Expl Agric. (2007), volume 43, pp. 269–287
doi:10.1017/S0014479707005005 *Printed in the United Kingdom*

THE ECONOMIC POTENTIAL AND FARMER PERCEPTIONS OF HERBACEOUS LEGUME FALLOWS IN GHANA

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(*Accepted 13 November 2006*)

SUMMARY

A technology for improving the productivity of short fallows using herbaceous legumes as cover crops was evaluated with farmers in the forest and savannah transition zones of Ghana. Legumes were relayed in maize 5–8 weeks after planting maize, depending on the legume species. An economic analysis of the technology compared with natural fallow over two cropping seasons (2001–2002) showed that the legume fallows were more profitable under the scenarios tested. Farmer assessment of the biological performance of the technology revealed the benefits of weed suppression and soil moisture conservation potential of the legume biomass as well as an improvement in the yield of the succeeding maize crop. However, farmers realized that planting legumes at close spacing and weeding before and after relaying are essential in the development of an appreciable biomass cover. The technology is suitable for farmers of all strata, in several major ecological zones of Ghana, and for planting on land with poorly secured tenure. However, at least two years of tenancy is required for the landless to derive some benefits from the legume fallow.

INTRODUCTION

The predominant farming systems in much of sub-Saharan Africa are based on shifting cultivation and related bush fallow systems with minimal reliance on improved farming inputs (Ehui and Spencer, 1990). Traditionally, the practice entails clearing and burning small plots of land for 1–5 years' cultivation and then abandoning the site for much longer periods (5–20 years) to allow natural vegetation growth to restore soil fertility. This system is a necessity in the tropics where the productivity of soil under cultivation declines rapidly. The efficiency of this practice is, however, dependent on the duration of the fallow phase and the structure, composition, biomass and functioning (mineral nutrient recycling) of the fallow vegetation (Nye and Greenland, 1960). A significant proportion of crop nutrients are found in the fallow biomass, which is recycled and made available to crops when the fallow vegetation is cleared. It is generally accepted that the capability of the soil to sustain crop production is higher with longer fallow periods as the fallow vegetation becomes richer with, particularly, trees.

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Until recently, sufficient arable land was available to allow use of this system. However, population growth and socio-economic changes in recent times have led to a relative shortage of cultivable land, imposing excessive demand on the natural resource base. Coupled with these demographic and socio-economic factors are ecological factors, particularly weather failures, including floods and drought, as well as natural and man-made disasters, such as wild fires, which have persistently degraded vegetation and soils. A combination of these factors has culminated in increasing cropping intensities, with reducing fallow periods.

The management of short fallow rotations is increasingly characterizing crop production in many farming communities in rural Africa. In much of Ghana, short fallow rotations of 1–5 years' duration are common. *Chromolaena odorata* and several grass species (including *Panicum maximum* (Guinea grass), *Cenchrus ciliaris* and many others), which in most cases are unable to restore adequately the fertility of the soil, dominate the fallow vegetation. Short fallow regimes thus cannot sufficiently restore soil fertility to maintain sustainable crop production in most farming communities in Ghana. Where these systems have prevailed for a period of time, problems of decreasing crop yields arising from declining soil fertility and higher weed incidence are common, and loss of access to other fallow products such as fuel wood, bush meat, stakes, props for rural construction and so on have been reported. An analysis of the constraints in crop production in the study area confirmed these observations (Obiri, 2003).

Improved or managed fallows are short-term fallow improvement technologies being widely promoted for soil fertility replenishment in the tropics (Niang *et al.*, 2002). According to Kaya and Nair (2001), these fallows are increasingly being experimented with as a measure for sustaining crop production in impoverished farming systems of sub-Saharan Africa. Managed fallows involve the deliberate planting of fast-growing, nitrogen-fixing leguminous shrub and tree species for improving soil fertility and nutrient conservation. Herbaceous legume fallows are another form of such fallows. They are simple, scale-neutral, low input alternatives that have the potential to improve and sustain crop productivity, particularly in annual systems, and are suitable for farmers with short tenancies. The terms 'green manure' and 'cover crops' can also be used in describing such technologies.

This research forms part of a larger study that was designed with the main objective of improving the productivity of shortened bush fallow systems by developing and testing planted fallow systems with farmers in a participatory manner based on their indigenous ecological knowledge, land-use, cultural, tenure and socio-economic circumstances. Both the agronomic and socio-economic aspects of the intervention were studied (Obiri *et al.*, 2000).

The main objective of this paper is to assess the potential of herbaceous legume fallows in improving farm income. Specifically, the paper evaluates the economic potential as well as farmer perceptions of a herbaceous legume fallow technology compared with a traditional fallow in on-farm trials in maize production systems in the forest and savannah transition zones of Ghana. The agronomic aspects were reported in Jatango (2005).

STUDY AREA

The study was undertaken on farmers' fields in three villages, Gogoikrom, Subriso III and Yabraso, in three districts, Atwima, Tano and Wenchi respectively, in the forest and savannah transition zones of Ghana. The districts were selected based on their ecology, which more or less determines the type of farming system and follows an ecological gradient from the moist semi-deciduous forest in Atwima through semi-deciduous forest in Tano to dry semi-deciduous forest-savannah transition in Wenchi. Atwima is in the Ashanti Region, and Tano and Wenchi are in the Brong Ahafo Region of Ghana. Gogoikrom, is situated about 13 km from Nkawie, the Atwima district capital and 48 km from Kumasi, the Ashanti regional capital. Subriso Number III is located at the northern border of the Tano District with the Ashanti Region and Yabraso is found 19 km northwest of Wenchi, the district capital.

All three study areas have a gently undulating topography and are characterized by a semi-equatorial climate marked by a bi-modal rainfall pattern (peaking in June and October), being wetter in Atwima and drier at Wenchi. The mean annual rainfall in Atwima ranges between 1400 and 1850 mm. It is about 1500 mm in Tano and ranges between 1140 and 1270 mm in Wenchi. Temperatures are fairly uniform across the three districts, with mean monthly minimum and maximum temperatures of 26 °C and 31 °C occurring in August and March respectively. Relative humidity is generally high at between 70 and 82 % (Atwima District Assembly, 1996; Tano District Assembly, 1996; Wenchi District Assembly, 1996).

A *Celtis-Triplochiton* floristic association predominantly characterizes the vegetation in Atwima whereas that of Tano comprises an *Antiaris-Chlorophora* floristic association, (IBRD, 1986, 1987), and that of Wenchi is typical of the *Antiaris-Chlorophora* association and guinea savannah woodland (IBRD, 1986). The original forest vegetation has largely been disturbed in all three districts mainly through indiscriminate bush burning, slash-and-burn agriculture, and logging and felling of trees for fuel over the last few decades. Thus, in certain parts of the districts, the vegetation is rapidly changing into *C. odorata* and grasses, notably *P. maximum*, with scattered trees and thickets. Grass-dominated vegetation progresses from relatively low in Atwima to high in Wenchi. The predominant soils found in the Atwima and Tano districts are the forest Ochrosols, although forest Ochrosols-Oxisol intergrades are also found in Atwima. In Wenchi, the soils are predominantly the savannah Ochrosols, with some Lithosols and Brunosols. Forest Ochrosols also occur within the deciduous forest part (Atta-Quayson, 1999).

The three study villages differ considerably in terms of size. Gogoikrom-Atwima is the smallest of the three villages with 58–60 houses and a population of about 500 people in 2000. Yabraso-Wenchi is medium-sized and had 175 houses with a population of 960 people in 2000. Subriso III-Tano, the biggest of the three, had 351 houses and a population of about 2560 people in 1998. The mean household size is about six people, although this ranges between one and 18. Approximately 50 % of the populations in the villages are illiterate, with the majority of these being women.

The population of each of the villages is multicultural, comprising of a number of ethnic groups, broadly classified as natives and settlers based on residential status which determines the land status of households and/or individuals, and consequently dictates the right of access to and control over the use of land, particularly for farming. Land for farming is typically owned by the indigenous people, but settlers and migrants secure usufruct rights by renting or sharecropping. While Gogikrom and Subriso III are dominated by settlers, the majority of whom are tenants accessing land for cultivation through mainly sharecrop arrangements and rental by cash, natives cultivating land owned through family ties dominated the population of Yabraso.

Crop production is the main livelihood activity, employing 98 %, 93 %, and 87 % of the people in Gogoikrom, Subriso and Yabraso respectively. However, this may be supplemented with the rearing of small numbers of sheep, goats, pigs and poultry, and variable off-farm employment for some people. Average cultivated plot sizes are 1.2 ha (range: 0.1–6.0 ha), 0.7 ha (0.1–3.0 ha) and 0.8 ha (0.1–4.4 ha) for Gogoikrom, Subriso and Yabraso respectively with at least 50 % of the plots being less than 1.0 ha.

A wide range of crops is grown as part of livelihood strategies, although there are certain key 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, and 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 (especially maize), although in Gogoikrom, the *abunu* tenure (50:50 shares) system after a tenant establishes a plantation allows both landowners and tenants to engage equally 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 maize is grown by landless men and women of all age groups as well as older landowner men. The latter are also more involved in plantain cultivation because it is a longer duration crop and requires a secure tenure, whereas pepper and groundnuts are generally grown by women of all age groups.

Farming is largely at the semi-subsistence level. Family (60 % used for nearly all farm operations) and hired (34 % for land preparation and weeding) labour are common sources of farm labour. However, a few people engage communal/pooled labour, particularly for harvesting. Hired labour, provided by seasonal male migrants from northern Ghana, is extensively used. Farm credit is limited as most farmers lack collateral required for lending by financial institutions. Income earned from crop enterprises constitutes the main source of funds for household use and farm investment. Extension services appear to be limited, being worse in Gogoikrom-Atwima than the other study villages. However, physical accessibility to administrative and market centres by road is fairly adequate, enabling regular movement by vehicle of goods and people.

Fallowing is the common means by which soil productivity is restored after limited periods of cultivation, often for not more than six years, particularly for food crops as farmers hardly use any other soil amendment measure, with the exception of a few cultivating tomato in Subriso III. Even for vegetables like tomatoes and garden eggs (aubergines), where inorganic fertilizer and other agrochemicals are applied to boost yield, the land may be fallowed for some 1–3 years after the crop has been relayed or rotated with cassava or maize to utilize the residual fertilizer. Consequently, short fallows characterize the food production systems. Such fallows range from one to five years in most cases with their vegetation characterized by *C. odorata* and several grass species such as *P. maximum*, *Pennisetum purpureum*, *C. ciliaris*, *Rottboellia exaltata,* and *Imperata cylindrica,* which do not enable sufficient soil fertility recovery. Farmers suggested that this has resulted mainly from increasing population pressure arising from an influx of migrants into the study communities. This is not only causing land scarcity but also the unavailability of relatively fertile soils for cultivation. Other important factors mentioned as causes of shortening fallow were adverse weather and persistent wild fires. Moreover, monetary needs of older landowners make it impossible to leave land under fallow for very long periods to restore its fertility adequately.

Major production constraints, which farmers cited in relation to shortening fallows, were poor soils and an increase in noxious weeds that reduce crop yield and increase labour costs, so reducing farm income. Nearly 20 different weed species were mentioned as growing on farms in the study villages. Most crop fields had to be weeded 2–3 times during the growing season due to high weed incidence. Furthermore, absence of reliable and inexpensive farmer credit support systems coupled with poor and seasonal fluctuating prices for farm produce often render their subsistence production unprofitable, subjecting farmers to perpetual financial constraints, despite the existence of adequate marketing outlets (Obiri, 2003).

METHODS

Planning technology, farmer selection, establishment, management and evaluation of experiments

The herbaceous fallow technology is one of four technologies that were evaluated with farmers to address the plethora of constraints related to shortening fallows, tenure and farm income in the study communities. It was identified through different sessions of stakeholder and farmer planning workshops and evaluated with farmers of Gogoikrom, Subrio III and Yabraso over two cropping seasons in 2001 and 2002. Researchers, using initial knowledge from the characterization of farming system/livelihoods of the area and a series of discussions with farmers, designed the technology. Farmers planted and managed the technology on their fields. Researchers also assisted by providing maize and legume seeds/planting materials and technical backstopping. No formal farmer selection criterion was employed and farmer experimenters voluntarily enrolled at village planning meetings.

All the major strata of farmers identified in the study area, i.e. land owners, tenants, men and women, participated in the experiment (Table 1). A total of 65 farmers aged between 20 and 86 years participated in the study over the three villages, with the majority being men. Most of the experimenters were literate, having been educated mostly up to the primary and middle school/junior secondary school level (about 6–10 years of formal education). In Gogoikrom a large proportion of participating farmers were male and the average age was a good deal less than in the other two

Table 1. Characteristics of farmer.

Characteristic	Gogoikrom-Atwima $n = 20$	Villages Subriso III-Tano $n = 29$	Yabraso-Wenchi $n = 16$	All villages $n = 65$
Gender				
Male	15	19	9	43
Female	5	10	17	22
Age (years)				
Mean	36	50	46	45
Range	20–52	25–86	35–78	20–86
Educational status				
Literate	8	18	10	36
None	12	11	6	29
Land status				
Own	8	18	9	35
Tenant	12	11	7	30
Experimental plot size (ha)				
Mean	0.2	0.3	0.3	0.3
Range	0.1–0.6	0.1–0.6	0.1–0.4	0.1–0.6
Cropping pattern				
Mono	12	20	13	45
Mixed	8	9	3	20
Previous land use				
Long fallow	5	0	0	5
Short fallow	10	7	9	26
Food cropped land	5	22	7	34

villages. Yet, surprisingly for a younger, mainly male, group of participants, literacy was considerably lower in Gogoikrom. Perhaps this difference can be attributed to the existence of a much larger proportion of settler tenants in this group.

About 60 % of the experiments were planted on land owned, usually through family inheritance, except in Gogoikrom, where most of the population are tenants, often cultivating maize on a 2:1 sharecropped basis. Farmers planted their experiments on variable plot sizes, ranging from 0.1 to 0.6 ha with a mean of 0.3 ha. The majority of these plots had either been cropped in the previous year or under a short fallow of up to three years. The absence of long fallow plots in Subriso and Yabraso probably illustrates the level of the decline in soil productivity in those areas. The legumes were relayed on mostly mono-cropped maize fields of the same maize variety, although one third of fields had mixed cropping.

Farmer experiments were jointly monitored by farmers, extension agents and researchers at three stages, i.e. beginning of the planting season, mid-way to harvest time and end of season, during which socio-economic and biophysical data were gathered by researchers. Each farmer experimenter rated the performance of the legume fallows against the control with indicators which they developed in the second year of experimentation. General perceptions and suggestions for improvement/modification were also solicited from both experimenters and non-experimenters through questionnaire interviews.

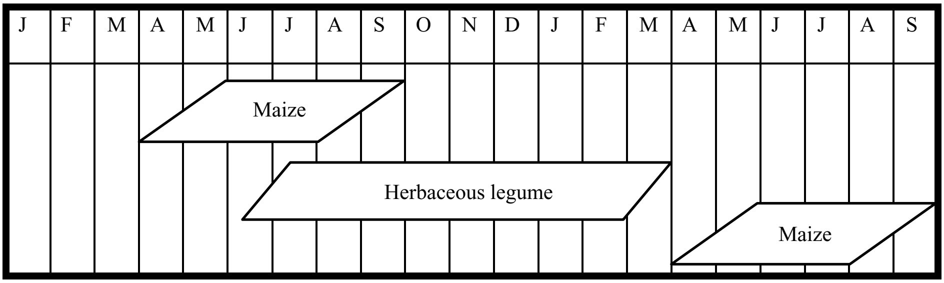

Figure 1. Maize-legume relay cropping calendar.

Description of legume fallow experiments

The legume fallow experiment/technology involved planting maize in the major season in between March and April and relaying a legume in the maize as a cover crop. The legume is relayed between June and July, usually 5–8 weeks after planting maize depending on the time of planting and legume species, earlier for non-creeping and later for creeping legumes to avoid strangling of the maize crop. The maize is harvested about 12–16 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/cover crop and natural fallow (on the control plot) were cleared between February and March and planted to maize, which was harvested between August and September (see Figure 1: diagonal lines show the range of planting and harvesting dates). Five herbaceous legume fallow treatments with *Mucuna pruriens*, *Lablab purpureus*, *Stylosanthes* spp., *Pueraria phaseoloides* and *Canavalia* spp. and a control were compared. The control treatment is the traditional/farmer's practice with no legume. No inorganic fertilizer was applied as farmers do not normally use this in maize cultivation in the study areas. In the traditional maize system, the farmer is likely to rotate a 2–3-year cropping phase with a 3–4-year natural fallow phase, on average.

Farmers sowed 2 kg of maize on variable plot sizes in lines between March and April at a spacing of 80 × 50 cm with 2–3 seeds per hole in lines. The mean farmer maize plot size was 0.3 (0.1–0.6) ha. The intervention plot measuring 40 × 30 m^2 (0.12 ha) was marked by researchers and laid within the farmer's maize field. It was demarcated into three treatment plots for legume species 1 and 2 and a control. Each farmer planted two legume species to compare with the control and was supplied with 2 kg of any of the large-seeded legume covers, *Mucuna*, *Canavalia* or *Lablab,* and 60 g of small-seeded species such as *Stylosanthes* and *Pueraria*. Creeping legumes (*Mucuna* spp., *Lablab purpureus, Pueraria* spp.) were sown on sole maize farms 7–8 weeks after sowing maize to avoid strangling of the maize crop while non-creeping ones (*Canavalia ensiformis*, *Stylosanthes hamata, S. guianensis*) were sown on both sole maize and mixed plots (maize-plantain-cassava-cocoyam mix) at 5–6 weeks after sowing maize. Sixty-five fields or experiments were planted across the three villages; however, data for this analysis were collected from 25 of those that repeated the experiments on the same plots over the two seasons.

Input-output data

For the analysis, a monocrop maize field, with and without the legume fallow and cultivated over two seasons (20 months), was considered. Several informed assumptions were made to overcome limitations in data collected. Input and output data used in the analysis were collected over the two seasons to cover value of production and costs ranging from land to maize marketing costs. 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 recorded by researchers from 5×5 m^2 demarcated plots laid in each treatment plot and then by farmers 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 timing of the labour required by engaging hired labour to clear a few farmer fields.

The input and output values estimated for the analysis are presented in Table 2. 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. The costs that vary over this period considered for the analysis are those of establishing the legume fallow, clearing the fallow and weeding the succeeding maize crop. The establishment cost covers cost of seeds and labour (per hectare) for sowing/relaying the legume and weeding it once afterwards to enhance growth and spread. The labour cost is the product of the man-days per hectare employed in undertaking an activity and the local daily wage rate. For the sake of uniformity, all farms were assumed to be rented, and the land cost was applied to reflect this.

The gross revenue per hectare is the product of the average farm gate price per 100 kg (1 maxi bag) of maize and maize yield per hectare for each treatment. Some

Table 2. Input and output values for the maize-legume technology.

Treatment	Total variable cost over two seasons ha^{-1} (¢)	Yield kg ha^{-1} 2001	Yield kg ha^{-1} 2002	Gross revenue ha^{-1} (¢) 2001	Gross revenue ha^{-1} (¢) 2002
Mucuna spp.	396 000	720	2204	648 000	2 204 000
Canavalia spp.	532 000	703	1980	633 000	1 980 000
Pueraria phaseoloides	328 000	918	1657	826 000	1 657 000
Lablab purpureum	301 000	711	1780	639 900	1 780 000
Stylosanthes spp.	317 000	990	1652	891 000	1 652 000
Legume mean	375 000	808	1855	728 000	1 855 000
Natural fallow	314 000	1002	990	902 000	990 000

For maize output, 100 kg = 1maxi bag =¢90,000 in 2001 and ¢100,000 in 2002 on average.
£1 = ¢11,000 in 2001 and £1=¢13,000 in 2002.

legume seeds may be consumed, but since the yields and consumption are not known, their value has not been included under revenue.

One of the advantages of adopting the legume fallow is the fact that the maize crop following the legume fallow will be weeded only once compared with twice for that on the natural fallow plot. 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. The farmer relays the legume 5–8 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.

Data analysis

The profitability indicators estimated are returns to labour, NPV (net present value) and IRR (internal rate of return). A sensitivity analysis, determining the effect of a 20 % increase in labour cost and 20 % increase and decrease in the price of maize as well as a 20 % decrease in maize yield on the NPV and IRR is also presented. A 10 % discount rate was used in assessing the profitability of the technology (Gittinger, 1982), discounting taking place on a monthly basis. Farmer perceptions are also analyzed descriptively and numerically.

RESULTS AND DISCUSSION

Financial analysis

Returns to labour. The labour requirements for adopting a legume or natural fallow, measured in man-days per hectare, are shown in Table 3. One man-day is equivalent to five hours of hired labour, popularly known as by-day labour in Ghana. Labour man-days per hectare required for the legume are the mean values for all the legumes. Obviously, more labour is required per hectare for adopting the legume fallow than if

Table 3. Labour requirements for maize-legume and natural fallow.

Activity	Labour (man days ha^{-1})
Planting legume	6.7
Weeding legume	16.7
Clearing legume fallow	7.0
Weeding legume maize plot (once)	15.0
Legume total	45.4
Clearing natural fallow	9.3
Weeding natural fallow maize plot (twice)	30.0
Natural fallow total	39.3

https://doi.org/10.1017/S0014479707005005 Published online by Cambridge University Press

Table 4. Returns to labour for total production over two seasons.

Treatment	Labour (man-days) ha^{-1}	Return (¢)ha^{-1}	Returns to labour (¢/man day) ha^{-1}
Mucuna spp.	44	1 921 000	44 000
Canavalia spp.	50	1 577 000	32 000
Pueraria phaseoloides	46	1 628 000	35 000
Lablab pupureum	43	1 580 000	37 000
Stylosanthes spp.	45	1 685 000	37 000
Legume mean	46	1 678 000	37 000
Natural fallow	39	1 099 000	28 000

Table 5. Labour requirements for clearing fallows.

	Labour for clearing fallow (man-days ha^{-1})	
Treatment	Average	Range
Lablab pupureum	4.7	4.4–5.2
Mucuna spp.	5.9	3.8–8.0
Stylosanthes spp.	6.7	6.4–7.3
Pueraria phaseoloides	7.8	7.5–8.1
Canavalia ensiformis	11.7	9.1–13.3
Legume mean	7.3	3.8–13.3
Natural fallow	9.3	7.8–10.7

the farmer decides to continue with a traditional fallow system. However the return to labour on a legume fallow is higher (e.g. about one and a half times in the case of *Mucuna*) than the natural fallow (Table 4).

Comparing the individual legume fallows, *Mucuna* yields the highest return to labour of ¢44 000, although all legume treatments provided returns well above the natural fallow control.

The main factor causing the differences among the legume species is their labour requirement for clearing the fallows for the second season maize (Table 5). This is related to individual species' biological characteristics. *Canavalia* has the highest labour cost because the shrub has strong vines/stalks and so requires more effort to clear than the others. *Pueraria*, which comes next after *Canavalia* in terms of 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.

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 when the extra labour is required for planting and weeding the legume 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 extra investment needs to be made in order to reap the extra benefits associated with any improved technology. Nevertheless, to relieve the labour constraint, the time for relaying legumes could be targeted to coincide with the first weeding of maize at about 5–6 weeks after planting maize, although *Mucuna* planted at this time could possibly strangle the maize crop if not checked. Most maize fields are weeded twice in a season. Hence, once the legume is relayed, the second weeding (which is necessary to enhance legume establishment and biomass spread) would benefit both the maize and the crop. This will save at least a third of the labour required if the legume is to be relayed after second weeding and then weeded once afterwards to enhance establishment.

Farmers often seek to reduce production costs, especially labour cost. Gockowski and Ndoumbé (1999) report that, even where land availability is not a constraint, farmers may be reluctant to clear long fallow fields due to the difficulty in doing so and may end up managing short fallows that are easier or require less labour to clear. Table 5 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 significant.

Cash flow analysis. The total stream of costs and benefits over two seasons of 20 months is presented in Table 6. A discounted monthly cash flow analysis over the 20 months (Table 7) confirms that it is profitable to plant the legume fallows as these have positive NPVs, ranging from ¢305 000 $ha^{-1}$for a *Lablab* fallow to ¢653 000 $ha^{-1}$for *Mucuna* at a 10 % discount rate (i.e. monthly discount rate of 0.797 %) whereas natural fallow exhibits a loss in NPV terms (Table 7). The monthly discount rate is computed from the formula:

$$r_m = (1 + r)^{1/12} - 1 \quad (1)$$

where r is the annual discount rate and r_m is the monthly rate (Bright, 2001).

The net cash flow for each month was then discounted using the monthly discount rate and the summation computed to arrive at the NPV, thus:

$$\mathrm{NPV} = \sum_{m=1}^{m=20} \frac{R_m - C_m}{(1 + r_m)^m} \quad (2)$$

where R_m is the revenue in month m, and C_m is the cost in month m.

Similarly, the IRR 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 %). The IRR (annual) was obtained from the formula:

$$\mathrm{IRR} = (1 + irr)^{12} - 1 \quad (3)$$

Table 6. Benefits and costs stream for maize-herbaceous legume fallows & maize-natural fallow.

	All legumes	*Mucuna* spp.	*Canavalia* spp.	*Stylosanthes* spp.	*Pueraria* spp.	*Lablab pupureum*	Natural fallow
Receipts							
Gross return (¢) (maize)	2 592 000	2 898 000	2 613 000	2 547 000	2 482 000	2 421 900	1 892 000
Labour costs							
Land preparation (clearing, burning &stumping)	251 909	234 380	275 472	240 083	247 861	226 083	258 361
Planting maize	130 000	130 000	130 000	130 000	130 000	130 000	130 000
Weeding maize (season 1)	162 500	162 500	162 500	162 500	162 500	162 500	162 500
Weeding maize (season 2)	75 000	75 000	75 000	75 000	75 000	75 000	162 500
Planting legume	40 000	40 000	40 000	40 000	40 000	40 000	0
Weeding legume	60 000	60 000	60 000	60 000	60 000	60 000	0
Harvesting maize	130 000	130 000	130 000	130 000	130 000	130 000	130 000
Hauling maize home	112 500	112 500	112 500	112 500	112 500	112 500	112 500
De-husking maize	60 937	60 937	60 937	60 937	60 937	60 937	60 937
Shelling maize	63 000	63 000	63 000	63 000	63 000	63 000	63 000
Bagging maize	40 000	50 000	43 750	31 250	37 500	43 750	25 500
Total labour costs	1 125 846	1 118 317	1 153 159	1 105 270	1 119 298	1 103 770	1 105 298
Other costs							
Land cost	250 000	250 000	250 000	250 000	250 000	250 000	250 000
Farm tool (machete)	40 000	40 000	40 000	40 000	40 000	40 000	40 000
Legume seeds	56 121	89 250	177 738	4 000	6 000	4 000	0
Seed maize	180 000	180 000	180 000	180 000	180 000	180 000	180 000
Storage (crib & chemicals)	108 000	108 000	108 000	108 000	108 000	108 000	108 000
Marketing costs							
Sacks	81 000	90 000	81 000	81 000	78 000	75 000	60 000
Loading & porterage	27 000	30 000	27 000	27 000	26 000	25 000	25 000
Tax	27 000	30 000	27 000	27 000	26 000	25 000	20 000
Transportation	145 000	160 000	145 000	145 000	140 000	135 000	110 000
Total expenses (¢)	2 040 000	2 096 000	2 189 000	1 967 000	1 973 000	1 946 000	1 898 000
Net cash flow (¢)	*552 000*	*802 000*	*424 000*	*580 000*	*509 000*	*476 000*	*−6 000*

Table 7. Profitability of maize-legume relay and maize-natural fallow.

Profitability	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 (¢)	418 000	653 000	410 000	404 000	347 000	305 000	−81 000

where *irr* is the monthly rate of return, i.e. the monthly discount rate at which the NPV would be equal to zero.

Sensitivity analysis. 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 products are two main determinants of profitability in smallholder, low external input systems,

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Table 8. Sensitivity analysis to a 20 % increase in labour cost.

Profitability	All legumes	*Mucuna*	*Stylosanthes*	*Canavalia*	*Pueraria*	*Lablab*	Natural fallow
Monthly IRR (%)	2.5	3.4	2.8	1.7	2.4	2.2	−2.0
IRR (%)	34	50	40	22	33	29	−22
NPV (¢)	308 000	573 000	331 000	183 000	261 000	243 000	−261 000

Table 9. Sensitivity analysis to a 20 % increase in maize price.

Profitability	All legumes	*Mucuna*	*Stylosanthes*	*Canavalia*	*Pueraria*	*Lablab*	Natural fallow
Monthly IRR (%)	5.8	6.4	6.6	4.8	6.1	5.4	3.5
IRR (%)	97	111	115	75	103	87	52
NPV (¢)	989 000	1 307 000	1 003 000	873 000	922 000	873 000	291 000

Table 10. Sensitivity analysis to a 20 % decrease in maize price.

Profitability	All legumes	*Mucuna*	*Stylosanthes*	*Canavalia*	*Pueraria*	*Lablab*	Natural fallow
Monthly IRR (%)	1.0	2.1	1.3	0.3	0.9	0.7	−4.5
IRR (%)	13	29	17	4	11	9	−43
NPV (¢)	37 000	243 000	66 000	−87 000	8 700	−17 000	−407 000

assuming all other factors that contribute to production, including the weather, are generally favourable.

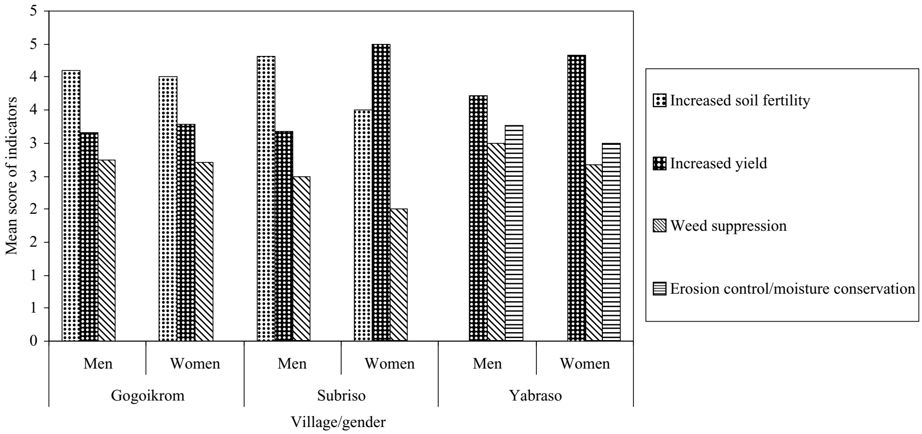
Labour costs are likely to appreciate with inflationary pressures. For instance, the daily labour wage (by-day) increased by ¢1000 each year during the three years (2000–2002) of the study in the villages. Even in real terms, labour costs are likely to rise due to increasing demand elsewhere in the economy. The effect of a 20 % increase in labour cost was therefore evaluated. Maize produced on the legume fallow plots is still profitable, but lower, on average, by nearly 14 %, with the rise in labour cost, while losses on the natural fallow plot are much greater (Table 8).

Maize prices often fluctuate, depending largely on the supply of maize at any particular point in time during the season and on transport costs. The effect of a 20 % increase or decrease in maize prices was evaluated. With the rise in maize price the legume fallow systems become even more profitable than the natural fallow, which does now reach a positive NPV, with the production in the *Mucuna* system being superior (Table 9).

On the other hand a decline in maize price adversely affects the profitability of both the legume and natural fallow systems, although production under all legumes is still profitable, except for *Lablab,* as shown by its negative NPV and the IRR less than the discount rate (Table 10). Were the labour cost increase and maize price decline to coincide, it is likely that only *Mucuna* and *Canavalia* would remain profitable, and this would be exacerbated if all costs were to rise by the same proportion as labour. With regard to yield variation, should drought in the second season reduce yield by 20 %, *Mucuna, Pueraria* and *Stlyosanthes* would remain profitable (Table 11).

Table 11. Sensitivity analysis to a 20 % decrease in maize yield.

Profitability	All legumes	*Mucuna*	*Stylosanthes*	*Canavalia*	*Pueraria*	*Lablab*	Natural fallow
Monthly IRR (%)	1.1	1.9	1.8	0.2	1.3	0.8	−2.5
IRR (%)	14.6	25.8	23.9	1.9	16.5	9.9	−26.3
NPV (¢)ha^{-1}	49 000	187 000	126 000	−100 000	61 000	−900	−249 000



Standard errors for the mean scores for the indicators range between 0.2 and 0.3

Figure 2. Farmers' indicators for evaluating maize-legume relay technology.

Farmer perceptions

In the second year of the study, a criterion for evaluating the performance of the technology was developed with farmers. A total of 69 participating and non-participating men and women farmers across the three villages were involved in this activity. After recapping the situational analysis of the farming system that led to the development of the maize-legume technology, individual experiences and observations with the technology were discussed. A list of several possible indicators for assessing the performance of the technologies was generated from the discussion. The four most important indicators were then identified from the list after prioritization to simplify ranking during evaluation of the technology by scoring the indicators with 10 matchsticks, giving the most important indicator the highest score. The mean scores were then computed and the results discussed with farmers. Increased soil fertility, increased yield, weed suppression/labour reduction and soil moisture conservation/erosion control emerged as the key indicators (Figure 2). According to Estrella and Gaventa (1998), indicators identified by farmers represent the implicit characteristics they value in technologies, and hence serve as their criteria for judging the impact of technological options. It is important that such indicators are measurable, easy to collect and benefit relevant stakeholders.

Farmers rated the performance of the legume fallows with scores ranging from 1 as much worse to 5 as much better, relative to the control (natural fallow) at the end of the second season with their indicators. Figure 3 shows farmers' evaluation of all legume fallows against natural fallow (control). About 80 % of the farmers rated the

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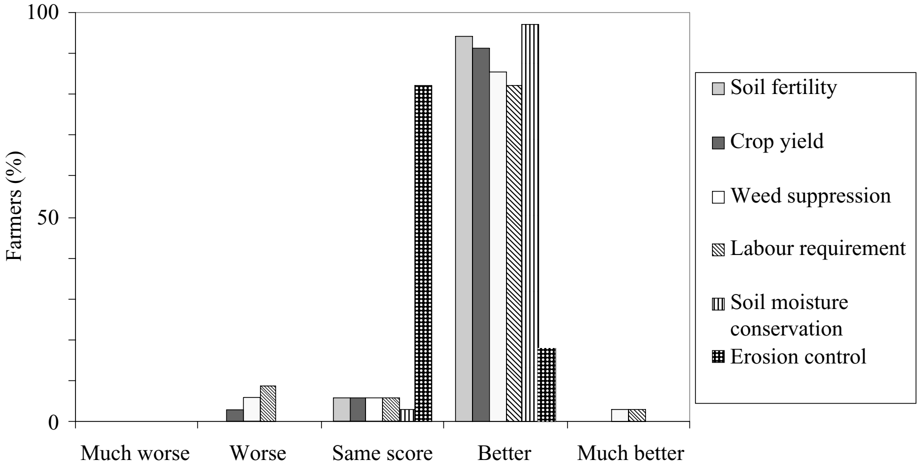

Figure 3. Farmers' evaluation of all legumes fallows versus natural fallow (control).

legumes' ability to improve soil fertility and crop yield, to suppress weeds (thereby reducing labour for clearing the fallow) and to conserve soil moisture as better than that of the control (natural fallow). The legumes and the natural fallow were rated the same for erosion control because erosion was not a problem on any of the fields. The few (18 %) who rated erosion control as better argued that if erosion were a problem, the legumes were more likely to control it better due to the ground coverage.

Farmers explained that the heavy biomass, i.e. the carpet of mulch, conserved moisture during the dry season to aid the decomposition of leaf litter, thereby improving soil conditions and crop yields in the next season. The heavy biomass coverage also resulted in the smothering of noxious weeds like *Panicum*, *Chromolaena* and *Rottboellia*, which thereby reduced labour for clearing the fallow in the next cropping season. A small proportion of farmers rated the legumes the same or much worse than the natural fallow 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 planted.

Mucuna versus *Canavalia*. The performance of common fallow legumes *Mucuna* and *Canavalia* were compared using the indicators. Edibility, observed to be essential with respect to farmer legume preference, was included (Figure 4, where scores show performance of *Mucuna* relative to *Canavalia*).

Mucuna was rated better than *Canavalia* with respect to soil fertility improvement, weed suppression and soil moisture conservation by about 75–80 % of the farmers. By growing more vigorously, *Mucuna* produced heavier vegetative cover than *Canavalia*. The greater biomass meant more litter rot and soil moisture conserved for improved soil fertility and better tillage in the next season. For these reasons, 50 % of the farmers also rated *Mucuna* better than *Canavalia* in improving crop yield. However, 33 % rated the ability of the two legumes in improving crop yield as the same, arguing that by

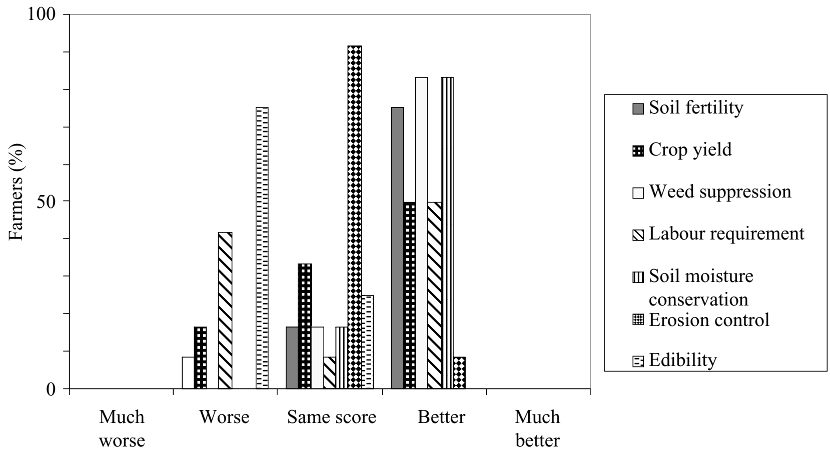

Figure 4. Farmers' evaluation of *Mucuna* vs. *Canavalia* fallows.

growing more vigorously *Mucuna* was likely to use a higher proportion of soil nutrients for its own growth than *Canavalia*. Thus, although *Mucuna* produced a higher biomass, the net effect would be the same for the two legumes. The remaining 17 % rated *Mucuna* worse than *Canavalia* in improving crop yield. This is because *Mucuna*, being more aggressive, strangled the maize crop on some fields, which could lead to a reduction in maize yield.

The ability of *Mucuna* to reduce labour requirements was rated better than that of *Canavalia* by about 50 % of the farmers. *Mucuna* being more aggressive in smothering weeds meant less labour for clearing *Mucuna* plots than for those of *Canavalia*. Both farmers' records of labour man days and scientists' clock-timed labour used in clearing the *Mucuna* and *Canavalia* at the beginning of the second season showed that clearing a *Canavalia* fallow requires twice the amount of labour than for *Mucuna* (Table 5). Yet, conversely, 42 % of the farmers rated *Mucuna* worse than *Canavalia* with respect to labour. The vigorous growth and entangling nature of *Mucuna* impedes weeding after planting. Although both *Mucuna* and *Canavalia* are edible, 75 % of the farmers rated *Mucuna* worse than *Canavalia* in terms of edibility. This is because *Canavalia* was being readily consumed in soups and stews while *Mucuna* required careful heat treatment for detoxification before consumption.

Farmers' perceptions of the performance of the legumes confirm those reported by farmers from other parts of Ghana and other areas of the developing world, where legume covers such as *Mucuna* are being promoted to enhance crop productivity. Weed suppression in fallows involving herbaceous legumes is widely reported (Akobundu and Poku, 1984; Ikuenobe and Anoliefo, 2003; Osei-Bonsu *et al.,* 1996). Farmers 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 (Loos *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. The aggressiveness of *Mucuna* in smothering weeds, thereby reducing labour for land preparation for the next crop was also reported. The Honduran farmers also observed that thick mulch from slashed *Mucuna* fallow suppressed weeds in the next crop, conserved moisture, and both the decaying mulch and the green *Mucuna* crop protected soil from eroding.

According to Buckles and Triomphe (1999), for about 36 % of farmers in their study, the most important reason for planting *Mucuna* was the fertilizer effect of the decaying *Mucuna* litter. Ease of land preparation and moisture conservation were also highly rated by a large proportion of the farmers, while weed control ranked as the second most important reason for a quarter of the farmers, but erosion control by only a few of them. Buckles and Triomphe (1999) considered that the Honduran farmers' perceptions of the *Mucuna* system could be grouped into criteria related primarily to land productivity (fertilizer effect, moisture conservation and erosion control) and those related primarily to labour productivity (ease of land preparation and weed control). This suggests that from the farmers' point of view, the appeal of the *Mucuna* system is its potential to respond simultaneously to both land and labour constraints to productivity.

M. pruriens and *C. 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 of Ghana grow small quantities of *Mucuna* and *Canavalia* for food. This practice has probably been in existence for a century or more. Farmers usually plant a few stands (4–8) of these legumes. The authors observed that about 70 % and 55 % of respondents interviewed in a survey on traditional use and knowledge of these two legumes in the forest and transition zones respectively knew their food value, and 90 % and 30 % of respondents consumed them regularly in soups and stews. However, none of the respondents interviewed had knowledge of the potential benefits of *Mucuna* or *Canavalia* as green manure or cover crops although a few knew about the use of legumes such as *Pueraria* and *Centrosema* as cover on plantations.

Although farmers have favourably assessed herbaceous legume fallows, potential problems observed with such technologies include risk of damage to maize by rodents which build their nests in the litter 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.*, 1991). Farmers in the study villages also observed some technical limitations while experimenting with the maize-legume systems. They noted that competition between weeds and the legumes retarded legume establishment if the plot is not weeded after the relay. In such cases aggressive weeds like *C. odorata* and *P. maximum* suppressed the legume. Moreover, the legumes were sown when maize was either tassling 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 such as cassava, plantain and cocoyam. They anticipated problems with, particularly, snakes, although none of them had encountered any.

CONCLUSIONS

The profitability of planted fallows is widely reported. Maize production in a legume shrub fallow system in the forest and savanna transition of Ghana can be reasonably lucrative, as indicated by the higher returns to labour, NPV and IRR compared with those of the traditional natural fallow. Relative profitability of 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 price makes maize production highly profitable, even under natural fallow. Conversely, a 20 % decline in maize price reduces profitability sharply, with production under natural fallow yielding the poorest income. *Mucuna* fallow is the most profitable under all tested conditions. Fallows with *Stylosanthes*, *Canavalia*, *Pueraria*, and *Lablab* are also profitable in that order but are severely affected when maize price is low. A decline in maize yield would also severely affect profitability of *Lablab, Canavalia* and natural fallows. The natural fallow is consistently the least profitable.

By the end of the two seasons it had been realized that there is a need to weed before sowing the legume seeds and at least once after sowing due to the aggressiveness of grass weeds and *acheampong* (*C. odorata*) in areas where maize is predominantly cultivated. 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 at eight weeks after planting maize for those who weed twice (due to high weed pressure) to avoid labour constraints for relaying legume. This is because money and labour are scarce between June and July when relaying of the legume is carried out. Weeding the legume at least once thereafter is also critical to successful establishment of legume biomass.

The irregularity in climatic conditions, particularly in rainfall pattern, makes it necessary for the planting of shrub legumes to be targeted to meet good rains and for legumes to be planted at closer spacing to enhance establishment or biomass coverage. It also became evident that farmers preferred multi-purpose legumes that produce grain for food and improve labour and land productivities (suppress weeds, improve soil) as well.

This technology has the potential for adoption by all strata of farmers and in several major ecological zones of the country where short fallows and poor crop productivity are severely reducing farm incomes. To be able to utilize the effects of the herbaceous legumes, access to land for at least two years is required by the landless. For farmers constrained by either very short tenure or landowners with limited land, it is possible to plant species such as *Mucuna* in the major season and to clear for second season maize to benefit from the biomass growth over 4–5 months. In fire-prone areas in Tano and Wenchi, a fire belt should be created around the legume fallow in the dry season to protect it from being burnt by wild fire.

Although the evaluation with herbaceous legume fallows reported is based on a limited period, this technology does appear to be a profitable option, as long as potential problems can be overcome. The use of legume species such as *Mucuna* for weed control and soil improvement is not only possible with maize but equally feasible in rotation with sole-cropped rice in the rice-based cropping systems in Atwima and other areas characterized by short fallows of 1–3 years. In Tano and Wenchi, annual rotations of long season *Mucuna* fallow with vegetables and yam have the potential to improve yields and minimize weed invasion.

Acknowledgements. This publication is an output from a research project funded by the United Kingdom Department for International Development (DFID) for the benefit of developing countries (R7446 NRSP Research Programme). The views expressed are not necessarily those of DFID. We are also very grateful to farmers of Gogoikrom-Atwima, Subriso III-Tano and Yabraso-Wenchi for their active collaboration.

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