

SOIL AND NUTRIENT CONSERVATION ORIENTED PRACTICES IN THE PHILIPPINES

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ABSTRACT

The paper discusses several upland farming systems in the Philippines which are based on nutrient recycling and soil conservation. Some are traditional practices developed by farmers themselves, while others have been introduced in modern development programs. Their impact on soil and water loss rates and soil properties are discussed, and compared with those resulting from current farmers' practices.

INTRODUCTION

When farmers shift from practices which promote erosion to a soil-conserving system, it is important to know how this affects soil conditions which are important to crop production. The extent of change depends on the type of soil conservation measure used, on the nature and quantity of biomass incorporated into the soil, and on the length of time since the conservation system was adopted. We could expect an established agroforestry system to be very different from a multi-cropped swidden from which fallow has been eliminated. A comparison of conservation farming with conventional practices should at least include the differences in their effect on soil erosion and nutrient loss, the influence of residue mulches on the physical and chemical properties of the soil, and on nutrient cycling and crop response.

This paper is primarily based on some conservation practices, some indigenous and some introduced from outside, which were evaluated against conventional farming in terms of soil conservation and productivity. The main objectives were:

- To describe selected soil conservation technologies, *and*
- To discuss and assess their effectiveness in minimizing soil erosion and in improv-

ing soil conditions for sustainable agriculture.

INDIGENOUS SOIL CONSERVATION SYSTEMS

Ifugao Rice Terraces

The Ifugao rice terraces in the Northern Philippines cover an area of about 40,000 ha (Beets 1990) and have existed for more than 2000 years (Halos 1982). Rice yields from the terraced fields are much higher than the national average. Essentially, the system is based on the construction of stone-walled terraces along hill slopes, to conserve soil and water (Pacardo 1984). Rice is grown on terraces and fertilized mainly with compost derived from pig manure. The pigs are raised in pens and fed rice bran and human excreta. No inorganic fertilizers or pesticides are applied to the rice paddies.

Omengan (1981) studied the nitrogen and phosphorus balance in rice paddies of this kind, and found that the movement of nutrients from soil to rice to people to pigs and back to the soil is close to equilibrium (Table 1). A net gain of 186 kg N/ha and 214 kg P/ha was noted. The traditional rice variety used in the system yielded 6.2 mt/ha.

Terracing is perhaps the prime factor con-

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tributing to the stability of the system. However, the pinugo (Ifugao term for family-owned forests) are also essential to the system, and are believed to be as old as the rice terraces themselves (Dacawi 1982). The pinugo forests are believed to be the main reason why the rice terraces are still intact and well-irrigated up to the present day. Such family forests range from a few hundred square meters to five hectares. Usually, a family that owns the largest pinugo has also the greatest number of rice terraces.

Fallow-till (“balabag”) System

Another interesting indigenous upland technology is the fallow-till rotation known as balabag, found among Naalad farmers in Naga, Cebu, Philippines. The balabag system is considered as indigenous agroforestry, combining agricultural and forestry crops in the same unit area. It is the same as the modern cyclical agroforestry wherein, land is cleared of perennial crops by cutting, cropped, fallowed then cleared and cropped again (Pulhin 1983). Fallowing is done to restore soil fertility. The area is compartmentalized to allow rotational cropping and fallowing, so that when one-half of the farm is under fallow (planted in *Leucaena glauca*), the other half produces corn as the main crop followed by tobacco.

As soon as the yields begin to gradually

decrease (after about five cropping cycles), cropping moves to where the fallow area has been cleared of leucaena trees. The branches are placed along the contours 1.5 m apart, using 50 cm leucaena stumps as supports to form barriers half a meter wide. Branches with leaves are placed along the base of the strips, to reduce the velocity of runoff water when it rains. The remaining leaves are scattered over the soil surface and allowed to decompose as an organic source of plant nutrients.

Comia *et al.* (1998) evaluated the effectiveness of the balabag system. Their results are shown in Table 2. They reveal that after about a century of five-year cyclical fallow-till, topsoil was deeper after either a two-year leucaena fallow or two-year balabag, than after a ten-year balabag, indicating the soil-conserving effect of the two former land uses. This was in spite of the fact that both were on gradients of 55-80%, steeper than the ten-year balabag. When the corn was harvested, soil bulk density in the 0-5 cm layer was lower (i.e. its porosity was greater) in both the two-year fallow and the two-year balabag, than in the 10-year balabag. The pH of the topsoil was alkaline in all three cropping systems, because of the limestone parent material. The level of organic matter (OM) in the topsoil after the two-year fallow was twice as high as the ten-year balabag, while the OM of the two-year balabag was three

Table 1. Nitrogen and phosphorus budget in the Ifugao rice paddy system for the dry-season rice crop

System component	N (kg/ha)	P (kg/ha)
Top 15 cm paddy soil	138.0	90.0
Recycled from preceding crop's residues	8.0	2.0
Recycled from preceding crop's weeds	1.0	1.0
Added through rice seedlings	3.5	0.5
Recycled from weeds at weeding	30.0	6.0
Recycled from crop at weeding	5.5	2.0
Loss through crop retransplant	-2.5	-1.0
Loss through soil attached to retransplanted crop roots	nil	nil
Added through precipitation	3.5	1.0
Added through irrigation	113.0	158.5
Lost through drainage	-81.0	-43.5
Lost in panicle harvest	-110.0	-25.0
Stored in crop residues	75.0	21.5
Stored in paddy weeds	2.0	0.5
Net gain (Input-Output)	186.0	214.0

Source: Omengan 1981

Table 2. Some physico-chemical characteristics of soil used for various cropping systems in Naalad, Cebu, Philippines during the 1997 wet season

Soil properties	Land use		
	Two-year fallow	Two-year <u>balabag</u>	Ten-year <u>balabag</u>
Mean gradient (%)	108.00	93.00	60.00
Soil depth (cm)	20.80	32.90	17.30
Bulk density (mt/m ³)	1.07	1.20	1.39
Total porosity (%)	60.12	54.67	47.55
pH	7.80	7.90	8.00
OM (%)	5.72	3.91	2.14
Available P (ppm)	23.17	22.00	16.67
Available K (ppm)	13.97	14.32	7.78
CO ² evolved (mg/100 g soil)	88.81	84.24	57.37

Source: Comia *et al.* 1998

times higher. Soil potassium in the first two systems was about double that of the ten-year balabag. The soil phosphorus and CO₂ developing during the two-year fallow and two-year balabag were 32% and 47% higher, respectively, than those in the ten-year balabag.

As shown in Table 3, the effect of the two-year balabag was superior to that of the ten-year balabag in terms of corn plant height and shelling percentage. However, it was similar with respect to the NPK content of the corn stover. The two-year balabag produced yields of corn grain and stover that were at least three times higher than those from the ten-year balabag. The levels of N, P and K that were recycled back into the two-year balabag farms were respectively three and four times greater than those from the ten-year balabag.

The sustainable corn yield when the balabag and crop residues are used is because there are enough soil nutrients for the plants, so more plant biomass is produced. This in turn means that more plant nutrients are recycled back into the system. Undoubtedly, the fact that the balabag system has not been used for several years, coupled with the decrease over time of the maize stover that was recycled back into the system, means that nutrient cycling in the ten-year balabag became less efficient. This in turn could be the main reason why corn response in the ten-year balabag was inferior to that of the two-year balabag. In effect, the ten-year balabag was a nutrient-depleting practice. Nevertheless, the leucaena fallow-balabag rotation has the same function of recycling nutrients as the traditional bush fallow, and adds biologically fixed nitrogen to the system. Clearly, the *Leucaena*-based fallow

systems must have been found mainly on soils that are not strongly acid (Garrity 1995). This may explain their successful use in Cebu, Philippines.

Growing Sweet Potato: Ikalahan Style

Traditional forest dwellers in the Ikalahan region of the Southern Cordillera, as well as in other mountainous regions of the Northern Philippines, have a unique way of producing sweet potato (Barker 1983). Shifting cultivation begins as the dry season ends. It is common for farmers to stagger the planting dates, and use different varieties with various maturation dates. In effect, yield is spread over the year, while a dense plant cover is maintained which helps protect the sloping land against erosion. The Ikalahans raise sweet potato because it grows well on their hilly land. It is also an important crop in Philippine agriculture.

Agroforests for Soil and Water Conservation

Agroforestry is defined as a farming system in which trees are grown on the same piece of land as crops. They may be intercropped or in some other spatial arrangement, or may be in a time sequence. There are both ecological and economic interactions between the tree and non-tree components (Beets 1990). A number of traditional farming systems contain a mixture of perennials and annuals. In the Philippines, particularly in southern Luzon, farmers have developed a multi-storey system of agroforestry. In this system, forest and fruit trees and food crops are grown in a multi-layered canopy. Sun-loving

Table 3. Agronomic performance and nutrient uptake by corn in two land use practices at Naalad, Cebu, Philippines (1997 cropping season)

Parameter	Land use	
	Two-yr balabag	Ten-yr balabag
Plant height (cm)	175.20	113.30
Shelling percentage	77.10	71.55
Grain yield (mt/ha)	1.82	0.50
Stover yield (mt/ha)	3.45	1.10
Nutrient content (stover)		
Nitrogen (%)	0.760	0.810
Phosphorus (%)	0.048	0.054
Potassium (%)	1.134	0.908
Nutrient uptake (stover)		
Nitrogen (kg/ha)	26.22	8.91
Phosphorus (kg/ha)	1.90	0.60
Potassium (kg/ha)	39.00	10.00

Source: Comia *et al.* 1998

species form the upper canopy, while shade-tolerant crops dominate the under storey. The system employs reduced tillage, and is sustainable mainly because of the year round vegetative cover, which conserves soil and water both in the short and in the long term. In addition, the agroforests provide food, fuel and income, and also utilize land space and family labor efficiently.

A typical multi-storey system in the Philippines combines these plant species: Coconut + Gliricidia with black pepper + Banana + Papaya + Coffee + Pineapple + Ginger. However, there is great variation in the combinations of crops.

INTRODUCED SOIL CONSERVATION MEASURES

Leucaena Based Alley Cropping

As early as 1978, the researchers of the Department of Agronomy of the University of the Philippines at Los Baños launched a corn/leucaena farming technology that minimizes soil erosion and increases corn yields in Cebu hilly lands (10 - 30% slope) from 300 to 1500 kg/ha. This was established by planting leucaena seeds at 30 cm between hills and 50 cm between rows, forming a double-row contour hedge four meters apart. Five rows of corn are planted between the hedgerows. The first cutting of leucaena herbage was made six months after planting at 50 cm stubble height, while subsequent pruning was done at 45-60 day intervals, depending on the planting season.

After three years of field trials, using the leucaena herbage as organic fertilizer, there was an average corn yield of 0.91 mt/ha (Table 4). This is comparable to the national average yield in the Philippines of 0.95 mt/ha. In addition, leucaena hedgerows also reduced soil erosion. This resulted in a gradual leveling of the alleys between the hedges, so that, in effect, natural terracing occurred. These results were confirmed by Pacardo and Montecillo (1983), who showed that soil erosion (runoff and soil loss) was greatest in the bare plot, and least in the corn/leucaena plot where stubble was retained (Table 5). Corn grain and stover yields under leucaena hedgerow treatments (Table 6) also improved (Pacardo and Montecillo 1983).

In a system in which leucaena hedges were planted at four-meter intervals, farmers may harvest 1-1.5 mt/ha of leucaena leaves (on a dry matter basis)* (Table 7). Every ton of dried leucaena leaves provides 37.9 kg N, 4.2 kg P and 11.9 kg Ca. The leucaena trees would be cut three times in each cropping season.

If all the leaves and twigs are applied to the field, the nutrients these represent over one cropping season would amount to 75.8-114 kg N, 8.4-12.6 kg P and 23.8-35.7 kg Ca (Mercado *et al.* 1982). This equals 168-253 kg urea, 42-63 kg superphosphate and 59.5-89-25 kg calcium carbonate. According to Dy (1982), one hectare of fully grown leucaena plants yields at least 20 mt of leaves and twigs each year. This gives about 40 kg P and 480 kg K.

It should be noted, however, that the leucaena is applied as an organic mulch. This biom-

ass has to undergo decomposition for the nutrients to become available to the crop. Leucaena leaves used as a mulch have a nitrogen efficiency of approximately 33% (Guevara 1976).

Desmanthus Based Alley Cropping

The effectiveness of another shrub legume, *Desmanthus virgatus*, was investigated as a component of alley cropping systems (Comia *et al.* 1994). Plots given conventional tillage (T1) were compared with alley cropping plots, some tilled and unmulched (T2), some tilled and mulched (T3), and some untilled and mulched (T4). The effect on erosion and various soil properties on a 17% slope was evaluated. The alley cropping plots consisted of 1m wide contour hedgerows (3 rows of *Desmanthus* planted 10 cm apart with 40 cm between rows) separated by alleys 5 m wide where corn and mungbean were grown in sequence. The hedgerows were pruned every 45-60 days to 50 cm height to provide green manure for the alley crops.

After three years of field trials, T2 was seen to be superior to T1 but inferior to T3 or T4 in terms of soil, water and nutrient conservation (Table 8). It is interesting to note that the alley cropping treatments T2, T3 and T4 had more effect on soil erosion than on runoff rate. This is best illustrated by the

99% reduction in annual mean soil loss but only 75% decrease in runoff from T4 compared with T1.

The effects could be attributed to the combined effect of contour tillage or no-tillage, recycling of hedgerow leaves and crop residues, and the nitrogen-fixing and soil-retaining ability of the contour hedges. In the 0-5 cm soil layer, the saturated hydraulic conductivity and air permeability during the pod development stage of the mungbean crop in T4 were at least twice the levels found in T1, while soil bulk density was lower (Table 9). Such results could be attributed to the improved soil structure brought about by the periodic addition of *Desmanthus* prunings and crop residues on the soil surface (Table 10).

Alley Cropping Based on Gliricidia or Banana

A variety of plants can be utilized by farmers as contour hedgerows, sometimes in various combinations (Paningbatan 1995). In one field trial, a row of Napier grass (*Pennisetum purpureum*) was planted between two rows of *Gliricidia* (*Gliricidia sepium*) seedlings. The hedgerows followed the contour of the erosion plots with 50 cm x 50 cm between rows and hills, respectively, to form a 0.5 m wide hedge. In the 5 m wide alleys between the

Table 4. Grain yield (mt/ha) of two corn cultivars at Carcar and Barili, Cebu, Philippines (6 cooperators each location) during 1978-80 cropping seasons

Year	Season kg N-P-K/ha	Carcar		Barili		Mean
		Phil DMR ¹ Comp. 1	Phil DMR Comp. 2	Phil DMR Comp. 1	Phil DMR Comp. 2	
1978	Wet season 60-30-30	1.12	1.15	1.53	1.29	1.30
	Dry season 60-30-30	1.20	1.48	1.34	1.31	1.35
1979 ³	Wet season 30-15-15	0.84	0.77	0.92	0.99	0.91
	Dry season 15-15-15	-	1.06	0.87	1.04	1.01
1980 ³	Wet season 7-7-7	-	0.80	IPB ² 114 0.96	-	0.88
	Dry season	-		IPB ² 114		
	No inorganic fertilizer	-	0.78	0.93	0.93	0.85

1) Philippine Downy Mildew Resistant (DMR) variety

2) Institute of Plant Breeding (IPB) variety

3) Plus application of leucaena leaves and twigs

Source: Mercado *et al.* 1982

* 1.5 mt of dried leucaena leaves represents c. 6 mt of fresh leucaena leaves. (Ed.).

Table 5. Runoff and soil loss over 7 months in Carcar and for 6 months in Barili, Cebu, Philippines

Treatment	Carcar		Barili	
	Runoff (mm)	Soil loss (mt/ha)	Runoff (mm)	Soil loss (mt/ha)
Bare (control)	87	3.95	53	7.08
Corn alone (stover removed)	30	0.85	33	2.77
Corn/leucaena (stubble retained)	2	0.02	13	0.89
Corn/leucaena (stubble removed)	4	0.01	16	1.03

Source: Pacardo and Montecillo 1983

Table 6. Dry matter yields (kg/ha) of corn in erosion plots at Barili, Cebu, Philippines during the 1983 wet cropping season

Treatment	Grain	Stover	Total
Corn ¹ alone (stover removed)	1,242	2,339	3,601
Corn/leucaena (stubble retained)	1,771	3,145	4,916
Corn/leucaena (stubble removed)	1,738	3,360	5,098

1) Philippine, Downy Mildew Resistant variety, Composite 2

Source: Pacardo and Montecillo 1983

Table 7. Leaf and branch production of leucaena trees at Carcar and Barili, Cebu, Philippines

Date of harvest	Cutting interval (days)	Average fresh weight of 4 samples (kg)	Average dry weight of 4 samples (kg)	Sampling area (m ²)
Carcar				
Mar. 10, 1980	60	14.60	4.87	5
Nov. 18, 1980	48	16.09	5.36	5
Jan. 14, 1981	56	17.55	5.85	5
Mar. 16, 1981	60	17.00	5.67	5
June 8, 1981	83	17.50	5.83	5
Mean	61.4	16.55	5.52	5
Barili				
April 9, 1979	60	13.50	4.50	5
Dec. 8, 1980	48	15.25	5.08	5
Feb. 9, 1981	61	16.85	5.62	5
April 9, 1981	60	12.75	4.25	5
Mean	57.25	14.59	4.86	5

Source: Mercado *et al.* 1982

hedgerows, corn was grown as the first crop, followed by peanut. The hedgerows were pruned every 45-60 days to about 0.5 m above the ground. This minimized shading, and provided branches to serve as green manure and/or mulch to the companion crops.

After four years of field trials at two sites in the Philippines, the annual soil loss from the alley cropping plots was much less than that found with farmers' traditional practices (Table 11). However, planting banana (*Musa sapientum*) along the contours was not as effective as *Gliricidia*, in terms of minimizing soil loss in runoff.

As to the nutrient balance of these alley cropping systems, Table 12 shows that at both sites, T1 and T2 resulted in a negative balance of all nutrients, associated with decreasing nutrient content of the soil (Santoso *et al.* 1995). These findings

indicate that T1 and T2 had depleted soil fertility, and would not be able to sustain long-term crop production. Conversely, the high-input alley cropping treatments increased P and K levels in the soil. However, the nutrients N, Ca and Mg were inadequate to satisfy crop needs under the systems studied.

It appears that alley cropping is effective in the context of soil and water conservation. There are also several reports of increased yields of annual crops grown between hedges of leguminous shrubs. However, alley cropping in the Philippines has not been widely adopted by farmers.

Probably one reason for this is because the alley crops and hedgerows compete, resulting in reduced yields of the former. However, the primary constraint is the large amount of labor needed to prune the hedges.

Table 8. Mean annual runoff and eroded soil in 1989-91 and losses of organic matter (OM) in 1990 under four cultivation practices in Laguna, Philippines

Treatment	Runoff (mm)	Eroded soil (mt/ha)	OM Loss			
			(kg/ha)	Total N ¹	P	K
T1 (Conventional tillage)	371 a	141.3 a	5916 a	296 a	2.5 a	266 a
T2 (Tilled, no mulch)	209 b	23.7 b	946 b	47 b	0.4 b	34 b
T3 (Tilled, mulched)	88 c	2.8 c	224 c	11 c	0.1 b	9 c
T4 (No tillage, mulched)	99 c	1.7 c	275 c	14 c	0.1 c	4 c
Rainfall (mm)						
Erosive events	1102 ²					
Annual mean	2286					

1. Calculated as 5% of OM. 2 Rainfall events that produced runoff.

Column means followed by a common letter are not significantly different at the 5% level, using Duncan's Multiple Range Test.

Source : Comia *et al.* 1994

Table 9. Clay topsoil (0-5 cm) bulk density and porosity as well as saturated hydraulic conductivity (Kw) and air permeability constant (ka) at 3 kPa matric tension after 3 years cropping under two cropping systems, (1989-91) in Laguna, Philippines

Treatment	Bulk density (mt/m ³)	Total porosity (%)	Kw (cm/h)	ka (μm ²)
T1 (Conventional tillage)	1.09 a	58.2 a	8.2 a	22.4 a
T4 (No tillage, mulched)	1.05 b	60.0 b	18.7 b	67.5 b

Column means followed by a common letter are not significantly different at the 5% level using least significant difference (LSD).

Source : Comia *et al.* 1994

Table 10. Mean annual dry matter (DMY, kg/ha) and their N, P and K contents (kg/ha) which were incorporated into the erosion plots by treatments during 1989-90 in Laguna, Philippines.

Treatment	DMY	N	P	K
Desmanthus prunings				
Tilled-mulched alley crop	4,144	128	9	79
Untilled-mulched alley crop	3,864	120	8	74
Maize stover				
Tilled-mulched alley crop	2,601	34	4	55
Untilled-mulched alley crop	2,439	36	5	51
Mungbean stover				
Conventional tillage	2,393	48	6	43
Tilled-unmulched alley crop	1,716	33	5	31
Tilled-mulched alley crop	1,680	34	5	32
Untilled-mulched alley crop	1,837	35	5	34
Annual total				
Conventional tillage	2,393	48	6	43
Tilled-unmulched alley crop	1,716	33	5	31
Tilled-mulched alley crop	8,429	195	17	166
Untilled-mulched alley crop	8,140	191	18	159

Source : Comia *et al.* 1994

CONCLUSION

Indigenous technologies that conserve soil, water and nutrients for sustained productivity have been developed by a number of farming communities. These practices may be replicated in other upland areas to solve the problem of land degradation. Alternatively, alley cropping has proven potential to control soil and nutrient losses, and produce yields that are similar to, if not better than, those of conventional farming.

The main challenge is to develop systems that minimize labor, or which incorporate hedgerow species that provide food and income to farmers. This situation requires a shift from researcher-implemented trials to studies of soil management in which farmers participate. Conservation farming advocates must start with what the farmers have. We must learn from their wisdom and work with them towards a sustainable agriculture.

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Table 11. Annual soil loss and sediment concentration (average over 4 years) as affected by soil-conservation practices in Mabini and Tanay sites, Philippines

Treatment	Soil loss (mt/ha)	Sediment concentration (kg/m ³)
Mabini		
T1 Farmers' practice	459	37.7
T2 Alley crop, low input	10	39.0
T3 Alley crop, high input	8	26.7
T4 Alley crop, high input	8	40.2
Tanay		
T1 Farmers' practice	235	21.1
T2 Alley crop, low input	38	7.5
T3 Alley crop, high input	30	1.0
T4 Alley crop, high input	57	6.6

Mabini: Soil = Ustorthent; Slope 11-21%; Length = 12 m

Average annual rainfall = 1320 mm.

Tanay: Soil = Kandiodult; slope = 15-50%; Length = 12 m.

Average annual rainfall = 1856 mm.

Treatments:

T1 Farmers' practice (up- and down-slope cultivation; corn-peanut).

T2 Alley crops: corn-peanut; hedgerows: Gliricidia + Napier (low-input technology).

T3 Alley crops: corn-peanut; hedgerows: Gliricidia + Napier (high-input technology).

T4 Alley crops: corn-peanut; hedgerows: banana + sapodilla (high-input technology).

Source: Paningbatan 1995

Table 12. Nutrient balance and change in nutrient status of the soil from 1990 to 1993 at Mabini and Tanay sites, Philippines

Treatment code	Nutrient balance (kg/ha)					Change in nutrient status of the soil				
	N	P	K	Ca	Mg	N (%) ⁽⁵⁾	P (mg/kg)	K	Ca (cmol/kg)	Mg
Mabini										
T1	-402	-69	-170	-51	-145	-0.04	-3.2	-0.30	-0.90	-0.10
T2	-307	-56	-111	-17	-154	-0.02	-0.3	-0.09	-0.50	-0.10
T3	-127	12	30	-27	-19	-0.01	0.2	0.20	-0.50	-0.10
T4	147	35	71	-23	-17	0.02	2.0	0.90	-0.70	-0.10
Tanay										
T1	-610	-30	-93	-27	-85	-0.08	-0.1	-	-0.85	-0.10
T2	-212	-25	-50	-9	-54	-0.07	-0.1	-	-0.65	-0.09
T3	-16	86	166	-18	-14	-0.03	1.9	0.04	-3.20	-0.08
T4	-40	89	167	-19	-13	0.04	1.6	0.01	-0.22	-0.09

Treatments:

T1 Farmers' practice (up- and down-slope cultivation; corn-peanut).

T2 Alley crops: corn-peanut; hedgerows: Gliricidia + Napier (low-input technology).

T3 Alley crops: corn-peanut; hedgerows: Gliricidia + Napier (high-input technology).

T4 Alley crops: corn-peanut; hedgerows: banana + sapodilla (high-input technology).

Source: Santoso *et al.* 1995

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