Soil Conservation and Fertility Improvement Using Leguminous Shrubs in Central Highlands of Kenya: NARFP Case Study

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Abstract

Declining land productivity with reduced crop yields has been a major problem facing smallholder farmers in the central highlands of Kenya. The major factors contributing to the reduced land productivity is soil impoverishment caused by continuous cropping without addition of adequate fertilizer and manure, and soil erosion on steep slopes. The National Agroforestry Research Project (NAFRP) initiated research work in 1992 to try and address these problems. The research work investigated the potential of using two leguminous shrubs (*Leucaena leucocephala* and *Calliandra calothyrsus*) for improving soil fertility and soil conservation on steep slopes. The studies were carried out both at on-station and on-farm.

Treatments where leafy prunings of calliandra and leucaena were incorporated yielded higher than the control treatments without prunings incorporation. Leucaena alley cropping system was beneficial and maintained crop yields at 4 t ha$^{-1}$ in most seasons. Calliandra hedgerow intercropping system on the other hand depressed crop yields. However calliandra was effective in controlling soil erosion when planted as a contour-hedgerow system. The contour hedgerows in addition to conserving soil produced additional benefits in terms of high quality animal fodder.

This study concluded that in the central highlands of Kenya where land is slopy, and similar areas, it is advisable for the smallholder farmers to plant leguminous fodder trees on terraces as contour hedgerows for both soil conservation and biomass production. The resulting biomass could be incorporated into the soil to improve soil fertility for farmers without livestock, or fed to livestock for farmers who own livestock. If the biomass is fed to livestock, possibilities of recycling nutrient through animal manure should be explored to ensure soil nutrient replenishment.

**Key words:** Alley-cropping, *Calliandra calothyrsus*, *Leucaena leucocephala*, Contour hedgerows, Leafy prunings (prunings), Fodder

Introduction

The central highlands of Kenya are densely populated with more than 500 persons Km$^{-2}$ (Government of Kenya, 1994) and declining land productivity with reduced crop yields has been a major problem facing smallholder farmers in the region (Kipkiyai et al., 1998). The major factors...
contributing to the reduced land productivity is soil impoverishment caused by continuous cropping with inadequate addition of fertilizer and/or manure, and soil erosion on steep slopes (Minae and Nyamai, 1988).

Land sizes are small, averaging 1.2 ha per household, and this promotes continuous cropping with limited scope for crop rotation and inadequate soil fertility replenishment. Nitrogen and phosphorus are the most limiting nutrients to crop production and high costs of inorganic fertilizers limit their sufficient use by majority of the smallholder farmers. Indeed a substantial number of farmers do not use fertilizers and the ones who use fertilizers apply below the recommended rates (Kihanda, 1996). Murithi et al. (1994) reported use of fertilizers by farmer to be less than 20 kg N and 10 kg P ha\(^{-1}\) against recommended rate of 60 kg N and Pha\(^{-1}\).

The topography of the central highlands of Kenya is gently to steeply rolling with a medium to high erosion hazard as determined by FAO (Kassam et al., 1992). The sloping topography and high rainfall has resulted to soils in the region being highly prone to water erosion (O'Neill, 1997; Ongwenyi et al. 1993). Water erosion carries away soil nutrients and, soil nutrient depletion has been reported to be taking place at an alarming rate in all the agroecological zones (Pieri et al., 1995). Leguminous trees species have shown some potential for soil fertility improvement and soil conservation. Soil fertility improvement can be achieved through biomass transfer, short term fallows, nitrogen fixation, re-activation of the 'N bulge' and phosphorus scavenging (Rosecrance et al., 1992; Amadalo et al., 1995; Jama et al., 1998; Hartemink et al., 2000). The leguminous trees have similarly shown potential of reducing soil erosion through five processes; interception of rainfall impact by tree canopy, surface runoff impediment by tree stems, soil surface cover by litter mulch, promotion of water infiltration and formation of erosion-resistant blocky soil structure (Nair, 1987; Young, 1989; Young and Sinclair, 1997). Researchers at other sites within East Africa AFRENA (ICRAF, 1991) have had success of varying degrees by incorporating fodder grasses and trees along the contours to both reduce soil erosion and provide products which would help convince the farmers that soil conservation can be profitable.

Despite the potentials for the use of tree shrubs for soil conservation and soil fertility improvement, their use in the region is limited (ICRAF, 1992). A survey carried out in Meru District (Murithi et al., 1994) found that 83 percent of the farmers surveyed had soil fertility problems while 91 percent had soil erosion problems. In the survey majority of farmers (93 percent) used manure for improving soil fertility with limited use of tree prunings while none of the farmers used trees for soil erosion control.

To address the aforementioned problems of soil fertility decline and soil erosion on steep slopes, the National Agroforestry Research Project (NAFRP), based at the Kenya Agricultural Research Institute (KARI),
Regional Research Centre-Embu, Kenya, conducted some research activities to investigate feasibility of using leguminous trees for soil fertility improvement and soil conservation. The research work was initiated in 1992 and this manuscript review consolidates the research work, highlighting the major findings and also discusses the dissemination potential. The leguminous shrubs used are *Leucaena leucocephala* (Lam.) de Wit and *Calliandra calothyrsus* Meissn. The two species have been shown to be the most appropriate species for soil improvement and crop sustainability through agroforestry research at Maseno, Kenya (Heinemann et al., 1990).

**Methodology**

**The study area**

The highlands of Central Kenya are characterized by a bimodal rainfall distribution, which ranges from 600 mm to 2000 mm annually in the mandate region of the National Agroforestry Research Project based in Embu. Agriculture is characterized by smallholder mixed farming activities, which include cash crops (coffee, tea and horticultural crops), food crops (Maize, beans, bananas and Irish potatoes) trees and livestock (dairy and beef cattle, goats, sheep, poultry and pigs). Nearly all farmers in the region practice dairy farming under zero and/or semi-zero grazing and the need for fodder is a main constraint (Minae and Nyamai, 1988). Napier grass (*Pennisetum purpureum*) is the major fodder and is generally produced in fodder plots or along the bunds of terraces where it is also used as stabilizer for the erosion control structures.

High population pressure (> 500 persons Km⁻²) has led to the subdivision of family farms into small units (app. 1.2 ha) which require intensive agricultural practices to produce enough food for home consumption and outside sales. This has led to the exploitation of lands of decreasing productivity and increasing soil erosion potential.

The soils are locally known as “Kikuyu Red Clay Loams”. They are deep (>2m), well drained, dusky red to dark reddish brown in colour with moderate structure (Mwangi, 1997). They are derived from rich, basic volcanic rocks and have been classified as Typic Palehumult (Humic Nitisols according to FAO-UNESCO, 1975).

**Research Activities**

Within the period 1992 and 1998 two on-station experiments and one on-farm experiment were carried out to address the problems of declining
Soil fertility and soil erosion on steep slopes. These experiments are described in the following sections.

Alley-cropping experiment

An alley-cropping was installed during 1992 at the Embu Regional Research Centre. The aim was to evaluate feasibility of using leafy prunings of calliandra and leucaena in a maize production system for soil productivity enhancement in both alley-cropping and monocropping systems. The experimental design was a Randomized Complete Block with four replicates. The plot dimensions were 9 x 10 m while the sample plot was 6 x 4.5 m. Maize (Zea mays L.) variety Hybrid 511 was the test crop. The experiment consisted of ten treatments. Six of these had fresh leaf prunings of tree species (leucaena and calliandra) applied. The prunings were obtained from hedgerows grown in situ (alley-cropped) or ex-situ (cut and carry) from other sources. The treatments were as follows:

Alley-cropping; no fertilizer

1. Calliandra; prunings incorporated
2. Leucaena; prunings incorporated
3. Calliandra; prunings removed to treatment 5
4. Leucaena; prunings removed to treatment 6

Maize only; no alley cropping; prunings from outside incorporated
5. Calliandra prunings from 3; no fertilizer
6. Leucaena prunings from 4; no fertilizer
7. Calliandra prunings + fertilizer (25 kg N ha⁻¹)
8. Leucaena prunings + fertilizer (25 kg N ha⁻¹)

Maize only; no alley cropping; no prunings
9. With fertilizer (50 kg N ha⁻¹)
10. Without fertilizer

The prunings were always lopped and soil-incorporated using hand hoes immediately before maize was planted. The weight of prunings applied to treatments 5 and 7, and 6 and 8 was equal to the weight of prunings obtained from Treatments 3 and 4.

Harvesting of maize was done by cutting maize plants at soil level. Maize cobs were manually separated from the stover, sun-dried and packed in paper-bags before threshing. After threshing, moisture content of the grains was determined using a moisture meter and grain weights adjusted to 12% moisture content.
Contour hedgerow experiments (on-station and on-farm)

An on-station contour hedgerow experiment was set up in 1993 with two objectives. First to determine the degree to which contour hedges of grasses and trees, in combination and alone, can reduce soil erosion and; secondly to determine the amount and quality of fodder the various combinations could provide over time. Due to the limited size of available land, the maximum number of sufficiently large plots were eight. Hence there were two replications of four treatments: the control (with no hedge), grass hedge (consisting of two rows of Napier grass) (*Pennisetum purpureum*), tree hedge (consisting of two rows of calliandra), and combination hedge (consisting of one row of calliandra and one row of Napier grass). The runoff plots measured 5 x 30 m on an 18% slope and runoff was measured by a tipping bucket system (Khan and Ong, 1997). Maize was grown on all the plots at the recommended density and the crop’s agronomic practices of the area followed as recommended.

Following promising results from the on-station experiment (O’Neill *et al.*, 1995), an on-farm experiment was initiated in 1996, with an objective of assessing the impact of contour hedges on soil and water conservation under direct farmer management practices. Treatments consisted (1) tree hedge consisting of two rows of calliandra (2) A grass hedge consisting of two rows of napier grass and (3) control with no hedges. They were replicated thrice on two different slopes (20% slope and 40% slope) within Kianjuki Catchment of Embu District, Kenya. Runoff was collected in drums/barrels at the lower part of runoff plots.

Results and Discussions

Alley-cropping experiment

In the alley cropping experiment highest mean yields were obtained from treatment 2 (leucaena alley crop + prunings) and treatments 5 and 6, (maize monocrop + prunings) and 7 and 8 (maize monocrop with prunings + 25 Kg N ha\(^{-1}\)) in most seasons over the 11 seasons under study (1993 – 1998) (Table 20.1). These treatments had significantly higher mean maize yields at 5 % probability level than all the other treatments. This is an indication that the soil-incorporated leafy prunings of calliandra and leucaena improved maize growth resulting to increased maize grain yields. The results agree with findings of Guevara (1976), Kang (1981) Evensen (1984) and Attah-Krah (1990) who reported significant maize yield increases following application of green manure. In the present study the leafy prunings incorporated into the soil (as green manure) at the beginning of the season decomposed and released nutrients especially nitrogen which enhanced crop performance (Mugendi *et al.*, 1999a).
Table 20.1: Mean maize grain yield (t ha⁻¹) for 1993-1998 seasons from various treatments in an on-station study at Embu, Kenya

<table>
<thead>
<tr>
<th>TRT</th>
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<th>SR 93</th>
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Means followed by the same letter within a column are not significantly different at P< 0.05

*Abbreviations: SR = short rains; LR = long rains*

*Source: (Mugwe and Mugendi, 1999)*
During the first phase of this experiment, from 1993 long rains (LR) to 1994 LR, nutrient deficiencies especially nitrogen and phosphorus (P) occurred and resulted in low crop yields (Mugwe et al., 1997). During 1994 LR, Mwangi (1997) reported phosphorus deficiencies in all plots except where fertilization was done. This was attributed to low native phosphorus as a result of high P-fixing capacity of these soils and that the biomass harvested from the hedgerows was low and contained little amount of P (about 0.2%) which could not supply adequate amounts of P into the soil to meet the crop demand (Mugwe et al., 1999). This agrees with findings of Palm (1995) and Salazar et al. (1993) who found insufficient amount of P in prunings of most tree species. As such, supplementation of P through the use of inorganic fertilizers was recommended.

Biomass production over the study period was generally low in the range of 1.1 to 3.5 Mg ha\(^{-1}\) season\(^{-1}\) (Table 20.2). Highest biomass production was obtained during 1997 SR and 1998 LR which was attributed to higher rainfall during the seasons due to El-nino phenomenon (Mugwe et al., 2000). The low biomass incorporated resulted in low nutrient contribution (containing approximately 60 kg N ha\(^{-1}\) season\(^{-1}\) or 120 kg N ha\(^{-1}\) yr\(^{-1}\)). This could not contribute sufficient amounts of nutrients to compensate fully for those lost in crop harvests (Mugendi et al., 1999a; Mugwe and Mugendi, 1999) as nitrogen removal by crop harvests in the plots that received prunings ranged from 150 kg to 269 kg ha\(^{-1}\) year\(^{-1}\) (Mugendi et al., 1999b). The results agree with those reported by Kang (1993), Nair (1993) and Scroth et al. (1995) where a small decline in soil fertility was observed in plots that had prunings applied. The findings, however did not agree with reports from the humid tropics where application of prunings to the soil resulted in increased soil organic matter and higher N, P, K, Ca, and Mg (Kang et al., 1985; Kang et al., 1990; Tian et al., 1993). The difference between the current study and studies in the humid tropics is that, whereas hedgerow species in the humid tropics produced 8 to 10 Mg ha\(^{-1}\) yr\(^{-1}\) of biomass (Young 1989) the trial at Embu produced less than half this amount (Table 20.3). The low biomass production of hedgerow species in alley cropping systems in most areas is one major drawback that limits the potential of prunings to improve fertility and productivity of soils (Mathews et al., 1992; Yadavinder et al., 1992; Young 1989; Nair, 1993).

Consistently higher yields were obtained in leucaena alley crop with prunings incorporated treatment (treatment 2) than the fertilizer alone and control treatments (Treatments 9 and 10) (Table 20.1). This is an indication that leucaena can be used effectively in alley cropping arrangements to improve crop yields (Mugendi et al., 1999a; Mugwe et al., 1999). This corroborates with findings of other studies (Kang, 1993; Xu, 1993) where biomass incorporation in alley cropping system
increased crop yields. Calliandra alley crop on the other hand gave significantly lower yields than leucaena alley cropping in the present study. Other researchers working with calliandra reported mixed performance. For instance, some have reported improved crop yields (Heinneman, 1992; Rosecrance et al., 1992), while Gutteridge (1992) reported depressed or marginal yields.

The poor performance of calliandra in alley cropping may be explained by the root morphology of the two species. Mugendi et al. (1999c) in this experiment showed that over 95% of all maize roots were located in the top 90 cm while for calliandra and leucaena it was 60% and 25% respectively (Table 20.3). This agrees with findings of other authors, for example, NAS (1993) who reported that calliandra trees develop strong superficial root system in addition to the taproot and Jama et al. (1997a) who demonstrated that calliandra had the highest root density in the top 0-5 cm compared to other tree species in Western Kenya.

Results from this experiment indicated that incorporation of prunings of calliandra and leucaena in a maize monocrop system improves crop yields. Also alley cropping with leucaena for soil productivity improvement is advantageous but not with calliandra. However, in already phosphorus deficient soils, soil productivity improvement through alley cropping using *Leucaena leucocephala* or *Calliandra calothyrsus* is advantageous. This is mainly because biomass produced from the hedgerows is low and contains low amounts of P that is insufficient to meet crop demands.

**Contour hedgerow experiments (On-station and on-farm)**

From the on-station contour hedgerow experiment O’Neill et al. (1998) reported that maize grain yields from 1993 long rains to 1997/98 short rains fluctuated with rainfall with a mean ranging from 0.64 t ha\(^{-1}\) during 1996 short rains (drought period) to 7.2 t ha\(^{-1}\) during 1997/98 (El Nino period). However there were no significant differences between treatments for maize grain yield during individual seasons (O’Neill et al., 1998). This is an indication that competition between the hedgerows of Napier/calliandra was not significant. Competition was however observed in the alley cropping experiment where calliandra was found to lower maize grain yields. Other studies, for example, those by Evensen, (1989), Fernandes (1990) and Rosecrance et al. (1992) have shown competition between hedgerows of trees and foodcrops. In the present study, lack of significant competition can be explained by the fact that the hedges were widely spaced with an inter-row spacing of 15 m compared to alley cropping system which had an inter-row spacing of 4.5 m.
Table 20.2: Amount of prunings incorporated into the soil over the study period (1993-1998) in an on-station study at Embu, Kenya

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<th>Trt</th>
<th>SR 93</th>
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<th>SR 95</th>
<th>LR 96</th>
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<th>Average N supplied per season</th>
<th>Average P supplied per season</th>
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Abbreviations: Trt = treatment (refer to page 5 for treatments description)

Nutrient concentration of prunings incorporated: N = 2.8 %, P = 0.2 % (Source: Mwangi, 1997)

Nutrient contribution = quantity of prunings * nutrient in the prunings
Table 20.3: Total root length for maize, leucaena and calliandra at various soil depths at maize grain-filling stage in the first season 1998 at Embu, Kenya

<table>
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<tr>
<th>Depth (cm)</th>
<th>Maize</th>
<th>Calliandra</th>
<th>Leucaena</th>
<th>SED</th>
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</tr>
<tr>
<td>210-240</td>
<td>0.1</td>
<td>3.4</td>
<td>8.2</td>
<td>2.6</td>
</tr>
<tr>
<td>240-270</td>
<td>0.1</td>
<td>4.2</td>
<td>7.4</td>
<td>3.2</td>
</tr>
<tr>
<td>270-300</td>
<td>0.1</td>
<td>3.8</td>
<td>6.6</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Source: Murithi et al. (1999)

The results of runoff, soil loss and fodder production presented in Table 20.4 indicate that contour hedges were effective in reducing soil loss. Soil loss in the control was substantially greater than in any of the control hedge treatments. This agrees with findings of other authors, for example, contour hedges of *Inga edulis* planted in a 16% slope at Yurimaguas, Peru with 2200 mm annual rainfall reduced soil loss on an Ultisol from 53 to 1 t ha⁻¹ yr⁻¹ and runoff form 12 % of the annual rainfall to only 2% (ICRAF, 1994). In Philippines, it was shown that contour-hedgerow intercropping technology was capable of achieving a 50 to 58% reduction in soil erosion on a 17-18% (Comia et al., 1994; Watson et al., 1995). Kieppe (1995) demonstrated that, hedgerows reduced soil erosion by 94% and runoff by 78% and that a combination of hedgerows and mulch conserved 98% of the soil and 88% of water at Machakos, Kenya. In addition to conserving soil and promoting terrace formation, the contour hedges produced biomass that could be used as fodder source (O'Neill et al., 1998). Indeed, Table 20.4 shows that the combination hedge (napier plus calliandra) produced the highest biomass in all seasons and consequently the highest crude protein.

Cumulative runoff and soil loss for three years in the on-farm trial (Table 20.5) was higher on the 20% slope than on the 40% slope. Angima (2000) attributed these difference to individuals farmers practices that dated back 30 years. The farmer on the 40% slope practiced better crop husbandry and crop rotation and periodically adds manure to his farm while the farmer on 20% slope did not. Manure has been found to contribute greatly to stability of soil aggregates making them less susceptible to erosion.
Table 20.4: Runoff, soil loss and fodder production in an on-station study at Embu, Kenya for the 1997 long rains and the 1997/98 short rains

<table>
<thead>
<tr>
<th>Runoff (mm)</th>
<th>Control</th>
<th>Napier</th>
<th>Calliandra</th>
<th>Combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997 long rains</td>
<td>108.0</td>
<td>49.0</td>
<td>48.0</td>
<td>40.0</td>
</tr>
<tr>
<td>1997/98 short rains</td>
<td>33.0</td>
<td>9.0</td>
<td>15.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Soil loss (t/ha)</td>
<td>51.0</td>
<td>10.0</td>
<td>38.0</td>
<td>20.0</td>
</tr>
<tr>
<td>1996 long rains</td>
<td>21.1</td>
<td>7.5</td>
<td>6.4</td>
<td>8.3</td>
</tr>
<tr>
<td>1997/98 short rains</td>
<td>-</td>
<td>1.5</td>
<td>1.0</td>
<td>3.6 + 0.7 = 4.3</td>
</tr>
<tr>
<td>Fodder - leafy dry matter (t/ha)</td>
<td>-</td>
<td>4.0</td>
<td>1.9</td>
<td>8.2 + 1.4 = 9.6</td>
</tr>
<tr>
<td>1997 long rains</td>
<td>-</td>
<td>103.0</td>
<td>255.0</td>
<td>252 + 170 = 422</td>
</tr>
<tr>
<td>1997/98 short rains</td>
<td>-</td>
<td>280.0</td>
<td>466.0</td>
<td>574 + 343 = 917</td>
</tr>
</tbody>
</table>

Assume 7 % CP for Napier and 25 % CP for calliandra.

Table 20.5: Cumulative runoff and soil loss for 3 years and total N and P losses in eroded sediments in an on-farm study at the Kianjuki catchment Embu, Kenya

<table>
<thead>
<tr>
<th>Treatment</th>
<th>20% slope</th>
<th>40 % Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Runoff (mm)</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>356 a</td>
<td>122 a</td>
</tr>
<tr>
<td>Hedge</td>
<td>298 b</td>
<td>186 b</td>
</tr>
<tr>
<td>Hedge</td>
<td>578 a</td>
<td>539 a</td>
</tr>
<tr>
<td>Control</td>
<td>410 b</td>
<td>393 b</td>
</tr>
<tr>
<td></td>
<td>Soil loss (Mg ha⁻¹)</td>
<td></td>
</tr>
<tr>
<td>Hedge</td>
<td>1.6 a</td>
<td>2.0 a</td>
</tr>
<tr>
<td>Control</td>
<td>0.9 b</td>
<td>1.4 b</td>
</tr>
<tr>
<td></td>
<td>P loss (Mg ha⁻¹ yr⁻¹)</td>
<td></td>
</tr>
<tr>
<td>Hedge</td>
<td>1.5 a</td>
<td>1.8 a</td>
</tr>
<tr>
<td>Control</td>
<td>1.0 b</td>
<td>1.4 b</td>
</tr>
<tr>
<td></td>
<td>N (Mg ha⁻¹ yr⁻¹)</td>
<td></td>
</tr>
</tbody>
</table>

Source: Adapted from Angima (2000) and Murithi et al. (1998)

The hedges were found to be effective in reducing both runoff, soil loss and nutrient loss (Table 20.5). The hedges reduced both runoff and soil loss by 30% over the control treatment which had no hedges (Angima, 2000). This agrees with studies carried out in Ibadan, Nigeria, where contour hedgerows of *Leucaena leucocephala* and *Glicidita sepium* on a 7 % slope showed 85 % reduction in both soil and nutrient loss compared
to conventional plowing (Young, 1989). Also, in Columbia, hedgerows of *Gliricidia sepium* reduced soil losses from 23-35 t ha\(^{-1}\) yr\(^{-1}\) under maize to 13 Mg ha\(^{-1}\) yr\(^{-1}\) on both 45% and 75% slope, resulting in a 48% soil loss reduction (Young, 1989).

In this study, there were more nutrients lost on the 40% slope than the 20% slope with the control plots loosing more than the hedge plots. Murithi *et al.* (1999) estimated an equivalent of over 200 kg ha\(^{-1}\) of TSP and 300 Kg ha\(^{-1}\) TSP lost by the control plots over the hedge plots for the 20% slope and 40% slope respectively. This also supports the farmer practices of applying farmyard manure on 40% slope than on gentle slopes of 20%. This underlines the need to control runoff and soil loss in these zones to retain nutrients for crop production and reduce pollution of rivers and reservoirs from eutrophication. Young (1997) has recently documented further experimental evidence on the effectiveness of contour hedgerows in controlling soil erosion. The evidence that covers diverse countries, varying slopes, different climates and soils indicate the contour-hedgerow systems reduced soil erosion by factors ranging from 2 to 58.

Results of this contour hedgerow experiments showed that calliandra planted along contour hedgerows is effective in controlling soil erosion. In addition, it produces biomass that contains high crude protein and can therefore be used effectively as animal protein supplement.

**Dissemination Potential**

These studies demonstrated beneficial effects on crop yields of incorporating prunings of calliandra and leucaena especially when biomass is brought from outside (ex-situ). It is also evident that alley-cropping with leucaena have great potential as a method of improving sustainable yields at about 4 t ha\(^{-1}\) in the region. However, it has been pointed out that the advantages of alley cropping seems to rest in the complementarity of resource capture (Ong and Black, 1995); while it has disadvantages in establishment costs and labour requirements. Therefore, despite this promising results shown by alley cropping with leucaena, the question of labour availability needs to be addressed properly before a wide adoption by farmers can be envisaged. This technology is labour-intensive with much of the demand for labour occurring during the start of the rainy season which is the busiest time of the year.

Calliandra alley-cropping system adversely affected crop yields and should not be recommended as an alley-crop species. Reasons advanced for this was that calliandra developed a strong superficial system that competed with associated foodcrops for growth resources. However, calliandra was found to be effective in controlling soil erosion when used as a contour hedge possibly because of the strong root system
that holds the soil together. In addition to conserving the soil, calliandra provides up to 24% crude protein and the large tonnage of biomass yield from using hedges as a soil conservation resource can supplement and in some cases substitute input protein rations in animals. Results from western Kenya (Jama et al., 1997) indicate that fodder trees like calliandra are most profitable when utilized as a protein supplement for livestock.

Further research by NAFRP have have shown potential for calliandra adoption by smallholder farmers for use in dairy production (Tuwei et al., 1999). On-farm feeding trials have confirmed the effectiveness of calliandra both as supplement to the basal diet and as a substitute for dairy meal. The trials found that one kilogram of dry calliandra had about the same amount of digestible protein as one kilogram of dairy meal; both increased milk production by roughly 0.75 kg under farm conditions (O'Neill et al., 1995, Paterson et al., 1996a). Following these findings a dissemination programme for calliandra was initiated in 1997 where the main focus was the use of participatory methods and involvement of partners (Tuwei and Mugwe, 1998).

The dissemination procedure involved working with farmer group nurseries. The group nurseries were provided with calliandra seeds to raise and transplant following the onset of the rains. An evaluation of planting niches adopted by farmers in Meru and Embu District showed that terraces were the most preferred niche by farmers for planting calliandra (Table 20.6). Majority (46%) indicated that they preferred planting calliandra along terraces for soil conservation on the steep areas. The calliandra planted on the contours for soil conservation could help retain and cycle N in the soil for sustainable agriculture. Studies by Jama et al. (1998) showed that calliandra roots develop and grow rapidly into the subsoil and capture NO$_3^-$ that accumulate in the subsoil even at low available phosphorus.

Table 20.6: Niches where farmers planted calliandra during 1999 in Embu and Meru Districts, Kenya

<table>
<thead>
<tr>
<th>Niche</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrace</td>
<td>83</td>
<td>46</td>
</tr>
<tr>
<td>External border</td>
<td>63</td>
<td>35</td>
</tr>
<tr>
<td>Homestead</td>
<td>38</td>
<td>21</td>
</tr>
<tr>
<td>Cropland</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Coffee</td>
<td>1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

N=178

Source: Tuwei and Mugwe (1999)
They also found that calliandra and sesbania reduced soil NO$_3^-$ in the top 2m by about 150 to 200 Kg kg N ha$^{-1}$ within 11 months after establishment and effectively captured subsoil NO$_3^-$ in western Kenya. At Embu (Experiment in this study), monocropped treatments (Maize only) accumulated higher amounts of mineral N (averaging 15-30 Mg NO$_3^-$ N kg$^{-1}$) in the 200-300 cm depth layer than treatments with calliandra and leucaena which had an average of 1-3 mg NO-N kg$^{-1}$ in the same depth (Mugwe, 1999).

In this region, where dairy production is predominant, farmers have the option of using prunings for direct incorporation into the soil to improve their soils or may be better off using the calliandra for fodder. If they use the prunings as fodder, they are then likely to benefit from increased milk production and possibly increased incomes (O'Neill et al. 1997; Franzel et al., 1999). The calliandra could be pruned for fodder 9 to 12 months after planting, and pruning continues at the rate of four or five times per year (Roothaert et al., 1998). However, harvesting of the biomass and removal from the site mines soil nutrients and a means of replenishing the soil nutrients is necessary. This could be achieved through recycling manure. This practice is feasible and economical and is likely to have high adoption rates. If adopted, soil conservation and fertility improvement could be enhanced.

Conclusions

These studies showed great potential for using Calliandra calothyrsus and Leucaena leucocephala for soil fertility improvement and soil conservation. Soil conservation improvement can be achieved through application of leafy prunings from the leguminous shrubs into the soil. In this study application of Calliandra and leucaena prunings into the soil significantly increased maize grain yields over the control treatment. The use of leguminous shrubs in an alley-cropping system however presented mixed results. Leucaena can be used successfully as an alley species and maintained maize grain yields at about 4 t ha$^{-1}$ in the region. Calliandra on the other hand was more competitive and depressed maize grain yields. However calliandra contour hedges were found to be effective in reducing soil loss, runoff and loss of soil nitrogen and phosphorus in eroded sediments. In addition, calliandra on contour hedges produced a large tonnage of biomass with high crude protein that could be used as animal fodder.

Considering that smallholdings in the central highlands of Kenya occur on sloping lands, and the importance of dairy production in the region, there is great potential for using calliandra contour hedges for soil conservation. The harvested prunings could either be used for soil fertility improvement through direct soil-incorporation or could be used
for fodder. Farmers in the region and similar areas should therefore be encouraged to adopt this practice. If used for fodder, feasibility of replenishing soil nutrients through recycling manure from the animals needs to be explored.

**Acknowledgements**

The authors would like to thank the Swedish International Development Agency (SIDA) and Rockefeller Foundation for funding this research work. The Sida funded this work through the National Agroforestry Research Project based at KARI, Embu. We would also like to acknowledge the contribution of collaborators from KARI, KEFRI and ICRAF in Kenya; and the staff of National Agroforestry Research Project at Embu, Kenya. We are indebted to the many farmers who provided their time and resources for this research.

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Soil Conservation and Fertility Improvement Using Leguminous Shrubs in Central Highlands of Kenya: NARFP Case Study


The Relationship Between Nitrogen Mineralization Patterns and Quality Indices of Cattle Manures from Different Smallholder Farms in Zimbabwe

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Abstract

The relationship between nitrogen mineralization is shown in agroforestry and cattle manures in Zimbabwe. The study was carried out in the lowveld region and on the northern highveld region of Zimbabwe and the results were statistically significant. The study also showed that the use of manure as a nitrogen source in agroforestry systems is an effective method of improving soil fertility.