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THE FOREST GROWTH CYCLE IN DRY DIPTEROCARP FOREST

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ABSTRACT

Determination of the process and rate of revegetation by using data on tree density, H^* (a coefficient indicating the ideal maximum tree height) and aboveground biomass were investigated in the dry dipterocarp forest (DDF) at Sakaerat Environmental Research Station (SERS), Pak Thong Chai District, Nakhon Ratchasima Province, Northeastern Thailand. The results revealed that the forest growth cycle (the gap phase, the building phase and the mature phase) were estimated to be 0-60,60-122,122-244. Rapid increase in basal area, H^* and high mortality of sapling were found during the gap phase. A slow increase in basal area, H^* and low mortality were found during the building phase, while the mature phase was characterized by an alomst saturated basal area, H^* and above-ground bio-mass. No gap indicators occured in the study forest.

INTRODUCTION

The canopy of a forest changes continually as tree grow up and die and others replace them. This state of equilibrium may conveniently be subdivided into a forest growth cycle of three phases : the gap phase, the building phase, and the mature phase (Whitmore, 1975). The phase are abstraction, not separate entities. The gap phase, comprising juvenile (seedling and sapling) trees, passes by growth into the building phase, which is a pole forest and itself mature by continual growth of its constituent trees.

Disturbances such as strong winds, heavy rains, lsnd slides, fires, etc., cause the death of canopy trees followed by gap formation (cf. White, 1979). After gaps are formed, revegetation proceeds in the gaps and finally they are closed by large grown trees. Since canopy trees of various crown sizes die at certain time intervals, different aged gaps of various sizes are patchily distributed in climax forests irrespective of the type. Patchy distribution of these different aged stands results in heterogeneity in the species composition and forest structure of the climax forests (e.g., Aubreville,1938; Watt, 1947; Richards, 1952; Falinski, 1978; Ohsawa, 1979; Reiners and Lang, 1979; Florence, 1981; Naka, 1982; Nakashizuka and Numata, 1982).

However, there is a fact that the time scale of regeneration of most forests are considerably long. For example, the mean residence times of forest canopy range from 50 to 200 years for climax forests from the tropical zone to the cool temperate zone (Hartshorn, 1978; Runkle, 1979; Florence, 1981; Nilroung, 1985; Suksomut, 1987). Thus, it is nearly impossible for a single researcher to follow the course of the revegetation continuously over such a long time.

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The purpose of this study is to clarify the process and rate of revegetation after gap formation in the dry dipterocarp forest (DDF) by comparing tree densities, basal area, H^* (a coefficient indicating the ideal maximum tree height) and above-ground biomass among different aged stands. The forest growth cycle (Whitmore, 1975) of DDF will be quantitatively explained

STUDY SITE

The study was carried out in the dry dipterocarp forest at Sakaerat Environmental Research Station (SERS), Pak Thong Chai District, Nakhon Rachasima Province, Northeastern Thailand (14° 30' N, 101° 55' E). The study area has a mountainous morphology with the degree of slope mostly varied from 10 to 30 percent or over. The elevation fo area ranges from 200 to 800 meters above mean sea level. The geology is a composition of fined grained sandstone and shale strata which are overlain in the valley depressions by alluvial and river terrace deposits. The soil is generally poor, characterized by a prominent development of lateritic. Soil texture is often sandy loam and clay loam. the climate of this region is classified as tropical Savanna type, according to the Köppen's climatic classification (Griffiths, 1987). Mean annual rainfall and temperature are 1,200 mm. and 26.5°C, respectively.

METHODS

The study was carried out in a relative long protected area with less human disturbance of the DDF in the southeast section of SERS. A study plot of 100 m x 300 m was set up on a smooth flat topography about 300 m altitude in January, 1982. The plot was divided into three subplots of 100 m x 100 m for each detail study, namely, the forest structure and floristic composition, the determination of age of trees and the forest growth cycle.

Forest structure and floristic composition

The study used the first portion of 100 m x 100 m which subdivieded into 100 subplots (10 m x 10 m). All trees over 4.5 cm in stem diameter at 1.3 m height above the ground (DBH) contained in each subplot were mapped, species recorded and measured of their DBH, total tree height (H) and height at the lowest main living branch (H_B).

The study was carried out by adopting quantitative ecological method as follows:

Specific diversity was determined by the Shannon-Wiener index of diversity, H(S), (MacArther and MacArther, 1961).

The importance value index (IVI) was determined by the method of Cottam (1949).

Stratification was studied adopting the method described by Ogawa *et al.* (1965) based on the H-H_B diagram. Species were separated into each layer and listed with number and relative dominance on the basis of basal area.

Determination of age of trees

Modified C.A.I. (Current Annual Increment) method developed by Misra *et al.* (1974) was applied for determination of age of trees.

Age of trees was determined from all standing tree which DBH (D) larger than 4.5 (cm.) in the whole plot.

In the present study the two consecutive observations on diameter refered to a small duration of time (one year, in present case 1990 and 1991), and hence it might be reasonable to assume a linear relationship between them as a first approximation.

Forest growth cycle

The study used the whole plot, quadrats were laid in apparently different aged stands.

Quadrat size ranged from 25 m^2 to 100 m^2, and were determined by the heights of the top layer trees in each stand. In this study, top layer trees were defined as trees whose crowns were directly exposed to the sunlight in each stand. the top layer in older stands were easily identified, but the identification was difficult in younger stands, teees heigher than the mean height of gap indicators in each stand were designated as the top layer trees.

In case of tropical region where growth rings seldom developed, gap age could be considered by a modified C.A.I (Current Annual Incerment) method developed by Misra *et al*. (1974). The age of the maximum sixed tree in the gap was considered to be equal to the age of the gap. The areas of gap were estimated by measuring the major and minor axes, assuming that canopy openings were ellipses.

All live trees over 1.3 m high in each quadrat were identified as to species and all standing dead trees over 1.3 m high were also indentified when possible, DBH and H were measured for all standing live and dead trees.

Ogawa (1969) proposed the following hyperbolic relation between DBH and H in forest stands.

$$1/H = 1/AD^{h} + 1/H^{*} \quad (m, cm) \qquad (1)$$

where D is DBH, and h, A and H^* are coefficient specific to forest. He showed that h was approximately equal to one for most mature forests, irrespective of fo-rest type. Assuming that h equal one, the other coeffici-ents, A and H^* for each stand were calculated by using the nonlinear least square method (Glass, 1967).

The aboveground dry weight (w_T) for DDF was estimated by using the relative growth method by Ogino *et al*. (1967) for hardwood trees in the dry dipterocarp forest in northeastern Thailand. They used the following equations:

$$W_S = 189 (D^2H)^{0.902}, (kg, m^2, m) \qquad (2)$$

$$W_B = 0.125\, w_S^{1.204}, (kg, m^2, m) \qquad (3)$$

$$1/w_L = 11.4/w_S^{0.9} + 0.172, (kg, m^2, m) \qquad (4)$$

where D, w_S, w_B and w_L, are DBH, and the dry weights of stem, branches and leaves of a tree, respectively, and total aboveground weight (w_T) of each tree was obtained by summing these partial biomass.

$$w_T = w_S + w_B + w_L \qquad (5)$$

RESULTS AND DISCUSSION

Floristic composition and forest structure

Floristic Composition Thirty five species and 544 trunk were found in 1 ha plot. The most abundant species was *Pterocarpus macrocarpus* Kurz. (15.2% of total trees), followed by *Shorea floribunda* Kurz. (14.-4%), *Shorea obtusa* wall (8.1%), and *Dipterocarpus intricatus* Dyer (5.8%) (Table 1). In case of *Shorea floribunda* Kurz., not only in density but also in frequency and basal area dominance, it occupied the first rank. Its dominance in the stand was decisive and stable, since the species maintains the top rank throughout the two layers of the forest. *Pterocarpus macrocarpus* Kurz. ranked next to *Shorea floribunda* Kurz. *in dominance. This species was also present in considerable amount throughout the two layers.* *Shorea obtusa* Wall., and *Dipterocarpus intricatus* Dyer, the third and the fourth important species were also present in considerable amount throughout the two layers.

The importance value index (IVI) (Cottam, 1949) of plot was determined as:

IVI = % relative density + % relative frequency + % relative dominance

where

$$\text{\% relative density} = \frac{\text{density of species i}}{\text{total plant density}}$$

$$\text{\% relative frequency} = \frac{\text{frequency of species i}}{\text{total frequency of all species}}$$

$$\text{\% relative dominance} = \frac{\text{total basal area of species i}}{\text{total basal area of all species}}$$

Table 1. Relative density, frequency, dominance and importance value index (IVI) of tree species with DBH larger than 4.5 cm in 1 ha plot.

Scientific name	% Relative			IVI
	Density	Frequency	Dominance	
Albizzia odoratissima Benth.	0.36	0.51	0.097	0.97
Antiaris toxicaria Lesch.	0.36	0.51	0.138	1.01
Antidisma laurifolium Airy Shaw	0.54	0.76	0.094	1.40
Aporusa villosa Baill.	1.81	2.54	0.353	4.70
Bombax anceps Pierre	0.36	0.51	0.142	1.00
Careya sphaerica Roxb.	0.90	1.27	0.516	2.69
Dalbergia cultrata Grah. ex Benth	0.90	1.02	0.475	2.40
D. oliveri Gamble	1.62	2.29	2.891	6.81
Dillenia obovata Hoogl.	6.14	5.09	1.125	12.47
Desmodium renifolium Schindl.	0.36	0.25	0.082	0.70
Diospyros chertioides Wall.	1.44	1.78	0.438	3.66
D. mollis Griff.	0.36	0.51	0.448	1.32
Dipterocarpus intricatus Dyer	5.96	7.12	20.577	33.66
Eugenia cumini Druce	0.18	0.25	0.167	0.60
Gardenia sootepensis Hutch.	0.18	0.25	0.026	0.46
Hybrid of D. intricatus	0.54	0.76	2.954	4.26
Irvingia malayana Oliv. ex A. Benn.	0.72	1.02	0.252	1.99
Kydia calycina Roxb.	0.36	0.25	0.064	0.68
Lannea coromandelica Merr.	1.26	1.27	0.398	2.93
Mangifera caloneura Kurz	1.44	1.78	2.487	5.71
Mitragyna brunosis Graib	6.65	6.11	1.546	14.15
Morinda coreia Ham	1.62	2.29	0.657	4.57
Nauclea brunnea Graib.	0.18	0.25	0.018	0.45
Parinari anamense Hance	0.18	0.25	0.167	0.60
Phyllanthus emblica Linn.	0.18	0.25	0.045	0.48
Pterocarpus macrocarpus Kurz	15.16	12.72	9.440	37.33
Quercus kerrii Graib	13.18	11.45	15.197	39.82
Sindora Siamensis Teijsm	2.17	3.05	2.747	7.97

Table 1. (cont.)

Scientific name	% Relative			IVI
	Density	Frequency	Dominance	
Shorea floribunda Kurz.	14.44	12.72	18.490	45.65
S. obtusa Wall.	8.12	6.87	10.141	25.13
S Siamensis Mig.	1.62	2.04	3.174	6.83
Terminalia chebula Retz.	0.36	0.51	0.061	0.93
Unindentified	0.90	1.27	0.173	2.35
Vatica odorata Syming	0.18	0.25	0.020	0.46
Vitex pinnata Linn.	3.24	3.56	1.151	7.96
Xylia xylocarpa Taub.	6.14	6.62	3.125	15.88
Total	100	100	100	100

The relative density was determined from all standing tree of DBH (D) larger than 4.5 cm, in the whole plo6 of 100 m x 100 m. The relative frequency was determined for one hundred 10 m x 10 m. subplots set by regularly subdividing the 100 m x 100 m plot. The relative dominance was obtained from the basal area at breast height, calcullated as $(\pi D^2/4$, of each tree in the whole plot.

Table 1 gives the relative values of density, frequency, and dominance on a basal area basis, and the importance value index (IVI) of all species with DBH larger than 4.5 cm. IVI values of the main species were as follows; *S. floribunda* Kurz. (45), *Q. Kerrii* (39), *P. macrocarpus* Kurz. (37), *D. intricatus* Dyer (33), *S. obtusa* Wall (25) , *Xylia xylocarpa* Taub. (15) and *Mitragyna brunosis* Craib (14).

Specific diversity of the plot was determined by the Shannon-Wiener index of diversity, and shown in Table 2.

The Shannon-Wiener index of diversity, H(S), (MacArther and MacArther, 1961) is;

$$H(S) = \sum_{i=1}^{s} p_i \log_2 P_i$$

Where, P_i = proportion of the number of individuals of species i to total number of individuals of all species

S = total number of species in the sample area

The Shannon-wiener index of diversity H(S) = 4.05 was comparable to the H(S) = 4.07 of a dry diptero-carp forest at the same locality studied by Sakulmelit (1976), but the number of species in the study plot seemed to be smaller than that in his dry dipterocarp forest stand. However, the value of H(S) was larger than in a dry dipterocarp forest at Nam Phrom and a mixed deciduous forest at the same locality studied by Sahunalu *et al.* (1979) which had a H(S) of 1.93 and 3.94, respec-

Table 2. Plot size, number of trees species and basal area of trees with DBH larger than 4.5 cm in the study plot.

Items	
Area of plot, m^2	10,000
Number of tree/ha	554
Number of species/ha	35
Basal area, m^2/ha	14.42
H(S) *	4.05

*Shannon-Wiener index of diversity.

tively, but smaller than that in a dry evergreen forest at Nam Phrom studied by Sahunalu *et al.* (1979) and Tsutsumi *et al.* (1983) which had a H(S) of 4.89 and 4.3, respectively.

Forest Structure

General Structure The forest is rather open and can be considered as 2-storied. The upper storey consists of *D. intricatus* Dyer, *S. obtusa* Wall., *S. floribunda* Kurz., *S. siamensis* Mig., *Q. kerrii* Craib, and sometime *P. macrocarpus* Kurz. and *X. kerrii* Craib & Hutch. The second storey composes of low shrubby trees such as *Strychnos nux-vomica* Linn., *Symplocos racemosa* Wall., *Diospyros ehretioides* Wall., *Apurosa villosa* Baill. and *Phyllanthus emblica* Linn..

The density of trees with DBH larger than 4.5 cm was 554/ha as mentioned before. As compared to a nearby dry dipterocarp forest stand studied by Sakulmelit (1976), which had a density of 803/ha, the study plot was less dense. It was also less dense than dry dipterocarp forest at Nam Phrom (Sahunalu *et al.*, 1979) and at Sakaerat (Ogino *et al.*, 1965) which had densities of 938/ha and 1,250/ha, respectively. When compared with other forest types studied by Ogawa et al. (1965), the tree density of the study plot was lower than that of a monsoon forest (synonym of mixed deciduous forest) at Ping Kong (713/ha), monsoon forest-savanna forest ecotone at Ping Kong (906/ha), tallevergreen forest at Khao Chong (1,175/ha) and dipterocarp savanna forest (synonym of dry dipterocarp forest) at Ping Kong (1,488/ha). When comparec with dry evergreen forest at Nam Phrom (Sahunalu et al., 1979), at Sakaerat (Visaratana, 1983) and a hill evergreen forest at Doi Pui studied by Vannaprasert (1985), which had densities of 1,088/ha, 1,488/ha and 726/ha, respectively, the stand density of the study plot was lower, but denser than that of mixed deciduous forest at Nam Phrom (238/ha) Studied by Sahunalu *et al.* (1979). The results of the study showed that tree density decreases with increasing aridity of the habitat, being maximum in tall evertgreen forest and minimum in dry dipterocarp forest (Table 3).

Herbs did not develop on the forest floor, except for scattered fired-tolerant cycad, *Cycas siamensis* mixed with *Arundinaria pusilla* Cheval & A. Camus, which is a characteristic type of floor vegetation in dry dipterocarp forest of Thailand. In general grasses will be dried and desicated during the dry season. Dead grasses and litter are regularly swept by ground fire in the dry season, which plays an important role in the maintainance of this forest type.

Crown Distribution As shown by a horizontal projection of all tree crowns above 4.5 cm in DBH (Fig. 1), tree crowns in the dry diptetocarp forest were discontinuous. Forest floor can be seen through crowns in a distant view. The vertically overlapping tree strata did not observed. The density of tree crowns was, however, apparently different in upper and lower part of the forest profile. Crown density of lower trees was farily high, though individual crowns were not continuous with each other. Crown of trees hingher than 10 m were widely distant like those of emergent trees in a closed forest. In a sense the forest has a two layered structure. The crown coverage of the top layer which by solid lines was about 50 % of the plot area, showing the normal coverage figure for ghis type of forest. Most of spaces not covered by the top layer were occupied by crowns of lower trees. The total coverage by crowns of trees larger than 4.5 cm in DBH was about 70 % of the plot area indicating that the forest was opened by tree crowns.

Forest Profile Fig.2 illustrates an example of profile (for the trees over 4.5 cm in DBH) of the strip of 10 m x 100 m, subplot I-X. The forest structure of this plot was basically same as that of the other dry dipterocarp forests. The top layer consisted of discontinuous crown of big trees higher than 10 m, such as *D. intricatus Dyer, P. macrocarpus* Kurz., *S. obtusa* Wall., *S. floribunda* Kurz., *M. caloneura* Merr., *Q. kerrii* Craib, *S. siamensis* Mig. The lower layer, lower than 10 m, consisted of small trees which crowns were

Table 3. Density of tree species with DBH larger than 4.5 cm in various forest types in Thailand

Vegetation type	Locality	Treedensity (no./ha)	Author
Dry dipterocarp forest	Sakaerat, Nakorn Rachasima	554	Present study
Dry dipterocarp forest	Sakaerat, Nokorn Rachasima	1,250	Ogino *et al.*, 1965
Dry dipterocarp forest	Ping Kong, Chiang mai	1,488	Ogawa *et al.*, 1965
Dry dipterocarp forest	Sakaerat, Nakorn Rachasima	803	Sakulmelit, 1976
Dry dipterocarp forest	Nam Phrom, Chaiyaphum	938	Sahunalu *et al.*, 1979
Monsoon forest-savanna forest ecotone	Ping Kong, Chiang Mai	906	Ogawa *et al.*, 1965.
Mixed deciduous forest	Ping Kong, Chiang mai	713	Ogawa *et al.*, 1965.
Mixed deciduous forest	Nam Phrom, Chaiyaphum	238	Sahunalu *et al.*, 1979
Dry evergreen forest	Nam Phrom, Chaiyaphum	1,088	Sahunalu *et al.*, 1979
Dry evergreen forest	Sakaerat, Nakorn Rachasima	1,488	Visaratana, 1983
Hill evergreen forest	Doi Pui, Chiang Mai	726	Vannaprasert, 1985
Tall evergreen forest	Khao Chong, Trang	1,175	Ogawa *et al.*, 1965
Tropical rain forest	Khao Pra Taew, Phukhet	1,540	Kiratiprayoon, 1986

*Ecotone between dry dipterocarp forest and mixed deciduous forest.

not continuous with each other. The same profile structure was also recoghized in the H-H_B diagram in Fig.3.

H-H_B diagram in Fig.3 shows that the crow curve for this stand has a minimun at about 10 m level. Correspondingly, trees higher than 10 m tend to be separately grouped against lower trees on the H-H_B dia-

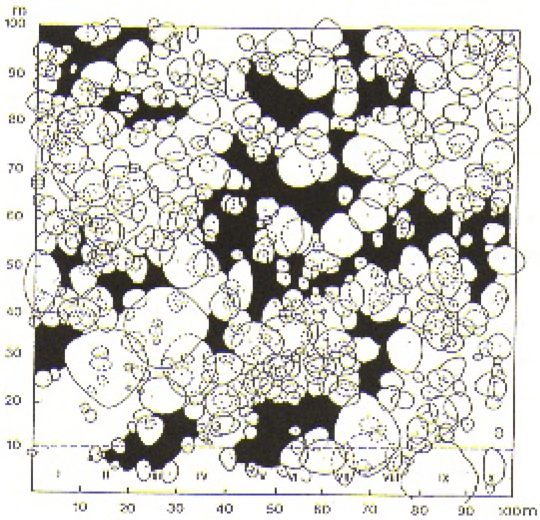

Fig. 1. Crown projection diagram of trees (DBH > 4.5 cm) and canopy gaps (shade area) of dry dipterocarp forest at SERS.

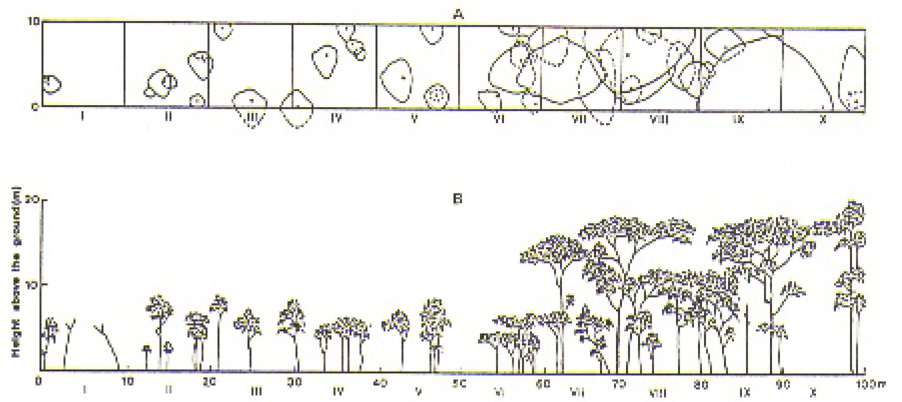

Fig. 2 Crown projection (A) and profile diagrams (B) of tree (DBH ≥ 4.5 cm) of dry dipterocarp forest at SERS.

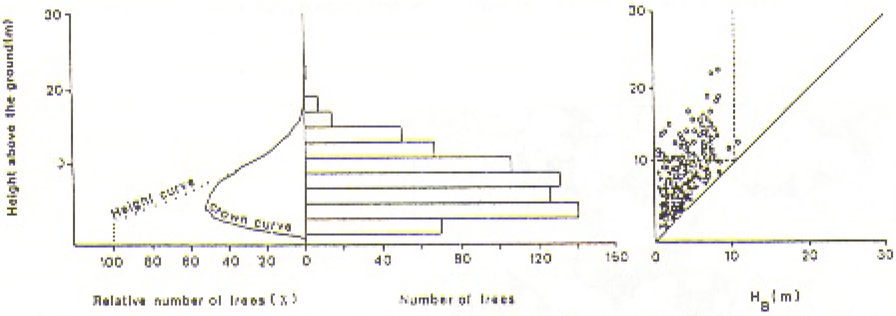

Fig. 3 Crown depth diagram and $H - H_B$ relation of trees (DBH ≥ 4.5 cm) in the dry dipterocarp forest at SERS.

Open circles : crown unshaded by other crowns.

Double circles : shaded by one other crown.

Solid circles : shaded by two or more crowns of other trees

gram. The step-like arrangement of the wide overlap on the H_B axis. A sudden increase of tree density below the 10 m level is also apparent in the trend of the height curve. The frequency histogram of tree height in Fig.3 again points to the existence of structural change at this level. These evidences agree in showing that the stand is made up of two layers, though they are rather vaguely differentiated. As recognized in the $H-H_B$ diagram, even the lowest indivivuals in this stand often receive direct sunlight without being shaded by taller tress. The layered structure in such an open stand is, therefore, not homologous with the stratification in a closed community, in which lower strata are usually shaded by overlying layers.

The vertical arrangement of trees in the stand suggests that there are two layers of trees with DBH larger than 4.5 cm, as shown in Fig. 2 and 3.

The number of trees in the top layer was 123 (22.2%) out of 554 trees. However, their total basal area was 60.05 % of the total, so the top layer was quantitatively dominant over the other layers. In the top layer, 3 out of 11 species were *Shorea* spp. They were *S. floribunda* Kurz., *S. obtusa* Wall., and *S. siamensis* Miq.

Determination of age of trees

A modified C.A.I. method developed by Misrs *et al.* (1974) was applied in this study.

In the present study the two consecutive observation on diameter refer to a small duration ot time (one year) and hence it is reasonable to assume a linear relationship between them as a first approximation.

Supposing the relationship between D_n and D_{n+1} as linear,

$$D_{n+1} = a + bD_n \qquad (6)$$

where

n = Current age (year)

n+1 = Age in successive year (current age +1)

D_n = Diameter at n year (cm)

D_{n+1} = Diameter at n+1 year (cm)

a = Constant

b = Annual Increment

The relationship bdtween DBH measured in 1990 (D_t) and DBH measured in 1991 (D_{t+1}) of 12 species are linear and can be substituted by the first order difference equation.

a, and b in eq, (6) can be estimate by least spuare method, the results are shown in Table 4.

The climatological data recorded by SERS (1969-1990) indicated that the climate are typical of the region and are monotonously repeated year after year with little annual fluctuaton. Hence it is assumed that the pattern of growth has remained on the average more or less the same as in year n and n+1.

The value of a, and b in Table 5 yields the equation for age determination, when tree diameter is known, the results are presented in Table 5.

Forest growth cycle

The canopy of a forest changes continually as the trees grow up and die, and others replace them. Whitmore (1975) proposed the forest growth cycle (the gap phase, building phase, and the mature phase) to understand the revegetation process in tropical rain forest in tropical Asia and Melanesia. His physiognomic approach to community of the tropical rain forest is applicable to the other types of climax forest.

In this study, the process and rate of revegetation following gap formation in DDF using data on the tree density, basal area, H^* and aboveground biomass are presented, from both the viewpoints mentioned above.

First the time scale of the forest growth cycle (Fig. 4) is dealt with. The first phase, the gap phase, is characterized by the high density and low height (shortemtha 10 m) of trees. Gap stand, defined as young stands, were at most 60 years old. So stand not older than 60 years old are regarded as the components of the gap phase. Aboveground biomass of gap stand (trees over 1.3 m heinght) was found to ranged from 1.3-24 t/ha, with a mean value of 9.4 +9.3 t/ha. The second phase, the building phase was found to consist of stands whose ages were between 60 and 122 years. The tallest trees reached the canopy, 20-25 m high and aboveground biomass (trees over 1.3 m height) ranged from 32-97 t/ha, with a mean value of 65 ± 21 t/ha. The third phase, the mature phase, consisted of stands whose ages were between 122 and 244 years. years. Aboveground biomass ranged from 52-148 t/ha, with a mean value of 122 ± 31 t/ha. Since trees smaller than 4.5 cm in DBH were not included in the calculations for this phase, the actual aboveground biomass should be a little larger than the values given. Since the mean residence time of the forest canopy was 224 years, the mature phase is expected to last for about 122 years, an average, in DDF at SERS.

The characteristics of the growth cycle of DDF at SERS is summarized in Fig.4. On average, 0.36-0.72 canopy trees per hectare dided, and gaps totalling 35-66 m^2 per hectare were formed annually. Standing dead and stem broken were the main causes of gap formation and both were scattered throughout the forest, hence mean gap size was small, 98 m^2. Eighty five percent of gaps were formed by only one gap maker, and the maximum number of gap makers per gap was 3.

The gap phase was characterized by high mortality of saplings and rapid increase in basal area and tree height (Fig.4.) During 60 years of gap phase, tree density (for trees over 1.3 m in heingt) decreased to 2,000/ha (Fig.4A) because of self-thinning due to the density effect. Basal area attained 12 m^2/ha, which is about 80% of the basal area of the mature phase (Fig. 4B). H* attained 20 m, about 65% of the H* of the mature phase (Fig.4C). No gap species occured in the DDF.

The building phase was characterized by lower mortality of trees and rate of forest growth in terms of basal area and heingt growth compared to the gap phase. The highest trees reach the forest camopy, 20-25 m

Table 4. Relationship between DBH in 1990 (D_n) and DBH measured in 1991 (D_{n+1} of some inportant trees species in the dry dipterocarp forest at SERS.

$D_{n+1} = a + b.D_n$

Species	a	b	r^2
Pterocarpus macrocarpus Kurz	0.6538	1.0118	0.9970
Shorea floribunda Kurz	0.3644	1.0093	0.9950
Quercus kerrii Craib	0.3950	1.0052	0.9967
Shorea obtusa Wall.	0.2364	1.0154	0.9972
Mitragyna brunosis Craib	0.1535	1.0658	0.9841
Xylia xylocarpa Taub.	0.6264	1.0028	0.9969
Dillenia obovata Hoogl.	0.3864	1.0050	0.9113
Dipterocarpus intricatus Dyer	0.5464	0.9977	0.9998
Vitex pinnata Linn.	0.4456	1.0419	0.9547
Aporusa villosa Baill.	0.3447	0.9930	0.9979
Shorea siamensis Mig.	0.6722	1.0008	0.9996
Morinda coreia Ham	0.5280	0.9940	0.9973

high. The remains of large fallen trees and stumps of gap makers also characterizes the phase.

After the building phase, the forest enters into the mature plhase, in which basal area, H* and above-ground biomass reached the maximum level of 14.4 m^2/ha, 29.6 m and 122 t/ha, respectively.

On average, this phase is expected to last for 122 years. Death of canopy trees, causing gap formation, was observed for this phase. It is the starting point for gap regeneration of the forest. During the forest growth cycle, aboveground biomass continuously increased from 9.4, 65 and 122 t/ha in the gap, building and matue phase, respectively (Fig.4D). Change in species composition was not ob-served during the forest growth cycle. Pioneer species, which normally appear only in the gap phase were ab-sent in this forest. Furthermore marked differences in species occurrence according to gap size could not be observed. The frequencies of species in gaps showed a positive correlation with closed forest.

On the other hand, Marks (1974) showed that hardwood species segregated their niches along a time sequence in addition to environment gradients inwhich revegetation proceeded following disturbaces in a typical northern hardwood forest in the United States. Various successional species maximized their importance at certain times along the time sequence.

One of the characteristics which is peculiar to DDF is the lack of pioneer species and the homogeneity of the ecological characteristics of component species. No clear segregation of niches could b observed among the component species of DDF. The reason is probably due to severe site factors, such as heavy drought, forest fire and soil properties. These factors act like a filtler

Table 5. Equation for age estimation of some inportant tree species in the dry dipterocarp forest at SERA.

Skpecies	Equation
Pterocarpus macrocarpus Kurz	$n=196.2834 \log (1 + 0.01805 D_a)$
Shorea floribunda Kurz	$n=284.7393 \log (1 + 0.0255 D_a)$
Quercus kerrii Craib	$n=443.9551 \log (1 + 0.0132 D_a)$
Shorea obtusa Wall	$n=150.6669 \log (1 + 0.0651 D_e)$
Mitragyna brunosis Craib	$n=36.1328 \log (1 + 0.4287 D_e)$
Xylia xylocarpa Taub.	$n=823.5026 \log (1 + 0.0045 D_a)$
Dillenia obovata Hoogl.	$n=461.6674 \log (1 + 0.0129 D_a)$
Dipterocarpus intricatus Dyer	$n=-7674.1323 \log (1 - 0.0005 D_a)$
Vitex pinnata Linn.	$n=56.0977 \log (1 + 0.0940 D_e)$
Aporusa villosa Baill.	$n=-327.7881 \log (1 - 0.0203 D_e)$
Shorea siamensis Mig	$n=2879.3825 \log (1 + 0.0012 D_e)$
Morinda coreia Ham	$n=-382.6117 \log (1 - 0.0114 D_e)$

which chooses the suitable species, and results in the selected species having very similar ecological characteristics regarding survival in the environmental conditions of DDF.

The turnover time of the forests were estimated to be 112 years (Hartshorn, 1978), 144 years (Brokaw, 1982) for tropical rain forests. In temperate deciduous forest, it was 42-333 years (Runkle, 1982) and 100-200 years for climax beech (*Fagus crenata* Blume) forests (Nakashizuka, 1984). The turnover time seems to be between 100 and 200 years for many forests in wet tropical to temperate climate. This was also supported by Leight (1975). The turnover time of forest stands corresponded with the time mentioned above. The dynamic equilibrium in a climax froest seems to be sustained by such regenerating and degenerating processes.

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REFERENCES

Ando, T., K. Chiba, T. Nishimura and T. Tanimoto. 1977. Temperate fir and hemlock forests in Shikaku. In : T. Shidei and T. Kira, ed., Primary Primary Productivity of Japanese Forests. JIBP Synthesis 16:213-245. Univ. of Tokyo Press, Tokyo.

Aubreville, A. 1938. La forest coloniale : les forest d' Afrique occicentale francaise. Ann. Acad. Sci. Paris 9 : 1-245.

Brokaw, N.V.L. 1982. Tree falls : frequency, timing,

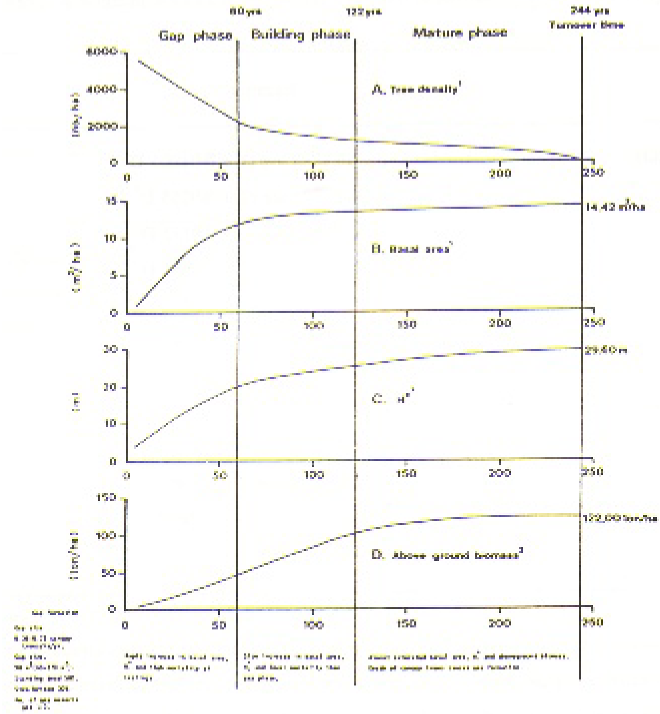

Fig. 4. Scheme of the forest growth cycle of dry dipterocarp forest at SERS.

[1] Trees over 1.3 m height.

[2] Gap phase and building phase trees over 1.3 m height, mature phase tress over 4.5 cm dbh.

and consequences. In "The Ecology of a Tropical Forest" (E.G. Leight, Jr., A.S. Rand, and D.M. Windsor, eds), pp. 101-108. Smithsonian Institute Press, Washington, D.C.

Cottam, C. 1949. The phytosociology of an oak woods in south-western Wisconsin. Ecol., 30 : 271-287.

Florence, J. 1981. Chablis et syvigenese dens une forest dense humide dempervirente du Gabon. These de Zome cycle, Ecologie vegetale. Universite Luis Pasteur de Strasbourg.

Glass, N.R. 1967. A technique for fitting nonlinear models to biological data. Ecol. 48 : 1010-1013.

Griffiths, J.F. 1978. Applied climatology an introduction. (2nd. ed.) Oxford University Press, Eng land. 136 p.

Hartshorn, G.S. 1978. Tree falls and tropical forest dynamics. "Tropical trees as living system" (ed. Tomlinson, P.D. & Zimmermann, M.H.), 617-638. Cambridge Univ. Press, London.

Kiratiprayoon, S. 1986. Comparative study on the structure of the rattan bearing tropical rain forests. M.S. thesis, Kasetsart Univ., Bangkok.

Leigh, E.G. 1975 Structure and climate in tropical rain forest. Amm. Rev. Ecol. Syst., 6: 67-86.

Misra, R., R.P. Singh and M.Singh. 1974. Determination of age of tree in natural tropical deciduous forest of Chakia. Trop. Ecol., 15 : 43-51.

MacArther, R.H. and J.W. MacArther 1961. On bird species diversity. Ecol., 42 : 594-598.

Naka, K. 1982. Community dynamics of evergreen broadleaf forest in southeastern Japan. I. Wind damaged trees and canopy gaps in an evergreen oak forest. Bot. Mag. Tokyo, 95 :358-399.

Naka, K. 1984. Community dynamucs of evergreen broadleaf forest in southeastern Japan. III. Re-vegetation in gaps in an evergreen oak forest. Bot. Mag. Tokyo, 97 : 275-286.

Nakashizuka, T. 1984. Regeneration process of climax beech forests. IV. Gap formation. Jap. J. Ecol., 34 : 75-85.

Nakashizuka, T. and M. Numata. 1982. Regeneration of climax beech forests. II. Structure of a forest under the influences of grazing. Jap. J. Ecol., 32 : 473-482.

Ogawa, H. 1969. An attempt at classifying forest types based on the relationship between teee height and DBH. In : T. Kira, ed., Comparative study of Primary productivity in forest ecosystem, progress report of JIBP/PT/F for 1986. pp. 3-17.

Ogawa,H. and H. Saito. 1965, Studies on forest ecosys tems. I. Productive structure and biomass of an evergreen forest in southern Kyushu. Proc. 12th Ann. meet. Ecol. Soc. Japan p.3 (in Japanese).

Ogawa, H., K. Yoda, T. Kira, and K. Ogino. 1965, Comp arative ecological studies on three main types of forest vegetation in Thailand : II Plant biomass. Nature and Life in Southeast Asia, 4 : 49-80.

Ogino, K., S. Sabhasri and T. Shidei. 1965. The estima-tion of the standing crop of the forest in nor-theastern Thailand. Vanasarn 23 : 67-79.

Ogino, K., D. Ratanawongw, T. Tsutsumi and T. Shidei. 1967. The primary production of tropical forest in Thailand. The southeast Asian studies. 5(1) : 122-154.

Richard, P. W. 1952. The tropical rain forest. Univ. Press. Cambridge.

Runkle, J.R. 1979. Gap phase dynamics in climax mesic forest. Ph.D. thesis, Cornell Univ. Press, Cam bridge.

Sahunalu, P., M. Jamroenpsuksa, P. Dhanmanonda, W. Suwannapinan and B. Prachaiyo. 1979. Compa-rative structural characteristics of three forest types at Nampeom basin, Chiyaphoom Prov-ince. For. Res. Bull. No. 63, Kasetsart Univ., Bangkok.

Sakulmelit, C. 1976. Growth of trees in dry dipterocarp forest at Sakaerat, Pakthongchai, Nakhonra-tchasima. M.S. thesis, Kasetsart Univ., Bang-kok.

Tsutsumi, T., K. Yoda, P. Sahuhalu, P. Dhanma-nonda and B. Prachaiyo. 1983. Forest : felling, burning and regeneration. In . Shifting cultiva tion, An experiment at Nam Phrom. Northeast Thailand, and its implications for upland farm ing in the monsoon tropic". (ed. Kyuma, K. and C. Pairintra). 13-60 Tokyo, Japan.

Vannaprasert, M. 1985. Structural characteristics and gap size distribution of the hill evergreem forest at Doi Pui, Chiengmai. M.S. thesis, Kasetsart Univ., Bangkok.

Watt, A. S. 1947. Pattern and process in the plant com-munity. J. Ecol., 35 : 1-22.

White, P.S. 1979. Pattern, process, and natural distur bance in vegetation. Bot. Rev., 45 : 229-299.

Whitmore, T.C. 1975. Tropical rain forest of the Far East. Clarlendon Press, Oxfrod.

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