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Growth of Trees Planted in Degraded Forest Land

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Abstract
Fast-growing tree species planted in the Makiling forest in Los Baños, Laguna and degraded forest land in Carranglan were examined to analyze the characteristics and productivity of these tree species in each area. *Acacia auriculiformis* was found to be the most adapted species to degraded land, followed by yemane (*Gmelina arborea*). Yemane showed excellent growth where the physical soil properties were improved. Yemane and teak (*Tectona grandis*) were fire-tolerant species and their growth gradually improved. Annual height increment of Dipterocarpaceae seedlings planted under A. *auriculiformis* ranged from 30 to 40 cm and the height of some of them exceeded 4 m. Litter on the Acacia forests amounted to more than 1,500 g/m2. The values were almost twice those of tree species for long-rotation forests in Los Baños.

Discipline: Forestry and forest products
Additional key words: fast-growing species, long rotation, plantation, underplanting

Introduction

Forest lands provide inhabitants with an important source for agroforestry activities. However, since these lands are usually located on slopes, agroforestry or agricultural activities in such areas are likely to lead to land degradation. Therefore, these lands must be used carefully to prevent them from becoming unproductive grasslands.

There are many patterns of land degradation where the original vegetation is destroyed and changes into grassland by fire and grazing. Since top soil erosion and runoff occur in bare land and residual soil becomes compact and hard, not only agricultural activities but reforestation also become difficult. The degradation of vast tracts of forest lands in the tropical regions exerts an adverse effect on the global environment. Re/afforestation is the most reliable and easiest method to recover the land productivity in such degraded areas. Tree growth is one of the important indices of land productivity. Therefore, we attempted to analyze tree growth as a reflection of the improvement of productivity by planting fast-growing tree species in a markedly degraded area, Carranglan, in central Luzon island, the Philippines (Fig. 1).

Study sites and meteorological characteristics

The studies were carried out in the Makiling forest of University of the Philippines at Los Baños (UPLB) and in Carranglan, Nueva Ecija. In addition, detailed analysis of the soil conditions including physical and chemical properties in the Makiling forest and Carranglan area were performed and reported by Yagi et al[1,8], and Ohta[5,6].

1) Makiling site

Makiling forest is located in the back of the Makiling botanical garden (MBG), behind UPLB at the foot of Mt. Maquiling (1,109 m). The natural

This study is a part of a collaborative project on the "Rehabilitation of degraded forest lands through the implementation of agroforestry systems" between the Tropical Agriculture Research Center (TARC) and the College of Forestry, University of the Philippines at Los Baños (UPLB).

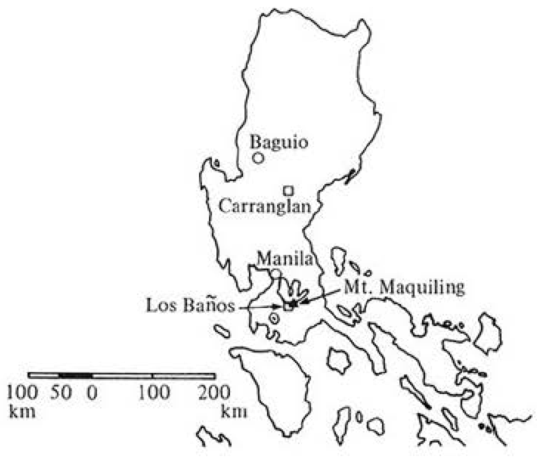

Fig. 1. Location of the research sites

vegetation of the lower part of Mt. Maquiling consists of tali depterocarp tree species[2], about 40 m high. The soil type is a Typic tropudalf of volcanic ash origin, with adequate physical properties[8]. The altitude of MBG is about 100–400 m above sea level. The yemane (*Gmelina arborea*) plantation was established in the Makiling forest in 1973, and the experimental plot (UP-YEMANE) was established by Kamo et al.[3] in February, 1986.

Walter's climatic diagram[7] drawn on the basis of the meteorological data recorded from 1950–1989 at UPLB is shown in Fig. 2.

A distinct dry season lasted for 4 months, from January to April. Seventy-seven percent of rainfall was observed from June to November. Temperature changes throughout the year were not appreciable and the temperature was slightly lower from December to March.

2) Carranglan site

Extensive grasslands cover part of the Carranglan area. Main grass species were cogon (*Imperata cylindrica*), talahib (*Saccharum spontaneum*) and samon (*Themeda triandra*). To change the grasslands into forests, the Japan and Philippines joint project on re/afforestation (RP-Japan project) has been implemented in the Carranglan area since 1976. Various tree species were planted as a trial. Some parts of the area are now covered with forests. A survey of these forests revealed the following characteristics.

A. auriculiformis stands were located in Monkiki, in the southeastern part of Carranglan[1]. The inclination of the sites was very gentle and the sites were almost flat. The survey plots, ACACIA1, ACACIA2, ACACIA3, ACACIA4 and ACACIA5

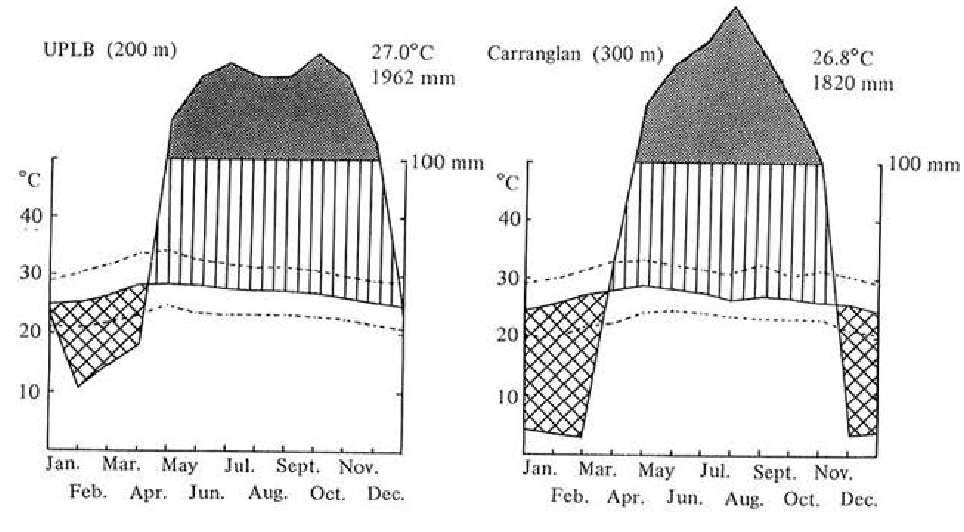

Fig. 2. Walter's climatic diagram recorded at the University of the Philippines at Los Baños and Carranglan

were set up in the area with almost identical conditions. ACACIAU was set up slightly apart from them but the stand conditions were not appreciably different from those of the others.

Trees were planted in the ACACIA1 and ACACIA2 plots in 1984. Canopies of these forests had not closed yet, and the forest floor was covered by dwarf talahib. Trees were planted in the ACACIA3, ACACIA4, ACACIA5 and ACACIAU plots in 1981. The forest canopies had already closed, and there were few plants on the forest floor with a thick litter cover. Thinning was performed in 1984, i. e. 20% thinning and 40% thinning for the ACACIA3 and ACACIA5 plots, respectively. Thinning was not performed for the ACACIA4 and ACACIAU plots. Palosapis (*Anisoptera thurifera*), gijo (*Shorea guiso*) and white lauan (*Pentacme contorta*) were planted under the *Acacia* trees in the ACACIA3, ACACIA4 and ACACIA5 plots in 1984.

Test plots, TEAK1, TEAK2, pine and yemane mixed stand, and pure pine stand were set up in the central trial plantation of the RP-Japan project site in 1977. They were located on a gently rolling hill at an elevation of 300 m a. s. l. YEMANE1 stand was set up near these plantations in 1984.

Trees were planted in the YEMANE2 stand in 1984 as a line planting trial near *Acacia* stands in Monkiki. The space between the lines was 6 m. Mahogany (*Swietenia macrophylla*), narra (*Pterocarpus indicus*) and other trees were planted between the lines, but no trees survived due to the occurrence of fire. These forests were considered to have experienced many fires previously.

Meteorological data were obtained from the RP-Japan project report[1]. Walter's climatic diagram[7] drawn on the basis of the data is shown in Fig. 2.

The rainfall pattern is characterized by heavy rain during the rainy season, with 89% of the total rainfall occurring from May to November, while there is almost no rain during the dry season, from December to April. There are often rainless periods for 3 to 5 months. Such severe dry spells prevent the development of the vegetation in affected areas. Silvicultural activities are also hampered.

Methodology

After setting up each survey plot, the diameter at breast height (DBH ; 1.3 m above from ground) and height of standing trees were measured using a diameter tape and a hypsometer (Blume Leiss), respectively. When a tree was lower than 10 m, a height pole was used.

Total height and diameter at 0.3 m height were measured for the seedlings of the Dipterocarpaceae species planted under the *Acacia* trees.

To determine the effect of the changes in the soil conditions caused by the construction of the RP-Japan office, the distribution of the trees planted behind the building was mapped by using a pocket compass.

To estimate the organic matter supply, accumulated litter was collected on the floor of the ACACIA1, ACACIA2, ACACIA4 and ACACIAU plots. All the litter and living plants in four 1 × 1 m quadrates were collected and weighed. Samples were then dried in a 90°C oven to obtain the total dry weight of organic litter.

Stem volume was estimated based on the volume table for Japanese natural Akita-sugi.

These activities were undertaken from May to July, 1990.

Structure and biomass of man-made forests

1) Diameter and height relation

Measurement of the height of all the trees correctly is time-consuming and laborious. It is well known that the relationship between the diameter and height (D-H relation) is expressed by a reciprocal equation[4]. Therefore, we measured the height of trees with various sizes in each stand, and statistically obtained the equation to determine the height of all the trees in the plot. The reciprocal equations were adapted to mature or dense forests, while power equations to young or sparse forests.

2) Growth of yemane trees at the UPLB site

The characteristics of the yemane plantation in UPLB were as follows:

As shown in Table 1, the number of dominant trees did not change and that of suppressed trees decreased during the recent 4 growing seasons in the UP-YEMANE plot. The sizes of the dominant trees increased. As shown in Fig. 3, the relationship between tree size and diameter increment was not clear. The upper limits of the diameter increment

Table 1. Outline of *G. arborea* stand

		Average		per hectare			
		DBH (cm)	Height (m)	No.	B. A.[b] (m^2)	Volume (m^3)	Total volume (m^3)
1990	Dominant	28.3	17.5	500	33.5	307.7	378.6
	Suppressed	18.3	13.2	350	9.6	70.9	
1986	Dominant[a]	25.7	16.5	500	27.7	245.2	315.8
	Suppressed	14.5	11.2	600	10.7	70.6	

a) : Recalculated from the data by Kamo et al. in 1986 based on the same volume as in 1990.
b) : B. A. ; Basal area.

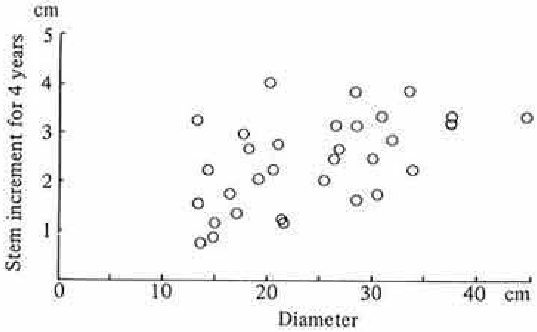

Fig. 3. Relationship between tree size and diameter increment in UP-YEMANE forest

were almost equal for all sizes while the lower limits showed a distinct tendency. Namely, even though some small trees grew well in many instances, the growth of trees with a small diameter was not satisfactory. The similarity of upper growth limit was caused by the growth decline of dominant trees and the accelerated growth of lower trees due to the decrease of foliage of the trees in the upper story of the forest. The rate of diameter increment was less than 1 cm per year, a very small value in comparison to that for the younger stages.

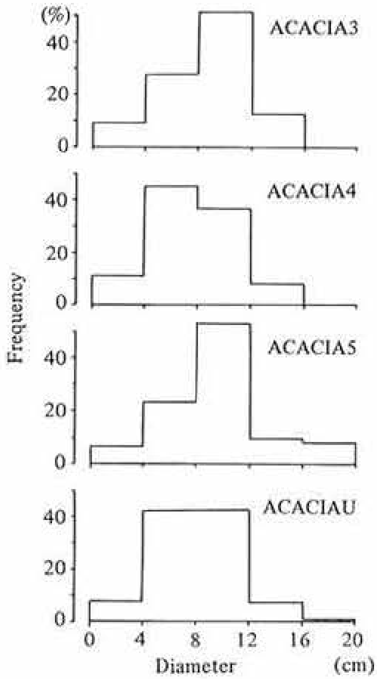

Fig. 4. Stem size distribution of *Acacia* plots

Total volume increased by 62.8 m^3/ha for the 4 growing seasons, as the annual average increment of the stem volume was about 16 m^3/ha. The growth rate for this period was about half of the value (32 m^3/ha) reported by Kamo et al.[3] for the first 13 years (Table 2). Though the rate of increment was still high, the stems of some trees were broken in the middle part, others were uprooted

Table 2. Biomass of *G. arborea* stand at Makiling, UPLB in 1986[3]

Species	Age	Standing crop (t/ha)				Stem volume (m^3/ha)
		Leaf	Branch	Stem	Total	
G. arborea	13	3.3	11.8	153 (8.5)	169	389 (32.0)

( ) : Annual increment.

Table 3. General description of surveyed stands in Carranglan

	Average		per hectare				
	DBH (cm)	Height (m)	No.	B. A.[a] (m^2)	Volume (m^3)	Total volume (m^3)	Remarks
ACACIA1	5.6	5.8	1,207	3.1	12.1	12.6	
	4.7	4.6	93	0.2	0.5		
ACACIA2	6.4	6.3	1,197	4.2	17.1	18.1	
	4.8	4.6	177	0.3	1.0		
ACACIA3	10.7	12.4	1,257	11.6	79.5	90.1	20% thinned
	6.3	8.9	600	1.9	10.6		
ACACIA4	9.9	11.9	1,064	8.6	57.7	72.7	
	6.4	9.1	832	2.7	15.0		
ACACIA5	11.1	12.5	1,090	11.4	82.1	93.4	40% thinned
	7.1	9.7	465	2.0	11.3		
ACACIAU	9.7	11.7	1,498	11.6	77.3	89.6	
	5.9	8.5	842	2.4	12.3		
TEAK1	5.3	4.2	1,591	3.8	11.1	11.1	
	4.8	3.9	10	0.0	0.1		
TEAK2	7.2	6.4	1,938	8.4	34.7	38.4	
	6.3	5.8	250	0.9	3.6		
YEMANE1	7.3	5.9	1,555	6.8	25.4	26.8	
	5.7	5.2	151	0.4	1.4		
YEMANE2	6.3	4.4	890	3.1	9.4	10.1	
	4.8	4.0	145	0.3	0.7		
Pure pine	12.2	6.3	1,590	19.7	70.3	70.9	
	10.9	6.1	48	0.5	1.6		
Pine	12.4	6.8	258	3.2	12.7	101.7	
and	9.6	5.8	1,220	3.6	35.0		
YEMANE+etc.	16.1	10.6	390	8.7	52.4		
mixed stand	6.8	7.4	130	0.5	2.2		

Upper rows indicate dominant trees. a) : B. A.; Basal area.

by the wind, and many lacked tops, suggesting that the forest might have become overmature.

3) Growth and biomass of the trees planted in the degraded cogon grassland in Carranglan

Description of the surveyed stand is shown in Table 3. As already mentioned, thinnings were performed in the ACACIA3 and ACACIA5 stands. Stem size distribution of *Acacia* plots is shown in Fig. 4, revealing the slight effect of thinning. Average diameter was large in the heavily thinned plot and the diameter size distribution was also affected. Usually the total stem volume is larger in a dense plot, unlike in this plot. The average annual growth rates for 8 growing seasons ranged from 9 to 11.7 m^3. Though these values were not high for the fast-growing species, in taking account of the degradation of the site conditions, the results appeared to be satisfactory. The growth rates of the trees in the ACACIA1 and ACACIA2 plots were 2.5 and 3.6 m^3 per year, respectively. The values were smaller than those for other stands, but since the site conditions are almost identical, the productivity may improve in the near future.

Although yemane is expected to adapt itself well even to unfavorable site conditions, the trees in the YEMANE1 and YEMANE2 plots did not grow well, especially, in the line planting sites where the floor surface was widely exposed and wild fire may have adversely affected the tree growth.

Teak is one of the popular tree species used for agroforestry in Indonesia and Thailand. However, teak planted in Carranglan experienced dieback year after year during the dry season. Although it was considered that teak was not suited to the degraded conditions, recently the extent of dieback has decreased and the survival rate has improved. Trees in the TEAK2 plot showed an increase of volume of 38.4 m^3/ha, exceeding the value recorded in the neighboring YEMANE1 plot. The change of the conditions in the teak stand may be ascribed to the fact that the roots were able to develop through the hard soil. In the TEAK1 plot, the trees were still small, and dieback of the shoots, 30–50 cm or more, caused by fire was observed. Teak was superior to *A. auriculiformis* in the ability of the lateral shoots to sprout after fire damage.

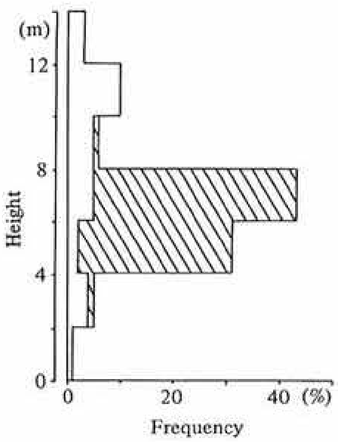

Fig. 5. Height distribution of trees in pine and yemane mixed stand
□ : Yamane and other trees.
▧ : Pine.

Table 4. Dipterocarpaceae tree species under planted

		Height (cm)	Diameter[a)] (cm)	Tree nos. investi-gated
ACACIA1	Palosapis	197(408)	2.1(4.0)	58
	Gijo	139(215)	1.4(2.2)	29
ACACIA4	Palosapis	178(385)	1.8(4.6)	29
ACACIA5	Palosapis	181(296)	1.9(3.1)	24
UP-YEMANE	Apitong	206(289)	1.4(2.2)	25

a) : Diameter measured at 30 cm above the ground level; diameter of apitong in UP-YEMANE was measured at 1.3 m above the ground level.
The numbers in parenthesis represent the largest values.

The growth of *Pinus kesiya* planted in 1977 was not adequate both in the PINE1 and PINE2 plots. However, yemane, planted in the same year as pine in the PINE2 plot, was dominant in the upper story of the pine forest (Fig. 5). Average height of pine was 7 m and the height of yemane exceeded sometimes 13 m, far surpassing the growth of yemane in the adjacent plots. The rapid covering of the surface by pine may have exerted a favorable effect on the growth of yemane, suggesting that the two-story planting may be a suitable silvicultural technique for afforestation of degraded lands.

Growth of underplanted Dipterocarpaceae trees

Long rotation tree species such as some Dipterocarp species, narra, mohogany, teak and others planted directly in the open space could not grow well and eventually died. Therefore, attempts were made to plant these tree species under nurse trees.

Palosapis and gijo planted under *Acacia* forests in 1984 in Carranglan and apitong planted under yemane trees in UP-YEMANE forest were investigated. Apitong may have been planted in 1987 or later. The results are shown in Table 4.

The growth speed was slower than that of the fast-growing tree species. However, despite the unfavorable site conditions, the trees grew steadily and the height of some of them exceeded 4 m. The correlation between the diameter at 30 cm above ground and tree height did not vary appreciably among the sites and species (Fig. 6). The results indicate that the satisfactory growth of the underplanted trees was due to the influence of leguminous tree species.

Growth of yemane trees planted around the RP-Japan project office

The former office building of the RP-Japan re/afforestation project was constructed in 1976. Though the planting record was missing, we estimated that the yemane forest was established behind the office thereafter.

We observed that the sizes of these yemane trees decreased depending on the distance from the building.

The location of the trees and their sizes are shown in Fig. 7. The diameter of the trees decreased with

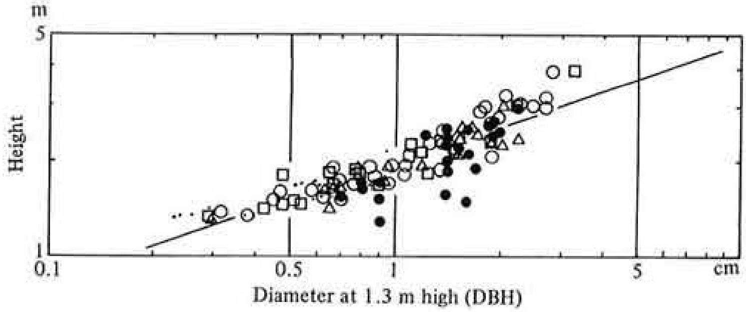

Fig. 6. Diameter and height relation of Dipterocarpaceae seedlings planted under trees
○ : Palosapis planted in the ACACIA3 plot.
□ : Palosapis planted in the ACACIA4 plot.
△ : Palosapis planted in the ACACIA5 plot.
• : Gijo planted in the ACACIA3 plot.
● : Apitong planted in the UP-YEMANE plot.

the increase in the distance from the building. Average diameter of the trees in the same row parallel to the building side is plotted in Fig. 8, which shows that the tree size was affected by the building up to a distance of 5 m. Since many families live around the office now, human influence is a factor to be considered. However, such a tendency was already recognized by us in February, 1982, when there were no inhabitants yet and the tree age was approximately 5 years. Therefore, we concluded that this particular phenomenon was caused by the soil conditions associated with the construction work. The soil, with properties similar to those in the surrounding areas, was excavated and spread around the construction site and the disturbance may have been stronger near the building. The trees grew well in front of the office, where such changes of the soil conditions may have occurred. A photograph of a yemane tree standing alone in front of the office was taken in February, 1982 (Plate 1). The diameter was 46.5 cm and height was 14 m, and the tree was less than 6 years old at that time.

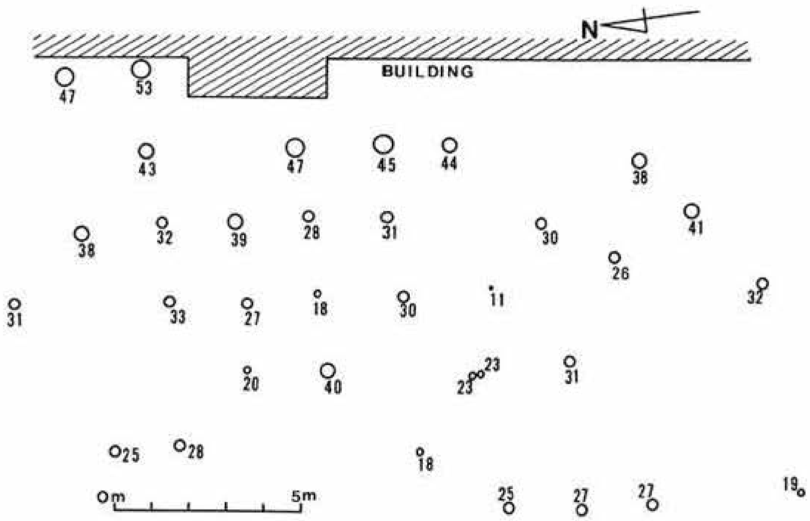

Fig. 7. Location of yemane trees planted behind the building
Numbers indicate the diameter (cm) of trees.

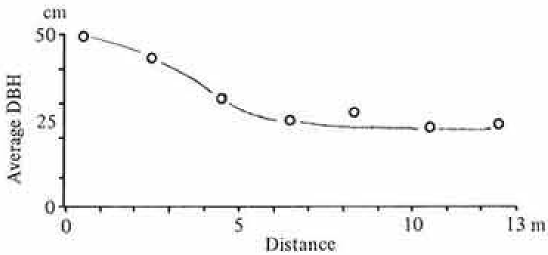

Fig. 8. Average diameter of trees in the same row along the building

These facts suggested that, except for the physical properties, the intrinsic fertility of the Carranglan soil was not so low as considered. If the soil were to be cultivated deeply to ameliorate the physical conditions in particular the texture, the growth of the trees may be improved.

The age of the yemane trees behind the office was still 14 years, but the tops of many trees and trunks of some trees were broken, suggesting a phenomenon of overmaturation of the forest. The yemane forest may not last long, and our estimation of the life span of an ordinary yemane forest is less than 15 years.

Plate 1. A solitary yemane tree less than 6-year-old standing in front of the office (Feb. 1982)

Amount of litter on the forest floor

The presence of litter on the forest floor is very important for the improvement and recovery of forest productivity. On the other hand, litter causes wild fires. There was a wild fire next to the ACACIAU plot, in March 1990, resulting in the destruction of more than 100 ha of *A. auriculiformis* stand at that time. The accumulated litter on the floor was burnt due to the strong wind. The stems of the trees were burnt and blackened up to 2 m height from the ground by fire but the leaves of the standing trees were not burnt, and still remained on the branches for several months after the fire, and very few trees were able to survive until the rainy season. This incident suggested that the presence of litter on the floor is important.

Average litter values for each *Acacia* plot are shown in Table 5.

The organic litter was considered to improve the low soil fertility at Carranglan. The amount of litter

Table 5. Amount of litter on the floor of *Acacia* forest and matured forest of MBG

(Dry weight/m²)

Site	Plot	Living plant	Leaf litter	Dead branch	Total
Carranglan	ACACIA1	192	330	—	522
	ACACIA2	324	296	25	645
	ACACIA4	—	1,253	314	1,567
	ACACIAU	49	1,386	287	1,702
Makiling	Mahogany	42	457	216	715
	Apitong	59	477	271	807
	Bagtikan	17	407	344	768

Table 6. Litter on the natural *Quercus crispula* forest in autumn

	Dry weight (g/m^2)	Water content ratio (%)
Thick litter plot	1,154	56.9
Thin litter plot	506	38.4
Almost bare plot	192	34.0

on the forest floor was compared with that of the MBG forest which was in good condition. Average litter weight of the mahogany, bagtikan and apitong, and bagtikan and palosapis forests is shown in Table 5.

Compared to the values of the *Acacia* plots, the amount of litter was smaller in the well-developed sites of MBG.

In the temperate zone, deciduous trees usually shed their leaves in autumn, resulting in the accumulation of thick litter on the forest floor. Table 5 shows the amount of litter in a well-developed *Quercus crispula* forest in autumn. Data were taken in 1986 by the senior author, in Kitakami mountains, Iwate, Japan. Even in the "thick litter plot", the amount of litter was less than that in the *Acacia* forests, while the amount of the "thin litter plot" was almost equivalent to the amount of litter of the mature forest in MBG (Table 6).

Considering the very slow decomposition speed in the pure *Acacia* forest, it may be suitable to establisha mixed forest with *Acacia* and other trees or to supply a larger amount of sunlight to the forest floor to accelerate the decomposition speed of litter.

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