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The Potential of Alley-Cropping for Hillside Farming in Rwanda

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THE POTENTIAL OF ALLEY-CROPPING FOR HILLSIDE FARMING IN RWANDA

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INTRODUCTION

Alley-cropping, practiced well, is a very promising agro-forestry intervention that can increase yields from any sized field by improving the nutritional status of the soil, check soil erosion and provide badly needed wood for fires and construction.

Any farming practice in which food crops and trees interact spatially or sequentially is defined as an agro-forestry system. Agro-forestry offers several advantages to its practitioners, including improvement of soil fertility, erosion control on steep slopes, provision of fuelwood and lumber, supply of livestock feed and environmental protection.

One way to practice agro-forestry is by alley-cropping in fields. The key elements are woody legumes, with 'alleys' between them in which food crops are sown. Typically the hedgerows are about 4 m apart and consist of a single or double line of legume plants, usually at very close spacing (10-50 cm apart). Some heavily seeding species, such as Leucaena leucocephala, are established by direct sowing. Close spacing, to give a solid barrier, is important on slopes where erosion control is a major objective.

Legumes are used because most species fix atmospheric nitrogen (N), and if the foliage is lopped and added to the alleys (either as a mulch or incorporated into the soil), this N is returned to the soil. The system requires careful management with repeated lopping of the hedgerows. The aim is to get maximum leaf production without excessive shading of the crop, so timing is crucial. The lopping regime will depend on local conditions and on the light requirements of the food crop at different stages of its growth. The lopping height will vary too, depending on the response of the legume used and the amount of shade required or tolerated by the food crop.

The main nutrient obtained from the legume leaves is N, but the hedge plants will also be deeper-rooting than the food crop and so can exploit lower levels of the soil and bring other nutrients and minerals to the surface. The incorporation of organic matter also improves the physical structure of the soil. If the legume is a good fodder species (such as Leucaena) some of the foliage may also be used as fodder, although this will represent a new removal of nutrients from the site.

A problem with alley-cropping is the necessity for continuous management. For an early-seeding species such as Leucaena (which usually seeds heavily after one year), neglect of the field could result in dense regeneration of Leucaena in the alleys--a major weed problem. The danger of weediness on the part of the legume is one reason why farmers should be cautious in adopting this system and be sure to choose species that will not get out of control under local conditions.

Alley-cropping has been developed as a low-input, sustainable alternative to traditional slash-and-burn systems in the sub-humid tropics. It can also be used in areas of existing settled agriculture to reduce dependence on expensive or unavailable fertilizer. The key advantage of alley-cropping is its sustainability. Research at the Farming Systems Research Program (FSRP) has shown that alley-cropping can increase crop productivity, particularly in low-input farming systems. Rwandan farmers scratch out a living from generally poor soils that are subject to severe erosion. The farmers of the Buberuka highlands of Rwanda provide a rigorous test of the benefits that can come from alley-cropping.

The northern Rwandan highlands are characterized by high altitude--most farms fall between 1,800 and 2,200 m--together with steep slopes that range from zero in the flat swampy valleys where little or no farming is done to gradients of over 100 % on the hillsides where farming is concentrated. Most slopes on farmlands vary between 40% and 70% gradients. Another characteristic of this area is that most highland soil is highly acidic; the average pH is 4.8.

Compared to other parts of Rwanda, rainfall in the northern sector is relatively high and frequent. The FSRP area is in a cool environment compared to other parts of Rwanda. The mean temperature range is 13 to 22°C.

The fundamental constraint to productive agriculture is scarcity of arable land. Population pressure has led to continuous cultivation of marginal land on hillsides that normally would serve as pasture. The consequences are

- lack of vegetation to protect the environment,
- loss of fertile top soil via erosion,
- low crop yields.

The scarcity of wood and fodder under these circumstances again forces people to harvest grasses on contours designed to check soil erosion. The discontinuities thereby created in the band of grasses along the contours permit terrible erosion to occur with the rapid development of gullies. Alley-cropping would therefore be a very appropriate practice in the Rwandan highlands.

METHODS

A general approach to agro-forestry begins by using information available at the agricultural research centers and other institutions engaged in agro-forestry research. Commonly, a multi-stage testing procedure is adopted with active farmer involvement to promote social acceptability. Researcher-managed trials are conducted to develop management alternatives in response to feedback provided by farmers. Farmers are trained in the use of new management operations. Researchers encourage and rely on farmers and extension agents to assist the farm research and, eventually, to disseminate the proven technologies.

The research procedure shown in Fig. 1 has three major components:

- information gathering and analysis (diagnosis);
- technology testing and farmer orientation;
- farmer training.

In Component 1, information is collected and analyzed with reference to its relevance to erosion control and soil fertility management in the area in which the FSRP works.

Component 2 has two stages. The first stage is to choose the best species according to the principal agro-climatic zones in the project area. Three sites were chosen for the start-up phase: the Buberuka Highlands, the Central Plateau and a swampy valley. During a field day, farmers were made aware of the proposed agro-forestry interventions, and cooperating farmers for stage two were chosen to continue the research process.

The second stage of Component 2 was to plot the locations of the farms of participating farmers (selected from stage one) on a soil and land use map of the project area to ensure fair representation of all of the microagroecological zones in the area. In all, 15 sites were used for testing. Shrubs included in the experiment were Leucaena, Calliandra, Sesbania and Markhamia. Lack of adequate planting materials and initial slow growth rates of Markhamia and Calliandra limited their testing to two sites in the Buberuka Highlands and Central Plateau regions.

Component 3 is farmer training. A hands-on, participatory workshop was held for some of the farmers who had had field trials on their land during the 1986-87 growing season. Extension workers responsible for the administrative sectors in which these trials were located were invited to the workshop. Farmers received training in the following aspects of agro-forestry:

- small-scale nursery establishment using local materials,
- establishment of alley-cropping on sloping land,
- pruning methods and the use of pruned materials.

Each farmer-researcher was asked to do five additional farm trials with neighboring farmers in collaboration with an extension worker and to monitor and evaluate these trials. Thus, both farmers and extension workers were intimately involved in the research and extension process.

PRELIMINARY RESULTS

It is difficult to find leguminous shrubs that posses all the characteristics required at high altitude as well as in cold environments. Characteristics needed are fast growth, ability to coppice well, ease of establishment and N-fixing capability. Among the species tested, Sesbania sesban showed the best potential. It is relatively tolerant to the acid soils encountered in the project area, and its growth rate is comparatively faster in the highland than in the lowland region. Dry matter yields at highland and lowland sites were 3,000 kg/ha and 2,100 kg/ha, respectively. Within these two ecological zones, shrubs grow almost two times faster in the rich valley soils than in the badly eroded scils of the highlands. On the lower soils, shrubs can attain a height of 4 m in eight to ten months. The most common method of establishment is the use of three-month-old tubed plants, but direct sowing in the field is also possible.

Sesbania is compatible with most food crops. However, investigations in the two major ecological zones of the project area revealed that when shrubs were grown in association with peas, they grew slowly during the initial stages of growth. The ability of Sesbania to regenerate after cutting depends on factors such as the ecological zone, land type, age, height and time of cutting. In general, regeneration of Sesbania is better in the highland than in the lowland region. Initial growth and regrowth are faster on moist and fertile lowland soils than on upland soils. A one-year-old shrub can barely survive the next two seasons if it is cut at a height of 0.5 m. Regeneration at this age is much better when cut at a height of about 1.5 m. The problem with the 1.5-m cutting height is that the lower branches shade the food crops beneath them. Survival of Sesbania diminishes sharply when it is cut at the end of the rainy season.

The problem is more serious on upland soils, especially when 'naked' pruning is done by removing all leaves. Partial pruning on the other hand, results in early shading and subsequent crop yield reduction near hedgerows. Another disadvantage with Sesbania is its alleged nematode susceptibility, but this can be offset or at least minimized by interplanting the rows of Sesbania with grasses that serve as deterrents to nematodes.

Even with the above peculiarities, a shrub life span of six to ten years is realistic by the following appropriate management practices:

- Cutting back to height of one meter eight months after planting.
- Pruning at the beginning of the rainy season.
- Partial pruning where dry-season cropping is done.

Leucaena ranks second to Sesbania in terms of growth performance. Applications of lime and manure increase its growth rate. It can attain a height of 2 to 3 m in one year. Unlike Sesbania, it grows faster in the lowland than in the upland region. Like Sesbania, its growth is favored by rich and continually moist soils. Limited experience in the project area and knowledge of its behavior in other regions indicate that Leucaena is more robust than Sesbania as regards regeneration after cutting. Regardless of how, when and where it is cut, regeneration is excellent even in those parts of the project area where the altitude is close to 2,400 m. Moreover, Leucaena used as fallow in rotation with other crops is reported to reduce the level of infestation of certain nematodes significantly. Apart from its initial slow growth rate, especially on infertile upland soils, Leucaena qualifies as a potential alley shrub in the zone of operation of the FSRP.

Calliandra ranks third after Leucaena. Its initial growth is extremely slow. For example, the height of three-month-old seedlings increased from 17.8 cm to 153 cm during five months when 5 tons/ha of manure and 0.75 tons/ha of lime were applied. Regeneration of Calliandra regardless of how, when and where it is cut is also good. Thus, Calliandra is a potentially a useful shrub for alley-cropping in the FSRP zone if given time and a moderately fertile soil.

Of all shrub species tested Markhamia showed the poorest growth performance. Although native to the FSRP area, its height after eight months was 43 cm whereas in plots where neither fertilizer nor lime was used the heights of Leucaena, Calliandra and Sesbania were 180 cm, 131 cm and 386 cm, respectively. To meet farmers' short-term and even long-term needs for erosion control, soil fertility improvement and wood, the current growth rate of Markhamia is considered too slow to be of much value in alley-cropping systems. Perhaps, a combination of Sesbania with Leucaena or Calliandra to take advantage of the fast growth rate of Sesbania and the robustness of the latter two may hold some promise.

FARMERS' FEEDBACK

As mentioned earlier, farmers were introduced to alley-cropping during training sessions. Feedback from farmers during training identified the merits of alley-cropping as follows:

- providing stakes for climbing crops (for example, beans);
- provision of fuelwood;
- provision of fodder;
- erosion control;
- improved soil fertility.

Under the intensive land use practiced in the FSRP zone, stakes can be obtained only from pruning after shrub establishment, and there is commonly insufficient time for shrub growth between crop seasons to provide a continuous supply of stakes. Farmers with enough land, therefore, are urged to practice rotational alley-cropping by alternating alley-cropped with non-alley-cropped sites. Farmers with limited land, however, are advised to rotate shade-intolerant crops with shade-tolerant ones in alley-cropping systems. For example, by pruning shrubs and planting maize in September, a farmer could get a second crop of dwarf beans or potatoes in April without pruning. This schedule gives twelve months for shoot growth to allow the proper size for stakes.

Biological gains from alley-cropping are generally criticized as being too long term when compared with the use of manures, composts and inorganic fertilizers. The factors that determine how rapidly soil-improvement benefits of alley-cropping can be achieved are shrub growth rate and the time required for prunings to decompose. Shrub growth rate is accelerated by fertile soil the same way as growth of ordinary agricultural crops is. Farmers, therefore, should be persuaded to respect routine farming procedures (fertilization, weed and insect control, etc.) with the introduction of the shrub as an ancillary component. Research at IITA, Nigeria and FSRP, Rwanda has shown that no significant losses in crop yields occur during shrub establishment but that the shrubs are established cheaply and their growth rates improve when routine farming practices are followed. In the FSRP area, growth of Sesbania, Calliandra and Leucaena intercropped with potatoes increased by about 30%, 25% and 10%, respectively, with the application of about 2.5 tons of manure/ha in one growing season of potatoes.

In a defined environmental setting, the rate shrub prunings decompose is a function of the carbon to nitrogen ratio (C:N) of the leaves. For quick nutrient release, prunings with a narrow C:N are preferred to those with wide C:N. Where environmental conditions favor growth of alley shrubs with large C:N (for example, cassia), pruning decay can be hastened by the addition of moderate quantities of fertilizer or manure.

Incorporation of prunings into the soil as green manure can also accelerate decomposition and increase the efficiency of nutrient use by food crops. Thus, depending on the kind of shrub used and the management strategy followed, the value of alley-cropping becomes apparent within one to two years after shrub establishment. Results obtained with Sesbania point to the positive contribution of alley-cropping towards sustained crop productivity in low-input agriculture traditional in the FSRP zone of Rwanda. Based on one season's results, the common practice of applying high rates of manure above 10 tons/ha for potatoes is unnecessary if prunings of Sesbania are also added.

The highest potato yield of 21 tons/ha was obtained from plots where prunings and 5 tons/ha of manure were applied. Plots that received only prunings yielded 20 tons/ha. The yields of the treated plots were dramatically better than the yield of the control plot where neither prunings nor manure was added. Although yields in the other treatments were higher than those obtained in the control plot, differences were insignificant. It is possible that applying high rates of manure would be beneficial in the long term. It is expected that soil fertility in plots where manure and prunings are regularly applied will build up with time whereas soil fertility in the control plot would decline.

In another trial with pole beans as the best crop, the use of Sesbania prunings alone or in combination with N fertilizer was superior to the control that had neither prunings nor N fertilizer added. About 70% of the stakes needed for the pole beans came directly from Sesbania. This represents a substantial saving in time and labor searching for the scarce stakes. Another interesting feature of this technology is the gradual development of terraces to check soil erosion. The height of the terraces one

year after establishment of Sesbania was about 10 cm. The rate of development of terraces is faster where slopes are steep and uncovered. To obtain good erosion control, grasses such as setaria should be planted between shrubs along the contours six months after the shrubs to minimize competition. Early growth of Leucaena was observed to be greatly reduced by the presence of setaria.

ADVANTAGES SUMMARIZED

Alley-cropping offers several advantages to hillside farmers in the FSRP area with respect to soil protection, nutrient conservation and overall improvement in land productivity. To date, Sesbania sesban, Leucaena leucocephala, Calliandra calothyrsus and Markhamia lutes have been tested in the region with Sesbania being superior in early growth and biomass production. But Sesbania is a delicate species and requires careful management. It can be killed by cutting below 1 m in height. For long shrub life, it is suggested that pruning be done when rains begin and at a height of 1 m for eight- to ten-month-old shrubs. Subsequent prunings should be related to the cropping sequence.

It may also be advisable for farmers to maintain a small nursery of Sesbania close to their houses to replace Sesbania plants that die as a result of careless management. Leucaena and Calliandra are not as sensitive as Sesbania, but their initial growth rates are slower. Initial growth could be enhanced, however, by use of manures or fertilizers. By having rows of the above-mentioned shrubs alongside continuous bands of grass on the contours, soil erosion is reduced. Stakes for trellis are provided during cutting back after shrub establishment. Thereafter, production of stakes and fuelwood is possible only when rotational alley-cropping is practiced. Alley-cropping with adapted shrub species can enhance soil fertility. The improvement could come faster if farmers invested some labor and fertilizer/manure during shrub establishment. A less-recognized but obviously important ingredient for the success of alley-cropping is patience.

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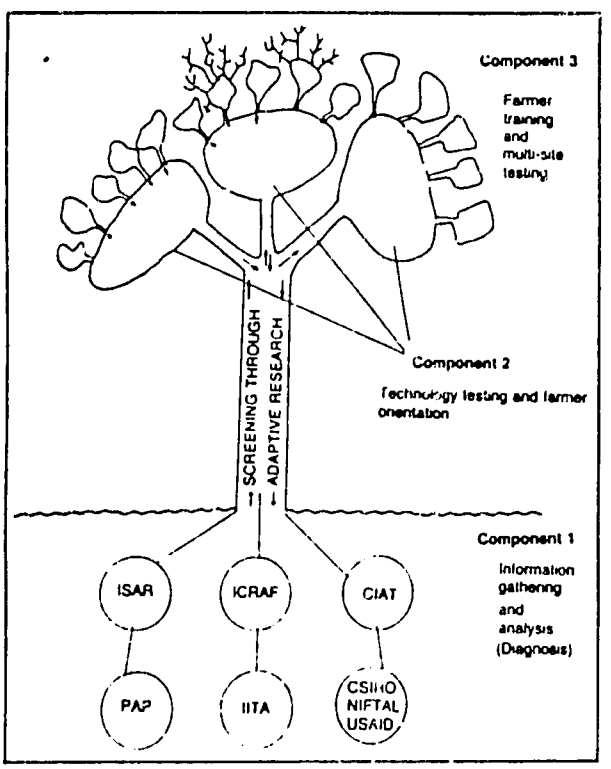

Fig. 1. Agro-forestry research methods