a total area of 119,481m^2 was claimed by the disaster while in the year 2012 the gully has covered an area of about 140.450m^2. The graph also reveals that by the year 2015 if urgent measures are not taken to address the menace, the gully is projected to destroy a total area of more than 150,000m^2. The expected claim is presented in Figure 7.

It is pertinent to note that the rate of gully expansion is on the increase annually at 6318.8m2. The devastated areas can be seen from the imageries of 2006, 2009 and 2012. This continuous increase in gully development is mainly as a result of the observed human activities in the study area that ranges from the improper channelling of runoff water, haphazard erection of buildings on steep terrain and water ways, to dumping of refuse on waterways. Others include poor construction evident by absence of anticipated runoff in the design of roads that have been eroded by the menace of gully as the roads were constructed without drainages to channel the runoff into the nearby stream.

The result presented in Figure 8 shows areas vulnerable to the gully erosion in which many buildings, trees, open space as well as access roads falling within the perimeter marked as vulnerable area. Such vulnerable

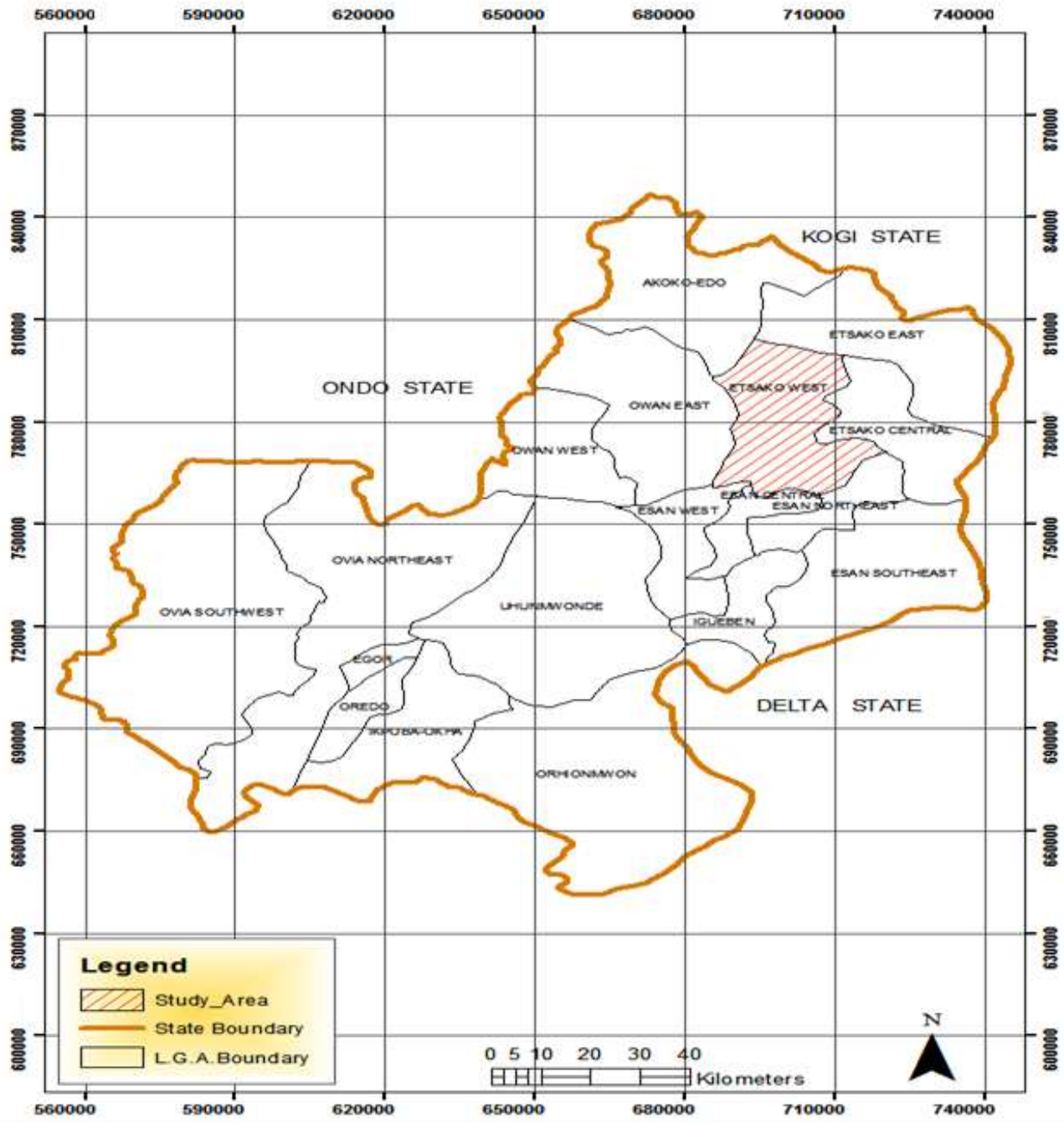

Figure 1. Edo State showing Etsako West LGA (Source: Produced from Arcmap10.1, 2013).

areas on the map are marked by buffering 1000m (1km) outward from the gully edge, taking into account the irregular shape of path created by the gully as well as its annual rate of expansion within the years under study. It could be deduced from the map that if the erosion menace is not urgently addressed, buildings and other vital infrastructure as well as vegetation that protect the top soils within the vulnerable areas will be devastated within few years.

Figure 9 depicts the terrain of the study area and shows general morphology as regards the devastating effects of the gully as can be seen on the gully path down slope. The erosion path can be seen cutting across the down slope of the terrain at 100 m. It also shows that the gully erosion is more destructive down the terrain between the heights of 120 and 100 m. The Digital Terrain Model Presented can be a useful tool in the reduction and correction of runoff flows down the slope, which is an

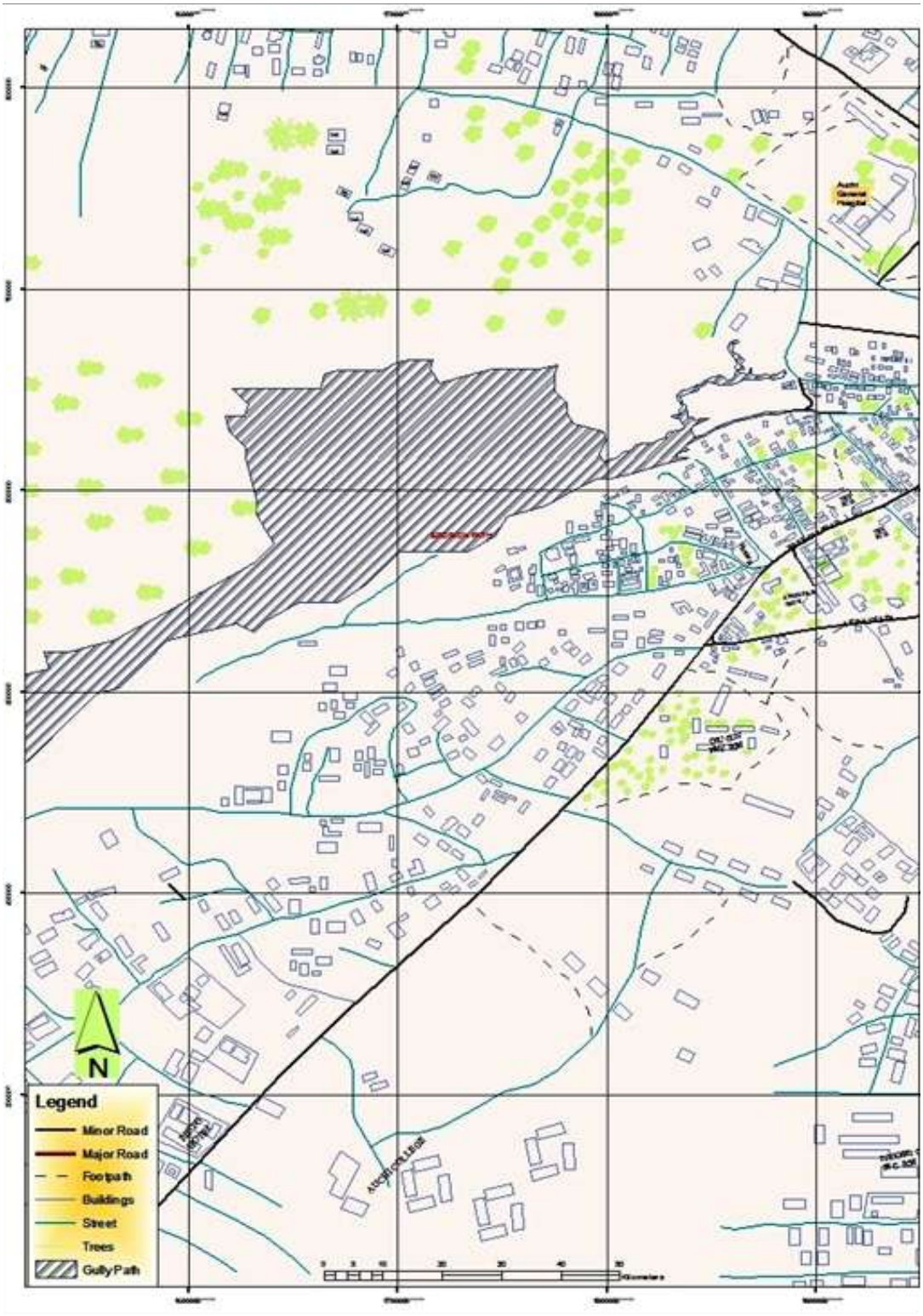

Figure 2. Auchi showing Land uses and Gully paths (Source: Produced from Archmap 10.1).

effective method of controlling and mitigating gully.

Figure 10 details the slope profile of the study area. It shows the actual sloping and indicates how the gully has eaten up earth material down slope. As can be seen, the slope is steep and is cutting across the land indicating erosion with a high intensity and thus huge devastating

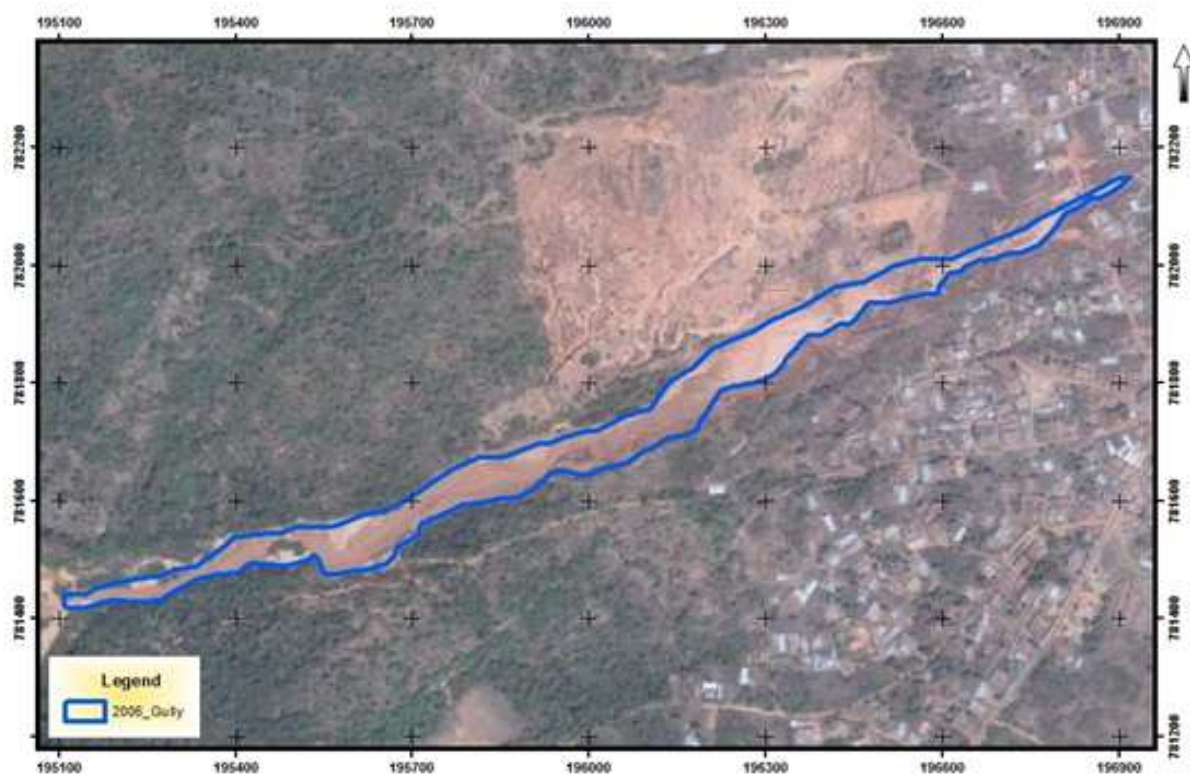

Figure 3. satellite imagery (spot 7) showing the gully in 2006 (Source: Spot image).

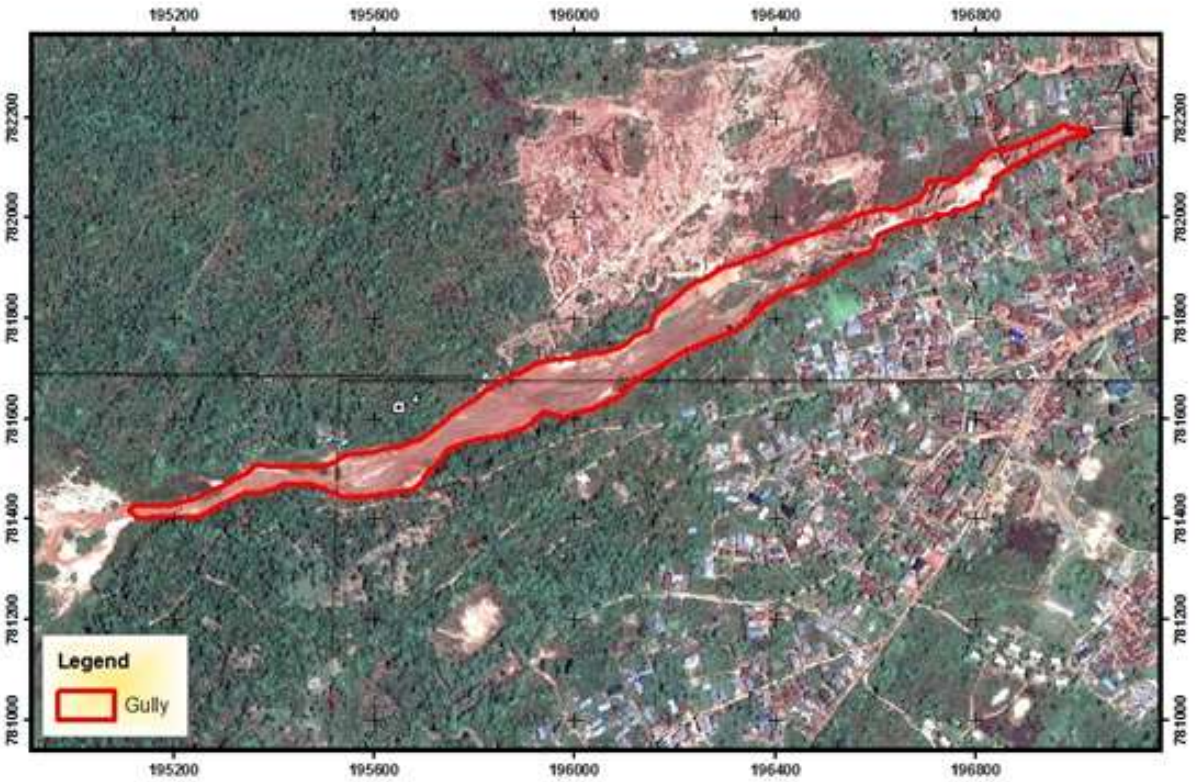

Figure 4. Satellite imagery (Spot 7) showing the gully in 2009 (Source: Spot image).

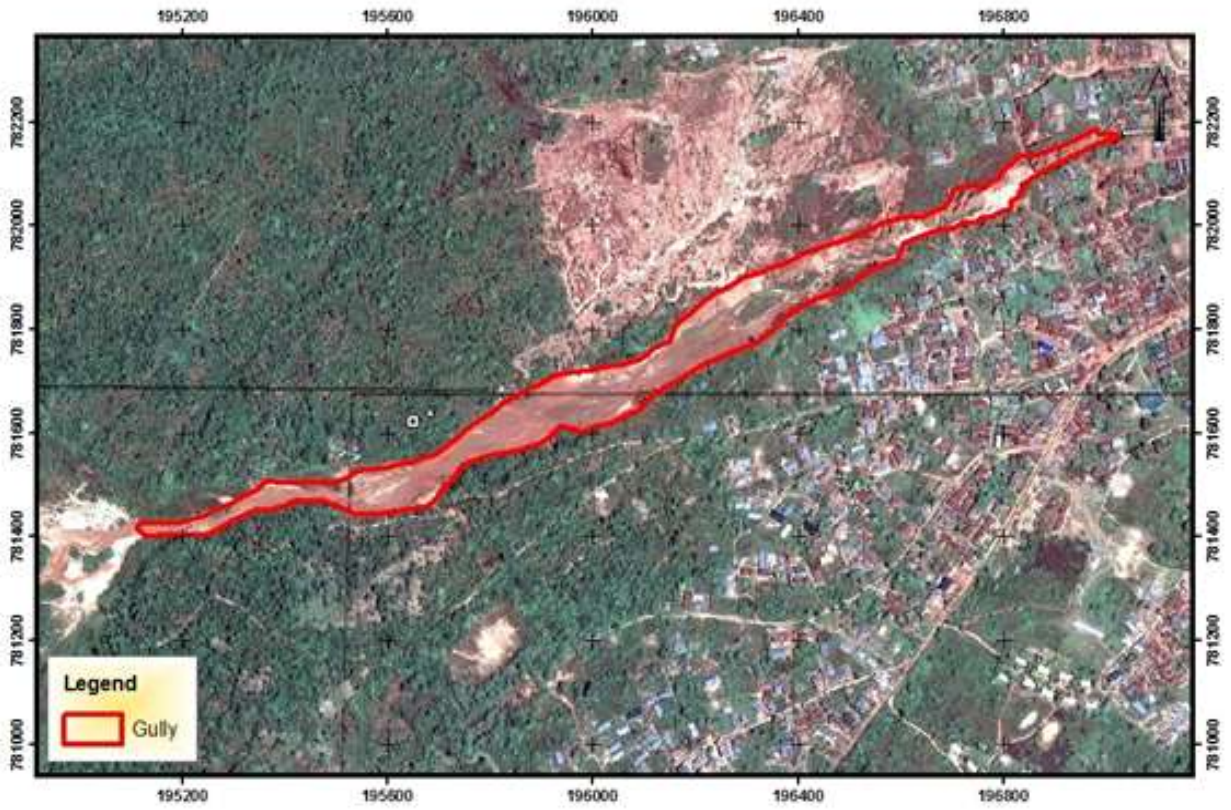

Figure 5. Satellite imagery (spot 7) showing the gully in 2012 (Source: Spot image).

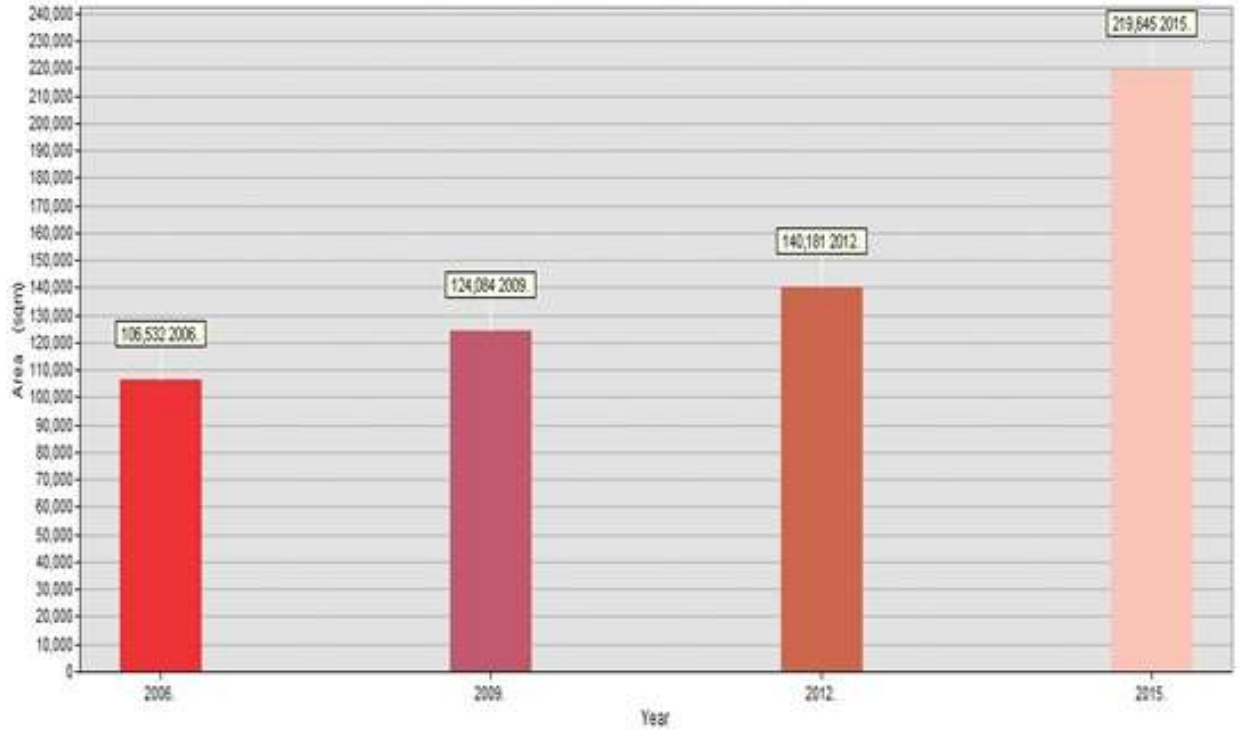

Figure 6. Graphical representation of gully expansion (m^2) of the study area.

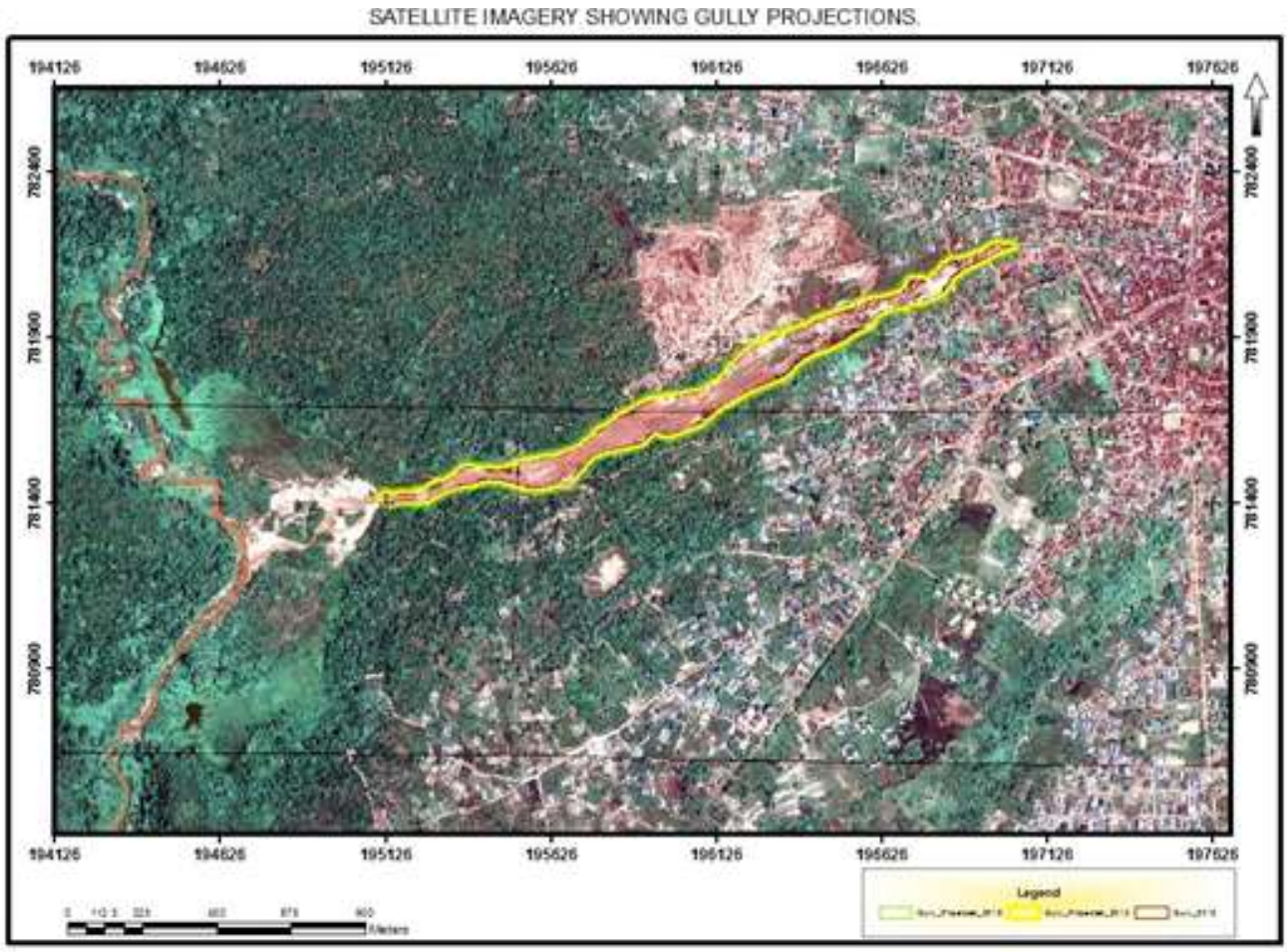

Figure 7. The area expected to be claimed by gully in 2015 (Source: Spot image).

effects. The slope profile can be used effectively in providing a basis for planning recommendations needed to address large area devastated by gully erosion and other forms of land degradation most especially where land filling method is to be adopted to reclaim land already lost due to erosion.

CONCLUSION

The result of this research has indicated that gully erosion is developing at an alarming rate expanding at 6318m^2 per annum, and between 2006 and 2012. Gully erosion devastated a total land area of 37913m^2 and it is expected to claim a total land area of 159407m^2 by the year 2015 if no effective control measure is adopted to address it. The use of softwares such as ArcGIS10.1, Surfa10 and Global mapper has proved effective in mapping and determination of the extent of gully erosion menace at near accurate level. Consequently, there is an urgent need to address the disaster so as to ameliorate its impact on the existing land uses.

RECOMMENDATIONS

In addressing the gully erosion menace, the following guidelines are recommended:

1. The erosion channels should be diverted from critical areas to areas with little or no risk as well as construction of concrete culverts to channel the erosion water.
2. There should be regular maintenance of roads to keep drains and culvert clean so as to prevent flooding and also installing diversion at drains and culverts where runoff velocity can cause erosion.
3. There should be massive public awareness campaign on the problems and consequences of gully erosion, as well as enacting environmental laws and serious penalties for offenders. This will go a long way in making the inhabitants adhere to environmental best practices thereby mitigating the menace.
4. The community should be encouraged and advised to contribute their quota in addressing the problem through traditional means and other cultural practices such as

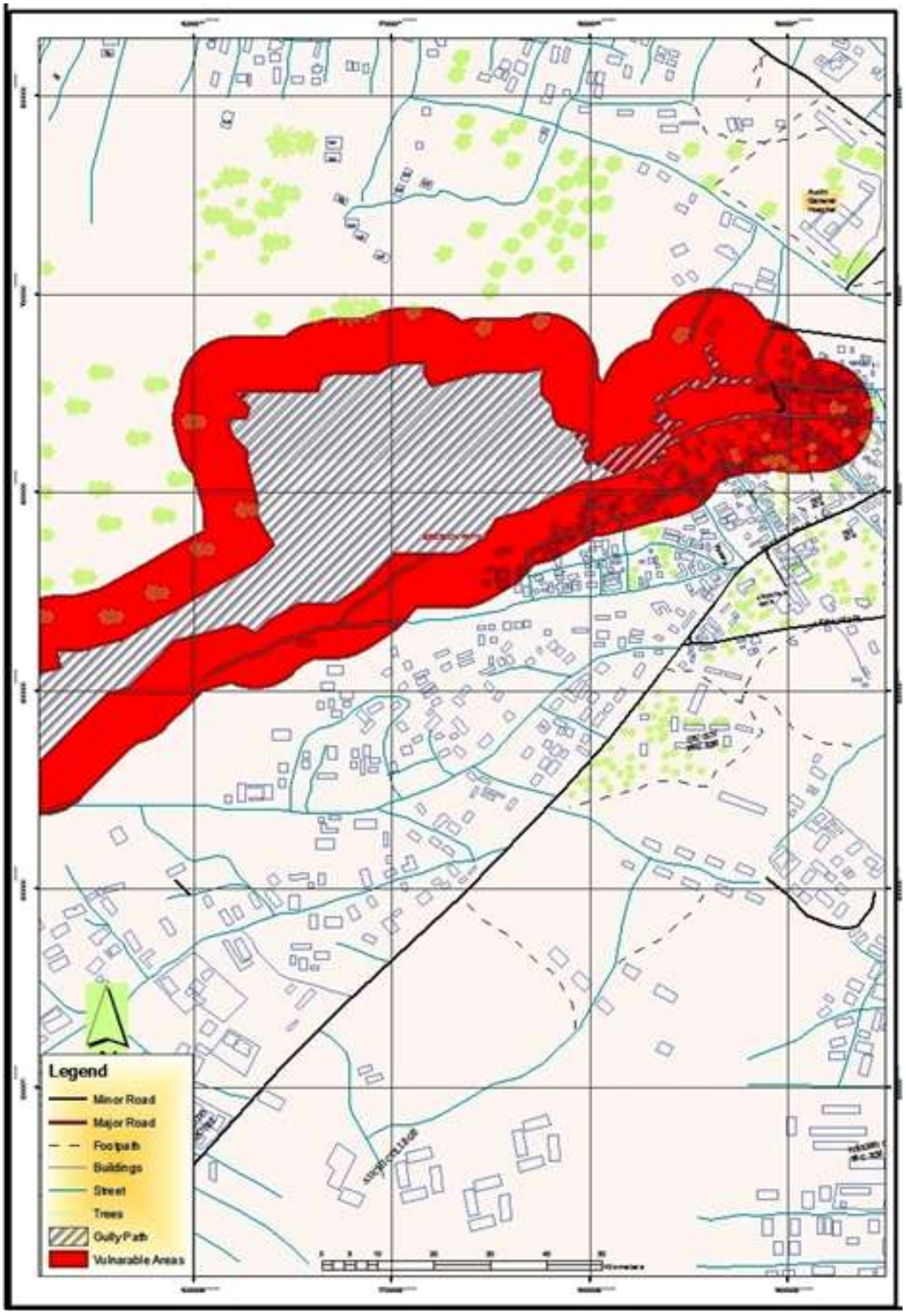

Figure 8. Vulnerable areas to erosion in Auchi, July 2013.

agro-forestry system, planting of cover crops in their farms, planting trees along the streets as well as other local factors that can mitigate the gully erosion.

Conflict of interests

The authors have not declared any conflict of interests.

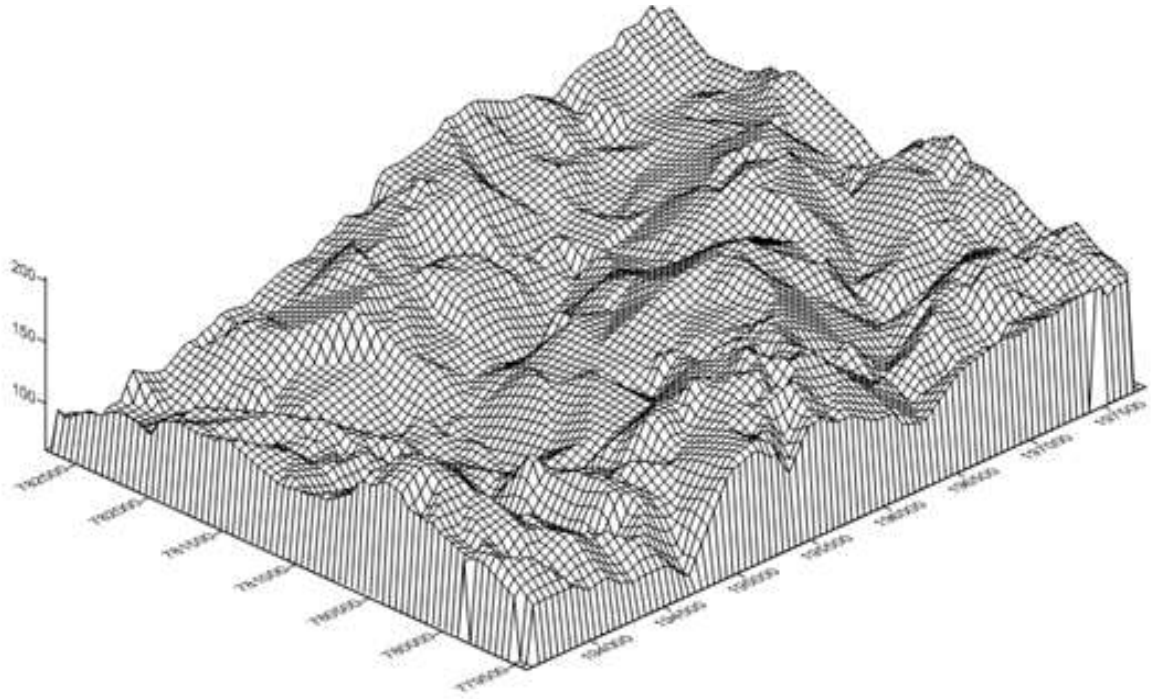

Figure 9. Digital terrain model (DTM) of the study area derived from DEM using ArcGIS10.1, excel sheet and Surfer10 softwares.

Figure 10. The slope profile of the study area plotted on global mapper using DEM of the study area.

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