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AN EVALUATION OF CAUSES, EXTENT, PATTERN AND EFFECT OF GULLY EROSION ON SOME SELECTED ARABLE LANDS IN YOLA SOUTH LGA, NORTH-EASTERN PART OF NIGERIA

Abdulqadir Abubakar Sadiq[1] and Ahmad Usman Ardo[2]

[1]Department of Agricultural Technology, Adamawa State Polytechnic P.M.B 2146 Yola Adamawa State Nigeria. Tel +234-70-68036372
[2]Department of Soil Science, Modibbo Adama University, Yola P.M.B. 2074, Adamawa State, Nigeria.

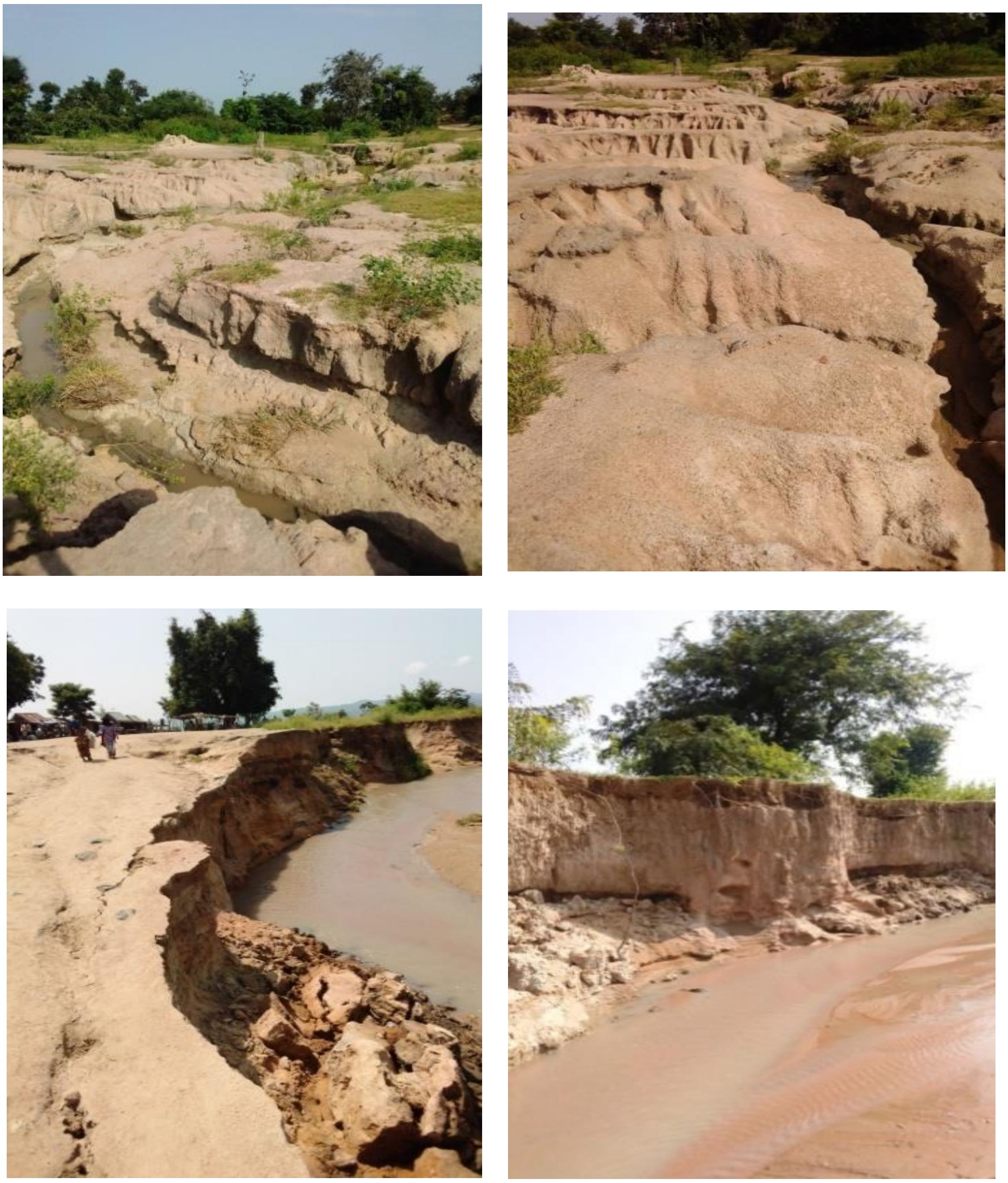
ABSTRACT: *The study attempts to estimate the causes, extent, pattern and effect of gully erosion on some selected arable lands in Yola South LGA, North-eastern part of Nigeria. Two hundred fifty (250) selected sampled farmers were administered well structured questionnaires in each farm location (Mbamba, Bole, Yolde pate and Wuro-chekke) on the causes, effects and control method of gully erosion and the obtained data were analyzed using simple descriptive statistics. Representative soil samples of the gully affected areas were collected and analyzed for soil related erosion properties (structure, texture, OM, porosity and permeability) using standard laboratory procedures. Direct on-field observation, identification and measurement of gully morphological parameters (size, shape, length, depth, width) were obtained and used to calculate extent of the gully (runoff area, gully density and soil loss) respectively. The result revealed that OM content of the area ranges from 1.52-2.10, porosity 38%-43%, clay loam and sandy loam were dominant. Overgrazing, improper land use and poor management were found to be the major cause of gully formation with medium to large size, U-V shapes with active and extreme damaged on arable lands. Total of 15 gullies were identified in the area with an average total length of 530 m, 14.3 m width, 11. 2m depth having an estimated runoff area of 7782 m^2, density of 0.04262 m/ m^2 and estimated soil loss of 2, 5409.8 M^3 respectively. Loss of productive land, sediment deposition on fertile land, siltation of dams and reservoirs were among the utmost effects of gully erosion in the area and most farmers saddled to adopt planting of trees and grasses, water ways constructions and sandbags techniques in an effort to curtail the existing menace in the area. To realize healthy and sustainable arable lands for optimum food production in the sty area, it is therefore recommended that effective training on the modern techniques of controlling and preventing of gully erosion should be given to the farmers by the extension agents coupled with proper land use and management techniques.*

KEYWORDS: Arable Lands, Causes, Effect, Erosion, Estimation, Extent, Gully, Pattern

INTRODUCTION

Soil erosion continues to be a major threat in many regions of the world most especially in tropical African countries due to both natural and anthropogenic factors causing devastating effects on the arable lands. Soil erosion is a significant environmental issue of common concern in the world today, serious water and soil loss resulting from what has become one of the main factors restraining local economic development (Chu, 1956, Poesen *et., al.*, 2003 and Tang, 2004). In the 2015 *Status of the World's Soil Resources* Report (FAO and ITPS, 2015), soil erosion was judged to be the number one threat to soil functions in five of seven regions (Africa, Asia, Latin America, Near East and North Africa, and North America); in the first four of those regions, the trend for erosion was deteriorating (FAO,2019). In twenty-first century, soil erosion by water has become a worldwide issue because of progressive decrease in the ratio between natural resources and population and to climate change. (Thlakma *et al.,* 2018). Water erosion is the single major process responsible for the loss of billions of tones of soils worldwide (Vahyala, *et al*,. 2018). The commonly recognized forms of water erosion are splash erosion, sheet erosion, rill erosion, gully erosion and stream bank erosion (FAO 1965; Dressing, 2003) of which gully erosion is the alarming and appalling stage compared with sheet and rill erosion. Gully erosion is a highly visible form of soil erosion that affects soil productivity, restricts land use and can threaten roads, fences and buildings (Nyssen *et al.* 2004; Avni 2005; Carey, 2006). Gully erosion is the erosion process whereby water concentrates in narrow channels and over short periods removes the soil. Gully erosion is considered one of the major issues of land sustainability because it can remove considerable volumes of sediment and productive soils (Aliakbar, *et al.*, 2018). The rate of gully erosion depends primarily on the runoff producing characteristics of the watershed, soil characteristics, alignment, size and shape of the gully and the slope in the channel. The gullies are one of the most complicated linear erosion features, due to their negative impacts generated on agricultural, rural, or urban areas, such as flash floods or landslides (Ben Slimane et al., 2016; Martínez-Casasnovas, *et al.*, 2009). The prediction of a gully's evolution is complicated, because they show different multistages, and are controlled by a large number of natural and anthropogenic factors (Hudson, 1995, Boardman, *et al.*, 1998; Ahmadi, 1999). Similarly, gully erosion is the most advanced stage of water erosion that also affects soil properties and depths, restricts specific land uses, and can threaten constructions (Gutiérrez, *et al.*,2011;Martínez-Casasnovas *et al.*,2013). Erosion by water is a serious problem in the tropics, especially in West Africa with its prevailing weather conditions of alternation of severe desiccation and high intensity rainfall coupled with erodible soils, which are often predominantly sandy in the surface layers (Aneke, 1986).

In West Africa, soil erosion gulps about 10-21 tons of top soils per ha on nearly gentle slopes of 0.4 - 0.8% and up to 30 - 35 tons on 1-2% slopes (Serageldin, 1987). In Nigeria, it has been reported that over 25 million tons of valuable top soils are lost annually to erosion (Ezedinma, 1982). Similarly, In Nigeria, World Bank (1990) estimated that soil erosion affects over 50 million people and account for loss of resources that amount to US 3000 million dollars per year. For decades, soil erosion has been a major environmental problem in Nigeria (Olofin, 1994)]. In addition, soil erosion. It has killed people, destroyed roads, destroyed homes, schools and farmlands and displaced poor people (Federal Republic of Nigeria, 2007). In the northeastern sub region of Nigeria; splash, sheet, rill and gully erosion may account for as much as 21tons of top soil loss per hectare per year (Adeniji, 2003). Though the region receives relatively low amounts of rainfall, serious erosion occur since the rains normally have large drop sizes and are of high intensities (Ekwue and Tashiwa, 1992). In Adamawa state, researches have shown that the different causes of soil erosion sprang from human activities for various purposes such as; intensive cultivation, over grazing, bush burning and deforestation. Soil erosion of various types and extent are also found in various parts of Adamawa state but most especially where man's activities have stripped off vegetation that normally holds and protects the soil (Thlakma *et al.*, 2018). Farmers in Yola and environs are seriously facing reduction in farm output annually due to the accelerated loss of topsoil through erosion from agricultural land which recognized as devastating threat to their profitable farming (Sadiq *et al.*, 2019a). Thus, plates below described the glaring effects of soil erosion on different farm locations of the study area.



Plates 1: Shows the Evidences of Devastating Effects of Gully Erosions on Farmlands in Yola South LGA, of Adamawa State.

Source: Pictures taking by the Author in September, 2019)

However, study has conducted recently by Sadiq *et al.*, (2019a) in the area titled "*Empirical analysis of farmers' perception on causes, variability and control measures of soil erosion on different lands in Yola and environs of Nigeria.*" which described soil erosion in general term without describing, identifying and quantifying the extent, morphological characteristics and pattern of gully erosions which caused exacerbated loss of substantial amount of soil damaging farmlands, reducing significant crop yield, silting of reservoirs, and dams and deposition of sediments on fertile farmlands. To address this threat, there is need to further evaluate the nature of gully erosion and its effect on arable lands in the area in order to fill-in the gap and provide sufficient and reliable information workable in providing practical recommendations towards curtailing the menace. Therefore, this research work is an attempt to estimate causes, extent, pattern and effect of gully erosion on some selected arable lands in Yola South LGA, North-eastern part of Nigeria.

Study Area

The study area is Yola South Local Government Area of Adamawa State which lies between latitudes 9013' North and 9012' North of the equator and between longitudes 12028' East and 12030' East of the Greenwich Meridian within an area of about 1139.1 square kilometers. The area is bordered in the East by Fufore LGA, in the West by Demsa LGA and in the south by Mayo-Belwa and Fufore LGAs. Yola South Local Government Area has a tropical type of climate marked by distinct dry and raining seasons. The dry season commences in November and ends in April; while the wet season is from May to September (Adebayo, 1999).

RESEARCH METHODOLOGY

The research work was based on both quantitative and qualitative primary data obtained from four (4) selected farm locations in the study area. The quantitative data were obtained from the used of well structured questionnaires administered to two hundred and fifty (250) sampled farmers from each farm location as independent sample area, where information about farming activities, causes, effects and control methods of gully erosions were recorded and analyzed using simple descriptive statistics where frequencies and percentages were presented. Similarly, on-field survey was intensively conducted in all farm locations where physical observation of landforms, vegetations and measurement of morphological characteristics and parameters of gully dimensions were identified and measured properly as depicted on plates 2 below. It was done through the dissection of gully length is into sections of same cross-(Stocking and Murnaghan, 2000) at an interval of 20 m where the depth, width and length of the gullies were measured using measuring tape and recorded accurately which was used to calculate the runoff area, gully density and total volume of soil loss on each farm locations. The width was measured at two points of the ridge top and at the middle point where averaged was obtained respectively. Representative soil samples of the gully affected areas in their disturbed forms were collected from each farm location. The collected samples were well labeled kept in a polythene bags and taken to the laboratory for analysis of properties affecting soil erosion which include organic matter contents, soil texture soil structure, pH and EC were analyzed using standard laboratory procedures which formed the qualitative data of the research work respectively. Other relevant information was sourced from journals, textbooks, proceedings and libraries which formed the secondary data accordingly.

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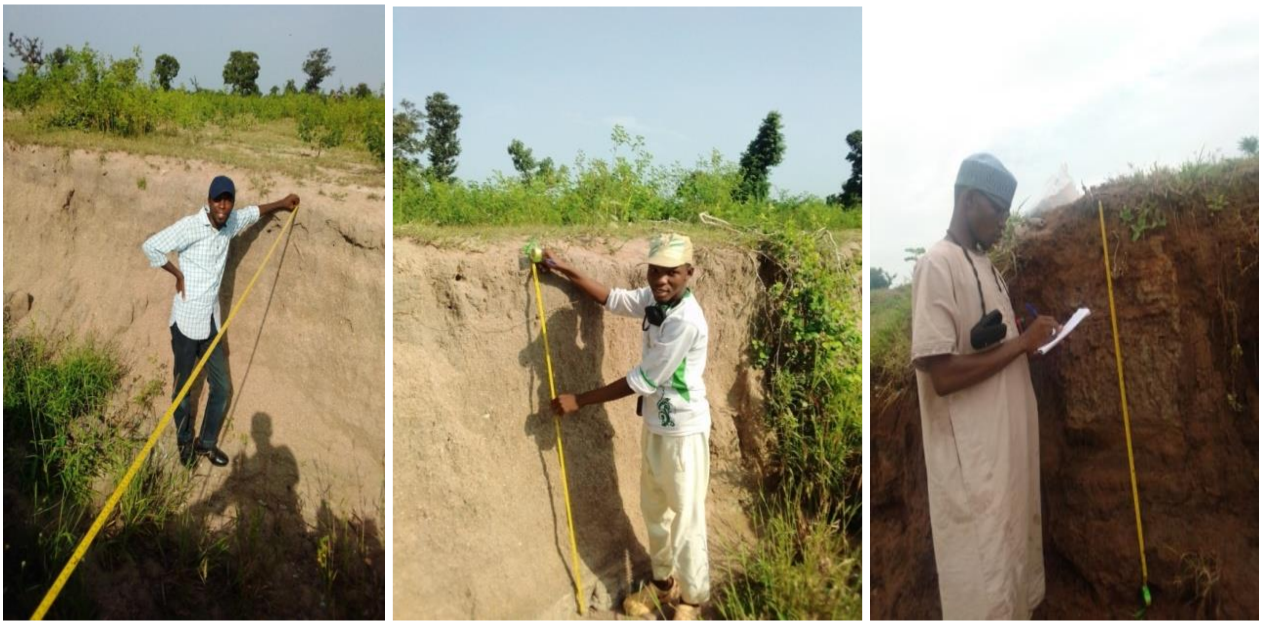

Plates 2: Shows the Physical Observation, Identification and Measurements of Gully Erosions on Different Farm Location in the Area During the On-Field Survey.

Source: pictures taking by the Author in September, 2019

RESULTS AND DISCUSSIONS

Table 1: Biophysical Parameters of Gully Eroded Farmlands in the Study Area

Farm Location	C.F Experience (years)	Present Land Use	Vegetation	Major Crop Grown	Major-Cropping System
Mbamba	5-45	Arable farming and animal grazing	Few tress and grasses	Rice, maize and cassava	Mono-cropping
Bole	5-30	Arable farming, animal grazing and Orchards	Tall grasses, trees and shrubs	Maize, groundnut, beans and rice	Mixed-cropping and Multiple cropping
Yoldepate	5-35	Arable farming and animal grazing	Few trees, grasses and shrubs	Maize and rice	Mono-cropping and Mixed cropping
Wuro-chekke	5-20	Arable farming and irrigation	Tall grasses and few trees	Rice, Sorghum and irrigation farming	Mono-cropping

Source: Field Survey, (2019).C.F =Conservation farming

Table 2: Some Soil Properties of Gully Affected Farmlands in the Study Area

Farm Location	Sand (%)	Silt (%)	Clay (%)	Bd (g/cm^3)	Porosity (%)	pH	EC	OC (%)	OM (%)
Yolde Pate	55	25	10	1.56	43	6.12	0.014	1.08	1.86
Bole	20	25	55	1.51	39	6.23	0.012	1.22	2.10
Wuro-chekke	15	25	60	1.50	38	5.45	0.011	1.13	1.95
Mbamba	65	24	11	1.58	40	5.23	0.013	0.88	1.52
Total Value	**155**	**99**	**136**	**6.15**	**160**	**23.03**	**0.050**	**4.31**	**7.43**
Mean Value	**38.75**	**24.75**	**34**	**1.53**	**40**	**5.75**	**0.0125**	**1.07**	**1.85**

Note: BD- bulk density, EC- electric conductivity, OC- organic carbon, OM- organic matter

Table 3: Causes of Soil Erosion on the Arable Lands in the Study Area

Farm Location	Bole		Yolde pate		Wuro-chekke		Mbamaba	
Effects	**FR**	**%**	**FR**	**%**	**FR**	**%**	**FR**	**%**
Over grazing due to high cattle population	38	15.2	31	13.2	23	9.2	37	14.8
Expansion of cultivation in marginal lands	37	14.8	33	12.4	34	13.6	23	9.2
Deforestation due to clearing of vegetation	34	13.6	28	11.2	29	11.6	21	8.4
Improper design of structures	10	4.0	40	16.0	32	12.8	18	7.2
Excessive rainfall	33	13.2	24	9.6	36	14.4	38	15.2
Improper land use and management	35	14.0	35	14.0	38	15.2	41	16.4
Deep and excessive tillage practices	30	12.0	34	13.6	31	12.4	38	15.2
Topography	33	13.2	25	10.0	27	10.8	34	13.6
TOTAL	**250**	**100**	**250**	**100**	**250**	**100**	**250**	**100**

Source: Field Survey, (2019). FR: Frequency

Table 4. Classifications of gully erosions on the arable lands in the study area

Farm Location	Dominant Gully Size	Dominant Gully Shape	Type of Gully Slope	Gully Continuation	Stage of the Gully Formation	Degree of Erosion	Activity
Yolde Pate	Large	U-shape and Trapezoidal	Steep	Discontinuous	*Healing stage*	Extreme	Less Active
Bole	Large	Trapezoidal and U-shape	Steep	Continuous	*Development stage*	Extreme	Active
Wuro-chekke	Small	V-shape	Moderate	Continuous	*Formation stage*	Severe	Active
Mbamba	Medium	V-shape	Steep	Continuous	*Development stage*	Extreme	Active

Source: Field Survey, (2019).

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Table 5: Extent and Morphological Characteristics of Gully Erosions on the Arable Lands in the Study Area

Farm Location	Number of Identified Gullies	Average Length of the Gully (m)	Average Width of the Gully (m)	Average Depth of the Gully (m)	Estimated Runoff Area (m^2)	Gully Density (m/m^2)	Total Volume of Soil Loss (M^3)
Yolde Pate	3	150	5.8	3.3	2, 610	0.0574	8,613
Bole	6	130	4.0	3.7	3, 120	0.0416	11, 544
Wuro-chekke	2	80	2.2	1.4	352	0.2272	492.80
Mbamba	4	170	2.5	2.8	1, 700	0.1000	4, 760
TOTAL	**15**	**530**	**14.3**	**11.2**	**7782**	**0.4262**	**25409.8**

Source: Field Survey, (2019).

Table 6: Effects of Gully Erosion on the Arable Lands in the Study Area

Farm Location	**Yolde Pate**		**Bole**		**Wurochekke**		**Mbamba**	
Effects	**FR**	**%**	**FR**	**%**	**FR**	**%**	**FR**	**%**
Loss of productive land	65	26.0	72	28.8	60	24.0	74	29.6
Destruction of farm facilities	18	7.2	33	13.2	30	12.0	35	14.0
Silting up of storage dams, lakes, waterways	25	10.0	19	7.6	41	16.4	15	6.0
Local lowering of the water table	15	6.0	10	4.0	23	9.2	11	4.4
Damage to infrastructures	38	15.2	18	7.2	13	5.2	20	8.0
Reduction of crop yield	39	15.6	53	21.2	34	13.6	40	16.0
Sediment deposition on arable lands	50	20.0	45	18	49	19.6	55	22.0
TOTAL	**250**	**100**	**250**	**100**	**250**	**100**	**250**	**100**

Source: Field Survey, (2019).FR: Frequency

Table 7: Control Methods of Soil Erosion Adopted by the Farmers on the Arable Lands in the Study Area

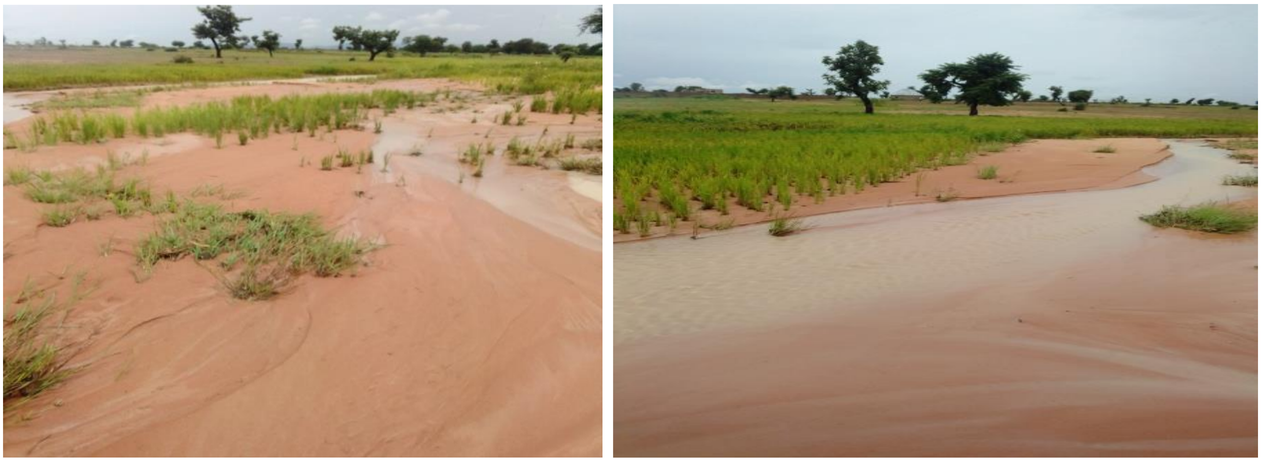
Farm Location	**Bole**		**Yolde pate**		**Wuro-chekke**		**Mbamaba**	
Control methods	**FR**	**%**	**FR**	**%**	**FR**	**%**	**FR**	**%**
Check dam constructions	18	7.2	30	12.0	20	8.0	35	14.0
Contour ploughing	27	10.8	35	14.0	15	6.0	30	12.0
Use of sand bags	45	18.0	55	22.0	45	18.0	55	22.0
Control grazing	15	6.0	15	6.0	15	6.0	25	10.0
Diversion of surface water techniques	25	10.0	35	14.0	45	18.0	15	6.0
Water ways construction	55	22.0	35	14.0	50	20.0	50	20.0
Planting of trees and grasses	65	26.0	45	18.0	60	24.0	40	16.0
TOTAL	**250**	**100**	**250**	**100**	**250**	**100**	**250**	**100**

Source: Field Survey, (2019).FR: Frequency

DISCUSSIONS

Mbamaba Farm Location

Results on biophysical parameters of gully eroded farmlands were presented on table 1. The results revealed that Mbamba farm location was under cultivation for the period of 5-45 years engaged in both arable and animal grazing systems. The vegetation is characterized with few tress and grasses and major crops grown were rice, maize and cassava as mono-cropping system res respectively. In addition, information on soil properties of gully affected areas were presented on table 2 where 65 % sand, 24% silt and 11 % clay constituted the soil texture, 1.58 g/cm^3 bulk density, 40 % porosity, 5.23 pH, 0.013 EC with an OC 0.88 % and OM 1.52 % correspondingly. Due to the high porosity and sandy particles of the soils might lead to reduction of rapid gully formation in the area through improving infiltration rate and reducing the run off capacity there by lowering the transportation processes. However, the OM content of the soil appeared to be low which might not cohesively bind the soil colloids to resist detachment from the hits rainfall intensity and in consequence increasing the erosivity rate of the soil particles. Among the factors that led to formation and development of gully erosion in the farm location as depicted on table 3, improper land use and management practices by most of the farmers appeared as the major cause (16.4%) contributed to the menace. Among such improper and poor agronomic practices adopted by most of the farmers include bush burning, removal of crop residues for economic purposes rather than recycling them to improve the soil organic matter among others which give rise to rejuvenation of gully erosion in the area. In addition, deep and excessive tillage practices as well as excessive rainfall each attributed to 15 % of the respondents. Most farmers employed the use of heavy tractors annually in ploughing beyond the plough layer of 10-15 cm there by destroying the soil structure, compaction and aggregate stability exposing it to speedy detachment and transportation by intensive rainfall and runoff respectively. Meanwhile 14.8 % of the farmers conceived it to overgrazing effects due to high cattle population in the area which posed greater calamity on soil degradation in the area. Thus, the area it was known to have occupied by the Fulani herdsmen for more than 50 years. Overgrazing affects soil structure, compaction rates, porosity, and top soil depletion which have led to soil erosion and reduced soil fertility. (Sadiq *et al.,* 2019b). Similar report was made by (FAO and ITPS 2015) on soil relict in the Jadan basin, Ecuador area where overgrazing led to excessive erosion and the soil has been completely stripped from most of the landscape in less than 200 years, exposing the highly weathered bedrock. Globally, Oldeman (1997), stated that 'on a global level, it is estimated that overgrazing is the cause of 35% of land. Table 4 presented the results on gully classification of the farm locations, at Mbamba area the dominant gully size was medium with V-shape structure developed on steep slope having an actively continuous development stage and extremely affecting the arable lands respectively. Thus, a gully is described as active when its walls are free of vegetation, however, when walls are stabilized by presence of a vegetation cover, they are described as inactive (Brady and Weil 2008). Moreover, the result on the extent and characteristics of gully erosions on the arable land were portrayed on table 5, at Mbamba farm location 4 gullies were identified with an average length of 170 m, average with of 2.5 m, average depth of 2.8 m having an estimated runoff area covered about 1, 700 m^2 and the gully density of 0.1000 m/ m^2 coupled with total soil loss of about 4, 760 M^3 respectively. On the effects of gully erosion in the area, loss of productive land was assessed 29.6 %. About one-third of land used for agriculture at global level has been affected by soil degradation where most of this damage was caused by water and wind erosion (Braimoh and Vlek, 2008). Sediment deposition on arable lands attributed 22% of the respondents. Owens *et al*., (2005) explained that an increase in sediment quantity lead to multiple effects. Among these effects lost of fertile agricultural lands and reservoirs appeared utmost in the farm location. Sadiq and Faruk, (2020) revealed that Mbamba farm location about 5-9 hectares of land were deposited with coarse-fine sandy soils (plates 3) of 5 years of sediment deposition to about 35 cm soil depth which presently imposed the arable land to an uncultivated land with damaged level of 60 % while an expected recovery period of 20 years with the projected damage remaining after recovery of 30 % as estimated from (USDA, NRCS, 1966) respectively.



Plates 9: Coarse Sandy Soils Deposited on Fertile Loamy and Clayey Soils at Mbamba farm Location in the Study Area

Source: Adopted from Sadiq and Faruk, 2020.

Moreover, 16 % of the farmers perceived to have reduced crop yield at Mbamba farm location as depicted on table 6 accordingly. In an analysis for Western Europe using the Revised Universal Soil Loss Equation (RUSLE) model estimates yield reductions of 0.4 percent annually for agricultural land that suffers from severe erosion (Panagos *et al.* 2016).In addition, according to the findings of Alemu and Awdenegest (2018) the result shows that, reduced in crop yield of 90% was affected on the farmlands due to exacerbated soil erosion at Southern Ethopia. Based on the control method of gully erosion by the farmers results were presented on table 7. From the result most farmers at Mbamba farm location (22%) adopted the use of sand bags as controlled method, 20 % attributed to water ways, planting of trees and grasses was employed by 16 % of the farmers in the area. These practices are considered more effective, simple and cheap methods among the small-scale farmers in the area towards curtailing the menace of gully erosion on their farmlands for optimum food production. Plates below depicted some glaring gully erosion at Mbamba farm location of the study area.

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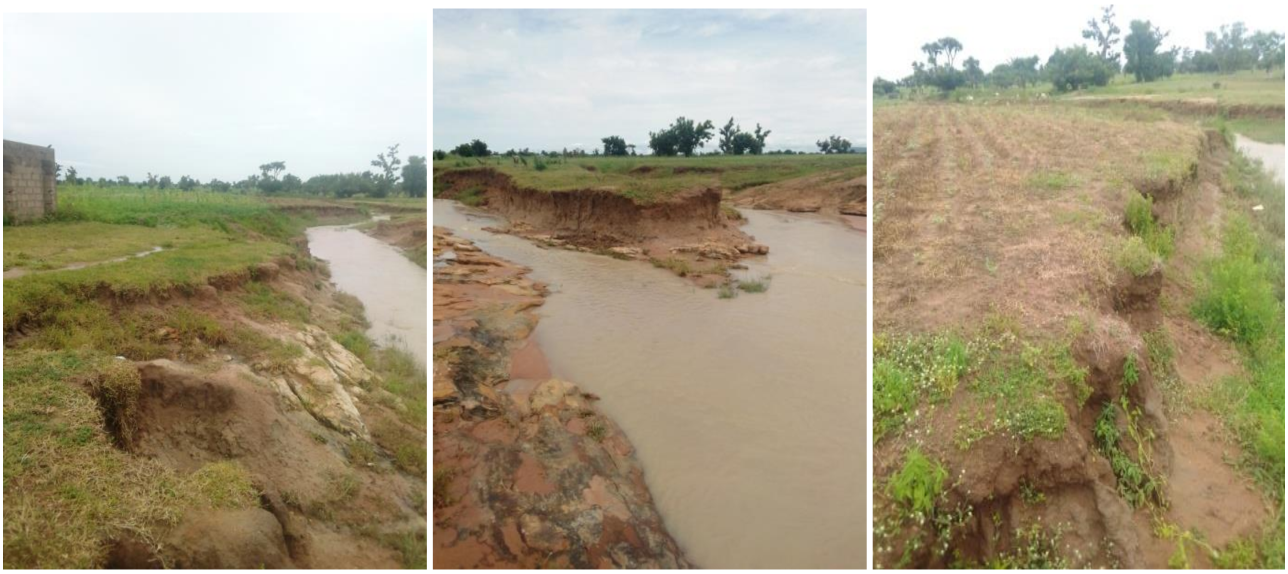
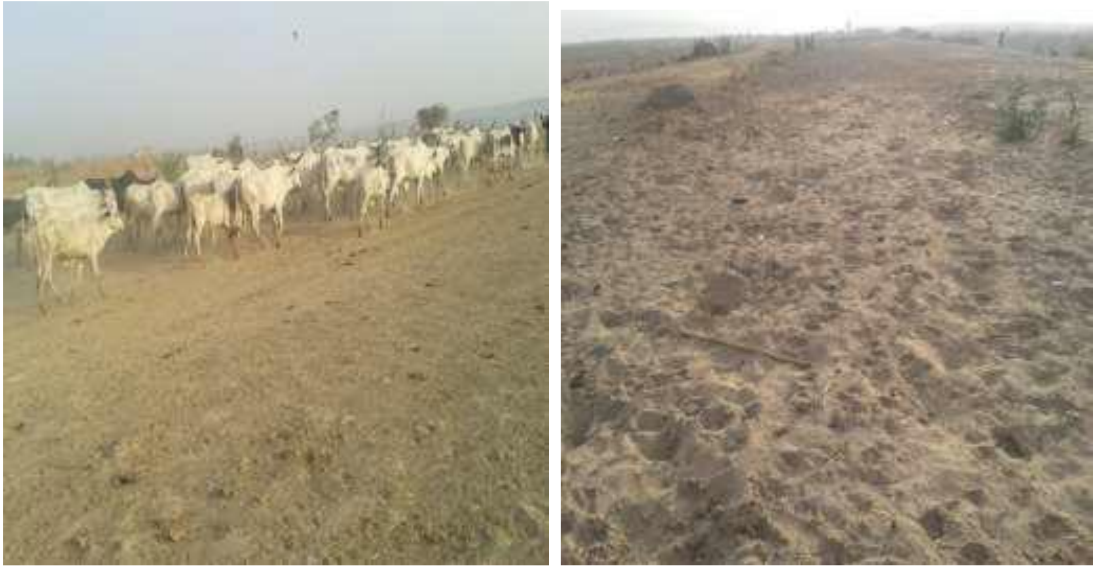


Plate 4: Shows Some Gully Erosions at Mbamba Farm Location in the Study Area
Source: Pictures taking by the Author on 29 September, 2019.

Bole Farm Location

About 5-30 years arable farming, animal grazing and Orchards farming activities were carried out at Bole farm location characterized with tall grasses, trees and shrubs vegetation. Majority of the farmers cultivated maize, groundnut, beans and rice in form of mixed and multiple cropping systems as presented on table 1 respectively. Clay soil was assessed with 55 %, silt 25 % and sand 20 % having a bulk density of 1.51 g/cm^3, 39 % porosity, pH 6.23, EC 0.012, OC and OM with corresponding values of 1.22 % and 2.10 as shown on table 2 correspondingly. The clayey nature of the soil in the area coupled with the OM content may easily predispose soils prone to erosion, because of the micropores availability in the soil which might lead to low infiltration and subsequently increasing run off progressively.

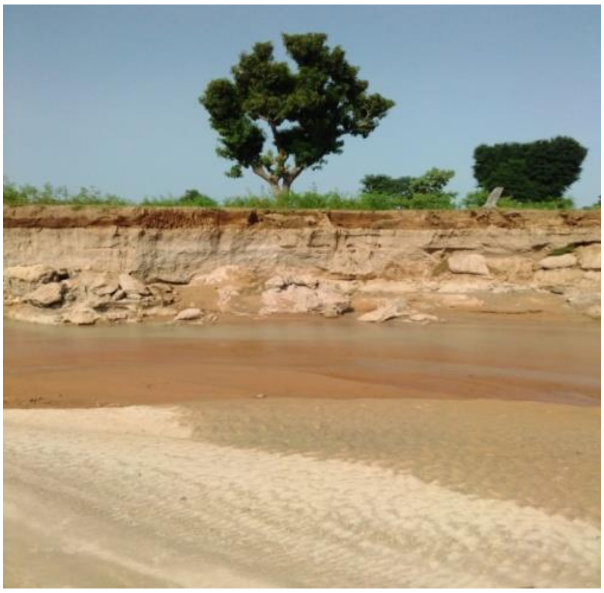
Similarly, on table 3 it was found out that overgrazing due to high cattle population in the area was assessed as the major cause of gully erosion in the area by 15.2 % of the farmers. Overgrazing implies excessive grazing or removal of grasses by animals, thereby exposing soils to degradation. Looking at the extensive nature of the production system in the area pastoralist and herdsmen moved their animals in and out of the area in accordance with seasonal changes as a consequence predisposing the soil to loss of organic matter, destruction of soil texture, structure and compaction which are premises of nutrients availability (see plates 5). Generally, it was revealed that overgrazing was perceived by 19 % of the respondents to had caused soil degradation in in Yola South LGA (Sadiq *et al*,. 2019c). Plates 5 below shows an evidence of overgrazing and its effects on soil properties in the study area.



Plates 5: The Grazing Animals Trampling on Farmlands thereby Destroying the Soil Structure

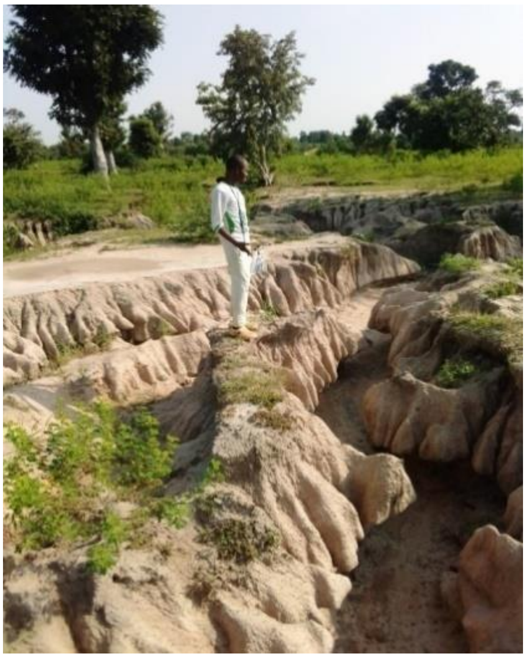
Source: Adopted from Sadiq et al,. 2019c.

Furthermore, about 14.8 % of the farmers linked it to expansion of cultivation in marginal lands. This might be connected to massive redeployment of most people into farming most especially in this current government where agriculture received holistic and ardent attention coupled with the migration of internally displaced persons from the northern part of the state that depend on farming as their primary functions led to invading of limited marginal land for farming purposes. Meanwhile improper land use and management attracted 14 % of the respondents, 13.6 % attributed it to deforestation due to clearing of vegetation. Sadiq,*et al.,* (2019b) further revealed that in Bole farm location unlike in most locations of the study area deforestation practices perceived by most of the farmers (26%) as the major cause of soil erosion. This might be inflicted to increase in population which leads to competition on marginal land around the area leading to intensive indiscriminate cutting down of trees and for other economic purposes. Generally, in Yola South LGA, of Adamawa State deforestation is among the main factor of soil degradation in the area, subsequently subjecting the area in to desert encroachment zone (Sadiq *et al.,* 2019c) .Thus, in Nigeria desertification is fast becoming a threat in the northern parts especially the states in the Sahel and Sudan Savannna areas (Uchegbu, 2002). Hence, deforestation may lead to soil erosion, loss of soil nutrients, and decrease in transpiration and evaporation losses, which may consequently lead to desert encroachment respectively. (sadiq, et al 2019 a). Likewise, 13.2 % of the farmers agreed to have caused by the nature of the topography as presented on table 3 accordingly. Sadiq and Shuwa, (2019) revealed that Bole is a riverine area sited on steeply (of about 20-22%) slope gradient with well rejuvenated rill to gully erosion having considerable devastation on farmlands and the area is located at the middle course of river chochi where lateral gully erosion was severe due high rate of transportation. Only 4 % conceived it to improper design of structures on the affected lands. Results on table 4 depicted the classification of gully erosions on the arable lands. At Bole farm location it was found that the size of the gully was dominantly large having both trapezoidal and U-shapes on a steep slope with continuous developmental stage actively causing an extreme damage to the farmlands in the area. Likewise, table 5 shows the result on the extent and characteristics of gully erosion on the arable lands, where 6 gully erosions were identified having an average length of 130 m, average width of 4.0 m, average depth of 3.7 m, affected an estimated runoff area of 3, 120 m^2 with density of 0.0416 m/ m^2 and 11, 544 M^3 of soil was lost annually on the various farmlands in the area. Thus, Murck, *et al*., (1996) estimated global rate of soil loss through erosion at over 25 billion tons per year for both rural and urban environments. Effects of gully erosion on arable lands were portrayed on table 6. The results revealed that at Bole farm location majority of the farmers (28.8%) agreed that loss of productive land by the gully erosion was the utmost effects coupled with reduction of crop yield which recorded 21.2 % (table 6). Also, sediment deposition on arable lands attributed to 18 % of the farmers and destruction of farm facilities received 13.2 % respectively. This finding concord with the recent findings of Sadiq *et al*.,(2019b) reported that an estimated average decline of 22% of farm productivity, was observed right from the time the land was put under cultivation to date, due to decline in soil fertility on arable farmlands of Yola South LGA. Not only that soil erosion negatively impacts on ecology and can lead to reduced crop productivity worsened water quality, lower effective reservoir of water levels, flooding and habitat destruction (Park *et al.,* 2011)]. For control method employed by the farmers, planting of trees and grasses was conceived by most of the farmers (26 %) in the area. Similar findings were reported by Sadiq and Shuwa (2019) explained that adoption of vegetative barriers as biological techniques was found to be most employed (24 %) by the farmers and agroforestry was adopted by 20 % due to the presence of tall trees in the area for sustainable food production. Hence, agroforestry is an important component of farming systems in humid tropics not only in terms of nutrient recycling and soil conservation but also in supplying food and firewood to the small farmers and ensuring overall sustainability of production (International Institute of Tropical Agriculture IITA.1986). Moreover, 22 % have adopted construction of water ways to redirect the water away from the farmlands and the use of sand bags attracted 18 % of the respondents in controlling the gully erosion as presented on table 7 correspondingly. Evidences of gully erosion were portrayed on plates 6 below.



(a)

(b)



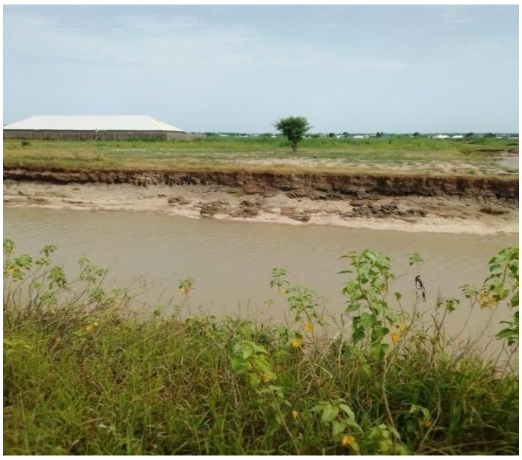
(c)

Plates 6: Evidence of Gully Erosion at Bole Farm Location in Yola South LGA

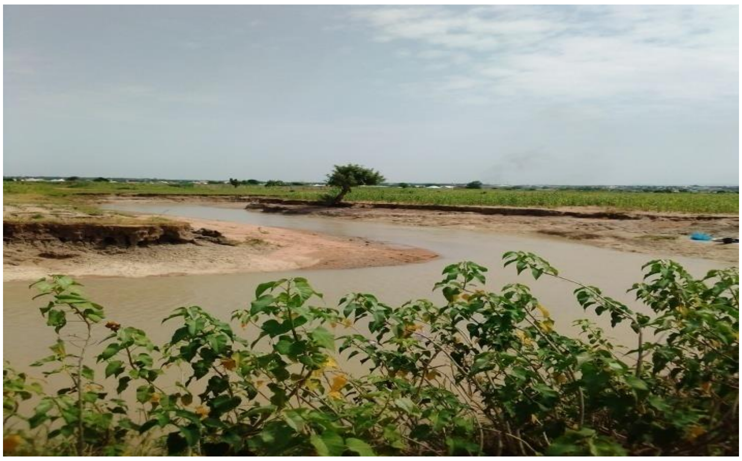
Source: Pictures taking by the Author on September, 28th 2019.

Yolde Pate Farm Location

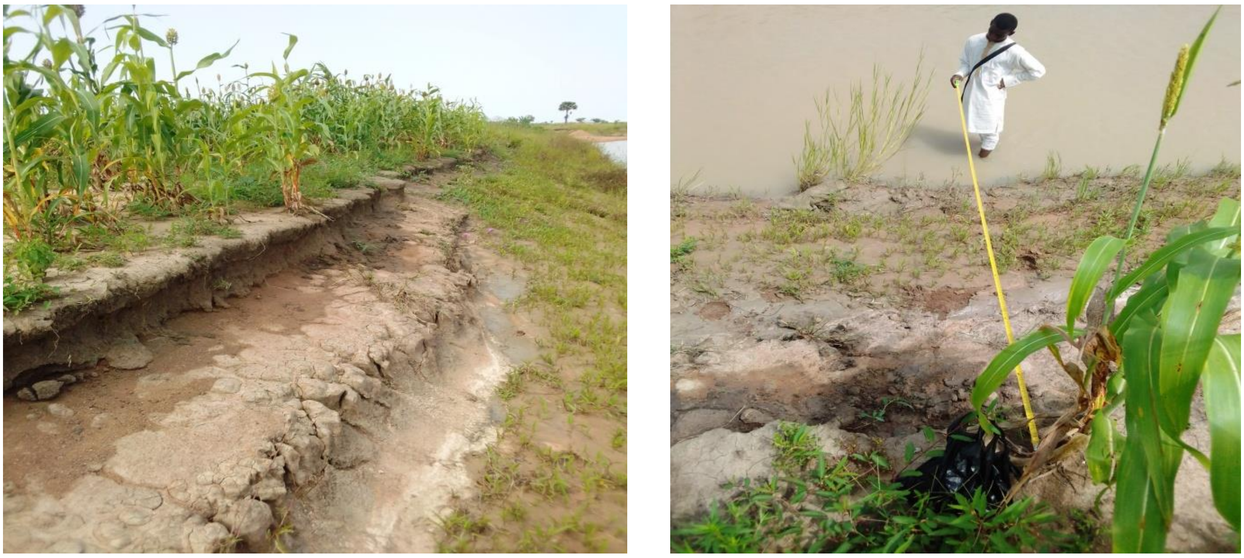
At Yolde Pate farm location cropping activities was revealed to carry out for about 5-35 % years (table 1) where arable farming and animal grazing were dominant and the vegetation composed of few tress, grasses and shrubs. The major crops cultivated in the area were maize and rice under mono-cropping and mixed cropping systems. Soil properties of the affected farm locations were depicted on table 5 which revealed that in the area sandy soil was dominant (55%), silt 25 % and 10 % clay. The bulk density of the soil was found to be 1.56 g/cm^3 , porosity 43 %, pH 6.12, EC 0.014 with OC 1.08 % and OM 1.86 as described on table 2. High infiltration rate might be associated with the soil type due to high porosity dominated with sandy particles thereby limiting the amount of runoff water that may cause the transportation of soil to generate erosion. However, the low OM of soil may not favaour the soil binding power to resist erosivity of water effectively. Among the causes of gully erosion in the area presented on table 3 shows that at Yolde Pate farm location improper design of structures was the major cause of gully erosion by 16 % of the respondents. Similar result was reported by Alemu and Awdenegest (2018) stated that lack of conservation structures attributed to about 61% of the farmers to have caused erosion in Alalicha watershed Southern Ethopia. Furthermore, 14% of them connected it to improper land use and management (13.6 %), deep and excessive tillage practices was also conceived by13.2 % of them agreed to have caused by over grazing due to high cattle population. This result is in conformity with the recent findings of Sadiq *et al.,* (2019b) who reported that overgrazing received 14 % of the farmers' perception as causal of soil erosion. The area is among the most intensive grazing activities thereby exposing the soil to erosion. Thus, according to the report of FAO and ITPS, (2015) an estimated rates of soil erosion of arable or intensively grazed lands have been found to be 100- 1000 times higher than natural background erosion rates. Furthermore, large gully erosion was appeared dominant in the area characterized with U-shape and trapezoidal shape on steep slope having a discontinuous nature under healing stage which caused an extreme damage on farmlands but with less activity potentials as depicted on table 4. Sadiq and Shuwa, (2019) explained that Yolde Pate area occupies a gentle to moderate slope rejuvenating rill to gully erosion having considerable effects on the arable farmlands dominated with maize and rice as major crops grown over 10- 25 years of farming respectively. Table 5 shows the extent and physical characteristics of gullies in the study area. The results revealed that at Yolde pate area 3 gullies were identified having an average length of 150 m, average width of 5.8 m, average depth of 3.3 m with an estimated runoff area of 2, 610 m^2 having a density of 0.0574 m/ m^2 with an annual soil lost of 8, 613 M^3 respectively. In the farm area, gully erosion was revealed as most variable and common with 27 % of the respondents (Sadiq et al.,2019b) Likewise, a study conducted in 2012 at Bangshika in Adamawa state of Nigeria, showed that volume of soil loss in gullies range from 697 M^3 to 3,362 M^3 (Babayi *et al.,* 2012). Similarly, loss of productive land was assessed (26%) as the major effects of gully erosion in the farm location as portrayed on table 6, followed by sediment deposition on arable lands 20 %, then 15.6 % attributed the effect to reduction of crop yield and 15.2 % of the farmers agreed to have damaged infrastructures in the area. Sadiq and Faruk, (2020) found that some farm locations at Yolde pate were deposited with loamy soil sediments with about 75 cm average depth over a period of 12 years covering about 15-21 hectares of farmlands, due to the gradual deposition of loamy clay soils with substantive quantity of fluvisols ignited the farmers in the area to take advantage of the deposition engaging in irrigation farming practices during dry season and rice farming on some areas in rainy season respectively. Generally, in Yola South LGA, about 73% of farmlands in the area are affected by erosion at different stages of development (Sadiq *et al.*, 2019b). A series of studies showed that the gully-based valley sediment yield accounted for 10% to 94% of the total watershed sediment yield (Poesen, *et al., 2003*). At Yolde Pate farm location result from table 7 shows that most of the farmers adopted the use of sand bags (22 %) while 18 % of them employed planting of trees and grasses and contour ploughing, diversion of surface water techniques and water ways construction each was adopted by 14 % of the farmers in the area towards controlling the gully threats on their farmlands effectively. This is because the techniques appeared more physical which required low technical know-how and easy to employ. Plates 7 below depicted some evidence of gully erosion at Yolde pate farm location.



(a)



(b)



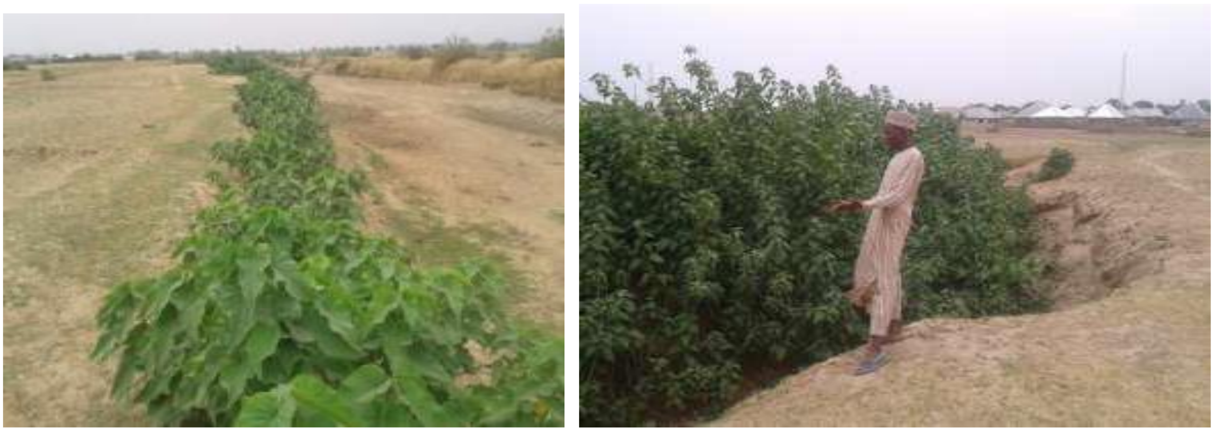
(c) (d)

Plates 7: Some Evidences of Gully Erosions at Yolde Pate Farm Location in Yola South LGA.

Source: Pictures taking by the Author on September, 22nd 2019.

Wuro-chekke Farm Location

Biophysical characteristics of gully affected farmlands were presented on table 1. Wuro-chekke farm location was revealed to have under cultivation for about 5-20 years dominated with arable and irrigation farming. The area is covered with tall grasses and few trees of vegetation while the major crop grown where the rice and local sorghum known as "*MUSKUWA*" under mono-cropping system. For the soil properties of the gully affected areas were presented on table 2, it shows that clay 60 %, silt 25 % and sand 15 % of the soil texture, bulk density 1.50 g/cm^3, porosity 38 %, pH 5.45, EC 0.011, OC 1.13 % and OM 1.95 % respectively. Presence of high clay content with moderate porosity may not favour good infiltration therefore resulting to high runoff on the arable lands and eventually developing rill to gully erosion in the area. Improper land use and management by the farmers attributed the major (16.4%) cause of gully erosion in the area. Alemu and Awdenegest (2018) in their study revealed that poor soil management practices (19%) and continuous cultivation (55%) have immensely contributed to the formation and development of soil erosion in the areaof Alalica Southern Ethopia. In addition, excessive rainfall and deep-excessive tillage practices each rated 15.2 % of the respondents, Sadiq and Shuwa, (2019) reported that excessive and intensive tillage may lead to severe loose in soil structure and endanger SOM. Minimum tillage not exceeding plough layer (15 cm) is recommended for the less compacted soils in the tropics. Over grazing contributed 14.8 % of the farmers and 13.6 % caused by topography as presented on table 4 respectively. In the area, the dominant size of the gully was identified as small characterized by V-shape, with moderate slope type in a continuous formation stage actively caused severe damage on the farmlands as described on table 5. The extent and characteristics of gully erosions on the arable lands were presented on table 6. The result explained that in the area 2 gullies were identified with an average length of 80 m, average width of 2.2 m, average depth of 1.4 m having an estimated runoff area of 352 m^2, with density of 0.2272 m/ m^2 causing a total volume of soil loss (492.80 M^3) correspondingly. Thus, the area has noticeable rill to gully erosion with notable steep topography having sediments and depositional materials spread over the low-lying adjacent areas (Sadiq and Shuwa, 2019). Among the effect of gully erosion in the area the trend remained the same as the loss of productive land was assessed by most of the farmers (24 %). On erosion effects decreasing farmland area and causing very serious harm to agricultural production, which has become a major source of river sediment (He, 2006; Wu and Cheng 2005). Hence, erosion has three primary effects on crop growth and yield: removal of the fertile surface soil horizon, incorporation of denser subsoil into the surface layer, and a possible decrease in the rooting zone of the soil. Meanwhile, sediment deposition 19.6 %, while silting up of storage dams, lakes, waterways attributed by 16.4 %, reduction of crop yield 13.6 % and destruction of farm facilities was contributed to about 12 % as described on table 7. Sadiq and Faruk (2020) explained that clayey soils are the original predominated in the area before it fluvially deposited with silt clay loam to an average depth of 55 cm over a period of 19 years covering about 22-60 hectares of arable lands. The perennial flooding of river Benue is mainly responsible for the deposition of fluvial fine textured forming an extensive organically rich soil forming floodplains (fluvisols). Sedimentation in lakes and reservoirs reduces life span and affects operation efficiency and costs, and in harbours and estuaries it requires dredging and its associated costs. Most of the farmers in the area have adopted planting of trees and grasses (24 %), construction of water ways was conceived by 20 % while use of sand bags and diversion of surface water techniques each was employed by 18 % of the farmers respectively. Sadiq and Shuwa (2019) reported that planting of vegetative barriers along farmlands boarder was dominantly employed by 30 % of the respondents with the aim of controlling and reducing rate of water run-off and soil lost on Wuro-chekke farm lands of Yola South LGA, Adamawa State.



Pates 8. The Use of Vegetative Plants as Barriers to Control Soil Erosion at Wuro-Chekke Farm Location.

Source: Adopted from Sadiq et al.,2019c.

CONCLUSION AND RECOMMENDATIONS

Soil erosion appeared as the major menace affecting soil ecosystem of the world which received ardent attention of scientific research towards ameliorating the adverse effects posed on the human population. In Yola South LGA, gully erosion which is the utmost threat of erosion among the type of water erosion seriously invading most of the arable lands in the area. The result revealed that the area is vulnerable to gully erosion development reducing significant farmlands, causing economic loss of yield, destroying dams and reservoirs due to siltation and sedimentation of transported debris. To ameliorate this hazardous scenario in the area complementary effort among the soil scientist, extension agents and decision makers should be collectively put in place towards finding possible workable solutions to the threat before getting out of hand. Thus, it is well said that *"prevention is better than cure".* This may be achieved through continuous and intensive training on preventive and control methods of the gully formation and development. In addition to that government at all levels should also key in towards providing necessary facilities required for the remediation. Similarly, proper land use and management should be adopted by the farmers in the area. Government should also intensify their effort towards providing sufficient and available grazing reserve lands under RUGA project. Thus, putting these strategies in to functional system the dream of good soil health will be actualized for sustainable and profitable food production for the growing population in the area and the country at large.

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