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On-farm Assessment of Contour Hedges for Soil and Water Conservation in Central Kenya

S.D. Angima, M.K. O'Neill and D.E. Stott*

ABSTRACT

This is ongoing research on the impact of contour hedges on soil and water conservation under direct farmer management practices at the Kianjuki catchment area of central Kenya. Twelve runoff plots (six on 20 % slope and six on 40 % slope) are set on two farms. There are two treatments with three replications for treatments with hedges and non-hedged plots. Data for three rainfall seasons indicated more soil conserved by hedges than the non-hedged control on both slopes. The advantages of using hedges as conservation strips were observed for both soil loss and fodder production. For the three seasons (1997 long and short rains and 1998 long rains), a seasonal average of 120 Mg ha^{-1} and 118 Mg ha^{-1} of soil were lost from the conserved plots compared to 157 Mg ha^{-1} and 151 Mg ha^{-1} for the control plots on the 20% and 40% slopes respectively. An average of 3.4 Mg ha^{-1} of fodder were harvested from the conserved plots for the 1998 long rains season. As part of the integration of agroforestry practices towards soil conservation, these results reflect a support practice subfactor of 0.99 for the 20 % slope and 0.98 for the 40 % slope for use in soil erosion prediction using the Revised Universal Soil Loss Equation (RUSLE).

INTRODUCTION

Due to the pressure on land in most developing countries from the ever-increasing population, bioengineering methods (use of vegetative strips and tree hedges) have proven to be beneficial to farmers as soil conservation structures, fodder for animals, and fuel wood for energy (Goudreddy, 1992). However, there is need to assess the impact of these contour hedges on soil and water conservation to aid in dissemination of this agroforestry intervention technology in soil and water conservation using on-farm practices. This study is set up on farmers' fields at the Kianjuki catchment in central Kenya, a representative site, climatically, for most of the East African Highlands.

OBJECTIVES

1. To assess the effect of contour calliandra-Napier hedges on soil and water conservation.
2. To calibrate a support practice sub-factor associated with the hedges for the Revised Universal Soil Loss Equation (RUSLE), soil erosion model.
3. Assess extent of nutrient depletion through erosion by measuring amounts of nitrogen and phosphorus in eroded sediments.

MATERIALS AND METHODS

The experiment consists of 12-runoff plots measuring 2.5-m by 9-m (6 on 20 % slope and 6 on 40 % slope) set up on a randomized complete block design of two treatments and three replications. The treatments are a) calliandra-Napier grass hedge across the bottom of the plot that consists of one row of calliandra and one row of Napier grass, and b) control plots with no hedge. Spacing within the hedgerows is 50 cm for Napier grass and 25 cm for calliandra. Spacing between the Napier grass row and calliandra row is 75 cm. The calliandra row precedes the Napier grass row upslope of the hedge to reduce the competition between hedge and the adjacent crops since calliandra is deep rooted. Prior to planting, calliandra was inoculated with *Rhizobium* spp. to ensure nodulation, enhancing the nitrogen fixing capability of the legume. Maize (*Zea mays* L.) was grown on all plots seeded at the rate of 53,000 plants ha^{-1}, which is the rate used by local farmers. Runoff and soil losses are collected using two 200-liter drums for each of the twelve plots. The pH of the sample is determined using a slurry of 2:1 water to air-dried soil. Total carbon is determined by dry combustion (CHN-600, Leco Corp., St. Joseph, MI). Percentages of clay and silt, and the particle size distribution are determined by the pipette method (Gee and Bauder, 1986). Percent organic carbon that is associated with the clay fraction (organic clay complexes) is determined by the dry combustion method. The percentage of sand and gravel are determined by wet sieving (Gee and Bauder, 1986). Amount of phosphorus in eroded sediments is determined by using 0.025 N HCl with 0.03 N NH_4F at pH 2.6 as the extracting solution (Franzmeier, et al., 1977). Then by reacting with ammonium molybdate solution and aminonaphthol-sulfonic acid solution, phosphorus is determined by color spectrophotometry (660 nm) using standards of 0 to 12-ppm

*S.D. Angima and M.K. O'Neill, International Center for Research in Agroforestry, P.O. Box 30677 Nairobi, Kenya; (present addresses for S.D. Angima is University of Missouri Extension, 100 W. Franklin, Courthouse, Room 16, Clinton, MO 64735 and M. O'Neill is Agricultural Science Center, New Mexico State Univ., P.O. Box 1018 Farmington, NM 87499); and D.E. Stott USDA-ARS National Soil Erosion Research Lab 1196 Soil Building West Lafayette IN 47907-1196. Sponsors: SIDA-Nairobi, and Rockefeller Foundation-New York. *Corresponding author: angimas@missouri.edu.

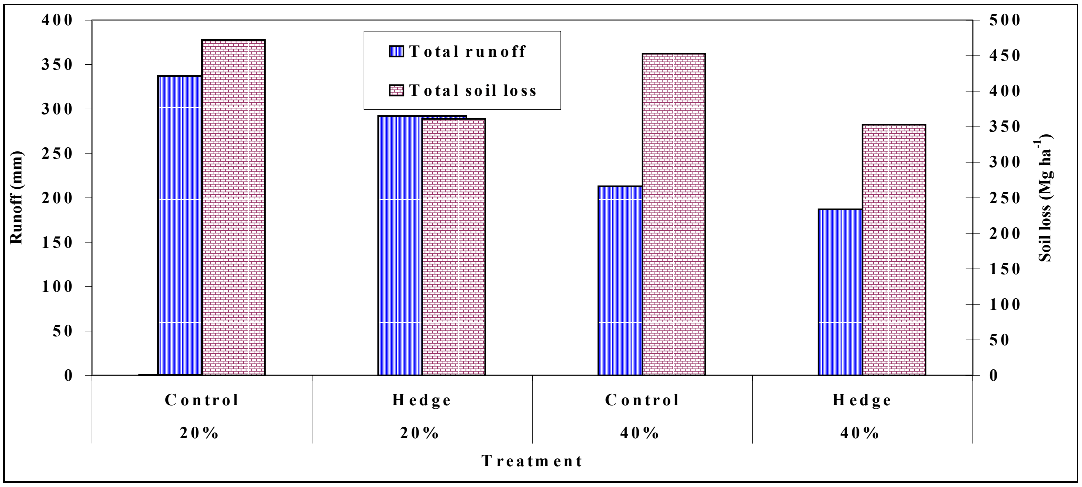

Figure 1. Cumulative runoff and soil loss for the period 1997 long rains and short rains, and 1998 long rains for the Kianjuki catchment site in central Kenya.

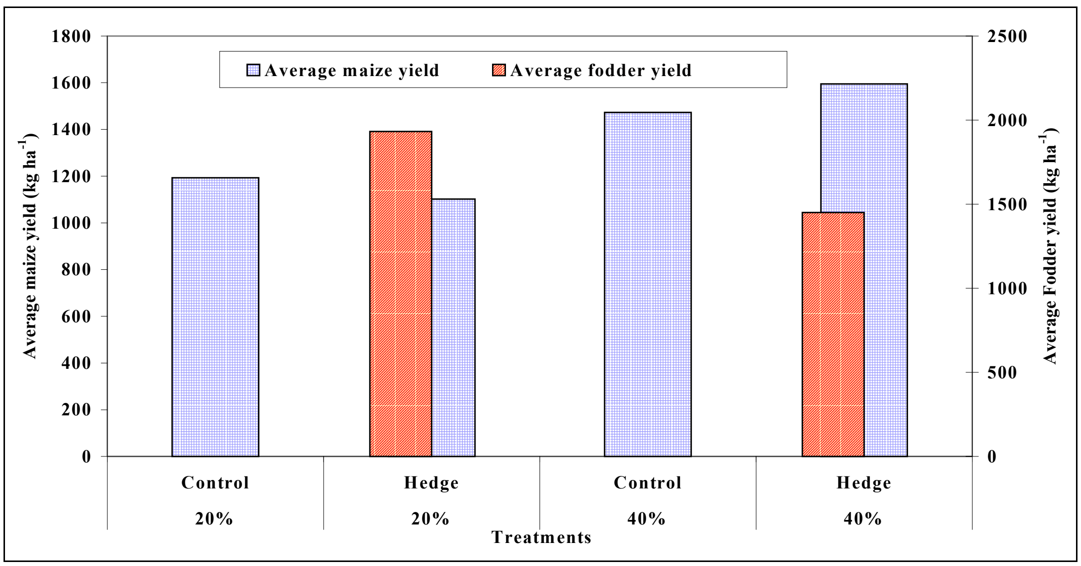

Figure 2. Average maize yield and fodder yield at the Kianjuki catchment site for two slopes in central Kenya.

phosphorus. Total nitrogen is determined by the Kjeldahl method that involves the digestion of the sample with concentrated H_2SO_4 and the NH^{4+} -N is determined from the amount of ammonia liberated by distillation of the digest with an alkali.

To compute the support practice subfactor for the calliandra-Napier hedges, the data gathered from the runoff plots were used based on the procedure for determining subfactors for soil conservation strips in RUSLE (Renard, *et al*., 1997). The following relationship is used to compute a support practice subfactor for conservation strips (Renard, *et al.,* 1997, Renard and Foster, 1983):

$$P_s = (g_p - B)/g_p \qquad [1]$$

Where P_s is the value of P factor for the agroforestry strips; g_p is the sediment load at end of runoff plot for control plots (i.e. total soil collected from runoff); and B is the amount of deposition considered to benefit the long term maintenance of the soil resource and is calculated by:

$$B = \sum_{i=1}^{n} M_i (1 - x_{i-1}^{1.5}) \qquad [2]$$

Where n is the number of strips, x is the relative distance from the top of the slope to the lower edge of the hedge, i is the subscript indicating a particular hedge, and M is the amount of deposition (i.e. difference of soil loss from control to that of treatment).

The sediment load g_p is calculated as

$$g_p = \sum_{i-1}^{n} D_{ni} \qquad [3]$$

Where D_{ni} is the net erosion on the control runoff plot.

Maize yields as well as fodder biomass yields are continually collected to assess the benefit gained by the farmers in using hedges for soil conservation. Fodder is harvested twice in the short rains season and thrice in the long rains season.

RESULTS AND DISCUSSION

Soil properties

Particle size analysis of the soil from the field showed a high percentage of clay (>50 %), silt (>18%), and sand (>12%) dominating the top 0-20 cm of the soil profile but varied between treatments and slope (Table 1). The differences in soil properties between the two slopes contributed to the inverse observations in runoff and erosion rates between the 20% and 40% slope (Table 2).

Erosion and land productivity

Runoff and soil loss were generally higher on the 20% slope than the 40% slope for the three seasons of 1997 long rains, 1997 short rains and 1998 long rains (Table 2, & Figure 1). Surprisingly, the steeper slope did not consistently have the greatest amounts of soil erosion for each season (Table 2). This was attributed to variations in soil properties between all the treatments for the two slopes (Table 2). The treatments on the 20% slope had significantly higher amounts of clay and significantly less sand than those on the 40% slope (Table 2). Higher clay contents in a soil leads to faster initial surface sealing which results to more runoff (Morgan, 1995). The 40% slope had significantly more silt and sand than the 20% slope, which leads to more erosion at higher rainfall amounts of high intensities on steeper slopes (Morgan, 1995). The 40% slope usually had higher erosion rates for rainfall events that exceeded 40 mm and these events were fewer than those below 40 mm. Organic C and organic-clay complexes in the soils were very low and did not significantly differ between any of the treatments and therefore did not play a big role in the erosion process nor were they responsible for differences seen between slopes (Table 1). The slope aspect also contributed to the observed differences in runoff amounts as more raindrops fell on the 20% slope than the 40% slope as a result of the slope angle coupled with the direction of winds during rainstorms that were dominantly blowing parallel to the slopes where the runoff plots were established within the catchment. The acceptable tolerable soil loss for renewable soil resources for the catchment area is estimated as 2.2 - 4.5 Mg ha^{-1} yr^{-1} for the top 0-20 cm of the soil and 4.5 - 10 Mg ha^{-1} yr^{-1} for the 25-50 cm layer (McCormack and Young, 1981). Taking this value for soil formation, it means that the catchment losses more soil than formation can replace and therefore raises the need for further conservation practices to be implemented for future agricultural support. Besides using vegetative hedges for soil erosion, other practices such as adding organic matter and constructing terraces on slopes will greatly reduce soil detachment and transportation respectively, resulting in reduced final erosion rates. This can be accomplished with joint efforts by research and the extension services by teaching and educating farmers on soil conservation methods that are appropriate for the locality in order to help attain sustainable farming for future generations.

For the same season (1997-1998), maize production on plots with hedges on the 20 % slope was on average 8% less than the control plots while on the 40% slope, maize yield was higher by 8% for plots with hedges compared to the control (Table 2, Fig. 2). The increase in maize production on the 40% slope could be attributed to a longer trend of less runoff and soil loss (Table 2). The more the soil resource is conserved the more we can expect to increase yield and in this case there is extra benefit accrued from fodder production when the hedges are used.

Analysis of eroded sediments for total soluble nitrogen and phosphorus for the 1997 long rains showed substantial losses of these nutrients in runoff. The amounts ranged from about 144-170 kg/ha for nitrogen and 101-134 kg/ha for phosphorus on the two slopes before the hedges had established (Table 3). Of all nutrients, N is required in the greatest quantity for plant growth, and most N is linked to existing soil organic matter SOM (Giller, et al., 1997). Across much of Africa, soils have come under intensive cultivation due to increased population pressure. This has led to gradual net losses of SOM and therefore N, due to reduced organic input and the faster rate of SOM turnover under cultivation has increased soil erosion (Giller, et al., 1997).

Both P and N are very essential elements for higher crop yields (Sanchez, et al., 1997). In other studies, Cassman, et al., (1993), Palm, et al., (1997), and Giller, et al., (1997), have shown that the combination of P replenishment with N replenishment can have synergism such as enhancing N fixation by legumes, while integration of P fertilizers with organic materials to supply N and K can potentially enhance P availability.

In order to alleviate poverty and food shortage in Africa, research has shown a great need to replenish and sustain P levels in the soils (Mokwunye, et al., 1996; Smaling, et al., 1997; Buresh and Smithson, 1997). Earlier studies had shown high inherent fertility but the present shorter duration unsustainable fallow systems have depleted P levels drastically (Sanchez, et al., 1997; World Bank, 1994). While all available forms of P fertilizers can be used to alleviate this problem (Wild, 1973; Le Mare, 1984; Sale and Mokwunye, 1993), there is need for ways to prevent P losses to increase the P-*capital* (Sanchez and Palm, 1996). In this study, the high losses of N and P on both slopes (Table 3) justify the great need to control runoff and soil loss to retain nutrients for crop production and to attain a reduction in river and reservoir pollution.

Erosion modeling with RUSLE

Using the data for the soil loss during the three seasons (Table 2), a support practice subfactor for the hedges was calculated using equation 1 (Table 4). These subfactors, though showing less capacity to control erosion at this phase (Renard, et al., 1997), are expected to improve after the hedges are fully established. The use of hedges can compliment use of other conservation structures such as terraces and cutoff drains as they provide better economic alternatives to other structures (Kebede and Hurni, 1992), in this case fodder production. This is especially important in small-scale mixed farming systems in the East African highlands where fodder scarcity is prevalent due to the decreasing farm size of 2-6 hectares (O'Neill, 1993). When the fodder from the hedges is fed to animals, the return in form of manure to the soils would increase organic matter that in turn will alleviate the erosion hazard thus contributing

Table 1. Soil chemical and physical properties for the treatment plots in the Kianjuki catchment of central Kenya

Slope Treatment	Clay ($g\ kg^{-1}$)	Silt ($g\ kg^{-1}$)	Sand ($g\ kg^{-1}$)	pH	Organic Clay Complexes: Inside Plot ($g\ kg^{-1}$)	Organic Clay Complexes: Eroded Sediments ($g\ kg^{-1}$)	Organic Carbon ($g\ kg^{-1}$)
20% Control	689 a †	184 d	127 d	4.7 b	21.0 a	15.0 a	11.3 a
20% Hedge	639 b	204 c	157 c	5.1 a	20.9 a	14.8 a	12.9 a
40% Control	532 d	288 a	180 a	4.6 b	20.6 a	14.1 a	11.8 a
40% Hedge	549 c	277 b	173 b	4.9 ab	20.8 a	14.7 a	12.2 a

† If the same letter appears within-column, differences are not significant at the 5% level by Duncan's multiple range test.

Table 2. Runoff, soil loss, maize yield and fodder yield for the period 1997 long rains, & short rains and 1998 long rains for the study site.

Treatment	20 % slope			40 % slope		
	1997 long rains	1997 short rains	1998 long rains	1997 long rains	1997 short rains	1998 long rains
			Runoff (mm)			
Control	92	134	111	64	56	93
Hedge	91	110	92	55	52	80
			Soil loss ($Mg\ ha^{-1}$)			
Control	89	168	216	101	77	276
Hedge	84	119	158	61	71	221
			Maize yield (kg/ha)			
Control	586	2366	628	722	2730	966
Hedge	513	2166	628	834	3081	870
			Fodder biomass yield (kg/ha)			
Calliandra			426			410
Napier			1507			1041

Table 3. Total soluble nitrogen (TSN) and phosphorus (TSP) in the eroded sediments for the two slopes before the establishment of the hedges.

Slope	TDN ($kg\ ha^{-1}$)	TSP ($kg\ ha^{-1}$)
20 %	170	101
40 %	144	134

Table 4. Support practice sub-factors for the calliandra-Napier hedge for use in RUSLE.

Slope (%)	Sediment Load (g_p)	Deposition (B)	Support Sub-factor (p)
20	472	1.8	0.99
40	453	7.8	0.98

towards a sustainable agricultural production system (Ohlsson and Shepherd, 1992).

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