3

Guidelines for Integration of Legumes into the Farming Systems of East African Highlands

Amede, T[1] and Kirkby, R[2]

[1]Research Fellow, Tropical Soils Biology & Fertility Institute of CIAT/Africa Highlands Initiative, P.O. Box 1412, code 1110, Addis Ababa, Ethiopia, t.amede@cgiar.org
[2]CIAT, Pan-African Coordinator, P.O. Box 6247, Kampala, Uganda. ciat-africa @cgiar.org

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Abstract

Grain legumes are major protein sources for animals and humans. Given that farmers export both grain and stover from the fields, the amount of residue left to the soil is too small to have a profound effect on soil fertility. Participatory research was conducted to evaluate the performance of six legume cover crops (Vetch, Stylosanthus, Crotalaria, Mucuna, Canavalia, and Tephrosia) and two food crops (Pea and Common bean) in southern Ethiopian Highlands, one of the African Highlands Initiative (AHI) sites called Areka, to be used for soil fertility improvement. Besides evaluating the biomass productivity of legumes, the objective of this research was to learn about the perception of farmers to LCC, feed and food legumes, to identify socio-economic factors affecting adoption and also to identify potential niches for their integration. For short term fallow (three months or less), Crotalaria gave significantly higher biomass yield (4.2 t ha^{-1})

followed by Vetch and Mucuna (2 t ha^{-1}), while for medium-term fallow (six months or more) Tephrosia was the best performing species (13.5 t ha^{-1}) followed by Crotalaria (8.5 t ha^{-1}). The selection criterion of farmers was far beyond biomass production, and differed from the selection criteria of researchers. Farmers identified firm root system, early soil cover, biomass yield, decomposition rate, soil moisture conservation, drought resistance and feed value as important biophysical criteria. Soil moisture conservation was mentioned as one important criterion and decreased in order of Mucuna (22.8%), Vetch (20.8 %), Stylosanthus (20.2 %), bare soil (17.1 %), Crotalaria (14 %), Canavalia (14 %) and Tephrosia (11.9 %), respectively. The overall sum of farmers' ranking showed that Mucuna followed by Croletaria are potentially fitting species. However, Vetch was the most preferred legume by farmers regardless of low biomass, due to its' early growth, high feed value and fast decomposition when incorporated into the soil. The most important socio-economic criteria of farmers for decision-making on which legumes to integrate into their temporal & spatial niches of the system were land productivity, farm size, land ownership, access to market and need for livestock feed. These indicators were used for the development of draft decision guides for integration of legumes into multiple cropping systems of East African Highlands.

Key words: Participatory research; soil degradation; legume cover crops; integration; decision-guide

Introduction

Grain legumes are important components of the farming systems of the East African highlands as they are the sole protein sources for animals and humans. Besides restoring soil fertility, legumes are grown in rotation with cereals mainly because, besides restoring soil fertility, they also accompany the staple cereals in the local dishes. However, as farmers export both grain yield and stover from the field, the amount of legume residue left to the soil is too small to have a profound effect on restoration of soil fertility.

Degradation of arable lands became the major constraint of production in East African Highlands, due mainly to nutrient loss resulting from soil erosion, lack of soil fertility restoring resources, and unbalanced nutrient mining (Amede *et al.*, 2001). However, most farmers in the region have very low financial resources to combat nutrient depletion, and hence research should be directed to seek affordable and least risky, but profitable amendments necessary to keep nutrient balance neutral (Versteeg *et al.*, 1998). In 1999 and 2000, researchers of the African Highlands Initiative (AHI) conducted farmers participatory research on maize varieties on a degraded arable land in Southern Ethiopia, Areka, by applying different inorganic sources of fertilisers. Although the soil is an Eutric Nitisol deficient in nitrogen and phosphorus (Waigel, 1986), high level application of inorganic N and P did not improve maize yield. The land was highly degraded and the organic matter was totally depleted. Lack of response to inorganic fertilisers because of low soil organic matter content was also reported elsewhere (Swift and Woomer, 1993). Organic inputs in the form of green manuring or otherwise could increase the total amount of nutrients added, and also influence availability of nutrients (Palm *et al.*, 1997). However, more than 50% of the organic resource available in the region is maize stalk, of which 80% is used as fuel wood (Amede *et al.*, 2001). The strong competition for crop residues between livestock feed, soil fertility and fuel wood in the area limits the use of organic ferilizers unless a suitable strategy that builds the organic resource capital is designed. Fallowing for restoration of soil fertility is no more practised in the region due to extreme land shortage.

One strategy could be systematic integration of legume cover crops into the farming system. Organic inputs from legumes could increase crop yield through improved nutrient supply/availability and/or improved soil-water holding capacity. Moreover, legumes offer other benefits such as providing cover to reduce soil erosion, maintenance & improvement of soil physical properties, increasing soil organic matter, cation exchange capacity, microbial activity and reduction of soil temperature (Abayomi *et al.*, 2001) and weed suppression (Versteeg *et al.*, 1998). There are several studies in Africa that showed positive effects of Legume Cover Crops (LCCs) on subsequent crops (Abayomi *et al.*, 2001; Fishler & Wortmann, 1999; Gachene *et al.*, 1999; Wortmann *et al.*, 1994). Studies in Uganda with Crotalaria (Wortmann, *et al.*, 1994; Fishler and Wortmann, 1999), and in Benin with Mucuna (Versteeg *et al.*, 1998) showed that maize grown following LCCs produced significantly higher yield than those without green manure. The positive effect was due to high N and P benefits and nutrient pumping ability of legumes from deeper horizons. However, the success rate in achieving effective adoption of LCCs and forage legumes in sub-Saharan Africa has been low (Thomas and Sumberg, 1995) since farmers prefer food legumes over forage or/legume cover crops in that the opportunity cost is so high to allocate part of the resources of food legumes to LCC. Therefore, there is a need to develop an effective guideline that targets different legumes types into different niches of different agro-ecologies and socio-economic strata.

The objective of this paper was, therefore a) to analyse the distribution of legumes in the perennial- based (Enset-based) systems, b) test the performance of legumes under short term and medium term periods, c) identify the potential causes of non-adoption of LCC, and d) develop preliminary decision guides that could be used to integrate LCC in small scale farms with various socio-economic settings.

Materials and Methods

Location, Climate and Soil

The research was conducted at the Gununo site (Areka), Southern Ethiopian Highlands. It is situated on 37° 39' E and 6° 51' N, at an altitude range between 1880 and 1960 m.a.s.l. The topography of the area is characterised by undulating slopes divided by V-shaped valleys of seasonal and intermittent streams, surrounded by steep slopes.

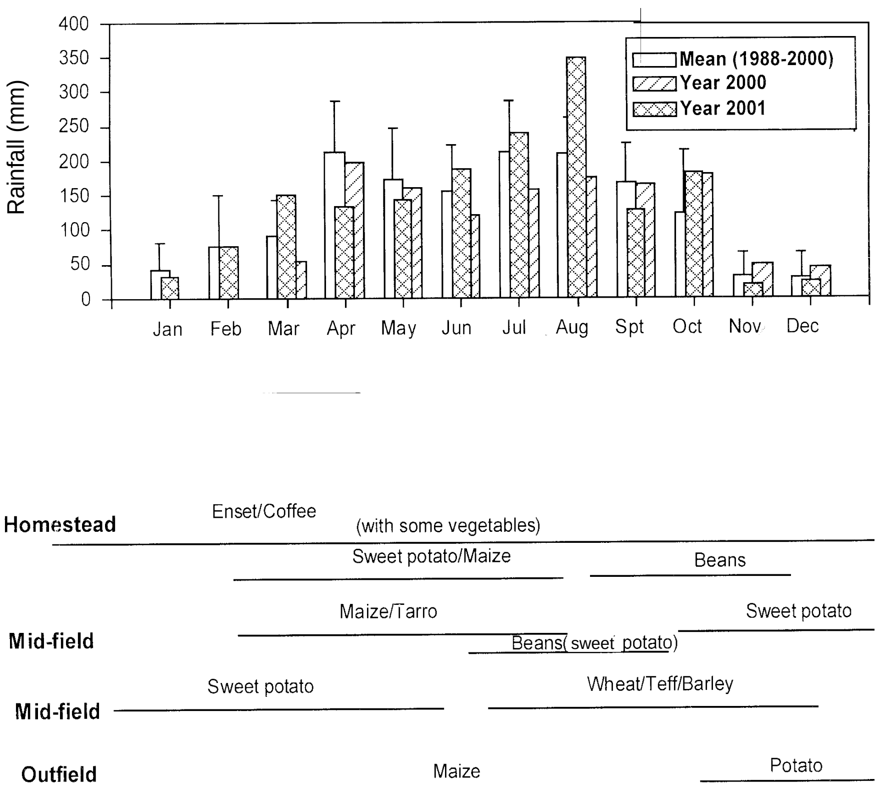
The mean annual rainfall and temperature is about 1350 mm and 19.5°C, respectively. The rainfall is unimodal with extended growing periods from March to the end of October, with short dry spell in June (Figure 3.1). The highest rainfall is experienced during the months of July and August and caused soil loss of 27 to 48 t ha^{-1} (SCRP, 1996).

The dominant soils in the study area are Eutric Nitiosols, very deep (>130 m), acidic in nature, and are characterised by higher concentration of nutrients and organic matter within the top few centimetres of the soil horizon (Table 3.1). These soils originated from kaolinitic minerals which are inherently low in nitrogen and phosphorus (Waigel, 1986). Soil fertility gradient decreases from homestead to the outfield due to management effects. The chemical properties of the Gununo soils are presented in Table 3.1.

Participatory evaluation of LCCs

The research site has relatively very high human population density with an average land holding of 0.5 ha $household^{-1}$. Using LCCs for soil fertility purposes is not a common practise in the area. LCCs were introduced into the system in 2000 following a farmers field school (FFS) approach so as to allow farmers to learn and appreciate various legumes uncommon to the area. The farmers research group (FRG) was mainly composed of men, despite the repeated temptation of researchers to include women. The legumes were planted in two planting dates. The on-farm experiments, also used for FFS, were planted on April 25, 2000 and July 1, 2000 and harvested on October 6, 2000 and January 6, 2001, respectively, using recommended seed rates. The interest of the farmers was to evaluate the effect of planting dates and length of fallow period on biomass productivity of respected species, and to identify the best fitting legumes for a short-term fallow (three months) or medium term (six months) fallow. Long-term fallow became impractical due to land scarcity. Thirty interested farmers, who were organised under one farmers research group (FRG), have studied six different species namely, Stylosanthus (*Stylosanthus guianensis*), Crotalaria (*Crotalaria ochroleuca*), Mucuna (*Mucuna pruriens*), Tephrosia (*Tephrosia vogelii*), Vetch (*Vicia dasycarpa*) and Canavalia (*Canavalia ensiformis*). All LCC were exotic species to the system except Stylosanthus. We also included two food legumes, namely common bean (*Phaseolus vulgaris*) and Pea (*Pisum sativum*), in the study that were existing in the farming system.

Figure 3.1: Crop calendar, rainfall amount and distribution, and crops grown in the farming system of Areka



The FRG studied and monitored growth and biomass productivity in short and long seasons of 2000. The researchers were involved mainly in facilitation of continual visits and stimulation of discussions among farmers. Farmers and researchers were recording their own data independently. After intensive discussion, the FRG identified six major criteria to propose one or the other legume to be integrated into the system. Since farmers considered soil water conservation as one important criterion for selecting LCCs, soil water content was determined under the canopy of each species at top 25-cm depth gravimetrically. Sampling was done in relatively dry weeks of November 2000, five months after planting. We considered four samples per plot, weighed immediately after sampling, oven dried the samples at 120°C for a week before taking dry weight. Legume ground cover was determined using the beaded string method, knotted at 10-cm interval and laid across the diagonals of each plot, 12 weeks after planting.

Table 3.1: Chemical Properties of Nitisols at Gununo site at the depth of top 20 cm

Soil fertility parameters	Analytical value
Total N (%)	0.05
Available P (ppm), Olsen	7
Organic matter (%)	1.2
pH (H_2O)	5.9
CEC (me/100g soil)	15
Exchangeable cations (me $100g^{-1}$ soil)	
Na^+	0.22
K^+	0.96
Ca^{2+}	14.04
Mg^{2+}	2.93

Source: Waigel (1986)

In August 2002, after farmers monitored the introduced legumes, 26 farmers from four villages selected species of their choice LCC and tested them in their farms together with a food legume, Pea. During the growing seasons of 2000 and 2001, we monitored which farmer selected what, how did they manage the LCCs in comparison to the food legume and for what purpose the legumes were used. Biomass production of the various legumes under farmers' management was also recorded. Besides structured questionnaire and formal survey (Pretty *et al.*, 1995), an informal repeated on-field discussion using transect walks were used to identify the socio-economic factors that dictated farmers to choose one or the other option and to prioritise the most important criteria of decision making using pair wise analysis matrix. Moreover, farmers invited non-participating neighbouring farmers for discussion; hence the decision made is expected to represent the community.

We have conducted an additional replicated experiment to evaluate biomass production of LCCs under partially controlled replicated experiment to verify earlier obtained results. It was also meant to identify the most promising species for short term fallow, as farmers were reluctant to allocate land for LCCs beyond three months. The species were planted on October 12, 2001 and harvested on January 10, 2001. The tested species were those most favoured by farmers for further integration namely Crotalaria (*Crotalaria ochroleuca*), Mucuna (*Mucuna pruriens*), Tephrosia (*Tephrosia vogelii*), Vetch (*Vicia dasycarpa*) and Canavalia (*Canavalia ensiformis*) replicated three times arranged in a randomised block design. The plot size was 12 m^2, with one-meter gangway between treatments. The field was weed free throughout the season by hand weeding. In all cases, phosphorus was applied at a rate of 13-Kg ha^{-1} to facilitate growth and productivity. Data on biomass production of the species was analysed by ANOVA using statistical packages (Jandel Scientific, 1998).

Using the qualitative and quantitative data obtained from the site, and by considering the hierarchy of indicators identified by farmers, we developed draft decision guides on the integration of legumes into the farming systems of the Ethiopian Highlands.

Crop management

The technology, green manuring, in Gununo was first tested in a researcher/farmer- managed participatory research on farmers fields, who were interested to try Legume Cover crops and select the appropriate green manure species that could be adapted to their agro-ecology and also fit into their farming systems. Seven species of legume cover crops namely Trifolium (T*rifolium quartinianum),* Stylosanthus (*Stylosanthus guianensis*), Crotalaria (*Crotalaria ochroleuca*), Mucuna (*Mucuna pruriens*), Tephrosia (*Tephrosia vogelii*), Vetch (*Vicia dasycarpa*) and Canavalia (*Canavalia ensiformis*) were planted on April 25, 2000 (Belg season), July 1, 2000 (Meher season) and August 28, 2000 (Birra), to evaluate the performance of those legumes under different planting dates. The legumes were harvested on October 6, 2000, January 6, 2000 and March 5, 2001, for Belg, Meher and Birra planting, respectively. The plot size was 2 x 10m and with 1m gang way between each treatment. The recommended seed rate was used. We have also considered two food legumes, namely common bean (*Phaseolus vulgaris*) and Pea (*Pisum sativum*), in the study but they are already in the farming system. The trial also served as farmers field school to introduce farmer communities to alternative soil improving legume cover crops. The farms used for

Belg planting are known by the community as the most degraded, and hence the fate of the LCCs to be accepted or rejected by the community relied on whether the LCC could improve the productivity of those farms. Short before maturity the LCCs of Belg planting were chopped and incorporated after three weeks time. A sweet potato crop, cultivar Gadisa was planted following the LCCs on October, 15, 2000 and harvested on March 10, 2001.

As soil water conservation was considered by farmers as one of the important criteria of LCCs, we determined soil water content under the canopy of each species at 25 cm depth gravimetrically in the relatively dry weeks of November, five months after planting.

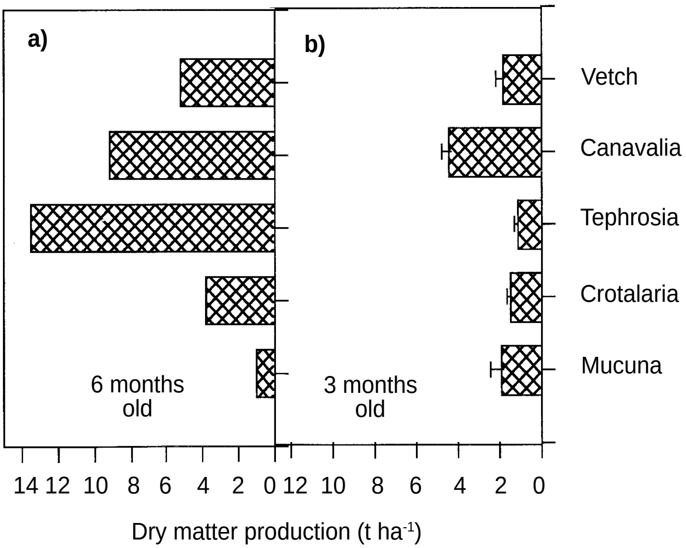
In July 2000, after farmers had repeatedly visited the Belg-planted green manure, we distributed seeds of their choice LCC together with improved Pea variety to 19 interested farmers to see what farmers were doing with those LCCs, where did they grow the food legume (pea) or LCC, and the type of management they were doing for the Pea or LCCs field. Besides structured questionnaires, we used participatory procedures of Pretty *et al* (1995) for data collection and follow-up.

Results and Discussion

Land use and Soil fertility management

Farming communities in Gununo prefer to build their homes on the top of the hills, in scattered hamlets surrounded by plantations of Enset, also called ‘false banana’ (*Enset ventricosum*) and coffee. The hamlets face towards the open communal fields, which people use for social occasions. The Wollaytas (which also includes Gununo communities) are reputed to be fond of trees for their own sake, growing trees and shrubs around their farm for spices, medicine, aromatic use, shade, farm implements and fuel wood. The farming system is a perennial based (Enset-based system) highly intensive system with a possibility of up to three cropping per year. Enset is a carbohydrate rich perennial crop, with strong spurious stem and edible bulbs and corm. Unlike the land holdings in the northern parts of Ethiopia which is characterised by land fragmentation, land holding in Areka is consolidated. Multiple cropping, in the form of intercropping, relay cropping and crop diversity, are practised by farmers thanks to the long growing season with uni-modal pattern of rainfall distribution (Figure 3.1). The farmers of Wollayta have divided their land into several plots for various purposes (Figure 3.1 and Figure 3.2). Trees are planted on valley bottoms, sloppy area, farm boundaries, in front of house and gully areas. Grazing land (tithering) are found in front of house (Deje). Some plots are left for cut and carry for livestock feeding. These plots have also different inherent soil fertility status (Figure 3.2), that is soil fertility declines with distance from houses (Eyasu, 1998).

Figure 3.2: Biomass production of various legume cover crops grown in Nitisols for three and six months of growing period under highland conditions (n=3)



The major land use systems in the community include homestead farms, (plot A in Figure 3.2) which are characterised by soils with high organic matter content due to continuos application of organic residue. These soils are dark brown to black in colour mainly due to high organic matter content. This part of the farm was used to grow most important crops such as enset, coffee, vegetables, planting materials for sweet potato and raise tree seedlings. In the system our two years survey showed that only about 3% of the homestead is occupied by legumes intercropped under the enset/ coffee plants (data not presented). Farmers are not applying inorganic fertiliser in this part of the farm. Homestead soils (Kareta) are characterised by high organic matter content due to continuous application of organic residue. Soils of the neighbouring field except the Kareta types are red in colour. Even the Kareta soils changed their colour due to organic matter application (PRA report, 1997). Red soils are less fertile and since the organic fertiliser sources are limited they require application of inorganic fertilisers. The homestead field is followed by the main field (plot B), which is characterised by red soils. Red soils are considered by the farmers as less fertile due to limited application of organic inputs, hence require application of inorganic fertiliser to get a reasonable amount of yield. In this part of the farm, farmers grow maize in association with taro, beans and sweet potato. This is also the part of land where legumes are growing most (Figure 3.2). Sweet potato is also planted as sole crop in this part of the land following long maturing maize during the small rainy season. The outfield (plot B in Figure 3.2) is the most depleted and commonly allocated for growing maize or potato using inorganic fertlizers. This plot does not receive any organic manure, legumes are rarely planted and the crop residue is even exported for different purposes. Farmers do not practice intercropping in this part of the land.

Although legumes are the major components of the system, the primary objective of the farmers is production of food grains as sources of protein followed by feed production as a secondary product, and not soil fertility. That is also partly the reason why the amount of land allocated for legumes decreases with distance from the homestead (decreasing soil fertility), excluding the enset field (Figure 3.2).

Participatory Evaluation of Legume Cover Crops

Seven green manuring cover crops were evaluated on-farm under three planting dates at the beginning (Belg), in the middle (Meher) and at the end of the growing season (Birra) of Areka, in 2000/2001. The rainfall amount and distribution is presented in Figure 1. The rainfall distribution was favorable and there was no extended dry spell within the growing season of 2000 and 2001. For the medium-term fallow, Tephrosia produced the highest dry matter biomass yield, 13.5 t ha^{-1} followed by Crotalaria, 9 t ha^{-1} (Figure 3.2). Most of the biomass accumulation in Tephrosia was observed four months after planting. The lowest yield was observed from Vetch, but it showed early vigour and matured much earlier than the other species. For the short-term fallow, Crotalaria was the best performing species followed by Mucuna and Vetch. On individual farmer's field, Crotalaria was the best performing species regardless of soil fertility. Similar results were reported from Uganda (Wortmann *et al.*, 1994). On the other hand, vetch and mucuna were performing best in fertile corners of the farms. For the Belg planting, the highest biomass yield (about 5t of dry matter ha^{-1}) was obtained from Crotalaria followed by Stylosanthsu and Trifolium (Table 3.2). The smallest biomass yield was obtained from Vetch. Crotalaria was the best performing species under this degraded soil. In the Meher planting, the highest dry matter yield (13.5 t ha^{-1}) was obtained from Tephrosia followed by Crotalaria. Like that of the Belg planting, the smallest yield was obtained from Vetch. This did not agree with the findings of Birra planting, when the amount of rainfall sharply declined two months after planting of the green manure, the highest dry matter yield was obtained by Crotalaria and Mucuna (about 2.9 t ha^{-1} dry matter). In this experiment plants were exposed to drought for extended period, and hence the yield obtained from Birra planting was relatively smaller than in the other two experiments. Although the Belg planting and Meher planting received about equal amount of rainfall (Table 3.2) dry matter production was the highest in Meher than in Belg planting. It could be explained by differences in soil fertility status of the two farms, whereby the land of Mr. Demeke (Belg planting) was highly degraded with a slope of about 18%. Unlike the results of Versteeg *et al.*, (1998), which indicated that mucuna performed better than other green manures (including crotalaria) to recover completely degraded soils, our data showed that Crotalaria performed much better than Mucuna in the degraded field of Mr. Demeke. When those species were planted in the driest part of the season, crotalaria and mucuna performed best and produced up to 2.9 t ha^{-1} dry matter within three months of time (data not presented). Although farmers who own livestock considered Stylos and Vetch for integration, resource-poor farmers went for Crotalaria and Canavalia.

Table 3.2: Tuber yield of Sweet potato following LCCs, Soil water content and ground cover of Legume Cover Cropsgreen manure in an on-farm trial, 2000. Data on ground cover (1 the least and 10 the highest) and soil water content (%) was taken when the plants were five months old (n= 4), and soil water was determined at harvesting

Species	Soil water (%)	Ground cover (1-10) rating
Canavalia	13.98	7
Vetch	20.78	5
Tephrosia	11.91	6
Mucuna	22.72	10
Crotalaria	14.05	7
Stylosanthus	20.22	9
Undisturbed soil	17.12	1
Mean	17.25	6.43
SED	4.10	2.94

Besides dry matter yield, we measured soil water content under the canopies of LCCs. The data from Meher planting showed that, the highest soil water content was obtained from mucuna and stylosanthus, which could be due to the self-mulching (Table 3.2). The ground cover (%) was the highest for Mucuna (100 %), and the lowest for vetch (60%). A similar result was obtained for mucuna in western Nigeria (Abayomi *et al.*, 2001). Higher soil water content under mucuna and stylosanthus (Table 3.3) implies that these species could improve soil water availability through reduction of evaporative loss. They also do not compete for water strongly if grown in combination with food crops.

Table 3.3: Farmers' criteria of selection of legume cover crops. According to farmers' ranking 6 was the highest and 1 the lowest (n=25)

Species	Firm roots	Eary soil cover	Bio mass	Rate of decomp-osition	Moisture conser-vation	Drought resista-nce	Feed value	Sum Total
Crotalaria	2	6	6	6	2	2	2	26
Vetch	1	5	5	4	1	1	6	23
Mucuna	6	4	3	3	6	6	4	32
Canavalia	5	3	4	1	4	5	2	24
Tephrosia	3	2	2	2	5	3	2	19
Stylosanthus	4	1	1	5	3	4	5	23

In Belg planting, all tested LCC were chopped and incorporated into the plots where they were grown. Mr. Demeke planted Sweet potato following the green manures with the residual moisture of 2000/2001, and obtained relatively higher tuber yield as an after effect of legumes (Table 3.3). The best performance was observed from those planted after Tephrosia and Mucuna followed by Canavalia & Crotalaria. Interestingly crop yield under the best performed legume (Crotalaria) was not the highest. Organic inputs from green manuring increased tuber yield possibly because it could increase the total amount of nutrients added, improve the soil-water holding capacity and also influence nutrient availability. Palm *et al.*, (1997) indicated that organic fertilisers could serve (i) as sources of carbon and energy to enhance microbial activity (ii) by controlling the net mineralisation - immobilization patterns (iii) as precursors to soil organic matter fractions and (iv) in complexing toxic cations and reducing the P sorption capacity of the soil.

Farmers evaluated the performance of LCCs in the fields individually or in groups through repeated visits. The selection criteria of farmers were beyond biomass production (Table 3.3). After intensive discussion among themselves, the FRG farmers agreed on seven types of biophysical criteria to be considered for selection of LCCs (Table 3.3). However, the criteria of choice had different weights for farmers of different socio-economic categories. None of the farmers mentioned labour demand as an important criterion. They considered firm root system (based on the strength of the plant during uprooting), rate of decomposition (the strength of the stalk and or the leaf to be broken), moisture conservation (moistness of the soil under the canopy of each species), drought resistance (wilting or non-wilting character of the leaf during warm days), feed value (livestock preference), biomass production (the combination of early aggressive growth and dry matter production) and early soil cover. For resource poor farmers (who commonly did not own animal or own few) food legumes green manure crops with fast biomass production (Crotalaria and Mucuna) were the best choices. For farmers who own sloppy lands with erosion problems mucuna and canavalia were considered to be the best: Mucuna for its mulching behaviour and canavalia for its firm root system that reduced the risk of rill erosion. Farmers with exhausted land selected crotalaria, as all the other legumes were not growing well in the degraded corners of their farms. On the other hand, farmers with livestock selected legumes with feed value and fast growth (Vetch and Stylosanths). In general, Vetch was the most favoured legume despite low dry matter production, as it produced a considerable amount of dry matter within a short period of time to be used for livestock feed. It was also easy to incorporate into the soil and found it to be easily decomposable due to its early aggressive growth. None of the farmers mentioned labour shortage as a potential constraint. The overall sum of farmers' ranking, however, showed that mucuna followed by crotalaria are the best candidates for the current farming system of Areka. Since Mucuna is aggressive in competition when grown in combination with other crops (Versteeg *et al.*, 1998) it could be used to increase soil fertility in well established Enset/Coffee fields, while Crotalaria and Canavaia could be used to ameliorate exhausted outfields. Canavalia is found to be best fitting as an intercrop under maize as it has deep root system and did not hang on the stocks of the companion crop (personal observation). The herbaceous LCCs feed and green manure legumes are reported as high quality organic resources (Gachene, *et al.*, 1999) to be used directly as organic fertilizers to improve the grain yield of subsequent crops (Abayomi *et al.*, 2001).

Farmers' management of experimentation with LCCs green manure

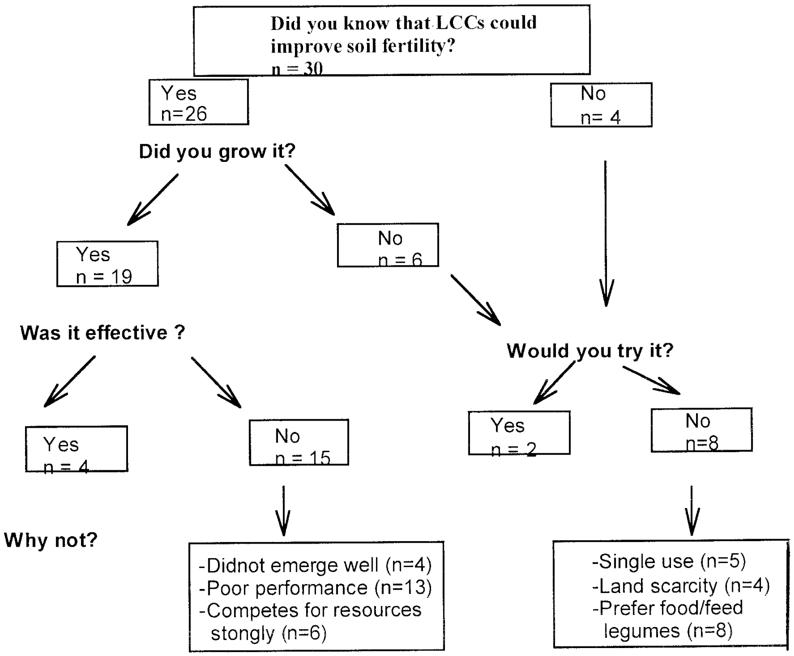
After thorough monitoring about the productivity and growth behaviour of LCCs in the experimental plots, about 19 farmers have tested various LCCs in their own farm. They tried mainly Canavalia, Crotalaria, Mucuna, Stylosanthus and Vetch. We observed that farmers have selected the most degraded corners of the farm for growing the LCCs and the fertile parts of their land for growing Pea (Table 3.4). About 50% of the trial farmers allocated depleted lands (degraded and abandoned) for the LCC. Further discussion with farmers revealed that they took this type of decision partly due to fear of risk, and partly not to occupy land that could be used for growing food crops.

Table 3.4: Spatial niches identified by farmers for growing Legume Cover Crops or Food legumes (Pea) in the growing seasons of 2000. Data shows number of involved farmers (%) grew legumes at different spatial niches (n=26)

Crop type	Sole in fertile soil	Sole in degraded soil	Relay under maize	Steepy Land	Border strips	abandoned land
Legume cover crops	0	28.6	7.1	14.3	21.43	21.42
Pea	64.29	0	35.7	0	0	0

From the total respondents, 86.6% of the farmers knew about the role of green manures as soil fertility restorers (Figure 3.3). However only 63% of them tested LCCs and of those who tested the green manures only 21 % responded LCCs were effective in improving the fertility status of the soil. About 79% believed that LCCs may not fit into their system mainly because they did not emerge well, or showed poor performance under depleted soils or are competing with food legumes for resources (labour, water and, land) (Figure 3.3). This could be explained by the fact that almost all of the farmers planted the LCCs on the degraded corners of their farm (Table 3.4), which in turn caused low biomass production and generally poor performance of LCCs (data not presented), especially at the initial stage of growth.

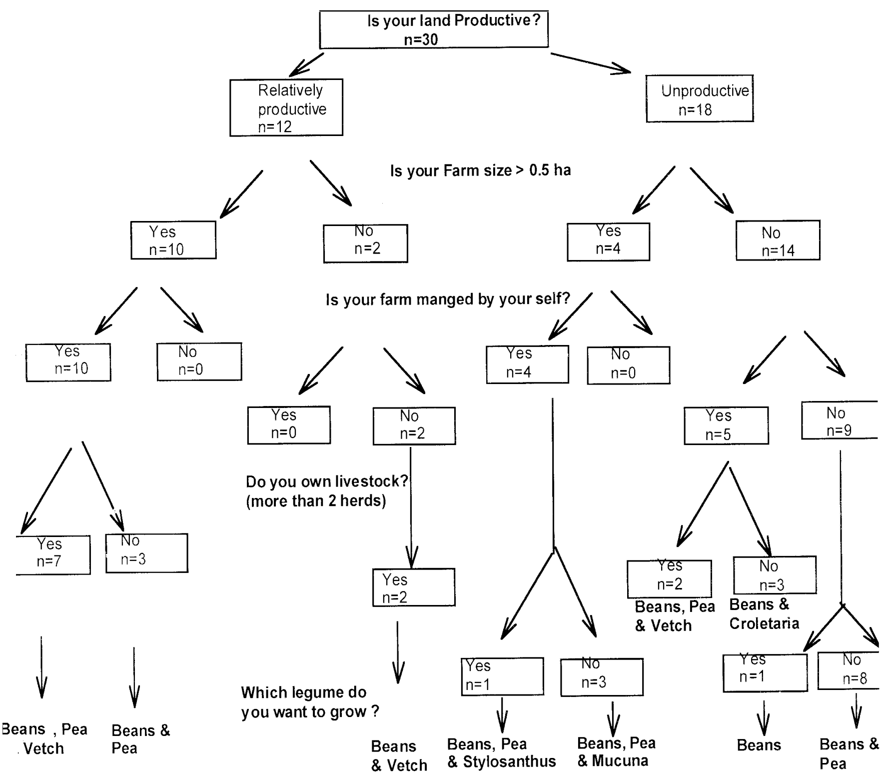
Figure 3.3: Guidelines for identification of factors of adoption or non-adoption of legume cover crops in multiple cropping systems of Areka



Socio-economic factors dictating guidelines for integration of legumes

Results from PRA studies augmented by structured questionnaire showed that there are 21 different factors that affect the integration of legumes. When farmers were asked to prioritise the most important factors affecting integration and adoption of legumes they mentioned a) farm size b) suitability of the species for intecropping with other crops for space and resources c) soil productivity of their land d) suitability for livestock feed e) marketability of the product f) toxicity of the pod to children and animals g) who manages the farm (self or share cropping) h)ownership of the farm i) length of time needed to grow the species and j) risk associated with growing LCCs in terms of introduction of pests and diseases. Earlier works suggested that farm size and land ownership affect integration of LCCs into small holder farms (Wortmann & Kirungu, 1999). After comparing those factors in a pair-wise analysis, four major indicators of different hierarchy were identified (Figure 3.4).

Figure 3.4: Tools for determining degree of integration of legumes into multiple cropping systems of Areka



1) *Degree of land productivity:* Farmers in Gununo associated land productivity mainly with the fertility status of the soil and distance of the plot from the homestead. The homestead field is commonly fertile due to continual supply of organic resources. Farmers did not apply inorganic fertiliser in this part of the farm. They remained reluctant to allocate a portion of this land to grow LCCs for biomass transfer or otherwise, but they grow food legumes, mainly beans, as intercrops in the coffee and enset fields. The potential niche that farmers were willing to allocate for LCCs is the most out field.They are well aware of the role of legumes in crop rotation, though they give priority to food legumes with immediate benefits. When it comes to integration of LCCs solely for the sake of soil fertility maintenance, farmers are unwilling to allocate the land which otherwise could be used to grow food crops.

2) *Farm size:* Despite very high interest of farmers to get alternative sources of inorganic fertilizers, the probability of farmers to allocate land for growing LCCs depended on the size of their land holdings. For Areka conditions, a farm size of 0.75 ha is considered large. Farmers with very small land holdings did not grow legumes as sole crops, but may integrate them into their system as intercrops or relay crops. Therefore, the potential niches for LCCs are partly occupied unless the farm is highly depleted.

3) *Ownership of the farm:* Whether a legume (mainly LCCs) could be grown by farmers or not depended also on the authority of the person to decide on the existing land resources, which is linked to land ownership and management. Those farmers who did not have enough farm inputs (seed, fertilizer, labour and/or oxen) are obliged to give their land for share cropping. In this type of arrangement, the probability of growing LCCs on that farm is minimal. Instead farmers who contracted the land preferred to grow high yielding cereals (maize & wheat) or root crops (sweet potato). As share cropping is an exhaustive profit-making arrangement, the chance of growing LCCs in such type of contract was almost nil. Without ownership or security of tenure, farmers are unlikely to invest in new soil fertility amendment technology (Thomas and Sumberg, 1995)

4) *Livestock feed:* In mixed farming systems of Ethiopia livestock is a very important enterprise. Farmers select crop species/varieties not only based on grain yield but also straw yield (as a crop residue or forage) when evaluating new variety or crop. Similarly legumes with multiple use were more favoured than those legumes that were appropriate solely for green manure purposes.

These socio-economic criteria of farmers together with the productivity experimental data from the field were used to develop decision guides to help farmers in selecting legumes to be incorporated into their land use systems as presented in Figure 3.5 and Table 3.5. As presented in Figure 3.4, farmers considered the degree of land productivity as the most important factor (placed at the highest heirarchy) for possible integration of legumes. Farmers who own degraded arable lands were willing to integrate more LCCs green manures while those who own productive lands of large size wanted to grow food legumes with additional feed values. However, all farmers decided to have food legumes in their system regardless of farm size or land productivity. Beans and Pea are already in the system and farmers found niches to grow them as they are also part of the local dishes. From the feed legumes, farmers favoured stylosanthus and vetch as mentioned above. Those farmers who wanted soil improving LCCs, selected crotalaria, as they found it better performing even under extremely degraded conditions. However, about 45% of the farmers with degraded arable lands are not willing to integrate LCCs, or grow green manures either because they did not manage their own farm, and hence share cropping /contract or have limited options of household income.

Figure 3.5: Guideline for integrating food, feed legumes and legume cover crops in small-scale farms

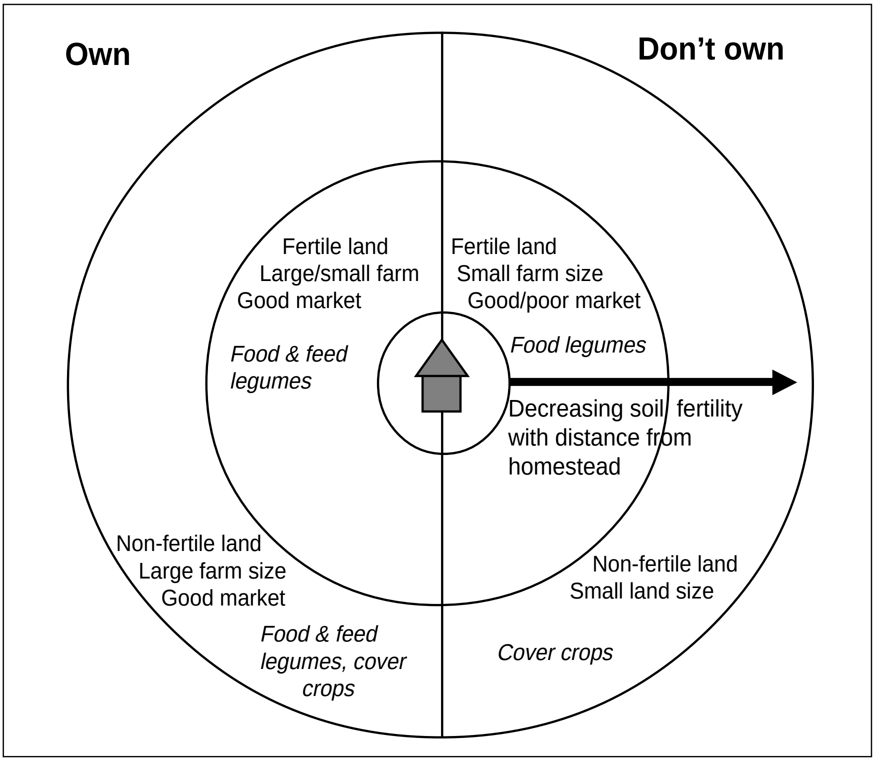


Table 3.5: Tools for identification of potential legume niches for possible integration into the multiple cropping systems of Areka developed in consultation with farmers

Position within the farm	Land size	Soil fertility status	Demand for fodder	Available niche	Best-best
	Large		High	Intercrop under enset/coffee vetch	Stylosanthus Desmodium
			Low	same	Beans/pea
Homestead		Fertile	High	Intercrop under ensey/coffee	Beans/pea
	Small		Low	same	Same
		Fertile	High	a) Intercrop with maize b) Relay under maize	a) Beans & Peas b)Vetch
	Large		Low	a) Sole b) Intercrop under maize	a) Beans/Pea b)Crotalaria/ Mucuna /Tephrosia
Outfield		Less Fertile	High	Relay crop/ short fallow	Vetch Stylosanthus
			Low	a) Relay crop b) Intercrop	a) Crotalaria b)Canavalia/ Tephrosia
		Fertile	High	Relay/Inter Under maize	a) Beans/Pea b)Vetch Stlosanthu
			Low	same	Pea/Beans
	Small	Less Fertile	High	Relay crop Short fallow	Stylosanthus/ Mucuna
			Low	Relay crop Short fallow	Crotalaria/ Canavalia

In general, given very high population pressure and associated land shortage, farmers in Areka may not allocate full season for LCC, but preferred fast growing LCCs for short term fallow. The probability of integrating LCCs into the system became even less when the land is relatively fertile. As the homestead Enset and darkua fields are relatively fertile (Figure 3.2) and used for intercropping/relay cropping purposes, growing LCC on that part of the land may not be the choice of farmers. On the other hand, farmers with large farm size and high degree of land degradation may go for selected LCCs. The potential niche available in the system would be the least fertile most-out field (Figures 3.1 and 3.2) where intercropping is not practised. The most out field is commonly occupied by potato in rotation with maize (Figure 3.1) with relatively less vegetative cover over the years.

The length of the growing period together with the amount and distribution of the rainfall dictates whether the system may allow growing legumes intercroped with maize, intercroped with perennials, or relay cropped with maize or sweet potato. In regions, where the growing season is extended up to eight months, and where the outfield became depleted to sustain crop production, LCCs green manures that could grow under poor soil fertility conditions in drought-prone months would be appreciated. Indeed, crotalaria performed very well under such conditions.

The Decision Guides

We are presenting three guidelines for integration of legumes into the farming systems of multiple cropping, perennial-based systems.

Maize is the major staple crop in the region, and about 45% of the arable land in Areka is allocated for maize. Table 3.3 shows a decision tree developed to improve nutrient availability of Maize with decreasing costs using organic resources in combination with inorganic fertilizers or sole. The decision trees were developed based on the following background information from the site.

1) Farmers preferred food legumes over non-food legumes regardless of soil fertility status of their farm.

2) The above ground biomass of grain legumes (grain & stover) is exported to the homestead for feed and food while the below ground biomass of grain legumes (beans and pea) is small to effect soil fertility. The probability of the manure to be returned to the same plot is less as farmers prefer to apply manure to the perennial crops (Enset & Coffee) growing in the home-stead.

3) The tested legumes may fix nitrogen to fulfil their partial demand (we have observed nodules in all although we did not quantify N-fixation), but in conditions where the biomass is exported, most of the crop residue of legumes or green manure are used as feed sources. Therefore, we did not expect significant effect on soil fertility. It is not clear whether the organic resource circulates back to the field in the form of manure.

4) LCCsGreen manures produced much higher biomass when planted as relay crops in the middle of the growing season than when planted at the end of the growing season as short-term fallows due to possible effects of end-of season drought.

5) The homestead field is much more fertile than the outfield,; hence those legumes sensitive to water and nutrient deficiency will do better in the homestead than in the outfield.

The first guide (Figure 3.3) is intended to assist researchers to get feed back information about technologies that were accepted or rejected by the farmers or farmer research groups. This guide will assist researchers not only to identify the major reasons for the technology to be accepted or rejected, but also to prioritise the reasons of resistance by farmers not to adopt the technology. This type of feed back will help to modify/improve the technology through consultative research to make technologies compatible to the socio-economic conditions of the community.

The second guide (Table 3.5) is intended to assist farmers and researchers in identification of potential legumes that could be compatible to the existing spatial and temporal niches. This guide was developed based on the fact that the outfield is larger in size than the homestead field, and land size, soil fertility status, feed demand and available niches in the system (see also Figure 3.4) determined the best-bets that could fit into the current land use system.

The third guide (Figure 3.5) is developed based on the data presented in Figure 3.4, and by taking into account the market effects. The most important criteria at the lowest level is the presence or absence of livestock in the household followed by who manages the farm, market access, the size of the land holding and the land quality. The factor that dictates the decision at the highest level was land productivity, which was governed mainly by soil fertility status. Growing food legumes was the priority of every farmer regardless of wealth (land size, land quality & number of livestock). Farmers with livestock integrated feed crops regardless of land size, land productivity and market access to products. However, the size and quality of land allocated for growing feed legumes depended on market access to livestock products (milk, butter and meat). Those farmers with good market access are expected to invest part of their income on external inputs, i.e. inorganic fertilisers. Hence farmers of this category did not allocate much land for growing LCCs, but applied inorganic fertilisers. In the homestead field, there was no land allocated for LCCs in the system, not only because farmers gave priority to food legumes, but it also became very expensive for farmers to allocate the fertile plot of the farm for growing LCCs. The most clear spatial niche for growing LCCs is the most out field, especially in poor farmers' field with exhausted land and limited market-driven farm products.

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