CASE STUDIES IN AGROFORESTRY DIAGNOSIS AND DESIGN NO. 2

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AGROFORESTRY SYSTEMS FOR SMALLHOLDER UPLAND FARMERS IN A LAND REFORM AREA OF THE PHILIPPINES: THE TABANGO CASE STUDY

by

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F O R E W O R D

As part of its programme of work ICRAF has established a Collaborative and Special Projects Programme (COSPRO) to strengthen the capability of national institutions to develop agroforestry systems. In order to cover a wide spectrum of agroecological and socioeconomic conditions, COSPRO is organized on the basis of geographical regions, on the assumption that regional land management systems share broadly similar cultural conditions. Within each of these regions, three or four major ecological zones are selected, to build a geographical/ecological framework in which a network of potential research sites are to be located. Southeast Asia is one of such geographical regions.

This second case in the ICRAF series on Case Studies in Agroforestry Diagnosis and Design is the result of collaborative activities undertaken by scientists from ICRAF, the Forest Research Institute (FORI) of the Philippine Council for Agriculture and Resources Research and Development, the Visayas State College of Agriculture (VISCA), University Pertanian Malaysia, and Kasetsart University, who joined together under the sponsorship of the Southeast Asian Regional Center for Graduate Studies and Research in Agriculture (SEARCA) to do the field work on which this case study is based. The findings of the field exercise were presented at the Southeast Asian Regional Seminar-Workshop on Agroforestry held at SEARCA in October, 1982. This led to the formulation of proposal for a research project to be implemented by the Philippine Institutions with the technical back-stopping of ICRAF.

The aim of the proposed research project is to develop improved systems of land management for upland farming systems in the Southeast Asian region, with special attention to the farming circumstances of the beneficiaries of a land reform programme in the study area on the island of Leyte in the Philippines.

The case study is the result of an application of ICRAF's Diagnostic and Design methodology (D&D) by a multidisciplinary team of scientists from the participating institutions. The purpose of the initial 'rapid appraisal' D&D exercise was to diagnose existing and future land management constraints and agroforestry potentials, design appropriate agroforestry systems and formulate plans for research to develop the candidate agroforestry technologies through a combination of on-farm and field station research. As the project progresses, the iterative D&D process will be repeated in modified form to take stock of project experience, refine the diagnosis and design, and introduce appropriate modifications into the research plan in order to optimize the productivity, sustainability and adoptability of the experimental technologies.

In due course, prototype agroforestry technologies and land management systems arising from this process will be evaluated for extension and adaptive research throughout a wider recommendation domain in Southeast Asia and in similar farming situations in other parts of the world.

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1. UPLAND FARMING AND LAND REFORM IN THE PHILIPPINES

The hazards of upland farming in the Philippines, as elsewhere in Southeast Asia, are notorious. Problems range the whole spectrum from shifting cultivation to permanent upland farming systems. In areas of high population density where permanent arable cropping has been the predominant form of land use for many generations of peasants, continuous cultivation without the possibility of fallow results in soil mining, accelerated erosion and diminishing yields. Although the system may eventually stabilize at a very low level, it holds little prospect of being able to meet a future of increased human population which cannot be realistically absorbed into the urban economy. Low cash incomes of peasant farmers and lack of adequate input supply and marketing infrastructures create a situation which offers little hope for improvement of the rural economy through conventional high-input approaches to agricultural intensification.

Land tenure issues compound the problem. Unlike among the shifting cultivators, where the main issue is insecurity of tenure over ancestral lands in the face of restrictive forest laws and increasing pressure from land-grabbing outsiders, the main problem in peasant farming is unequal distribution of land and other productive resources between smallholders, often tenant, farmers and large, often absentee, landowners. In some cases the traditional systems of rights and obligation safegurded a reasonably stable symbiosis. With modernization and the breakdown of these traditions, however, landlord-tenant relations have become increasingly exploitative in many areas. In response to mounting political pressures, the government has sought to implement land reform through various programmes. One such programme is "Operation Land Transfer," which is being implemented in the Tagbango case study area on the island of Leyte.

In Tabango the relationship between ecological and tenure problems in upland farming systems takes on a particularly interesting and challenging form to developers of agroforestry technologies. There are basically two main forms of land use in the area: coconut-based perennial tree crop systems and permanent upland cultivation of field crops. As presently practiced, the coconut-based farming system, with or without additional tree crops and livestock grazing in the understorey, appears to be a productive and sustainable land use system, but permanent upland cultivation is not. Although the tree crop system is feasible for farmers with upwards of 5 hectares at their disposal, the major part of the coconut system is held by a small number of large landowners.

In areas not designated as "land reform areas" large landowners are expanding their tree crop holdings using the labour of landless farmers to plant the trees in return for the right to cultivate annual crops until the canopy closes and forces them out. Eviction, in this case, is accomplished by the tree rather than the landlord. While they do have the option of remaining on the large haciendas as wage labourers, most farmers would prefer to be independent smallholders, or at least permanent share-croppers on open land.

To meet the small farmers' need for land the Operation Land Transfer (OLT) programme, in areas where it is being implemented, buys out the landlord and offers the farmers eventual title, after a specified pay-back

period, to the land they have traditionally cultivated as tenants. The problem faced by many of the beneficiaries of this programme is that the amount of land to which they can thus lay claim is quite small, usually under two hectares. This is too small to contemplate a transition to the tree crop systems for farmers who must meet their families' daily subsistence needs. They are left, then, with the upland field crop system which, under traditional technology, is only marginally productive and highly subject to a severe form of the upland degradation syndrome.

In Tabango we are confronted with the land use paradox of sustainability without equity and equity without sustainability. If land reform is to succeed in Tagbango, and similar situations throughout the Philippines, new technologies will have to be developed to place smallholder upland farming on a sustainable footing. This is where agroforestry may have a role to play. The specific form which that role could take is the subject of this case study.

2. DESCRIPTION OF THE STUDY AREA

2.1 Site Location

Tabango Municipality is located in the northern part of the island of Leyte in the Philippines, about 159 km from Tacloban City, between the municipalities of Villaba and San Isidro. Comprising an area of some 129 km^2, the municipality is traversed by unpaved all-weather roads. Coastal areas along the VisayanSea are accessible by boat. Tabango has a total of 13 local administrative units known as barangays. Due to the inaccessibility of some of the barangays during heavy rains, the study was confined to five barangays: Poblacion, Catmon, Omaganhan, Taoing and Campokpok.

2.2 Topograhy

Mostly hilly with moderate to steep slopes draining to the Visayan sea. The highest peak is Mt. Canturaw with an elevation of 362 ft above sea level. Level lowland areas are limited to about 25 percent of the total land area.

2.3 Climate

The Project area is situated in the humid tropics, with an annual average rainfall between 2000 and 2500 mm. The water balance is usually positive (rainfall in excess of evaporation) through 9 of 12 months, from May/June to Feb/March. The growing period is approximately [illegible] days/year. As the rainfall is to a large extent influenced by tropical depressions and storms (2-4 per year) its inter-annual variability is considerable. This results in temporary drought situations as well as heavy rains representing high erosion hazards.

The mean temperature at sea level is around 27°C, with little annual variation (2.5°). The absolute maximum and minimum range between 34° and 22°C respectively. The elevation effects the mean temperature with a loss rate of 0.55°C per 100 m.

Nebulosity follows the seasonal changes in rainfall distribution and is accordingly high. The average duration of bright sunshine is between 40 and 50% of the astronomical day length.

High relative air humidity (70-80%) is again in accordance with the general climatic pattern.

The prevailing wind directions change from NE in January to WSW in July. The mean windspeed is generally [illegible] m/s.

2.4 Population

As of 1980 the total population of Labange Municipality was 29,3[illegible]6. Males comprise 50.41 percent and females 49.59 percent of the population. The annual grude population growth rate is 1.6 percent and the average population density is 234/km².

2.5 Economy

The major minicipal products are maize, coconuts and rice. Employment and monthly income are as follows:

EMPLOYMENT

Self-employed farmers	- 45 percent
Labourers	- 40 percent
Other employed	- 15 percent

MONTHLY INCOME

Less than 100 pisos	- 14 percent
100 to 800 pisos	- 68 percent
more than 800 pisos	- 18 percent

2.6 Agroecological Zones within the Study Area

a) level topography (0-5% slope) or Class A cropland which can be cultivated using ordinary methods of farming; erosion hazzard very slight to nil

b) sloping cropland (5-60% slope) which should be cultivated using special conservation practices since the soil is subject to moderate erosion hazzards

2.7 Criteria for Differentiation of Farming System

Farms in the study area can be classified into different farming system types on the basis of land tenure, farm size and production emphasis. The main classes are as follows:

Land tenure

- owner cultivators
- beneficiaries of a government land reform programme known as Operation Land Transfer (OLT); according to the Ministry of Agrarian Reform about 8000 ha. in the area are now under the land reform programme, benefiting some 1,88[illegible] tenants
- leaseholders; this category is reportedly being phased out by the OLT (the survey team only encountered one farmer in this category)

Owner cultivators and OLT beneficiaries constitute about 90 percent of the farmers.

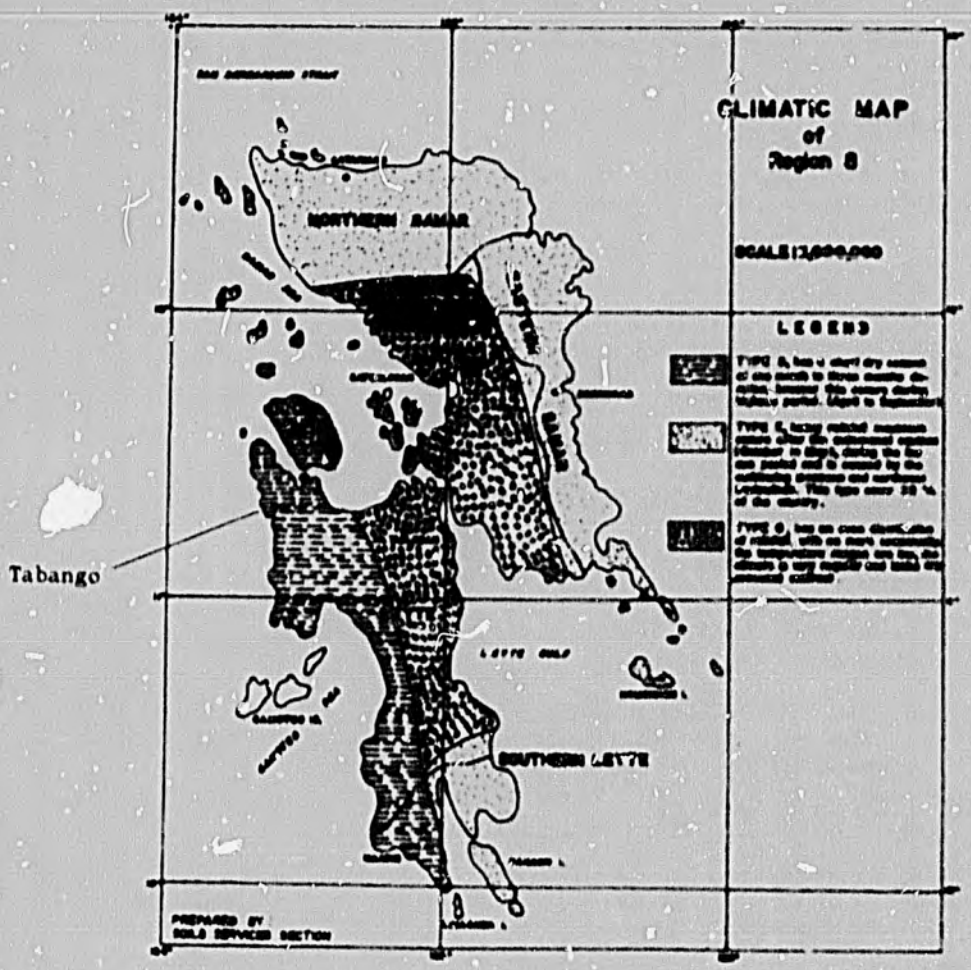


Figure 1. Site location and climatic map of the study area on the island of Leyte in the Philippines.

Farm size

- less than 2 ha
- 2 to 5 ha.
- more than 5 ha
- large hacienda

Most farmers cultivate no more than 5 ha. The majority of these operate farms of 1.5 to 2 ha.

2.8 Production Emphasis

Table 1. Production emphasis of the predominant farming systems in the Tabango study area.

	Primary Production Emphasis	Secondary Production Emphasis
Annual Crops	subsistence staples rice maize cash crops peanuts mung beans	supplementary foods & cash crops cassava sweet potato & other roo bananas
Perrenial Crops	cash crop coconut	cash crop Leucaena leucocephala (ipil-ipil) for leaf-meal and fuelwood
Farm Animals	draught power carabao (water buffalo) cash income pigs	subsistence consumption chickens

2.9 Characteristics of the Selected Farming System

The following information summarizes the salient characteristics of a typical farm in the farming system selected for priority emphasis by the diagnostic and design team:

Agroecological characteristics

- topography: upland slopes ranging from 10-60 percent (avg = 30%)
- soil: clay to clay loam, generally deep
  pH = 7.7
  % N (total) = 0.06 - 0.14%
  % OM = 0.4 - 2.5%
  P (available) = trace, particularly in upper slopes,
  22 - 32 ppm in lower slopes
- erosion hazzard: sheet and rill erosion notable on many farms

Tenure status

- OLT beneficiaries

Farm size

- 1-2 ha.

Production system

Table 2. The role of major crop and livestock components in the selected farming system and their associated cultural practices. Where two or more purposes are served the primary one is underlined.

CROP/ANIMAL	PURPOSE	CULTURAL PRACTICE
Primary		
maize	subsistence, cash, animal feed	monocrop in rotation
rice	subsistence, cash, animal feed	monocrop in rotation
peanut	cash	monocrop in rotation
mung bean	cash	monocrop in rotation
Secondary		
sweet potato	subsistence, cash	monocrop in rotation
cassava	subsistence	monocrop
banana	subsistence, cash, feed	boundary planting
ipil-ipil	cash, fuelwood	scattered rows and clusters on farm
Animals		
carabao	draught animal	grazing on roadsides and neighbouring coconut plantations
pigs	cash, social consumption	scavenging and supplementary feed
chickens	subsistence	scavenging and supplementary feed

Cropping schedule for major crops:

	Planting	Harvesting
Maize	April-May	July-August
peanut	Sept	Dec-January

Average crop yields:

Maize	5 sacks/ha (250 kg/ha)
peanut	10 sacks/ha

3. DIAGNOSIS OF MAJOR LAND USE PROBLEMS AND POTENTIALS

The results of the diagnostic survey and analyses carried out by the regional D&D team are presented in Fig. 2. This is a combined causal network and flow diagram which depicts, from left to right, the major household supply problems. The flow of related inputs and outputs (unbroken lines), and the causal factors which contribute (broken lines) to the creation of the identified problems.

3.1 Problems in the Household Supply System

Contrary to initial expectations, the diagnostic survey revealed that there are no presently perceived problems in the staple food and fuelwood

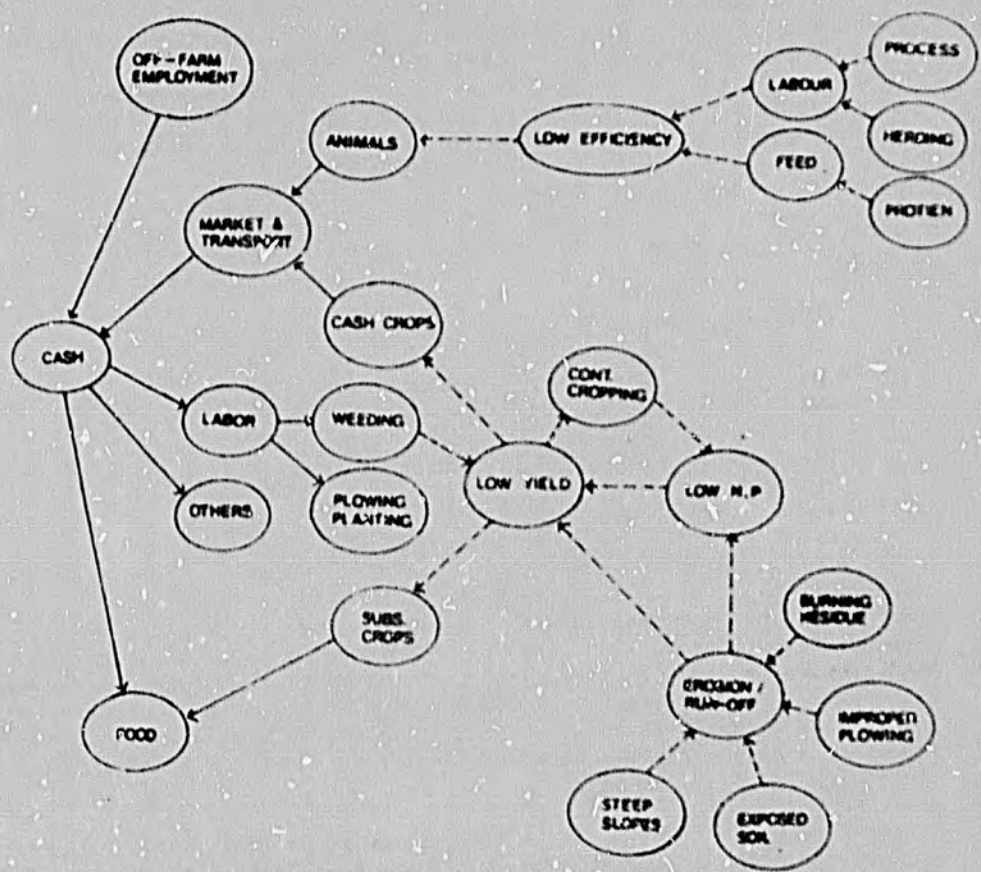


Figure 2. Combined causal network and flow diagram of the farming system problematique in Tabango, Leyte. Depicted from left to right are the major household supply problems, the flow of related inputs and outputs (unbroken lines), and the causal factors which contribute to the creation of the identified problems (broken lines).

supply subsystems of households in the target farming system. Domestic needs for fuelwood are reported to be adequately met by the ready supply of coconut fronds in the general area together with farm plantings of *Leucaena leucocephala*. Although, farm produced staple foods are in most cases insufficient to meet the annual needs of some households, the dominant strategy of the household economy is one of mixed subsistence and cash crop production, supplemented by income from off-farm labour (mainly agricultural labour on other farms in the area). Since cash income is sufficient to meet the needs for supplemental purchase of food, food shortage *per se* is not felt to be a problem. This does, however, constitute a drain on household cash resources.

Inadequate cash income

Insufficient cash for purchase of other household needs (clothing, educational expenses, and non-food consumer items) and for capitalization of farm improvements emerges, therefore, as the main household supply problem in the survey area. The main sources of cash income are proceeds from the sale of cash crops (mainly peanuts and mung bean), livestock (pigs) and earnings from off-farm employment, as shown in Table 3.

Table 3. Sources of cash income

Source of Income	Percentage of Farmers Surveyed (N=10)
Off farm employment	90
Peanuts	90
Pigs	80
Mung bean	50
Maize	20
Rice	20
Sweet potato	20
Banana	10
Ginger	10
Onion	10

The main drains on household cash resources are food purchases to supplement farm production of staples and hired labour for weeding, land preparation and planting. Some 50 percent of the household surveyed own no carabao and must spend an average of ₱250 per crop (2 crops/year) to hire the services of a ploughman and carabao. This lack of a draught animal is a severe capital constraint which, given the low net income, is very difficult to remedy.

Income from sale of cash crops and livestock is generally insufficient to meet the cash needs of the household and most farmers resort to off-farm employment to supplement farm earnings. Of the 10 farmers surveyed who fall into the category of the target farming system, 8 engage in off-farm agricultural labour and one is self-employed as a maker of wooden ploughs. All farmers expressed interest in increased income from farm sources, but the survey team did not detect a notably high level of entrepenurial aspiration among this group of farmers.

3.2 Causal Factors Responsible for Household Cash Problems

On the income side, the main factors associated with low on-farm cash production are shown in Fig. 2 as causal complexes or "syndromes" responsible for *low yield* of field crops and *low-efficiency* of the pig production enterprize.

Low Yield Syndrome

Continuous permanent cropping without mineral nutrient inputs and inadequate soil conservation practices have resulted in low nutrient status of the soils and low and declining yields of both subsistence and cash crops (e.g. 250 kg/ha of maize). The small farm size and low productivity of the land necessitates a permanent cultivation regime with no opportunity to rest portions of the land in order to restore soil fertility, thus perpetuating the low yield syndrome. The non-use of mineral fertilizers is attributable both to the lack of cash resources and the lack of a local infrastructure for supply of agricultural inputs.

Sheet and rill erosion processes further exacerbate the degradation syndrome on these farms through continued nutrient losses and poor crop stands. Erosion hazards are substantial under the prevailing conditions of steep slopes and cropping practices which leave the soil exposed to heavy rains following field preparation. Improper ploughing practices and the burning of agricultural residues are major contributing factors in soil erosion. The fact that the farming system is still operational at all, even at low levels of yields, is attributable to the depth and only moderate erodibility of the soil. Nevertheless, at an estimated rate of loss of 1 cm of soil per year, this system of poor husbandry cannot be sustained indefinitely.

The prevailing tillage practice is to plough the field in lines perpendicular to the main slope. However, since the fields typically exhibit an undulating topography with minor slopes in variation to the main slope, the ploughing pattern usually deviates substantially from recommended contour ploughing practices, with the result that severe erosion occurs in areas of downslope furrows. From discussion with farmers it is clear that the decision to plough perpendicular to the main slope is mainly based on the desire to conserve the energy of the draft animals and not specifically intended to prevent erosion. Although proper contour ploughing would more efficiently satisfy both erosion control and energy conservation purposes, no cases of contour ploughing by smallholders were observed in the entire survey area.

The retention of agricultural residues on the fields would also tend to mitigate both erosion and low-fertility problems, but all farmers surveyed reported a strong inclination to gather up crop residues and burn them. The main reason given for removal of crop residues from the fields was to avoid interference with ploughing operations, since with the traditional chisel plough used in the area maize stalks and other residues tend to bunch up in front of the plough, making tillage difficult. The expressed reason for burning the gathered residues was not any conscious desire to release nutrients to the soil, but rather to destroy potential habitats for rodent pests.

All of this is done without any evident consideration for erosion control and maintenance of soil fertility, although both of these factors are acknowledged by farmers as major contributing causes of declining yields. The only notable fertility conserving measure practiced by the majority of farmers is the rotation of cereal crops with grain legumes.

Low Efficiency of the Livestock Enterprise

The low time-use efficiency of carabaos (water buffalo) as draft animals is a noteworthy latent constraint on agricultural production, but not one which admits of an easily conceivable and feasible solution. These

animals, unlike oxen, must be rested and allowed a cooling-off period in water after brief periods of draught labour. Nevetheless, the slow work pace of the carabao seems to accord quite well with the somewhat leisurely attitude to work of the local farmers, and there seems to be little scope at present for any attempt to disrupt this congenial symbiosis by substitution of more efficient draught animals.

The main addressable livestock constraint, therefore, is the low efficiency of the pig production enterprise, which is present as a source of cash income and socially expendable wealth (fiesta contributions, etc.) on most farms. Inefficiency arises in connection with the labour requirements of the present system of feeding and the nutritional inefficiency of the present diet. Free range pig feeding is not possible on most farms because of the danger of damage to one's own and neighbour's crops. Consequently, labour is required to move and tether pigs from time to time. Supplemental feeding of rice bran and shredded banana stalk is commonly practiced, but this does not make up for the lack of high quality protein in the diet. The resulting slow rate of live weight gain yields rather low returns to labour invested in the pig enterprise.

4. DERIVATION OF DESIGN SPECIFICATIONS

The following list of design specifictions may, for convenience, be divided into *functional specifications* derived from analysis of intervention points in the system suggested by the combined causal network/flow diagram (Fig. 2) and *other design specifications* derived from the general understanding of resource constraints and farmers' strategies gained in the course of the diagnostic survey exercise.

4.1 Functional Specifications

To reduce the outflow of cash:

a) Reduce the need for hired labour by reducing

-- the amount of tillage required for field preparation
-- the level of labour required for weeding

b) Reduce cash expenditure on supplementary food purchases by increasing on-farm production of staples by removing or mitigating the yield-reducing constraints. This could be done by:

-- improving the availability of nutrients (mainly N&P)
-- reducing erosion by

- adopting proper contour ploughing practices
- instituting a feasible system of organic matter maintenance on the fields

To increase the inflow of cash:

a) Incorporate new cash crops into the farming system

b) Improve the productivity of existing cash crop enterprizes (see b above)

c) Improve the efficiency of the main livestock enterprise by

-- producing a more balanced pig ration from potential farm feed sources
-- reducing the labour requirements of pig feeding by

- introducing improved processing technology
- substituting the current tethering practice by an efficient pen feeding regime

4.2 Additional Design Specifications:

To be appropriate and *adoptable* by farmers in the context of their existing farming system (i.e. without major infrastructural or motivational changes) candidate technologies must:

a) have low capital requirements and must not rely on inputs which are not generally accessible to small farmers in the area,

b) be efficient in the use of available labour resources (i.e at prevailing levels of effort acceptable to the majority of farmers) and must not exacerbate labour bottlenecks in the farming system,

c) make efficient and intensive use of scarce land resources

d) not contribute unduly to increased pest problems,

e) be consistent, in the case of new cash crops, with marketing potentials in the area.

5. ALTERNATIVE TECHNOLOGIES

Cash deficit was identified at the diagnostic stage as the main symptom of the farming systems in the Tabango area, a problem that motivates farmers to look for off-farm income. The causal diagram in Fig. 2 indicates that this deficit stems mainly from factors in the operation of cropping and animal production enterprises within the farm. Of the two a higher priority should be placed on improvement of cropping enterprises, since they constitute the main source of both food (maize) and cash (peanuts).

Low soil fertility and soil erosion were singled out as the main causes of low crop yields, indicating the most promising points for technological interventions in the system. Table 4 summarizes some of the alternative practices, of an agroforestry and non-agroforestry nature, envisaged by the multidisciplinary team as having the potential to overcome those constraints.

5.1 Non-agroforestry Alternatives

Although a thorough discussion of these options vis-a-vis the identified constraints is beyond the scope of this document, it is worth mentioning some of the reasons leading to the selection of an agroforestry alternative, most of them linked to the design specifications discussed above.

In the field of soil nutient deficiency the introduction of inorganic fertilizers would most certainly overcome the biophysical constraint. However, such an input would further strain the already scarce cash resources available at the farm level. Even if a credit programme were made available, there is no existing infrastructure for distributing fertilizers. Compost could be an interesting alternative, particularly to avoid residue burning. However, lack of knowledge and labour requirements may prevent its adoption.

Green manuring with appropriate herbaceous species has been shown to improve soil fertility, but land and labour scarcity and local attitudes against growing a crop solely for the purpose of improving the soil, would tend to prevent the acceptance of conventional green manuring practices by farmers.

One of the problems farmers would face in trying to incorporate residues is the type of ploughing equipment in use, which does not have a mould-board to turn the soil over. Substituting the existing chisel plough by

Table 4. Possible non-agroforestry and agroforestry interventions to solve or mitigate the diagnosed problems.

PROBLEMS	INTERVENTIONS	
CASH OUTFLOW	NON-AGROFORESTRY	AGROFORESTRY
1. Low Yield		
- N.P. deficiency	- Mineral fertilizer - Composting - Green manure	- Legume tree mulching
- Residue burning	- Mould-board ploughing - Composting - No-tillage	- Mulching for minimum tillage
- Water erosion		
.Steep slopes	- Terracing	- Hedges across slopes
.Improper ploughing	- Contour ploughing - No-tillage	- Contour hedges
.Exposed soils	- Perennial crops - Relay cropping - Mulching	- Mulching
2. Tillage		
- Carabao		
.Hired ploughing	- No-tillage	- Mulching for minimum tillage
.Working capacity	- Oxen - No-tillage	- Mulching for minimum tillage
- Weeding	- Mulching	- Mulching
CASH INFLOW		
1. Low Yield (Peanuts)		
Same as outflow	- Same as outflow	- Same as outflow
2. Swine Production		
- Feed sources	- Balanced ration	- Gabi & leaf meal in hedgerow intercropping
- Feed processing	- Mechanical shredder	
- Management	- Appropriate housing	
3. Cash Sources		
- Crops	- Pineapple - Black pepper - Ginger	- Hedgerow intercropping of: .Pineapple .Black pepper + Ipil[2] Leaf Meal .Ginger
- Livestock	- Cattle Fattening	

a mouldboard plough would be a relatively costly option, possibly requiring stronger animal traction. It is known that no-tillage methods will improve soil and water conservation as well as reduce traction energy and labour requirements, but the specialized knowledge and equipment required, together with high cost and problems with the supply of herbicide may again prevent its widespread adoption. There is a need, moreover, to provide for a source of mulch which should not compete unduly with the main crops for light, moisture, nutrients and space and/or time in the cropping regime.

The investment required for construction of proper bench terraces would seem to rule them out as a locally adoptable alternative. Contour ploughing would certainly be a feasible erosion mitigating alternative, to which farmers ought to be introduced. At the moment there is a kind of "across the slope" ploughing, not precisely as a soil conservation practice but to avoid having the carabao go up and down the slope.

A permanent vegetation cover would certainly decrease the impact of erosive factors. However, establishing perennial crops (like coconuts) would compete with food and cash crops for the use of scarce land, depriving the smallholder family of its livelihood for quite a few years (it could become a visble alternative, however, for holdings of 5 ha or larger). Relay cropping would also provide a permanent protective cover, but its efficiency may be impaired by the low soil fertility level.

The efficiency of tillage operations could possibly be improved by substituting the carabao (short effective working time) by oxen, but this may be a very difficult change to introduce and it may disrupt a cherished symbiosis between Visayan farmers and carabaos. At any rate, it would appear that in the medium to long run land pressure may tend to displace animal traction from smallholdings, particularly if and when free access to grazing under the coconuts of the larger plantation owners is restricted.

Cash income could be increased by substituting alternative cash crops for peanuts, but the rate of adoption may be slow under existing marketing conditions. Cattle fattening does not appear as a sustainable alternative for smallholders, since fodder production will compete with food and cash crops for land and labour.

5.2 Agroforestry Alternatives

Collumn 3 in Table 4 summarizes the interventions of an agroforestry nature which were considered by the team for addressing specific constraints in the diagnosed system. From the discussions at the design stage of the D&D process there emerged a general design concept for an agroforestry land management system which appears to have the potential to remove or mitigate several of the most limiting constraints. The team decided, therefore, to focus its attention on the elaboration of this design concept as a prelude to the planning of a research project to develop and test the proposed agroforestry system. The results of the teams' thinking, as developed initially in the rapid appraisal mission and later in the followup phase of the D&D process are presented below.

5.2.1 Design concept: hedgerow intercropping or alley cropping system

The use of mulch from a nitrogen-fixing tree as a source of organic fertilizer for the predominant field crops appeared to the team as a promising technique for restoring and maintaing soil nitrogen at an increased level. The possibility for arranging such trees in hedgerows

along contour lines in the field suggested itself as a way of forming vegetative barriers capable of arresting soil erosion which in time would result in the development of natural terraces. The existence of contour hedgerows would also force farmers to plough along contour lines, thus reducing inter-row erosion.

The food and/or cash crops normally grown by farmers could be intercropped between the hedges with the expectation that, if such a system were perfected, the increase in productivity from organic fertilization would more than offset the reduction in cropping area alloted to the main crops. Moreover, if the hedges were composed of leucaena or other fodder-producing trees or shrubs, the tops could be used to produce leaf-meal during those times of the year when the prunings were not being used for mulching. Firewood could also be produced as a by-product of other management practices. It was further envisaged that the space alloted to the hedgerows could be intercropped in a two-storey arrangement with shade tolerant root crops grown at the side of the hedge, and vine crops (such as black pepper) grown within the hedgerow by planting self-pruning tree species at 10 meter intervals or more in the hedgerow to serve as live supports for the vines. See Fig. 3 for an artist's conception of the proposed system.

This design concept will be recognized as a variation on the "alley cropping" theme found in the literature (Parera, 1976; Guevarra, 1976, 1978; Benge, 1979; de la Rosa, 1980; IITA, 1980a, 1980b; Wilson and Kang, 1980; Wilson and Raintree, 1980; Raintree and Turay, 1981; Kang, Wilson and Siplons, 1981; Metzner, 1981; Evensen, 1982). As a form of "zonal cropping" (Huxley, 1980), alley cropping is a type of agroforestry system which may allow simplification of management procedures by dealing with each zonally arranged component largely as a sole cropping enterprise within the cropping system.

Evaluation of different alley cropping system, however, has shown (Verinumbe, 1981; Balasubramanian, 1983) or predicted (Hoekstra, 1983, Torres, in press) variable results in different environments, indicating the need to generalize with caution and distinguish clearly between specific design variations on the general alley cropping theme. The concept of alley cropping or, more generally, hedgerow intercropping implies a "family of technologies" often linked to each other only by the shared attribute of some form of zonal arrangement of woody and herbaceous components.

The specific hedgerow intercropping system depicted in Fig. 3 is only a *design prototype*, intended to convey the general idea of the team's proposal and to serve as a starting point for the research envisaged as necessary to develop an optimal system for the farming conditions of the Tagbango area. The product of such research, assuming the project is successful in developing an optimal site-specific system, would itself revert in the dissemination phase to the status of a prototype for adaptive research throughout the potential recommendation domain.

Although various hedgerow intercropping systems of this general type are known to exist in the Philippines and in other forms elsewhere in South-east Asia, it is doubtful whether any such system has gone through the process of reiterative development and refinement which would be characteristic of a systematic and cost-effective approach to the development of system-specific agroforestry technology (ICRAF, 1983a, 1983b). At the

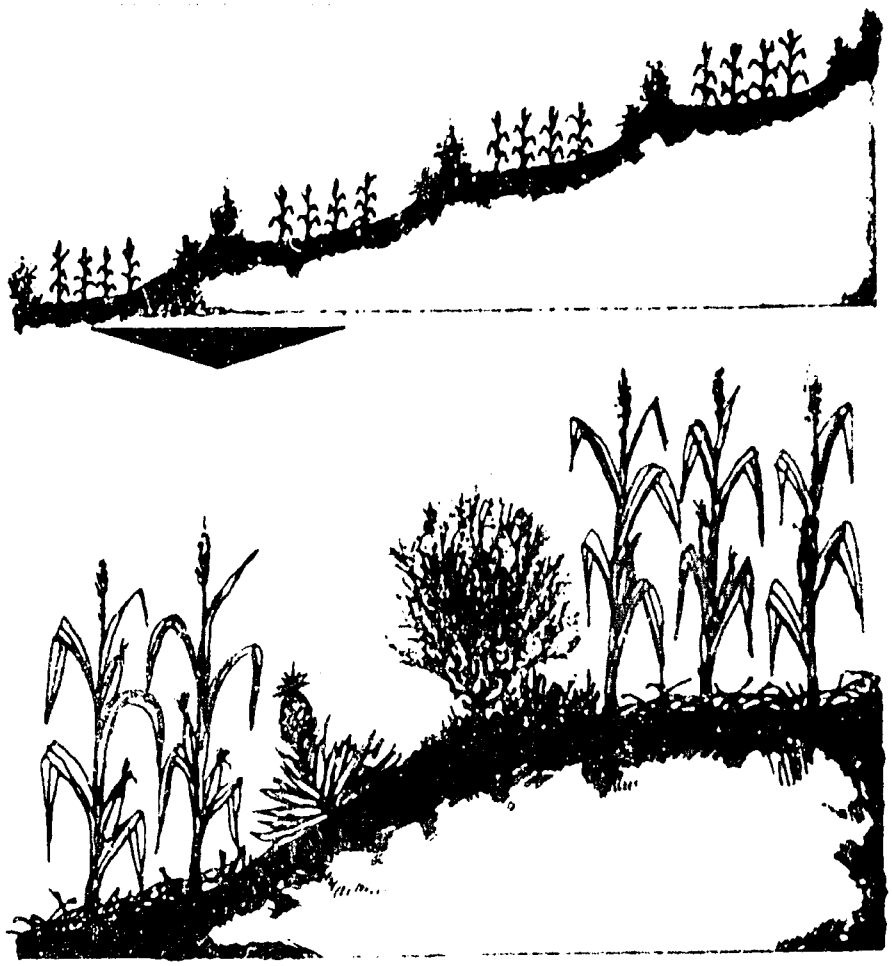


Figure 3. Artist's conception of the experimental hedgerow intercropping system proposed for research at the Tabango site.

outset of such a process it is essential to set forth the desirable characteristics of the eventual technological product (i.e. the design specifications) which would make it appropriate and adoptable in the context of the target land use system.

In addition to addressing the functional requirements of soil fertility improvement (mainly increased nitrogen) and erosion control, an appropriate alley cropping system for the target group in Tabango would also possess the following desirable characteristics:

a) be efficient in the intensive use of land
b) be efficient in the use of labour and not create labour bottlenecks
c) not increase pest problems beyond an acceptable level
d) be flexible as regards management for different products on different farms and at different times of the year
e) allow for the possibility of minimum tillage management in the eventuality of reduced draught power on the smaller farms
f) not involve management complexities which the local farmers, after a sufficient demonstration and trial period, would not be willing to accept.

5.2.2 Plant ideotype for the tree/shrub component of the system

Although maize is virtually a "given" as a component of any widely adoptable alley cropping system developed for the Tabango site, the choice of the most appropriate tree/shrub component for the system is an *open question for research*. In addition to specifying the desirable characteristics of the proposed system, it is helpful to set forth the desirable characteristics of plant components prior to screening (Raintree, 1981). The following characteristics have been identified as features of the ideotype for the ideal tree/shrub component of hedgerow intercropping systems of the type proposed for Tagbango:

a) high N-fixation capacity
b) fast-growing
c) able to coppice vigorously and yield required volume of suitable mulch material under acceptable cutting regime
   - vigor and yield requirements will vary with cutting frequency deemed acceptable to user (which will be affected by labour availability, shading effects and mulch requirement to achieve desired benefits)
   - suitability of mulch material determined by various characteristics (e.g. rapidly decomposing leaves for quick release fertilizer, slowly decomposing leaves for weed and runoff control, desirability of insect-repellent properties, nutritional quality and palatability if herbage to be managed for fodder by-product, etc.)
d) deep rooting habit for drought resistance, recycling of subsoil nutrients, and minimal surface root competition with associated arable crops
e) easy and economic establishment
f) high yields of economic by-products (feed and firewood)

It is difficult to assign priorities to the various characteristics prior to on-farm trials to assess performance in terms of features desired by the end-user. Other, more detailed plant physiological characteristics may be identified as the research progresses. It may also be necessary

to think of satisfying the total package of requirements by a *combination* of hedgerow species if they are not optimally combined in a single species.

5.2.3 Ex ante evaluation of the proposed system

The basic hypothesis behind the proposal of the experimental hedgerow system is that the increments in crop yield due to organic nitrogen inputs from the nitrogen-fixing woody component would increase the productivity per unit of intercropped land. Available information was analysed to evaluate the potential contribution of leucaena hedgerows and to formulate a more quantitative hypothesis on the impact on grain and fuelwood yields of the intercropping of leucaena hedgerows with maize (Torres, in press).

The use of data on *Leucaena leucocephala* in the following computations is made without prejudice to the eventual selection of other woody components for the hedgerow role, although the choice of leucaena as an initial "best bet" component for the prototype system is justified on several grounds: 1) leucaena does possess most of the characteristics of the plant ideotype for the tree/shrub component of the system (although it does not have slowly decomposing leaves, which might be desired if a more durable mulch is required for a minimum tillage variant of the system); 2) the giant "Salvador type" leucaena varieties are a well-established feature of the existing farming system (though not in the arrangement envisaged in the proposed design); 3) sufficient data on the performance of leucaena and associated crops exist in the literature to allow a *first order approximation* of its performance under the proposed conditions (this is not the case for most of the woody species often mentioned as having potential for agroforestry). The following calculations, therefore, give an approximate indication of the performance of *one variant* of the prototype system.

Based on production data from the humid tropics it was assumed that a linear meter of leucaena closely planted in a hedgerow would produce about 1 kg of "leafy" dry matter per year with a nitrogen content of 3.5%. and around 650 g of fuelwood. It was further assumed that an increase of 5.3 or 6.3 kg of maize per kg of nitrogen applied as leucaena mulch would be obtained from such practice. Results of this speculation in terms of kg of maize per ha of intercropped land for different baseline maize productions are shown in Table 5. Increases in grain yield expressed as percentage of baseline production are shown in Fig. 4. (Torres, in press).

Table 5. Estimated yields of maize per hectares of intercropped land, as affected by baseline production of maize

Leucaena inter-row spacing (cm)	maize baseline production (kg ha⁻¹) 500	1000	1500	2000
– Applying ratios derived from *observed* yields				
150	2310	2120	2110	2170
300	1405	1560	1805	2085
450	1103	1373	1703	2056
600	953	1280	1653	2043
– Applying ratios derived from *reduced* yields (75% of observed)				
150	1800	1710	1770	1880
300	1150	1355	1635	
450	933	1236	1589	
600	825	1178	1568	

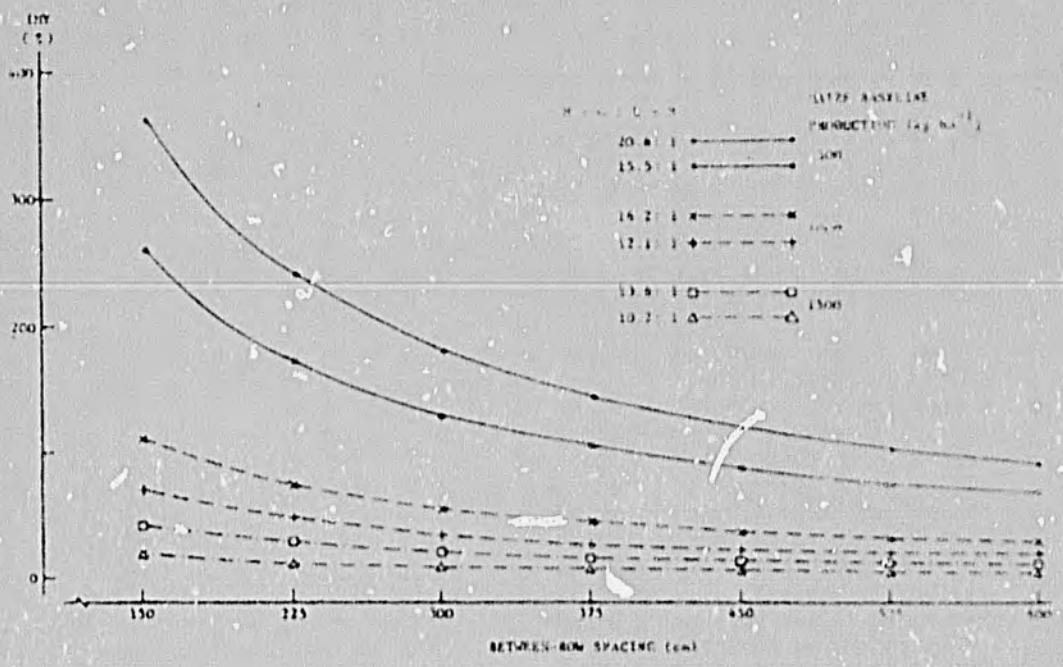


Figure 4. Increase in maize yield per unit of intercropped land (IMY).

As mentioned above, the existing production level at Tagbango appears to be in the order of 250 kg ha^{-1}. Under these circumstances the hypothetical relationships shown in Fig. 4 indicate that even at the wider inter-row spacing, increases in physical production is higher than 30%. Should those relationships be supported by experimental evidence, espacement would still depend on economic considerations, particularly in relation to the labour cost: maize price ratio. The proposed practice would obviously require higher labour inputs than the present system, but it should be noted that at the 150 cm spacing and 1: 6.3 ratio the increase in maize yield would be equivalent to about 60 man days (assuming 1.1 pesos per kg of maize and a salary of 7 pesos day^{-1}) which could be expected to offset the increased labour input.

Table 6. Estimated potential fuelwood production per hectare of intercropped land.

Leucaena between-row spacing (cm)	Stem production kg ha^{-1}	m^3 ha^{-1}
150	1610	3.50
300	805	1.75
450	537	1.17
600	403	0.88

In addition to the potential benefit to be derived from an increase in maize production, a hectare of hedge intercropping at 150 cm spacing would supply enough fuelwood to satisfy annual requirements of 8 persons (Table 6), and the equivalent value of another 40 man-days of labour could be obtained if one of the hedgerow harvests is sold for leafmeal production (assuming that 50% of the "leafy" portion would be accepted for leafmeal at a price of 500 pisos per ton of leafmeal).

It should be emphasised, however, that *the potential of this technology must still be tested under field conditions* before being considered for dissemination to farmers. That, in fact, is what is envisaged as part of the research proposed in the next section of this report.

6. RESEARCH PROPOSAL

Accepting that the quantitative hypothesis formulated in the previous section is based upon some experimental evidence, the designed technology prototype could already be tested on-farm, while more controlled experiments are carried out concurrently to test hypothetical relationships (to allow for a better understanding of fundamental processes) and to try alternative components.

It is proposed, therefore, that research activities be carried out at 3 sites: on farmers' fields, in a local field station (to be developed on land generously offered by the Tabango Mayor) and at the VISCA campus. In general, information emerging from those sites will reach the development stage in the short (2 years), medium (4 years) and long (6 years) term, respectively (meaning the period of elapsed time before they are ready to be disseminated by the extension system).

In this context it is suggested that the following research activities be implemented in the different sites.

6.1 Intercropping with leucaena hedges (1)

Site: Farmers' field
Period: Immediate (short term).
Problems to Overcome:

i) Low N and P
ii) Soil erosion
iii) Improper ploughing

Objectives

General: Utilization of leguminous trees in croppings with contour hedges to reduce water run-off, and increase N and P availability to the interplanted crops

Specific: (i) To examine the effect of between hedge distances on the yields of crops established on farms with different baseline productions and slope gradients

(ii) To examine the effect of cutting frequencies on the leucaena yield and labour input

(iii) To examine the overall effect of the proposed system on water run-off, erosion, and soil and chemical properties.

Research Design

a) Technology components and management:

i) Leucaena cultivars - local giant K8 or K28 (best bet)
ii) In-row planting distance of leucaena - 15 cm, along contour lines
iii) Height of cutting of leucaena - 15 cm (best bet) after allowing 6 months for establishment
iv) Lemon grass to be planted on the uphill sites of hedges
v) Crop cultivars - local

b) Treatment Variables:

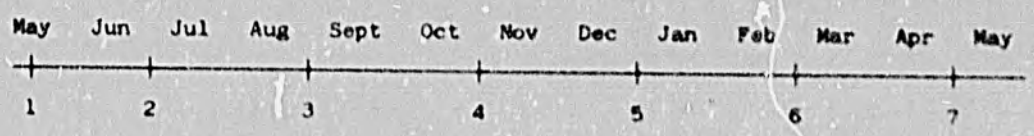
i) Distance between hedges

- 3 inter-row spacings to be tested on different farms, according to existing maize production levels: Farms with 250 kg ha^{-1}: 1, 3 and 5 maize rows between hedgerows; Farms with 500 kg ha^{-1}: 1, 2 and 3 maize rows between hedgerows

ii) Slope gradient - 20%, 40%
iii) Frequency of cutting of hedges

- 2 frequencies will be tested

(1) Farmer's way
(2) 6 cuttings as shown (first cutting 10 days before planting maize)



iv) Replications: 3

c) Criteria for Farm Selection

i) Field extending from ridge to lower slope
ii) Uniform major slope
iii) Minimum width of 50 m

Total farms required: 12

d) Parameters to be Monitored

i)	Yield of crop	Field Researchers
ii)	Yield of leucaena	" "
iii)	Labour input	" "
iv)	Farmer's observations	" "
v)	Rainfall measurement	" "
vi)	Soil chemical and physical properties	VISCA scientists
vii)	Run-off and erosion control	" "

6.2 <u>Intercropping with leucaena hedgerows (2)</u>

Site: Field Station (in Tagbango)
Period: Medium term
Problems to Overcome:

i) Low N and P
ii) Soil erosion
iii) Improper ploughing

Objectives

General: Utilization of leguminous trees in croppings with contour hedges to reduce water run-off, and increase N and P availability to the interplanted crops.

Specific: (i) leucaena cultivar
(ii) height of cutting hedges
(iii) within row tree spacing in hedges, and
(iv) rate of green manure application in terms of:
- leucaena leaf production
- crop yield
- labour input, and
- nutrient (N and P) cycling

Research Design

a) Technology components and management similar to 6.1
b) Treatment Variables

i) Leucaena cultivars: 2, (i) giant and (ii) local
ii) Height of hedge cutting - 2 treatments
iii) Within row spacing of leucaena trees - 3 spacing

i) 15 cm
ii) < 15 cm
iii) > 15 cm

iv) Rate of green manure application (mulching) - 3 treatments (separate leucaena stand to be established, to supply needs for additional mulch)

v) Replications: 2

c) Parameters to be Monitored

i) Yield of crop	Field Researchers
ii) Yield of leucaena	" "
iii) Labour input	" "
iv) Nutrient (N & P) cycling	VISCA Scientists

6.3 Hedgerow intercropping of cash crops

Site: Field Station (in Taghango)
Period: Medium term
Problems to Overcome:

a) Cash shortages

Objectives:

General: To examine the feasibility of introducing some cash crops as components of hedgerows

Specific: (i) To examine the effect of cash crop inclusion in the hedgerow on labour input

(ii) To examine the effect of cash crop inclusion in the hedgerow on the yields of leucaena agronomic crops and cash crops

Research design

a) Technology components and management

i) Hedgerow species, distance between plants, height of cutting and frequency of cutting, similar to 6.1

ii) Lemon grass to be planted on the uphill side of hedgerow

iii) For pepper, 10 m distance between supporting poles

iv) All cash crops to be planted on the downhill side of hedgerow

b) Treatment Variables:

i) Types of cash crops

a) Black pepper (*Jacaranda copaia*, *Gliricidia*, *Erythrina*, *Sesbania* as poles at intervals within the hedgerow)

b) Ginger
c) Pineapple
d) Gabi

c) Parameters to be monitored:

i) Labour input
ii) Yield of leucaena
iii) Field of cash crop
iv) Yield of agronomic crop

6.4 Mulch farming with contour hedges of other species

Site: Research Station (VISCA Campus)
Period: Long term
Problems to Overcome:

i) Low N and P
ii) Soil erosion
iii) Labour requirements for cultivation and weeding

Objectives

General: Utilization of trees in farming with contour hedges to reduce water run-off, tillage and weeding while increasing N and P.

Specific: (i) To examine the possibility of using other N-fixing and coppicing woody perennials as hedge species for providing mulch and nutrient (N & P) e.g. *Erythrina*'.

(ii) To determine the most suitable cutting height and within row spacing for sufficient leaf production

(iii) To determine the required quantity of mulch for effective control of weeds and soil erosion.

Research Design

a) Technology components and management:

i) Species, selected on the basis of:

1) N-fixing, P-pumping capability
2) Broad and slow decomposing leaves (non-deciduous)
3) Deep rooting
4) Fast growing and good coppicer (e.g. *Erythrina*, *Gliricidia* and *Sesbania*)

b Treatment Variables:

i) Height of hedge cutting - 2 levels
ii) Within row spacing of Erythrina trees - 2 spacings
iii) Mulch rate of application - 3 rates (based on potential production)

c) Parameters to be Monitored:

i) Leaf production
ii) Content of N and P in leaves
iii) Weed growth
iv) Crop yield
v) Erosion

REFERENCES

Balasubramanian, V. 1983. Alley cropping: can it be an alternative to chemical fertilizers in Ghana? Paper presented at the Third National Maize Workshop, 1-3 February 1983, Kwadeso Agricultural College Kumasi, Ghana (mimeo).

Benge, M.D. 1979. Use of leucaena for soil erosion control and fertilization. Agency for International Development. Washington. (mimeo)

de la Rosa, J.M. 1980. A Study of the Growth and Yield of Corn Intercropped with Varying Population of Giant Ipil-Ipil (*Leucaena leucocephala*) on a Hillside. Unpublished B.Sc. Thesis. Dept. of Agronomy and Soils, Visayas State College of Agriculture. Leyte, Philippines.

Evensen, C.L.I. 1982. Synopsis of leucaena/maize green leaf manuring study. College of Tropical Agriculture, University of Hawaii. Honolulu. (mimeo)

Guevarra, A.B. 1976. Management of *Leucaena leucocephala* (Lam. de Wit) for Maximum Yield and Nitrogen Contribution to Integrated Corn. Unpublished PhD. Dissertation. College of Tropical Agriculture. University of Hawaii, Honolulu.

Guevarra, A.B. A.S. Whitney and J.R. Thompson. 1978. Influence of intrarow spacing and cutting regimes on the growth and yield of leucaena. Agronomy Journal 70: 1033-37.

Hoekstra, D.A. 1983. *Leucaena leucocephala* hedgerows intercropped with maize and beans: an ex ante analysis of a candidate agroforestry land use system for the semi-arid areas in Machakos District. Working Paper No. 3. ICRAF. Nairobi.

Huxley, P.A. 1980. Agroforestry research: the value of existing data appraisal. *In*: T. Chandler and D. Spurgeon (eds). International Cooperation in Agroforestry. ICRAF. Nairobi.

ICRAF, 1983a. Guidelines for agroforestry diagnosis and design. Working Paper No. 6. ICRAF. Nairobi.

ICRAF. 1983b. Resources for agroforestry diagnosis and design. Working Paper No. 7. ICRAF. Nairobi.

IITA. 1980a. Alley cropping: an improved bush fallow system. Research Highlights for 1979. International Institute of Tropical Agriculture. Ibadan.

IITA. 1980b. Tree fallow and in-situ vine support. Research Highlights for 1979. International Institute of Tropical Agriculture. Ibadan.

Kang, B.T., G.F. Wilson and L. Sipkens. 1981. Alley cropping with maize (*Zea mays* L.) and leucaena (*Leucaena leucocephala* Lam. de wit) in Southern Nigeria. Plant and Soil 63: 167-179.

Metzner, H. 1981. Innovations in agriculture incorporating traditional production methods; the case of Amarasi (Timor). Applied Geography and Development 17: 91-107.

Parera, V. 1976. Lamtoro, salah satu jenis tanaman penghijauan di kabupaten Sikka, Nusa Tenggara Timur. Majallah Pertanian Nomor 3. Sambur, Indonesia.

Raintree, J.B. 1981. Conservation farming with multipurpose tree legumes: an underdeveloped branch of tropical agroforestry research. *In*: L. Buck (ed). Proceedings of the Kenya National Seminar on Agroforestry. ICRAF. Nairobi.

Raintree, J.B. and F. Turay. 1980. Linear programming model of an experimental leucaena-rice alley cropping system. IITA Research Briefs 1(4): 5-7. International Institute of Tropical Agriculture. Ibadan.

Torres, F. *In press*. Potential contribution of leucaena hedgerows intercropped with maize to the production of organic nitrogen and fuelwood in the lowland tropics. Agroforestry Systems, forthcoming.

Verinumbe, I. 1981. Economic evaluation of some zero-tillage systems of land management for small-scale farmers in South-western Nigeria. Unpublished PhD Dissertation. Dept. of Forest Resources Management, University of Ibadan. Ibadan.

Wilson, G.F. and B.T. Kang. 1980. Developing stable and productive biological cropping systems for the humid tropics. *In*: B. Stonehouse (ed). Biological Husbandry: A Scientific Approach to Organic Farming. Butterworth. London.

Wilson, G.F. and J.B. Raintree. 1980. The leucaena-maize-yam alley cropping system. International Institute of Tropical Agriculture. Ibadan. (mimeo).