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GULLY EROSION CONTROL USING WIRE NETTING DAM IN RAMAT POLYTECHNIC, MAIDUGURI

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Abstract: *The study titled Gully Erosion Control Using Wire Netting Dam in Ramat Polytechnic, Maiduguri Borno State was carried out. The control structure was constructed in the Ramat Polytechnic premises, near the Football field. The survey of the gully was carried out using Measuring instruments and pegs, after which the protection was constructed. The difference in the volume of the eroded channel due to the effect of the control structure was calculated by using the trapezoidal rule for calculating volume of irregular shapes. The result of the experiment gave the initial volume of eroded channel as* $0.303m^3$ *and the final volume as* $0.204m^3$ *with an effective difference of* $0.990m^3$*. The use of local materials such as wire netting for gully erosion control has proved to be effective. Therefore, there is a need to encourage people to practice this method of controlling erosion in their farms, villages and settlement areas, because is cheap and easy to construct.*

Keywords: *Gully Erosion, Wire Netting, Dam, Control Structure*

Introduction

Wire netting is flexible steel netting with hexagonal holes and is available in a galvanized or polyvinyl chloride (PVC)-coated finish. Wire netting can extremely be used for a number of applications such as, erosion brought about by climate or land-use change. Gully erosion is defined as steep-sided channels, often with steeply sloping and actively eroding head scarp landscape usually ranging from 30cm to 30m deep, caused by the intermittent flow of water, usually during and immediately following heavy rains (Poessen *et al*, 2003).

Gully erosion is active and of alarming rate due to soil texture and structure, slopes, rainfall, human's activities such as deforestation, over grazing, excessive cultivation, bush burning and construction work amongst others.

Natural erosion occurs primarily on a geologic time scale, but when man's activities alter the landscape, the erosion process can be greatly accelerated. The type of erosion that inspires fear in the lives of people in the southeastern part of Nigeria is gully erosion. Gully erosion can simply be defined as the erosion process whereby runoff water accumulates in narrow channels and removes consideration amount of soil from the narrow channel over a short period. According to Sidorchuk (2001), Gully erosion is a linear deep erosion feature with active head cut, unstable side walls, subject to mass movement, and non-graded longitudinal profile, with temporal water flow.

Gully erosion is the terminal phase of a four-stage erosion process involving splash, sheet, rill, and gully. The process begins by water falling as raindrops and flowing on the soil surface. Splash erosion results when the force of raindrops falling on bare or sparsely vegetated soil detaches soil particles. Sheet erosion occurs when these soil particles are easily transported in a thin layer, or sheet, by flowing water. If this sheet runoff is allowed to concentrate and gain velocity, it cuts rills and gullies as it detaches more soil particles. As the erosive force, of flowing water increases with slope length and gradient, gullies become deep channels and gorges. The greater the distance and slope, the more difficult it is to control the increasing volume and velocity of runoff and the greater the resultant damage.

Gullies could be considered as signals of disturbance and accelerated soil, destabilization of hill slopes, and lowering of water table in alluvial aquifers. Apart from the loss in soil fertility and continuous diminutions of cultivable land, there is additional loss of properties to include loss of homes, household belongings, farm crop and utilities (Danladi and Ray 2014). Erosion by gullies can be an acute problem causing high sediment yield, removal of fertile protection and support for plants and erosion control.

Erosion generally degrades land and affects not just plants and animals but is capable of taking away human life, though it is a natural disaster but ways of preventing it can be thought about.

Ramat polytechnic premises suffers from several gully erosion point which require solution otherwise it can cause threat to adjacent structures in those areas. Hence there is the need to construct control structure that can reduce or prevent further increase in the gully cross section.

Aim and objectives of the study

The aim of the study is to determine the effectiveness of wire netting dam for gully erosion control, with the following objectives:

i. To design wire netting dam.
ii. To determine the initial volume of the gully channel.
iii. To determine the final volume of the gully channel after the raining season.

Globally, environmental issues have become major concern to governments and citizen of various nations, including Nigeria. The environment, which is at the heart of economic, social, cultural and human activities, has been disrupted by man's neglect and abuse pollution, deforestation, erosion, flooding, landslides, global warning etc are the aftermaths of this abuse in and on the ecosystem. By virtue of Nigeria's spatial extent and its location in the tropical latitudes, the country encompasses various climatic regimes and physiographical units, which have severely exposed the country to the destructive influences of climatically induced hazards including flooding, erosion drought and desertification (FM Env, 2005).

One serious geo-environmental hazard is soil erosion defined simply as, a systematic removal of soil, including plant nutrients from the land surface by the various agents of denudation (Ofomata, 1987). Soil erosion is a widespread environmental problem in Nigeria occurring in many parts of the country under different geologic, climatic and soil conditions. The degree of occurrence varies considerable from one part of the country to another; as well as the types and factors responsible for their initiation and development (Onwueme and Asiabaka, 1992).

The consequences of the occurrence of erosion are usually several and frequently hazardous to humans and their environment which are usually classified as on-site and offsite impacts.

In Nigeria, extensive areas of agricultural lands are eroded every year and most of these lands (cultivated and grazing) are change in to gullies. Gully erosion is geographically a widespread problem and is the worst stage of soil erosion. It is common in the semi-arid region, characterized by denuded landscape and flash floods. In the Ethiopian highlands, gullies are particularly severe and widespread covering large tracts of areas (Shibru 2003). Gully erosion is more difficult and expensive to control than sheet and rill erosion. It is also more spectacular than the other forms of erosion. Contrary to sheet and rill erosion, the damage done to land by gully erosion is permanent. Gully erosion also causes depreciation in land value by lowering the water table and depleting the available water reserves. Building and infrastructure are also undermined by rapidly advancing gullies.

On the other hand, in a lot of places poorly managed footpaths and cattle trafficking lines have been transformed to sever gully areas. Land degradation due to soil erosion, particularly gully erosion by water, is the main threat in the Amhara Region (Shibru 2003). This is manifested by the presence of s lot of gully affected area in all part of the region. Fertile farming / cropping fields, grazing fields, foot slopes of degraded hillsides, foot trails and cattle trafficking lines have been significantly affected by gully erosion. Besides, side drains of tarmac and gravel and roads, access and internal access roads, downstream area from bridges, culverts and fords have also been seriously affected. In the Tanah Belles Integrated Water Resources Development Project (TBIWRDP) area only, which is covering 85,026ha about 2% or 1370ha is affected by gully erosion (ENTRO, 2014). This has been verified by the Baseline Study carried out in ENTRO 2014. By implication, it means that Amhara National Regional State with a total area of 157,077 km2 (15% of the country) well over 300,000ha of its land is affected by gully erosion. This is disregarding other stages of erosion such as sheet, rill and stream bank erosion. The severity of gully affected area has also been well noted at national and regional levels (ENTRO, 2014).

. Therefore, this gully prevention and control guideline is prepared to provide consolidated and detail information for field workers, Woreda experts and discusses the characterization and its different control options in delivering advice to farmers to prevent any gully formation and also cure existing ones. When gully rehabilitation is planned, it will be important to consider the priority areas, its purpose, the required amount and type of physical and biological structure to be used, which would have the potential to heal the gully are crucial element that need to be considered during planning and implementation phases. It is in line with this that the preparation of the guideline has got prime attention and provide detail description on how to rehabilitate gully affected areas and bring them under productive use.

In view of the aforementioned facts, this gully characterization and gully control Guideline is timely, with the objective to provide basic knowledge of gully formation, its characterization/mapping and practical approaches for its control in the context of overall watershed development and management. The manual will be useful to professionals working at regional, zonal and Woreda levels including development agents in delivering their technical advice effectively and efficiently to formal in order to reduce the problems associated with gully and promote application of effective gully rehabilitation measures. It will enable watershed managers in assessing gully erosion and guide them about the actual biophysical gully treatment measures. It also serves as a reference material to cascade down similar trainings to development agents and the land users at large. Therefore, readers of this guideline are advised to use the guideline as a learning tool and a practical guide, which could be further enriched through practical field experiences considering the specific situation of a given area.

Process of Soil Erosion and Gully Formation

Commonly speaking, soil erosion generally refers to detachment and transportation of soil and soil material from the place of origin by water, wind, ice or gravity and deposition to another place. Broadly, erosion can be classified into two categories: Geological Erosion - Natural Erosion Accelerated Erosion caused by mankind

Geological type of soil erosion is a natural phenomenon and happens without the intervention of human being. When the soil removal to that of soil formation is compared, it is not critical to consider geological erosion as that of accelerated erosion.

Accelerated (man made) soil erosion is defined as the rapid removal of soil brought about by the intervention of man in the process of earning livelihood. When soil is bare of its natural protective vegetation because of human intervention, the soil is exposed directly to the abrasive action of the element of erosion mainly wind and water of which erosion by water is a significant contributor for soil erosion and land degradation.

The process of water erosion starts with rainfall. Raindrops which do not touch plants will have the splash effect, defined as the impact of raindrop on the soil surface. Soil aggregates are smashed and their particles thrown in all directions. From the surface, water can infiltrate the soil through pores, as long as they are not saturated. Excess water moves as overland flow ("runoff") down slope and detaches additional soil particles. When runoff is evenly distributed, sheet erosion occurs. Water usually tends to concentrate along the lowest parts of a soil surface and forms small channels called rills. Overland flow that concentrates in channels leads to the formation of rills and gullies. Rills are usually small and can be easily removed by tillage. Rill erosion is much more easily noticed than inter rill erosion. if unchecked, rill may extend into the subsoil resulting in gully erosion. Another cause of gully erosion is an increase in flood flow, which may be caused by deterioration of vegetation in a catchment and the concentration of flow in roads, footpaths, poorly maintained cutoff drains, waterways and cattle tracks, etc.

Erosion by water can occur as splash, sheet, rill, stream bank and gully erosion. This research work gives emphasis for gully erosion

Gully Erosion

Gully erosion is the erosion process whereby water concentrates in narrow channels and over short periods removes the soil. Erosion produces channels larger than rills. As the volume of concentrated water increases and attains more velocity on slopes, it enlarges the rills into gullies. Gully can also originate from any\depression such as cattle trails, footpaths, cart tracks, and traditional furrows and indicated neglect of land over long period of time.

Some gullies may be formed as a result of tunnel erosion, also known as piping. Tunnels develop particularly where the soil is highly sodic. Runoff water passes through cracks and macrospores (mole channels, termite holes, etc.) and on reaching the slowly permeable sodic subsoil, it moves laterally as sub-surface flow. Clay dispersions (as a result of high sodium content) may occur along the flow lines and lead to the formation of tunnels. Eventually, the roof of the tunnel may collapse and a gully is created.

The gully channels carry water during and immediately after rains and distinguished from rills, gullies cannot be obliterated by normal tillage. Thus gully erosion is the advanced stage of rill erosion much as rill erosion is the advanced stage of sheet erosion. The soil conservation society of America defines a gully as " a channel or miniature valley cut by concentrated runoff but through which water commonly flows only during and immediately after heavy rains: it may be dendritic or branching or it may be linear, rather long, narrow and of uniform width". On the other hand, in terms of stability criteria it can be classified as stable, meta-stable and unstable.

The rate of gully erosion depends primarily on the producing characteristics of the slope in the channel. The following stages of surface gully development are generally recognized:

Stage 1: Formation stage - In this stage the rill erosion scour of the top soil in the direction of general slope as the runoff water concentrates. This stage normally proceeds slowly where the top soil is fairly resistance to erosion.

Stage 2: Development stage - In this stage there occurs upstream movement of the gully head and enlargement of the gully in width and depth. The gully cuts to the C-horizon, and the parent material is also removed rapidly as water flows.

Stage 3: Healing stage - In this stage, vegetation starts growing in the gully.

Stage 4: Stabilization stage - In this stage, gully reaches a stable gradient, gully walls attain a stable slope and sufficient vegetation cover develop over the gully surface to anchor the soil and permit development of new topsoil.

Factors Affecting Gully Formation

Most of the gullies are formed due to human activities. Some of the major causes of gully formation are over grazing due to high cattle population, expansion of cultivation in steeper or marginal lands, cultivation without taking care of surplus runoff water, deforestation due to clearing of vegetation, unsatisfactory waterways and improper design of culverts and other structures. Generally, a gully is caused by a rapid expansion of the surface drainage system in an unstable landscape. Gully erosion is affected by several factors. Some factor. Some factors determine the potential hazard while others determine the intensity and rate of gully advance. The factors affecting gully erosion can be categorized into two groups: man-made and physical factors.

Mad-made factors

Improper land use

In developing countries, rapidly-increasing population usually migrate upland to occupy forests or rangeland. Most migrants cut trees, burn litter and grasses and cultivate crops on hillsides without using appropriate conservation measures. After a few years, the productivity of the soil is lost because of sheet, rill and gully erosion, and the land is abandoned. This kind of cultivation, (slash and burn or shifting cultivation) is repeated by farmers on other hillsides until the land loses its productivity there as well. Thus, the whole of an area may be completely destroyed by gulling as the gully heads advance to the upper ends of the watershed. Often the land development works, like, construction of water storage structures, drains and bunds, are not done properly. Consequently, failure of hydraulic structures or breaching of bunds occurs often resulting in sudden release of high volume of water. This results in the formation of gully particularly on steep lands.

Forest and grass fires

Many forest fires are caused by the uncontrolled burning used in shifting cultivation. These fires can easily spread into the forest and destroy the undergrowth and litter. Grass fires are usually ignited by farmers near the end of the dry season in order to obtain young shoots for their livestock or new land for cultivation. On slopes, the soil that is exposed after forest and grass fires is usually gullied during the first rainy season.

Overgrazing/free grazing

High cattle population and overgrazing constitute a major factor for gully formation in Ethiopia in general and Amhara region in particular. Uncontrolled overgrazing leads to denudation of vegetation and exposure of land to torrential rains. Overgrazing removes too much of the soil's protective vegetation over and trampling compacts the soil; thus the infiltration capacity of the land is reduced. The increased run-off caused old ones. Cattle grazing in and around active gullies extend the nick point and dimensions of the gullies. The fact that many gully affected lands are concentrated in the lower lying grazing fields is also adhered to the communal ownership of these lands.

Gully classes based on size

One gully classification system is based on size-depth and drainage area. Table 1 describes small, medium and large gullies as per the standard commonly used in many soil water conservation manuals. Some literatures may put slightly different numbers.

Gully classes	gully depth (m)	gully drainage area (ha)	Discharge (m^3/sec)
a) Small gully	<1.5	<10	<0.1
b) Medium gully	1.5 to 3	10 to 30	0.1 to 1
c) Large gully	>3	>30	>1

(Source: Thomas, 1997)

Gully classes based on shape

(a) U-Shaped gullies are formed where both the topsoil have the same resistance against erosion. Because the subsoil is eroded as easily as the topsoil nearly vertical walls are develop on each side of the gully. These types of gullies are created in areas where the soil is cohesive with high clay content.

(b) V-Shaped gullies develop where the subsoil had more resistance than topsoil against erosion. This is the most common gully form particularly in sandier and less cohesive soils. In the long term, many U-Shape gullies become V-Shape as the sides continue slumping until a stable angle develops.

(c) Trapezoidal gullies can be formed where the gully bottom is made of more resistance material than the topsoil and subsoil because the erosion rate along the gully bank is greater than long the bottom (Thomas, 1997).

Gully classes based on continuation

(a) Continuous gullies consist if many branch gullies. A continuous gully has a main gully channel and many mature or immature branch gullies. A gully network (gully system) is made up of many continuous gullies. A multiple-gully system may be composed of several gully networks.

(b) Discontinuous gullies may develop on hillsides after landslides. They are also called independent gullies. At the beginning of its development, a discontinuous gully does not have a distinct junction with the main gully or stream channel. Flowing water in a discontinuous gully spreads over a nearly flat area. After some time, it reaches the main gully channel or stream. Independent gullies a whole area without there being any continues gully, or they may occupy a whole area without there being any continuous gullies (FAO, 1987).

MATERIALS AND METHODS

The study was conducted in Ramat Polytechnic, Maiduguri, Borno State, Nigeria. The city is located between latitude 11055'N and longitude 130160E (Usman and Ibrahim, 2019). It lies on a vat sedimentary basin, which is flat with gentle undulations at an average elevation of 395m above sea level.

Feasibility Studies: Feasibility study was carried out to determine the extent of the gullying slope using rise/run method, soil type using physical inspection and soil textual analysis respectively.

Materials used for construction

The materials used for construction are beam level, plumb bulb, measuring tape, wire netting, pegs, broken blocks, scissors, nails, mallet and hammer.

Construction of the Wire Netting Dam: A row of wooden post were derived into the gully bed across the channel supported with smaller pieces of broken blocks and mixture of cement which made it stand very firm, the wire netting which extended at flood level in the downstream of the eroded channel were filled with broken blocks. The protection was made in such a way that it creates a barrier across the gully which will cause the burden carried by the run-off to be deposited along the channel from the base of the barrier and gradually, the gully will be filled because the structure only allows run-off water to pass through it but do not allow the soil particles to pass through hence there will be deposition.

Design Calculation

At the beginning of the experiment the length, width and depth of the gully were measured. The above parameters were used to calculate the initial area and volume of the eroded channel before constructing the wire netting dam across the gully channel.

Considering the nature of the eroded area which was irregular in shape, that lead to the application of Simpson's rule while determining the area of the eroded channel at every 6m interval

The value as proposed was calculated using Simpson rule, that is:

A = $^{S}/_{3}$ $(F_0 + L_0) x\ \Sigma_{\text{even ordinate}} + 2$ x $\Sigma_{\text{even ordinate}}$

Where:

A = x sectional area

F + L = first and last ordinates

In trapezoidal rule:

V = X $(A_{1/2} + A_2 + A_3 \ldots A_a + A_{a2})$

Where:

V = volume of eroded channel (m3)

X = total length of the gully channel (m)

A1, A2, A3… $A_{n-2,}\ A_{n-1,} A_n$ are the cross-sectional areas at every 5m distance along the channel as considered.

i. Determination of initial area at 6m interval along the gully channel using Simpson's rule.
ii. Final area at 6m interval along gully channel using Simpson rule
iii. Initial and final volume of the gully using trapezoidal rule
iv. Finally, volume of the sediments along the gully bed is calculated as volume of the sediment = initial volume - final volume

RESULTS AND DISCUSSIONS

The initial length of the gully was measured and found to be 30m long with irregular width and depth along the gully bed. The initial volume of the gully section under consideration was 0.303m and the final length of the gully and final volume of the experiment was found to be maintained at 30m with a final volume of 0.204m. The result shows that 0.204m of sediments has been deposited along the gully channel with barely half of the initial gully volume being reduced due to the effect of the control structure.

The construction of wire netting dam protection to control erosion have been proven effective as deposition of sediment has taken place and also prevented the gully channel from increasing its volume.

The Table of initial and final Depth of the Gully

The initial and final depth of the gully channel was calculated using the result obtained from the exercise. At every five meter (5m), the depth is given by difference between the reduced level on the ground surface and reduced level of the inside of the gully channel.

Table 1 Initial and Final volume of the Gully

Distance (M)	Initial volume (M^3)	Final volume (M^3)	Difference (M)
5	0.503	0.280	0.223
10	0.502	0.260	0.242
15	0.403	0.240	0.163
20	0.400	0.230	0.170
25	0.404	0.202	0.202
30	0.303	0.204	0.990

Width of the Gully Channels was obtained by using Measuring Tape at Every Five (5m) distance along the surface of the Gully Channel

Table 2 The Width of the Gully

Distance (M)	Initial volume (M^3)	Final volume (M^3)	Difference (M)
5	0.503	0.280	0.223
10	0.502	0260	0.502
15	0.403	0.240	0.163
20	0.400	0.230	0.4
25	0.404	0.202	0.202
30	0.303	0.204	0.303

DISCUSSIONS

The project on gully erosion control using wire nettings material have been carried out and proven to be good method of controlling gully erosion. Since soil erosion depth on rainfall intensity, a rainfall data for Maiduguri was obtained from a weather station at Maiduguri Airport in order to determine the mean annual rainfall.

Table 3

The data below shows the monthly rainfall obtained from the weather for the 2021. The value of which has been used for determining the mean annual rainfall.

Table 3 The Metrological Data

MONTH	MONTHLY RAINFALL (MM)
January	0.00
February	0.00
March	0.00
April	0.00
May	0.00
June	110.32
July	230.24
August	785.23
Total	**375.30mm**

Source: Maiduguri International Airport Weather Station, 2021.

CONCLUSION

From the result obtained in the experiment the wire netting dam has been proven to be very effective in the control of gully erosion. This is because the wire netting dam filled with broken blocks was relatively permanent structure which can take its effect for many years. The permanent structures are more durable and can be used to cause an appreciable control of gully erosion.

REFERENCES

Danladi, A & Ray, H.H. (2014) Socio-economic effect of gully erosion on land use in Gombe Metropolis, Gombe State. Journal of Geography and Regional Planning Vol. 7 (5) pp. 97-105

Egboka, B.C.E. and Okpoko, E.I., (1984). Gully erosion in the Agulu-Nanka region of Anambra State, Nigeria. Proceeding of the Harare symposium. IAHS Publication, 144:335-347

FAO (1987) performance of Gully Erosion control measure in Southeastern Nigeria. Journal Article of in AGRIS. Vol III pp. 163-172

Federal ministry of Environment (2005). National Erosion and Floor control policy,

Eastern Nile Technical Regional Office (ENTRO 2014) principles and practices of Watershed Management A Field Guide.

https://www.dirzon.com/Doc/ReaderAsync?target=telegram%3AWatershed%20management_field_guide-1.pdf

Maiduguri International Airport weather station (2021). weather Report from Metrological station.

Nwankwor, G.I; Ubong P. Udoka. 1., Boniface C. Egboka and Alex I. Opera. (2015). The mechanics of Civil - works induced Gully Erosion: Applications to development of preventive measures in south Eastern Nigeria. Applied Ecology and Environmental sciences, 3(2):60-65

Ofomata, G.E.K (1987). Soil Erosion in Nigeria: The View of A Geomorphologies. University of Nigeria, Nsukka Inaugural Lecture Series No. 7. ppl -43

Onwueme, I.C and Asiabaka, C.C (1992) Erosion as an Interactive force in the Human Environment. Erosion Research Centre, FUTO

Poesen, J., Nachtergaele, J.,Verstraeten, G., Valentin, C (2003). Gully erosion and environmental change: importance and research needs catena 50. 91-133.

Shibru Daba. 2003. CATENA, Volume 50, pp 273-291 https://doi.org/10.1016/s0341-8162(02)00135-2

Sidorchuk, A., Yu. 2001. Calculation of the rate of erosion in soil and cohesive sediments. Pochvovedeniye (soil science), 8: p. 1001-1008, (in Russian, English translation published in 2001, Eurasian Soil science, 34/8: p.893-900) (PDF) process-Based Models for Simulation and prediction of Erosion-Related Organic Carbon Losses on the National Scale: an Example for New Zealand Available from: https://www.researchgage.net/publication/228997031_process-Based_Models_for_Simulation_and_prediction_of_Erosion-Related_Organic_carbon_Losses_on_the_Natinal_scale_an_Example_for_New_Zealand [accessed Jan 14 2022].

Thomas, D.B. (1997). soil and water conservation. Manual for Kenya https://roadforwater.org/wp-content/upqloads/2019/11/Gully-assessment-and-prevention.pdf

Usman M.I. Ibrahim S.D Maize crop production constraint in coastal soil of Terengganu Region, Malaysia. (2019). International academic research consortium journals (IARCJ). Vol 8. No 1. 118-126.