S-11 Study on biomass of re-greening forest

Item	Description
1.Purpose result expected	To clarify the growth rates of planted trees under different site conditions (flooding depth, flooding duration, planting density), to provide basic data for predicting growth.
2.Samples, plot location, quantity, method of sampling	3 trees (each?) of 2 species around the edges of plots used for the research topics described above will be selected as objects of study. Bali site: Number of trees: 2 tree species X 3 plots X 3 trees = 18 trees Lombok site: Number of trees: 2 tree species X 3 plots X 3 trees = 18 trees
3.Measurement methods	1. Diameter (at base of roots) and tree heights will be measured. 2. Weights of above-ground organs including trunk, branches, leaves and above-ground roots will be measured.
4.Measurement interval	The measurement intervals are as follows: Bali site: Measurements about 2 years after planting and again 2 years after that Lombok site: Measurements about 2 years after planting and again 2 years after that
5.Analysis method	Dry weights of each organ will be measured as a function of forest age for each tree species and each set of site conditions. The relationship between organ growth and site conditions will be found.
6.Reporting periods (Midterm, final)	Midterm report: November 1995 Final report: 1997

(2) Research results

Priorities have been set for the research topics based on the research plan, considering the availability of land to conduct the tests and the wishes of the Indonesian side, and work on 7 of these research topics has already started.

1) Study on growth and survival rates of seedling in different environmental condition.

Purpose: To find the relationship of survival and growth rates to site conditions for each

planting site and each tree species.

<Bali site>

Servey:

A terrace test was conducted in tambak No. 32 of Block II to clarify the ground level height best suited for survival and growth of each tree species under differ ing conditions (environment) of flooding frequency, flooding duration, etc. (Fig. 2-2-14).

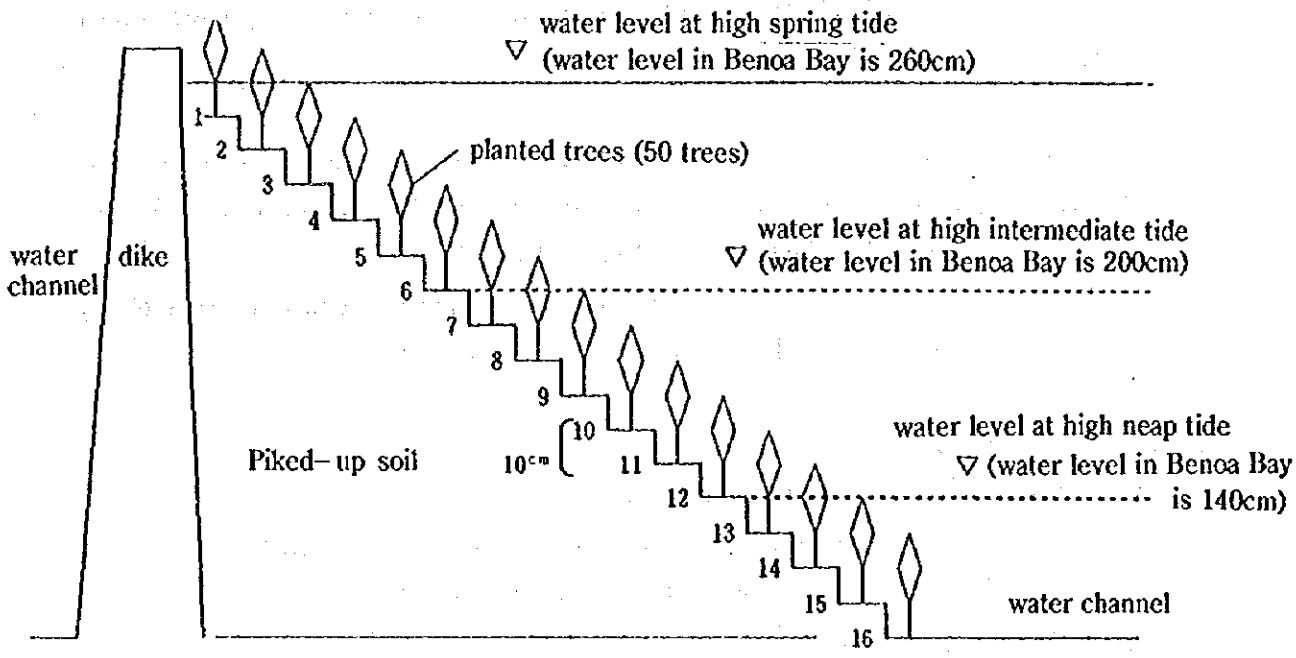


Fig. 2-2-14 Conceptual diagram of terrace test

A) Terraces of height difference 10cm, width 2m and length 45m were constructed.

B) Terraces were constructed over a 4-month period, from May to August during the dry season.

C) Soil used to construct the terraces was discarded soil dug out to construct the nursery adjacent to the Center.

D) The highest terrace level was set to 250cm according to the Benoa Bay tide height table. According to this table, at M spring tide the high tide is 260cm, the low tide 0cm; at intermediate tide the high tide is 200cm, the low tide 60cm; at neap tide the high tide is 140cm, the low tide 120cm.

Trees were planted in August 1993 during the dry season and in December 1993 during the rainy season.

(a) The full-scale test started with the planting in December 1993.

Trees planted were of the 4 species *Rhizophora mucronata*, *Rhizophora apiculata*, *Bruguiera gymnorrhiza* and *Avicennia marina*. The number of trees planted was 50 on each terrace.

(b) Pre test planting in August 1993

Trees initially planted were of the 3 species *Rhizophora mucronata*, *Rhizophora apiculata* and *Bruguiera gymnorrhiza*. Then *Xylocarpus granatum* and *Ceriops tagal* were planted in a supple mentary planting.

The number of trees planted was 10 on each terrace; of these 5 were planted in their pots, by the state Forestry Agency.

In both cases (a) and (b), growth of height, number of leaves opened and rate of loss by withering were measured for each tree, and the correlations with terrace flooding frequency and high tide height at neap tide were found.

In case (b), root system survey, leaf area measurement and measurement of dry weights of each organ were also conducted.

Results and discussion:

(A) Results of the full scale test, and discussion

a) The frequency of flooding of the terrace test site by sea water was observed over the 3 month period from September to December 1994 (Table 2-2-12).

Table 2-2-12 Flooding frequency of each terrace

Terrace No.	1	2, 3	4 ~ 6	7 ~ 9	10 ~ 12	13 ~ 16
(times/month)						
Flooding	0	11	21	31	41	50
	|	|	|	|	|	|
frequency	10	20	30	40	50	60

b) Height growth rates of each species on each terrace were found and compared (Fig. 2-2-15).

Except for *Avicennia marina*, the remaining 3 tree species reached their maximum growth on terrace No. 14; the growth rates declined on terraces No. 16 and 16. *Avicennia marina* reached its maximum growth on terrace No. 10; below that its growth declined.

At levels below terrace No. 14 all trees of species *Avicennia marina* withered and

died, so nothing could be measured.

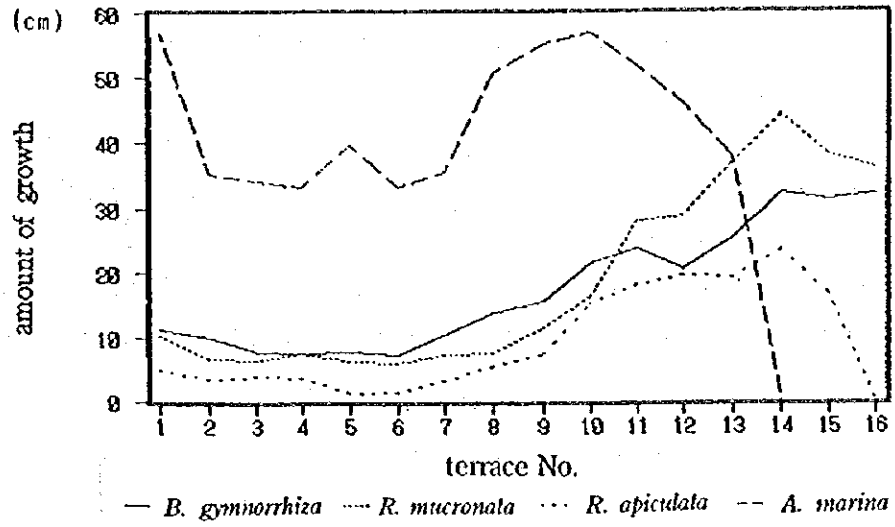


Fig. 2–2–15 Ground level height and height growth of each species

At the terrace at which the growth of height started to decline, it is believed that the flooding frequency and flooding duration interfered with respiration and assimilation, which suppressed growth.

As a result of measurement of soil salinity at each level (at 0 to 5cm depth), it was found that the salinity on terraces No. 1 and 2 was lower than that on terraces No,. 3 to 8. It is believed that fresh water was supplied, reducing the salinity (Table 2–2–13).

Table 2–2–13 Soil salinity on each terrace

Terrace No.	1	2	3	4	5	6	7	8
Soil salinity (‰)	2.91	2.59	4.04	5.88	4.30	3.80	3.85	3.14

Terrace No.	9	10	11	12	13	14	15	16
Soil salinity (‰)	2.49	2.16	1.65	1.55	1.89	1.85	1.82	2.08

Since morning dew was observed to form on the terraces even during the dry season, it is considered likely that dew and rain that fell on the service road penetrated to terraces No. 1 and 2, which are adjacent to the service road.

Consequently, the data from terraces No. 1 and 2 have been excluded from the analysis.

c) The number of leaves that opened was found for each tree species on each terrace, and compared (Fig. 2-2-16).

The increase in the number of leaves was large for Rhi zophora mucronata on terraces No. 11, 12, 13 and 14, and for Rhizophora apiculata on terraces No. 10, 11 and 12, so it is believed that these species grew to be most healthy on these terraces.

Bruguiera gymnorrhiza and *Avicennia marina* showed double peaks, but the peak on terraces No. 1 and 2 was discarded as explained above. The remaining peak was found for *Bruguiera gymnorrhiza* on terraces No. 8, 9, 10 and 11, and for *Avicennia marina* on terraces No. 8, 9 and 10, showing that these species grew to be most healthy on these levels.

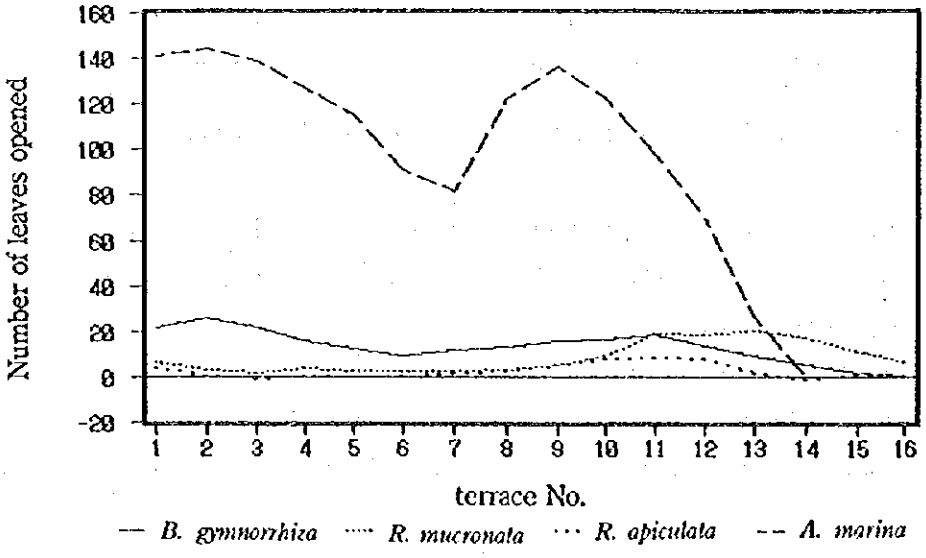


Fig. 2-2-16 Increase of number of leaves at each ground level height for each species

d) The rates of wilting and dying were found for each tree species on each terrace and compared (Fig. 2-2-17).

The wilting and dying rates of *Rhizophora apiculata* and *Avicennia marina* became high at levels where they were flooded frequently, at and below terrace No. 13 for *Rhizophora apiculata* and at and below terrace No. 11 for *Avicennia marina*. *Bruguiera gymnorrhiza* and *Rhizophora mucronata* also showed increases in the rate of wilting and dying at and below terrace No. 12 and terrace No. 16, respectively, although the increases were not as extreme as for the first two species.

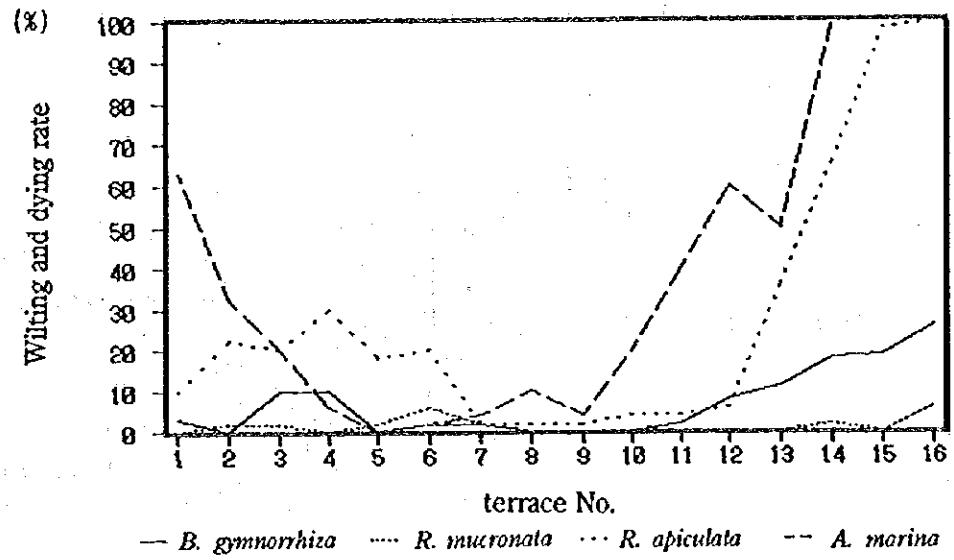


Fig. 2–2–17 Wilting and dying rate as a function of ground level height for each species

e) From the results of a), b), c) and d) above, it was decided that ground height levels that meet the following conditions are suitable for growing each tree species (Fig. 2–2–18 and Fig. 2–2–19):

(a) The amount of height growth tends to increase, and if possible is at its peak.

(b) the increase in the number of leaves is at or near its peak.

(c) The wilting and dying rate is 20% or less.

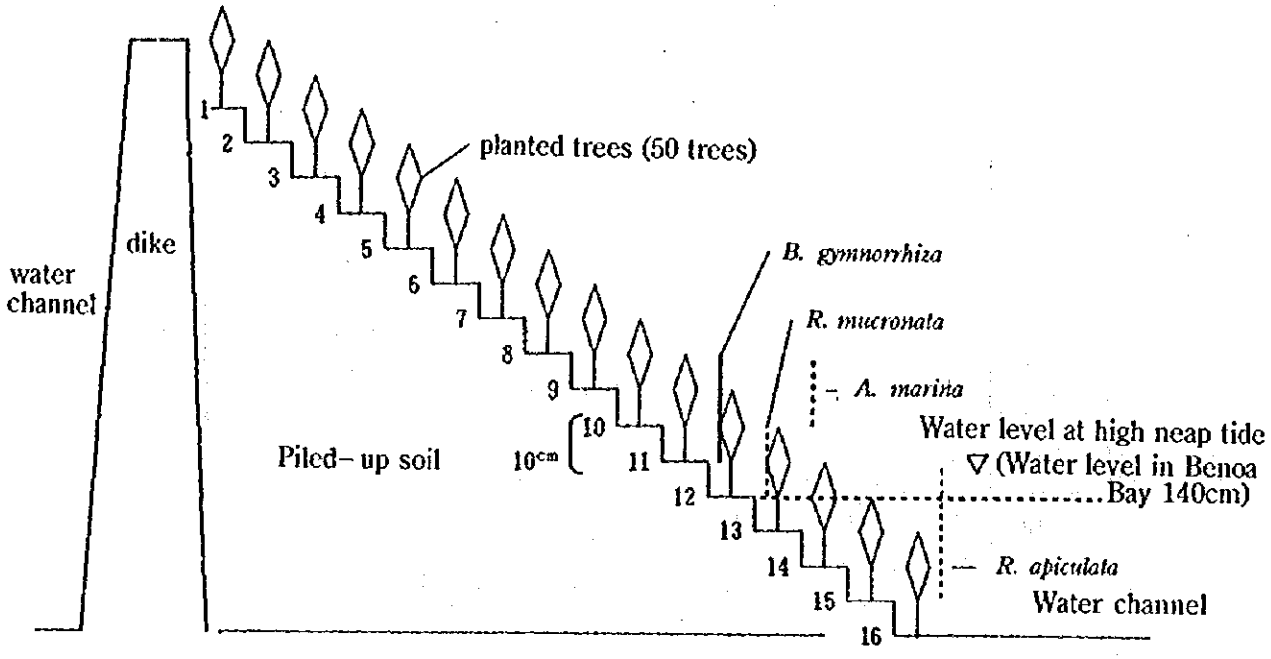


Fig. 2-2-18 Suitable ground level heights for each tree species at high neap tide

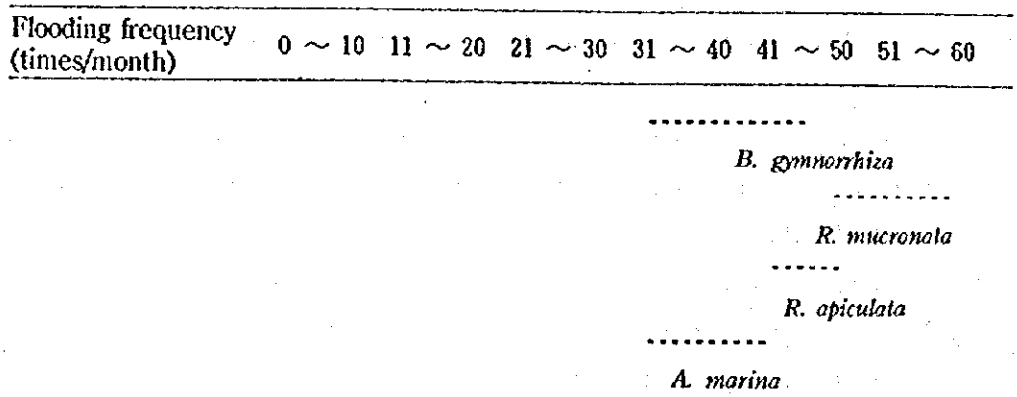


Fig. 2-2-19 Appropriate flooding frequency for each tree species

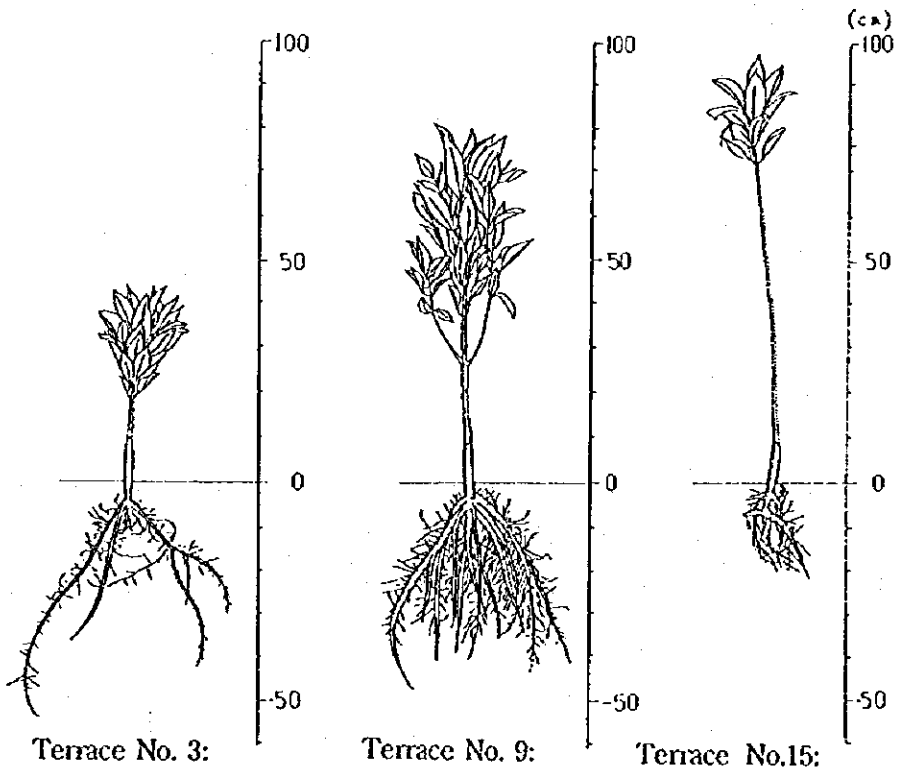
f) The plan for continuing work will be based in these test results.

(B) Pre test results and discussion

a) One year after planting trees were dug up and their root systems investigated. The results were classified according to whether the ground level height was at, above or below the appropriate ground level height arrived at in (A) above (Table 2-2-14, Fig. 2-2-20).

b) At the suitable ground level heights, root systems had many roots and they were well-developed. At high ground level height the roots grew deeper into the soil to seek water, but the roots were still of diameter 5mm or more and there were a good many hairs.

On low ground root systems had few roots and the roots did not spread out much.



Terrace No. 3: high neap tide level + 90cm

Terrace No. 9: high neap tide level + 30cm

Terrace No.15: high neap tide level − 30cm

Fig. 2-2-20 Growth forms for different ground level heights

Table 2-2-14 Survival and growth conditions on terraces above, at and below the most appropriate ground level height

Terrace No / level	(high ground height) No. 3	(appropriate ground level height) No.9	(low ground level height) No. 15
(A) Root depth (cm)	58.5	46.4	27.0
(B) Root width (cm)	54.8	6.2	16.0
(C) Number of roots per tree of 5mm or greater diameter	3.8	9.8	4.3
(D) T/R ratio (excluding part with viviparous seeds)	1.73	2.79	3.12
(E) Average growth of height after planting (cm)	17.8	42.7	61.9
(F) Average increase of number of leaves after planting	36.3	59.0	11.7
(G) Leaf area/tree (cm^2)	641.2	1,016.5	278.5
(H) Number of branches/tree	14.0	18.0	22.3
(I) Wilting and dying rate (%)	20.0	0.0	40.0

c) The weight ratio of the above-ground parts to the underground part (the T/R ratio) was smallest for trees at high ground level, making it appear as though the trees were stable and growing well, but the above-ground part grew less that at the suitable ground level height.

d) Regarding the leaf area per tree, the difference between appropriate ground level height and other ground level heights is clear. This is believed to be because having a greater number of leaves is advantageous for assimilation. On ground such as these former shrimp ponds where the flooding depth is deep, maintaining a superior material production capability from an early age is believed to improve the chances for survival and growth.

e) At the terraces of appropriate ground level height, *Rhizophora mucronata* and *Rhizophora apiculata* were observed to have grown branch roots 9 months after planting. This is believed to be because growth was faster than at other ground level heights, so that the trees reached the stage of growing supporting roots more quickly.

f) In the comparison of growth 1 year after planting, there was a great difference in the

form of growth of the trees, for example in the factors discussed in b), c) and d) above, at different ground level heights.

Consequently, the fact that the ground level height affects survival and initial growth so that the trees can satisfy the desired criteria is well established.

<Lombok site>

Survey method:

Plots were established extending from inland to the ocean (July and november, 1993) and having different condi tions of ground level height, soil and presence of roots remain ing from earlier cuttings (February 1994), and height growth, number of leaves and number of branches were measured (Table 2--2--20, Fig. 2--2--21).

Table 2--2--20 The site environment of each plot

Factor		Plot															
		A	B	C	D	E	F	G1	G2	H	I	J	K1	K2	K3	K4	K5
Soil	muddy					*	*	*	*	*	*	*	*	*	*	*	*
	sandy	*	*	*	*		*	*	*	*	*	*					
Flooding depth	shallow			*	*	*	*	*	*	*	*	*	*	*	*	*	*
	intermediate		*														
	deep	*															
Roots remaining from previous cuttings	many					*	*	*	*	*							
	few										*	*	*	*	*	*	*
	none	*	*	*	*												

Note) Asterisks indicate the site environments of each plot.

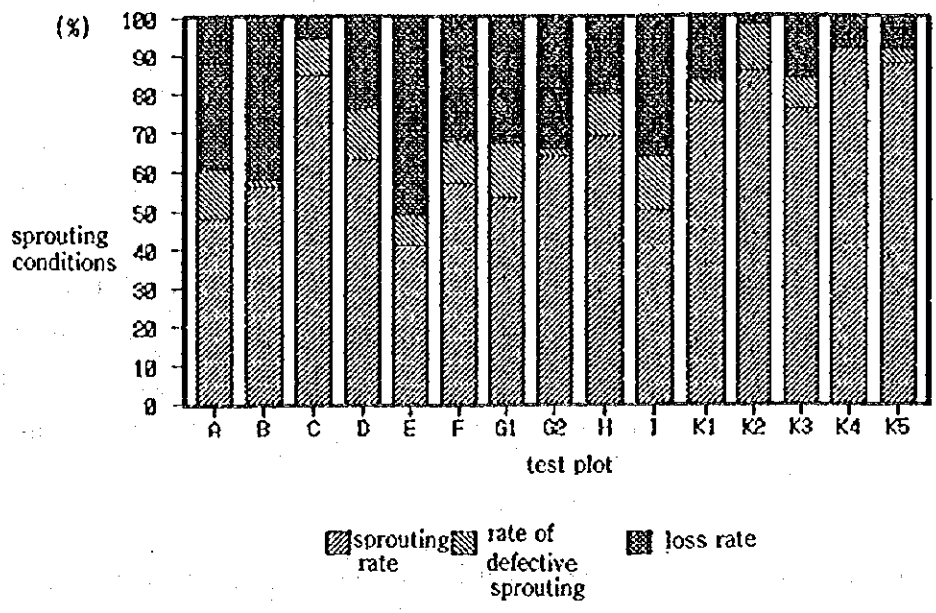


Fig. 2--2--21 Sprouting conditions for each site environment

Results and discussion:

A) From the results on test plots A, B and C, there were great losses among the directly planted seedlings on plots A and B where the ground level height is low and the flooding depth is deep. The causes of this are believed to be washing away by waves and predation by crabs, but since there were few crab holes on the sandy ground, it is believed that washing away by waves was the main cause. In response to this problem, a test was conducted of preventing trees from being washed away by driving stakes around shallow shoals where the tidal flow is strong (September 1994); there is a need to establish a similar test plot in the vicinity of plot A (Fig. 2--2--22).

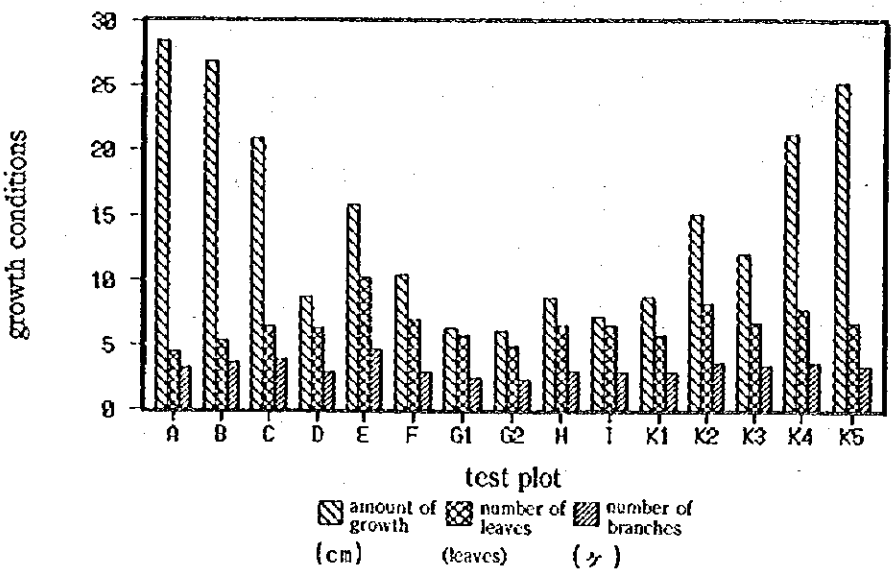


Fig. 2--2--22 Growth conditions for each site environment

B) On plots E, F, G1, G2, H and I, most of the soil is muddy mixed with sand, the ground level is high, and there are many roots from trees that formerly lived on the sites. Many crabs live on these plots; a survey involving digging old roots up at locations on plots G, E and F where trees had been lost, at the locations where the most trees were lost it was found that about 30% had been broken, apparently by crabs. Considering that crabs seem to like to live in this kind of environment, in the future where this kind of site environment exists it will be necessary to consider such measures as planting large seedlings or, where damage to trees by crabs can be expected, planting trees with high density.

C) On plots K1, K2, K3, K4 and K5, growth and survival of directly--planted seedlings are

compared according to seed size. Short er seeds gave greater growth and lower loss rates. This is be lieved to be because the trees need to grow high in order to overcome long flooding duration, and there is little wave action to wash the seedlings away. In addition, in this kind of site environment there was little of the crab damage described in B) above, so overall the loss rate was low, only 8%.

D) The rate of defective sprouting reflects the number of seedlings that survive but have top parts that are naked of leaves and fail to show growth of shoots. As a result of a sur vival survey of areas planted in the 1993/94 fiscal year, the defective sprouting rate was found to average 16%. Regarding the cause of this, Mr. Nakamura, a short-term expert, did a survey in which he extracted some of the seedlings that showed defective sprouting, and found wood borers on 67% of them.

Consequently, when seeds are gathered they should be checked for evidence that wood borers have entered, and only healthy seeds should be gathered.

2) Examination on planting method

Purpose: To develop low cost methods of planting that will promote the survival rate and growth of the planted trees.

Study method:

<Bali site>

Experimental plots involving the use of furrows, fertilization, charcoal, etc. were established for each tree species. The plots involving the use of furrows and upland seeding were established in August 1993 and December 1993. Pots involving the use of fertilization were established in August 1993 and December 1994. Plots involving the use of char coal were established in August 1993.

The plots established in August 1993 were as follows:

Tree species: 3 tree species (*Rhizophora mucronata*, *Rhizophora apiculata*, *Bruguiera gymnorrhiza*)

Planting methods: 6 methods (furrows, charcoal, fertili zation, potted).

<Lombok site>

A test was conducted with stakes driven to prevent seedlings from being washed away.

Results and discussion:

The results of a survey taken 7 months after the experimental plots were established in August showed that *Rhizophora mucronata* planted on cultivated ground showed good growth, and this method is being adopted in the operational reforestation. The survival rates of seedlings planted on furrows after 7 months were high, but many leaves were

disfigured by insect damage.

From the results of survey of plots established in December, upland seeding results in improved water drainage around the roots, but the number of crabs increases resulting in considerable damage by predation. In addition, since the roots can be exposed by ero sion with danger of the tree being washed away, it is necessary to drive stakes to prevent blowdowns.

The results with charcoal are for Rhizophora apiculata, so a full scale test was performed.

Dense planting was started with the test in December 1994.

In the case of Rhizophora mucronata, planting by

dense planting gave better growth than planting of 1 tree (as a result of the survey taken 8 months after planting; see Table 2-2-21).

Table 2-2-21 Comparison of growth in the ??? test

Tree species		Growth of height (cm)	Number of leaves opened (number of leaves)
Rhizophora mucronata	1 tree	33.5	5.1
	3 trees	36.8	5.2
	* 5 trees	36.0	8.7
Bruguiera gymnorrhiza	* 1 tree	33.2	- 0.8
	3 trees	25.0	- 1.7
	5 trees	26.6	- 2.5

Note) Asterisks indicate tree planting densities that tended to give good growth.

3) Study on planting density

Purpose:

The growth process of planted trees for each planting density was compared and the effect of planting density on initial growth and the form of the trees was surveyed to find the most suitable tree planting density for the purpose of reforestation.

Survey method:

<Bali site>

Plots with the same site conditions but different tree planting densities were established for each tree species in the tambaks.

Experimental plots with tree planting densities of 2 X 3, 2 X 2, 2 X 1, 1 X 1 and 0.5 X 0.5 meters were established.

On these plots, 4 tree species were planted: *Rhizophora apiculata*, *Bruguiera gymnorrhiza* and *Avicennia marina*.

Trees were planted in June and August 1994.

Results and discussion:

<Bali site>

The trend was measured in June and August 1 yearafter planting.

<Lombok site>

A test site was established during the 1994 fiscal year, and the study started.

4) Trial and study on planting at delta area

Purpose:

To develop methods of planting artificial forests on sandy tidelands and on sand deposits within coral reefs.

Survey method:

A 4.2 hectare experimental plot was established on sandy land on the shore of Benoa Bay. The tree species planted were *Rhizophora mucronata* and *Avicennia marina*.

Results and discussion:

About 1 month after planting fine particles of oil and mud (unconfirmed) and barnacles had become attached to the trees; 70% of the trees had hard and thick leaves (3 to 5mm thick in the case of *Rhizophora mucronata*); the leaves were covered with grime, and wilted and died 4 months later.

As a comparison test, an area was established in which adhering oil and barnacles were removed twice a month. There sults of this test were as follows.

It is clear that oil coated muddy soil was one of the causes of tree losses, but since this is a local problem only a small scale follow up survey is planned.

5) Study and demonstration on planting each provenance seed

Purpose:

To grow seedlings of each tree species from seeds gathered from different areas around Indonesia, and compare their growth. The results become basic data for the selection of tree species and seed source areas.

Survey method:

A total of 7 tree species, including the 5 principal species used in the reforestation, *Rhizophora mucronata*, *Rhizophora apiculata*, *Bruguiera gymnorrhiza*, *Avicennia marina* and *Sonneratia alba*, and 2 other species, *Xylocarpus granatum* and Ceriops tagal, were planted in the educational and exhibition forest at the Center Site.

Table 2-2-22 Comparison of survival when oil and other adhering substances are removed

	number of trees at start of test (3 months after planting)	number of trees at time of survey (2 months after start of test)	(planted February 1994) (survival rate %)
removal area	34	26	(76%)
test object area	27	1	(4%)

Seeds were to be gathered from the following areas: Northern Sumatra, Central Sumatra, Western Java, Central Java, Eastern Java, Bali, NTB, Kalimantan, Southern Sulawesi, NTT and Irian Jaya.

Seedlings were grown from the gathered seeds and replanted still in their pots.

Results and discussion:

Seeds were gathered from 7 locations during the 1994/95 fiscal year.

Since the optimum flowering and fruiting seasons in each area were not known, the necessary number of seeds of all species could not be obtained. It will be necessary to gather seeds again and obtain the required number of seeds of each species during the current fiscal year.

Forest planting with trees grown from seeds gathered in the 1993/94 fiscal year was started after seedlings were grown in pots.

6) Study and trial on planting of every seedling's form

Purpose:

To investigate the relationship between the form of the seedlings at the time of replanting (potted seedlings, direct planting of seedlings, bare-rooted seedlings, natural seedlings , direct planting of seeds) and survival rate and thus decide on the appropriate form of seedlings to use for each tree species, considering the need to shorten the seedling growing time, cost, seedling growing conditions, etc.

Survey method:

(A) Seedlings of the 3 tree species *Rhizophora mucronata*, *Rhizophora apiculata* and *Bruguiera gymnorrhiza* were planted at their appropriate ground level heights on the terraces in Block II No. 32, and then the test was performed by replanting potted seedlings after 2, 4, 6 and 8 months. About 30 trees were planted in July 1994.

(B) Natual seedlings of *Sonneratia alba* was planted in an area set aside for testing the survival and growth natural seedlings after replanting.

(C) On Gili Petagan Island at the Lombok site, an area was established for comparison of potted and directly planted seedlings. 100 seedlings each of *Rhizophora mucronata*, grown

to 60cm over 5 months, were planted potted and directly.

Growth of height, number of leaves opened, distance between branches and survival rate were measured in each test.

Results and discussion:

(A) Only a short time has passed since the test started, so a definitive result has not yet been obtained, but the directly planted *Bruguiera gymnorrhiza*, although they did sprout, failed to show growth of shoots after 2.5 months. This study is continuing on this and other species.

Table 2-2-23 Survival rate of natural seedlings after replanting for different gathering methods

Method	Survival rate	Planting interval
Extraction from ground without dirt	0 %	4 months after planting
Digging up with dirt	72 %	4 months after planting

(B) A growth and survival test of natural seedlings of *Sonneratia alba* seedlings was performed; 8 months later leaves started to open on the 58% of trees that survived that long, so these are considered to have survived.

(C) As of 6 months after replanting, the survival rate of directly planted seedlings was low, only 55%. Of these, shoots failed to appear on 27% although they had not withered (the maturity of the seeds was checked). It is believed that the problem in many cases was wood borers, as in case D at the Lombok site discussed in (2) 1) above. In addition, it is believed that most of the 18% that disappeared were washed away by the waves, as in case A) at the Lombok site discussed in (2) 1) Above. These results will become basic data for selecting either direct planting or planting of potted seedlings, with a comparison of the cost also entering into the decision.

7) Trial and study silvo-fishery

Purpose:

To conduct a trial of a Silvo fishery model which will make it clear that a mangrove forest functions well as a forest habitat for aquatic organisms and, at the same time, provide a useful method of utilizing the tambaks for forests from which the local people will derive benefit.

Study method:

Three sites on tambaks with deep flooding depth adjacent to the Bali natural forest were selected; one site was used for a normal planted forest, one site was left as an abandoned tambak, and one site was converted to a model Silvo fishery pond for comparison (Table 2-2-24).

Table 2-2-24 Details of the Silvo-fishery pond

number of tambak		area	use of the site	tree species planted (and planting interval)
Block II	No. 19	0.58 ha	Silvo- (1 x 1 m) fishery	*Rhizophora mucronata* *Avicennia marina* *Rhizophora apiculata* *Bruguiera gymnorrhiza*
	No. 18	0.58 ha	general planting (2m x 2m)	*Rhizophora mucronata*
	No. 17	0.56 ha	unplanted control area	--

Water gates were constructed in April 1994, the test was started, and fishes and plankton were gathered in July.

The test was restarted from August 1994, and the change observed after he site was let stand for one year.

Results and discussion:

It had already been shown that more fish are attracted to the Silvo-fishery pond than to the control pond (Table 2-2-25). In the future the relations among growth of the replanted mangrove forest, quantity of plankton, and amount of fish gathered will be investigated.

Table 2-2-25 Aquatic organisms gathered at the start of the test

Gathering location	Aquatic organisms (fish, shrimp, etc.)	Amount gathered
No 19	333 organisms	7.00 kg
No 18	35 organisms	0.22 kg
No 17	22 organisms	0.07 kg

Sea water was samples, and the species and quantity of plankton determined at the edge of the natural forest when the sea reached that location at high spring tide, inside the natural forest, in the seedling growing plot and in the model Silvo-fishery pond (species were determined by a JICA expert, Mr. Tsumura, who worked on the JICA multi species seedling production techniques development plan; Table 2-2-26).

Table 2-2-26 Plankton gathered (unit: number of organisms)

I T E M	Harpacticoda	Mysidacea	Egg	Other
Test gathering location				
No. 19	42	–	3	2
No. 18	22	–	–	–
No. 17	16	–	–	4

In order to increase the quantity of organisms gathered in the future, it will be necessary to take thorough measures to prevent organisms that once enter the ponds from escaping.

It is believed to be necessary to determine the quantities and species of plankton periodically, and also to determine the effect of shading of the planted trees, in the future.

8) Study on criteria of supplementary planting (not started yet)

Purpose:

To investigate criteria for supplementary planting that is suitable for the purpose of the reforestation, and to set the planting time, species planted, planting method, planted area, etc.

Study method:

Plots were established for each tree species corresponding to the amount of loss by withering. The cause of with ering is to be determined and suitable countermeasures taken, and experimental plots where supplementary planting is to be done h(with different proportions of supplementary planting) and not done established.

Results and discussion:

In the production forest and the conservation forest, as a rule supplementary planting is to be done when whole groups of plants are lost by withering (including in the forest at the Lombok site). In addition, as a rule supplementary planting is to be done in the educational and exhibition forest.

When the condition of loss by withering is determined, when there are 2 or more locations where the same tree species has about the same survival rate different amounts of supplementary planting will be done and the results compared.

The supplementary planting survey should be done at least 6 months after planting, when the survival rate has stabilized.

In the areas that were planted in the 1993/94 fiscal year, in tambaks where the rate of withering loss is high the cause will be investigated and additional trees of species suitable for the ground level height of each tambak planted.

9) Study on water gate contral (not started yet)

Purposes:

(A) To cut openings in the dikes of the tambaks, flood the tambaks with sea water and then drain them, and investigate the effect on the water environment and on the survival and growth of the planted trees.

(B) To develop techniques for controlling the flooding of the tambaks by sea water and drainage of the sea water, using the water gates.

Study method:

4 former shrimp ponds are being used for this study. A water gates is dug in dikes on all 4 sides of one of the ponds (all of the dikes around that tambak), in dikes on 2 opposite sides of another tambak and in the dike on one side of another tambak. Two water gates are dug in dikes on all 4 sides of a tambak. Each cut is 1m across the bottom and 3m across the top. *Bruguiera gymnorrhiza* will be planted at (2m × 2m) intervals.

Results and discussion:

(A) The survival rate in each of the areas was low. The causes of this high rate of withering were believed to be inappropriate flooding frequency and flooding interval, and poor drainage. The species planted in 1993/94 were selected on the basis of water depth in the water gates at high intermediate tide, and it is believed that the probability of poor drainage is high.

(B) It is expected that it will be difficult to secure adjacent groups of tambaks to test water gate control in the future, so rather than controlling water gates for a group of tambaks at one time, methods of construction that permit adjustment of the amounts of sea water supplied to and drained from a single tambak will be developed.

10) Study on salinity control (not started yet)

Purpose: To compare the survival and growth rates of planted trees at different salinities, and to develop a method by which the salinity can be easily diluted. As a result of a survey of former shrimp ponds where it is easy to form brackish water using river water or other fresh water, experimental plots are to be established in Block II No. 43 (river water) and No. 56 (spring water).

11) Study on biomass of re-greening forest (not started yet)

Purpose: Data for the purpose of clarifying the growth rates of planted trees under different site conditions (flooding depth and flooding duration) will be used as basic data

for predicting growth.

Dry weights of the 450 trees involved in the pretest for the terrace test were measured.

This study was for the purpose of comparing the forms of initial growth of trees planted on the different terraces. Consequently, work on the present research topic, to predict the amount of production per hectare in the future, is considered to have not started yet.

In the future, a planting density test of trees on adjacent plots will be conducted.

(3) Manual for the spread of planted forests (draft)

1) Forests planted in former shrimp ponds

A) Determination of planting method etc.

(a) Selection of tree species

(i) Measure the water level and flooding frequency of sea water at high neap tide, and plant tree species judged to be appropriate for each ground level height (for the tree species which is appropriate for each ground level height, see the results of the terrace test).

(b) Selection of location

(ii) Avoid planting trees immediately after the termination of shrimp growing operations; allow about 1 year for the site to be cleaned up before starting to plant forests.

(iii) In former shrimp ponds in which there is always stagnant water present, ordinary planting is avoided and instead earth is piled up to create raised ground on which to plant trees.

B) Transport of seedlings

(a) From the seedling plot to the former shrimp pond

(i) Transfer 40 selected potted seedlings to a plastic box and load the boxes on trucks (10 boxes per 2 ton truck) for transport.

(ii) If the planting area is beyond the end of the vehicle road, transfer the boxes to one wheeled wheelbarrows for transport to the former shrimp pond where the trees will be planted.

(b) Transport within the former shrimp pond

(iii) Transfer the potted seedlings to snowboards with rope at tached (10 or 20); the people who will do the planting then pull the snowboards to the planting sites.

C) Planting

(a) Planting holes

(i) Holes the same size as the pots containing the seedlings to be replanted are dug by workers wearing cotton gloves.

(b) Planting

(ii) Fix both ends of a rope with the planting intervals marked on it to fix the planting locations.

(iii) Remove the seedlings from the pots, being careful not to cut the roots or break the clods of soil in the pots.

(iv) Plant the trees so that the bases of their roots are exactly at ground level.

(v) Pile the soil that was dug out to make the planting holes loosely around the roots.

(c) Pots

(vi) Collect the used pots after the seedlings are replanted and burn them completely in an incinerator.

D) Growing the trees

(a) Stakes

(i) Make bamboo stakes 130cm long and 25mm in diameter.

(ii) Drive the stakes into the ground to a depth of 30cm at the edges of the earth transferred from the pots.

(iii) Tie the top part of each seedling to a stake with a loop of hemp rope (the loop starts and ends at the stake and the seedling is in the apex).

(iv) The need for stakes varies from one tree species to another. Stakes are always needed for *Rhizophora mucronata*.

(v) For other tree species, the need for stakes depends on the size of the tree.

(b) Trash

(vi) Make bamboo nets with 5 to 10cm openings and string them across the water gates to prevent trash from entering.

(vii) Collect any trash that enters the planting area and burn it completely in an incinerator.

(c) Tree diseases and insect pests

(viii) If scale insects or gold beetles, or damage from them, are discovered, wash them off with sea water.

2) Planting a forest in the tideland in a river mouth

A) Determination of the planting method etc.

(a) Selection of tree species

(i) Referring to the species composition of the surrounding natural forest, measure the water level and sea water flooding frequency at high neap tide and select the most appropriate tree species for the tideland where the planting is to be done (refer to the results of the terrace test for the appropriate tree species for each ground level height).

(b) Selection of location

(ii) Start planting from the tideland with the longest dry period, where survival is most likely.

B) Transport of seedlings

(i) Transfer 40 selected potted seedlings to a plastic box and load the boxes on trucks (10 boxes per 2 ton truck) for trans port.

(ii) Transfer the boxes to a boat for transfer to the tideland where planting is to be done.

(iii) Then transfer the pots to snowboards with ropes attached (10 to 20 pots per snowboard) to be pulled to the planting site by the planting workers.

C) Planting

(a) Planting holes

(i) Holes the same size as the pots containing the seedlings to be replanted are dug by workers wearing cotton gloves.

(b) Planting

(ii) Fix both ends of a rope with the planting intervals marked on it to fix the planting locations.

(iii) Remove the seedlings from the pots, being careful not to cut the roots or break the clods of earth in the pots.

(iv) Plant the trees so that the bases of their roots are exactly at ground level.

(v) Pile the earth that was dug out to make the planting holes loosely around the roots.

(c) Pots

(vi) Collect the used pots after the seedlings are replanted and burn them completely in an incinerator.

D) Growing the trees

(a) Stakes

(i) Make bamboo stakes 130cm long and 25mm in diameter.

(ii) Drive the stakes into the ground to a depth of 30cm at the edges of the earth transferred from the pots.

(iii) Tie the top part of each seedling to a stake with a loop of hemp rope (the loop starts and ends at the stake and the seedling is in the apex).

(iv) The need for stakes varies from one tree species to another. Stakes are always needed for *Rhizophora mucronata*, but for other tree species, the need for stakes depends on the size of the tree.

(b) Trash, barnacles, seaweed

(v) If stems and leaves become covered with sand particles mixed with oil, barnacles, etc., wash them off with sea water (twice per month).

(vi) Plant trees after the season of thickest seaweed growth has 4 passed.

(c) Tree diseases and insect pests

(vii) If scale insects etc., or damage from them, are discovered, wash them off with sea water.

(d) Human damage

(viii) Post signs to prevent net fishermen etc. from entering the planting area.

3) Planting a forest on clear cut land within an atoll

A) Determination of planting method etc.

(a) Selection of tree species

(i) Referring to the species composition of the surrounding natural forest, measure the water level and sea water flooding frequency at high neap tide and select the most appropriate tree species for the tideland where the planting is to be done (refer to the results of the terrace test for the appropriate tree species for each ground level height).

(b) Selection of location

(ii) Start planting from the tideland with the longest dry period, where survival is most likely.

B)Transport of seedlings (seeds) for direct planting

(i) Select only young seedlings that are not broken and seeds that do not show evidence of damage by or entrance of harmful insects.

(ii) Bundle 50 of the seedlings for direct planting and transport them to the planting site by boat.

(iii) Repack the seedlings in plastic containers, 100 to a container, for final transport to the actual planting site.

C) Planting (direct planting)

(i) Fix both ends of a vinyl rope with the planting intervals marked on it to determine the planting locations.

(ii) Insert the seedlings into the ground, inserting the Voots about 15cm, taking care to avoid coral and old roots that might damage them.

D) Growing the trees

(a) Stakes

(i) Make bamboo stakes 130cm long and 25mm in diameter (for use in locations where the tidal current is swift or the water is deep).

(ii) Insert the stakes 30cm deep into the soil at the edges of the earth taken from the seedling pots.

(iii) Tie the top parts of the seedlings to the stakes with loops of hemp rope; each loop starts and ends at the stake, and the seedling is inside the apex.

(iv) The need for stakes varies from one tree species to another. They are always necessary for Rhizophora mucronata; the need for stakes in other species depends on the size of each seedling.

(b) Seaweed

(v) Plant the forest after the thickest seaweed growth season has passed.

(c) Tree diseases and harmful insects

(vi) If scale insects or evidence of damage by them are discovered, wash them off with sea water.

(d) Human damage

(vii) Post signs to prevent fishermen using nets from entering the planting area.

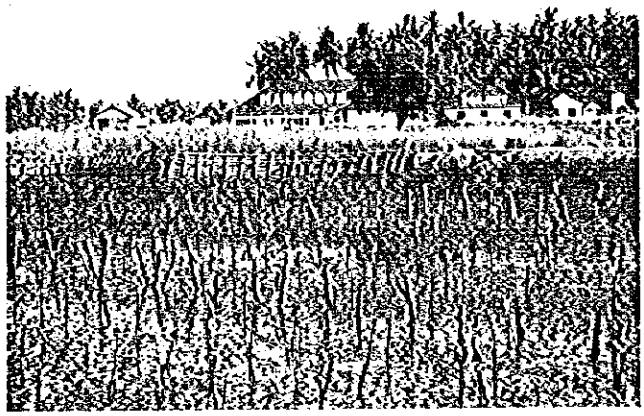


Photo 1 A forest replanted in a former shrimp pond (Bali, production forest, 1993/94)

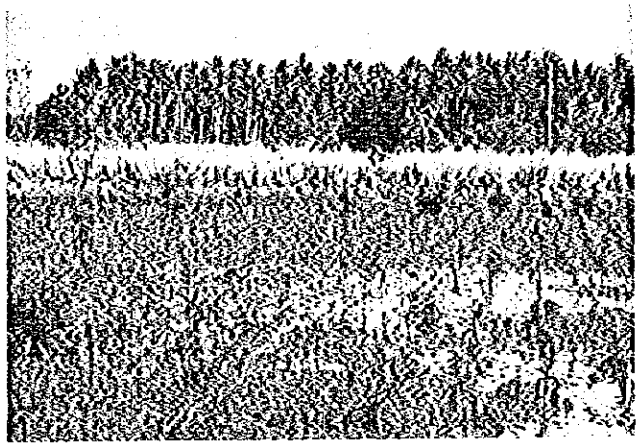


Photo 2 The condition of a forest planted in a former shrimp pond (Bali, production forest, 1994/95)

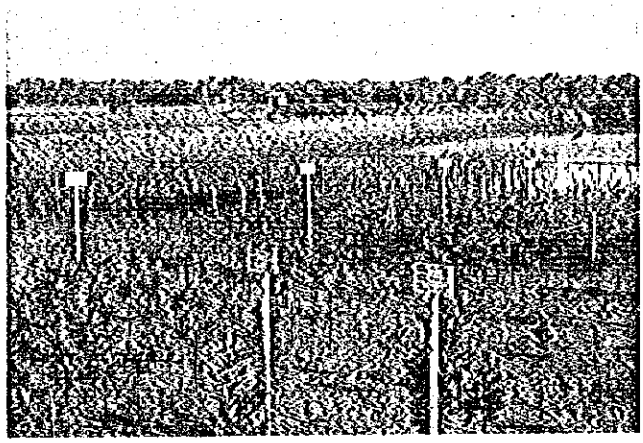


Photo 3 The terrace test site (Bali)

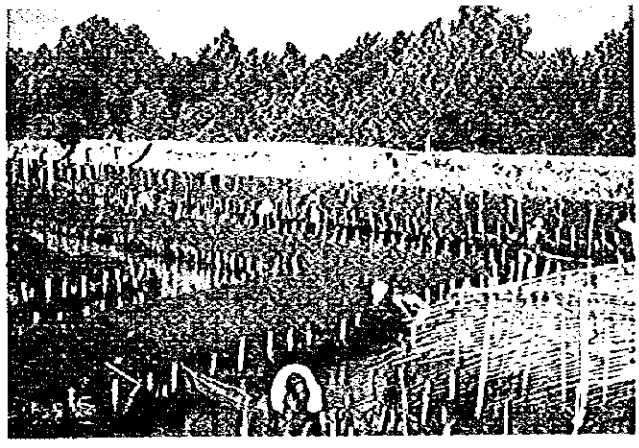


Photo 4 A Silvo-fishery (during a fish-gathering survey -- Bali)

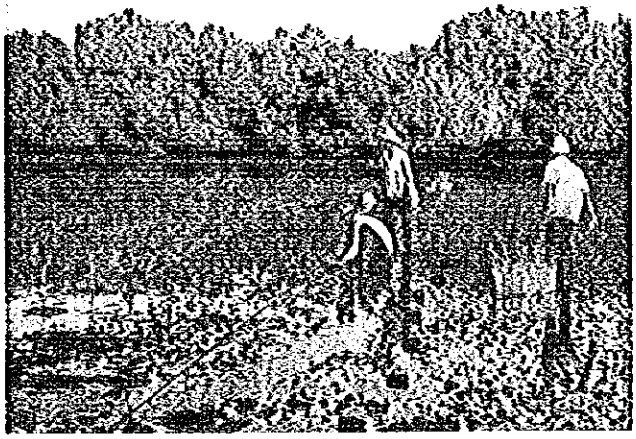


Photo 5 Condition of a replanted forest in a tideland (Bali, 1993/1994)

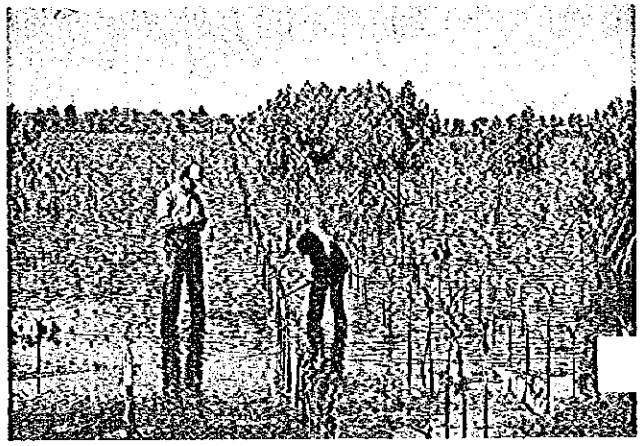


Photo 6 A forest replanted within a coral reef (Lombok, production forest, 1993/1994).

Photo 7 Direct planting (Lombok)

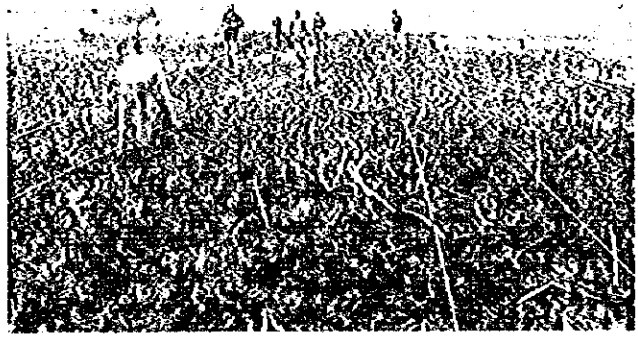


Photo 8 Establishing an experimental plot to study the effect of site environment on growth (Lombok)

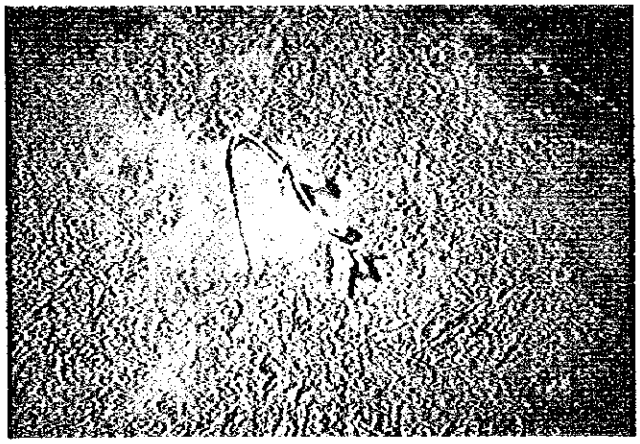


Photo 9 Oil and sand particles adhering to trees planted in a tideland (bali)

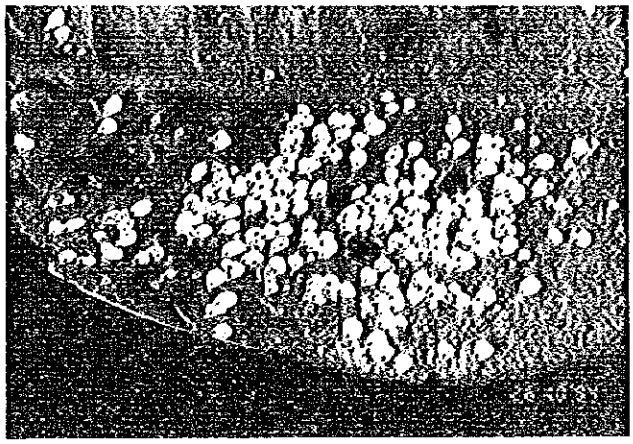


Photo 10 Damage caused by scale insects (Bali)

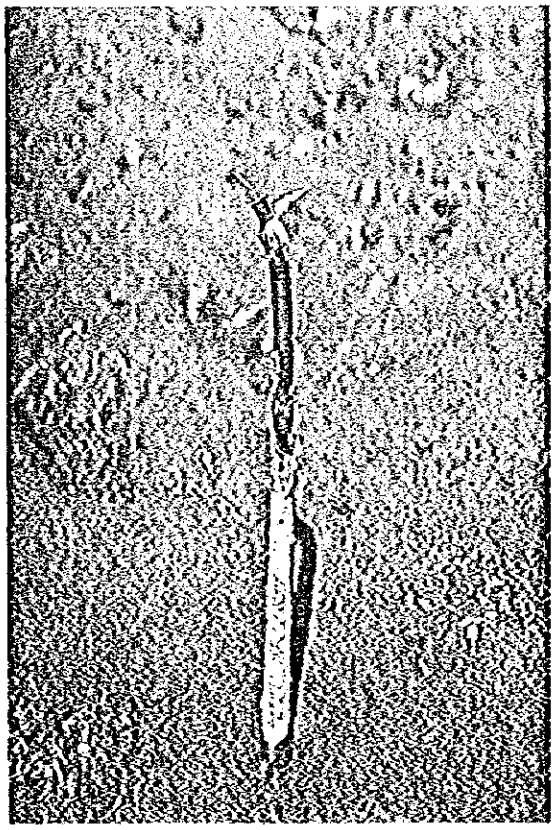


Photo 11 Trees that show defective sprouting (Lombok)

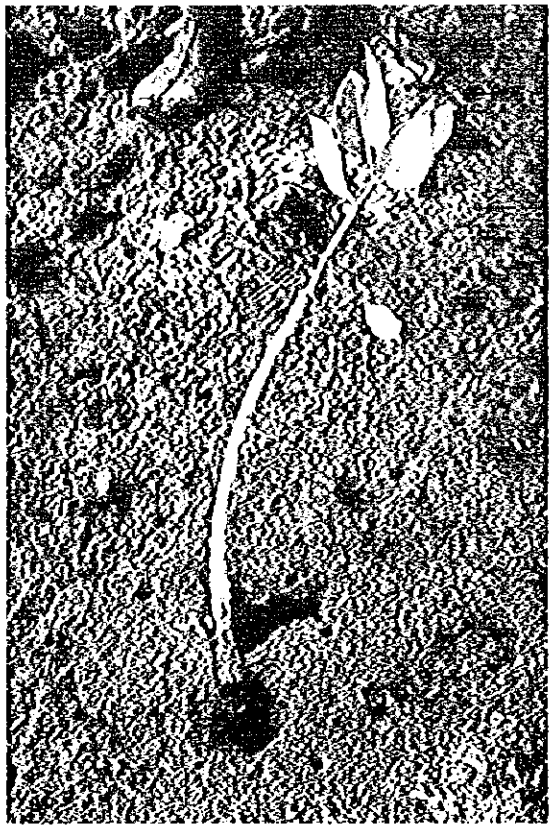


Photo 12 Damage caused by crabs (Lombok)

III . Report on ecosystem

1. Progress of the study

(1) Schedule of the study on ecosystem

The purpose of project in the field of ecology is to collect data necessary for the nursery and afforestation projects and to give indirect aids to them. At the same time, it is also very important to transfer knowledge obtained during the surveying activities and techniques used for the survey as the form of distribution activities. This report is the summary of the results and methods of surveys arranged by the specialists with the aid of counterparts. This report was prepared to assist the understanding of the function of mangrove and its importance as the ecosystem not only by the technical staffs engaged in forest ry but also by residents related to the social forestry.

Among the contents of the report, interim reports, etc. were prepared for those capable to be summarized as described later.

(2) Results of the study

1) Settlement of footway and guidebook of settlement of footway

In the forest of mangrove, survey is performed by walking. Walking in the forest is very difficult and is also dangerous. In order to survey safely and effectively during the limited days of official trip in the term of office, plain footway for survey was settled.

The lengths of footway are 700 m in Bali site (in natural forest of BENOA Bay including 170 m within the fixed test site and 1,950 m in Gili Sulat Island including 120 m within the fixed test site. BUGAKE to the settlement of footway, etc. such as position and structure of footway are described in a separate guidebook (reference 6).

2) Guidebook for aerial photograph using balloon containing helium gas

Vegetation maps were prepared using balloons containing helium gas. In order to transfer the techniques concerning handling of balloon containing gas and aerial photograph taking, a separate guidebook was prepared to describe the definite procedures (reference 7).

3) Photographic book of 7 kinds of tree used for mangrove afforestation

Among forestry technicians in Indonesia, there are staffs engaged in mangrove afforestation for a long time. In this country, however, information concerning mangrove

species has not yet been distributed enough and technicians on the spot are frequently unable to identify species for afforestation. This is one of the reasons of failure in afforestation. In order to assist technicians on the spot to understand major mangrove species, a separate photographic book of 7 kinds of tree used for afforestation in this project was prepared (reference 3).

4) Preparation of photographic book of mangrove species for technicians on the spot

On future extension of mangrove afforestation in this country, there may be mistakes of species for afforestation due to lack of knowledge on mangrove species. In addition to the spe-cies used for afforestation in this project, there are many species used for afforestation in the other sites. A photographic book will be thus prepared in order to deepen the recognition on the difference in various species and to introduce species adopted to various local characteristics of afforestation sites. During the term of office, slides were prepared for about 51 kinds of mangrove species. Slides will be prepared for those not taken yet and photographic books will be issued in order concerning representative families and genus.

5) Exhibition, etc. of photograph panel of mangrove species

Photograph panels of representative mangrove species are noticed in the Office. Mangrove species collected in Indonesia were preserved in specimen bottles filled with alcohol and are displayed for gross confirmation by visitors. At meetings held by the local forestry department (KANWIL), panels, etc. were lent.

6) Preparation/exhibition of specimen of inhabitants in mangrove forest

Specimens of crabs, prawn, and other animals inhabiting in natural mangrove forest and at the site of old farm were preserved and exhibited.

7) Other activities

References concerning techniques and researches in this country as well as references concerning mangrove in surrounding countries of Indonesia were collected and stored in the Office of this project. They were used for the progress of the project. In addition, technical information provided by national society of supporters was also arranged and stored. As the results, though not yet sufficient concerning technical information in Indonesia and abroad, famous literatures and references concerning classification were collected.

Technical information obtained during official trips and local information concerning

mangrove forest were also collected and recorded.

In addition, in order to distribute knowledge concerning mangrove and related plant and animal species, the above de scribed printed matters were distributed and explanation of exhi- bited specimens were performed for visitors, persons of related organizations, participants of mangrove seminars, and participants of panel discussion.

2. Survey and research plans, and accomplishments

(1) Research topics and plans related to ecosystem

1) Study on vegetation

Item	Description
1. Purpose, result expected	Fulfill the basic information concerning afforestation and nursery projects by surveying the scheduled afforestation site with respect of its condition before deforestation, present vegetation, growth environment, and presence or absence of neighboring seed collection forest.
2. Sample, plot: Site, number, method	Scheduled afforestation site: Lombok Island Seed collection forest: Coastlines of Bali and Lombok Islands
3. Determination method	Scheduled afforestation site: Aerial photographing using balloon containing gas and exploration on the spot. Seed collection forest: Exploration on the spot.
4. Time of determination	Scheduled afforestation site: Balloon containing gas in August, 1993 Exploration in September, 1994 Seed collection forest: At any time
5. Analytical method	In scheduled afforestation site in Lombok Island, distribution of vegetation in present and before deforestation is surveyed and appropriate sites and trees for afforestation are investigated. The presence or absence of seed collection forest is checked at each exploration site. When present, condition of the forest, area, kind of trees, etc. are summarized in a report. Any other findings during survey are adjusted and recorded.
6. Time of report	Midterm report: December, 1994 Final report: December, 1997

2) Study on environmental conditions of natural and man-made forest

Item	Description
1. Pupose, result expected	Adaptability of various kinds of tree to natural environment such as water depth is investigated to obtain basic information concerning afforestation.
2. Sample, plot: Site, number, method	Representative sites in natural forest and afforestation sites in Bali and Lombok Islands are surveyed.
3. Determination method	Ambient temperature, water temperature, water depth (height of ground), and light environment are recorded using automatic recorders and surveying instruments.
4. Time of determination	Height of ground is determined after the settlement of observation footway. Determinations of the other parameters are started within 4 years after the arrival of surveying instruments.
5. Analytical method	Each determined parameter is compared between the natural forest and afforestation sites. Appropriate environmental conditions are thus examined.
6. Time of report	Midterm report: December, 1994 Final report: December, 1997

3) Study on soil sedimentation

Item	Description
1. Purpose, result expected	The rate and amount of accumulation of soil in natural forest are determined for the quantification of land forming function.
2. Sample, plot: Site, number, method	One test site each is settled in natural forest in Bali site and Lombok site. Ten acryl plates are settled in each test site. Another test site is also settled in scheduled afforestation site in Bali site.
3. Determination method	Thickness of the earth and sand on each acryl plate and weight of the earth and sand at absolute dryness are determined.
4. Time of determination	One year
5. Analytical method	The mean amount of accumulation is compared between natural forest and scheduled afforestation site.
6. Time of report	Midterm report: December, 1994 Final report: December, 1997

4) Study on litter production and growth

Item	Description
1. Purpose, result expected	In natural forest, actual condition, growth condition, and amount of litter production of mangrove forest are investigated to provide basic information concerning afforestation and ecology.
2. Sample, plot: Site, number, method	In natural forest, 3 plots are settled and investigation of each tree is performed. Bali site: One site in Sonneratia alba forest One site in Rhizophora apiculata forest Lombok site: One site in mixed natural forest
3. Determination method	For each tree with 3 cm or more in diameter, height, diameter, kind of tree, and crown are investigated. At each plot, 10 litter traps are settled and weight of each organ at absolute dryness is measured.
4. Time of determination	Investigation of each tree is performed once a year for 4 years. Litters are collected once a week for 5 years.
5. Analytical method	Growths of diameter and height as well as the amount of litter production are recorded to grasp the dynamics of forest.
6. Time of report	Midterm report: December, 1994 Final report: December, 1997

5) Study on process of regeneration in natural forest

Item	Description
1. Purpose, result expected	Renewal process in natural forest is investigated to obtain conditions allowing renewal. It provides basic reference for afforestation technique.
2. Sample, plot: Site, number, method	In the fixed test sites settled in the above section 4), sub-plots are settled and investigation of each tree is performed.
3. Determination method	Bali site: One site in Sonneratia alba forest One site in Rhizophora apiculata forest Lombok site: One site in mixed natural forest as well as some small plots for investigation of growth of young trees
4. Time of determination	The area of sub plot is about 5 m × 5 m. Investigation of each young tree with diameter of 3 cm or less is performed on height, diameter, and kind of tree.
5. Analytical method	Once per 2 months for 4 years. Based on the determined parameters, the relationship between the growth/disappearance of young tree and light environment or depth of water is investigated.
6. Time of report	Midterm report: December, 1994 Final report: December, 1997

6) Study on fauna at the reforestation site

Item	Description
1. Purpose, result expected	Fauna is surveyed in natural forest and afforestation site. It provides basic reference concerning biological resource cultivation function.
2. Sample, plot: Site, number, method	Accompanying to the other investigations, the survey is performed in natural forest and scheduled afforestation site. Special test sites are not settled.
3. Determination method	Long-term specialists perform photographing and collection. When necessary, short term specialists perform identification and detailed investigation.
4. Time of determination	At any time
5. Analytical method	The present conditions are adjusted through preparation of specimens, photographs, and distribution maps.
6. Time of report	Midterm report: December, 1994 Final report: December, 1997

7) Study on pest and biological damages

Item	Description
1. Purpose, result expected	Harmful insects and animals in natural forest and afforestation site are investigated. It provides basic reference for afforestation project.
2. Sample, plot: Site, number,method	In natural forest and afforestation site, the degree and characteristics of damage are investigated at any time.
3. Determination method	Long-term specialists perform photographing and collection. When necessary, short term specialists perform identification and detailed investigation.
4. Time of determination	At any time
5. Analytical method	The results are adjusted through preparation of specimens of harmful insects and animals as well as their photographs.
6. Time of report	Midterm report: December, 1994 Final report: December, 1997

8) Study on phenology of main (selected) species

Item	Description
1. Purpose, result expected	The maturation process of seed of trees used for afforestation is observed. It provides basic reference concerning seed collection procedures and nursery procedures.
2. Sample, plot: Site, number, method	Sample trees which are easy to observe are selected. Survey is performed from blooming to maturation of seeds.
3. Determination method	Seven kinds of tree are observed in Bali site. Periodical observation and recording are performed for the cycle from formation of buds, blooming, pollination, fruition, maturation, to fall of seeds.
4. Time of determination	Once a week for each kind of tree. Completed when the process is clarified.
5. Analytical method	From the results of many blooming flowers, the average duration of each growth stage is calculated and figure of average maturation process is prepared.
6. Time of report	Midterm report: December, 1994 Final report: December, 1997

9) Study on seed production

Item	Description
1. Purpose, result expected	The production amount of seeds in natural forest is investigated quantitatively at different times. It provides basic reference concerning nursery production projects.
2. Sample, plot: Site, number, method	In vicinity to Bali site, seed traps are settled for7 kinds of tree for the collection of their seeds.
3. Determination method	For the collected seeds, the number, weight, length, disease, insect damage, etc. are investigated.
4. Time of determination	Once a week for 5 years
5. Analytical method	From the annual fluctuation of production amount of seeds of each kind of tree, the average production amount per unit area is estimated.
6. Time of report	Midterm report: December, 1994 Final report: December, 1997

(2) Results of the research

1) Study on vegetation

A) Survey on vegetation at the Lombok site

a) Survey on present vegetation

・ Survey on vegetation in Lombok Island

Information of coastlines with mangrove forest in Lombok Island was previously obtained by interviewing to NTB State Forestry Department. The growth condition of mangrove forest and seed collection forest was surveyed.

Lombok Island occupies one third of the area of NTB State. On the other hand, population in Lombok Island occupies two thirds of that in NTB State. Therefore, there are deve loped villages not only in the inland area but also in the coastal area. Utilization and development of land have been advanced for a long time. Mangrove forest in the coastal area is thus consid ered to have been decreased from early times. Especially in recent years, the rate of decrease has been accelerated by the development of farms of fishes and prawn. BRLKT (forest preservation center) has performed affores tation of mangrove as a part of social forestry. The result is supposed to be not sufficient.

Results:

Along the coastlines of Lombok Island, 26 sites (Fig. 2-3-1) were surveyed. The obtained results are summarized in Table 2-3-1. The member species were consisted of 19 strict mangrove species, 7 sub mangrove species, 13 minor mangrove species, and 14 non mangrove aceanophyte species.

The constitution of species is similar to that in Bali Island.

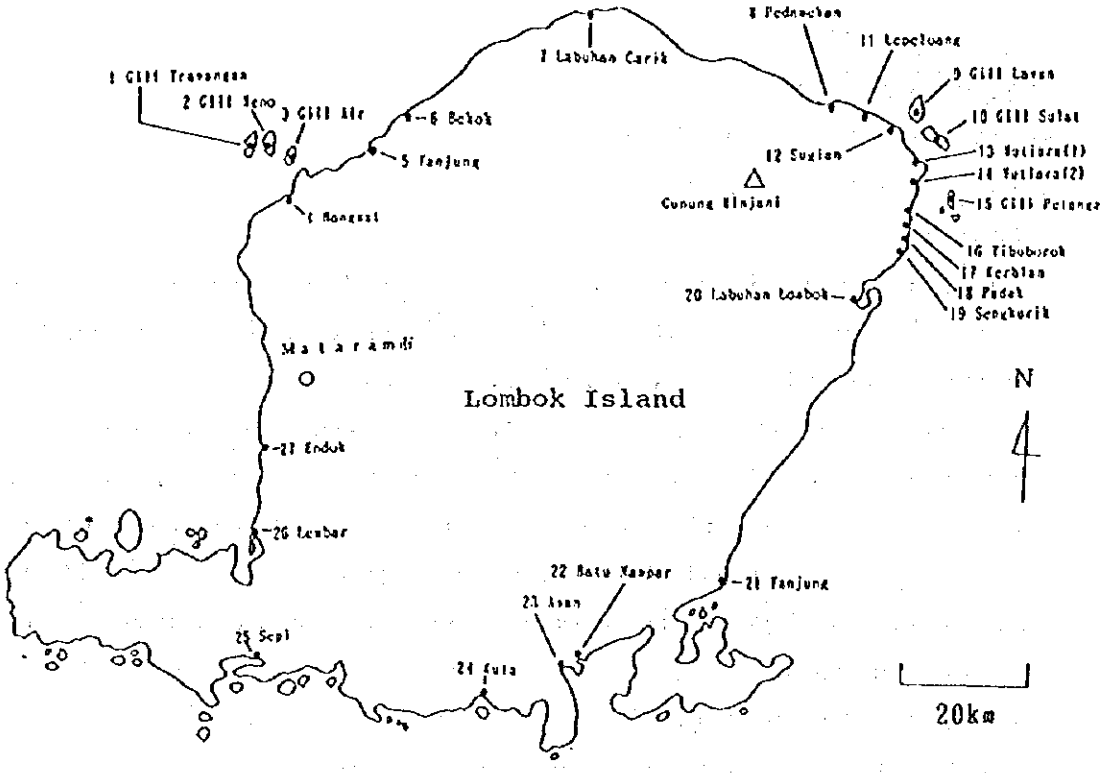


Fig. 2-3-1 Surveyed sites for flora in Lombok Island

· Survey on present vegetation in Lombok site

In August, 1993, aerial photographs were taken using a balloon containing gas over the schedule afforestation site in order to survey present vegetation. Based on the photographs and maps, roots cut down and vegetation were surveyed on the spot during a period of September 14-17, 1994 in order to prepare vegetation map (Fig. 2-3-2).

Table 2-3-1 List of mangrove secies and oceanphyte species in Lombok Island

1. Strict mangrove species		
1	*Avicenniaceae*	*Avicennia alba Bl.*
2		*A. lanata Ridl.*
3		*A. Marina (Forsk.) Vierh.*
4		*A. officianalis L.*
5		*Xylocarpus granatum Koenig*
6		*X. mekongensis Pierre*
7	*Myrsinaceae*	*Aegiceras corniculatum (L.) Blanco*
8		*A. floridum Roem. & Schult.*
9	*Rhizophoraceae*	*Rhizophora apiculata BL.*
10		*R. X lamarckii Montr.*
11		*R. mucronata Lamk.*
12		*R. stylosa Griff.*
13		*Bruguiera cylindrica (L.) BL.*
14		*B. gymnorrhiza (L.) Lamk.*
15		*Ceriops decandra (Griff.) Ding Hou*
16		*C. tagal (Perr.) C.B. Rob.*
17	*Rubiaceae*	*Scyphiphora hydrophyllacea Gaertn. f.*
18	*Sonneratiaceae*	*Sonneratia alba I. Smith*
19		*S. caseolaris (L.) Engler*
2. Sub mangrove species		
20	*Asclepiadaceae*	*Finlaysonia obovata*
21	*Combretaceae*	*Lumnitzera racemosa Willd.*
22	*Euphorbiaceae*	*Excoecaria agallocha L.*
23	*Myrtaceae*	*Osbornia octodonta F. Muell. loc. cit.*
24	*Palmae*	*Nypa fruticans (Thunb.) Wurmb.*
25	*Sterculiaceae*	*Heritiera littoralis Dryand. in Aiton*
26	*Pteridaceae*	*Acrostichum aureum Linnaeus*
3. Minor mangrove species		
27	*Acanthaceae*	*Acanthus ilicifolius L.*
28	*Apocynaceae*	*Cerbera odollam Gaertner*
29	*Bignoniaceae*	*Dolichandron spathacea (L.f.) K. Schumann*
30	*Lecythidaceae*	*Barringtonia racemosa (L.) Spreng.*
31	*Leguminosae*	*Caesalpinia bonduc (L.) Rorb.*
32		*C. crista L.*
33		*Derris trifoliata Lour.*
34		*Pongamia pinata (L.) Pierre.*
35	*Lythraceae*	*Pemphis acidula Forst.*
36	*Malvaceae*	*Hibiscus tiliaceus L.*
37		*Thespesia populenea (L.) Solander er Correa*

38	*Pandanaceae*	*Pandanus tectorius Soland. er Balf.*
39	*Verbenaceae*	*Clerodendron inerme Gaertn.*
4. Non mangrove sppecies		
40	*Aizoaceae*	*Sesuvium portulacastrum*
41	*Asclepiadaceae*	*Calotropis gigantea R. Br.*
42	*Cactaceae*	*Opuntia vulgaris*
43	*Casuarianaceae*	*Casuarina equisetifolia (L.) J.R. et Forst.*
44	*Chenopodiaceae*	*Halosarcia halocnemoides*
45	*Compositae*	*Pluchea indica*
46	*Combretaceae*	*Terminalia catappa Less.*
47	*Convolvulaceae*	*Ipomoea pes-caprae*
48		*I. alba L.*
49	*Ebenaceae*	*Diospyros littorea*
50	*Geamineae*	*Spinifex littoreus*
51	*Goodenniaceae*	*Scaevola taccada (Gaertn.) Rorb.*
52	*Gutliferae*	*Calophyllum inophyllum L.*
53	*Phamnaceae*	*Zizyphns maurtiana Lam.*

Natural mangrove forest covering the surroundings of the island was almost disappeared due to illegal felling by local residents in 1970's. In 1980's, State Forestry Department of NTB State made afforestation on the spot. However, it had poor results.

Results:

The results are summarized in Table 2-3-2. They were summarized as follows:

1. In general, the present vegetation is clearly concentrated to .LM4
   high ground surrounding the islands and high ground at sand bar areas between islands. At log ground sites, a few trees are scattered to show groups with low height and crowns not closed.
2. The number of trees were many in the following order: Rhizophora apiculata > Rhizophora stylosa > Pemphis acidula >> Rhizophora mucronata > Ceriops tagal >> Excoecaria agallocha >> Sonneriatia alba.
3. R. apiculata occupied 70-80% of the total number of trees. It was also the predominant species with respect of the occupied area. However, their average height was as low as 3-4 m with no tree exceeding 8 m in height.
4. Many R. stylosa grew with R. apiculata. In site No. 25, there was a group of trees with 8-10 m in height covering about 1 ha of area. There was, however, no other

tree exceeding 4 m in height.

5. In site No. 20, there was a group of P. acidula covering from the beach line to inland. As compared with adjacent sandy beach, the area well tolerated invasion by waves. Therefore, P. acidula has a possibility to be used as a kind tree for prevention of invasion of dry coral sandy beach.
6. About 100 trees of C. tagal of 2–4 m in height grew on sites Nos. 5 and 11 with relatively high ground accumulating coral sand.
7. Along the beach lines on sites Nos. 2 and 27, about 20 trees of S. alba grew. Probably because they are used as firewood in this district, there were new remains of trunks after illegal felling by local residents.
8. Along the beach lines on sites Nos. 15–17, 5 trees of Xy–locarpus mekongesis of 2–4 m in height grew. They were not seen in low ground.
9. There were about 100 trees of R. mucronata on sites Nos. 17 and 18. There were few trees in the other sites. The remaining 2 groups were considered to be remaining forest planted by the State Forestry Department of NTB in 1980's. The reason why this kind of tree did not grow in a wide area in this district as were the case of R. apiculata and R. stylosa was unknown.

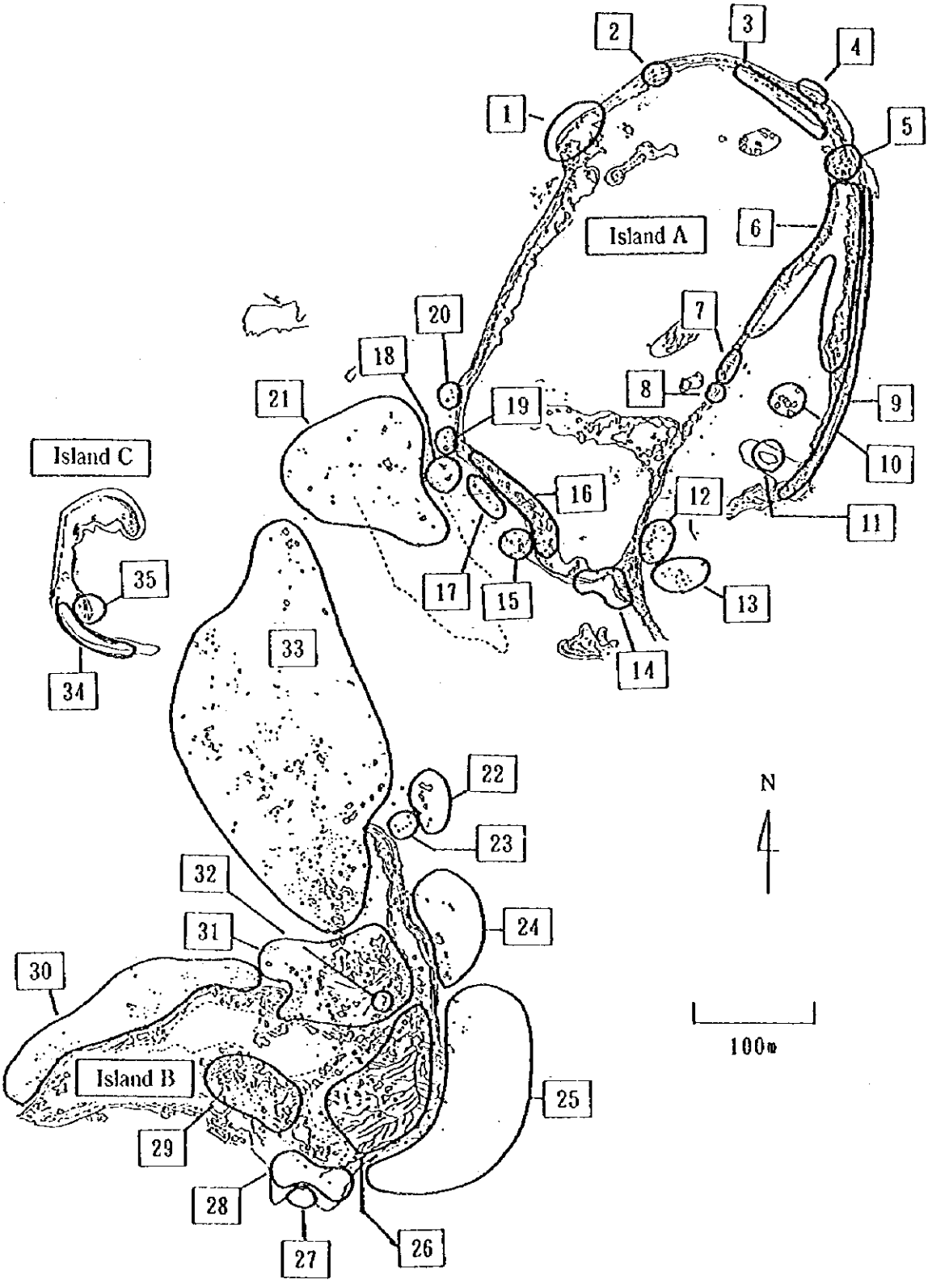


Fig. 2-3-2 Actual vegetation map in Gili Petangan Island

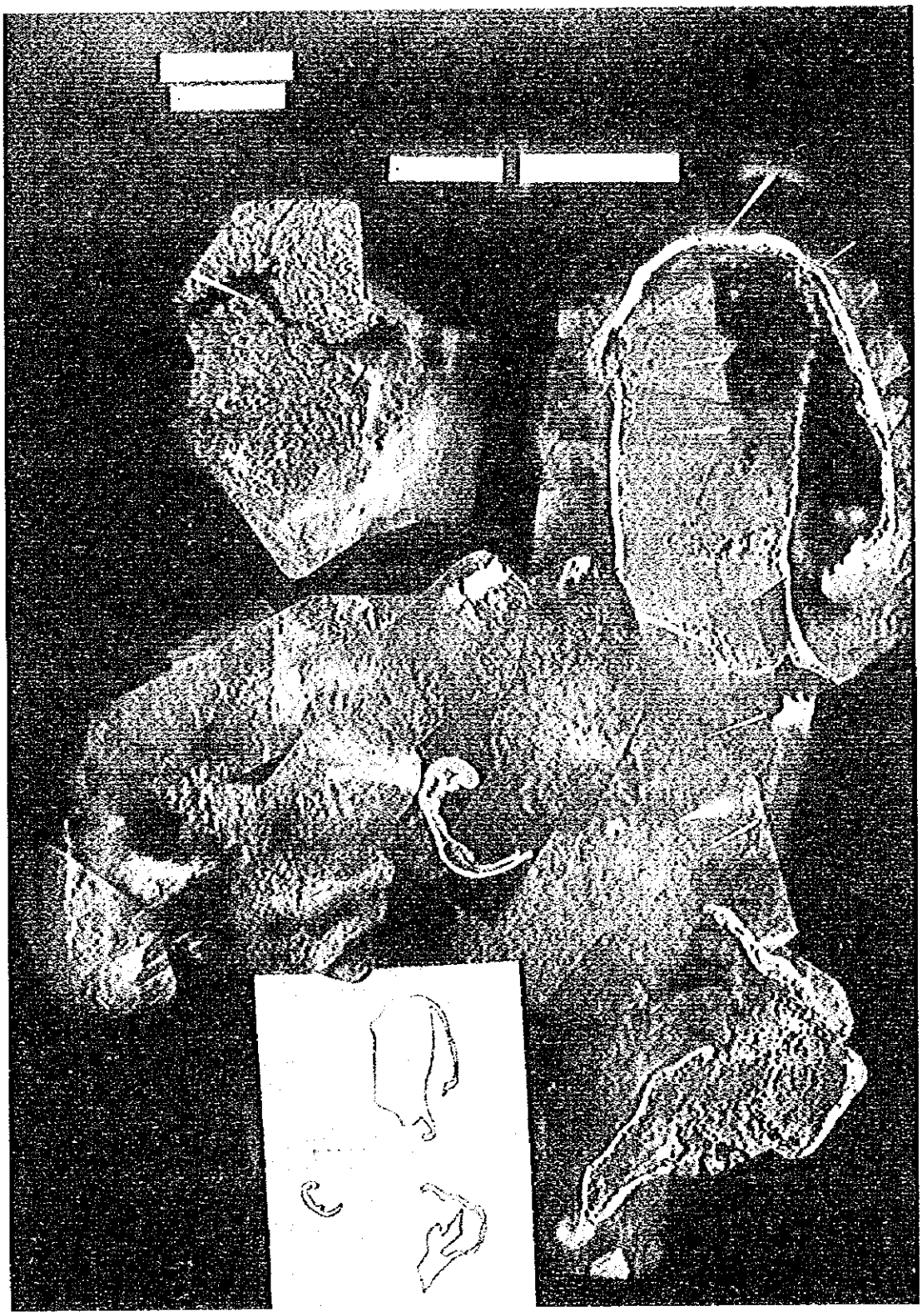


Photo. 1 Gili Petangan Island

Table 2-3-2 List of characteristics of groups in Gili Petangan Island

Group No.	Predominant species	Note
Island A		
1	*P. acidula*	Group from white coral beach to flat inland. h = 2-3 m. Area = 0.2 ha.
2	*S. alba*	Only 1 tree was left on the beach at the previous survey. The trunk had been lost by secret felling by this time of survey.
3	*P. acidula*	Group from white coral beach to flat inland.
4	*R. stylosa*	About 5 trees grow on the beach. h = 2 m.
5	*R. stylosa* *P. acidula* *C. tagal*	Three kinds of tree grow together on white dry sand at the most recess area of the bay. h = 2-3 m.
6	*R. stylosa* *R. apiculata*	Land on the recess area of the bay with rather dry mixture of reddish brown mangrove mud and white sand. h = 2-3 m.
7	*E. agallocha*	It grows on a little higher land than the beach. h = 4-6 m.
8	*S. alba*	A few trees grow on the beach. h = 4-6 m.
9	*P. acidula*	It grows from white coral beach to the higher delta.
10	*R. apiculata*	It grows on a little higher land of the bay. h = 2-3 m.
11	*C. tagal*	It grows on higher land than group 10. h = 2-4m.
12	*R. apiculata*	A few trees grow on sand beach of the bay. h = 2-3 m.
13	*R. stylosa* *R. apiculata*	A few trees grow on the mouth of the bay. h = 2-3 m.
14	*R. apiculata*	A few trees. h = 2-3 m.
15	*R. stylosa*	A few trees. h = 2-3 m.

(Note): h, height of tree.

Table 2-3-2 List of characteristics of groups in Gili Petangan Island (No.2)

Group No.	Predominant species	Note
16	*E. agallocha* *R. stylosa* *R. apiculata*	They grow on a little higher land than thebeach. h = 2-4 m. R. stylosa and R. apiculata also grow together. Probably due to the gradual advance of the beach to the sea, they are supposed to be left behind.
17	*R. mucronata*	Since it is not seen in the other districts except for No. 18 of the island, a few trees are considered to be the remaining ones planted previously by the State Forestry Department. h = 2-4 m.
18	*R. stylosa* *R. mucronata*	A few trees. h = 2-3 m.
19	*R. apiculata*	A few trees. h = 2-3 m.
20	*R. apiculata*	A few trees. h = 2-3 m.
21	*R. apiculata*	A few trees. h = 2-4 m. It is common to groups Nos. 19-21 that individual trees are consisted of some to ten stands with the highest central one abundant in leaves.
Island B		
22	*R. apiculata*	A few trees. h = 2-4 m.
23	*R. stylosa*	A few trees. h = 2-3 m.
24	*R. apiculata*	A few trees. h = 2-4 m.
25	*R. stylosa*	Many trees with crowns beginning to be closed. Area = 1 ha.
26	*R. apiculata* *E. stylosa*	Many trees with crowns not closed. Area = 3 ha. h = 2-8 m. The approximate ratio of R. apiculata:R. stylosa is 6:4.
27	*S. alba*	About 10 tress consist a valuable group in this district. h = 2-6 m.
28	*P. acidula* *C. inerma*	They grow on a little higher land than the beach. h = 1-2 m. C. inerma has thicker and smaller leaves than those in Bali Island probably due to consistent water shortage.

(Note): h, height of tree.

Table 2-3-2 List of characteristics of groups in Gili Petangan Island (No.3)

Group No.	Predominant species	Note
29	*R. apilulata* *R. stylosa*	Many tress with crowns not closed. Area = 2 ha. h = 2-6 m. The approximate ratio of *R. apiculata*: R. stylosa is 6:4.
30	*R. apiculata* *R. stylosa*	A few trees. h = 2-6 m. The approximate ratio of *R. apiculata*: R. stylosa is 6:4.
31	*R. apiculata*	Many trees with crowns not closed.
32	*A. marina* *A. officinalis*	There are about 5 A. marina trees which are characterized by the weeping branches as weeping willow. They are identified to be A. marina from the structure of bloom as well as qualities of leaf and fruit. h = 5 m. There is only one A. officinalis growing in mixture with A. marina. h = 6 m.
33	*R. apiculata* *R. stylosa*	Many trees with crowns not closed. Area = 2 ha. h = 2-6 m. The approximate ratio of *R. apiculata*:*R. stylosa* is 8:2.
Island C		
34	*P. acidula*	A few trees grow on a little higher land than the beach. h = 1-2 m.
35	*R. apiculata*	A few trees. h = 2-3 m.

(Note): h, height of tree.

P. Acidula: Pemphis acidula Forst.
S. alba: Sonneratia alba j. Smith.
R. stylosa: Rhizopora stylosa Griff.
C. tagal: Ceriops tagal (Perr.) C.B. Rob.
R. apiculata: Rhizophora apiculata BL.
E. agallocha: Excoecaria agallocha L.
R. mucronata: Rhizophora mucronata Lamk.
C. inerma: Clerodendron inerma Gaertn.
A. marina: Avennia marina (Forsk.) Vierh.
A. officinalis: Avicennia officinalis L.

Discussion:

1. In the present vegetation, no clear zonal structure was formed. There were, however, differences in distribution among species with respect of the height of ground. It is supposed to be necessary to select trees for afforestation based on their characteristics.
2. Along the beach line of Island A, with the remaining support roots of *Rhizophora* genus, there were many root stumps of X. mekongesis and S. alba of 30-100 cm in diameter. The root stumps of both species were seen about 30 cm above the ground indicating

the washing away of surface soil of an extensive area after felling. The significant influence of complete felling over a large area was suggested.

3. As compared with the above described 2 species, support roots of *Rhizophora* genus distributed to lower ground and remained on the marginal phase and covered a wide area. Support roots were the characteristics of *Rhizophora* genus. The above ground parts of support roots were considered to rot at early phase after felling, fell with the remaining trunk, and washed away to the open sea. So, the diameter of trunk was not able to be estimated.
4. *R. mucronata* and *R. apiculata* were not distinguished from the remaining support roots.
5. The margin of mangrove forest in Gili Petangan Island was considered to be surrounded zonally with R. stylosa as was the case of margins of forest on the western beaches of Gili Sulat Island and Gili Lawan Island with similar environmental conditions.
6. Based on this survey, the previous natural forest in Gili

   Petangan Island was considered to have the following zonal structure: From the inland to sea, *X. mekongesis*, *S. alba*, mixed forest of *R. mucronata* and *R. apiculata*, forest predominant with *R. mucronata* and *R. apiculata*, and *R. stylosa* were seen.
7. It was considered to be appropriate to use native species in vicinity such as *R. mucronata*, *R. apiculata*, *S. alba* and *Avicennia marina* for afforestation in Gili Petangan Island.

b) Growth environment of mangrove

・ Division of growth environment

Based on the survey on vegetation, the growth environment of mangrove was the place not exposed to direct waves from open sea. The environment was largely divided to the following 4 divisions:

1. Tideland inside of coral reef of solitary island

   Predominant species: *R. mucronata, R. apiculata*

   Site: 1 Gili Trawangan, 3 Gili Air, 9 Gili Lawan, 10 Gili Sulat, 15 Gili Petangan (see Fig. 2–3–1)

   Salt concentration: Similar to sea water with little supply of fresh water
2. Tideland on recessed area of bay

   Predominant species: Different according to miniature topography

   Site: 20 Labuhan Lombok, 22 Batu Nampar, 23 Awan, 24 Kuta, 25 Sepi, 26 Lembar (see Fig. 2–3–1)

   Salt concentration: Lower then sea water due to abundant supply of fresh water from underground water or rive water from the

background mountains

3. Mouth of river

Predominant species: Species consisting groups differs largely according to salt concentration. A. marina in relatively high salt concentration and relatively high ground. Sonneratia cascoralis, Dolichandron spathaceae, etc. in relative low salt concentration.

Site: 4 Bangsal, 5 Tanjung, 6 Bekok, 7 Labuhan Carik, 8 Pedamekan, 11 Lepeloang, 12 Sugian, 13 Mutiara (1), 14 Mutiara 81), 16 ibuborok, 17 Kerbian, 18 Padak, 19 Sengkurik, 21 Tanjung Luar, 27 Endok (see Fig. 2–3–1)

Salt concentration: Lower then sea water due to abundant supply of fresh water from river water

4. Inland lake of solitary island with closed waterway to open sea

Predominant species: *Avicennia marina*

Site: 2 Gili Meno (see Fig. 2–3–1)

Salt concentration: Higher than sea water with little supply of fresh water

· Growth environment of *Avicennia marina* and *Sonneratia alba*

As the general characteristics of mangrove forest, the formation of zonal structure and A. marina and *S. alba* as the pioneer species in the front. Based on the results of survey, growth environment of *A. marina* and *S. alba* were summarized as follows:

Avicennia marina

- In the above described tideland inside of coral reef (1), it did not grow in the front with any exposure to wave. It grew on high ground with rather solid soil surrounding the sand bar as the natural bank to prevent waves completely.
- In the above described environments (2) and (3), *A. marina* may appear in the front on relatively high ground.
- In the above described environment (4), *A. marina* grew in the front.
- Child trees of *A. marina* were observed on relatively high ground without wave exposure.

In other words, the sites with *A. marina* in the front were relatively high ground with calm waves and with high salt concentration that prevented growth of other species. The results of survey were almost coincided to those obtained by experiments in the fields of afforestation and nursery. They were considered to be

useful for future afforestation techniques.

Sonneratia alba

- In the above described environments (1), (2), and (3), there were some trees grown without any child trees.
- Child trees of S. alba were commonly seen on relatively high ground with calm waves.
- In the above described environment (4), there was no growth of S. alba.

The sites where the child trees of both species were observed were similar. It was probably because low ground was an inhibitory factor for growth of seedlings just after germination due to its short length to result in too much time under the sea water. There was thus a possibility that the area of afforestation could be extended to a lower ground than under the natural condition by using large seedlings.

- Mangrove forest under high salt concentration

The above described site (4) is Meno Lake in Gili Meno Island located in north western direction of Lombok Island. The lake was about 3 ha in area. It was considered to be formed by the closure of creek with sand bars. The salt concentration was as high as 7.3%.

There was mangrove forest of about 10 ha surrounding the lake. It was consisted of *A. marina*, the predominant species in the front, *A. marina* and *C. tagal* zone in its behind, and *Scyphiphora hydrophyllacea*, *E. agallocha*, and *Bruguiera cylindrica* zone in further behind.

On the day of survey, the water level was measured at the time of full tide. The surface of the lake was 40 cm lower than the surface of sea water.

It is unknown whether sea water infiltrated into the lake through the sand bar at the time of full tide since salt concentration of underground water was not determined.

At least, A. marina in the mangrove forest was considered to adopt the high salt concentration of the lake for a long time. It was thus considered valuable themes to determine salt concen tration of underground water in this area as well as to collect the seed of *A. marina*, plant it under normal salt concentration to compare its growth with conventional species.

c) Seed collection forest

From this survey, a relatively wide area of mangrove forest was left in 2 islands

(1171.9 ha), namely, Gili Sulat Island and Gili Lawan Island among the Lombok Island. In the other districts, there were only narrow areas of forest or only a few trees under no favorable conditions.

Even when there was no illegal felling by local residents, some excess utilization of the branches and leaves such as feeding to livestock was observed. Dee to such strong pressure of development, mangrove forest left in vicinity to villages was supposed to disappear in near future.

For the future afforestation of mangrove, it is supposed to be necessary to provide some protective measures for seed collection forest in order to assure the collection of seeds.

B) Survey on vegetation in Bali site

Survey was performed on the following 4 spots: Coast of BENOA Bay, West Bali National Park, seaside low marsh in vicinity to Negara City, and Nusa Lembongan Island (Fig. 2-3-3). The other coasts will be surveyed one after another in future. Species that have been observed in Bali Island until now are summarized in Table 2-3-4.

They are consisted of 17 strict mangrove species, 7 sub mangrove species, 14 minor mangrove species, and 15 non mangrove (oceanophyte) species.

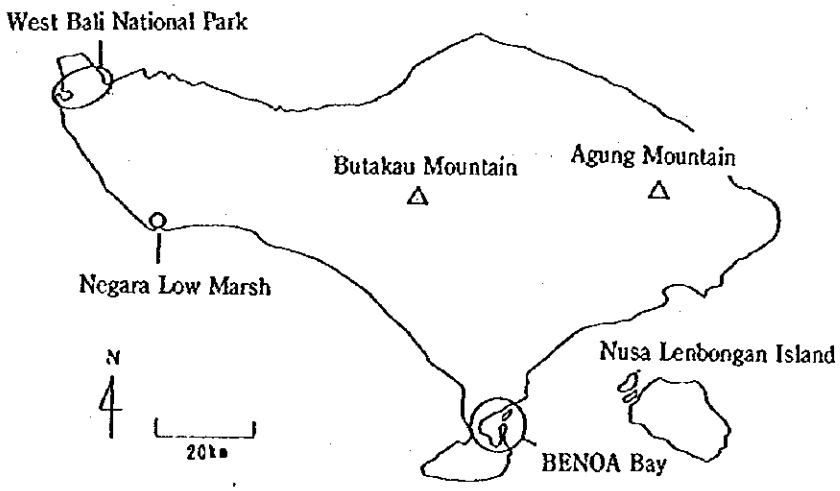


Fig. 2-3-3 Sites of survey for vegetation in Bali Island

Table 2-3-3 Remaining and usable seed collection forest

Kind of tree	Geographical name								
	GS	GL	GM	LE	SE	SA	GP	LL	KU
R. apiculata	○	○	×	△	△	×	△	×	×
R. mucronata	○	○	×	△	△	×	×	×	×
B. gymnorrhiza	△	△	×	△	△	×	×	×	×
C. tagal	○	△	×	×	×	×	×	×	×
S. alba	△	△	×	○	○	○	×	△	○
A. marina	×	×	○	○	×	○	×	△	×
S. alba	×	×	×	×	×	×	×	×	×

Abbreviation of kind of tree

R. apiculata: *Rhizophora apiculata Bl.*
R. mucronata: *Rhizophora mucronata Poir.*
B. gymnorrhiza: *Bruguiera gymnorrhiza Lam.*
C. tagal: *Ceriops tagal C.B. Rob.*
S. alba: *Sonneratia alba J. Sm.*
A. marina: *Avicennia marina Forsk.*
X. garanatum: *Xylocarpus granatum Koenig.*

Abbreviation of geographical name

G.L.: Gili Sulat, G.L.: Gili Lawan, G.M.: Gill Meno, LE: Lembar, SE: Sepi, SA: Mutiara (1), Mutiara (2), G.P: Gili Petangan, L.L: Labuhan Lombok, KU: Kuta

Explanatory note of marks

○ : Appropriate
△ : Not much amount
× : Inappropriate or very small amount

Table 2-3-4 List of mangrove species and non mangrove species (oceanophytes) in Bali Island

1. Strict mangrove species		
1	*Avicenniaceae*	*Avicennia lanata Ridl.*
2		*A. marina (Forsk.) Vierh.*
3	*Meliaceae*	*Xylocarpus granatum Koenig*
4		*X. mekongensis Pierre*
5		*X. moluccensis (Lamk.) Roem.*
6	*Myrsinaceae*	*Aegiceras corniculatum (L.) Blanco*
7		*A. A floridum Roem. & Schult.*
8	*Rhizophoraceae*	*Rhizophora apiculata BL.*
9		*R. X lamarckii Montr.*
10		*R. mucronata Lamk.*
11		*R. stylosa Griff.*
12		*Bruguiera cylindrica (L.) BL.*
13		*B. gymnorrhiza (L.) Lamk.*
14		*Ceriops decandra (Griff.) Ding Hou.*
15		*C. tagal (Perr.) C.B. Rob.*
16	*Sonneratiaceae*	*Sonneratia alba J. Smith*
17		*S. caseolaris (L.) Engler*
2. Sub mangrove species		
18	*Asclepiadaceae*	*Finlaysonia obovata*
19	*Combretaceae*	*Lumnitzera racemosa Willd.*
20	*Euphorbiaceae*	*Excoecaria agallocha L.*
21	*Myrtaceae*	*Osbornia octodonta F. Muell. loc. cit.*
22	*Palmae*	*Nypa fruticans (Thunb.) Wurmb.*
23	*Sterculiaceae*	*Heritiera littoralis Dryand. in Aiton*
24	*Pteridaceae*	*Acrostichum aureum Linnaeus*
3. Minor mangrove species		
25	*Acanthaceae*	*Acanthus ilicifolius L.*
26		*A. ebracteatus Vahl.*
27	*Apocynaceae*	*Cerbera manghas L.*
28	*Bignoniaceae*	*Dolichandron spathacea (L.f.) K. Schumann*
29	*Lecythidaceae*	*Barringtonia asiatica (L.) Kurz.*
30		*B. racemosa (L.) Spreng.*
31	*Leguminosae*	*Caesalpina bonduc (L.) Rorb.*
32		*Derris trifoliata Lour.*
33		*Pongamia pinata (L.) Pierre.*
34	*Lythraceae*	*Pemphis acidula Forst.*
35	*Malvaceae*	*Hibiscus tiliaceus L.*
36		*Thespesia populenea (L.) Solander er Correa*
37	*Pandanaceae*	*Pandanus tectorius Soland. ex. Balf.*

38	*Verbenaceae*	*Clerodendron inerme Gaertn.*

4. Non mangrove species

39	*Aizoaceae*	*Sesuvium portulacastrum*
40	*Asclepiadaceae*	*Calotropis gigantea R. Br.*
41	*Cactaceae*	*Opuntia vulgaris*
42	*Casuarianaceae*	*Casuarina equisetifolia (L.) J.R. et Forst.*
43	*Compositae*	*Pluchea indica*
44	*Combretaceae*	*Terminalia catappa Less.*
45	*Convolvulaceae*	*Ipomoea pes-caprae*
46		*I. alba L.*
47	*Geamineae*	*Spinifex littoreus*
48	*Goodenniaceae*	*Scaevola taccada (Gaertn.) Rorb.*
49	*Gutliferae*	*Calophyllum inophyllum L.*
50	*Hernandiaceae*	*Hernandia peltata Meisn.*
51	*Phamnaceae*	*Zizyphus maurtiana Lam.*
52	*Verbenaceae*	*Lantana camara L.*
53		*Vitex ovata*

Table 2-3-5 List of mangrove species and non mangrove species (oceanophytes) in BENOA Bay

1. Strict mangrove species

1	*Avicenniaceae*	*Avicennia lanata Ridl.*
2		*A. marina (Forsk.) Vierh.*
3	*Meliaceae*	*Xylocarpus granatum Koenig*
4		*X. mekongensis Pierre*
5	*Myrsinaceae*	*Aegiceras corniculatum (L.) Blanco*
6	*Rhizophoraceae*	*Rhizophora apiculata BL.*
7		*R. X lamarckii Montr.*
8		*R. mucronata Lamk.*
9		*R. stylosa Griff.*
10		*B. gymnorrhiza (L.) Lamk.*
11		*Ceriops decandra (Griff.) Ding Hou.*
12		*C. tagal (Perr.) C.B. Rob.*
13	*Sonneratiaceae*	*Sonneratia alba J. Smith*
14		*S. caseolaris (L.) Engler*

2. Sub mangrove species

15	*Asclepiadaceae*	*Finlaysonia obovata*
16	*Combretaceae*	*Lumnitzera racemosa Willd.*
17	*Euphorbiaceae*	*Excoecaria agallocha L.*
18	*Myrtaceae*	*Osbornia octodonta F. Muell. loc. cit.*

19	*Palmae*	*Nypa fruticans (Thunb.) Wurmb.*
20	*Pteridaceae*	*Acrostichum aureum Linnaeus*
3. Minor mangrove species		
21	*Acanthaceae*	*Acanthus ilicifolius L.*
22		*A. ebracteatus Vahl.*
23	*Apocynaceae*	*Cerbera manghas L.*
24	*Bignoniaceae*	*Dolichandron spathacea (L.f.) K. Schumann*
25	*Lecythidaceae*	*Barringtonia asiatica (L.) Kurz.*
26	*Leguminosae*	*Caesalpina bonduc (L.) Rorb.*
27		*Derris trifoliata Lour.*
28		*Pongamia pinata (L.) Pierre.*
29	*Lythraceae*	*Pemphis acidula Forst.*
30	*Malvaceae*	*Hibiscus tiliaceus L.*
31		*Thespesia populenea (L.) Solander er Correa*
32	*Pandanaceae*	*Pandanus tectorius Soland. ex. Balf.*
33	*Verbenaceae*	*Clerodendron inerme Gaertn.*
4. Non mangrove species		
34	*Aizoaceae*	*Sesuvium portulacastrum*
45	*Asclepiadaceae*	*Calotropis gigantea R. Br.*
36	*Cactaceae*	*Opuntia vulgaris*
37	*Casuarianaceae*	*Casuarina equisetifolia (L.) J.R. et Forst.*
38	*Compositae*	*Pluchea indica*
39	*Combretaceae*	*Terminalia catappa Less.*
40	*Convolvulaceae*	*Ipomoea pes-caprae*
41	*Geamineae*	*Spinifex littoreus*
42	*Goodenniaceae*	*Scaevola taccada (Gaertn.) Rorb.*
43	*Guttiferae*	*Calophyllum inophyllum L.*
44	*Phamnaceae*	*Zizyphus maurtiana Lam.*
45	*Verbenaceae*	*Lantana camara L.*
46		*Vitex ovata*

a) BENOA Bay

There were many villages along the coast of this area that have been developed for a long time. Mangrove forest has been used for a long time by local residents as the supplier of timber, salt field, farm of fishes, and field of fisheries. Since 1970's, illegal felling might have been decreased due to rigid control as preservation forest or shift of fuel to gas or kerosene. Still, there are some traces of illegal felling in natural forest.

Species observed in this area are summarized in Table 2-3-5. They are consisted of 13 strict mangrove species, 6 sub mangrove species, 14 minor mangrove species, and

13 non mangrove (*oceanophyte*) species.

As described above, these have been disturbance by people for a long time in this aea. Though there was few differences in species consisting the mangrove forest between this area and Lombok Island, it is characteristic that the number of mangrove tees growing on high ground at inland was very small. By the recent development for tourists, the sites with growing mangrove trees has been further decreased. So, it might be a possibility that formation of sample forest becomes necessary in this project.

Zonal structure at the coast of BENOA Bay is not clear due to artificial disturbance. Roughly dividing, however, there are S. alba and R. apiculata in the front and *A. marina, Avicennia lanata, B. gymnorrhiza. X. garanatum,* and *Aegiceras corniculatum* in the intermediate zone before the inland. Along the bypass road constructed along the coast of this bay, there are further terrestrial area. Though small in number, *Lumnitzera racemosa, Clerodendron inerma,* and *Osbornia octodonta,* etc. appear in this area. Along rivers with very low salt concentration, *Sonneratia caseolaris* and *D. spathacea* appear.

Condition of natural forest along the observation footway is as follows: *S. alba* is predominant in the front but young trees of *R. apiculata* have already invaded into it. Mean height of trees in natural forest are highest in the front consisted of *S. alba* followed in tendency by lower and younger trees of the other species to inland. It was supposed to be so because trees in inland areas are felled easily and those observed are young ones beginning to grow after the disappearance of big trees.

Natural regeneration method of *Sonneratia alba*

S. alba is the predominant species in mangrove forest of BENOA Bay. It grows from the front to almost inland areas. Its seedlings or young trees are scarcely observed in vicinity to the front of natural forest. The causes are too deep water and dark environment in the forest that make growth impossible even when germination occurs. By the observation of *S. alba* along the footway, it is indicated that not a few trees are involved in renewal by hidden extension (Photos. 2--5). There might be a possibility that those supposed to be separate trees are really a single tree at a considerably incidence (Photo 6). In order to obtain reference for future afforestation method, survey to grasp the actual condition is necessary.

b) West Bali National park

Species observed in this area are summarized in Table 2--3--6. They are consisted of 16 strict mangrove species, 7 sub mangrove species, 14 minor mangrove species, and

14 non mangrove (oceanophyte) species.

Since the area is a park, artificial disturbance of vegetation is less significant than that of BENOA Bay. Mangrove forests are preserved at better conditions. There are thus some places showing relatively clear zonal structures. There are also many mangrove trees remained.

Distribution of *Rhizophora x lamarkii Montr*

In "The Botany of Mangrove", Mr. Thomlinson said that R. X lamarkii was not distributed at this area. Its growing at this are was, however, confirmed by Mr. Ir. Undang, a clerk of West Bali National park).

Surveys on the other districts, growing of this species has been also confirmed at Plau Selangan Island in BENOA Bay, Nusa Lembongan island, and Lombok Island.

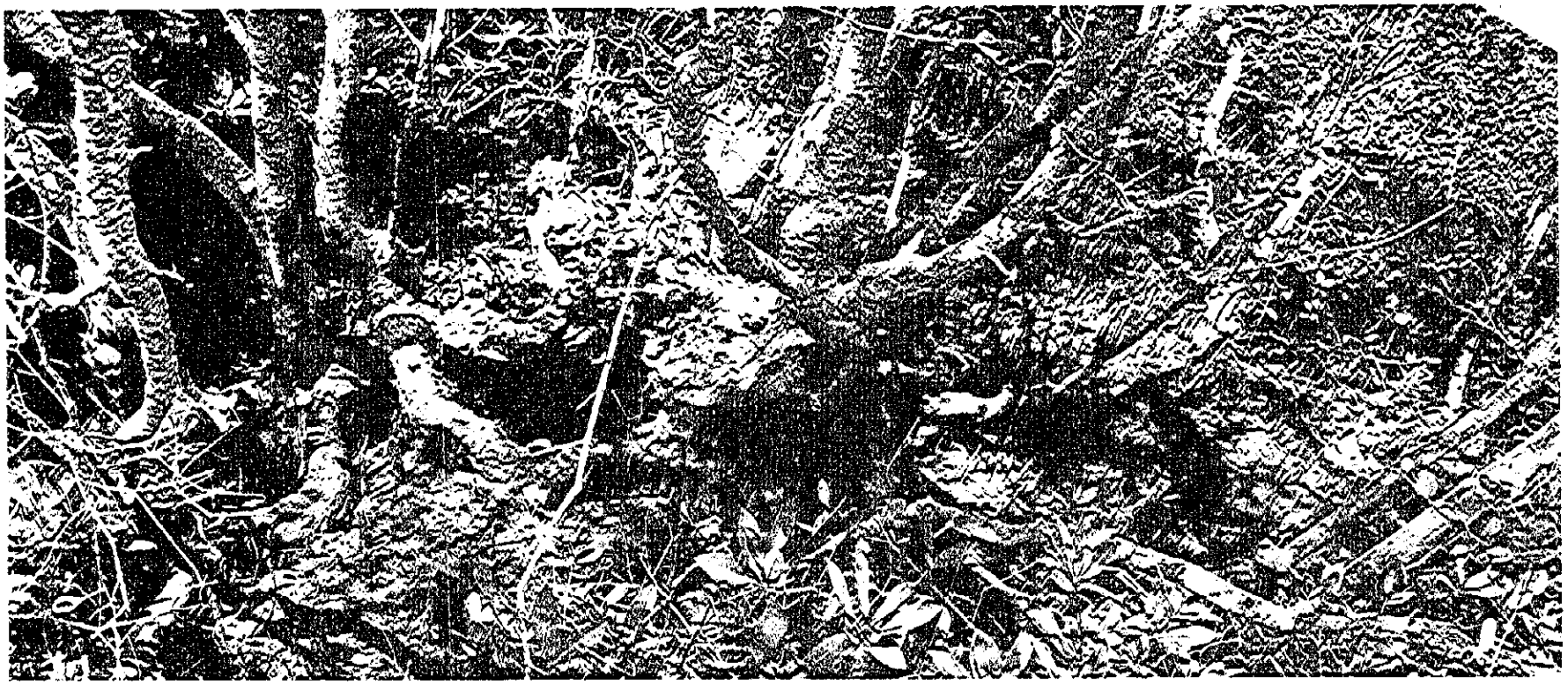


Photo. 2 Regeneration by hidden extension of Sonneratia alba J.Smith in natural forest of BENOA Bay, Example 1

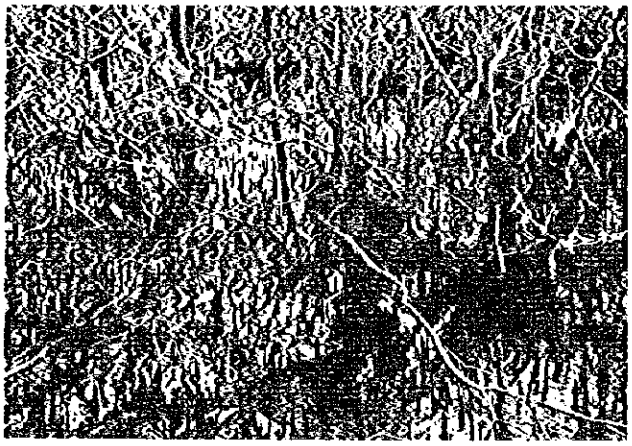


Photo. 3 Regeneration by hidden extension of Sonneratia alba J. Smith in natural forest of BENOA Bay, Example 2

Photo. 4 Regeneration by hidden extension of Sonneratia alba J. Smith in natural forest of BENOA Bay, Example 3

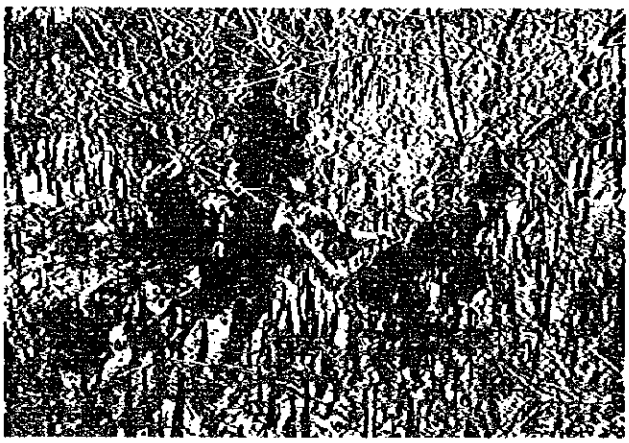


Photo. 5 Regeneration by hidden extension of Sonneratia alba J. Smith in natural forest of BENOA Bay, Example 4

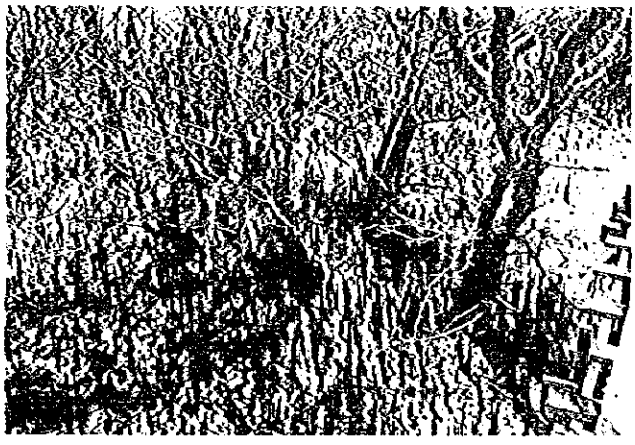


Photo. 6 Regeneration by hidden extension of Sonneratia alba J. Smith in natural forest of BENOA Bay (Group of individual trees supposed to be connected under the ground), Example 5

Table 2–3–6 List of mangrove species and non mangrove species (oceanophytes) in West Bali National Park

1. Strict mangrove species		
1	*Avicenniaceae*	*Avicennia lanata Ridl.*
2		*A. marina (Forsk.) Vierh.*
3	*Meliaceae*	*Xylocarpus granatum Koenig*
4		*X. mekongensis Pierre*
5		*X. moluccensis (Lamk.) Roem.*
6	*Myrsinaceae*	*Aegiceras corniculatum (L.) Blanco*
7		*A. floridum Roem. & Schult.*
8	*Rhizophoraceae*	*Rhizophora apiculata BL.*
9		*R. X lamarckii Montr.*
10		*R. mucronata Lamk.*
11		*R. stylosa Griff.*
12		*Bruguiera cylindrica (L.) BL.*
13		*B. gymnorrhiza (L.) Lamk.*
14		*Ceriops decandra (Griff.) Ding Hou.*
15		*C. tagal (Perr.) C.B. Rob.*
16	*Sonneratiaceae*	*Sonneratia alba J. Smith*
2. Sub mangrove species		
17	*Asclepiadaceae*	*Finlaysonia obovata*
18	*Combretaceae*	*Lumnitzera racemosa Willd.*
19	*Euphorbiaceae*	*Excoecaria agallocha L.*
20	*Myrtaceae*	*Osbornia octodonta F. Muell. loc. cit.*
21	*Palmae*	*Nypa fruticans (Thunb.) Wurmb.*
22	*Sterculiaceae*	*Heritiera littoralis Dryand. in Aiton*
23	*Pteridaceae*	*Acrostichum aureum Linnaeus*
3. Minor mangrove species		
24	*Acanthaceae*	*Acanthus ilicifolius L.*
25		*A. ebracteatus Vahl.*
26	*Apocynaceae*	*Cerbera manghas L.*
27	*Bignoniaceae*	*Dolichandron spathacea (L.f.) K. Schumann*
28	*Lecythidaceae*	*Barringtonia asiatica (L.) Kurz.*
29		*B. racemosa (L.) Spreng.*
30	*Leguminosae*	*Caesalpina bonduc (L.) Roxb.*
31		*Derris trifoliata Lour.*
32		*Pongamia pinata (L.) Pierre.*
33	*Lythraceae*	*Pemphis acidula Forst.*
34	*Malvaceae*	*Hibiscus tiliaceus L.*
35		*Thespesia populnea (L.) Solander er Correa*
36	*Pandanaceae*	*Pandanus tectorius Soland. ex. Balf.*
37	*Verbenaceae*	*Clerodendron inerme Gaertn.*
4. Non mangrove species		
38	*Aizoaceae*	*Sesuvium portulacastrum*
39	*Asclepiadaceae*	*Calotropis gigantea R. Br.*
40	*Cactaceae*	*Opuntia vulgaris*
41	*Compositae*	*Pluchea indica*
42	*Combretaceae*	*Terminalia catappa Less.*

43	*Convolvulaceae*	*Ipomoea pes-caprae*
44		*I. alba L.*
45	*Geamineae*	*Spinifex littoreus*
46	*Goodenniaceae*	*Scaevola taccada (Gaertn.) Rorb.*
47	*Guttiferae*	*Calophyllum inophyllum L.*
48	*Hernandiaceae*	*Hernandia peltata Meisn.*
49	*Phamnaceae*	*Zizyphus maurtiana Lam.*
50	*Verbenaceae*	*Lantana camara L.*
51		*Vitex ovata*

c) Low marsh in vicinity to Negara City

Several rivers flow into the low marsh to result in advanced dilution of seawater. It was said that there are extensive mangrove forest in old days. At present, however, the area of mangrove forest has been decreased by development of farms and paddy fields at this area. It is still supposed that there are many remaining species of mangrove preferring low salt concentration. Such kinds of mangrove species are not observed in the other area in Bali Island. It is thus considered to be necessary to perform survey for sample collection.

Species of *Rhizophoraceae* family such as *R. mucronata* and *R. apiculata* are said to remain at this are. It is necessary to perform survey for seed collection forest at the same time with the above described survey.

Group of Nypa fruticans

At the site with advanced dilution of seawater adjacent to a paddy field, the sole and relatively united group of N. fruticans remains. The trees are 3–5 m in height and the forest occupies 5 ha. Even now, the forest is used for various purposes by the local residents.

d) Nusa Lembongan Island

In the north part of Nusa Lembongan Island, ther is a mangrove forest of about 200 ha. Since the island is small and lacks no large river, salt concentration is considered to be almost the same as that of seawater. By the observation from the sky, zonal structure might remain in the forest. Exploration of vegetation on the spot inside of the mangrove forest has not been performed.

The survey performed in March 1993 revealed that the predominant species was *R. stylosa* and there was no *R. mucronata*. Relatively favorable growth of the forest of *S. alba* was observed.

Survey of vegetation in combination with survey of seed collection forest is required

in future.

e) Seed collection forest

The survey on this time suggested that there might be no significant problem from the viewpoint of supply of seeds since there are mangrove forests with large areas in vicinity to BENOA Bay and in West Bali National Park (Table 2-3-7). However, it is supposed to be necessary to take some protective measures for seed collection forests for advancing aff orestation of mangrove forest in future.

2) Study on environmental conditions of natural and man-made forest

A) Vegetation and height of ground at Lombok site

For this survey, the fixed test site for survey of individual tree that located about 80m into the inland from the seaside margin of natural forest in Gili Sulat Island. A fixed plot of 30 m × 30 m in area was divided by 5 m mesh. Intersecting points of the mesh were subjected to measurement of height (cm) using a water level. Topographical maps were prepared from the results indicating contours with 20 cm notch. For each contour division, the area, number of trees, and kinds of tree were clarified in order to investigate the relationship of height of ground and vegetation.

Table 2-3-7 List of seed collection forest

Kind of tree	Geographical name			
	BENOA Bay	West Bali National Park	Negara City	Nusa Lembongan Island
R. apiculata	○	○	—	—
R. mucronata	○	○	—	—
B. gymnorrhiza	○	○	—	—
C. tagal	○	○	—	—
S. alba	○	○	—	—
A. marina	○	○	—	—
X. granatum	○	○	—	—

Abbreviation of kind of tree

R. apiculata:	*Rhizophora apiculata Bl.*
R. mucronata:	*Rhizophora mucronata Poir.*
B. gymnorrhiza:	*Bruguiera gymnorrhiza Lam.*
C. tagal:	*Ceriops tagal C.B. Rob.*
S. alba:	*Sonneratia alba J. Sm.*
A. marina:	*Avicennia marina Forsk.*
X. granatum:	*Xylocapus granatum Koenig.*

Explanatory note of marks

○ : Appropriate
△ : Not much amount
— : Not surveyed
× : Inappropriate or very small amount

As an example, you seen in Fig. 2–3–5 that the are between contours 60 cm and 80 cm was 163 m 2 and there were 25 trees of *R. apiculata* growing. The density of growing trees was thus 1,534/ha.

In the survey of height of ground, the starting point was first determined as follows since there was no official bench mark in Gili Sulat Island: The heights of ground were measured at 3 points along the seaside margin of natural forest which was the borderline formed by the present vegetation (Fig. 2–3–4). The average height of ground of these 3 values was used as the starting point. The 3 points were average ones along the margin of forest without exposure to strong currents or waves.

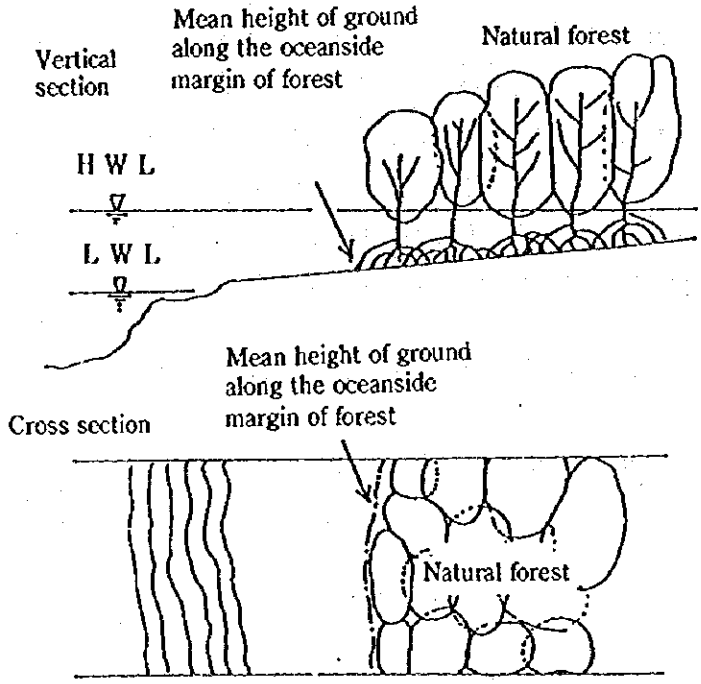
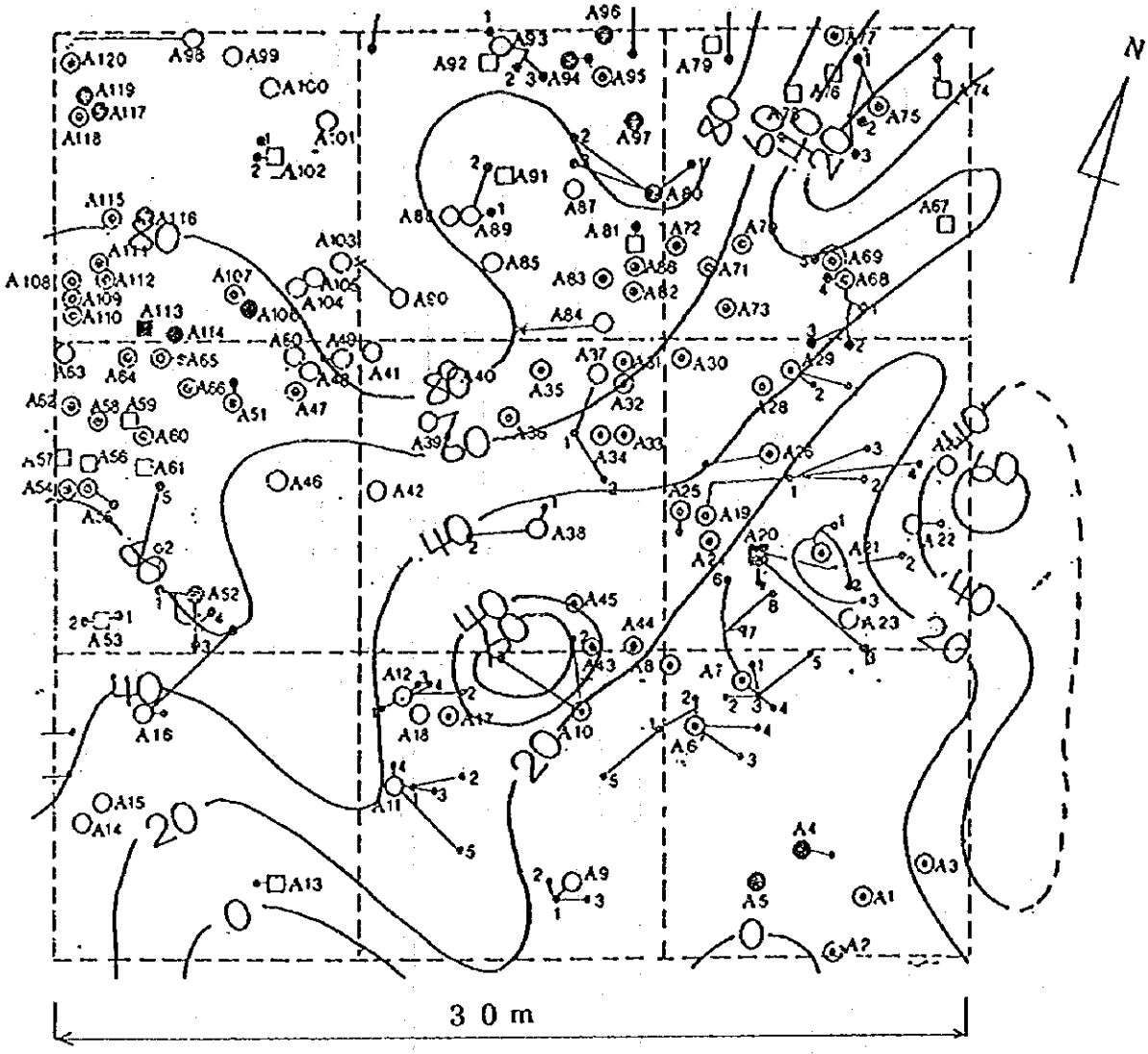


Fig. 2–3–4 Mean height of ground along the oceanside margin of forest

Results:

In the fixed test site, the ground became higher from the south to the north. The area from 0 to 40–60 cm in height was covered with mangrove mud. Higher area was a rather solid ground covered with white coral sand (Fig. 2–3–5).



Contour, unit: cm

Explanatory note ○●◎□■ : Main trunk : Sub trunk

◎ : *Rhizophora apiculata BL.*

○ : *Rhizophora mucronata Lamk.*

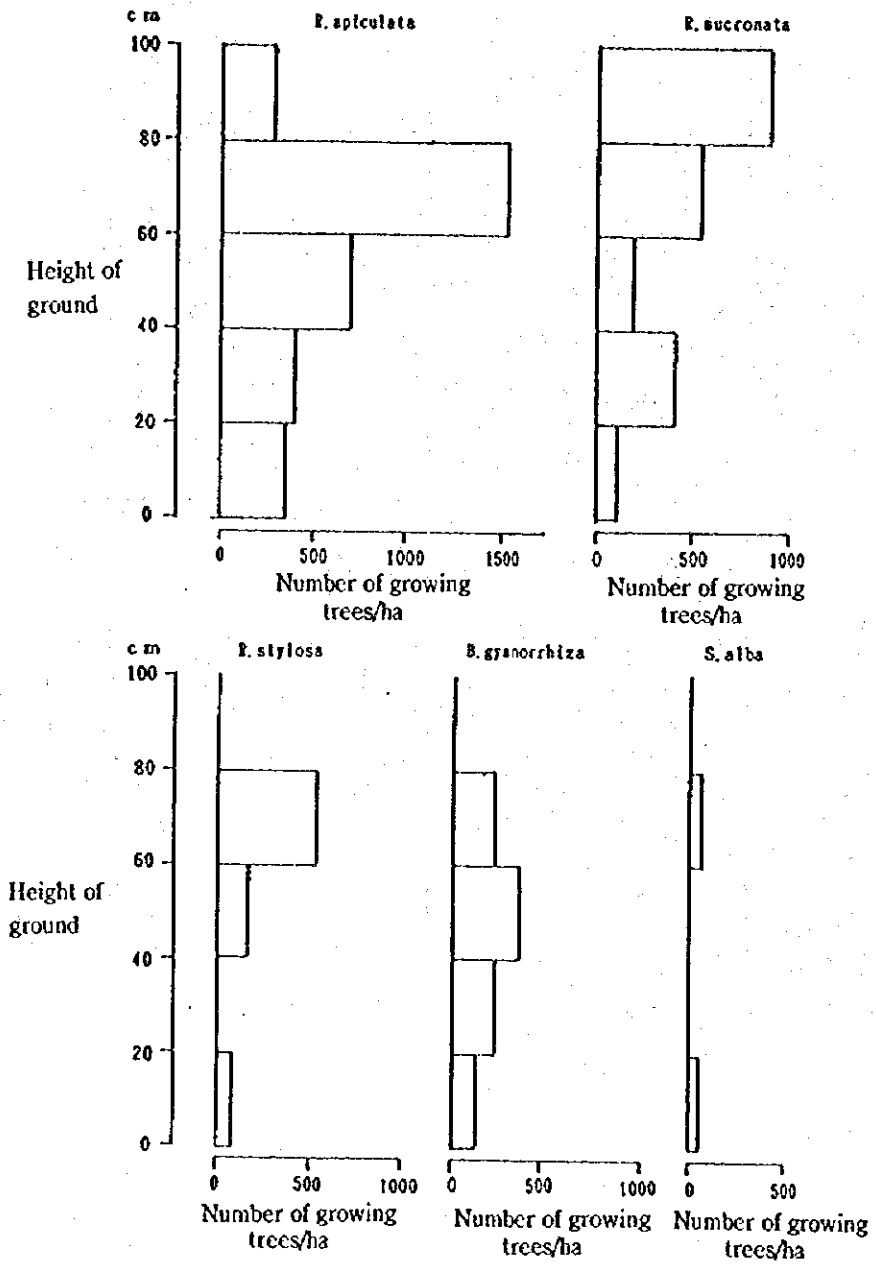
● : *Rhizophora stylosa Griff.*

□ : *Bruguiera gymnorrhiza (L.) Lamk.*

■ : *Sonneratia alba J. Smith*

× : Position of root

Fig. 2-3-5 Topography and kind of growing trees in Permanent Aurvey site (in Gili Sulat Island)



Explanatory note

R. apiculata	: *Rhizophora apiculata Bl.*
R. mucronata	: *Rhizophora mucronata Lamk.*
R. stylosa	: *Rhizophora stylosa Griff.*
B. gymnorrhiza	: *Bruguiera gymnorrhiza (L.) Lamk.*
S. alba	: *Sonneratia alba J. Smith*

Fig. 2-3-6 Number of growing trees of each species for each height of ground in Pennanent Survey site (in Gili Sulat Island)

a) *R. apiculata* grew within a range of 0–87 cm in height of ground in the fixed test site (Fig. 2–3–6). The highest density of tree was seen within the range from 41 to 80 cm in height of ground. The results were almost coincided to those obtained by survey in Bali site as described later in section B) and by terrace afforestation test.

b) *R. mucronata* grew within a range of 0–87 cm in height of ground. The highest density of tree was seen within the range at 61 cm or higher in height of ground. It was considered to grow at any places irrespective of the height of ground. Along the other observation footway in Gili Sulat Island, inside of natural forest was observed and only a few influences of the height of ground were detected. The results were somewhat different from those obtained by terrace affor estation test.

c) *B. gymnorrhiza* showed an increasing tendency of the density of tree at places of 41 cm or higher in height of ground.

In this survey, the starting point was set for the sake of convenience at the average height of ground along the seaside margin of natural forest. Heights of ground with individual growing trees were relative ones to the starting point. From the obtained results, the starting point was seemed to be appropriate as the standard point for survey. In other words, the height of ground of the starting point was supposed to indicate the limit of forest formed by the long term adaptation process to the natural environment in the vicinity. Therefore, it was supposed to be possible to determine the range of afforestation in the vicinity based on the height of ground of the starting point. As an example as shown in Fig. 2–3–7, when the average height of the ground long the seaside margin of natural forest in vicinity to the scheduled afforestation site was at the sea surface, the appropriate range of afforestation in the scheduled afforestation site was considered to be set at areas higher than the sea surface.

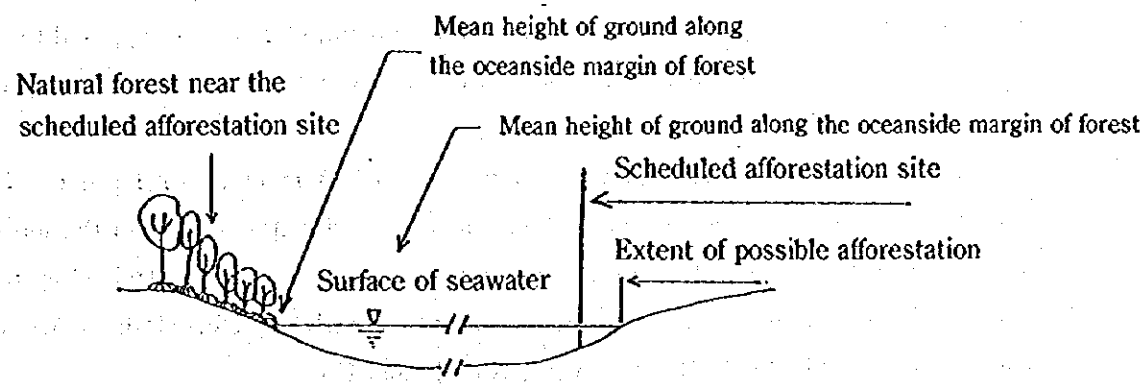


Fig. 2–3–7 Determination of extent of possible afforestation using mean height of ground along the oceanside margin of forest

B) Vegetation and height of ground at Bali site

Heights of ground (cm) were determined at every 10 m interval along the observation footway constructed from the south tip of Block II to the seaside margin of natural forest using a water level. In addition, for the comparison of depth of water, 7 observation stakes were settled (Fig. 2–3–8 and Table 2–3–8). As described in the above section A), the starting point of the height of ground was settled to be the average one calculated from 12 points at the seaside margin of natural forest. In the survey of vegetation, characteristics were recorded on both sides along the footway at every 10 m interval (Table 2–3–9 and Fig. 2–3–9). The results were compared with those obtained by the terrace afforestation test and those determined by the similar survey along the observation footway n Lombok site (of Gili Sulat Island') Fig. 2–3–10).

Results:

a) The vertical range of growth of *R. apiculata* in natural forest was from 10 cm in the height of ground in vicinity to the margin of front to 94 cm (Fig. 2–3–10, kind of tree No. 11).

The density of *R. apiculata* was low from 516 to 440 m of the distance on the footway (10–35 cm in height of ground).

However, the growing trees showed less branches, relatively prominent main trunks, and favorable growth conditions (Table 2–3–9, Fig. 2–3–9). On the other hand, results of the terrace afforestation test showed unfavorable growth at 10 cm of height of ground (terrace Nos. 15–16) (Fig. 2–3–10, kind of tree No. 15).

The difference was considered to be ascribed to markedly different environmental conditions such as light, ambient temperature, ground temperature, and wind which were eased in natural forest as compared with the terrace test site by the existence of upper storied *S. alba*. The smaller density of tree in natural forest was supposed to be ascribed to withering at early phase of growth due to influence of depth of water differing from that in afforestation site.

R. apiculata with increasing numbers from 400 to 330 m of the distance on the footway (35–45 cm in height of ground) and thus invaded considerably into the forest predominant with *S. alba*. The results were almost coincided to those obtained by the terrace afforestation test when considering that *R. apiculata* preferred the range of height of ground (Fig. 2–3–10, kind of tree Nos. 11 and 15).

From 160 to 380 m of the distance on the footway (41–68 cm in height of ground), *R. apiculata* trees were many but low in height of tree to be under competitive

conditions with *A. lanata* and *A. corniculatum* which preferred relative high grounds (Table 2-3-9).

From 160 to 20 m of the distance on the footway (15-55 cm in height of ground), pure forest of *R. apiculata* was formed. Considering the height of ground, the appropriate site for *R. apiculata*, the results were almost coincided to those obtained by the terrace afforestation test (Table 2-3-9, kind of tree No. 15 in Fig. 2-3-10).

b) On the site of old farm in Block II, there were places dug down to the level of average height of ground along the seaside margin of natural forest as shown by the comparison of heights of ground of stakes Nos. 1 and 4 in Fig. 2-3-8 and Table 2-3-8. The averse effects to afforestation trees such as long immersing time were afraid.

c) *A. corniculatum*, *A. lanata*, and *O. octodonta* grew along waterways about 40 cm higher than the average height of ground along the seaside margin of natural forest. They are supposed to prefer rather high grounds (Table 2-3-9, Fig. 2-3-9).

d) *A. lanata* showed high density and favorable growth at 41-68 cm of height of ground. The height of ground was almost coincided to that with favorable growth of *A. marina* in the terrace affo restation test. From these results, afforestation of *A. lanata* at the same range of height of ground as *A. marina* was considered to pose no problems (Fig. 2-3-10, kind of tree Nos. 13 and 16).

e) Comparison of results of survey in Bali site and Lombok site (Fig. 2-3-10)

- Mangrove species showed different ranges of distribution according to height of ground.
- Trees of *Rhizophoraceae* family such as *R. mucronata* showed a wide vertical range of distribution but they also showed a tendency to have more restricted range in height of ground with favorable growth.
- *R. stylosa* distributed up to 80 cm of height of ground. In general, *R. stylosa* was seen along the seaside margin of natural forest. The group of *R. stylosa* observed on about 80 cm in height of ground was seemed to be a remaining one after elevation of ground of former creek area by accumulation effects.
- The vertical distribution of *A. marina* was quite different between Gili Sulat Island and BENOA Bay in Bali site. It was supposed that for some reason there was no other site for possible growth of *A. marina* in Gili Sulat Island.

Based on the above results, it was important to select kinds of tree at afforestation according to the height of ground.

This time, the results obtained in different sites such as natural forest in Lombok site or Bali site and terrace afforesta tion site with the standard of average height of ground along the seaside margin of natural forest. There were still some suspicion to determine whether it was an appropriate method due to small number of sites of survey. As far as the results of com parison of *R. apiculata*, the average height of ground long the seaside margin of natural forest was seemed to have a possibility to become the common index as the standard height of ground.

Table 2-3-8 Position and height of ground of observations takes for water depth in the vicinity of BENOA Bay

Number of observation stake	Height of ground	Position of observation stake
1	-3cm	Front of natural forest
2	12cm	Tip of footway (516 m)
3	72cm	Side of north end of footway of natural forest (40 m)
4	7cm	Site of old farm (Block II, No. 42)
5	17cm	Terrace test site (Block II, No. 32)
6	20cm	Exhibition forest (Block II, No. 3)
7	73cm	Site of old farm (Block II, No. 11)

(Note): The standard height (0 cm) was the average height of 12 points around the observation stake 1. Height of ground is the height of position indicating "0 cm" of the observation stake.

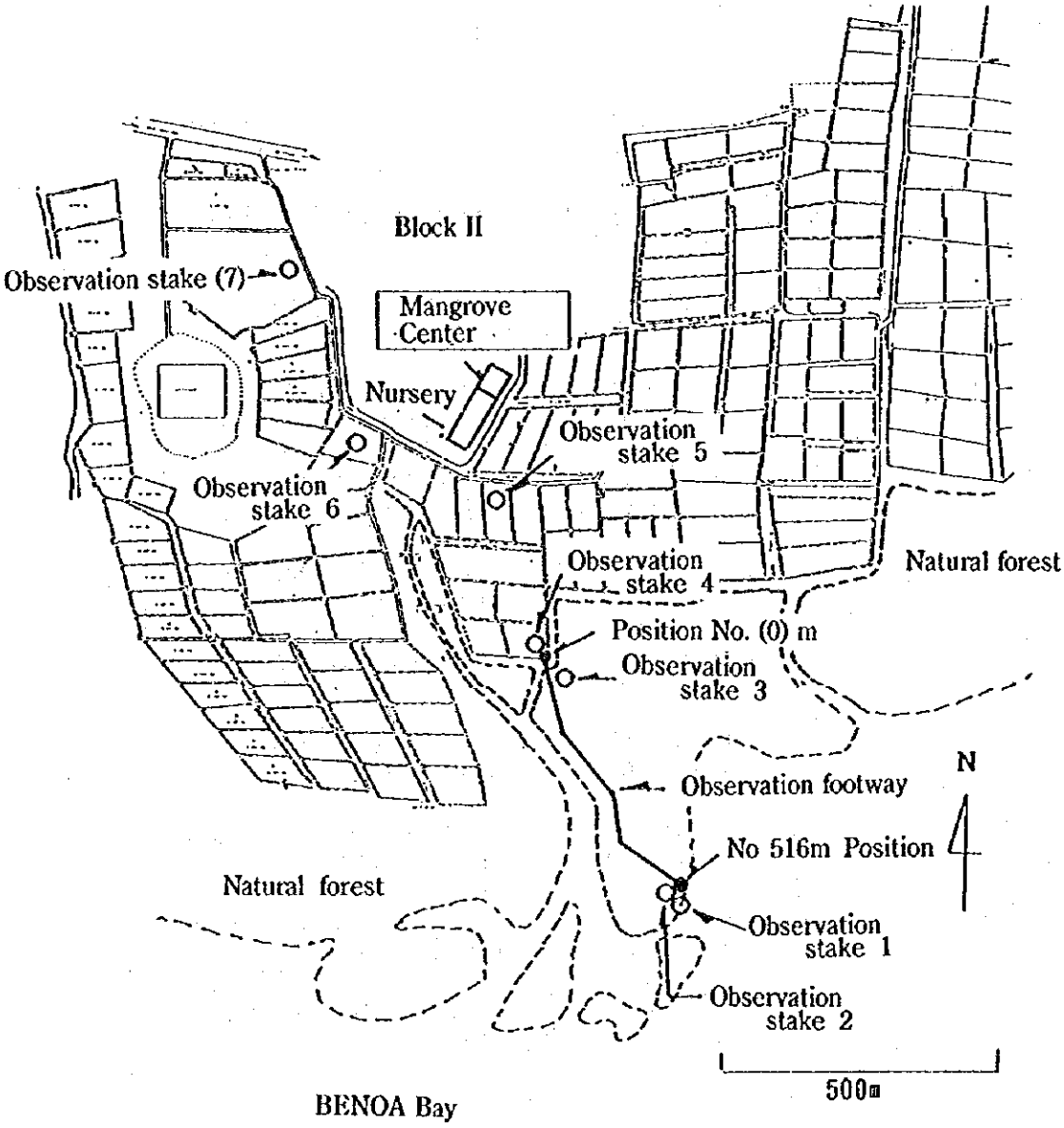


Fig. 2-3-8 Site for measurement of height of ground in natural forest and on the site of tambak in Bali site

Table 2-3-9 Height of ground and vegetation in natural forest (No.1)

Point of observation	Height of ground	Vegetational condition
Margin of forest*	0cm	Growth of *so* (h = 15 m) on the front with no young tree
516m	10cm	Growth of *so* (h = 15 m) and *api* (7 m) at a ratio of 9:1
510m	13cm	Growth of *so* (h = 15 m) and *api* (7 m) at a ratio of 9:1 with young tree of *api*
500m	21cm	Growth of *so* (h = 15 m) and *api* (7 m) at a ratio of 9:1 with young tree of *api*
490m	24cm	Growth of *so* (h = 15 m) and *api* (7 m) at a ratio of 9:1 with young tree of *api*
480m	30cm	Growth of *so* (h = 15 m) and *api* (7 m) at a ratio of 9:1 with young tree of *api*
470m	29cm	Growth of *so* (h = 15 m) and *api* (8 m) at a ratio of 9:1 with young tree of *api*
460m	30cm	Growth of *so* (h = 15 m) and *api* (12 m) at a ratio of 9:1 with young tree of *api*
450m	34cm	Growth of *so* (h = 15 m) and *api* (13 m) at a ratio of 9:1 with young tree of *api*
440m	35cm	Growth of *so* (h = 15 m) and *api* (8 m) at a ratio of 9:1 with young tree of *api*
430m	39cm	Growth of *so* (h = 15 m) and *api* (8 m) at a ratio of 8:2 with young tree of *api*
420m	37cm	– ditto –
410m	37cm	-- ditto --
400m	35cm	Growth of *so* (h = 15 m) and *api* (10 m) at a ratio of 8:2 with young tree of *api*

(Note): Margin of forest was in vicinity to observation stake 1 in Fig. 2-3-8.
The standard height was the average height of 12 points around the margin of forest.

Table 2--3--9 Height of ground and vegetation in natural forest (No.2)

Point of observation	Height of ground	Vegetational condition
390m	39cm	Growth of *so* (h = 15 m) and *api* (4 m) at a ratio of 6:4 with young tree of *api*
380m	37cm	Growth of *so* (h = 15 m) and *api* (3 m) at a ratio of 6:4 with young tree of *api*
370m	33cm	Growth of *so* (h = 15 m) and *api* (3 m) at a ratio of 6:4 with young tree of *api*
360m	38cm	Growth of *so* (h = 10 m) and *api* (3 m) at a ratio of 6:4 with young tree of *api*
350m	35cm	– ditto –
340m	46cm	– ditto –
330m	45cm	Growth of *so* (h = 12 m) and *api* (7 m) at a ratio of 6:4 with young tree of *api*
320m	59cm	Growth of *so* (h = 10 m), *api* (5 m), *cor* (2 m) and *lana* (8 m) at a ratio of 4:4:1:1 with young tree of *api* and *cor*
310m	51cm	Growth of *so* (h = 8 m) and *api* (4 m) at a ratio of 6:4
300m	53cm	Growth of *so* (h = 10 m) and *api* (3 m) at a ratio of 6:4
290m	57cm	Growth of *so* (h = 10 m) and *api* (4 m) at a ratio of 5:5
280m	66cm	Growth of *api* (3 m) at a ratio of 5:5
270m	64cm	Growth of *so* (h = 8 m), *api* (3 m), *cor* (3 m) and *lana* (7 m) with crowns not closed
260m	68cm	Growth of *so* (h = 6 m), *api* (4 m), *cor* (2 m) and *lana* (7 m) with crowns not closed
250m	–30cm	Natural waterway
240m	54cm	Growth of *so* (h = 7 m), *api* (3 m), *cor* (2 m) and *lana* (6 m) with crowns not closed

Table 2-3-9 Height of ground and vegetation in natural forest (No.3)

Point of observation	Height of ground	Vegetational condition
230m	65cm	Growth of *so* (h = 4 m), *api* (3 m), *cor* (2 m), *lana* (6 m) and *osbo* (4 m) with crowns not closed
220m	52cm	Growth of *so* (h = 7 m), *api* (4 m), *cor* (3 m) and *lana* (4 m) with crowns not closed
210m	47cm	Growth of *so* (h = 8 m), *api* (5 m) and *cor* (2 m) with crowns not closed
200m	50cm	Growth of *so* (h = 10 m), *api* (6 m) and *cor* (3 m) with crowns not closed
190m	47cm	Growth of *so* (h = 10 m), *api* (3 m), *cor* (2 m) and *lana* (7 m) with crowns not closed
180m	41cm	Growth of *so* (h = 8 m), *api* (3 m), *cor* (2 m) and *lana* (7 m) with crowns not closed
170m	47cm	Growth of *so* (h = 5 m), *api* (4 m), *cor* (1 m) and *lana* (7 m) with crowns not closed
160m	42cm	Growth of *api* (4 m), *cor* (3 m) and *lana* (5 m) with crowns not closed
150m	55cm	Growth of *api* (4 m) with crowns closed
140m	42cm	Growth of *api* (6 m), *api* (3 m) and *cor* (3 m) with crowns closed
130m	52cm	Growth of *api* (7 m) with crowns closed
120m	33cm	Growth of *so* (8 m) and *api* (7 m) with crowns closed
110m	39cm	Growth of *api* (7 m) with crowns closed
100m	33cm	Growth of *api* (8 m) with crowns closed
90m	32cm	Growth of *api* (9 m) with crowns closed
80m	29cm	Growth of *api* (8 m) and *mcr* (7 m) with crowns closed
70m	15cm	Growth of *api* (6 m) with crowns closed

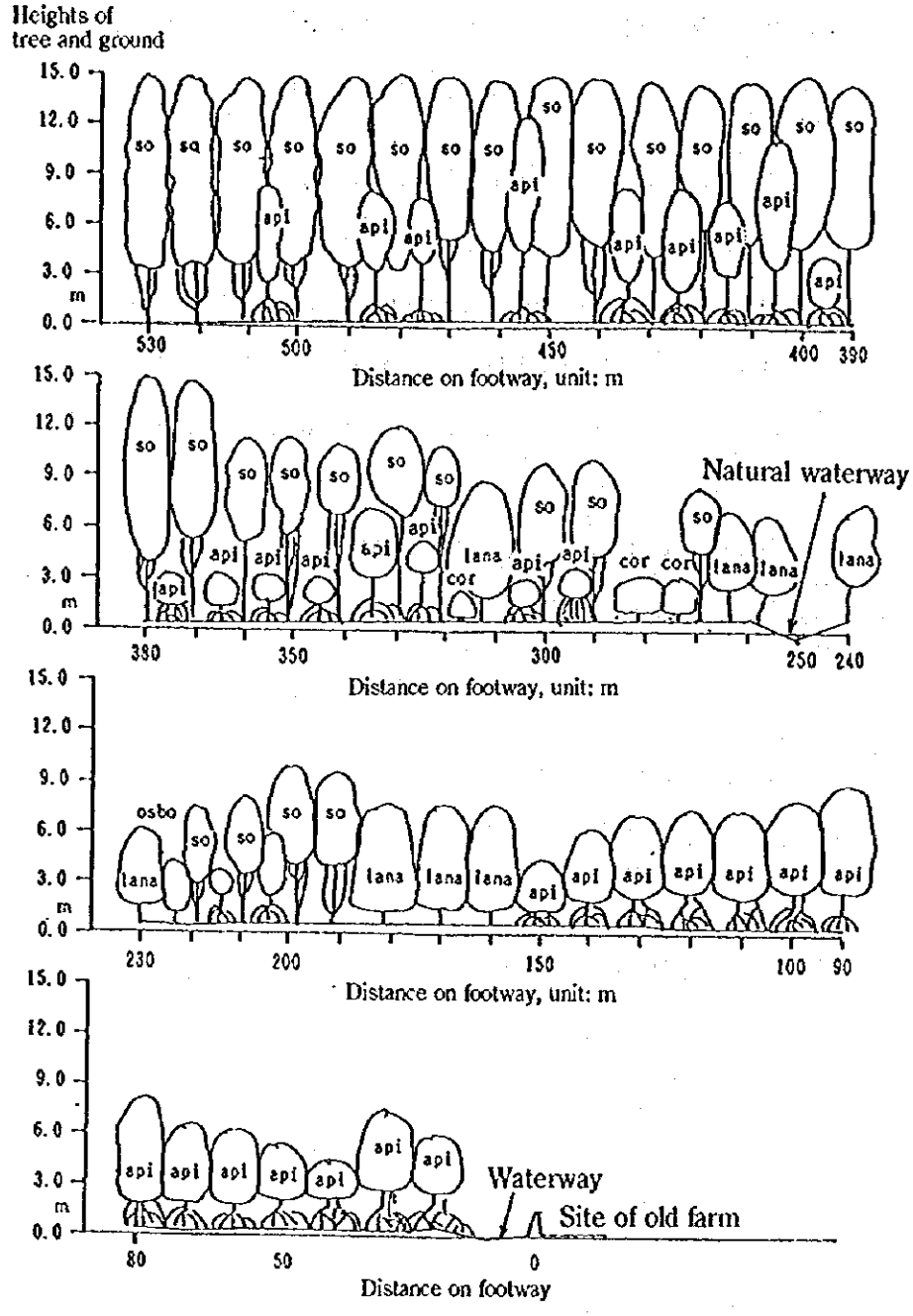
Table 2–3–9 Height of ground and vegetation in natural forest (No.4)

Point of observation	Height of ground	Vegetational condition
60m	39cm	Growth of *api* (6 m) with crowns closed
50m	37cm	Growth of *api* (5 m) with crowns closed
40m	39cm	Growth of *api* (5 m) with crowns not closed
30m	31cm	Growth of *api* (7 m) with crowns not closed
20m	45cm	Growth of *api* (5 m) with crowns not closed
10m	−20cm	? waterway
0m	174cm	Bank of the site of old farm

(Note): Points of observation were settled every 10 m along the observation footway.
Height of the ground on the side of footway was measured.

Explanatory note

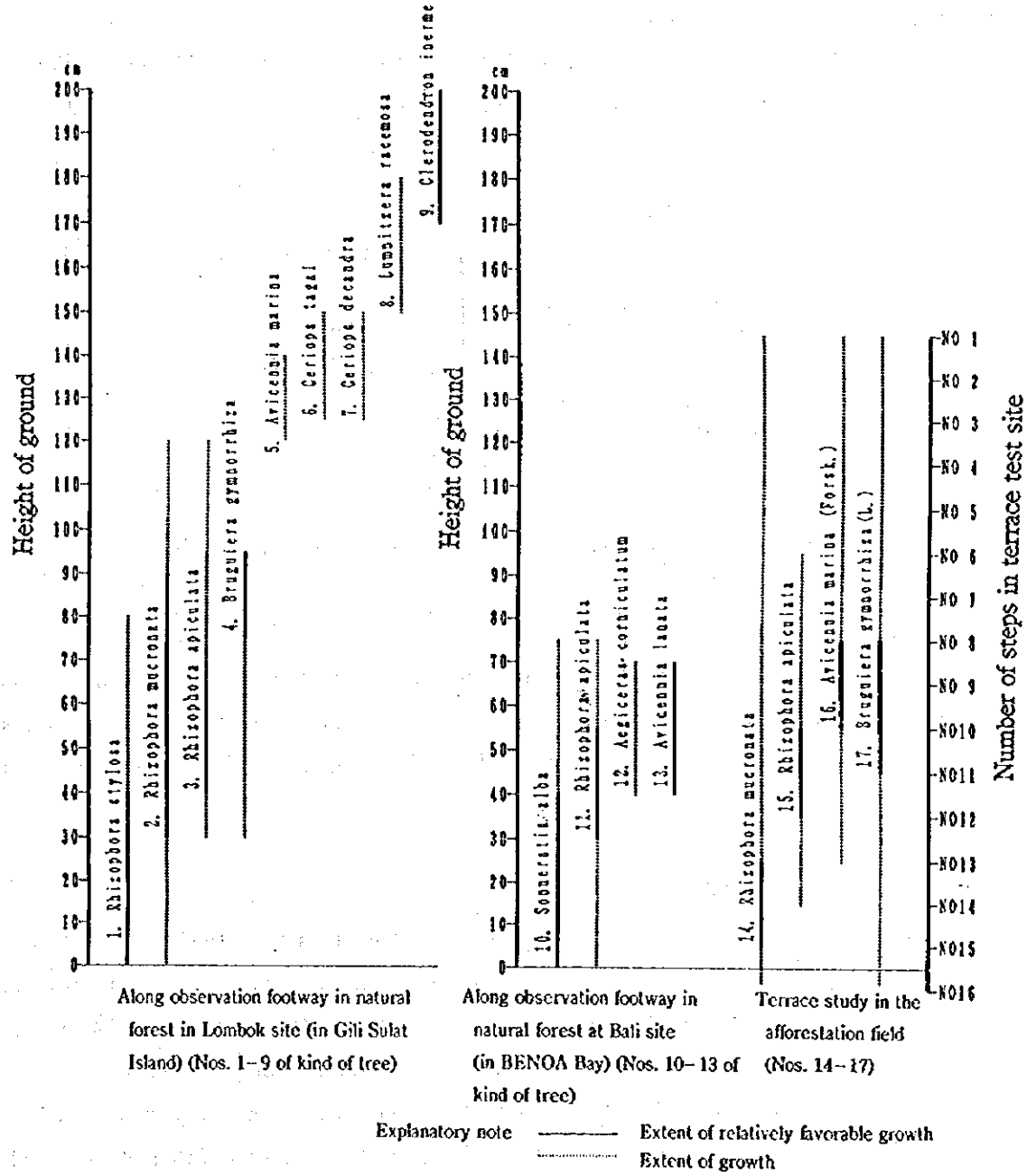
so : *Sonneratia alba J. Smith. alba*
api : *Rhizophora apiculata BL.*
cor : *Aegiceras corniculatum (L.) Blanco*
lana : *Avicennia lanata Ridl.*
osbo : *Osbornia octodonta F. Muell. loc. cit.*
mcr : *Rhizophora mucronata Lamk.*



Explanatory note

so	: *Sonneratia alba J. Smith. alba*
api	: *Rhizophora apiculata BL.*
cor	: *Aegiceras corniculatum (L.) Blanco*
lana	: *Avicennia lanata Ridl.*
osbo	: *Osbornia octodonta F. Muell. loc. cit.*
mcr	: *Rhizophora mucronata Lamk.*

Fig. 2-3-9 Vertical Zonation vegetation map in natural forest in Bali site



(Note): . The "0 cm" height of ground is the average height of ground along the margin of natural forest.

. The absolute "0 cm" heights in Lombok site (Nos. 1–9 of kind of tree) and in Bali site (Nos. 10–17 of kind of tree) are not equal.

. The "0 cm" heights along observation footway in natural forest and in terrace study in the afforestation field in Bali site are common.

. The upper end of No. 16 step of terrace is 6 cm lower than the average height of ground along margin of natural forest.

Fig. 2–3–10 Comparison of growing extent of each kind of tree

3) Study on soil sedimentation

At each site for survey, 10 acryl plates (15 cm x 15 cm, Fig. 2-3-11) were settled on the margin of ground as shown in the figure at almost equal interval. Weights at absolute dryness of earth and sand accumulated on the plates were measured one year later.

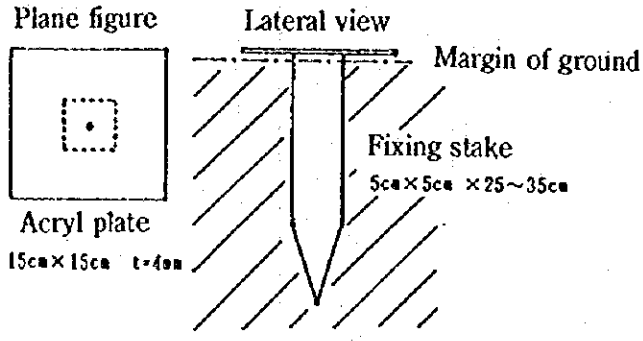


Fig. 2-3-11. Apparatus to survey accumulation amount of soil

Results:

Determination of accumulation amount started in January 1994. Results were thus not yet obtained in present. Based on the observation until now, the following various problems were indicated. The methods should be examined again after the one year survey period.

- Survey in Gili Sulat Island

Ten acryl plates were settled in the fixed test site in January 1994 and the survey has been continued. Except for the acryl plate settled in the natural waterway in natural forest, the other plates were unseen under accumulated mud. Some measures were required for the accumulation phenomena due to the following problems:

1. Acryl plates were settled on the margin of ground. They were frequently buried by soil transferred to the surface by crabs and squilla at preparation of their dens. Such accumulation might be impossible to be distinguished from the actual accumulation amount.
2. There was no invasion of local residents. However, researchers rolled up surface soil by walking at each survey such as individual tree survey. It became determination error in accumulation amount.

- Survey in natural forest of Bali site

Ten acryl plates were settled in January 1994 along the footway of palm logs constructed by the infrastructure project in natural forest located south of Block II.

The survey has been continued. Acryl plates were unseen under accumulated mud. Some measures were required for the accumulation phenomena due to the following problems:

1. Acryl plates were settled on the margin of ground. They were frequently buried by soil transferred to the surface by crabs and squilla at preparation of their dens. Such accumulation might be impossible to be distinguished from the actual accumulation amount.
2. It was revealed that local residents walk frequently in the area for collection of crabs and prawn in natural forest. Breakage of acryl plates and rolling up of surface soil were induced by their walking. They posed determination error in accumulation amount.

4) Study on litter production and growth

A) Survey in Lombok site

In the north western part of Gili Sulat Island (Fig. 2–3–12), a square fixed test site of 30 m x 30 m was settled in forest about 80 m from the margin of forest (Fig. 2–3–14). The tes site was selected to be with average figures of fo rest representing the vicinity. In order to prevent damages to the root system induced by the survey, a wooden footway of 175 m in length was constructed in the test site.

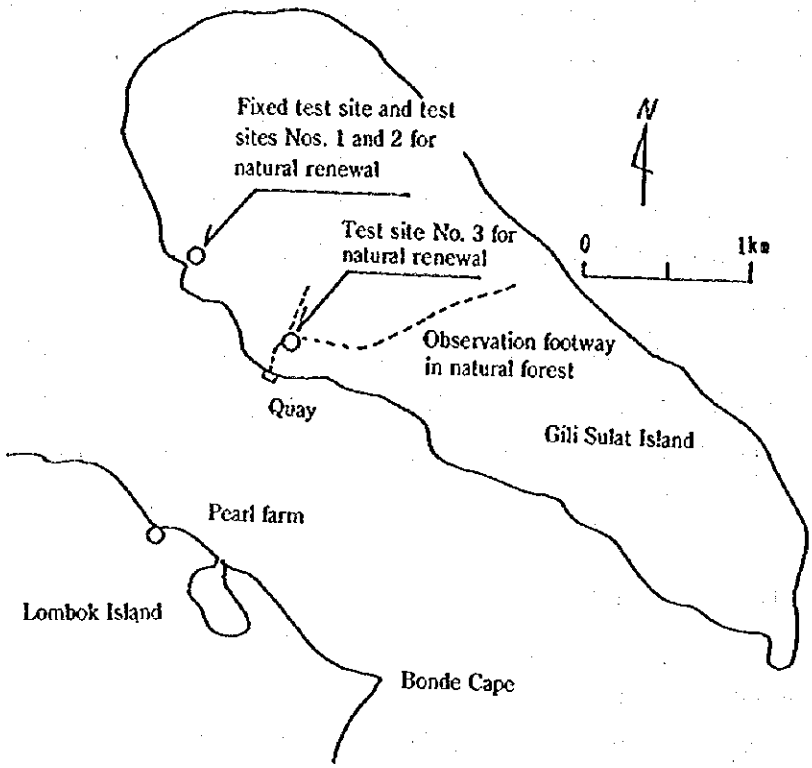


Fig. 2–3–12. Fixed test site and test site for natural renewal

For the survey of individual trees, the test site was divided to small blocks of 10 m × 10 m. Wooden stakes were settled on the intersecting pints of the borders. Each small block was further divided to plots of 5 m × 5 m using nylon tapes. Individual trees of 3 cm or more in diameter were numbered with numbering tapes and paint.

The diameters of trees of *Rhizophora* genus were measured at the height of 2 m where the trunks were separated from the root system. There wer some trees of *Rhizophora* genus that showed marked horizontal elongation of branches lower than the trunk (root system' with similar functions to trunk and possessed roots. Such trees were said to have multiple trunks. In such cases, the thickest trunk was named as the main trunk and other connected with branches (root system) were named as sub trunks (Fig. 2–3–13). The distinguishing whether the tree was an individual one was done by confirmation of connection of root system at the time of low tide.

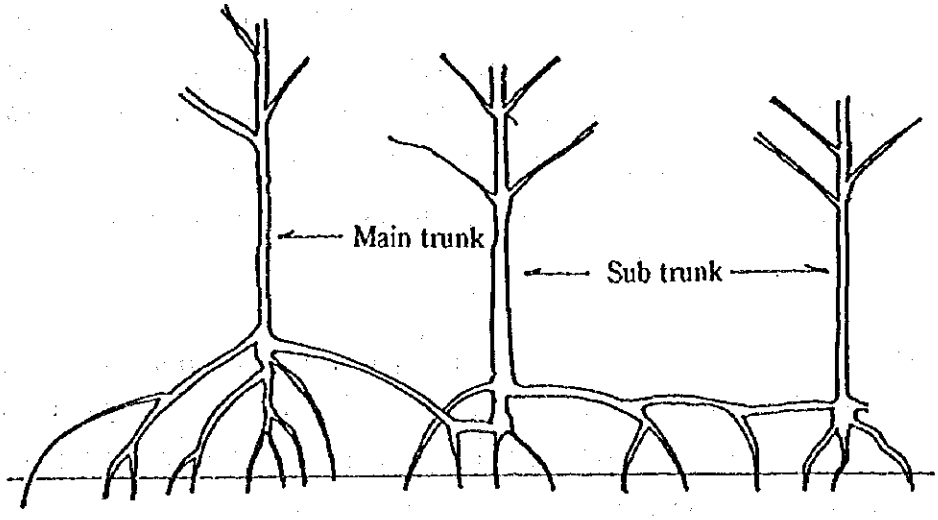


Fig. 2–3–13. Shape of tree Rhizophora apiculata BL

Results:

There were 118 trees in the test site and thus the density of stand was 1,311/ha. Including 79 sub trunks, the density of stand was 2,189/ha. The trees were consisted of 47.5% of *R. apiculata*, 27.1% of *R. mucronata*, 12.7% of *B. gymnorrhiza*, 11.0% of *R. stylosa*, and 1.7% of *S. alba* (Table 2–3–10, Fig. 2–3–15).

Table 2–3–10 Number of trees in fixed test site in Gili Sulat Island

Division	*api*	*mcr*	*sty*	*bru*	*son*	Total	Density of stand
Main trunk (number of trees)	56	32	13	15	2	118	1, 311
Sub trunk	36	23	8	8	4	79	878
Total	92	55	21	23	6	197	2, 189

Unit: stand Density of stand: stand/ha

Explanatory note
api : Rhizophora apiculata BL.
mcr: Rhizophora mucronata Lamk.
sty : Rhizophora stylosa Griff.
bru : Bruguiera gymnorrhiza (L.) Lamk.
son : Sonneratia alba J. Smith

The height of upper storied trees was 13–15 m. Distribution of diameter showed decreases in number of trees as the diameter increased from 4 cm. The decrease stopped at about 14–16 cm in diameter. Then, the number of trees of 18 cm in diameter increased and again it decreased as the diameter increased (Fig. 2–3–16).

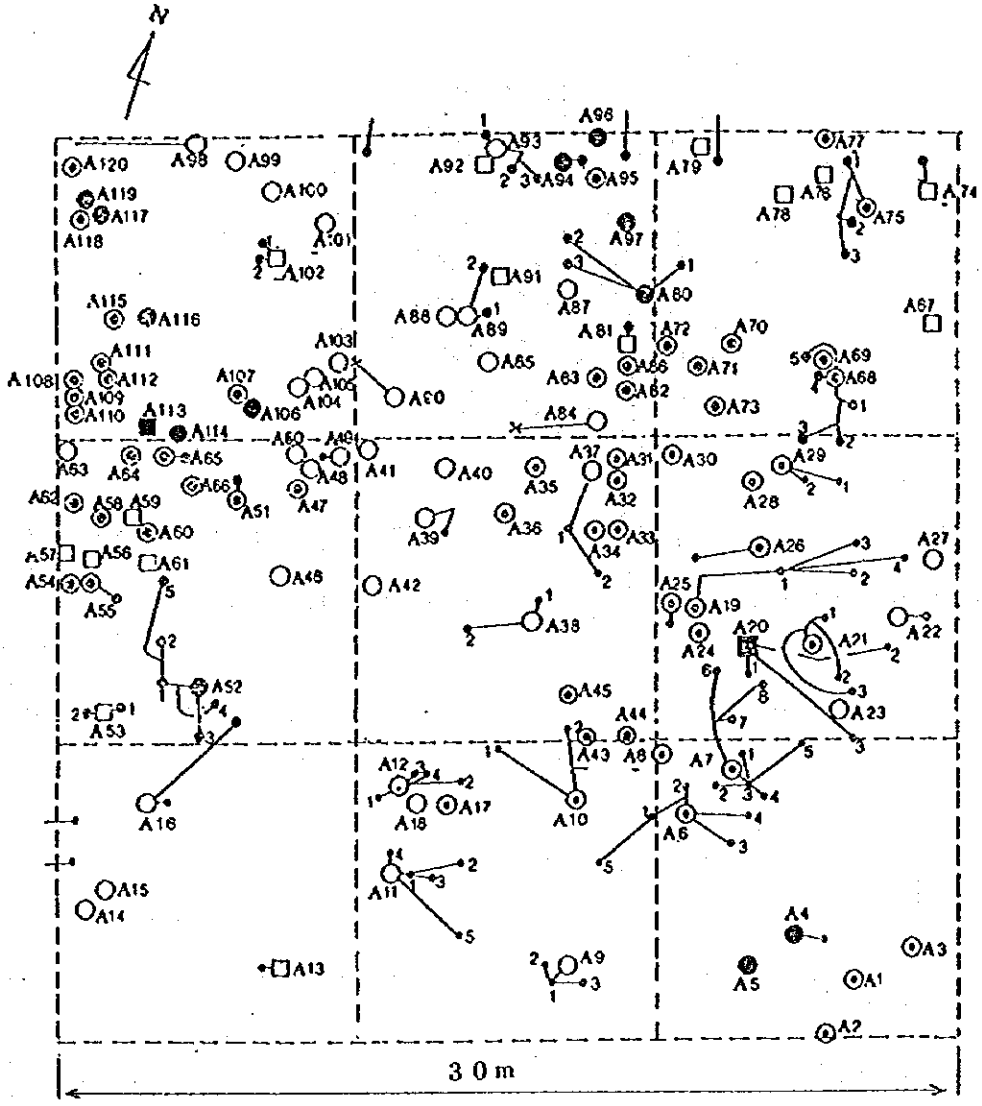
The other findings in the test site were as follows:

1. In previous survey, the forest was near the front of sea and predominated by *R.*

stylosa. Then, the margin of forest advanced to the sea. As the result, the natural environment of the test site might be mild and replacement to *R. apiculata* and *R. mucronata* has been advanced. As described in 2.-2)-A), *R. apiculata* has a tendency to grow on rather high ground and *R. mucronata* grows extensively irrespective of the height of ground. It was thus considered that *R. mucronata* invaded at first.

2. The tree of *R. apiculata* was commonly consisted of one trunk with multiple sub trunks. The cause of such a shape of tree was obscure whether the nature of species or creeping of branches left after loss of the trunk by illegal felling or strong wind. In the test site, there were trees with only sub trunks left after illegal felling of the main trunk. It indicated that the sub trunks could grow independently when separated from the main trunk. Based on this result, *R. apiculata* was supposed to have a possibility of renewal by hidden extension.

3. Almost all the trees of *R. mucronata* had only one main trunk. Observation in the other district in natural forest, there were very few trees with sub trunks on extended branches (root system) as *R. apiculata*, though a few trees had multiple trunks forked at the root.



(Note): Diameter was measured at 2 m above the margin of ground.

Subject trees were those with diameter of 3 cm or more.

Explanatory note ○●◎□■ : Main trunk :Sub trunk

◎ : *Rhizophora apiculata Bl.*

○ : *Rhizophora mucronata Lamk.*

● : *Rhizophora stylosa Griff.*

□ : *Bruguiera gymnorthiza(L.) Lamk.*

■ : *Sonneratia alba J. Smith*

× : Position of root

Fig. 2–3–14. Location of individual tree in paranment survey site (in Gili Sulat Island)

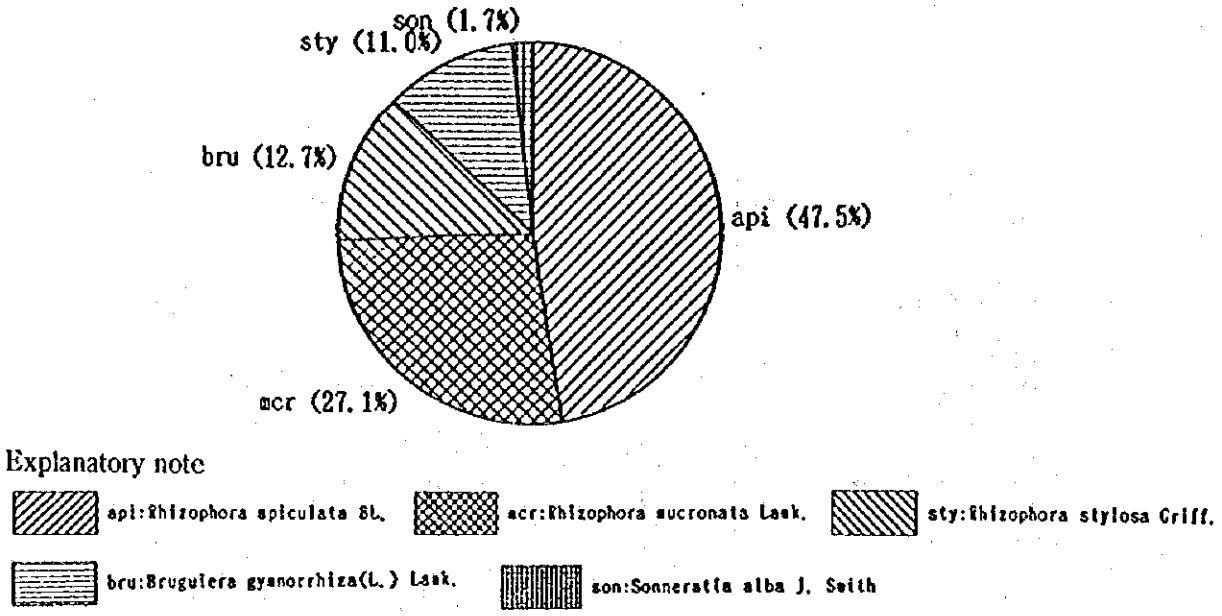


Fig. 2-3-15. Species composition of mangroves in permanent survey site (in Gili Sulat Island)

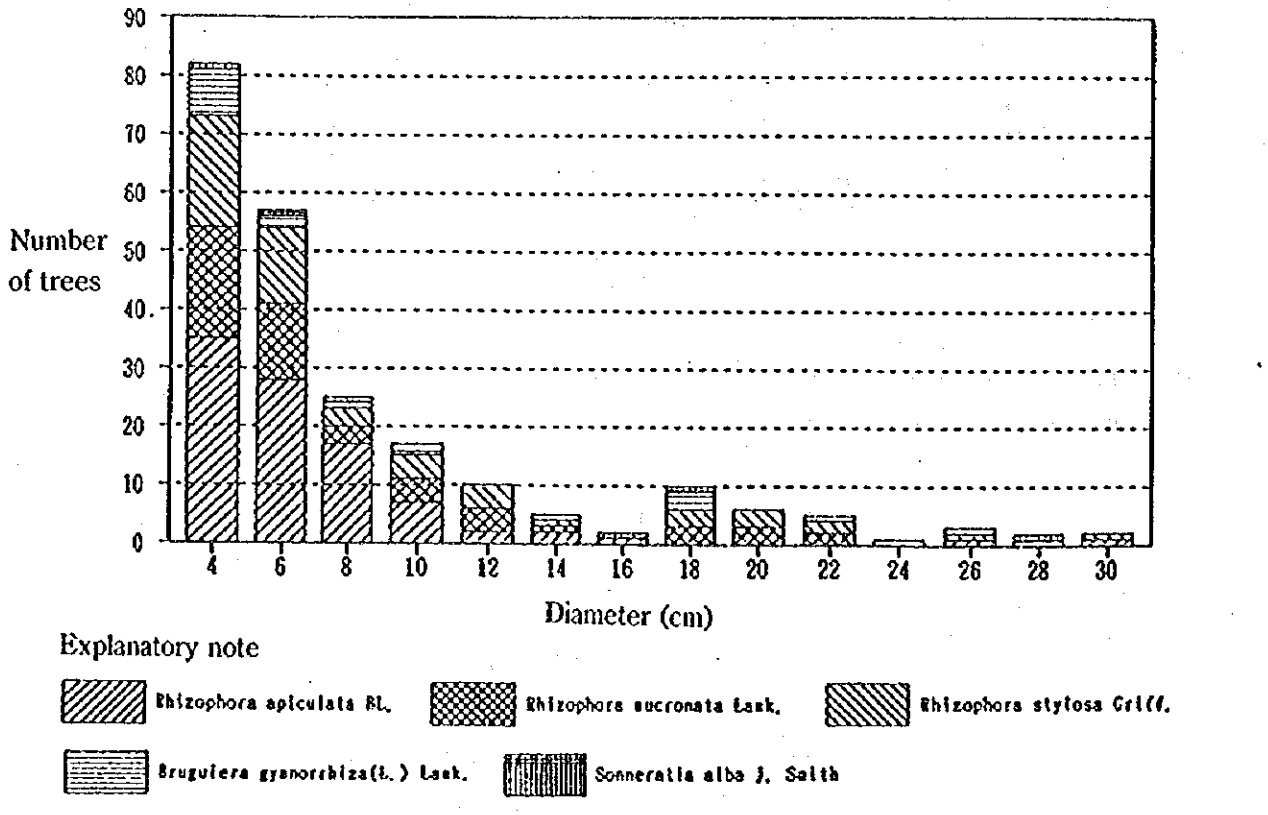


Fig. 2-3-16. Distribution of diameter of each mangroves in permanent survey site in Lombok site (of Gili Sulat Island)

4. As shown in Fig. 2-3-16, the number of trees of about 15 cm in diameter was smaller than those with smaller or larger trees. It was considered to be due to selective felling by local residents for pillars or firewood.

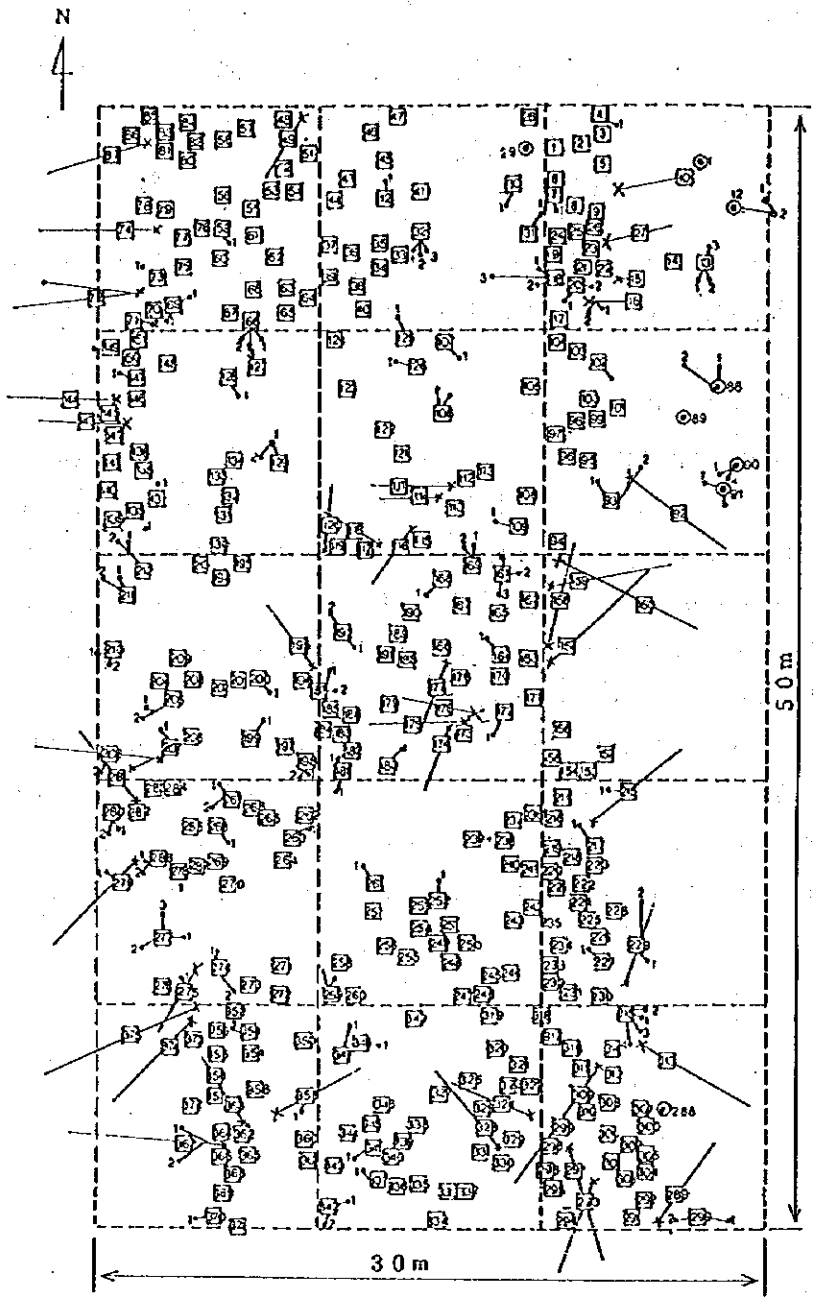
5. There were trees of *S. alba* showing renewal by hidden extension. According to the observation as well as the cases described in 2)-B), *S. alba* was supposed to have a possibility of rooting when branches near the ground were buried in the ground.

(2) Survey in Bali site (in BENOA Bay)

(a) Survey on individual tree and survey of litter in natural forest of *S. alba*

There was a natural forest of *S. alba* in the south of the office of this project. A fixed test site of 30 m × 50 m was settled in the forest (Fig. 2-3-17). The test site was selected to be with average figures of forest representing the vicinity. In order to prevent damages to the root system induced by the survey, a wooden footway of 100 m in length was constructed in the test site.

For the survey of individual trees, the test site was divided to small blocks of 10 m × 10 m. Wooden stakes were settled on the intersecting pints of the borders. Each small block was further divided to plots of 5 m × 5 m using nylon tapes. Individual trees of 3 cm or more in diameter were numbered with numbering tapes and paint.



(Note): Diameter was measured at 2 m above the margin of ground.
Subject trees were those with diameter of 3 cm or more.

Explanatory note
◎□ : Main trunk :Sub trunk
◎ : *Rhizophora apiculata BL.*
■ : *Sonneratia alba J. Smith*
× : Position of root

Fig. 2-3-17. Location of individual tree in permanant survey site in Bali site (in natural forest of BENOA Bay)

Results:

There were 375 trees in the test site and thus the density of stand was 2,500/ha. Including sub trunks, the density of stand was 3,360/ha. The trees were consisted of 98.4% of *S. alba* and 1.6% of *R. apiculata* (Table 2-3-11). The height of upper storied trees was 10-12 m. Distribution of diameter showed decreases in number of trees as the diameter increased from 4 cm (Fig. 2-3-18).

Table 2-3-11 Number of trees in permanent survey site in Bali site (of BENOA Bay)

Division	*son*	*api*	Total	Density of stand
Main trunk (number of trees)	369	6	375	2,500
Sub trunk	123	6	129	850
Total	492	12	504	3,360

Explanatory note Unit: stand Density of stand: stand/ha
son: Sonneratia alba J. Smith
api: Rhizophora apiculata BL.

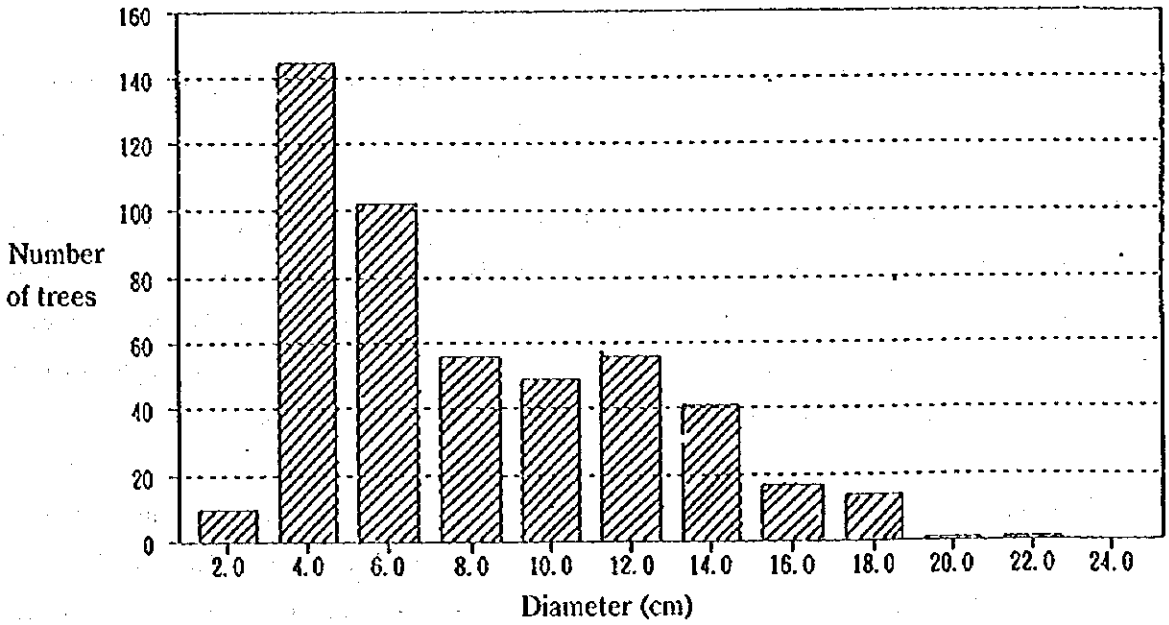


Fig. 2-3-18. Distribution of diameter of tree in permanent survey site in Bali site (of BENOA Bay)

The other findings in the test site were as follows:

1. Young trees of *S. alba* did not grow in the test site. Since the species preferred light, the amount of light was considered to be insufficient under parent trees. On the site of old farm with sufficient light exposure, there were some places showing growth of young trees of *S. alba* after germination of seeds.

2. Young trees of *R. apiculata* grew in the test site. THere was a young tree reaching to the height of 9 m. In future, the test site will be considered to be shift from *S. alba* forest to *R. apiculata* forest.

3. There were some *S. alba* trees showing regeneration by hidden extension. Considering the distribution of trees, there wer some types forming small groups. Though the root portions of these trees were covered with surface soil and not seen, regeneration by hidden extension was supposed to occur as described in 1)-B). The reason of regeneration by hidden extension was considered to be the contact of very low branches near the margin of ground with the ground and rooting was induced.

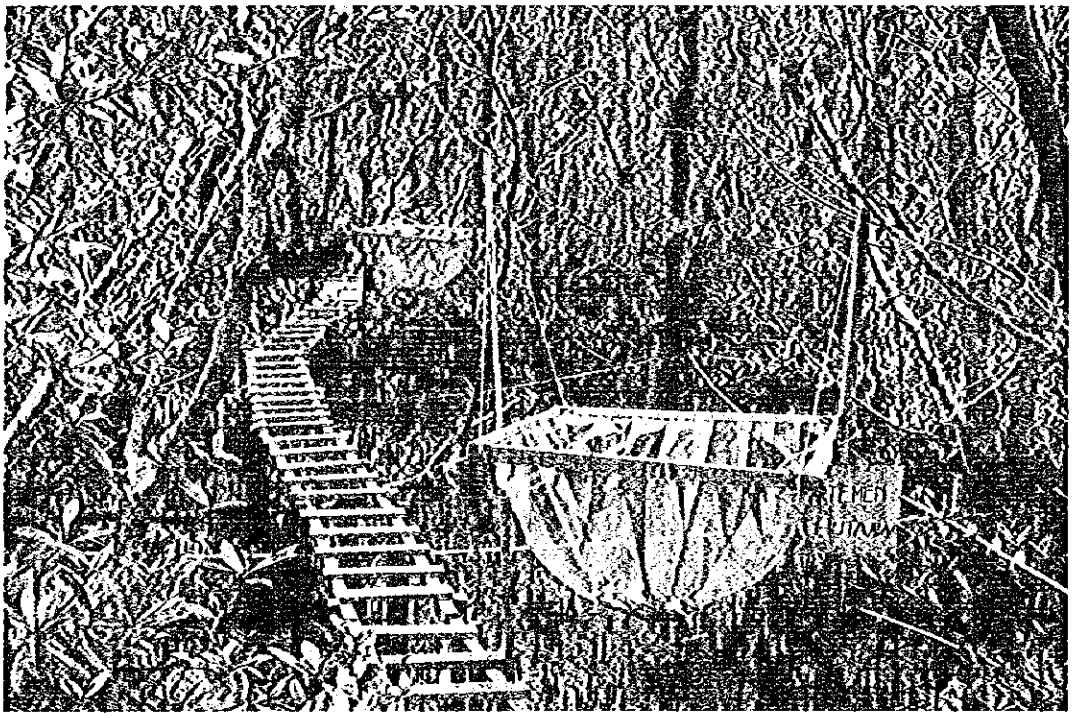
Survey of fall litter

1. The amount of litter was 17.6 t/ha.year. The fall litter was consisted of 68.6% of leaves, 16.9% of genital organs, 14.3% of branches, and 0.3% of others (Fig. 2-3-19).

2. The amount of litter increased from the end of dry season to the start of rainy season. In the other seasons of the year, the amount of litter was almost constant with no marked fluctuation.

3. Almost all the litter was washed away from the forest by the 2 times of high tide in a day. There was no site in natural forest with layered accumulation of litter. A small amount was accumulated in the corners of site of old farm. But the majority was considered to be washed away into the sea. The role of mangrove to supply organic substances to the coastal districts was thus said to be very important.

4. As far as observed in day time, a large amount of litter was not eaten by crabs. By the observation of a recess site in natural forest in Gili Sulat Island, crabs and KIBAUMININA fre quently ate litter not washed away from the forest by the daily tides.



Survey of fall litter

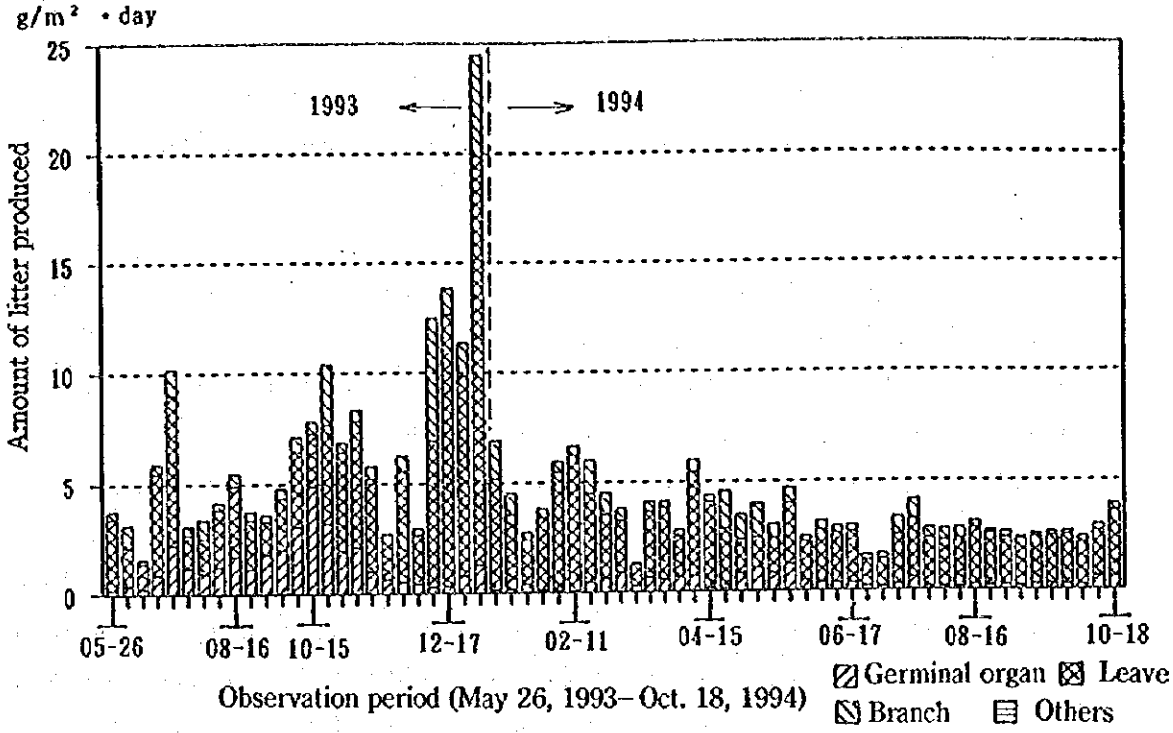


Fig. 2–3–19. Amount of litter produced in Bali site (forest of *Sonneratia alba*)

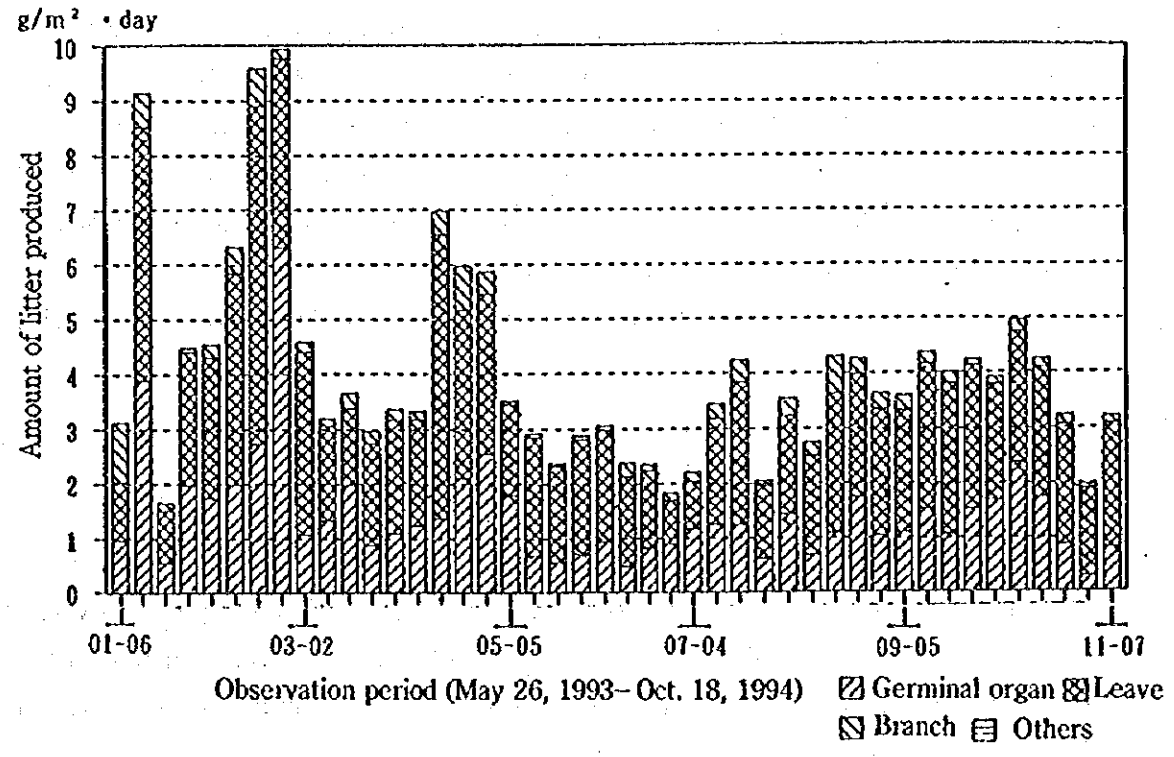


Fig. 2–3–20. Amount of litter produced in Bali site (forest of *Rhizophora apiculata*)

(b) Survey of litter in natural forest of *R. apiculata*

A fixed test site is now under settling in natural forest of *R. apiculata* in the south of the Office. Outline of the subject site was as follows: The average height of tree was 6–7 m with crowns not closed. The low branches have been withered up to about 2 m from the ground.

In the scheduled test site, there was a tree of *A. corniculatum*, a light preferring tree, that had been died recently. There are some weakened *S. alba* trees around th test site. There findings indicated that the forest was predominated once with light preferring trees such as *S. alba* and *A. corniculatum* about 10–15 years ago. Then, *R. apiculata* began to invade into the site and replaces them now as the predominant species.

The shape of *R. apiculata* tress in the test site was forked at the root to have multiple trunks remaining the chara cteristics of single trees. However, as compared with single trees growing in the site of old farm, both the numbers of supporting roots and trunks were smaller. Their shape was thus an intermediate one between the clear shaped one in closed area of natural forest in Gili Sulat Island and the single tree in the site of old farm.

Results:

1. The amount of litter was 14.64 t/ha.year. The litter was consisted of 57.5% of leaves, 36.1% of germinal, 6.4% of branches, and a trace of others (Fig. 2–3–20).
2. As was the case of *S. alba* forest, almost all the litter was washed away from the forest by the 2 times of high tide in a day. There was no site on the spot with layered accumulation of litter. As was the case of *S. alba* forest, its role to supply organic substances to the coastal districts was very important.
3. As was the case of *S. alba* forest, only a very small amount of litter was eaten by crabs, etc.

5) Study on process of regeneration in natural forest

The test site No. 1 was settled in a fixed test site at 0–20 cm of height of ground. The surface soil was mangrove mud as soft as to be muddy to 20 cm in depth at survey. The subject trees were smaller than those subjected to survey of individual tree in the fixed test site (3 cm or more in diameter). It was performed to fill the opening between the data of young trees and upper storied trees.

The test site No. 2 was settled in a fixed test site at 80–100 cm of height of ground.

The surface soil was coral sand and the ground was relatively solid.

The test site No. 3 was settled along the observation foot-way at 330 m inside from the margin of the forest and at about 90 cm of height of ground. The surface soil was mangrove mud as soft as to be muddy to 30 cm in depth at survey.

Results:

The test site No. 1 was exposed to the least light among the 3 test sites because the crown of upper storied trees was closed. The young trees were all *R. mucronata*. It was considered to be because no other species could not grow at the early phase due to the dark and low ground environments.

The test site No. 2 had more opening in the crown since the crown of upper storied trees was not completely closed. The young trees were *R. apiculata*, *R. mucronata*, and *B. gymnorrhiza*.

Just above the test site No. 3 was covered by the crown of *R. mucronata*, the mother tree. However, it was surrounded by areas with largely opened crowns due to illegal felling. It was exposed to the most light among the 3 test sites due to sufficient side light. The young trees were all *R. mucronata* probably because it was just beneath the crown of *R. mucronata* tree. Though there were adult trees of *B. gymnorrhiza* adjacent to the test site, no young tree of *B. gymnorrhiza* was seen.

Surveys were performed in July, September, and November, 1994. The following discussion was made on the obtained results:

1. During the 3 times of survey, there were trees died and disappeared. Further observation is required because the causes of death/disapperance were unknown (Tables 2-3-12, 2-3-13, 2-3-14). The number of dead/disappeared trees was the smallest in test site No. 3 with the most light exposure.

Table 2-3-12 Result of survey of test site No.1 for natural renewal

Kind of tree	July 14	Sept. 15	Nov. 15	Change in number
R. mucronata	21	19	17	-4
Total	21	19	17	-4

(1994)

R. mucronata: Rhizophora mucronata Lamk.

Table 2-3-13 Result of survey of test site No.2 for natural renewal

Kind of tree	July 14	Sept. 15	Nov. 15	Change in number
R. mucronata	4	4	3	-1
R. apiculata	10	9	7	-3
R. stylosa	2	1	1	-1
B. gymonrrhiza	3	3	3	0
Total	19	17	14	-5

(1994)

R. mucronata : *Rhizphora mucronata Lamk.*
R. apiculata : *Rhizophora apiculata BL.*
R. stylosa : *Rhizophora stylosa Griff.*
B. gymnorrhiza : *Bruguiera gymnorrhiza (L.) Lamk.*

Table 2-3-14 Result of survey of test site No.3 for natural regeneration

Kind of tree	July 14	Sept. 15	Nov. 15	Change in number
R. mucronata	34	34	34	0
R. mucronata	0	52	52	0*
Total	34	86	86	0

R. mucronata : Rhizphora mucronata Lamk.

(1994)
* Additional observation

2. There was a young tree of B. gymnorrhiza with 47 joints and 57 cm in the length of stem in test site No. 2. In general, one joint is formed for 1.5-2 months. Thus, the subject tree has lived as such young condition for 5.8-7.8 years. It is obscure why the tree does not show longitudinal growth.
3. Settlement of test site and survey in it using observation footway made walking easy and safe as well as to ease various operations at a certain degree. It is possible to increase the test sites with different conditions such as afforestation in natural forest.
4. Around test site No. 2, crown of trees in the forest was opened by illegal felling. In sites other than those just beneath the mother trees, there were fluctuations in distribution of young trees. The reason of such fluctuation was unknown. It remains as the problem to be surveyed whether it is induced by miniature topography.

6) Study on fauna at the reforestaation site

This survey will be performed by short-term specialists in individual fields. Long

term specialists only took photographs and caught them to make specimens when any animals were observed in natural forest and afforestation sites.

Species observed are listed below according to the classifi cation. Especially of birds, various birds are said to stop in Bali island since it is on the course of migrants flying between the Northern and Southern Hemispheres.

With respect of crabs, a variety of species were observed. Cardisoma carnifex, a large terrestrial species, lived at inland areas. Semi-terrestrial Grapsidae lived in concrete sluice, etc. at the site of old farm. Ocypodidae families preferred the site of old farm and tide land in natural forest. Three kinds of Portunidae crabs, which were edible, were also confirmed.

The animals recorded were found in the surroundings of the Office if not specified otherwise.

Bird, 10 kinds

- Pulumed egret
- Wood sandpiper
- Swinhoe's snipe
- Black-backed imperial pigeon
- Kingfisher
- Four other birds including bird(s) of prey

Crustacean, 20 kinds

(Identified by Dr. Hiroshi Suzuki,
Faculty of Fisheries, Kagoshima University, Japan)

- Penaeidae, 3 kinds
  - Penaeus semisulcatus (Photo. 7)
  - Penaeus (Fenneropenaeus) indicus
  - Metapenaeus moyebi (Photo. 8)
- Alpheidae, 1 kind
  - Alpheeus lobidens
- Laomediidae, 1 kind
  - Laomedia astacina
- Thalassinidae, 1 kind
  - Thalassina sp.
- Portunidae, 3 kinds
  - Portunus pelagicus (Photos. 9, 10)

Scylla serrata (2 types) (Photos. 11, 12)

Thalamita crenata (Photos. 13, 14)

Grapsidae, 3 kinds

Metopograpsus latifrons (Photos. 15, 16)

Sesarmops ?impressum (Photo. 17)

Neoepisesarma (Neoepisesarma) lafondi

Gecarcinidae, 1 kind

Cardisoma carnifex

Ocypodidae, 7 kinds

Uca (Thalassuca) vocans (Photos. 18, 19)

Uca (Deltuca) dussumieri dussumieri (Photos. 20, 21, 22)

Uca (Deltuca) coarctata coarctata (Photos. 23, 24, 25)

Uca (Deltuca) demani demani (Photos. 26, 27, 28)

Uca (Australuca) bellator bellator (Photos. 29, 30, 31, 32, 33)

Macrophthalmus (Venitus) latreillei (Photos. 34, 35, 36, 37)

Macrophthalmus (Marcotis) pacificus (Photos. 38, 39)

Mesh: 2 cm

Xanthidae (not identified) (Photos. 40, 41)

Reptile, 5 kinds

Varanus (in natural forest)

Sea snake (in natural forest, small in size, black and yellow spots, venomous)

Snake (in nursery, small, black in color)

Snake (in water at the site of old farm, large, black in color, venomous)

Snake (in natural forest, small, green in color, venomous)

Mammal, 2 kinds