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Effects of Gully Erosion on Infrastructure in Katsina-Ala Town, Benue State

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Abstract: ***Gully erosion has serious consequences if left unchecked or uncontrolled and these effects range from ecological, social and economical effect. It also poses potential threat to the physical infrastructure. The objectives of this study were to, map out gully sites in Katsina-Ala Town using GIS techniques, assess the relationship between gully parameters and their effects on infrastructure in Katsina-Ala Town, evaluate the effects of gully erosion on infrastructure in Katsina-Ala town and suggest appropriate recommendations for measures of control. Data were collected using primary and secondary sources, analysis was done using descriptive and inferential statistics, Findings from the study revealed that: a strong correlation exists between gully width and damages on physical infrastructure, weak correlation between depth of gullies and damages to infrastructure and moderate correlation between gully length and physical infrastructure damage in the study area; gully erosion has affected or has potential effects on 67 buildings, 10 pipelines, 25 electric poles 47 streets and 21 culverts. The study recommends preventive measures to avert the adverse effects of gully erosion on infrastructural facilities in Katsina-Ala town.***

1. Introduction

Soil erosion by water body is a serious and growing problem in many countries of the world (Afegbua, Uwazuruonye & Jafaru, 2016). Ideally, the natural environment provides the frame work necessary for the existence of life including that of human beings. However, the environment undergoes several forms of degradation that threaten to rob it of its supportive roles. According to Franco (2010), the factors that determine erosion by wind and water are soil type, topography, climate, vegetation and human activity.

Afegbua, Uwazuruonye and Jafaru (2016) maintained that there is no soil phenomenon that is more destructive worldwide than soil erosion, it is a worldwide problem that is not particular to any country. In Nigeria, it is also reported to be single most threatening form of land degradation ravaging over 80% of the country's landmass (Oyedepo & Oluwajana, 2013). Again, the loss of soil from both agricultural and non-agricultural land continues to be a serious problem in the United States. Pineo and Barton (2009) further explained that soil erosion thus poses a great danger to human livelihood depending on soil resources which have no immediate alternative.

Over the years, tremendous contributions were recorded in understanding the behavior of gully erosion and its controlling factors by many scholars using different criteria. Poesen (2011) observed that Gullies are among the morphological indication of long periods of soil erosion revealing the effects of atmospheric adjustment for example heavy rain fall and land use practices in the landscape. This phenomenon is the principled geomorphic feature which loosens human environment relations and brings about particular socio-economic circumstances.

Ehiorobo and Audu (2012) investigated gully erosion in an urban area and reported that gully erosion occur due to extreme overflow of fluid with a very high speed and energy to remove and transmit soil particles downhill slope. In Nigeria, several of the gullies that occurred in towns were due to inappropriate termination of drains and stream paths, the increase in gully pools by the side of a few water courses resulting from changes in land use practices remains a source of worry. Many scholars have examined the vulnerability of soil to inter-rill and rill erosion, but little research explored the propensity of soils to gully erosion.

Shit and Maiti (2012) argued that gully erosion is one of the major devastating catastrophe that speed up soil erosion. The incidence of this hazard signifies a severe type of land degradation that deserves a very exceptional consideration. Rill-gully erosion represents an essential basis of sediment in various environments. The impact of gully erosion has attracted the attention of many scholars including Conoscenti, Angileri, Cappadonia, Rotigliano, Agnesi, & Marker, (2014) viewed that gully erosion causes a significant soil and water losses, decreases crop yield, degrades of ecosystem, roads and bridges, farmlands as well as settlements.

In Nigeria, generally, the threat of soil erosion today is more obvious than any time in history. To produce more food, areas under cultivation necessarily have to be expanded and clearing and burning of steep, forested slopes and ploughing grassland occur. In addition, population pressure has led to rapid urbanization, overgrazing rangelands and over exploitation of timber resources. These activities degrade or remove natural vegetation. Moreso, the fine particles washed from these areas are subsequently deposited in near-low-lying landscape sites on river flood plains or in downstream reservoirs, lakes, river and harbours; these sediments pollute the river with high economic and social cost implications. For instance, in Imo State of Nigeria, erosion has ravaged about 120,000km^2 of land area, 8 villages destroyed and about 30,000 people relocated. In addition, erosion problems in both Imo and Anambra States of Nigeria have been observed to have caused an estimated loss of metric tons of soil, leading to high economic costs of over two hundred million naira (200,000,000.00) per annum. In Akure, Ondo State, erosion effects include: Rendering of road ways non-motorable through creation of gullies, carving in (slope instability) of drains ditches that were not lined, Flooding of road ways during rain due to blockage of drains, pollution of water bodies in the environment as a

result of sediment deposition, destruction of pavement infrastructure i.e. pavement, culverts and drainages. In Auchi, Edo State, erosion has led to the death of several people and destruction of settlements and other facilities (Oyedepo & Oluwajana 2013; Auzet, 2005).

Similar studies on erosion have been carried out by various scholars in various regions of the country. Mansur (2014) in Jigawa State, Dalil, Ilegieuno, Babangida, & Husain (2016). in Edo State, South Western Nigeria and Danladi and Ray, (2014) in Gombe State constitute a few examples.

Soil erosion is a product of process and time. This implies that when the full impact of the process is not estimated and timely combated, the result will be disastrous. This study therefore will help in bringing to knowledge the extent to which gully erosion has affected the infrastructure facility in Katsina-Ala Township. This study shall also initiate and encourage healthy environmental management and sustenance.

2. Material and Methods

Study area

Katsina-Ala Local Government Area (LGA) lies between latitudes 7° 5′ 0″ N and 7° 30′ 0″ N, longitudes 9° 15′ 0″ E and 9° 55′ 0″ E. It is one of the 23 (LGAs) of Benue State. It is located in the North-Eastern part of the State and shares boundaries with Taraba State in the North-East, Ukum Local Government in the North, Logo in the North-West, Buruku in the West, Ushongo in the South and Kwande in the South-East of Benue State. The town itself lies between latitudes 7° 9′ 0″ N and 7° 11′ 0″ N, longitudes 9° 16′ 0″ E and 9° 18′ 30″ E, the town covers and an area of about 15.05km^2 and lies on the South-western part of the local government and is situated on the loop of River Katsina-Ala (Figure 1)

According to the 2006 national census, Katsina-Ala town has a population of 23,801 with f 12,962 males and of 10,839 females (National Populations Commission 1991). It inhabits a heterogeneous urban population composed of Tiv, as the majority, Etulo, Hausa, Igbo and Yoruba communities. The Etulo reside along the River banks as fishermen; Hausa constitute a crop of dry season farmers, most of who were attracted to the town by previous trading activities of Yoruba and Igbo businessmen.

The population of the town is primarily engaged in agriculture, civil service, trading, transport business, fishing, brick making and sand harvest. Others are carpentry and farming as well as education. It is these activities that hold and sustain the town.

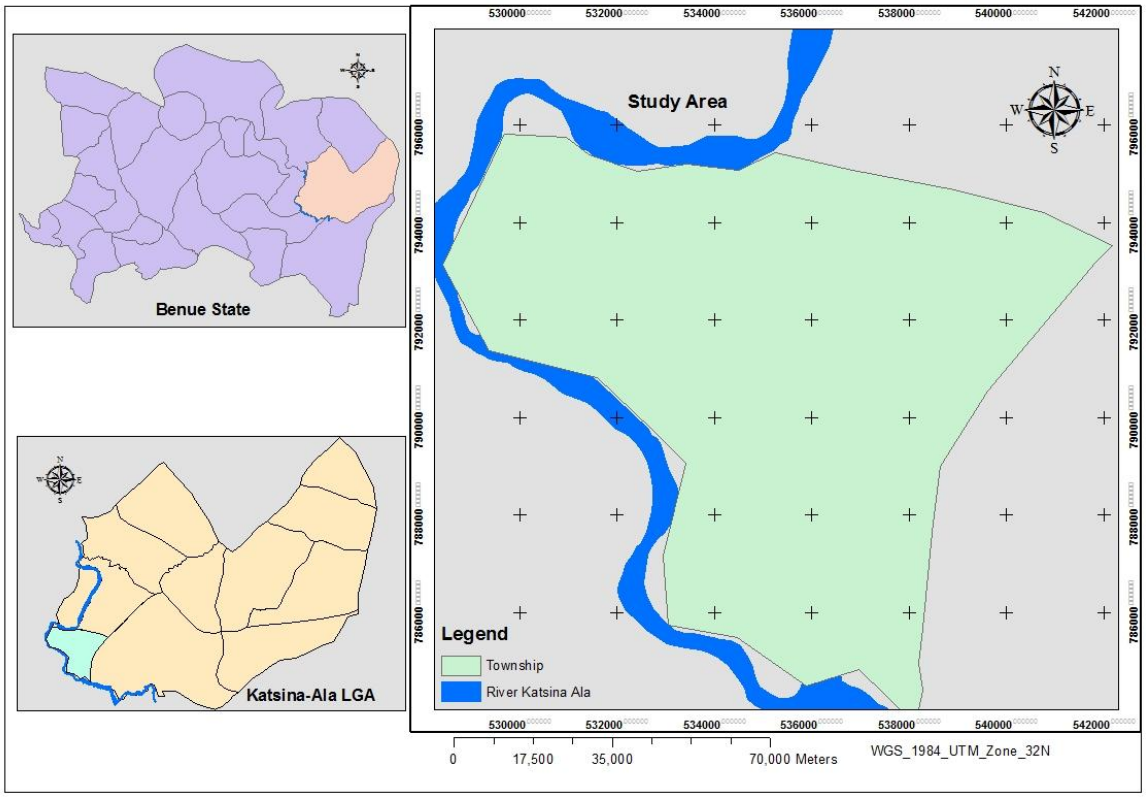

Figure 1: Katsina-ala Local Government Area showing Township ward

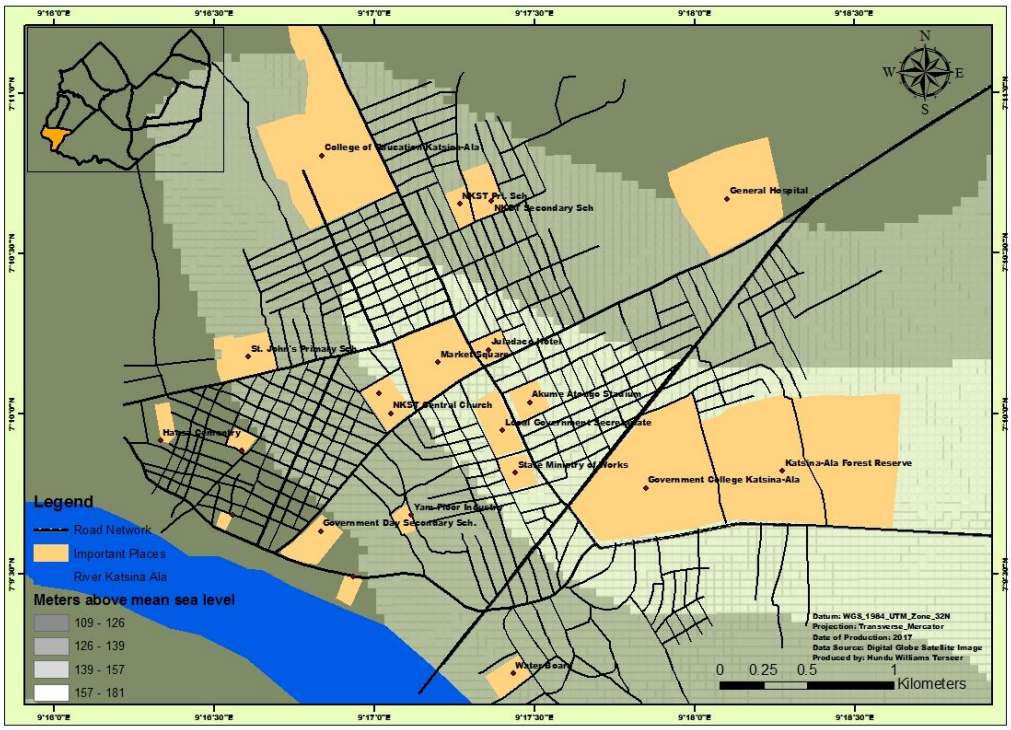

Figure 2: Map of Katsina-Ala Town

Research design
This involves all the streets within the settled are of the town, various physical infrastructure in the town which include buildings, roads/streets, electric poles, water connections, farms or gardens, drainage channels and culverts and recreational resort.

To carry out this study, the following data were obtained in line with the objectives of the study. Data on the total number and dimensions of gullies in the study area was obtained using GIS and remote Sensing techniques. Data on the effects of gully erosion on infrastructures such as collapsed buildings, fallen electric poles, cut transport routes, exposition/disconnection of water lines, collapse of drainage channels and culverts along gully sites and so on.

Sampling design
Built-up areas of the town were used for the study. This enabled a more complete and valid assessment of the problem under study. Thus, streets within the specific areas were followed and the required data obtained appropriately.

Data and method of data collection
Data collected for this study was through a combination of remote sensing and GIS techniques and field observation and measurement. Gully sites were identified; erosion frequencies, gully depth and width were measured using field observation. Lengths of gullies were measure using GIS and remote sensing techniques. A Spot 5 Satellite image of the study area and Google Earth Pro image of 2016 were used to create spatial dataset of the required data including gully sites and streets. Global Positioning System (GPS) was used to collect data on collapsed infrastructure such as buildings, electric poles, culverts, pipe lines and culvert. This was achieved through the use of five (5) Research Assistants for effective data collection exercise. Log books were created for proper documentation and record keeping.

Measurement of gully characteristics

Gully Length
Lengths of gullies were automatically measured using ArcGIS 10.2 software. Gullies where identified through satellite image and digitized into GIS environment using ArcMap Software. A geodatabase of the gullies were created using ArcCatalouge Software from which the length of each gully was automatically determined.

Bed and shoulder widths:
Gully widths were taken at each of the sampled points for shorter gullies of 15m interval. For longer gullies, the measurement was taken at every two of the sampled points which made an interval of 30m. At each of these points, the tape was stretched across the gully bed and shoulder to the opposite bank and readings were taken in meters. This process was continued to the mouth of each gully at the end of which a mean value was derived for the width of the gully.

Gully depth:
The depths of each of the gullies were obtained with the use of ranging poles and the linen tape. One of the poles was fixed at the deepest of the gully bottom (at sample points where shoulder width were taken) stretching the tape across the gully over the ranging pole. One of the assistants noted where it met the tape, and the appropriate measurement were taken and recoded. Where one pole was not enough to cover the depth, two poles were tied together to increase their lengths. It is these depths measured at such point that was computed into a mean value of depth for each of the gullies.

3. Result and Discussion

Gully Sites in Katsina-Ala Town and their characteristics

Field Survey and satellite image analysis reveal that there exist six (6) major gully sites in Katsina Ala Township (Figure 3). In this study, the gullies are described using relative location; the gullies are spatially distributed in the township. For purpose of identification, the gullies are numbered from Sites A to F and Site A, E, F navigate through North-Western part of the town towards the bank of the River Katsina-Ala while sites B, C, and D navigate through North-Eastern part of the town towards the river.

Table 17: Gully Parameters in the Study Area

Description	Width	Depth	Length
Gully A	5.82	2.20	1268.67
Gully B	2.95	1.88	286.33
Gully C	3.53	4.36	958.68
Gully D	4.81	3.91	1495.88
Gully E	5.12	3.82	270.05
Gully F	3.98	3.18	838.65

Source: Field Survey, 2017

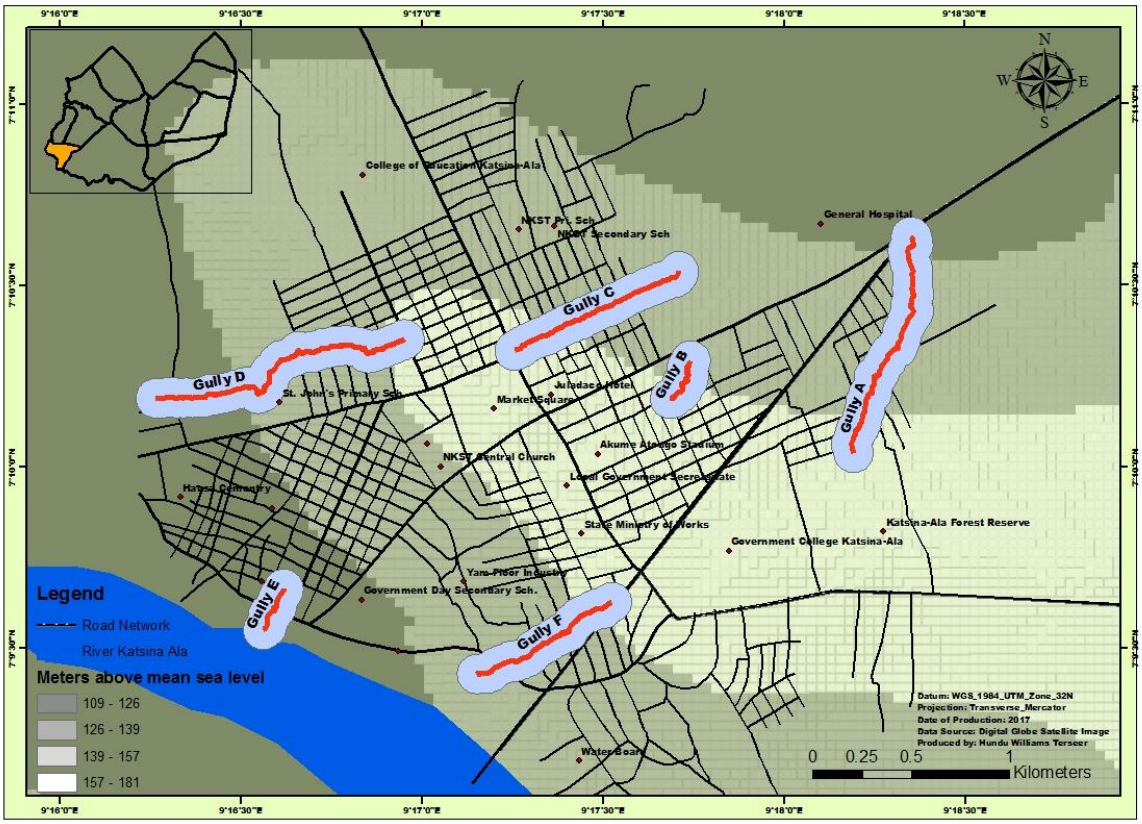

Figure 3: Katsina-Ala Town showing Gully Sites

The relationship between gully parameters and magnitude on physical infrastructure in Katsina-Ala Town

Gully width and physical infrastructure in the Study Area

The effect and magnitude of gully erosion on physical infrastructure in the study area is determined by gully width, depth and length. The relationships between the these gully parameters and their effect and magnitude on infrastructure in the study area have being assessed using Pearson product moment correlation coefficient (r) (Table 2)

Table 2: Relationship between width of Gullies and their magnitude on physical infrastructure in the Study Area using Pearson Product Moment correlation (r)

Physical Infrastructure	Width	Depth	Length
Buildings	0.73	0.42	0.63
Pipes	0.86	0.06	0.15
Poles	0.38	0.04	-0.05
Streets	0.72	0.67	0.75
Coverts	0.92	0.33	0.27

Source: Author's Computation, 2017

Results obtained from Pearson product moment correlation coefficient (r) on the relationship between magnitude and effect of gully width on physical infrastructure in the study area revealed that there is a strong correlation between gully width and collapse of buildings (r=0.73), gully width and damaged pipe lines (r=0.86), gully width and streets affected (r=72), gully width and damaged coverts (r=0.92) but a weak correlation between gully width and electric poles affected (r=0.38). This implies that as the gullies get wider, more buildings, pipelines, streets and coverts are affected, (Table 2).

Gully depth and physical infrastructure in the Study Area

Results on the relationship between magnitude and effect of gully depth on physical infrastructure in the study area revealed that there is a strong correlation between gully depth and damaged streets (r=0.67), but a weak correlation between gully depth and damaged pipe lines (r=0.06), gully depth and damaged electric poles (r=0.04), gully depth and damaged culverts (r=0.33) and gully depth and damaged buildings (r=0.42). This implies that the depth of the gullies

have little or no effect on pipelines, electric poles, coverts and buildings but has significant effects on streets (Table 2).

Gully Length and physical infrastructure in the Study Area

Results on the relationship between magnitude and effect of gully lengths on physical infrastructure in the study area revealed that there is: a strong correlation between gully length and damaged streets (r=0.75), gully lengths and damaged buildings, but a weak correlation between gully length and damaged pipe lines (r=0.15), gully length damaged coverts (r=0.27), and a negative correlation between gully lengths and damaged electric poles (r=-0.05). This implies that the length of the gullies have little or no effect on pipelines, electric poles, coverts but have significant effects on streets and buildings (Table 2).

Effect of Gully Erosion on physical infrastructure in Katsina-Ala Town

Table 3 Gully Impact on physical Infrastructure in Katsina-Ala Town

Description	Buildings	Pipeline	Electric Poles	Streets	Culverts
Gully A	10	2	7	12	4
Gully B	5	4	3	12	6
Gully C	13	0	1	3	7
Gully D	23	3	0	7	2
Gully E	3	1	5	10	2
Gully F	13	0	9	3	0
Total	**67**	**10**	**25**	**47**	**21**

Source: Field Survey 2017

Table 3 shows data presentation on infrastructures affected by gully erosion in Katsina-Ala Township, from the presentation, it can be observed that six (6) major gullies were identified labeled (A – F) and infrastructure facilities such as buildings, pipelines, electric poles, streets and culverts. Results show that Gully 'A' affected 10 buildings, 2 pipelines, 7 electric poles, 12 streets and 4 culverts; Gully 'B' affected 5 buildings, 4 pipeline, 3 electric poles, 12 streets and 6 culverts; Gully 'C' affected 13 buildings, 1 electric poles, 3 streets and 7 culverts; Gully 'D' affected 23, buildings, 3 pipelines, 7 streets and 2 culverts; Gully 'E' affected 3 buildings, 1 pipeline, 5 electric poles, 10 streets and 2 culverts; Gully 'F' affected 13 buildings, 9 electric poles, and 3 streets. Holistically, 67 buildings has been affected by gully erosion in the study area and this by extension, has negatively impacted on the household members, ten pipelines are affected which directly and indirectly has health implication, 25 electric poles are affected which has direct effect on power supply, 47 streets are affected which negatively affects movement around and within the Township and directly or indirectly affect smooth running of business activities and 21 culverts are also affected aggravating gully erosion and negatively affecting transportation in the study area see (table 3).

4. Conclusion

This study attempted to investigate the effects of gully erosion on physical infrastructure in Katsina-Ala town.. To achieve the purpose for the study, gully sites in Katsina-Ala Town were mapped using GIS techniques, the relationship between gully parameters and their effects on infrastructure in Katsina-Ala Tow assessed and evaluated and appropriate recommendations for measures of control made. Data were collected using primary and secondary sources and analysis was done using descriptive and inferential statistics. Findings from the study also show a strong correlation between gully width and damages on physical infrastructure, weak correlation between depth of gullies and damages in physical infrastructure and moderate correlation between gully length and physical infrastructure damage in the study area. Findings further revealed that a huge infrastructure is already affected by impact of gully erosion in the study area.

5. Recommendations

Based o he findings of the study, the following recommendation have been made to curb the menace of gully erosion.

1) Efforts should also be made by relevant authorities to enact a law against location of engineering structures on waterways.
2) The government at all levels in Nigeria should take it as matter of urgency to yield to addressing issues relating to erosion especially gully erosion at an early stage so as to avoid loss of lives of the inhabitants and their properties.
3) Erosion along the roads and other affected settlements may be controled through the provision of appropriate drains and in the case of roads through sufficient maintenance.
4) Drainage network should be constructed within the township to pave way for smooth flow of water especially during heavy rainfall.

References

[1] Abdulfatai, I. A., Okunlola, I. A., Akande, W. G., Momoh, L. O., & Ibrahim, K. O. (2014). Review of gully erosion in Nigeria: Causes, impacts and possible solutions. *Journal of Geosciences and Geomatics*, *2*(3), 125-129.

[2] Afegbua, U. K., Uwazuruonye, J., & Jafaru, B. (2016) Investigating the Causes and Impacts of gully erosion in Auchi, Nigeria.

[3] Aminu, J. Gimenez, R. & Bennett, S. (2009) Gully erosion processes and modeling, Proc. Fourth International Symposium on Gully Erosion, Pamplona, Spain, September 2007, Earth Surface Processes and Landforms 34;1839-1984.

[4] Auzet A.V.(2005) From soil erosion knowledge to soil protection and runoff prevention – COST 623. Soil Conservation and Protection for Europe

[5] Ayele, G. K., Gessess, A. A., Addisie, M. B., Tilahun, S. A., Tebebu, T. Y., Tenessa, D. B., ... & Steenhuis, T. S. (2016). A biophysical and economic assessment of a community-based rehabilitated gully in the Ethiopian highlands. *Land Degradation & Development*, *27*(2), 270-280.

[6] Baets, S, D. Quine, T, A. & Poesen, J. (2014) Root strategies for rill and gully erosion control. *Journal of Soil Biology 40(2014),297-323*

[7] Bissonnais, Y. (2015). Relative contribution of rill/interrill and gully/channel erosion to small

reservoir siltation in Mediterranean environments. *Land Degradation & Development. DOI, 10*.

[8] Boardman, J. (2014) How old are the gullies (dongas) of the Sneeuberg Uplands, Eastern Karoo, South Africa. *Catena 113, 79-85*

[9] Casasnovas, J, A. (2003) A spatial information technology approach for the mapping and quantification of gully erosion. *Journal of Gully Erosion and Global Change 50(2-4), 293-308.*

[10] Conoscenti, C., Angileri, S., Cappadonia, C., Rotigliano, E., Agnesi, V., & Marker, M. (2014) Gully erosion susceptibility assessment by means of GIS-based regression: A case of Sicily (Italy). *Journal of Geomorphology 204(1),399-411*

[11] Daba, S., Rieger, W., & Strauss, P. (2003) Assessment of gully erosion in eastern Ethiopia using photogrammetric techniques. *Journal of Gully Erosion and Global Change 50(2-4),273-291*

[12] Dalil, M., Ilegieuno, A. A., Babangida, M. U., & Husain, A. (2016). Assessment of the impacts of gully erosion on Auchi settlement, Southern Nigeria. *Journal of Geography and Regional Planning*, *9*(7), 128-138.

[13] Danladi, A., & Ray, H. H. (2014). Socio-economic effect of gully erosion on land use in Gombe Metropolis, Gombe State, Nigeria. *Journal of Geography and Regional Planning*, *7*(5), 97.

[14] Desmond, W, E. & Antonina, C. (2014) Using 137 CS and 210 Pbex measurements and conventional surveys to investigate the relative contributions of inter rill/rill and gully erosion to soil loss from a small cultivated catchment in Sicily. *Journal of Soil & Tillage Research 135, 18-27*

[15] Dube, E., Nhapi, I., Murwira, A., Gumindoga, W., Goldin, J. & Mashauri, D, A. (2014) Potential of weight of evidence modeling for gully erosion hazard assessment in Mbire District-Zimbabwe. *Journal of Physics and Chemistry of the Earth 67- 69(2014),145-152*

[16] Ehiorobo, J, O. & Audu, H, A, P. (2012) Monitoring of gully erosion in an Urban area using Geo-information technology. *Journal of Emerging Trends in Engineering and Applied Sciences 3(2),270-275.*

[17] Franco A.M.P., Cassol E.A., Pauletto E.A and Pinto L. F.S(2010). Flow hydraulic Characteristics and interrill erosion susceptibility of natural and constructed Soils from Candiota Coal Mining Area, RS, Brazil.19th World Congress of Soil Science, Soil Solutions for a Changing World, 1 – 6 August 2010, Brisbane, Australia.

[18] Frankl, A., Deckers, J., Moulaert, L., Van Damme, A., Haile, M., Poesen, J., & Nyssen, J. (2016). Integrated solutions for combating gully erosion in areas prone to soil piping: innovations from the drylands of Northern Ethiopia. *Land Degradation & Development*, *27*(8), 1797-1804.

[19] James, L, A. Watson, D, G. & Hansen, W, F. (2007) Using LiDAR data to map gullies and head water stream under forest canopy: South Carolina, USA. *Catena 71 (1), 132-144.*

[20] Le Roux, J. J., & Sumner, P. D. (2012). Factors controlling gully development: comparing continuous and discontinuous gullies. *Land Degradation & Development*, *23*(5), 440-449.

[21] Li, Y. Poesen, J. Yang, J, C. Fu, B. & Zhang, J, H. (2003) Evaluating gully erosion using 137 Cs and 210 Pb/ 137CS ratio in a reservoir catchment. *Journal of Soil and Tillage Research 69(1-2),107-115.*

[22] Mansur, A. (2014). An Assessment of gully erosion in Dutse Sahelian Zone of Jigawa State, Nigeria, and its adverse consequences on the socio-economic development of the State. *Journal of Agriculture and Environmental Sciences*, *3*(3), 17-25.

[23] Musa J.J, Abdulwaheed S., & Saidu M. (2010). Effect of surface runoff on Nigerian rural roads A case study of Offa Local Government Area. *AU J.T. 13(4): 242-248*

[24] Obidimma, C. E. & Olorunfemi, A., (2011). Resolving the gully erosion problem in Southeastern Nigeria: innovation through public awareness and community – based approaches, *Journal of Soil Science and Environmental Management, 286-287*

[25] Ojha, G. & Shrestha, R. (2007). Bio-engineering measures for stabilizing cut-slopes of Dipayal-Mellekh road, far Western Nepal. *Bulletin of Department of Geology, Tribhuvan University, Kathmandu, Nepal, Vol. 10, 79-88.*

[26] Osadebe, C. C. & Enuvie, G., (2008). *Factor analysis of soil spatial variability in gully erosion area of Southeastern Nigeria: A case study of Agulu- Nanka-Oko Area, Scientia Africana, 7 (No.2), pp. 45*

[27] Owolabi, A.O. (2009). Para-transit Modal Choice in Akure Nigeria: Application of behavioural models. *Institute of Transportation Engineers Journal, Vol. 79(1), 54 – 58*

[28] Oyedepo, O. J., & Oluwajana, S. D. (2013). Impact of erosion on street roads: A case study of Sijuwade Area Akure Ondo State Nigeria. *Chemistry and Materials Research, ISSN*, 2224-3224.

[29] Pineo R., & Barton S.,(2009). Preventing Erosion. Sustainable Landscapes Series. College of Agric and Natural Resources.University of Delaware.

[30] Poesen, J. (2009). The potential of 3D gully monitoring with GIS using high resolution aerial photograph and digital photogrammetry system, Geomorphology 111:48-60(doi:10.1016/j. geomorh.2008.05.047)

[31] Poesen, J. (2011) Challenges in gully erosion research. *Journal of Landform Analysis 17(5-9) Paolo, P.*

[32] Shit, P, K. & Maiti, R. (2012) Effects of plant root density on the erodibility of lateric top soil by simulated flume experiment. *International Journal of Forest, Soil and Erosion 2(3),137-142*

[33] Slimane, A. B., Raclot, D., Evrard, O., Sanaa, M., Lefevre, I., & Le Stemler, S. (2001). An overview of content analysis. *Practical Assessment, Research & Evaluation, 7(17).*

[34] Torri, D. & Poesen, J. (2014) A review of topographic threshold conditions for gully head development in different environments. *Journal of Earth Science Reviews 130(2014), 73-85*

[35] Valentin, C. Poesen, J. & Li, Y. (2005) Gully erosion: Impacts, factors and control. *Journal of Global Issue 63(2-3),132-153*

[36] Wang, T. He, F. Zhang, A., Gu, L. Wen, Y., Jiang, W., & Shao, H. (2014) Aquantitative study of gully erosion based on object oriented analysis techniques: A case study in Beiyanzikou. *Scientific World Journal 2014(2014),417325*

[37] Yitbarek, T. W., Belliethathan, S., & Stringer, L. C. (2012). The onsite cost of gully erosion and cost-benefit of gully rehabilitation: A case study in Ethiopia. *Land Degradation & Development*, *23*(2), 157-166.