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ORIGINAL RESEARCH ARTICLE

The Environmental Impact of Gully Erosion and Its Implications for Soil Loss in Northern Adamawa state, Nigeria

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ABSTRACT

Gully erosion has become a significant environmental issue, dramatically contributing to soil degradation and adversely affecting soil fertility, water quality, and ecosystem health worldwide. This study investigates the extent and impact of gully erosion in Northern Adamawa State, Nigeria, focusing on five local government areas comprising Madagali, Michika, Mubi North, Mubi South and Maiha Local Government where 163 gully sites were identified. Using a 30-meter measuring tape, the dimensions of each gully were recorded, resulting in a total gully length of 12,349.4 meters. The Field Office Technical Guide (FOTG) methodology was applied to calculate the volume of displaced soil, which was found to be 73,133.15 cubic meters. Furthermore, the study estimated an annual soil loss of approximately 58,471.05 tonnes. These results highlight the severe implications of gully erosion, such as significant soil fertility loss, decreased agricultural productivity, damage to infrastructure, and negative socio-economic impacts. The study underscores the urgent need for comprehensive soil conservation and land management strategies, including reforestation, terracing, and community engagement, to mitigate these adverse effects and restore environmental stability.

Introduction

Gully formation plays a crucial role in the erosion of soil, significantly shaping the Earth's surface over the past decade (Nwankwo & Nwankwoala, 2018; Egboka et al., 2019). . It is also a widespread phenomenon globally, with detrimental effects on soil fertility, water quality, and ecosystem health. The emergence of gullies leads to substantial soil loss and is a major contributor to environmental degradation (Nwankwoala & Igbokwe, 2019). Moreover, gully formation alters overland flow patterns, reduces runoff lag time, and increases runoff volume. The increasing focus on studying gully erosion underscores the importance of understanding its impacts and the diverse factors influencing it (Amangabara, 2014; Nwankwoala & Igbokwe, 2019). In Africa, approximately 29 million hectares of land have been impacted by gully erosion (Hurni et al., 2010), leading to a significant decrease in agricultural productivity (Osore & Moges, 2014; Mekonnen et al., 2015; Rijkee et al., 2015; Mukai, 2017). In Nigeria, the World Bank recognized three main environmental problems: soil degradation and loss, water contamination and deforestation of which gully erosion is a subset of each of these problems and causes damage (Agagu, 2009). Furthermore, in 2009, the World Bank Country report on Nigeria listed gully erosion as one of the top five hazards threatening the countries environment (Mbaya, 2013). Mbaya, 2017 also opined that the demographic increase and various infrastructural development meant to improve the standard of living of the people has on the other hand devastated the environment especially where uncoordinated development is taking place in Gombe State . Each yearly rainy season is accompanied by increases in gully length, depth and width. Soil erosion as an environmental hazard has attracted the attention of many researchers and government organizations. The knowledge of the different gully erosion parameters which include the gully erosion duration, the width, the depth, and the height of various gully incidences are issued investigated in this study in order to assess the environmental impact of gully erosion.

Materials and Methods

Study Area

Mubi Region, which presently encompasses the northern part of the former Sardauna province, now constitutes the Adamawa Northern Senatorial District which comprises Madagali, Michika, Mubi North, Mubi South and Maiha Local Government. Positioned between latitudes 9°00' to 10°11' N and longitudes 13°00'11'' E to 13°45'11'' E of the Meridian, the region shares boundaries with Borno State to the North, Hong and Song Local Government Areas to the West, and the Republic of Cameroon to the South and East (Ikusemoran, 2009) as shown in figure 1. Covering a land area of 4,728.77 km2, the region had a population of 681,353 according to the 2006 National Population Census. The relief of the Mubi Region is divided into three zones: highlands/mountains along the Cameroon border in the east, uplands with elevations between 400 and 800 meters covering about 40% of the region, and lowlands along the River Yedzeram in the western part of Michika and Madagali Local Government Areas (Adebayo, 2004). The wet season lasts from May to September, with annual rainfall ranging from 900mm to 1050mm. The main soil types are lithosols, luvisols, and gleyic cambisols. The region falls within the Sudan savanna belt, characterized by grasses, aquatic weeds along river valleys, dry land weeds, shrubs, and woody plants. Agriculture is a major employer in the region, with most households engaged in subsistence farming (Adebayo and Dayya, 2004). Rainfall erosivity ranges between 481m to 192m, with about 15.5mm to 15.8mm of rainfall per day and a potential evapotranspiration rate of 4.5m to 4.6m. The area has a tropical wet (April-October) and dry (November-March) climate, with mean annual rainfall ranging from 700mm to 1,050mm (Adebayo, 2004). The vegetation is typical of the Sudan savanna, with short grasses interspersed with shrubs and a few trees (Adebayo, 2004)..The soils of the study area belong to the order lithosols, characterized by shallow depths and stoniness due to rock-basements close to the surface (Adebayo, 2004). Lithosols are one of the upper categories in the FAO/UNESCO soil classification system (Aduayi et al., 2002) and typically support orchard-type vegetation because of their limited fertility (Nwaka et al., 1999). Additionally, arenosols and regosols, which are relatively young soils with minimal profile development or homogenous sands, are found on mountain sites within the 213 and 232 units where weathering is slight and involves no accumulation of weathering products (Aduayi et al., 2002).

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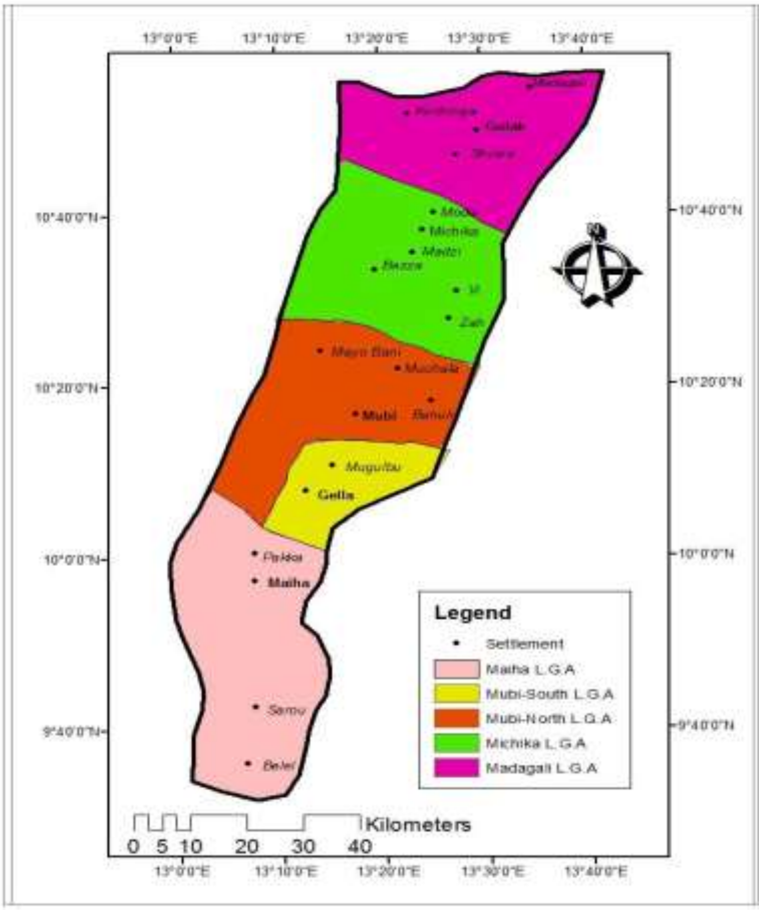

Figure 1: The Study Area

Methodology

A 30m measuring tape was used to determine the length, the width, and the depth of the gullies in the study area. In each site, measurement of each gully length, width and depth were undertaken at every interval of less than or equals to 0.2km² (200m)² radius for short gully and more than 200m² for long gullies. Total number of 163gully sites wer identified in the five Local Government of the study area as depicted in Plate I.

Calculation of Soil Loss by Gully Erosion

The field office technical guide (FOTG) was used to calculate the average soil loss due to gully erosion activities (Hassen and Banditer, 2020). The formula used is as given bellow.

V= L *[(Wt + Wb)/2]* df ------1

Where

L = the total length in meter

Wt = the average top width in meter

Wb = the average bottom width in meter

Df = the average depth measured in meter

V = the displaced volume in cubic meter

To convert this calculated volume to a weight of soil, lost over time (tones/ year) equation 2 was used.

E = [(V*W/1000)/y]* N----------2.

Where E = the soil loss in tonnes per year

V = the volume in cubic meter calculated above

W = the average weight of the soil in kilogram per cubic meter (Bulk destiny)

1000 = the weight in kilogram per tone

Y = the numbers of years the gully has been active

N = the number of similar classic gullies

Plate I: A Secondary School Degraded by Gully Erosion in Pakka, Maiha Local Government Area

Results and Discussion

The detailed analysis of gully measurements in the study area reveals a significant erosion problem characterized by the presence of extensive and numerous gullies. The total length of the gullies is an impressive 12,349.4 meters, signifying that erosion processes have markedly reshaped the landscape. This extensive gully network suggests substantial soil loss, which can have profound impacts on the environment and land usability.

The measurements further indicate that the gullies' total width at the top is 806 meters, while the total width at the bottom is 563.2 meters, and the total depth is 230.3 meters. The area contains 163 gullies, demonstrating a high density of these erosion features. The high number of gullies implies that the area is highly susceptible to erosion, potentially due to factors such as soil composition, land use practices, vegetation cover, and climatic conditions.

When these measurements are averaged, each gully's top width is approximately 4.94 meters, and the bottom width is about 3.46 meters. The wider top compared to the bottom indicates that erosion processes are actively widening the gully heads and walls, which could be driven by surface runoff that expands these features. The average depth of the gullies is 1.41 meters, suggesting that while the gullies are relatively shallow, they still contribute significantly to soil erosion and sediment transport. Even these shallow gullies can lead to notable soil loss, reducing the soil's fertility and affecting agricultural productivity and landscape stability.

Volume of Soil Displaced

The total volume of soil displaced, amounting to 73,133.15 cubic meters, vividly demonstrates the severity of erosive processes occurring in the study area. This substantial figure is a cumulative result of numerous gullies that have formed and expanded, contributing to extensive soil removal from the landscape. Gully erosion, which occurs along drainage lines due to surface water runoff, is particularly destructive. Unlike other forms of erosion, gully erosion creates deep channels that can become entrenched in the landscape, making them challenging to remediate and leading to long-term soil degradation.

Annual Soil Loss

When this displaced volume is converted into annual soil loss, the magnitude of the erosion problem becomes even more apparent. The annual soil loss is calculated to be approximately 58,471.05 tonnes per year. This figure underscores the relentless and ongoing nature of soil erosion in the area. Such a high rate of soil loss indicates that the problem is not only significant but also persistent. If this rate of erosion continues unchecked, it could lead to increasingly severe consequences over time, including further landscape degradation, reduced agricultural productivity, and more frequent and severe hydrological impacts such as flooding and reduced groundwater recharge.

Implication of Soil Loss

The results of the study, which indicate significant gully erosion and soil loss in the study area, have profound implications for various aspects of the environment, agriculture, infrastructure, and socio-economic conditions. This detailed discussion explores these implications in depth.

Environmental Implications

Soil Fertility and Ecosystem Health: The displacement of 73,133.15 cubic meters of soil, translating to an annual loss of approximately 58,471.05 tonnes, highlights a severe degradation of soil quality. Topsoil, which is crucial for plant growth due to its high nutrient content, is being eroded away. This loss diminishes the land’s ability to support vegetation, leading to reduced plant cover and, consequently, a loss of habitat for wildlife. The declining soil fertility can also result in the loss of biodiversity as plant and animal species that depend on the nutrient-rich topsoil struggle to survive.

Hydrological Changes and Water Quality: Gully erosion affects the hydrological cycle by increasing surface runoff and reducing water infiltration into the soil. This can lead to more frequent and severe flooding, as well as reduced groundwater recharge, impacting both the quantity and quality of available water. Sediment from eroded soil can enter rivers and streams, causing sedimentation that degrades water quality and affects aquatic ecosystems. The increased turbidity can harm fish and other aquatic organisms, disrupting local ecosystems.

Agricultural Implications

Decline in Agricultural Productivity: The loss of fertile topsoil means that crops have less access to essential nutrients, resulting in lower yields and reduced agricultural productivity. This can have a direct impact on food security, particularly in regions where agriculture is a primary source of livelihood. Farmers may face increased costs as they try to compensate for nutrient loss with fertilizers, which can be economically burdensome and unsustainable in the long term.

Land Degradation: Severe gully erosion can render large areas of land unusable for agriculture. Deep gullies dissect the landscape, making it difficult or impossible to farm the affected areas. Over time, this can lead to the abandonment of agricultural land, reducing the overall area available for farming and impacting local food production.

Infrastructure Implications

Damage to Infrastructure: Erosion can undermine the foundations of buildings, roads, bridges, and other infrastructure, leading to instability and potential structural failure. This poses significant safety risks and can result in substantial economic costs for repairs and maintenance. For instance, roads affected by gully erosion may become impassable, disrupting transportation and access to essential services.

Increased Maintenance Costs: The continuous erosion problem means that infrastructure maintenance costs will likely rise over time. Local governments and communities may need to allocate more resources to repair damaged infrastructure, diverting funds from other critical areas such as education and healthcare.

Socio-Economic Implications

Economic Losses: The combined impact of reduced agricultural productivity, increased costs of cultivation, and damage to infrastructure leads to significant economic losses for local communities. Farmers and landowners may experience declining incomes, which can exacerbate poverty and reduce the overall quality of life in rural areas.

Food Security and Nutrition: With declining agricultural productivity and potential food shortages, communities may face challenges related to food security and nutrition. Dependence on external food sources may increase, which can be particularly problematic in times of crisis or supply chain disruptions.

Migration and Social Displacement: In severe cases, the degradation of land may force communities to abandon their homes and migrate to other areas in search of better opportunities. This social displacement can lead to overcrowding in urban areas, putting additional strain on urban infrastructure and services. Migration can also disrupt social networks and traditional ways of life, contributing to social instability.

Mitigation and Management

To address the severe implications of gully erosion and soil loss, it is crucial to implement effective soil conservation and land management strategies:

Reforestation and Afforestation: Planting trees and other vegetation can help stabilize the soil, reduce runoff, and restore ecological balance. Trees act as a natural barrier against erosion, with their roots helping to bind the soil together.

Terracing and Contour Farming: These agricultural practices can reduce soil erosion on slopes by slowing down water flow and encouraging water infiltration. Terracing creates flat areas on steep slopes, while contour farming follows the natural contours of the land, both of which can help prevent soil loss.

Construction of Check Dams and Sediment Traps: These structures can help manage surface runoff, capture sediment, and prevent further gully formation. Check dams slow down the flow of water, reducing its erosive power, while sediment traps capture eroded soil, preventing it from being washed away.

Community Engagement and Education: Involving local communities in soil conservation efforts and educating them about sustainable land management practices is crucial. Community-driven initiatives are often more successful and sustainable in the long term, as they ensure local ownership and commitment to conservation efforts.

Conclusion

The study reveals the extensive and severe impact of gully erosion in Northern Adamawa State, Nigeria. The presence of 163 gullies, with a total length of 12,349.4 meters, has led to a substantial soil loss of 73,133.15 cubic meters, translating to an annual loss of 58,471.05 tonnes. This significant erosion problem highlights the urgent need for effective soil conservation strategies. To mitigate the adverse effects, recommended measures include reforestation and afforestation to stabilize soil and reduce runoff, terracing and contour farming to slow water flow and enhance infiltration, and constructing check dams to manage runoff and prevent further gully formation. Additionally, community involvement and education are crucial for the sustainability and success of these initiatives. By integrating these strategies, the severe impacts of gully erosion can be mitigated, leading to improved soil fertility, agricultural productivity, and environmental stability in the region.

Recommendation

To effectively mitigate the severe impact of gully erosion Northern Adamawa State, Nigeria, a comprehensive approach to soil conservation and land management is essential. Reforestation and afforestation efforts should be prioritized to stabilize the soil and reduce runoff, as the roots of trees and vegetation help bind the soil together. Implementing terracing and contour farming can significantly reduce soil erosion on slopes by slowing water flow and enhancing water infiltration, thereby preventing further gully formation. Additionally, constructing check dams and sediment traps can manage surface runoff, capture sediment, and minimize the erosive power of water, effectively preventing the expansion of gullies. Community engagement is crucial; local communities should be actively involved in soil conservation initiatives to ensure ownership and long-term commitment to sustainable practices. Education programs should be established to raise awareness about the importance of soil conservation and teach sustainable land management techniques. By integrating these strategies, the adverse effects of gully erosion can be mitigated, leading to improved soil fertility, agricultural productivity, and environmental stability in the region.

References

Adebayo, A. A. & Daya, S. (2004). Assessment of Human Impact on Land use and Vegetation Cover Change in Mubi Region, Adamawa State, Nigeria; Remote Sensing and GIS approach. *Global journal of environmental sciences* 2, 1-12.

Adebayo, A. A. (2004). Mubi Region: A Geographical Synthesis (lst Ed). Paraclete Publishers, Yola-Nigeria: 32-38.

Adebayo, A. A. and Tukur, A. L. (1999). Adamawa State in Maps, 1st Ed., Yola, Paraclete Publishers, 8.

Aduayi, E. A., Chude, V. O., Adebusuyi, B. A. & Olayiwola, S. O. (2002). Fertilizer

Use and Management Practices for Crops in Nigeria (3rd Ed.), Federal Ferti1izerDepartment, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria, Garko International Limited.

Agagu, K.O. (2009). Threats to the Nigerian Environment: A Call for Positive Action. Paper Presented at the 7th Chief S.L Edu memorial Lecture, Organized by the Nigerian Conservation Foundation.

Amangabara, G.T. (2014). Understanding Effective Gully Control Measures in Imo State, Nigeria. *Canadian Open Soil and Erosion Journal*, 1(1): 1-9.

Egboka, B.C.E; Orji, A.E & Nwankwoala, H.O (2019). Gully Erosion and Landslides in South-eastern Nigeria: Causes, Consequences and Control Measures, *Global Journal of Engineering Sciences, 2019, 2(4):1 – 11,* DOI:10.33552/GJES.2019.02.000541

Hassen, G., & Bantider, A. (2020). Assessment of Drivers and Dynamics of Gully Erosion in case of Tabota Koromo and *Geoenvironmental Disasters*, *7*, 1-13.Koromo Danshe Watersheds, South Central Ethiopia.

Hurni, H., Abate, S., Bantider, A., Debele, B., Ludi, E., Portner, B. Zeleke, G. (2010). Land Degradation and Sustainable Land Management in the Highlands of Ethiopia. In *Global Change and Sustainable Development: A Synthesis of Regional Experiences from Research. Perspectives of the Swiss National Centre of Competence in Research (NCCR) North-South.*

Ikusemora, M. (2009). Mubi Region, a Geographical Synthesis, Worldcat.org, Paraclete, Yola Nigera. *Journal of Arid Agriculture.* 9, 89-98, Maiduguri, Nigeria.

Mbaya L. A (2017). Spatial Analysis of Gully Erosion Control Measures in Gombe Town, Gombe State Nigeria, *Advances in Image and Video Processing, Volume 4 No 5,); pp: 17-28*

Mbaya, L.A. (2013). A Study of Inter-relations among Gully Variables in Gombe town, Gombe State, Nigeria. Wudpecker J Geogr. Regional Plan. 1(1):001-006.

Mekonnen, M., Keesstra, S. D., Baartman, J. E., Ritsema, C. J., & Melesse, A. M. (2015). Evaluating sediment storage dams: structural off-site sediment trapping measures in northwest Ethiopia.*Cuadernos de Investigación Geográfica* . https://doi.org/10.18172/cig.2643.

Mukai, S. (2017). Gully Erosion Rates and Analysis of Determining Factors: A Case Study from the Semi-arid Main Ethiopian Rift Valley.*Land Degradation and Development*. https://doi.org/10.1002/ldr.2532

Nwaka, G. 1. C., Alhassan, A. B. & Kunduri, A. M. (1999). A Study of Soils Derived from Basalt in North Eastern, Nigeria 11. Physio-Chemical Characteristics and Fertility Status.

Nwankwoala, H.O & Igbokwe, T (2019). Geotechnical Assessment for Gully Erosion Control and Mangement in Agulu-Nanka, Southeastern Nigeria. *Middle East Journal of Scientific Research, 27(8): 644-654*

Osore, A., Moges, A., & Engineering, U. (2014). *Extent of Gully Erosion and Farmer's Perception of Soil Erosion in Alalicha Watershed, Southern Ethiopia*. *4* (15), 74–82.

Rijkee, P., Keesstra, S., & Gethahun, M. M. (2015). *Low-land Gully Formation in the Amhara Region , Ethiopia* . *17* (2011), 15827.