EFECTOS DE PLANTACIONES DE ACACIAS SOBRE LA COMPOSICIÓN DE ESPECIES, LAS PROPIEDADES DEL SUELO, LA MINERALIZACIÓN Y EL MICROCLIMA EN PRADERAS DE MT. MAKILING, FILIPINAS

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RESUMEN

Las actividades de rehabilitación mejoran funcionalmente los ecosistemas degradados a través del cambio positivo de composición de especies, propiedades del suelo, mineralización y microclima. Los cambios en estas condiciones son evaluados en el área de estudio de Mt. Makiling que ha estado protegida contra incendios durante los últimos 12 años. El área se quemó extensamente en 1991 y fue reforestada mediante plantaciones de *Acacia mangium* y *Acacia auriculiformis*. Se seleccionó tres sitios de estudio en el año 2003, de los cuales dos fueron plantados con *A. mangium* y *A. auriculiformis* y uno permanecía dominado por'*Imperata cilíndrica* y *Saccharum spontaneum*.

Durante 12 meses, entre agosto 2003 y junio 2004, se midió temperatura y humedad relativa del aire cada hora y temperatura del suelo cada 2 h por 11 meses, usando HOBO data loggers. *A. auriculiformis* mostró mayor crecimiento en altura y DAP que *A. mangium*, en plantaciones de 10 años de edad. Sin embargo, en las plantaciones de *A. mangium* aparecieron más especies. Las concentraciones de N en el suelo en las plantaciones de acacias fueron significativamente mayores que las registradas en las praderas. La razón C/N en el suelo en las praderas fue significativamente mayor que la medida en plantaciones de *A. mangium*. La variación estacional de la mineralización neta en N fue marcada, con valores máximos en septiembre en las plantaciones de acacias. Las praderas mostraron no sólo mayor temperatura del aire, humedad relativa y temperatura del suelo que las plantaciones de acacias sino que también mayores variaciones por hora. Lo mayores máximos de temperatura del aire, humedad relativa y temperatura del suelo fueron registrados en abril. Los resultados indican que las calidades de sitio en praderas han sido mejoradas con las actividades de rehabilitación.

Palabras claves: *Acacia auriculiformis*, A. *mangium, plantaciones, efecto sobre suelo*

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EFFECTS OF ACACIA PLANTATION ON TREE SPECIES COMPOSITION, SOIL PROPERTIES, MINERALIZATION AND MICROCLIMATE IN GRASSLAND OF MT. MAKILING, PHILIPPINES

SUMMARY

Rehabilitation activities improve degraded ecosystems functionally, by changing positively species composition, soil properties, mineralization and microclimate.

The study area in Mt. Makiling was rehabilitated and protected from fire for over 12 years, and changes in species composition, soil properties, mineralization and microclimate were examined. After the area was burned extensively in 1991, reforestation was done by planting *Acacia mangium* and *Acacia auriculiformis*. Three study sites were selected in 2003: two sites were planted with *A. mangium* and *A. auriculiformis*, and one was still dominated by *Imperata cylindrica* and *Saccharum spontaneum*.

Air temperature and relative humidity were monitored every hour for 12 months and soil temperature every 2 hours for 11 months using HOBO data loggers in Aug. 2003 – Jun. 2004. *A. auriculiformis* showed higher growth of height and DBH than those of *A. mangium* in 10-year-old plantation. However, more species appeared in *A. mangium* plantation than in *A. auriculiformis* plantation. Soil nitrogen concentrations in the *Acacia* plantations were significantly greater than those in grassland. The soil C/N ratio in grassland was significantly greater than that in *Acacia mangium* plantations. Seasonal variation in net N mineralization was pronounced, with peak values occurring in September at *Acacia* plantation site. Grassland showed not only higher air temperature, relative humidity and soil temperature than *Acacia* plantation but its larger variations per hour. Highest peak of air temperature, relative humidity and soil temperature were shown in April. The result showed that site qualities in grassland have been improved by rehabilitation activities.

Keywords: *Acacia auriculiformis*, A. *mangium, plantations, soil propiertes.*

INTRODUCTION

Tropical forests comprise nearly 50% of the world's forest, but during recent years they disappear at a rate of 16 million ha per year (FAO, 2001). The significance of this statistics is that large-scale defore-station occurs in most developing countries, particularly in Tropical Asia and Latin America, which show the highest loss at an annual rate of more than 1%. The main factors contributing to the degradation of the forest ecosystem are shifting cultivation, forest fire, illegal logging, and over-logging. In addition, the widespread extent of *Imperata cylindrica* makes it difficult for degraded ecosystems to be restored to their original state. To rehabilitate degraded forest ecosystems successfully, tree species that can overcome *I. cylindrica* have to be introduced. Nitrogen fixing tree species as pioneer species are recommended in grasslands because they are fast growing and are more effective in competing with *I. cylindrica* (Banerjee, 1995). Thus, *Acacia* species are planted for rehabilitation of barren land such as mining and other areas (Jim, 2001). *Acacia mangium* and *Acacia auriculiformis* are major fast-growing plantation species used not only for pulp and timber production but also for multi-purposes in the tropical Asia Region. Their importance as plantation species can be attributed to rapid growth, rather good wood quality, and tolerance to a range of soil types and pH values (Yamamoto *et al.*, 2003).

The Philippines has a total land area of 30 million ha. Fifty-three percent of the land area, equivalent to 15.88 million ha, is considered forest lands. However, as of 1996, only 5.49 million ha of forestlands are actually covered with forest. In 1999, only 800,000 ha were primary forests (dipterocarp forests), about 2/3 of which was degraded. Most grassland ecosystems in the Philippines were formerly forested areas that have been initially converted to upland agriculture and progressively degraded by such unsustainable land use systems as shifting cultivation.

Forest soil often contains inadequate soil nitrogen levels limiting forest growth and productivity (Knoepp and Swank, 1998). Measured rates of soil mineralization, used as indices of N availability, often correlate well with site productivity and forest growth (Keeney, 1980; Knoepp and Swank, 1998; Liu and Muller, 1993). Annual net nitrogen (N) mineralization, the rate at which mineral N becomes available in the soil for uptake by plants through the decomposition of organic matter, has been shown to be an important factor limiting production in non-fertilized forest ecosystems (Nadelhoffer *et al.*, 1983; Nadelhoffer *et al.*, 1984).

The rates of net N mineralization varies with forest type, stand age, elevation, and topographic position (Garten Jr. and Van Miegroet, 1994; Garten Jr. *et al.*, 1994; Knoepp and Swank, 1998; Liu and Muller, 1993; Polgase and Attiwill, 1992; Powers, 1990). These differences are attributed to site variations in soil organic matter, temperature and soil water availability (Adams and Attiwill, 1986; Garten Jr. *et al.*, 1994; Powers, 1990). Because plants absorb nitrogen from the soil, differences in nitrogen of plant leaves resulted in the variation of soil nitrogen. Temperature and solution pH also influence relative uptake rates of NH^+_4 and NO_3^- (Barber, 1995). Also, variation of net mineralization may affect differences of nitrogen content of plant leaves. Garten Jr. and Van Miegroet (1994) examined correlations between measures of soil N availability and both mean foliar $\delta^{15}N$ values ($^{15}N/^{14}N$ ratio) and mean enrichment factors ($\varepsilon_{p\text{-}s} = \delta^{15}N_{leaf} - \delta^{15}N_{soil}$). However, they measured net mineralization using aerobic laboratory incubation method. This method usually yields poor indices of rates of mineralization in the forest due to sampling and incubation procedures (Adams and Attiwill, 1986). In this study, estimation of mineralization was measured by using *in situ* soil incubation that is reflected in much closer natural environment (Adams and Attiwill, 1986).

The pace of natural regeneration differs by time and degraded area. Artificial regeneration has to be applied to areas that are difficult to regenerate naturally or to accelerate speed of restoration. Vegetation type, structure, and canopy closure influence the microclimate (Martius *et al.*, 2004; Raich and Tufekciouglu, 2000). The microclimate is the result of the interactions among various biological, biophysical, hydrological, and topographical factors in an ecosystem. The microclimate could be considered the 'pulse' of an ecosystem because of its direct and indirect effects on most ecosystem processes and *vice versa* (Xu *et al.*, 2004). Plant cover changes soil temperature and moisture, and these effects often differ among vegetation types (Gates, 1980), therefore, vegetation plays a critical role in shaping the microclimate through the change of energy and water balance across the landscape (Xu *et al.*, 2002).

Tree stands modify the microclimate in terms of reduced air and surface soil temperature, increased relative humidity, and reduced irradiance compared to grasslands (Dela Cruz and Luna, 1994; Luna *et al.*, 1999). The microclimate is a factor that determines the environmental conditions for forage productivity (Feldhake, 2001), crops, and soil organisms (Martius *et al.*, 2004). Knowledge of the physical and chemical properties of soil has enabled foresters to assess the capacity of sites to support productive forests. The concept of soil quality includes assessment of soil properties and processes as they relate to the ability of soil to function effectively as a component of a healthy ecosystem (Schoenholtz *et al.*, 2000).

Tree species composition, soil properties, net N mineralization, and microclimate were investigated in *Acacia* species plantations. The objectives of this study were to identify the effects of 10-year *Acacia* plantation (*Acacia mangium* and *Acacia auriculiformis*) on the above parameters in a former grassland area of Mt. Makiling, Philippines.

MATERIALS AND METHODS

Study Sites

Mt. Makiling Forest Reserve is located in South Central Luzon, Philippines (121°14' E, 14°08' N) and covers an area of 4,244 ha. Mt. Makiling is an isolated volcanic cone, but no eruption has been recorded in human history. The climate is tropical monsoon in character, with two pronounced seasons: wet from May to December and dry from January to April. The average annual precipitation is 2,397 mm, and the annual temperature ranges 25.5 - 27.5 °C. The dominant soil type of the area is clay loam which is derived from volcanic tuff with andesite and a basalt base (Luna *et al.*, 1999). The original vegetation surrounding the mountain base has been cleared, and the land has been cultivated. However, remnant individuals in the ravines indicate that a dipterocarp forest zone was once present in the lowlands. The dominant dipterocarp species still in the area are *Parashorea malaanonan*, *Shorea guiso*, and *Shorea contorta*. However, the lesser presence of dipterocarp species indicated that the species has suffered heavy utilization in the past with the result that numerous non-dipterocarp tree species have now formed a species-rich secondary tropical rain forest (Dela Cruz and Luna, 1994; Luna *et al.*, 1999). The study sites are located in Sitio Kay Inglesia on the southwest slope of Mt. Makiling at 500 masl. This area had been previously cultivated and perennially burned prior to the 1990s. The last time it was burned extensively was in April 1991. To restore this fire-degraded area, *A. mangium* and *A. auriculiformis* were planted between 1993 and 1997 accompanied by intensive protection from fire.

Tree Species Composition and Growth

In 2003, three sampling sites were established in the study site, a 10-year-old *A. auriculiformis* plantation and a 10-year-old *A. mangium* plantation. A total of nine sample plots (plot size: grassland 10x10 m, *Acacia* plantations: 20x20 m) were established whose elevation ranged from 520 - 535 masl. All of the tree species with a diameter at breast height (DBH) above 5 cm were identified, and their DBH was measured along with height and crown diameter. Tree height was measured using a clinometer and a pole of fixed length using the formula below (Curtis, 1983).

All trees were marked using numbered plastic labels and were plotted on a coordinate axis. Two regeneration quadrants (2x2 m) were established in each plot, and all seedlings in the quadrant were identified and measured for root collar diameter and height.

$$H_t = h_0 \frac{(P_t - P_1)}{(P_2 - P_1)}$$

Where, H_t : height at the top of tree (m), h_0: length of fixed-length pole (m), P_t : angle measurement to the top of tree (%), P_1: angle measurement to the base of the tree (%), and P_2: angle measurement to the top of the pole (%).

Soil Nutrient Analysis

Soil samples were collected at 0 - 10 cm, and the samples were sieved with a 2 mm sized mesh, air-dried, and kept in a dry place. Total C and N were determined by combustion methods (Minagawa *et al.*, 1984) using a IsoPrime- EA, micromass in the National Instrumentation Center for Environmental Management (NICEM). The cation exchange capacity (exchangeable Ca^{2+}, Mg^{2+}, K^+, and Na^+) was determined by ICP (Inductive Coupled Plasma) emission spectrometer after leaching of <2 mm air-dry soil with 1 M CH_3COONH_4 at pH 7.0 (Sparling and Schipper, 2002).

Net Mineralization

Replicate plots were established at each site. The two plots were 20 m ´ 20 m in size and were separated by a distance of less than 30 m. To keep soil profile, mineral soil samples (0~10 cm depth) were collected using PVC pipes with 15 cm diameter and the PVC pipes were sealed by polyethylene bags. Net N mineralization in field soils was measured by calculating the mean change over time in mineral N concentration of replicate soil samples incubated *in situ* in closed PVC pipes. Ammonium-N uptake by tree roots is assumed to be prevented by incubation in PVC pipes. Oxidation of ammonium to nitrate in the bags can be assumed not to be substantially altered in incubated soils. The pipes prevent both nitrate leaching losses and uptake of nitrate by roots. Therefore, the sum of ammonium-N plus nitrate-N accumulated in incubations must be used to calculate net N mineralization. The change in ammonium-N concentration measured in incubations is referred to as net ammonification and the change in nitrate is nitrification. Net N mineralization, net ammonification and nitrification in incubated soils are measured by subtracting the mean inorganic N concentrations of initial control soil samples, taken from the 0 – 10 cm mineral soil layer of sites at the start of an incubation period, from mean concentrations accumulated in incubated samples at end of the same period. These rates are expressed and are calculated using the following equations (Nadelhoffer *et al.*, 1984):

$$\Delta NH^{+}_{4} - N = NH^{+}_{4} - N_{a(t+1)} - NH^{+}_{4} - N_{i(t)}$$
$$\Delta NO^{-}_{3} - N = NO^{-}_{3} - N_{a(l+1)} - NO^{-}_{3} - N_{i(t)}$$
$$N_{min} = \Delta NH^{+}_{4} - N + \Delta NO^{-}_{3} - N$$

Where;
$NH^{+}_{4} - N_{i(t)}$ = mean NH^{+}_{4}-N content of initial, non-incubated soil samples at the start of interval t
$NH^{+}_{4} - N_{a(t+1)}$ = mean NH^{+}_{4}-N content of accumulated in incubated soil samples at the end of interval t
$\Delta NH^{+}_{4} - N$ = net ammonification in incubation
$NO^{-}_{3} - N_{i(t)}$ = mean NO^{-}_{3} -N content of initial, non-incubated soil samples at the start of interval t
$NO^{-}_{3} - N_{a(t+1)}$ = mean NO^{-}_{3} -N content of accumulated in incubated soil samples at the end of interval t
$\Delta NO^{-}_{3} - N$ = net nitrification in incubation
N_{min} = net N mineralization in incubation

And;
All units are kg N/ha in 0-10 cm soil.

Four initial non-incubated soil samples were collected and 20 incubations were set-up in regular spacing at each plot at the start of each incubation interval. Samples in PVC pipes were buried at each plot in November 2003. Collected samples were transported with ice to the laboratory. All taken to the laboratory were processed within 24 h after arrival at the laboratory. Each sample was homogenized and 10 g subsamples were shaken with 150 ml 1N KCl for two hours. The supernatant solutions were analyzed for ammonium-N and nitrate-N. At same time ambient incubated soil was collected and analyzed for comparing amount of loss and uptake (Nadelhoffer *et al.*, 1984).

Microclimate Measurements

Monthly rainfall data (September 2002–March 2003) were collected from two nearby rain gauge stations which have different altitudes of 100 and 300 masl. Three HOBO Pro Series Data Loggers (On-set computer Corporation, Porasset, MA, USA) for monitoring air temperature and relative humidity and three soil temperature loggers (On-set computer Corporation, Porasset, MA, USA) were established in the grassland, *A. aurifculiformis* and *A. mangium* sites. Soil temperature recorded at a depth of 5 cm. The data loggers for air temperature and relative humidity were established at an aboveground height of 2 m. Data were recorded at 1-h intervals for air temperature and relative humidity and at 2 h intervals for soil temperature. The mean, standard deviation, minimum and maximum of HOBO data were computed by month. To identify variations of the microclimate among sites, the mean of the absolute value of change was calculated per hour.

Data Analysis

The effect of *Acacia* plantation on mineralization, soil chemical properties, and microclimate were evaluated with ANOVA models. After each ANOVA, Least significant difference (LSD $p<0.05$) was conducted on all parameters. All statistical analyses were undertaken using the statistical package (MINITAB, release 13.20).

RESULTS

Tree Species Composition

The relative coverage (RC) of both *Acacia* plantation areas was about 80 %. However, relative density (RD) of the *A. auriculiformis* plantation was 70 %, and this was higher than that of the *A. mangium* plantation. *Ficus septica,* as a naturally regenerated species, showed the highest values of RC and RD in both *Acacia* plantation areas. Particularly, the RBA and RD values of *F. septica* were greater in the *A. mangium* plantation than in the *A. auriculiformis* plantation. The total number of occurring species was six in the *A. mangium* plantation and three in the *A. auriculi-formis* plantation. In the *A. auriculiformis* and *A. mangium* plantations, mean DBH and height were 10 cm and 8 m, and 9 cm and 5.7 m, respectively. Six tree species appeared in the grassland, but all of these had a DBH below 5 cm excluding one, *F. septica* (Table 1).

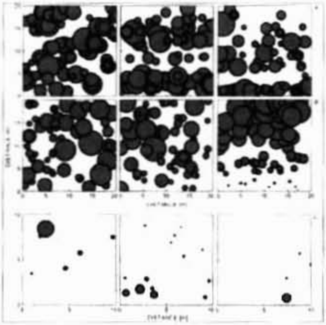
Table 1

RELATIVE DENSITY (RD) AND RELATIVE COVERAGE (RC) OF TREE SPECIES IN *Acacia auriculiformis* AND *Acacia mangium* PLANTATIONS (1)

Species		*A. auriculiformis*		*A. mangium*		Remarks
		RD [%]	RC [%]	RD [%]	RC [%]	
Acacia auriculiformis		69.6	82.7	-	-	Planted in 1993
Acacia mangium		-	-	37.6	75.2	Planted in 1993
Calliandra calothyrsus		0.5	0.1	17.5	6.3	Planted in 1995
Gmelina arborea		14.1	10.1	0.5	0.3	Planted in 1994
Pterocarpus indicus		4.9	1.9	2.6	1.0	Planted in 1994
Swietenia macrophylla		0.5	0.1	1.0	0.2	Planted in 1999
Syzygium nitidum		-	-	1.0	0.5	Planted in 1994
Fagraea fragrans		-	-	3.1	2.0	Natural
Ficus nota		-	-	0.5	0.1	Natural
Ficus septica		5.4	2.0	28.4	11.4	Natural
Ficus variegate		-	-	0.5	0.2	Natural
Gliricidia sepium		0.5	1.6	-	-	Natural
Leucaena leucocephala		4.3	1.5	5.2	2.1	Natural
Neonauclea bartlingii		-	-	2.1	0.8	Natural
Stand density		1,533 trees·ha^{-1}		1,617 trees·ha^{-1}		
Total basal area	mean DBH [cm]	19.1 $m^2 \cdot ha^{-1}$		14. 8 $m^2 \cdot ha^{-1}$		
Acacia spp.	mean height [m]	10.3		9.2		
		8.0		5.7		

(1) Tree species were measured and recorded when the DBH was above 5 cm only. Most occurring tree species (*Alstonia macrophylla*, *Cratoxylum sumatranum*, *Ficus septica*, *Macaranga tanarius*, *Neonauclea bartlingii*, and *Wendlandia uvariifolia*) had a DBH below 5 cm.

Figure 1 shows the distribution of tree species in both *Acacia* plantations, and the size of the circle represents the crown diameter of the trees. *Calliandra calothyrsus* appeared in both *Acacia* plantations with more *C. calothyrsus* seedlings in the *A. auriculiformis* plantation than in the *A. mangium* plantation. Seedlings of *Diplodiscus paniculatus* showed the highest value of emergence in terms of naturally regenerated species followed by *Ervatamia pandacaqui*, *Ficus congesta*, and *F. septica* in descending order (Figure 2).



The distribution of tree species in both *acacia* plantations and the size of thecircle represent the crown diameter of trees

Figure 1

SPATIAL DISTRIBUTION AND CANOPY CLOSURE OF TREE SPECIES IN THE STUDY SITES *Acacia auriculiformis* (*A*), *Acacia mangium* (*B*), AND GRASSLAND (*C*).

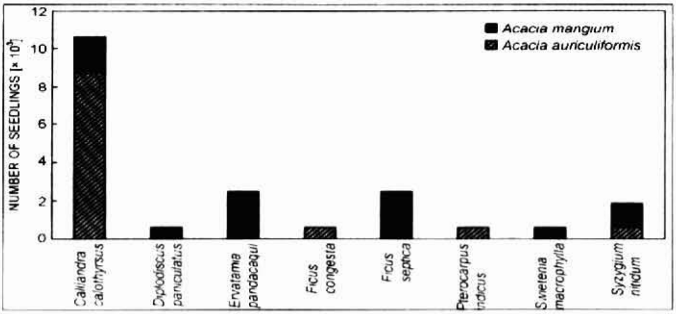


Figure 2
VARIOUS SEEDLING EMERGENCE
IN THE BOTH *Acacia mangium* AND *Acacia auriculiformis* PLANTATIONS

Nitrogen Mineralization

Seasonal net N mineralization estimates in the 0 -10 cm soil were shown in Figure 3. Seasonal variation was pronounced, with peak values occurring in September at *Acacia* plantation site. During some month net N mineralization of *A. auriculiformis* was negative. And net N mineralization of grassland was negative during study period. Negative N mineralization values could result from immobilization of soil ammonium-N during periods when microbial decomposition of fresh litter was high (Nadelhoffer *et al.*, 1984). Negative values of *Acacia* plantation showed during dry season (January). This result suggests that denitrification or volatilization could be occurred at the study site and these activities may result from high temperature (Barber, 1995; Coleman and Fry, 1991; Coleman and Crossley Jr., 1996; Jordan, 1985). Significant differences ($p<0.05$) in both *Acacia* plantation existed during September and November.

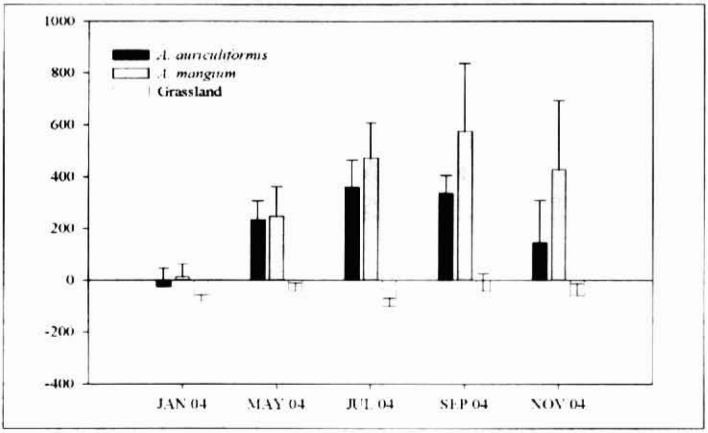
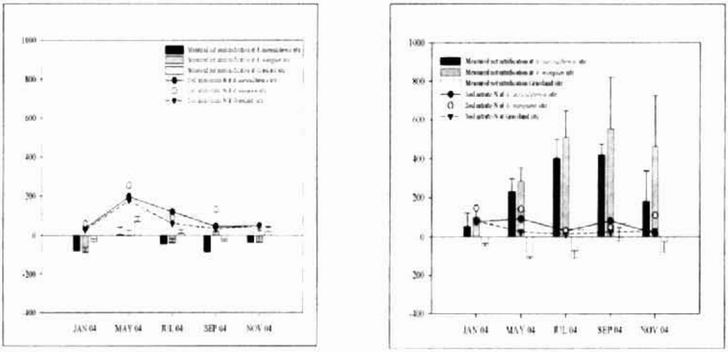


Figure 3
NET MINERALIZATION OF STUDY SITES

Net ammonification for study sites were shown in Figure 4. Net ammonification was sometimes negative. Net negative ammonification in incubations can occur when the rate of nitrification exceeds the rate at which organic N is mineralized to ammonium-N (Nadelhoffer *et al.*, 1984). Ambient soil ammonium-N was always higher than measured ammonium-N at all study sites (Figure 4). The peak of soil ammonium-N was in the month of May. Massive litterfall after dry season provide lots of organic materials to soil (Barber, 1995; Coleman and Fry, 1991; Coleman and Crossley Jr., 1996; Jordan, 1985). However, net nitrification showed positive value at *Acacia* plantation except grassland site. Grassland site always had net negative nitrification (Figure 4). This phenomenon could result from supply of little organic material, low soil pH, lack of microorganism, and high temperature (Barber, 1995; Coleman and Crossley Jr., 1996; Jordan, 1985).



Bars indicate standard deviation

Figure 4
NET AMMONIFICATION (LEFT) AND NITRIFICATION (RIGHT) OF STUDY SITES

Soil Properties

Organic carbon concentrations were not significantly different between *A. auriculiformis* and grassland. However, *A. mangium* site showed higher value than that of grassland (Table 2). Soil nitrogen concentrations in the *Acacia* plantations were significantly greater than those in grassland (Table 2). The soil C/N ratio in grassland was significantly greater than that in *Acacia mangium* plantations. In this study, available phosphorus showed very low values as less than 3.0 mg/kg in all of the study sites (Table 2). Potassium, Sodium, Magnesium and Calcium showed that their values were higher in *Acacia* plantation than in grassland (Table 2).

Table 2
SOIL PROPERTIES OF THE STUDY SITES (MEAN ± SE)

Sites	Organic Carbon(%)	Total Nitrogen(%)	C/N ratio	Available P(mg/kg)
A.auriculiformis	3.90±0.35ab	0.32±0.03a	11.87±0.26b	2.60±0.24a
A. mangium	4.12±0.11a	0.31±0.01a	13.10±0.15ab	2.70±0.29a
Grassland	3.30±0.20b	0.24±0.01b	13.69±0.25a	2.10±0.28a

Table 2 (*Continued*)

Sites	K(mg/Kg)	Na(mg/Kg)	Mg(mg/Kg)	Ca(mg/kg)
A.auriculiformis	694.74±52.81a	51.29±6.31a	1,173.7±117.75a	3,348.4±227.46a
A. mangium	646.12±48.28a	47.03±3.11a	1,095,1±120.04a	3,355.3±344.32a
Grassland	187.22±20.86b	26.83±1.74b	639.0±32.87b	2071.8±39.08b

Values with same letters are not significantly different ($p < 0.05$) within a column, using Fisher's LSD test

Microclimate as an Effect Factor on Improvement of Site Quality

Total annual rainfall in 2003 was 1,811.5 mm at 100 masl and 1,769.2 mm at 300 masl. Total annual numbers of rainy days were 210 and 119 d at 100 and 300 masl, respectively (Figure 5). Thus, the amount and pattern of rainfall and number of rainy days may differ according to altitude and location. Of the total annual rainfall, about 3% (100 masl) and 4% (300 masl) fell from January to April.

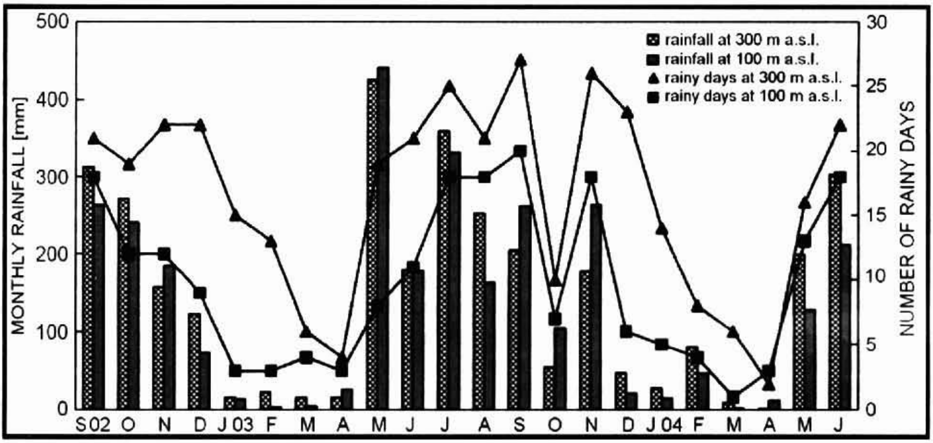


Figure 5

MONTHLY RAINFALL SEPTEMBER 2002–JUNE 2004 AT RAINFALL GAGE STATION LOCATED IN CALAMBA NEAR THE STUDY SITES AT 100 AND 300 masl

The mean air temperature in April was the highest air temperature of the sites. The annual fluctuation of air temperature was increased from December to April and was decreased after April. Grassland had both the lowest minimum air temperature and highest maximum air temperature in the study sites and exhibited a strong trend of air temperature variation (Table 3).

Table 3
MEAN AIR AND SOIL TEMPERATURES (°C) BY AREA AND BY MONTH

	Treatment	Mean air temperature±S.D.	Mean soil temperature±S.D.
Area	*A. auriculiformis* plantation	23.69±2.57^{a}	23.16±1.22^{a}
	A. mangium plantation	23.75±2.71^{a}	23.21±1.84^{a}
	Grassland	24.70±3.72^{b}	25.37±1.97^{b}
Month	April, 2004	26.09±3.72^{a}	26.05±2.04^{a}
	May, 2004	25.43±2.82^{b}	25.30±1.59^{b}
	October, 2003	24.23±2.58^{c}	23.69±1.52^{d}
	March, 2004	24.17±3.54^{c}	24.19±2.06^{c}
	August, 2003	24.17±2.25^{c}	24.15±0.61^{c}
	November, 2003	24.00±2.58^{c}	23.33±1.35^{e}
	June, 2004	23.72±1.92^{e}	24.28±1.30^{c}

Relative humidity could not be compared among treatments due to the loss of data from the A. auriculiformis plantation.

Within columns, means with the same letter are not significantly different using Tukey's mean comparison test at 0.05 level.

The relative humidity of the grassland was higher than that of the *A. mangium* plantation; however, this parameter exhibited a trend similar to air temperature where variation in the grassland was larger than in the *Acacia* plantation (Data not shown). This indicates that the large variation of air temperature produced morning and night dew on the humidity sensor of HOBO. Soil temperature in the grassland showed a higher value than the *Acacia* plantation, and the highest soil temperature was in April. Soil temperature also showed a trend similar to air temperature (Figure 6 Right). Change of air temperature per hour and relative humidity per hour values were larger in the grassland than the *Acacia* plantations. In the grassland, air temperature changed 0.8°C per h, which was about two times the change of air temperature per h in the *Acacia* plantations (Figure 6 Left). However, the change of soil temperature was not significant among the sites. Table 8 shows the results of ANOVA for air and soil temperature among the sites and by month. Differences in air and soil temperature were statistically significant between grassland and the *Acacia* plantations. April and May, the dry and hot season in the Philippines, showed the highest values of air and soil temperature (Table 3). Soil temperature was strongly correlated with air temperature, and r^2 was 0.91 (Figure 6 Right). This result indicates that soil temperature can be estimated using air temperature at this study site.

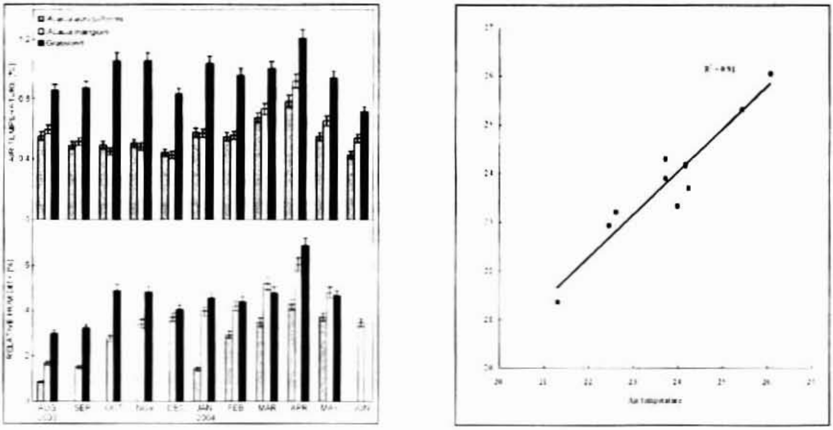


Figure 6
VARIATIONS OF AIR TEMPERATURE & RELATIVE HUMIDITY PER HOUR BY MONTH (LEFT) AND RELATION BETWEEN AIR TEMPERATURE AND SOIL TEMPERATURE AT ALL SITES (RIGHT)

DISCUSSION AND CONCLUSIONS

The findings in this study showed that *Acacia* plantation improved site qualities such as soil properties, nutrient cycling, and microclimate. Otha (1990b) reported that soil of grasslands is poor in nutrients, more compact, and has more limited soil fauna compared to natural rainforest stands. Otha (1990a) also found that soil physical properties that were improved by afforestation include bulk density and porosity although the effects were limited to the thin superficial soil layer (0-5 cm).

The study also gave a brief account on soil physical and chemical properties in grassland and in plantation. A young tree plantation not only provides control of soil moisture evaporation but improves soil physical properties as indicated by increased bulk density and total pore space distribution. However, while the acidity of grassland was found to be alleviated, plantation soils had lower pHs partly due to increased production of organic acids associated with accelerated organic matter decomposition. In the study, total C and total N contents decreased significantly with afforestation which is a common phenomena in the tropical monsoon zone. Litterfall data suggest that litterfall of *Acacia* sites affected net mineralization of plantation sites and site qualities.

Several researches reported that net primary production (NPP) such as litterfall production improved nutrient cycling particularly net mineralization (Bridgham *et al.*, 1998; Fassnacht and Gower, 1999; Pastor and Bockheim, 1984; Pastor *et al.*, 1984; Reich *et al.*, 1997; Vitousek and Sanford, 1986; Vitousek and Howanth, 1991; Vitousek *et al.*, 1993). Pastor *et al.* (1984) reported a strong relationship between net litter production and net mineralization for six forest ecosystems occurring along a natural N-availability gradient in southern Wisconsin. Reich *et al.* (1997) showed that aboveground net primary production (ANPP) and N mineralization differ more strongly with soil type/parent material than with forest type. Ellsworth and Reich (1996) reported that early successional species showed strong photosynthesis - N content of leaf relationship in Amazonian tree species. That is why pioneer species such as *Acacia* species need to be planted in degraded area to compete with grasses.

Seasonal variation in net mineralization was pronounced within site and *Acacia* plantation sites showed higher value of net mineralization than that of grassland (Figure 3). Grassland showed negative value during incubation period. These negative values could be caused by high denitrification losses of nitrate during the study period. Denitrification was affected by soil temperature, pH, and aeration (Barber, 1995). In study sites, grassland showed higher air temperature and soil temperature than those of *Acacia* plantation sites (Tables 3). Also, variation of air and soil temperature was bigger in grassland than in *Acacia* plantation sites (Figure 6).

These results suggest that microclimate affected net mineralization in the study sites. The microclimate data suggest that planting of pioneer tree species in degraded areas such as grassland, where there are no mature forests as a seed source, improves regeneration, air temperature, soil temperature, and relative humidity. In the study sites, the *A. auriculiformis* plantation had a fewer number of naturally regenerated species than the *A. mangium* plantation. This was due mostly to a higher canopy coverage rate (Figure 1) and a thicker litter layer, and slower decomposition rate. The *Acacia* plantation sites had less variation per hour of both air temperature and relative humidity, while the grassland had the highest maximum and minimum values of both air and soil temperature. Thus, introduction of tree species to grassland stabilizes the microclimate and accelerates natural regeneration and growth of seedlings.

After forest degradation, natural succession might eventually occur enabling the forest to recover by itself. However, as Lamb (1998) emphasized, the return to a mature forest or original forest could take a long time even if no further disturbances take place and sufficient residual forest remains nearby to act as a source of plants and animals. Lamb (1998) also mentioned that plantation species would limit soil erosion and aid nutrient cycling. In the previous study of Jang *et al.* (2004), it was shown that total nitrogen content and available phosphorus were significantly higher in the plantation areas. These results indicate that *Acacia* planting affected the natural regeneration process and development of invasive seedlings. The *A. mangium* plantation had more naturally regenerated species than the *A. auriculiformis* plantation (Table 1). Lugo *et al.* (1993) reported that there is little difference in understory development beneath different plantation species, while others have found significant differences between species (Fimbel and Fimbel, 1996; Keenan *et al.*, 1997; Kuusipalo *et al.*, 1995; Parrotta, 1995). Forest soil often contains inadequate soil N levels, limiting forest growth and productivity (Knoepp and Swank, 1998). In the current study sites, the total N content in grassland was 0.15% while the *Acacia* plantations measured above 2%. A total N concentration below 0.2% hampers plant growth (Jim, 2001); therefore, this result could explain why tree species are difficult to invade and develop their seedlings in grassland.

Several values of soil chemical properties were higher in the *Acacia* plantation than in the grassland (Table 2). These results suggest that *Acacia* plantation is capable of improving soil qualities. The identification of enzyme activities in conjunction with soil respiration and composition of the soil microflora provides the most reliable index of microbial activity in soil (Casida, 1977). Arunachalam *et al.* (1999) reported that dehydrogenase activity was higher in a 4-year-old alder plantation than in natural grassland and that dehydrogenase activity increased with increasing stand age in the forest re-growths. Figure 1 shows that the *Acacia* plantations had larger plant cover than the grassland. This indicates that the *Acacia* plantations produce a greater amount of litter than that of grassland. In conjunction with another study (Maithani *et al.*, 1996), results of this study suggest that increasing the plant cover, which produced a greater amount of litter, improved the soil nutrient pool.

Microclimate factors were significantly different between the *Acacia* plantations and the grassland. Grassland had the highest maximum and lowest minimum temperatures in both air and soil. Vegetation plays a critical role in shaping the microclimate through the change of energy and water balance across the landscape (Xu *et al.*, 2002). Tree leaves protect against fluctuation of temperature through evaporation cooling or shading (Kimmins, 1996). Air temperature affects growth and development of woody plants directly by inducing injury and indirectly by influencing physiological processes and yield and quality of fruits and seeds (Kozlowski and Pallardy, 1997). This may explain why tree species composition and development of seedlings differ between the *Acacia* plantation areas and grassland. From the regression analysis, soil temperature was significantly correlated with air temperature (Figure 6 Right), and soil temperature was improved in the *Acacia* plantations compared to the grassland. Barber (1995) reported that the soil's physical and chemical properties as well as irradiance and soil temperature affect root growth which, in turn, affects nutrient uptake.

The variation rate per hour of microclimate factors were calculated (air temperature and relative humidity). Kimmins (1996) reported that the rate of temperature change is sometimes more important than the actual temperature. Grassland showed the highest values of both air temperature and relative humidity. Particularly, the variation rate was high during the dry season (Figure 6 Left). Additionally, the *Acacia* plantations played an important role as windbreaks for the regenerated tree species inside the study site. Benzarti (1999) reported that a tree windbreak allows increased water use efficiency of *Medicago sativa* inside the windbreak and decreases air temperature in the study site.

In conclusion, the *Acacia* plantations had a greater number of naturally regenerated species than grassland, and this showed that invasive tree species developed their growth and coverage. In the grassland, a total of six species (*Alstonia macrophylla, Cratoxylum sumatranum, F. septica, Macaranga tanarius, Neonauclea bartlingii,* and *Wendlandia uvariifolia*) were found. However, all species had DBH values below 5 cm except *F. septica* indicating more recent establishment and slower growth. Planting *Acacia* improved site qualities (canopy coverage, litterfall, decomposition, soil properties, and soil enzyme activity) and microclimate factors (air temperature, soil temperature, and relative humidity) and decreased the variation rate of these factors in the study sites.

Therefore, this study suggests that this type of plantation is efficient in accelerating regeneration of tree species and improving site qualities (microclimate, soil condition, *etc.*) However, in the longer term larger individuals may begin competing with the over-story plantation species for soil resources (Lamb, 1998). These matters could be solved by technical management such as thinning. As restoration indices, species diversity, net mineralization, soil nutrient, soil C/N ratio, soil enzyme activity, and microclimate can be used for evaluation parameters in the young stage of restoration of degraded tropical region in Kay Inglesia, Mt. Makiling.

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