THE MATURING MANGROVE PLANTATIONS OF THE COASTAL AFFORESTATION PROJECT

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PREFACE

The conclusions and recommendations given in the report are those considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages of the project.

The designations employed and the presentation of the material and maps in this document do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

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ABSTRACT

In 1986 an inventory was carried out of the maturing mangrove plantations of the Coastal Afforestation project. "Maturing" were considered those plantations established prior 1980 that could be delineated on the available 1984 aerial photographs.

Plantations were started in the four Coastal Afforestation Divisions of Chittagong, Noakhali, Barisal and Patuakhali in the year 1966 initially consisting only of species trials of limited extent. The afforestation programme gained momentum in the years 1974-1975 with the establishment of over 4000 Ha of plantation annually.

The purpose of the inventory was to obtain up-to-date figures on area, stocking and growth of the main plantation types of average to good conditions.

Results show that the area established before 1980 presently available amount to some 15000 ha, the balance being failed, eroded, encroached or heavily damaged by cyclones and tidal bores. Two thirds of the area (approx. 10000 ha) is covered by plantations of average to good conditions and one third is under stocked and of poor productivity (the latter has been excluded from sampling).

94% of the area has an age of 8 to 12 years, planted during the period 1975-1979.

Keora (Sonneratia apetala) is the most important mangrove species, forming 67% of all planted area. Keora is the principal species in all Divisions except Chittagong where it covers only a limited area in the north. Its productivity tends to be higher in the western side of the coastal belt.

	Patuakhali	Barisal	Noakhali	Chittagong (north)
MAI* (m^3/ha/year)	9.4	7.9	7.5	5.8

Diameter-age and height-age curves show that Keora in Barisal and Patuakhali grows better than in Noakhali and Chittagong where the species presents also poorer sanitary conditions and premature mortality. These facts could justify the adoption of two different rotation periods such as 20 years for Patualkali and Barisal and 15 years for Chittagong and Noakhali.

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* Mean annual increment in m^3/ha/year without thinning of stands with crown coverage of over 70%.

Baen (Avicenria spp) is the principal species of Chittagong Division. Its productivity varies widely due to total lack of silvicultural treatments (often excessively dense) and to ecological conditions.

	Chittagong South	Chittagong North
MAI* (m^3/ha/year)	1.3 - 1.9	6.9

The present unmanaged condition shows a reasonable growth in the area north of Sangu River but appear stunted in the southern part.

Mounded plantations have been established on the "higher chars" (drier accretions) of Noakhali and part Chittagong Division for a total of 1483 ha. Mainly composed of Babul (Acacia Nilotica) these plantations show overall poor results reaching an estimated MAI of 3 m^3/ha/year only in the most successful stands, that amount to only 18% of the area covered by this system of planting

All types of plantations urgently require thinning and early spacing, in case of broadcast sown stands, to balance growth and to normalize production

The maturing mangrove plantations have been mapped on 64 sheets of the available SPARRSO "Land Accretion and Plantation Map" at a scale 1 : 10000.

The area is divided into over 1200 units (DLU's) homogenous by density, species and age, with areas that varies from 1 to over 100 hectares (14 ha per unit on average). Each DLU have been individually numbered, described and entered into the computerized Resource Management System data Base. Such units have often irregular shapes. As an aid to the implementation of management prescriptions the units (or DLUs) have been grouped by contiguous common year of establishment. These age groups, that amount to 273 units of 55 ha on average, have more regular shapes that will facilitate their location in the field.

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* Mean annual increment in m^3/ha/year without thinning of stands with crown coverage of over 70%.

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** Separate from main report

1. INTRODUCTION

Afforestation of the coastal belt of Bangladesh has started in 1966 in connection with the construction of WAPDA Enbankments, with the objectives of protecting lives and properties from natural calamities such as cyclones and tidal bores and of stabilizing the newly accreted lands. Originally limited to the enbankment areas, the afforestation work gained mementum in 1974-'75, considerably increasing the area planted and interesting virtually all areas presenting accretion processes.

Production of wood, mainly as firewood, is at present the main objective in the perspective of the IDA assisted Second Forestry project.

The present inventory has been designed to provide the first information on the conditions and growth characteristics of the maturing mangrove stands, planted prior to 1980, for the establishment of a rationale Resource Management System.

2. DESCRIPTION OF THE AREA

Spread all along the coastal belt of Bangladesh (see map at page 4), the afforestation work is located in one of the most active river deltas on Earth, characterized by a very dynamic erosion/accretion process. Such a process tends to "move" and extend the land southward, eroding the northern side of the islands and accreting on the southern side where the water current reduces speed and sedimentation process takes place.

Data on available accreted land produced by SPARRSO from two separate surveys, based respectively on 1981 and on 1984 aerial photography, allow us to assess the accretion rate during the three years period as a difference between the two estimates.

Accretions
(area in Ha)

	1981	1984	1984 - 1981
Stable (ready for planting)	62063	50811	
Planted 1981 - 85*	--	39456	
Stable + planted	62063	90267	28204
Mud flats	34630	37024	2394
Total accretion	96693	127291	30598

Comparision of the two surveys gives and annual accretion rate of over 10000 ha. The eroded area cannot be at present consistently estimated but is assumed to be much lower than the accretion, leaving a widely positive margin for the afforestation programme.

Hydrology, land formation process, ecological status, floristic successions and silvicultural information are exhaustively treated in FRI Bulletin No. 2 "The Mangrove and Mangrove Forest of Bangladesh" by S. Das and N.A. Siddiqi to which we refer for such issues.

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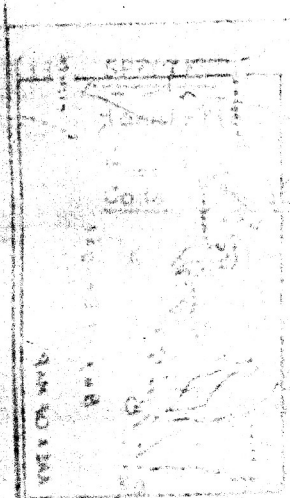
* Planted on "84" stable area.

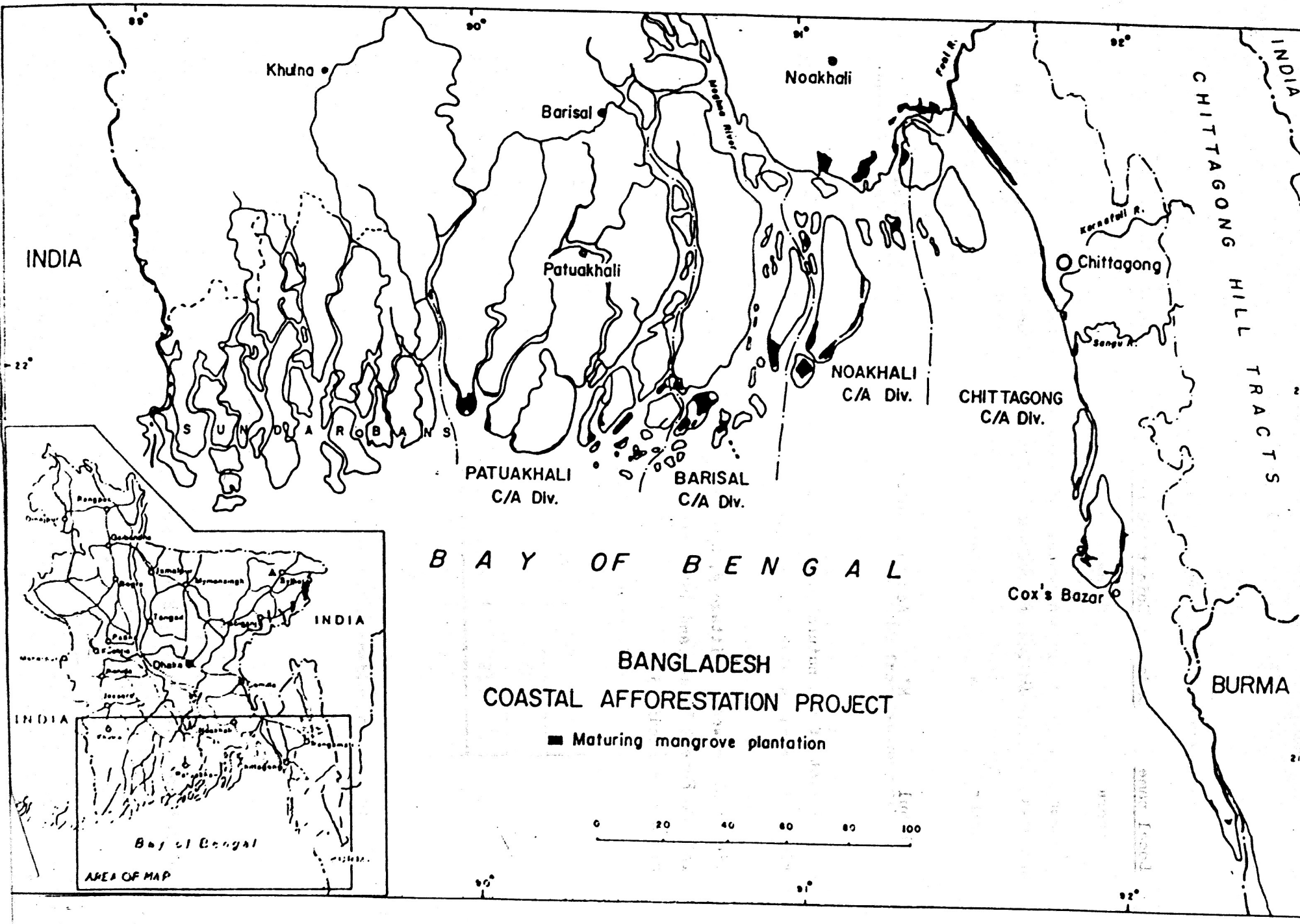
The important plantation species cited in the present report are :

Local name	Code	Scientific name	Remarks
Keora	K	Sonneratia caseolaris	Most important mangrove species.
Baen	B	Avicennia officinalis	Main species in Ctg. Dvn.
Gewa	G	Excoecaria agallocha	Covers very limited area in Noakhali Division.
Kankra	Ka	Bruguiera gymnorrhiza	Planted or underplanted with very poor resultsl Staunted growth.
Babul	M*	Acacia nilotica	Species planted on the drier land. Main component of *Mounded plantations.

A list of the natural or planted species encountered in the mangrove plantation area is given in Appendix 7.

The area is divided into four Coastal Afforestation Divisions namely, from east to west, Chittagong, Noakhali, Barisal and Patuakhali and subdivided into 28 Forest Ranges and 198 Beats or Plantation Centres. Full list is given in Appendix 3.




Khulna
Barisal
Noakhali
Patuakhali
Chittagong
Cox's Bazar
INDIA
BURMA
CHITTAGONG HILL TRACTS
SUNDARBANS
PATUAKHALI C/A Div.
BARISAL C/A Div.
NOAKHALI C/A Div.
CHITTAGONG C/A Div.
BAY OF BENGAL
BANGLADESH
COASTAL AFFORESTATION PROJECT
Maturing mangrove plantation
0 20 40 60 80 100
AREA OF MAP

3. METHODOLOGY

3.1 PHOTOINTERPRETATION

The interpretation has been carried out on colour infrared aerial photographs at scale 1 : 50000 of the 1983/84 national coverage. Two sets of such photographs (285 x 2 = 570) have been printed by SPARRSO and delivered through a period of four months from February to May '86. In spite of the best effort of darkroom technicians, SPARRSO's poor printing equipment has been responsible for the poor quality of the prints.

(i) AGE - Based on available information such as Forest Department's plantation index maps and on field verification, all existing plantation established prior to 1980 have been demarcated on the photographs and divided into 5 years age classes with the maximum possible accuracy :

Age class	Years
6B	1966 - 1969
7A	1970 - 1974
7B	1975 - 1979

At a later stage, after the completion of the field work, with considerably more field information, most age classes have been subdivided into individual years of planting. This has not always been possible, mainly due to the poor quality of records, therefore, several areas still carry only the broad 5 year class specification.

(ii) SPECIES - Different species and species composition have been identified, checked in the field and coded as follows :

Code	Species	Composition %	Remarks
K	Keora	80%	Easy identification, Dark red tone.
B	Baen	80%	Easy to separate from K but difficult from G.
G	Gewa	80%	Easy to separate from K but difficult from B.
Ka	Kankra	80%	Easy to identify although bright red tone may be due to undergrowth and climber always associated.

Code	Species	Composition %	Remarks
S_1/S_2	Mixed	S_1= 50 to 80%	S_1 and S_2 are any of the previous species.
		S_2= 20 to 50%	Most common mixture are K/B and B/K.
M	(Babul et al.)		This does not represent a species but a planting system : the mounded plantation which is mainly composed of Babul with few Gewa and others.

(iii) DENSITY - The density is represented by the crown coverage as a percent of the area. It has been coded :

Code	Crown coverage
1	70 - 100%
2	30 - 70%
3	less than 30% considered under-stocked and excluded from sampling.

Planted areas with very low density, say less than 5%, are not visible owing to the small photo scale and therefore have not been delineated.

For Mounded plantations (species code M) the "Density" code is mostly related to the growth conditions. It doesn't provide values within the individual mound (where the density can be always assumed as full) but only among the heap crowns in relation to the ground coverage.

Code	Crown coverage	Remarks
1	70 - 100%	Most heap crowns touch each other creating a rather continuous canopy.
2	40 - 70%	Few heap crowns touch each other creating a broken canopy.
3	0 - 40%	All heap crowns are small and well distinct (stunt growth).

Interpretation parameters have been checked in the field and with FD territorial officers.

The differentiation of Keora plantations from pure natural stands of Keora of Patuakhali Division presented some difficulties. This has been difficult not only on the air-photo but also in the field. The appearance of

'75, '76 plantations and the naturally regenerated dense Keora stands, look so much the same that even local officers got frequently confused and contradictory. As a result the lines dividing the natural Keora from the planted Keora in Pathargata, Amtali and Mohipur Ranges of Patuakhali Division are approximate and should be considered indicative only. As a matter of fact, the more these lines are straight the more they are reliable because they follow visible plantation boundaries. The natural stands in such areas have been also interpreted and divided into two classes : dense (crown cover $\geq 50\%$) and open (crown cover $< 50\%$). The similitude of the two formations, planted and dense natural, is such that the same management approach can be applied to both of them.

The scale and printing quality of the aerial photographs utilized are of a standard considerably lower than what is commonly requested for plantation inventory purposes, especially in the case of very young stands. Individual small trees are not visible in such small scale photographs and it is to be expected that density classification of younger stands will be of reduced reliability ; probably tending to classify at a lower density level. As a result of the limited sensitivity to height assessment of such photographs, density may be over-estimated for stands with dense natural undergrowth.

3.2 FIELD WORK

Scattered over hundreds of islands or chars all along the bay of Bengal, the mangrove plantations present considerable access difficulties. With the exception of few areas of Chittagong Division (such as Mirsarai and Sitakunda Ranges) that are accessible by road, all other areas can be reached only by water. Furthermore, this is restricted to the winter period (November to April), when the sea is relatively calm. Winter time is also the only period of the year when the soil of the planted chars is sufficiently dry to permit walking and surveying work. Another limiting factor is given by the tide, since most of the inner channels used to reach the selected sampling sites, are navigable only with high tide for a few hours daily.

Field work has been carried out during the period December '85 - May '86. During December '85 and Janyary '86, when the infrared air-photos were not yet delivered, the field work was concentrated in Chittagong Division for which 1 : 50,000 1984 (B/W) photo coverage was available. From February through May the sampling and verification work has been carried out at Patuakhali, Barisal and Noakhali Forest Divisions, with the logistic support of Divisional Motor Launches, Range Trawlers and a project speed boat.

Additional data have been collected from Chittagong Division during August '86.

The field programme greatly benefited from the availability of the preliminary copies of SPARRSO's "Land Accretion and Plantation Map". This map, that has also been used at a later stage as base for the inventory mapping work, has a scale of 1 : 10000 and have been prepared from the same 1984 photographs utilized for the photointerpretation.

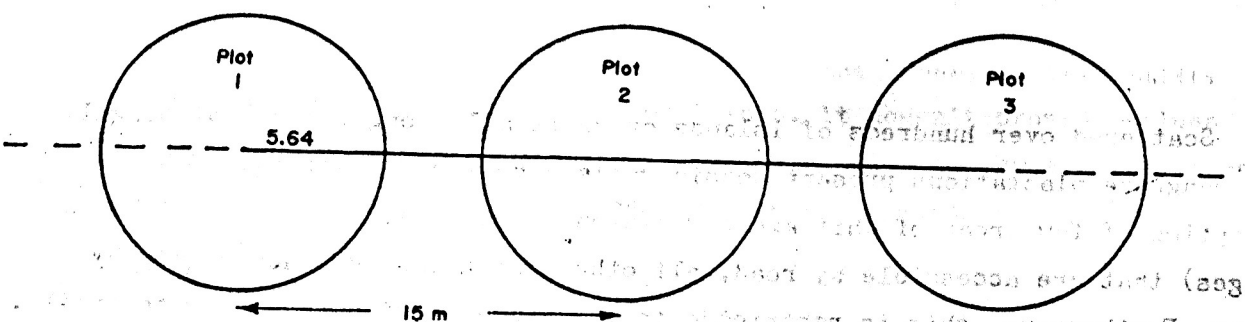
Considering the relatively small scale of the photographs (1 : 50000) and their consequent unsuitability for field orientation, the presence of SPARRSO maps proved essential during plot location and survey work.

3.3 SAMPLING DESIGN

3.3.1 NORMAL PLANTATIONS

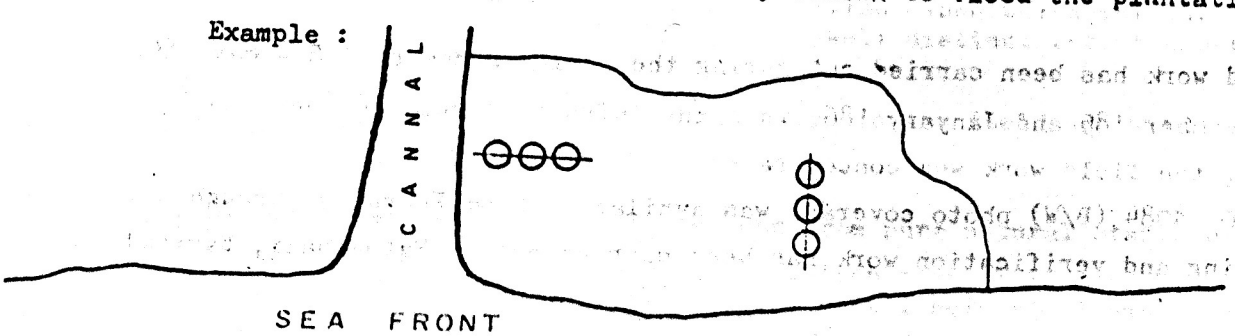
Sampling units composed by 3 circular sample plots of 0.01 or 0.02 hectar each have been utilized.

The radius of the circular sample plot is 5.64 m (0.01 ha) for plantation with spacing 3' x 3' (0.9m x 0.9m) and 4' x 4' (1.2m x 1.2m) and is 7.38m (0.02 ha) for plantations with spacing 6' x 6' (1.8m x 1.8m), the latter being very rare. Configuration of the sampling Unit :



The orientation of the long axis of the sampling unit depends of the configuration of the stratum (plantation) in which the unit is located. It is always oriented toward the nearest water point such as channel or sea front from which tidal waters are periodically coming to flood the plantation.

Example :



Distance from the flood water source has proved to be a predominant and very sensitive factor for growth and sanitary condition of planted species, especially for Keora . The peculiar orientation of Sampling Unit axis has been designed with the aim of sampling different growth and sanitary conditions within the stratum.

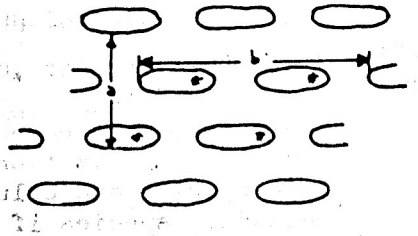
Randomly selected on the photographs, the S.U. location has been transferred onto the maps by projector, the point selected representing the centre of plot No. 2. The orientation of S.U. axis and consequently the locations of the other two plots has been then selected following the principle described above.

3.3.2 MOUNDED PLANTATIONS

A limited "check sampling" has been adopted to provide elementary information for the plantation established under "mound" system in Noakhali F.D.

Considering the peculiar and irregular spacing system of such plantations, the sampling unit has been designed to include four complete mounds (heaps) which are considered as four sample plots

Due to the irregularities of original spacing among mounds, each S.U. has its own measured area as shown below :



a and b are the distances to be measured in the field for each S.U.

* mounded patches where measurement have been taken.

On the average each S.U. measured 515 m^2, ranging from a minimum area of 438 m^2 to a maximum of 588 m^2.

Randomly selected on the air-photos, the S.U. location has been transferred by projector onto the map, the point selected identifying the nearest mound as the No. 1 of the sampling unit.

3.4 DESCRIPTION OF FIELD FORMS

Two kind of forms has been utilized for the field data collection : Inventory Form for each sample plot and Sample Trees Form for three trees

within the plot (where available) having DBH of 10cm or more and height of 3m or more, for volume calculations.

3.4.1 INVENTORY FORM FOR NORMAL PLANTATIONS

A field form used during the inventory of normal plantations is shown in Appendix 1A.

The following is a description of the columns of the field sheet.

Name of the team leader, date of work, photo number and map number are to be written on the right hand corner of the field sheet.

Columns	Description	Codification
1 - 2	Deck	11 : already filled in
3	District	1 : Chittagong 2 : Noakhali 3 : Barisal 4 : Patuakhali
4 - 6	Range and Beat	As per list given in Appendix 3
7 - 9	Sampling Unit	From 001 onward
10	Plot number	1, 2 or 3
11 - 15	Stratum photointerpretation code = Data processing code (after possible adjustment)	
11 - 12	Species code	See below. This code does not have a digit for utilization. Column 12 for main species and column 11 for secondary species if any.
13 - 14	Age = Year of planting	Eg.: 78 for the year 1978.
15	Density = Crown cover as seen on the aerial photograph. Planting distance, survival rate and actual ground stocking are not considered.	1 or 2.
16 - 17	Soil	Not used.
18	Plot size	1 for 0.01ha plot and 2 for 0.02ha plot.
The above data are common for the plot and are valid for each tree in the plot		
19 - 20	Tree number	01 to 40 : already printed on the sheet.
21 - 23	Species code	See below. This code has a digit for utilization.
24 - 26	Diameter in mm at reference	From 040 to ...

Columns	Description	Codification
27 - 29	Total height in dm	From 030 to ....
30	Measurement method	1 (instrument)
		2 (estimation)
31 - 32	Quality	
31	Sanitary aspect	1 to 5 as noted below
32	Stem quality	1 to 4 as noted below
33	Sample tree measured for volume function	0, 1, 2 or 3
34 - 35	Clump	From 01 to ....

Species Code

Keora : 101
Bain : 202
Gewa : 403
Kankra : 304
Goran : 605
Babul : 206

The first digit is the utilization code :

1 : mainly baling boards in packing newsprint ; also box planking, bobbins and shuttering in building construction.
2 : posts, poles, core of mud wall, firewood, fencing.
3 : rafters, scantlings, firewood.
4 : pulp and paper, match boxes, box planking, dunnage in ships.
5 : tanning
6 : 2 + 5.

Code no.	Sanitary aspect
1	Sound
2	Diseased
3	Dying crown side branches
4	Top dying
5	Dead.

	Stem quality
1	Straight stem with few small branches (pole quality)
2	Straight stem with big side branches (small posts and firewood)
3	Twisted stem with or without branches (firewood)
4	Damaged stem.

3.4.2 INVENTORY FORM FOR MOUNDED PLANTATIONS

A field form used during the inventory of mounded plantation is shown in Appendix 1-A.

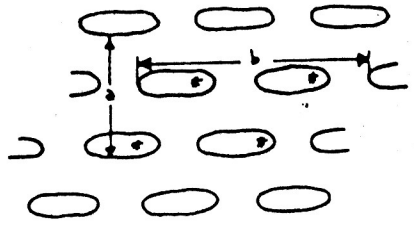
The data collection has followed the format and the recording instruction given for normal plantations (see 3.4.1 above) except for the following specifications :

Columns	New specifications
7,8 & 9	New numbering will start from 001 to 012.
10	Plot number. Now to be intended as heap number (individual mounded patch). There will be 4 heaps in one S.U. to be numbered from 1 to 4. For every heap a new sheet has to be filled up.
11 & 12	These columns will have to be kept blank.
18	Plot size will be coded no. 3.
30	The height will be measured by Hypsometer for the tallest tree of each heap (code 1). All the others will be estimated (code 2).

Under "observation" will be marked :

1 - the dimensions of the S.U. according to sketch below. This will be marked on the first sheet (first heap) of each sampling unit only.

2 - on every sheet (heap) will be marked, per species, the number of trees with diameter below 4.0cm.



a and b are the distances to be measured in the field for each S.U.

*mounded patches where measurement will be taken.

3.4.3 SAMPLE TREES FORM

A field form used for sample trees data collection is shown in Appendix 1-B. The following is a description of the columns of the field sheet.

Name of the Team leader is to be written on the right hand corner of the field sheet.

Columns	Description	Codification
1 - 2	Deck	12 already filled in.
3 - 6	Locality Code	As listed in Appendix 3.
7 - 9	Sampling Unit	From 001 onward
10	Plot number	1, 2 or 3
11 - 12	Day	01, 02 to 31
13 - 14	Month	01, 02 to 12
15 - 16	Year	86

The above data are common for the plot and valid for three tree in the plot.

17 - 20	Serial number	0001, 0002 9999
21 - 23	Species code	See 3.4.1 above
24 - 25	Tree number (in plot)	01, 02 40
26 - 28	Total height in dm	From 030dm to ....
29 - 31	Diameter in mm at 1.3m	From 100mm to ....
32 - 34	" " " " 2.0m	Top diameter = 75mm
35 - 37	" " " " 3.0m	- do -
38 - 40	" " " " 4.0m	- do -
41 - 43	" " " " 5.0m	- do -
44 - 46	" " " " 6.0m	- do -
47 - 49	" " " " 7.0m	- do -
50 - 52	" " " " 8.0m	- do -
53 - 55	" " " " 8.0m	- do -

Note : D.O.B. = Diameter over bark, S.B.T. = Single bark thickness.
D.I.B. = Diameter inside bark, D.B.T. = Double bark thickness.

3.5 SAMPLING SIZE

A total of 113 sampling units (varying in size according to spacing and to plantation system) were distributed over the plantation areas. The system, stratified random sampling, has followed the principles applied for the inventory of Chittagong and Cox's Bazar plantations. Although C/A plantations are comparatively simpler, considering the homogeneous type of plantation mainly composed by two species only and the very narrow age-range, with 94% of the area planted within the period 1975 - 1979.

Sampling Units have been distributed over the four Divisions proportionally to the plantation area as follow :

No. of Sampling Units	C.A. Divisions
25	Chittagong
45	Noakhali
18	Barisal
25	Patuakhali
113	

Additional data of 10 Sampling Units (each composed by 5 x 0.01ha plots along a line) collected by territorial officers of Gorokgata Range, Chittagong Division and 16 SU (normal 3 plots system) from Patuakhali and Barisal Divisions have been also used for compilation of results. A total of 773 sample trees have been measured, mainly from the sample plots, for the preparation of volume functions.

The sample trees, with a minimum DBH of 10 cm, have been selected to cover the widest range of diameter and height values for both main species, Keora and Baen.

KEORA (SONNERATIA SPP.)

No. of trees	Division
91	Chittagong
236	Noakhali
133	Barisal
214	Patuakhali
674	

BAEN (AVICENNIA SPP.)

No. of trees	Division
99	Chittagong and Noakhali
Total = 773	

Due to the average small size of Baen trees even when comparatively old, only 57 trees were found within the sample plots exceeding 10cm DBH. Consequently 42 more trees have been measured outside the sample plot area.

Contingent factors such as availability of inventory teams (only two teams available from FRI Inventory Division, while other FD teams were engaged in Sylhet inventory), water transport facilities and limited duration of the field season during which plantation areas could be reached have represented a limitation to the field programme.

3.6 COMPILATION OF RESULTS

Sample plot and sample trees data have been recorded, checked and largely processed by IBM System 34 computer at Bangladesh Agricultural Research Council (BARC) and consequently transferred into 5¼ inch diskettes to be used by project's IMB Pc AT computer at Forest Department Dhaka.

List and description of data files produced is given in Appendix 2.

3.6.1 STAND PARAMETERS

Sample plot data have been analyzed to produce average values per stratum by age classes and by individual year.

Average plot values have been used to give current MAI and actual condition without thinning.

With the specific objective of providing the newly established computerized Resource Management System (RMS) with the required inputs, inventory data has been used as follows :

- To produce provisional thinning and yield tables; measurements of the best plot trees have been analyzed to give diameter and height growth functions of remaining trees (final crop = in a simulated thinning regime). See provisional growth functions in Appendix 5.
- To provide each stand with the most location specific information, average number of trees per hectare, average DBH and average height have been computed from the values of the nearest sampling units covering the same forest stratum.

In spite of all efforts to give location or stand specific parameter values, as input to RMS, it has to be clearly stated that the sampling design followed was not a stand by stand sampling as required by RMS, but a stratified random system, therefore, at the present stage, stand specifications given in Appendixes 8 and 9 are to be considered indicative only and large variations are to be expected. Such information, however, will improve with pre and post operational sampling data collected as part of the thinning programme.

3.6.2 VOLUME FUNCTIONS

Sample trees data have been used to produce volume functions relating total tree volume over bark (Vt) and volume under bark, up to 10cm top diameter (V10), to DBH and total height.

Owing to the very small average tree size (most strata have average DBH value below 10cm) the second function (vol U.B. at 10cm) based on the present data is not significant. Moreover, for plantation mainly aimed to produce fuelwood, the total volume over bark seems the more appropriate and important.

Ten functions have been produced :

Keora Vt for each Division (4)
Keora V10 for each Division (4)
Baen Vt for all Divisions (1)
Baen V10 for all Divisions (1)

3.7 MAPPING AND AREA COMPILATION

The "Land Accretion and Plantation Map" prepared by SPARRSO for the coastal belt and off-shore islands of the Country has been used as base-map on which photointerpretation details have been transferred.

SPARRSO's maps has a scale of 1 : 10000, with a sheet format of 5 x 5 minutes, and has been based on photographic enlargement of the same photographs used for our stratification.

The SPARRSO maps show features such as roads, embankments, channels etc., accretion area divided into "stable" and "mud flats" and plantation areas divided into "old" and "young". The young plantation compartments show individual year of establishment from 1981 to 1986.

The inventory stratification is largely located within the broad "old" plantation area. The new stratification has been transferred on the base map by monoplotting system that, in the case of flat terrain, presents no difficulties and good accuracy.

The final map shows all original SPARRSO's details and the stratification of the maturing plantations. The index map in Appendix 4 gives sheet number and location of all map series.

The 1980 plantation areas have been excluded from the year-wise SPARRSO's survey and also from the stratification because they were too young to be reliably classified by density classes on the 1983-84 photographs. However, according to F.D. index maps, 1980 plantation areas have been delineated on the map wherever possible and as accurately as possible, in relation to the surrounding planted areas. Their boundaries were not clearly visible on the aerial photographs and have not been surveyed. Their delineation has to be considered indicative only.

All individual DLU's (Descreet Land Unit) have been numbered and listed by Range for easy location and identification.

Many of these units, that are homogeneous by density, species composition and age, present irregular shapes which makes their delineation in the field difficult and, consequently, management prescription would be difficult to implement.

To partially solve this problem all DLU's have been grouped by contiguous common year of establishment.

This has led, in most cases, to a delineation of the original compartment that has lately differentiated into various density and species classes.

Management prescriptions, such as thinning, will be applied to annual plantings therefore group-wise, and several density classes will eventually be merged into broader and more rational units.

A full list of such age groups by Range is given in Appendix 9.

Area has been compiled and double checked for each DLU by Electronic Planimeter and rounded to the nearest hectare.

Area of each "age group" as total of all DLU's included is given in Appendix 3.

The maturing mangrove plantations (established prior 1980) have been mapped on 64 map sheets of the SPARRSO's series.

The area is divided into over 1200 DLU homogeneous by density, species and age of 14ha on average with dimensions that varies from 1ha to over 100ha. Such DLU's have been further grouped by age to form a total of 273 sub-blocks of 55ha on average and more regular shapes.

4. RESULTS AND COMMENTS

4.1 AREA BY STRATUM AND AGE

Area tabulation is given in the next few pages for the total project area and by each Coastal Afforestation Division.

Strata are identified by density classes (1 = over 70% crown cover, 2 = 30 to 70%, 3 = less than 30%) and by main species (over 50% of species composition

Species codes : K = Keora
B = Baen
G = Gewa
Ka = Kankra
M = Mounded plantations (Babul).

The age marked with asterisks : 6B* 7A*. 7B* represent the areas for which a specific year of establishment could not be identified. Such areas have been related only to the broad age class 6B, 7A and 7B.

4.1.1 COMMENTS

The total area (established prior 1980) amounts to 15,058 ha. This represent the planted area visible on the 1984 aerial photographs. Plantations which are too sparse to be delineated on the available photographs, eroded away, destroyed by tidal bore, or encroached for shrimp cultivation, are excluded from the present tabulation. Although afforestation work started in 1967, 94% of all presently available planted area belongs to the age class 7B, which covers the planting period 1975-1979.

66% of the area, of density classes 1 and 2, represent the most successful plantations that need silvicultural treatment such as thinning to normalize the production. The balance area of density class 3, (34%) identifies the less successful plantations, with a canopy too open to benefit from thinning operations.

Strat	67	68	69	69A	Tot 6B	70	71	72	73	74	74A	74C	74AI	75	76	77	78	79	79A	79C	TOTAL	
1-K					0					132	3	135	767	1351	1021	1001	883	443	5626	5761		
2-K					0					7	2	9	64	243	271	415	496	451	1938	1947		
3-K				7	7					25		25	94	281	155	306	513	764	2113	2145		
Tot K	0	0	0	7	7	0	0	0	0	164	5	169	925	1835	1447	1720	1892	1858	9677	9853	65%	
1-B	5	44	57		106	5	20			24	81	130	11	106	79	66	86	438	786	1022		
2-B	16	18	25		59					1	21	22	28	122	128	79	126	223	706	787		
3-B	1	56	10		67		5				94	99		59	12	56	29	279	435	601		
Tot B	22	118	92	0	232	5	25	0	0	25	196	251	39	287	219	201	241	940	1927	2410	16%	
1-G		0			0					29		29	12	2				9	23	52		
2-G		0			0							0	12	6	2			73	93	93		
3-G		0			0					28	1	29						292	292	321		
Tot G	0	0	0	0	0	0	0	0	0	57	1	58	24	8	2	0	0	374	408	466	3%	
1-Ka					0							0							0	0		
2-Ka					0							0							0	0		
3-Ka					0							0	70	300	237	73	166		846	846	6%	
TotKa	0	0	0	0	0	0	0	0	0	0	0	0	70	300	237	73	166	0	846	846		
1-M	0	0			0					36	5	41	14			9		33	56	97		
2-M	0	0			0					31	16	47	4		27	19		68	118	165		
3-M	0	0			0		4			67	18	89	8	218	243	155	66	442	1132	1221		
Tot M	0	0	0	0	0	0	4	0	0	134	39	177	26	218	270	183	66	543	1306	1483	10%	
1 Tot	5	44	57	0	106	5	20	0	0	221	89	335	804	1419	1100	1076	969	1123	6491	6932	46%	
2 Tot	16	18	25	0	59	0	0	0	0	39	39	78	108	371	428	511	622	815	2855	2992	20%	
3 Tot	1	56	10	7	74	0	9	0	0	120	113	242	172	858	647	590	774	1777	4818	5134	34%	
6 TOT	22	118	92	7	239	5	29	0	0	380	241	655	1084	2648	2175	2177	2365	3715	14164	15058	100%	
I					1.587							4.349							94.06	100		

Table 2 : Area (in ha) by stratum and age . Chittagong C/A Division

Strat	67	68	69	6B*	Tot 6B	70	71	72	73	74	7A*	Tot 7A	75	76	77	78	79	7B*	Tot 7B	TOTAL
1-K			0		0							0	4	63	41	108	53		269	269
2-K					0							0	2	87	94	51	19		253	253
3-K					0							0	10	54	11	43	126	2	246	246
Tot K	0	0	0	0	0	0	0	0	0	0	0	0	16	204	146	202	198	2	768	768
1-B	5	44	57		106	5	20			24	23	72	11	86	67	54	83	422	723	901
2-B	16	18	25		59						10	10	28	120	122	79	126	214	689	758
3-B	1	56	10		67		5				94	99		41	12	52	29	251	385	551
Tot B	22	118	92	0	232	5	25	0	0	24	127	181	39	247	201	185	238	887	1797	2210
1-G		0			0							0							0	0
2-G		0			0							0							0	0
3-G		0			0							0							0	0
Tot G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-Ka					0							0							0	0
2-Ka					0							0							0	0
3-Ka					0							0							0	0
TotKa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-M	0	0			0							0	9						9	9
2-M	0	0			0					8		8							0	8
3-M	0	0			0		4					4	3	6	52	34	34	190	319	323
Tot M	0	0	0	0	0	0	4	0	0	8	0	12	12	6	52	34	34	190	328	340
1 Tot	5	44	57	0	106	5	20	0	0	24	23	72	24	149	108	162	136	422	1001	1179
2 Tot	16	18	25	0	59	0	0	0	0	8	10	18	30	207	216	130	145	214	942	1019
3 Tot	1	56	10	0	67	0	9	0	0	0	94	103	13	101	75	129	189	443	950	1120
6 TOT	22	118	92	0	232	5	29	0	0	32	127	193	67	457	399	421	470	1079	2893	3318
Z					6.992							5.816							87.19	100

Table 3 : Area (in ha) by stratum and age . Noakhali C/A Division

Strat	67	68	69	68	Tot 6B	70	71	72	73	74	7A	Tot 7A	75	76	77	78	79	7B	Tot 7B	TOTAL
1-K					0					108	3	111	129	408	593	506	400	300	2336	2447
2-K					0					7	2	9	1	9	56	169	214	295	744	753
3-K					0					25		25	56	109	16	96	87	482	846	871
Tot K	0	0	0	0	0	0	0	0	0	140	5	145	186	526	665	771	701	1077	3926	4071
1-B					0						58	58		20	12	12	3	14	61	119
2-B					0					1	11	12		2	6			9	17	29
3-B					0							0		18		4		28	50	50
Tot B	0	0	0	0	0	0	0	0	0	1	69	70	0	40	18	16	3	51	128	198
1-G					0					29		29	12	2				9	23	52
2-G					0							0	12	6	2			73	93	93
3-G					0					28	1	29						292	292	321
Tot G	0	0	0	0	0	0	0	0	0	57	1	58	24	8	2	0	0	374	408	466
1-Ka					0							0							0	0
2-Ka					0							0							0	0
3-Ka					0							0			237				237	237
TotKa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	237	0	0	0	237	237
1-M					0					36	5	41	5			9		15	29	70
2-M					0					23	16	39	4		27	19		66	116	155
3-M					0					67	18	85	5	212	191	121	32	210	771	856
Tot M	0	0	0	0	0	0	0	0	0	126	39	165	14	212	218	149	32	291	916	1081
1 Tot	0	0	0	0	0	0	0	0	0	173	66	239	146	430	605	527	403	338	2449	2688
2 Tot	0	0	0	0	0	0	0	0	0	31	29	60	17	17	91	188	214	443	970	1030
3 Tot	0	0	0	0	0	0	0	0	0	120	19	139	61	339	444	221	119	1012	2196	2335
G TOT	0	0	0	0	0	0	0	0	0	324	114	438	224	786	1140	936	736	1793	5615	6053
Z					0							7.236							92.76	100

Table 4 : Area (in ha) by stratum and age . Barisal C/A Division

Strat	67	68	69	6B*	Tot 6B	70	71	72	73	74	7A*	Tot 7A	75	76	77	78	79	7B*	Tot 7B	TOTAL
1-K					0					24		24	278	228	239	216	202	278	1441	1465
2-K					0							0	15	35	56	113	66	72	357	357
3-K					0							0		4	92	124	49	185	454	454
Tot K	0	0	0	0	0	0	0	0	0	24	0	24	293	267	387	453	317	535	2252	2276
1-B					0							0						2	2	2
2-B					0							0							0	0
3-B					0							0							0	0
Tot B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
1-G		0			0							0							0	0
2-G		0			0							0							0	0
3-G		0			0							0							0	0
Tot G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-Ka					0							0							0	0
2-Ka					0							0							0	0
3-Ka					0							0	70	272		73	153		568	568
TotKa	0	0	0	0	0	0	0	0	0	0	0	0	70	272	0	73	153	0	568	568
1-M	0	0			0							0						18	18	18
2-M	0	0			0							0						2	2	2
3-M	0	0			0							0						42	42	42
Tot M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62	62	62
1 Tot	0	0	0	0	0	0	0	0	0	24	0	24	278	228	239	216	202	298	1461	1485
2 Tot	0	0	0	0	0	0	0	0	0	0	0	0	15	35	56	113	66	74	359	359
3 Tot	0	0	0	0	0	0	0	0	0	0	0	0	70	276	92	197	202	227	1064	1064
G TOT	0	0	0	0	0	0	0	0	0	24	0	24	363	539	387	526	470	599	2884	2908
2					0							0.825							99.17	100

Table 5 : Area (in ha) by stratum and age . Patuakhali C/A Division

Strat	67	68	69	6B+	Tot 6B	70	71	72	73	74	7A+	Tot 7A	75	76	77	78	79	7B+	Tot 7B	TOTAL
1-K					0							0	356	612	148	171	228	65	1580	1580
2-K					0							0	46	112	65	80	197	84	584	584
3-K				7	7							0	28	114	36	43	251	95	567	574
Tot K	0	0	0	7	7	0	0	0	0	0	0	0	430	838	249	294	676	244	2731	2738
1-B					0							0							0	0
2-B					0							0							0	0
3-B					0							0							0	0
Tot B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-G					0							0							0	0
2-G					0							0							0	0
3-G					0							0							0	0
Tot G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-Ka					0							0							0	0
2-Ka					0							0							0	0
3-Ka					0							0		28			13		41	41
TotKa	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	13	0	41	41
1-M	0	0			0							0							0	0
2-M	0	0			0							0							0	0
3-M	0	0			0							0							0	0
Tot M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 Tot	0	0	0	0	0	0	0	0	0	0	0	0	356	612	148	171	228	65	1580	1580
2 Tot	0	0	0	0	0	0	0	0	0	0	0	0	46	112	65	80	197	84	584	584
3 Tot	0	0	0	7	7	0	0	0	0	0	0	0	28	142	36	43	264	95	608	615
6 TOT	0	0	0	7	7	0	0	0	0	0	0	0	430	866	249	294	689	244	2772	2779
%					0.251							0							99.74	100

4.2 AVERAGE STAND PARAMETER VALUES BY STRATUM AND AGE CLASS PER C/A DIVISION

All results are based on field measurements of trees with DBH of 4 cm or above from stands of density classes 1 and 2. SE% are given with 95% confidence limit.

4.2.1 CHITTAGONG DIVISION

The plantations of Chittagong Division are composed of Baen (68%), Keora (22%) and by the Babul dominated Mounded plantations (10%).

The Mounded plantations are mainly located in the north part of the Division, in Ranges Mirsarai and Sitakunda. They show stunted growth and can be considered totally unproductive.

Keora plantations have been established only on the northern part of the Division, in Mirsarai, Sitakunda and Headquarter Ranges. Some Keora of natural origin is available in Teknaf Range along Naf River.

Baen species (Avicennia officinalis, A. alba, A. marina etc.) are found over the all Division but two broad areas have been identified where Baen appears to perform quite differently. The best stands are located on the northern part of the Division while the central and southern part show plantations with poor or stunted growth. The approximate boundary between these two broad sites can be located south of the mouth of Sangu River. For this reason average values are given separately for Chittagong North and Chittagong South.

AVERAGE STAND PARAMETER VALUES BY STRATUM AND AGE CLASS

Chittagong Division North

(Ranges : 1-Mirsarai, 2-Sitakunda, 3-Headquarter and part 4-Banskhali)

Stratum and age class 1/	No. trees/ha		DBH		Height		Tot. Vol/ha	
		SE%	cm	SE%	m	SE%	m^3	SE%
1K7B	1685	29	9.1	11	7.9	11	49.0	30
2K7B	1000	43	8.2	28	6.5	35	21.5	78
1B7B	2309	30	8.4	16	6.1	11	62.4	44
2B7B	1050	7	5.0	48	4.3	5	9.8	84

1/ Stratum indicates : density (1 = over 70%, 2 = 30 to 70%) ; dominant species (K = Keora, B = Baen, M = Mounded plantation). Age class : 7A = '70 - '74, 7B = '75 - '79

AVERAGE STAND PARAMETER VALUES BY STRATUM AND AGE CLASS

Chittagong Division South

(Ranges : Part 4-Banskhali, 5-Kutubdia,
6-Gorokgata, 7-Teknaf)

Stratum and age class 1/	No. trees/ha		DBH		Height		Tot. Vol/ha	
		SE%	cm	SE%	m	SE%	m^3	SE%
1B7A	1397	28	5.6	12	3.8	18	18.1	47
1B7B	1364	59	5.1	6	3.9	16	17.0	73
2B7B	1050	7	5.0	48	4.3	5	9.8	84

The high SE% values are due to the high diversity of the stands even within a limited area as a result of total lack of management.

Baen plantations of Chittagong South are extremely dense. The values given concern only the trees exceeding 4 cm of DBH while there are approximately 2000 trees/ha with DBH below 4 cm in all age classes.

Several areas of Baen in Gorokgata Range (DLU 83 to 86 and 89 to 93, year 1977) show extremely high density and stunted growth with an average of 5800 trees/ha ; all below 4 cm DBH.

Mean Annual Increment (MAI) for
plantations of density class 1.

	Age classes	
	7A	7B
Keora (North)	-	5.8 m^3/ha/year
Baen (North)	-	6.9 m^3/ha/year
Baen (South)	1.3 m^3/ha/year	1.9 m^3/ha/year

4.2.2 NOAKHALI DIVISION

Noakhali plantations are mainly composed of Keora (67%) and the Babul dominated Mounded plantation (18%). The balance area is covered with some Baen and very poor Gewa and Kankra stands.

AVERAGE STAND PARAMETER VALUES BY

STRATUM AND AGE CLASS

Stratum and age class 1/	No. trees/ha		DBH		Height		Tot. Vol/ha		
		SE%	cm	SE%	m	SE%	m^3	SE%	
1K7A	2172	20	9.3	10	8.4	9	69.4	19	Yr. '74
2K7A	1717	-	9.2	-	8.8	-	55.3	-	
1K7B	2475	13	8.9	10	8.3	8	68.6	15	
2K7B	1786	36	8.6	15	7.3	11	40.1	35	
1B/K7A	1750	27	11.1	25	8.2	20	99.9	22	Yr.'72,'73

MOUNDED PLANTATION

Stratum and age class 1/	No. trees/ha		DBH		Height		Tot. Vol/ha	
		SE%	cm	SE%	m	SE%	m^3	SE%
1 & 2M7B	1177	23	7.8	16	5.6	16	27.2*	-
3M7B	705	28	6.3	8	4.3	5	11.0*	-

* These volume values are indicative only since volume function for Mounded Plantation species (mainly Babul) are not available.

4.2.3 BARISAL DIVISION

Barisal plantations are mainly composed of Keora of the age class 7B (67%). The balance area is covered by very poor or totally failed Kankra and Gewa plantations located in Monpura Range.

AVERAGE STAND PARAMETER VALUES

BY STRATUM AND AGE CLASS

Stratum and age class 1/	No. trees/ha		DBH		Height		Tot. Vol/ha		
		SE%	cm	SE%	m	SE%	m^3	SE%	
1K7A	750	-	16.2	-	13.2	-	86.6	-	Limited area yr.'74
1K7B	2135	26	10.9	18	8.9	14	74.5	20	
2K7B	1143	20	12.6	11	9.5	16	62.8	21	

Average MAI for Keora of density class 1 is 7.5 m^3/ha/year.

1/ Stratum indicates : density (1 = over 70%, 2 = 30 to 70%) ; dominant species (K = Keora, B = Baen, M = Mounded plantation). Age class : &A = '70 - '74, &B = '75 - '79.

4.2.4 PATUAKHALI DIVISION

Patuakhali plantations are composed by 99% of Keora of the age class 7B.

AVERAGE STAND PARAMETER VALUES

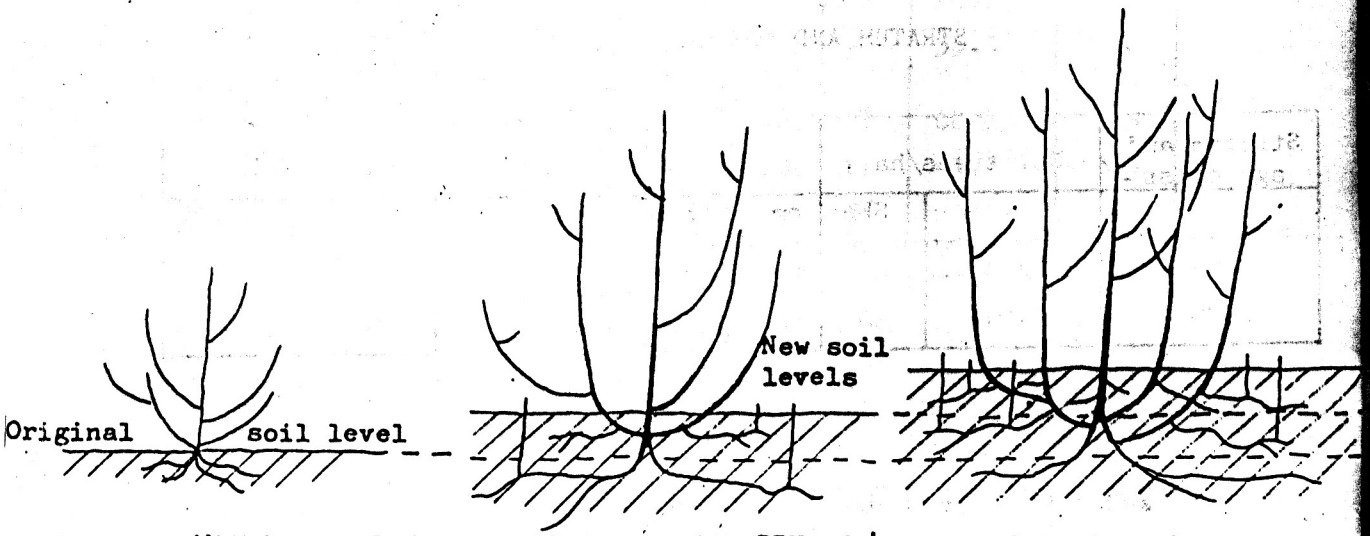
STRATUM AND AGE CLASS

Stratum and age class 1/	No. trees/ha		DBH		Height		Tot. Vol/ha	
		SE%	cm	SE%	m	SE%	m^3	SE%
1K7B	2380	21	10.4	12	9.7	11	87	19
2K7B	1143	20	12.6	11	9.5	16	62.8	21

Average MAI for Keora of density 1 is 9.4 m^3/ha/year.

4.3 "CLUMP" TABLE

The siltation process over the young plantation often induces the individually planted saplings to produce strong side branches that, with the continuation of the process, develop into semi-independent trees in a clump.



Within sampled area all trees with DBH of 4 cm or above have been measure whether individual or part of a clump but coded accordingly. The table below shows that about $\frac{1}{4}$ of all trees presently available in the plantation are part of clumps developed from individual saplings.

"CLUMP" TABLE

KEORA

	Tot. no.	Individual trees no.	%	Clump trees no.	%	No. of clumps	Trees per clump
Tot. Ctg.	498	339	68	159	32	68	2.3
Tot. Noak	2164	1494	69	670	31	308	2.2
Tot. Bar	997	762	76	235	24	108	2.2
Tot. Pat	1566	1360	87	206	13	91	2.3
Gran. Tot	5225	3955	76	1270	24	575	2.2

BAEN

Tot. Ctg.	537	370	69	167	31	72	2.3
Tot. Noak	79	79	100	-	-	-	-
Gran. Tot	616	449	73	167	27	72	2.3

4.4 STEM QUALITY BY SPECIES AND COASTAL DIVISION

As explained in 3.4.1, a stem quality assessment has been made for each measured tree according to the following classes :

Quality classes

1 = Straight stem with few small branches - Pole quality.
2 = Straight stem with big side branches - small post and firewood.
3 = Twisted stem with or without branches - firewood.
4 = Damaged stem - firewood.

Results :

NUMBER OF TREES BY STEM QUALITY AND COASTAL DIVISION

Species : Keora

	Qual. 1		Qual. 2		Qual. 3		Qual. 4	
	No.	%	No.	%	No.	%	No.	%
Chittagong	230	46	51	10	209	42	8	2
Noakhali	1469	68	506	23	156	7	33	2
Barisal	616	62	206	21	103	10	72	7
Patuakhali	998	64	295	19	247	16	26	1
Total	3313	63	1058	20	715	14	139	3

Species : Baen

Chittagong	223	42	106	20	206	38	2	-
Noakhali	20	25	27	34	30	38	2	3
Total	243	39	133	22	236	38	4	1

Overall stem quality seems to be good, especially considering that thinning can further improve the situation. Keora and Baen in Chittagong show, however, a condition poorer than Keora of the other Divisions.

4.5 SANITARY CONDITIONS

During the first reconnaissance of mangrove plantation of Chittagong Division areas with premature mortality were noticed in Keora stands of 8 to 10 years.

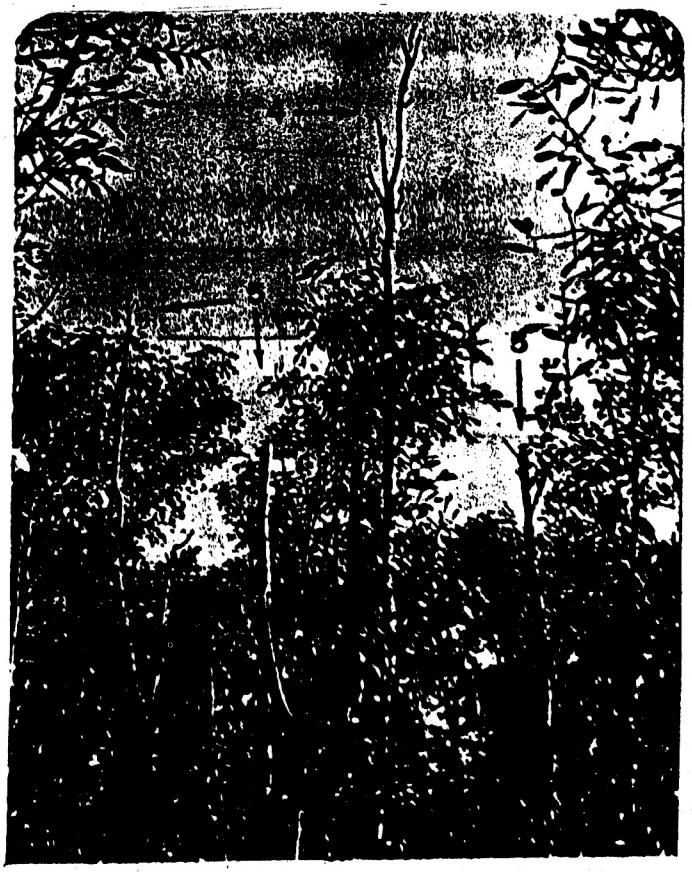
To provide information on the consistency and location of the phenomenon all trees in the sample have been coded for sanitary aspect in the following classes :

1 - Sound
2 - Diseased (fungi, insect attack, leaf loss etc.)
3 - Dying crown side branches
4 - Top dying
5 - Dead

Examples of the various sanitary conditions are shown in the following field photographs :

Example of borer attack, sanitary aspect 2.
Barisal C/A Division Kukrimukri Range.
Keora 76 wind damaged stand.

Examples of sanitary aspect 1, 3 and 4. Chittagong C/A Division Sitakunda Range. Keora 1976.



Example of sanitary aspect 4 and 5. Ctg. C/A Division. Sitakunda Range. Keora 1976.

The tables below give the results of the sanitary aspect assessment by Coastal Division and species.

SANITARY ASPECT OF KEORA BY YEAR OF PLANTING
(VALUES IN PERCENTAGE)

CHITTAGONG DIVISION

Sanitary Aspect	Year of establishment										
	70	71	72	73	74	75	76	77	78	79	Tot.
1 Sound							21	18	10	41	22
2 Diseased							24	35	68	46	42
3 Dying side branches							30	13	21	12	20
4 Top dying							17	34	1	1	13
5 Dead							8	-	-	-	3

NOAKHALI DIVISION

1 Sound			100	92	71	78	79	80	94	93	84
2 Diseased			-	-	17	17	15	11	4	5	11
3 Dying side branches			-	4	9	1	2	3	1	1	3
4 Top dying			-	4	2	3	1	3	1	1	1
5 Dead			-	-	1	1	3	3	-	-	1

BARISAL DIVISION

1 Sound					71	69	55	67	75	79	69
2 Diseased					2	9	26	11	18	21	14
3 Dying side branches					11	12	4	6	1	-	5
4 Top dying					11	9	14	11	4	-	9
5 Dead					5	1	1	5	2	-	3

PATUAKHALI DIVISION

1 Sound					..	82	88	67	97	94	87
2 Diseased						3	4	20	-	3	5
3 Dying side branches						6	4	9	1	-	4
4 Top dying						5	3	4	2	2	3
5 Dead						4	1	-	-	1	1

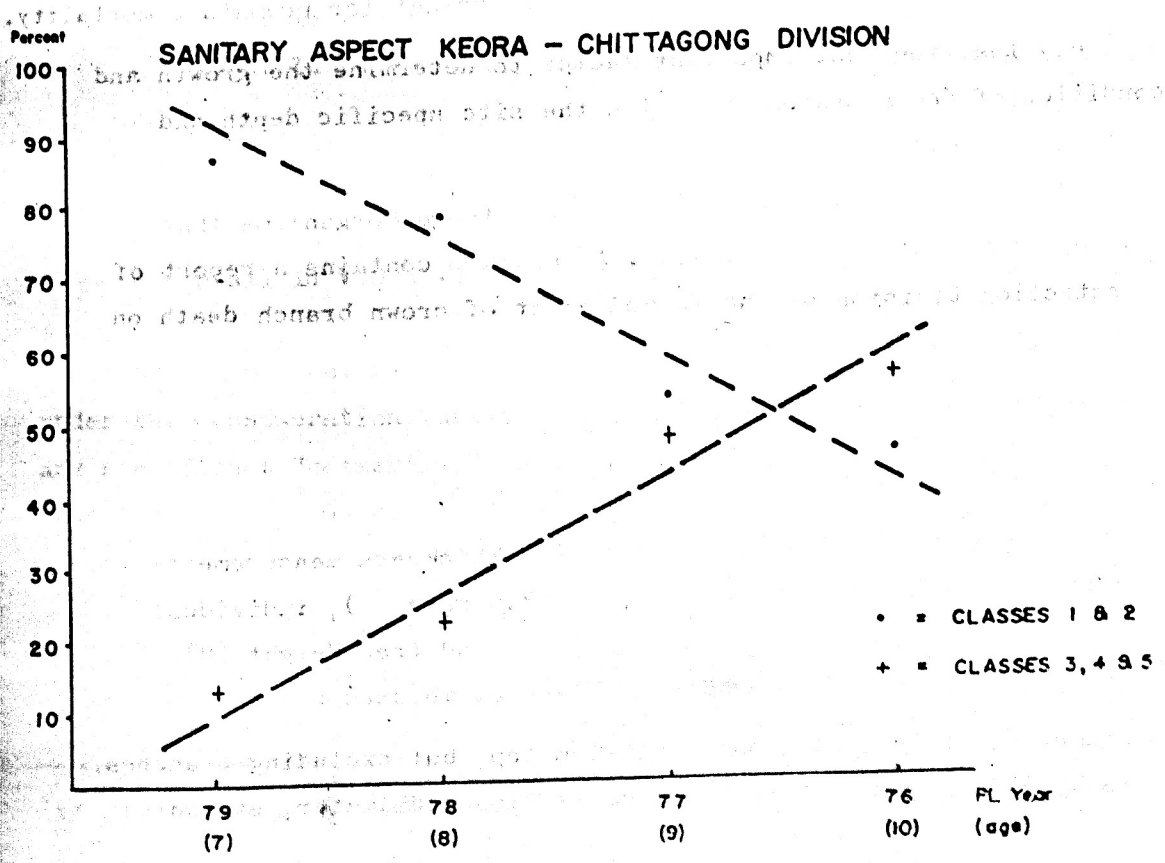
SANITARY ASPECT OF BAEN BY YEAR OF PLANTING

(VALUES IN PERCENTAGE)

CHITTAGONG DIVISION

Sanitary Aspect	Year of establishment										
	70	71	72	73	74	75	76	77	78	79	Tot.
1 Sound	69				100	100	89	86	91	100	86
2 Diseased	21				-	-	7	10	5	-	9
3 Dying side branches	-				-	-	-	2	-	-	1
4 Top dying	10				-	-	4	2	4	-	4
5 Dead	-				-	-	-	-	-	-	-

As evident from the tables above the condition can be considered critical only for Keora of Chittagong Division where the percentage values show a definite trend of deterioration with age. The diagram below shows the variation of the combined percentage values for classes 1 and 2 and of combined percentage values for classes 3, 4 and 5 in relation to age. Classes 1 and 2 have been combined under the consideration that though partially affected the situation is possibly reversible. Classes 3, 4 and 5 have been combined under the consideration that the situation is probably irreversible.



It is clear from field observations that the sanitary condition tends to deteriorate with the distance from the water (sea front, tide canals etc.).

Seasonal defoliation of Keora is a frequent phenomenon that can affect large areas in late winter period, sometimes giving the impression of a dead forest. The plants, however, do not seem to suffer much from the leaf loss and reproduce a full healthy crown with the first monsoon rains.

Borer attack can present a much more serious problem. Large areas of Keora such as in Kukri Mukri Island already show consistent borer attack. At this time it tends to affect mainly the wind damaged and consequently weakened stands, but in the future it could threaten larger areas reducing the growth and the quality of the produce.

Under the guidance of FRI Soil Science Division, soil samples have been taken from the sampled areas at different depths with the purpose of verifying a possible link between the soil characteristics and the sanitary conditions of the plantations.

Results of soil samples analysis given in Appendix 6, show, however, that soil characteristics alone cannot be considered responsible of the various sanitary conditions of the plantations. A certain difference in Bulk density (gm/cc) has been noticed between the soil near the charas and the soil of higher areas but still within a range that cannot account for premature mortality.

It is likely that the most important factor to determine the growth and sanitary condition of Keora stands lies with the site specific depth and duration of tidal flooding.

Weakened stands tend to be easy targets for pathogen organisms that become the direct cause of trees mortality. Appendix 6 contains a report of FRI Forest Protection Division on the fungal agent of crown branch death on Keora of North Chittagong.

4.6 VOLUME FUNCTIONS FOR KEORA AND BAEN

From 1 metre sectional stem-diameter and bark-thickness measurements on 773 sample trees (674 Keora and 99 Baen ; see 3.5 page), individual tree volumes were calculated and related to DBH (D) and tree Height (H). Multiple regression analysis was done for two type of volumes :

(i) Total Volume (Vt) : including bark and stem top, but excluding branches.

(ii) Volume to 10 cm : stem volume to 10 cm sectional diameter, excluding bark and branches.

Following are the derived regression equations :

(i) Vt = TOTAL VOLUME

Keora by C/A Division

		(R)[1]	(n)[2]
K-Ctg	$\ln Vt = -8.66152 + 1.58656 \times \ln D + 0.77152 \times \ln H$	(0.98)	(91)
K-Noa	$\ln Vt = -9.29715 + 1.70514 \times \ln D + 0.95088 \times \ln H$	(0.98)	(236)
K-Bar	$\ln Vt = -9.23507 + 1.69673 \times \ln D + 0.92309 \times \ln H$	(0.98)	(133)
K-Pat	$\ln Vt = -8.75215 + 1.75034 \times \ln D + 0.64233 \times \ln H$	(0.92)	(214)
			(674)

Baen for all C/A Divisions

		(R)	(n)
B-all	$\ln Vt = -7.33298 + 1.56418 \ln D + 0.20443 \ln H$	(0.82)	(99)

(ii) V10 = VOLUME INSIDE BARK TO 10 CM TOP DIAMETER

Keora by C/A Division

		(R)	(n)
K-Ctg	$\ln V10 = -13.63792 + 2.73639 \ln D + 1.30860 \ln H$	(0.78)	(91)
K-Noa	$\ln V10 = -19.62856 + 4.04311 \ln D + 2.37599 \ln H$	(0.72)	(236)
K-Bar	$\ln V10 = -15.69425 + 3.15776 \ln D + 1.67549 \ln H$	(0.85)	(133)
K-Pat	$\ln V10 = -14.33283 + 3.69540 \ln D + 0.51765 \ln H$	(0.75)	(214)
			(674)

Baen for all C/A Divisions

B-all	$\ln V10 = -11.16265 + 2.78288 \ln D + 0.22273 \ln H$	(0.73)	(99)

For the present report only Total Volume (Vt) functions have been used under the consideration that the average tree size is too small to produce any significant "commercial" volume (V10). Poles, posts and firewood are the main produces of the plantations at this stage.

1/ R = Multiple correlation coefficient

2/ n = Number of sample trees

4.7 STAND PARAMETERS IN RELATION TO AGE. AN INDICATION OF GROWTH

The following graphs relate sampling unit average values of DBH, Height and No. of trees/ha to the age of the stands at the time of sampling. These cannot be considered growth curves because they do not represent the same stands at different ages (as for permanent sample plots), but different stands at different ages and in locations sometimes far apart. Another limitation is given by the narrow age ranges, in most cases only 6 years wide. Data extrapolated from such a narrow "period of observation" must be used very carefully even for short rotation species.

Nevertheless it is possible to delineate broad areas where the species analized show different growth tendencies. Keora appear to grow better, and hence to support longer rotation periods, on the western areas grossly identifiable by the Divisions of Barisal and Patuakhali, while growth appear to slow down already at the age of 10 to 12 years on the eastern areas of Noakhali and Chittagong Divisions (Meghna and Feni river deltas).

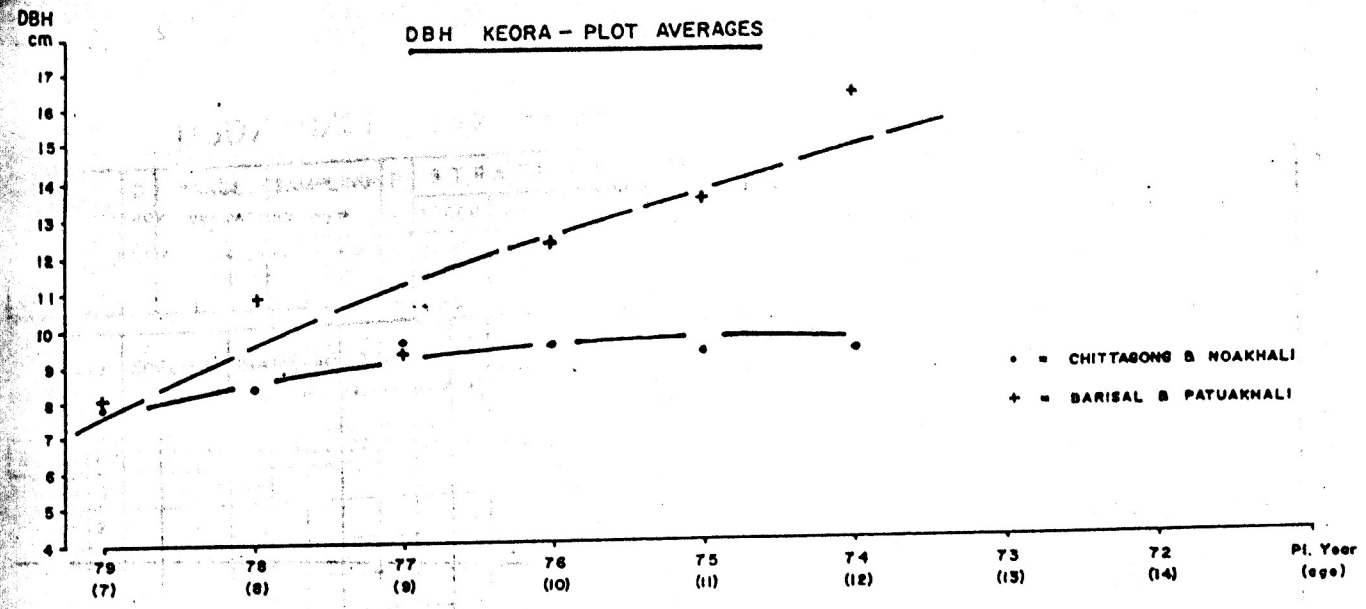
Baen, that has been consistently planted only in Chittagong Division, shows reasonable growth in the northern part from Feni River to Sangu River, while it shows poor or no growth at all on the southern area.

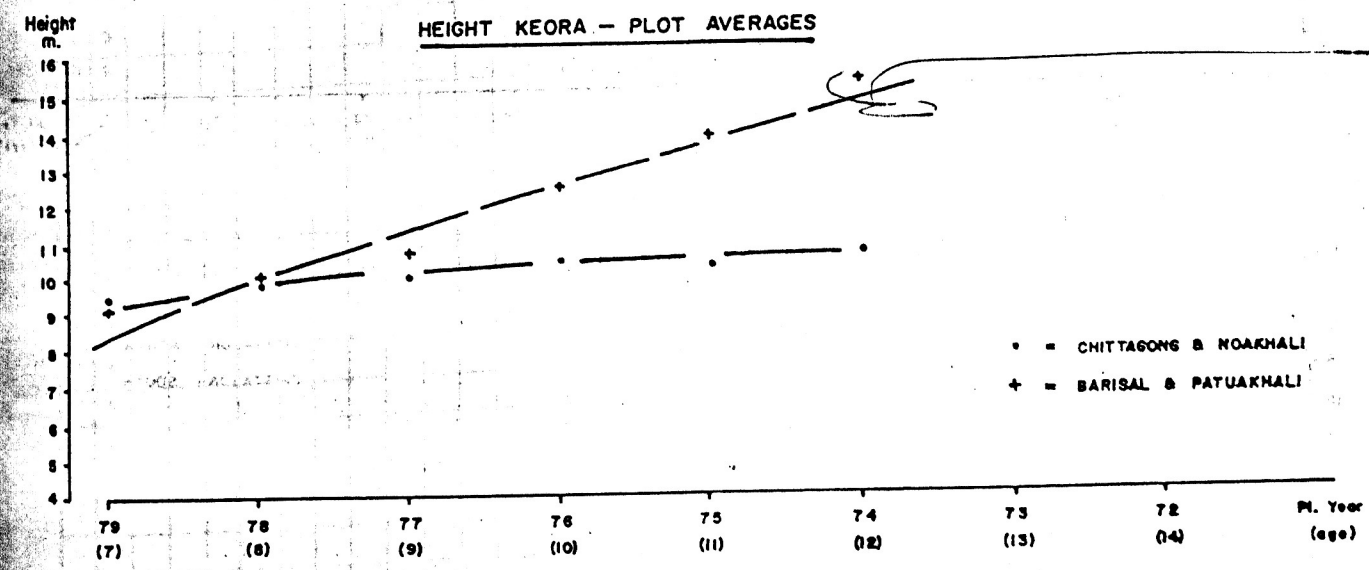
Lack of silvicultural treatments, such as early spacing of broadcast sown areas in concomitance with less favourable ecological conditions, are responsible for such a poor performance.

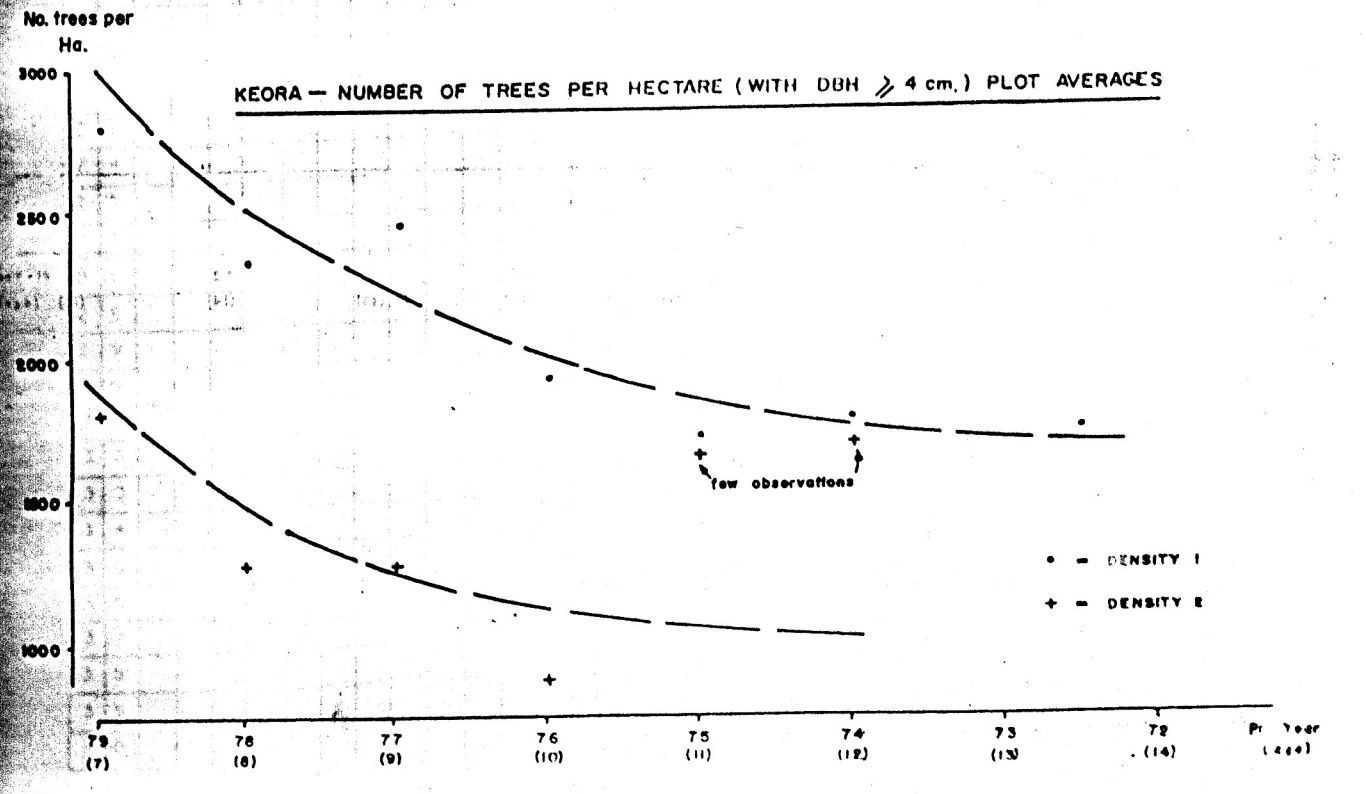
This also explain the totally irrational stocking of many southern Baen areas which makes, at present, a relation between No. of trees/ha and age completely meaningless.

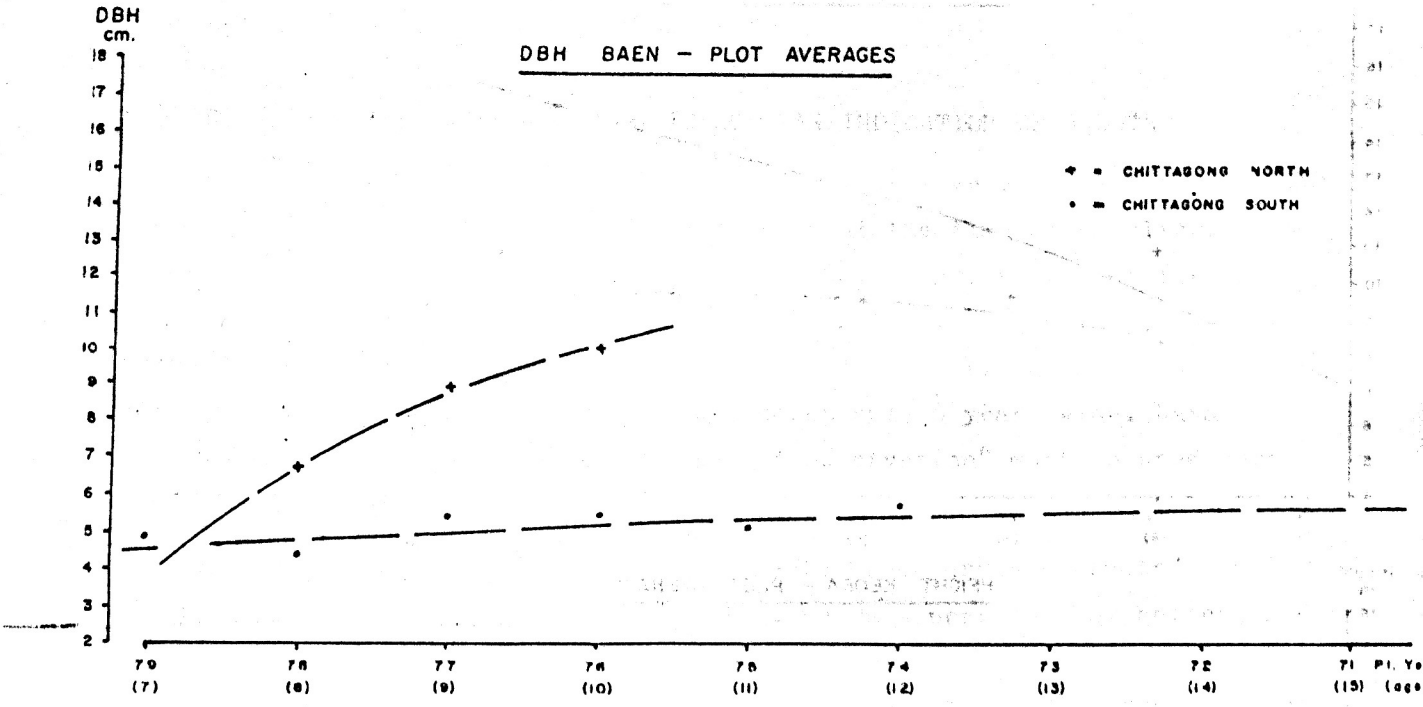
Based on above considerations and with the purpose of supplying the computerized Resource Management System with growth models, a set of provisional growth functions have been developed from individual tree measurements and age for Keora and Baen.

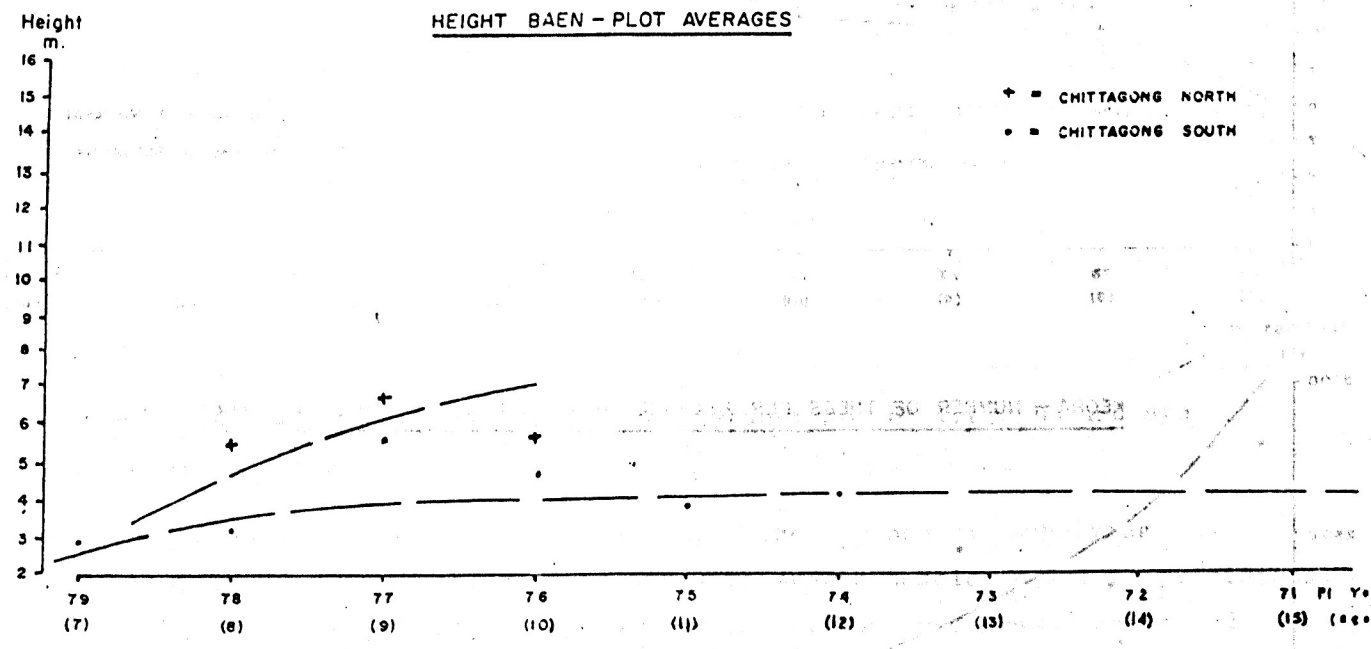
Functions and graphs are given in Appendix 5.


DBH
cm
DBH KEORA – PLOT AVERAGES
17
16
15
14
13
12
11
10
9
8
7
6
5
4
• = CHITTAGONG & NOAKHALI
+ = BARISAL & PATUAKHALI
79 (7)
78 (8)
77 (9)
76 (10)
75 (11)
74 (12)
73 (13)
72 (14)
Pl. Year (age)


Height
m.
HEIGHT KEORA – PLOT AVERAGES
16
15
14
13
12
11
10
9
8
7
6
5
4
• = CHITTAGONG & NOAKHALI
+ = BARISAL & PATUAKHALI
79 (7)
78 (8)
77 (9)
76 (10)
75 (11)
74 (12)
73 (13)
72 (14)
Pl. Year (age)


No. trees per Ha.
KEORA – NUMBER OF TREES PER HECTARE (WITH DBH ≥ 4 cm.) PLOT AVERAGES
3000
2500
2000
1500
1000
few observations
• = DENSITY I
+ = DENSITY II
79 (7)
78 (8)
77 (9)
76 (10)
75 (11)
74 (12)
73 (13)
72 (14)
Pl. Year (age)


DBH
cm.
DBH BAEN – PLOT AVERAGES
+ = CHITTAGONG NORTH
• = CHITTAGONG SOUTH
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
79 (7)
78 (8)
77 (9)
76 (10)
75 (11)
74 (12)
73 (13)
72 (14)
71 (15)
Pl. Yo
(age


Height
m.
HEIGHT BAEN – PLOT AVERAGES
+ = CHITTAGONG NORTH
• = CHITTAGONG SOUTH
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
79 (7)
78 (8)
77 (9)
76 (10)
75 (11)
74 (12)
73 (13)
72 (14)
71 (15)
Pl. Yo
(age