BIOPHYSICAL AND ECONOMIC EVALUATION OF HEDGEROW INTERCROPPING USING SCUAF IN LAMPUNG, INDONESIA

I Wayan Rusastra , Sri Hery Susilawati [1], Gelar Satya Budhi and Peter Grist[2]

ABSTRAK

Studi ini mengungkap dampak jangka panjang (20 tahun) tiga sistem usaha tani dengan menggunakan pendekatan model bioekonomik, yang disebut *Model Soil Change Under Agro Forestry (SCUAF)*. Teknik konservasi introduksi usaha tani tanaman lorong Flemingia dibandingkan dengan dua jenis sistem usaha tani tradisional yaitu perladangan berpindah dengan masa bera tiga tahun dan sistem usaha tani tanaman pangan sepanjang tahun. Tingkat erosi dan kesuburan lahan menurun secara drastis pada sistem usaha tani tradisional, khususnya pada sistem usaha tani tanaman pangan sepanjang tahun. Dalam 20 tahun, sistem usaha tani tradisional ini kehilangan volume lahan hampir 20 kali, dan unsur hara (*soil nutrient*) mendekati tiga kali lebih besar dibandingkan dengan teknologi konservasi tanaman lorong. Produktivitas tanaman menurun pada ketiga sistem usaha tani, tetapi penurunan cukup tajam (81 %) terdapat pada sistem usaha tani tanaman pangan sepanjang tahun dan hanya 30 persen pada sistem usaha tani tanaman lorong. Sistem perladangan berpindah memiliki *Net Precent Value* (NPV) paling rendah. Dalam jangka panjang, teknologi konservasi tanaman lorong mampu memberikan keuntungan finansial yang tertinggi dan dapat menjamin keberlanjutan usaha tani. Namun demikian, teknologi introduksi ini membutuhkan dukungan modal yang relatif besar pada tahap awal, sehingga dalam implementasinya perlu didukung dengan kebijaksanaan perkreditan di samping kepastian status penguasaan lahan.

Kata kunci : Teknologi konservasi tanah, sistem usaha tani tanaman lorong, model SCUAF, avalusi biofisika dan ekonomi.

ABSTRACT

This study reveals long term (20 years) impact of three farming systems using an approach of bio-economic model called Soil Change Under Agro Forestry (SCUAF). An introduced conservation technique of Flemingia inter-cropping system was compared to two traditional farming systems i.e. shifting cultivation with three years fallow and a long year food crop farming system. Soil erosion rate and land fertility decreased drastically on land used for traditional farming system especially for that of the long year food crop farming system. In 20 years, the traditional farming system lost soil volume almost 20 times and soil nutrient for almost three times compared to that of hedgerow inter-cropping farming system technique. Plant productivity for all techniques decreased, however, the long year food crop farming system experienced the most (81 %) compared to hedgerow inter-cropping using SCUAF (30 %). Net Present Value (NPV) for shifting cultivation was the lowest. In a long term, the hedgerow inter-cropping using SCUAF gives the highest financial profit and assures farming sustainability. However, this introduced technology requires relatively high capital support at the initiation phase so that it needs PRIVATE credit policy support besides land holding status certainty.

Key words : Soil conservation tecnology, hedgerow farming system, SCUAF model, biophysical and economic evaluation.

1) Center for Agro-Socio Economic Research (CASER), Bogor, Indonesia
2) Center for Resource and Environmental Studies (CRES), The Australian National University (ANU), Canberra.

INTRODUCTION

Most areas of Indonesia outside of Java are dominated by Podzolic soil (Ultisols and Oxisols) with characteristics of low soil productivity, acidity associated with aluminium toxicity, and very high risk of soil erosion and degradation (Anonymous 1994a). Inadequate soil management and shifting cultivation practices by local farmers has resulted in degradation of soil and part of this land have been abandoned and become dominated by *imperata cylindrica.*

Some interventions have been introduced by the government to farmers to prevent further degradation of this land. Among the soil conservation technologies that have been introduced, hedgerow intercropping (alley cropping) is widely recommended. It has advantages, such as a low cost of construction, maintenance of soil productivity and the potential to be applied on most soil conditions (Susilawati et al., 1997). The reviewed studies indicate that the synergic effect of soil productiviy increase, and soil erosion rate reduction, may increase food crop production. In addition, some hedgerow intercropping systems have shown significant reduction in farming cost per unit output compared to mechanical soil conservation technologies, due to decreases in labour use and other input reductions (Haryati et al., 1993).

Menz and Grist (1996) revealed a number of studies and descriptions of hedgerow intercropping systems which have been conducted in terms of both biophysical and socioeconomic perspectives. But as yet there have been no studies in Indonesia to quantify the longer run consequences of hedgerow intercropping. This is mainly due to lack of available long-term, comprehensive, and consistent data.

Soil changes under agroforestry (SCUAF), is a simple deterministic model, which can predict rate of soil erosion, soil depth, and other aspects of soil fertility, and their effects on crop productivity, based on information of the initial soil characteristics, climate, and soil conservation technologies under consideration (Young and Muraya, 1990). Some studies using this model have been conducted in the Philippines (Nelson et al., 1996a, 1996b), and using aggregated data and information in the Asian region (Menz and Grist 1996, Grist and Menz 1996). These studies indicate that SCUAF has the capacity to show desirable linkages between soil fertility and economic viability of the system. Menz and Grist (1996) revealed that the maintenance of an adequate level of soil fertility is a guiding principle in determining sustainability of crop in focus. This knowledge is very important in determining the soil conservation technology design suitable for a given location.

Base on this background, the objectives of this study are : (1) to evaluate the long-term effects of hedgerow intercropping and two traditional farming system (*Imperata* fallow and continuous open-field) on soil fertility, erosion and soil depth; (2) to asses the synergic effect of changing soil characteristics and yield on food crop production over time; (3) to conduct a financial analysis by calculating cumulative discounted net revenue of the three soil conservation technologies; and (4) to derive conclusions and policy implications based on the result of this study.

RESEARCH METHODOLOGY

Farming System Defined

Three soil conservation farming system are considered in this study. The first is hedgerow intercropping, based on the research of Adiningsih and Mulyadi (1993) in Terbanggi - Lampung, Sumatera. The other two are variants of open-field farming : a continuous cropping system; and, an *imperata* fallow farming system. In densely populated grassland areas such as Lampung, most arable land is cropped intensely to fulfil household consumption, and to provide source of income. The Imperata fallow farming system commonly applied by farmers is three years of fallow with *imperata*, followed by one year of cropping. Due to population pressures on the land, there is a strong tendency to apply a continuous farming system. A descriptions of the three farming systems simulated using SCUAF in this studiy is presented in Table 1.

Table 1. Descriptions of the Three Farming System Simulated Using SCUAF in Terbanggi – Lampung, Sumatera

Farming System	Description
1. Continuous open-field farming system	Repeated annual cropping of rice-maze and soybean-maize in a field without hedgerows.
2. Three years *imperata* fallow followed by one year of open field cropping	Annual cropping of rice-maize and soybean-maize, without hedgerow for one year, fallowed by 3 years of follow, where the land reverts to *Imperata cylindrica* grassland
3. *Flemingia* **hedgerowintercropping**	*Flemingia* hedgerow intercropping

The study site was dominated by *Imperata cylindrica* before the implementation of the farming system. *Flemingia congesta* was used as a hedgerow and a source of organic matter for the alley cropping treatment. No additional chemical fertilizer was applied in this study. *Flemingia* was periodically cut at intervals of six weeks, with the leaf biomass used as mulch. *Flemingia* hedgerows occupied 20 percent of the available land, and the remaining 80 percent was cultivated. Within the cultivated area, 80 percent was planted with rice or soybean, and 20 percent with maize.

Parameterizing SCUAF

SCUAF predicts the amount of soil erosion and the level of nitrogen and carbon in a soil profile. Changes in soil nitrogen and carbon are based on the information of climate, soil physical factors and soil chemical factors, in addition to the type of crops and farming system under consideration

SCUAF's agroclimatic parameters were set to reflect the characteristics of the climate and soil at Terbanggi, Lampung. The climate in study site can be categorized as lowland humid with annual rainfall of 3,200 mm. The soil is imperfectly drained clay oxisols with acid soil reaction (pH 5.2 – 5.3) and moderate slope class (Adiningsih and Mulyadi 1993). The research findings also indicate that the initial carbon and nitrogen in the top soil (0 – 20 cm) are 1.70 and 0.14 percent, respectively, providing an initial topsoil C:N ratio is 12.14. In the subsoil (20 – 40 cm depth), the initial carbon content is 0.62 percent. Since little information is available on the rate of carbon and nitrogen transformation and movement at this site, most of SCUAF's default parameters for carbon and nitrogen transformation in this type of environment have been accepted.

The initial net primary production (NPP) of *Flemingia* is 10,650 kg DM $ha^{-1}year^{-1}$ (Adiningsih and Mulyadi 1993), when moisture content is taken at 30 percent. The proportions of *Flemingia* leaf, wood and fruit are 66 percent, 33 percent, and 1.0 percent. Roots as a fraction of above ground NPP for both tree and crop are 40 percent and 25 percent, respectively. The NPP of *Imperata* is 4,020 kg DM $ha^{1}year^{-1}$, with the roots a further 40 percent of above ground NPP (Castillo and Siapno 1995; Soerjani, 1970). The accumulated standing biomass of *Imperata* was returned to the plant/soil system as residue following each year of fallow.

The nitrogen fraction of the dry mass of the plant parts was only experimentally measured for *Flemingia* leaf, at 2.63 percent. The nitrogen fraction of the other plant parts were not available, so SCUAF default values of 0.50 for wood and 1.50 for root were used. For maize, the N fraction of the leaf, fruit and root were taken from Nelson *et al.* (1996b) to be 2.00, 3.00, and 1.50 percent respectively. The nitrogen content of the plant parts of rice and soybean, are assumed to be similar to that of maize.

Input, Costs and Returns

To assess the profitability of the three farming systems over a period of 20 years, a cost-benefit analysis was applied. Food crop production, over the twenty years considered in this analysis, was derived using the SCUAF model. Crop yield was multiplied by the market price to calculate crop revenue. As SCUAF calculates a combined, rather than an individual crop yield, it was necessary to calculate a weighted average price to apply to that yield. The weighted average price of this output is Rp 295 per Kg. The calculation of this figure is based on the prices of upland rice, corn, and soybean at Rp 240, Rp 260, and Rp 850 per Kg respectively (Anonymous, 1994b), and the proportion of each commodity of 55.0, 36.0, and 9.0 percent of total food crop yield, respectively (Adiningsih and Mulyadi, 1993).

Cost varies depending on the type of farming system used. For the hedgerow conservation technology, the costs comprise: labor costs for land clearing; labor cost for hedgerow planting and management; labor costs for food crop production; and, seed costs (legume and food crops). According to Zaini and Lamid (1993), the labor requirement for manual *Imperata* land clearing in the first year is approximately 140 mandays/hectare. Later years requiring only 40 mandays per hectare. The labor requirement for hedgerow land preparation, planting and pruning, is 52 mandays (Haryati et al., 1993). For food crop production, labor used per hectare was 49.2 mandays (Anonymous, 1994b).

Based on this information, the total labor requirements for the hedgerow intercropping system in the initial year, normal years, and in the hedgerow planting year are 241.2, 89.2, and 141.2 mandays/hectare. For the continuous open-field farming system, the total labor requirement for the first year is 189.2 mandays, and 89.2 mandays/hectare for the other years. Total labor used for the *imperata* fallow system is 189.2 mandays/hectare, which consists of labor for *Imperata* land clearing, food crop production and management. The labor wage rate is the same for all activities, at Rp 1,700 per manday (Anonymous, 1994c).

Other than seed (legume and crop seed) no inputs are required. The seed requirement for legumes in the hedgerow intercrop is 10 Kg per hectare, with total value of Rp 17,500 (Haryati et al., 1993). In all systems, the seed requirement for the food crop is assumed to be the same, due to the similar cropping pattern. The quantities of seed used for upland rice, soybean, and maize are 23.7 kg, 18.9 Kg, and 6.3 Kg, with the market price of Rp 445.8, Rp 1,230 and Rp 907.5 per Kg respectively (Anonymous, 1994b). The total seed cost for food crops, therefore, is Rp 39,530 per hectare.

Cost Benefit Analysis

Cost-benefit analysis is a technique for comparing the stream of net-benefit produced over time by competing investment opportunities, in this case hedgerow intercropping relative to the two traditional farming systems. The net present value (NPV) of each soil conservation farming system over n years can be calculated from equation 1, where Bt and Ct are the benefit and costs in year t, and r is a discount rate.

$$NPV = \sum_{t}^{n} \frac{(Bt - Ct)}{(1 + r)^{t}}$$

Equation 1. General Form of the Cost-Benefit Function.

A discount rate of 18 percent is used for the cost-benefit analysis of the three farming systems. This is equal to the interest rate given by the state bank to depositors of the national savings program. A twenty year period was chosen for the cost-benefit analysis. The results of the analysis are presented as the cumulative NPV from each farming method over this period. The advantage of using cumulative NPV is that it reveals the sensitivity of the analysis to the choice of planning horizon, in addition to graphically displaying the influence of major assumption on the ordering of the farming method under consideration.

Farmer's decision to adopt or reject hedgerow intercro ping is a private one. A field level cost-benefit analysis from the perspective of farmer's can shed light on farmers decision to adopt the proposed technology or continue with traditional farming system.

RESULT AND DISCUSSION

Soil quality factors

The factors of soil quality considered in this analysis are soil erosion, soil depth, labile nitrogen, and plant-available mineral carbon. Cumulative soil loss is most severe under continuous traditional open-field farming (Figure 1). Total cumulative soil erosion under continuous traditional farming over twenty years is 6,693 tonnes per hectare compared to 506 tonnes per hectare under *Imperata* fallow and 314 tonnes per hectare under hedgerow intercropping. Erosion in the cropping year of the *Imperata* fallow system is much lower than that for continuous open-field farming (averaging 94.2 tonnes per hectare compared to 330 tonnes per hectare), but it is still higher than for hedgerow intercropping (16 tonnes per hectare).

In general the results of this study are similar to the findings of Nelson *et al.* (1996b) in the Philippines. The cumulative soil loss predicted from hedgerow intercropping over twenty-five years is the lowest of those studied, followed by reduced fallow farming. The highest erosion was observed in the continuous open-field farming system.

Nelson *et al.* (1996b) also show that the reduced fallow farming system, in the year of cropping, produces a rate of erosion similar to continuous open-field farming. The fallow length considered in this study is three years. Menz and Grist (1996) showed that even with a ten year *Imperata* fallow period, soil fertility is not able to recover to produce a sustainable system. They revealed that fallow length shorter than 20 years results in an unsustainable farming system. However, for most smallholders, it is not economically viable to reduce the cropped area to the low levels required to maintain a twenty year fallow length.

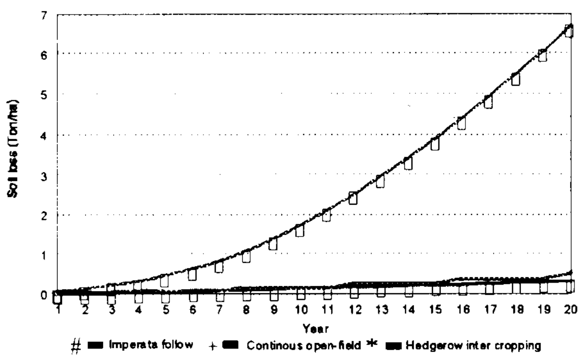

Figure 1. Cumulative Soil Erosion Overtime for Three Soil Conservatin Technologies in Lampung, Indonesia

Figure 2, represents the change in soil depth for the three farming systems over time. There is little significant difference between the hedgerow intercropping and *Imperata* fallow system. After 20 years, the soil depth of both farming systems is the same, at 98 cm. For continuous open-field farming, predicted soil depth declined continuously over time. By year 20, 40 percent of the soil was lost, i.e. the depth of soil remaining is 60 cm.

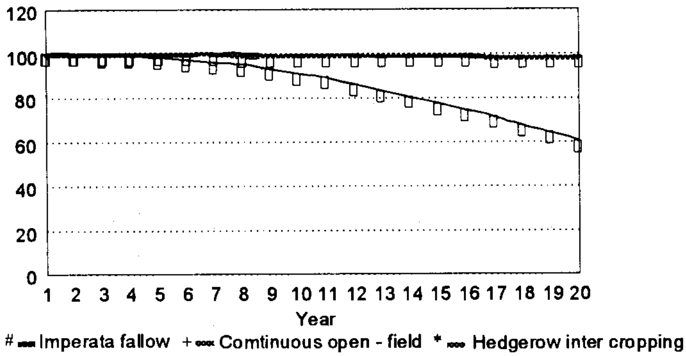

Figure 2. Change in Soil Depth Over Time for Three Soil Conservation Technologies in Lampung, Indonesia.

The severe increase of cumulative soil erosion under the continuous open-field results in a sharp decline in labile nitrogen and carbon over time (Figure 3 and 4). The *Imperata* fallow system, with a moderately increasing trend of soil erosion, has a modest declining trend of both labile nitrogen and carbon over time. On the other hand, the hedgerow intercropping shows a slow-moving decline in labile nitrogen and carbon over time.

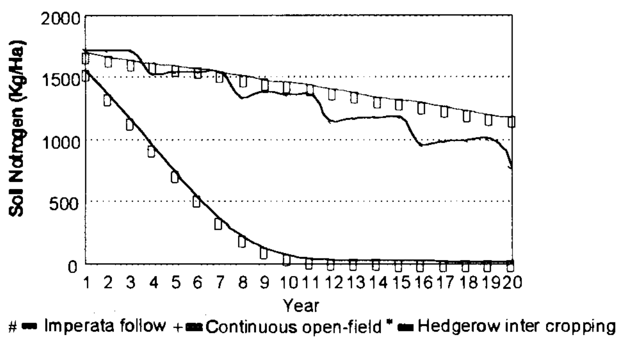

Figure 3. Change in Labile Nitrogen Over Time for Three Soil Conservation Technologies in Lampung, Indonesia

Predicted soil nitrogen and carbon are highest for *Flemingia* hedgerow intercropping, due to the cycling of nitrogen, carbon and organic matter through prunings. The mulching of hedgerow prunings also shows the capability to reduce soil erosion. The organic matters contributed by the *Imperata* fallow had little impact on soil fertility, with only a minor conversion of carbon and nitrogen during the fallow period. Both elements decline significantly in the year of cropping within the *Imperata* fallow farming system (Figure 3 and 4).

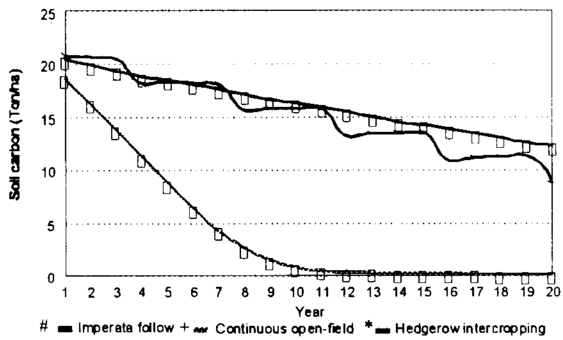

Figure 4. Change in Labile Carbon Over Time for Three Soil Conservation Technologies in Lampung, Indonesia

Food Crop Yield

In the first four year, crop productivity under continuous open-field cropping is highest. This is due to the greater proportional area under crops (100%), compared to the hedgerow intercropping situation (80%). Under the *Imperata* fallow system, crop yield only occurs on one – fourth of the land so crop planted is four times the level of crop production shown in Figure 5.

The rate of soil loss and decline in soil quality in all three farming systems explains the predicted pattern of food crop production presented in Figure 5. Predicted crop production per hectare declines under all three farming systems, but declines considerably more under the continuous open-field farming system. This is associated with the sharp decline in labile nitrogen and carbon under the continuous cropping system. *Flemingia* hedgerow intercropping was able to sustain food crop production at a higher level than the other two farming systems.

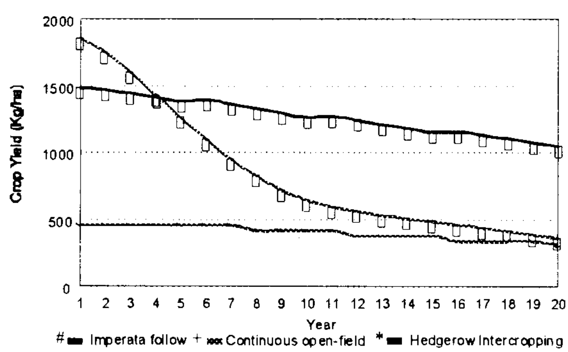

Figure 5. Change in Food Crop Yield Over Time for Three Soil Conservation Technologies in Lampung, Indonesia

Under hedgerow intercropping, crop production decreased approximately 30 percent over the 20 year period, from 1,481 kg in the initial year to 1,046 kg by year 20. For continuous open-field farming, production decreased 81 percent (from 1,852 kg to 352 kg), with the major part of this decline occurring in the first 10 year (from 1,852 kg to 642 kg). Production decline for *Imperata* fallow was 33 percent. This indicates that *Flemingia* hedgerow intercropping comes closest to maintaining sustainable food crop production in the long-term.

Economic Outcome

Cost-benefit analysis was applied to assess whether a higher crop yield in the future can offset the costs of establishment and maintenance of the respective systems. The result is presented in terms of cumulative discounted net revenue (NPV) for each farming methode over the twenty years of the analysis.

Considering a wage rate of Rp 1,700 per manday, and a discount factor of 18 percent, the continuous open-field system has a higher NPV than hedgerow intercropping for the first 10 years (Figure 6). Initially, hedgerow intercropping generates lower net benefits due to the higher labor requirement for establishing hedgerow, in addition to lower food crop yields because of lower cropping area.

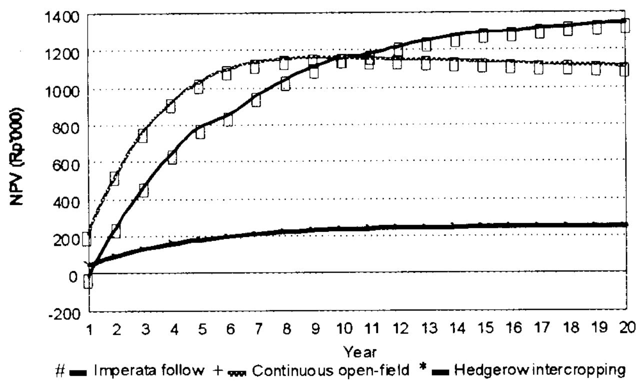

Figure 6. Comulative Net Present Value Over Time for Three Soil Conservation Technologies in Lampung, Indonesia

The hedgerow intercropping system in year 20 still has a positive annual return of Rp 6,700. The cumulative NPV of the hedgerow intercropping, continous open-field, and *Imperata* fallow farming systems by the end of analysis (year 20), are Rp 1.34 million, Rp 1.11 million, and Rp 252,000, respectively. This shows that hedgerow intercropping is more profitable over the long-term.

CONCLUSION AND POLICY IMPLICATIONS

The predicted changes in soil factors, food crop yield, and economic outcome, indicate that the *Flimengia* hedgerow intercropping produces a reasonably sustainable farming system in the long-term. The synergic effect of soil loss reduction and significant productivity improvement resulting from increased food crop production generates higher cumulative NPV compared to the traditional farming system. After 20 years, the averages food crop yield of hedgerow intercropping was over 100 percent higher, and its cumulative NPV by the end of the analysis was 20 percent higher, than that of the traditional farming system.

Hedgerow intercropping becomes an attractive option in the long-term if farmer can access credit at a rate of 18 percent per year. By using a discount rate of 18 percent, the NPV of the introduced soil conservation technology in the first year is negative, due to the significant labor requirement for hedgerow establishment. Therefore, capital is the first limiting factor for the adoption of the hedgerow farming system, in addition to land tenure status and small size of land ownership. The farmer need capital for salaries and in-kind payment for hired labor and collective forms of exchange labor in establishing the hedgerow, as well as for household consumption. Strategies to reduce the capital burden faced by the farmers are, among other things; to develop farmers collective saving groups, to launch subsidized credit to the farmers (*KUT*, or *Kredit Usaha Tani*), and to encourage farmers to organise a collective from of echange labor for hedgerow establishment.

The limiting factor of land size must be substituted with the selection of suitable planted shrubs or trees to maximize the benefits (from fuel wood or fodder) of alley cropping adoption for soil conservation purposes. By doing so, the trade-off between food crop planted area and benefits gained from legume species can be eliminated. In dealing with land holding status as one determining factor in farmers' willingness to adopt the hedgerow intercropping technology, the government must give some incentives to the farmers in terms of land ownership rights. It is worthwhile to develop these incentive further, so that there is legal certainty on cultivated land.

Eventhough the hedgerow intercropping technology can be implemented under most soil conditions, modifications are still needed to suit the technology to the specific location. The legume species and food crop commodities must be suitable geographically and be in line with farmer interests. Therefore research and development studies have to be conducted in order to find out alley cropping farming systems suitable for each region throughout the country. The proposed soil conservation technologies should address the issues of soil fertility indicators, food crop yield, and long-term profitability before the technology is recommended and implemented by farmers in the field, with the use of models such as SCUAF.

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