Timber Tree-Based Contour Hedgerow System On Sloping Acid Upland Soils: The Use of ^{15}N In Quantifying Tree-Crop Interaction In Agroforestry System

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ABSTRACT

As the population pressures in the upland increase, agroforestry is inevitably the most appropriate technology to enhance the productive and protective functions of farming systems to benefit both the people living inside and outside the watersheds in a suitable manner. Contour hedgerow is one of the agroforestry systems suitable for sloping uplands where farmers grow tree crops as hedgerows and food crops as alleycrops. Smallholder farmers in Southeast Asia have begun farming timber trees in association with food crops on fertile soils as the dominant enterprise using their own capital resources. A collaborative study between the International Centre for Research in Agroforestry (ICRAF) and Philippine Nuclear Research Institute (PNRI) was established to evaluate the performance of fast growing timber trees as hedgerows on subsistence cereal based farming systems, and the role of N-fixing trees as interplant in enhancing the growth of the trees as well as the cereal crops. There were 4 fast growing timber trees being compared: *Acacia mangium* (N-fixing), and *Swietenia macrophylla* (non-N-fixing), *Gmelina arborea* (non-N-fixing), *Eucalyptus deglupta* (non-N-fixing). *A. mangium* was also used as interplant to determine its influence on the growth of non-N-fixing trees as well as to the cereal crops. Ammonium sulfate enriched with 10.12 ^{15}N atom percent was applied in solution to the upland rice, as alleycrop, at the rate of 60 kg N/ha in the isotope subplot in 2 splits: 30 days after emergence and at panicle initiation stage. This study was conducted in acid upland soil in Claveria, Misamis Oriental.

Acacia mangium grew faster compared with *G. arborea, E. deglupta,* while *S. macrophylla* grew slower. The growth of *E. deglupta* and *G. arborea* was positively affected by N-fixing interplant in low soil fertility environment. *G. arborea* and *A. mangium* produced the highest lateral pruning biomass supplying organic nutrients to the associated annual crops. The amount of nutrient yields was proportional to the volume of pruning biomass. Upland rice rows close to the trees had reduced plant height and grain yield. *G. arborea* was found out to be the most competitive affecting over-all yield of upland rice. But its competitiveness was reduced when interplanted with *A. mangium.* Grain yield was affected by the different hedgerow species and N-fixing interplant. Row analyses indicated that the first crop of rice was significantly affected by the hedgerow regardless of species. But *G. arborea* was the most competitive providing the lowest over-all rice yield. Soil nutrients were not affected by the different hedgerow species. Available P was affected by soil depth.

Planting of N-fixing timber trees has no significant effect on Fertilizer Nitrogen (FN) yield, % fertilizer Nitrogen Utilization (FNU) of both grain and straw observed on Total Dry Matter Yield (TDMY), Nitrogen Yield (NY), % Nitrogen Derived From Fertilizer (%Ndff) of both grain and straw.

This study will be continued to understand more in-depth the tree-soil –crop interactions, particularly on the long term N dynamics of this agroforestry system.

INTRODUCTION

Sustainable land use is one of the focal issues in the debate about rural development in the Philippines uplands where 20 million people eke-out living. Appropriate technologies, people's active participation and proactive policies are key components to achieve sustainable upland development. Appropriate technology addresses both the production and conservation objectives of the resource poor upland farmers in the context of their biophysical and socio-economic environments.

In the Philippine's increasing population, accompanied by dwindling for crop production in the lowlands farmers into the uplands in the Philippines. About 30% of the country's total population is now living in upland areas with slopes greater that 18% (Cruz and Zoza Feranil, 1988). Pressure for increased crop production for subsistence has led to the transformation of the hilly areas to agricultural production uses.

In the mid-1970's greatest interest in soil conservation technology, involving alternate hedgerows and alleycropping in areas along a slope, was prevalent in the Philippines (Garrity, 1993). Since the introduction of the hedgerow technologies, modified versions have evolved incorporating indigenous technologies, which are less labor intensive. Allowing trees and shrubs to grow during fallow period to restore soil productivity after several years of extensive cropping were one of the indigenous technologies tried by farmers (Fernandez et al, 1992). Fast growing multipurpose species (MPTS) were introduced as revegetating and rehabilitating agents to stabilize slopes and to ensure a more suitable, higher crop productivity (Gelor and Austral, 1996). Intercropping with annuals while MPTS are in their initial stages of growth is seen to offer somewhat an increase in the productivity and profitability of the systems (Miah et al., 1993).

Smallholder farmers in Southeast Asia Have independently began farming timber trees on the frontiers of infertile grassland soils as dominant enterprise using their own capital resources (Garrity and Mercado, 1994). Farmers in Claveria, Northern Mindanao, are planting timber trees initially as hedgerows with annual crops of maize, upland rice and cassava. Timber yield can improve the farm's economic productivity. The current increase in demand for fuel and timber trees is the major factor in the development of smallholder timber production systems (Garrity and Mercado, 1994).

Acid upland soils occupy about 30% of the Philippine's 30 M hectares. These soils are characterized by sloping land, high soil erodability, strong acidity and low available nutrients. Farmers in these areas recognized soil erosion as a major threat to sustainable crop production. The introduction of Natural Vegetative filter Strips (NVS) dramatically enhanced the adopting of soil conservation by these upland farmers. NVS is a 50-cm wide of uncultivated strip where natural vegetation is allowed to grow naturally. This natural vegetation acts as soil filters and slows down the lateral movement of water thus dramatically minimizing soil erosion (95%). There are now over 3000 farmers in Northern and Central Mindanao, appreciated the role of NVS in controlling soil erosion, and they are maximizing the benefits of NVS by planting fruit and timber trees, fodder grasses and legumes, and other perennials such as coffee and pineapple on or above the NVS.

Table 1: Pruning biomass in dry weight (tons/ha) and N, P, K (kg/ha) of different contour hedgerow species in acid upland soil. Patrocenio, Claveria, Misamis Oriental. Crop Year: 1999-200

Treatments	Biomass (Tons/ha)	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)
T1-*E. deglupta*	-	-	-	32.26
T2-*E. deglupta* +*A. mangium*	2.82	68.81	3.10	-
T3-*S. macrophylla*	-	-	-	63.89
T4-*S. macrophylla* + *A. mangium*	4.67a	126.09	5.60	21.03
T5-*G. arborea*	1.07c	24.40	1.61	37.24
T6-*G. arborea* + *A.mangium*	2.31bc	66.76	3.00	8.10
T7-*A. mangium*	0.92c	20.88	0.92	-
Mean	2.29			
CV	33.51			

Planting timber trees on the NVS is now widely adopted. But these farmers are resource poor with no or little cash to be able to purchase fertilizers. They likely use their little amount of fertilizer to their food crops than to their trees. But the economic potential of the timber trees is tremendous as the demand for timber is increasing while the supply is diminishing. The use of N-fixing trees is widely recognized as an approach to enhance the growth and yield of associated non-N-fixing trees or crops. The commonly selected fast growing timber trees in Northern Mindanao are: *Gmelina arborea, Acacia mangium, Eucalyptus deglupta,* and *Swietenia macrophylla.* These trees are valued for their quality wood, pulp and paper, as telephone/electric poles, furniture and veneer. Adoption of agroforestry offers slots of trade-off farmers to consider in choosing what species to use particularly on the aspect of tree-crop interaction. Among these species, *A.mangium* is the only N-fixing tree and has also showed good adaptation to infertile acid soils. This study will also provide the opportunity to look at the positive tree-tree interaction under infertile acid soil environments.

The objectives of the study were: 1) to evaluate the performance of popularly selected timber trees as contour hedgerow species on acid upland environment in 350 meter above sea level (mast), 2) to determine the effect of N-fixing tree, as interplant, to the growth of non-N-fixing trees, but with premium timber value (N and P dynamics under infertile acid soil), 3) to determine the effects of these timber tree species on the growth and yield of the annual food crop (upland rice) looking at the above and below ground interaction, and 4) to quantify N uptake of upland rice as influence by N-fixing tree in infertile acid upland environment using ^{15}N.

This experiment is drawn from our hypothesis to wit: 1) N-fixing tree enhance the growth of non-N-fixing trees in contour hedgerow systems under infertile acid upland soils, 2) different timber trees will per form differently as contour hedgerow species, and will respond to varying elevations, 3) species that grow faster have early negative effect on the growth and yield of associated food crops influencing above and below ground environments, and 4) N-fixing trees (like *A. mangium)* enhance the N and P uptake of upland rice under acid upland soils.

MATERIALS AND METHODS

Description of study area

This study was conducted in Claveria, Misamis Oriental, Mindanao, Philippines (8^0 38' N; 124^0 25'E), and 40kms northeast of Cagayan de Oro City. It lies on an undulating plateau between a coastal escarpment and a mountainous interior, ranging elevation from 350 to 950masl. Soils, in Claveria, are classified as acid upland fine mixed isohyperthermic, Ultic Haplorthox with a depth more than a meter (Garrity and Austin, 1995). There are two pronounced seasons in the area: the wet season (May to October) and the dry season (November to April). The majority (79%) of the upland farms in Claveria are situated on slopes ranging from 3-60%, thus erosion is a major concern of the farmers. The dominant crops planted are maize, upland rice, sweet potato, vegetables and cassava.

Tree hedgerows

There were four timber tress species being compared: *Acacia mangium* (N-fixing), *Gmelina arborea* (non-N-fixing), *Eucalyptus deglupta* (non-N-fixing), and *Swietenia macrophylla* (non-N-fixing). We also employed two sub-treatments: with interplant of N-fixing and with no interplant. The experiment was established in Patrocinio (350masl). The location is located in the municipality of Claveria, Misamis Oriental Philippines. The tree hedgerows were established last April to May 1999. The seedlings were raised in the nursery for 4 months before they were out-planted. During planting, 50 grams of 14-14-14 (N-P_2O_5- K_2O) was applied as basal foe each hill. Monthly monitoring on plant height and stem diameter commended in July 1999 across all sites. Samples for tissue nutrient analyses were collected last December 1999 prior to the application of ^{15} N isotopes. The trees were pruned twice. We employed a formative pruning to ensure straightness of the bole, and to reduce shading to the companion crop. The pruning biomass was applied as mulch

Table 2: Plant height, grain yields and total dry matter of upland rice (PSB Rc 3) as influence by different hedgerow in an upland acid soils. Patrocenio, Claveria, Misamis Oriental. Dry Season 1990.

Treatment		Plant height (cm)	Grain yield (t/ha)	Total dry matter (t/ha)
T1 -	*E. deglupta*	92.05ab	1.46	5.57
T2 -	E. deglupta + *A. mangium*	90.76ab	1.93	6.68
T3 -	*S. macrophylla*	91.99ab	1.70	6.27
T4 -	*S. macrophylla + A. mangium*	96.90a	1.50	6.70
T5 -	*G. arborea*	83.17b	1.43	5.33
T6 -	*G. arborea + A. mangium*	90.34ab	1.39	5.45
T7 -	*A. mangium*	90.07ab	1.09	6.09
Mean		90.75	1.50	6.01
CV		5.20	30.64	19.84

In columns, means having a common letters are not significantly different by DMRT at 5% level.

Upland rice

Upland rice was planted in Patrocenio using the variety PSB Rc 3 provided by the Philippine Rice Research Institute (PhilRice). Fertility levels used were: 60 kg N/ha, 20 kg P/ha and 20 kg K/ha. Seeding rate was 100 kg/ha. Furadan granules (Deltamithrin) were applied as basal at the rate of 18 kg/ha. Two-interow cultivation was done: 15 and 30 days after emergence (DAE). This was followed by two hand-weeding at 30 and 45 DAE. Rice bugs were controlled by spraying Decis insecticide. Rice was harvested at 120 DAE.

N-15 application

Ammonium sulfate enriched with 10.12% atom excess was applied in solution at the rate of 60 kg N/ha in the isotope sub-plot in 2 splits (at 30 DAE and at panicle initiation). The isotope sub-plots measured 2x1m lined with plastic sheet in all sides to avoid contamination or leakage. For the treatment with tree interplanting and without interplanting, the isotope plot was constructed one meter away from the hedgerows. Other nutrient applications and agronomic practices were followed as being recommended in the area.

Table 3: Soil chemical properties as affected by soil depth and different hedgerow species in an acid soils in Patrocenio, Claveria, Mis.Oriental, Philippines.

Treatments	pH	OM*	N*	P⁰	K&
0-15 cm					
T1-*E. deglupta*	4.58	3.23	0.16	4.74	0.09
T2-*E. deglupta +A. mangium*	4.60	3.06	0.16	8.08	0.14
T3-*S. macrophylla*	4.73	2.23	0.11	4.54	0.12
T4-*S. macrophylla+ A.mangium*	4.43	2.45	0.17	4.57	0.80
T5-*G. arborea*	4.50	3.03	0.15	5.40ab	0.07
T6-*G. arborea + A. mangium*	4.56	3.43	0.17	6.24ab	0.10
T7-*A. mangium*	4.53	5.04	0.15	4.55	0.08
Mean	4.54	2.92	0.15	5.45	0.08
CV	15.85	25.61	16.52	31.27	35.6
R^2	0.45	0.35	0.62	0.54	0.46
Pr>F	0.35	0.60	0.07	0.17	0.32
15-30 cm					
T1-*E. deglupta*	4.66a	2.78ab	0.14ab	3.36	0.08
T2-*E. deglupta +A. mangium*	4.53ab	2.59ab	0.12ab	4.36	0.12
T3-*S. macrophylla*	4.70a	2.34b	0.12b	3.32	0.13
T4-*S. macrophylla+ A.mangium*	4.56ab	3.07ab	0.15ab	4.52	0.09
T5-*G. arborea*	4.50ab	3.45ab	0.17ab	4.6	0.07
T6-*G. arborea + A. mangium*	4.36b	3.72a	0.18a	5.01	0.08
T7-*A. mangium*	4.67a	3.08ab	0.15ab	4.35	0.08
Mean	4.57	3.00	0.12	4.21	0.09
CV	2.77	20.3	20.36	39.65	35.06
R^2	0.61	0.51	0.50	0.27	0.46
Pr>F	0.08	0.23	0.23	0.77	0.32

In columns, means having common letters are not significantly different by DMRT

*-%

° ppm

& meq/100g

Harvesting of Rice and chemical analyses

Upland rice was harvested at 120 DAE. The crop was harvested separately for each unit plot row by row. Grain and straw yields were recorded plot wise. Other agronomic parameters were also recorded. Grain and straw were weighed, oven-dried and ground separately and prepared for total N and N-15 determinations. Total N and ^{15}N analyses were done at the IAEA Laboratory Seibersdorf, Austria. Other chemical and physical analyses were performed at the Soil Chemistry Research Laboratory, Bureau of Soils and Water Management. The isotope data were used to estimate percent nitrogen derived from fertilizer and other isotope data.

Table 4: Soil chemical properties as influence by soil depth and different hedgerow species in an acid upland soil. Patrocenio, Claveria, Misamis Oriental.

Treatments	Ca&	Mg &	Na&
0-15 cm			
T1-*E. deglupta*	0.63a	0.43	0.11ab
T2-*E. deglupta + A. mangium*	1.08ab	0.42	0.11ab
T3-*S. macrophylla*	1.33a	0.53	0.12a
T4-*S. macrophylla + A. mangium*	0.85ab	0.37	0.09
T5-*G. arborea*	0.76ab	0.33	0.06b
T6-*G. arborea + A. mangium*	0.78ab	0.31	0.06ab
T7-*A. mangium*	0.75ab	0.32	0.07b
Mean			
CV	35.37	33.00	29.53
R^2	0.57	0.37	0.57
Pr>F	0.12	0.54	0.13
15-30 cm			
T1-*E. deglupta*	0.86	0.34	0.11abc
T2-*E. deglupta + A. mangium*	0.95	0.34	0.12ab
T3-*S. macroophylla*	1.21	0.44	0.13a
T4-*S. macrophylla + A. mangium*	0.81	0.31	0.09abc
T5-*G. arborea*	0.76	0.31	0.06bc
T6-*G. arborea + A. mangium*	0.7	0.29	0.08c
T7-*A. mangium*	0.9	0.33	0.07bc
Mean	0.89	0.34	0.09
CV	45.11	39.32	31.1
R^2	0.27	0.18	0.63
Pr>F	0.79	0.93	0.06

In columns, means having common letters are not significantly different by DMRT

&- meq/100g

Results and discussion

Tree performance: Collecting of the monthly tree height and stem diameter was done last July 1999. *Acacia mangium* had the highest plant height among all the species tested in Patrocenio (**Figure 1.**), and this was followed by *Gmelina arborea* with interplant *A. mangium. Swietenia macrophylla* was the slowest grower.

The interplanting of N-fixing tree had enhanced the growth of *E. deglupta.* The growth of *G. arborea* was also enhanced where soil fertility is low like in Patrocenio. The result suggests that *G. arborea* competes with the associated crop for the applied nutrients. The results also suggested that interplanting of N-fixing trees would enhance the growth of non-N-fixing trees when soil inherent fertility is low and the application of nutrients from external source is also minimal.

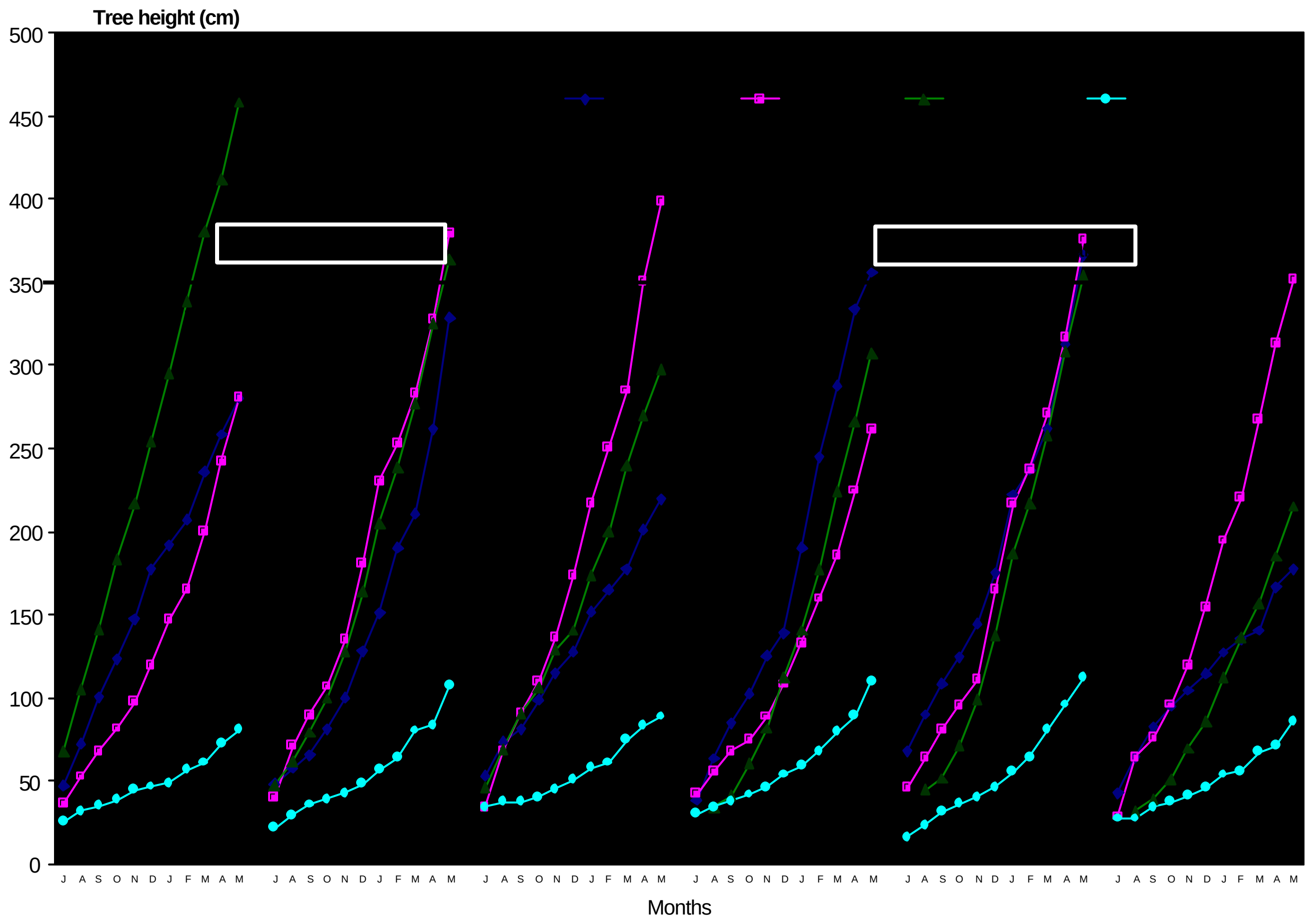

Fig. 1. Tree height of different timber tree species as influenced by different elevations and interplant. Claveria, Misamis Oriental, The Philippines

Crop performance

Upland rice.

Pruning biomass. The trees were pruned to produce good bole form, reduce shading and as a source of organic nutrients to the crop. The running biomass and different amounts of N, P, and K are presented in **Table 1**. The pruning was combined data for both species in a treatment (in the case when there was an interplant). In treatments with *A. mangium* interplant, *E. deglupta* had the lowest pruning biomass, as it did not produce big canopy. No pruning was derived from *S. macrophylla* as it grew very slow. A combination of *S. macrophylla and A,mangium had the highest pruning biomass* (4.67 tons) but all the pruning came from *A. mangium.* This was followed by the combination of E *deglupta* + *A.mangium* and *G.arborea* + *A.mangium,* producing 2.82 tons and 2.31 tons, respectively.

Table 6: Rice plant nutrients at harvest as influenced by the different hedgerow species in an upland acid soils, Patrocenio, Misamis, Oriental, Philippines.

Treatments	N*	P*	K*	Ca*	Mg*	Na*
Grains						
T1-*E. deglupta*	1.24	0.17	0.29	0.76	0.12	0.03
T2- *E. deglupta + A. mangium*	1.35	0.20	0.32	0.07	0.12	0.03
T3-*S. macrophylla*	1.29	0.16	0.03	0.08	0.13	0.03
T4-*S. macrophylla + A. mangium*	1.39	0.16	0.28	0.07	0.11	0.03
T5-*G. arborea*	1.24	0.16	0.28	0.08	0.11	0.03
T6-*G. arborea + A. mangium*	1.37	0.18	0.32	0.08	0.11	0.03
T7- *A. mangium*	1.38	0.17	0.29	0.08	0.11	0.03
Mean	1.323	0.17	0.30	0.78	0.12	0.03
Straw						
T1-*E. deglupta*	0.89	0.08	1.31	0.29	0.26	0.08
T2-*E. deglupta + A. mangium*	0.89	0.08	1.37	0.27	0.23	0.08
T3-*S. macrophylla*	0.89	0.13	1.53	0.29	0.26	0.08
T4-*S. macrophylla + A. mangium*	1.00	0.11	1.33	0.28	0.28	0.07
T5-*G. arborea*		0.09	1.16	0.29	0.33	0.08
T6-*G. arborea + A. mangium*	1.04	0.09	1.61	0.30	0.27	0.08
T7-*A. mangium*	0.79	0.08	1.37	0.29	0.28	0.08
Mean	0.93	0.10	1.35	0.29	0.27	0.08

In columns, means having common letter are not significantly different by DMRT at 5% level
*-%

The N, P, and K content of the prunings showed that the amount of nutrient yields was directly related to the amount of pruning. The amount of N ranged from nil to 126 kg/ha. For P and K content, T_4 obtained the highest amount, 5.60 and 63.89 kg/ha, respectively. Plots with *A. mangium* had high N and P yield compared with other species. The results suggested that *A. mangium* and *G. arborea* were the highest pruning producers compared with other species. But *G. arborea* was more competitive with associated crops compared with *A. mangium. Acacia mangium* would be more ideal as hedgerow because it grows fast but it doesn't compete with the associated crops in nutrient uptake and the lateral branches should be regularly pruned to reduce shading to the companion crops.

The first upland rice crop was planted in December 1999 and harvested in April 2000 in Patrocenio site. The plant height, grain yield and total dry matter yield are presented in **Table2**. The upland rice had mean height of 90.75 cm. Upland rice with *S. macrophylla* + *A. mangium* had the highest plant height of 96.90 cm, followed by *E. deglupta. G. arborea* had the shortest plant height of 90.34 cm. Interplanting of N-fixing tree, *A.mangium,* did not give positive result to plant height of upland rice. The grain yield had the average of 1.50 tons/ha. The yield was affected by the rice (panicle) blast thus having low harvest index of 0.25, resulting to low grain yield. The panicle blast infection was found in all treatments. The low yield if upland rice with *A. mangium* was due to higher panicle blast infection, as it was related directly to high N uptake, as indicated in high total dry matter yield. There was no statistical significant between treatments. The average total dry matter yield (TDYM) was 6.01 tons per hectare. But treatments with *A. mangium* interplant had high TDMY, except when the *A. mangium* was combined with *G. arborea* eradicated the positive effect of N-fixing interplant. The slow growth of *S. macrophylla* did not affect the growth of the upland rice resulting TDMY.

Table 7: total N yield of upland rice as influence by different hedgerow species in an acid upland soils, Patrocenio, Claveria, Misamis Oriental

Treatment	N yield Kg/ha
T1	103.78ab
T2	111.85a
T3	79.17c
T4	104.31ab
T5	88.23bc
T6	118.94a
T7	112.50a
CV	20.3

Means in column having common letters are not significantly Different by DMRT at 5% level

Soils

Soil samples were collected on December 13,1999 prior to the establishment of upland rice in Patrocenio site. Samples were taken in two depths: 0-15 cm and 16-30 cm, across all the hedgerow treatments. The soil samples were air-dried and analyzed for pH, organic matter, total available Nitrogen (N), available phosphorus (P), exchangeable potassium (K). The results are presented in **Table** 3.

The pH ranges from 4.36 to 4.73. There was no statistical difference between species and soil depths. The organic matter ranges from 2.23% to 3.72% across all treatments and depths. OM was not affected by soil depth. Percent (%) available N ranges from 0.11% to 0.18%. Although it was not statistically different, the 0-15cm depths had higher N than the 16-30 cm depth. Available P ranges from 3.36ppm to 8.08ppm. The surface area (0-15 cm) had higher available P than the sub-surface layer (16-30 cm). Exchangeable K ranges from 0.07 meq/100g to 0.14 meq/100g. There was no significant difference between depths and the hedgerow species.

Table 8: Dry matter yield, N yield, %Ndff, fertilizer N yield and % FNU from straws of upland rice grown at ICRAF, Claveria, Mis. Oriental.

Treatments	Dry matter yield (kg/ha)	N Yield (kg/ha)	%Ndff	FN Yield (Kg/ha)	% FNU
T1-*E. deglupta*	3780.6a	33.68a	42.90ab	14.03a	18.90a
T2-*E. deglupta* + *A. mangium*	2770.2b	23.87a	53.83a	12.78a	24.89a
T3-*S. macrophylla*	3511.6ab	31.23a	48.22ab	13.26a	23.72a
T4-*S. macrophylla* + *A. mangium*	2768.9b	30.13ab	48.33ab	13.76a	28.56a
T5-*G. arborea*	3599.6a	35.63a	39.40 b	13.75a	24.62a
T6-*G. arborea* + *A. mangium*	2761.3b	28.11ab	52.32a	13.73a	22.87a
T7-*A. mangium*	3114.4ab	26.82ab	47.06ab	12.23a	28.12a

Means in column having a common letters are not significantly different by DMRT

The Calcium (Ca), Magnesium (Mg), and Sodium (NA) analysis of the soils are shown in **table** 4. There was no significant difference in micronutrient contents such as Ca, Mg, and Na across different species and soil depths.

Table 9. Seed yield, grain N yield, %Ndff, FN yields and %FNU of upland rice sown in acid soils of Claveria, Mis. Oriental

Treatments	Seed yield (Kg/ha)	Grain yield (Kg/ha)	% Ndff	FN yield (Kg/ha)	% FNU
T1-*E. deglupta*	1370.0a	16.91a	41.62ab	6.82a	30.25a
T2-*E. deglupta* + *A.magium*	1330.7a	17.86a	50.57a	8.96a	39.84a
T3-*S.macrophylla*	1430.0a	18.78a	41.14ab	8.54a	37.94a
T4-*S. mycrophylla* + *A. mangium*	1740.2a	24.14a	42.88ab	10.28a	45.67a
T5-*G.arborea*	1674.6a	24.91a	37.28b	8.85a	39.37a
T6-*G. arborea* + *A.mangium*	1243.5a	17.02a	46.86ab	8.25a	36.58a
T7-*A. mangium*	1609.6a	21.28a	46.33ab	10.11a	44.97a

Plant nutrients analyses of hedgerow species

Plant samples from the different timber trees species were collected to determine the nutrient content of the leaves. The samples were oven-dried and analyzed on N, P, K, Ca, Mg, and Na. The results of the analyses are presented in **Table5**. The P content of the leaves ranges from 0-10% to 0.15%. *S.macrophylla* had the highest K content (1.73%). *A.mangium* had the highest Ca content (0.57%). *G. arborea* had the highest Mg content of the leaves (0.36%). *A. mangium* obtained the highest content.

Table 10: Plant height, grain yield and total dry matter of corn as influenced by different hedgerow plantings of timber trees in acid upland soils of Patrocenio, Claveria, Mis. Oriental (Wet Season,1990).

Treatments	Plant Height (cm)	Grain Yields (kg/ha)	Total dry matter yield (kg/ha)
T-1	217.33	5.54	10.12
T-2	217.33	5.47	10.82
T-3	217.00	5.44	11.34
t-4	218.68	5.58	11.30
T-5	223.00	5.26	10.70
T-6	222.00	5.85	12.45
T-7	236.00	5.53	11.76
CV	4.27	10	13.38

Table 11: Plant height, grain yield, and dry matter yield of corn as influence by timber and legume tree planting in hedgerows, Patrocenio, Claceria, Mis. Oriental (Dry Season, 1999).

Treatments	Plant height (cm)	Grain yields (kg/ha)	Total dry matter yield (kg/ha)
T-1	188.66	3.74	7.37
T-2	189.33	3.08	6.22
T-3	183.66	3.30	6.61
T-4	192.33	3.28	7.13
T-5	181.00	2.64	5.58
T-6	194.66	3.61	7.77
T-7	189.00	3.69	7.70
CV	3.97	20.98	24.83

Plant Nutrient analyses of upland rice and total N Yield

Upland rice samples were collected at maturity to determine the N, P, K, Ca and Mg. The results of the analyses are presented in **Table 6.** N content of the grain and straw of upland rice had increase by the presence of *A. mangium* interplant. The P content ranges from 0.16to 20%. K, Ca, Mg and Na average content 0.30%, 0.78%, 0.12%, respectively. The P, K, Ca, Mg, and Na contents of the rice straws were not affected by the presence of the N-fixing interplant. The results showed that interplanting of N-fixing tree enhances the N content of grain and straw but the other nutrients were not affected.

The total N yield of upland rice as influence by hedgerow species is presented in **Table7.** N-fixing tree (*A. mangium)* had significantly increased the total N yield when planted individually or as interplant with the other species. But N yield was highest when *G. arborea* was interplanted with *A. mangium*. The result suggests that N-fixing tree enhances the availability of N to the agroforestry systems. Therefore, it is a necessary component if agroforestry has to be sustained.

DMY, N yield, %Ndff, %FN yield of upland rice straw

In **Table8**, data on DMY, N yield, %Ndff, %FN yield (Fertilizer Nitrogen Yield) and (Fertilizer Nitrogen Utilization) of rice straw are given. Highest value on DMY (3780 kg/ha) and N yield (35.68 kg/ha) were obtained when upland rice was planted between single species of timber trees. The high values may be due to lesser competition for sunlight; water and soil nutrients in single tree plantings. The observed effects were similar to the results obtained by MAMBIAR et al. (1983) in groundnut. Trang and Giddens (1980) and Walhua and Miller (1978) also supported this view.

For N yield, the data obtained also followed the same trend. Single planting had a better effect on N yield of rice than planting two different species. This indicated that plant uptake for N was better in single timber tree planting. There was significant difference on their means according to analyses by DMRT.

In contrast to the above results, data on %Ndff showed the reverse. Both planting of *E. deglupta* + *A. mangium* (T_2) and *G. arborea* + *A. mangium* (T_6) obtained higher %Ndff compared with single timber tree plantings. This showed that N uptake of rice from fertilizer was better when grown along hedgerows of timber and legume trees. Significant differences were observed on treatment means according to analysis by DMRT.

Slight changes were only noted for data on FN yield of rice straw. Values obtained from experiment showed that interplanting of N-fixing and non-N-fixing timber tree species had little effect on FN Yield. Ofori and Stern (1987) stated that current N transfer from legumes occur only under certain conditions. Sanginga (1995) noted differences on N contribution of N-fixing tree. And this he observed depends largely on management practices.

For %FNU, higher fertilizer nitrogen was observed when timber trees were interplanted (T_2 and T_4) with *A. magium.* The high %FNU obtained from *A. mangium* planted alone suggested that this N-fixing legume had an influence on the fertilizer nitrogen utilization of upland rice. Nevertheless, the values obtained were not significant according to analysis by DMRT.

Table 12. Effects of different treatments on %N, P, K and other parameters of corn leaves (Row 1, $1_{st\ sampling}$) planted at ICRAF, Claveria, Misamis , Oriental

Treatments	%P	%K	%N	%a.e.	%Ndff	DM (kg/ha)	N yield (Kg/ha)	FNY (Kg/ha)	%FNU
T-1	0.09ab	0.95a	1.05a	0.36a	3.71a	71.80a	0.75a	0.05a	0.04a
T-2	0.15ab	0.86a	1.55a	0.30a	3.16a	73.21a	1.23a	0.04a	0.07a
T-3	0.18ab	1.28a	1.53a	0.27a	2.84a	84.27a	1.37a	0.03a	0.06a
T-4	0.23a	1.08a	1.54a	0.34a	3.58a	70.10a	1.07a	0.03a	0.06a
T-5	0.25a	0.97a	4.31a	0.31a	3.20a	86.40a	1.07a	0.03a	0.05a
T-6	0.18ab	1.14a	1.57a	0.23a	2.65a	61.91a	0.92a	0.02a	0.04a
T-7	0.17ab	0.92a	1.05a	0.28a	2.96a	58.99a	0.61a	0.01a	0.02a

Means in column with the same letters are not significantly different by DMRT

Seed Yield, N Yield, %Ndff, FN Yield and %FNU of upland rice

Data on seed yield, N yield and other parameters of grains are shown in **Table 9**. The highest grain yield was obtained in T_4 (1740.2 kg/ha). T_5 followed with 1674.6 kg/ha. However, the values obtained were considerably low. This may be due to shading effect. Trang and Giddens (1980) noted that shading reduced photosynthesis. The observation of Sanginga (1995) revealed that N from alley crops might have been lost due to leaching or immobilization. The differences observed however, was not significant according to analysis by DMRT.

With respect to grain N yield, single row planting of *G. arborea* (T_5) obtained the highest N yield although slightly lower (24.14 kg/ha). Single row planting of *A. mangium* was third (21.28 kg/ha). No significant difference was observed on their means according to DMRT.

For %Ndff, higher amounts of N derived from fertilizer was noted in T_2 (50.57). T_3 was second with 47.14%. Significant differences were observed on the treatment means according to analysis by DMRT. Therefore, %Ndff was largely affected by interplanting timber trees with legume tree.

Table 13. Analysis of %P, %K, and other data collected from corn leaves harvested at ICRAF, Claveria, Mis. Oriental (Row 2 1_{st} sampling.

Treatments	%P	%K	%N	%a.e.	%Ndff	DMY (kg/ha)	N yield (kg/ha)	FNY (kg/ha)	%FNU
T-1	0.15a	0.92a	1.19a	0.30a	3.09a	75.80a	0.88a	0.02a	0.04a
T-2	0.16a	0.85a	1.60a	0.16a	1.69a	89.97a	1.54a	0.02a	0.04a
T-3	0.17a	0.90a	1.80a	0.15a	1.62a	89.16a	1.67a	0.03a	0.05a
T-4	0.16a	0.87a	1.40a	0.19a	1.99a	83.65a	1.19a	0.02	0.03a
T-5	0.16a	0.83a	1.17a	0.21a	2.24a	83.68a	0.98a	0.02a	0.03a
T-6	0.15a	1.05a	1.41a	0.14a	1.53a	77.06a	1.07a	0.01a	0.02a
T-7	0.14a	0.76a	1.06a	0.23a	2.46a	68.26a	0.73a	0.02a	0.03a

Means in columns with the same letters are not significantly different by DMRT

On the other hand, varying responds were noted on %FNU of upland rice. T_4 obtained the highest value (45.67). T_7 closely followed with 44.97%. Although the treatment means were not significantly different, the data obtained showed high %FNU in T_4 (45.67%). This showed that upland rice obtained more N from fertilizer than from the soil N. Probably, The N fixed by legume tree is not available yet or had not been reach yet by upland rice.

Table 14. Analysis of corn leaf and stalk (Row 1) obtained at ICRAF, Claveria, Mis. Oriental

Treatments	%P	%K	%N	% a.e.	%Ndff	DMY (kg/ha)	N yield (kg/ha)	FNY (kg/ha)	%FNU
T-1	0.09a	1.38a	0.59a	0.30a	3.43a	619.7a	5.52a	0.15a	0.26a
T-2	0.09a	0.87a	0.72a	0.16a	2.39a	1256.0a	6.14a	0.13a	0.21a
T-3	0.06a	1.18a	0.72a	0.15a	2.77a	867.3a	4.61a	0.12a	0.21a
T-4	0.10a	1.40a	0.82a	0.19a	3.10a	721.3a	7.52a	0.14a	0.23a
T-5	0.07a	1.45a	0.74a	0.21a	3.04a	896.0a	4.08a	0.09a	0.15a
T-6	0.07a	1.61a	0.85a	0.14a	2.55a	525.0a	5.94a	0.09a	0.15a
T-7	0.08a	0.97a	0.60a	0.23a	3.20a	515.3a	4.16a	0.06a	0.11a

Means in columns with the same letters are not significantly different by DMRT

Table 15. Percent P and other data obtained from corn leaf and stalk (Row 2) harvested at ICRAF, Claveria, Mis. Oriental

Treatments	%P	%K	%N	%a.e.	%Ndff	DMY (Kg/ha)	N yield (Kg/ha)	FNY (Kg/ha)	%FNU
T-1	0.09a	0.88a	0.60a	0.30a	2.72a	967.7a	5.52a	0.15a	0.26a
T-2	0.09a	1.08a	0.75a	0.21a	2.16a	891.3a	6.14a	0.13a	0.21a
T-3	0.06a	0.93a	0.82a	0.14a	1.50a	1036.0a	7.61a	0.12a	0.21a
T-4	0.10a	1.02a	0.79a	0.18a	1.90a	963.0a	7.52a	0.14a	0.23a
T-5	0.07a	0.95a	0.60a	0.24a	2.32a	699.0a	4.08a	0.09a	0.15a
T-6	0.07a	1.28a	0.73a	0.15a	1.57a	773.7a	5.94a	0.09a	0.15a
T-7	0.08a	0.81a	0.62a	0.15a	1.67a	786.7a	4.16a	0.06a	0.11a

Means in columns with the same letters are not significantly different by DMRT

CONCLUSION

Planting trees on farm is now a common feature in smallholder upland agriculture enhancing economic and environmental functions. Timber trees are widely used by farmers as a way of enriching their natural vegetative strips (NVS) in acid upland areas in Northern and Central Mindanao, Philippines, to enhance soil conservation and to meet the growing timber market locally and internationally. Timber trees are now becoming a cash crop. Agroforestry is now recognized as the most appropriate upland technology to enhance sustainability of the upland farming on sloping acid upland soils. The choice of appropriate species and understanding of their interactions with associated annual food crops are necessary to maximize the benefits of all the components of the systems.

Table 16. Percent P and other data on corn ears (Row 1) harvested at ICRAF, Claveria, Mis. Oriental

Treatments	%P	%K	%N	%a.e.	%Ndff	DMY (Kg/ha)	N yield (Kg/ha)	FNY (Kg/ha)	%FNU
T-1	0.15a	0.36a	0.84a	0.34	3.58a	887a	7.59a	0.25a	0.42a
T-2	0.18a	0.31a	0.98a	0.24	2.33a	2098a	20.93a	0.57a	0.95a
T-3	0.19a	0.32a	0.87a	0.26	2.73a	2174a	17.33a	0.51a	0.90a
T-4	0.20a	0.27a	0.91a	0.29	3.01a	839a	7.37a	0.22a	0.37a
T-5	0.19a	0.30a	0.94a	0.30	3.13a	955a	7.21a	0.24a	0.41a
T-6	0.19a	0.31a	1.00a	0.24	2.52a	535a	5.23a	0.12a	0.22a
T-7	0.21a	0.37a	0.87a	0.34	2.78a	550a	4.72a	0.17a	0.29a

Means in columns having the same letters are not significantly different by DMRT

Table 17. Percent P, %K and other parameters of corn ear harvested at ICRAF, Claveria, Mis. Oriental

Treatments	%P	%K	%N	%a.e.	%Ndff	DMY (Kg/ha)	N yield (Kg/ha)	FNY (Kg/ha)	%FNU
T-1	0.15a	0.27a	0.87a	0.30	3.07a	933a	7.92a	0.24a	0.40a
T-2	0.15a	0.26a	0.95a	0.21	2.24ab	15425a	12.61a	0.26a	0.45a
T-3	0.16a	0.31a	1.01a	0.14	1.51b	2248a	21.91a	0.40a	0.67a
T-4	0.18a	0.25a	0.91a	0.18	1.92ab	950a	8.52a	0.16a	0.27a
T-5	0.14a	0.31a	0.83a	0.24	2.47ab	857a	7.01a	0.16a	0.27a
T-6	0.18a	0.23a	0.84a	0.15	1.61b	1090a	8.78a	0.13a	0.23a
T-7	0.18a	0.24a	0.74a	0.15	1.59b	858a	5.40a	0.08a	0.13a

Means in columns with the same letters are not significantly different by DMRT

This study has provided the information on the comparative growth of popularly selected tree species such as *E. deglupta, A. mangium, S. macrophylla and G. arborea* as hedgerow on sloping acid upland soils on different elevation belts and their effects on soil fertility as well as to the associated annual crops such as upland rice.

The growth of *E. deglupta* and *G. arborea* was enhanced by the N-fixing interplant (*A. mangium*) particularly in areas where sol fertility (inherent or applied) is low. *S. macrophylla* is suppressed when interplanted with fast growing N-fixing interplant.

Fast growing timber tree species (e.g. *A. mangium*) can sufficiently provide pruning biomass from lateral branches to meet the N and K requirements of the associated food crops, but P requirements must be taken from external source (e.g. inorganic source).

In making accurate measurements to determine N uptake from soil fertilizers, N-15 isotope is an indispensable tool.

N-15 isotope is very useful in quantifying the exact amount of fertilizer N being utilized by rice plants or determining the amounts being lost through leaching, volatilization, dinitrification or other processes.

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REFERENCES

Cruz, MC and Zoza-Feranil I. 1988. Policy implication of population pressure in the Philippine uplands. Washigton, DC: Paper of the World Bank/ CIDA Study on Forestry, Fisheries and Agriculture Resource Management.

Garrity DP 1993. Sustainable land-use systems for sloping lands in Southeast Asia In: Technologies for sustainable agriculture in the tropics. Madison, America Society of Agronomy, Crop Science Society of America and Soil Science Society of America: ASSA Special Publication #56.

Fernandez ECM, Garrity, D.P., Scout LT and Palm CA. 1992. Use of potential of domesticated tree for soil improvement. In: Leaky RRB. And Newton AC (eds) Tropical trees: the potential for domestication and the rebuilding of forest resources. Edinburgh, UK. August 23-28, London HMSO: Proceedings of a conference. Pp: 137-147.

Garrity DP and Mercado AR Jr. 1994. Reforestation through agroforestry: Market driven smallholder timber production in the frontiers. **In**: Raintree JB and Francisco HA (eds) marketing of multipurpose tree products in Asia. Proceedings of an international workshop in Baguio City, Philippines, December 6-9, 1993. Bangkok, Thailand: Winrock International.

Garrity DP and Agustin PC. 1995. Historical landuse evolution in tropical acid upland ecosystem. Agriculture, Ecosystems and Environment 53:83-95

Gellor, JM and Austral, TP. 1996. Grassland revegetation and rehabilitation in Mt. Musuan using timber and multipurpose tree species (MPTS) **In**: Strengthening Research and Development for Sustainable Management of the Grasslands.
Proceedings of the first National Grasslands Congress of the Philippines. September 26-28, 1990. College, Laguna, UPLB: ERDB. Pp 131-135.

Miah GMD., Garrity, D.P., Scott, L.T. and Palm, CA 1993. Comparative performance of multipurpose tree species grown alone and in association with annual crops. Bogor, Indonesia: ICRAF.

Nambiar, P.C.T., Rao, M.R., Reddy, M.S., Floyd, C., Dart, P.J. and Willey, R.W. 1983. Effect of interplanting on nodulation and N_2 fixation by groundnut. Exp. Agri. 19:79-86.

Ofori, F. and Stern, W.R. 1987. Cereal legume intercropping systems. Adv. Agron 41:41-90.

Sanginga, N.1995. Management of biological processes in alley farming: Need for more research. IAEA TECDOC 785, IAEA, Viena, Austria.

Trang, K.M. and Giddens, J.980. Shading as environmental factors affecting growth, nodulation and symbiotic nitrogen fixation by soybeans. Agron. J. 72:305-308.

Wahua, T.A.T. and Miller, D.A. 1978. Effects of shading on N_2 fixation, yield, plant composition of field-grown soybean. Agron. J. 70:3887-392.