ECOLOGICAL STUDIES OF MANGROVE FORESTS IN SOUTHERN THAILAND

——ROOT EXCAVATION BY THE TRENCH AND RANDOM MONOLITH METHOD——

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INTRODUCTION

On the west coast of Malay peninsula, a wide spreading mangrove forest covers the area of 178, 156 ha in Thailand (Aksornkoae et al. 1975). The forest is rich in flora and highly developed in structure. Mangrove forest of southern Thailand belongs to Indo-Malesian Group in the Old World mangal (Chapman, 1975). The local people intensively exploit the forest for charcoal and log. But there still remain the forest stands which can be regarded as the natural mangrove forests.

Mangrove ecosystem develops on the coastal area between inland and sea. It grows on the solar energy incident upon and the nutrients brought in from upper stream. And it releases the nutreints to the aquatic ecosystem through the litter productions.

Mangrove develops a peculiar root system to survive in saline, anaerobic substratum with tidal movements. A certain proportion of roots dies every year and are decomposed. It is well known that mangrove root system offers a spawning-bed for various kind of aquatic organisms. Therefore, the ecological study of mangrove root will afford an important imformation both for the forestry and fishery.

Several authors studied on the morphology of mangrove roots (Ogura 1940, Gill and Tomlinson 1977). Biomass of mangrove forest, aerial root and root are estimated by Golley et al. (1962), Golley et al. (1975), Lugo and Snedaker (1973), Briggs (1977), and Christensen (1978). The detailed quantitative study on underground mangrove roots are highly needed.

The present study forms a part of a series of the mangrove ecology conducted in Ranong, southern Thailand, by "Forest ecological study of Thai-Japanese joint integrated project on mangrove productivity and development" since 1981.

In the joint project, the forest ecology group has three themes, *i. e.* 1. Ecological equilibrium and carbon cycling of mangrove ecosystem, 2. Regeneration process of mangrove forest, 3. Species ecology of mangrove tree species.

The stand structure and floristic composition has been analyzed. Biomass of above-ground level and root has been estimated by the method of allometry.

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The present study is aiming at the estimation of the root biomass and the analysis of the underground structure of mangrove forest. the distribution pattern of root density obtained from the trench method as well as random sampling was analyzed to simulate the root biomass.

STUDY SITE

The study site for the present study locates on Ranong province, southern Thailand near to the Isthmus of Kra, Malay Peninsula. A permanent plot (Hatsaikhao plot: 50×260m) was established in 1981 on an estuarine bank of river Ngao, apart 12km south-east from Ranong city (9°58′N, 98°38′E, Fig. 1).

The zonal structure observed here, was the *Sonneratia* zone on the front, followed by the *Rhizophora* dominating zone on the back. The Sonneratia zone is a narrow belt along the coast line. Dominant species are *Sonneratia alba* accompanied by *Rhizophora mucronata*, *Aegiceras corniculatum* and some other dwarf shrubs. Advancing further into inland, *Rhizophora* zone follows often a narrow belt of transitional *Bruguiera* spp, *R. mucronata* and *R. apiculata*. *Rhizophora* zone forms almost pure stand of *R. apiculata* and is morphologically the most developed one. On the forest floor, the prop roots of *R. apiculata* develop. The first high tree layer is as high as 30m in average forming a continuous and dense canopy. Dense shrub layer exists under the canopy.

Hatsaikhao plot (50×260m) was placed perpendicular to the Andaman sea. The first 60m from the coast is in the *Sonneratia* zone and the rest is in the *Rhizophora* zone. The plot was subdivided into 10×10m subplots. All the trees larger than 4cm/10cm were recorded of their species and location. Trunk diameter at breast height or above prop root, total height, height of living branch, and that of prop root were measured.

Tree density was 1245 trees/ha. The largest trunk diameter and height were 67.0cm and 35.5m. Mean diameter was 10.9cm. Total basal area was 20.98m²/ha. *R. apiculata* shared 79.1% in tree number, *B. gymnorrhiza* 8.8%, *B. cylindrica* 6.7%. Another 5.4% was composed by *R. mucronata*, *Ceriops decandra*, *C. tagal*, *B. parviflora*, *Heritiera litoralis* and

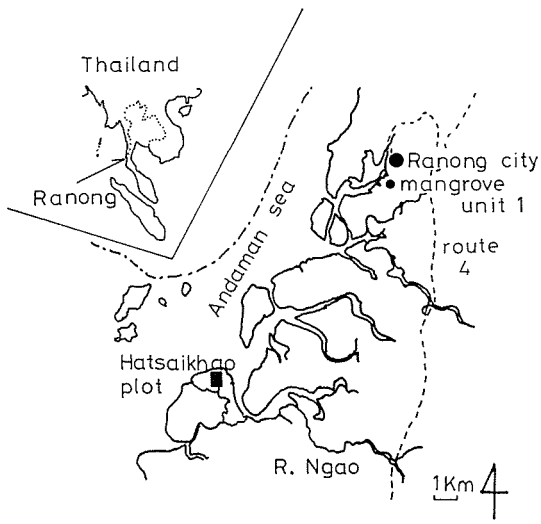

Fig. 1 Survey area and the location of Hatsaikhao permanent plot.

Intsia species.

According to the biomass study recently conducted (Ogino et al. in preparation), the stem, branch, leaf and root biomass of *Rhizophora* zone of Hatsaikhao plot for the trees of diameter larger than 10cm were estimated at 278, 56, 7.2 and 139 t/ha, respectively.

The mangrove forests in southern Thailand are quickly disappearing due to illicit felling by the local people. The area of permanent plot was by no means the exception of the illicit felling. In the permanent plot where 538 trees of over 4cm trees were marked in December 1981, 23 trees were cut, 6 trees died by November, 1982. Within another year additional 61 trees were harvested. By July, 1984 almost all the remaining trees were felled illegally (Vipak Jintana, personal communication). Thus, the plot became practically naked to lose the meaning of permanent plot. In December, 1983, another permanent plot was established in the adjacent area to the campus of Mangrove Research Center at Ranong.

ROOT SAMPLING METHODS

Underground root amount was estimated by the method of soil block excavation. Two types of soil blocks were adopted. The one was the systematic excavation of a trench, the other the random sampling of soil monoliths. Details are given as follows;

1. Trench In November and December, 1982, a trench was laid out between two big *R. apiculata* trees (diameter 44.5cm and 43.6cm, in Fig. 2) in *Rhizophora* zone adjacent to Hatsaikhao plot. The length of the trench was 15.5m, 20cm in width. The trench was subdivided lengthwise into 31 compartments, which are vertically composed of 10 horizons to reach to 1m in depth. Thus, 310 soil blocks were studied altogether. Each compartment was numbered from Compt. 1 to 31 in a row from the direction of tree No. 4 to No. 17 (Fig. 2).

A 15×20m plot was set up for the measurements of trees surrounding the trench as shown in Fig. 2. Tree location and species were recorded. Trunk diameter and height were measured. There were 22 trees in the plot and basal area totaled to 33.25m²/ha.

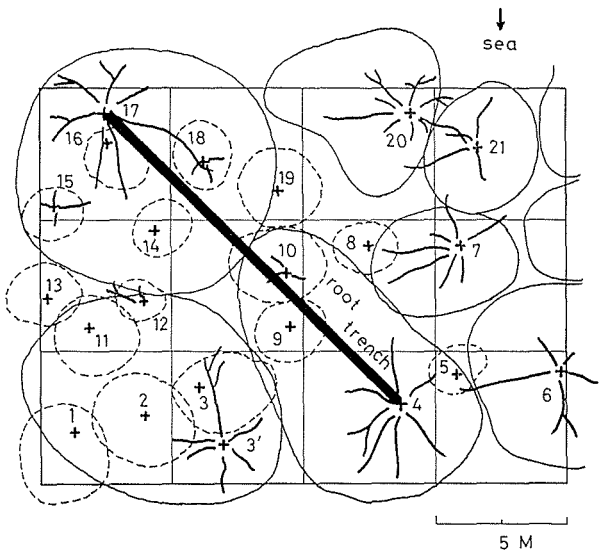

Fig. 2 The location of trench.

2. Random sampling of soil monoliths In December, 1983, 34 soil monoliths of 20×50×100cm were randomly sampled in *Rhizophora* zone of Hatsaikhao plot, as is illustrated in Fig. 3. Each monolith was subdivided into 10 horizons of soil blocks of 10cm thick. Thus, 340 soil blocks were studied altogether.

3. Root sampling procedure The root sampling process was same to both of the two methods mentioned above. The prop roots above ground were first cut and harvested to weigh fresh. Either a trench or a ditch was dug. Intruding water was bailed out. Soil blocks were sawn by small handsaws, and were packed in a plastic bag to carry to the seashore. All the contents were washed in the seawater on 1mm meshed screen to separate living roots from mud, sand, and/or other odd materials. At the forester's office in Ranong, the living roots were sorted into 8 root diameter classes, 0–2mm, 2–5mm, 5–10mm, 10–20mm, 20–30mm, 30–40 mm, 40–50mm and >50mm. The roots, thus sorted, were weighed fresh by beam balances. Small amount of fresh roots were sampled from each diameter class, and oven-dried at 105°C

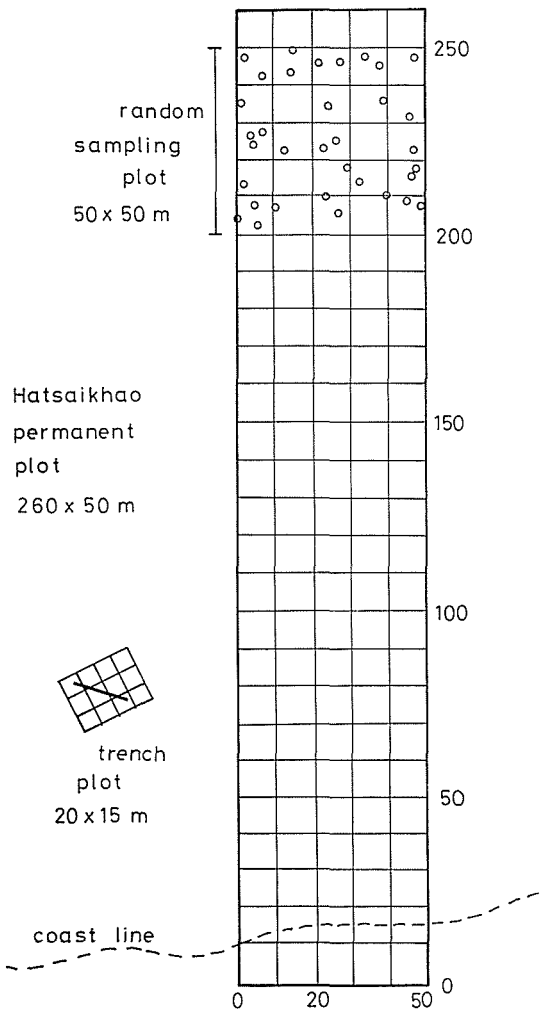

Fig. 3 The location of random sampled soil-monoliths in Hatsaikhao permanent plot.

for 96 to 120 hours until they reached to a constant weight for dry weight measurement. The conversion rates from fresh weight to dry weight were determined as given in Table 1.

Table 1. Conversion rates from fresh to dry weight according to root size (mm).

	0-2	2-5	5-10	10-20	20-30	30-40	40-50	>50mm	prop root
1982	0.190	0.215	0.252	0.233	0.338	0.464	0.459	0.559	0.575
1983	0.144	0.182	0.197	0.227	0.284	0.374	0.355	0.470	0.542

RESULTS AND DISCUSSION

1. Root biomass

Total dry weight of all the roots excavated amounted to 135.6kg/3.1m^3 and 46.8kg/3.4m^3 for the trench and random sampling of soil monoliths, respectively.

Simple conversion of the root density of the trench into the root biomass gave the figures as 437.4t/ha in total. Break down into size classes were 220.5t/ha (0-2mm), 4.3t/ha (2-5mm), 10.4t/ha (5-10mm), 26.0t/ha (10-20mm), 43.4t/ha (20-30mm), 33.3t/ha (30-40mm), 19.6t/ha (40-50mm), and 79.9t/ha (>50mm). Above ground prop roots were 118.3t/ha, to the underground roots of 319.1t/ha.

The results from the random sampling of soil monoliths gave 137.8t/ha in total and 60.4 t/ha (0-2mm), 5.3t/ha (2-5mm), 7.9t/ha (5-10mm), 18.9t/ha (10-20mm), 13.6t/ha (20-30mm), 16.8t/ha (30-40mm), 7.6t/ha (40-50mm) and 7.3t/ha (>50mm). The above ground prop roots were 31.5t/ha, to the underground roots of 106.3t/ha.

In all size classes, the results of estimation by the random sampling of soil monoliths was less than that of the trench. The former is three times larger than the latter. It is most likely the effect of the cuttings and the uneven, non-uniform distribution of roots in the soil to be attributable to the great difference of the estimations by the different methods. The root distribution pattern in Hatsaikhao plot will be discussed into details elswhere (Komiyama et al. in preparation).

The percentage of fine roots (0-2mm) to total roots was found very high, 50.4% and 43.9 % for the trench and the random samplings, respectively. Tabuchi et al. (1983) also mentioned of the high percentage of fine roots (72.3%) in a mangrove forest at Kapoer district, about 90km south of Hatsaikhao plot.

The biomass estimates so far reported from forest ecosystems are listed in table 2. In the table several estimates of root biomass are also incorporated. The high percentage of fine roots are reported in Amazon caatinga forest (Klinge 1978) and a tropical rain forest in Brazil (Stark 1977), although their categories of fine roots were less than 6mm in diameter. The mangrove forest in Hatsaikhao is characteristic to the big root biomass and the high percentage of fine roots.

2. Horizontal root distribution

In the trench method all compartments were linked in a row. The distribution of root density over the compartments give the imformation on the horizontal root distribution pattern in relation to the location of big trees.

In Fig. 4 the distribution of root of various size categories in the trench was illustrated.

Table 2. Root biomass estimates (t/ha) and fine root % in various kind of forest ecosystems.

Forest type	Shoot biomass	Root biomass	Prop root biomass	Fine root biomass	Fine root%	references
TM. Thailand	341.2	437.4	118.3	220.5	50.4	this
TM. Thailand	341.2	137.8	31.5	60.4	43.9	study
TM. Panama	46.1	14.4	50.0	—	—	10
TM. Florida (overwash)	—	—	52.0	—	—	16
overwash	—	—	41.9	—	—	16
riverine	26.6	—	14.6	—	—	16
riverine	37.2	—	3.1	—	—	16
riverine	22.9	—	22.3	—	—	16
fringe	24.9	—	27.2	—	—	16
fringe	25.6	—	17.2	—	—	16
scrub	4.7	—	3.2	—	—	16
island	—	8.0	25.8	—	—	16
succession	8.1	14.1	—	—	—	16
TM. Puerto Rico	162.5	189.8	116.4	—	—	9
TM. Thailand (3y. old)	14.6	—	6.2	—	—	1
(6years old)	39.2	—	10.8	—	—	1
(9years old)	75.3	—	17.8	—	—	1
(11years old)	116.3	—	18.7	—	—	1
(12years old)	128.6	—	20.7	—	—	1
(13years old)	147.1	—	20.3	—	—	1
(14years old)	165.0	—	22.9	—	—	1
Temp. M. Australia	144.5	147.3	—	—	—	4
Temp. M. Australia	112.3	160.3	—	—	—	4
TM. Thailand (15y. old)	97.6	—	61.2	—	—	6
TM. Malaysia (5y. old)	89.1	—	—	—	—	19
(18years old)	175.5	—	—	—	—	19
(28years old)	211.8	—	—	—	—	19
TRF. Brazil	—	255.0	—	50.0	19.6	14
TRF. Brazil	—	55.6	—	31.9	57.3	26
TRF. Ivory Coast	—	49.0	—	—	—	11
TRF. Brazil	335.0	56.0	—	—	—	12
Tropic. caatinga	—	132.0	—	92.4	70.0	15
Temp. Cryptomeria	123.4	33.4	—	3.5	10.2	28
Temp, cypress	139.3	43.0	—	4.7	11.0	29
Temp. artificial	200.0	40-60	—	0.1-1.0	0.2-1.0	13
Temp. fir	158.8	48.1	—	8.6	17.9	3
Temp. spruce(35y. old)	119.0	44.4	—	9.6	2.2	20
Sitka spruce	—	25.0	—	3.5	14.0	7
white spruce	—	—	—	1.25	—	21
white spruce	—	—	—	6.96	—	23
Pseudotsuga	—	13.7	—	—	—	22
pine-birch	—	10.6	—	—	—	25
Taiga. pine	—	26.0	—	—	—	24

TM, M-mangrove, TRF-tropical rain forest, Temp-temperate

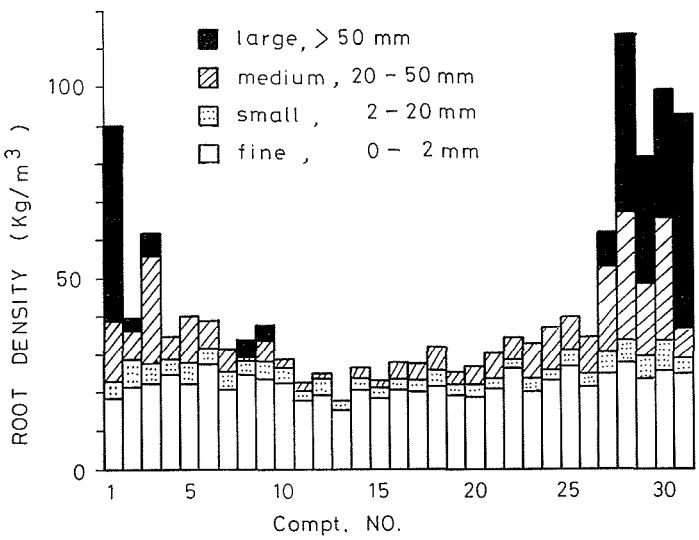

Fig. 4 Horizontal root distribution in trench.

The size class <2mm was categorized as fine roots, 2–20mm as small roots, 20–50mm as medium roots and >50mm as large roots, as Tabuchi et al. (1983) did.

Total root density was higher near to the both ends of the trench, where the proportions of large or medium roots were very high. Number of prop roots of tree No. 4 and 17 were accounted for the higher rates of larger roots. In the middle parts of the trench, total root density became lower and the proportion of fine roots higher.

Fig. 5 shows the root density of the random sampling of soil monoliths. The compartments of the higher proportion of larger roots (such as Compts. 5, 7, 25 and 30) were located near to big trees. The compertments of higher proportion of fine roots (such as Compts. 9, 10, 11, 21 and 22) were located far from the big trees.

It could be concluded from the observation that the large or medium roots occurs massively in the vicinity of big trees, while the fine or small roots distributes uniformly over the wider area of the mangrove forest.

3. Vertical root distribution

Vertical distribution pattern of root was illustrated in Fig. 6 summing the root densities of the same horizon for 31 or 34 compartments in the trench and the random sampling of soil monoliths, respectively.

Total root density was the biggest in the prop root horizon or ground surface, 27.0% for the trench and 22.9% for the random sampling. The deeper the horizon, the root density the less. It is worth to note even in the 10th horizon, considerable amount of fine roots are still existing. Large roots were found only in surface and upper horizons. Medium roots penetrated deeper upto 80cm depth but the mode of the distribution was in the first horizon. Small roots distributed in all the horizons above and underground, but the mode was in the second and third horizons. Fine roots also distributed in all the horizons except above ground surface and its mode in the deeper horizons.

It was concluded that the smaller the root size the deeper the distribution became. The

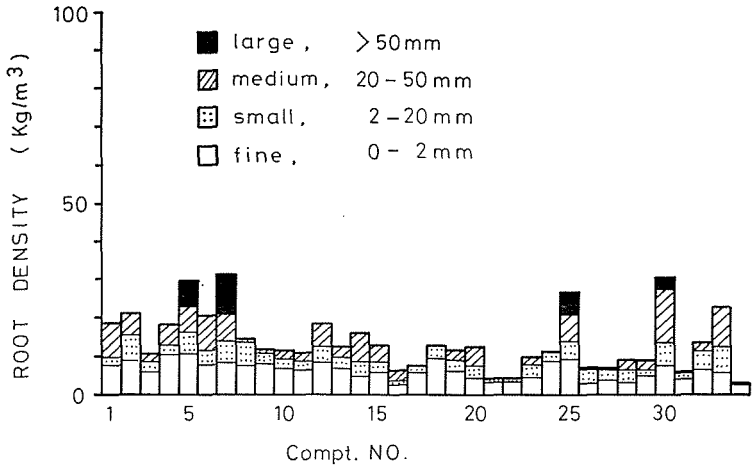

Fig. 5 Horizontal root distribution in random sampled soil-monoliths.

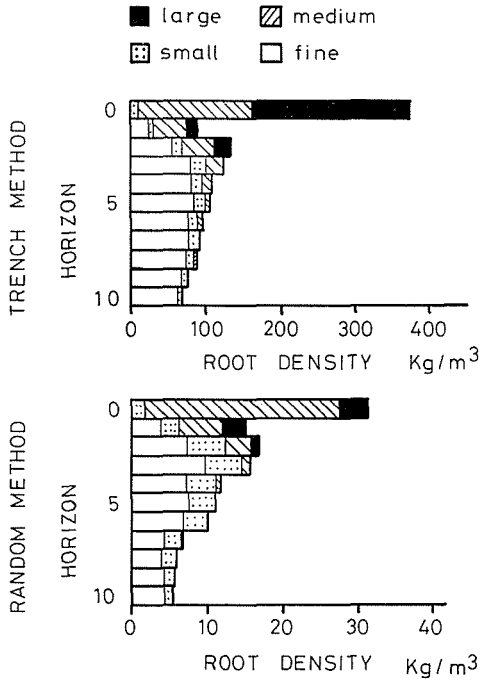

Fig. 6 Vertical root distribution.

fine roots were found to distribute rather evenly over wide range of depth. Considerable amount and even distribution of fine roots attracted our keen attention.

SUMMARY

Root biomass study was conducted in a mangrove forest at Hatsaikhao permanent plot, Ranong, southern Thailand. A trench and the randon sampled soil-monoliths were excavated in Novenber-December, 1982 and 1983.

Total root biomass for both methods were estimated at 437.4t/ha and 137.8t/ha, respectively. Fine root (<2mm) biomass at 220.5t/ha (50.4%) and 60.4t/ha (43.9%), respectively. Above-ground prop root biomass at 118.3t/ha and 31.5t/ha, respectively.

Larger roots occured massively in the vicinity of big trees, while the fine or smaller roots distributed uniformly over the wider area of mangrove forest. The smaller the root size, the deeper the root distribution became.

The mangrove forest in Hatsaikhao is characteristic to the big root biomass and the high percentage as well as the uniform distribution of fine roots.

Literature cited

1. Aksornkoae, S. (1975): Structure, Regeneration and productiuity of Mangroves in Thailand. ph. D. Dissertation. Michigan State University. 109pp.
2. Aksornkoae, S., Kongsangchai, J. (1982): Mangrove forest in Thailand. Royal Forestry Department. 38pp.
3. Baskerville, G. L. (1966): Dry matter production in immature balsam fir stands: roots, lesser vegetation and total stand. For. Sci., 12 49-53.
4. Briggs, S. V. (1977): Estimates of biomass in a temperate mangrove community. Austral. J. Ecol. 2, 369-373.
5. Chapman, V. J. (1975): The salinity problem in general, its importance, and distribution with special reference to natural halophytes. In Plants in saline environments. Poljakoff-Mayber, A. and Gale, J. edited, Springer Verlag, 7-24.
6. Christensen, B. (1978): Biomass and primary production of *Rhizophora apiculata* Bl. mangrove forest in southern Thailand. Aqua. Bot. 3, 43-52.
7. Deans, J. D. (1979): Fluctuations of the soil environment and fine root growth in a young spruce plantation. Pl. & Soil. 52, 195-208.
8. Gill, A. M., Tomlinson, P. B. (1977): Studies on the growth of red mangrove (*Rhizophora mangle* L.) 4. the adult root system. Biotropica 9(3), 145-155.
9. Golley, F. B., McGinnis, J. T., Clements, R. G., Child, G. I. and Duener, M. J. (1975): Mineral cycling in a tropical moist forest ecosystem. University Georgia Press.
10. Golley, F. B., Odum, H. T. and Wilson R. F. (1962): The structure and metabolism of a Puerto Rico red mangrove forest in May. Ecol. 43, 9-19.
11. Huttel, C. (1975): Root distribution and biomass in three Ivory Coast rain forest plots. In Tropical Ecological Systems, 123-130.
12. Jordan, C. F., Escalante, G. (1980): Root productivity in an Amazonian rain forest. Ecology 61(1), 14-18.
13. Karizumi, N. (1974): The mechanism and function of tree root in the process of forest production II. root biomass and distribution in stands. Bull. Gov. For. Exp. Sta. No. 259, 1-99.
14. Klinge, H. (1973): Root mass estimation in lowland tropical rain forest of central Amazonia, Brazil. II. coarse root mass of trees and palms in different height classes. Anais Academia Brasileira de Ciencias 45(3/4), 595-609.
15. Klinge, H., Herrera, R. (1978): Biomass studies in Amazon caatinga forest in southern Venezuera. 1. standing crop of composite root mass in selected stands. Trop.

Ecol. 19, 93-110.

16. Lugo, A. E., Snedaker, S. C. (1974): The ecology of mangroves. Ann. Rev. Ecol. & Syst. 5, 39-64.
17. Ogura, Y. (1940): On the types of abnormal roots in mangrove and swamp plants. Bot. Mag. Tokyo, LIV No. 646, 389-403.
18. Ogino K., Tamai, S., Tabuchi, R., Nakasuka, T., Aksornkoae, S., Sabhasri, S. (1984): Forest ecological studies of mangrove ecosystem (1) biomass of mangrove forest, Ranong, southern Thailand. In preparation.
19. Ong, J. E., Gong, W. K., Wong, C. H. (1982): Studies on nutrient levels in standing biomass litter and slash in a mangrove forest. BIOTROP Project No. 1.4.7, 48 pp.
20. Ovington, J. D. (1957): Dry-matter production by *Pinus sylvestris* L. Ann. Bot. 21 (82), 288-313.
21. Persson, H. (1980): Spatial distribution of fine root growth, mortality and decomposition in a young Scots pine stand in Central Sweden. Oikos 34(1), 77-87.
22. Reynolds, E. R. C. (1970): Root distribution and the cause of its spatial variability in *Pseudotsuga taxifolia* (*poir.*) Britt. Plant & Soil 32, 501-517.
23. Safford, L. O. (1973): Biomass of fine roots in a White Spruce plantation. Canad. J. of For. Res. 2(3), 169-172.
24. Saurina, N. I., Kameneckaja, I. V. (1969): The amount of roots of *pinus sylvestris* in the pinetum hylocomioso-cladinosum of the southern taiga. Bjull Mosk. Obsc. Ispyt. Prir. 74(5), 96-100.
25. Shakova, O. V. (1976): Occupation of the soil by roots in the Pinetum and Betuletum Oxalidoso-myrtillosum. lesovedenie No. 1, 88-91.
26. Stark, N., Sprat, M. (1977): Root biomass and nutrient storage in rain forest oxisols near San Carlos De rio Negro. Trop. Ecol. 18, 1-9.
27. Tabuchi, R., Ogino, K., Aksornkoae, S., Sabhasri, S. (1983): Fine root amount of mangrove forest: a preliminary survey. Indian J. Plant Sci. 1, 31-40.
28. Yamada, I., Shidei, T. (1968): On the root biomass of *Cryptomeria japonica* stands. Bull. Kyoto Univ., For. No. 40, 67-80.
29. Yamakura, T., Saito, H., Shidei, T. (1972): Production and structure of under-ground part of Hinoki (*Chamaecyparis obtusa*) stand (I) estimation of root production by means of root analysis. Jap. J. For. 54(4), 118-125.