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Estimation of soil losses within plots as affected by different agricultural land management

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Abstract Proper agricultural land management strategies improve soil structural properties, thereby reducing soil loss by water erosion. This study was conducted to estimate soil losses from plots of different agricultural land management using the Water Erosion Prediction Project (WEPP) (95.7) model. The study took place in a semiarid region in Kenya. The mean annual rainfall was 694 mm. The WEPP (95.7) model was initially used to estimate total sediment loading from the catchment into a reservoir. The estimate was about 2871 t corresponding to an average sedimentation rate of 1063 t km^{-2} year^{-1}, which was about 76% of the measured total sediment inflow into the reservoir. Soil losses were estimated within 10 plots on the catchment of different sizes and slopes with the following treatments: conventional tillage (hand hoeing) with maize and soybean intercropping (HOCOBE); conservation tillage (disc plough) with maize and soybean intercropping (COBEAN); conservation tillage with only maize cultivation (CNTCORN); and conservation tillage with only soybean cultivation (CNTBEAN). The soil loss reduction of COBEAN, CNTCORN and CNTBEAN relative to HOCOBE ranged between 27–47%, 16–29% and 12–25%, respectively, depending on the size and slope of the plot. In general, conservation tillage reduced soil loss relative to conventional tillage. However, with conservation tillage, the single cropping system resulted in greater soil loss than the intercropping system. In the case of single cropping with conservation tillage, the soil loss reduction for maize ranged between 4 and 9%, relative to soybean. Overall, the study showed that there would be a significant reduction of soil losses from plots if conservation tillage with an intercropping system (maize and soybean) were to be adopted on agricultural lands in semiarid regions.

Key words agricultural land; semiarid regions; soil loss; tillage; water erosion; WEPP (95.7) model

Estimation des pertes de sol au sein de placettes, sous l'effet de différents modes de gestion agricole

Résumé De bonnes stratégies de gestion agricole améliorent la structure du sol et de ce fait permettent de réduire la perte de sol par érosion hydrique. Cette étude a été conduite dans le but d'estimer les pertes de sol subies par des placettes présentant différents modes de gestion agricole, en utilisant le modèle WEPP (Water Erosion Prediction Project—Projet de Prédiction de l'Erosion Hydrique) (95.7). L'étude a été menée dans une région semi-aride du Kénya. La pluviométrie moyenne y est de 964 mm par an. Le modèle WEPP (95.7) a été initialement utilisé pour estimer le transfert total de sédiments du bassin versant vers un réservoir. L'estimation s'est élevée à environ 2871 t, ce qui correspond à un transfert annuel moyen de 1063 km^{-2} an^{-1}, et représente à peu prés 76% de l'afflux sédimentaire total mesuré à l'entrée du réservoir. Les pertes de sol ont été estimées pour 10 placettes de dimensions et de pentes différentes sur le bassin versant, et pour les techniques culturales suivantes: labour conventionnel (sarclage à la houe) avec rotation de maïs et de soja (HOCOBE); labour de conservation (charrue à disques) avec rotation de maïs

Open for discussion until 1 June 2003

et de soja (COBEAN); labour de conservation avec culture de maïs seule (CNTCORN); et labour de conservation avec culture de soja seule (CNTBEAN). La réduction de la perte de sol de COBEAN, CNTCORN et CNTBEAN par rapport à HOCOBE varie entre 27 et 47%, 16 et 29%, 12 et 25% respectivement, selon la dimension et la pente de la parcelle. En général, le labour de conservation réduit la perte de sol par rapport au labour conventionnel. Pourtant, dans le cas du labour de conservation, le système de culture unique produit une perte de sol plus grande que le système de rotation. Dans le cas d'une culture unique avec labour de conservation, la perte de sol est diminuée de 4 à 9% avec le maïs, par rapport au soja. En somme, l'étude a montré qu'il y aurait une réduction significative des pertes de sol des placettes si le système cultural avec labour conventionnel et rotation culturale (maïs et soja) était adopté sur les terres arables des régions semi-arides.

Mots clefs terre agricole; régions semi-arides; perte de sol; labour; érosion hydrique; modèle WEPP (95.7)

INTRODUCTION

Land development for various purposes occurs ubiquitously in the world and these human activities often increase storm runoff and accelerate soil erosion (Yen, 1985). The assessment and understanding of soil erosion and sedimentation processes are essential components of soil and water conservation. An integral part of soil and water conservation is to control soil erosion, particularly through sound land and water management techniques, and to devise methods and design techniques to mitigate the harmful effects of soil loss and sediment movement (Shahin, 1993).

The lower rainfall in semiarid areas compared to that in humid climates does not necessarily result in a corresponding low level of soil erosion by water (FAO, 1987). This is mainly due to the torrential and erratic nature of the rains (FAO, 1987), excessive weathering or erodibility of the soil (Goudie & Wilkinson, 1977), almost total lack of natural protection against detachment of soil due to sparse vegetation, especially at the beginning of the rainy season (FAO, 1987; Pilgrim *et al.*, 1988) and increased biotic interference (FAO, 1973). Even though governments and individuals have been working cooperatively to reduce soil erosion and sediment movement on agricultural lands, much remains to be done. On the one hand, soil loss is still the most important factor that renders agricultural land infertile and, on the other hand, it is the largest pollutant to streams and lakes (FAO, 1993). The rates at which the processes of erosion transport and deposition of sediment act are dependent on such variables as rock or soil type, topographic relief, plant cover, climate and land use (Elwell, 1984; Shahin, 1993). The Water Erosion Prediction Project (WEPP) (95.7) model used in this study considers these variables.

Several simulation models, such as the Universal Soil Loss Equation (USLE), (FAO, 1993), the Modified Soil Loss Equation (MUSLE) (Onstad, 1984), the Soil Loss EstiMator for Southern Africa (SLEMSA) (Elwell, 1984) and Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS) (Knisel, 1980), are available. However, the WEPP (95.7) model is an upgrade model to cover other factors such as the depositional portion of landscape profiles and other hydrological processes which affect erosion but are not considered by the above models (Laflen *et al.*, 1991; FAO, 1993; Flanagan & Livingston, 1995).

Sediment is the main product of soil erosion from surface water runoff (Ongwenyi *et al.*, 1993). Therefore, the design of soil and water conservation structures requires information on soil loss and sediment movement from the catchment. Such data can be obtained easily if the soil loss monitoring systems in the catchments are adequately instrumented with an automatic gauging and monitoring network (FAO, 1987). However, most semiarid regions in developing countries such as Kenya, where the study was carried out, do not have erosion and sediment monitoring systems installed. This is due to the constraints of resources and funds (Sharma, 1993). According to Ongwenyi *et al.* (1993), about three-quarters of Kenya's adult population are engaged in agriculture. They observed that the population increase has led to an expansion of agricultural lands into more fragile marginal lands in the semiarid and arid areas. Jaetzold & Schmidt (1983) also reported that these semiarid areas, which housed big ranches during colonial times, have seen an increase in population and active cultivation of the land since the 1970s. This has resulted in accelerated soil erosion and high sedimentation rates (Ongwenyi *et al.*, 1993). Changes in land use have an influence on erosion and reservoir sedimentation and this has been investigated in Kenya by many researchers (e.g. Edwards, 1977; Muya, 1990). Ongwenyi *et al.* (1993) compared soil erosion from different catchment areas under different land-use patterns in Kenya and concluded that the rates of erosion and sediment yield increase in catchments subject to agricultural activities. They stressed that these soil losses are much greater in semiarid and arid parts of the country. Thus, to curb soil erosion in semiarid areas, especially in Africa, appropriate methods of land use or conservation measures have to be adopted, hence the importance of this study. The objectives of this study were to use the WEPP (95.7) model (a) to estimate soil loss from the catchment into the reservoir under the present land-use and agricultural practices, and (b) to estimate and compare soil losses from selected plots on the catchment under different land uses and agricultural practices.

MATERIALS AND METHODS

The study was conducted on the catchment of Ndaragwiti Reservoir, a semiarid area in Sipili region of Ng'arua Division, Kenya. The site is approximately 1.0 km northwest of Sipili township and lies along longitude 36.4°E and latitude 0.5°N. The parent material of the soils consists of tertiary basic igneous rock deposits on volcanic foot ridges (Jaetzold & Schmidt, 1983). The soils are well drained, shallow to moderately deep, reddish brown, firm clay with moderately thick humic topsoil (Ortholuvic Phaeozems). The site has annual average rainfall of 694 mm, with a long rainy season, from April to August, and a short rainy season from October to November. However, the rainfall in general is unreliable and erratic during the year. The mean daily temperature ranges from 8.1 to 26.4°C during the rainy season and from 6.7 to 27.5°C during the dry seasons. The site lies in the lower Highland Agro-ecological Zone described as Wheat/Maize-Barley Zone (Jaetzold & Schmidt, 1983). The vegetation is grassland with very few scattered trees. The whole catchment of about 2.7 km^2 was under cultivation. About 70% of the land was prepared by hand hoeing (conventional tillage), whilst the other 30% was by disc ploughing. The farmers had only one cropping season due to the unreliability of the second rains. Maize (*Zea mays*) was the main crop intercropped with soybeans (*Glycine soja*) between rows. Planting time was usually between March and April and harvesting time between August and October.

The study could be divided into three parts. In the first part, the catchment was divided into five blocks (B), and subdivided into 22 hillslopes or plots (P) according to the orientation and type of tillage method (hand hoeing or disc ploughing) of each hillslope. The slope length and steepness as well as the area of each hillslope were determined. Two types of soil samples—undisturbed and disturbed—in three replicates were collected from each hillslope at three or four points and at 0–10 cm, 10–20 cm and 20–30 cm depths. These samples were used to determine some physical and chemical properties of the soil, required by the model. The particle size distribution was determined by hydrometer method (IITA, 1979). The gravel concentration was determined using the "wet" sieving method (Kemper & Rosenau, 1986). The bulk density was determined by the core method (Blake & Hartge, 1986). Saturated hydraulic conductivity was determined by the constant head method (Klute & Dirksen, 1986) and the soil water characteristics were obtained by the pressure chamber method (Klute, 1986). The Walkley-Black method (Nelson & Sommers, 1986) was used for determining organic matter. The cation exchange capacity (CEC) was obtained by a method described by Udo & Ogunwale (1978). In addition to the soil parameters determined in the laboratory, soil erodibility, critical shear stress and soil albedo were calculated using formulae documented by Flanagan & Livingston (1995).

The second part of the study involved climatic data collection. Climatic data from 1967 to 1996 of Rumuruti (8936064) were collected from both the Kenya Meteorological Department and the Hydrology Division of the Ministry of Land Reclamation, Regional and Water Development, Kenya, to supplement each other in terms of data quality. The mean monthly maximum and minimum temperatures, mean monthly solar radiation and mean monthly precipitation were calculated and used as monthly climatic parameters for the model. Climatic data for the simulation year, 1996, were also used to determine the daily values of rainfall amount, rainfall duration, maximum and minimum temperatures, solar radiation, wind speed and direction, and dew point required by the model. The reservoir was desilted in December 1995 and therefore it was taken that the sediment deposit in early February 1997 was the effect of 1996, hence 1996 being selected as the simulation year.

In the third part of the study, ten plots of different sizes and shapes (designated B1P2, B1P3, B2P2, B2P3, B3P1, B3P3, B4P2, B4P4, B5P1 and B5P3) were randomly selected under the following treatments: conservation tillage (disc plough), with maize and soybean intercropping (COBEAN); conventional tillage (hand hoeing) with maize and soybean intercropping (HOCOBE); conservation tillage with only maize cultivation (CNTCORN); and conservation tillage with only soybean cultivation (CNTBEAN). Conservation tillage consisted of disc ploughing, primary and secondary hand hoeing, planting and cultivation for weed control. Conventional tillage had similar cultural operation dates and types to conservation tillage except that a manually operated hand hoe was used instead of a disc plough.

The reservoir was fed only by runoff through three channels. The watershed model was then run three times to estimate sediment loading into the reservoir from three subcatchments that fed the three channels.

SIMULATION MODEL

The WEPP (95.7) model is a comprehensive process-based, field-scale simulation model capable of estimating soil loss and sediment yield. The model considers sediment flow from the catchment, as well as along a well-defined water flow course, and estimates both sediment inflow and outflow of a reservoir. Numerous processes, such as hydrological, hydraulic, soil (impacts of tillage) and erosion processes, plant growth, plant residue and climate, for both hillslope and channel as well as impoundment, are computed within the model. Flanagan & Livingston (1995) have documented the model and its input data requirements.

The basic erosion equations for hillslopes and channel of the WEPP are respectively (Laflen *et al.*, 1991):

$$D_i = K_i I_e^2 G_e C_e S_f \tag{1}$$

where D_i is the sediment delivery from the hillslope to a nearby channel (kg m^{-2} s^{-1}); K_i is hillslope erodibility (kg s m^{-4}); I_e is effective rainfall intensity (m s^{-1}); G_e, C_e and S_f (= 1.05 – 0.85exp(–4sin$a$)) are ground cover, canopy cover and slope adjustment factors, respectively; and a is the slope of the surface towards a nearby channel.

$$D_r = D_c(1 - G/T_c) \tag{2}$$

where D_r is the channel detachment (deposition) rate (kg m^{-2} s^{-1}); $D_c = K_r(t_s - t_c)$ is the channel detachment (deposition) capacity (N s m^{-3}), where K_r is the channel erodibility (s m^{-1}), t_s is the hydraulic shear stress of flowing water (N m^{-2}) and t_c is the critical hydraulic shear stress (N m^{-2}); G is the sediment load (kg m^{-1} s^{-2}); and T_c is the transport capacity of the channel flow (kg m^{-1} s^{-1}).

The WEPP (95.7) model is run under two categories: the Hillslope WEPP (95.7) model and the Watershed WEPP (95.7) model. The Hillslope model estimates the sediment yield from the hillslope whilst the Watershed model estimates the sediment yield from the whole catchment. The Hillslope model requires four input data files for each monitored hillslope. These include a climate file, a slope file, a soil file and a plant/management file. The input data for the Watershed model include the soil loss (output) of the Hillslope model, a channel file and an impoundment file.

The climate file involves two types of climatic data: simulation year(s) data and observed years data. The simulation year(s) data are the data for the year or years of interest, i.e. the period within which the sediment is being estimated. These data include daily values of rainfall amount, rainfall intensity, maximum and minimum temperatures, wind speed, wind direction, solar radiation and dew point. The observed years data include average monthly values of rainfall amount, maximum and minimum temperatures, and solar radiation for any number of years provided they are available and more than the simulation years.

The slope file comprises slope orientation thus aspect of the profile, number of slope points, length and steepness at each slope point from the upper end of the hillslope.

The soil file includes number of soil layers, depth of soil layer from the soil surface and soil properties, such as interrill and rill erodibilities, critical shear, percentages of sand, clay, and organic matter, cation exchange capacity, hydraulic conductivity and gravel concentration.

The plant/management file includes land use, crop types, cropping system, cropping pattern, inter-row distance, inter-crop distance, rooting depth, height of crop at maturity, root to shoot ratio, planting and harvesting times, types of implement used for cultivation, primary tillage depth, secondary tillage depth, and number of secondary tillages.

The channel file consists of channel slope data, channel soil data, and plant/management data. These data are determined in the same way as the hillslope data above. The impoundment input file includes bottom width, side slopes and stage of the spillway, size of impoundment, number of stage-area-length points, minimum and maximum stage, and area at which water overflows through the spillway.

RESULTS

Table 1 shows some physical and chemical properties of the soil on the catchment. The clay content of the soils in blocks B2, B3 and B5 increased with depth, while that in B1 remained relatively uniform and that in B4 showed no regular pattern. For the sand fraction, blocks B2, B3 and B4 showed no regular pattern, the percentage of sand in B1 increased with depth and in B5 it decreased with depth. The silt fraction decreased with depth in B2 and B3, increased with depth in B4, while B5 showed no regular pattern. Generally, the gravel concentration in all the blocks increased with depth. Block B4 had the highest average gravel concentration of 7.8% at 20–30 cm depth and B1 had the least value of 1.2% at 0–10 cm depth. However, B2 had higher gravel concentration at all depths, ranging from 4.4 to 7.2%, and B1 had the lowest value from 1.2 to 3.8%. The coefficient of variation ranged from 46.7 to 100%. The hydraulic conductivity showed a slight decrease with depth in all the blocks. It was noted that blocks with high clay content had low hydraulic conductivity and *vice versa*. The mean clay percentage of blocks B1, B2, B3, B4 and B5 were respectively 58.4, 48.2, 50.9, 52.2 and 45.1 and their corresponding mean hydraulic conductivities were 0.79, 1.75, 1.23, 1.15 and 1.81 mm h^{-1}. The average organic matter content generally decreased with depth, though the variation was small (from 2 to 3%). The CEC values ranged from 29.6 to 46.2 meq·100 g^{-1}. The higher values of CEC indicated the clayey nature of the soil (Flanagan & Livingston, 1995).

The mean annual rainfall was 694 mm. The year 1977 had the highest total rainfall of 1181.1 mm, followed by 1974 (1021.1 mm) and then 1990 (1019.2 mm), with the least of 410.6 mm occurring in 1984, as shown in Fig. 1. Each of the remaining years had total rainfall less than 900 mm. The rainfall sequence followed a "zigzag" pattern (Fig. 1) with twelve years below and ten years above the mean rainfall, while the remaining years were almost equal to the mean rainfall. A "high" rainfall was likely (about 74% probability) to be followed by a "low" rainfall the following year, taking the mean rainfall as a reference. It was observed that only a few months of rainfall in each year contributed most of the rainfall.

It is interesting to compare the WEPP (95.7) model estimate and the measured sediment deposit in the reservoir. The average reservoir trap efficiency was taken as 90% corresponding to a capacity–inflow ratio of around 0.8 on the Brune's (1953) curves. This gave the measured annual inflow of about 3778 t. The model estimated the total annual sediment deposit in the reservoir to be approximately 2206 t and the total annual sediment inflow to be approximately 2871 t. This gives an average sediment yield rate of 1063 t km^{-2} $year^{-1}$ for the 2.7 km^2 catchment. This estimated value was about 76% of the measured inflow sediment. The model estimate was considered good, as the model did not include wind erosion. This value was comparable to sediment yield reported by Muya (1990) for Kalundi basin, Kenya, which had similar environmental conditions to the study site.

The mean annual soil losses produced by each plot during the cropping season, as estimated by the model, are shown in Fig. 2. Generally, disc ploughing resulted in less soil loss than hand hoeing, irrespective of whether intercropping or single cropping

Table 1 Average values of soil physical and chemical properties of the catchment.

Block	Depth (cm)	Parameters*	Sand (%)	Silt (%)	Clay (%)	Gravel conc. (g 100g^{-1})	Bulk density (g cm^{-3})	Saturated hydraul. conduct. (mm h^{-1})	Organic matter (%)	CEC (meq· 100 g^{-1})
B1	0–10	Mean	22.5	19.0	58.8	1.2	1.17	0.74	3.8	39.2
		SD	1.7	3.4	4.7	1.2	0.08	0.21	0.2	2.6
		Cv	7.6	17.9	8.0	100.0	6.80	28.40	5.2	6.6
	10–20	Mean	24.8	16.5	58.7	3.7	1.21	0.77	3.2	36.2
		SD	1.3	4.3	3.3	3.3	0.10	0.14	0.4	0.9
		Cv	5.2	26.1	5.6	89.2	8.30	19.70	12.5	2.5
	20–30	Mean	20.6	15.4	58.0	3.8	1.28	0.87	2.3	33.7
		SD	5.3	3.5	8.0	2.3	0.18	0.25	0.3	1.1
		Cv	19.9	22.7	13.7	60.5	14.60	28.70	13.0	3.3
B2	0–10	Mean	28.8	28.1	43.1	4.4	1.22	2.60	3.8	32.6
		SD	5.3	7.7	9.4	4.2	0.24	2.06	0.6	5.1
		Cv	18.4	27.4	14.0	95.5	19.60	79.20	15.7	15.6
	10–20	Mean	29.0	22.6	48.4	5.1	1.29	1.46	3.3	33.0
		SD	5.7	2.7	6.8	5.0	0.17	1.09	1.2	5.3
		Cv	19.6	11.9	14.0	98.0	13.30	74.70	36.4	16.1
	20–30	Mean	26.1	20.9	53.0	7.2	1.26	1.26	2.7	29.6
		SD	2.4	6.9	8.0	5.5	0.07	1.07	0.5	4.6
		Cv	9.2	33.0	15.0	79.4	5.60	89.20	18.5	15.5
B3	0–10	Mean	26.9	25.6	47.5	3.0	1.21	1.41	3.9	40.2
		SD	3.3	5.8	4.0	2.0	0.13	0.74	0.3	8.2
		Cv	12.3	22.7	8.4	66.7	10.70	52.30	7.7	20.4
	10–20	Mean	27.4	22.1	50.5	3.7	1.22	1.27	3.4	39.2
		SD	5.0	6.3	6.2	2.3	0.12	0.63	1.5	6.6
		Cv	18.2	28.5	12.3	62.2	9.80	49.60	44.1	16.8
	20–30	Mean	26.8	18.5	54.7	5.6	1.28	0.91	2.9	36.2
		SD	4.9	5.5	3.0	3.6	0.06	0.16	0.2	7.9
		Cv	18.3	29.7	5.5	67.9	6.3	17.60	16.9	21.8
B4	0–10	Mean	25.0	21.2	53.8	3.0	1.29	0.88	3.7	46.2
		SD	2.7	2.5	4.1	1.7	0.10	0.13	0.7	3.4
		Cv	10.8	11.8	7.6	56.7	7.7	14.70	18.9	7.3
	10–20	Mean	21.5	22.7	55.8	5.3	1.32	0.08	2.9	40.4
		SD	4.0	2.4	4.6	3.8	0.09	0.21	0.3	2.1
		Cv	18.6	10.6	8.2	71.6	6.80	26.30	10.3	5.2
	20–30	Mean	28.3	24.4	47.3	7.8	1.23	1.77	2.3	38.2
		SD	9.9	6.3	15.9	5.6	0.15	20.9	0.5	1.7
		Cv	34.9	25.8	33.6	71.8	12.20	11.81	21.7	4.4
B5	0–10	Mean	30.2	27.6	42.2	1.5	1.27	2.39	3.1	35.7
		SD	8.1	6.0	7.1	0.7	0.24	1.65	0.7	6.5
		Cv	26.8	21.7	16.8	46.7	18.90	69.00	22.6	18.2
	10–20	Mean	28.8	25.4	45.8	3.6	1.24	1.76	2.8	33.6
		SD	8.9	6.0	11.7	2.4	0.22	1.76	0.5	5.4
		Cv	30.9	23.6	25.5	66.7	17.70	100.0	17.9	16.1
	20–30	Mean	26.6	25.9	47.3	4.1	1.32	1.27	2.5	32.4
		SD	4.9	2.1	3.7	2.3	0.20	0.46	0.5	5.6
		Cv	18.3	8.1	7.8	56.1	15.20	15.20	20.0	17.3

* SD: standard deviation; *Cv*: coefficient of variation.

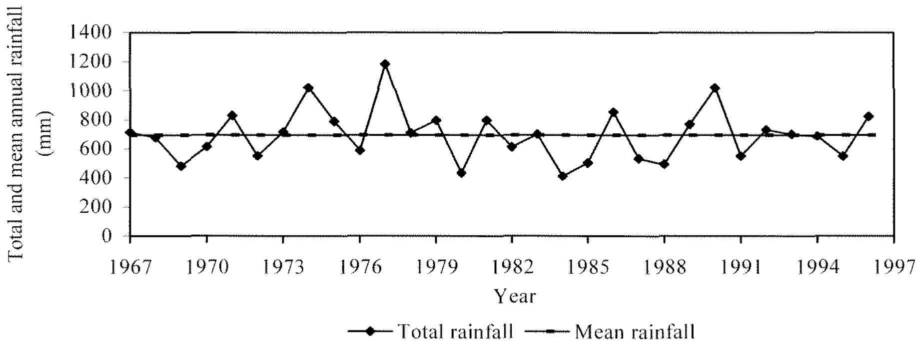

Fig. 1 Annual rainfall variation of Rumuruti.

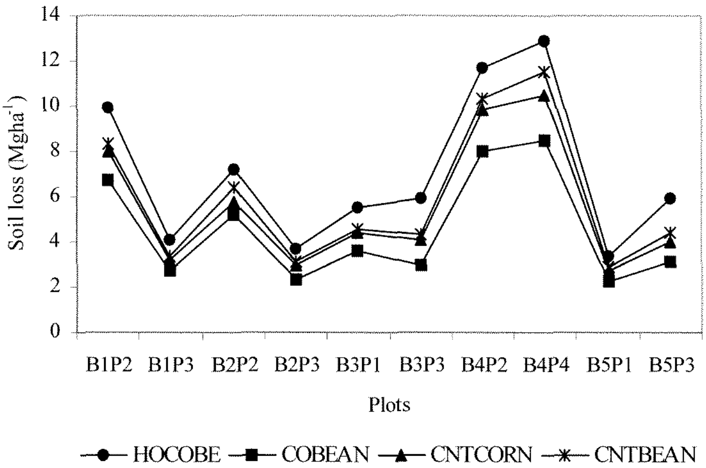

Fig. 2 Estimated mean annual soil losses from the plots under different farm management.

was used. The disc plough with soybean and maize intercropped (COBEAN) resulted in the least soil loss, followed by disc plough with only maize cultivated (CNTCORN), and then disc plough with only soybean cultivated (CNTBEAN), while hand hoeing with maize and beans intercropped (HOCOBE) had the highest soil loss. In comparison, the soil loss reduction of COBEAN and HOCOBE ranged between 27 and 47%, that of CNTCORN and HOCOBE between 16 and 29%, and that of CNTBEAN and HOCOBE between 12 and 25%, depending on the size and slope steepness of the plot. The soil loss reduction of CNTCORN and COBEAN relative to CNTBEAN ranged between 4 and 9% and 19 and 21%, respectively. The study showed that, with the same tillage method, single crop cultivation produced higher soil loss than two crops intercropped, in the order CNTBEAN > CNTCORN > COBEAN. This indicates that single crop cultivation with conventional tillage would have higher soil loss than the cultivation that was being practised by the farmers (maize and soybean intercropped with conventional tillage). Generally, conventional tillage resulted in higher soil loss than disc ploughing. This could be attributed to increases in surface roughness

Table 2 Basic data of the hillslopes.

Plots	Area (ha)	No. of slope points	Slope steepness (m m^{-1})	Normalized distance from top to point (m m^{-1})	Length of plot (m)
B1P2	21.6	3	0.00	0.00	313.0
			0.33	0.43	
			0.24	1.00	
B1P3	17.2	3	0.00	0.00	277.3
			0.15	0.64	
			0.11	1.00	
B2P2	11.5	4	0.00	0.00	229.6
			0.47	0.26	
			0.59	0.69	
			0.26	1.00	
B2P3	30.1	4	0.00	0.00	263.6
			0.17	0.37	
			0.24	0.91	
			0.29	1.00	
B3P1	7.5	4	0.00	0.00	477.0
			0.47	0.17	
			0.08	0.50	
			0.06	1.00	
B3P3	20.9	3	0.00	0.00	193.0
			0.20	0.88	
			0.29	1.00	
B4P2	16.8	4	0.00	0.00	245.0
			0.30	0.17	
			0.32	0.86	
			0.39	1.00	
B4P4	9.3	4	0.00	0.00	364.2
			0.66	0.13	
			0.48	0.57	
			0.17	1.00	
B5P1	3.7	2	0.00	0.00	178.3
			0.14	1.00	
B5P3	13.5	4	0.00	0.00	621.3
			0.14	0.39	
			0.24	0.79	
			0.13	1.00	

and porosity of the soil during ploughing, which enhance surface water retention and percolation. The soil losses from the plots follow the same pattern (Fig. 2), indicating that the soil properties on the plots were similar. Therefore, the basic factors that influenced the soil losses within the plots were the tillage and cropping systems.

Table 2 shows the basic characteristics of the plots at the time of the study. From Fig. 2 and Table 2, it can be seen that the quantity of soil loss was not influenced by the size of the plot, but by slope steepness and arrangement. Of the four treatments compared, plot B4P4, which had the highest soil losses of 12.5, 8.5, 10.5 and 11.5 Mg ha^{-1}, had a size of 9.3 ha, whilst plot B2P3, the biggest plot at 30.1 ha, produced 3.7, 2.3, 3.0 and 3.1 Mg ha^{-1}, respectively. Plot B4P4 had a slope steepness of 0.66, 0.48 and 0.17 m m^{-1} from its upslope to downslope (Table 2). This indicated that slope steepness had much influence on soil loss. Generally, plots with steeper upslope had greater soil loss than those with different arrangements of slope steepness (Fig. 2, Table 2).

CONCLUSIONS

The mean annual soil losses from single cropping systems (maize or soybean) were higher than those from intercropping systems (maize and soybean) for the disc plough. However, the mean annual soil losses from the intercropping system under conventional tillage were higher than those from the single cropping systems using the disc plough. The mean annual soil losses from maize cropping were slightly higher than those from soybean cropping with the disc plough.

The study showed that both tillage and cropping systems had influence on soil losses within plots. However, the tillage system had greater influence than the cropping system. Thus, if soil loss by water erosion is a serious problem in semiarid agricultural lands, as it is in Sipili, conventional tillage with an intercropping system may not be an effective management system. Even though intercropping resulted in less soil loss than single cropping, intercropping using conventional tillage produced higher soil loss than single cropping using a disc plough. Therefore the continuous use of conventional tillage with intercropping may be decreasing the top layer of the agricultural lands.

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