Effects of tillage direction on sediment yield in the Chanchaga Basin

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Abstract: Sediment yield changes the hydrological cycle of rivers and reduces dam water storage because of poor ridge direction. In light of this, the study aims to assess the effect of tillage direction on sediment yield. The experimental design was mixed factorial, with four treatments (groundnut, cowpea, soybean, and no crop) and three replicates planted on the ridge across and along the slope. Sediment data got for two years on the field (2018-2019). Sediment yield calculated using the Standard method. The data were analysed using ANCOVA at α=0.05. The ridge along the slope lost twice as much sediment as the across slope ridge. The ridge along the slope was statistically significant (*p*-value=0.024; *p*-value=0.027) in Koropa and Shatta. The average sediment yield increased from 28.91 to 72.80 t $ha^{-1}yr^{-1}$ at the Koropa, while annual soil deposits for ridge along the slope were 33.66 and 38.06 t $ha^{-1}yr^{-1}$ at the Shatta. The ridge that ran perpendicular to the slope produced different results. The irrational ridge had a strong effect on sediment yield than the across slope ridge because of intensive soil cultivation. Except for cowpea, the results showed that the ridge along the slope still produced high sediments under soybean and groundnut. The irrational ridge is the main cause of water pollution, soil infertility, river sedimentation, and water depletion in the dam. There is a need to ban ridge along the slope in the Chanchaga Basin.

Keywords: tillage erosion, rainfall, contour line ridges, polynomial regression, cover crops, ANCOVA, runoff, sediment yield

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1 Introduction

Because of climate change and human activity, sediment yield in rivers and streams is still rising (Lu et al., 2019). Soil cover, soil texture, soil composition, porosity/permeability, and topography are all factors that contribute to soil erosion (Rehman et al., 2015; Dinka, 2020). Aside from these factors, a cover crop decreases soil and nutrient loss by reducing rainfall kinetic energy, which increases soil detachment resistance (Bhat et al., 2019; Lu et al., 2019; Zhang et al., 2010). The effects of sediment on the river include alterations of hydrological patterns, destruction of aquatics organisms, and pollution of surface water (Plentovich et al., 2020; Chen et al., 2020). It also induces reservoir sedimentation, which reduces the amount of water available for irrigation and drinking (Daramola et al., 2019).

Rainfall and runoff accelerate water erosion, and the ridge's storage capacity is overwhelmed on the land, resulting in surface runoff and throw away topsoil. Many studies have shown that the exponential model fit rainfall and runoff. Furthermore, Pena-Angulo et al. (2019) claim

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that rainfall, runoff, and sediment yield have a non-linear relationship. According to Zokaib and Naser (2012), there is a weak correlation between soil loss and runoff. Intensive and continuous soil cultivation damages the soil structure by sealing the surface, resulting in soil degradation. The concave and convex landscape also affect sediment yield. Convex landscapes lose soil over time, although the concave landscape aggrades soil, according to Blanco and Lal (2008). In the quest to identify the class of erosion, Molla and Sisheber (2017) classified soil erosion from low to extreme (150 – 716 t ha^{-1} yr^{-1}).

There are about three methods of estimating sediment yield, and these include measurement of land level changes, runoff measurement using catch pit and flow splitters (Lawrence, 1996). Most studies used runoff measurement using catch-pit to estimate the amount of soil loss (Munodawafa, 2012; Gabiri et al., 2015; Rehman et al., 2015). Runoff measurement through catch-pits could not entirely account for coarse sediments in the surface runoff because of most of them lacks sedimentation tank that separates coarse sediment from the suspended one on the field.

Many studies have found that across slope ridge (contour tillage) enhances infiltration and decreases soil and water loss (Guo et al., 2019; Tan et al., 2015; Liu et al., 2014; Quinton and Catt, 2004). On the other hand, the ridge along the slope causes soil depletion, infertility, erosion, and sediment yield (Dinka, 2020; Oladosu et al., 2019). It also causes excessive erosion and sediment yield due to intensive soil cultivation (Tan et al., 2015). According to Blanco and Lal (2008), soil transported by downslope tillage was twice that transported by contour tillage for mouldboard plough. Some research used cowpea and groundnut to mitigate the impact of water erosion (Rehman et al., 2015; Gabiri et al., 2015; Ewemoje and Kuti, 2021).

The contour ridge reduces erosion rates by 49.5 percent (Faharani et al., 2016). Furthermore, Blanco and Lal (2008) discovered that manual hoeing for downslope tillage in China resulted in erosion losses ranging from 48 to 151 t ha^{-1} yr^{-1}. Non-rational ridge is the primary cause of increased soil erosion and reservoir sedimentation in the Tagwai Dam (Oladosu et al., 2019). The effect of ridges across and along the slope has never been assessed in the Chanchaga basin, as some farmers prefer irrational ridge to contour ridges because cultivating on a nearly level (2%) to very gentle (3%) and gentle slopes (5 percent) is less expensive. As a result, the soil erosion and degradation rates in the Koropa and Shatta sub-basins are high. In the selected areas, assessing the effect of ridging across and along the slope on sediment yield is still lacking.

The sediment yield in the unploughed land was higher than the straw mulch and grass plots, according to Egharevba and Ibrahim (2006). Furthermore, Nda et al. (2017) reported that sediment concentrations were low in the Sabo Dagga River. Annual sediment loads in the Kwadna sub-basin are estimated to be 109.88 t ha^{-1} yr^{-1} (Adesiji et al., 2019). None of these studies has looked at the impact of ridges across and along the slope on sediment yield. As a result, the study aims to see how ridge across and along the slope affect sediment yield.

2 Materials and methods

2.1 Description of the study

An experiment was carried out in Paikoro and Bosso Local Government Areas of Minna, Niger State, which comprise of Chanchaga and Zungeru rivers. Koropa area lies on Latitudes 9˚ 32’ 03.78’’, 9˚ 31’ 29.87’’ N and Longitudes 6˚ 34 04.37’’, 6˚ 35’ 02.83” E. Shatta area lies on Latitudes 9˚ 42’ 34.75’’, 9˚ 41’ 13.84’’ N and Longitudes 6˚ 31’ 17.90’’, 6˚ 32’ 26.04’’ E as shown in Figure 1. Sandy loam was found in Koropa. Shatta's soil resembles loamy sand. April is the start of the rainy season, which lasts until October. Between October and November, the dry season begins and ends in March. The average annual temperature was 27.5°C, and the average annual rainfall was 1229 mm. Sandstones, loam, and sandy loam are all present in the soils. The soil has a good degree of fertility and drains well. The rate at which water reaches the soils is extremely quick. Groundnut, cowpea (bean), and soybean are the most widely planted crops in these regions.

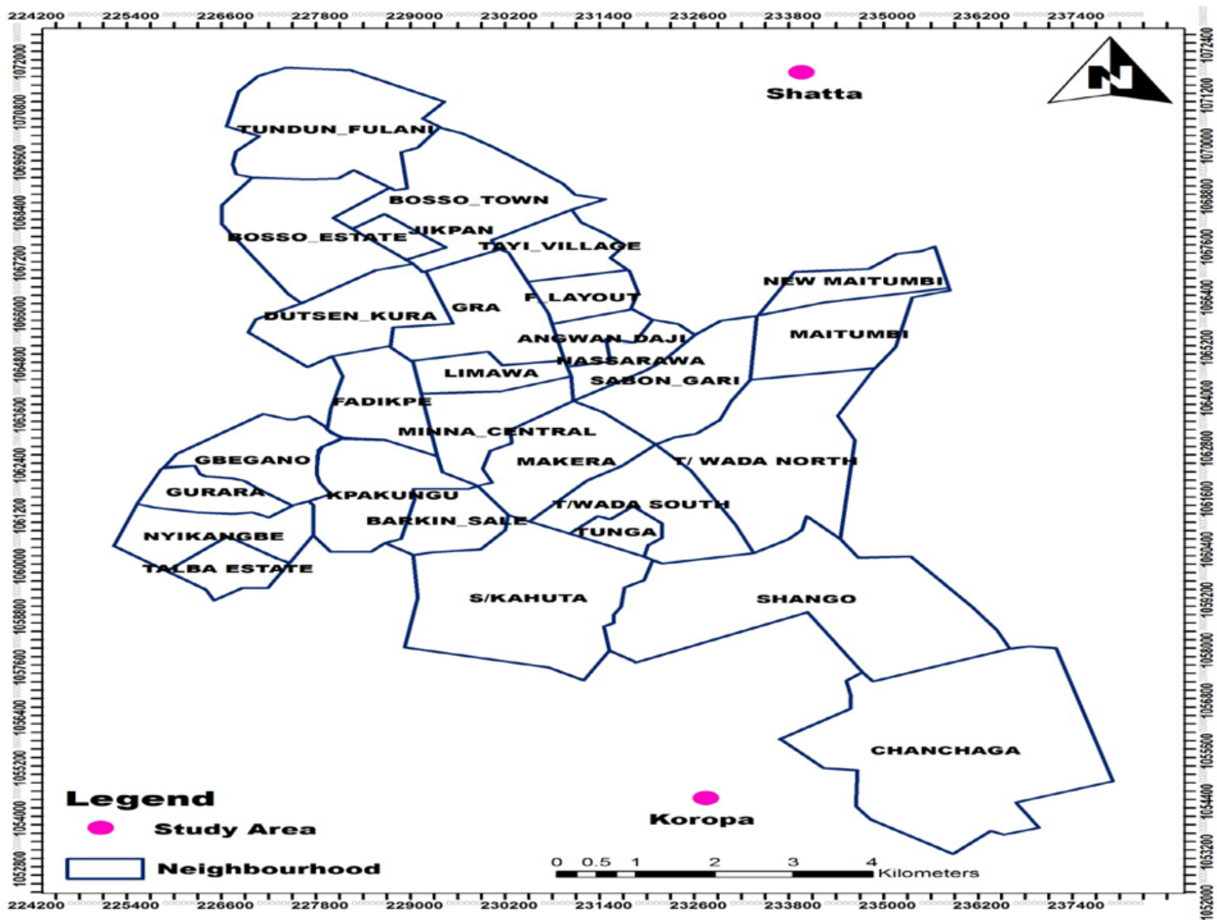


Figure 1 Location of the study

2.2 Experiment design and sediment measurements

In the Chanchaga basin, twenty-four experimental plots with similar slopes of 2%, 3%, and 5% were located near streams and rivers. Figure 1 shows the development of twelve (12) runoff plots on agricultural land in the Koropa and Shatta sub-basins. Every runoff plot was 11 m^2 in length and width (5.5 m and 2 m), exactly one-fourth the size of a typical USLE plot (Grace and Carter, 2000). Corrugated sheet was used to surround runoff plots, which protruded 20 cm above and sunk 10 cm below the earth's surface (Obani et al., 2016; Iwara, 2014). To store suspended and coarse sediments, a sedimentation tank was integrated into the runoff plot and storage tank. The sedimentation tank (20 L) and runoff plot were linked by a 5.5 cm long pipe (Grace and Carter, 2000; Moreno-de Las Heras, 2010; Jourgholami et al., 2017). As shown in Appendix I, another 8.2 cm long pipe (3 cm diameter) was used to attach the sedimentation tank to the 220 L storage tank (Moreno-de Las Heras, 2010; Jourgholami et al., 2017). Each plot had a 240 L storage tank. The length of the pipe was determined by the land's terrain.

The experimental design was mixed factorial, with four treatments (groundnut, cowpea, soybean, and no crop) and three replicates planted on the ridge across and along the slope (2 levels) on the runoff plots to minimise the number of runoff plots from 16 to 12 and save money and time. Each ridge stood 30 cm tall and was spaced 1 metre apart. The ridge along the slope and no crop served as the control of the experiment. Cowpea and groundnut seeds were planted differently in each plot, with plants spaced 0.2 m apart. Soybean was also planted with a 0.4 m spacing. In Kano, Ousmane and Ajeigbe (2009) suggested spacing between 0.20m and 0.25m for cowpea and groundnut. The crops spacing was kept the same as it was applied in the study locations. The tillage depth used in these areas was 30cm with a manual hoe. Crop progression is not taken into consideration because of the nature of this work. Rain gauges (Labcare) cylinders were mounted 30 cm above the ground level to collect rainfall data on the field. After three weeks of planting in the first year, the soil in each runoff plot was amended. Weeds were removed from each plot on a regular basis in between crop cycles. For two years, the experiment was carried out in Koropa and Shatta (2018, 2019).

The coarse soils (20 L) were removed in each sedimentation tank, and the water in each tank was transferred to the storage tank (220 L). Each storage tank's runoff water was measured using a plastic ruler. After vigorously stirring the total water, a 1 L runoff sample was taken. Soil loss in the bottle was allowed to settle at the bottom (1 L). The suspended sediment was then isolated from the runoff using a decantation process before being dried in a laboratory oven at 105°C for 24 hours. The amount of runoff water contained in the barrel was determined (Raghavendra, 2014).

$$Depth\ of\ runoff\ (m) = \frac{Volume\ (m^3)}{Area\ (m^2)} \quad (1)$$

The geometry of the tank had a top radius of 0.275 m, a bottom radius of 0.275 m, and a middle radius of 0.29 m. The barrel is 0.87 metres tall (height). Equation 2 includes the formula for calculating the volume of a barrel (https://www.onlinemath4all.com/barrel-volume-calculator.html.)

$$Volume\ (\text{Litre}) = \frac{h\pi\,(2R^2)+r^2}{3} \quad (2)$$

Where,

$r_1 =$ top radius of barrel (m)

$r_2 =$ bottom radius of barrel (m)

R = middle radius of barrel (m)

h = height of barrel (m)

The weight of soil loss in water and coarse sediment (Moreno−de Las Heras, 2010; Sensory and Kara, 2014; Ngetich et al., 2014; Gabiri et al., 2015) was measured in kilogrammes. The amount of runoff water collected in the cylindrical barrel was measured. To calculate soil loss, Equation 3 was used (Raghavendra, 2014).

$$Soil\ loss\ (Kg\ ha^{-1}) = Runoff\ (L) \times Soil\ loss\ (kg\ L^{-1}) \times \left(\frac{10{,}000}{Area\ (m^2)}\right) \quad (3)$$

Equation 4 was used to calculate sediment and is the total deposits that left each plot in the Koropa and Shatta sub-basins.

$$Sediment\ yield\ (\text{Kg ha}^{-1}) = Soil\ loss\ \left(\frac{Kg}{ha}\right) + coarse\ sediment\ \left(\frac{Kg}{ha}\right) \quad (4)$$

2.2.1 Mechanical and chemical analysis of the soil

Soil pH ranged from 5.00 to 5.80, and since soil pH regulates nearly all physiochemical reactions in the soil, the pH was able to hold water and avoid erosion (Ahaneku and Sadiq, 2014). Chanchaga and Maikunkele have the same textural class (sandy loam), while Shatta has loamy sand (Ahaneku and Sadiq, 2014). The Chanchaga soil particle size distribution included 74.10 percent sand, 10.16 percent silt, and 15.74 percent clay (Ahaneku and Sadiq, 2014). The soil was acidic, with a moderate amount of sodium that could be exchanged (Kuti et al., 2018).

2.3 Data analysis

The rainfall, runoff and sediment data were subjected to polynomial regression, and regression to determine their interactions. An analysis of covariance (ANCOVA) was used to evaluate the effect of contour and irrational tillage on sediment yield. The least significant difference (LSD) was also performed on the sediment yield to test their level of significance (Addinsoft, 2019). All analysis was done in XLSTAT 2019 and SPSS 23 version.

3 Results and discussion

3.1 Relationship between rainfall and sediment yield

The sediment yield model description is shown in Appendix II a. Rainfall and sediment yield had a poor relationship and did not affect total deposits loads, with coefficients of determination of 0.49 and 0.27, respectively (Appendix II a).

Appendix II b includes the coefficient values. Unstandardized beta for cubic and squared rainfall is statistically significant (p=0.001). A quadratic fits cubic rainfall and sediment yield in the Koropa sub-basin. In the Shatta, different outcomes were discovered. The explanation for this is that it only had one watershed.

3.1.1 Relationship between sediment yield and runoff

The relationship between runoff and sediment yield in the Koropa and Shatta sub-basins is shown in Table 1. The R^2 value (coefficient of determination) was similar to one. With an R^2 of 1, the regression perfectly suits the results. The results show that in the Koropa sub-basin, the exponential model matches both runoff and sediment yield, while in the Shatta sub-basin, the linear model fits them both. The explanation for this is that as rainfall increases by one, total deposit loads increase under the ridge along the slope, cover crops, and slope and agrees with previous research (El-Hassanin et al., 1993; Mingguo et al., 2007).

Table 1 Regression results of runoff depth (x, mm) and sediment yield (Y, t ha^{-1}) for Koropa and Shatta

Plot station	Power Expression and R^2	Quadratic Expression and R^2	Linear Expression and R^2	Exponential Expression and R^2
Koropa	$y = 144.83x^{1.1216}$ $R^2 = = 0.7642$	$y = -0.0044x^3 + 2.1366x^2 + 154.85x$ $R^2 = 0.6085$	$y = 307.65x$ $R^2 = 0.7978$	$y = e^{0.1262x}$ $R^2 = 0.7991$
Shatta	$y = 133.63x^{1.0118}$ $R^2 = 0.8346$	$y = 0.0012x^3 - 0.5401x^2 + 198.94x$ $R^2 = 0.5678$	$y = 145.6x$ $R^2 = 0.8347$	$y = e^{0.0706x}$ $R^2 = 0.7798$

3.1.2 Descriptive statistics of biannual sediment yield

In Koropa and Shatta, the sediment yield data points were 54 and 45, respectively.

Table 2 Descriptive statistics of biannual sediment yield

Location	Observations	Minimum	Maximum	Mean (Kg ha^{-1})
Koropa	12	11818.211	182139.068	71904.192
Shatta	12	21406.714	127356.957	54870.373

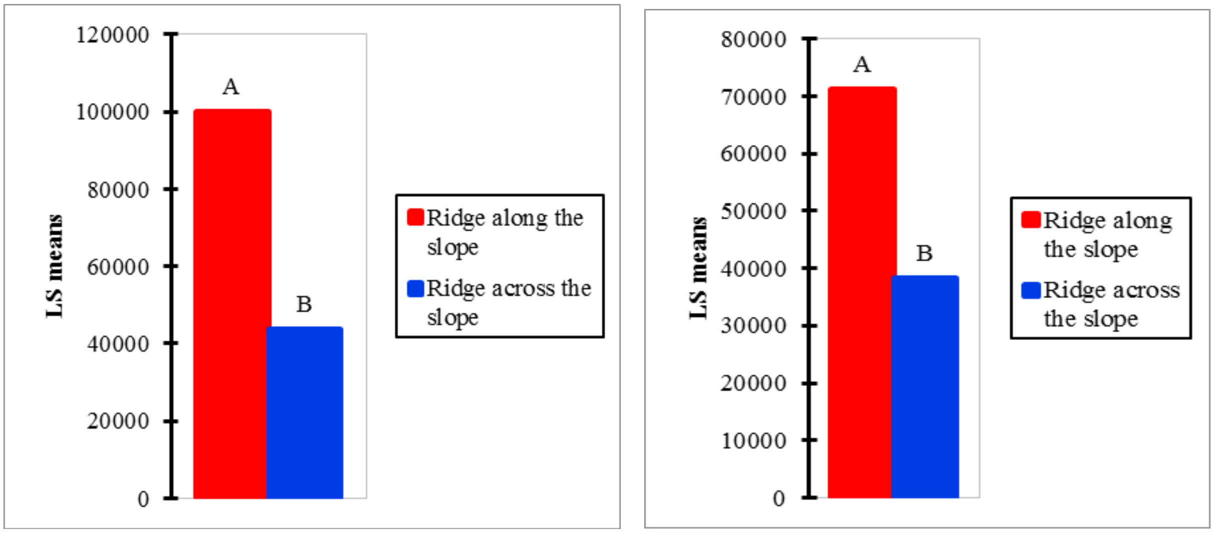
Table 2 shows the descriptive statistics of sediment yield in the Koropa and Shatta. 71.904 t ha^{-1} yr^{-1} and 54.870 t ha^{-1} yr^{-1} are the average biannual sediment yield. Sediment deposition appears to be increasing due to excessive rainfall and intensive soil cultivation in Koropa rather than Shatta. The results support previous research (Tan et al., 2015; Oladosu et al., 2019).

3.2 Effects of tillage direction on sediment yield

The model parameters show the sediment yield (Appendix III). The results prove that the ridge without crop has a severe effect (p-value=0.002) on sediment yield, followed by the ridge along the slope (strong effect with p-value=0.024), soybean (strong effect with p-value=0.035) in Koropa. The groundnut and slope have no significant influence on sediment yield (p-value>0.05). In Shatta, ridge without crop have severe effect (p-value=0.000), followed by the ridge along the slope (strong effect with p-value=0.027), soybeans (strong effect with p-value=0.031) and slope (weak effect with p-value=0.048). The cowpea and ridge across the slope have no value, implying no effect on sediment yield, as shown in Appendix III. The groundnut has no significant influence on sediment yield. It implies that these factors have different effects on sediment yield, except cowpea, ridge across the slope, groundnut, topography (Koropa). The effects of contour and non-rational ridge is more pronounced on sediment yield because of continuous cultivation soils and heavy rainfall. The results validate the existing studies (Tan et al., 2015; Oladosu et al., 2019; Ewemoje and Kuti, 2021).

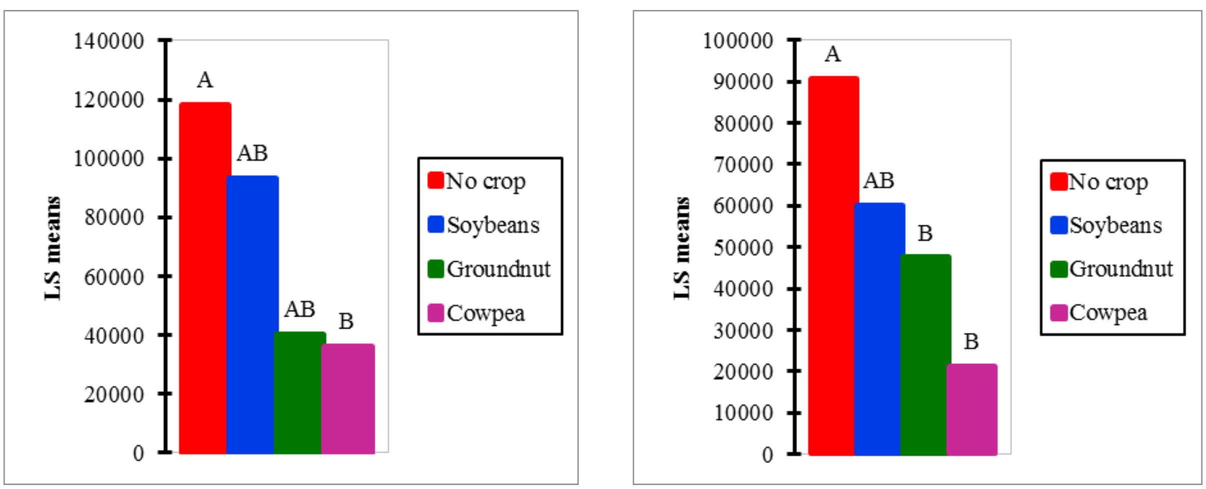
Figures 2a and 2b demonstrate a comparison of sediment yield under contour line ridges. The letter A represents sediment loss from the ridge along the slope, and letter B stands for sediment yield from ridge across the slope (B). Letter A and B (A) are substantially different in Koropa and Shatta (Figure 2a and 2b). Sediment delivery by the ridge along the slope was twice the contour ridge because of its intensive soil cultivation, which does not allow surface runoff to infiltration into the soil, transporting the topsoil in each location. This finding was in agreement with previous studies (Blanco and Lal, 2008). The results of LSD supported that ridge along the slope has a strong impact on sediment yield.

Figures 3a and 3b show a comparison of sediment yield under various cover crops. The sediment losses from ridge without crop (A) and soybean (AB) were the same because the two means shared at least one letter. The letters A and AB stand for "ridge without crop-related sediment losses" and "groundnut sediment losses," respectively (Figure 3a). Despite the fact that two means share at least one letter, the letters A (sediment losses from ridge without crop) and B (sediment losses from cowpea) are statistically distinct. As shown in Figure 3a, the letters AB (groundnut sediment losses) and B (cowpea sediment losses) are similar in Koropa.



(a) Koropa (b) Shatta

Figure 2 Comparisons of sediment yield under contour line ridges



(a) Koropa (b) Shatta

Figure 3 Comparison of sediment yield under selected cover crops

The letters A (ridge without crop) and AB (soybean) are not significantly different since they share at least one letter. Furthermore, the letters A (no crop) and B (groundnut) have a wide variety of meanings (Figure 3b). The letters A (ridge without crop) and B (cowpea) are significantly different because they share no letter. The letters AB (soybean) and B (groundnut) are not statistically different since they share at least one letter. Furthermore, since two means share at least one letter, the letters B (groundnut) and B (cowpea) are statistically indistinguishable. As a result, cowpea sediment losses were low, as shown in Shatta (Figure 3b). The explanation for this is that cowpea and groundnut reduce water erosion and promote runoff by reducing raindrop impact. The findings matched those of others research (Rehman et al., 2015; Gabiri et al., 2015; Ewemoje and

Kuti, 2021). The reason for these variations in both locations is due to different soil types.

The normality test for sediment loss shows in Appendix IV. The residual follows a normal distribution. The *p*-value (computed) was higher than the usual significance level alpha (0.05) and cannot reject the null hypothesis (*Ho*). The result of Levene's test shows in Appendix V. The variances across the total soil loss and contour line ridges are identical: the reason is that the p-value (estimated) was higher than the significance level (0.05) and cannot reject the usual null hypothesis *Ho*. Appendices V1 and VII show the homogeneity of the regression slopes in the Koropa and Shatta sub-basins. The result shows that there is no interaction between slope gradients and contour line ridges. The analysis of covariance fulfils the assumption.

3.2 1 Ridge across the slope

At the Koropa, sediment yield averaged 10.98 and 31.12 t ha^{-1} yr^{-1} for the contour ridge in 2018 and 2019. (Table 3). In 2018 and 2019, the average sediments in the Shatta sub-basin were 14.61 and 23.41 t ha^{-1} yr^{-1}, respectively (Table 3). Koropa has higher sediment losses than Shatta, which may be attributed to the very gentle slope, heavy rainfall, and numerous (12) watersheds.

3.2.2 Ridge along the slope

In the Koropa, the average total soil loss varied between 28.91 and 72.80 t ha^{-1} yr^{-1} for the ridge along the slope. The annual soil deposits in the Shatta sub-basin between 2018 and 2019 were 33.66 and 38.06 t ha^{-1} yr^{-1} (Table 3). Because of the 12 watersheds and gentle slope, sediment yield from the non-rational ridge is more pronounced in Koropa than in Shatta.

Table 3 Effect of contour line ridges and cover crop on sediment yield

			Koropa		Shatta	
Ridges form	Cover crops	Slope	Annual SY (2018) (t ha^{-1} yr^{-1})	Annual SY (2019) (t ha^{-1} yr^{-1})	Annual SY (2018) (t ha^{-1} yr^{-1})	Annual SY (2019) (t ha^{-1} yr^{-1})
RAL	Groundnut	5	23.02	24.06	41.52	23.87
RAL	Soybean	3	28.14	119.25	29.27	58.67
RAL	Cowpea	2	7.74	29.01	11.94	13.28
RAL	Cowpea	3	15.57	56.14	13.28	9.88
RAL	No crop	2	35.83	89.33	35.78	65.47
RAL	No crop	5	63.15	118.99	70.16	57.20
		Average	28.91	72.80	33.66	38.06
RAC	Groundnut	2	3.50	8.32	8.46	12.95
RAC	Groundnut	3	7.88	25.40	10.28	28.99
RAC	Soybean	2	7.49	30.91	9.10	26.16
RAC	Soybean	5	17.32	48.59	23.74	16.88
RAC	Cowpea	5	10.11	17.76	14.39	17.33
RAC	No crop	3	19.60	55.74	21.68	38.16
		Average	10.98	31.12	14.61	23.41
		Whole average	19.95	51.96	24.13	30.74

Note: SY= sediment yield; RAC= ridges across the slope; RAL= ridges along the slope.

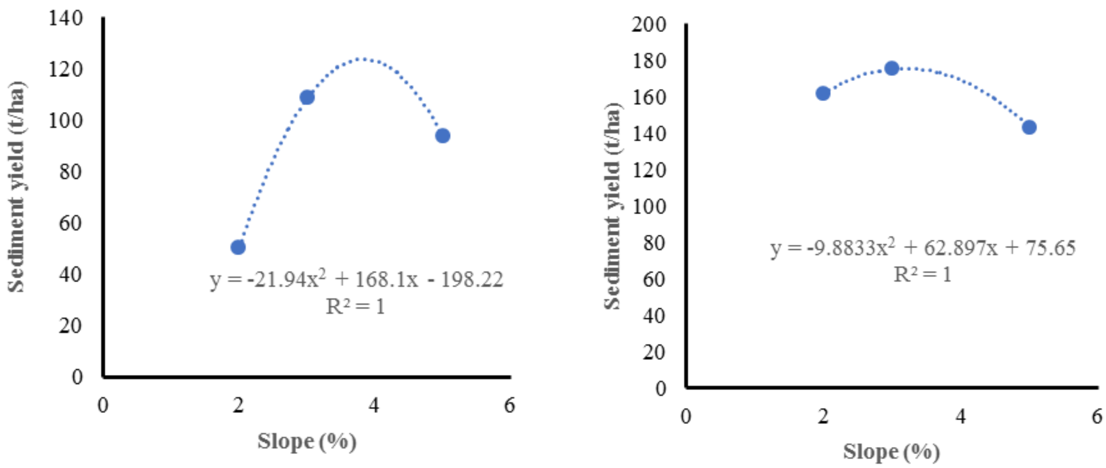
3.3 Effect of different slope gradients on sediment yield

3.3.1 Relationship between slope gradients and sediment yield

The relationship between slope gradients and sediment yield is depicted in Figures 4 and 5. The values for the coefficient of determination (R^2) values were all equal to one. With an R^2 of 1, the regression suits the data perfectly. Under contour line ridge and cover crops, a strong agreement existed between slope gradient and sediment yield. The concave landscape was found to be the best match for the relationship between slope gradient and sediment yield (Figures 4a and 4b). Figures 5a and 5b also show concave and convex landscape. The explanation for this is that Koropa's landscape is concave due to its very gentle slope and sandy loam. Shatta portrays both convex and concave because of the loamy sand and gentle slope. The findings corroborate previous research (Blanco and Lal, 2008).

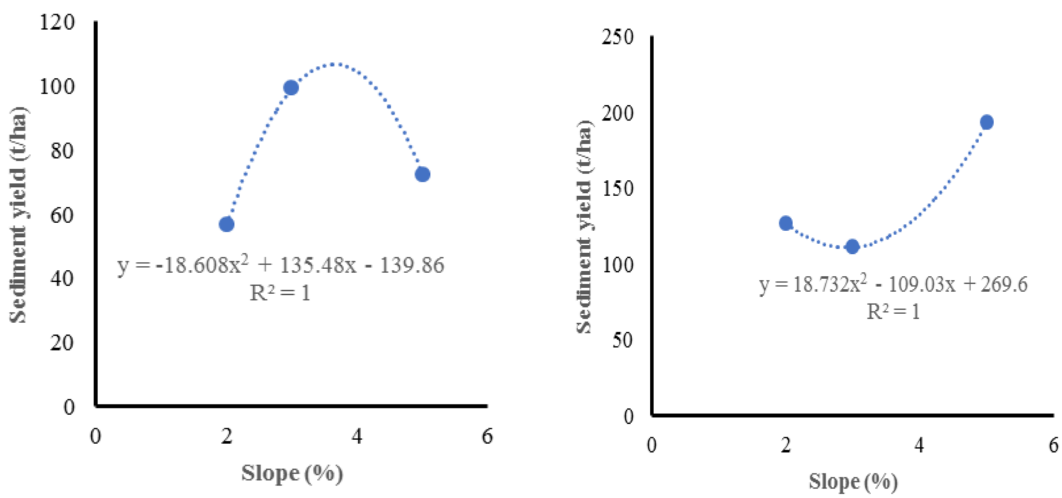
3.3.2 Effect of different slope gradients on sediment yield

In 2018, average sediment loads on the 2% slope were 13.64 t ha^{-1} yr^{-1}, but in 2019 they averaged 39.39 t ha^{-1} yr^{-1} at the Koropa (Table 4). The Shatta yielded similar results, varying from 16.32 t ha^{-1} yr^{-1} to 29.47 t ha^{-1} yr^{-1} under various cover crops and contour line ridges (Table 4). At the Koropa, gross soil depositions averaged 17.80 and 64.13 t ha^{-1} yr^{-1} at the 3 percent topography. Deposit loads in the Shatta ranged from 18.63 t ha^{-1} yr^{-1} to 33.92 t ha^{-1} yr^{-1} (Table 4). The Koropa experienced an average total soil loss of 28.40 t ha^{-1} yr^{-1} and 52.35 t ha^{-1} yr^{-1} at a slope of 5%. Soil depositions in the Shatta range from 37.45 t ha^{-1} yr^{-1} to 28.82 t ha^{-1} yr^{-1} (Table 4). In comparison to 2018, heavy rainfall caused significant variation in sediment yield in 2019. In the slopes of 2%, 3%, and 5%, the presence of cowpea decreases sediment losses from unreasonable ridges. The slope with the highest sediment losses was 3 percent, which was concave in nature. The findings back up previous research (Blanco and Lal, 2008).



(a) ridges across the slope (b) ridges along the slope

Figure 4 Relationship between slope gradient and sediment yield under contour line ridges in the Koropa



(a) ridges across the slope (b) ridges along the slope

Figure 5 Relationship between slope gradient and sediment yield under contour line ridges in the Shatta

3.3 Discussion of results

3.3.1 Relationship among rainfall, runoff and sediment yield

Because of the across slope ridge and vegetation cover, rainfall has a slight influence on sediment yield; the striking effect of raindrops on soil has been significantly reduced (Morgan, 2005). In the Koropa, the relationship between rainfall and total soil loss was non-linear, while both of them had a linear relationship in the Shatta. Our results contradict previous research (Pena-Angulo et al., 2019).

A quadratic model fits cubic rainfall and sediment yield in Koropa, and a strong relationship exists between runoff and sediment yield, which contradicts previous research (Zokaib and Naser, 2012; El-Hassanin et al., 1993; Mingguo et al., 2007). The explanation for this is that ridges along the slope and cover crops also increase runoff and sediment yield. Moreover, a linear relationship existed between them in the Shatta, which contradicts previous studies (Pena-Angulo et al., 2019) because of the ridge along the slope, loamy sand, gentle slope and vegetation cause high sediment losses and confirms previous studies (McCool and Williams, 2008; Blanco and Lal, 2008).

Table 4 Effect of different slope gradient and cover crops on sediment yield

Ridges form	Cover crops	Slope	Koropa Annual SY (2018) (t ha^{-1} yr^{-1})	Koropa Annual SY (2019) (t ha^{-1} yr^{-1})	Shatta Annual SY (2018) (t ha^{-1} yr^{-1})	Shatta Annual SY (2019) (t ha^{-1} yr^{-1})
RAC	Groundnut	2	3.50	8.32	8.46	12.95
RAC	Soybean	2	7.49	30.91	9.10	26.16
RAL	Cowpea	2	7.74	29.01	11.94	13.28
RAL	No crop	2	35.83	89.33	35.78	65.47
		Average	13.64	39.39	16.32	29.47
RAC	Groundnut	3	7.88	25.40	10.28	28.99
RAL	Soybean	3	28.14	119.25	29.27	58.67
RAL	Cowpea	3	15.57	56.14	13.28	9.88
RAC	No crop	3	19.60	55.74	21.68	38.16
		Average	17.80	64.13	18.63	33.92
RAL	Groundnut	5	23.02	24.06	41.52	23.87
RAC	Soybean	5	17.32	48.59	23.74	16.88
RAC	Cowpea	5	10.11	17.76	14.39	17.33
RAL	No crop	5	63.15	118.99	70.16	57.20
		Average	28.40	52.35	37.45	28.82

Note: SY= sediment yield; RAC= ridges across the slope; RAL= ridges along the slope

3.3.2 Effect of tillage direction on sediment yield

The average soil deposits from the contour line ridge are 19.95 and 51.96 t ha-1 yr-1 for Koropa. For ridge across and along the slope, 24.13 and 30.74 t ha-1 yr-1 are the average sediment losses in Shatta (Table 3). The findings conflict with previous research (Adesiji et al., 2019), which might be due to non-spatial hydrological response units of the different sub-basins.

The average sediment losses from ridge along the slope ranged between 28.91 and 72.80 t ha-1 yr-1 for Koropa, and it also varied from 33.86 to 38.06 t ha-1 yr-1 for Shatta. The findings matched those of others research (Blanco and Lal, 2008). The rationality is that soil loss from non-rational ridge doubled sediment losses from ridge across the slope. Dissimilar results were observed for contour ridge (Table 3) as it decreases sediment yield (Table 3). The findings support the previous studies (Faharani et al., 2016). The reason is that across slope ridge decreases erosion rates by 54 percent and 46 percent in Koropa and Shatta.

In ridge along the slope, the average sediment yield had values of 28.908 and 72.796 t ha-1 yr-1 in the Koropa sub-basin. Total soil loss possessed mean values of 33.658 and 38.062 t ha-1 yr-1 in 2018 and 2019 for the Shatta sub-basin. The erosion class ranged from high to very high and agree with the previous studies (Molla and Sisheber, 2017) as non-rational ridge loses the topsoil and induces erosion and sediment yield (Tan et al., 2015).

The ridge along the slope had significant effects (p-value=0.024; p-value=0.027) on sediment losses in Koropa and Shatta (Appendix 3) and affects the hydrological pattern of the river and water quality. Soil deposition transferred by non-rational tillage often affects aquatics species and induces river/dam sedimentation. The results corroborate with earlier research (Oladosu et al., 2019). The explanation for this is that continuous soil cultivation coupled with non-rational ridge hinders penetration and percolation of runoff and aggravates sediment loads. Since leguminous crops can withstand raindrop impact, the cowpea decreases sediment yield in the ridge across and along the slope followed by groundnut (Table 3). The findings back up previous research (Gabiri et al., 2015; Rehman et al., 2015).

3.3.3 Effect of slope gradients on sediment yield

Slope gradients affect soil deposition in Shatta because of the concave and convex landscape. The former exhibited in Koropa. The findings back up previous studies (Blanco and Lal, 2008; McCool and Williams, 2008). As a result, the Koropa sub-basin transports more sediment than the Shatta sub-basin. In the Shatta, soil deposition rises as the slope increases at 2 percent, 3 percent, and 5 percent (Appendix III). The findings are consistent with previous research (Fox and Bryan, 2000; Liu et al., 2001).

4 Conclusion

The effect of tillage direction on sediment yield was assessed in Koropa and Shatta. Results showed that the exponential and linear models correctly predicted runoff and sediment yield. It suggests that the runoff and sediment yield had a close relationship. In 2018 and 2019, the annual sediment yield for non-rational ridge increased from 28.91 to 72.80 t ha^{-1} yr^{-1} in 2018 and 2019. Different results were found in the across slope ridge. The results show that irrational ridge affected sediment yield by polluting the surface water and kills aquatic species (fish). Besides, it causes river/dam sedimentation. Ridge across slope helps to mitigate erosion. The ridge along the slope should be discouraged in the Chanchaga Basin.

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References

Adesiji, A. R., O. A. Gbadebo, J. J. Musa, E. O. Asogwa, M. O. Odekunle, and J. A. Mangey. 2019. Estimate of bedload transport and scour depth in Kwadna watershed in Minna, Niger State, Nigeria. *International Journal of Water Resources and Environmental Engineering*, 11(8): 170-179.

Addinsoft. 2019. XLSTAT Statistical and Data Analysis Solution. Boston, USA: Addinsoft. Accessed at: https://www.xlstat.com. 18th Feb., 2019.

Ahaneku, I. E., and B. O. Sadiq. 2014. Assessment of heavy metals in nigerian agricultural soils. *Polish Journal of Environmental Studies*, 23(4): 1091-1100.

Blanco, H., and R. Lal. 2008. *Principles of Soil Conservation and Management*. New York, United States: Springer-Verlag New York Inc.

Bhat, S. A., M. U. D. Dar, and R. S. Meena. 2019. Soil erosion and management strategies. In *Sustainable Management of Soil and Environment*, 73-122. Meena, Ram S., Kumar, S., Bohra, J. S., & Jat, L. M. Eds., Singapore: Springer. https://doi.org/10.1007/978-981-13-8832-3_3

Chen, X., Z. Liang, Z. Zhang, and L. Zhang. 2020. Effects of soil and water conservation measures on runoff and sediment yield in red soil slope farmland under natural rainfall. *Sustainability*, 12(8): 3417.

Daramola, J., T. M. Ekhwan, J. Mokhtar, K. C. Lam, and G. A. Adeogun. 2019. Estimating sediment yield at Kaduna watershed, Nigeria using soil and water assessment tool (SWAT) model. *Heliyon*, 5(7): e02106.

De Silvan, D. P. R., M. T. Silva, and E. P. De Souza. 2016. Influence of and use change on sediment yield: a case Study of the Sub-Middle of the São Francisco River Basin. *Journal of the Brazilian Association of Agricultural Engineering*, 36(6): 1005-1015.

Dinka, M. O. 2020. Quantification of soil erosion and sediment yield for ungauged catchment using the RUSLE model: a case study for Lake Basaka catchment in Ethiopia. *Lakes and Reservoirs: Research and Management*, 25(2): 183-195.

El-Hassanin, A. S., T. M. Labib, and E. I. Gaber. 1993. Effect of vegetation cover and land slope on runoff and soil losses from the watersheds of Burundi. *Agriculture, Ecosystems and Environment*, 43(3-4): 301-308.

Egharevba, N. A., and H. Ibrahim. 2006. Prediction of sediment yield in runoff from agricultural land in the Southern Guinea Savanna Zone of Nigeria. *West African Journal of Applied Ecology*, 10(1). https://www.ajol.info/index.php/wajae/article/view/45709.

Ewemoje, T. A., and I. A. Kuti. 2021. Effect of tillage direction on phosphorus loss from sediment yield and surface runoff. *FUOYE Journal of Engineering and Technology*, 6(1): 1-6. http://journal.engineering.fuoye.edu.ng/index.php/engineer.

Faharani, S. S., F. S. Fard, and A. Asoodar. 2016. Effects of contour farming on runoff and soil erosion reduction: a review study. *Elixir Agriculture*, 101(1): 44089-44093.

Fox, D. M., and R. B. Bryan. 2000. The relationship of soil loss by interrill erosion to slope gradient. *Catena*, 38(3): 211-222.

Gabiri, G., J. A. Obando, M. M. Tenywa, J. G. Majaliwa, C. L. Kizza, A. Zizinga, and Buruchara. 2015. Soil and nutrient losses under cultivated bush and climbing beans on terraced R.humid highland slopes of Southwestern Uganda. *Journal of Scientific Research and Reports*, 8(3): 1-16.

Grace, J. M., and E. A. Carter. 2000. Impact of harvesting on sediment and runoff production on a Piedmont site in Alabama. In *Presented at 2000 ASAE Annual International Meeting, Paper No.* 005019. St. Joseph, Mich.: ASAE.

Guo, S., L. Zhai, J. Liu, H. Liu, A. Chen, H. Wang, and Q. Lei. 2019. Cross-ridge tillage decreases nitrogen and phosphorus losses from sloping farmlands in southern hilly regions of China. *Soil and Tillage Research*, 191(1): 48-56.

Iwara, A. I. 2014. Evaluation of the variability in runoff and sediment loss in successional fallow vegetation of Southern Nigeria. *Soil and Water Research*, 9(2): 77–82.

Jourgholami, M., E. R. Labelle, and J. Feghh. 2017. Response of runoff and sediment on skid trails of varying gradient and traffic intensity over two-year period. *Forest Journal*, 8, 472, 1-13. Doi: 10.3390/f8120472.

Kuti, I. A., B. A. Adabembe, J. J. Musa, P. A. Adeoye, M. Animashaun, H. Aroboinosen, and M. E. Akhare. 2018. Assessment of soil salinity and irrigation water quality of Chanchaga irrigation scheme I, Minna, Niger State. *FUOYE Journal of Engineering and Technology*, 3(1): 57-60 http://journal.engineering.fuoye.edu.ng/index.php/engineer.

Lawrence, P. 1996. *Guidelines on Field Measurement Procedures for Quantifying Catchment Sediment Yield*. UK: HR Wallingford Ltd.

Liu, J., Z. Shi, X. Yu, and H. Zhang. 2014. Influence of micro-topography, ridge geometry, and rainfall intensity on soil erosion induced by contouring failure. *Soil and Tillage Research*, 136(1): 1-8.

Liu, Q., L. Chen, and J. Li. 2001. Influences of slope gradient on soil erosion. *Applied Mathematics and Mechanics*, 22(5): 510-519.

Lu, R., Y. Liu, C. Jia, Z. Huang, Y. Liu, H. He, and G. L. Wu. 2019. Effects of mosaic-pattern shrub patches on runoff and sediment yield in a wind-water erosion crisscross region. *Catena*, 174(1): 199-205. https://doi.org/10.1016/ j.catena. 2018.11.022.

McCool, K., and D. Williams. 2008. Soil erosion by water. *Encyclopedia of Ecology (1st Edition)*, Jorgensen, S. E., & Fath, B. D. Eds. Amsterdam: Elsevier. pp 3284-3290.

Mingguo, Z., C. Qiangguo, and C. Hao. 2007. Effect of vegetation on runoff-sediment yield relationship at different spatial scales in hilly areas of the Loess Plateau, North China. *Acta Ecologica Sinica*, 27(9): 3572-3581.

Moreno‐de Las Heras, M., J. M. Nicolau, L. Merino‐Martín, and B. P. Wilcox, 2010. Plot‐scale effects on runoff and erosion along a slope degradation gradient. *Water Resources Research*, 46(4): 1-12. https://doi.org/10.1029/2009WR0078 7.

Molla, T., and B. Sisheber. 2017. Estimating soil erosion risk and evaluating erosion control measures for soil conservation planning at Koga watershed in the highlands of Ethiopia. *Solid Earth*, 8(1): 13.

Morgan, R. P. 2005. *Soil Erosion and Conservation*. USA: Blackwell Science Ltd.

Munodawafa, A. 2012. Quantifying nutrient losses with different sediment fractions under four tillage systems and granitic sandy soils of Zimbabwe. *Research on Soil Erosion*, Godone, D., & Stanchi, S. Eds., INTECH: UK. Pp 119. doi:10.5772/52163.

Nda, M., O. D. Jimoh, and M. S. Adnan. 2017. Estimation of sediment concentration of River Dagga, Chanchaga Basin, Niger State, Nigeria. *Lecture Notes in Civil Engineering, 1467–1477*. Pradhan, B.ed., UK: Springer Nature Singapore Pte Ltd. doi:10.1007/978-981-10-8016-6_106

Ngetich, K. F., J. Diels, C. A. Shisanya, J. N. Mugwe, and Mucheru-Muna. 2014. Effects of selected soils and water conservation techniques on runoff, sediment yield, and maize productivity under sub-humid and semi-arid conditions in Kenya. *Catena*, 121(1): 288-296. https://doi.org/10.1016 /j.catena.2014.05.026.

Obani, C. C., I. E. Ahaneku, and E. C. Ugwu. 2016. Effect of different groundcovers on runoff and soil loss in the Humid Tropics. In *Proceedings of the Conference on Agricultural Mechanization in Nigeria*, 306-317. Nigeria, 1- 4 August.

Oladosu S. O., L. M. Ojigi, V. E. Aturuocha, C. O. Anekwe, and R. Tanko. 2019. An investigative study on the volume of sediment accumulation in Tagwai dam reservoir using bathymetric and geostatistical analysis techniques. *SN Applied Sciences*, 1(5): 492.

Ousmane, B., and H. A. Ajeigbe. 2009. Cowpea and Groundnut Seed Production Practices. Available at: https://biblio1.iita.org/bitstream/handle/20.500.12478/2799/U09ProcOusmaneCowpeaNothomNodev.pdf?sequence=1andisAllowed=y. 27-03-2017.

Pena-Angulo, D., E. Nadal-Romero, J. A. González-Hidalgo, J. Albaladejo, V. Andreu, V. Bagarello, and J. Campo. 2019. Spatial variability of the relationships of runoff and sediment yield with weather types throughout the Mediterranean basin. *Journal of Hydrology*, 571(1): 390-405. https://doi.org/10.1016/j.jhydrol.2019.01.059.

Plentovich, S., T. Mizerek, M. K. Reeves, F. Amidon, S. E. Miller, and M. Nanbara. 2020. Coastal strand and mangrove swamps of the mariana islands. In Encyclopedia of the World's Biomes, eds. M. I. Goldstein and D. A. DellaSala, vol. 1, 185-197. Amsterdam: Elsevier.

Raghavendra, G. 2014. Estimation of Soil Loss by Using Multiplot Divisor. Available at: https://pt.slideshare.net/Raghu1522/ presentations. 27-03-2017

Rehman, O. U., M. Rashid, R. Kausar, S. Alvi, and M. R. Sajjad. 2015. Assessment of runoff and sediment losses under different slope gradients and crop covers in semi-arid watersheds. *Soil and Environment*, 34(1): 75-81.

Tan, C., X. Cao, S. Yuan, W. Wang, Y. Feng, and B. Qiao. 2015. Effects of Long-Term Conservation Tillage on Soil Nutrients in Sloping Fields in *Regions Characterised by Water and Wind Erosion*. Available at: https://doi.org/ 10.1038/srep17592. 27 March, 2017.

Quinton, J. N., and J. A. Catt. 2004. The effects of minimal tillage and contour cultivation on surface runoff, soil loss and crop yield in the long-term Woburn Erosion Reference Experiment on sandy soil at Woburn, England. *Soil Use and Management*, 20(3): 343-349.

Sensory, H., and O. Kara. 2014. Slope shape effect on runoff and soil erosion under natural rainfall conditions. *iForest-Biogeosciences and Forestry*, 7(2): 110-114.

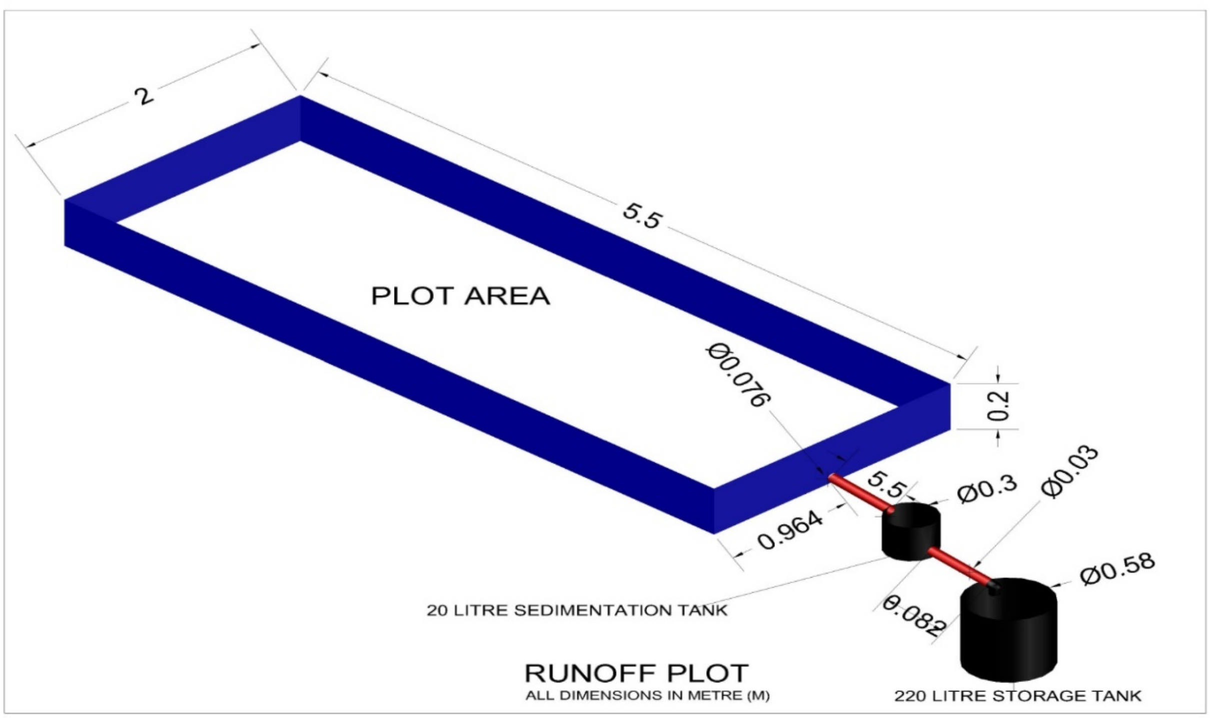
Zokaib, S., and G. H. Naser. 2012. A study on rainfall, runoff, and soil loss relations at different land uses-a case in Hilkot watershed in Pakistan. *International Journal of Sediment Research*, 27(3): 388-393.

Zhang, G. H., B. Liu, and L., Wang. 2010. Effects of Caragana korshinskii kom. Cover on runoff, sediment yield and nitrogen loss. *International Journal of Sediment Research*, 25(3): 245-257.

Appendices

Appendix I

Runoff plot



Appendix II a

Model Summary of sediment yield

R	R Square	Adjusted R Square	Std. Error of the Estimate
	Koropa		
0.699	0.489	0.458	11617.088
	Shatta		
0.522	0.272	0.219	10115.143

Note: The independent variable is rainfall

Appendix II b

Coefficient of sediment yield

			Koropa		
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
Rainfall	-1477.581	1318.090	-1.179	-1.121	0.268
Rainfall ** 2	95.688	42.846	5.097	2.233	0.030
Rainfall ** 3	-1.073	0.405	-3.548	-2.651	0.011
(Constant)	10232.05	11855.248		0.863	0.392
			Shatta		
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
Rainfall	196.122	1274.437	0.288	0.154	0.878
Rainfall ** 2	-0.682	35.292	-0.079	-0.019	0.985
Rainfall ** 3	0.40	0.292	0.325	0.137	0.892
(Constant)	6628.503	13477.247		0.492	0.625

Appendix III

Model parameter of sediment yield (Kg/ha)

Source	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
		Koropa				
Intercept	-18086.748	32149.435	-0.563	0.594	-96753.579	60580.084
Slope	7835.299	6097.104	1.285	0.246	-7083.778	22754.375
RAC	0.000	0.000				
RAL	56112.305	18638.894	3.010	**0.024**	10504.577	101720.034
Cowpea	0.000	0.000				
Groundnut	3995.022	26883.817	0.149	0.887	-61787.306	69777.350
No crop	82108.482	16293.448	5.039	**0.002**	42239.852	121977.112
Soybean	57164.995	21122.194	2.706	**0.035**	5480.851	108849.140
		Shatta				
Intercept	-18074.617	10807.743	-1.672	0.145	-44520.210	8370.977
Slope	6834.276	2752.913	2.483	**0.048**	98.141	13570.411
RAC	0.000	0.000				
RAL	32996.808	11377.261	2.900	**0.027**	5157.655	60835.961
Cowpea	0.000	0.000				
Groundnut	26317.239	16034.161	1.641	0.152	-12916.937	65551.415
No crop	69441.724	10136.702	6.851	**0.000**	44638.108	94245.339
Soybean	38903.701	13898.064	2.799	**0.031**	4896.365	72911.038

Note: RAC is ridge across the slope, RAL is ridge along the slope

Appendix IV

Normality test

Koropa	
W	0.933
p-value (Two-tailed)	0.408
alpha	0.05
Shatta	
W	0.928
p-value (Two-tailed)	0.360
alpha	0.05

Appendix V

Levene's test

Koropa	
F	2.084
DF1	1
DF2	10
p-value (Two-tailed)	0.179
alpha	0.05
Shatta	
F	0.017
DF1	1
DF2	10
p-value (Two-tailed)	0.900
alpha	0.05

Appendix VI

Homogeneity of regression slopes (sediment yield) at the Koropa

Source	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
Intercept	-13684.413	45666.389	-0.300	0.776	-131073.595	103704.770
Slope	6891.941	8701.655	0.792	0.464	-15476.373	29260.255
RAC	0.000	0.000				
RAL	49508.803	53105.647	0.932	0.394	-87003.600	186021.207
Cowpea	0.000	0.000				
Groundnut	1793.855	34831.776	0.052	0.961	-87744.071	91331.781
No crop	80850.672	16622.644	4.864	**0.005**	38120.808	123580.536
Soybeans	56221.638	26457.916	2.125	0.087	-11790.597	124233.873
Slope * RAC	0.000	0.000				
Slope * RAL	1886.715	15022.399	0.126	0.905	-36729.589	40503.018

Note: RAC= ridge across the slope; RAL= ridge along the slope

Appendix VII

ANCOVA summary for homogeneity of regression slopes (sediment yield) at the Shatta

Source	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
Intercept	-20032.973	23112.706	-0.867	0.426	-79446.071	39380.124
Slope	7253.924	5542.021	1.309	0.247	-6992.294	21500.141
RAC	0.000	0.000				
RAL	35934.343	31219.697	1.151	0.302	-44318.437	116187.124
Cowpea	0.000	0.000				
Groundnut	27296.417	20443.448	1.335	0.239	-25255.135	79847.969
No crop	70001.254	10079.682	6.945	**0.001**	44090.609	95911.900
Soybeans	39323.349	17685.348	2.223	0.077	-6138.284	84784.982
Slope * RAC	0.000	0.000				
Slope * RAL	-839.296	8793.914	-0.095	0.928	-23444.770	21766.179

Note: RAC= ridge across the slope; RAL= ridge along the slope