

## タイ国南部のマングローブ林の現存量

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## Standing Biomass of Mangrove Forests in Southern Thailand\*1

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### I. Introduction

Mangrove forests develop along sheltered coast lines and estuaries where salt water penetrates, and they are found around the world in the tropics and the subtropics. In recent years, mangrove forests have decreased gradually because of destruction by selective cutting for charcoal, firewood, and construction timber or clear cutting prior to tin mining, especially in southeast Asia. We should reserve ecosystems of mangrove forests because of their natural conservation and association with many invertebrates eaten as sea foods.

The proper management of mangrove ecosystems requires basic understanding of their productivity. The estimation of standing biomass and analysis of the standing structure of mangrove forests are very important for their management. Although there are many studies on the zonation of vegetation in mangrove swamps (CLARKE and HANNON, 1967, 1969, 1970; MACNAE, 1968; THOM *et al.*, 1975; CHAPMAN, 1976; SAMINGAN, 1980; CHAMBERS, 1980; SIVAKUMAR, 1980) and on the physiology of mangrove plants (SCHOLANDER *et al.*, 1955; GOLLEY, *et al.*, 1962; SCHOLANDER *et al.*, 1962; MILLER, 1972; LUGO *et al.*, 1975, 1976), few measurements have made of biomass and stand structure (GOLLEY *et al.*, 1962, 1975; LUGO *et al.*, 1976; CHRISTENSEN, 1978).

In November 1981, the Thai-Japanese Joint Research Team on Mangrove Productivity and Development was established, and a field survey was started in Ranong on the west coast of the Malay Peninsula. The purpose of this study is thus to clarify the standing structure and dynamics of mature mangrove forests.

### II. Study Site and Methods

A permanent plot was established in the estuary

at Khong Ngao Hatsaikao, Ranong. A transect of 50×260-m was placed perpendicularly to the coastline and divided into 130 subplots (10×10 m). On forty of the subplots, trees greater than four centimeters in diameter were measured for diameter and height, but on the rest subplots any trees over ten centimeters in diameter were measured. The diameter was measured 30 cm above the highest root collar for *Rhizophora* species and 130 cm above the ground for other species. Height of the tree, root collar and lowest living branch also were measured. All trees were numbered with white paint and then recorded on a map. The crowns of canopy also were mapped.

Fifteen large trees of *Rhizophora* spp. and 11 of *Bruguiera* spp. were harvested in the vicinity of the permanent plot for estimating the standing biomass. They were selected to cover the range of the diameter distribution, and were cut at the highest root collar for *Rhizophora* spp. and at the base for *Bruguiera* spp. Fallen trees were cut 0.3 m and 1.3 m above the cutting point with the remainder being cut into two meters segments.

From each part, leaves, branches, flowers and fruits, aerial roots, and bark were stripped, and the diameter with and without the bark was measured. The roots of fallen trees were pulled out of the ground by a portable winch. Samples were dried at 80°C for 48 hours in an oven for estimating dry-weight biomass. Light intensity in the mangrove forest was measured by illuminometer simultaneously with that in openings, and the relative light intensity was calculated as a percentage of the full light in the open.

### III. Results

Species composition was analyzed on the subplots where *Rhizophora* spp. were dominant but associat-

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Table 1. General description of the study forest

Tree species	Mean diameter (cm)	Mean tree height (m)	Basal area (m <sup>2</sup> /ha)	No. of trees (No./ha)
<i>Rhizophora apiculata</i> BL.	11.1 (20.2)	10.57 (11.59)	20.78 (2.47)	985 (50)
<i>Rhizophora mucronata</i> POIR.	5.6 (7.2)	7.02 (7.06)	0.03 (0.35)	13 (77)
<i>Bruguiera cylindrica</i> BL.	6.6	8.75	0.30	83
<i>Bruguiera gymnorrhiza</i> LAMK.	15.0	14.38	2.68	110
<i>Bruguiera parviflora</i> W. & A.	6.4	9.04	0.05	15
<i>Ceriops tagal</i> C. B. ROBINSON	4.9	6.80	0.01	5
<i>Ceriops decandra</i> DING HOÜ	4.8	6.54	0.05	25
<i>Derris indica</i> BENNET	6.5	8.58	0.02	5
<i>Heritiera littoralis</i> DRY.	10.8	12.62	0.05	5
<i>Sonneratia alba</i> SMITH	(61.3)	(13.15)	(8.57)	(27)
<i>Aegiceras corniculatum</i> BLANCO	(4.3)	(3.14)	(0.06)	(40)
<i>Avicennia alba</i> BL.	(11.53)	(7.6)	(0.11)	(10)
<i>Avicennia officinalis</i> LINN.	(17.0)	(10.2)	(0.23)	(10)
Total	10.9 (17.1)	10.64 (8.32)	23.97 (11.79)	1,246 (214)

Numbers in parentheses are values in the *Sonneratia* Zone.

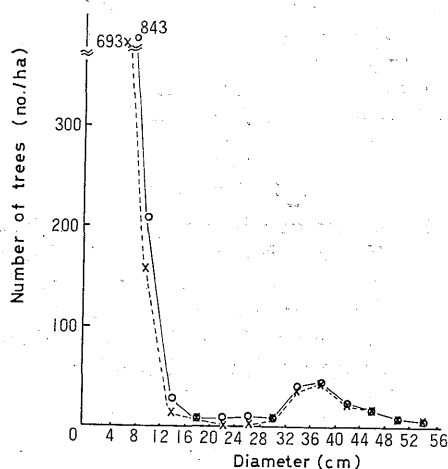


Fig. 1. Frequency distribution of diameters for all tree species and for *R. apiculata*

○ All tree species; × *R. apiculata*

ed with *Bruguiera* spp. (Table 1). Tree density of the *Sonneratia* Zone, dominated by *Sonneratia alba* SMITH in association with *R. apiculata* BL. and *R. mucronata* POIR., was very low (214 trees per ha).

In this study we dealt chiefly with the area after excluding the *Sonneratia* Zone to clarify the standing structure and biomass of a closed stand in a mangrove forest. Trees with a diameter of more than four centimeters totaled 1,246 per hectare, and the basal area was 23.97 m<sup>2</sup>/ha. About 80 percent of the trees were *R. apiculata* and 6~9 percent *B. gymnorrhiza* LAMK. and *B. cylindrica* BL. The average diameter on the permanent plot was 10.9 cm, and *R. apiculata* had the largest diameter (55 cm). While the total basal area of the permanent plot was very small, 86.7 percent of it

was *R. apiculata*, *B. gymnorrhiza*, and *B. cylindrica* accounted for 11.2 and 1.3 percent respectively of the basal area. The frequency distribution of diameters more than four centimeters is shown in Figure 1. The largest frequency occurred in the smallest diameter group. The number of trees decreased rapidly with increasing diameters until the diameter reached 16 cm, and was more or less constant in the diameter range of 16 to 30 cm. As diameters surpassed 30 cm, the density started increasing and finally maximized at about 36 cm.

It was very difficult to measure the heights of all sample trees in the closed-forest, therefore indirect estimations of heights were made on the permanent plot. A diameter ( $D$ )-tree height ( $H$ ) curve could be approximated by the hyperbolic equation:

$$1/H = A/D^b + 1/H^* \quad (1)$$

where  $A$  and  $h$  are constants specific to the stand and  $H^*$  is another constant representing the possible upper limit of tree height ( $H$ ). The relationship between diameter and tree height is shown in Figure 2. This relationship can be derived from the diameter 0.3 m above the highest root collar ( $D_{0.3}$ ) for *Rhizophora* spp. or from the diameter 1.3 m above the ground ( $D_{1.3}$ ) for other species and the tree height ( $H$ ) because *Rhizophora* spp. usually have stilt roots at high levels which affect the value of the diameter 1.3 m above the ground. The tallest height estimated from Equation (1) for *Rhizophora* spp. was 30.9 m, for *Bruguiera* spp., 24.7 m.

The allometric relationships between each component and the square of the diameter multiplied by the tree height ( $D^2 \cdot H$ ) of sample trees were studied (Fig. 3). The simple allometric equation was approximated by:

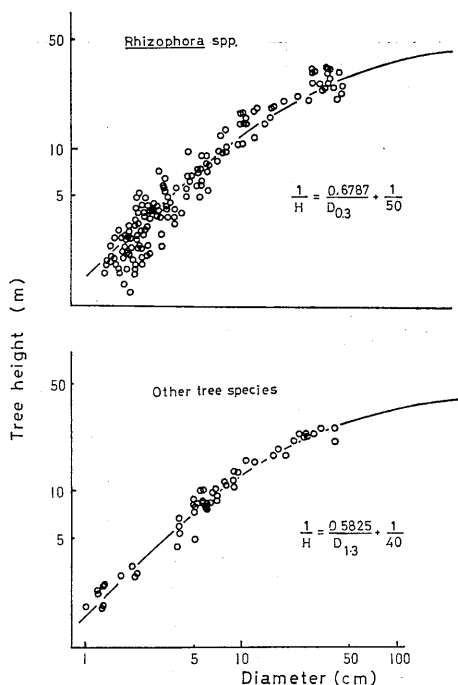


Fig. 2. Hyperbolic relationship between tree height and diameter

Table 2. Coefficients *a* and *b'* of allometric equations (*b'*=log *b*)

Component	<i>Rhizophora</i> spp.		<i>Bruguiera</i> spp.	
	<i>a</i>	<i>b'</i>	<i>a</i>	<i>b'</i>
Leaves	0.5632	1.9229	0.5403	2.0237
Branches	1.0313	0.7615	0.8735	1.3571
Stems	0.9646	1.6274	0.9586	1.6280
Flowers	1.2632	-2.2332	1.0849	-1.6113
Roots	1.0525	0.9885	0.9085	1.2745

$$W_x = b \times (D^2 \cdot H)^a \quad (2)$$

where  $W_x$  stands for the dry weight of stems when *x* is *s*, of branches when *x* is *b*, of leaves when *x* is *l*, of flowers and fruits when *x* is *f*, and of roots when *x* is *r*. For *Rhizophora* spp., the diameter 0.3 m above the highest root collar ( $D_{0.3}$ ) was adopted, and the length of the tree above this point was used as *H* in the calculations. The diameter at breast height and the total length of the tree above ground (*H*) were adopted in calculations for other species.

The dry weight of stems ( $W_s$ ) was correlated closely with the product of the square of  $D_{0.3}$  (or  $D_{1.3}$ ) multiplied by the tree height (*H*) (Fig. 3). Because the fit of the  $W_x - D^2 \cdot H$  curves (Eq. (2)) was satisfactory in other relationships, the dry weight of each part was estimated from the observed value

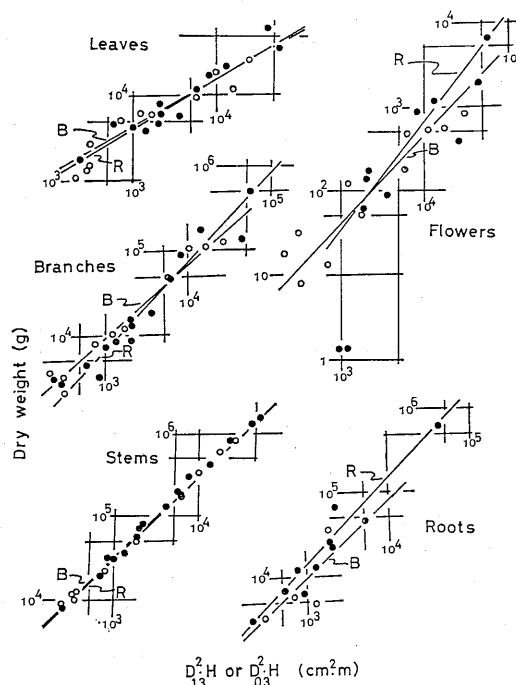


Fig. 3. Allometric relationships for *R. apiculata* (R) and *Bruguiera* spp. (B) between the dry weight of leaves, branches, stems, flowers, and roots per tree and the square of the diameter multiplied by the tree height ( $D_{1.3}^2 \cdot H$  or  $D_{0.3}^2 \cdot H$ )  
● *R. apiculata*; ○ *Bruguiera* spp.

Table 3. Estimated stand biomass of trees ( $D \geq 4$  cm) on the permanent plot

Component	<i>Rhizophora</i> spp.	Other species	Total
Stems (ton/ha)	192.481	21.676	214.157
Branches (ton/ha)	52.875	5.333	58.208
Leaves (ton/ha)	6.749	1.382	8.131
Fruits and flowers (ton/ha)	0.632	0.041	0.673
Above-ground (ton/ha)	252.737	28.432	281.169
Roots (ton/ha)	111.571	6.063	117.634
Total (ton/ha)	364.308	34.495	398.803
Leaf area (ha/ha)	5.91	0.67	6.58

of  $D_{0.3}^2$  (or  $D_{1.3}^2$ )  $\times H$ . The coefficients of allometric equations "*a*" and "*b*" in Equation (2) were determined as shown in Table 2.

The regression coefficients "*a*" of branches, stems, and roots were approximately 1 (Table 2). The dry weights of these part linearly increased with increases of  $D^2 \cdot H$  in Figure 3. However, the coefficient for leaves was less than 1; therefore, the increasing rate of leaf weight decreased with  $D^2 \cdot H$ . The growth rate of the trees must decrease with age or increasing tree size because the bio-

mass of photosynthetic parts (leaves) does not increase as fast as that of non-photosynthetic parts. Conversely, the increasing rate of the dry weight for flowers and fruit increased with increasing  $D^2 \cdot H$  as coefficient "a" of flowers and fruits was 1.2632, considerably greater than 1. These results suggest that bigger trees have proportionately more flowers than smaller trees.

The standing biomass can be obtained by summing up the weight of all of the trees. The standing biomass, except for the *Sonneratia* Zone is shown in Table 3.

Roots occupied 29 percent of the total standing biomass, of which stems, branches, leaves, and flowers were 34, 15, 2, and 0.2 percent, respectively. However, flower biomass may be overestimated as 10 of 26 sample trees did not have any flowers.

Light intensity in the stand was measured when mean full light intensity in an open area was 68,900 lux, and then relative light intensity was calculated. The mean value of the relative light intensity in this stand was 10.9 percent of the full light intensity, and the maximum and minimum intensity were 69.0 and 1.22 percent, respectively.

#### IV. Discussion

The diameter distribution in a natural forest normally has a reverse-J shape. However the distribution in this area is bimodal (Fig. 1). This difference may be due to the harvesting of trees with a size of about 20 cm for timber and charcoal. This practice has resulted in the rapid reduction of the tree size in this region.

The total leaf biomass for the permanent plot was 8.1 ton/ha. Comparison of the biomass in this area with that of other mangrove forests showed that the former was slightly greater than that of other forests which had 6 ton/ha on average.

The maximum was 13.3 ton/ha, and the minimum was 0.7 ton/ha (LUGO and SNEDAKER, 1974). LUGO and SNEDAKER (1974) estimated the total above-ground biomass of Florida mangrove forest to be 279.2 ton/ha, of which the prop roots were 116.4 ton/ha. In this study, the estimation for the total standing biomass above-ground was 281.3 ton/ha. The value on the permanent plot was much greater than that of any other mangrove forest in the world. KIRA (1978) also estimated the biomass of tropical rain forests at Pasoh, Malaysia; 7.61 ton/ha of leaves, 75.98 ton/ha of branches, 337.7 ton/ha of stems, and 421.3 ton/ha of total above-ground biomass. The estimates of branches, stems, and the total above-ground appear to be higher than those of this mangrove forest. However, NAGANO

and KIRA (1978) assumed the biomass of an evergreen forest at Minamata, Japan, to be 7.1 ton/ha in leaves, 280 ton/ha in stems, 330 ton/ha in the total above-ground biomass, and 74 ton/ha in roots. The leaf biomass for the permanent plot was somewhat smaller than that at Minamata, whereas the root biomass of the mangrove forest was greater. Because *Rhizophora* spp. have a larger amount of above-ground roots and because the tree height is considered to be the distance above the highest root, the stem biomass should be smaller.

The leaf-area index (LAI) in the area can be calculated from the leaf biomass and the leaf area/leaf weight ratio. The LAI value of 6.6 ha/ha was larger than expected. A value of 3.7~4.2 ha/ha was reported on Phuket Island, Thailand by CHRISTENSEN (1978), and that of 4.4 ha/ha in Puerto Rico was reported by GOLLEY and others (1962). The difference of LAI in this stand from others may be ascribed to the tree age of their areas, and which were younger than that of this study area.

Although all others, excluding *R. apiculata*, represent 21 percent of the total number of trees, the ratio of standing biomass for the other species to the total was only 8.6 percent. This effect would be caused by the small range of the diameter distribution in other species. The root biomass for *Rhizophora* spp. was 31 percent of the total standing biomass. According to GOLLEY and others (1962, 1971, 1975), a similar figure was 65.3 percent in Panama and 57 percent in Puerto Rico. If, however, the average tree heights (7~8 m), the basal areas (13.6 m<sup>2</sup>/ha), and the ages in their study areas are taken into account, they may have overestimated their root biomass, and thus it may not exceed half of the total standing biomass.

Relative light intensity on the permanent plot was higher than that of evergreen forests in the temperate or warm-temperate zone which range from 0.5 to 3 percent (TADAKI, 1963). This difference may be due to the fact that blade angles (ARAKI, 1972) of mangrove trees are lower than those of temperate forests. MONSI and SAEKI (1953) reported that the relative light intensity was reduced by the LAI. The equation is:

$$I/I_0 = \exp(-KF) \quad (3)$$

where  $I$  and  $I_0$  represent light intensity inside and outside of the stand, respectively.  $F$  is the LAI, and  $K$  is an extinction coefficient.  $K$  of the site was calculated 0.34 which was lower than that of the warm-temperate forests (0.4~0.5) (TADAKI, 1963). This difference might be caused by the foliage structure of mangrove forests with an absorption rate of incident light lower than that of the warm-temperate forests, that is, foliage of man-

grove forests is more clumped or the blade inclination is more acute than that of the warm-temperate forest (TAMAI and SHIDEI, 1973).

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