Agricultural Journal 8 (1): 1-12, 2013
ISSN: 1816-9155

Mapping of Gully Susceptible Areas on Agricultural Lands in Katsina State, Nigeria Using Remotely Sensed Data

[1]A. Mu'azu, [1]S.A. Yelwa and [2]A. Bashir
[1]Department of Geography, Usmanu Danfodiyo University, P.M.B. 2346, Sokoto, Nigeria
[2]Department of Geography, Taraba State University, Jalingo, Nigeria

Abstract: Gully erosion is one of the major land degradation problems in Katsina State. This problem has been there for a long time and primarily on agricultural lands. It is mostly remarkable in the semi-arid areas where the rains are infrequent and torrential on the landscape with little or no vegetation cover. Gully erosion lessens soil productivity through physical loss of top soil reduction in rooting depth, removal of plant nutrients and loss of water which turns the landscape into a steep, bare-sided miniature valleys or gorges. In Katsina State, there is inadequate information on the magnitude of land degradation caused by gully erosion despite the fact that such information is very vital for planning and for ecological sustainability. This study utilised dekadal 1 km spatial resolution Normalised Difference Vegetation Index (NDVI) data from Advanced Very High Resolution Radiometer (AVHRR) onboard the National Oceanic Atmospheric Administration (NOAA) Meteorological satellites so as to highlight agricultural lands vulnerable to gully erosion in Katsina State. The dekadal data for 4 years covered the period from 1992-1996. However, data for 1994 had problems due to the satellite acquisition and hence, was excluded in the assessment. A subset Digital Elevation Model (DEM) covering Katsina State was also utilised in conjunction with the NDVI dataset and converted into latitude/longitude projection so as to facilitate the assessment of both the NDVI and DEM datasets on the same projection. Because data derived from AVHRR has a legacy of noise as well as being contaminated with clouds, the dekadal dataset was recomposited so as to reduce these effects. The results of vulnerable areas visited and analysed within a GIS environment were presented in a table and figures. In general, the Daura and Malumfashi zones are most affected in degradation of the agricultural landscapes. However, in terms of length, width and depths of gullies, the locality close to Mashi is the most affected compared to all the other sites within the 3 zones. Finally, the use of remotely sensed data, particularly the AVHRR-NDVI data which is freely available can enhance the study of agricultural lands susceptible to gully erosion when performed within a GIS environment. The study will surely go a long way in bridging the gap between conventional methods and modern techniques and the result obtained particularly from this study if utilised will certainly assist policymakers in mounting or revising policies relating to environmental management. Funds meant for ecological purposes if judiciously utilised as well as the intensification of any existing afforestation programme if sustained, will help reverse the decline in agricultural productivity caused by the menace of gullies around these localities.

Key words: NOAA-AVHR, NDVI, gully, erosion, agricultural lands, remotely sensed data, GIS

INTRODUCTION

Gully erosion is one of the major land degradation problems in Katsina State. This problem has been there for a long time and primarily on agricultural lands. It is mostly remarkable in the semi-arid areas of Katsina State where the rains are infrequent and torrential on the landscape with little or no vegetation cover. Gully erosion lessens soil productivity through physical loss of top soil reduction in rooting depth, removal of plant nutrients and loss of water which turn the landscape into a steep, bare-sided miniature valleys or gorges (Gregory, 1977). Katsina State is well known not just for its intensive human activities which it supports but also for its accelerated gullying recurring almost on yearly basis as a result of a combination of climatic and anthropogenic factors. The nuisance gully erosion has been causing in this state was more prominent between 1976 and 1978. It has been estimated that about 787 km within the Sudan Savannah land, part of which falls in Katsina State had been ravaged by gully erosion, particularly between 1993-95. It recent times, however, the extent of devastation caused by this gully erosion within the landscape of Katsina State has not been empirically determined using modern techniques such as satellite-based remotely sensed data. The processes of

Corresponding Author: A. Mu'azu, Department of Geography, Usmanu Danfodiyo University, P.M.B. 2346, Sokoto, Nigeria

gully erosion, which mostly occur in areas where the rains are infrequent, is usually accompanied with changes in the landscape morphology. In the long run, this produces changes in the inhabitants' socio-economic lives. The view by Selby (1985) is that gully erosion often destroy valuable farmlands and threatens to undermine housing, eroded sediments, Choke River channels and when spread over valley floors ruin crops, fill drainage ditches and bury roads. On the other hand, gully formations are associated with problems of high rate of productive decline. It is in line with this view that Lal (1999) affirmed that in the process of gully formations, there used to be alterations in soil properties and the washing away of arable farmlands ephemerally and consequently the decline of crop yields. Lal (1999) went further to cite some attributing factors responsible for gully erosion which include removal of vegetation cover, overgrazing, lack of safe disposal of water from roads, construction sites, public buildings, footpaths, a drawn pipe installed with no provision of safeguard of the soil against cutting and the action of rain water generally. These are many of the factors that are leading to the severe gully erosion manifesting in many parts of Katsina State, particularly around the agricultural landscape.

In Katsina State, there is inadequate information on the magnitude of land degradation caused by gully erosion despite the fact that such information is very vital for planning and development purposes. Accordingly, satellite remote sensing appears to be one of the most viable techniques that can be used for such purpose because it allows generation of consistent, multi-spectral, multi-temporal, synoptic coverage of large area under uniform illumination condition (Ojanuga, 1986; Wilkie and Finn, 1996; Lunetta, 1998; Abubakar and Ayuba, 2001). The data generated through this technology can be evaluated within a Geographical Information Systems (GIS) environment for the assessment of the nuisance gullying is making in many agricultural lands across the state.

The purpose of this study, therefore, is to utilise a 1 km spatial resolution Normalised Difference Vegetation Index (NDVI) data from Advanced Very High Resolution Radiometer (AVHRR) onboard the National Oceanic Atmospheric Administration (NOAA) Meteorological satellites so as to highlight agricultural lands vulnerable to gully erosion in Katsina State.

The study area: Katsina State is one of the 36 states of Nigeria created from the former Kaduna State on 23 September, 1987. The state is located approximately between latitude 11°07'49 and 13°20'00 N and between longitude 6°52'03 and 9°02'40 E. It is bordered to the North by Niger Republic, to the East by Jigawa and Kano States, to the South by Kaduna State and to the West by Zamfara State (Fig. 1). The state covers an area of about 24,192 km^2.

Katsina State partly falls in the Sudan and partly in Sahel savannah zone which are characterised with semi-arid climate. However, the boundary between the Sudan and the Sahel now gradually shifting due to climatic factors (Tucker *et al*., 1991), thereby resulting in

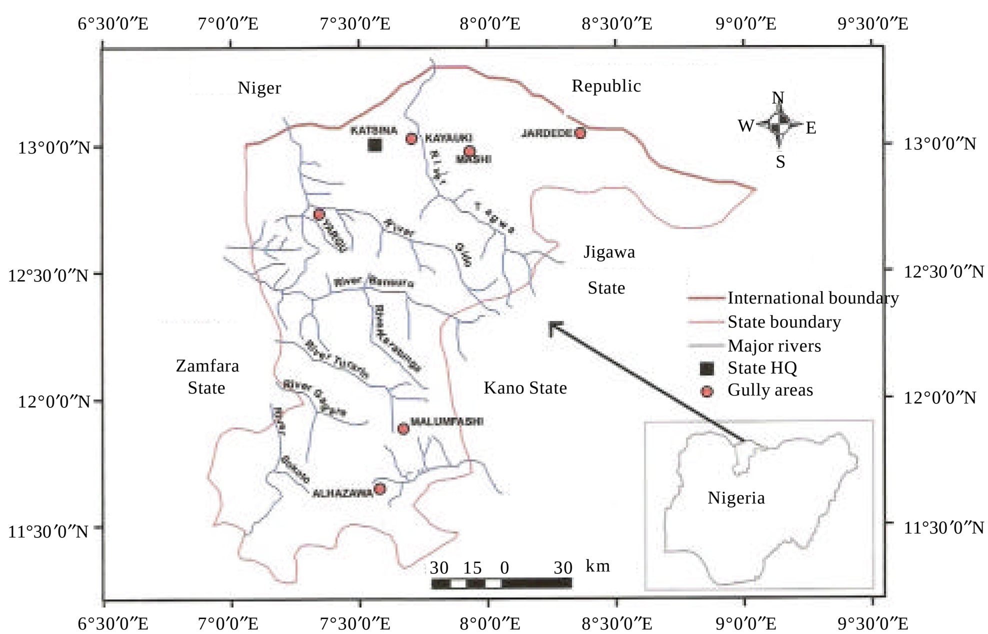

Fig. 1: Location of the study area within Katsina State in Nigeria

most of the areas falling in the Sahel region. The state has a population of 5,792,528 (based on the 2006 Census), a growth rate of 3.2% and a population density of about 160 people per square kilometers. Except very few wealthy individuals, most of the rural people in the state are peasant farmers and nomardic herders exploiting most of the little agricultural lands, thereby making it more vulnerable to soil and gully erosion. The relief is generally undulating with an elevation of between 305-610 m with isolated inselbergs and residual ironstone capped hills that are 610-905 m above mean sea level. The climate of Katsina State is determined by its geographical location as it lies between the upper part of Sudan savannah and the lower Sahel region of Nigeria. The prevailing of the Southwesterly Trade Winds (SWTW) influence the rainfall and temperature conditions around this area.

Accordingly, the movements of these SWTW across the state influence its rainfall which comes between the months of May and October. The mean annual rainfall is between 1016-1143 mm in the Southern part of the state and <635 mm in the Northern part. The mean relative humidity is <50% between January and February but could be as high as 80% between June and July.

Temperatures are high for most times of the year, reaching a daily maximum of over 40°C in April and daily maximum of 21°C between December and January (Adamu, 2000). With regards to the drainage pattern across the state, it can be said that extensive drainage basins with long slow flowing rivers occur seasonally which take their sources from the dissected basement complex plains and numerous streams with high discharge emptying into the major rivers such as Rima and Kaduna Rivers, respectively. Some tributaries, however, have been harnessed where dams such as Ajiwa, Jibiya, Koza, Mairuwa and Zobe dams were constructed and are being utilised for pipe borne water supply and for irrigation farming. As for its soil, it is based on the structural patterns of its geology and geomorphology. However, from the broad classification of the USDA soil taxonomy, the main soil types found in this part of the Sudan-Sahel region where Katsina State is located is generally covered by 3 main classes: Alfisols; Inceptisols and Entisols (Adamu, 2000). They consist of young immature well-drained soils formed from parent material, rich in quartz and crystalline rocks of basement complex and sedimentary deposits. The soils are characterised by low structural stability and are susceptible to surface crusting, soil compaction and erosion. They also possess low water retention capacity which can be subjected to drought (Areaola, 1982).

MATERIALS AND METHODS

For the purpose of this study, a 1 km NOAA-AVHRR-NDVI data in dekadal (10 days composite) images covering the study area were obtained in digital format from the United States Geological Survey (USGS) website where they were archived. The dekadal data for 4 years covering the periods of 1992, 1993, 1995 and 1996 were utilised. Data for 1994 had problems due to the satellite acquisition and hence data for this year was excluded in the assessment. The whole dataset was radiometrically and atmospherically corrected (Eidenshink, 1992; James and Kalluri, 1994). A subset digital elevation model covering Katsina State was also utilised in conjunction with the AVHRR-NDVI dataset. The down loaded NDVI dataset was initially imported into IDRISI 32-GIS and remote sensing software in Goode’s interrupted homolisine projection. This was later converted into latitude/longitude projection (Clark Labs, 2001) so as to facilitate the assessment of both the NDVI and DEM dataset which should be in latitude/longitude projection. NDVI data derived from AVHRR, however, has a legacy lot of noise as well as being contaminated with clouds; hence, the dekadal data was re-composited into annual mean images using Holben (1986)’s recomposition technique. The DEM image of Katsina State, on the other hand, was windowed from the DEM image of Nigeria derived from the GTOPO30 digital elevation model (USGS, 1998).

For the purpose of ground truthing, field measurements and accessibility within the study area, a total of 21 sites were selected out of which only 12 most affected sites were well measured and documented. These sites were divided into 3 zones; namely, Daura, Katsina and Malumfashi. In Daura zone 4 sites (Jardede:3, Mashi:1); in Katsina zone 6 sites (Kayauki:3, Yargamji: 3); while in Malumfashi zone 2 sites (Malumfashi:1, Alhazawa:1) were visited and assessed. Surface characteristics on the visited sites which provides records of surface conditions that can be related to satellite remote sensing data (Harris, 1987) were also determined and recorded. A Germin-12 Global Position System (GPS) was used at each point to determine its correct location within the affected area. The information in the form of latitude, longitude, altitude readings were determined and later imported into a digital elevation model overlayed on different annual NDVI images (1992-1996) covering the study areas within Katsina State using IDRISI-32 GIS/Remote Sensing Software and analysed within a GIS environment. At each affected area, a tape, ranging poles and compass were used for direct field measurement so as to determine the length, width and depths of the gullies. Some photographs were also taken so as to show the extent of degradation around the vulnerable areas in some agricultural fields and digital base maps were derived.

Justification for the use of NDVI derived from NOAA-AVHRR: Initially, NOAA-AVHRR data was designed for cloud monitoring (Diallo *et al*., 1991;

DeFries *et al*., 1995; Cracknell, 1997). The satellite instrument was designed with 5 detectors, 2 of which are sensitive to the wavelengths of light ranging from 0.55-0.70 and 0.73-1.0 μm. With these AVHRR detectors, researchers can measure the intensity of light coming from the earth in visible and near-infrared wavelengths and quantify the photosynthetic capacity of the vegetation in a given pixel (an AVHRR pixel is 1 km^2) of land surface. In general though, if there is much reflected radiation in near-infrared wavelengths than the visible wavelengths then the vegetation in that pixel is likely to be dense and may contain some type of forest. If on the other hand, there is very little difference in the intensity of the visible and near-infrared wavelengths reflected then the vegetation is probably sparse and may consist grassland, tundra or desert. Thus, the NDVI from AVHRR is calculated as:

$$NDVI = (NIR-VIS)/(NIR+VIS)$$

Where:
NDVI = The normalized difference vegetation index
NIR = The near-infrared wavelength
VIS = The visible wavelength light

Furthermore, this dataset is obtainable for scientific research free-of-charge. And although, the AVHRR has been designed for a specific purpose initially, several studies have affirmed that NDVI data derived from AVHRR can successfully be utilised for vegetation studies generally (Eidenshink, 1992; James and Kalluri, 1994; De Fries *et al*., 1995; Cracknell, 1997; Yelwa, 2002) and more especially to understand the photo-synthetic activity of biomass in the environment (Tucker *et al*., 1991). The main reason behind this is because in order to understand or determine the density of green on a patch of land, researchers must observe the distinct colours (Wavelenghts) of visible light and near infrared sunlight reflected by the plants. When sunlight strikes objects in the landscape, certain wavelengths of this spectrum are absorbed and other wavelengths are reflected. Thus, the pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 0.4-0.7 μm) for use in photosynthesis. The cell structure of the leaves, on the other hand, strongly reflects near-infrared light (from 0.7-1.1 μm). The more leaves, therefore, a plant has the more these wavelengths of light are reflected, respectively. Therefore, because of the versatility of this NDVI data derived from NOAA-AVHRR satellite, it can also be extended to studies related surface terrain features such as soil, water or ice and hence, extended to this particular study covering some selected agricultural lands in Katsina State.

RESULTS AND DISCUSSION

The results of this study about gully vulnerable areas on some agricultural lands in Katsina State are presented in table and figures. Table 1 contains a summary of the ground truthing measurements of the gullies in some sites

Table 1: Summary information derived from direct field measurement of the gully sites around some agricultural farmlands

			Measurement of the gully sites visited (m)		
Zone	Town/village (closest to gully channel location)	Geographical location of gully site	Length (range)	Width (range)	Altitude (from top to bottom)
Daura	Jardede (i)	13°04' 400"N 08°23' 278"E	1-369	1-42	484.46-476.70
	(ii)	13°04' 326"N 08°23' 243"E	1-202	1-11	487.67-482.19
	(iii)	13°04' 253"N 08°23' 880"E	1-96	1-9.09	488.28-482.49
	Mashi (i)	12°59' 231"N 07°57' 912"E	1-788.9	1-59	509-481.88
Katsina	Kayauki (i)	13°00' 723"N 07°42' 369"E	1-279	1-9.40	494.69-471.83
	(ii)	13°00' 733"N 08°42' 341"E	1-156	1-4.60	491.03-479.01
	(iii)	13°00' 788"N 08°42' 242"E	1-78	1-20	489.11-471.02
	Yargamji (i)	12°56' 381"N 07°14' 136"E	1-189.2	1-9.20	449.66-447.4
	(ii)	12°56' 423"N 07°14' 083"E	1-236	1-8.05	445.31-444.09
	(iii)	12°56' 351"N 07°14' 16"E	1-132.3	1-8	446.53-445.31
Malumfashi	Malumfashi (i)	11°47' 071"N 07°37' 666"E	1-713	1-16	623–606.24
	Alhazawa (i)	11°24' 250"N 07°30' 906"E	1-352	1-8.40	701.30-693.42

Field measurements; geographical locations were based on GPS readings (Germin- 12 GPS)

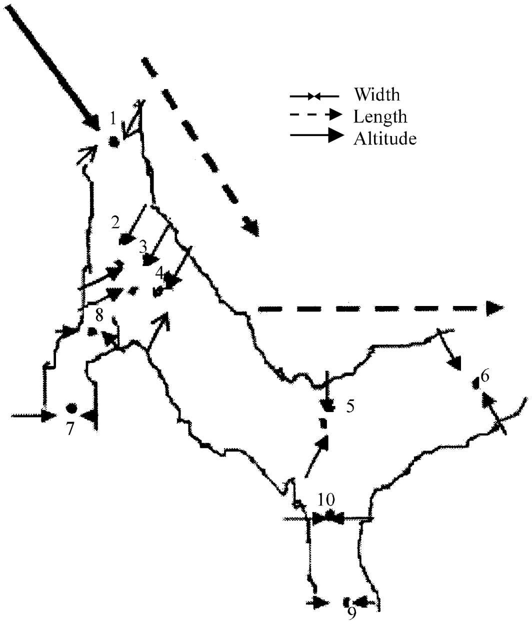

Fig. 2: Schematic illustration of the assumed geometry of Jardede gully formation; smaller arrows pointing each other are indicating the width of a point from the slumping walls; medium thick arrow is shows the direction and the length of the gully channel; the bigger arrow is illustrating the altitude of the first point; •: Control points (1-10)

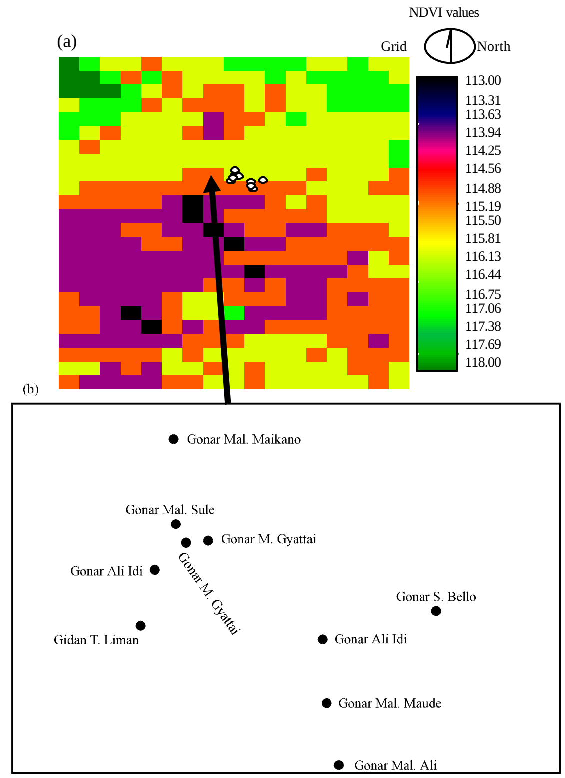

Fig. 3: a) AVHRR-NDVI image of Jardede showing gully formation site; b) Location of the gully formation site mapped illustrating points affected by gully slumping sidewalls; •: Control points (1-10)

within agricultural lands using a 1 km spatial resolution AVHRR-NDVI dataset. The other section of the results is presented in Fig. 2-20. In general, the Daura and Malumfashi zones are most affected in degradation of the agricultural landscapes. However, in terms of length, width and depths of gullies, the locality close to Mashi is the most affected in all the sites visited and assessed within all the three zones. In Fig. 20, scenes of some devastated sites are illustrated.

In the Daura zone, for example, there has been a rapid increase in the rate of gully formation and development. In Jardede area channel (i); the damaged area in length covered by the gully was about 369 m at which there was gradual increase in widening pace from 1-9 m along control point 1 close to Malam Maikano's farm. This stretched further to about 22 m accross Sanusi Bello's farmland (the last point on the channel measured). The starting point of the measurement along this channel had a height (top) of 484.46-482.19 m (bottom height) indicating a gradual incising of the gully. This steadily deepened to a height of 476.70 m at the last point measured. The other 2 channels discharge their water into the major channel (i). At Jardede channel (ii), the gully length measured about 202 m; the width had a 2 m headcut up to 11 m on other sides; whereas, the height level of the channel deepening was significantly low about 2 m (top to bottom height). As for Jardede (iii), the extent of the gully length was about 96 m at which the deepening of the gully was observed, from a starting point (near Mal. Ali's house). At the last control point here, the height was observed to be 482.49 m with gradual depression of the gully sides. A schematic illustration of the gully channel is prsented in Fig. 2-4.

The second area in the Daura zone was Mashi (Table 1 and Fig. 5-7) which show illustrations of the gully site as well as the measurements. Here, the length of the gully formation range from 1-788.9 m. Importantly, along this channel there was a wider indentation and deepening of the gully sides. From the head cut the gully formation had a depth of about 13 m. The second control point at the bottom of the gully opposite a Tamarind (Tsamiya) tree at the Western side of the gully had a depth of was 15 m which nearly slumped into the channel. This

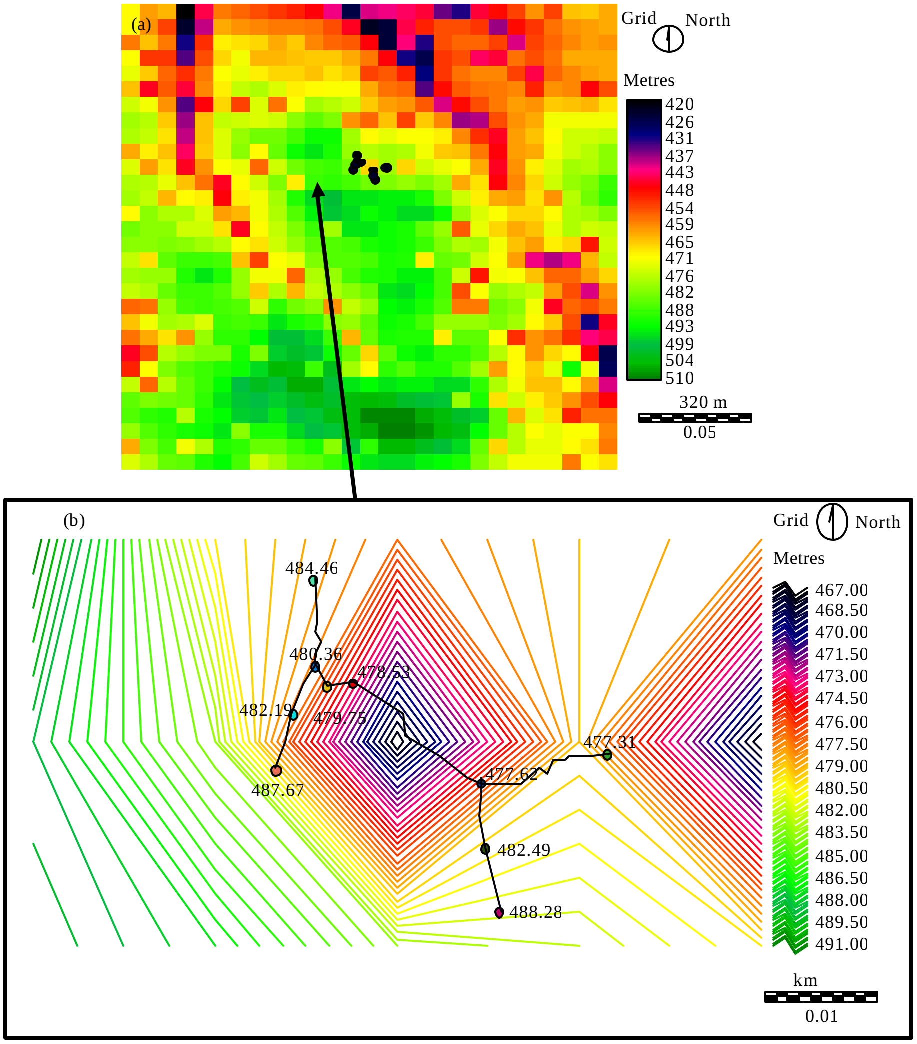

Fig. 4: a) Digital altitude image of Jardede illustrating gully points; b) Interpolated contour map of Jardede illustrating point height and gully channel

gradually widening and deepening continued up to the last control point extending into the farmland of Alhaji Abashe. The widening of the gully channel is evidently clear (Fig. 5-7 and 20 c,d) from the first point the width was 4 m but steadily increased to about 11.25 m along Malam Sani Tela's farm, thereby extending to the other adjoining farmlands at Kayauki village and it measured 279 m long. The widening of this channel (Fig. 8-10) was observed from a point one near Alhaji Rabe Mainama's farm house ranging from 3.5-9.40 m up to a farm house belonging to Malam Faruk. At Kayauki channel (ii) the length of the gully was about 156 m. At Kayauki channel (iii), it is however, smaller in terms of the damage compared with the 1st and 2nd sites.

In Fig. 11-13, the results of the assessment at Yargamji sites are presented. At gully channel (i), the areal damage around the farmlands was less compared to other places as the channel length measured 189.2 m and the gully width was about 9 m. At Yargamji (ii), the damage the gullies inflicted to the farmlands around this locality was less but the village was vulnerable as the gully extended to about 236 m in length; while, there was an expansion of about 6 m. At Yargamji (iii), the channel however, extended to about 132 m long with a depth of about 1 m.

In Fig. 15-17, the results of the assessment at the Alhazawa locality within Malumfashi zone are presented. Compared with the main Malumfashi locality, the damage here was less. However, at Alhazawa site the gully extended in length slightly over 350 m. This channel gradually increased up to a point near the edges of Malam Ibrahim Mamman's farm. The depth of the gully formed here was about 8 m.

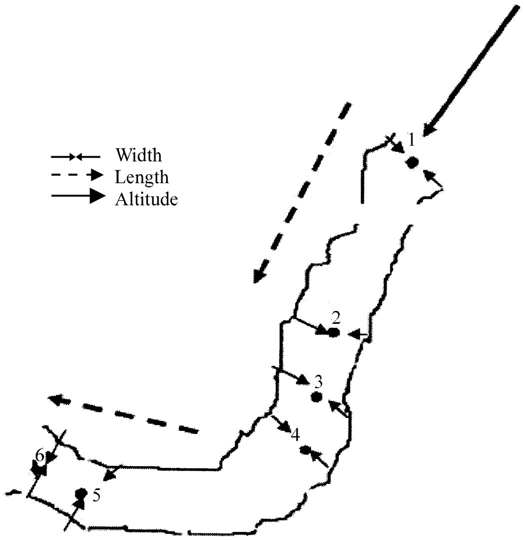

Fig. 5: Schematic diagram of Mashi gully formation channel; smaller arrows are indicating width; broken arrows indicate length; the thick arrows indicate the altitude; •: Control points (1-6)

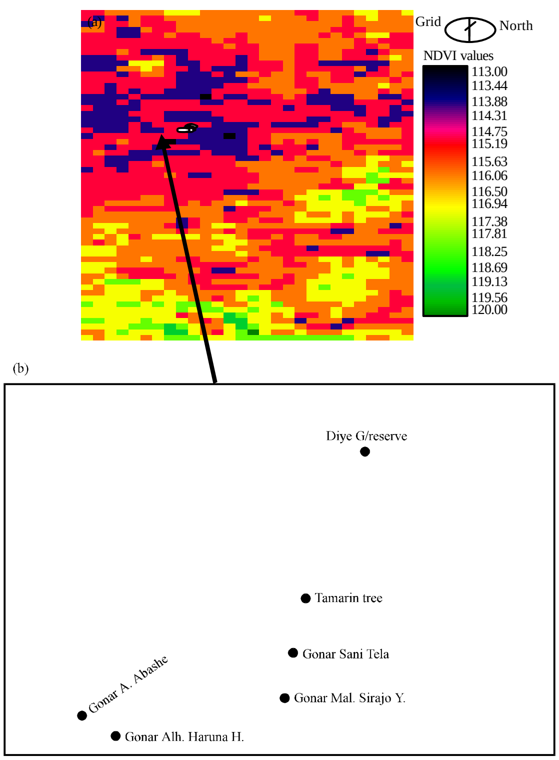

Fig. 6: a) Windowed AVHRR-NDVI image of Mashi with an arrow showing the gully points; b) Mapped field site of gully formation illustrating the affected gully points; •: Control points (1-6)

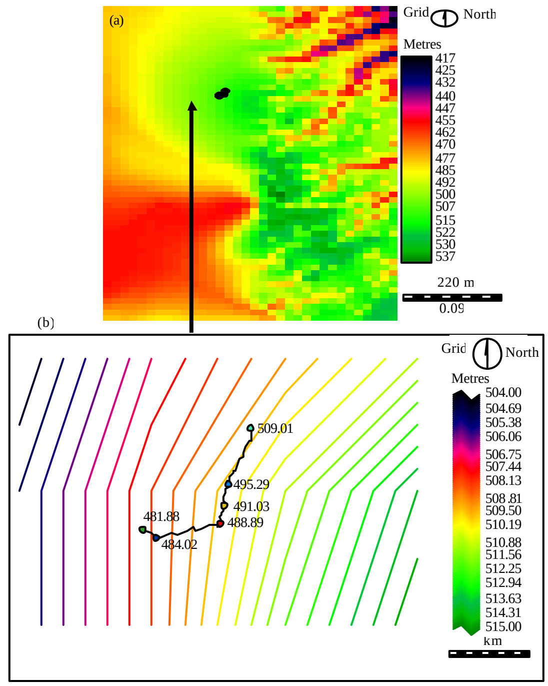

Fig. 7: a) Windowed digital elevation image of Mashi used to illustrate gully point heights; b) Interpolated contours of gully formation channel illustrating height of gully points

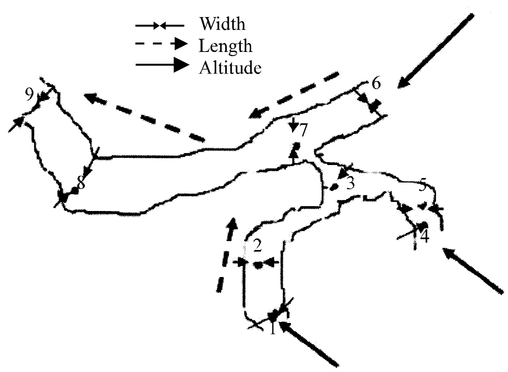

Fig. 8: Schematic diagram of gully formation channels in Kayauki; thick arrows are indicating point height; the dissected arrows are showing the length; the thin arrows are illustrating the width; •: Control points (1-9)

The Malumfashi locality in this zone (Fig. 17-19) was one the most affected and second most affected with the study area within the sites visited. At this gulley channel, there was very clear evidence of devastation particularly within the Diyes Reserve Area and a farmland belonging to one Muhammadu Gyattai. However, the

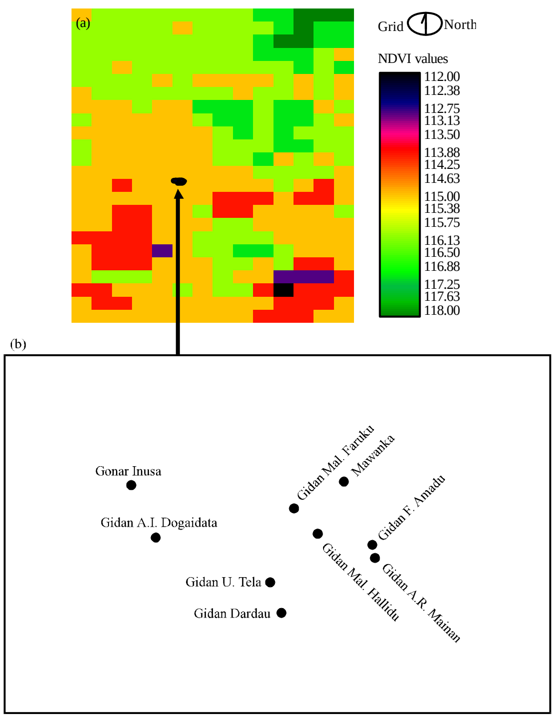

Fig. 9: a) Windowed AVHRR-NDVI image of Kayauki ; b) An extract map of the gully formation site with the name of affected individuals; •: Control points (1-9)

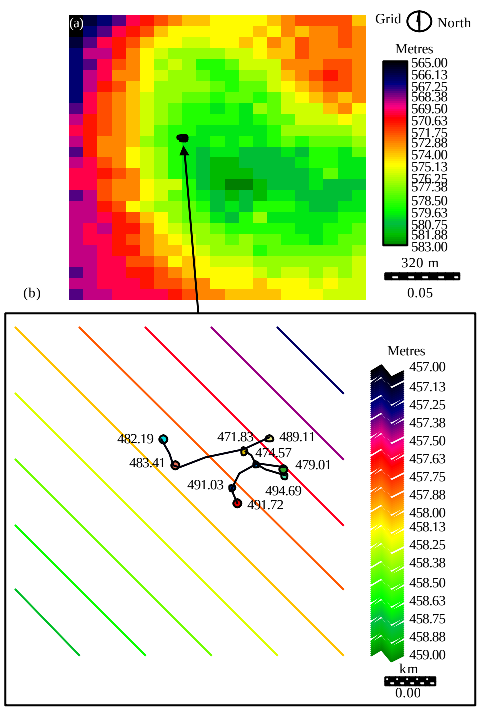

Fig. 10: a) Digital elevation image of Kayauki; b) Interpolated contours illustrating gully point height and the channel route

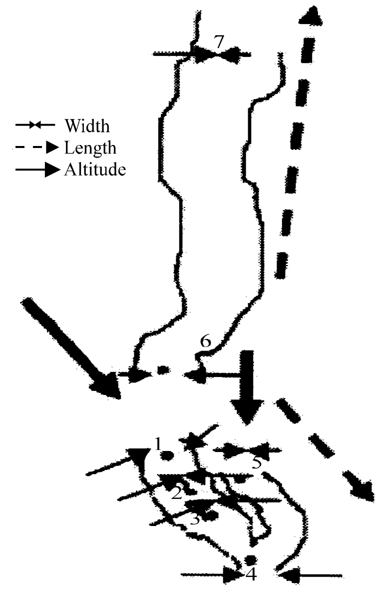

Fig. 11: Gully formation channel of Yargamji; smaller arrows are indicating width; medium arrows are indicating the length of the gully and direction of flow; the bigger arrow indicating the altitude of the points; •: Control points (1-7)

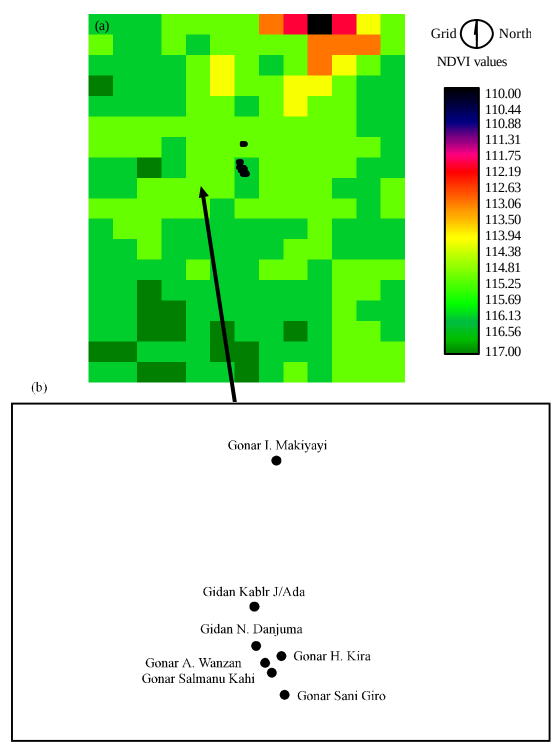

Fig. 12: a) Windowed AVHRR-NDVI image of Yargamji gully points; b) Out-line map of the gully formation points Yargamji; •: Control points (1-7)

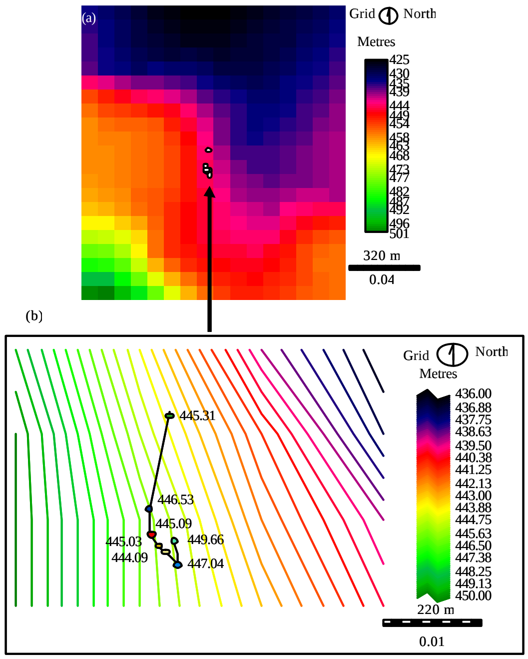

Fig. 13: a) Digital elevation image of Yargamji showing gully formation points; b) Interpolated contour of Yargamji slope height illustrating gully formation point heights

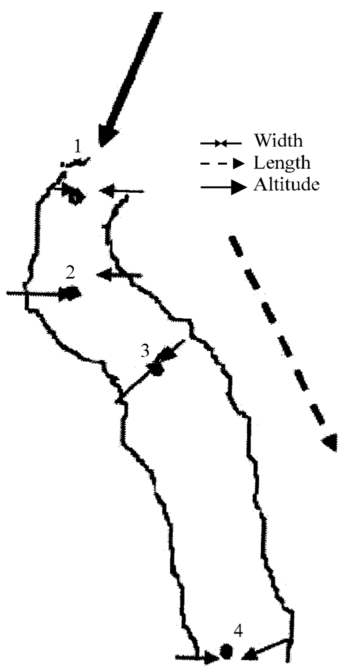

Fig. 14: Schematic diagram of the gully formation channel Alhazawa illustrating its geometry; smaller arrows are indicating the width; medium the length; bigger arrow are indicating the altitude level of a point; •: Control points (1-4)

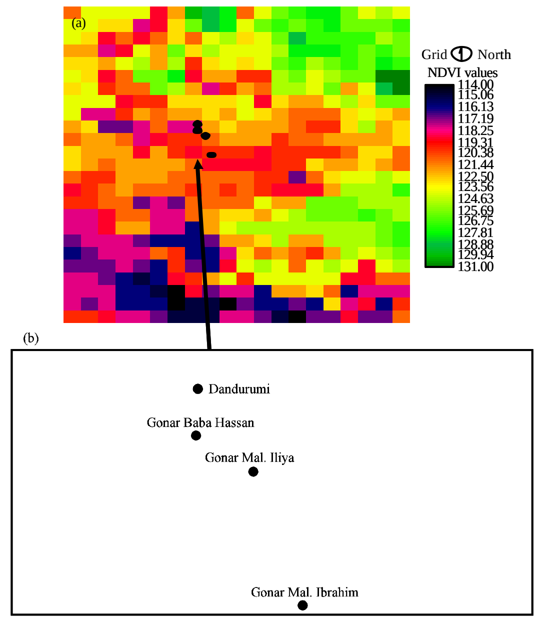

Fig. 15: a) Windowed AVHRR-NDVI image of Alhazawa; b) Extracted gully formation points map of Alhazawa; •: Control points (1-4)

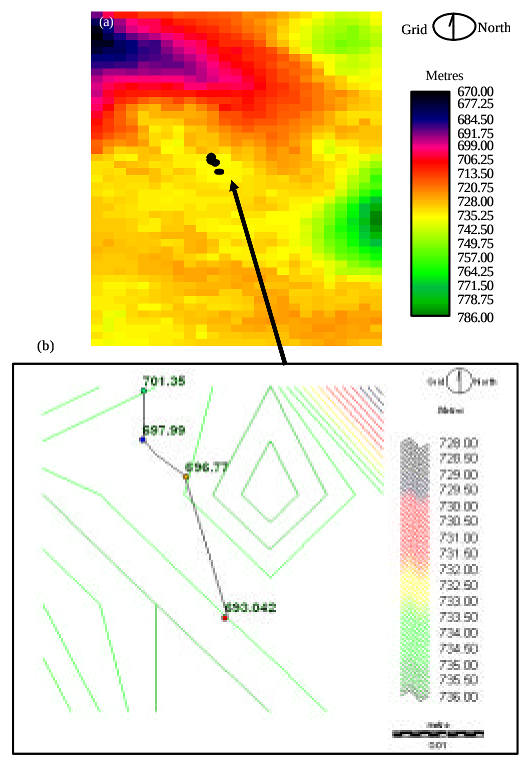

Fig. 16: a) Windowed altitude image of Alhazawa illustrating gully formation points; b) Interpolated contour map of Alhazawa gully formation points

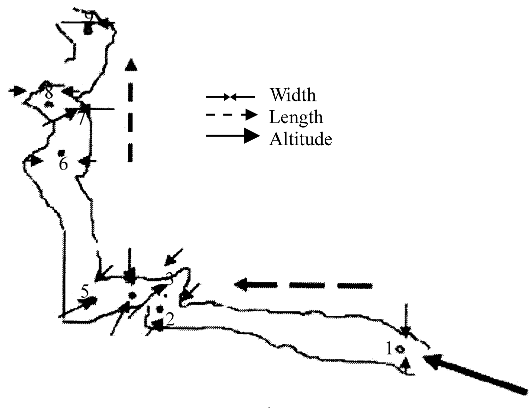

Fig. 17: Gully formation assumed geometry of Malunfashi; smaller arrows are indicating width; medium shows the length of gully and direction of flow; bigger arrow are showing the altitude and the starting point; •: Control points (1-9)

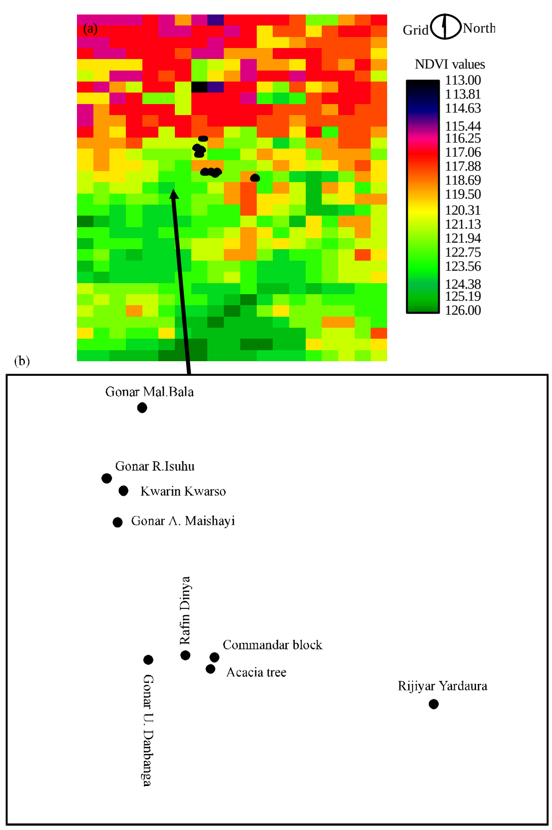

Fig. 18: a) Windowed AVHRR-NDVI image of Malumfashi gully formation site; b) Map of gully formation site illustrating the points; •: Control points (1-9)

elongation of this channel through many farmlands was enormous. For example, while it extends, it also widened

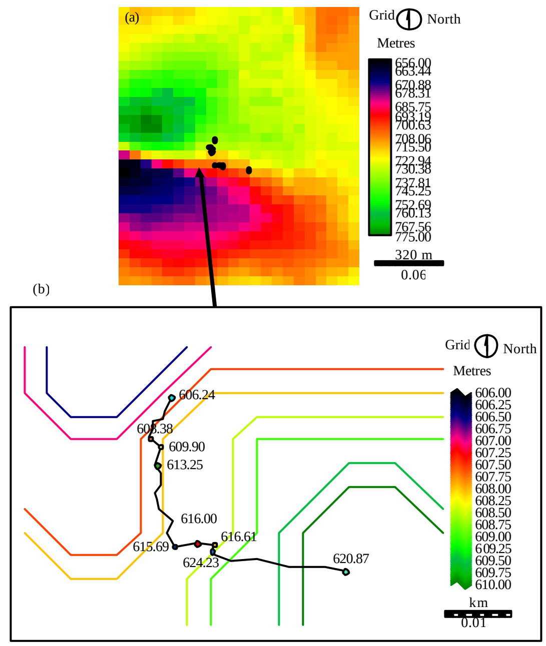

Fig. 19: a) Windowed altitude image of Malunfashi showing gully formation points; b) Interpolated contour map illustrating gully points height and channel

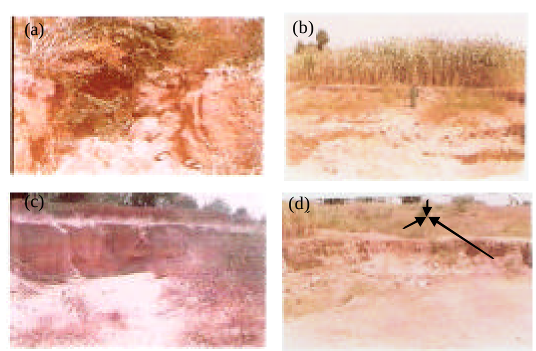

Fig. 20: Sample pictures of sites devastated with gully erosion around agricultural lands; a) Part of Diye reserve area; b) A farm site around Malumfashi; c) Part of a farmland belonging to Muhammadu Gyattai; d) A site between Malumfashi town and Kwarso village

to about 16 m from the first control point near Rijiyar Yardaura through to Ummaru Danbanga's farmland up to the last control point at Malam Bala's farmland. Accordingly, the view of both Gregory (1977) and Statham (1977) reaffirms the combine action of many factos rapid mass movements, sliding and widening of the gully sides in this locality as the gradual increase in failure and susceptivilty of the soils at the gully edges makes it easier for the seasonal rivers and tributaries around to chock with essesive quantities of solid matter, thereby making it easier for most of the area liable to serios erosion and flooding.

CONCLUSION

This study demonstrated that from the results presented for far, it is very clear that gully formations in all the sites visited sites had inflicted enormous negative impact not only on agricultural lands around but to the general environment in Katsina State.

From results obtained in this study, it can be agued that the spatial variation of the severe nature of the gullies is partly due to the soil type which is composed of unconsolidated red-brown sands that render the area porous and susceptible to erosion and partly due to misuse of the natural resources in the form of deforestation, faulty farming systems including overgrazing. It is in this regard that Zheng (2002) and Schwab *et al*. (1991) were of the view that the establishment of vegetation along the channel banks and head-cut areas that an effective way of preventing classical gully growth can be achieved. Terracing on gully slopes and building retention structures in the gully channels accordingly, are also other ways to control the menace of gully erosion (Schwab *et al*., 1991). However, if proper care is not taken to control, the menace of gully formation and development more extensive damage will continue to destroy the natural landscape and lead to extensive damage to vast arable farmlands as was observed in many agricultural lands visited and many more in Katsina State.

Although, these reasons can be cited as reasons why gullies were widening in these sites visited and assessed, this can further be attributed to the rainfall pattern in the state as well as the variation in nature and composition of the soils in each of the localities in the different zones. A heavy torrential rainfall, for example, is usually characterised with a large volume of runoff water that is discharged rapidly. This nuisance in most cases lead to the collapsing of the gully sides, thereby increasing the rate of erosion of the gully channels which encroached to other farmlands. Another factor that can be attributed to this menace is the un-sustained ecological management and control programmes in the state.

Finally, the use of remotely sensed data, particularly the AVHRR-NDVI data which is freely available can enhance the study of agricultural lands susceptible to gully erosion when performed within a GIS environment. The study will surely go a long way in bridging the gap between conventional methods and modern techniques and the result obtained particularly from this study if utilised will certainly assist policy makers in mounting or revising policies relating to environmental management, judicially utilising funds meant for ecological management of the environment as well as the intensification of the a forestation programme so that the general landscape can be sustained. If these are done, it will help reverse the decline in agricultural productivity cause by the menace of gullies around.

ACKNOWLEDGEMENTS

Researchers are grateful to the National Oceanic Atmospheric Administration (NOAA-NASA) for the use of the Advanced Very High Resolution Radiometer-Normalised Difference Vegetation Index (AHHRR-NDVI) 1 km data as well as the United States Geological Survey (USGS) for the use of the GTOPO30, Global 30 Arc-seconds digital elevation model data to conduct this study.

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