Tree Growth and Productivity in Degraded Forest Land

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Abstract

Rapid forest recovery is important in degraded forest lands of the tropical region. There are various types of degraded forests due to frequent burning for shifting cultivation and overgrazing. To recover the land productivity in such areas, re/afforestation is the most reliable method. Tree growth is one of the important indices of land productivity. Therefore, we will report on the growth and productivity of man-made-forests established in several degraded lands.

1. A heavily disturbed and vast watershed covered with cogon grass is present in Carranglan, Philippines. Afforestation trials started in 1976. More than 20 species were examined for the adaptation trials, and *Acacia auriculiformis* showed the best growth followed by *Gmelina arborea*. The main problem for forest establishment is the occurrence of wild fire.

2. A wide area of grasslands is present in Indonesia, too. Afforestation trials have been implemented since 1981 in Benakat, Sumatra island. As the site conditions were more favorable in Benakat than in Carranglan the growth of the planted trees in Benakat was better. *Peronema canescens*, an indigenous tree species to this island, grew well and is expected to become a suitable silvicultural meterial.

3. Man-made-forests consisting of some indigenous dipterocarp species and valuable tree species in slightly disturbed areas in the Philippines and Java island were studied. These species were *Parashorea malaanonan, Anisoptera thurifera, Dipterocarpus grandiflorus, Swietenia macrophylla* in the Philippines and *Shorea stenoptera, S. selanica* and *Dipterocarpus retusus* in Java island, Indonesia. These examples suggest that if appropriate silvicultural methods are adopted it is possible to establish forests consisting of dipterocarps and other valuable tree species by the planting method. The conditions and processes of establishment of these valuable forests must be defined to develop re/afforestation techniques.

Introduction

Rapid reforestaion is important in degraded forest lands of the tropical region. There are various types of degraded forests due to frequent burning for shifting cultivation and overgrazing. Since top soil erosion and runoff occur in the denuded land and residual soil becomes compact and hard, not only agricultural activities but reforestation also become difficult. Degradation of vast forest lands in the tropical regions exerts an adverse effect on the global environment and inhabitants. To recover the land productivity in such areas, re/afforestation is the easiest and the most reliable method. Tree growth is one of the important indices of land productivity.

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Exotic tree species are usually used for the re/afforestation programs and industrial plantations. Because the characteristics of those tree species are well known, they grow fast and their productivity is high. Although the diversity of such forests may be low, there are few forests with indigenous tree species. Man-made dipterocarp forests are not frequently observed and it is generally assumed that dipterocarp forests cannot be reestablished or once the tropical forest is destroyed, the restoration of the dipterocarp forest is impossible. However there are examples of planted dipterocarp forests that grow well and valuable species forests in tropical countries. We will present an outline of some of the forests with fast-growing tree species, dipterocarp forests and forests with valuable species observed in the Philippines and Indonesia.

This study is a part of the projects entitled "Rehabilitation of degraded forest lands through the implementation of agroforestry systems" and "Evaluation of the ecological functions of tropical forests". The former project has been conducted at College of Forestry, University of the Philippines at Los Banos (UPLB) and the latter at the Forest Research and Development Center (PPPH), Indonesia in collaboration with the Tropical Agriculture Research Center, Tsukuba, respectively.

Methodology

At first, sample plots 0.04ha to 0.3ha were set up in each stand, then the diameter at breast height (dbh ; 1.3m above ground) and height of all the standing trees were measured using a diameter tape and a hypsometer (Blumeleiss), respectively. If a tree was lower than 10m, a height pole was used. The stem volume was estimated based on volume table for Japanese natural Akita sugi.

Study area and meteorological characteristics

1) Carranglan, central Luzon, the Philippines

There are extensive grasslands in Carranglan. The main grass species are cogon (*Imperata cylindrica*), talahib (*Saccharum spontaneum*) and samon (*Themeda triandra*). The predominance of those grasses and low value for height (below 50cm) indicate the low productivity of the land (Ohta, 1990a,b). To change the grasslands into forests, the Republic of the Philippines-Japan technical cooperation project for afforestation in the Pantabangan area (RP-Japan project) has been implemented in the Carranglan area since 1976. More than 30 tree species were planted as a trial and several parts of the area are being changed into forests, presently (BFD and JICA, 1987). We surveyed those forests.

Meteorological data (from 1978 to 1985) were obtained from the RP-Japan project report (BFD and JICA, 1987). The mean annual rainfall is 1,820mm. 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 or less than 10mm per month during the dry season, from December to April. There are often rainless periods lasting for three to five months. Such severe dry spells prevent the development of the vegetation in affected areas. Silvicultural activities are also hampered. The mean annual temperature is 26.7°C.

The inclination of the *Acacia auriculiformis* stands is very gentle and almost flat. Sample plots, ACACIA1, ACACIA2, ACACIA3, ACACIA4 and ACACIA5 were set up in areas with almost identical conditions. ACACIAU was set up a little apart from them but the stand conditions did not differ appreciably from the others. ACACIA1 and ACACIA2 were planted in 1984. Canopies of those forests have not closed yet, and the floor is covered by dwarf talahib. ACACIA3, ACACIA4, ACACIA5 and ACACIAU were planted in 1981. The canopies were already closed, and there were few plants on the floor, with a thick litter cover. Thinning was performed in 1984, i.e., 20% thinning and 40% thinning were performed in the ACACIA3 and ACACIA5 plots, respectively. Thinning was not performed in the ACACIA4 and ACACIAU plots.

Sample plots were also set up in the *Tectona grandis* stand as TEAK1, TEAK2. *Pinus kesiya* stand (PINE1) and *P.kesiya* and *G.arborea* mixed stand (PINE2) were also established. They were planted in 1977 in the central trial plantation of the RP-Japan project site. They were located on a gently rolling hill of 300m asl. YEMANE1 was set up in the *G.arborea* (yemane) stand near these forests. YEMANE2 was set up in a line planting stand of *G.arborea* near *Acacia* stands in Monkikki. The space between the lines was 6m. *Swietenia macrophylla* (mahogany), *Pterocarpus indicus* (narra) and others were planted between the lines, but no trees survived until the period of survey due to fires. These forests were considered to have experienced many fires before. The YEMANE1 and YEMANE2 stands were planted in 1984. Field works for our study were conducted from May to July, 1990.

2) Benakat, Sumatra, Indonesia

Grasslands are widely spread in Sumatra island, Indonesia. Afforestation trial in alang-alang (*Imperata cylindrica*) grassland in Benakat was started, as a re/afforestation project by the Indonesian government in cooperation with JICA, from December, 1981. More than 50 tree species were planted, and it was found that *Acacia mangium* was the optimum species for rapid forest establishment in grasslands at the initial stage of afforestation. The trees showed a good growth. As already reported by Tanimoto (1981), the height of the alang-alang communities exceeded 120cm and often reached 160cm. Therefore, it is considered that the productivity of the land was not as low as that in Carranglan. Man-made forests covering 3,100 ha were established until the termination of the project in 1988. We surveyed three of them consisting of *S. macrophylla*, *A.mangium* and *Peronema canescens* trees. *S. macrophylla* and *P. canescens* forests were 11 years old and *A. mangium* forest was 8 years old.

In addition, 10-year-old *A. mangium* and *G. arborea* tree which grew well in front of the house of the Benakat nursery center were measured. The trees were planted in January, 1982 and our field works were performed in April, 1992.

3) Man-made forests around UPLB

UPLB was established in 1908. Mt. Maquiling (1,109m) was standing behind UPLB. There was a cogon grassland spreading widely at the foot of the mountain at that time and planting started after the university was established. There are various plantations around UPLB. The potential vegetation in the lower part of Mt. Maquiling consists of tall dipterocarp tree species, the soil type is a Typic tropudalf of volcanic ash origin, with adequate properties (Yagi *et al*., 1989). The altitude of MBG (Maquiling Botanic Garden) is about 100–400m asl.

The meteorological data (recorded from 1950 to 1989) at UPLB are as follows: mean annual rainfall is 1,962mm and mean annual temperature is 27.0°C. There is a distinct dry season lasting for four months, from January to April. Seventy-seven percent of rainfall is observed from June to November.

Four man-made forests were surveyed in May to July, 1990. There were two *S. macrophylla* stands, a mixed forest of *Parashorea malaanonan* (bagtikan) and *Anisoptera thurifera* (palosapis) and a mixed forest of *P. malaanonan* and *Dipterocarpus grandiflorus* (apitong). The ages of these forests are not known, but judging from the history of UPLB, they were younger than 80 years old, because before UPLB was established, there was a grassland spreading widely there and the afforestation activity started thereafter (Brown, 1919).

4) Experimental forests of Forest Research and Development Centre (PPPH), Bogor

Haurbentes experimental forest of PPPH was located in Jasinga, approximately 60km from Bogor at about 250m asl. Annual rainfall ranges from 3,000 to 4,000mm and there were about 140 to 260 rainy days a year (PPPH,1990). There is no distinct dry season. Quadrats approximately 50m × 50m were set up in the experimental forest and many kinds of *Shorea* species were planted. The inclination was about 7°. The year of planting was indicated on the explanatory label attached on the trees. The big trees, some of them exceeding 100cm in diameter and 40m in height, were introduced from Kalimantan and planted in 1940. Some of the medium-sized trees, about 30cm to 50cm in diameter, were planted in 1950 or 1953 and introduced from Kalimantan, too. Therefore it is difficult to determine the age of the plantation. Planted tree species consisted of *Shorea stenoptera, S. pinanga, S. mecistopteryx* and others. A small amount of vegetation except for the *Shorea* seedlings was observed on the forest floor due to the dense canopy.

Dramaga experimental forest of PPPH is located at 9km from Bogor. Annual rainfall is about 3,500 mm and there are 187 rainy days a year. We measured the *Dipterocarpus retusus* stand planted in 1957 and *S. selanica* stand planted in 1958 (PPPH, 1990). Dramaga experimental forest is located on flat land. The site was divided into square blocks and each block measured 50m × 50m. Many tree species were planted in each block. *S. selanica* trees, introduced from Maluku and planted in 1958, and *D. retusus* trees, introduced from Sumatra and planted in 1957, were measured.

Growth and biomass of the trees planted in the degraded samon, talahib and cogon grasslands

1) Carranglan area (samon, talahib, and cogon grassland)
Description of the surveyed stand is shown in Table 1.

Table 1 General description of surveyed stands in Carranglan

	Average		Per hectare				Remarks
	dbh (cm)	height (m)	No.	B. A. (m²)	Volume (m³)	Total Volume (m³)	
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		
YAMANE2	6.3	4.4	890	3.1	9.4	10.1	
	4.8	4.0	45	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	12.1	101.7	
and	9.6	5.8	1,220	3.6	35.0		
YAMANE+etc.	16.1	10.6	390	8.7	52.4		
mixed stand	6.8	7.4	130	0.5	2.2		

* Upper rows are dominated trees and lower rows the suppressed trees.

The average yearly growing rates for 8 growing seasons ranged from 9m³ to 11.7m³. Though these values were not high for fast-growing tree species, in taking account of the unfavorable site conditions, the results are deemed satisfactory. The growth rate of the young ACACIA1 and ACACIA2 stands was 2.5m³ and 3.6m³ per year, respectively. The values were lower than those of other stands, but since the site conditions seemed to be almost indentical, the productivity could improve in future.

G. arborea was expected to adapt itself well even to the poor soil conditions, but the YEMANE1 and YEMANE2 stands, which were planted in 1984, grew poorly. The growth was especially poor in line planting sites where the floor surface was widely exposed. It is also possible that wild fires may have adversely affected the tree growth. We observed that in the *G. arborea* stand planted near the central office of the project where the physical properties of the soil were more favorable, the diameter of the trees reached 30cm to 50cm and the tree height 13m to 16m. Therefore, it was assumed that this species can not grow well in a site with such poor conditions.

Tectona grandis (teak) planted in Carranglan experienced dieback year after year during the dry season in the initial period after planting. Therefore the foresters considered that this species was not suited to degraded conditions. However recently the extent of dieback has decreased and the survival rate has improved. The TEAK2 site showed a total volume of 38.4m^3/ha exceeding the value of the neighboring YEMANE1 site. The changes in the conditions in the TEAK2 site may be ascribed to the fact that the roots could develop farther and more widely through hard soil. In the TEAK1 site, the trees were still small in size, and dieback of shoots, 30-50cm or more, caused by fire was observed. *T. grandis* and *G. arborea* were superior to *A. auriculiformis* in their ability of lateral shoot sprouting after fire damage. Therefore they are important species for grassland afforestation.

The growth of *Pinus kesiya* planted in 1977 was poor both at the PINE1 site and PINE2 site. But the growth of *G. arborea*, planted in the same year as pine in PINE2, was dominant in the upper story of *P. kesiya*. Average height of *P. kesiya* was 7m and the height of *G. arborea* exceeded sometimes 13m, far surpassing the growth of *G. arborea* in the adjacent plots. The rapid covering of the surface by *P. kesiya* may have exerted a favorable effect on the growth of *G. arborea*. If it were the case, two-story planting or mixed forest establishment may be a promising silvicultural technique for afforestation on degraded lands.

2) Benakat, Sumatra island (cogon grassland)

The results are shown in Table 2.

Table 2 General description of surveyed forest in Benakat

	Average		Per hectare		
	dbh (cm)	height (m)	No.	B. A. (m^2)	Volume (m^3)
S. macrophylla					
DOMINANT	20.0	16.4	640	21.2	188
SUPPRESSED	10.8	11.7	300	3.0	21
TOTAL			940	24.2	209
A. mangium					
DOMINANT	19.2	21.3	664	20.1	232
SUPPRESSED	11.1	14.5	248	2.6	23
TOTAL			912	22.7	255
P. canescens					
DOMINANT	11.7	11.8	856	14.1	99
SUPPRESSED	6.0	8.4	160	0.5	3
TOTAL			1,016	14.6	102

* Upper rows indicate dominant trees and lower rows the susppressed one.

Annual increment of stem volume per hectare of each species was as follows: *S. macrophylla*, 19m^3; *A. mangium*, about 32m^3 and *P. canescens*, 9m^3. These values were not as high as those reported in forests with fast-growing tree species but not so small. However damage by insects was observed in the *S. macrophylla* site. To produce valuable stem/timber, tending methods should be improved and developed. The shape and growth speed of *P. canescens* trees were not satisfactory. *S. macrophylla* and *P. canescens* were economically important and *P. canescens* is sometimes called white teak. Therefore, further studies are needed to determine the cause of these phenomena.

The outline of two forests in front of the house of Benakat nursery center is shown in Table 3.

Table 3 General description of the *A. mangium* and *G.arborea* forests in front of the Benakat nursery center house

	Average		Per hectare		
	dbh (cm)	height (m)	No.	B. A. (m^2)	Volume (m^3)
A. mangium					
DOMINANT	24.6	21.8	641	31.8	360
SUPPRESSED	8.7	10.9	32	0.2	1
TOTAL			673	32.0	361
G. arborea					
DOMINANT	24.2	17.7	497	23.7	219
SUPPRESSED	12.8	12.6	240	3.3	24
TOTAL			737	27.0	243

* Upper rows indicate dominant trees and lower rows the suppressed ones.

Though they were only 10-year-old, they showed the heighest value of total stem volume. Annual stem increment was 36m^3 in *A. mangium* and 24m^3 in *G. arborea*, respectively. As these data included edge trees, the values may be larger than those for a forest under usual conditions. However maximum productivity in the optimum stand could be estimated from these data.

Growth and biomass of planted dipterocarp and *S. macrophylla* forests

1) Man-made dipterocarp and *S. macrophylla* forests around UPLB

The outline of four man-made forests around UPLB is indicated in Table 4.

Table 4 General description of man-made forest in UPLB

	Average		Per hectare			
	dbh (cm)	height (m)	No.	B. A. (m^2)	Volume (m^3)	Total Volume (m^3)
Swietenia	43.4	29.1	281	44.6	636	795
macrophyla I	18.5	16.8	521	16.1	158	
Swietenia	52.3	31.7	224	52.0	764	897
macrophylla II	18.2	17.1	181	5.7	56	
Parashorea	44.8	30.1	188	31.0	444	800
malaanonan	23.3	18.9	200	9.2	94	
Anisoptera	46.8	30.4	50	9.1	131	
thurifera	20.0	17.3	131	4.9	50	
Parashorea	42.9	28.7	81	13.9	200	440
malaanonan	18.5	15.9	30	1.1	11	
Dipterocarpus	26.9	23.8	200	12.2	153	
grandiflorus	13.4	14.2	390	6.6	58	

* Upper rows indicate dominant trees and lower rows the suppressed ones.

Assuming that the *S. macrophylla* forests were 70-year-old, average yearly increment of the stem volume ranged from 11.5m³ to 13m³ per hectare. Since the standing crop of 70-year-old *Cryptomeria japonica* (sugi), one of the important silvicultural tree species showing good growth in Japan, was 897m³ per hectare and the average stem volume increment was 12.6m³ per hectare (1st grade stand based on the yield prediction table of Kanto-Abukuma district), the man-made forests around UPLB were almost equivalent to the value of a fine *C. japonica* stand.

In the mixed forest of *P. malaanonan* and *D. grandiflorus*, younger and smaller *D. grandiflorus* trees were planted between sparse large *P. malaanonan* trees. As the *D. grandiflorus* trees were small, the total stem volume was small. Assuming that the *P. malaanonan* trees were 70-year-old and *D. grandiflorus* 30-year-old, respectively, the annual increment of stem volume was about 10m³ per hectare. This value was lower than that of the other stands. However a large number of trees may have already been harvested. Especially in the *P. malaanonan* and *D. grandiflorus* mixed stand, a large number of *P. malaanonan* trees had been harvested to plant *D. grandiflorus*. Judging from these estimations, these forests exhibit a high productivity and could become a source of good timber plantations. These observations suggest that fine plantations as these can be established even in disturbed land.

2) *Shorea* spp. plantation in Haurbentes, Jasinga, Bogor

Main species in Haurbentes experimental forest was *Shorea stenoptera*. The results are shown in Table 5.

Table 5 General description of surveyed stand in Haurbentes

	Average		Per hectare		
	dbh (cm)	height (m)	No.	B. A. (m²)	Volume (m³)
DOMINANT	51.4	33.3	121	33.9	510
SUPPRESSED	11.2	12.3	545	7.0	68
TOTAL			666	40.8	578

* Upper rows indicate dominant trees and lower rows the suppressed ones.

The average diameter of the canopy trees reached 51.4cm and average height was 33.3m. As already mentioned, some of the trees were 100cm in diameter and 40m in height. The density of the dominant trees was low but that of the suppressed was 545 per hectare. There were young naturally regenerated trees and small seedlings. If the harvest of canopy trees could be adequate, fine succession forest could be obtained. Stem volume was 578m³ per hectare. For a 50-year-old forest, the average annual stem increment of standing trees would be 11.6m³. This value was comparable to that of temperate forests.

3) *D. retusus* and *S. selanica* plantation in Dramaga experimental forest

The results are shown in Table 6.

Basal area of the *D. retusus* stand in Haurbentes was almost the same as that of the *D. retusus* stand in Dramaga. However these forests were taller than the *Shorea stenoptera* forest at Haurbentes. Therefore, the total stem mass was 20% higher than that in the *D. retusus* stand. The *S. selanica* stand taller and the basal area was larger than that of the *D. retusus* stand. Total stem volume was the largest among the surveyed stands. If the information on planting year was correct, average annual stem increment per hectare was 20.4m³ in the *D. retusus* stand and 26.7m³ in the *S. selanica* stand, respectively. Considering that the stand ages were only about 35 years, the diameter and height were very large. These stands are fine samples for establishing a valuable forest.

We presented several attempts to recover degraded forest lands and discussed the possibility of establishing a dipterocarp forest and forests with other valuable tree species. Further studies should aim at analysing the process of establishment of such fine forests and writing a manual of re/afforestation based upon actual data for sustainable management.

Table 6 General description of D.retusa and S.selanica plantation

	Average		Per hectare		
	dbh (cm)	height (m)	No.	B. A. (m^2)	Volume (m^3)
D. retusus					
DOMINANT	43.7	40.0	196	30.4	563
SUPPRESSED	23.1	22.4	232	11.2	151
TOTAL			428	41.6	714
S. selanica					
DOMINANT	52.8	43.3	184	42.3	829
SUPPRESSED	32.6	29.7	60	5.2	81
TOTAL			244	47.5	910

* Upper rows indicate dominant trees and lower rows the suppressed ones.

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