NATURAL RESOURCES SYSTEMS PROGRAMME

PROJECT REPORT[1]

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DEVELOPING AND TESTING TECHNOLOGIES WITH FARMERS

1.0 Introduction & objective

This annex describes the process for designing and characterizing the interventions (also referred to as technologies) experimented with farmers in the three project villages, i.e. Gogoikrom-Atwima, Subriso III-Tano and Yabraso-Wenchi. The Bush Fallow Rotations Project adopted a Participatory Technology Development (PTD) approach for testing and developing with farmers' the interventions for improving the productivity of shortening fallows. Douthwaite *et al.* (2002 citing van Veldhuizen *et al.,* 1997) described this process of involving farmers in research as one by which outside facilitators and rural people interact to enable the target groups have a greater capacity to adapt a new technology to their conditions and the facilitators have a better understanding of traits and characteristics of local farming systems. Thus, a PTD approach ensures that a technology becomes more applicable to farmer circumstances and enhances a higher uptake to ultimately improve and sustain the livelihoods of farm households.

The PTD process involved four main stages namely, diagnosis and analysis, planning, implementation and evaluation as indicated in Figure 1 in Annex A. The first stage i.e. diagnosis and analysis involved characterization of the farming/livelihood systems in the study areas and have been reported in detail in Obiri *et al.* (2000) and Obiri (2003). The remaining stages are reported in this section. The methods employed and issues of interest during the PTD process are summarized in Table 1.1

Table 1.1 Issues and methods employed for designing & characterizing technologies

Objective	Issues investigated	Data collection method	Data analysis method
Describe the process of designing and characterizing interventions/ technologies with farmers	-Characteristics of livelihoods & farming system -Identification of suitable technologies -Establishment/experimentation of technologies on farms -Economic & farmer evaluation of technologies & adoption potential -Farmer behaviour/attitudes in participation and adoption -Strengths & weaknesses of process -Outstanding issues for future work	-PRA (key informant interviews & community meetings, farm visits, etc.) -Individual/household interviews -Stakeholder workshops -Plot level data -Periodic monitoring & Evaluation	Descriptive Economic

The initial characterization described the setting in which the study was undertaken as a multicultural/ethnic one characterized by small scale crop production economies which employ simple farm implements such as the machete and hoe for cultivating the land. Crop production, the main livelihood activity, may be supplemented with the rearing of small numbers of sheep, goats, pigs and poultry and variable off-farm employment by some people. Approximately 50% of the population in the villages, majority of who are women are illiterates and extension services appear to be limited, being worse in Gogoikrom-Atwima. However, physical accessibility to administrative and market centers by road is fairly adequate enabling regular vehicular movement of goods and people.

Two main livelihood systems, native and settler were distinguished in the three villages. The criteria for this classification was primarily based on origin/residential status of farmers, which determined the land status of households and/or individuals and consequently dictates the right, access to and control over the use of land particularly for farming. While Gogoikrom and Subriso III are dominated by settlers, the majority of whom are tenants accessing land for cultivation through mainly sharecrop arrangement and rental by cash, natives cultivating land owned through family ties dominated the population of Yabraso.

A wide range of crops are grown for livelihood, however, there are major ones based on the relative proportions of farms under their cultivation. Cocoa, maize, rice, plantain, and oil palm are the major crops cultivated in Gogoikrom. Maize, plantain, yam, cassava, pepper, groundnut, tomato and oil palm are the main crops in Subriso III while yam, maize cassava, groundnut, pepper and cashew are the main crops cultivated in Yabraso. The majority of the landless are involved in the cultivation of the shorter duration food crops, although in Gogoikrom, the abunu tenure (50:50 shares after a tenant establishes plantation) allows both landowners and tenants to equally engage in the production of cocoa, a tree crop. Generally, all farmers in specific villages cultivate all crops, however, gender and age niches associated with crop production are found particularly, in Subriso, where young landowner men are more involved in vegetable cultivation, while it is maize for landless men and women of all age groups as well as older landowner men. Older landowner men and women are also more involved in plantain cultivation because it is a longer duration crop and requires a secured tenure whereas pepper and groundnuts are generally for women of all classes.

It was observed that the majority of the people fallowing crop fields were landowners. Fallowing was the common measure by which soil productivity was restored after limited periods of cultivation often not more than 6 years, particularly for food crops as nearly zero percent of farmers use any other soil amendment measure with the exception of a few cultivating tomato in Subriso III. Even for vegetables like tomato and garden eggs where inorganic fertilizer and other agrochemicals are applied to boost yield, the land may be fallowed for 1-3 years after the crop has been relayed or rotated with cassava or maize to utilize the residual fertilizer. Consequently, short fallows characterized the food production systems. Such fallow range from 1 to 3 years or more with their vegetation characterized by *Chromolaena odorata* and several grass species like, *Panicum maximum*, *Pennisetum purpureum*, *Cenchrus ciliaris*, *Rotboellia exaltata* and *Imperata cylindrica*, to mention a few. Farmers explained this has resulted mainly from increasing population pressure resulting from influx of migrants into the study communities that is not only causing land scarcity but also the availability of relatively fertile soils for cultivation. Other important factors mentioned for causing shortening fallow were weather adversities and persistent wild fires. Moreover, monetary needs of older landowners make it impossible to leave land under fallow for very long periods to adequately restore its fertility.

Major production constraints farmers enumerated in relation to shortening fallows were poor soils and an upsurge in noxious weeds that decline crop yield and increase labour cost, reducing farm income. Nearly 20 different weed species were mentioned to grow on farms in the study villages. Most crops fields had to be weeded 2-3 times during the growing season due to high weed incidence. Furthermore, absence of reliable and less expensive farmer credit support systems coupled with poor and seasonal fluctuating prices for farm produce often renders their subsistence production unprofitable subjecting farmers to perpetual financial constraints although there are adequate marketing outlets.

2.0 Development of research protocols & on-farm experiments

Initial protocols of interventions were developed for the various study areas. These were derived after an analysis of baseline information of the study areas taken into consideration production constraints in relation to land status of farmers and cropping systems with respect to fallow rotations at a stakeholder/planning workshop. The emerging issues of concern for redress were mainly poor yield and its links with soil fertility decline, noxious weeds, short term access to farmland and financial problems encountered by the farmers.

2.1 Stakeholder workshop interventions

Table 2.1 summarizes the inventions proposed at the stakeholder workshop. The planted tree fallow (woodlot), tree-food crop, enrichment planting with high value trees, maize-legume relay, permanent plantain and intensified livestock/compost interventions were proposed as alternatives for both Tano and Wenchi to ease declining soil fertility, weeds and cash problems. The tree related interventions were thought more appropriate particularly to landowners who might be in the position to plant trees or fallow for longer periods and probably interested in protecting and improving the productivity of the land in the long term. It was thought that people would be proactive in protecting their farms and surrounding vegetation from bush fires if they invest in planting trees of high value.

Table 2.1 Interventions proposed at stakeholder workshop

District	Intervention Name	Intervention Proposed	Description	Problem Addressing
Tano & Wenchi	Planted tree fallow followed by woodlot	Establish planted tree fallows during cropping phase that suppress weeds and are productive (tree fallow serve as a woodlot that can be harvested for wood and sold for cash	Fast growing species – e.g. *Gliricidia, Cassia*, plus high value timber species e. g. *Tectona grandis*) established in food crop. Harvest poles and then timber and return to cropping	Declining soil fertility Increase in weeds Need for cash (wood production for cash)
	Tree – crop establishment in food crop	Establish trees during food crop phase that suppress weeds and are productive	High value trees established in food crop phase, possibly plus cover crops for conversion to tree-crop system e.g. cashew, cocoa, oil palm	Declining soil fertility Increase in weeds Need for cash Declining availability of forest and long fallows
	Enrichment planting	Plant or retain high value trees on food croplands.	High value trees established at low density in food crop phase and protected during fallow phase to result in permanent agroforestry system (trees in fields).	Declining soil fertility Declining tree cover Need for cash
	Relay cropping legumes and maize	Relay crop/main season maize with a legume (either a cover crop or grain legume)	Long season *Mucuna*, Canavalia or *Vigna* planted at tassling stage of main season maize (60 days after planting/possibly during the last maize weeding). The legume will add nitrogen and smother weeds increasing soil fertility, reducing weeds and increasing yield of subsequent crop (which may be any crop)	Declining soil fertility Short land tenure No opportunity to fallow Increase in weeds

	Permanent plantain system	Plant trees and cover crops for shade and mulch with plantain	Trees (hedge species – e.g. *Flemingia, Gliricidia, and Inga edulis*) established in food crop. Fallow for two years, cut back trees to hedges and establish plantain (cocoyam) and perennial cover crops (e.g. *Peuraria* but preferably something that doesn't climb). Harvest plantain for one or two ratoons. Fallow for two years *ad infinitum*	Declining availability of forest and long fallows Need for long fallow for good yields of plantain and cash
	Intensified livestock and compost	Intensify livestock production and promote compost production	Control livestock movement, increase livestock numbers, improve feed for livestock (fodder banks); collect more dung and mix with other residues to make compost, apply compost to crops and increase yield at the same time as increasing livestock productivity and cash income	Declining soil fertility Need for fertilizer Need for cash
Atwima	Cocoa established with a cover crop	Initiate land clearance for cocoa by establishment of a food legume inter-crop to increase soil fertility and reduce weed infestation by the time of cocoa planting	In March clear land and establish a cover crop/maize relay intercrop. Short duration cover crop could be *Mucuna* (8 months) and longer duration, *Pueraria* (2 years). Shade trees are established at the same time. In April, food crop and cocoa establishment	Declining soil fertility; Increase in weeds lead to problems in establishment of cocoa
	Organic/inorganic fertiliser usage	Increasing resource levels to overcome declining soil fertility	Use of organic and inorganic fertilisers, as prescribed by the Cocoa Research Institute of Ghana (CRIG)	Declining soil fertility reducing cocoa yields
	Manipulation of cocoa shade	Increase productivity of shade species, or identify species with soil-improving properties	Early shade is intended to comprise of the farmers' food crops and the treatments will be the farmers' normal practice of inter-planting with plantain, cassava, maize and cocoyam. Identification of potential late shade species will be by farmer survey of desirable criteria and species' characteristics, and by ecological survey and use of existing data sets	Requirement for shade reduces cocoa yields directly and indirectly by utilization of crop land Declining soil fertility
	Improved cocoa germplasm	Planting of new, improved hybrid varieties	Replacement of traditional Amelonado stock with improved hybrids developed by the Cocoa Research Institute of Ghana	Declining cocoa yields because of varietal drift and pest/disease problems

The maize-legume relay was purposely to cater to the needs of the non-landowners with short tenancy of at least two years and for those landowners who might not be in the position to fallow because they probably do not have adequate land to permit fallow rotations. The livestock intervention was for all classes of farmers interested in improving the production of livestock as a supplementary income source for supporting the household and farm as well as source of organic manure for improving soil fertility. Interventions for Atwima were cocoa-based because of the project's aim to improve and sustain cocoa yields using multi-strata cocoa agroforests in that area.

2.2 Prioritizing interventions

The above interventions were represented pictorially (Figure 10-Annex A) and presented to farmers in the study villages for rating. Figures 2.1-2.3 show the pattern in farmers' rating of the workshop proposed interventions in the three villages.

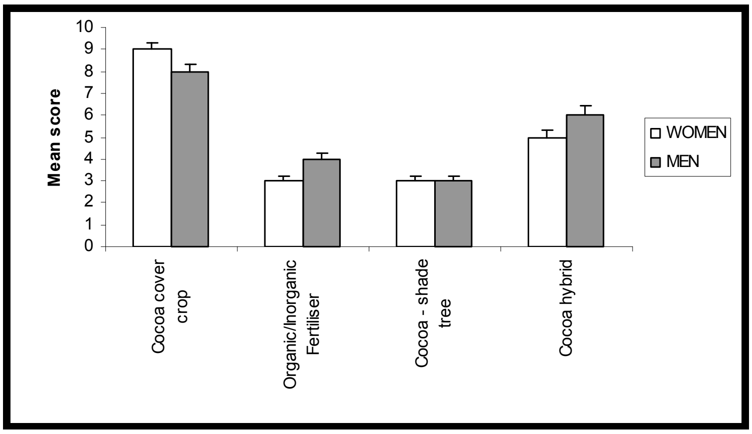


Figure 2.1: Mean scores for interventions at Gogoikrom-Atwima

In Gogoikrom both male and female farmers were highly in favour of the cocoa-cover crop intervention particularly due to its potential to control weeds once the cover crop is in place, Figure 2.1. Farmers indicated weed incidence was one of their biggest problems on the farm. This was followed by the cocoa hybrid mainly for its early and higher yielding attributes. The next choice was the cocoa-fertiliser intervention which scored higher than the cocoa-shade tree due to its potential to increase yields in the short term. The cocoa-shade tree was the least preferred because it involved the planting of shade trees with cocoa, which farmers thought could possibly lead to destruction of their cocoa farms by timber concessionaires.

The permanent plantain system, followed by livestock and maize interventions were the most popular intervention preferred at Subriso III, Figure 2.2. Reasons farmers gave for rating the permanent plantain system as their most preferred choice included the fact that plantain can be cultivated as a long duration crop and can fruit for 10 to 15 years if properly maintained. Plantain also requires less weeding than other crops (once every 3 - 4 months is sufficient) for it to establish.

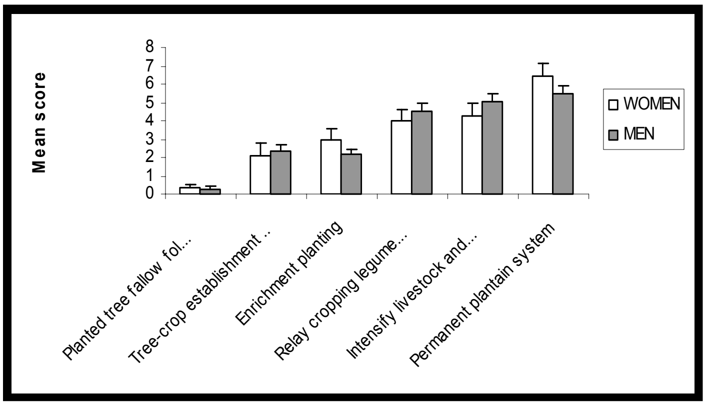


Figure 2.2: Mean scores for interventions at Subriso No. 3-Tano

The livestock-compost intervention was the next preferred for economic, food security and socio-cultural reasons. Livestock could be sold to generate cash for farming and household needs and could also be used as collateral to access credit from others in times of financial difficulties.

Relay cropping maize with legumes was rated next to livestock-compost because maize is an important food source and has a number of uses e.g. kenkey (ground, fermented, boiled maize), roasted maize that stores well used by hunters, pito brewing. Maize can be stored for a long time and is important for bridging the hungry season (March/April). It is a short duration crop that can easily be grown by all people including seasonal migrants in need of quick money. Maize is also exported to other nearby countries in the Sahel area, e.g. Burkina Faso.

Conversion to tree-crop systems was the next choice after maize because although cocoa is regarded as an important crop, the prevailing ecology and soils are not suitable for its cultivation by most people. However, oil palm cultivation is rising and so the tree-crop system might be desired by some people. The enrichment planting and planted tree fallow/woodlots were the least popular options probably because annual bush fires make this kind of investment unattractive, besides not being a common practice. It was generally observed from further disaggregating of the data that non-landowning settlers were not in favour of the tree-crop, enrichment planting and the planted woodlot interventions probably because the prevailing tenure is not favourable for adopting such systems.

The pattern of rating in Yabraso is shown in Figure 2.3. Enrichment planting had the highest score followed by maize-legume relay, tree-crop, permanent plantain, livestock-compost and planted tree fallow in that order. Enrichment planting was the most popular for both men and women because majority of the inhabitants of Yabraso are natives cultivating their own lands, thus regard this intervention as more or less a long term undertaking to be rated first. Also, the fruit tree aspect was most desirable as species like cashew (*Anacardia occidentale*) and mango (*Mangifera indica*) are becoming increasingly integrated into the farming system as alternatives to cocoa.

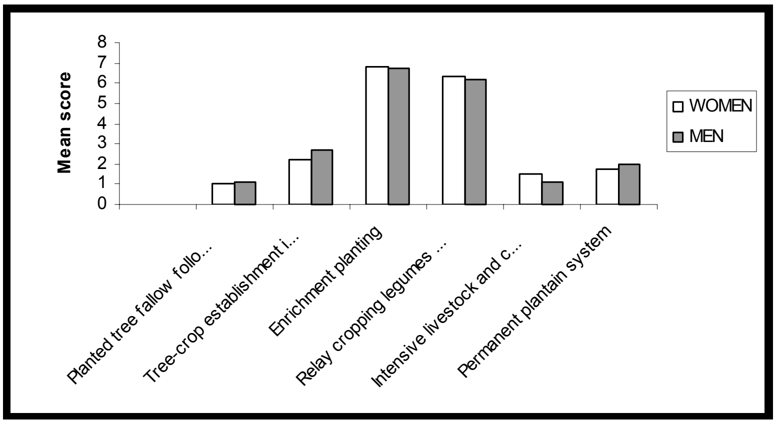


Figure 2.3: Mean scores for interventions at Yabraso-Wenchi

Relay cropping legume with maize was rated next because although a short term crop, maize is important for food and cash and is grown by all farmer categories in the village. Tree-crop appears to be the next after the maize system probably because such systems with particularly, fruit trees as cashew, mango and timber species like teak (Tectona grandis) is gaining prominence in the Yabraso area. Although some farmers desire to plant plantain on the forest land, the prevailing dry ecology does not favour its production. Livestock-compost and planted tree fallow were the least because livestock such as goat was regarded notorious in destroying farms and the planted tree fallow was highly prone to persistent wild fires in the dry season.

Table 2.2: Profile of on-farm experiments in Gogikrom, Subriso III and Yabraso

Farm type	**Trial/cropping system**	**Legume/tree species**	**Problem to address**	**Village**
Mono crop	Sole maize-cover crop relay	*Mucuna* spp *Lablab purpureus* *Pueraria* spp *Canavalia ensiformis* *Clitoria ternatea* *Stylosanthes hamata* *Stylosanthes guianensis*	Soil fertility, weeds, short tenure, no fallow (settlers)	Gogoikrom Subriso III Yabraso
Mixed crop	Maize intercropped with cassava, plantain, etc. – cover crop	*Canavalia ensiformis* *Stylosanthes hamata* *Stylosanthes guianensis*	Soil fertility, weeds, short tenure, no fallow (settlers)	Gogoikrom Subriso III Yabraso
	Yam intercropped with maize, cassava, cashew, etc –cover crop	*Canavalia ensiformis* *Stylosanthes hamata* *Stylosanthes guianensis*		Yabraso
Mixed	Plantain-tree-cover crop	*Canavalia ensiformis* *Gliricidia sepium* *Flemingia microphylla*	Soil fertility-long productive period, stakes, poles, fuelwood, lodging, cash	Gogoikrom Subriso III
Planted fallow	Tree fallow -Whole field planted	*Gliricidia sepium*	Soil fertility, weeds, wood (cash)	Subriso III Yabraso
Mixed	Cocoa-shade tree	*Albizia zygia* (Okoro) *Newbouldia laevis* (Sesemase) *Tetrapleura tetreptera* (Prekese) *Terminalia ivorensis* (Emire) *Entandrophragm angolense* (Edinam) *Pericopsis elata* (Kokrodua) *Entandrophragma utile* (Utile)	Soil fertility – long productive period, Weeds Trees of important ecological & socio-economic values integrated on cocoa farms Tree cover- long fallows Wood sales-extra cash	Gogoikrom

The results of the ratings and the discussions that followed lead to the development of on-farm trial protocols for the three study sites, Table 2.2. The cocoa-shade tree, maize-legume relay, permanent plantain and improved fallow protocols were developed for Gogoikrom-Atwima. This was because cocoa, maize and plantain are commonly grown in the area. The improved fallow was added on to see whether some landowners could adopt it for improving the productivity of the short fallow systems practiced for rice and maize production systems which are normally fallowed from 1 to 3 years or more. It was realized from the discussions with the farmers that although cocoa-legume cover crop and cocoa-fertilizer were most preferred, farmers complained of the possibility of the creeping legume they referred to as carpet to climb or strangle the cocoa. Also fertilizers both organic and inorganic are difficult to come by and are not usually applied on tree crops.

Maize-legume relay, permanent plantain and improved fallow interventions were suggested for Subriso III-Tano. Maize and plantain are predominantly grown and were among the interventions most desired by farmers. Moreover these production systems are commonly fallowed from 1 to 3 years or more. The livestock system could not be pursued although farmers expressed much interest because there was a MoFA project in the district working on that aspect.

Maize-legume relay, yam-legume relay (suggested by farmers), improved fallow and tree-crop interventions were suggested for Yabraso-Wenchi. Maize and yam are commonly grown in the area and desired by most farmers. Again these systems are commonly fallowed from 1 to 3 years or more. Tree-food crop systems with cashew, mango and teak tree species are increasingly being adopted in the area. Also farmers showed much interest in enrichment planting which involved planting or retaining high value trees on food croplands, which they mistook as fruit trees with food crops.

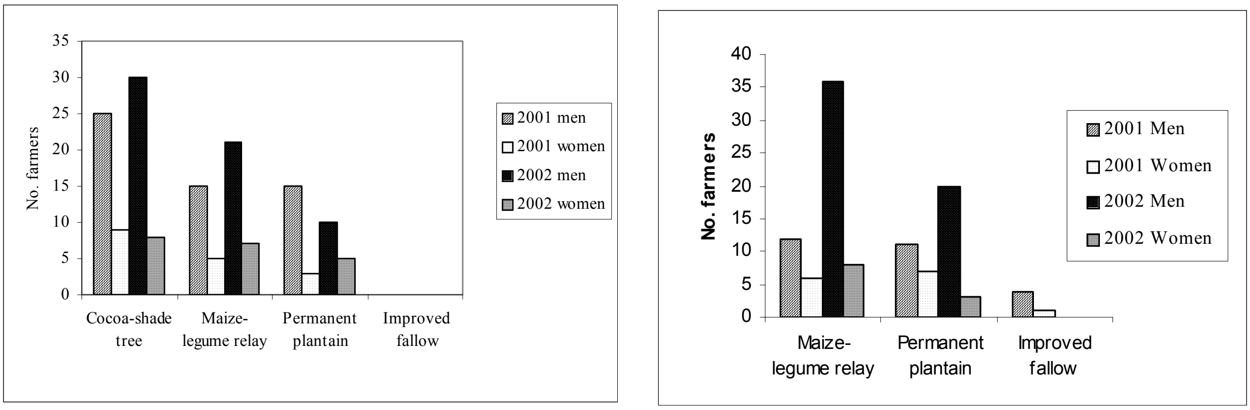
3.0 On-farm experimentation

3.1 Farmer choice of on-farm experiments (2001 & 2002)

The on-farm trial protocols were presented and discussed with farmers in the respective study villages. Farmers exercised their choice of experiments at the beginning of the 2001 and 2002 farming seasons, Figures 2.4-2.6.

In Gogoikrom-Atwima cocoa-shade tree was the most desired for both men and women for 2001 and 2002 since it is the mainstay of the people. This was followed by maize and plantain which are supplementary crops cultivated for food and cash while establishing cocoa farms. A total of sixty-nine and seventy-six farmers were listed for the on-farm experimentation during the first (2001) and second (2002) years respectively with some trying more than one and/or repeating some experiments in the second year.

At Subriso III –Tano maize-legume relay was the overall most preferred experiment followed by permanent plantain and improved fallow for both years, Figure 2.5. In the second year, forty-four people showed interest in the maize-legume relay, about twice the number doing so in the first year. This was attributed to the fact that maize is short duration crop maturing in 3 months to sell for early cash after the dry/lean season particularly for men. It was also because farmers realized the project demanded nothing by way of produce or money from the 2001 participants after the harvest, which some of them feared was going to be the case.



Figures 2.4 & 2.5: Farmer choices of interventions for on-farm experimentation at Gogoikrom-Atwima & Subriso III-Tano for 2001 & 2002

There were more men than women at the meeting, reflecting in the big difference in numbers between men and women for the three experiments, particularly, in the second year. Unlike Gogoikrom few landowners including a woman expressed the desire to try the improved fallow in the first year, which could actually not be implemented due to shortage of stocks of the fallow species (Gliricidia) at the project's nursery. During the second year however, no one showed interest in the improved fallow possibly because no one tried it in the first year.

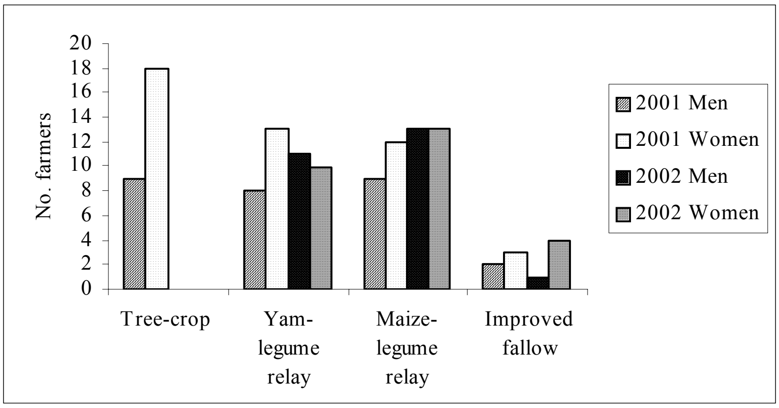


Figure 2.6: Farmer choices of interventions for on-farm experimentation at Yabraso-Wenchi for 2001 & 2002

Figure 2.6 indicates the pattern in choice of intervention for on-farm experimentation at Yabraso-Wenchi. A total of seventy-three and fifty-two farmers were listed for on-farm experimentation for 2001 and 2002 respectively. There were more women than men at the meetings for listing farmers in both years conversely to Gogoikrom and Subriso where there more men than women. Most people chose yam and maize over improved or planted tree fallow for experimentation.

Although majority of farmers preferred to plant cashew and oil palm for the tree-food crop intervention in 2001 as the people tend to regard particularly, cashew as the new cocoa of the area it was realised that the seeds were expensive and so not easy to come by so could not be implemented.

3.2 Establishing on-farm experiments

Two types of trial were established. The first was researcher-managed trials established on station for the collection of more accurate biophysical data for backstopping/compliment on-farm data and also serve as demonstration. The biophysical data collected comprised biomass assessment of fallow species particularly, screening of these species, studying the effect of planting date and density, phosphorus, etc on herbaceous and tree fallow species. The second type of trials was on-farmer fields experimented as researcher designed and farmer managed on-farm experiments. Table 3.1 indicates the respective roles farmers and researchers played during the experimentation process.

Table 3.1: Researchers & farmers' contribution in experimentation

Activity	Researchers & Farmers Roles
Field preparation	Farmer
Design of experiment	Researcher
Selection fallow and test species	Researcher with input from farmer discussion
Supply of planting materials	Researcher
Nursery activities	Farmer (indigenous trees and cocoa) & researcher all other species
Planting experiment	Farmer & researcher
Weeding	Farmer
Data collection	Researcher
General observations	Farmer & researcher
Monitoring &evaluation	Farmer & researcher
Crop harvest	Farmer
Marketing of crop	Farmer

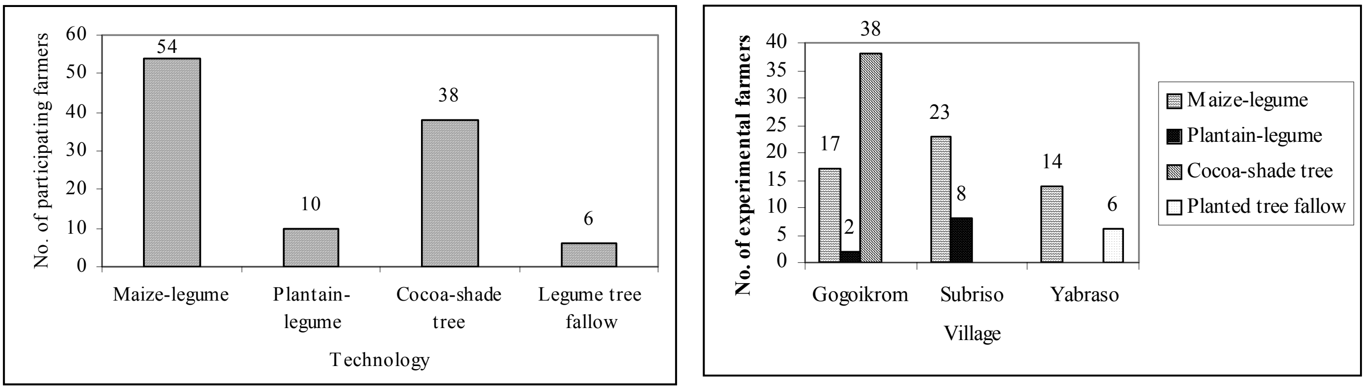
Researchers provided seeds for the experiments and advised on planting and management. Farmers provided their land and labour for planting and weeding. Researchers also marked plots. Each participating farmers' intended trial plot was first visited/inspected to ensure that it was ready for planting before some planting materials were distributed to farmers for planting on these plots. This was to ensure uniformity in planting material (for the maize, tree seedlings and cocoa) and as an incentive for participation. Researchers based on earlier discussions with farmers on technological components and the local cropping patterns developed field protocols comprising ground design/layout of the experiment and combination of species to facilitate experimentation and to appropriately fit the experiments into the prevailing cropping systems. The protocols for the various experiments have been described under the respective sections below.

Farmers planted maize and yam the way they would normally do in any pattern they wished. The researchers assisted with the planting of legume covers in a regular pattern. For the plantain and improved fallows researchers assisted farmers with marking out the positions of trees, plantain, and legume covers as well as planting of these species in a regular pattern.

For the cocoa experiment, farmers planted the cocoa seedlings and plantain (early shade for cocoa) the way the would normally plant or in any manner they preferred, after the tree positions had been regularly marked or pegged at 12 x 12m triangular spacing by researchers and farmers together. The farmers then planted seven different indigenous trees species (Table 2.2) wherever they deemed fit at the pegged positions. It must be noted that these indigenous tree species were identified by farmers as suitable shade trees on cocoa farms during the characterization study.

3.2.1 Profile of participating farmers

A total of 108 farmers participated in all the trials over the two years (2001 & 2002) in all three study villages, Figures 3.1 & 3.2. Maize had the highest number of farmers experimenting, followed by cocoa, permanent plantain and improved/tree fallow in that order.



Figures: 3.1 & 3.2a: Total number of farmers experimenting in 2001 and 2002

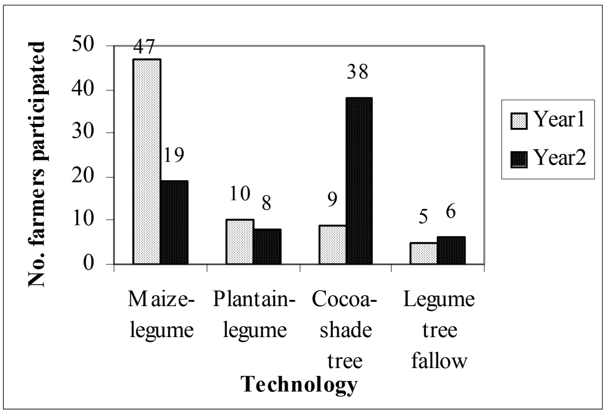


Figure 3.2b: Participation trend over two seasons/years

Table 3.2: Participation trend over two seasons/years

Technology/intervention	Year1	Year2	Repeated	New	Did not repeat	Total (2001 & 2002)
Maize-legume	47	19	12	7	35	54
Plantain-legume	10	8	8	0	2	10
Cocoa-shade tree	9	38	9	29	0	38
Legume tree fallow	5	6	5	1	0	6
Total farmers = 108						

The trend in participation is shown in Figure 3.3b and Table 3.2. The drop in the number for the maize in the second year was mainly because some farmers were discouraged as a result of the poor performance of the experiments in the first year and particularly for Yabraso it was because a Ghana Government-African Development Bank food security project was offering credit for maize cultivation. Thus, although a number of farmers listed for participation and were supplied with seeds, they declined from relaying the legume. In Gogoikrom interest shifted towards the cocoa-shade tree technology as cocoa was more of a priority than maize.

Table 3.3 summarizes the characteristics of the trial farmers. Generally, the proportion of male farmer experimenters was higher for maize, plantain and cocoa trials than the female experimenters probably because there were usually, more males than females at the village meetings during the period of listing farmers. Conversely, for the planted tree fallow in Yabraso the proportion of female experimenters was higher than that of the males.

All the four farmer categories, i.e. native males, native females, settler males and settler females comprising both landowners and non-landowners took part in experimenting the maize, plantain and cocoa trials whereas only natives (landowners) experimented with the improved/tree fallow in Yabraso.

Table 3.3: Profile of trial farmers

FARMER CHARACTERISTIC	MAIZE LEGUME-RELAY	PERMANENT-PLANTAIN	COCOA-SHADE TREE	IMPROVED/TREE FALLOW
Site				
Gogoikrom-Atwima	28%	30%	100%	-
Subriso III-Tano	43%	70%	-	-
Yabraso-Wenchi	28%	-	-	100%
Farmer category				
Native female	16%	20%	5%	67%
Native male	22%	30%	8%	33%
Settler female				
Settler male	15%	20%	16%	-
	47%	30%	71%	-
Gender	69%	60%	79%	33%
Male	31%	40%	21%	67%
Female				
Age (years)				
Mean	45	46	45	51
Range	20-86	29-53	23-82	40-78
Educational status				
Literate (%)	57	82	38	86
None (%)	43	18	62	14
Cropping type				
Mono crop	67%	100% Plantain-legume mix	100%	100% tree legume fallow
Mixed crop	33%			
Plot size				
Mean farmer plot size (acre)	0.7 (0.2-1.4)	-	-	-
Intervention plot size (acre/msq)	1200m^2	42 x 30 m^2	54 x 48 m^2	40 x 20 m^2
Land status of trial plot				
Land owner	54%	70%	21%	100%
Tenant	46%	30%	79%	-
Tenant tenure to trial plot				
Sharecrop	57%	100%	100%	-
Rent by cash	24%	-	-	-
Free	19%	-	-	-
Previous use of land				
Long fallow land	9%	10%	72%	-
Short fallow land	38%	10%	22%	-
Food cropped land	53%	(80% not mentioned)	6%	100%

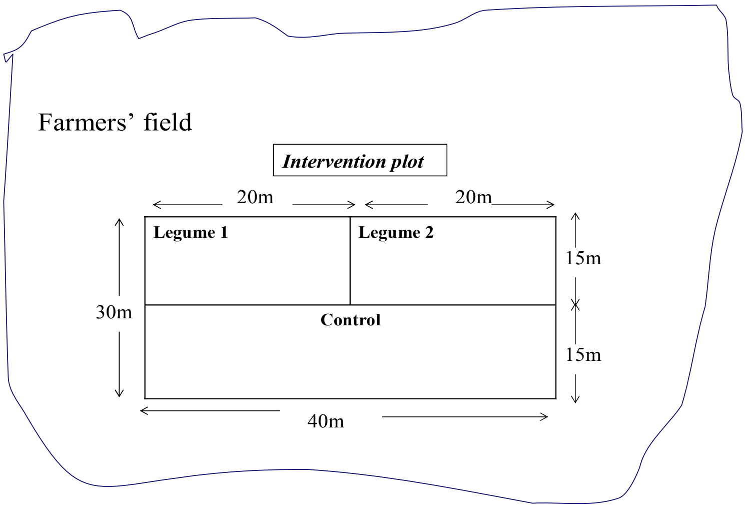
Over 50% of the experimental farmers for all the technologies were literate except those for cocoa of which the majority had had no formal education. Both the young and old participated in planting the maize-legume technology with a mean age of 45 years. The higher proportion of native and settler males experimenting the maize -legume is also because maize is predominantly grown by males across the three villages. More settler males tried the cocoa-shade tree which, could also be explained by the fact that although all farmer categories do grow cocoa in Gogoikrom, the population of the village is dominated by settler non-landowning males. Furthermore, the abunu tenure to cocoa land makes it possible for these settler non-landowners to establish cocoa plantations as future assets. It appears that whereas both landowners and non-landowners may easily experiment or adopt the maize legume relay, the permanent plantain may be more appropriate for landowners, since plantain is more of a perennial food crop and the planting of trees to improve the soil require a secured tenure.

An important issue that must be noted from Table 3.2 is the fact the maize experiment was being established from mainly short fallow and previously cropped lands almost equally by landowners with secured tenancy and non-landowners with insecure short tenancies with a mean tenancy period of 2 years (1-3 range, median (2) and mode (1)). This will put more pressure on the soil nutrient resource base, which is in consonance with the underlying reasons for suggesting this intervention at the stakeholder workshop. The fact that maize is a short duration crop and is currently an important food and cash crop across the three villages for all categories of farmers makes the maize-legume relay technology very appropriate for adoption as maize cultivation is being increasingly intensified which can lead to further degradation of the farm environment.

3.2.2 On-farm experiments

3.2.2.1 Maize - Legume Relay Experiment

The maize-legume relay was experimented in all three villages with Subriso III having the highest number of farmers participating, Table 3.3. Across the 3 villages, both native and settler male and female farmers participated with 69% of them being men. Two thirds of the experiments were planted to monocrop maize with a third in mixtures of maize with cassava, plantain, cocoyam, etc. Nearly half of the farmers planted the experiment on land they owned and the remaining fields were planted largely on sharecropped land. The majority (53%) of the experimental fields had been previously cropped to maize or yam, although a couple of them had been planted to short and long fallow lands respectively. Figure 3.1 shows the ground layout of the maize-legume relay experiment. Farmers at their own convenience between March and June sowed 2kg of maize on variable plot sizes of their choice. The mean farmer maize plot size was 0.7 (0.2-1.4).



(1200sqm = 0.12ha)

Figure 3.1: Ground layout of maize-legume relay on-farm experiment

The intervention plot measuring 40 x 30m^2 was marked by researchers and laid within farmers maize field. It was demarcated into 3 treatment plots for legume species 1 and 2 and a control. The control plot was twice the size of each of the legume ones to make comparison of the outcome of the experiment at the end of the season more meaningful to the farmer. Details of the experiment are outlined in the biophysical aspect of the study.

The legumes were relayed after 8 weeks of sowing maize during the first year. Each farmer was supplied with 750 grains of the large seeds of legume covers like mucuna, canavalia, and lablab and 60 grams of small seeded legumes like stylosanthes, pueraria in the first year. Creeping legumes like *Mucuna spp., Lablab purpureus, Pueraria spp., Clitoria tenatea* were sown on sole maize farms while non-creeping ones like *Canavalia ensiformis*, *Stylosanthes hamata* and *Stylosanthes guianensis* sown on mixed farms (maize-plantain-cassava-cocoyam, etc).
The quantity of legume seeds planted, time of planting and the planting distances adopted in the first year did not favour establishment with respect to production of enough biomass and spread of legume to suppress weeds. There was inadequate rain after sowing of the legume. Also there was competition from weeds because farmers did not weed after sowing the legume as well as problems of shading by the maize and other food crops. Consequently, the quantities of legume seeds were doubled and the within row spacing halved in the second year to quicken ground coverage and ensure to sufficient biomass production before the end of the rains.

The legumes were relayed quite early, 4-6 six weeks after sowing maize (when the first weeding is usually done and the maize would be at knee height) depending on the species and cropping pattern. Canavalia, a non-creeper was sown at 4 weeks on both mono and mixed fields, whereas Mucuna, a creeper was sown at 5-6 weeks after sowing the maize on monocrop fields. The legumes were planted from late may to July depending on when the farmer planted his maize. The number of legume varieties was reduced to *Mucuna* spp., *Pueraria spp* and *Canavalia ensiformis* during the second year due to unavailability of seed for all the other species like the *Stylosanthes* and *Clitoria* used in the first year.

Rainfall was fairly evenly distributed throughout the growing period in the second year. Consequently, legume establishment on most farmer fields was impressive. Plates 1-2 show some of the farmer fields with Mucuna and the control (without legume) respectively. Mucuna is much faster at growing and spreads faster than Canavalia and Pueraria. On some of the farmer fields, mucuna coverage and/or biomass was so heavy that its vines strangled and covered some maize plants together with well formed cobs.

Some biophysical data on growth and biomass production of legumes, weeds and maize yield was gathered over the two years. Maize yield data was estimated from 5m x 5m plots laid within each treatment plot to ensure uniformity/accuracy. Details are presented in the biophysical section of the report. More data on effect of legumes on soil, maize yield and weeds will be collected during the 2003 growing season for further analysis. Data on labour for clearing legume fallow as against the control has been gathered at the onset of the 2003 growing season for cost benefit analysis of labour-yield relationships.

Yam-cover crop/legume Intervention

The yam – legume experiment was tried at Yabraso. The design of the experiment was the same as that for maize, Figure 3.1. The farmers planted their own yam seeds. They planted their yam fields by December (dry season), the previous year. Non-creeping legume covers like Canavalia ensiformis, Sylosanthes hamata and Stylosanthes guianensis were sown during the rainy period since yam fields were mixed (yam-cassava). Also the yam crop matures in about 8 month and so creeping legumes are likely to push down stakes shading the vines to reduce tuber development.

Interest in the yam-legume relay however waned as the Stylo species relayed in the first year performed poorly due to insufficient rain after sowing. It was also observed that there were cassava and sometimes cashew on the plots after the yam had been harvested since this system was a mixed one. For this reason it was not possible for some of the farmers to repeat the experiment on the same field. Only one woman farmer whose field was previously under a monocrop yam could be planted. The new entrants listed could not experiment because stylo seed was in short supply. No meaningful data was gathered over the two years of experimentation on this experiment.

Plate 1. a) and b) Maize – canavalia, and c) maize - mucuna interventions in the on-farm trials

Plate 2: Control in the on-farm trials

Plate 3: Permanent plantain system

3.2.2.2 Permanent Plantain Intervention

The permanent plantain system was experimented in Gogoikrom and Subriso III with 70% of the farmers in Subriso III. The experimenters comprised both native and settler male and females and the majority (60%) of them were men. 70% of the experiments were planted on land owned and 30% planted on land acquired through sharecrop arrangements. 10% each of the experimental plot had been cleared from land previously under short and long fallow respectively but for 80% of experimental plots the previous use was not mentioned.

The design of the experiment comprised two rows of plantain spaced at 3m x 3m between two rows of leguminous tree species (*Gliricidia sepium, Flemingia microphylla*) spaced at 6m x 1m and two rows of leguminous shrub *(Canavalia ensiformis)* at 1m x 0.5m spacing between two rows of plantain. Each permanent plantain trial plot measures 42m x 30m and is divided into four portions of dimensions 21m x 15m. The four areas were each planted to plantain and Canavalia, plantain and Flemingia, plantain and Gliricidia or sole plantain, Figure 3.2. The Gliricidia and flemmingia were pruned when necessary and the biomass applied on the plot as mulch to decompose to improve the soil and control weeds to sustain plantain production over a longer period. The flemmingia may have to be replanted at least after two years. The canavalia may have to be replanted annually or after two years.

In the first year, 450 seeds of *Canavalia ensiformis* and 80 seedlings from poly-potted seedlings of *Flemingia macrophylla* and *Gliricidia sepium* were planted. In the second year, the quantity of seeds of canavalia was increased to 1260 and seedlings of flemingia and gliricidia increased to 160. This was to ensure better ground cover in a shorter time.

During the first year, farmers preferred to plant the experiment during the minor season i.e. September and October because when planted earlier with the major season rains in May-June, the pseudostems were likely to grow very tall and become highly prone to wind throw by strong winds at the onset of the next major season between February and April. When planted later with the minor season rains in September/October, the stems are shorter and can withstand the strong winds.

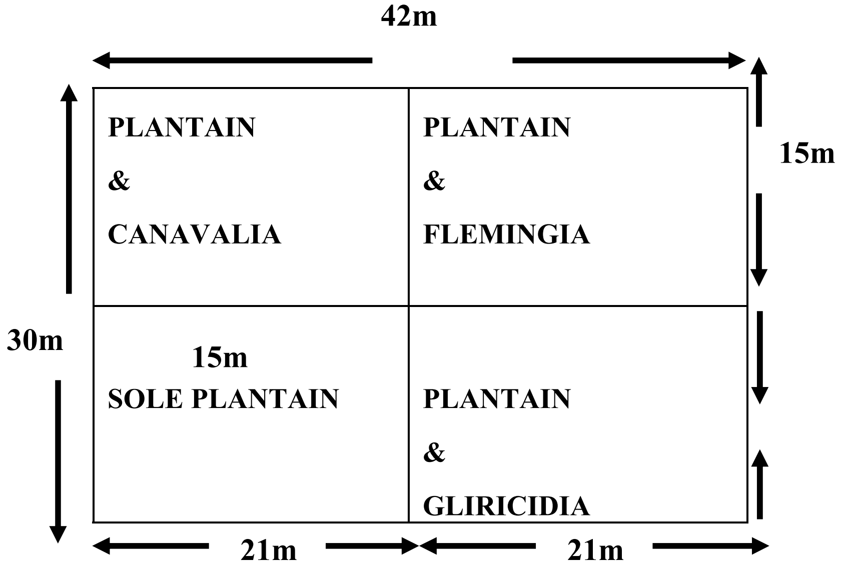


Figure 3.2: Plot layout of permanent plantain experiment

However, it was realized during experimentation that early drought during the minor season affected the uptake/establishment of the plantain suckers and legumes. Thus, the outcome of the experiment at the end of the first year was quite poor.

Consequently, during the second season the experiment was planted earlier (May-June) when there was enough rain to ensure that the plant species obtained adequate moisture for proper establishment. Nearly all first year fields were re-established in the second year. The result of the experiment at the end of the second year was impressive. Plate 3 indicates the permanent plantain experiment with the Gliricidia portion on a farmers' field at Gogoikrom-Atwima in October 2002.

Initial data on growth and biomass production for Gliricidia and Flemmingia has been gathered, although not sufficient to warrant any meaningful analysis at the biophysical portion of the report. Since this is more of a perennial system more data particularly on the effect of legume mulch on soil, weed development and plantain yield as well as costs and revenues will be collected when appropriate in the coming years for a more a comprehensive assessment of the experiment. However, an ex-ante analysis of the profitability of the technology has been done to access its potential for adoption.

3.2.2.3 Improved/Tree Fallow

The improved/tree fallow experiment was tried at Yabraso-Wenchi. The experimenters comprised solely natives, 67% of whom were women. All the experiments were planted on land owned and which had previously been cropped for an unspecified number of years.

Figure 3.3 shows the design for the improved fallow experiment. It is comprised of two blocks/plots of 20 x 20m each under a leguminous tree *Gliricidia sepium* spaced at 3m x 1m and natural fallow (farmers' practice).

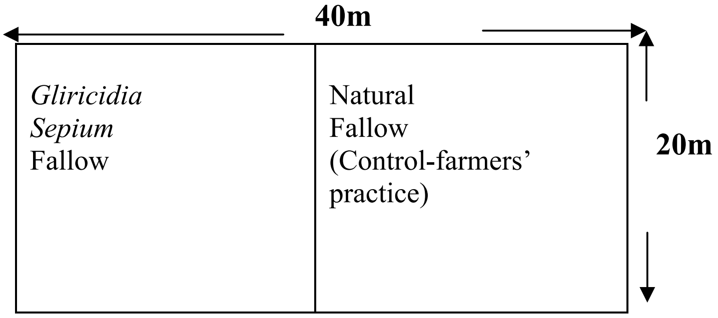


Figure 3.3: Plot layout of improved fallow experiment

A farmers' field going into fallow was planted to the experiment. In the first year, gliricidia seedlings were planted with the minor season rains, in September. Farmers' indicated that it was from this period onwards that they would normally harvest particularly, all maize and leave fields to go into fallow if desired. However, the sudden drought during the minor season resulted in the seedlings establishing poorly. One farmer also lost her field to the dry season wild fires.

All the first year fields were re-established in the second year. This was done during the rainy period (May-June) to ensure adequate moisture for good plant establishment. The within row spacing was also halved to quicken canopy closure since no food crop would planted in the alleys. If the technology is to be planted in the major season, then it might be worth planting maize in the alleys for the first three months when the gliricidia seedlings would have taken off to prevent wasting the prepared alley space.

The farmer will clear the fallow after 2-3 years, which is the current length of fallow period in most places, and cultivate the plots the two plots to any crop of his/her choice. The productivity of the gliricidia and natural fallows with respect to particularly, yield of succeeding crop, labour used in clearing and fallow products will be assessed. Again, an ex-ante analysis of the profitability of the technology has been done to access its potential for adoption

3.2.2.4 Multi-strata Cocoa Agroforest /Cocoa-Shade Tree Experiment

Cocoa (*Theobroma cacao*) contributes about 29% to the GDP of Ghana (GIPC, 2003). The crop is grown by thousands of smallholders, the majority of whom are tenants and are operating under the *abunu* (50:50) sharecropping arrangement or caretakers under the *abusa* (33:67) sharecropping arrangement. Under the *abunu* arrangement the tenant establishes the plantation upon acquisition of the land from a landowner to whom he/she pays variable sums of money as an initial goodwill rent for the use of the land. Usually, the tenant bears all the cost of establishing the plantation, although some landowners may assist with planting materials at their own will. The plantation is then shared 50:50 between the tenant and landlord. In the *abusa* case, the landowner only engages a permanent hand as a caretaker who maintains the plantation and is paid with a third of cocoa produce/proceeds from the plantation at harvest with all the cost being borne by the owner.

The cocoa-shade tree experiment was planted at only Gogoikrom-Atwima where cocoa production is the mainstay of the people. All farmer categories comprising male and female natives and settlers participated in the experiment. 79% of these farmers were men with the majority being settlers. Majority (79%) of the experimenters were tenants all of whom planted the experiment on land acquired through the *abunu* sharecrop arrangement. Most (72%) of the fields planted to the experiment had been cleared from long fallow lands however, 22% were from short fallow land and 6% from long fallow land previously cropped to maize-cassava-plantain for at least two years.

Typical traditional cocoa fields in their initial years of establishment are often in mixtures with cocoyam, plantain, cassava and maize with coppice shoots of desirable naturally occurring tree species. Consequently, the experiment was set up to mimic this pattern. Each farmer plot under the experiment is 24 x 54 m (1296m^2) comprising two blocks of hybrid cocoa and seven indigenous shade tree species per block intercropped with plantain, cassava, etc. The blocks have no specific experimental design but each has a control where instead of shade tree species, cocoa is planted. This is because farmers do not normally plant trees on cocoa farms. They traditionally retain indigenous forest tree species after clearing the vegetation to provide permanent shade for cocoa. Thus, most trees found on cocoa farms occur naturally and are those desired, so that if no desirable tree is naturally present, the farm is left devoid of trees with the provision of early shade with plantain, cocoyam, cassava and maize.

Each farmer planted 320 hybrid cocoa seedlings (160 per block) and food crops (early shade) in any pattern desired with no regular spacing (the way they normally plant crops) but planted the tree seedlings at 12m x 12m triangular spacing. The shade tree positions were jointly marked and pegged with the researchers.

Farmers are very selective with types of tree species they keep on cocoa fields as not all trees are suitable companions for cocoa. Some have deleterious or allelopathic effects and others have heavy crowns that reduce aeration on the farm and intercept rain water, preventing it from reaching the ground. Trees, that habour pests or pathogens that damage the crop and deplete the soil of moisture, essential to cocoa growth are also undesirable for the provision of shade for cocoa. Farmers listed desirable indigenous shade tree species, some of which they planted in the experiment. Usually, tall trees and/or those with light crowns are preferred possibly because cocoa trees require more filtered sunlight as they mature (Young, 2003).

Trees that contribute to soil moisture availability for the cocoa particularly during the dry season as well as those with some economic and/or food values are desirable. In selecting the trial shade trees, researchers also considered in addition to farmers criteria of desirable attributes, the availability of seeds especially from the natural vegetation for easy propagation.

Since, desirable shade tree species occur naturally and by chance if not planted, and farmers are persistently killing coppice shoots of economic timber and valuable traditional shade species such as the *Milletia excelsa* (Odum) and others to avoid the risk of uncompensated damage to their plantations in future by timber concessionaires, the probability of having sufficient trees to provide the necessary functions on the traditional cocoa field is currently low and is contributing to a decline in the productivity of cocoa.

The benefits of shade trees on cocoa fields are numerous. Shade trees moderate weather elements, creating a favourable microclimate that protects cocoa from desiccation, sun scorch and winds. Beer *et al.* (1998) report the benefits of shade trees on cocoa fields to include reducing the stress on cocoa by ameliorating adverse climatic conditions, for instance, buffering high and low temperature extremes by as much as 5^oC. Shade trees also act as nutrient pumps moving nutrients from deeper soil layers to the upper layers for use by the cocoa to enhance its productivity. According to Beer *et al.* (1998) shade trees reduce nutritional imbalances, although they may also compete for growth resources. However, careful management of shade trees allows the farmer to earn extra income from timber. As much as 14 mg ha^{-1} yr^{-1} of litter fall and pruning residues containing 340 kg N ha^{-1} yr^{-1} and 4-6 m^3 ha^{-1} yr^{-1} of merchantable timber have been harvested from commercially species such as *Cordia alliodora* in Central America. It is also reported that maintaining 10 large or 15 medium trees per hectare helps to reduce damage on cocoa caused by insect pests such as capsid. Other benefits of shade trees include reduction of weeds and some parasitic plants on cocoa (PAN UK, 2001). According to farmers of Gogoikrom-Atwima, shade trees serve as alternative hosts to parasitic plants such as the mistletoe, which otherwise uses the cocoa as a host plant, depriving it of growth nutrients, thereby reducing yield.

Farmers reported a productive period of 50-100 years and Young (2003) reported 75-100 years for shade grown cocoa. Apart from improving cocoa productivity, the planted shade trees will also provide additional socio-economic and environmental services, thereby diversifying income and enriching the environment or the ecology. According to Weise, (2003) the advantages of growing cocoa in association with numerous tree species by small farmers diversifies production, enures better protection of soils, contributes to cutting back of greenhouse gas emissions and serves as a basis for sustainable incomes. Furthermore, the resulting agro ecosystem diversity ensures ecological and financial stability that reduces uncertainty and risk for farmers (Ramirez *et al*., 2001)

The cocoa experiments were planted in August in the first year. This was because the seedlings to be transplanted were not ready by June when farmers normally prefer to plant cocoa as the rains peaks around this time and there is adequate moisture in the ground to ensure survival of seedlings. This severely affected uptake and establishment of both cocoa and shade trees, as the minor season rains did not extend well into the season.

Furthermore, only 9 farmers planted the experiment in the first year. This was because both cocoa and tree seedlings were inadequate as the farmers failed to raise these seedlings in large numbers for their own use communally. Those who contributed in raising the seedlings planted the experiment in the first year. This situation generated conflict between some members of the village as they felt left out although listed for experimentation.

To overcome the conflict, farmers were supplied with cocoa and shade tree seed to raise and transplant on their farms in the second year at their own convenience. This arrangement was suggested by the farmers during the evaluation of the first year's activities with them. Farmers raised the seedlings either at their backyards or on their farms. This was also to ensure that enough planting material is produced on time for the second years' planting. Most of the first year cocoa fields were replanted in June during the second year and number of farmers rose to 38. Some initial growth and socio-economic (farmer characteristics, cost of establishment, etc.) data has been collected as the cocoa-shade tree experiment is a long term one. However, an ex-ante analysis of the profitability of the technology has been done to access its potential for adoption

3.3 Monitoring of On-farm Experiments

The on-farm experiments were monitored through periodic visits to each plot at least once in every one-two months by researchers, extension and farmers. During these visits the performance particularly, the growth of the legume and tree species were observed. Farmers' behaviour/attitudes and perceptions towards participation as well as other management (labour, cash, etc.), tenure and natural factors that were affecting on-farm experimentation were also noted during the monitoring visits.

It was realized from the monitoring visits that some farmers in the three villages normally weeded their maize fields once which was contrary to the thrice reported in the PRA/baseline. An analysis of the questionnaire survey revealed that most maize fields were weeded twice although some would weed once for the simple reason that maize is a short duration crop, maturing in three months. Discussion with some farmers indicated that the ideal is 2-3 times but in practice, most farmers may prefer to do it once if weed incidence is not high. Also, insufficient money to engage labour for a second and third weeding during the lean period may prevent some people from weeding more than once, if the cobs are quite developed by 8 weeks.

In facts, if the maize is planted April to May ending, June-July is the time for the second weeding (i.e. 8 weeks after sowing), which the team designated (GTZ experience, (Loos, 2000)) as the ideal time for relaying the legume to prevent the legume from strangling the maize. However, the baseline information showed that this period coincides with the time most farmers have little or no money to engage labour because all money would have been invested in the farm, the previous years food reserves for sale might have dwindled and crops not yet ready for harvesting. Also, even if money were not limiting, labour is scarce during this period as the northern migrants providing the bulk of hired labour would have gone back to work on their farms and the local settlers are also busy on their fields. Family labour is often relied on during this period but this is often inadequate as majority of the households have only 1-4 people involved in farm production with at least 2 or more plots to be worked in any one particular season. This naturally delays the second weeding on some fields.

It was observed that most fields were quite weedy at the time the farmers were to under sow the legumes. At 8 weeks the maize stand was dense and towered with very thick weed undergrowth. Some of the farmers were not willing to do a second weeding before relaying the legume. While some farmers felt the legumes had the potential to smother weeds, thus, there was no need weeding before sowing, others expected the project to assist with money to weed. In some cases even if the weeds were cleared it was difficult to sow legume and there was bound to be shading from the maize, which could delay establishment of the legume.

According to farmers the first weeding is crucial and the strategy some of them employ is to delay weeding from 4 weeks after sowing maize to about 6 weeks after sowing depending on the aggressiveness of the weed type(s) found on the farm, so that weeding is done only once. After the maize cobs have formed i.e. about 8 weeks, there is no need for the second weeding. A second weeding might be done when weeds are so aggressive such that failure to do it might result in crop failure. Some farmers may delay sowing maize till about May/June or may do it very early in February with the first rains to get the crop matured in 3 months and to avoid weeding more than once. These are all strategies to reduce labour cost. A second weeding might also be done if maize is intercropped with other crops like cassava, plantain, cocoyam, cashew, etc. to enhance their growth.

From the above, it was realized that the time suggested for relaying the legumes, i.e. 8 weeks after sowing maize might be ideal to prevent creeping legumes from strangling the maize but in reality does not tie in well with the normal practice and socio-economic circumstances for some farmers at this designated time. The legume probably have to be sown at the time farmers did the first weeding, 5-6 weeks after sowing maize to alleviate labour problems and ensure good establishment if the objectives of soil fertility improvement, weed suppression, reduced labour, etc. were to be achieved. There may be the need to cut back vines of species like mucuna to prevent them from strangling the maize crop, which could lead to a reduction in maize yield. This was observed on some fields during the second year when some farmers planted mucuna after 5 weeks of sowing maize. Fischler *et al.* (1999) reported that early sowing/planting of mucuna 3-4 weeks after sowing of maize at the first weeding reduced maize yield by 24%. However, a further delay in inter-sowing combined with cutting back of vines climbing on maize could reduce competition of the mucuna with maize. Efficiently managing mucuna and other green manures increases their productivity and can reduce labour costs, resulting in increased net benefit.

It was generally realized from the monitoring visits that most farmers developed partial attitudes towards the experiments in the first year, with the exception of those experimenting the cocoa which happened to be a valuable asset. For instance, most of them did not bother to weed their plots after planting the legumes. Again for some it was simply because they were anticipating financial support from the project for doing so while others felt the legumes could smother the weeds. Despite all the initial briefings and discussions on technological components and conditions under which the experiments would be conducted, some farmers were still doubtful of the credibility of researchers. While some of them planted the maize so close that it was impossible to relay the legume, others intercropped the maize with rice and others quickly harvested and sold out the maize when it was due for yield assessment. Some tenant farmers in Subriso also discontinued participation because they claimed their tenancies were terminated at the end of that growing season, thus lost access to the experimental plot in the second season.

3.4 Exposure visits

Farmer field trips were organized during the first and second years of experimentation to expose farmers to researcher experiments and those of farmers participating in a GTZ project in other parts of the Brong Ahafo Region. These trips were to enlighten farmers and enable them interact to learn from each other and others outside the project. The trips were organized on taboo days to ensure that as many farmers as possible could go on the trip. The appropriate date was decided at meetings with farmers participating in the experimentation in the three villages. At each village dates that coincided with taboo days (Tuesday for Gogoikrom and Subriso and Friday for Yabraso) were suggested. Eventually, a consensus was reached for dates in August-September that fell on a Tuesday as the Yabraso farmers often attended funerals on Fridays. A date between August and September during the major season was chosen as farmers were less busy with farming activities during this period and fields not yet harvested to allow meaningful observations/judgments to be made.

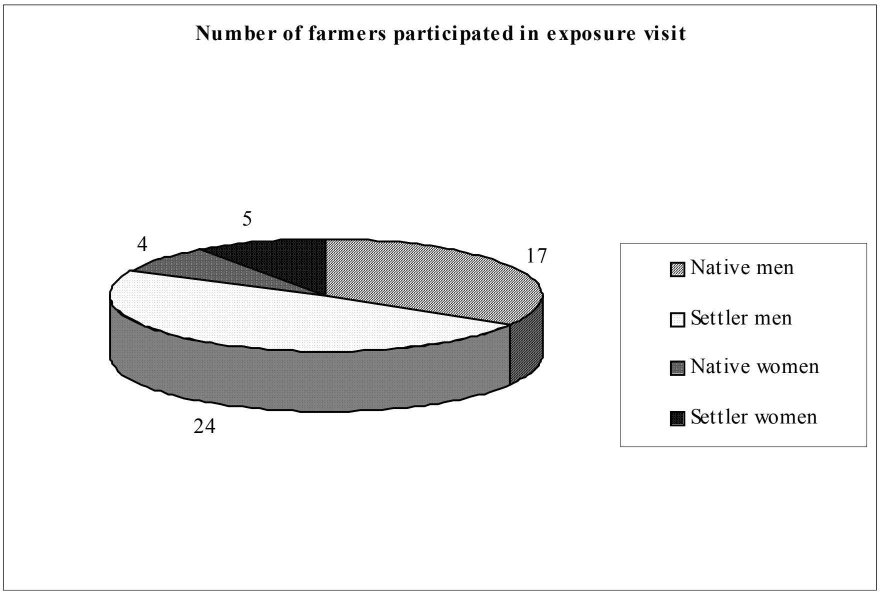


Figure 3.4: Category of farmers on exposure visit per year

An average of 50 farmers belonging to the four farmer categories went on the exposure visit per year, Figure 3.4. The number and category of farmers were non-purposely selected as there was no restrictions as to who to embark on the trip. As many of the experimenters and non-experimenters who were willing to go and were able to make it on the appointed dates went on the trip.

3.4.1 Exposure visit to the Wenchi Agricultural Station

The main objective of the Wenchi trip was to enable farmers observe and assess the trial species (both herbaceous and woody) at fist hand, especially their characteristics with respect to farm production. It was realized during the monitoring visits that although some of the species had been planted on their fields, they were not yet established, hence making them doubtful of species characteristics, potentials and disadvantages on the farm.

About 50 male and female native and settler participating farmers from the 3 villages together visited the project demonstration plot at the Wenchi Agricultural Research Station during the first year. The trip was organized well into the first season in September because it was by then that the plots were well established and could enable a meaningful assessment. Farmers in Gogoikrom had earlier on in January visited the project demonstration plot established in the village with similar fallow species as those found at Wenchi to observe the physical characteristics of the fallow species and to aid in informing their decision and choice of experiments for on-farm.

Tables 3.4 and 3.5 summarize farmers' assessment of the 7 herbaceous and woody trial legume species with respect to weed smothering, biomass production and soil fertility improvement potentials as well as suitability for different cropping patterns/systems (e.g. mono and mixed cropping) and fallow improvement.

Table 3.4: Farmer's Assessment of Trial Species at Wenchi Agric. Station

Species	Farmer's Assessment
Gliricidia sepium	Dense shade controls weed growth Leaf litter drop improves soil fertility
Tephrosia candida	Shade controls weed growth Leaf litter drop improves soil fertility
Flemingia mycrophylla	Shade controls weed growth Leaf litter drop improves soil fertility
Stylosanthes spp	Effective for weed control Reseeding problem high Slow growth (observed on-farm)
Mucuna spp	Fast growth (observed on-farm) Climbing could strangle crops Effective for weed control
Canavalia spp	Fast growth (observed on-farm)
Lablab spp	Fast growth (observed on-farm) Creeping nature not good for cocoa (could strangle crop) Effective for weed control
Pueraria spp	Effective for weed control

Shade from Gliricidia, Tephrosia and Flemingia stands was judged good at suppressing weeds. Farmers also observed that leaf litter from these woody legumes could decompose to improve the soil, especially its fertility, Table 3.4. The herbaceous legumes like the Stylos, Mucuna, Lablab and Pueraria were assessed to be effective for weed control as a result of their dense vegetative carpets covering the soil surface. Some farmers observed the Stylos to be slow growing on their farms while others observed Mucuna to be very fast growing. The creeping vines on Mucuna and Lablab could strangle crops as they were seen climbing old maize stalks, Panicum and Pennisetum grasses on the plot.

In Table 3.5, farmers observed mucuna and gliricidia to be the better than the others with respect to spread as they grow fastest. The stylos and mucuna were adjudged better at smothering weeds because they grow profusely while gliricidia was the best fallow species as its fast growth coupled with the heavy tree biomass could rejuvenate the soil in a shorter time. It should be remembered from the PRA that farmers regard tree fallows to be best at improving soil fertility.

Table 3.5: Farmer's Assessment of Trial Species at Wenchi Agric. Station.

Parameter	Suitable species	Reasons
Ability to spread and cover land faster	Mucuna Gliricidia	Grow very fast
Ability to smother weeds better	Stylos Mucuna	Grow profusely
Best Fallow species	Gliricidia	Grows very fast. Being a tree that can produce lot of biomass
Suitability for mixed cropping systems	Gliricidia	Does not climb Tree with fast growth
Suitability for mono cropping systems	Gliricidia	-
Ability to improve crop yield better	Gliricidia Mucuna	Grow very fast. Biomass and shade (moisture) improve soil.

Gliricidia was also adjudged the best species for both mono and mixed cropping systems. Being a tree that grows fast and does not climb, farmers believe Gliricidia could mix well with crops as it is not likely to suppress them. This is not surprising because farmers are used to leaving some trees on farms whereas most of them have never experienced the legume-relay techniques. Although cowpea, sweet potato, groundnut and melon mixed with other crops may trail on the ground beneath the other crops, they are not relayed purposely to improve the soil. No reason was given for its being the best for monocrop systems.

Gliricidia and Mucuna were the most fascinating species as they were observed to be very fast at growing and had dense vegetative growth which when combined with moisture conserved beneath their vegetative cover could enhance decomposition. Thus farmers believed these species had the greatest potential for suppressing weeds and improving the soil in a shorter time to enhance yield.
In all, it appeared the weed smothering and vegetative growth or biomass production potentials of the species were readily recognized as these were indicators they could readily observe physically on the field.

Questions on species management (time to prune trees for mulch, time to clear legumes in order to plant food crop, reseeding of legumes, etc) and edibility were also raised. It was learnt that the trees could be pruned anytime they appear to shade the food crops. Also species like Gliricidia could be planted for 1-3 or more years before clearing depending on use. Gliricidia to be used for poles and charcoal could be left longer for up to five years. Flemmingia and Tephrosia may be similarly treated but were likely to die off with severe drought. The problem of reseeding could best be managed by early weeding of the emerged plants to prevent further seeding at maturity. Concerning edibility of the legumes, it was learnt that mucuna and canavalia grains are treated by boiling to remove the seed coat and detoxify before consumption.

Farmers also assessed the effects of 2 planting dates of the mucuna legume cover, 4 and 8 weeks after planting of maize on maize performance and establishment of the legume (a researcher established plot) while on the field. The farmers observed that 8 weeks after planting of maize could be a better time relaying legumes with the maize. This was because mucuna being a creeper had begun strangling the maize even before it was ready for harvesting when planted at 4 weeks after sowing maize. This could particularly increase labour for harvesting maize.

3.4.2 Exposure visit to GTZ sites

During the second year 52 farmers comprising largely male and female participating and a few non-participating farmers of Gogoikrom and Subriso III went on exposure visit to GTZ-MOFA farmer's plantain experimental plots in the Asunafo District of the Brong Ahafo Region. Yabraso farmers did not go on this trip because emphasis was on the plantain system, which was not relevant for them. The objective of this trip was mainly to enable the farmers learn more of plantain-legume systems which they knew little about as simple alternatives for improving plantain production.

The farmer experiments visited included plantain-legume (Canavalia, cowpea), plantain-animal manure and plantain-household residue systems. The farmers owing these experiments explained how they went about establishing their fields and what they expect to gain. The farmers in addition had the opportunity to visit GTZ maize-legume (mucuna, Canavalia and pigeon pea) experiments in the Sunyani District. The visiting farmers asked several questions some of which bothered on the management of the legumes and manure. The briefings from farmers, GTZ and MOFA staff on the various experiments visited strengthened the visiting farmers understanding of strategies for improving productivity of maize and plantain systems. Having seen other farmers like themselves establishing and managing experiments might motivate them to collaborate more actively and show more concern for the experiments on their fields.

Visits to the on-farm plots in September 2002 after the exposure visit for farmer assessment of their experiments revealed that some farmers had began putting into practice some of the new ideas learnt on the second exposure trip. It was observed that one of the farmers in Gogoikrom had cleared and cultivated the Mucuna and control portions of his maize-legume experiment as a minor season crop, leaving the Canavalia portion. The farmer did not give any good reason for his action. However, it was learnt from one GTZ staff during the second exposure trip that Mucuna could improve soil fertility for good yields in a short time. Also, one farmer who had established the plantain-canavalia system reported of gaining about 4 million cedis from sale of Canavalia seeds/grains. These could be possible reasons for cultivating the Mucuna portion of his experiment/fallow to maize and leaving the canavalia un-cleared.

While the above might explain the farmers behaviour, it demonstrated the possibility of relaying Mucuna early in the major season to improve the soil for minor season production in September for those who plant their maize early i.e. February ending-March and might have only a years' tenancy to the use of a comparatively poor land. One other farmer in Gogoikrom had also cleaned the debris on his plantain farm and applied as mulch at the base of the plantain stands. This technique he said was learnt from one of the GTZ farmers who had established the plantain-residue system with the plantain developing bigger bunches of fruit as a result of the organic matter. Farmers probably learn techniques more quickly from each other than observations they make from scientist's experiments. Thus exposure visits particularly; to successful farmer fields even within the community might be useful in enhancing their understanding and encourage them to innovate with new technologies. Visits to unsuccessful farmer fields during the season may also be useful in discussing the pros and cons of the technology and identify issues that are important for attaining the desired objectives.

4.0 Evaluation of on-farm experiments and adoption

In this section, economic and farmer evaluations of the on-farm experiments are presented and their potential adoption assessed. Table 4.1 indicates the methods employed for data collection and analysis as well as issues investigated in evaluating the potentials of the technologies.

Table 4.1 Methods and issues investigated for evaluation and adoption of technologies

Objective	Issues investigated	Data collection method	Data analysis method
Evaluation of technologies	•Economic assessment -Profitability of interventions compared with farmer practice -Determinants of participation/adoption Land status/ tenure, gender, age, profitability of technology, labour, etc.	•Plot level farm data records -Farmer characteristics -Plot characteristics -Input-output estimation	•Cost/Benefit analysis •Descriptive •Chi-square test
	•Farmer assessment/perceptions -Labour requirements -Soil fertility, crop yield & income improvements -Desirable aspects, limitations & modification of technology design -Prospects of technology adoption & diffusion	•Matrix of indicators for farmer assessment •Questionnaire interviews of participants & non participants •Group interviews/discussion with participants and non-participants	Descriptive

4.1 Economic evaluation

This section presents an *ex-ante* assessment of the profitability of the technologies as compared to the farmer practice, i.e. if the technology is not adopted. The economic assessment is necessary as it provides a fundamental step in assessing the adoption potential and desired sustainability of an innovation. It is observed that the economic viability of a technology has often been an important consideration in determining its adoption by farmers (Baum *et al*., 1999), although socio-economic parameters including constraints characterizing their livelihoods are also important.

The experiments are of a long-term nature and the available data is not sufficient for an *ex-post* analysis, thus justifying the reason for the *ex-ante* analysis. According to Cairns and Garrity (1999), it is crucial to estimate an innovation's benefits and costs over an entire cycle even if this must be estimated without complete data, as actual observations may not be feasible over cycles that extend for years or even decades. Economic/profitability indicators estimated include gross margins, returns to labour, Benefit-Cost Ratio (B/C ratio), Net Present Value (NPV), Land Expectation Value (LEV), Equivalent Annual Value (EAV) and Internal Rate of Return (IRR). A sensitivity analysis has also been carried out to assess effects of changes in two key parameters - the price of labour and output, on the profitability of the technologies.

4.1.1 Data collection and analysis

4.1.1.1 Data collection methods

Data sheets were designed for recording farmer and plot characteristics as well as input and output figures for each farmer plot over two cropping seasons in 2001 and 2002. Data collected comprised age, tenure/access to land, previous use of the land, farm size, labour, timing of activities, inputs and costs and output and prices.

The data on characteristics/profile of participating farmers and their respective plots was recorded at the start of the experiment/cropping season between March-April for all technologies. Labour and material costs for establishing all technologies were collected during the course of the season by way of periodic monitoring visits. The maize – legume relay technology is an annual system, hence, it was possible to gather some data for one rotation or production cycle over the two seasons to estimate the effect of the legume fallow on maize yield. The remaining three technologies have longer gestation periods; hence, it was only possible to gather some initial data on farmer and plot characteristics in the first year and labour and material costs for some plots over the two years. The economic data collected on all four technologies has been supplemented with on-station data and secondary data from work done under similar conditions on smallholder fields elsewhere in Africa for an ex-ante profitability analysis of the technologies. Details on data collected for each of the technologies are described under their respective sections below.

4.1.1.2 Analytical methods

The data was analyzed using the Microsoft Excel Computer software. The analytical methods include gross margins, returns to labour and Cost Benefit Analysis (CBA), estimating the Benefit-Cost ratios (B/C ratio), Net Present Values (NPV), Internal Rates of Return (IRR), Land Expectation Values (LEV) and Equivalent Annual Value (EAV) as well as a sensitivity analyses are used for appraising the economic performance of the technologies. A 10% discount rate used by the World Bank for agricultural projects is applied in assessing the profitability of all four technologies (Gittinger, 1982). Table 4.1.1 summarizes the profitability indicators and respective decision criteria.

Table 4.1.1.: Economic indicators used for profitability assessment

Profitability indicator	Formula	Decision criteria	Technology
Gross margin	(Extra gross returns) – (Extra variable costs)	GM > 0	Maize-legume relay
Returns to labour	$\frac{Extra\ \Pr ofit}{Labour / ha}$	RL >1.0	Maize-legume relay
Discounted returns to labour	$\frac{(NPV + Discounted\ labour\ \cos t)}{(Discounted\ labour\ \cos t)}$	DRL >1.0	Plantain-legume
B/C Ratio	$\frac{\sum B_t}{(1+r)^t} \Big/ \frac{\sum C_t}{(1+r)^t}$	BCR ≥ 1.0	Plantain-legume Cocoa-shade tree Gliricidia fallow
NPV	$\sum_{t=0}^{t=n} \frac{(B_t - C_t)}{(1+r)^t}$	NPV ≥ 0	Maize-legume relay
LEV	$NPV\, x \frac{(1+r)^n}{(1+r)^n - 1}$	LEV ≥ 0	Cocoa-shade tree Plantain-legume
EAV	$NPV\, x \frac{(1+r)^n\, x r)}{(1+r)^n - 1}$	EAV ≥ 0	Gliricidia fallow
IRR	$\sum \frac{(B_t - C_t)}{(1+r)^t} = 0$	IRR $\geq$ r	Maize-legume relay Plantain-legume Cocoa-shade tree Gliricidia fallow

B=benefit, C=cost, t=time in years or rotation/production period, r =discount rate, n= nth month during the rotation.

4.1.2 Profitability Analysis

4.1.2.1 Maize-Legume Relay Technology

The maize-legume technology involves relaying maize with leguminous cover species, mainly *Mucuna spp., Lablab pupureum*, *Pueraria phaseoloides*, *Canavalia spp* and *Stylosanthes spp*. Mucuna, Pueraria and Lablab are creeping species and so are relayed on monocrop maize fields between 6-8 weeks after planting the maize to prevent strangling of the maize. Canavalia and Stylosanthes are erect species and were relayed on some mixed maize plots around 5-6 weeks but were also planted on monocrop fields. The field may be weeded once 3-4 weeks after planting the legume to enhance establishment where weeds are aggressive. Each farmer plot measured 40 x 30 m^2, comprising 3 sub-plots planted to three treatments. In the first season two of the sub-plots each measuring 20 x 15 m^{2,} were relayed with any two of the legume species, i.e. treatments one and two to enable each farmer to compare the performance of the two. The third plot measuring 40 x 15 m^2 is the control, without any legume. The maize is harvested at about 12 weeks after planting and both fields with and without legumes are left under fallow for about eight months to go through the dry season. In the second season the legume and natural fallow (on control plot) are cleared between February and March and planted to maize, which is harvested between August and September. The cropping calendar is presented in Figure 4.1.1.

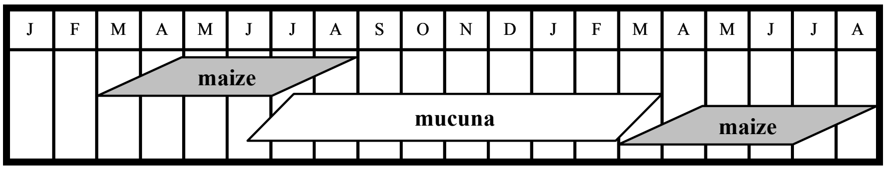


Figure 4.1.1: Maize-legume relay cropping calendar

In the traditional maize system, the farmer is likely to rotate a two to three year cropping phase with a three to four year natural fallow phase on average. The profitability indicators estimated for the maize-legume technology relay are the gross margins, returns to labour, NPV and IRR. A sensitivity analysis, determining the effect of a 20% increase in labour cost and 20% increase and decrease in the price of maize on the NPV and IRR is also presented.

For the analysis, monocrop maize field with and without the legume fallow cultivated over two seasons (20 months) is considered. Input and output data used in the analysis were collected over the two seasons and covers total production costs ranging from land cost to maize marketing costs. This is mainly because maize production has become cash oriented, although maize is also important for household food security. Production costs and prices for maize output were estimated from average farm gate figures prevailing in the three study villages in 2001 and 2002.

Maize yield was estimated by researchers and then by farmers and was recorded at harvest between August and September. This was followed by researcher and farmer estimations of labour for clearing the legume fallow at the beginning of the following season (March-April). The accuracy of the farmers' labour estimates on clearing the eight months' fallow was verified with clock timing of the labour required by engaging hired labour to clear a few farmer fields.

The output data on maize yield collected from farmers' fields was not used in the analysis due to inconsistencies in farmer behaviour. Some farmers did not repeat the experiment on the same plots in the second year as was done in the first year. Also some who repeated on the same plot as the first year did not plant the same legumes as species like the stylo, pueraria and clitoria were in short supply in the second year, thus it was difficult to estimate maize responses for specific legume species although it was possible to estimate general legume effects irrespective of species. To correct for this shortfall, data on maize yield from 8 months legume fallows of the species experimented on-farm that were established and cropped during the same period from on-station plots in the Wenchi District was used in the analysis. The on-station data on maize yield were adjusted downwards by 10% to take into account production under farmers' conditions. It is reported that yields obtained on farmers fields are approximately, 10% lower than that from on-station plots due to differences in management (CYMMIT, 1998). The research station is in the savanna transition zone and is close to one of the experimental village sites, Yabraso in the Wenchi District. Moreover, the *Panicum maximum-Chromolaena odurata* vegetation mix characterizing this site is a replica of that currently characterizing most maize fields in the three study areas.

The input and output values estimated for the analysis are presented in Table 4.1.2. The labour cost is a product of the man-days per hectare employed in undertaking an activity and the local daily wage rate. The establishment cost covers cost of seeds and labour for sowing/relaying the legume and weeding it once afterwards to enhance growth and spread.

Table 4.1.2: Input and output values for the maize-legume technology

Treatment	Legume fallow establishment cost (¢)	Total variable cost over 2 seasons (¢)	Adjusted Yield kg/ha 2001	Adjusted Yield kg/ha 2002	Gross revenue/ha 2001 (¢)	Gross revenue/ha 2002 (¢)
Lablab purpureus	145,996.00	301,329.00	711.0	1780.0	639,900.00	1,780,200.00
Mucuna spp.	228,865.00	395,680.00	720.0	2204.0	648,000.00	2,203,920.00
Stylosanthes spp.	143,996.00	317,329.00	990.0	1652.0	891,000.00	1,652,400.00
Pueraria phaseoloides	145,996.00	328,218.00	918.0	1657.0	826,200.00	1,656,900.00
Canavalia spp.	317,734.00	531,512.00	703.0	1980.0	632,610.00	1,980,000.00
Legume mean	**196,577.00**	**374,814.00**	**808.0**	**1855.0**	**727,542.00**	**1,854,684.00**
Natural fallow	0.00	314,222.00	1002.0	990.0	901,530.00	990,000.00

For maize output, 100kg=1maxi bag =¢90,000 in 2001and ¢100,000 in 2002 on average[1]

The gross revenue per hectare is a product of the average farm gate price per 100kg (1 maxi bag) of maize and maize yield per hectare for each treatment. The legume is planted in the first season and its benefit is reaped in the next. The entire production period over the two seasons is about 20 months. This is the length of time it takes the farmer to realize the benefits from his/her decision to adopt the technology. The costs that vary over this period considered for the analysis are costs of establishing the legume fallow, clearing the fallow and weeding the succeeding maize crop. One of the advantages of adopting the legume fallow is the fact that the maize crop following the legume fallow will be weeded once compared with twice for that on the natural fallow plot. This accounted for the comparatively higher total variable labour cost for the natural fallow.

The extra cost a farmer incurs in adopting the technology by planting any of the legume species is that for its establishment, comprising seed and labour costs for planting and weeding before and after planting/relaying the legume. It is assumed that the farmer relays the legume between 5 and 8 weeks after sowing maize, i.e. the time the first or second weeding may be done depending on the species (earlier for non-creeping and later for creeping species). Consequently, the cost of weeding before planting the legume may be assumed to be zero, as it would be the same whether the legume is adopted or not. Thus, legume relayed at first or second weeding takes advantage of the weeding labour in May-July and no extra cost is incurred by the farmer by using the technology at this time when money and labour are scarce, as it is the lean period.

The cost of seed for the five legume species used in the analysis is estimated from that of mucuna and canavalia based on their level of use i.e. demand and supply in the country, although the project supplied the initial seed stock obtained at no cost from IITA-Nigeria, supplemented by some purchased from the Crop Research Institute-Ghana and GTZ-Sunyani, Ghana. This approach was adopted as seeds of *Mucuna* and *Canavalia spp.* are available on local markets while that of Stylosanthes, Pueraria and Lablab are not, making it difficult to price a kilogram of seeds from these species. It is currently anticipated that seed multiplication from farmer and on-station fields would provide subsequent supplies. However, it might be necessary to incorporate seed cost in the analysis as the acquisition of legume seed for establishing the fallow is a key extra cost to the farmer.

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[1] £1=¢11,000 in 2001 and £1=¢13,000 in 2002.

Table 4.1.3 Estimating legume seed cost

Legume spp	Supply	Demand	Cost/kg (¢)	Quantity/ha (kg)	Cost /ha (¢)
Canavalia	High	High	3,000.00	59.30	177,740.00
Mucuna	High	Medium	1,500.00	59.50	89,250.00
Pueraria	Medium	Medium	1,500.00	4.00	6,000.00
Stylo	Medium	Low	1,000.00	4.00	4,000.00
Lablab	Low	Low	1,000.00	4.00	4,000.00

Since mucuna and canavalia are readily available, they can be assumed to have a higher supply. The cost of a kilo of mucuna is 1500 cedis and that of canavalia is 3,000 cedis. The price per kilo of canavalia is higher than that of mucuna because canavalia has a food value, in addition to being used as short fallow species, thus has a higher demand. The price of mucuna is half that of canavalia indicating a medium demand. Although mucuna has a food value as some local varieties are consumed (Osei-Bonsu *et al.*, 1996) it is reported to contain toxins which limits its consumption as the beans have to be treated before consumptuion, thus can be said to have a medium demand.

Pueraria is under sown on oil palm plantations in some areas to control weeds and so can be assumed to have medium supply and demand and priced as Mucuna. Stylosanthes has been promoted in some livestock rearing areas as fodder species and may be easily obtained from livestock research stations and some NGO's, hence its supply can be ranked medium. However, its demand is low because the practice hasn't been widely adopted or not common among livestock farmers, thus the price is rated lower. Lablab is priced lowest as stylo. It is not readily available and may be obtained with some difficulty even from research stations in Ghana, thus its supply is low. Likewise its demand as it is not common or used for any other purpose.

Gross margins

In computing the gross margins, it was assumed that all other costs except those that vary between legume and natural fallow are constant over the two seasons. For simplicity, it is assumed that the legume is relayed at 8 weeks after planting the maize, when the maize would have developed cobs and would be nearing its physiological maturity. Hence, the effect of the legume on first season maize yield (i.e. maize response to legume) would be zero or negligible so the actual effect of the legume on maize yield is obtained during the second season cropping. This explains the reason for using only the gross field benefits from season two in estimating the gross margins and returns on labour (below).

Table 4.1.4: Gross margin for establishment of legume fallow

Treatment	Legume establishment cost/ha (¢)	Gross field returns/ha (¢)	Gross margin/ha (¢)
Mucuna spp.	228,865.00	2,203,920.00	1,975,055.00
Canavalia spp.	317,734.00	1,980,000.00	1,662,266.00
Pueraria phaseoloides	145,996.00	1,656,900.00	1,510,904.00
Lablab pupureum	145,996.00	1,780,200.00	1,634,204.00
Stylosanthes spp	143,996.00	1,652,400.00	1,508,404.00
legume mean	**196,517.00**	**1,854,684.00**	**1,658,176.00**
Natural fallow	0.00	990,000.00	990,000.00

Table 4.1.4 shows that the cost of establishing the legume or planting any one of the legume fallows is quite small when compared to the value of the returns gained. Maize production, if any one of the legume fallows is planted, is profitable compared to the natural fallow. Gross margins ranging from approximately ¢ 1.5 to ¢2.0 million may be earned from only one fallow rotation of about 8 months of the legume species compared with about ¢ 990,000 with the natural fallow or when the farmer does not adopt the technology.

Table 4.1.5: Gross margin for total production over two seasons of 20 months

Treatment	Total cost that vary over two seasons/ha (¢)	Returns/ha (¢)	Gross margin/ha (¢)
Mucuna spp.	395,680.00	2,203,920.00	1,808,240.00
Canavalia spp.	531,512.00	1,980,000.00	1,448,488.00
Pueraria phaseoloides	328,218.00	1,656,900.00	1,328,682.00
Lablab pupureum	301,329.00	1,780,200.00	1,478,871.00
Stylosanthes spp.	317,329.00	1,652,400.00	1335071.00
Legume mean	**374,814.00**	**1,854,684.00**	**1479870.00**
Natural fallow	314,222.00	990,000.00	675,778.00

Maize with legume fallows is still more profitable than without them, although the total labour cost was higher for some of the legume systems compared with the natural fallow when all costs that vary over the two seasons are considered (Table 4.1.5).

Two main factors account for the natural fallow being the least profitable option. Firstly, maize yield is certainly bound to decline when a short fallow field is cultivated consecutively over two seasons without any added nutrients, except that from a short fallow of 8 months growth. The vegetation at this stage comprises mainly herbaceous plants mixed with some grasses depending on the dominant plant species in the soil seed bank. A mixture of *Chromolaena odurata* and *Panicum maxima* was common. Secondly, the absence of the legume mulch, which could otherwise boosts maize growth and reduce weeds means weed incidence will be higher in maize under the natural fallow system, necessitating two weedings compared to once with the legume fallow. This makes the natural fallow system more expensive, reducing the gross margin further as observed in Table 4.1.5.

Both Tables 4.1.4 and 4.1.5 show that mucuna fallow is the most profitable, attracting a gross margin of about ¢2 million (about twice that of the natural fallow) when only establishment is considered and ¢ 1.9 million (2.5-3 times that of the natural fallow) when all variable costs over two seasons production are considered. Differences in labour costs are explained by the different labour requirements for clearing each fallow type. Details are presented in the section on returns to labour below.

Returns to labour

The labour requirements for adopting a legume or natural fallow, measured in man-days per hectare are shown in Table 4.1.6. One man-day is equivalent to five hours on the average of hired labour, popularly known as by-day labour in Ghana. Obviously, more labour is required per hectare for adopting the legume fallow than if the farmer decides to continue with his traditional fallow system.

Table 4.1.6: Labour requirement of the maize-legume relay technology

Treatment	**Labour (man days/ha)**
Labour planting legume	6.70
Labour weeding legume	16.70
Clearing legume	7.00
Weeding legume maize plot (once)	15.00
Legume mean	**45.70**
Clearing natural fallow	9.30
Weeding natural fallow maize plot (twice)	30.00
Natural fallow total	**39.30**

A farmer adopting any one of the legume species has an opportunity to earn about ¢80,000 on the average for each extra man day of labour invested in establishing any one of the legume fallows (Table 4.1.7). Comparing the individual legume fallows, mucuna yields the highest return to labour of ¢95,000. It must be noted that the cost of one man day of labour (5 hours) in the study villages at the time of data collection was ¢7,000, thus a farmer is likely to gain 11 times on the average if any legume is planted and up to 14 times if mucuna is planted in the fallow. Similarly, the legume fallows give higher returns to labour than the natural fallow, when all the variable costs over the two seasons are considered (Table 4.1.8).

The main factor causing the differences among the legume species is their cost of clearing for the second season maize. This is more related to individual species biological characteristics. Canavalia has the highest labour cost because the shrub has strong vines/stalks and the plant may thrive over two seasons if not cleared (i.e. biennial) and so requires more effort to clear as compared to the others. Pueraria, which comes next after canavalia in terms labour requirements is a perennial plant and so more labour is required to clear the carpet of live biomass. On the other hand mucuna and the others are short lived. Thus they naturally dry out or die off over the dry season leaving a carpet of mulch at the onset of the next season to clear, making it easier to prepare such fallow fields for planting.

Table 4.1.7: Returns to labour for establishment of legume fallow

Treatment	**Labour (man days)/ha**	**Gross Revenue (¢)/ha**	**Returns to labour (¢/man-day) /ha**
Mucuna spp	23.33	2,203,920.00	94,456.00
Canavalia spp	23.33	1,980,000.00	84,860.00
Pueraria phaseoloides	23.33	1,656,900.00	71,012.00
Lablab pupureum	23.33	1,780,200.00	76,297.00
Stylosanthes spp	23.33	1,652,400.00	70,819.00
Legume mean	23.33	1,854,684.00	79,489.00
Natural fallow	0.00	990,000.00	

Table 4.1.8: Returns to labour for total production over two seasons

Treatment	Labour (man days)/ha	Gross Revenue (¢)/ha	Returns to labour (¢/man day) /ha
Mucuna spp	44.20	2,203,920.00	49,882.00
Canavalia spp	50.10	1,980,000.00	39,558.00
Pueraria phaseoloides	46.10	1,656,900.00	35,932.00
Lablab pupureum	43.00	1,780,200.00	41,397.00
Stylosanthes spp	45.00	1,652,400.00	36,718.00
Legume mean	**45.70**	**1,854,684.00**	**40,610.00**
Natural fallow	39.30	990,000.00	25,204.00

On the whole, it is evident that the additional labour invested in establishing or adopting any of the legume fallows is compensated for by the higher maize yield of the succeeding maize crop. However, there might be a problem, as the time the extra labour required for planting and weeding the legume planted coincides with the period of both money and labour scarcity. One can, however, argue that the cost of labour invested in undertaking the extra labour activities is negligible when compared to the potential benefit derived from the legume as indicated by the increase in yield of the succeeding maize crop. In any case some amount of extra investment needs to be made in order to reap the extra benefits associated with any improved technology.

Table 4.1.9: Labour requirements for clearing fallows

Treatment	Labour clear (man days/ha)	Gross revenue (¢/ha)	Returns to clearing labour (¢/man days)
Mucuna spp.	5.9	2,203,920.00	376,739.00
Canavalia ensiformis (strong vines & biennial)	11.7	1,980,000.00	168,942.00
Pueraria phaseoloides (perennial*)*	7.8	1,656,900.00	212,969.00
Lablab pupureum	4.7	1,780,200.00	381,199.00
Stylosanthes spp.	6.7	1,652,400.00	247,736.00
Legume fallow	**8.4**	**1,854,684.00**	**252,751.00**
Natural fallow	9.3	990,000.00	106,681.00
All treatments	$F = 1.827$ P-value =0. 153		
Legume mean vs. natural fallow	F =0.271 P-value = 0.612		

Farmers often seek to reduce production costs and for that matter labour cost. Gockowski *et al.,* (1999) report that, even where land is not a constraint, farmers may be reluctant to clear long fallow fields due to difficulty in doing so and may end up managing short fallows that are easier or require less labour to clear. Table 4.1.9 shows that all the legume fallows are less expensive to clear than the natural fallow except, that of canavalia for reasons explained above, although the differences in labour man days are not significantly different. Thus an added advantage for adopting the legume is the higher returns to labour for clearing the legume fallows compared with that of the natural fallow. Canavalia is a biennial plant, dying off after two seasons and so if both the canavalia and natural fallows are left over a longer period, say two seasons without clearing, the natural may turn out to be more expensive to clear as its vegetation at that stage would be denser and may comprise tree coppices, while that of the canavalia will be withering and easier to clear.

Cash flow analysis for maize-legume

The total stream of costs and benefits over two seasons of twenty months is presented in Appendix 1. A monthly cash flow analysis over the 20 months production further confirms that, it is profitable to plant the legume fallows as these have positive net present values, ranging from ¢305,000 for a Lablab fallow to ¢653,000 for a Mucuna one at 10% discount rate (Table 4.1.10). Similarly, the internal rates of return for the legume fallows were much higher, ranging from 37% for Lablab to 65% for Mucuna fallow when compared with that of the natural fallow, -1%.

Table 4.1.10: Profitability of maize-relay and maize-natural fallow technologies

Profitability Indicators	All legumes	*Mucuna spp*	*Stylosanthes spp*	*Canavalia spp*	*Pueraria phaseoloides*	*Lablab pupureum*	Natural fallow
Monthly IRR (%)	3.3	4.3	3.6	3.0	3.0	2.7	-0.1
Annual IRR (%)	48.0	65.2	52.2	44.8	44.6	37.3	-1.0
NPV (¢)	418,440.00	653,097.00	410,259.00	404 ,221.00	347,013.00	304,585.00	-80,905.00

Sensitivity analysis for maize-legume relay

The performance of the legume fallows relative to the natural fallow is fairly stable under a range of possible changes in two key parameters namely, labour costs and produce price. Labour costs and price of agricultural produce are two main determinants of profitability in smallholder low external input systems, assuming all other factors that contribute to production, including the weather, are fairly favourable. Labour costs are bound to appreciate since wages usually increase annually. The daily labour wage (by-day) increased by ¢1,000.00 each year during the three years (2000-2002) of the study in the villages. Assuming this increases labour costs by 20% on the average, maize produced on the legume fallow plots is profitable at a 10% discount rate, while that on the natural fallow plot is not (NPV = -¢261,000.00) (Table 4.1.11).

Table 4.1.11: Sensitivity analysis on 20% increase in labour cost

Profitability indicators	All legumes	Mucuna	Lablab	Canavalia	Pueraria	Stylo	Natural fallow
Monthly IRR (%)	2.8	3.9	2.2	2.6	2.4	2.9	-2.0
IRR (%)	39.2	58.8	29.5	36.6	33.4	40.5	-21.6
NPV (¢)	361,035.00	657,907.00	246,772.00	352,654.00	266,372.00	335,053.00	-260,690.00

Maize prices often fluctuate depending on the supply of maize at any particular point in time during the season and transport costs. Transport costs may not influence maize price at the farm gate, it is rather the weather that exerts much influence on supply. Since production is rain-fed, total maize output in any one year is determined by weather conditions, which have become very irregular in recent times. Unfavourable weather causes a decline in total yields, hence, a decline in supply and a rise in price and vice versa when the weather is favourable. Assuming farmers encountered unfavourable weather, say early drought that reduced maize yield and caused a 20% increase in maize price on the average.

Assuming also that maize yield from a legume fallow plot was not significantly affected due to the moisture retaining properties of the legume mulch and associated improved soil conditions (Buckles & Triomphe, 1999). The legume fallow systems will be much more profitable than the natural fallow as Table 4.1.12 shows.

Table 4.1.12: Sensitivity analysis on 20% increase in maize price

Profitability indicator	All legumes	Mucuna	Stylosanthes	Pueraria	Canavalia	Lablab	Natural fallow
Monthly IRR (%)	6.2	7.0	6.6	6.1	5.9	5.4	3.5
IRR (%)	105.0	125.0	116.0	104.0	98.0	88.0	52.0
NPV (¢)	1,042,769.00	1,392,114.00	1,006,934.00	927,579.00	1,041,988.00	877,138.00	290,857.00

Table 4.1.13: Sensitivity analysis on 20% decrease in maize price

Profitability indicator	All legumes	Mucuna	Canavalia	Stylosanthes	Pueraria	Lablab	Natural fallow
Monthly IRR (%)	1.4	2.7	1.3	1.3	0.9	0.7	-4.5
IRR (%)	18.0	37.0	17.0	17.0	11.4	8.9	-42.7
NPV (¢)	89,994.00	328,119.00	82,446.00	69,631.00	14,408.00	-12,724.00	-406,855.00

On the other hand assuming favourable weather, for instance adequate and well-distributed rainfall is encountered, which increased total maize output, thus raising supply and consequently lowering maize price by 20%. This adversely affects the profitability of both the legume and natural fallow systems, although production under all legumes, except that of Lablab is still profitable at 10% discount rate. Table 4.1.13 shows the results.

To summarize, maize production in a legume shrub fallow system is quite lucrative, as indicated by the higher gross margins, returns to labour, NPV and IRR compared with that of the traditional natural fallow. Maize production in the legume system is also fairly stable under increases in labour costs but very sensitive to fluctuations in maize prices. A 20% increase in maize prices makes maize production highly profitable, even under natural fallow. Conversely, a 20% decline in maize prices reduces profitability sharply, with production under a Mucuna fallow yielding the most income and that under natural fallow the poorest income. Mucuna fallow is the most profitable under all tested conditions. Fallows with stylosanthes, pueraria, canavalia and lablab are also profitable in that order but are severely affected when maize price is low. The natural fallow is consistently the least profitable.

4.1.2.2 Permanent plantain system

The permanent plantain system involves rows of tree and shrub legumes with plantain planted in the alleys, Figure 3.2. It is essentially an alley cropping system involving *in situ* mulch production that can support the productivity of plantain on a sustained basis. Four treatments were considered for the on-farm experiment, namely, plantain-*Gliricidia sepium*, plantain-*Flemingia macrophylla*, plantain-*Canavalia ensiformis* and plantain-no legume (control). All the four treatments are planted on each farmer's plot as replicates. The benefits of the plantain-legume technology include increasing plantain yield by way of improving soil fertility and conserving soil moisture, which are critical in sustaining productivity in plantain. In addition to biomass from pruning the hedgerow applied as mulch, hedgerows continually add organic material to the soil through litter fall, tree roots and exudates and by way of biological nitrogen fixation if the hedgerow species is leguminous (Dvorak, 1996).

Mulch also reduces weed growth despite the additional increase in labour requirements for managing hedgerows with respect to pruning and application of the mulch. Other possible benefits of the system include the provision of wind breaks by the hedgerow, firewood, stakes and fodder. The use of the leguminous cover crop *Canavalia ensformis*, to effectively control weeds and improve soil productivity in plantain-based systems on farmer fields in the Asunafo District of the Brong Ahafo Region of Ghana has been reported by Osei-Adade *et al.,* (2001). Ruhigwa *et al.,* (1995) also reported reduced labour for weeding a plantain-alley cropping system with mulch from *Senna siamea, Dactyladenia barteri* and other species

Although some work has already been done on the effect of *Flemingia macrophylla* and *Canavalia ensiformis* mulch on plantain in Ghana, these studies did not consider economic assessment of the effect of the legume mulch on particularly plantain yield and labour (two principal economic parameters that are of importance to farmers). In this *ex-ante* economic analysis, only the plantain-gliricidia and the control (i.e. plantain-no legume) treatments are considered. The comparative advantage of the gliricidia mulch on plantain yield is taken to be its potential to sustain production over a 10-year productive period after which the hedgerows may have to be replaced. The extra costs a farmer incurs in adopting the technology are that for legume seeds/seedlings and labour to plant/establish the hedgerow in the first year. It also includes labour to prune the hedgerow and apply the biomass as mulch over the productive life of the hedgerow. Costs saved may be reduction in labour for weeding upon application of the mulch and labour for land preparation every three to four years following natural fallow as this is done only once in a hedgerow system.

For this analysis, the control with sole plantain is assumed to be the traditional system if a farmer does not adopt the technology and is managed under a 3-year cropping and 4-year natural fallow rotation system. It was observed from the initial characterization of the farming system that, the average cropping and fallow phases for plantain fields is 3 or 4 years, ranging from 2-6 years in Gogoikrom and Subriso III. Due to the declining soil fertility and increasing land scarcity, most plantain fields are cropped for 3 years and fallowed for 4 years where the farmer has sufficient land. On the other hand, where land is limiting the farmer may choose to grow the plantain for two years and fallow the land for three years.

By not adopting the technology, the farmer saves on money and labour for establishing the legume hedgerow, pruning and mulch application. However, his opportunity cost for doing so is the extra weeding labour cost that he has to incur if he is to weed thrice in a year. Assuming his fallow management regime is sufficient to enable appreciable production, he loses the benefits of windbreak, which is particularly important in recent times to save plantain from lodging during windstorms at the onset of the rainy/cropping season of every year.

Data on farmers and their plot characteristics as well as some initial input-output data on establishment of the technology were collected in 2001 and 2002. Other primary data were drawn from participatory budget information for plantain production in Subriso III collected during the initial livelihoods characterization (Moss *et al*., 2000). The participatory data is on the traditional plantain system covering resources, costs and returns on a monthly basis for plantain production over 3 years after which the land is fallowed.

Since the plantain-legume technology was only properly established in 2002, it has been possible to estimate only labour used for establishing the technology in the first year (2002) from farmer experimental plots. Labour estimates for pruning and mulching used in this *ex-ante* analysis has been drawn mainly from work reported by some authors like Avila (1992) and Dvorak (1996), for pruning and mulching in *Leucaena Leucocephala* alley cropping systems on farmer fields in Western Nigeria (due to limited information on labour for managing gliricidia hedgerows in the literature) and from other work on gliricidia hedgerows reported by Sumberg *et al.* (1985). Other sources of information for the analysis include Ruhigwa *et al*. (1995) and Banful *et al*. (2000). The experiments are on-going on farmer fields; consequently, details on seasonal plantain yields and labour requirements for pruning, mulching and weeding from the 2003 cropping season onwards will be estimated for more accurate economic analysis in the future.

Major costs included in the analysis are that for land, tools, planting materials (plantain suckers and *Gliricidia sepium* seedlings) and labour for establishing and managing the plot over one production cycle. It is assumed that the bulk of the produce would be sold at the farm gate; hence, no marketing costs are included. About 70% of the experimental farmers are landowners (who do not pay for the use of land) as plantain is a longer duration crop requiring a more secured tenure. However, tenants are becoming involved due to its cash value. Some may rent the land (pay by cash) and others sharecrop on an *abunu* basis. The cost of land is estimated as that of the average cost for rented land.

Refilling of the plantain plot is done annually after the first year in order to increase the density of the plantain stand following harvesting of bunches in subsequent years. It is assumed that this activity is done with about 10% of the quantity of suckers planted in the first year (Moss *et al.,* 2000). Annual suckers used for this operation are obtained from the existing stock on the plot at no cost. This is income foregone, which has been estimated as an annual cost of production in addition to annual weeding, pruning, and mulch application, that constitute the annual maintenance schedule for the technology. If the farmer has more than what is required for refilling, he may sell the remaining suckers to others for an income. On other hand, if for some reason (e.g. the mother plants are not very productive, nematode and termite attack, drought and wind/rainstorms leading to severe lodging, etc.) his stock of suckers is inadequate for refilling, he may have to purchase them from others or from the market.

Pruning labour is hypothesized to be a function of tree species, tree number and time elapsed between prunings. Environmental conditions between prunings affect tree growth and pruning labour. Sumberg *et al.* (1985) reported that about 18 man-days per hectare are required for pruning a gliricidia hedgerow system. The total pruning labour required over a season will depend on the pruning frequency (Dvorak, 1996). An optimal cutting interval of 12 weeks is recommended for *Gliricidia sepium* hedgerows (Simon and Stewart, 1992). For this analysis it is assumed that two prunings of the gliricidia hedgerows per year are appropriate, the first in March/April at the on-set of the rains and the second done 3-4 months (between June and July) afterwards since farmers are already burdened with labour problems during the periods when the pruning is essential for achieving its aim. The first pruning in March for each season requires more labour than the second, as there would be about 8 months of growth from August of the previous year. The second pruning with only 3-4 months growth would obviously require less labour. It is anticipated that successive pruning will increase the overall labour requirement for the season but at a deceasing rate (Dvorak, 1996). This is because the total pruning and mulching labour is likely to decline as the hedgerow ages, but due to the unavailability of such information it will be assumed to be the same over the 10 years. Year zero is for establishing the gliricidia hedgerow and so no pruning and mulching are undertaken.

For the purpose of estimating the effect of the mulch on weed control, it was assumed that number of weedings will reduce from 3 to 2 from the first to the second year of mulching and remain constant until the end of a productive period of 10 years for the plantain or hedgerow. The first weeding is done in April and the second in October before the dry season.

Only one production cycle or rotation is considered in comparing the profitability of the plantain-legume and plantain-natural fallow options. Plantain bunches (fruits) are the only tangible product earning returns from the system. Plantain begins fruiting about 18 months after planting. The seasonal yield pattern for plantain under the traditional three-year cropping and four-year natural fallow natural fallow system as reported by farmers in the participatory crop budget in Subriso III is as shown in Figure 4.1.2. Production peaks in November in the first harvest year after a natural fallow is cleared, where about 150 or more plantain bunches per hectare may be harvested. This declines by 30% in the subsequent years since production relies on inherent fertility of the soil, until the plot is fallowed after the third harvest year.

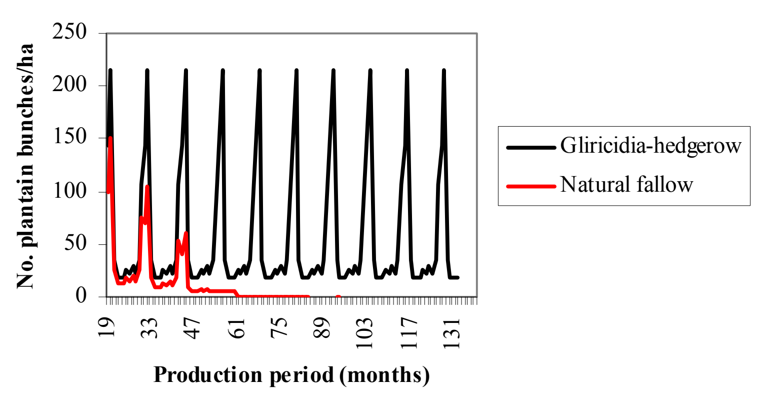


Figure 4.1.2: Seasonal plantain yield pattern over one production cycle

As stated above the gliricidia hedgerow technology is expected to improve and sustain plantain yield over a longer period of time. It is assumed that the gliricidia mulch increases plantain yield in the hedgerow system by 43% over the sole plantain (Smith, 1992). The yield pattern is assumed to be constant over the productive life of the plantain (Figure, 4.1.2), although it may decline with decline in biomass production as the hedgerow ages. For the sole plantain treatment, no tilling or maintenance activity is undertaken during the fallow as land is left to rest, although a few bunches may be harvested from remnants of plantain stands in the fallow vegetation in the first few months. It is assumed that the quantity of plantain harvested gradually declines to zero as the fallow ages.

All input costs and prices were assumed to be constant over the 10-year production period. Although wage rate for daily labour increased each year by ¢1000 over the period of research, a daily labour wage of ¢7000 paid in 2002 was used throughout in the analysis. The average price per bunch of plantain in 2002 estimated at ¢5,000 remained constant during the productive period of the plantain. In real terms there are seasonal variations in price of plantain, usually determined by both supply (dictated by weather conditions) and demand (urban and foreign markets).

Cash flow analysis for plantain-legume

The stream of costs and revenues over one production cycle for the plantain-gliricidia and plantain-natural fallow are presented in Appendix 2. Discounting the annual stream of costs and revenues, it is observed that plantain production in general is profitable at a 10% discount rate whether a farmer adopts the *in-situ* mulch system or continues with the traditional fallow option. However, production is more profitable when *in-situ* gliricidia mulch is applied, as the B/C ratio, EAV and IRR values of the gliricidia-hedgerow option are higher than those for the natural fallow option (Table 4.1.14). This can be explained by the fact that, production under the hedgerow system is intensive with constant income flows once the hedgerow is in place. On the other hand, income is lost due to the break in production to fallow to enable soil fertility recovery or replenishment under the natural fallow option. The superiority of the plantain-gliricidia hedgerow over the plantain-natural fallow production system is further confirmed by its higher discounted return to labour value of 2.9 as compared with 1.3 for the natural fallow, although it requires about thrice the amount of labour resource primarily for planting and managing the hedgerow.

Table 4.1.14: Profitability of plantain-Gliricidia sepium and plantain-natural fallow technologies

Profitability indicator	Plantain - Glicidia sepium hedgerow	Plantain - Natural Fallow
B/C Ratio	2.4	1.2
EAV	¢1,680,654.00	¢122,000.00
IRR	49%	20%
Discounted Return to Labour (DRL)	2.9	1.3
Discount rate = 10%		

Although the plantain-legume technology has the potential to reduce weeds, thus reducing weeding labour and cost, it increases total labour requirements due to the extra labour required for hedgerow pruning and application of mulch. MacLean *et al*. (2003) argue that, although establishing and maintaining hedgerows is labour intensive, family labour if available can readily perform the necessary operations even on 1-3 ha farms. Adding that, the more labour available the better the benefit from alley cropping. For labour-scarce families, mulching without incorporation of the mulch biomass is the best option since this biomass incorporation is labour intensive. Labour demands may however, decline over the years as the system stabilizes.

Sensitivity analysis for plantain-Gliricidia hedgerow/natural fallow

The annual price of labour or local wage rate and the average price of a bunch of plantain are continuously appreciating in Ghana. Hence, the stability of the plantain system would somehow depend to a large extent on the yield or quantity of the number of bunches harvested. Thus plantain yield may rather be an important factor to consider for the risk assessment/sensitivity of the profitability of plantain production. As indicated above, plantain production in Ghana is currently prone to two main production elements, namely soil productivity (fertility and nematodes) and the weather. These make yield highly unstable. Table 4.1.15 confirms the fact that stability in plantain production is highly dependent on yield enhancement factors.

Table 4.1.15: Sensitivity analysis of plantain-Gliricidia sepium hedgerow and plantain-natural fallow technologies

Factor	Profitability indicators	Plantain –gliricidia hedgerow	Plantain-natural fallow
Base case	B/C Ratio	2.4	1.2
	EAV (¢)	1,680,654.00	122,000.00
	IRR (%)	49	20
	DRL	2.9	1.3
20% Increase in yield	B/C Ratio	2.8	1.4
	EAV (¢)	2,263,442.00	138,475.00
	IRR (%)	59	32
	DRL	3.5	1.6
20% Decrease in yield	B/C Ratio	1.9	0.94
	EAV (¢)	1,097,865.00	-197,96.00
	IRR (%)	37	6
	DRL	2.2	0.92

A 20% increase in plantain yield favours both the gliricidia hedgerow and the natural fallow systems. The gliricidia hedgerow option with relatively better soil conditions is still profitable when yield declines by the same proportion while the profitability of the natural fallow is adversely affected. Thus, the plantain-gliricidia technology is comparatively stable and worth adopting.

4.1.2.3 Cocoa-shade tree technology

A detailed description of the cocoa-shade tree technology planted is presented in Chapter 3. The technology comprises two blocks measuring 24 x 54 m (1296m^2) of hybrid cocoa and seven indigenous shade tree species per block, intercropped with plantain, cassava and other crops. It is designed to mimic the traditional system but improved with planted shade trees. Each farmer planted 320 hybrid cocoa seedlings (160 per block) and food crops (early shade) in any pattern desired with no regular spacing (the way they normally plant crops), but planted the tree seedlings at 12m x 12m triangular spacing. The control is the traditional practice, where selected natural coppice shoots of indigenous trees are retained after clearing of the vegetation to provide shade for the cocoa. However, the volume of such shade tree species is declining on cocoa fields, reducing cocoa productivity.

It is hypothesized that the indigenous shade trees planted will sustain cocoa yield and prolong its productive life, while the productive period of cocoa on the control plot with no planted shade trees will be lower. In other words, the optimum plantation age is assumed to be higher if farmers adopt the practice of planting desirable shade trees than when they continue with the traditional practice. Thus cocoa in planted shade tree systems are expected to yield higher returns than those grown in the traditional systems. A productive period of eighty years for the cocoa is considered for this analysis, although this length of time may be uneconomic.

Data employed for the analysis is largely from primary sources gathered from 2001 to 2002, supplemented with secondary data. A seasonal cropping calendar on cocoa production developed during the initial farming system characterization provided basic information on the series of activities undertaken over the productive life of the cocoa. Data on farmer and plot characteristics and on inputs and outputs were gathered in the first year of establishment of the technology.

The cocoa yield pattern over the eighty year production period was estimated from data on cocoa collected from a sample of 25 farmers comprising both participating and non-participating farmers on their traditional cocoa fields under different stages of growth. This strategy was used as a proxy for the estimation of cocoa yields and costs of operation beyond the first year of establishment, as the farmer experiments only began in 2001. Data on quantities of cocoa sold and price per kilo in various years were also gathered on these proxy cocoa fields from farmer cocoa sales record books. Adapting work done by Ryan *et al.* (2003) which showed a positive relationship between the age of a cocoa plantation and its yield, a cocoa yield curve was fitted from a regression of the age of the plantation on cocoa yield. Table 4.1.16 shows the result from the regression in which natural log of cocoa was the dependent variable.

Table 4.1.16: Output from a regression of age of cocoa plantation on cocoa yield

	Coefficients	Standard Error	*t*- Statistic	*p-value*
Intercept	-1.822	1.688	-1.079	0.300
Age of cocoa plantation (YRS)	-0.166	0.047	-3.563	0.004
Natural log of age	3.931	1.014	3.877	0.002
$R^2 = 0.54$; F = 7.56				

The results of the regression showed a significant relationship between the natural log of cocoa yield and plantation age and its natural log, i.e. $R^2 = 0.54$ and F = 7.56. Figure 5.3 shows the derived cocoa yield pattern, with a maximum yield of about 800kg/ha occurring in year 25. The equation for estimating the yield of cocoa in any year during the eighty-year production cycle is, therefore, as follows:

Y= exp (-1.822 - 0.166 x age + 3.931 x ln (age)-----(1)

Where Y is cocoa yield/ha and age is age of the cocoa plantation in years.

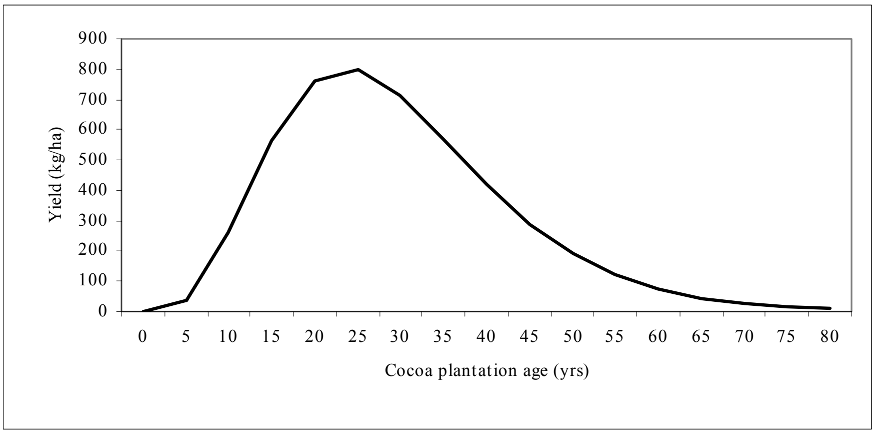


Figure 4.1.3: Derived cocoa yield pattern in the traditional system

A mixture of cocoa varieties, amelonado and amazonia and the hybrid are planted in the traditional system. The hybrid cocoa used in the technology is early maturing and high yielding, beginning to fruit in the fourth year with a productive life of over 50 years depending on the level of shading and how the plantation is maintained, i.e. regular weeding/brushing, removing epiphytes such as the mistletoe, spraying against insect pests such as capsids and mealy bugs and fungal diseases such as the black pod and destroying trees attacked by the swollen shoot virus.

Costs of production and prices considered in the analysis were estimated at 2002 figures at the farm gate. Extra costs incurred by the farmer in adopting the technology are that for tree seedlings and labour cost for establishing the trees, i.e. pegging, digging holes and planting. The first four years of production are considered as the establishment phase of the crop. Cocoa closes canopy in about the eighth year. After this period, the costs of all operations undertaken are assumed to be the same until the end of the productive life.

Costs related to protecting the cocoa (removing epiphytes, spraying against pests and diseases, etc.) are important but could not be estimated because farmers interviewed hardly undertook these activities and so were unable to assign costs. No marketing costs are considered as the bulk of the produce, including cocoa, is sold at the farm gate. As mentioned above, there are numerous tenants involved in cocoa cultivation. In order to simplify the analysis, the cost of land for cocoa production is assumed to be the value of the initial sum of goodwill money paid by tenants involved in sharecropping under the *abunu* arrangement as this is the common mode of access to land for cocoa cultivation by most people, including some landowning families with insufficient land resources.

Returns estimated from the treatments include that of food intercrops, i.e. maize, plantain, cocoyam and cassava in the establishment phase. These are planted as nurse crops providing early shade and are also important in providing early cash and food for the farm household and cash for the maintenance of the cocoa, while awaiting cocoa proceeds. Cocoa output, i.e. bags of processed beans per hectare, is the only long-term tree product estimated in the analysis.

Since the experiment is long-term, the real effect of the shade tree on cocoa yield, i.e. the ability of the shade tree to improve and sustain cocoa production is assumed to be its ability to prolong cocoa yields up to 80 years. The income lost if the farmer does not adopt the technology, i.e. continues with the traditional practice of not planting trees on his cocoa farm (but is likely to have fewer stands of naturally occurring trees) is the lower total cocoa output harvested, since maximum production will lower. He also loses possible income from tree products, including timber, fruits, medicine and so on.

It is known that a cocoa plantation is less productive with insufficient shade trees (PAN, 2001). This means a reduction in the maximum point of production and/or a reduction in the age at which the maximum yield occurs, but the question is by how much? There seems to be limited quantitative information on the effect of indigenous tree shade on cocoa, particularly the marginal yield differences between optimum shade and that below the optimum. Consequently, hypothetical cases were considered in order to estimate the yield pattern for the improved and traditional cocoa systems with and without planted shade trees.

The Ryan *et al.* (2003) equation takes into account optimum shade for cocoa, which gives a maximum yield of 1200 kg/ha. Adapting the equation for the traditional Ghanaian system with insufficient shade (i.e. equation 1) gave 800kg/ha.

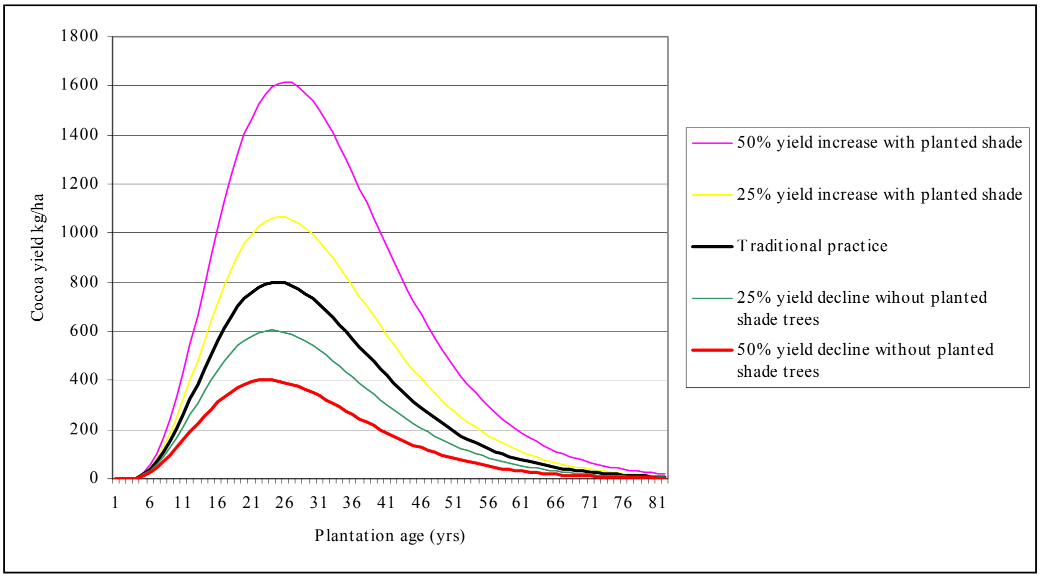


Figure 4.1.4: Derived cocoa yield patterns in planted and without planted shade tree systems

Assuming the cocoa shade tree technology ensures optimum shade, then there is the possibility of improving yield by about 50% (i.e. (1200– 800)/800) kg/ha). Moreover, shade tree population is continuously depleting on cropland, which means yields are likely to decline in the future. Consequently, 50% minimum and maximum changes in yield about the traditional system were assumed for determining the curves for the planted and without planted shade trees scenarios (Figure 4.1.4). The equations for these are as follows:

$$= \exp(-1.822-0.166 \times age + 3.84 \times \ln(age) \text{ ------ } (2)$$
$$= \exp(-1.822-0.166 \times age + 3.71 \times \ln(age) \text{ ----- } (3)$$
$$= \exp(-1.822-0.166 \times age + 4.02 \times \ln(age) \text{ ----- - } (4)$$
$$= \exp(-1.822-0.166 x age + 4.15 \times \ln(age) \text{ ----- } (5)$$

The age at which the maximum yield occurred increased slightly from 24 years in the traditional system to 25 years with 50% yield increase whereas it declined to 22 years, if yield decreased by the same proportion (Figure 4.1.4). This suggests that improvement in yield as a result of the planted tree shade may be more important.

Cash flow analysis for cocoa-shade tree

The discounted cash flows are presented in Appendix 3. Economic indicators estimated are the B/C Ratio, NPV, LEV and IRR. The summarized discounted cash flow analysis for the cocoa with planted shade trees and that for traditional technologies (Table 4.1.17). The important extra variable costs between the planted shade and traditional options are those for purchasing and transporting indigenous tree seedlings and labour for planting. These are the extra costs resulting from adopting the technology.

The results presented in Table 4.1.17 show that cocoa production is in general profitable at 10% discount rate. Duguma *et al.* (2001) report that even with no value assigned to the tree species, cocoa production in smallholder systems in Cameroon was profitable. However, production is more profitable with planted shade trees. This increased the BCR, LEV and IRR, from 1.6, 10.6 million, and 30% in the traditional system to 2.2, 22.8 million, and 38% respectively, if planted shade improved yield by 50%.

Table 4.1.17: Summary discounted cash flow-cocoa with and without planted shade trees

Economic indicator	Without planted shade trees (50% yield decrease)	Without planted shade trees (25% yield decrease)	Base (traditional practice)	With planted shade trees (25% yield increase)	With planted shade trees (50% yield increase)
B/C Ratio	1.17	1.40	1.60	1.87	2.19
NPV (¢)	2,665,224	7,041,963	10,616,185	16,683,806	22,751,427
LEV (¢)	2,666,526	7,045,402	10,621,371	16,691,955	22,762,539
IRR	20%	30%	30%	35%	38%
Max NPV (¢)	2,670,990	7,044,317	10,617,418	16,684,496	22,751,842
Max LEV (¢)	2,706,679	7,117,530	10,707,101	16,820,541	22,933,981
Age of maximum NPV (yrs)	52	60	64	68	71
Age of maximum LEV (yrs)	41	42	44	44	44

The optimum rotation age from the standpoint of the LEV is a little over 40 years for the planted and without planted shade tree scenarios over the 80 year rotation, although planting shade trees will improve income and enhance the ecosystem and provide other benefits to the farmer.

Sensitivity analysis for cocoa shade tree

Cocoa production is still profitable with a fall in cocoa price, although quite sensitive to this change. A 20% reduction in cocoa price reduced profitability generally across all scenarios. Profitability is marginal under this condition if yield declines by 50%.

Table 4.1.18: Sensitivity of profitability of the cocoa-shade tree technology

Economic indicator	Without planted shade trees (50% yield decrease)	Without planted shade trees (25% yield decrease)	Base (traditional practice)	With planted shade trees (25% yield increase)	With planted shade trees (50% yield increase)
B/C Ratio	1.00	1.19	1.3	1.56	1.81
NPV (¢)	56223	3281227	5762089	10616185	15470282
LEV(¢)	56250	3282829	5764903	10621371	15477838
IRR	10%	24%	24%	30%	34%
Max NPV (¢)	70815	3285764	5764385	10617418	15471047
Max LEV (¢)	72133	3325224	5816349	10707101	15597853
Age of maximum NPV (yrs)	42	54	60	64	68
Age of maximum LEV (yrs)	42	42	44	44	44

According to Osei-Bonsu *et al.* (2002) shade for cocoa is becoming a critical issue in Ghana as a result of extensive deforestation. The implication is that if farmers are not encouraged to plant shade trees, cocoa productivity will be severely affected in the future. Unless prices appreciate, downward changes in prices will render production marginally profitable, becoming unprofitable if yield reduces below 50%.

The optimum rotation age however, remains the same whether trees are planted or not or prices appreciate or fall. The present shade level is just sufficient to ensure economic production up to about 44 years. However, it would be more profitable if improved, and returns are likely to double by this time. This suggests that the economic rotation age (probably irrespective of cocoa variety) is about 40 years. It may be more economic to replant the plantation after 40 years, rather than waiting until the 80 years practiced in the traditional system as production.

4.1.2.4 Planted Gliricidia/Tree Fallow

The planted tree fallow experiment was planted in Yabraso-Wenchi, involves two 20m x 20m blocks, one planted to a gliricidia fallow and the other left under natural fallow. This analysis involves the comparison of maize production following one gliricidia fallow rotation with that following natural fallow.

The entire period under consideration is about 30 months, i.e. 2.5 years. The gliricidia is planted in May-June in the first season (2002) and the fallow is cleared in February in the third season (2004) and cultivated to maize which is harvested in September for sale and/or storage. The stream of costs and revenues for the gliricidia and natural fallows are presented in Appendix 4. The extra costs the farmer incurs in adopting the technology covers gliricidia seedlings (3,300 plants per hectare) and transportation of the seedlings to the farm; labour for clearing, lining, pegging, digging wholes, planting and ring weed the gliricidia once in the first year to aid establishment. Land cost is assumed to be zero since the technology is likely to be adopted by only landowners who due to their land status may be interested in tree fallows. It is also assumed that only one weeding of the succeeding maize is required after the gliricidia fallow but twice in the natural fallow as gliricidia shades out weed completely and the mulch suppresses/delays weed growth. Returns from maize and stakes are the potential income earned from the system.

Data for the analysis was drawn from primary data collected for input-output analysis for maize crop production during the initial characterization, supplemented by other data from the maize-legume and plantain-legume sections 4.1.2.1 and 4.1.2.2 as well from work done by Kaya & Nair 2001 on *Gliricidia sepium* fallow in southern Mali. All inputs and output values were estimated at 2002 figures at Yabraso, except that of the gliricidia seedlings and stakes which are not tradable items in the area.

The Mali case was adapted in estimating maize yield. According to Kaya & Nair (2001) soil parameters did not change but maize yield after the gliricidia fallow improved over that of a grass fallow at the end of two seasons of the fallow. Differences in ecological factors particularly soils & rainfall between Mali and Wenchi (Table 4.1.19) are likely to influence the growth of fallow vegetation or development, hence fallow productivity. This ultimately will affect maize yields with that of Wechi, which has better growth conditions likely to be better than obtained in Mali.

Table 4.1.19: Ecological differences between Wenchi-Ghana & Southern Mali

Site characteristic	Wenchi	Southern Mali
Ecology	Forest-savanna transition	Sahel
Soils	Sandy clay loam-savanna orchosols (with some lithosols and brunosols)	Sandy loam
Rainfall pattern	Bi-modal	Uni-modal
Rainfall amount	1140-1270 mm	850mm

Sources: Atta-Quayson (1999) and Kaya & Nair (2001)

Although gliricidia is one of the most researched multipurpose agroforestry speices, many of the studies relating to smallholder production have been on its use for mulching in alley cropping systems. Due to the lack of data or information on the performance of gliricidia fallows in the savannah transition areas of the tropics or SSA, the Mali figures will be adopted to portray the possible effect of such a fallow on the livelihoods of farmers in the study area. In the Mali study, maize yield following the gliricidia fallow increased about 3 times over that of the natural grass fallow (Table 4.1.20). Average maize yield following 2-3 years natural fallows in Yabraso (from input-output data collected for the livelihood characterization) was estimated as the base yield i.e. the yield without the technology or if the farmer does not adopt the gliricidia fallow which is considered as the control treatment in the experiment.

Table 4.1.20: Maize yield after *Gliricidia sepium* and natural grass fallow in Mali

Technology	Maize yield kg/ha	% Increase	No. of times
G. *sepium* fallow	2170	203.9216	3.039216
Grass fallow	714		

Source: Kaya & Nair (2001)

Table 4.1.21: Maize yield after *Gliricidia sepium* and natural fallow in Yabraso (adapting the Mali case)

Technology			Maize yield kg/ha	No. of bags (100kg = 1 maxi bag)	Price/bag (¢)	Output value (¢)	Cost that vary/ha (¢)	Total cost/ha (¢)
Natural fallow	Base	100%	1410.0	14.1	100,000.00	1,410,000.00	125,829.00	995,846.00
Gliricidia fallow	Base increase	304%	4285.4	42.9	100,000.00	4,290,000.00	1,104,888.00	2,336,870.00

Stake is not normally purchased for yam production, labour cost of gathering paid by a few; otherwise standing dead trees are used as support for trailing yam vines. The cost of stake was estimated from Subriso where it is sold at variable prices ringing from ¢40.00-¢180.00 per one. In pricing stakes, it is assumed that the stake may cost at least ¢100.00 using the average figure from Subriso since it has no market value or the demand for it is low but may gain value in the future as deforestation is intensifying in the area. The quantity of stakes produced was assumed to be equivalent to the number of gliricidia seedlings planted per hectare, if each seedling develops into a single tree.

Table 4.1.22: Summary discounted cash flow analysis for maize following *Gliricidia sepium* and natural fallows

Profitability indicator	Gliricidia fallow	Natural fallow
B/C Ratio	1.8	1.4
NPV	¢1,585,279.00	¢303,072.00
EAV	¢747,722.00	¢142,949.00
Monthly IRR	4%	9%
IRR	62%	184%

More cash resources are invested but higher return is earned from the gliricidia fallow as compared with the natural fallow. To adopt the gliricida fallow, the farmer requires about nine times cash resources as that required for the natural fallow while the return from the gliricidia is about 3.5 times that for the natural fallow (Table 4.1.21). Both fallow alternatives are profitable but that planted to gliricidia is more profitable yielding higher NPV and EAV of ¢1.5 million and ¢750,000, that are about 3 times that of the natural fallow (Table 4.1.22). The IRR values indicate otherwise because of the initial costs incurred in planting the gliricidia fallow which does not occur for the natural fallow, making their cash flow patterns differ. This shows that the IRR may not a very good indicator of profitability in this case.

Both fallows are still profitable should labour cost increase and the price of maize falls by 20%, although the gliricidia is superior and more stable. However, these fallow options may be very sensitive to downward price trends as the 20% decline in maize price sharply reduced the NPV and EAV values to nearly half of the base scenario for the gliricidia and a third of that for the natural fallow, (Table 4.1.23).

Table 4.1.23: Sensitivity analysis of *Gliricidia sepium* and natural fallows

Factor	Profitability indicator	Gliricidia fallow	Natural fallow
Base case	B/C Ratio	1.8	1.4
	NPV (¢)	1,585,279.00	303,072.00
	EAV (¢)	747,722.00	142,949.00
	Monthly IRR	4%	9%
	IRR	62%	184%
20% labour cost increase	B/C Ratio	1.6	1.2
	NPV (¢)	1,326,434.00	183,054.00
	EAV (¢)	625,634.00	86,341.00
	Monthly IRR	3%	6%
	IRR	51%	91%
20% maize price decrease	B/C Ratio	1.4	1.1
	NPV(¢)	909,917.00	80,856.00
	EAV (¢)	429,177.00	38,137.00
	Monthly IRR	3%	3%
	IRR	43%	49%

On the whole all the fallow productivity improving technologies are more profitable than their traditional alternatives. Although in certain cases the alternative technologies relying on natural soil fertility were profitable, this might not be sustainable as profitability sharply declined with either a 20% decline in yield or produce price. Increases in labour cost reduce profitability moderately, probably because labour increases as a result of the new technologies are not very high. This seems to suggest that an improved productive potential of the soil as well as stable and appreciating produce prices are critical in improving the livelihoods of small producers. While the former can be handled at the local farm level, the later is policy and weather oriented over which farmers have no control. Therefore with a fairly good marketing potential, improving the productivity of the land resource for particularly, crop production should be of prime concern as this is the main economic activity of most rural communities. However, post harvest management of the produce is another priority area if farm livelihoods are to benefit from improved fallow productivity.

4.2 Farmer evaluation

Farmer evaluation is recognized as an essential step in the monitoring and evaluation aspects of any participatory research process. This is because of the belief that prior to the diffusion of a new technology among farmers, there is need, not only to test the technology under farm conditions but also essential to allow its potential users to evaluate and give a feedback (David, 1995) that may be useful in refining the technology.

It is increasingly being recognized that, although economic analysis may be valuable in supporting agronomic evaluations/analysis of the feasibility of an innovation, innovations that may be promising from agronomic, ecological and economic view points may have other short comings that may be identified by farmers. For instance, the taste of a certain cassava variety or the odour of poultry manure may deter some farmers from adopting otherwise, very sound and simple improved varieties or soil fertility innovations (Baum *et al.,* 1999). It is thus important to undertake farmer assessment of on-farm innovations to compliment agronomic and economic evaluations. It is believed that farmers' assessment or perceptions of technologies developed with them will aid in determining the usefulness of the technologies to farmer's circumstances and aid in better understanding of some complex socio-economic factors that may impinge on farmer's decisions on the use of the technology, thereby identify any loopholes that require addressing to make the technologies attractive for adoption.

The essential questions that were explored in attaining this objective are the following:

1. How valuable are the fallow improvement technologies to farmers' with respect to their ability to satisfy both farm production/biophysical and household/socio-economic needs?

2. How do farmers express these values or by what indicators can these values be measured?

3. What are farmers' experiences and impressions of the workability/practicability of the technologies with respect to the components/design and management requirements including strengths and weaknesses?

4. Do the technologies stand any chance of being taken up? If so, what aspects?

5. What factors are likely to influence the uptake of the technologies by the different farmer strata in the villages and what issues do farmers perceive to be critical in enhancing the uptake of the technologies?

These questions have been explored by way of evaluating farmers' perceptions of the value of the technologies to their farms and households, farmer's perception of the workability of the technological components including the design, identification of management constraints, potential modifications or adaptations and potential spread of the technologies in the study area.

4.2.1 Data collection & analysis methods

There a number of approaches to farmer evaluation. Methods used do vary from informal to formal and so is the level of farmer participation (David, 1995; Degrande 2001; Cramb & Purcell, 2001; Kanmegne & Degrande 2002; McDonald & Obiri, 2003). Participation may be externally initiated and led by outsiders/scientists, internally initiated and led by farmers or jointly by farmers and outsiders/scientists depending on the objective of the research. In the case of this study, farmers participated in every stage of the evaluation process but the process was initiated and led by scientists primarily to enable both parties to learning from the dynamics of the process as the main project was research oriented.

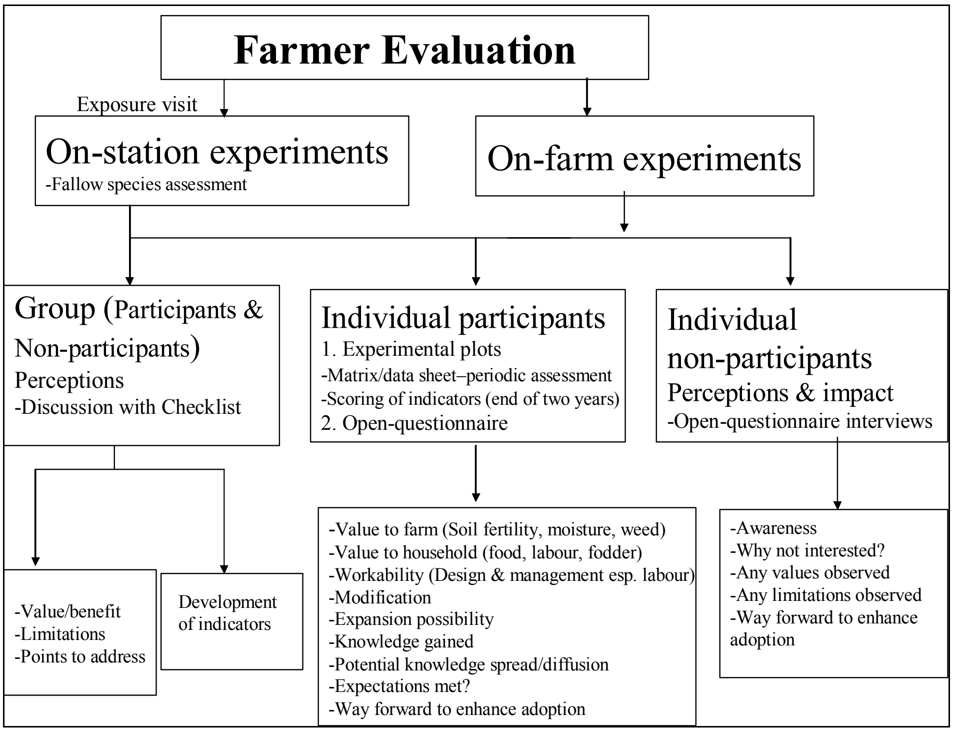


Figure 4.2.1: Farmer evaluation methods

Both informal and formal methods were used in eliciting the performance of the experiments and their potential adoption from group and individual participating and non-participating farmers. The methods and tools employed for the evaluations of the technologies with the farmers in the study area are illustrated in Figure 4.2.1. The farmer evaluation process was in three stages during which the methods in Figure 4.2.1 were applied in collecting the relevant data for this analysis over two years/seasons, 2001 and 2002 (Figure 4.2.2). The first stage involved a bi-monthly monitoring and evaluation schedule for individual farmer experiments from the start throughout each cropping season done by scientists and respective farmers by use of a matrix data sheet. The first monitoring visit during this stage was to ascertain whether farmers had planted their fields. Thereafter, performance of the experiments, specifically, growth of food crops, trees and legumes; issues relating to farmer management of their experiments with respect to labour, behaviour/attitudes, perceptions, tenure and environmental factors impacting on the process were documented.

The second stage group assessment of performance of the technologies, potential adoption and appraisal of project impact. This was achieved through group discussions in village meetings with both participating and non-participating farmers. The analysis of farmers' perceptions at this stage during the first year helped in identifying factors that affected experimentation on farmers' fields and gaps/issues that required redress. It also helped in planning new strategies to enhance experimentation in the second season or year. In the second year (2002) a criterion of indicators for evaluation of the experiments were first developed with the farmers with which they later used to assess their experiments during a participant survey in the third stage. This exercise was done midway in the second year because it was thought that farmers would have had at least two years experience with the technologies at this stage, thus would be in a better position to identify appropriate indicators.

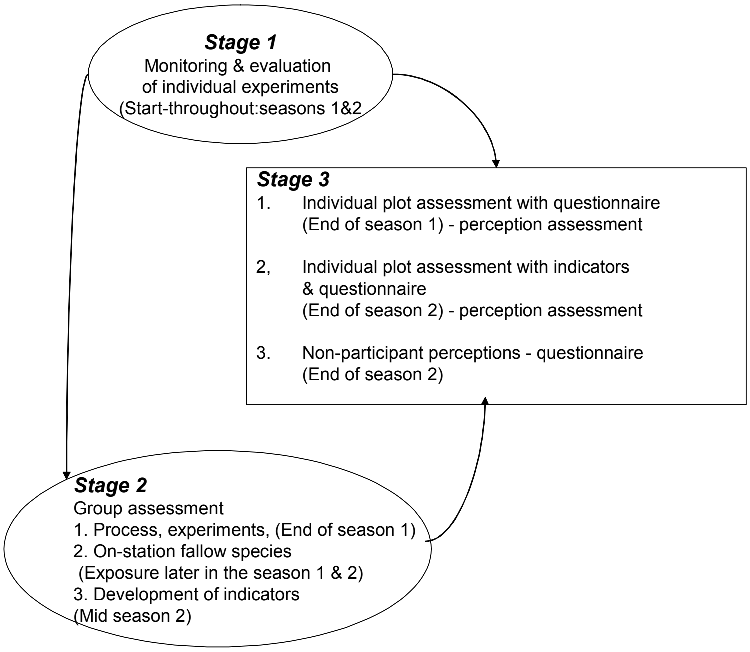


Figure 4.2.2: Farmer evaluation process

The third stage involved an individual assessment of the performance of the on-farm experiments with each participating farmer of his/her field at the end of each season. The objective at this stage was to assess farmers' perceptions of the performance of the technologies with respect to establishment, e.g. the ability of shrub legumes in the maize-legume relay to spread and form thick carpet/produce biomass and their ability to smoother weeds.

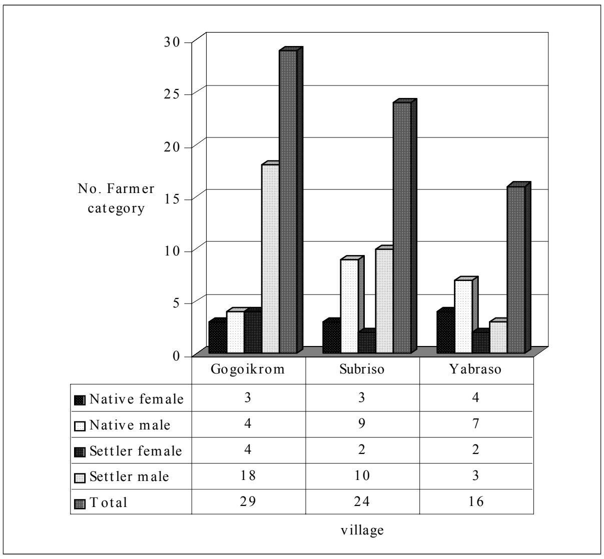
Perceptions of soil fertility improvement potential of the legumes and their usefulness to the farm household for food and other household needs; effect on labour requirements, constraints encountered in experimentation and any suggestions for improving future work were also assessed. Other issues solicited included interests for participating, and reasons for not participating, whether the technologies had generally met farmers' expectations, appropriateness of technology design and modifications perceived likelihood of extension to other parts of the farm and aspects to be adopted and/or extended, any new learning experiences and diffusion of new ideas learnt both within and outside the village. Open-ended questionnaire interviews of individual participating farmers were conducted for this assessment. A total of 83 (52 and 31 in the first and second years respectively) male and female farmers were interviewed on the technologies each experimented, comprising 65% for maize, 14% plantain, 16% cocoa and 5% improved fallow.

Also in the third stage of the second year an open-ended questionnaire interview of 99 non-participating male and female farmers (33 on average per village) was also conducted. Information gathered was similar to that for the participant survey and group appraisal in the second stage to validate individual opinions but of particular interest were issues on management constraints, benefits, technology design, possible modification and potential adoption and spread. It also included appraisal of project activities to identify strengths and weaknesses for redress in future work. Details on the process for the development of the evaluation criteria and indicators identified are presented in section 4.2.2.

The Microsoft Excel computer software has been used in analyzing the information gathered descriptively and presented in graphs and tables as below.

5.2.2 Development of indicators for evaluating technologies

In farmer participatory research, indicators are useful in enhancing farmers and researcher's knowledge, thereby reducing uncertainties and improving decision-making regarding production and resource management. Indicators identified by farmers represent the implicit characteristics they value in technologies, hence serve as their criteria for judging technological options. "A good indicator is determined by its usefulness, ease of collection and the number of stakeholders benefiting from the information it provides" (Cramb and Purcell, 2001). Using the acronym SMART, indicators should be specific, measurable, action-oriented, realistic and time-framed (Estrella and Gaventa, 1998). In the case of farmers, indicators could be measures of farm productivity or sustainability and so on. It must be noted that an indicator that may be useful to researchers, e.g. macro nutrient content of the soil after a legume fallow may be of no interest to farmers, who might prefer increased yield for this same measure as it will be difficult for them to appreciate macro nutrients. Consequently, in involving farmers in identification of indicators for measuring technology performance, compromises need to be made to ensure that appropriate ones are chosen. However, the scientists' indicator is equally important in explaining the basis for increased yield farmers may easily measure. The important thing is that indicators agreed on are within the scope of the project/technology under consideration.



	Gogoikrom	Subriso	Yabraso
■ Native female	3	3	4
□ Native male	4	9	7
■ Settler female	4	2	2
□ Settler male	18	10	3
▨ Total	29	24	16

Figure 4.2.3: Farmer categories involved in criteria development in the study villages

With respect to this study, indicators with which, farmers could use to evaluate the performance of the technologies or their experiments were developed with groups of male and female native and settler farmers in general village meetings of both participating and non-participating farmers held in each of study the villages. A total of 69 farmers comprising respectively, 30 and 39 native and settler men and women across the three villages were involved in the criteria development. Figure 4.2.3 shows the categories of farmers who participated in the exercise. All the four farmer categories identified in the livelihood characterization stage of the study were represented and somehow depicted their relative proportions as found in the villages (Obiri, 2003).

The following procedure of steps was followed in arriving at the indicators.

- Group discussion with experimenters & non-experimenters in general village meeting
- Situational analysis/recapping on farming system needs necessitating the technologies
- Individual experiences & observations with technologies discussed
- Eliciting and listing of indicators
- Prioritizing indicators
- Scoring of indicators with counters (match sticks)
- Trends in scoring discussed and reasons noted

At each village each of the technologies being experimented in that particular village was first discussed one after the other in relation to its characteristics to assess farmers understanding of the inter-linkages between the technologies and the farming systems. During the discussion, some participating farmers gave their experiences and perceptions of the performance of their experiments and the impact expected. A list of indicators for each experiment was then generated from the discussion that followed. A maximum of at least the three most important indicators was accordingly listed from the earlier list generated. Usually, in a participatory process, a number of useful indicators may emerge, however, it may be helpful to select a few, particularly, those that are theoretically and logically linked in some causal relationship (Cramb and Purcell, 2001 citing Pacchco *et al*., 1998).

Each farmer scored each set of indicators for the respective experiments with 10 matchsticks, giving the most important indicator the highest score. The mean scores for each set of criteria were then computed and the results presented to the farmers. The trend in results of the scores was discussed to ensure that they met farmers' expectation and were reasonably within the context of the project. There were primarily no differences in the scoring pattern among the four farmer categories. However, the results of the scores have been differentiated on gender basis due to the small numbers of native and settler women.

Indicators for evaluating maize-legume relay technology

The maize-legume relay experiment was tried in all three-study villages. The indicators farmers identified as important for measuring the performance of this technology and associated mean scores are presented in Figure 4.2.4.

Three main indicators namely, increased soil fertility; increased yield and weed suppression were identified and scored in that order of importance by farmers at Gogikrom and Subriso III. In Yabraso erosion control/moisture conservation was identified in addition to increase in soil fertility and weed suppression.

On scoring the indicators, both men and women farmers placed the most emphasis on the ability of the technology to improve soil fertility and the least on weed suppression. Farmers acknowledged that soil fertility was paramount on a maize field as this determines crop yields and level of weed pressure, thus it attracted the highest score in Gogoikrom (4.1) and Yabraso (4.3). Increased maize yield was the second important indicator with scores of 3.2, 3.3 and 3.8 in Gogikrom, Subriso and Yabraso respectively

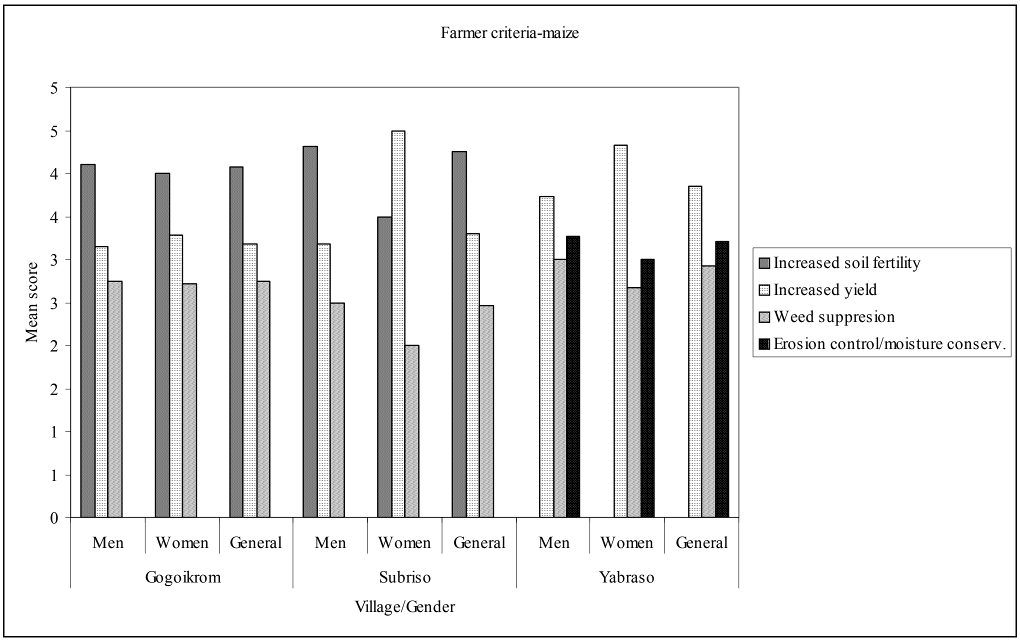


Figure 4.2.4: Farmers' indicators for evaluating maize-legume relay technology

Reasons farmers gave for the observed trend in ranking or scoring indicate that increased soil fertility and increased maize yield are related. The attainment of an improvement in soil fertility improves crop growth and hence yields. In order words, increased maize yield is the measurable indicator that farmers will use as a proxy for judging the effectiveness of the legumes in improving soil fertility. Weed suppression attracted the least scores of 2.7 and 2.4 in Gogoikrom and Subriso because farmers believe that when soil fertility is improved, crop growth is enhanced which can possibly shade out weeds. Moreover, improving crop yield may improve income that could be used in controlling weeds, if they are problematic. In Yabraso farmers observed that the ability of the legumes to spread and cover the soil surface conserved soil moisture and could also control soil erosion that could ultimately lead to improve yields. This had a mean score of 2.9 following improved soil fertility.

Indicators for evaluating permanent plantain/plantain-legume technology

The plantain-legume technology was tried in Gogoikrom and Subriso. There were slight differences in the performance indicators identified in the two villages, although improved plantain yield and weed suppression were similarly identified. In Gogoikrom, improved soil fertility, increased plantain yield and weed suppression were identified and scored in a similar manner as was done for the maize (Figure, 4.2.5). At Subriso farmers identified two additional indicators, i.e. planting material availability and reduced logging together with improved crop yields and weed suppression. Available planting material had the highest score of 3.1, followed by reduced lodging, 2.9 before increased crop yield and weed suppression. . Both men and women rated the indicators in a similar manner. However, Gogoikrom farmers placed most emphasis on soil fertility in a plantain system, while those in Subriso were more concerned with planting material and lodging. In both villages, weeds suppression was not considered a priority as farmers explained (as done for the maize system) that with weed suppression is automatically achieved if soil fertility is improved and crop growth is enhanced.

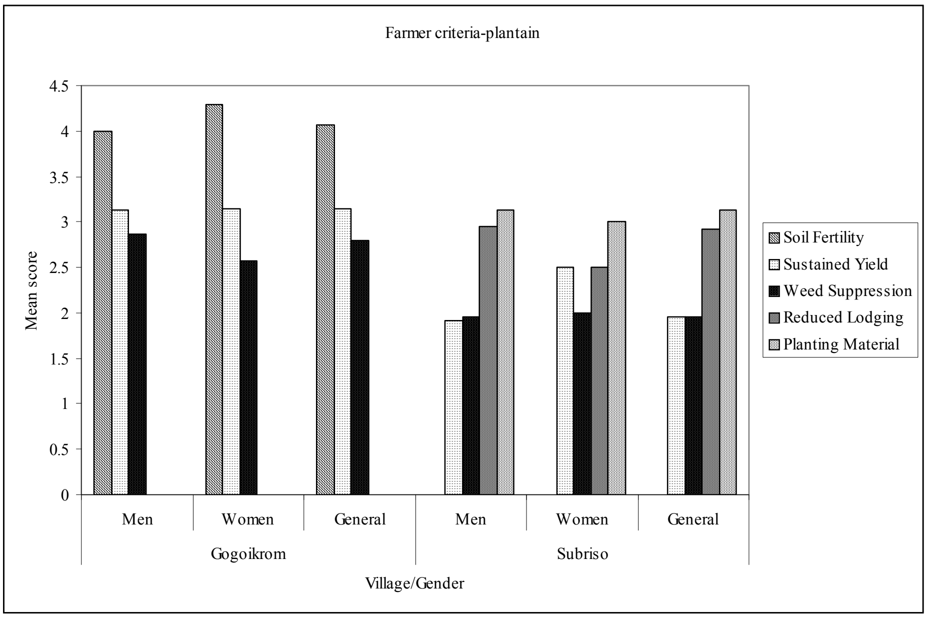


Figure 4.2.5: Farmers' indicators for evaluating permanent plantain technology

Subriso is characterized with the cultivation of more short fallow fields than Gogoikrom. Judging from farmers' ecological knowledge on fallows and soil fertility, soils in Subriso may be relatively poorer than those found in Gogoikrom, which has more, fields cultivated from long fallows. One would therefore expect more emphasis on soil fertility and weed suppression in Subriso, where these problems appear to be more prominent. Surprising emphasis was rather placed on plantain planting material i.e. suckers, mainly because of its economic value for earning extra income if sold and its importance in expanding the plantain farm.

The plantain suckers planted in the experiment were pared. Paring is an extension recommendation, which entails slashing or cleaning of the basal portion (roots and buds) of the sucker to rid it of nematodes. Farmers observed that the pared sucker grew faster (will yield earlier), developing numerous other suckers at the base, which can be sold and also facilitate expansion. Sucker development is also important in fortifying the mother plant at the base against lodging, which explains the reason for scoring reduced lodging second. Lodging in plantain is on the increase in recent times due to windstorms at the onset of the rainy season.

Indicators for evaluating cocoa-shade tree

The mean scores for the indicators for the cocoa-shade tree experimented only in Gogoikrom-Atwima are shown in Figure 4.2.6. The highest score of 5.2 out of 10 was given for high yield followed by shade and then timber. The general argument was that the hybrid cocoa used for the experiment is fast growing, early maturing and known to give high yields. Moreover, a cocoa plantation is a valuable economic asset yielding regular income for at least five decades or more. For a cocoa farm the next priority is for shade to protect the young cocoa and later from sun scorch during the dry season. Timber from the intercropped shade trees is also a valuable asset however, it takes too long a time to realize its income, and thus it attracted the least score of 2.3 out of 10.

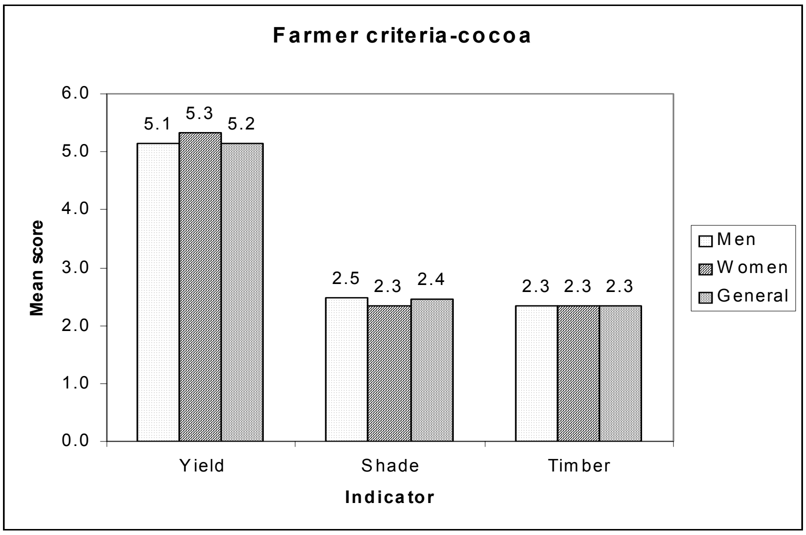


Figure 4.2.6: Farmer indicators for evaluating cocoa-shade tree technology-Gogoikrom-Atwima

Indicators for evaluating improved/Gliricidia sepium fallow

The indicators for the improved fallow technology was identified and scored by farmers of Yabraso-Wenchi, (Figure 4.2.7). Generally, improved soil fertility was adjudged the most important indicator for the *Gliricidia sepium* fallow, attracting a mean score of 3.5 out of 10 with alleviation of deforestation being the least important with a score of 1.6. Improved soil fertility was paramount because it is very essential for the production of maize and yam, the two principal crops grown. Scientifically, these are heavy feeders requiring adequate soil nutrients for good yields. Farmers observed *Gliricidia sepium* to be very fast growing producing heavy vegetative material capable of improving soil fertility.

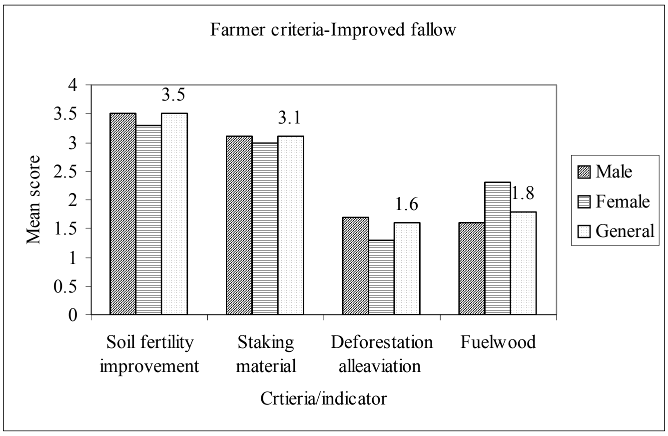


Figure 4.2.7: Farmer indicators for evaluating Gliricidia sepium fallow experiment-Yabraso-Wenchi

Wood/poles from *Gliricidia sepium* could be used as yam stakes and fuelwood. Yam is one the key food-cash crops produced in the area. Farmers explained staking of the yam is essential to ensure better yield of tuber. However, the volume of staking material is increasingly dwindling due to persistent annual wild/bush fires. Similarly, fuelwood stocks although not in short supply are also dwindling. The farmers observed that planting a *Gliricidia sepium* tree fallow would in the long run contribute to the alleviating deforestation, which is fast catching on in the area.

Men and women rated the indicators in a similar manner, except for fuelwood, for which, women placed more emphasis (mean score of 2.3 against 1.6) than men. This is obvious as women are responsible for fuelwood collection for household use. Problems relating to soil fertility and stakes are key constraints to both genders.

4.2.3 Farmer perceptions of technologies

By the end of the two seasons of experimentation, farmers had a fair judgment of the technologies with respect to particularly, their performance, value, and limitations in design. The maize – legume relay technology, because it is an annual system, had gone through two production cycles, although the third cycle to substantiate the effect of the legume on production was yet to be undertaken. Nevertheless, farmers were able to assess it better than the other three, which are perennial with effects to be estimated in the long-term. Consequently, the farmer perceptions of the technologies presented below are largely related to the maize-legume relay with some limited assessment of the perceptions on the permanent-plantain, cocoa-shade tree and *Gliricidia sepium* fallow technologies.

4.2.3.1 Value of the technologies to the farm and household

Maize-legume relay

The outcome of farmers perceptions on this technology have been reported separately for the first and second years of experimentation to primarily show the pattern in farmer judgements as their knowledge of the technologies increased over the two years.

Perceptions of technology value in the first year

Table 4.2.1 summarizes farmers' perceptions on the maize-legume technology at the end of the first season/year of experimentation. Despite the poor establishment of the legume covers on most fields, mainly as a result of insufficient rain after legumes seeds had been sown, farmers made some important observations in relation to the value of the legumes associated with the technology. On some of the maize fields where legume biomass production and spread were good, weed suppression was observed by over 50% of the farmers interviewed in each village. *Chromolaena odurata* was commonly smothered across the villages in addition other weeds such as *Centroscema pubescens, Euphorbia heterophyllum, Sporobulus* sp. and *Cenchrus ciliaris.* However, other noxious weeds such as *Rotboellia exaltata, Panicum maxima, Pennisetum purpureum* and *Eleusine indica* could not be smothered by the shrub legumes, probably due to the poor coverage or spread on some fields.

Two important soil fertility aspects or fertilizer functions of the legumes observed by at least 60% of the farmers were soil moisture conservation and litter/carpet of mulch from the decaying biomass. These are two of the main indicators by which farmers judge the fertility status of a soil. Thus a higher proportion of them anticipated the moist soil conditions under the mulch carpet and the decaying biomass would improve soil fertility, which together with weed suppression will contribute to higher yields that may ultimately, leads to improved income.

Table 4.2.1: Summary on farmers' perception of the Maize/-Legume Relay Technology

Parameter	**Farmer Perception of on-farm experiments**		
	Gogoikrom (n=12)	**Subriso III (n=15)**	**Yabraso (n=13)**
Weed smothering	Smothering of weeds (*Chromolaena odurata* & *Centrosema pubescens*) observed by 60% of farmers. *Rottboella exaltata, Cida acuta*, *Panicum maxima* and tree saplings could not be smothered	Smothering of weeds (*Chromolaena odurata*, *Sporobolus* sp, *Centrosema pubescens*, *Euphorbia heterophyllum*) observed by 71% of farmers	Smothering of weeds (*Chromolaena odurata* & *Cenchrus ciliaris*) observed by 56% of farmers. Elephant grass (*Pennisetum sp*) & *Eleusine indica* could not be smothered
Fertilizer function	20% observed cool soil under mulch 40% expect litter/mulch to rot to improve soil 40% do not anticipate any effect due to poor establishment of *Stylosanthes spp*., *Clitoria spp.* and *Canavalia spp.*	7% observed cool soil under mulch/litter 57% expect litter/mulch to rot as organic matter to improve soil 22% expert weed suppression to improve soil 14% do not anticipate any effect due to poor establishment of *Stylosanthes spp*., *Clitoria* and *Canavalia spp.*	11% expect mulch by legume to enhance soil moisture conservation 89% expect leaf litter drop from legume to rot, add organic matter to the soil to enrich or improve fertility for improved yield.
Labour requirement	60% expect decrease in labour to clear as a result of partial weed suppression by lablab, Mucuna spp. and *Canavalia spp.* (Farmers expect labour to decrease by half that of control).	79% expect decrease in labour to clear as a result of suppression of some noxious weeds by lablab, *Mucuna spp* and *Canavalia spp.* (Farmers expect labour to decrease by half). 21% anticipates no difference labour due to poor establishment of e.g. *Stylosanthes spp.*	89% expect labour requirement for esp. clearing to decrease as a result of weed suppression by legumes
Food	50% harvested *Canavalia spp.* grains for stew and soup	29% harvested *Canavalia spp.* grains for stew and soup	56 % harvested *Canavalia spp.* grains for stew and soup
Fodder	20% cut *Stylosanthes spp.* as fodder for sheep and goats	7% observed sheep & goat consumed *Stylosanthes spp.* on the farm	11% observed sheep & goat consumed *Stylosanthes spp.* on the farm
Farm Income improvement	70% expect farm income to improve as a result of expected increase in maize yield through weed suppression and improvement in soil condition (fertility, moisture)	86% expect farm income to improve as a result of increase in maize yield through weed suppression and improvement in soil condition (mulch/organic matter/fertility, moisture)	100% expect that if legumes establish well, weed suppression together with moisture conservation and legume litter drop will rot to improve soil fertility and hence, yield and farm income

40% and 14% of the participating farmers in Gogoikrom and Subriso were doubtful of the legumes such as *Clitoria spp*. and *Canavalia spp*. improving fertility of the soil on their fields because these species performed poorly. Although the legume fallows had not been cleared by the time of evaluation, 60% and over of the farmers believed labour required for this activity would reduce by at least half when compared to the control as a result of weed suppression in the legume fallows. Again, a few farmers in Subriso did not anticipate any change in labour on their fields due to poor establishment of the legume species planted.

The value of the legumes for household food and livestock fodder was also realized. About 50% of the farmers interviewed in Gogoikrom and Yabraso and 29% in Subrsio harvested grains from Canavalia for use in soups and stews. The use of Stylosanthes species as livestock fodder is well known. Although growth in the Stylosanthes was not encouraging due to moisture insufficiency, a handful of the farmers who planted it in their fallows, harvested it for livestock feed in Gogoikrom, where sheep and goats are particularly, kept in pens and stall fed during the cropping season. On the other hand, livestock is usually kept on free range to graze in Subriso and Yabraso, thus sheep and goats were observed by a few farmers grazing the Stylo in the planted legume fallows in these villages

Perceptions of technology value in the second year

Farmers used the criteria of indicators for judging the maize-legume relay technologies they enumerated at the second stage of the process in season 2 to rate its performance at the end of season 2. The results of farmers' assessment of the performance of the legumes planted in relay to maize compared to the control in the with respect to soil fertility, crop yield, weed suppression, labour requirements, soil moisture conservation and erosion control are presented in Figure 4.2.8. A score of 1 to 5 was given to farmers' rating of each indicator compared to the control as much worse, worse, same, better, much better in that order.

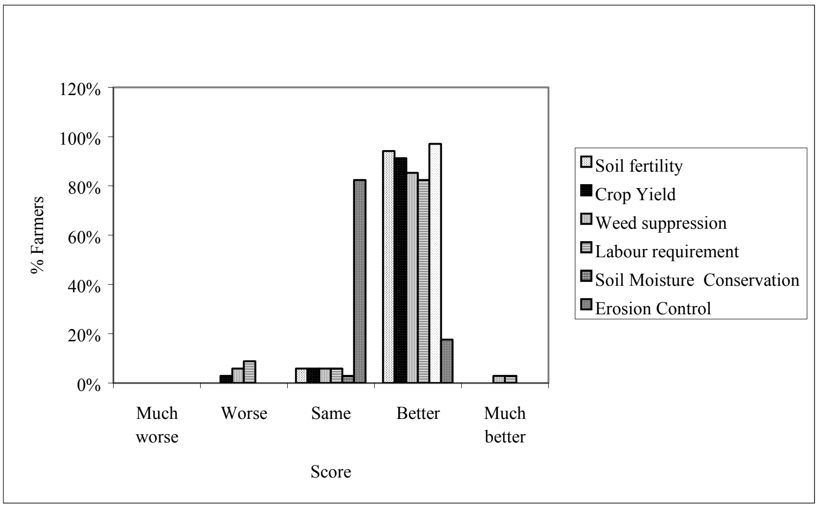


Figure 4.2.8: Farmers' evaluation of all legumes versus control in the maize-legume relay

The legumes ability to improve soil fertility and crop yield as well as suppress weeds and reduce labour for clearing the fallow and conserve soil moisture were rated better than that of the control by at least 80% of the farmers with the exception of erosion control. The comparison of legume plot against control for erosion was rated same because erosion was not a problem on any of the fields. The few (18%) who rated erosion better argued that if erosion were a problem, the legumes would have been able to control it better due to the ground coverage.

Weed suppression and soil moisture conservation were the effects of the legumes farmers had realized as at the time of assessment (September, 2002). That for soil fertility, improved crop yield and reduced labour was on their perceptions based mainly on biomass of legume coverage and spread. Farmers' believed that the heavy biomass and spread/coverage by the legumes, which has smothered aggressive/noxious weeds like *Panicum, Chromolaena, and Rotbolia* will conserve moisture particularly, during the dry season and aid the decomposition or rottening of the leaf litter. The suppression of the aggressive weeds will reduce labour for clearing in the next cropping season and the leaf litter rot will improve soil condition, thereby improving yield.

A small proportion of farmers rated the legumes same or much worse because the legumes established poorly on their fields, either due to water logging as a result of excessive rains or failure to weed after the legume seeds were sown around five weeks after sowing maize.

The performance of *Mucuna spp* was compared with that of *Canavalia spp*. against the parameters above including edibility observed to be essential with respect to farmer preference of legumes (Figure 4.2.9). These were the common fallow legumes used for the maize-legume relay.

The performance of *Mucuna spp*. with respect to soil fertility improvement, weed suppression and soil moisture conservation was rated better that of *Canavalia spp*. by about 75%-80% of the farmers. This was because *Mucuna spp* was more vigorous at growing producing heavier vegetative cover and spreading for better coverage than *Canavalia spp*. The heavier biomass meant more litter rot and soil moisture conserved for better tillage the next season and the aggressiveness in smothering weeds meant less labour for clearing *Mucuna spp.* plot as compared to the *Canavalia spp*. plot.

With respect to crop yield 50% of the farmers rated *Mucuna spp.* better than *Canavalia spp*. while 33% and 17% rated it as same and worse respectively. The 50% who rate it better explained *Mucuna spp.* was better at producing biomass coverage and suppressing weeds, thus will improve the soil for better yield than *Canavalia spp*. would do. The 33% rating the two legumes as same, argued that *Mucuna spp.* was faster at growing than *Canavalia spp*. and thus although produced more vegetative cover would at the same exhaust the soil of nutrients for its own growth. The remaining 17% explained that *Mucuna spp.* was more aggressive than *Canavalia spp*. and thus had began strangling the maize crop covering developed/matured cobs which could lead to a decline in maize yield as compared to yield from the *Canavalia spp*. plot.

42% of the farmers rated *Mucuna spp*. worse than *Canavalia spp.* with respect to labour. Farmers observed that the rapid growth and entangling nature of *Mucuna spp*. makes it difficult to weed after planting. They also argued that more biomass and leaf litter on *Mucuna spp.* plot meant more work or difficulty in clearing the *Mucuna spp.* plot as compared to that of *Canavalia spp*. The labour analysis in Section 4.1 showed the reverse. Both farmers' records of labour man days and scientists clock timed of labour used in clearing the mucuna and canavalia in the 2003 season showed that clearing a canavalia fallow requires twice the amount of labour required for clearing that for mucuna.

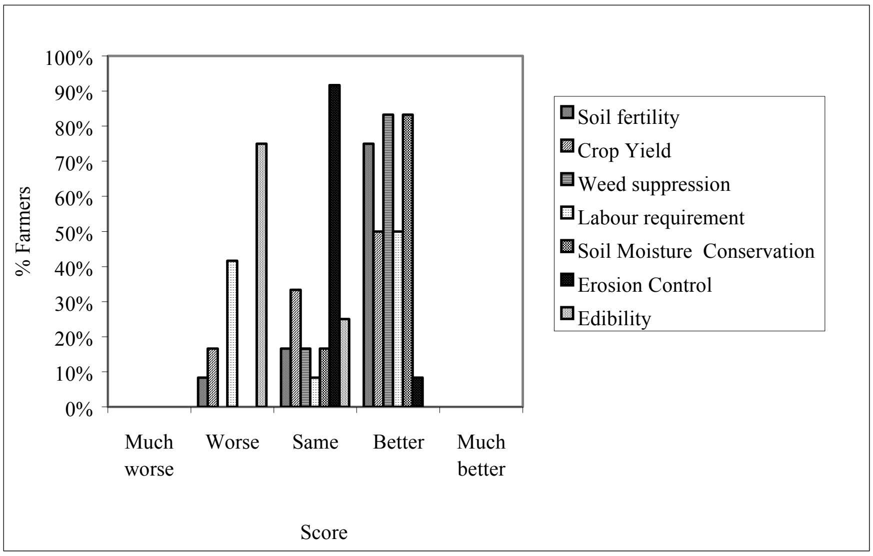


Figure 4.2.9: Farmers' evaluation of Mucuna spp vrs Canavalia spp. in the maize-legume relay

Although both *Mucuna* and *Canavalia spp*. are edible, 75% of the farmers rated *Canavalia spp*. better than *Mucuna spp* in terms of their edibility. This is because *Mucuna spp* contained some toxins in the seed coat, which required careful heating for detoxification whereas *Canavalia spp.* was being readily used in the preparation of soups and stews.

On the whole, farmers similarly assessed the positive effects of the maize-legume systems in both the first and second years. Their perceptions of the performance of the legumes confirm that reported by farmers from other parts of Ghana and other areas of the developing world, where particularly, mucuna systems are being promoted to enhance crop productivity. For instance, farmer's testing mucuna systems in other parts of the Brong Ahafo Region of Ghana appreciated its effects on weed suppression and improvements in soil physical properties and crop yields (Heinz *et al.,* 2000). Similarly, Buckles and Triomphe (1999) reported that farmers in Honduras acknowledged the fertilizer effect as a result of mucuna leaf litter improving soil fertility as well as its aggressiveness in choking out weeds, thereby reducing labour for land preparation before planting the next maize crop. The Honduras Farmers also observed that the thick mulch from slashed mucuna fallow suppressed weeds in next crop and conserved moisture. Both the decaying mulch and green mucuna crop protected soil from eroding.

According to Buckles and Triomphe, for about 36% of farmers in the study, the most important reason for planting maize in a mucuna system was the fertilizer effect of the decaying mucuna litter. Ease of land preparation and moisture conservation were also rated first by a large proportion of the farmers, while weed control rated as the second most important reason by a quarter of the farmers and erosion control by only few of them. Buckles and Triomphe were of the view that the Honduran farmers perceptions of the mucuna system can be grouped into criteria related primarily to land productivity (fertilizer effect, moisture conservation and erosion control) and criteria related primarily to labour productivity (ease of land preparation and weed control). This suggests that from farmers' point of view, the appeal of the mucuna system is its potential to respond simultaneously to both land and labour constraints to productivity.

Mucuna pruriens and *Canavalia ensiformis* are among the most promising legumes currently being studied in the humid tropics. In Ghana, the traditional food uses of mucuna and canavalia could possibly make them an option for farmers with limited land, labour or rainfall. Osei-Bonsu *et al.,* (1996) reported that many farmers in the forest and transitional zones grow small quantities of mucuna and canavalia for food. This practice has probably been in existence for about a century or more. Farmers usually plant few stands of these legumes, 4-8 stands. They observed that about 70% and 55% of respondents interviewed in a survey on traditional use and knowledge on these two legumes in the forest and transition zones respectively knew their food value. 90% and 30% of respondents in the forest and transition zones respectively consumed them regularly in soups and stews. However, none of the respondents interviewed had knowledge on the potential benefits of mucuna or canavalia as green manure or cover crops although a few knew about the use of legumes such as *Pureria spp*. and *Centroscema spp*. as cover on plantations.

Although farmers have favourably assessed herbaceous legume fallows, potential problems observed with such technologies acknowledged by farmers include risk of damage to maize by rodents that build their nests in the littler layer for protection against predators (Buckles and Triomphe, 1999). Farmers in Benin have also reported snakes under the mulch carpet in Mucuna systems (Manyong *et al*., 1999).

Farmers in the study villages also observed some limitations while experimenting with the maize-legume systems. They observed that competition between weeds and the legumes retarded legume establishment in the first year. The aggressive nature of weeds such as *Chromolaena odurata* (*acheampong)* and *Panicum maxima* (*eserè*) suppressed the legume. Moreover, the legumes were sown when maize was either tussling or developing cobs by which time the legume was likely to suffer from shade effects. This situation was worsened if the farm was a mixed one with other crops like cassava, plantain and cocoyam. They anticipated problems with particularly snakes, although none of them had encountered one.

Permanent Plantain/Plantain-legume technology

Farmers had little to say by way of their perceptions of the plantain-legume technology at the end of the first year as the fields were still in the establishment phase. This is because farmers suggested planting of the experiment during the minor season to prevent lodging by strong winds at the onset of the rainy season in early April, the following year. However, on some fields, farmers observed that the legume species planted in the experiment namely, *Canavalia ensiformis, Gliricidia sepium* and *Flemingia macrophylla,* had the potential to thrive throughout the dry season, a characteristic, which they believed would enable soil moisture conservation to enhance plantain growth. Moisture is critical for plantain during the dry season as the stem of the crop usually desiccates due to the low relative humidity during this period, retarding growth and causing warping and/or toppling.

The technology was rated against the listed indicators at the end on the second season. Four farmers, comprising one woman and three men were available to individually rate their experiments. Their perceptions are summarized in Figures 4.2.10-4.2.11.

All three legume treatments were generally judged better than the control for nearly all the indicators. These perceptions were based on the fact that biomass produced from the legumes will decompose, ultimately, enhancing plantain growth while conserving moisture and suppressing weeds. However, in some cases one or two of the farmers felt the legume treatments did not differ from the control with respect to planting material development and lodging. This might be explained by the fact that suckers planted in both the legume treatments and the controls were similarly pared. Farmers observed that this causes proliferation in sucker development as the pared one grows into a mother plant. According to farmers, the level of planting material i.e. plantain sucker development by the mother plant has an influence on the degree of lodging in plantain. The suckers fortify the mother plant against lodging, hence, the higher the number, the better the fortification.

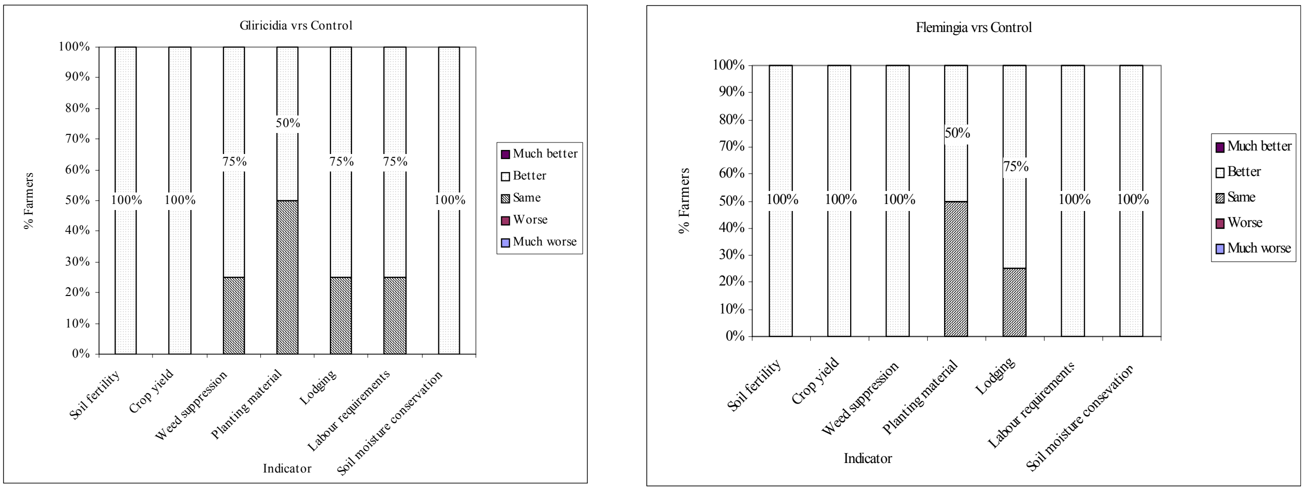


Figure 4.2.10: Farmer perceptions on plantain-gliricidia and flemingia against the control

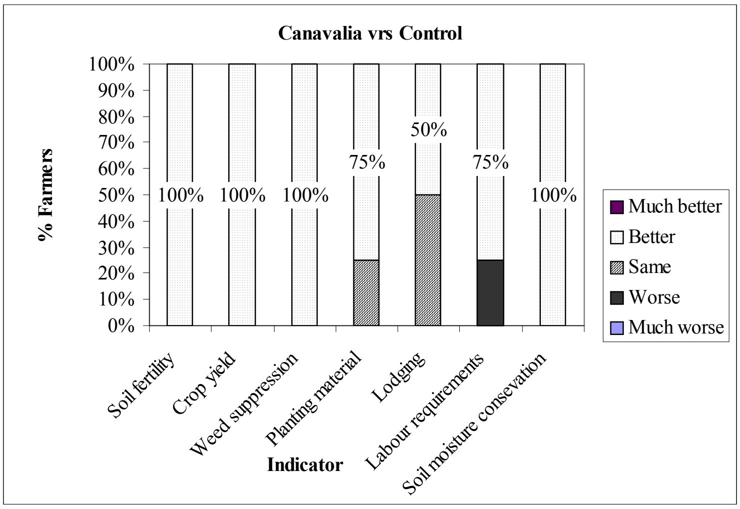


Figure 4.2.11: Farmer perceptions on plantain-canavalia against the control

One man rated the labour requirements for the gliricidia and the control to be the same with the reason that while weed control might be a problem in the control, the gliricidia will require cutting (i.e. pruning) which involves labour. The woman was of the view that the shrubby nature of canavalia planted in the alleys hinders weeding, making the canavalia treatment more labour intensive (rated worse) than the control.

Cocoa-shade tree

The cocoa – shade tree technology is the most long-term (up to 80 years rotation possible) system of the four technologies farmers experimented. Thus even at end of the second year, the majority of farmers could not readily rate the technology against the set indicators, i.e. increased cocoa yields, protection from shade and timber, as the experiments were in the establishment phase.

Nevertheless, about 17% of the farmers, based on their traditional knowledge of the benefits of shade in cocoa system, scored the technology with the planted shade trees better than the control with respect to all three indicators. The main reasons being the trees providing shade to reduce sun scorch, conserving moisture (for both soil and cocoa trees especially, in the dry season) and improving the soil to improve cocoa growth and yield as well as the possibility of timber to be harvested. Two out of the 18 (11%) farmers interviewed for the cocoa rated the technology with and without the planted shade as the same. They reported of having sufficient naturally occurring shade trees on the control plot, hence, the long term effects between the two systems were likely to be similar.

Improved/*Gliricidia sepium* Fallow

The rotation period considered for the gliricidia fallow is as least three or five years depending on the availability of land and the end use of the fallow. Farmers could not express their perceptions on this technology during the first year assessment as the giricidia had not yet taken off due to inadequate moisture. Two female farmers out of the six who planted this technology in Yabraso rated its performance at the end of September 2002. Basically, each perceived the gliriciia fallow as being better than the natural fallow in all respects. Particularly, the luxurious biomass of the gliricidia is expected to improve soil fertility and crop yield. Its branches if well developed could be harvested for use as stakes more readily and also for fuelwood.

4.2.3.2 Workability of technologies

Technological components and design

Table 4.2.2 summarizes farmers' assessment of aspects related to the design of the technologies.

Desirable aspects

The systematic planting of the various components of the experiments was an aspect that farmers commonly desired. While this increased maize plant density, it eased working in the plantain and cocoa. The legumes and shade trees were also desired. The legumes smothered weeds and had the potential of improving the soil whereas the shade trees of the cocoa experiment would alleviate dry season sun scorch of cocoa.

Farmers observed that the wider spacing adopted for the cocoa and shade trees would enhance spreading of their branches for the development of more cocoa pods. Farmers usually plant cocoa by direct seeding and densely to ensure faster canopy closure to reduce weeding labour. Ideally, the cocoa should be later thinned out to enhance branching and pod development after the plantation is well established. However, most farmers are reluctant at thinning due to the extra labour involved and difficulty in cutting down fruit bearing trees to waste the fruits. Farmers claimed the wider and regular spacing (3mx3m) adopted would save the extra labour spent in thinning out, facilitates working on the farm especially, replacement of dead cocoa seedlings and prevent wasting of cocoa planting material.

Table 4.2.2: Summary on farmers' assessments of aspects of the design of on-farm experiments

Trial design	Maize legume-relay	Permanent plantain	Cocoa –shade tree	Planted tree fallow
Aspect liked	Legumes (82%): weed suppression, increase soil fertility Line planting (58%): more maize planted	Line/row planting-Eases work Paring of plantain -Increase yield & planting material Legumes-soil improvement likely from biomass rot	Regular planting/spacing of coca & shade trees -Eases work esp. weeding & replacement of dead seedlings Planting of shade trees -Protection against dry season sun scorch	Legume species-fast growing
Aspects not liked	*Mucuna spp* (18%): Weeding after planting *Mucuna spp* difficult Time of planting legume, i.e. *Mucuna spp* (41%)-*Mucuna spp* strangled crop (5-6 weeks)	*Canavalia spp*. close spacing retards weeding	Wider spacing enhances weed growth	None
Modification	Time of planting legume, esp. *Mucuna spp*: 6-8weeks to prevent strangling	*Canavalia spp*. spacing -Plant in rows to ease weeding labour	None	None
Aspect likely to adopt/extend to other farms	Line planting of maize (82%): increase yield Legumes (42%): suppress weeds *Canavalia spp*. –food	Legumes -Improve soil Row planting plantain, Flemingia and *Gliricidia sepium* -Ease weeding labour Paring plantain suckers -Increase planting material & ensures fortification of mother plant against lodging	Spacing -No later thinning & pruning of cocoa required -More branch spread of cocoa for more yield Shade trees -Dry season shade protection for cocoa	Legume species

Paring of plantain is a relatively new extension recommendation aimed mainly at enhancing plantain maturity and reducing nematode and termite infestation prevalent on plantain farms. The technology involves cleaning of the basal part of suckers intended for planting by cutting off roots and root nodes and shortening the stem of the sucker. The debris containing possible disease pathogen is left behind and the sucker taken for planting at the intended site. This also reduces the weight of suckers especially, if they are to be transported to other fields for planting. Farmers' in Gogoikrom and Subriso III did not seem to know this technique probably because it has not been introduced to them.

Undesirable aspects

Undesirable aspects of the experiments were more related to the growth habits of Mucuna spp for the maize-legume relay, spacing of the Canavalia spp. for the permanent plantain and wide spacing of the cocoa and shade trees of the cocoa experiment. Mucuna spp is fast growing and its creeping vines spread very fast entangling all available plants retarding weeding and harvesting of maize. This occurred in the 2002-growing season when the legume seeds were sown quite early between 5 and 6 weeks after sowing maize to ensure that the legume plants obtained adequate rain for good establishment. This was because of the poor legume establishment due to inadequate rain after sowing the legumes in the previous year when the legumes were planted 7-8 weeks after sowing maize.

Similarly, *Canavalia spp.* established poorly in the previous year, hence the dense shrubby vegetation produced with adequate rain in 2002 retarded weeding. For the cocoa, although farmers anticipate more branch spread due to the wider spacing, they are of the view that this at the same time enhances weed growth increasing weeding labour.

Modification in technology design

With regards to modification, farmers suggested sowing *Mucuna spp* seeds later than 5-6 weeks, probably, 8 weeks after sowing maize to prevent strangling as those who planted their legumes between 7-8 weeks had fewer problems with the *Mucuna spp.* However, experience over the two years of experimentation shows that the time for sowing the legumes to ensure good establishment depended more on the weather. Due to irregular nature of the weather, it appears the suitable time has to be gambled between 5 and 8 weeks of sowing maize. 2002 was particularly, a normal year with good rains well distributed throughout the growing season, thus apart from sowing early, the legumes had adequate rain for better establishment as compared to 2001 when the rains reduced in amount and frequency shortly after legumes were sown. Some farmers suggested that due to the shrubby nature of the *Canavalia spp.* it should be planted at wider pacing between rows to facilitate weeding.

Technology design aspects to adopt/extend

Almost all the participating farmers expressed the desire to adopt/extend the regular planting pattern and the legumes/trees for all the experiments for reasons elaborated above. Planting in rows or regular pattern eases working on the farm especially weeding and also increases yield. Planting in rows is an age-old extension recommendation aimed at increasing yield per unit area. Ironically, farmers in most farming communities do not practice this simply because more labour is used in this systematic planting as compared with the random/irregular planting commonly done.

For the permanent plantain, the desire to adopt the paring technique for the plantain suckers was to increase planting material availability & ensure fortification of mother plant against lodging particularly, by strong winds associated with early rains at the onset of the growing season. Legumes in maize & and particularly, *Gliricidia sepium* in the plantain will be adopted because of the high potential for smothering weeds whereas for the shade trees in the cocoa it is because of its protection of the crop in the dry season.

4.3 Adoption potential

This section briefly dilates on the adoption potential of the technologies. It was hypothesized at the onset of the study that working with farmers in a participatory manner to design and develop the technologies for improving fallow productivity would enhance their adoption as this would enable short falls that are likely to impede adoption to be addressed during the experimentation process.

The literature is replete with numerous factors that influence small farmers' adoption decisions of improved agricultural technologies in the developing world. Commonly reported ones include those relating to land availability, land and tree tenure, labour availability and cost as well as the profitability of the technology relative to the old practice. Other important factors that have been reported are the duration it takes for benefits to be realized, the need for the technology (i.e. whether technology solves a perceived problem), availability of technological inputs including seeds, cash to purchase the necessary inputs, the know-how and/or access to information or extension advice. Other classical adoption determinants that have also been reported relate to education level of farmers, age, and gender and so on. Most of these factors may have relevance for this study; however, some key ones that may be of relevance to the technologies in relation to the management of fallows and crop production in the study villages are discussed below. Table 4.3.1 summarizes the general adoption potential of the technologies as influenced by three main factors/characteristics namely gender, land wealth/status and age of the farmers in the villages.

Table 4.3.1: Percentage of farmers in village population[1], participating in experiments[2] and not participating in experiments[3] across study villages

	Villages											
Farmer categories	**Gogoikrom-Atwima**			**Subriso III-Tano**			**Yabraso-Wenchi**			**Total**		
	VP[1]	**EF[2]**	**NE[3]**	**VP[1]**	**EF[2]**	**NE[3]**	**VP[1]**	**EF[2]**	**NE[3]**	**VP[1]**	**EF[2]**	**NE[3]**
Gender												
Male	74	76	68	62	72	56	67	48	75	68	69	66
Female	26	24	32	38	28	44	33	52	25	32	31	34
Land wealth												
Native landowner men	8	5	14	18	41	4	36	35	36	21	21	20
Native landowner women	6	5	9	10	16	6	35	48	30	17	17	17
Settler landowner men	16	9	36	18	13	22	1	0	2	12	8	15
Settler landowner women	4	3	5	8	9	8	1	0	2	4	4	4
Settler landless men	50	62	18	31	19	39	25	13	30	35	40	31
Settler landless women	16	16	18	14	3	22	2	4	2	11	10	12
Age groups (years)												
<35	35	29	50	26	3	40	18	0	25	26	16	35
35-45	28	31	18	37	31	40	46	61	40	37	37	37
46-55	24	26	18	18	34	8	23	17	25	21	27	17
>55	14	14	14	19	31	12	13	22	10	15	20	11

Table 4.3.2: Comparing participating & non-participating farmer in study villages

Chi-square test	Gogoikrom	Subriso III	Yabraso	Total/All villages	Degrees of freedom	Significance 0.05	Significance 0.01
Gender	0.49	2.18	5.59*	0.19	1	3.84	6.63
Land status	15.74**	24.80**	4.71	4.09	5	11.07	15.09
Age	3.31	22.89**	9.48*	14.40	3	7.81	11.34

Chi square test: * significant at $p = \leq 0.05$; ** significant at $p = \leq 0.01$

A farmer's inherent innovativeness may naturally determine his or her desire to either try new things or decline from doing so. However, any production decision made in smallholder systems is a combination of several factors including resource capacity, culture, values and so on. The interaction between gender, age and land wealth influenced farmers' decision to participate in experimentation. To be able to participate in experimentating any of the technologies implied having an appropriate tenure associated with particular test crop to enable the farmer benefit from the innovation. Moreover, gender roles within the household as well as gender and age niches associated with particular test crops also influenced the desire to experiment.

4.3.1 Gender, age & land wealth/status

Generally, all the main community groupings participated in trying nearly all the experiments in the first and/or second year, except the planted tree fallow in Yabraso, for which only native landowners showed interest. The population in the study villages is dominated by male household heads or decision makers in crop production, thus naturally men are more likely than women to be involved in implementing activities aimed at attaining improved changes in some aspects of the farming system. Consequently, more men than women participated in the experimentation and are likely to be the prime adoptors of the technologies, although in Yabraso there were more women experimenters. The Yabraso exception for the women is probably because majority of the population are native men and women landowners hence, these women have a higher autonomy over their production decisions as although may be married, they usually cultivate lands belonging to their own individual families or inherited from parents. The equally higher proportion of male non-experimenters could be due to restrictions imposed by land status, age and gender niches in crop production particularly among younger and landless men in Subriso and Yabraso.

Generally, the probability of adoption can be expected to be higher for land-rich/landowners than for land-constrained/tenant farmers (Buckles & Triomphe, 1999). There is a higher chance for more of the landowners particularly, native middle aged and older landowners taking up the technologies in Subriso and Yabraso than the landless and younger people in these villages. The native middle aged and older people especially, the men appear to be more stable in terms of land and/or cash resources; hence may be in a better position to cope with the uncertainties and risks associated with adopting new technologies and are more likely to take interest in long term conservation issues. Whereas the landless and the general younger population appear to be fluid and more oriented to short term cash opportunities. For the landless majority who could not participate in these villages, insecured tenure to sharecropped (Subriso) or rented land (Yabraso) discouraged participation as tenancy to their maize fields may only be for one year, although accessing land may not be too much of a problem. Some tenants who planted the maize-legume relay technology discontinued participation as they lost access to the use of their plots in the second season. The seemingly favourable *abunu* tenure for cocoa in Gogoikrom contributed to the greater participation of settler landless men.

Adoption of fallow management innovations may be very sensitive to realities of uncertainties surrounding land tenure (Cairns & Garrity 1999). Secured land tenure encourages farmers to consider long-term planning horizons for adoption of agroforestry technologies. A low incidence of shared tenancy (i.e. most people own land) may enable farmers capture the full benefits of investments in long term land improvements. Land tenure security consequently affects farmers planning horizons and the confidence with which they expect to benefit from long-term investments in soil improvement (Nelson *et al.,* 1998). Shared tenancy is quite high among the landless in the study areas, although rental by cash is more common in Yabraso-Wenchi as it provides a relatively easy means for accessing land for cultivation without having to pay for the cost of using the land upfront. Consequently, Settler landowner men showed less interest in participation particularly in Gogoikrom and Subriso where a couple of settler landowners are found. The observed trend in Gogoikrom is unclear as some men of this age group participated in planting the maize technology but dropped out in the second year. However, in Subriso they are more involved in vegetable production, thus are unlikely to take up technologies related to maize that is usually cultivated by the landless and elderly landowner men or plantain for the elderly landowners. The high proportion of young people who did not show interest in Gogoikrom was because maize is predominantly cultivated by younger landless men from the north having limited tenancy to maize plots.

Generally, fewer women showed interest in participation. Women tend to be more occupied than men due to the extra responsibility for household chores. Thus they are less likely to participate fully in such activities (Obiri, 2003). For the majority of the landless settler women in all the villages, the chance to participate in planting any of the technologies may rest on their spouse's willingness to participate as the men are usually responsible for the joint fields they usually cultivate. In Subriso and Yabraso, these people are less likely to participate in trying any of the technologies as their husbands were less interested. However, those in Gogoikrom may have the chance to share in the experience of trying the cocoa-shade tree technology.

Several studies in Africa in the 1990's revealed that women farmers were unable to adopt agroforestry innovations including improved fallows. The main limiting factors were lack of knowledge of the new technology, lack of access to seeds or seedlings and cash or credit to acquire them. It was observed that structural factors such as lack of land and labour by women posed more serious problems to adoption prospects than factors more amenable to policy intervention such as lack of knowledge or seedlings (Galdwin *et al.,* 2003).

4.3.2 Others

Other indirect fators that can be inferred from the study to explain the adoption potential of the technologies include literacy levels, profitability of technologies, labour requirements and the availability of planting material.

4.3.2.1 Education

The proportion of literate farmers who tried the experiments was slightly higher (55%), compared to 45% of the illiterates. This trend seems to suggest that there might be other important factors that propelled farmers to participate and that formal education may have little influence on adoption of the technologies. However, it also gives an indication that the technologies can be adopted by both literate and illiterate farmers because the techniques involved are not complex, although being literate could motivate innovativeness and the urge to try new things.

4.3.2.2 Profitability of technologies

High establishment costs increase the risk of negative returns from agroforestry interventions with trees and shrubs in the short term reducing incentives for adoption (Nelson *et al.,* 1998). The economic assessment of the technologies in section 4.1 indicates that the technologies are profitable both in the short and long-terms which should make them attractive for adoption. They do not require huge capital outlay, as returns gained far exceeds seeds and labour costs that may be incurred.

4.3.2.3 Labour

Farmers are often constrained with labour. It is often believed that most small-scale farmers are unable to engage additional labour due to their usually poor financial status. Thus, so long as the labour demands associated with an innovation is not so high and as long as labour is readily available, and unless other factors take precedence, adoption of an innovation should be enhanced. Also, a technology is attractive for adoption if its returns to especially labour are higher than farmer's traditional practice. The return on labour was high for the technologies farmers experimented. The extra labour costs are for planting and managing the fallow species. Although, this is not substantial for all the technologies except for the plantain-legume which involves a higher labour investment in periodic mulching and pruning, labour to relay and weed the legume may pose slight problems. Available cash resources are low during the period this activity is done even if labour is to be hired and demand for labour to weed is high. However, the technology has the potential to reduce weeding in the subsequent cropping season and moreover; the return on labour is high.

4.3.2.4 Availability of planting materials

Availability of adequate and appropriate planting material, i.e. seeds & seedlings of tree species may favour agroforestry adoption. Of equally importance is the means of procurring the planting material, especially financial resources for purchasing and transporting the material. While the seeds of the herbaceous legumes tend to be less expensive and farmers are likely to plant fields of less than a hectare in size, cost of seeds for these fallow species may not pose much constraint to adoption. Moreover, they do not need to be propagated in the nursery making them easier to manage. The cost of acquiring the indigenous tree seeds may be low as they can be collected from the wild and the quantity planted may be low, although nursing into seedlings is required, which the farmer can do at his own leisure at the backyard but will require labour for watering. However, the purchase and transportation of gliricidia seedlings may discourage its adoption as this require a comparatively, higher investment.

The seeds of the herbaceous legume fallow species such as mucuna and canavalia and that of the tree legumes (gliricidia) are available locally in the regions where the study was conducted. The sources may not be known to the farmers in their local areas, however, these species seed profusely, thus enabling farmers to collect/harvest sufficient quantities for subsequent use. A potential market may develop in the future for these species in the traditional communities as the technologies gain prominence and farmers harvest more than they need for their own use. The indigenous tree species used in the cocoa experiment are locally available in the wild in the village and its surrounding communities. Since farmers already possess the knowledge for nursing seedlings, techniques for collection and processing the tree seeds in order not to loose viability may be important in ensuring sufficient quantities for planting and to encourage adoption.

4.3.3 Knowledge gained and spread

The impact of a project or a new technology at the end of farmer participatory research process can be realized in many ways over different time-frames and forms part of a complex causal sequence, with one aspect of the possible effects leading to the development of the other. Thus, some effects may be immediate (e.g. organized farmer groups resulting from the FPR process), intermediate (adoption of the technology) and long term (e.g. improvement in fallow productivity /crop yields and ultimately, farm income) (Cramb & Purcell 2001).

New knowledge acquired

Farmers who experimented with the maize-legume relay, permanent plantain and the improved/planted tree fallow mentioned their experience with the legumes for improving soil fertility and suppressing weeds as the new knowledge they have acquired. Obviously, before the introduction of the technologies, no farmer in any of the three villages had ever deliberately planted any plant species to enhance fallow productivity or planted trees in plantain to enhance yield. 12% of the participating farmers interviewed reported of seeing non-participating farmers planting Canavalia spp. on their fields. This is not surprising as Canavalia spp. is being consumed.

Similarly, the cocoa experimenters in Gogoikrom mentioned the deliberate planting of shade trees as the new thing learnt as shade trees on cocoa fields are often from naturally occurring coppice shoots of desirable trees left during clearing of the vegetation to plant cocoa.

As mentioned earlier on, planting in rows or systematically in lines is an age-old extension practice which farmers have not adopted because it is laborious. However, most of the participating farmers mentioned this as a new planting technique learnt. This probably, means farmers had not appreciated the trade offs between the extra labour required and the usefulness of the technique in increasing yield and facilitating work on their farms until now. At least 53% of the participating farmers interviewed had observed some non-participating farmers planting their maize and plantain in rows. For the cocoa farmers planting systematically at wider spacing was entirely new as this had never been done in the village. The paring of plantain suckers associated with the permanent plantain experiment was also a new technique farmers had learnt, as this had never been done in Subriso III and Gogoikrom where this experiment is being tried. Farmers are very appreciative of the fast development of pared suckers planted as they produce many other suckers at the base making available planting material for extension of the plantain farm or sale to earn income.

Potential knowledge spread/diffusion

It is known that the adoption of any new technology is usually a slow process and that in most cases the diffusion of new agricultural practices that become widely adopted usually begin very slowly before gathering momentum (Dillman, et al. 1989). Thus although the number of farmers participating at this initial stage may be low, diffusion prospects are high.

88% of the farmers trying the various technologies reported of having ever discussed or had a conversation concerning the new techniques they had learnt with friends & relatives in their respective villages as well as some visiting friends from nearby villages such as Techimantia (Subriso III). In Gogoikrom-Atwima, some nearby villages like Abasua and Kyenedaso got interested in trying the cocoa-shade tree experiment. The chief of *Abasua* had already started a tree planting project with his subjects, thus planting cocoa and shade trees was a an opportunity to encourage his people to plant trees. To some extent it could be argued that their interest for experimenting was mainly to benefit from the hybrid cocoa seeds being supplied by the project.

4.3.4 Farmers interests and expectations

Farmer interests for participating

An assessment of the fundamental reasons underlying farmers' interests at participating in trying the various technologies revealed that the supply of planting materials such as cocoa, legume, tree & maize seeds were the principal factor that enticed all the farmers to participate. Of course the project supplied those planting materials as incentives for participation except the legume and tree seeds and seedlings that were not readily available.

It was also realized that the economic value of test crop attracted especially, farmers in Gogoikrom-Atwima and Subriso III-Tano. In Gogoikrom about forty farmers participated in the cocoa-shade tree experiment over the two years whereas the numbers for the plantain and maize declined. This is because cocoa is the main cash crop at Gogoikrom and especially, the hybrid being used is not easy to come by. In Subriso, maize and plantain are very important cash earners thus more farmers got interested in trying the maize and plantain technologies than in Gogoikrom.

Some of the farmers also reported that they participated in trying the technologies because they were anticipating financial support for farming from the project whereas for a few others it was because they realized that it was an opportunity to improve the soil, obtain food for sale & consumption as well as access planting material for subsequent use.

Why farmers not participating

A survey of 99 (average 33 per village) non-participating farmers at the end of the second season showed that over 80% of them were aware of the experiments in the respective villages. The main reason given for not participating for the majority was not being present in the village at the time participants were being listed. This was however doubtful as despite the adequate notice given in all the villages, most of the farmers were in their homes unconcerned when the meetings for listing farmers were convened. For the majority of them it was either because they did not own land and therefore felt reluctant to experiment or for those who were capable of accessing land, it was due to the usual uncertainty that farmers express with trying innovations.

Some farmers participated in the first year but did not continue in the second year. According to these farmers it was because of the poor outcome of the previous year's experience of the intervention. The legumes established poorly on most fields, hence, could not perform the job/result farmers anticipated, e.g. suppress weeds. As mentioned above, this was due to inadequate rains after planting, which discouraged some farmers from continuing or even others from joining in the second year. Lost of tenure to use of their experimental plot in the second year also prevented the continued participation of some tenant farmers.

For some non-participating farmers it was because they realized the project provided no financial support. In fact in Yabraso-Wenchi, a second project was initiated in 2002 at the village entitled Food Security Project. This was FAO-Ghana Government/African Development Bank Project aimed at improving food production in the short term. The project provided credit in the form of cash, seed maize and fertilizer inputs to the tune of 1.5 million cedis. Consequently, although a number of farmers got listed for the fallow project and were supplied with planting materials, they shifted to join the Food Security Project to benefit from the cash and fertilizer credit.

Whereas some farmers never attended any of the project village meetings because they thought those meetings were politically oriented and thus lost the chance of participating, others who were present but failed to participate as they feared that proceeds resulting from the experiment would be taken away by the outsiders.

Expectation Met?

The maize-legume relay experiment was the only one that had produced some immediate results to meet farmers' expectation at the time of the evaluation in September 2002. 88% of the maize farmers observed that noxious weeds suppressed such as *Panicum maximum, Rotbolia exaltata,* *Cenchrus ciliaris* and *Chromolaena odurata* had been smothered on their fields. They also observed moist soil conditions beneath the legumes. The legumes established well in the second year and formed very thick carpet of biomass in some cases. Reduction in noxious weeds which often compete with the maize crop for soil nutrients and moist soil farmers anticipate would increase maize yield when their experimental fields are cultivated in the 2003 growing season. They explained that these conditions coupled with decomposition of the legume biomass will enhance maize growth. Farmers trying the plantain, cocoa and planted tree fallow technologies believed their expectations would be met as there are enough positive signs of their experiments achieving good results.

4.3.5 Prospects of Continued Participation & Extension of Technologies

At Gogoikrom, 90% of the farmers expressed desire to continue the experiment for the benefits of weeds suppression, soil improvement and effect on the farm from continuous cover cropping. 80% said they could expand the technology to other farms for the same reasons). One woman who tried the maize-legume technology expressed the desired to discontinue after the first season due to the poor performance of the Styloxanthes spp she relayed. For the cocoa experiment farmers would like to continue to take advantage of the provision of improved planting material and shade trees to protect the cocoa and enhance yield.

Similarly, at Subriso III and Yabraso, the participating farmers also showed interest in continuing the experiment and extending the technology to other fields, mainly because of suppression of noxious weeds, which can reduce labour, required for clearing. It was also because of the potential of the technology to improve soil fertility to improve crop yield. For two of the farmers (women), it was because of the edible nature of Canavalia spp. For others, it was to observe the long-term effect of the technology on crop production.

4.3.6 Suggestions to improve technologies & encourage uptake

Farmers made some suggestions for improving the intervention and encourage participation (Table 4.3.1).

Table 4.3.1: Suggestions to improve technologies & encourage uptake

Gogoikrom	Subriso III	Yabraso
1. Dual purpose legumes preferred 2. At least one weeding required to improve establishment of legume cover 3. Legumes and trees should be planted early to take advantage of rains for better establishment 4. Increase number of shade trees in cocoa	1. Legume should be planted early to take advantage of rains for better establishment 2. Increase size of experimental plot 3. Assist with other inputs (cutlasses, etc. at subsidized prices)	1. Maize should be sown earlier in the rainy season 2. Legume should be planted early in the rainy season for better establishment (one farmer suggested 6-7 weeks after planting of maize) and to prevent rodents removing seeds 3. Increase quantity of legume seeds and tree seedlings 4. Closer spacing of legume cover for better density and coverage

A very important issue that was critical to the success of particularly, the maize legume relay experiment was the need to weed before sowing the legume seeds and at least once after sowing due to rapid weed growth particularly of grasses and *acheampong* (*Chromolaena odurata*) at the areas where maize is predominantly cultivated.

It also become evident that farmers preferred dual-purpose legumes which could produce grain for food and suppress weeds, improve soil, etc. as well. Most of the farmers were in high anticipation of financial support from the project, which they mentioned was the key issue that discouraged some of them from active participation.

Some farmers suggested planting the legumes randomly, i.e. unsystematically. It is easier to sow seeds unsystematically, like they do for maize. Bush fire destroyed some of the experiments in the dry season. To this farmers suggested the planting of evergreen trees to protect their fields from bush fire.

5.0 Summary, Conclusions & Recommendations

5.1 Summary & Conclusions

The main objective of the Bush Fallow Rotations Project was to design /develop with farmers' technologies for improving the productivity of shortening fallows in a participatory manner to suit their ecological and socio-economic/cultural conditions. It was observed from the initial characterization that the livelihoods of at least 90% or more of the population in the project villages depended largely on the cultivation of land/soil, as crop farming was the main occupation and income source for households.

Soil/crop productivity on most fields particularly those cultivated to food crops, is sustained through fallowing. The implication is that fallows are critical in sustaining livelihoods. However, fallow periods have declined and numerous associated problems of which poor soils, high weed pressure, poor yields and farm income are paramount. It is mostly landowners who fallowed land when its productivity declined for periods ranging from 1-4 years while tenants often abandoned such lands after deriving the maximum benefit out of them in search of better ones. Thus where the population of landless food producers were high as found in all three villages, exploitation without any obligation to ensure sustenance of the productive capacity of soil resources threatens the sustenance of the livelihoods of the people.

Developing appropriate technologies for increasing the productivity of short fallows to sustain farm production and livelihoods was thus imperative. However, farmers are often reluctant to adopt research recommendations mainly due to lack of understanding on the part of research and extension of the constraints under which farmers operate, necessitating the PTD approach to ensure that technologies developed for improving fallow productivity. Developing or testing a new technology with the potential users forms a link between research and development (Kwesiga *et al.,* 1999) making agricultural research more effective (Frost, 2000 citing Okali *et al.,* 1994) as the technology devloped suites farmers socio-economic/cultural settings, thus, enhances the prospects of adoption for a higher impact on poor farmers' fields (World Bank, 1996) and ultimately, their livelihoods.

For the past two decades or so various forms of soil fertility restoration technologies are being pursued to address the decline in productivity under shortening fallow rotations. These range from organic (animal and green manure, compost, mulch, short-term intensive fallows, agroforestry, etc.) and inorganic/chemical fertilizers. Short-term intensive fallow systems commonly called improved fallows involving short-rotation herbaceous, woody and/or other perennial species are being increasingly, considered as an alternative means of sustaining crop production in impoverished farming systems of Sub-Saharan Africa (Kaya *et al.,* 2001). The fallow is enriched with fast-growing trees, shrubs or vines to accelerate soil nutrient recovery with little external inputs, while employing traditional farming skills. Maize-legume relay, permanent plantain, tree-crop, planted tree fallow, cocoa-shade tree and livestock-compost are four of such technologies that were proposed at a stakeholder/planning workshop to address the plethora of constraints related to shortening fallows, tenure and farm income in the study communities, as described in the preceding sections.

Farmers rated these interventions. The discussions on reasons for their choices and iterations lead to the identification of priority on-farm experiments appropriate for the three study villages. Farmers in rating interventions dwelled more on the economic and food importance of the test crop component, i.e. maize and plantain for food and cash, cocoa for cash and asset, etc. It was also observed that they were consistent in their preferred choices, which were often appropriate first for their socio-economic standing with respect to security of tenure and then prevailing cropping and ecological systems.

Five main interventions/technologies were finally identified as suitable for on-farm experimentation in the study villages. The main objective of experimenting under farmer conditions was to develop, test and/or demonstrate new technologies/innovations that are to be adopted by farmers. Maize-legume relay, permanent plantain, and cocoa-shade tree technologies were suitable for Gogoikrom-Atwima; maize-legume relay, permanent plantain and planted tree fallow were suitable for Subriso III – Tano, while maize-legume relay, yam-legume relay and planted tree/Gliricidia fallow were ideal for Yabraso-Wenchi. The experiments were essentially designed by researchers but managed by farmers. A total of 108 farmers tried these technologies over two years/seasons, i.e. 2001 & 2002, comprising 54 for maize-legume relay, 38 for cocoa-shade tree, 10 for plantain and 6 for the planted tree/Gliricidia fallow across the study villages. An average of 50 farmers were also taken on exposure visits to the projects' demonstration site and that of a GTZ project undertaking similar experiments with farmers each year for the two years of experimentation.

Farmer experiments were monitored jointly by farmers and researchers at three stages i.e. beginning of the planting season through mid-way to harvest time/end of season, during which socio-economic and biophysical data was gathered by researchers and farmer perceptions were solicited.

The potential of fast growing leguminous species including *Mucuna spp, Cajunus cajan, Canavalia spp, Gliricidia sepium* and several others to improve soil fertility and effectively control weeds at lower costs on crop lands while providing edible grain and extra income from their sale is widely reported. Systems involving the use of these species in a short fallow system can be described as low cost and low inputs but profitable and environmentally safe or friendly technologies that can be used to reclaim degraded lands while improving the livelihoods of poor people.

The results from farmers' assessment of the experiments in the first year showed that some farmers observed both the biological and socio-economic potentials of the technologies, particularly, the maize-legume relay which was is an annual system, although legume biomass production/spread was not encouraging due to insufficient moisture after planting the legume. Timely planting of experiments, reduction of spacing for legumes in the maize and planted tree fallow, timely production of adequate planting materials for plantain, planted tree fallow and cocoa-shade tree and timely supply of planting materials for all experiments were identified as key activities that required tackling in the second year if the experiments were to be successful. Addressing these concerns in the second year, coupled with fairly evenly rainfall distribution throughout the growing season culminated in good establishment for all the experiments. The permanent plantain, cocoa-shade tree and planted tree fallow experiments are more perennial. However, farmers anticipated positive results judging from the luxurious vegetative growth of the plants.

An ex-ante economic analysis assessing profitability revealed that the technologies are more profitable than their respective alternative land uses, i.e. traditional practices. Higher gross margins and returns to labour for the maize-legume relay compared with the natural fallow with a Mucuna fallow being the most promising for adoption, although Canavalia also has an added advantage for use as food. An assessment of the labour required for clearing the legumes in the 2003-planting season by clock timing, showed a slight reduction in the man-days of labour per hectare for clearing any of the legume fallows (7 man-days/ha) when compared with the natural fallow (9 man-days/ha) over 8 months of growth. However, returns to labour for adopting any legume fallow is about 2.5 times that of the natural fallow. According to Avila (1992) a technology developed to improve an agricultural system is appropriate if it uses labour efficiently since labour is a scarce and expensive resource. Ratios of land/labour and capital/labour are high; hence an appropriate technology should offer a high income/unit of labour ratio.

Cash flow analysis for all technologies also produced higher B/C ratios, NPV, EAV, LEV and IRR where appropriate compared with the alternative traditional land uses. A sensitivity analysis showed that the technologies are also quite stable in the face of increases in labour costs, since the extra cost invested if adopted; mainly labour costs are comparatively lower than the returns earned. They are nevertheless quite sensitive to decreases in produce prices, as this caused a sharp decline in the NPV LEV, EAV, and IRR values. Cocoa at the moment enjoys a stable price which appreciates annually and so may not be affected, but the maize and plantain systems characterized by seasonal fluctuations in prices may be hampered if yields decline, emphasizing the need to improve the productivity of the traditional systems managed under natural fallow rotations.

Farmers' also evaluated their experiments with criteria of indicators they developed in the second year mainly based on their perceptions. Their assessment of the performance of the maize-legume relay revealed that at least weed suppression and moisture conservation by legume cover had been realized. Judging from this, farmers were hopeful of an increase in the yield of a succeeding maize crop in the coming season as they anticipate decomposition of the legume biomass and conserved moisture to improve soil fertility. They also anticipated a reduction in the labour for clearing the legume fallow as compared to the *Panicum maximum*, *Cenchrus ciliaris* and *Rotbolia exaltata* grass and/or *Chromolaena odurata* fallow on the control plot.

In the development of indicators for judging the performance of their experiments, farmers were very objective, emphasizing effects that were of immediate need to their socio-economic circumstances and were priority problem areas in the farming system. This became apparent during the actual evaluation of the experiments. The results point out that the ability of the technologies to increase yields, food and cash were of major interest as these are valuable to their immediate socio-economic needs just like they did while prioritizing the interventions for on-farm experimentation. Overall, all the indicators were primarily interlinked with a net effect of improved land productivity that ultimately leads to improved crop yields.

The mean scores of the ratings of the indicators by both genders seem to suggest that there are probably no distinct gender differences or preferences for the impact farmers expect to derive from the technologies. Soil fertility improvement is paramount in enhancing yields in maize systems in all villages. Improving soil fertility in plantain production is also desirable in Gogoikrom and Subriso but improving plantain planting material availability for extra income, expansion of farm and for fortification against lodging will further improve plantain productivity and income from this crop in Subriso. Planted leguminous tree fallows may be desirable for their potential in improving soil fertility in Yabraso currently, although by-products such as stakes and fuelwood may curtail scarcity in these products particularly, in the future. Once soil fertility is improved in any of the cropping systems, weed suppression may be attained. Erosion control is probably not a problem at the moment in all villages. With cocoa, improving yield is a priority of which shade trees play a role but economic products from the trees are not of immediate concern.

Farmers' perceptions of the performance of the technologies in both the first and second years were primarily based on the physical effects they readily observed or deduced and followed a causal-linkage pattern. The reasons they advanced for the effects enumerated were based on their experience or traditional ecological knowledge where the effects were yet to be realized. These arguments were comparable to findings made by researchers in most cases. For instance, biomass production potential of legumes could be an indication for its soil improvement potential. Also level of leaf litter/mulch produced, moisture conserved & weed suppression determine the legumes potential in increasing crop yield.

On the whole, the technologies are attractive for adoption by farmers judging from the profitability analysis. Farmers' often prefer technologies that yield quick returns in the short term, thus particularly; the maize-legume, permanent plantain and the Gliricidia fallow are suitable for adoption in the short term. For those farmers having long-term goals for assets and future security, the cocoa-shade tree should be attractive as the farmer has a more diversified system, allowing him/her to earn income over a longer period with added benefits from tree products. In conclusion it can be deduced from the above that for soil/land improvement technologies to make desired impacts, their ability to improve crop yields and provide an additional product such as food or extra income opportunity i.e. multipurpose could be important in enticing farmers in the adoption of such technologies.

5.2 Factors Influencing Farmers' Experimentation & Adoption

A number of practical issues arose during the two years of experimentation with farmers. The challenge to develop appropriate technologies that can improve and sustain short fallows for adoption with farmers was predicated by factors like gender, age, land status, labour, wild fires, farmer enthusiasm and willingness to experiment, suspicion of motives of researchers and land tenure. Other issues of importance were farmers' preference for the value of the test crop and the effect or the outcome of the first year of experimentation.

5.2.1 Gender, age & land wealth/ status

Gender, age and land status of farmers were found to be important in dictating farmer decisions to participate in the development of the technologies. Generally, men, older people and native landowners are in a better position to absorb the initial risk of trying the new technologies as they are key decision makers, are better resourced in terms of land and are more likely to be interested in land improvement or conservation measures in the long term.

The favourable tenure conditions for cocoa cultivation enabled both landowners and non-landowners to try the cocoa-shade tree experiment. Although maize can be grown under all tenure conditions, i.e. own, sharecrop, rent or free land by all classes of farmers some tenant farmers did not participate because of short tenancy. It must be remembered from the characterization of production systems above that although tenure to maize land may range from 1-4 years, majority of maize tenant farmers in the three villages often have one-year tenancy to cultivate sharecrop or rented land. Similarly, for the permanent plantain system only few tenants who acquired sharecropped land for about 3-4 years were able to participate. No tenant farmer or non-landowner showed any interest in trying the planted tree fallow as they believed it was a technology for landowners.

Some tenant farmers participating in experimentation discontinued or lost interest in repeating the experiment in the second year because they lost access to the use of the experimental plot in the following season. In one case where a farmer established her experiment on a family owned land in the first year, another family member having the right to the use of that same parcel cleared the immature legume fallow in the absence of the participating farmer for her own use. This means even for family owned land, a somewhat secured tenure is required over a period of time for farmers who do not have absolute control over their farmland to derive the expected benefit from planted fallows.

It is observed that poverty and lack of control over productive resources may make it more difficult for farmers to repeat an experiment over a series of years to enable the confirmation of observations through replication over time (Sumberg & Okali, 1997 citing Amanor, 1994).

5.2.2 Farmers' objective for participation

Although participatory research may have many advantages over earlier approaches, its application is often driven by diverse farmer interests for participation (Frost, 2000 and Bellon, 2001). It was observed from the study that farmers' willingness to participate may be governed by their aim for participation and their understanding or perception of the objectives of the project. However, farmers often had other expectations outside project objectives. Although farmers may be aware of the poor nature of soils and potential benefits of adopting or participating in soil improvement measures, they are often more concerned with immediate gains. Majority of the farmers in the project villages cooperated in providing the relevant information at the various stages of the project. Some farmers were enthusiastic following through the project and experiments over the project period of three years. However, majority (90%) of those who participated in the experimentation did so because they expected some material inputs like seeds, and so on as well financial gains from the project.

5.2.3 Labour & cash resources

The process of integrating farmers in technology development was quite enlightening to the researcher. It was observed that farmers performed cultural operations especially, planting and weeding at their own pace depending on the availability of labour or money to engage labour for doing so. It is known that poverty, drudgery and risk–averse behaviour hamper the ability of farmers to experiment (Sumberg & Okali, 1997).

Labour, particularly for weeding after the experiments had been established was a problem to most of the participating farmers for all the technologies. This contributed to most of the plots not establishing well in the first year irrespective of the drought that occurred. Across the three villages most farmers cultivate on the average two or more farms during any particular season. Hired labour (by-day) is commonly used to supplement family labour for weeding. It was realized that by-day labour as well as money was scarce during the weeding period, i.e. June-August. Farmers relied largely on family labour for weeding which delayed this operation.

For the maize-legume relay experiment, some of the farmers were not willing to do a second weeding before relaying the legumes in the first year (necessary to facilitate growth) because they were expecting financial aid from the project, while others wanted to test the weed smothering potential of the legumes. Moreover, although money and labour are scarce during June-August when this activity is done, the maize is physiologically matured at 8 weeks after planting, hence no need to waste scarce resources on weeding maize for legume to be relayed. However, returns to labour on adoption of the legume is high, a mean of about ¢80,000 per hectare is earned for an extra man-day of labour (worth ¢7,000 in 2002) invested and a gross revenue twice that of the natural fallow could be earned. According to Loos (2000) labour requirements can be rated low since planting of the relay legumes might be combined with the last weeding of the maize crop. Labour for weeding in the succeeding crop will be much reduced due to less weed load as compared with that of the natural fallow re-growth.

5.2.4 Credibility & uncertainty

Some farmers were also suspicious of the motives of scientists in involving them in experimentation. Those who tried the maize-legume relay especially were skeptical about ownership of maize proceeds from the experiment even though their ownership of proceeds had earlier been assured. This discouraged some from relaying the legume in the first year. Others relayed the legumes but quickly harvested for sale before yield assessment was due. Suspicion could possibly be one of the reasons why some farmers refused to weed their experiments after planting the legume. Generally, farmers' ability to try innovations is lessoned by a reduced capability to follow through with experiments and to carry out the risks associated with unproved practices (Sumberg & Okali, 1997 citing Amanor, 1994 & Winarto, 1994) particularly with outsiders.

5.2.5 Outcome of first season experimentation

Although, the potential benefits of herbaceous legumes in improving crop productivity in smallholder systems are widely reported, the technologies were quite new to the farmers. Thus, there is the tendency for the majority who may not be restrained by tenure or particular crop or gender related production niches to sit on the fence, waiting for the outcome on the innovators' fields. This means the outcome of the experiments in the first year is important in inducing uptake.

The outcome of experiments in the first year did not meet the expectation of some farmers. This dissuaded their enthusiasm to continue the trial in the second year as they opted out explaining that they did not realize any impact, causing the reduction in participants in the second year for particularly the maize-legume relay as reported in Chapter 6. As indicated above, some farmers who planted the maize-legume relay did not weed their experiments after the legumes were relayed. This coupled with the sudden drought that occurred and the fact that some of the maize stands were so thick and so shaded the emerging legumes lead to poor establishment of the legumes.

It became apparent from discussions with the farmers that due to the reoccurring irregular weather pattern and erratic nature of rains, time for sowing the legume seeds was important. Some legume species that take longer time to germinate are thus likely to establish poorly if not planted in good time or targeted properly to meet good rains. This accounted for the poor performance of particularly, the *Stylosanthes spp*. on most of the fields where it was planted. In all the three villages it was realized that the legume species needed to be planted early enough and weeded at least once after the relay to ensure good establishment or spread during the major season.

5.2.6 Multipurpose technologies & value of test crop

According to Kaya *et al.* (2000) improved fallows would not be attractive to farmers, if such technologies did not produce other benefits other than soil fertility improvement and higher crop yield. The technologies introduced for fallow improvement had multipurpose objectives of improving and sustaining soil productivity for higher yields, catering to short tenure problems (maize-legume relay) and diversifying household food and income sources (shrub legumes for food and fodder; tree legumes in plantain and planted fallow for wood, i.e. stakes and poles; planted indigenous shade trees in cocoa for wood, fruits and medicines).

The value of the test crop attracted participation. In Gogoikrom, the cash and asset values of cocoa apart from the somewhat secured tenure enticed most farmers to experiment the cocoa-shade tree experiment over the maize and plantain. The immediate cash and food values placed on maize and plantain in Subriso III and for maize and yam in Yabraso lead to the majority of farmers opting to try experiments with these crops over the planted tree fallow. Snapp *et al.* (2002) observed among smallholder farmers in Malawi, that although the majority of them recognized the potentials of legume technologies in improving crop productivity, their adoption was not straightforward as higher priority was placed on food and cash values with soil fertility being a secondary concern. They argued that improvements in soil fertility in developing countries were likely to be pursued as a by-product of market development. In order words it is only when markets for technological components are attractive that soil fertility improvement may achieve a higher adoption.

5.2.7 Wild fires

The annual wild fires that often sweep through both cultivated and uncultivated fields particularly in the Wenchi area during the dry season pose a threat to the fallow interventions. For instance some of the planted tree and herbaceous legume fallows were burnt at the end of the first season on both farmers' fields and on station at the Wenchi Agricultural Station. Protection of the planted fallows from bush fires is critical if their impacts are to be realized. According to Frey *et al.*, (2001) leguminous cover cops have the potential to shorten fallow periods from 4-6 to 1-2 years subject to control of bush fires.

In conclusion the study confirms that for land and soil improvement technologies to make desired impacts, their ability to improve crop yields and provide an additional product such as food or extra income opportunity i.e. multipurpose could be important in enticing farmers in the adoption of such technologies. It is observed that farmers often have multiple criteria for assessing new technologies, including economic profitability, risk, and contribution to food security, time taken to see a return on investment and labour requirement. To be widely adopted, new technologies should perform better in meeting these criteria than existing technologies (Canter, 1996).

The study also showed that tenure, age and gender differences may also be important in technology adoption. Men (including male tenants in Gogoikrom) above 35 years and landowners (including native landowner women in Yabraso) are potential adopters. Tenants in Subriso and Yabraso are limited by unsecured tenure while women in general seem to be constrained by gender roles limiting participation in community decision making and implementation of development processes.

5.3 Recommendations

5.3.1 Recommendation Domains

From the overall analysis of issues above the following technologies can be recommended as appropriate for improving farm productivity under shortening fallows in the three study areas.

5.3.1.1 Maize-Legume Relay

The maize-legume relay is potentially recommended for all the areas, i.e. Gogoikrom, Subriso III and Yabraso and could generally be adopted in other areas of the forest and savannah transition zones (Table 7.1). In addition to being suitable for these agro-ecological zones, all farmer segments irrespective of residential status, land status, gender cultivate maize for both food and cash. Although appearing to be gender neutral, the technology may be more suitable for men as they are more men involved in its cultivation in all three study areas (i.e. 83%, 69% and 55% for Gogoikrom, Subriso III and Yabraso respectively). Farmers' explained that handling maize particularly for marketing is laborious, hence makes its production more suitable for men. Moreover, the crop is commonly cultivated on land previously under a short fallow or cropped and could be grown twice in a season on the same plot. This obviously depletes soil nutrients faster, hence, making the annual legume-relay relevant for sustaining soil productivity in maize systems.

Table 5.1: Recommendation domain for maize-legume relay technology

Farmer Category	Districts/Agro-ecology	Features
Natives Settlers Men Women Landowners Tenants	Atwima Tano Wenchi Forest (Moist, semi-deciduous & dry) Savannah-transition	• Short duration • Short tenure but at least 2 years • Legume relay at 5-7 weeks after sowing maize • Labour for weeding at least once establishment of legume critical • Protection of fallow against bush fire important for biomass & soil moisture conservation • Possible adaptation for rice, vegetable sand yam systems in Atwima, Tano and Wenchi respectively

The landless are commonly involved in maize cultivation across the study sites. However, duration of tenure and security during the tenancy period may restrain landless people from adopting the technology. To be able to utilize the effects of the herbaceous legumes, access to land for at least two years is required. For farmers constrained by either very short tenure i.e. one year tenancy or landowners with limited land, it is possible to plant species such as mucuna in the major season and clear for second season maize to benefit from improved maize yield from the biomass growth over 4-5 months.

The legume needs to be relayed between 5 and 7 weeks after sowing maize depending on the legume species and cropping pattern. Legume could be relayed at 5 weeks if erect or non-creeping species like canavalia are desired and in mixed systems. The legume could also be relayed after 5 weeks (6-8) for monocrop maize and if species such as mucuna (creeping) is desired, to minimize strangling of maize. Also maize should be harvested soon as matured to avoid the mucuna covering the maize cobs to reduce yield.

The time of relaying legume should coincide with either first weeding for those who might weed once at six weeks after sowing maize or second weeding for those who prefer to weed twice(due high weed pressure) to avoid labour constraints for relaying legume. However, weeding at least once after the legume is relayed is important for enhancing legume establishment, i.e. growth and spread. In fire prone areas in Tano and Wenchi, there is need for creating a fire belt around the legume fallow in the dry season to protect it from being burnt by wild fire.

The use of some legume species as mucuna in rotation with sole cropped rice for weed control and soil improvement is equally feasible in the rice-based cropping systems in Atwima characterized by short fallows of 1-3 years. In Tano and Wenchi, annual rotations of long season mucuna fallow with yam have the potential to improve yields and minimize weed evasion.

5.3.1.2 Permanent Plantain (Plantain-legume)

The permanent plantain (i.e. plantain-legume) technology is suitable for Atwima and Tano because the ideal ecology for plantain production is found in these areas and more particularly, for Tano where trees are becoming deficient on farmlands (Table 7.2). Also in Tano, where plantain is the second important crop after maize by way of the proportion of farms under its cultivation, the crop is likely to be cultivated on land previously under short fallow, which may not sustain production for more than two years, hence, the relevance of the permanent plantain technology in the Tano area. This will enable the legume to enhance the productive life of the crop. Consequently, the technology has wider application in moist forest and semi-deciduous forest ecologies.

Table 5.2: Recommendation domain for permanent plantain technology

Farmer Category	Districts/Agro-ecology	Features
Natives Settlers Men Women	Atwima Tano Forest (Moist & semi-deciduous)	• Land owners • Long tenure • Labour for pruning to mulch • Possibility of planting annuals (e.g. maize, vegetables) in the alley in first year

The analysis of livelihoods and profile of farmers who participated in planting the permanent plantain technology in Atwima and Tano showed that all farmer categories, i.e. natives and settlers as well as landowners, tenants, men and women grow plantain. However, the technology might be more suitable for landowners as 85% and 50% of plantain-based farms were found on land owned in Subriso III (Tano) and Gogoikrom (Atwima) respectively. Furthermore, 70% of the permanent plantain experiments were established on land owned by the experimenters.

Plantain is a longer duration crop and the tree component of the technology might make it more suitable for landowners. Nonetheless, it is possible for tenants to use herbaceous legumes that are annuals such as canavalia instead of the tree legumes like gliricidia where the tenure system does not permit tenants to plant trees. Tenants desiring to adopt the technology require a longer tenancy, greater than 3 years to realize the benefits of the legume.

The permanent plantain technology has the potential to enhance and sustain yield. However, investment in labour for pruning the legume hedgerow and application of the biomass is essential if these benefits are to be realized. There is the possibility of planting suitable short duration crops such as maize and vegetables in the alleys for the first year. This will reduce weeding labour and ensure that some benefits are derived from the alley spaces that otherwise would be left unplanted.

5.3.1.3 Cocoa Shade-Tree

The cocoa-shade tree technology is relevant for Atwima and other areas in the moist forest and semi-deciduous forest areas as their ecology and soils (long fallow) are suitable for cocoa production (Table 7.3). Although the crop is cultivated on land cleared from long fallows with fertile soils, the technology is also relevant as there is the need to increase the quantity of desirable shade trees particularly, on hybrid cocoa farms to protect the crop from sun scorch during the dry season and sustain the productive capacity of the soil and the crop over a longer period.

Table 5.3: Recommendation domain for cocoa-shade tree technology

Farmer Category	District/Agro-ecology	Features
Natives Settlers Landowners Tenants Men Women	Atwima Forest (moist & semi-deciduous)	• Increase quantity of shade trees for hybrid cocoa • Secured tenure

The cocoa-shade tree technology is long term but suitable for adoption by all farmer categories in the Atwima area and other areas in both the moist and dry semi-deciduous forest zones. This is because all farmers irrespective of gender, residential and land statuses do grow cocoa in the area. Analysis of livelihoods and profile of farmers experimenting the technology indicates that the technology could conveniently be adopted by tenants cultivating cocoa under the *abunu s*harecrop arrangement as this provides a relatively favourable tenure secured for the tenant to benefit from the technology in the long term. Under the *abunu* tenure, the plantation after it is established is shared 50:50 between the tenant and the landlord. Security is ensured through legal documentation, with each party retaining his/her portion for good.

5.3.1.4 Planted Tree fallow

The fact that 65% and 73% of lands cultivated in Subriso III and Yabraso respectively had previously been under short fallow and/or cropped makes the planted tree fallow technology relevant for Tano and Wenchi areas as well as other areas in the semi-deciduous forest and savannah-transition zones. The technology however is suitable for adoption by landowner men and women as they are involved in tree crop production in these areas. The tenure systems in the area do not allow tenants to plant trees unless such landless people purchase land outright. Planting of trees is generally tantamount to owning land in most areas in Ghana. Moreover, landowners were found likely to fallow land when its productivity declined while tenants often abandoned land when tenancy expired or productivity declined.

Table 5.4: Recommendation domain for planted tree fallow technology

Farmer Category	District/Agro-ecology	Features
Landowners Men Women	Tano Wenchi Forest (dry semi-deciduous) Savannah-transition	• Landowners • Labour for ring weed at least once to for establishment of Gliricidia critical • Protection against dry season wild fire (fire belt)

Natural fallows in the study areas are not weeded. Nevertheless, the planted tree fallow requires an investment in labour to do ring weeding at least once around the tree seedlings during the first year of planting. This is necessary to reduce competition from weeds and enable a higher seedling uptake for better establishment.

The vegetation of Tano and Wenchi areas predominantly characterized with grasses is highly prone to destruction by wild fires in the dry season. Consequently, some labour is also necessary for creating a fire belt around the fallow during the dry season to protect it from being destroyed by wild fires.

5.3.2 Recommendations for PTD Process

The PTD process adopted was quite elaborate and iterations were helpful in shaping the experiments. However, some issues require consideration for future work.

5.3.2.1 Exposure

Exposure visits are essential in enhancing farmers' understanding of experiments much earlier in the technology development process and to minimize doubts, fears or uncertainty in trying the experiments. Consequently, these visits should be embarked on quite early during the experimentation period, particularly to fellow farmer fields and possibly before or soon after listing for experimentation.

5.3.2.2 Value of technology

Farmers showed preference for cash and food value for fallow species other than soil fertility improvement. This was evident when they were rating the interventions for experimentation and again during the appraisal of the first year's performance of the experiments and the project in general with farmers. There is a need to strike a balance between soil fertility and food values. The choice of *Canavalia spp* as one of the fallow species was very good in this regard. Farmers on realizing the food value of this legume had begun saving seeds and planting it in mixtures on their own.

5.3.2.3 Frequency of interaction & level of farmer involvement

Experience from this study shows that a participatory technology development process could be an expensive one requiring sufficient resources or logistics and well planned programmed of activities with farmers that will enable regular contact or interaction with farmers, especially in the case where, the technology is entirely new to farmers.

There are four main ways by which farmers and scientists can collaborate in developing new technologies depending on the objective of the research (Bellon, 2001, Degrande 2001). The project adopted the researcher designed and farmer managed approach. However, because farmers were doubtful of researchers' motives, they failed to recognize their freedom in experimentation as they often waited for researchers' advice before carrying out an activity, which sometimes caused delays.

There is need to change the strategy on the level of farmer involvement in the process of experimentation and evaluation of outcomes. Farmers should be encouraged to have more control over the experiments thereby balancing scientific rigorousness with the flexibility of farmers leading the process in the future to encourage innovativeness. For instance, farmers participating in the cocoa technology in Gogoikrom raised and transplanted seedlings individually at their backyards or farms on their own instead of doing so in a community nursery. This facilitated the production of adequate planting material and timely transplanting of the seedlings for better survival.

To ensure a higher level of participation it is important to shift towards the joint researcher-farmer designed and managed or the farmer designed and managed approaches now that farmers appreciate the usefulness of the technologies and have some experience. Village or cross site demonstration workshops including field days during which participating farmers can present their experiences and train others in trial establishment and management will go a long way in spreading the knowledge and enable farmers to experiment on their own with little outside influence from researchers and extension, who may facilitate by back stopping with technical advice when needed. In this case farmers can plant the experiments with whichever crop and legumes desired, manage on their own and harvest seeds at their own time. This approach will reduce cost and save time and enable more people to explore their innovativeness. It is widely known that farmers are knowledgeable, well articulated on the bio-physical and socio-economic features of their traditional farming environment and are capable of conducting experiments on their own initiative (Bellon, 2001). These attributes should be harnessed to make farmers more proactive and enhance adoption.

5.3.3 Policy Recommendations

When development policies are favourable, the adoption of farm innovations can be enhanced. The study revealed that the practice of fallowing land naturally is the main method for restoring soil fertility in most farming areas in the country. It also revealed that indeed fallow periods have shortened as most lands being cultivated to food crops at the moment are from land previously under short fallows, 1-4 years, characterized with chromolaena and grass vegetation which farmers generally regards as being relatively low in fertility. However, majority of farmers depend mainly on tilling such lands for livelihood. Hence, improving the productivity of these short fallow systems should be of national concern for policy redress.

The study showed that landowners did fallow land when its productivity declined while tenants hardly did so. A higher proportion of farmers involved in the cultivation of food-based systems, particularly, maize, rice, yam, etc. in some farming areas may be tenants who apart from not fallowing derive the maximum from the land before abandoning. The productivity of soils in such areas and livelihoods are under threat if landowners do not actively adopt suitable soil improvement technologies to sustain production.

Consequently, landowners need to be encouraged to adopt technologies for improving land for renting and sharecropping at higher values. Land tenure is one of the important factors influencing adoption of legume fallow systems. Buckles & Triomphe (1999) observed in northern Honduras that landowners and farmers with larger plots were more likely than other farmers to adopt the mucuna system to grow maize. A third of the landless respondents in their study planted at least some of their maize in an established mucuna field rented from a landowner. Farmers with more land than they can cultivate diverted some to the establishment of mucuna fields for rent or later use themselves. Tenants were willing to pay a premium of 60 to 70% to cultivate maize on land planted to mucuna, a clear indication of the potential of the field. This tenure arrangement can conveniently be adapted to the Ghanaian farming situation. Landowners in the study area and indeed other areas where soil productivity is constraining crop production and livelihoods can be encouraged to improve the productivity of farmland by adopting improved fallow techniques and thereby rent land at higher fees or sharecrop 50:50 (*abunu*) basis for food crops as opposed the 33:67 *(abusa)* for landlord and tenant practiced currently.

Farmers' motivation to adopt technology should be supported by the government and its development partners. The government also needs to task the Ministry of Food and Agriculture, District Assemblies and Members of Parliament and others responsible for rural areas to find appropriate avenues for educating landowners for adopting improved fallow techniques.

Institution of awards for best fallow farmers at the district and national levels on annual farmers' day needs to be considered as an incentive for encouraging landowners frequently giving out land for sharecropping or renting to supplement farm income to minimize this behaviour and/or adopt suitable fallow improvement techniques such as the planted tree fallow. This might also force farmers to find suitable means for protecting planted fallows from destruction by wild fires.

Government may have to consider putting in place policies for the provision of small grants that can serve as incentives for landowners to take land out of intensive or extensive cultivation for fallowing. Some possible sources of such grants may be from ongoing schemes such as the District Assemblies common fund and poverty alleviation fund. Some funds from the on-going Food Security Programme funded by the African Development Bank could also be directed for use in improving the productivity of short fallow systems, which might be more sustainable in the long term than the current inorganic fertilizer systems being promoted with the fund. Adequate measures would need to be put in place for efficient implementation and monitoring of such schemes to minimize farmers and officials abusing this facility.

Farmers in the study areas had expectation for credit or material input provision. This was the reason why 90% of the farmers participated in the trials. It might be important for researchers to make provision for some level of incentives in their budgets to donors or funding agents during project preparation to encourage participation in trying experiments.

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ANNEX C: Socio-Economic Issues (Beatrice Darko Obiri)

Appendix 1
Summary costs & returns for maize-legume and maize-natural fallow technologies

	All legumes	***Lablab pupureum***	***Mucuna spp***	***Canavalia spp***	***Pueraria spp***	***Stylosanthes spp***	**Natural fallow**
Receipts							
Gross return (¢)	**2,592,342.00**	**2,421,900.00**	**2,898,000.00**	**2,612,610.00**	**2,482,200.00**	**2,547,000.00**	**1,891,530.00**
Expenses							
Land cost	250,000.00	250,000.00	250,000.00	250,000.00	250,000.00	250,000.00	250,000.00
Farm tool (machete)	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00	40,000.00
Legume seeds	56,121.00	4,000.00	89,250.00	177,738.00	6,000.00	4,000.00	0.00
Seeds (maize)	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00
Storage (Crib & chemicals)	108,000.00	108,000.00	108,000.00	108,000.00	108,000.00	108,000.00	108,000.00
Labour	1,125,846.00	1,103,770.00	1,118,317.00	1,153,159.00	1,119,298.00	1,105,270.00	1,105,298.00
Marketing costs							
Sacks	81,000.00	75,000.00	90,000.00	81,000.00	78,000.00	81,000.00	60,000.00
Loading & poterage	27,000.00	25,000.00	30,000.00	27,000.00	26,000.00	27,000.00	25,000.00
Tax	27,000.00	25,000.00	30,000.00	27,000.00	26,000.00	27,000.00	20,000.00
Transportation	145,000.00	135,000.00	160,000.00	145,000.00	140,000.00	145,000.00	110,000.00
Total expenses (¢)	**2,039,967.00**	**1,945,770.00**	**2,095,567.00**	**2,188,897.00**	**1,973,298.00**	**1,967,270.00**	**1,898,298.00**
***Net cash flow* (¢)**	*552,375.00*	*476,130.00*	*802,433.00*	*423,713.00*	*508,902.00*	*579,730.00*	*-6,768.00*

Appendix 2

Summary cost and returns for Plantain-*Gliricidia sepium* and Plantain-natural fallow

ITEM	**Plantain-*Gliricidia sepium***	**Plantain-natural fallow**
Receipts		
Gross return (¢)	**20,725,000.00**	**9,387,500.00**
Expenses		
Land cost	625,000.00	125,0000.00
Farm tool (machete & chisel)	180,000.00	126,000.00
Planting materials		
Plantain suckers & transport	703,200.00	1,101,680.00
Gliricidia seedlings &transport	1,500,000.00	0.00
Labour	7,110,650.10	3,750,453.10
Marketing costs		
Loading & poterage	0.00	0.00
Tax	0.00	0.00
Transportation	0.00	0.00
Total expenses	**10,118,850.00**	**6,228,133.00**
Net cash flow	10,606,150.00	3,159,367.00

Appendix 3

Summary cost and returns for cocoa with planted and without planted shade trees

ITEM	Without planted shade trees 50% yield decline	Without planted shade trees 25% yield decline	Traditional (insufficient shade)	With planted shade trees 25% yield increase	With planted shade trees 50% yield increase)
Receipts					
Gross return					
Food crops	5949433	6373393	5949433	5949433	5949433
Cocoa	101246015	154509732	207492472	259365589	311238707
Total returns	**107195448**	**160883125**	**213441904**	**265315022**	**317188140**
Expenses					
Land cost	321725	321725	321725	321725	321725
Agrochemicals (fungicides & insecticides)	0	0	0	0	0
Sprayer rental	0	0	0	0	0
Planting materials					
Food crops(Plantain, maize, cassava, cocoyam)	818525	818525	818525	818525	818525
Cocoa seedlings & transport	1512500	1512500	1512500	1512500	1512500
Indigenous tree seedlings &transport	0	0	64815	64815	64815
Labour					
General land preparation & maintenance	13811486	13811486	13811486	13811486	13811486
Food crops (planting, harvesting& haulage)	474835	474835	474835	474835	474835
Cocoa(planting,disease & pests control, harvesting & processing)	66228489	84337713	99929325	99929325	99929325
Indigenous tree seedlings (planting)	0	0	52232	52232	52232
Marketing costs	0	0	0	0	0
Total expenses	**83167560**	**101276785**	**116985444**	**146231804**	**175478165**
Net cash flow	*24027887*	*59606340*	*96456461*	*119083218*	*141709975*

Appendix 4

Summary cost and returns for *Gliricidia sepium* fallow-maize & natural fallow-maize systems

	Gliricidia fallow	**Natural fallow**
Receipts		
Gross return	**4615368.32**	**1410024.27**
Maize	4285368.32	1410024.27
Stakes	330000.00	0.00
Expenses		
Land	0.00	0.00
Farm tools		
Machete	40000.00	40000.00
Chisel	6000.00	0.00
Gliricidia seedlings	330000.00	0.00
Maize seed cost	80000.00	80000.00
Maize sacks	126000.00	42000.00
Labour for land preparation to plant gliricidia seedling	108953.72	0.00
Labour line, peg, dig planting holes, transport & plant Gliricidia seedlings	350000.00	0.00
Labour for ring weeding gliricidia	189934.08	0.00
Labour clearing gliricidia fallow	126000.00	0.00
Labour clearing natural fallow	0.00	125828.72
Labour for planting maize	60000.00	60000.00
Labour for weeding 1 (maize after fallow)	150000.00	150000.00
Labour for weeding 2 (maize after fallow	0.00	150000.00
Labour harvesting maize	110982.61	36516.85
Labour carting maize home	150000.00	100000.00
De-husking	50000.00	50000.00
Shelling	126000.00	42000.00
Bagging	35000.00	17500.00
Loading at farm gate (1000cedis/bag)	21000.00	7000.00
Assembly tax (waybill) at village (500cedis/bag)	21000.00	7000.00
Transportation to market		
Maize (5000/bag)	210000.00	70000.00
Farmer (in & out=4000cedis)	4000.00	4000.00
Market tax (500 cedis/bag)	21000.00	7000.00
Potering at market (500 cedis/bag)	21000.00	7000.00
Total expenses	**2336870.41**	**995845.58**
Net Cash Flow	**2278497.91**	**414178.69**