

## THE FOREST GROWTH CYCLE IN VARIOUS FOREST TYPES

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### บทคัดย่อ

การพิจารณาถึงขบวนการและอัตราของการทดแทนของพืชพรรณโดยอาศัยข้อมูลที่เกี่ยวข้องกับความหนาแน่นพื้นที่หน้าตัด  $H^*$  (สัมประสิทธิ์ของความสูง ที่มากที่สุดของต้นไม้เท่าที่จะเป็นไปได้) และมวลชีวภาพเหนือพื้นดิน ได้ทำการศึกษาในป่าเต็งรัง ป่าดิบเขา และป่าไม้ใบกว้างซึ่งไม่ผลัดใบที่มีไม้ *Symplocos prunifolia*, *Acer rufinense* ผสมกับ *Symplocos prunifolia* และ *Acer rufinense* เป็นไม้เด่น ผลการศึกษาพบว่าวัฏจักรการเจริญเติบโตของป่าไม้ (gap phase, bilfing phase และ mature phase) อยู่ในช่วง 0-60, 60-122, 122-244 มี 0-50, 50-100, 100-150 ปี และ 0-42, 42-70, 70-180 ปี สำหรับป่าดิบแล้ง ป่าดิบเขา และป่าไม้ใบกว้างซึ่งไม่ผลัดใบตามลำดับ การเพิ่มขึ้นอย่างรวดเร็วของพื้นที่หน้าตัด,  $H^*$  และอัตราการตายของต้นไม้ที่พบอยู่ในช่วงของ building phase สำหรับในช่วงของ mature phase นั้นพบว่า พื้นที่หน้าตัด,  $H^*$  และมวลชีวภาพเหนือพื้นดินนั้นอยู่ในสภาพเกือบคงที่ ในกรณีของป่าไม้ใบกว้างซึ่งไม่ผลัดใบนั้น ชนิดไม้ซึ่งเป็น gap indicator จะมีปริมาณมากในช่วงของ gap phase และค่อย ๆ ลดลงในช่วงของ building phase และจะหมดสิ้นไปในช่วงของ mature phase ในขณะที่ไม้ oak จะค่อย ๆ กลายเป็นไม้เด่นขึ้นเรื่อย ๆ ตามเวลาที่ผ่านไป ในกรณีของป่าเต็งรัง และป่าดิบเขานั้นปรากฏว่าไม่มี gap indicator ปรากฏให้เห็น

### ABSTRACT

Determination of the process and rate of revegetation by using data on tree density, basal area,  $H^*$  (a coefficient indicating the ideal maximum tree height) and above-ground biomass were investigated in dry dipterocarp forest (DDF), hill evergreen forest (HEF), evergreen broadleaved (EBF) and EBF (S, M and A types). 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 years; 0-50, 50-100, 100-200 years; 0-42, 42-70, 70-180 years for DDF, HEF and all EBF types, respectively. Rapid increase in basal area,  $H^*$  and high mortality of saplings 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 almost saturated basal area,  $H^*$  and above-ground biomass. In the case of EBF, gap indicators flourished in the gap phase, but their dominance declined in the building phase, and finally they were excluded from the mature phase. On the other hand, evergreen oaks steadily increased their dominance as time passed. No gap species occurred in the DDF and HEF.

### INTRODUCTION

The canopy of forest changes continually as trees grow 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 phases are abstractions, 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, land 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; Whitmore, 1978; Ohsawa, 1979; Reiners and Lang, 1979; Florence, 1981; Naha, 1982; Nakashizuka and Numata, 1982).

However, there is the fact that the time-scale of regeneration of most forests is considerable. 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; Naka, 1982; Nitroung, 1985; Suksumut, 1987). Thus it is nearly impossible for a single researcher to follow the course of the revegetation continuously over such a long time.

The purpose of this study is to clarify the process and rate of revegetation after gap formation in various forest types by com-

paring tree densities, basal area,  $H^*$  (a coefficient indicating the ideal maximum tree height) and aboveground biomass among different aged stands. The forest growth cycle (Whitmore, 1975) in various forest types will be quantitatively explained.

### MATERIAL AND METHODS

Tree height and diameter records were extracted from studies already made in various forest stands of different forest formations in Japan and Thailand. The localities of the study areas, forest types and authorities for the records are summarized in Table 1. All the forests were stabilized and fully matured.

A 3-ha area of 100 x 300 m was selected as a study area in each stand. Quadrats were laid in apparently different aged stands.

Quadrat size ranged from 25 m<sup>2</sup> to 100 m<sup>2</sup>, and was 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 was easily identified, but the identification was difficult in younger stands. Trees higher than the mean height of gap indicators in each stand were designated the top layer trees.

In the tropical region where growth rings seldom developed (Stand 1 and 2), gap age could be considered by the allometric relationships between age and DBH (for detail see Nilroung, 1985 and Plongsuwan, 1987). In the temperate region where annual rings were present in the basal wood of the sample trees (Stand 3-6), trees were cut down at the base, or cores of their stems were sampled as low as possible using an increment borer. The ages of gaps could be estimated by their growth analysis (Nakashizuka, 1984). The year of an abrupt increase of annual growth rate was regarded as the year when the gap was made. When such an abrupt growth increase was not observed clearly, the age of the maximum sized tree in the gap was consi-

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Table 1. Outline of the localities of the study area, forest types and authors of the studies from which the data were taken.

No.	Locality	Forest type and author
1	Sakaerat Environmental Research Station (SERS), Pak Thong Chai District, Nakhon Rachasima Province, Northeastern Thailand (14° 30' N, 101° 55' E)	Dry dipterocarp forest (Dhanmanonda, 1987)
2	Huay Nam Dung Watershed Station, Mae Taeng District, Chiang Mai Province, Northern Thailand (10° 18' N, 98° 35' E)	Hill evergreen forest (Plongsuwan, 1987)
3	Kasugayama Forest Reserve, Nara City, Southwestern Japan (34° 41' N, 135° 51' E)	Evergreen broadleaf forest (Naka, 1984)
4	Kasugayama Forest Reserve, Nara City, Southwestern Japan (34° 41' N, 135° 51' E)	Evergreen broadleaf forest (S, M and A types)* (Naka, 1984)

\* Stand types, S, M and A represent stands dominated in physiognomy by *Symplocos prunifolia* on the ridge, *Acer rufinerve* with *S. prunifolia* at mid-slope, and *A. rufinerve* at the bottom of the slope respectively.

dered to be equal to the age of the gap. The areas of gaps 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 identified when possible. Diameter at breast height (DBH) and tree height (H) were measured for all standing live and dead trees.

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

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

where D is DBH, and h, A and H\* are coefficients specific to the forest. He showed that h was approximately equal to one for most mature forests, irrespective of forest type. Assuming that h equal one, the other coefficients, A and H\* for each stand were calculated by using the non-linear least square method, and their curves were drawn.

The above-ground weight ( $w_T$ ) for Stand 1 was estimated by using the relative growth method proposed by Ogino *et al.* (1967) for hardwood trees in the dry dipterocarp forest

in northeastern Thailand. They used the following equations :

$$w_S = 189 (D^2 H)^{0.902}, \quad (\text{kg, m}^2 \cdot \text{m}) \quad (2)$$

$$w_B = 0.125 w_S^{1.204}, \quad (\text{kg, m}^2 \cdot \text{m}) \quad (3)$$

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

where D, and  $w_S$ ,  $w_B$  and  $w_L$ , are DBH, and the dry weights of stem, branches and leaves of a tree, respectively, and above-ground weight of a tree ( $w_T$ ) was obtained by summing these partial biomasses :

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

The above-ground weight ( $w_T$ ) for Stand 2 was estimated from its DBH and H using the following equations (6, 7), which were given by Ogawa *et al.* (1961). They used the following equations for hard-wood trees in the hill evergreen forest in northern Thailand.

$$w_C = 0.06851 (D^2 H)^{0.8396}, \quad (\text{kg, cm}^2 \cdot \text{m}) \quad (6)$$

$$w_T = 0.04518 (D^2 H)^{0.6230}, \quad (\text{kg, cm}^2 \cdot \text{m}) \quad (7)$$

where D, and  $w_C$ ,  $w_L$ , are DBH and the dry weights of stem plus branches and leaves of a tree, respectively, and  $w_T$  is the sum of  $w_C$  and  $w_B$ .

The above-ground weight ( $w_T$ ) for Stand 4 - 6 was estimated from its DBH and H using the following equations (8)-(10), which were given by Ogawa and Saito (1965) for hardwood trees.

$$w_S = 0.0396 (D^2 H)^{0.9326}, \quad (\text{kg, cm}^2 \cdot \text{m}) \quad (8)$$

$$w_B = 0.00602 (D^2 H)^{1.027}, \quad (\text{kg, cm}^2 \cdot \text{m}) \quad (9)$$

$$1/w_L = 26/w_{TC} + 0.02, \quad (\text{kg, kg}) \quad (10)$$

where D, and  $w_S$ ,  $w_B$  and  $w_L$ , are DBH, and the dry weights of the stem, branches and leaves of a tree, respectively, and  $w_{TC}$  is the sum of  $w_S$  and  $w_B$ . For coniferous trees, equations (11) - (14) (Ando *et al.*, 1977) were used.

$$w_S = 0.8882 D^{1.8071}, \quad (\text{kg, cm}) \quad (11)$$

$$w_B = 0.0113 D^{2.4586}, \quad (\text{kg, cm}) \quad (12)$$

$$w_L = 0.0655 D^{1.7083}, \quad (\text{kg, cm}) \quad (13)$$

$$w_{LN} = 0.0386 D^{1.4553}, \quad (\text{kg, cm}) \quad (14)$$

where  $w_{LN}$  is the dry weight of the leaves for that year. The above-ground weight of a tree ( $w_T$ ) was obtained by summing the dry weight of each organ. The above-ground biomass for each stand was calculated by summing up  $w_T$ .

## RESULTS AND DISCUSSION

### The 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 rainforest in tropical Asia and Melanesia. His physiognomic approach to the 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 dry dipterocarp forest, hill evergreen forest, and evergreen broadleaf forest (S, M and A types) using data on the tree density, basal area, H\*

(a coefficient indicating the ideal maximum tree height) and above-ground biomass are presented, from both the viewpoints mentioned above.

### Dry dipterocarp forest (DDF)

First the time-scale of the forest growth cycle (Figure 1) is dealt with. The first phase, the gap phase, is characterized by the high density and low height (shorter than 10 m) of trees. Gap stands, defined as young stands, were at most 60 years old. So stands not older than 60 years old are regarded as the components of the gap phase. Above-ground biomass of gap stands (trees over 1.3 m height) was found to range from 1.3 - 24 t/ha, with a mean value of  $9.4 \pm 9.3$  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 above-ground biomass (trees over 1.3 m height) ranged from 32-97 t/ha, with a mean value of  $65 \pm 21$  t/ha. The third phase, the mature phase, consisted of stands whose ages were between 122 and 244 years. Above-ground biomass ranged from 52-148 t/ha, with a mean value of  $122 \pm 31$  t/ha. Since trees smaller than 4.5 cm in DBH were not included in the calculations for this phase, the actual above-ground biomass should be a little larger than the values given. Since the mean residence time of the forest canopy was 244 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 Figure 1. On average, 0.36 - 0.72 canopy trees per hectare died, and gaps totalling 35-66 m<sup>2</sup> per hectare were formed annually. Standing dead and broken stem were the main causes of gap formation and both were scattered throughout the forest, hence mean gap size was small, 98 m<sup>2</sup>. Eighty five percent of gaps were formed by only one gap maker, and the maximum number of gap makers per gap was 3.

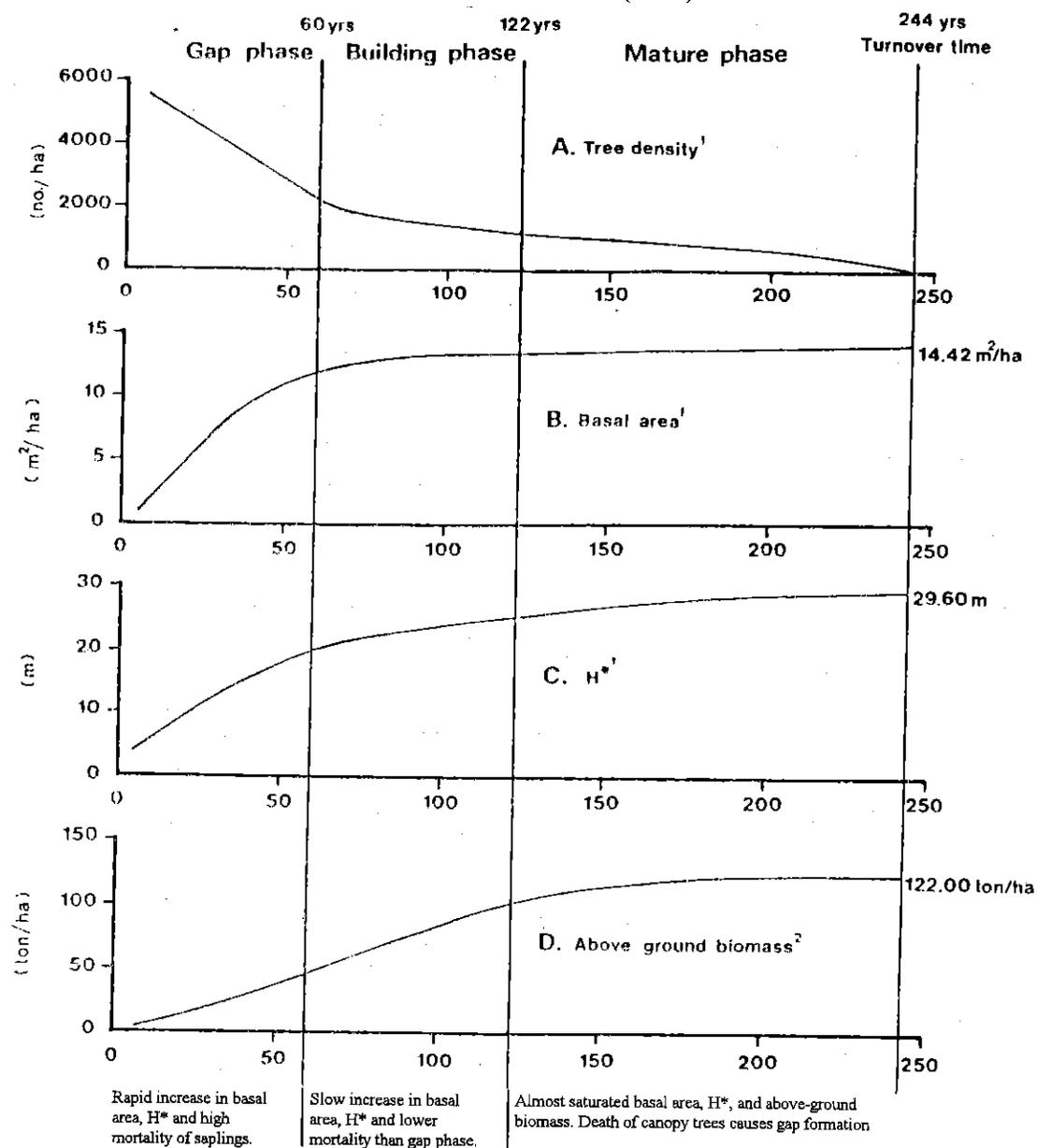


Figure 1. Scheme of the forest growth cycle of dry dipterocarp forest at SERS, Pak Thong Chai District, Nakhon Ratchasima Province, Northeastern Thailand.

<sup>1</sup> Trees over 1.3 m height.

<sup>2</sup> Gap phase and building phase trees over 1.3 m height, mature phase trees over 4.5 cm dbh.

The gap phase was characterized by high mortality of saplings and rapid increase in basal area and tree height (Figure 1). During 60 years of the gap phase, tree density (for trees over 1.3 m in height) decreased to 2,000/ha (Figure 1 A) because of self-thinning due to the density effect. Basal area attained 12 m<sup>2</sup>/ha, which is about 80 % of the basal area of the mature phase (Figure 1 B).  $H^*$  attained 20 m, about 65% of the  $H^*$  of the mature phase (Figure 1 C). No gap species occurred in the DDF.

The building phase was characterized by lower mortality of trees and rate of forest growth in terms of basal area and height compared to the gap phase. The highest trees reached the forest canopy, 20-25 m 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 phase. The basal area,  $H^*$  and above-ground biomass reached the maximum level of 14.4 m<sup>2</sup>/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, above-ground biomass continuously increased from 9.4, 65 and 122 t/ha in the gap, building and mature phase, respectively (Figure 1 D). Change in species composition was not observed during the forest growth cycle. Pioneer species, which normally appear only in the gap phase were absent 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 environmental gradients in which revegetation processes followed disturbances 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 be 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 filter which chooses the suitable species, and results in the selected species having very similar ecological characteristics regarding survival in the environmental conditions of DDF.

#### Hill evergreen forest (HEF)

First the time scale of the forest growth cycle (Figure 2) is dealt with. The first phase, the gap phase, is characterized by the high density and low height (shorter than 18 m) of trees. Gap stands, defined as young stands,

were at most 50 years old. So stands not older than 50 years old are regarded as the components of the gap phase. Above-ground biomass of gap stands (trees over 1.3 m height) was found to range from 1.7 to 52 t/ha, with a mean value of  $18 \pm 16$  t/ha. The second phase, the building phase was found to consist of stands whose ages were between 50 and 100 years. The tallest trees reached the canopy, 30-40 m high and aboveground biomass (trees over 1.3 m height) ranged from 72-197 t/ha, with a mean value of  $134 \pm 57$  t/ha. The third phase, the mature phase, consisted of stands whose ages were between 100 and 200 years. Aboveground biomass ranged from 150-300 t/ha, with a mean value of  $200 \pm 87$  t/ha. Since trees smaller than 4.5 cm in DBH were not included in the calculations for this phase, the actual above-ground biomass should be a little larger than the values given. Since the mean residence time of the forest canopy was 200 years, the mature phase is expected to last for about 100 years, and average, in HEF at Huay Nam Dung Watershed Station.

The characteristics of the growth cycle of HEF at Huay Nam Dung Watershed Station are summarized in Figure 2. On average, 0.57 - 1.14 canopy trees per hectare died, and gaps totalling 40-80 m<sup>2</sup> per hectare were formed annually. Standing dead and broken stem were the main causes of gap formation and both types were scattered throughout the forest, hence mean gap size was small, 142 m<sup>2</sup>. Sixty percent of gaps were formed by only one gap maker, and the maximum number of gap makers per gap was 4.

The gap phase was characterized by high mortality of saplings and rapid increase in basal area and tree height (Figure 2). During 50 years of gap phase, tree density (for trees over 1.3 m in height) decreased to 3,900/ha (Figure 2 A) because of self-thinning due to the density effect. Basal area attained 26.6 m<sup>2</sup>/ha, which is about 70% of the basal area of the mature phase (Figure 2 B).  $H^*$  attained

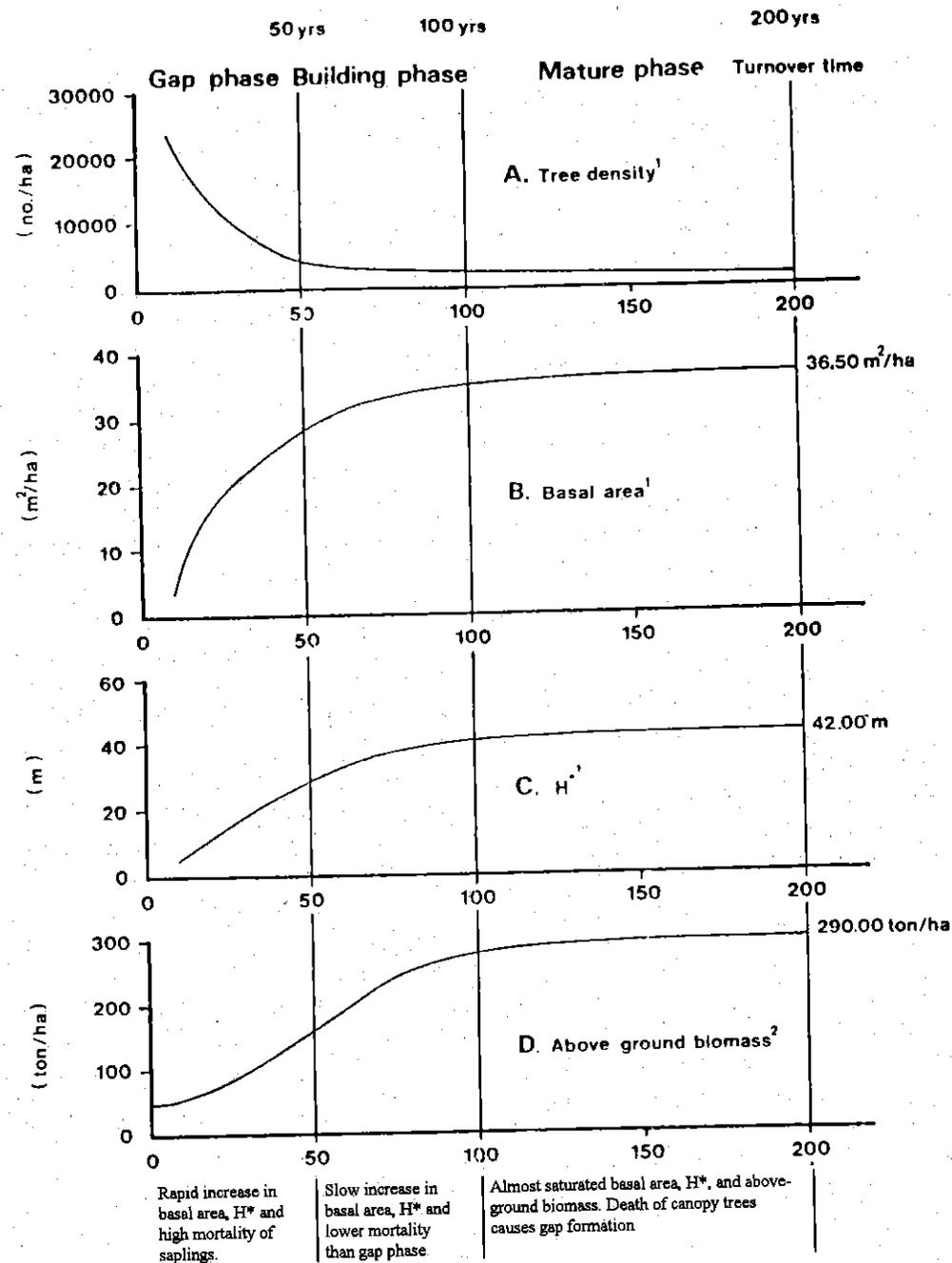


Figure 2. Scheme of the forest growth cycle of hill evergreen forest at Huay Nam Dung Watershed Station, Mae Taeng Districts, Chiang Mai Province, Northern Thailand.

<sup>1</sup> Tree over 1.3 m height.

<sup>2</sup> Gap phase and building phase trees over 1.3 m height, mature phase tree over 4.5 cm dbh.

27 m, about 65% of the H\* of the mature phase (Figure 2 C). No gap species occurred in the HEF.

The building phase was characterized by lower mortality of trees and rate of forest growth in terms of basal area and height growth compared to the gap phase. The

highest trees reached the forest canopy, 30-40 m high. The remains of large fallen trees and stumps of gap makers also characterized the phase.

After the building phase, the forest enters into the mature phase. The basal area, H\* and above-ground biomass reached the maximum

level of 36.5 m<sup>2</sup>/ha, 42.2 m and 200 t/ha, respectively. On average, this phase is expected to last for 100 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, above-ground biomass continuously increased from 18, 134 and 200 t/ha, in the gap, building and mature phase, respectively (Figure 2 D). Change in species composition was not observed during the forest growth cycle. Pioneer species, which normally appear only in the gap phase were absent 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.

#### Evergreen broadleaf forest (EBF)

First the time scale of the forest growth cycle (Figure 3) is dealt with. In the preceding paper (Naka, 1982), gap stands were defined as stands that were at most 42 years old. So stands not older than 42 years old are regarded as the components of the gap phase. The gap phase is characterized by the high density and low height (shorter than 15 m) of trees. Above-ground biomass ranged from 1.2 to 200 t/ha with a mean value of  $74 \pm 64$  t/ha. Second, the building phase consists of stands whose ages are between 42 and 70 years. Relative dominance of evergreen oaks gets ahead of that of gap indicators during this phase. In this study, the actual building phase is represented by 70 year old stands. The highest trees reach the forest canopy, 20-25 m high, and are mostly evergreen oaks. Large fallen trees and stumps of gap indicators also characterize the phase. Above-ground biomass ranges from 71-236 t/ha with a mean value of  $136 \pm 88$  t/ha. Third, relative dominance of evergreen oaks is

much higher in the mature phase than the building phase. Canopy trees mainly consist of evergreen oaks. Above-ground biomass of 438 t/ha is relatively large because the above-ground biomass in a 2.2 ha plot, calculated from the above-ground biomass data for overstorey trees in 10 x 15 m<sup>2</sup> quadrats, range from 0 t/ha (in quadrats with no overstorey trees) to 629 t/ha. Since trees smaller than 20 cm DBH were not included in the calculations, the actual aboveground biomass should be a little larger than the value.

Species composition successively changes as revegetation proceeds in gaps. In the gap phase, gap indicators flourish. But their dominance declines in the building phase, and finally they are excluded from the mature phase. On the other hand, evergreen oaks steadily increase their dominance as time passes. It takes about 70 years for gaps to be closed by large grown trees. Since the mean residence time of the forest canopy was 180 years (Naka, 1982), the mature phase is expected to last for about 110 years on the average in the Kasugayama Forest Reserve.

The gap phase was characterized by high mortality of saplings and rapid increase in basal area and tree height (Figure 3). During 42 years of gap phase, tree density (for trees over 1.3 m in height) decreased to 10,000/ha (Figure 3 A) because of self-thinning due to the density effect. Basal area attain 34 m<sup>2</sup>/ha, which is about 55% of the basal area of the mature phase (Figure 3 B). H\* attained 19 m, about 74% of the H\* of the mature phase (Figure 3 C).

The building phase was characterized by lower mortality of trees and rate of forest growth in terms of basal area and height growth compared to the gap phase. The highest trees reach the forest canopy, 20-25 m high. The remains of large fallen trees and stumps of gap makers also characterized the phase.

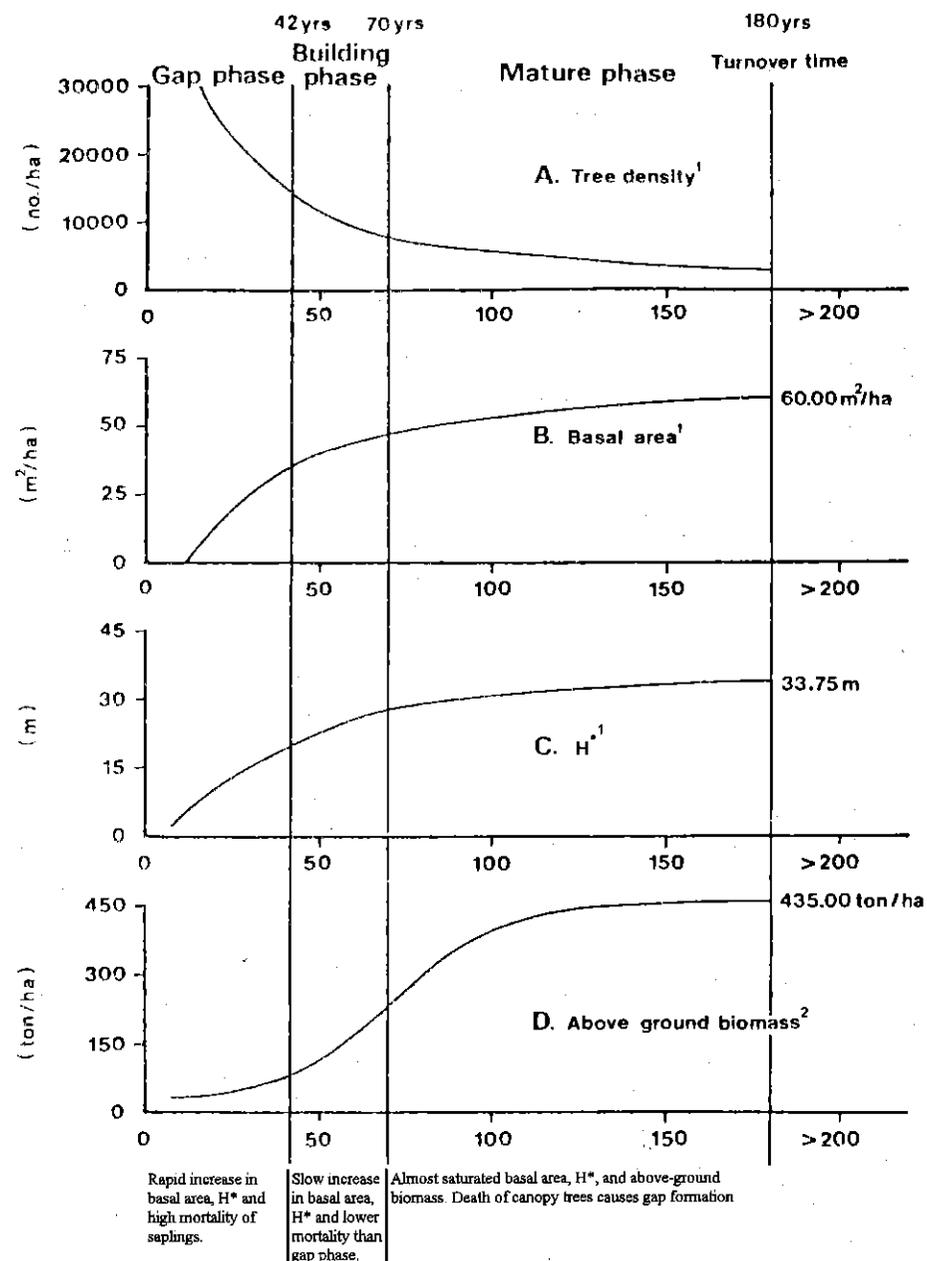


Figure 3. Scheme of the forest growth cycle of evergreen broadleaf forest at Kasugayama Forest Reserve, Nara City, Southwestern Japan.

<sup>1</sup> Tree over 1.3 m height.

<sup>2</sup> Gap phase and building phase trees over 1.3 m height, mature phase tree over 4.5 cm dbh.

After the building phase the forest enters into the mature phase, in which basal area,  $H^*$  and aboveground biomass reached the maximum level of 62  $m^2/ha$ , 25.7 m and 438 t/ha, respectively. On average, this phase is expected to last for 110 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, above-ground biomass continuously increased from 74, 136 and 438 t/ha in the gap, building and mature phase, respectively (Figure 3 D). The frequencies of species in gaps showed a negative correlation with closed forest.

The growth cycles of evergreen broadleaf forest (S, M and A types) are illustrated in

Figures 4, 5 and 6 respectively. Similar results as mentioned above were obtained too.

## CONCLUSION

The turnover times of the forests were estimated to be 112 years (Hartshorn, 1978), 144 year (Brokaw, 1982 b) 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 climates. This was also supported by Leigh (1975). The turnover time of 6 forest stands corresponded with the time mentioned above. The dynamic equilibrium in a climax forest seems to be sustained by such regenerating and degenerating processes.

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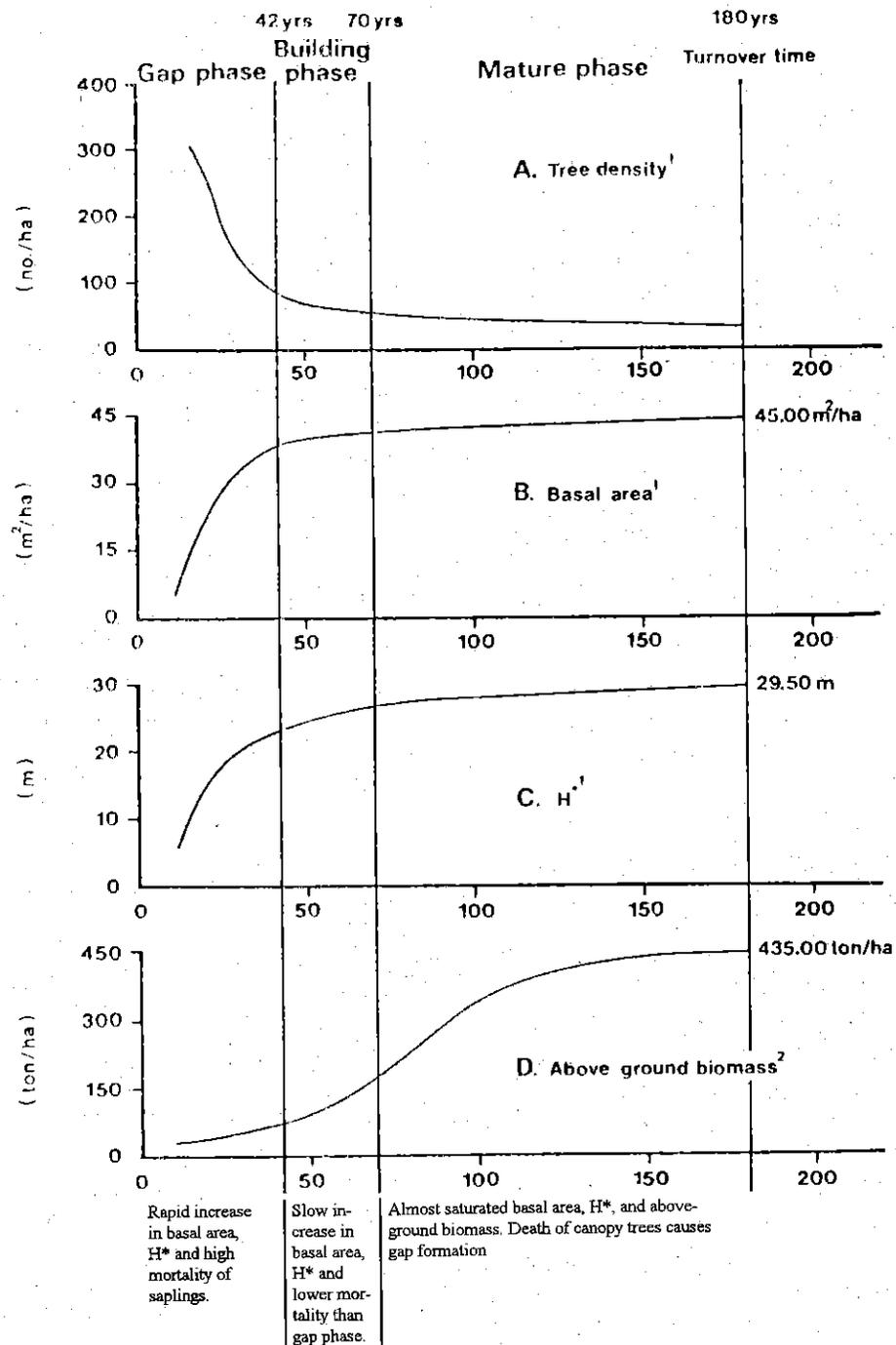


Figure 4. Scheme of the forest growth cycle of evergreen broadleaf forest (S type) of Kasugayama Forest Reserve, Nara City, Southwestern Japan.

<sup>1</sup> Tree over 1.3 m height.

<sup>2</sup> Gap phase and building phase trees over 1.3 m height, mature phase tree over 4.5 cm dbh.

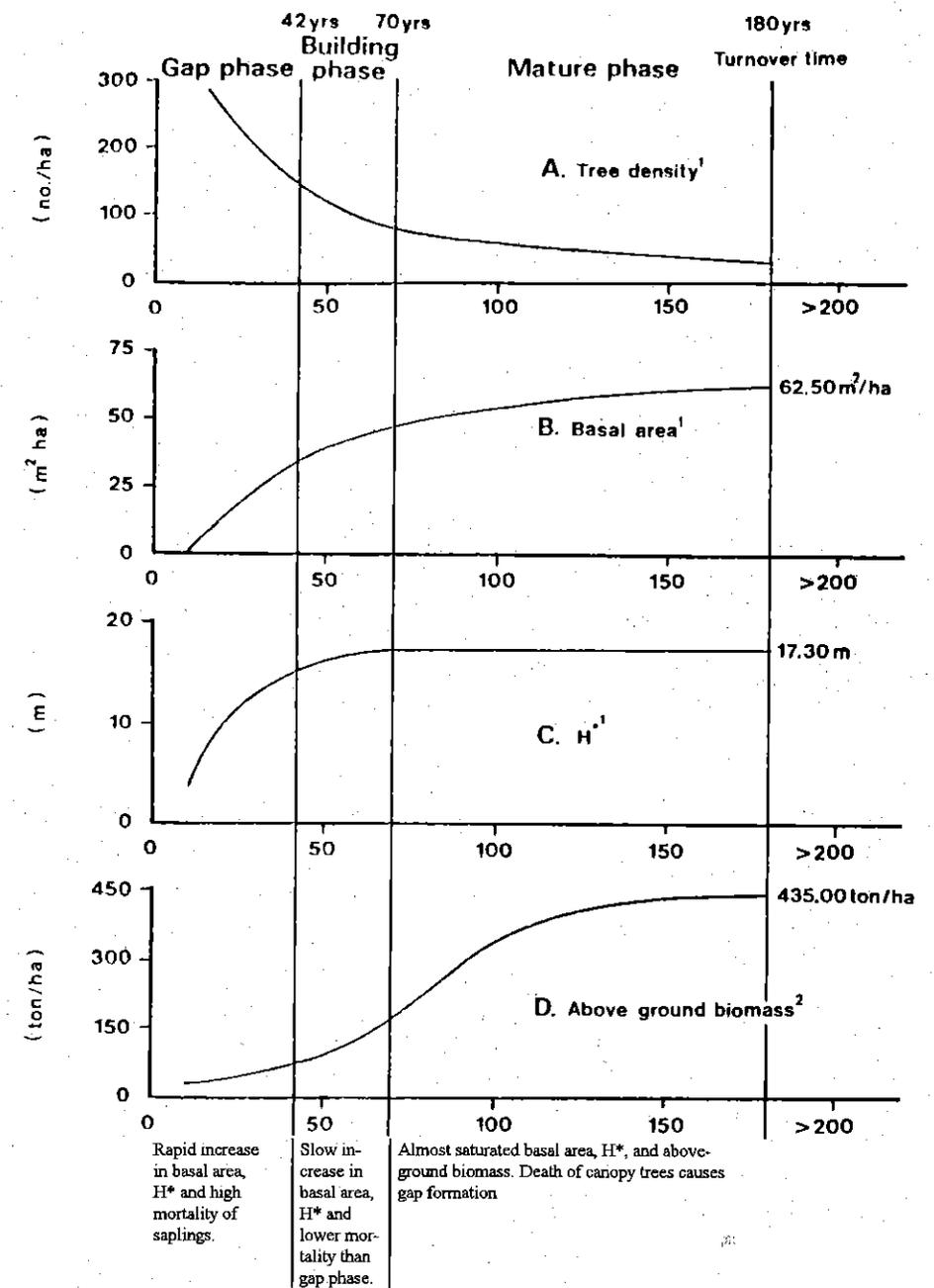


Figure 5. Scheme of the forest growth cycle of evergreen broadleaf forest (M type) of Kasugayama Forest Reserve, Nara City, Southwestern Japan.

<sup>1</sup> Tree over 1.3 m height.

<sup>2</sup> Gap phase and building phase trees over 1.3 m height, mature phase tree over 4.5 cm dbh.

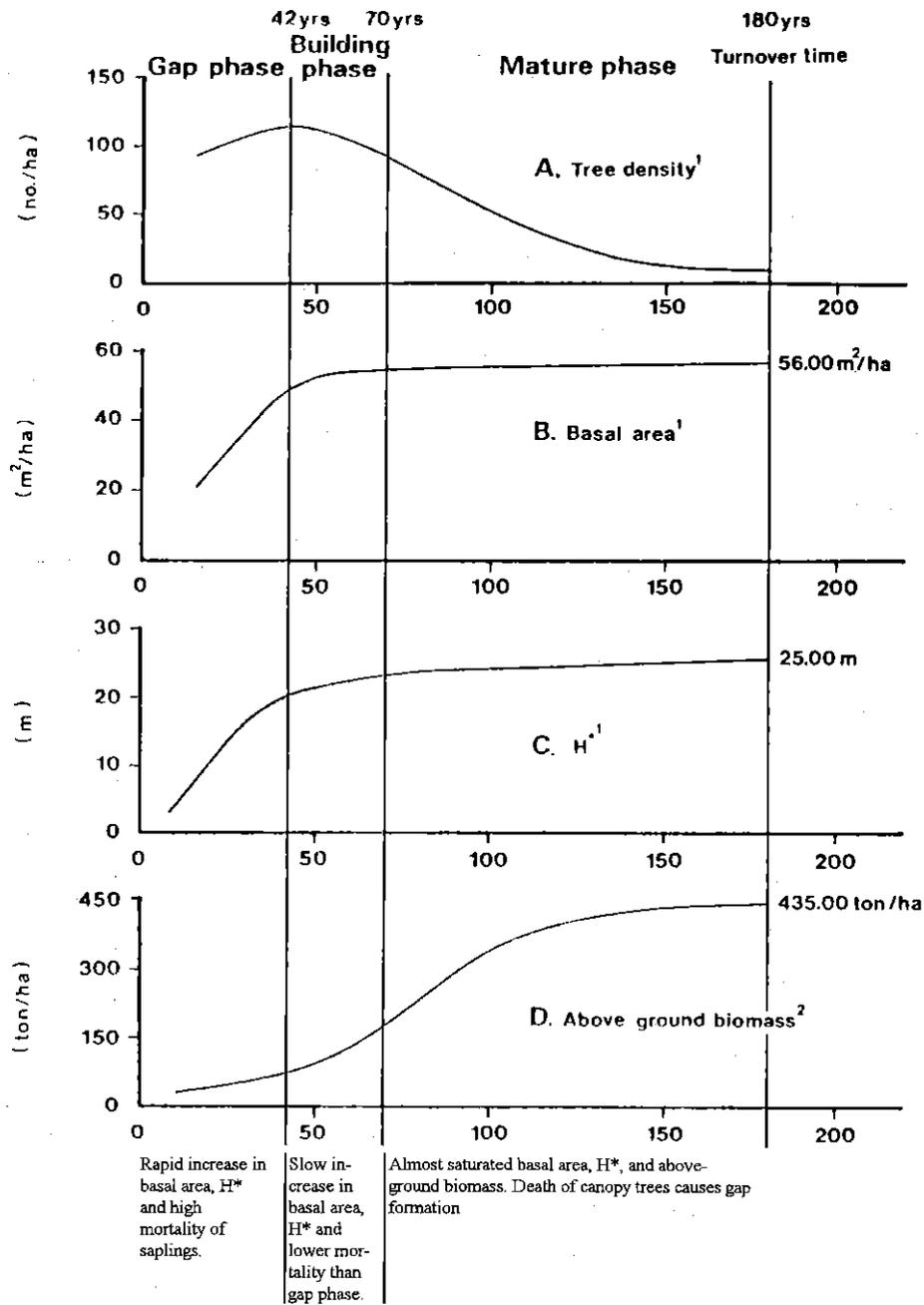


Figure 6. Scheme of the forest growth cycle of evergreen broadleaf forest (A type) of Kasugayama Forest Reserve, Nara City, Southwestern Japan.

<sup>1</sup> Tree over 1.3 m height.

<sup>2</sup> Gap phase and building phase trees over 1.3 m height, mature phase tree over 4.5 cm dbh.