Farmers’ evaluation of on-farm contour hedges for soil conservation and nutrient cycling: A case of Central highlands of Kenya

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Abstract: Decline in soil fertility, soil erosion and insufficient fodder production are some of the major problems facing agricultural production in central highlands of Kenya. Researcher-designed but farmers-managed trials were started on farms of 32 willing farmers with an aim of exploiting the multipurpose attribute of agroforestry species to address these problems. The selected farms were arable lands with a slope of between 5 and 33%. The set up consisted of double Calliandra calothyrsus, Leucaena leucocephala and napier grass hedges planted in a zig-zag pattern at an intra-row spacing of 0.25 m or 0.5 m and a variable inter-row spacing, and arranged as 2×3 complete factorial. Farmers were allowed to continue with their normal farming operations after setting up the trials. Nine months later, both the trial and non-trial farmers evaluated the impact of the hedgerows on the farms. The trial farmers reported a yield of 0.6 and 0.4 kg of calliandra and leucaena leaf biomass, respectively, per metre of hedge and an average increment of 1.5 litres of milk/day/animal fed on the leguminous species. 61 and 59%, respectively reported the ability of hedges to control soil erosion and enhance soil fertility at a relatively low cost with 46% and 34% citing lack of labour and planting materials as the major constraints to full use of these technologies. At the end of evaluation, 100% of trial farmers expressed their willingness to continue with the technology, while 93% of non-participating farmers showed interest in joining the trials.

Keywords: Calliandra, fodder, leucaena, Napier grass, soil erosion

Introduction

Land scarcity, declining soil fertility and insufficient animal feeds are increasingly viewed as critical problems affecting agricultural productivity and human welfare in tropical Africa (Cooper et al., 1996; Sanchez et al., 1997). The topography of central highlands of Kenya is gently to steeply rolling with medium to high erosion hazard as determined by FAO (Kassam et al., 1992). Several methods exist for control of soil erosion by water. In Kenya most soil conservation efforts have focused on the use of contour ploughing, residue lines, terraces and cut-off drains. However, farmers are more likely to adopt soil conservation measures like contour hedgerows that provide other benefits such as retrieval of leached nutrients (and thus enhance soil fertility) and provision of fodder for livestock.

Hedgerows control soil loss, leading to progressive development of terraces through accumulation of soil up-slope of the hedge and stabilisation of terrace banks by stems and roots (Young and Sinclair, 1997). Such systems provide sustainable alternatives for areas like central highlands of Kenya, where human population density is increasing rapidly, to the point where large-scale land management is no longer possible and therefore even slopes whose gradient is not recommended for cultivation are cleared for crop production. Calliandra and leucaena have shown remarkable success in soil conservation and nutrient cycling and retention within an agroforestry system. Through biological nitrogen fixation (BNF), erosion control and green manure/leaf litter, calliandra and leucaena can improve soil quality and increase yields of associated crops (NRC, 1983; NFTA, 1988).

Current research has shown that development efforts are more effective when there is full involvement of the beneficiaries (farmers). This is even more so when research is done on-farm. The need for on-farm testing and feedback from farmers on new technologies is more critical in the case of a complex composite technology such as contour hedge technology. In October 2001, following a Participatory Rural Appraisal (PRA), which highlighted soil erosion, soil fertility decline and inadequacy of livestock feeds as the main felt needs of the farmers, researcher-designed but farmer-managed trials involving contour hedgerows were set up on farmers’ fields in Kirege sub-location, central highlands of Kenya. The overall objective of the trial was to improve soil nutrient management by use of fast-growing agroforestry trees namely Calliandra calothyrsus and Leucaena leucocephala for soil erosion conservation and nutrient cycling and to determine the farmers’ perception to these technologies.

Materials and methods

The trials are in Kirege sub-location, Mugwe Location, Chuka division, Meru South district (around Chuka town), which is a predominantly maize growing zone in central highlands of Kenya. According to agro-ecological conditions (usually based on tem-
perature and moisture supply), this area lies in the upper midland zones (UM2-UM3) (Jaetzold and Schmidt, 1983). It lies on the slopes of Mt Kenya at an altitude of approximately 1500 m above sea level, with an annual mean temperature of about 20 °C and annual rainfall varying from 1200 to 1400 mm. The rainfall is bimodal, with a long rains season (LR) a short rains one (SR). The LR is from March to June and SR from October to December. The predominant soil types are Humic Nitisols, commonly called the red Kikuyu loams. They are deep, well weathered, free-draining, with a friable clay texture and moderate to high inherent fertility.

The farming systems of this area have a complex integration of both crops and livestock. A wide variety of species and breeds of livestock as well as crop species are found within individual farm holdings. Coffee (Coffee arabica) and tea (Camelia sinensis) are the major cash crops grown in the area. Despite the predominance of two cash crops, individual farmers consider self-sufficiency in food production important. Maize (Zea mays) and beans (Phaseolus vulgaris) are the main food crops grown by farmers. Other food crops include Irish potatoes (Solanum tuberosum), sweet potatoes (Ipomea batatas), bananas (Musa spp.), Cassava (Manihot esculenta) and various fruits and vegetables. Most farmers have titles to their land, thus tenure is relatively secure. The average farm size is about 1.5 ha per household with the majority of farmers owning between 0.4 and 3 ha. The area is highly populated with a population of about 621 persons per km² (GoK, 1999) and therefore a high pressure on land with intense competition between various enterprises.

Households for contour hedgerow trials were selected based on owner’s willingness, slope of land, size of land under food crops, gender (effort was made to balance gender of trial farmers), household distribution to make sure all villages were represented, and accessibility of the farm to make learning and demonstration of technologies easy to all farmers. The slopes and contours were predetermined by use of a clinometer and surveyors’ level, respectively. Thirty-two households were recruited and facilitated to start the trials on their farms.

The trial consisted of 6 treatments laid down along the contours in a randomised complete block design (RCBD) with farms representing blocks. The plot sizes were at least 10 m long with a variable inter-row spacing (hedge to hedge) depending on the slope of land in question. The intra-row spacing (tree to tree) was 0.25 or 0.5 m double row arranged in a zigzag manner. The six treatments were:

1. Calliandra tree hedges
2. Leucaena tree hedges
3. Napier grass hedges
4. Calliandra tree hedges + Napier grass hedges
5. Leucaena tree hedges + Napier grass hedges
6. Control

Within each farm, treatments under evaluation were arranged as $2 \times 3$ complete factorial (with or without Napier grass and no trees, leucaena and calliandra). The rationale for choosing the above treatments was to allow the following key contrasts to be compared:

(i) Soil erosion component:

a) Treatment 6 vs. all others (is erosion a constraint?)

b) Treatment 3 vs. 1 and 2 (does Napier grass contour rows control erosion more effectively than tree hedges?)

c) Treatment 1 vs. 2 (does either calliandra or leucaena serve as a better species for soil erosion control?)

d) Treatment 1 and 2 vs. 4 and 5 (is erosion controlled improved by the inclusion of Napier grass within calliandra and leucaena hedges?)

(ii) Recovery of subsoil nitrogen:

a) Treatment 1 and 2 vs. 3 (do trees recover subsoil nitrogen more efficiently than Napier?)

b) Treatment 6 vs. 1 and 2 (are trees effective in recovering subsoil nitrogen?)

(iii) Fodder biomass and quality component:

a) Treatment 4 and 5 vs. 1 and 2 (does inclusion of Napier within calliandra and leucaena hedges lead to production of quantitative and qualitative?)

Farmer evaluations were conducted in June 2002 by use of questionnaires, checklists and flip charts. Both the trial and non-trial farmers participated in the evaluation. Three of the trial farms were selected at random for evaluation. The owners of these farms were supposed to educate others on the experiences with the technologies they had adopted when the farmers visited their farms. For ease of farm visits, the farmers were divided into six groups, each with a chairperson and a secretary (farmers) and a resource person (a member of the research or extension personnel). After the field visits each group assembled separately and discussed its observations; i.e. successes and failures associated with the technologies, while recording all the points and comments on flip charts. The group output was then presented and discussed in plenary to the entire evaluation team.

Results and Discussion

Farmers’ perception

Farmers identified fodder production, soil fertility management, soil erosion control and production of fuel wood as the main roles played by calliandra and
leucaena. Fodder production (63 %), soil fertility management (61 %) and soil erosion control (59 %) were the primary perceived benefits, while source of firewood (1.9 %) was only a secondary benefit (Figure 1).

![Frequency of role perceptions](image)

**Figure 1. Perceived roles of calliandra and leucaena contour hedgerows by farmers of Kirege sub-location**

Sample size 105. Respondents identified more than one attribute - hence % total to > 100

The main driving forces to adoption of calliandra and leucaena contour hedges in this locality are the role they play in provision of fodder for livestock, control of soil erosion and enhancement of soil fertility. Prior to introduction of these species into the locality Napier grass (*Pennisetum purpureum*) was the main source of animal feed for most farm families.

Supplementation was not common because many families were not financially capable. Napier grass is not a very high quality feed because it has low levels of crude protein and high fibre content making it's digestibility relatively low. On the other hand calliandra and leucaena are very high in crude protein, which improves livestock diet and also acts as a source of N when incorporated into the soil (Paterson, 1994). Calliandra and leucaena send roots deep into subsoil, drawing up leached nutrients, which shallow rooted crops have no access to. This, plus their ability to fix nitrogen enhances soil fertility. Nutrients taken up by trees from below the rooting zone of annual crops become an input when transferred to surface soil in form of leaf litter, roots and prunings (Schroth, 1995).

**Prunings**

The three randomly selected farmers explained to others the benefits they had realised from the hedges since the trials were started. They had realised an average of 0.6 and 0.4 kg of calliandra and leucaena prunings, respectively per metre of the hedge. The fact that calliandra produced more prunings means that calliandra played a bigger role in recycling nutrients and providing animal feeds. They cited the role these species had played in improving their animals' health and milk production as the most encouraging role towards the uptake of this technology. The recycled nutrients from the agroforestry species are transferred to the topsoil upon incorporation of either prunings or the manure from animals fed on them. All these farmers fed the prunings to animals. They reported an average increment of 1.5 litres of milk per day after the animals were fed on these leguminous species. However they could not ascertain the increment resulting from each species because the animals were fed in mixtures of feed.

The ability of leguminous feed to improve livestock productivity has been widely studied. In Embu, Kenya the replacement value of calliandra as a fodder supplement has been found to be in the region of 3 kg fresh material (= 1 kg dry matter) equivalent to 1 kg of dairy meal with 16 % crude protein for grade Friesian and Ayrshire dairy cattle (Paterson *et al.*, 1996). Reynolds and Jabbar, 1994 observed that supplementation of pregnant and lactating dams with leguminous feeds raised the survival rates of their off springs from 45 %, on a grass only diet, to 95 % when leguminous feed constituted 40 % of the ration.

**Soil erosion control**

Farmers also seemed to appreciate the role played by hedges in soil erosion control. Hedges control soil erosion when tree roots hold soil together and when natural terraces form on their upper side. They listed some of the reasons they were certain that hedges were capable of controlling soil erosion. Visible formation of natural terraces, accumulation of trash upslope of the hedge and appearance of gullies on the controls (with no hedges) were quoted by 42 %, 39 % and 19 % of the farmers, respectively as some of the parameters they used in visualising the ability of tree hedges to control soil erosion (Table 1).

**Table 1. Parameters used by farmers in Kirege Sub-location to visualize ability of hedges to control soil erosion**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible forming terraces</td>
<td>55 (42 %)</td>
</tr>
<tr>
<td>Accumulation of trash upslope of hedge</td>
<td>50 (39 %)</td>
</tr>
<tr>
<td>Gullies on the control</td>
<td>25 (19 %)</td>
</tr>
</tbody>
</table>

*n* = 130

als that are washed from other parts of the farm on a higher gradient. All these materials pile up leading to
formation of a natural terrace. Terrace formation reduces the slopes length and steepness, indicating the potential for reduction of soil loss. Angima et al. (2000) during a topographic survey with calliandra, leucaena and Napier hedges realised that the plots with hedges showed an overall slope reduction, the combination hedge (leucaena + calliandra) had the lowest overall decrease in slope of 0.1%, while the grass + tree hedge showed 0.2% decrease in slope above the lower hedge. On the other hand, control plots showed a 0.2% increase in slope. Erosion per se is not the main objective of many agroforestry practices that have erosion control potential (Nair et al., 1995). The best results can be obtained if agroforestry technologies are combined with other relevant land use technologies in accordance to the biophysical conditions of the farm and farmers’ production objectives. This means that sustainable biological soil erosion control should not be considered in isolation but with other land use approaches and needs.

Management
All the farmers experienced difficulties in establishing the hedges. The most common problems were insufficient labour for planting, pruning and management (46%), lack of planting materials (34%) and interspecific competition with crops (20%) (Figure 2).

Farmers complained that that there was a significant decline in maize yield near the calliandra hedges. They said that even though there was a yield depression near leucaena hedges it was insignificant compared to the benefits achievable from the agroforestry tree. This is in line with Mugendi et al. (1999) who when working in the same area (central highlands- Embu), reported greater maize yield decline for maize grown near calliandra tree hedges than for maize grown near leucaena hedges. This (competitiveness of calliandra tree hedges compared to leucaena) was explained by root morphology of the two species. Calliandra trees develop a strong superficial root system in addition to tap root (NAS, 1983), whereas leucaena is reported to have a strong tap root system that develops few lateral roots, which also grow downward following emergence with lateral root development tending to be confined in the lower levels of the soil (NAS, 1977; van Noordwijk et al., 1996). Indeed Jama et al. (1998) demonstrated that calliandra had the greatest root density in the top 15 cm of soil when compared to four other multipurpose tree species (Eucalyptus grandis, Sesbania sesban, Markhamia lutea and Gravillea robusta) evaluated in western Kenya. This means that calliandra depend on the same soil layer as maize for nutrients and water, which leads to competition and hence decreased maize grain yields. The decline may have also been due to above ground competition especially in farms where farmers were late for pruning.

From the results shown in Figure 2, it is evident that for contour hedge technology to fully benefit these farmers, a solution to these problems has to be found. Lack of planting materials can be handled by involving farmers in establishing and managing there own tree nurseries while getting professional advice from the scientists. This was done at the start of the trials but it still has to be redone for the sake of those who did not get sufficient seedlings. On the other hand, the problem of competition between the hedgerow trees with crops requires proper training for farmers in appropriate methods and time for pruning the leaves and roots of the hedgerow trees. The main bottleneck to efficient utilisation of hedgerow technology in Kirere is labour required for planting, pruning and transferring the pruning to animals or farm (incorporating). Hedgerow technology is labour-intensive. It requires on average an additional 90 man days ha\(^{-1}\) to prune and transfer prunings to appropriate use, yet demand for labour peaks during the rainy season when conflicting labour requirements are greatest (Nair, 1993). The additional labour for persons already occupied at peak labour demand in the season is more costly than when additional demand comes during the slack periods and the costs of production increase considerably if additional labour must be hired (Mugendi et al., 1999). Although the additional labour costs may be offset by increase in milk (due to the high level of crude protein in leguminous feeds) and crop yields (as a result of nutrient cycling, BNF and soil and water conservation), the cost may serve as a disincentive to full adoption of this technology.

Adoption
All the trial farmers expressed their willingness to continue with the trials, while 93% of the non-participating farmers showed interest in starting the
participating farmers showed interest in starting the technologies in their own farms (Table 2).

Table 2. Indications of willingness of Kirege farmers to continue or adopt contour hedges technology

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of farmers/group</th>
<th>No. with hedges</th>
<th>No. willing to join trials</th>
<th>No. of trial farmer willing to continue with trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>17</td>
<td>7</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Group 2</td>
<td>18</td>
<td>4</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Group 3</td>
<td>26</td>
<td>5</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>Group 4</td>
<td>13</td>
<td>3</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Group 5</td>
<td>8</td>
<td>0</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Group 6</td>
<td>23</td>
<td>3</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>105</td>
<td>22 (21%)</td>
<td>78 (93%)</td>
<td>22 (100%)</td>
</tr>
</tbody>
</table>

This clearly shows that the farmers' perceived benefits derived from these technologies far outweigh the negative impacts outlined above. Considering the immediate use to which these farmers put the prunings (Table 3), one can easily conclude that the major driving force to adoption of contour hedgerows in this locality is fodder provision. This is particularly enhanced by the fact that these trees are fast-growing enabling availability of fodder within a short time after pruning. This means that provision of fodder provides an important entry of soil conservation measures by use of agroforestry in this area.

Table 3. Uses into which contour hedge trial farmers put their prunings

<table>
<thead>
<tr>
<th>Use to livestock</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fed to livestock</td>
<td>35</td>
<td>76</td>
</tr>
<tr>
<td>Used as fuel</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Incorporated into farm</td>
<td>10</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>100</td>
</tr>
</tbody>
</table>

Muriithi, (1998) observed that 45% of the farmers in central highlands buy commercial dairy meal (nominally 16% crude protein) to supplement their cows' diet. However, farmers complain about the price ratio between dairy meal and milk not being favourable, lack cash for buying sufficient dairy meal, dubious/variable nutritive value of the dairy meal and high transport costs for the dairy meal from the market to the homestead (Franzel et al., 1999). The economic analysis carried out on the importance of calliandra as a source of fodder by Franzel et al. (1999) revealed that after planting, a farmer with an average of 500 shrubs would earn an extra US$ 130 per year either through increased milk production or through reduced purchase of dairy meal. This partly explains why most of the farmers used calliandra and leucaena prunings as animal feeds and shows a high potential for adoption especially now that they have realised their ability to increase milk yields and hence act as substitutes for dairy meal besides other advantages. The only non-trial farmers (7%) (Table 2) who did not show interest in having these technologies on there farms cited insecurity of tenure as the reason behind their non-willingness. This means that issues of tenure are very important in understanding agroforestry technology adoption and may greatly influence the uptake of technologies. Burrow (1996) argues that secure tenure over land or clear rights to its use is of crucial importance in adoption of long-lived land management interventions.

Conclusions

Farmers in Kirege sub-location adopt calliandra and leucaena contour hedgerows due to the role these species play in fodder production, soil erosion control, soil fertility enhancement and provision of fuel wood. The biggest challenge that is facing farmers in adoption of these technologies is labour required for management, pruning the hedges and transfer of the prunings to the preferred use such as feeding the animals and incorporating of the prunings into the farms. Provision of fodder is a very important use that the farmers have for the agroforestry trees besides their role in recycling nutrients and control soil erosion, and this therefore is a strong entry point for promoting agroforestry in Kirege sub-location.

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