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Public awareness generation for the reforestation in Amazon tropical lowland region

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Abstract: Based on the great success the senior author had in Japan and other places in SE Asia, the two authors started similar activities in the Brasilian Amazon lowland cities. In order to demonstrate to the concerned citizens and to the youth, experiments were undertaken in which one could demonstrate how the population in general could assist the reforestation of the largely threatened tropical forest. Two kinds of experiments were carried out to demonstrate the reforestation with native trees from the Amazon lowland tropical forest. In one experiment, small numbers of species that could be identified as representing the potential natural vegetation (PNV) were planted. In the other experiment, many kinds of species including fast -growing pioneers were planted. After 9 years, we measured tree height and DBH in both experimental forests and compared species composition, stand volume, tree density and species diversity. The results suggested that inclusion of pioneer tree species in the planting did not result in earlier biomass accumulation and increasing more rapidly species diversity.

Resumen: Basados en el gran éxito que tuvo el primer autor en Japón y otros lugares del sureste asiático, ambos autores iniciaron actividades similares en ciudades ubicadas en las tierras bajas de la Amazonia brasileña. Se realizaron experimentos con el fin de demostrar tanto a los ciudadanos preocupados como a los jóvenes cómo puede la población en general colaborar en la reforestación del bosque tropical, el cual está fuertemente amenazado. Se llevaron a cabo dos tipos de experimentos para demostrar la reforestación con árboles nativos del bosque tropical amazónico de tierras bajas. En un experimento se plantó un número pequeño de especies identificadas como representativas de la vegetación natural potencial (VNP). En el otro experimento fueron plantadas muchas clases de especies, incluyendo pioneras de rápido crecimiento. Después de nueve años, medimos la altura y el DAP de los árboles en ambos bosques experimentales y comparamos la composición de especies, el volumen del rodal, la densidad de árboles y la diversidad de especies. Los resultados sugieren que la inclusión de especies pioneras en el plantado no se tradujo en una acumulación de biomasa más temprana ni en un incremento más rápido de la diversidad de especies.

Resumo: Com base no grande sucesso que o autor sénior teve no Japão, e outros lugares no SE Asiático, os dois autores iniciaram actividades similares nas cidades das terras baixas da Amazónia Brasileira. A fim de demonstrar aos cidadãos preocupados e à juventude, como a população em geral pode ajudar na reflorestação da floresta tropical fortemente ameaçada, foram efectuados ensaios. Dois tipos de ensaios foram levados a cabo para demonstrar a reflorestação com espécies nativas da floresta tropical das terras baixas da Amazónia. Numa experiência, um pequeno número de espécies que podem ser identificadas como representativas a vegetação natural potencial (PNV) foram plantadas enquanto noutro ensaio, muitas espécies, incluindo pioneiras de rápido crescimento, foram plantadas. Depois de 9 anos, foram medidas a altura e o DAP nos dois ensaios e comparada a composição específica, o volume em pé, a densidade das árvores e a diversidade específica. Os resultados sugerem que a inclusão de espécies arbóreas pioneiras na plantação não resultaram numa acumulação mais acentuada da biomassa e no acréscimo mais rápido da diversidade específica.

Key words: Amazon, diversity, pioneer, potential natural vegetation, restoration, tree growth, tropical lowland forest.

Introduction

In recent years, tropical forest has rapidly disappeared from the world. For global environmental protection, methods of forest restoration should soon be established. Many researchers have proposed various methods of tropical rainforest restoration, such as planting pioneer trees for harvesting pulpwood, agro-forestry using useful tree species. One reliable forest restoration method is the restoration of native forests by native trees, based on vegetation-ecological theories (Lohmann 2001; Miyawaki 1993a, 1993b, 1996, 1998, 1999; Miyawaki *et al.* 1993; Miyawaki & Golley 1993). This method involves the survey of potential natural vegetation (sensu Tuxen 1956), utilization of pot seedlings and site preparation on a soil mound. When this method is used, developed forests can be established comparatively quickly. There are many successful examples in Japan and Malaysia. However, in order to use this method, much more time is needed for vegetation investigation and growing the large numbers of tree pot-seedlings.

In the tropical Amazon region, vegetation investigations have not been sufficiently carried out. Supplying native tree seedlings has also been insufficient. So we examine the alternative technique of combining economic tree species and tree species of the potential natural vegetation. If this method is applied, large amount of forest biomass may accumulate comparatively early because of the fast growth of useful pioneer trees. Also diverse forests may be formed from the many pioneer and PNV species.

Since 1992 we have been carried out a regeneration experiment on tropical forest using the above-mentioned method in the Amazon River basin near Belem. After 9 years we measured trees in the experimental forest and compared the result with that the data from another experimental forest in which PNV species were mainly planted. In this paper we report pioneer mixed forest did not show large biomass and species diversity.

Materials and methods

In 1992 we created the experimental forest on a factory site near Belem. Pot seedlings of trees were planted at a density of 3 per m^2, as had been done in Japan and Malaysia. Over 50 tree species were used (Table 1). Simultaneously, we created an experimental forest on an abandoned field around Breves, in which the PNV species, *Virola surimanensis*, was mainly planted. Its planting method and seedling density were the same as in the Belem forest. The list of species planted in Breves forest is shown in Table 2. Fig. 1 shows the locations of the experimental forests. We established 25 permanent quadrats of 5 x 5 m^2 in the Belem experimental forest, and measured tree height and DBH periodically. In the Breves forest, we did not establish permanent quadrats. In March 2001 we measured trees in three permanent quadrats in the Belem forest. At the same time we established three 5 x 5 m^2 quadrats and measured tree height and DBH in the Breves forest. Previous land use at Belem and Breves were somewhat different, a factory at Belem, and on the abandoned field at Breves. However, we considered the conditions of the two sites as were almost the same because the land properties are the same as the fertile soil from the Amazon basin. We calculated trunk densities and basal area proportions for every species from the measurement data from each quadrat. Based on those values, we calculated D^2H as the index of the forest biomass and the Shannon-Wiener function (H') as the index of species diversity.

Table 1. Tree species planted in the 25 quadrats at Belem.

Name of species	Family
Annona sp.	Annonaceae
Aspidosperma desmanthum	Apocynaceae
Avicennia nitida	Verbenaceae
Bagassa guianensis	Moraceae
Bombax spruceanum	Bombacaceae
Brosimum ovatifolium	Moraceae
Calophyllum angulare	Hypericaceae
Carapa guianensis	Meliaceae
Cariniana integrifolia	Lecythidaceae
Cassia alata	Leguminosae
Cassia mangium	Leguminosae
Cedrella fissilis	Meliaceae
Cedrella glaziovii	Meliaceae
Cedrella odorata	Meliaceae
Ceiba pentandra	Bombacaceae
Citrus sp.	Rutaceae
Cordia goeldiana	Boraginaceae
Diplotropis purpuria	Leguminosae
Eschweilera matamata	Lecythidaceae
Eugenia cumuni	Myrtaceae
Eugenia moleccensis	Myrtaceae
Euterpe oleracea	Arecaceae/Palmae
Hevea brasiliensis	Euphorbiaceae
Inga alba	Leguminosae
Joannesia princeps	Euphorbiaceae
Macrobium bifolium	Leguminosae
Macrolobium acaciaefolium	Leguminosae
Ochroma lagopus	Bombacaceae
Ormosia getuilana	Leguminosae
Paraqueiba paraensis	Icacinaceae
Pterocarpus amazonicus	Leguminosae
Rizophora mangue	Rhizophoraceae
Simaruba amara	Simaroubaceae
Spondias lutea	Anarcardiaceae
Sterculia speciosa	Sterculiaceae
Swartizia acuminata	Leguminosae
Swartizia leptopetala	Leguminosae
Swietenia macrophylla	Meliaceae
Tabebuia serratifolia	Bignoniaceae
Tapirira guianensis	Anarcardiaceae
Terminalia tanibouca	Combretaceae
Theobroma grandfllora	Sterculiaceae
Theobroma sylvestris	Sterculiaceae
Trattinickia burserifolia	Burseraceae
Vatairea guianensis	Leguminosae
Virola guianensis	Miristicaceae
Virola melinoni	Miristicaceae

Table 2. Tree species planted at Breves.

Name of species	Family
Virola surinamensis	Miristicaceae
Tabebuia serratifolia	Bignoniaceae
Aspidosperma desmanthum	Apocynaceae
Stifftia crysantha	Leguminosae
Protium sp.	Burseraceae
Ceiba pentandra	Bombacaceae
Carapa guianensis	Meliaceae
Cordia goeldiana	Boraginaceae
Swietenia macrophylla	Meliaceae
Euplasia pinata	Lauraceae
Dipterix odorata	Leguminosae
Hymenaea courbaril	Leguminosae
Virola surinamensis	Miristicaceae

Results

Comparison of tree species composition in the two forests

Tree species compositions of six quadrats are shown in Table 3. Individuals of *Virola surinamensis*, the representative tree species of the PNV in this region, survived in both experimental forests. In the Belem forest, however, the numbers and basal area of *Virola surinamensis* were very small. In the Breves forest, however, many *Virola* individuals planted at the initial stage survived and constituted about 30% - 80% of the basal area. Also, the PNV species *Tabebuia serratifolia* was grown in both forests, but its basal area proportion in the Belem forest was lower. *Carapa guianensis*,

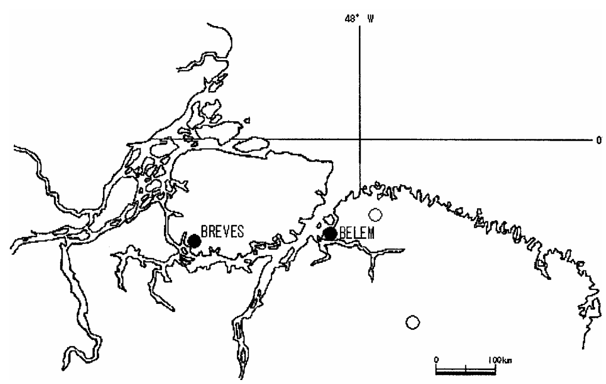

Fig. 1. The locations of two experimental forests (solid circles). Open circles show other sites of restoration experiments.

Table 3. Composition of trees in six quadrats. Hatched numerals show the values of unplanted species.

Name of species	RBA(%)					
	Belem			Breves		
	P1	P2	P3	P1	P2	P3
Virola surinamensis	5.87		0.36	29.45	80.39	66.46
Tabebuia serratifolia		2.98	2.01	7.47		11.85
Carapa guianensis	31.75	56.37	11.32	29.37		
Diplotropis purpuria	2.20					0.15
Ceiba pentandra	0.21					6.11
Terminalia tanibouca	1.35		8.73			
Bagassa guianensis	2.11		9.17			
Inga alba		33.78	0.34			
Cedrela glaziovii		6.87	47.43			
Aspidosperma desmanthum				1.24		0.46
Cedrela odorata	56.51					
Pterocarpus amazonicus			12.45			
Tapirira guianensis			4.01			
Cordia goeldiana			2.27			
Theobroma grandflaum			1.26			
Sterculia speciosa			0.65			
Cecropia spp.				16.53		
Vismia cayannensis				15.11		
Synphonia globulifera				0.83		
Swietenia macrophylla					11.11	
Bertholletia excelsa					8.43	
Dipterix odorata					0.07	
Hymenaea courbaril						14.97

Diplotropis purpuria, *Ceiba pentandra* were grown in both experimental forests. In the Breves forest, unplanted species such as *Cecropia* spp., *Vismia cayannensis*, *Synphonia globulifera*, *Bertholletia excelsa*, *Diplotropis purpuria* were also recorded. These species might invade from surrounding forests.

Comparison of the forest structure

Maximum tree height and maximum DBH in each quadrat are shown in Table 4. The difference of maximum tree height between the forests was very little. The ranges of maximum tree height were 9.8-13 m in the Belem forest and 7.8 -11.7 m in the Breves forest. The difference in maximum DBH between the two experimental forests was also small. Fig. 2 shows the pattern of maximum DBH and D^2H in the two forests. There was a correlation between maximum DBH in the quadrats and D^2H. The regression coefficient for maximum DBH vs. D^2H in Belem was smaller than in Breves, indicating that biomass in the Belem forest was smaller than in the Breves forest. Table 5 shows the tree densities of every quadrat. The range of tree densities in the Belem forest was 0.3-

Table 4. Maximum tree height and maximum DBH in the six quadrats.

	Belem			Breves		
	P1	P2	P3	P1	P2	P3
Maximum tree height (m)	11.11	7.76	11.7	13.0	9.34	12.8
Maximum DBH (m)	19.3	10.2	14.1	12.5	9.9	13.3

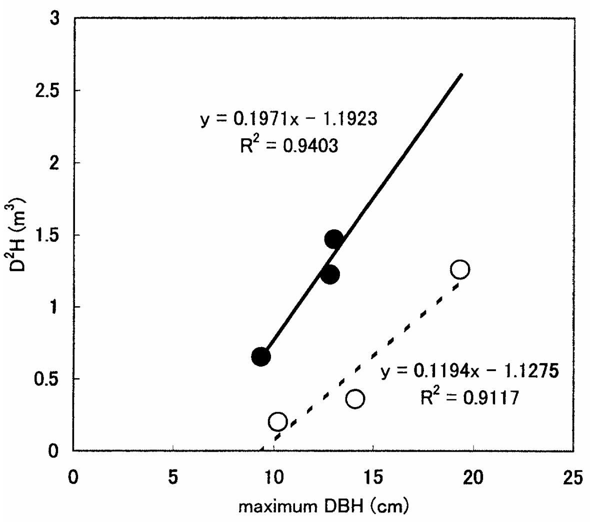

Fig. 2. Scatter diagram of D^2H and maximum DBH (●: Breves, ○: Belem)

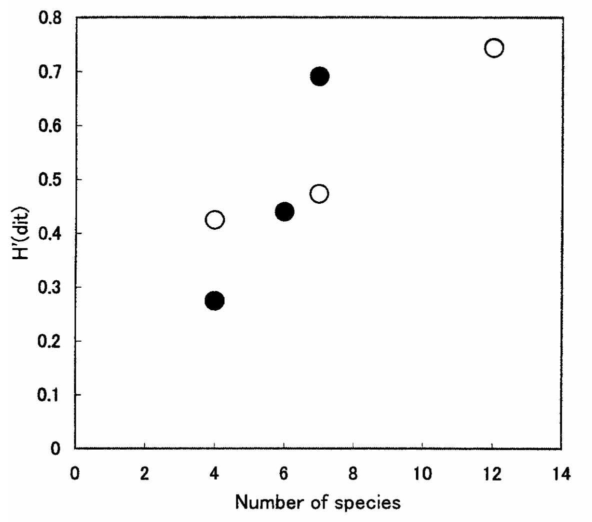

Fig. 3. Scatter diagram of H' and number of species (●: Breves, ○: Belem)

Table 5. Tree density (ind. m^{-2}) in the six quadrats.

	Belem			Breves		
	P1	P2	P3	P1	P2	P3
Density	0.48	0.32	0.64	2.48	1.76	0.96

0.6 individual m^{-2} but 1-2.5 individual m^{-2} in the Breves forest. Tree densities in the Belem forest were less than half those in the Breves forest. All these experiments were done under close cooperation with local action groups and youth groups. This enabled us to generate early awareness and interest in similar activities.

Comparison of species diversity

Fig. 3 shows the Shannon-Wiener function (H') plotted against number of species. The number of species was 4 - 12, and the range of H' was 0.27 - 0.74. Species diversities of both experiment forests almost overlapped in this diagram. In spite of planting many tree species, species diversity of the Belem forest did not rise very much.

Growing process of the trees in the Belem forest

In the Belem forest, tree density was low and species diversity was not high as expected. The data from Belem were analyzed in 1995, 1998 and 2001 (Fig. 4). In 1995, the fast-growing pioneers *Ochroma lagopus* and *Joannis princeps* reached 14 m in height, and the more slowly growing pioneer *Ceiba pentandra* occupied the middle layer. Main species of the PNV such as *Virola* spp. and *Tabebuia serratifolia* were grown in the lower layer. In 1998 *Ochroma lagopus* and *Joannis princeps* reached 16 m in height, but some trees of these species fell down. Many *Ceiba pentandra* in the middle layer died and disappeared. Many trees of *Vilora* and *Tabebuia serratifolia* were growing badly in the lower layer. In 2001 many pioneer species disappeared and the number of the PNV tree species decreased considerably. These results indicate that pioneers in the middle layer and climax species in the lower layer were weakened and killed by breakdown and suppression by *Ochroma lagopus* and *Joannis princeps* in the upper layer.

Discussion

In the Belem experimental forest, we first planted many pioneer. The pioneers *Ochroma lagopus* and *Joannis princeps* showed vigorous growth at the beginning and reached 16 m in height after 6 years. However, after 9 years, maximum height of the Belem forest came to equal that of the Breves forest, in which pioneer tree species had not been planted very much. In addition, many tree individuals including the tree species of the PNV died by breakdown and suppression by *Ochoroma lagopus* and *Joannis princeps*,

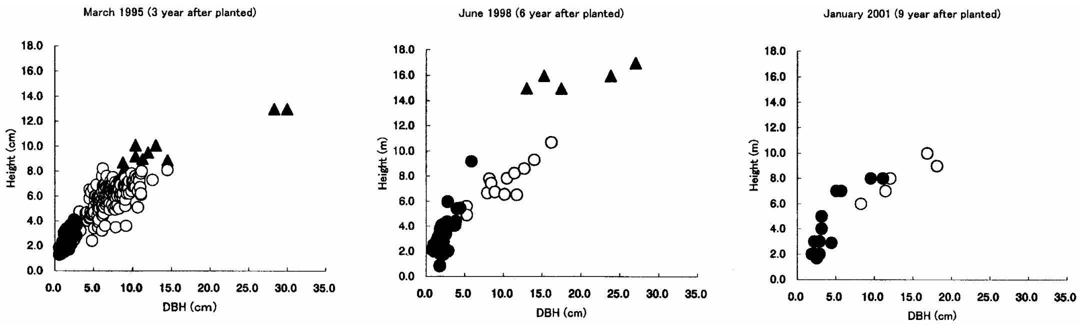

Fig. 4. DBH-Height relationships of the Belem experimental forest in 1995, 1998, 2001 (●: *Tabebuia serratifolia*, *Virola* spp., ○: *Ceiba pentandra*, ▲: O*chroma lagopus*, *Joannis princeps*).

which grow so fast. As a result, many tree individuals disappeared and forest biomass decreased in spite of the many tree species planted. The species diversity of the forest did not rise as expected. Rather, in the Breves forest, in which mainly tree species of the PNV were planted, species diversity rose because secondary species such as *Cecropia* invaded the experimental forest from the surroundings. Generally the pioneer species grow fast, produce many seeds, short lives, are weak in competition and require much sunlight (Brokaw 1985; Whitmore 1990). The reason why considerable numbers of *Ceiba pentandra* in Belem died seems to be insufficient light under the canopy of *Ochroma lagopus* and *Joannis princeps*.

In the Belem forest, fast-growing pioneer species developed shallow horizontal roots before soil conditions changed to those of mature sites. The stems of these species broke and fell down in the somewhat strong winds. As a result, the broken pioneer stems killed many individuals of the PNV species, which waited in the lower layer. On the other hand, the Breves forest grew well for 9 years, because of planting mainly *Virola surinamensis*, which composed the mature Varzea forest (Prance 1989; Worbes *et al.* 1992). In the future the Breves forest is expected to change to be more natural by self-thinning and invasion of native trees. From this study, we concluded that, for tropical forest restoration surely in the longterm, seedlings of species from the mature potential natural vegetation should mainly be used, if the number of species is not sufficient, and that planting pioneer species like pulpwood trees, which grow so fast, may be avoided unless other reasons suggest their utilisation. The entire activity found great response by the local population especially by young children.

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