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Full Length Research Paper

Changes in litter, decomposition, nitrogen mineralization and microclimate in *Acacia mangium* and *Acacia auriculiformis* plantation in Mount Makiling, Philippines

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The objectives of this study were to examine litter, decomposition, net mineralization and microclimate by two leguminous species planted for the restoration of degraded area. The total annual litter fall in *A. mangium* site was 11.44±0.59 (mean ± standard error) t ha^{-1} yr^{-1} and *A. auriculiformis* site was 8.72±0.57 t ha^{-1} yr^{-1}. Decomposition constant (*k*) of *A. mangium* and *A. auriculiformis* were 1.27 and 1.12, respectively. Seasonal variation of net mineralization was pronounced, with peak values occurring in September at *Acacia* plantation site. Grassland showed higher air temperature, relative humidity and soil temperature as well as a larger variation per hour in these parameters compared to the *Acacia* plantations. The highest air temperature, relative humidity and soil temperature were measured in April during the dry season. These results showed that planting *Acacia* improved site qualities (litter fall, decomposition, and net mineralization) 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 improving site qualities.

Key words: Decomposition, litter, microclimate, nitrogen mineralization.

INTRODUCTION

Tropical forests comprise nearly 50% of the world's forest, but during recent years, they are disappearing at a rate of 1,300,000 hectares per year (FAO, 2001). The Philippines has a total land area of 30 million hectares. 53% of the land areas, equivalent to 15.88 million hectares, are considered forest lands. However, as of 1996, only 5.493 million hectares of forest lands are actually covered with forest. In 1999, only 800,000 hectares 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. To rehabilitate degraded forest ecosystems successfully, tree species that can overcome *Imperata 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 areas as well as are used for multipurpose trees in agroforestry systems (Nair, 1993; Jim, 2001).

After introduction of pioneer species in degraded areas, succession will eventually occur in rehabilitated area. In primary succession, cycling and supply of nutrients are important factors in an ecosystem. Nitrogen is the primary nutrient; however, it is insufficient in the ecosystem. The supply of needed nitrogen in plants comes mostly from the nitrogen in soil. Nitrogen in the organic matter came

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initially from the atmosphere via plants and microorganisms that have decomposed and left resistant and semi-resistant organic compounds in the soil during development. The bulk of soil nitrogen is present in the upper soil horizon, where the bulk of organic matter is located (Barber, 1995). Nitrogen in the above-ground biomass does not differ widely. However, the forest floor (litter layer) assumes greater significance as N reservoir as the system matures (Jurasinski et al., 2012; Keeney, 1980).

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; Liu and Muller, 1993; Knoepp and Swank, 1998). 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 and Aber, 1984).

The rates of net N mineralization vary with forest type, stand age, elevation and topographic position (Powers, 1990; Polglase et al., 1992; Liu and Muller, 1993; Garten et al., 1994; Garten and Miegroet, 1994). These differences are attributed to site variations in soil organic matter, temperature and soil water availability (Adams and Attiwill, 1986; Powers, 1990; Garten et al., 1994; Fassnacht and Grower, 1999).

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 (Raich and Tufekcioglu, 2000; Martius et al., 2004). 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 conditions, 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 light intensity as compared to grasslands (Dela Cruz and Luna, 1994). Microclimate is a factor that determines the environmental conditions for forage productivity (Feldhake, 2001), crops and soil organisms (Das and Das, 2010; Kim et al., 2011; Martius et al., 2004). *Acacia mangium* and *Acacia auriculiformis* are major fast-growing plantation species used not only for pulp and timber production but for multi-purposes in the tropical Asia region. Their importance as plantation species can be attributed to rapid growth, rather than good wood quality and tolerance to a range of soil types and pH values (Yamamoto et al., 2003).

We investigated litter production, decomposition, net mineralization and microclimate in *Acacia* spp. plantations to identify the effects of tree planting on these parameters in a former grassland area on Mount Makiling, Philippines, from August 2003 to June 2004. The objective of this study is to examine the effects of *A. auriculiformis* and *A. mangium* in terms of their changes, after ten years of planting in grassland areas.

MATERIALS AND METHODS

Study sites

Mount Makiling Forest Reserve is located in South Central Luzon, Philippines (121°14'E, 14°08'N) and covers an area of 4,244 ha. Mount 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 from 25.5 to 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 have 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 Mount Makiling at 500 m a.s.l. 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.

Litter production

Litter was collected at intervals of one month from December 2003 to November 2004 using 0.25 m^2 wide and 70 cm with 1 mm mesh size. Collected litters were sorted out into leaf, non-leaf (composed of twigs, trash and occasional insect remains) and reproductive part (flower, fruits and seeds). Litter was placed in a paper bag and was dried in an oven at 65°C and the components were weighed separately. Total litter was obtained by adding their weights (Fassnacht and Gower, 1999).

Decomposition

Nylon bags (mesh 1.5 mm^2) measuring 20 × 20 cm, each containing 15 g oven dried leaf litter were pinned to the forest floor and exposed to the natural process of decay. At monthly interval,

Table 1. Litter production (mean ± SE) of litterfall components in the sites.

Site	Leaf (t/ha/year)	Non leaf (t/ha/year)	Reproduction part (t/ha/year)	Total (t/ha/year)
A. mangium	9.25 ± 0.49[a]	2.11 ± 0.16[a]	0.08 ± 0.02[a]	11.44 ± 0.59[a]
A. auriculiformis	7.06 ± 0.45[b]	1.62 ± 0.31[a]	0.05 ± 0.02[a]	8.72 ± 0.57[b]

Values with same letters are not significantly different (P < 0.05) within a column, using Fisher's least significant difference (LSD) test.

four bags were harvested, weighed, oven-dried, reweighed and discarded. Twenty-four bags composed of a plot. Decomposition was expressed as percentage loss in the weight of the litter initially subject to decay. Monthly change in weight was determined (Fassnacht and Gower, 1999).

Decomposition rate constant (*k*) was estimated using the equation of Olson (1963) as follows:

$$\frac{X}{X_0} = e^{-kt}$$

where X_0 is the original amount of litter, X is the amount of litter remaining at a later time, e is the base of natural logarithms and t is the time that elapsed between X_0 and X.

Net mineralization

Replicate plots were established at each site. The two plots were 20 × 20 m in size and were separated by a distance of less than 30 m. To keep soil profile, mineral soil samples (0 to 10 cm depth) were collected using polyvinyl chloride (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 0 to 10 cm mineral soil layer of sites at the start of an incubation period, from mean concentrations accumulated in incubated samples at the end of the same period. These rates are expressed and are calculated using Nadelhoffer et al. (1984) Equations.

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 1 N KCl for 2 h. 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 to March 2003) were collected from two nearby rain gauge stations that have different altitudes of 100 and 300 m a.s.l. 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. auriculiformis* and *A. mangium* sites. We recorded soil temperature at a depth of 5 cm. The data loggers for air temperature and relative humidity were established at an above-ground 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. We computed the mean, standard deviation, minimum and maximum of HOBO data by month. To identify variations of the microclimate among sites, we calculated the mean of the absolute value of change per hour.

RESULTS

Litter fall production

The total annual litterfall in *A. mangium* site (mean ± SE) was 11.44 ± 0.59 t/ha/year and *A. auriculiformis* site was 8.72 ± 0.57 t/ha/year. Significant differences in leaf component of litter production existed among sites. Of the mean total annual litter production, the leaf litter constituted 80.8%, non-leaf constituted 18.4% and reproduction part constituted 0.8% at *A. mangium* site, and the leaf litter constituted 80.1%, non-leaf constituted 18.5% and reproduction part constituted 1.4% at *A. auriculiformis* site (Table 1).

There was distinctly seasonal pattern of litterfall in the sites. Two peaks of litterfall in year were observed: the main one in the dry season (January to April) and a lesser at the end of rainy season (December). The seasonal patterns of both sites were similar, with high litterfall in dry season. The fall of reproduction parts (flowers and seeds) showed in June and July (Figures 1 and 2).

Decomposition

The changes in dry weight of each leaf litter remaining in the litter bag over the experimental period (10 months) are as shown in Figure 3. The dry weight loss of leaf litter of *A. mangium* and *A. auriculiformis* showed 39 and 35%, respectively (Table 2). Decomposition constant (*k*) of *A.*

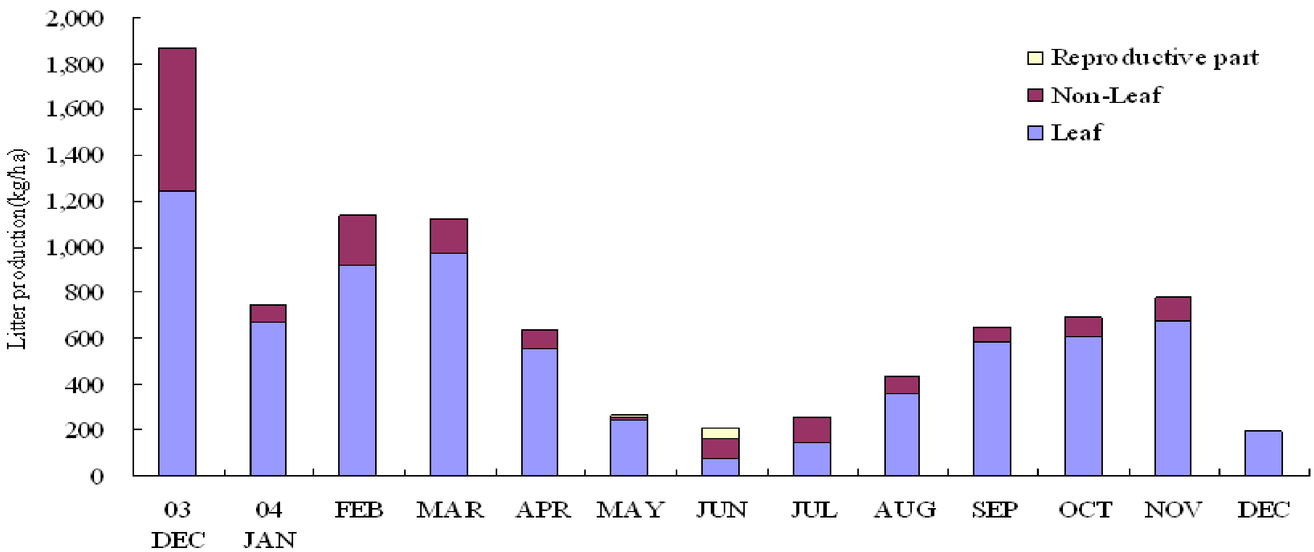

Figure 1. Litter fall production of Acacia mangium site.

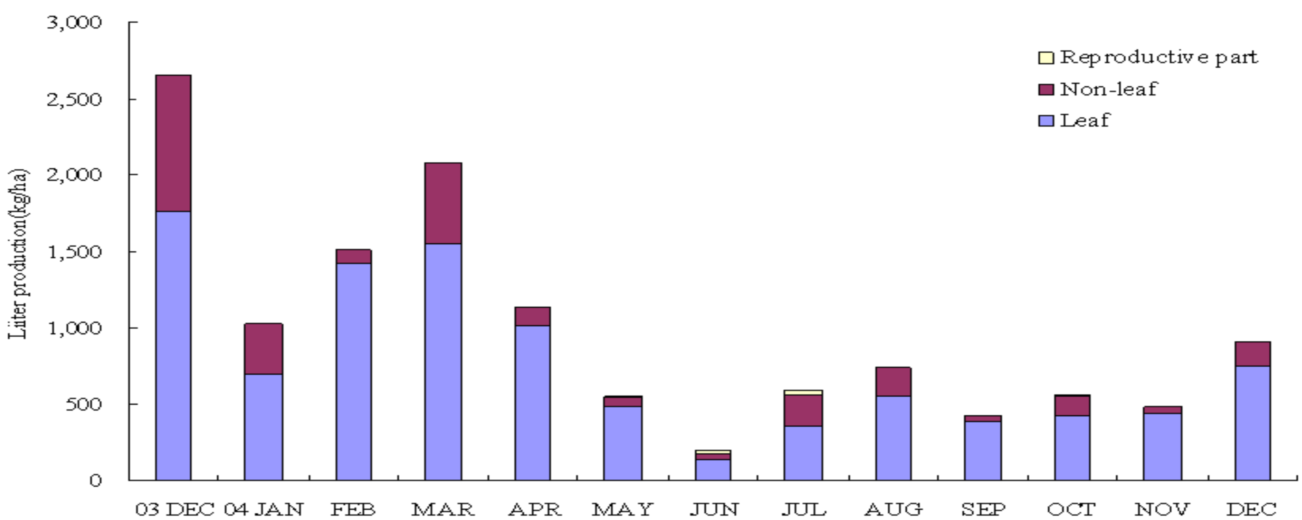

Figure 2. Litter fall production of Acacia auriculiformis site.

mangium and *A. auriculiformis* were 1.27 and 1.12, respectively. However, there was no significant difference between two species. The half time (year) in dry weight loss of *A. mangium* and *A. auriculiformis* was calculated as 0.64 and 0.56, respectively.

Nitrogen mineralization

Seasonal net N mineralization estimates in the 0 to 10 cm soil is as shown in Figure 4. 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 the study period. Negative N mineralization values could result from immobilization of soil ammonium-N during the periods when microbial decomposition of fresh litter was high (Nadelhoffer et al., 1984). Negative values of *Acacia* plantation were observed during the dry season (January). This result suggests that denitrification or volatilization could occur at the study site and these activities may result from high temperature (Fukasawa, 2012; Barber, 1995; Coleman and Fry, 1991; Jordan, 1985). Significant differences ($P < 0.05$) in both *Acacia* plantation existed during September and November.

Net ammonification for study sites are as shown in Figure 5. Net ammonification was sometimes negative.

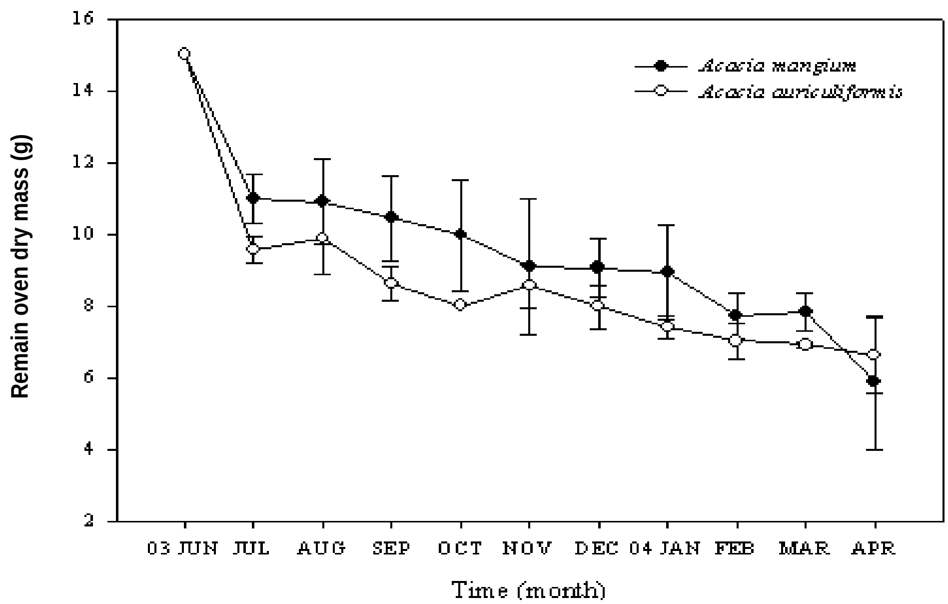

Figure 3. Remaining weight in litter bags. Bars indicate standard deviation.

Table 2. Decomposition rate (*k*) and other parameters of the leaf litter dry weight in the site.

Species	Remaining litter (mean ± SE) (%)	Decomposition constant *k* ($year^{-1}$)	Half time (year)	95% time (year)
A. mangium	39.73 ± 4.33[a]	1.27[a]	0.64[a]	2.76[a]
A. auriculiformis	35.23 ± 4.18[a]	1.12[a]	0.56[a]	2.43[a]

Values with same letters are not significantly different (P < 0.05) within a column, using Fisher's least significant difference (LSD) test. SE means standard error.

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 5). The peak of soil ammonium-N was in the month of May. Massive litterfall after dry season provide lots of organic materials to the soil (Barber, 1995; Coleman and Fry, 1991; Coleman and Crossley, 1996; Jordan, 1985; Kumar and Goh, 2000).

However, net nitrification showed positive value at *Acacia* plantation except grassland site. Grassland site always had net negative nitrification (Figure 6). This phenomenon could result from supply of little organic material, low soil pH, lack of microorganism and high temperature (Barber, 1995; Coleman and Crossley, 1996; Jordan, 1985).

Microclimate

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).

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 (Table 4). 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 (Table 5). Change of air temperature per hour values were larger in the grassland than the *Acacia* plantations. In the grassland, air temperature changed at 0.8°C per h, which was about two times the change of air temperature per h in the *Acacia* plantations (Figure 7).

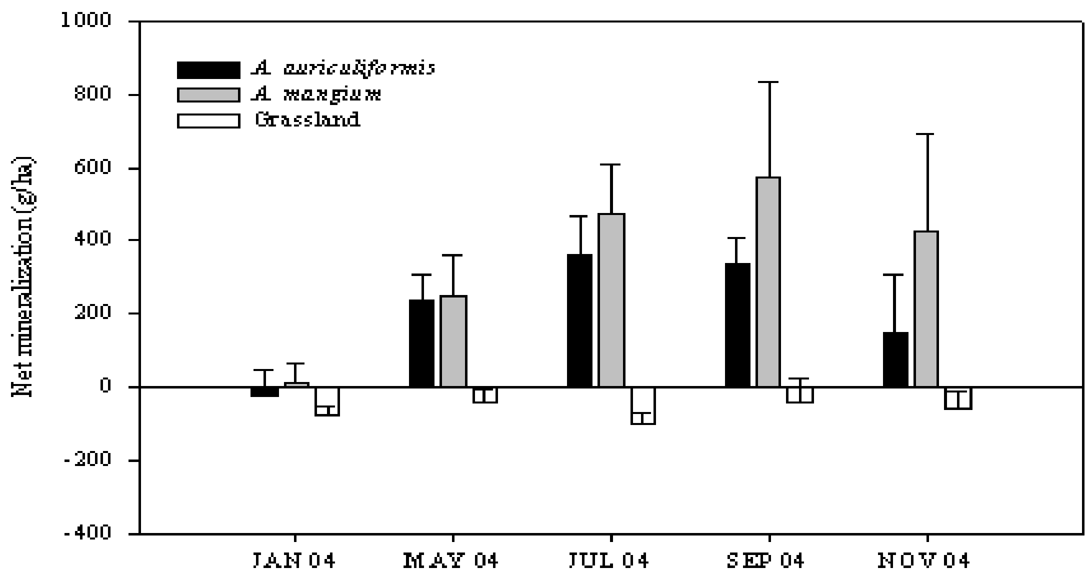

Figure 4. Net mineralization of study sites. Bars indicate standard deviation.

Table 3. Air temperature (°C) of the study sites by month.

Month	*A. auriculiformis*				*A. mangium*				Grassland			
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
August, 03	23.8	1.87	20.2	31.9	23.9	2.04	19.8	32.8	24.8	2.97	20.2	38.3
September	23.4	1.68	20.6	30.3	23.4	1.76	20.6	29.5	24.4	2.93	20.6	36.6
October	23.8	1.81	20.2	31.5	23.7	1.68	20.2	29.5	25.1	3.56	20.2	37.0
November	23.6	1.77	20.2	30.3	23.5	1.60	20.2	30.7	24.9	3.61	20.2	37.0
December	21.1	1.70	17.9	26.0	20.9	1.55	17.5	25.2	22.0	2.99	17.5	31.5
January, 04	22.1	2.17	18.3	29.1	22.0	2.15	18.3	29.9	23.3	3.81	18.3	36.6
February	22.2	2.28	17.5	31.5	22.3	2.28	17.5	31.1	23.3	3.75	17.1	34.9
March	23.8	2.93	19.4	32.3	24.0	3.25	19.4	34.4	24.8	4.24	19.4	35.7
April	25.6	2.83	21.3	32.8	25.9	3.23	21.0	35.3	26.8	4.53	21.3	37.0
May	25.0	2.09	20.2	30.7	25.2	2.42	20.2	32.8	26.1	3.60	20.6	36.1
June	23.4	1.48	20.6	28.3	23.6	1.81	20.2	29.9	24.1	2.32	20.2	34.0

DISCUSSION

The findings in this study showed that *Acacia* plantation improved site qualities such as nutrient cycling and microclimate. Otha (1990a) reported that soil of grasslands is poor in nutrients, more compact and has more limited soil fauna as compared to natural rainforest stands. Otha (1990b) also found out 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 to 5 cm). 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 above-ground 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* spp. need to be planted in degraded area to compete with grasses.

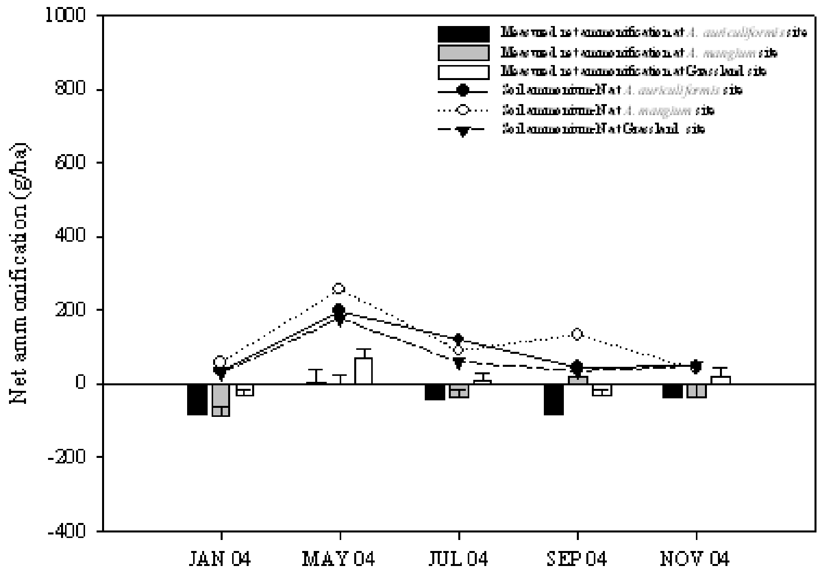

Figure 5. Net ammonification of study sites. Bars indicate standard deviation.

Table 4. Relative humidity (%) of the study sites by month.

Month	*A. auriculiformis*				*A. mangium*				Grassland			
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
August, 03	93.6	5.75	70.3	100.5	96.4	6.95	65.5	103.9	92.9	10.80	49.4	103.8
September	*	*	*	*	97.7	5.22	74.1	103.1	95.0	10.37	52.0	103.8
October	*	*	*	*	85.9	7.54	58.3	100.9	84.8	15.24	39.7	102.6
November	*	*	*	*	75.3	12.98	33.3	99.6	88.5	16.60	30.8	103.8
December	*	*	*	*	65.7	10.79	29.9	83.1	90.3	13.72	31.8	103.5
January, 04	85.6	8.36	61.7	98.1	72.7	11.77	33.3	86.7	88.5	15.39	35.2	103.8
February	85.7	10.23	49.2	99.5	70.8	14.41	22.1	88.0	88.6	16.41	35.2	103.8
March	83.1	11.16	47.6	99.1	62.6	17.92	16.6	86.7	86.9	18.68	31.8	103.8
April	79.0	13.34	45.6	101.1	52.9	19.49	12.3	85.3	78.3	24.76	19.9	103.8
May	69.3	14.87	24.0	96.7	63.1	17.17	20.0	86.2	90.6	18.81	24.3	103.8
June	*	*	*	*	59.8	16.56	22.6	94.9	*	*	*	*

*Means loss of data due to a broken sensor. SD means standard deviation.

Decomposition data showed similar decomposition rate between *A. mangium* and *A. auriculiformis* and fast decomposition rate than temperate region (Figure 3). This result means fast nutrient cycling in tropical region than in temperate region. However, *I. cylindrica* decomposed slowly than legume plants in the tropical savanna (Ibewiro et al., 2000). This result suggests that soil qualities could not be improved from organic matters. Knops and Koenig (1997) reported that soil fertility including both N and P correlated significantly with summer leaf nutrients.

Seasonal variation in net mineralization was pronounced within site and *Acacia* plantation sites showed higher value of net mineralization than that of grassland (Figure 4). 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 (Garrett et al., 2012; Barber, 1995). In study sites, grassland showed higher air temperature and soil temperature than those of *Acacia* plantation sites (Tables 4 and 5). Also, variation of air and soil temperature was bigger in grassland than in *Acacia* plantation sites (Figure 7). 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

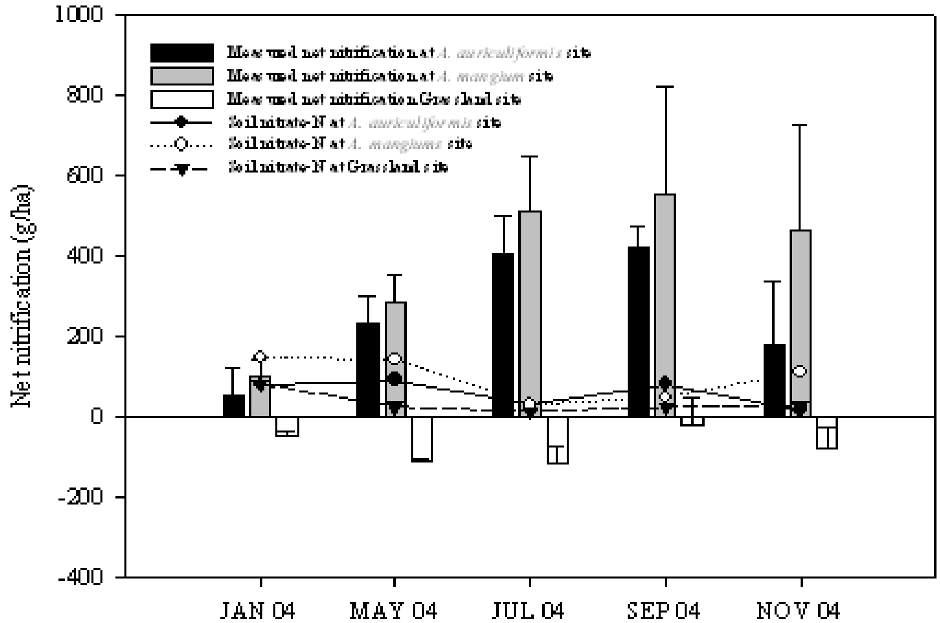

Figure 6. Net nitrification of study sites. Bars indicate standard deviation.

Table 5. Soil temperature (°C) of the study sites by month.

Month	*A. auriculiformis*				*A. mangium*				Grassland			
	Mean	**SD**	**Min.**	**Max.**	**Mean**	**SD**	**Min.**	**Max.**	**Mean**	**SD**	**Min.**	**Max.**
August, 03	23.7	0.36	22.9	24.8	23.9	0.32	23.2	24.8	24.8	0.41	23.6	25.6
September	23.4	0.37	22.5	24.4	23.5	0.34	22.9	24.4	24.9	1.84	17.1	28.7
October	23.2	0.67	22.1	24.4	23.1	0.68	22.1	24.4	25.7	2.04	19.0	30.7
November	23.1	0.45	21.3	24.0	22.8	0.62	20.6	26.3	24.9	2.12	19.8	31.9
December	21.1	0.81	19.0	23.2	20.4	0.98	17.9	22.9	22.6	1.35	20.2	26.7
January, 04	22.1	0.86	20.6	24.4	21.7	1.24	19.8	26.0	25.1	1.35	22.5	28.7
February	22.3	1.01	19.8	25.2	22.4	1.72	19.4	29.5	24.9	1.40	21.7	29.5
March	23.2	1.10	21.0	26.3	23.2	1.80	19.8	29.5	26.0	1.79	22.5	31.1
April	24.6	0.70	23.2	26.3	25.5	1.70	22.9	31.1	28.0	1.70	25.2	32.3
May	24.4	0.73	22.9	26.7	24.9	1.70	22.1	30.3	26.6	1.29	24.0	31.1
June	23.6	0.63	22.5	25.2	23.9	1.33	21.7	29.1	25.4	0.94	23.6	27.9

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 mostly due to a higher canopy coverage rate 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 was significantly higher in the plantation areas.

Microclimate factors were significantly different between the *Acacia* plantations and the grassland. Grassland had the highest maximum and lowest

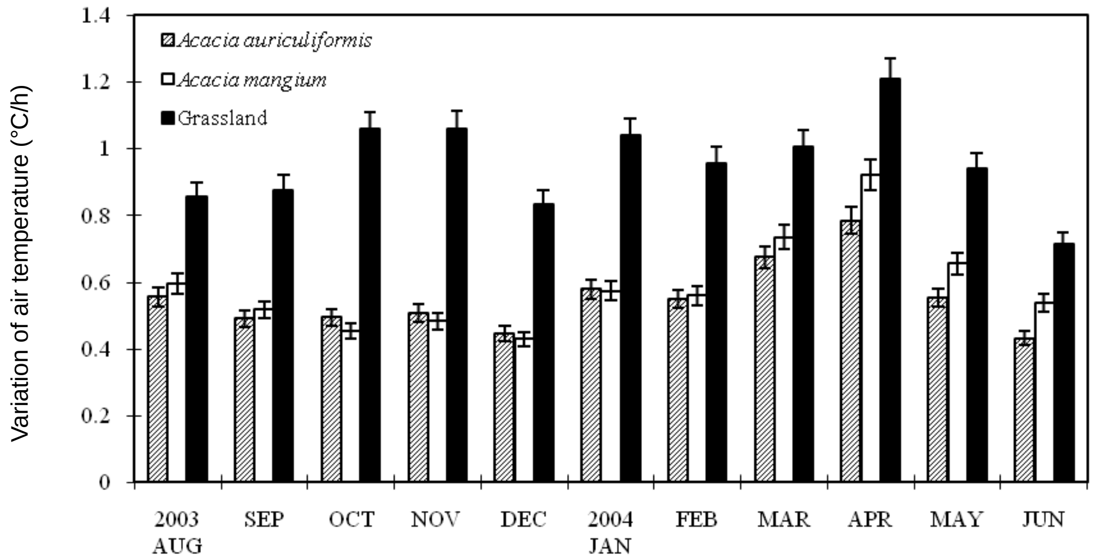

Figure 7. Variation of air temperature (up) per hour by month in the sites.

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, 1997). 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).

The variation rate per hour of microclimate factors were calculated (air temperature and relative humidity). Kimmins (1997) 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, variation rate was high during the dry season (Figure 7). 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.

Conclusion

Conclusively, planting *Acacia* improved site qualities (litterfall, decomposition and net mineralization) 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 improving site qualities. However, in longer term, larger individuals may begin competition with the over-story plantation species for soil resources (Lamb, 1998). These matters could be solved by technical management, such as thinning.

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REFERENCES

Adams MA, Attiwill PM (1986). Nutrient cycling and nitrogen mineralization in eucalypt forests of south-eastern Australia. Plant Soil, 92: 341-362.

Banerjee AK (1995). Rehabilitation of Degraded Forests in Asia World Bank, New York, p. 48.

Barber SA (1995). Soil Nutrient Bioavailability. - A Mechanistic Approach. John Wiley and Sons, New York, p. 414.

Benzarti J (1999). Temperature and water-use efficiency by lucerne (*Medicago sativa*) sheltered by a tree windbreak in Tunisia. Agrofor. Syst., 43: 95-108.

Bridgham SD, Updegraff K, Pastor JP (1998). Carbon, nitrogen, and phosphorus mineralization in Northern Wetlands. Ecol., 79:1545-1561.

Coleman DC, Fry B (1991). Carbon Isotope Techniques. Academic Press, San Diego - London - Boston - New York - Sydney - Tokyo - Toronto, p. 274.

Coleman DC, Crossley DA Jr. (1996). Fundamentals of Soil Ecology. Academic Press, San Diego - London - Boston - New York - Sydney - Tokyo - Toronto, p. 205.

Das T, Das AK (2010). Litter production and decomposition in the forested areas of traditional homegardens: A case study from Barak Valley, Assam, Northeast India. Agro. Syst., 79: 157-170.

Dela Cruz LU, Luna AC (1994). Effects of *Acacia auriculiformis* and *Gmelina arborea* on soil and microclimate of a degraded grassland in Nueva Ecija, Philippines. JIRCAS Int. Symp. Ser., 1: 46-54.

Ellsworth DS, Reich PB (1996). Photosynthesis and leaf nitrogen in five Amazonian tree species during early secondary succession. Ecol., 77: 581-594.

FAO (2001). State of the World's Forest. Words and Publications, Oxford, p. 181.
Fassnacht KS, Gower ST (1999). Comparison of the litterfall and forest floor organic matter and nitrogen dynamics of upland forest ecosystems in north central Wisconsin. Biogeochem., 45: 265-284.
Feldhake CM (2001). Microclimate of a natural pasture under planted *Robinia pseudoacacia* in central Appalachia, West Virginia. Agrofor. Syst., 53: 297-303.
Fukasawa Y (2012). Effects of wood decomposer fungi on tree seedling establishment on coarse woody debris. For. Ecol. Manag., 266: 232-238.
Garrett LG, Kimberley MO, Oliver GR, Pearce SH, Beets PN (2012). Decomposition of coarse woody roots and branches in managed *Pinus radiata* plantations in New Zealand - A time series approach. For. Ecol. Manag., 269: 116-123.
Garten Jr CT, Huston MA, Thoms CA (1994). Topographic variation of soil nitrogen dynamics at Walker Branch Watershed, Tennessee. For. Sci., 40: 497-512.
Garten Jr CT, Van Miegroet H (1994). Relationships between soil nitrogen dynamics and natural ^{15}N abundance in plant foliage form Great Smoky Mountains National Park. Can. J. For. Res., 24: 1636-1645.
Gates DM (1980). Biophysical Ecology. Springer - Verlag, New York, p. 611.
Ibewiro B, Sanginga N, Vanlauwe B, Merckx R (2000). Nitrogen contributions from decomposing cover crop residues to maize in a tropical derived savanna. Nutrient Cycling Agr. Syst., 57: 131-140.
Jang YH, Lee DK, Lee YK, Woo SY, Abraham ERG (2004). Effects of *Acacia auriculiformis* and *Acacia mangium* plantation on soil properties of the forest area degraded by forest fire in Mt. Makiling, Philippines. J. Kor. For. Soc., 93: 315-324.
Jurasinski G, Jordan A, Glatzel S (2012). Mapping soil CO_2 efflux in an old-growth forest using regression kriging with estimated fine root biomass as ancillary data. For. Ecol. Manag., 263(1): 101-113.
Jim CY (2001). Ecological and landscape rehabilitation of a quarry site in Hong Kong. Rest. Ecol., 9: 85-94.
Jordan CF (1985). Nutrient cycling in tropical forest ecosystems. John Wiley & Sons, Chichester-New York-Brisbane-Toronto-Singapore, p. 190.
Keeney DR (1980). Prediction of soil nitrogen availability in forest ecosystems: A literature review. For. Sci., 26: 159-171.
Kimmins JP (1997). Forest Ecology. Simon and Schuster, New York, p. 596.
Kim YS, Makoto K, Takakai F, Shibata H, Takami S, Kentaro T, Ryusuke H, Takayoshi K (2011). Satomura Green house gas emissions after a prescribed fire in white birch-dwarf bamboo stands in northern Japan, focusing on the role of charcoal. Eur. J. Res., 130: 1031-1044.
Knoepp JD, Swank WT (1998). Rates of nitrogen mineralization across an elevation and vegetation gradient in the southern Appalachians. Plant Soil, pp. 235-241.
Knops JMH, Koenig W (1997). Site fertility and leaf nutrients of sympatric evergreen and deciduous species of *Quercus* in central coastal California. Plant Ecol., 130: 121-131.
Kozlowski TT, Pallardy SG (1997). Physiology of Woody Plants. Academic Press, San Diego - London - Boston - New York - Sydney - Tokyo - Toronto, p. 411.
Kumar K, Goh KM (2000). Biological nitrogen fixation, accumulation of soil nitrogen and nitrogen balance for white clover (*Trifolium repens* L.) and fiedl pea (*Pisum sativum* L.) grown for seed. Field Crops Res., 68:49-59.
Lamb D (1998). Large-scale ecological restoration of degraded tropical forest lands: The potential role of timber plantation. Rest. Ecol., 6: 271-279.
Liu Y, Muller RN (1993). Above-ground net primary productivity and nitrogen mineralization in an mixed meophytic forest of eastern Kentucky. For. Ecol. Manage., 59: 53-62.
Luna AC, Osumi K, Gascon AF, Lasco RD, Palijon AM, Castillo ML (1999). The community structure of a logged-over tropical rain forest in Mt. Makiling forest reserve, Philippines. J. Trop. For. Sci., 11: 446-458.
Martius C, Höfer H, Garcia MVB, Römbke J, Förster B, Hanagarth W (2004). Microclimate in agroforestry systems in central Amazonia: Does canopy closure matter to soil organisms?. Agrofor. Syst., 60: 291-304.
Nadelhoffer KJ, Aber JD, Melillo JM (1983). Leaf-litter production and soil organic matter dynamics along a nitrogen-availability gradient in southern Wisconsin (U.S.A.). Can. J. For. Res., 13: 12-21.
Nadelhoffer KJ, Aber JD, Melillo JM (1984). Seasonal patterns of ammonium and nitrate uptake in nine temperate forest ecosytems. Plant Soil, 80: 321-335.
Nair PKR (1993). An Introduction to Agroforestry. Kluwer Academic Publishers, Dordrecht, p. 499.
Olson JS (1963). Energy storage and the balance of producers and decomposers in ecological systems. Ecol., 44: 322-332**.**
Otha S (1990a). Influence of deforestation on the soils of the Pantabangan area, Central Luzon, the Philippines. Soil Sci. Plant Nutr., 36: 561-573.
Otha S (1990b). Initial soil changes associated with afforestation with *Acacia auriculiformis* and *Pinus kesiya* on denuded grasslands of the Pantabangan area, Central Luzon, the Philippines. Soil Sci. Plant Nutr., 36: 663-643.
Pastor JP, Aber JD, McCalaugherty CA, Melillo JM (1984). Aboveground production and N and P cycling along a nitrogen mineralization gradient on Blackhawk Island, Wisconsin. Ecol., 65: 256-268.
Pastor JP, Bockheim JG (1984). Distribution and cycling of nutrients in an aspen-mixed-hardwood-spodosol ecosystem in Northern Wisconsin. Ecol., 65: 339-353.
Polgase PJ, Attiwill PM (1992). Nitrogen and phosphorus cycling in relation to stand age of *Eucalyptus regnans* F. Muell. Plant Soil, 142: 157-166.
Powers RF (1990). Nitrogen mineralization along an altitudinal gradient: Interactions of soil temperature, moisture, and substrate quality. For. Ecol. Manage., 30: 19-29.
Raich J, Tufekciouglu A (2000). Vegetation and soil respiration: Correlations and controls. Biogeochem., 48: 71-90.
Reich PB, Grigal DF, Aber JD, Gower ST(1997). Nitrogen mineralization and productivity in 50 hardwood and conifer stands on diverse soils. Ecol., p. 78.
Vitousek PM, Sanford RL (1986). Nutrient cycling in moist tropical forest. Ann. Rev. Ecol. Syst., 17: 137-167.
Vitousek PM, Howanth RW (1991). Nitrogen limitation on land and in the sea: How can it occur? Biogeochem., 13: 87-115.
Vitousek PM, Walker LR, Whiteaker LD, Matson PA (1993). Nutrient limitations to plant growth during primary succession in Hawaii volcanoes national park. Biogeochem., 23: 197-215.
Xu M, Chen J, Qi Y (2002). Growing-season temperature and soil moisture along a 10km transect across a forested landscape. Clim. Res., 22: 57-72.
Xu X, Qi Y, Chen J, Song B (2004). Scale-dependent relationships between landscape structure and microclimate. Plant Ecol., 173: 39-57.
Yamamoto K, Sulaiman O, Kitingan C, Choon LW, Nhan NT (2003). Moisture distribution in stems of *Acacia mangium*, *A. auriculiformis* and hybrid *Acacia* trees. Jap. Agr. Res., Quart., 37: 207-212.