Impacts of vegetative contour hedges on soil inorganic-N cycling and erosional losses in Arable Steep-lands of the Central Highlands of Kenya

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Abstract

Moderate to steep landscapes and severe soil, water and nutrient losses characterize over 40% of arable land in the central highlands of Kenya. To study the effectiveness of biological methods in management and enhancement of productivity of these arable steep-lands, we established contour double row hedges of sole *Calliandra*, *Leucaena* and napier and combination hedges of either *Calliandra* or *Leucaena* with napier. Hedges were established on slopes exceeding 5%, pruned regularly and the resulting biomass cut into fine pieces, which were then incorporated into the plots they served. We then evaluated these plots for inorganic-N changes with depth, soil conservation and soil loss/crop growth relationships. We observed accumulation of inorganic-N in the sub-soil in the control and napier plots but a reduction of sub-soil inorganic-N and its re-accumulation in the top-soil in the leguminous hedge plots after 20 months of trial. The first season on average, registered higher soil losses ($P = 0.004$) than the second season for treatments with hedges and vice versa for the control. During the first season there were significantly lower ($P < 0.001$) soil losses in plots with hedges relative to the control on slopes exceeding 10% but with the exception of napier, no significant differences among different types of hedges. We observed higher soil loss reduction in the combination hedge relative to individual tree hedges across the two seasons ($P = 0.012$). The relationship between cumulative soil loss and any of the four crop growth parameters i.e., grain weight, plant height, stover weight and total above ground biomass was negative, linear and highly significant ($P < 0.0001$), indicating decreased crop growth with soil loss. We conclude that there are heavy productivity losses as a result of soil erosion in arable steep-lands of the central highlands of Kenya and that well spaced, managed and combined contour hedges of leguminous trees and napier can reduce soil and nutrient losses from steep arable landscapes while simultaneously enhancing soil fertility

Key words: Contour hedges, inorganic-N, soil fertility, soil erosion, slope

Introduction

Recent studies in the central highlands of Kenya have revealed leaching of up to 300 kg N $ha^{-1}yr^{-1}$ (Mugendi et al., 2003) and a soil loss of 150–200 t $ha^{-1}yr^{-1}$ (Angima, 2000). At modest soil loss level of 10 t $ha^{-1}yr^{-1}$, it is estimated that soils lose on average 28 kg N, 10 kg P and 33 kg K $ha^{-1}yr^{-1}$(Mantel and Van Engelen, 1999). Construction of physical soil conservation structures is expensive, laborious and time-consuming, and farmers do not have adequate resources to invest in construction due to scarcity and multiple competing enterprises that characterize the households. This leads to low adoption of physical soil conservation technologies and hence heavy soil and nutrient losses. In addition to causing serious monetary losses to farmers, soil loss pollutes rivers and other water bodies potentially causing eutrophication, bottom water hypoxia and health hazards to both humans and animals (Cast, 1985; Duijvenbooden and Matthijsen; 1987; Justic et al., 1995). The usefulness of contour hedges as alternatives to physical soil conservation

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structures has been demonstrated in Kenya (Raintree and Torres, 1986; Angima; 2000), Nigeria (Lal, 1989) and Java Indonesia (Pacardo and Montecillo, 1983). Basically, contour hedgerows control soil erosion by two mechanisms: (1) the hedgerows act as permeable barriers for slowing the flow of runoff and (2) The pruned biomass which is deposited as green manure between the hedges provides a protective cover from raindrop impact (Young, 1997).

Incorporating leguminous pruning residues from contour hedges improves soil fertility as these materials decompose and release nutrients, which translates into better crop production (Yemoah et al., 1986; Mugendi et al., 1999). Apart from improving the soil nutrient status, the pruned residues may also increase the soil organic matter content (Yemoah et al., 1986). This in turn improves the soil physical properties, creating favorable conditions for plant growth. In alley cropping trials of nine leguminous trees with maize in Hawaii, Rosecrane et al. (1992) reported an increase in maize yields with addition of tree pruning mulches. For every kilogram of nitrogen applied in form of mulch, approximately 12 kg of additional maize grain yield was produced. Most of these studies however, have been done on-station and therefore do not adequately simulate farm situations, where many uncontrolled factors account for poor performance of technologies that are successful on-station. Studies combining soil conservation aspects of agroforestry with nutrient enhancement/management and crop production which is the ultimate farmers' goal are also few.

To address these problems, we established an on farm trial with thirty-three farms in the central highlands of Kenya to determine the extent of top-soil loss through water erosion and the effectiveness of leguminous (*Calliandra calothyrsus* Meissner and *Leucaena trichandra* (Zucc.) Urban) and non leguminous (napier grass) vegetative contour hedges in soil conservation and nutrient enhancement.

Materials and methods

Description of the study area

This study was conducted in Chuka Division, Meru South District, which is a predominantly maize growing zone in the central highlands of Kenya. The area is on the eastern slopes of Mt Kenya at an altitude of approximately 1500 m above the sea level. Mean annual rainfall is 1200 mm, distributed in two distinct seasons; the long rains (mid March to June) with an average precipitation of 650 mm and the short rains (mid October to December) with an average of 550 mm of rainfall. The average monthly maximum temperature is 25°C and the minimum is 14°C. The long-term monthly average temperature is 19.5°C. The soils of this area are mainly humic Nitisols (FAO, 1990) equivalent to Paleustalf in the USDA soil taxonomy system (Soil Survey Staff, 1990) with an average soil reformation rate of 2.2–4.5 Mg ha^{-1} per year for the top 0–25 cm soil depth and 4.5–10 Mg ha^{-1} per year for the 25–50 cm soil depth (McCormack and Young, 1981; Kilewe, 1987). They are deep, well weathered with friable clay texture with moderate to high inherent fertility.

Experimental design and methodology

Slopes and contours of 33 trial farms were determined by use of a clinometer and surveyors level, respectively. We evaluated mono-specific hedges of: *Calliandra*, *Leucaena*, napier and combination hedges of *Calliandra* + napier and *Leucaena* + napier. Plots with no hedges served as controls in each farm. Each hedge was made up of 2 rows of the above species arranged in interlocking/zig-zag manner with inter-row spacing of 0.25 m and intra-row spacing of 0.5 m. The plots were 10 m long with variable inter-hedge spacing calculated according to Young (1997) as follows:

$$W = 200/S\% \quad (1)$$

where W = inter-hedge spacing in metres and S% is the per cent slope. Where there was a napier + either *Calliandra* or *Leucaena*, the tree row preceded the napier grass row upslope. Each farm represented a block. The aim of blocking was to minimize the effects of site variation so that the treatment effects could be more accurately quantified using statistical tests. Care was taken to ensure that none of the plots fell on obvious convex zones of higher than average net erosion, or deposition zones of net sedimentation. We also trenched the plots on the upper lateral borders to prevent eroded sediments from up-slope areas from entering into the test plots.

After planting, the hedges were left for one year to become well established after which they were regularly pruned every 2 months to a height of 50 cm for