Assessment of soil erosion in cultivated fields using a survey methodology for rills in the northern part of Taraba State, Nigeria

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Abstract: *This study assessed soil erosion from 10 cultivated fields in the two comparable topographies using a survey methodology that focused on rills. The results revealed that rills were developed in all the 10 surveyed farms of the two contrasting land-use sites. The farm sizes on the hill slope site were lower but had the highest total numbers of rills compared to flatland farms. The field measurement of the rills parameters revealed greater length and depth of erosion in the hill slopes farm areas than on the flatland farm site. The magnitude and rates of rill erosion were also much higher and within the threshold range for the country-cultivated fields considered severe on the hill slope site than on the flatland site. This unveiled that soil erosion inform of rill erosion is a threat to agricultural production in the hill slope site. It was recommended that the expectations and perceptions of farmers be integrated into future studies to provide empirical evidence of farmers' preference for cultivating hillslope sites while there are flatlands.*

KEYWORDS*: Cultivated fields, Flatland farms, Hill slope, Rill erosion, Yorro.*

INTRODUCTION

The outermost layer of the earth's crust is extremely thin when compared with the rest of the crust. It is hardly half a meter thick; yet, human existence depends primarily on it (Adimassu, et al., 2014; Yusuf, et al., 2017). Within this very thin layer is the soil, an exceedingly fragile zone where nearly all of the man's food, fiber, and industrial crops are cultivated and on which all of his livestock are reared (Andrews, et al., 2004; Banwart, 2011; Zemba & Yusuf, 2012). The soil has been under assault from human and non-human agencies for thousands of years, and the precise type, and the magnitude, as well as the duration of the assault, varied in space, sometimes enormously. Similarly, there have been many variations in the socioeconomic and spatial expression of, and the attempted remedies for the impact of these assaults on the soil. The best-known or, at least, the most talked about, result of the assaults on the soils is soil erosion (Olowolafe, 2002; Yusuf, et al., 2017).

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Soil erosion is recognized as the single most important soil degradation process affecting the productive capacity of agricultural soil, and making it vulnerable to degradation, with resultant loss of valuable soil qualities, and its consequent negative effects on productivity, food security, and wellbeing of rural farmers (Yusuf, et al., 2016; Yusuf et al., 2017). In most agricultural regions of Nigeria, like most African countries, despite, an increasing concern among soil scientists, agriculturalists, environmentalists, and policymakers as to whether agricultural soils will always be enough to feed, clothe and shelter the expected 9.3 billion inhabitants of the country by the year 2050 (Adebayo, 2014; Zegeye et al., 2010). Despite also, the highly diverse and favorable soil and climatic conditions in certain ecological zones, soil productivity, and food security have remained variable and indeed on the decline, especially in the study region, where there is heavy land dependence with a low-external-input farming system, rapid population growth, poor attention to soil resources, and the need to maximize production to meet the needs of the growing population (Yusuf, & Garba, 2016).

Soil productivity and sustainable food production and food security in this region are thus threatened by soil erosion. Soil erosion manifested in the form of rills across the region, but at varying rates and levels of intensity, and assumes catastrophic dimension within a very short time in those areas such as hill slopes and flood plains where land is used beyond its capabilities and by those methods of soil and crop management that are ecologically incompatible (Adimassu et al., 2014; Sotona, et al., 2013; Yusuf, et al., 2015). The impact of soil erosion in the study region is observable with over eighty percent (80%) of the cropped land areas being wedged by varying levels and forms of rill erosion. Such impacts of rill erosion often translate into low yield, famine, low standard of living, migration of rural dwellers, food insecurity, and poverty (Yusuf et al., 2016;Yusuf, et al., 2015).

Hence, this unveils the danger of soil erosion activities and the need for a concerted effort in the fight against its effects. Moreover, since subsistence agriculture is the main mode of employment in rural Nigeria, and since, the soil is directly the basis of rain-fed agriculture. A clear understanding of the forms of soil erosion becomes imperative to the successful execution of any meaningful agricultural production in the country in general and the study region in particular. The prime objective of this study was to measure rill erosion magnitude, types, and severity of the two contrasting land-use sites in the study region.

MATERIALS AND METHODS

Methods

To achieve the objectives of the study, a reconnaissance survey of the study region was undertaken; where the major topographical, agricultural land use sites, areas with the severity of rill erosion, and farming systems, that are dominant in the region were identified. Also, many comparable agricultural land use sites (hill slope and flatland areas) were identified under a similar geographical setting concerning climate and crop types.

Multi-stage sampling techniques were then employed; firstly, the study area was divided into eleven wards based on their shared socio-economic and geophysical features as well as the types and levels of soil erosion and the presence of soil conservation measures. Secondly, from these clusters (wards), 3 wards, constituting 30% of the wards in the LGA area were purposively selected. Geographic location, population intensity, agricultural potential, and possibilities of representing the socio-economic characteristics of rural life were the most important considerations in selecting the wards. Thirdly, from each of the three wards sampled, two villages were randomly selected. Thus forming a sample size of 6 villages, in which one village was chosen based on the severity of rill erosion, land use, accessibility and representativeness of the study area, and the need to have two comparable hill slope and flatland farms representative of the study region for rill erosion measurement.

Fourthly from the village purposively selected, two comparable sites (hill slope and flatland areas) were randomly chosen for rill erosion measurements, and subsequently, ten representative farm plots; five farms plots each from the hill slope and flatland areas were selected randomly. The selected farms from the hill slope were within the slope angle range of 5-30%, while, those on the flat land were in the slope angle range of 0-4%. The reasons for the selection of ten farm plots were because; the study was a field-scale survey that requires large skilled labour manpower, the season for data collection (rainy season), and the researcher's believed that the ten farms can represent the whole region. However, sample farms were selected using homogeneity criteria of management and cropping history, slope characteristics, and conservation practices.

Fifthly, the farm plots under the hill slopes were categorized into three slope positions, based on FAO (2007) slope classification criteria: the upper slope zone (18-30%), which is moderately steep, middle slope zone (8-17%), which is sloping, and downslope zone (5-7%), which is gently sloping fields. Based on their relative slope positions, 3 farms were selected from the mid-slope and one each from the upper and downslope positions, (more mid-slope farms were selected because they represented the slope angle of much of the cultivated farms in the study region). On the flatland site, the surveyed farms were regarded as having uni-modal slope areas.

At both sites, the farms selected were under continuous cultivation and grown with guinea corn. The total area of the ten farms was 8.5ha; with 5.6ha and 2.9ha for the flat and hill slope farms respectively. The study was conducted between July to September 2021, when the greatest amount of rainfall (intense and erratic tropical rains), triggering substantial soil losses was recorded in the study region. During this period of the year, the soils are saturated at field capacity and the crops do not provide sufficient cover for the soil. However, due to limited time frames and budget constraints, only the length, width, and depth of the rills were carefully measured despite the significant impacts of channel size and shape of rills on measurement accuracy.

Assessment of rill erosion

Measurement of rill erosion dimensions and counting rills was carried out at the encounter of the emergence of every fit rill on the sampled farms. This was achieved by frequently visiting the farms immediately after rainfall storm had occurred. The measurement was carried out using a graduate leveling staff and meter tapes. Farm sizes were taken using meter tapes while slope angles around the rills were taken using an Abney level.

(a) Rill length measurement

The length of the fit rill was measured from their initial point of emergence up to the point where the eroded soils were deposited. While, the length of rills that comes laterally and merged with a central rill, was measured from their starting point to their point of convergence with the main rill. Measured rill length values allow for the determination of different magnitudes and volumes of rill to be calculated, which in turn, allowed for estimation of soil loss rates, rills density, and area of actual damage by the rill, as well as the proportion of area covered by the rills of the total farm sizes with an acceptable margin of error.

(b) Rill widths measurement

Widths of rills were measured at three points along a rill length to give a better estimate of the rill mean width because the width of rills varied along the rill.

(c) Rill depth measurement

Depths measurements of rills were taken at two or three points at a point and several points along the length because the depth of rills varied along the rill. Many studies including those of (Yusuf, et al., 2015; Zegeye et al., 2010) reported that both the rill width and depth measurements are used for the determination of rill volumes, which in turn, allowed for approximation of magnitudes and rates of soil loss for the farms with an acceptable margin of error.

From each farm plot in both sites, maximum fit rills, both in number and dimensions, were attained by 30th September 2021, after which no significant changes were recorded in the rill dimensions, despite the progressive soil losses when rainfall occurs. Thus, only the maximum values recorded were analyzed as representative of the total soil loss by rill erosion.

During the investigation, in-farm observations of the presence of surface runoff from areas in the upslope direction entering into the fields, rill networks within farms their patterns, and incidence of deposition were made. Similarly, the percentage of the crop canopy coverage was estimated whenever each rill measurement was undertaken. However, measurement of damages caused by the siltation of eroded materials was not made, as well as on-site rainfall measurements, because the only best approach to erosion measurement due to rills is an estimation of soil losses, and they exclude soil loss by the inter-rill erosion processes (Poesen, et al., 2003; Gessesse, et al., 2010)

METHODS OF RILL DATA CALCULATION

To achieve the objectives of the study, both quantitative and qualitative aspects of data analysis were used. The quantitative aspect of data analysis involved the calculation of the magnitude of rill erosion damage: the eroded soil volumes, areas of the actual damage, rates of erosion, and rill densities, as well as the percentage of area covered by the rills of the total area of survey farms from the measured length, width, and depth dimensions of the rills. While; the qualitative aspect described the qualitative data, which gave reasons for rill initiation and development (Gessesse et al., 2010; Wagenbrenner, et al.t, 2010; Zegeye et al., 2010).

The volume of soil lost from a rill (m^3) was calculated from the product of depth (m), Width (m), and length (m). Before this, the average width and depth of the rill were converted to meters by multiplying by 0.01. The calculated volume is equivalent to the amount of soil loss due to rill formation. From each of the farm plots, the total volume of soil loss (m^3) was obtained simply by summing the volumes of all homogenous rill dimensions. The calculated value was converted to a volume per square meter of farms, by dividing the volume of soil lost (m^3) by the square meter of farm area (m^2). The calculated value is equivalent to soil loss in (m^3/m^2). The soil volume from a given field was calculated using the formula

$V = \Sigma (Li\, Wi\, Di)\, Ni$--Equation *3.1*

Where,
V is the volume of a rill in m^3ha^{-1}
L is the rill length (m) of the rills
D is the rill depth (m) of the rills
W is the width (m) of the rills
N is the number of rills,
i is the number of homogeneous dimensions.

The volume of eroded soil was also expressed in terms of the weight of eroded soil by multiplying the calculated volume of soil loss in (m^3/m^2) by the measured bulk density of the soil at each of the 10 agricultural fields in the study region, and expressed the values in terms of annual soil loss rate (t/ha/yr) (Hancock, et al., 2008; Øygarden, 2003; Robichaud, et al., 2010). The total volumes of soil loss from a site were obtained by summing the volume of eroded soil in (m^3/m^2) from all farms. The calculated values were then converted into per unit hectare of land to express the annual rate of soil loss using equation 3.1.

Calculation of the area of the actual damage

The area of actual damage per unit hectare (total area surface covered by rills themselves) was obtained from the product of width and length dimensions of each homogenous rill segment by using equation 3.2.

AAD=Σ (Li Wi) Ni --equation 3.2

A Where,
AAD is the area of actual damage by rill in m^2ha^{-1}
L is the rill length (m) of the rills
W is the rill width (cm) of the rills
A is the area of each field (ha)
N is the number of rills, and
i is the number of homogenous dimensions.

Calculation of rill densities

The rill density was calculated by dividing the total rill lengths (obtain by summing up the measured length values of all rills) by the total area of the survey farms and expressed per unit hectare of land using equation 3.3.

$$D = \frac{\Sigma (Li)\, Ni}{A} \text{ --equation 3.3}$$

Where,
D is the rill density (mha^{-1}),
L is the rill length (m) of the rills
A is the area of each field (ha)
N is the number of rills, and
i is the number of homogenous dimensions.
The rill densities were also converted into per unit hectare of land.

Calculation of rill erosion damage

Rill erosion damage in terms of soil loss (t/ha) was calculated by the formula

$$SL\ (t/ha) = \frac{\text{Wt. of SL (t)}}{\text{Farm size}} \times 10{,}000 \text{ --equation 3.4}$$

Where SL is the rill erosion damage in (t/ha^{-1})
Wt.SL is the weight of soil loss (t)

Calculation of farm size

Farm sizes (m^2) were obtained by multiplying the length and width of the sampled farms. The number of rills originating from upper fields and rills initiated within the farms and their contributions to soil loss was identified in the study. The study did not employ advanced statistical techniques because it was based on survey data, which cannot be taken as accurate measurements of soil loss (Cerdan, et al., 2002; Di Stefano, et al., 2013). (Casalí, et al., 2006), also, suggested that advanced statistical methods should not be employed to analyze rill survey data. The qualitative data generated through the in-field observations were used to substantiate and augment the findings from the quantitative rill survey data.

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The study region

This article is based on a survey undertaken on two contrasting landscapes; the highland and flatlands in Yorro Local Government Area (LGA) of Taraba State, latitude 8^0 43^1 N and longitude 11^0 37^1 E (Fig 1). The area comprises the Mumuye and Kwaji districts and falls within the northern Guinea ecological zone of Nigeria, with a total land area of 1, 275 km^2 (Yusuf, 2014;Yusuf et al., 2016).

The climate of the region is characteristically of the tropical climate marked by dry and rainy season with the mean annual rainfall ranging from 819-1761 mm. the maximum temperatures, is moderately hot ranging from 26^0C and 28^0C, and the minimum temperatures range between 15^0c and 21^0c, and with relative humidity dropping to about15% in January and February, with Earth temperature at 0-20 cm soil depth (25-30^0C), evaporation rate (2-5 cm/day), and sunshine hours (6-7) per day in both sites (Yusuf, 2014).

The study area can be categorized into two zones on the bases of relief configuration; the highlands or mountain ranges and the lowlands. The highlands stretch from the east through south to west in chains of mountains (circular form) and formed part of the Atlantika Shebshi and Adamawa massifs ranges (compact group of mountains) (Ray & Yusuf, 2011; Yusuf, 2014). The highlands inhabit 65% of the area, with an altitude fluctuating from an average of 1, 800-2, 400 meters above sea level and characterized by undulating and rugged topography with steep slopes. The lowland occupied about 45% of the region's landmass was relatively gentler and flat with elevations ranging from 100 to 550 meters (Yusuf, & Garba, 2016).

The major soil groups in both sites are the hydromorphic and ferruginous tropical Soils subgroup that developed in crystalline acid rocks and sand parent materials with a well-drained sandy surface horizon over a clay subsoil. Though the soils are naturally fertile for agricultural productivity, they are susceptible to erosion especially if the vegetative cover is removed, and have low water holding capacity (Yusuf, & Garba 2016).

Entirely rain-fed agriculture is the principal economic activity in the study area and is destined mainly for home consumption. Farm business is a family affair with the head of the household as the decision-maker. Common crops cultivated include yam, Guinea corn, cassava, maize, and vegetables. Besides crops, the inhabitants also keep livestock such as cattle, sheep, and goats in large numbers (Yusuf, 2014). Other occupational activities such as pottery, cloth weaving, mat making, and blacksmithing are also carried out in the area (Yusuf, 2014; Yusuf, & Garba, 2016).

The major soil conservation practices applied by the farmers in both sites were traditional trenches known locally as. "Lambatu" was meant for safe disposal of surface runoff, stone, and soil bunds, known locally as "Kunya", for water erosion control and the application of organic and inorganic fertilizers to improve the fertility of the soil. The differences between the two sites in terms of land use and management practices were negligible (Yusuf, 2014).

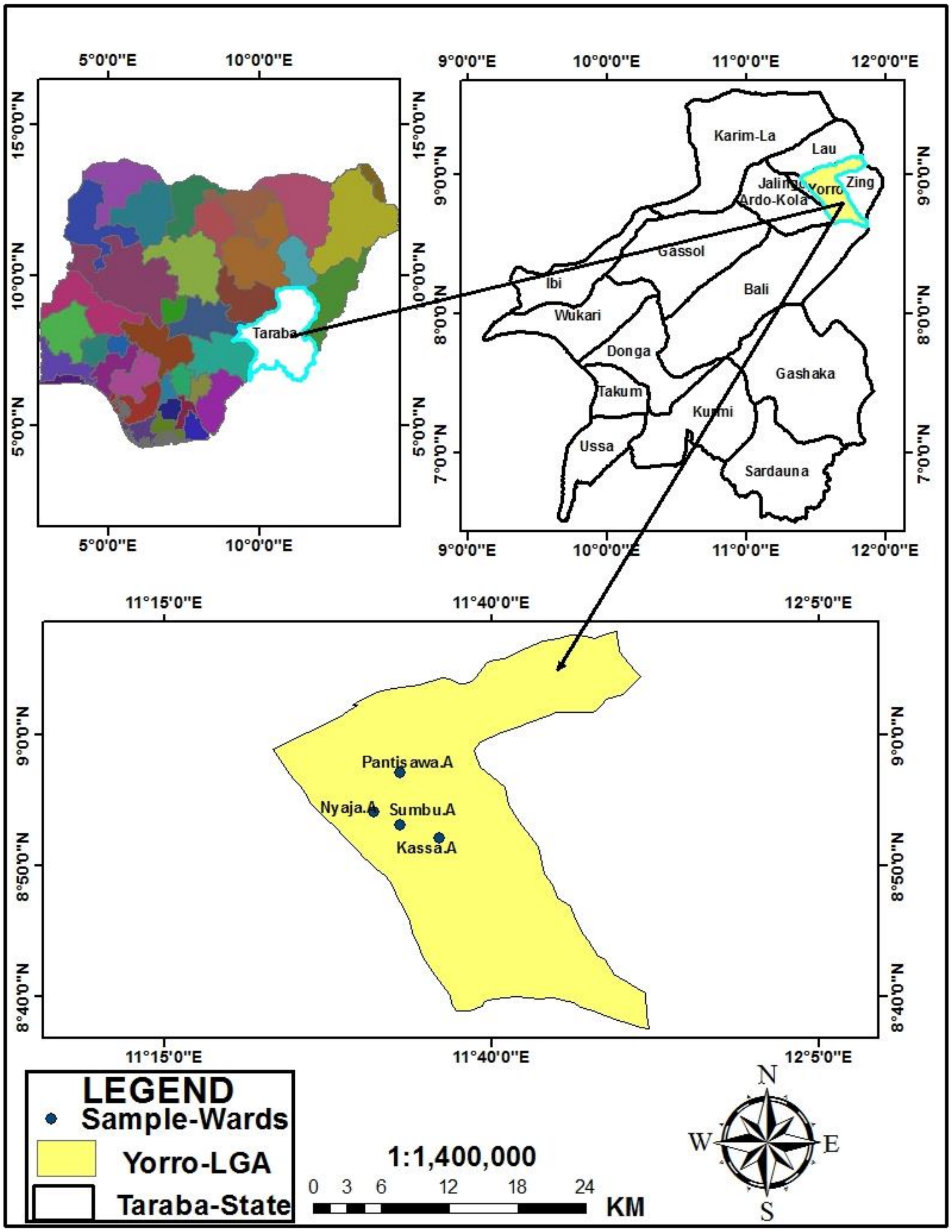

Fig. 1 Map of Taraba State showing Yorro

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RESULTS AND DISCUSSIONS

The result presented is based on a comparison of land use sites about on-farm effects of soil erosion within a sole rainy season over three measurement intervals; July, August, and September 2021.

Rill characteristics

Farm Site	Erosion survey period	No. of rills	Erosion features			Slope Range (%)
			Av. Length m	Av. Width (m)	Av. Depth (m)	
Hillslope	July	40	40.6	.160	.0941	5-30
	August	35	34.8	.128	.0872	
	September	30	26.4	.122	.0853	
	Grand total	**105**	**101.6**	**.368**	**.2266**	
	Grand mean	**35**	**33.9**	**0.14**	**0.889**	
Flatland	July	36	27.2	.176	.0581	0-4
	August	34	26.3	.173	.0565	
	September	23	16.0	.155	.0524	
	Grand total	**93**	**69.5**	**.505**	**.167**	
	Grand mean	**31**	**23.2**	**0.17**	**0.0557**	

Rills were measured in a total of ten surveyed farms at both the hill slope and flatland sites. Farm sizes ranged between 0.5 ha and 0.8 ha with mean values of 0.6 ha, and between 0.7 ha and 1.5 ha with mean figures of 1.1ha for the hill slope and flatland farms respectively. The hill slope site had the lowest total number of farm sizes 2.9 ha compared to 5.6 ha for the flatlands. Table 1 shows the measured parameters of the rill in the cultivated fields during the three survey phases (July –September, 2021) in the two contrasting land-use sites.

Table 1: Measure parameters of rills in the cultivated fields during the three survey phases (July – September 2021) in the two contrasting land-use sites.

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The results on measure parameters of rills on the sampled plots fields (Table1) show that a total of 105 rills with mean values of 35 rills were recorded on 2.9 ha of arable land at the hill slope site while 93 rills with mean values of 31 rills were recorded on 5.6 ha of arable land on the flatlands site. This means that the hill slope farms had a relatively larger number of rills than flatland farms. The differences in the number of rills formed imply that the site has significant effects in terms of the proportion of rills formation. This finding buttressed the earlier results reported by (Bocco, 1991; Cerdan et al., 2002). According to (Hancock et al., 2008; Yusuf, et al., 2015), soil erosion in the form of rill erosion is a serious problem in agricultural fields particularly in the hill slope site.

The differences in the number of rills formed could probably be related to differences in the biophysical factors such as rainfall characteristics and slopes gradient of the cultivated fields. As detailed by (Aksoy & Kavvas, 2005; Auzet, et al., 1993) cultivation of a hill slope environment accelerates the loosening of the cohesion of the underlying support from the base and such initiates erosion from the base. Similarly, on steep slopes, the velocity of overland flow is relatively high and the infiltration rates lower than on comparatively gentle slopes and/or flat plains. Thus, while the increase in velocity has the potential to dislodge and carry away soil, the buildup of surface runoff on hill slopes has the comparable ability in increasing rill erosion occurrence.

On the average length of rills, the results showed that it ranged between 26.4 m and 40.6 m, with a grand mean of 33.9 m at the hill slope site, and between 16 m and 27.2 m, with a grand mean value of 23.2 m at the flatland arable lands. This means that the hill slope farms had a relatively larger number of rill lengths than flatland farms. This finding, concerning rill length, showed that the site has significant effects in terms of rill length development. High rainfall intensities, the slope gradient, and slope length of the cultivated fields could be the reasons for differences in the mean length of rills values. Moreover, transect walks in the entire region confirmed that soil conservation practices were implemented on the flatland farms in amount, and type, in comparison with the hill slope farms.

Farm Sites	Erosion Survey period	Area of actual damage		Soil Loss Volume	Weight of Soil loss (t)	Rill Density	Soil loss (t/ha^{-1})	Soil loss due to inter-rills (30%)	Total Soil Loss (Rills + inter-rills)
		m^2	%	m^3	t	mha^{-1}	t/ha^{-1}	t/ha^{-1}	t/ha^{-1}
Hill Slope	July	259.84	.90	24.451	47.19	0.28	11.21	3.63	14.84
	August	155.904	54	13.595	26.24	0.21	9.05	2.72	11.77
	September	96.624	0.33	8.242	15.91	0.14	3.78	1.13	4.91
	Total	512.368	1.77	46.288	89.34	0.63	24.04	7.48	**31.52**
	Average	170.789	0.59	15.429	29.78	0.21	7.08	2.50	10.51
Flatland	July	172.339	0.31	10.013	10.91	0.09	1.95	0.59	2.54
	August	154.697	0.28	8.740	9.53	0.08	1.70	0.51	2.21
	September	57.04	0.10	2.989	3.26	0.03	0.58	0.17	0.75
	Total	384.076	0.69	21.742	23.70	0.20	4.23	1.27	**5.50**
	Average	128.025	0.23	7.247	7.90	0.07	1.41	0.42	1.84

The rill's mean width values averaged between 0.122 m and 0.160 m, with a grand mean value of 0.14 m in the hill slope farms, and between 0.155 m and 0.176 m with a slightly higher grand mean value of 0.17 m, in the flatland arable lands. As observed during field observation rill widths are generally larger on flatland farms, and most rills were initiated from outside the farm floor, before cutting into the inner farm. The reasons for the smaller rill widths on the hill slope farms, compared to flatland farms could be related to the surface roughness of the soil before and after planting which increases infiltration and decreases runoff was considered the major source of rills and sheet erosion in the region.

The average rill depth ranged between 0.0853 m and 0.0941m with a grand mean of 0.889 m for the hill slope arable lands. These values are slightly higher then the rill mean depth values of 0.0524 m and 0.0581m with a grand mean of 0.0557 m recorded on the flatland farms. The differences in rill depth values between the contrasting land-use sites suggest the significant effects of the site that can be a link to rill depth development in the study region. However, as observed during the field survey, the life span of most rills on both sites was not uniform throughout the measurement periods. Most of the shallow rills lost their depths and widths by sedimentation and by the growing crops and the roots anchorages that hold the soils. While some of the rills that joined the broader rills disappeared after a while.

The magnitude and rate of soil loss by rills

Table 2: The magnitude of rill damage on the two contrasting last use sites during the survey phases (July – September 2021) in the study region

Table 2 reveals that the area of actual damage (m^2ha^{-1}) ranged between 96.624 m^2 and 259.84 m^2, with mean values of 170.789 m^2, and between 57.04 m^2 and 172 m^2 with slightly lower mean values of 128.025 m^2 for the hill slope and flatland arable lands respectively. This, therefore, suggests that the site has significant effects on the total area of actual damage (total surface area covered by the rill themselves) in the study region. This finding supported the conclusions of (Boix-Fayos et al., 2006; Cerdan et al., 2002), that, soil erosion occurs in various forms depending on land use, but the mountainous regions and sloppy lands, where agriculture is practiced are especially more prone to severe erosion hazards following excessive deforestation, faulty cultivation, overgrazing, and developmental activities. Slope gradient, the slope length of the cultivated fields, and the contribution of conservation practices that were adopted at the flatland site in amount and type in comparison with the hill slope site farms could be the reasons for the differences.

The volume of soil lost from the rills (m^3) ranged between 8.242 m^3 and 24.451 m^3 with mean values of 15.429 m^3 for the hill slope arable lands, and between 2.989 m^3 and 10.013 m^3 with lower mean figures of 7.247 m^3 for flatlands arable lands. This means that more volumes of soil were lost on the hill slope farms than on the flatland farms in the study region. This finding, for volumes of soil lost, suggests the presence of a significant impact of sites in the study region. However, when compared to the volumes of soil loss estimated to occur from cultivated fields in the country, the estimated volumes of soil losses in the hill slope farms is much higher and within the threshold range for the country-cultivated fields considered severe. This result is consistence with the findings earlier reported by (Adebayo, 2014; Sotona et al., 2013;Yusuf, et al. , 2015) for the ecological zone.

The total soil loss (t/ha^{-1}) recorded over the three measurement intervals (July to September) on the hill slope site 24.04 t/ha^{-1} (equivalent to 53.97Mg ha^{-1}per year) is comparably higher than those recorded on the flatland sites 4.23 t/ha^{-1} (equivalent to 9.50 Mg ha^{-1} per year). This means that erosion has a more damaging effect on the hill slope site in terms of soil lost (t/ha^{-1}), than on the flatland site. This finding concurred with the explanation provided by (Aksoy & Kavvas, 2005; Auzet et al., 1993), that, soil erosion, which is manifested in the form of sheet, rills and gullies occur across the region, but at varying rate and level of intensity, and assumes catastrophic dimension within a very short time in those areas such as desert fringes, hill slopes and flood plains where land is used beyond its capabilities and by those methods of soil and crop management that are ecologically incompatible. The influence of rainfall intensities, slope gradient of the cultivated fields, and effective soil conservation techniques practiced at the flatland site could be the reasons for the differences.

However, when compared to 10-40 t/ha^{-1} (equivalent to 22.45-89.81Mg ha^{-1} per year) soil loss rates regarded as problematic for cultivated fields in the country, the estimated soil loss rates in the flatland site is much lower. The exclusion of inter-rill erosion could be the reason for such deficiencies in soil loss rates. The measurement of rill erosion does not consider soil loss from the land between the rills and thus underestimates the actual erosion due probably to difficulty in inter-rills measurements.

According to (Boix-Fayos et al., 2006; Rienzi, et al., 2013; Romero, et al., 2007), the contribution of inter-rill erosion can be more than 30% of the total soil loss in fields where rills are present. (Di Stefano et al., 2013; Gessesse et al., 2010) also reported that rill erosion underestimates 30% of the actual soil loss. (Yusuf, et al., 2015; Zegeye et al., 2010), also assumed 30% as actual soil loss, for the contribution of inter-rill erosion to soil loss in their studies. Also for this study, therefore, the researcher assumed that the measured rill erosion rates underestimated soil loss by 30%. Therefore, the soil loss through inter-rill erosion was about 7.48 tha^{-1} (equivalent to 16.79 Mg ha^{-1} per year) for all farms on the hill slope and 1.27 tha^{-1} (equivalent to 2.85 Mg ha^{-1}per year) for farms on the flatland. The hill slope site had the highest grand mean values compared to the flatland site. This means that the magnitude of rill erosion is more severe on the hill slope site, compared to the flatland site.

Similarly, assuming that, the measured rill erosion rates underestimated soil loss by 30%, the actual soil loss rates were 31.52 t/ha (equivalent to 70.77 Mg ha^{-1} per year) on hill slope and 5.50 t/ha (equivalent to 12.35Mg ha^{-1} per year) on the flatland. These estimates are within the range of soil loss rate under cultivated fields for the region regarded as severe for the hill slope and moderate for the flatland. This implies that soil erosion is a threat to agricultural production in the hill slope site and hence, the need to understand farmer's reason for cultivating the hill slope areas while flatland exists in the study region.

Rill Classification

A study by (Ekwue & Tashiwa, 1993; Govers, 1991) suggested that the classification of erosion rills could be undertaking by taken into account the rill width dimensions only. It was in light of these conclusions, that (Bewket & Sterk, 2003; Zegeye et al., 2010) used the rill widths to categorize rill erosion, for their studies on an assessment of soil erosion in cultivated fields using a survey methodology for rills in the Chemoga watershed, and of the rill erosion assessment in cultivated lands and farmers perception of soil erosion in Delbo Wogene micro-watershed both in Ethiopia respectively. To this end, only the rill widths were used to categorize rills erosion into size categories for this study, as the present study region has similar environmental conditions and is constrained by the same response mechanism. According to (Bewket & Sterk, 2003), rills can be classified as small or shallow (≤15cm), medium (16-30cm), large wide rills (31-45cm), and very large (≤46cm). Accordingly, three classes of rill were identified, small or shallow (≤15cm), medium (16-30cm), and large (31-45cm). Table 3 shows the characteristics of rills attained through a rill erosion survey at the two contrasting topography over the three measurement phases (July, August, and September 2021).

Table 3: Characteristics of rills attained via rill erosion survey (July- September 2021), at the two contrasting sites of the research region.

Rill Features	Hill slope Farms					Flatland Farms				
	July	Aug	Sept	Total	%	July	Aug	Sept	Total	%
Small	8	6	4	18	17.1	25	12	4	41	44.1
Medium	37	8	17	62	59.1	21	10	11	42	45.2
Large	13	7	5	25	23.8	6	3	1	10	10.7
Total no. of rills	58	21	26	105	100	31	17	18	93	100

Small (≤ = 15), medium (16-30cm), large (31-45cm) and very large (≥ 46)
Source: calculated from rill data obtained from field studies, 2021

From Table 3, the total number of rills recorded on the hill slope farms (105), and the flatland farms (93) during the three survey phases were categorized into rill size classes. The rill size categories varied from small (≤15cm), medium (16-30cm), and large (31-45cn), with an irregular flow pattern. Though the frequency differs, the highest percentages of the average number of rills were recorded in the medium (59.1%) and large size (23.8%) categories at the hill slope farms, and on the medium (45.2%) and small sizes (44.1%) categories on the flatland farms over the corresponding measurement periods.

Following this classification, the hill slope farms fall into the small, medium, and large size categories, with the medium accounting for the lion's share. The fact that the majority of the rill was medium, suggests that the rills may not start and end within the same fields without sedimentation features. Sedimentation indicates the redistribution of material. When sediments are transported out of the farms borders, fine materials and organic matter, which plays a vital role in soil productivity, might be transported outside the fields suspended in surface runoff. The large size category in the hill slope site suggests either high rainfall during the study period that was very erosive or the soils are very erodible or a combination of both (Di Stefano et al., 2013).

Similarly, in the flatland farms, the total number of rills was in the small and medium-size classes. The medium-sized rills contributed the largest share of the total soil loss corresponding to the number of rills. The contribution of the medium size rills to the total soil loss and the total area of actual damage was higher proportionate to their contribution to the total number of the rills. This analysis also suggests there is not much difference in categories of rills in the ten farms at the two contrasting topography. This might, therefore, be the farmer's reason for cultivating hill slopes while flatland exists.

This means that most of the rills developed on the hill slope farms were in the medium and large-scale categories while those on the flatland farms are in the medium and small-scale sizes. These differences in the sizes of rills suggest that the site has significant effects on the types and the development of rills categories or rills categorization in the research region.

CONCLUSION

The main focus of this study was to assess soil erosion from cultivated fields in the two comparable topographies through a survey methodology that focused on rills. The vision was to weigh the magnitude of soil loss. 10 representative cultivated fields (five farms plots each from the hill slope and flatland) were selected by a random sampling technique and used for this study. The results revealed that rills were developed in all the 10 surveyed farms of the two contrasting land-use sites. The farm sizes on the hill slope site were lower than those on the flatland site but had the highest total numbers of rills compared to flatland farms. The field computation of the rills parameters revealed that greater length and depth of erosion occurs in the hill slopes farm areas than on the flatland farm site. The magnitude and rates of rill erosion were also much higher and within the threshold range for the country-cultivated fields considered severe on the hill slope site than on the flatland site. The results for the types of rill categories revealed that the hill slope farms fall into the medium and large size groups while flatland farms on the small and medium-size classes. The medium class rills on either site had the highest proportion of the number of rills and were the largest contributors to the total soil loss and the total area of actual damage at both sites. This unveiled that soil erosion inform of rill erosion is a threat to agricultural production in the hill slope site. It was recommended that the expectations and perceptions of farmers be integrated into future studies to provide empirical evidence of farmers' preference for cultivating hillslope sites while there are flatlands.

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