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MINISTRY OF WATER RESOURCES

BANGLADESH WATER DEVELOPMENT BOARD

MEGHNA ESTUARY STUDY

TECHNICAL NOTE MES-018

RAPID ASSESSMENT OF MANGROVE FORESTRY RESOURCES

August 1998

DHV CONSULTANTS BV

in association with

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DANISH HYDRAULIC INSTITUTE

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Technical Note on:

RAPID ASSESSMENT OF MANGROVE FOREST RESOURCES

Dhaka , June 1998

Project Name	:	Meghna Estuary Study (MES)
Location	:	Meghna Estuary
Key words	:	Mangrove plantation, growth and yield Sampling method, form factor, height, stocking, volume Financial analysis

Introduction

An assessment of the mangrove forest resources was carried out in January 98 in order to obtain an overview of the perspective for forestry development in the Meghna Estuary. Existing research data was reviewed, particularly from the BFRI (Bangladesh Forest Research Institute) in Chittagong, and all 4 Coastal Forest Divisions were visited.

Sample plots were measured in a wide range of age classes in order to gain further insight of the forest parameters pertaining to the main species Keora (Sonneratia apetala), although no intent was made to carry out a statistically valid survey. The resulting data were compared with existing research data. A financial analysis was made based on the findings. The results were analysed and used to evaluate forestry management options in the estuary.

1. Resource Assessment

1.1 Mangrove plantation area

The Forest Department (FD) compiles data on the mangrove forest area through the Coastal Afforestation Divisions of Chittagong, Noakhali, Bhola and Pathuakhali. The information is compiled from reports of annual plantings per range from the respective divisions. Several studies indicate that more than 100,000 ha were planted from the early seventies till now. In the highly dynamic environment in which the plantation are established, some are bound to be lost due to different factors, and several studies have tried to estimate major causes for loss and the corresponding resultant forested area. The losses are mainly attributed to erosion, but heavy siltation is also a major threat. It is therefore evident that the mangrove coverage is difficult to assess and monitor, also considering the lack of maps and sophisticated tools in the ranges, which in many cases mean that the reported figures are estimates.

The Forest Department has through its recent FRMP project acquired digital data of the coastal mangrove areas based on SPARSSO maps of 1:10,000, but these have not been made available to the MES.

Table 1 shows the yearwise gross planted mangrove areas in the 4 Coastal Afforestation Divisions (in the MES area) according to the Planning Cell of the Forestry Department from 1970 up to 1992, and adjusted up to 1998.

Table 1: Yearwise plantations in the coastal zone according to Forestry Department

Planting Years	Avg. Yr	Avg. Age	CTG	NOA	BHO	PAT	Total ha
1971-75	73	25	1,119	1,001	670	494	3,284
1976-80	78	20	8,656	9,673	5,543	5,150	29,022
1981-85	83	15	9,396	14,620	10,864	5,548	40,429
1986-90	88	10	8,612	12,758	6,394	4,658	32,422
1991-95	93	5	5,968	9,760	2,997	3,368	22,093
1996-00	98	1	3,600	4,500	1,820	1,054	10,974
yrws98_2.xls			**37,351**	**52,312**	**28,288**	**20,272**	**138,224**

Table 2 shows the total planted mangrove forest area, sorted by Coastal Afforestation Divisions (CA Div) and age class, according to various sources as indicated.

In order to verify these data, the MES digitised the mangrove forest resource in the Satellite images already available to the MES. (Landsat TM 96) to give a more accurate area estimate.

Table 1: Total Mangrove forest area per CA Division (ha)

CA Div	FD Total planted (up to 92)	Existing acc. to WB (up to 92)	Losses (ha) acc. to WB (- 92)	FD Total planted (up to 98)	MES (Landsat TM 96)
CTG	29637	12,535	17,102	37,351	5,764
NOA	35736	24,027	11,709	52,312	30,359
BHO	20732	11,022	9,710	28,288	9,428
PAT	16007	9,835	6,172	20,272	10,779
cadiv.xls	102,112	57,419	44,693	138,223	56,330

It can be seen that the data presented from the WB source is very close to the MES estimate. It is therefore assumed that there has been no net changes in the plantations area since then in other words, losses have been equal to plantings between 92 and 98. The "losses" column is computed from the Total planted as per the FD, minus the WB/FD data for the existing plantations in 1992.

The MES data is taken to be more accurate than the 1992 data, at least regarding the total area although some undefined areas exist (approx. 1905 ha) West of Bhola. Also, there may be some confusion as to the area in the Chittagong division, which may have been registered under Noakhali, resulting in too low figures for Chittagong and too high for Noakhali. In all cases it seems that the FD 1998 figures for gross area planted are unrealistically high.

The yearwise plantation table shown in **table 3** was elaborated under the assumption that the MES data are the most accurate. They have therefore been adopted for the wood volume calculations in this study.

In **table 3** the relative age class distribution has been assumed to be the same as for the FD 98 data. Until better data on ageclass distribution is available, the forest area calculated from the TM imagery is taken to be correct. There seems no doubt that the total mangrove plantation area is much less that anticipated.

Table 3: Yearwise plantations in existence 1998 as verified by MES

Ageclass	Yr	Age	CTG	NOA	BHO	PAT	Total ha
1971-75	73	25	137	721	224	256	1,338
1976-80	78	20	1,210	6,374	1,980	2,263	11,827
1981-85	83	15	1,686	8,880	2,758	3,153	16,476
1986-90	88	10	1,352	7,121	2,212	2,528	13,213
1991-95	93	5	921	4,852	1,507	1,723	9,004
1996-00	98	1	458	2,410	749	856	4,472
yrws98_2 xls			**5,764**	**30,359**	**9,428**	**10,779**	**56,330**

2. Growth and yield of the mangrove plantations

2.1 Sampling method

The sampling was conducted in the 4 Coastal afforestation Divisions. No scientific sampling scheme was followed, but the plots were selected from a wide range of age classes and site conditions. In each plantation a "representative area" was selected and depending on age and stand conditions a plot size of either .01 ha or 0.03 ha (circular plot of either 5.64m or 10m radius). Additional subplots were made in some cases.

A total of 42 sample plots were measured (23 stands with 19 sub plots) and the pertinent forest parameters calculated. the results are presented in **Annex 1**.

The mean tree method was used, the diameter of each tree in the plot was measured using diameter tape. Height was measured on two trees based on "average tree", i.e. one tree with diameter approximately corresponding to the calculated average diameter on all the sample trees in the plot. Suuonto clinometer was used.

One or two such "average trees" were felled in order to calculate the form factor, in approximately half the sample plots. The volume for estimating form factor was calculated measuring the cross section of each tree at 1 m intervals, for the main section. the bottom section was assumed cylindrical, and the top assumed a cone. The total tree stem volume was computed by adding the three sections. The volume of the branches was also computed, using Huberts formula, by measuring the branch mid section diameter and length, and this volume was then added to the stem volume.

The total cylindrical volume based on the diameter at 1.3 metres (dbh) was then calculated and compared to the true volume calculated, and it was thus possible to calculate the form factor for both the total stem volume and for the total tree volume including the branches.

The form factors thus derived are presented in **Annex 2.**

2.2 Data analysis

2.2.1 Form Factor

The form factor analysis shows that the form factor is very close to 0.5 for total stem volume and close to 0.6 for the total tree volume including the branches. It was decided to use total stem volume and 0.5 as the form factor for volume calculations. See **Annex 1**.

2.2.2 Height

Height was plotted against diameter and age which showed at good logarithmic correlation, indicating a good spread in age classes. Maximum height recorded was 21.8 m.

It was evident from the height in **figure 1** that there was a marked difference in site quality among the divisions, with the Chittagong division showing clearly less height growth for this species.

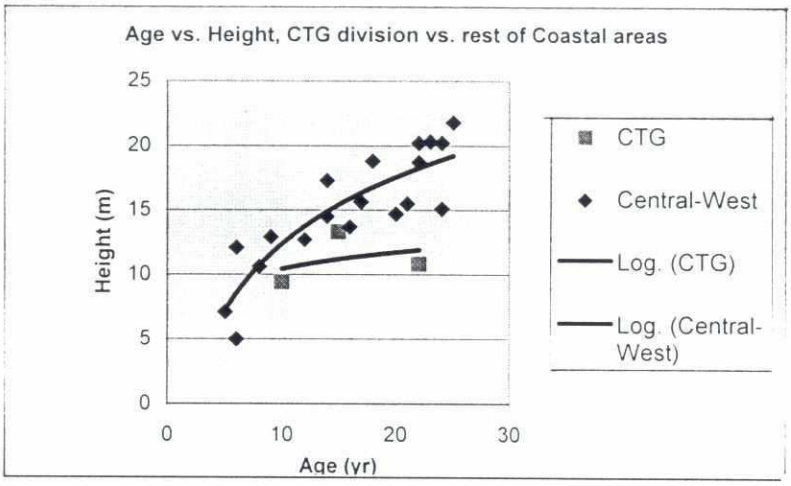

Figure 1: Age plotted against height

Within the divisions there is a marked site variation, as between Chittagong and the rest. Plotting height against age, it was evident that the Chittagong division was clearly lower that the rest (Noakhali, Bhola and Pathuakhali), referred to as Central-West in the figure, prompting for grouping accordingly for volume calculations. In this study growth parameters have therefore been assuned to be the same for the Central-West areas, whereas reductions have been made for Chittagong.

2.2.3 Stocking

The number of stems per hectare plotted against age (figure 2) show a consistent reduction of stems over time in the plantation. This would indicate that Keora as a light demanding tree has a large natural selection and mortality rate as a result of crowding and age, which to some extent facilitates its management, as thinning are probably not as required as with other species. It also has a remarkably good self pruning effect, if managed at not too large spacing.

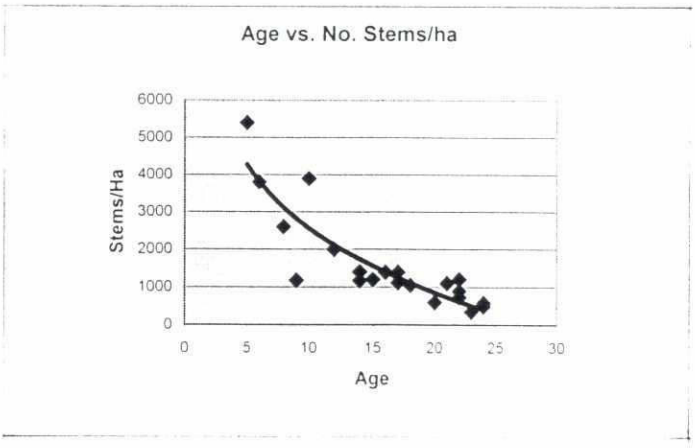

Figure 2: Stems per hectare and age

2.2.4 Basal area and volume

The average basal area does not vary much over age, from about 18 m2/ha at age 5 to about 25 at age 25 on average, but the data show a large variation (range 7-35m2/ha over age 5 to 25 years).

The volume figures are very close to the figures presented by the BFRI, as can be seen in **Annex 4** and in the resulting total volume calculations below. In general the figures show a high productive potential for Keora, especially in the Central-West part of the estuary, albeit with a large variation. As described above Chittagong deviates from this and shows a lower potential, and is therefore exluded from the calculated trend line in the figure. See **figure** 3.

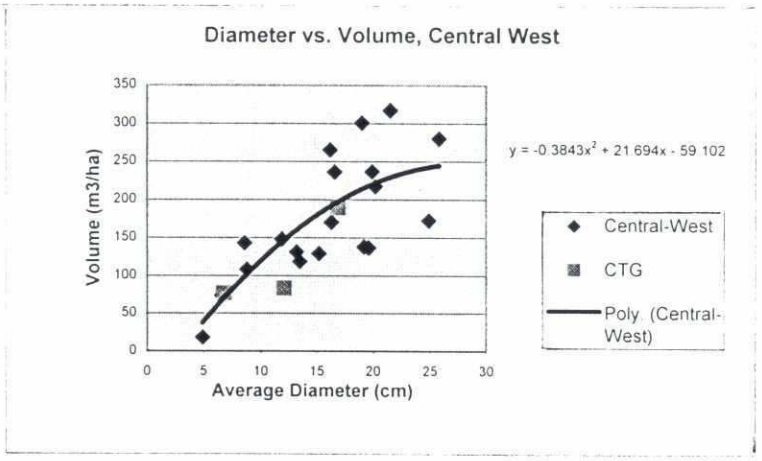

Figure 3: Diameter vs. Volume showing an average trend line (best fit) for the sample plots

2.2.5 Increment

The mean annual increment (MAI) plotted against age (grouped in age classes of 5 year intervals, class 0=0-4 years, 1=5-9 years etc) is shown in **Figure 4**. It is not surprising to find that the MAI of Keora drops off after about the age of 12 years, as is the case with other light demanding tree species, but it could also be attributed to rising land levels in the older plantations.

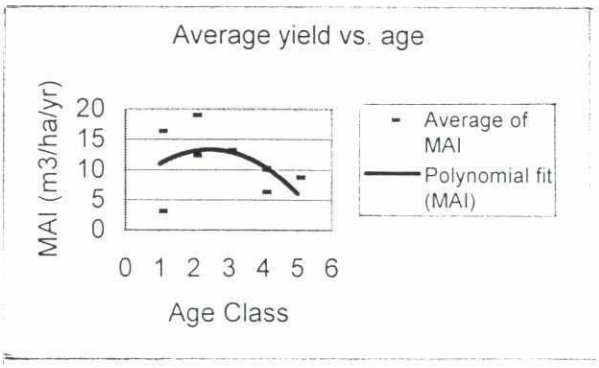

Figure 4: Average yield over stand age (5 yr. ageclass intervals)

2.2.6 Total volume estimation

The difficulty in establishing with certainty the exact area of the mangrove plantations makes it very risky to estimate total volumes, as the calculations are based on the volume per *area unit* (hectare). Furthermore, it is very difficult to take into account the variability in productivity per unit area, even with a systematic sampling method a large number of plots would be necessary to take into account the large and dynamic variation in growth of Keora per unit area found in the estuary.

Also, *Drigo et.al, 1987* found that about one third of the planted area was for some reason unproductive and was left out of the inventory carried out that year. In the present study we do not take such unproductive areas into account, which means that the volume figures presented correspond to only productive forest.

We do however make a correction for the observed lower growth in the Chittagong area for Keora, and in the present calculations we have taken the volume to be one third that of the Western areas.

Table 4 shows the results of the total volume calculation using the relative age class distribution found in the FD figures for gross planted areas up to 1998 (see table 3), the stand parameters in Annex 3, and the assumptions otherwise explained. A breakdown of the total volumes per age class and CA Division is presented in Annex 4.

Table 4: Total volume of Keora mangrove plantations in Meghna Estuary

AgeClass	MES 1) 98 Total ha	MES 2) Total Vol 98 m3	BFRI-1 3) Total Vol 98 m3	BFRI-2 4) Total Vol 98 m3
1971-75	1,338	281,930	260,197	113,064
1976-80	11,827	2,270,752	2,155,078	1,647,025
1981-85	16,476	2,899,446	2,694,677	3,212,136
1986-90	13,213	1,631,297	1,740,988	2,207,974
1991-95	9,004	332,177	620,296	1,170,212
1996-00	4,472	10,418	1,702	-
mesvol1.xls	56,330	7,426,020	7,472,938	8,350,412

NOTE:
1) Total area as estimated by MES, age distribution as per FD
2) Volume calculated using MES findings, Total Stem Volume
3) Volume according to BFRI yield table based on Latif et. Al, total stem volume
4) Volume according to BFRI volume tables for individual trees, using MES observed no. of trees per hectare, Stem volume > 7 cm

For the reasons given above, these figures should not be regarded as exact, but a large error margin for the volumes must be accepted. However, it is evident that large volumes are available in the older age classes for production purposes.

3. Financial analysis

A financial analysis was made using the assumptions for plantation establishment presented in Annex 5.

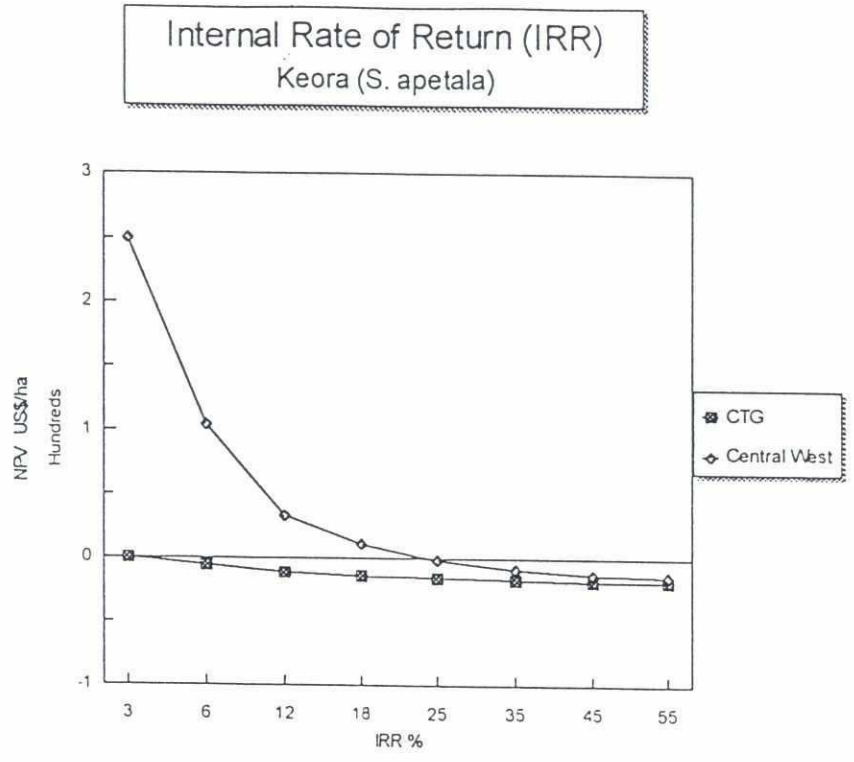

Figure 5 : Internal Rate of Return

The rotation length was set to 12 years, which based on the yield graphs give maximum volume production, and would also return the highest interest for a given investment. The rotation age would thus vary with the magnitude of costs, revenue sales prices and interest rates.

The Net Present Value (NPV) was calculated for a base calculation interest rate of 12%, for two different cases:

-The graph showing "Central West" corresponds to the base assumptions from Annex 5 & 6, with a wood yield of 9 m3/ha/yr.

- The graph showing "CTG" corresponds to the base assumptions from Annex 5 & 6, but with a lower yield as would be expected in the Chittagong CA division. (3 m3/ha/yr.)

All other assumptions are the same for the two cases (see Annex 5-6).

NPV for different interest rates was plotted, and IRR determined (represented in the graph as the interest rate for which the discounted revenues are equal to the discounted costs, i.e. NPV equal to zero).

It can be seen in the figure that the IRR for Keora in the Western areas is about 25%, and for the Chittagong area only 3%, indicating that with the given market interest rates, and assumptions as indicated, it would not be feasible to invest in forestry for economic reasons in the Chittagong area, but much more so in the Western part of the estuary.

Of course other factors than yield are variable, e.g. sales price. Guaranteeing a higher sales price for the raw wood products would change the picture for Chittagong in a favourable way.

4. Conclusions

Based on the sample data collected, and the general observations made during the sampling, some aspects have been confirmed regarding the potential for forestry development in the estuary:

The options for forestry development in the estuary have been elucidated in other MES documents and categorised in separate components, namely as conservation forestry, commercial production forestry, forestry for protection, forestry for conversion to other uses and social forestry.

The present sampling has focused particularly on the technical/financial aspects of forestry, as the basis for developing commercial forestry, which suggest the following:

there is a relatively high growth potential in the estuary, larger in the west than in the east

financially, it is shown that it would be feasible to invest in forestry, provided the market conditions and all other assumptions were guaranteed. It would only hold for the Western part (Noakhali, Bhola, Patuakhali), not in the Chittagong area

there is a large and mature standing stock of timber which could be utilised for industrial purposes (a volume of around 2 mill cubic metres (+-25%?) in the plantations from before 1980)

rotation lengths can be shorter (than 20-25 years) if dictated by returns to capital invested, or maximum production is desired (other issues may dictate different rotation lengths)

The data collected and analysed has clarified several aspects related to the rational use of the coastal mangrove forest resource. Apart from the data collected, a series of observations regarding the destiny of the plantations in relation to the successional nature of the mangroves have been made.

The observations clearly show that there is need of urgent interventions in order to maintain productivity. There is need of management measures to ensure the transition towards other species in the more stabilised parts of the estuary, where Keora is no longer producing.

Interesting experiments with under planting have been undertaken and shown great promise, particularly in the Western part of the estuary. The most successful species are Gewa and Sundri, but also Passur, Khalssi, Hantal and Shingra is doing very well under thinned stands of Keora. In other stands natural regeneration of Gewa show great promise of being able to take over after Keora in a resemblance of natural succession in Sundarbans. In other highly raised areas, non-mangrove species have shown promise.

There is an urgent need to define clear management objectives and determine which areas are to be managed for what purpose. In this respect, there is great lack of spatial information, particularly at range and division level. The problems presented in this study to define clearly the forest areas bear witness to this. At range level only sketch maps exist, which are difficult to update and maintain. On the other hand, the stand based management system seems highly relevant for this type of plantation forest, and should be encouraged. Inventories based on stand stratification would yield very useful information at range level for management purposes, in comparison with general stratification strategies bearing on the whole estuary.

It is inevitable that GIS systems must be integrated in effective land use planning, particularly considering the highly dynamic nature of the estuary with large physical changes (erosion, cyclones etc).

It would be desirable to transfer management responsibility from higher levels to the CA division level for decisions regarding land use within theirs jurisdiction, and for the CA Divisions to suggest land classification compatible with the bio-physical condition present. This could be combined with the socioeconomic information available at other levels and institutions in order to prescribe an effective resource management acceptable to the people, for the benefit of the future sustainability and development.

Overall, there is a potential for developing forestry in the estuary, but at the same time there is great pressure on the resources, and particularly the problems of resettling the landless people is urgent. This highlights the need of a people oriented approach, where communities are encouraged to become involved in the planning and use of the resources. The Forestry Master Plan has outlined some intentions of allocating land for settling people from the respective CA Divisions, and this should be followed up.

ANNEXES

Annex 1: Sample plots
Annex 2: Form factor analysis
Annex 3: Forest stand parameters used in calculating total volumes
Annex 4: Total volumes per ca division
Annex 5: Plantation establishment costs
Annex 6: Financial analysis
Annex 7: References

ANNEX 1

Sample plots in Keora mangrove plantations

No.	Div	Range	Centre	Plant yr	Plot date	Age	AgeCls	D avg	Dg	Hdg	P size	N/plot	N/ha	G/ha	F	Vol ha	MAI	Note
1	PAT	Golachipa	Kankunipara	86	16-Jan-98	12	3	11.9	12.2	12.7	0.01	20	2000	23.38	0.5	148.46	12.4	
2	PAT	Golachipa	Kankunipara	81	16-Jan-98	17	4	15.9	16.4	14.6	0.01	11.2	1120	23.66	0.5	172.71	10.2	5 plots
3	PAT	Golachipa	Kashem	76	16-Jan-98	22	5	21.5	21.9	18.7	0.01	9	900	33.90	0.5	316.98	14.4	4 plots
4	PAT	Char Montaz	Char Taposhi	93	17-Jan-98	5	2	6.6	7.0	7.1	0.01	54	5400	20.78	0.5	73.77	14.8	
5	PAT	Char Montaz	Char Taposhi	89	17-Jan-98	9	2	13.5	14.1	12.9	0.0314	37	1178.34	18.40	0.5	118.68	13.2	
6	BHO	Kukri Mukri	Char Digal	84	18-Jan-98	14	3	16.2	16.7	17.3	0.0314	44	1401.27	30.69	0.5	265.50	19.0	
7	BHO	Kukri Mukri	Char Digal	92	18-Jan-98	6	2	4.9	5.0	5.0	0.01	38	3800	7.46	0.5	18.65	3.1	
8	BHO	Kukri Mukri	Kukri Mukri	76	18-Jan-98	22	5	19.9	20.2	20.2	0.0314	23	732.484	23.47	0.5	237.09	10.8	2 plots
9	BHO	Kukri Mukri	Kukri Mukri	74	18-Jan-98	24	5	25.8	26.8	20.2	0.057	28	491.228	27.71	0.5	279.87	11.7	
10	BHO	Kukri Mukri	Kukri Mukri	75	18-Jan-98	23	5	24.9	24.9	20.3			350	17.00	0.5	172.55	7.5	relascope (17m2/ha)
11	PAT	Kukri Mukri	Char Jamir	92	18-Jan-98	6	2	8.6	8.9	12.1	0.01	38	3800	23.64	0.5	143.02	23.8	
12	PAT	Golachipa	Ashabaria	90	15-Dec-97	8	2	8.8	10.0	10.6	0.01	26	2600	20.42	0.5	108.23	13.5	3 plot
13	PAT	Char Montaz	Sonar Char	84	16-Dec-97	14	3	16.3	16.0	14.5	0.01	11.7	1170	23.52	0.5	170.55	12.2	3 plot
14	PAT	Char Montaz	Sonar Char	77	16-Dec-97	21	5	15.2	13.9	15.5	0.01	11	1100	16.69	0.5	129.36	6.2	2 plot
15	PAT	Char Montaz	Char Taposhi	82	16-Dec-97	16	4	13.2	13.2	13.7	0.01	14	1400	19.16	0.5	131.24	8.2	3 plot
16	PAT	Char Montaz	Char Rustam	80	16-Dec-97	18	4	19.0	19.7	18.8	0.01	10.5	1050	32.00	0.5	300.84	16.7	3 plot
17	PAT	Char Montaz	Char Bestin	81	16-Dec-97	17	4	17.3	18.1	16.7	0.01	14	1400	36.02	0.5	300.79	17.7	3 plot
18	CTG	Sitakunda	Bogachhattar	76	22-Jan-98	22	5	12.1	12.7	10.8	0.0314	38	1210.19	15.33	0.5	82.78	3.8	50% Baen (Avicennia)
19	NOA	Jahajmara	Char Kamala	74	24-Jan-98	24	5	19.6	19.8	15.1	0.0314	18.5	589.172	18.14	0.5	136.96	5.7	Gewa/Kakra regen. D=7.0, H=5m
20	NOA	Jahajmara	Char Kamala	78	24-Jan-98	20	5	19.2	19.9	14.7	0.0314	19	605.096	18.82	0.5	138.33	6.9	
21	CTG	Mirsharai	Bamansunda	88	25-Jan-98	10	3	6.8	7.3	9.4	0.01	39	3900	16.32	0.5	76.72	7.7	
22	CTG	Mirsharai	Mogadia	83	25-Jan-98	15	4	16.9	17.3	13.3	0.0314	38	1210.19	28.45	0.5	189.17	12.6	5% Baen
23	NOA	Char Bata	Char Bata	73	10-Sep-97	25	6	20.2	20.5	21.8	0.0314	19	605.096	19.97	0.5	217.69	8.7	

mesfor.xls

MES Jan 98

Form Factor analysis

ANNEX 2

Id no.	D1.3	S 1.3	Length cm	Cyl Vol 1.3 Cm3	Sub-Sect Vol	Main Sect. Vol	Top Sect. Vol	Total stem Vol	Branch Vol	Total Vol cm3	F total	F Stem
1	11.4	102.0703	1195	121974.063	12271.846	53077.993	109.681	65459.520	5871.323	71330.843	0.585	0.537
4	6.0	28.2743	620	17530.087	3216.991	6332.665	1.309	9550.965	1272.541	10823.507	0.617	0.545
5	14.4	162.8602	1270	206832.407	17436.625	74041.448	96.944	91575.017	22903.231	114478.249	0.553	0.443
13	16.5	213.8246	1420	303631.003	24605.739	129843.988	0.471	154450.198	23883.880	178334.078	0.587	0.509
6	16.8	220.6851	1675	368877.955	24500.103	156181.530	13.378	180695.011	16442.900	197137.910	0.532	0.488
7	4.8	18.0956	495	8957.309	2123.717	3374.856	48.747	5547.320	1628.287	7175.607	0.801	0.619
11	8.9	62.2114	1060	65944.072	6361.725	27422.177	22.619	33806.521	2567.231	36373.752	0.552	0.513
20	18.8	277.5911	1470	408058.957	28652.110	160095.169	26.389	188773.669	25019.801	213793.470	0.524	0.463
21	7.5	44.1786	820	36226.490	4778.362	14620.972	3.351	19402.686	2329.569	21732.255	0.600	0.536
23	15.3	183.8539	1110	204077.780	18626.503	80403.566	15.080	99045.149	19582.097	118627.245	0.581	0.485

Forest Stand parameters used in calculating total volumes

Ageclass	Avg. age	Diameter (dbh) (MES)	No. Stems/ha (MES)	Vol. Ha (MES) 1)	Vol. Ha (BFRI-1)	Vol. Ha (BFRI-2)
5	25	21	350	226.9117	209.42	91.00
4	20	18	750	206.8048	196.27	150.00
3	15	16	1500	189.5572	176.17	210.00
2	10	11	2500	132.9877	141.93	180.00
1	5	5	4000	39.7405	74.21	140.00
0	1	3	5000	2.5093	0.41	0.00

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NOTE:

MES: Parameters taken from MES figures (see text)

1) Volume calculated using MES findings, Total Stem Volume, $Vol=-0.3843D^2+21.69D - 59.102$ (see figure 3)

BFRI-1: Volume according to BFRI yield table based on Latif & Castillo (Journal fo Forest Science, vol. 19, no. 1&2, 1990

BFRI-2: Volume according to BFRI volume tables for individual trees, using MES

observed no. of trees per hectare. Latif, M.A. BFRI Bulletin no. 8, Forest Inventory Division.

Total Volumes per Division and age class

MES

Ageclass	Age class	Ctg	Noa	Bho	Pat	Total ha	CTG Vol m3	NOA Vol m3	BHO Vol m3	PAT Vol m3	Total Vol m3
1971-75	5	137	721	224	256	1,338	9,322	163,668	50,829	58,111	281,930
1976-80	4	1,210	6,374	1,980	2,263	11,827	75,084	1,318,232	409,395	468,040	2,270,752
1981-85	3	1,686	8,880	2,758	3,153	16,476	95,873	1,683,206	522,743	597,624	2,899,446
1986-90	2	1,352	7,121	2,212	2,528	13,213	53,940	947,012	294,107	336,238	1,631,297
1991-95	1	921	4,852	1,507	1,723	9,004	10,984	192,838	59,888	68,467	332,177
1996-00	0	458	2,410	749	856	4,472	344	6,048	1,878	2,147	10,418
		5,764	30,359	9,428	10,779	56,330	245,548	4,311,004	1,338,841	1,530,627	7,426,020

BFRI-1

Ageclass	Age class	Ctg	Noa	Bho	Pat	Total ha	CTG Vol m3	NOA Vol m3	BHO Vol m3	PAT Vol m3	Total Vol m3
1971-75	5	137	721	224	256	1,338	8,604	151,052	46,911	53,631	260,197
1976-80	4	1,210	6,374	1,980	2,263	11,827	71,260	1,251,081	388,540	444,198	2,155,078
1981-85	3	1,686	8,880	2,758	3,153	16,476	89,102	1,564,332	485,825	555,418	2,694,677
1986-90	2	1,352	7,121	2,212	2,528	13,213	57,567	1,010,690	313,884	358,847	1,740,988
1991-95	1	921	4,852	1,507	1,723	9,004	20,511	360,098	111,833	127,853	620,296
1996-00	0	458	2,410	749	856	4,472	56	988	307	351	1,702
		5,764	30,359	9,428	10,779	56,330	247,099	4,338,241	1,347,300	1,540,298	7,472,938

BFRI-2

Ageclass	Age class	Ctg	Noa	Bho	Pat	Total ha	CTG Vol m3	NOA Vol m3	BHO Vol m3	PAT Vol m3	Total Vol m3
1971-75	5	137	721	224	256	1,338	3,739	65,637	20,384	23,304	113,064
1976-80	4	1,210	6,374	1,980	2,263	11,827	54,460	956,142	296,943	339,480	1,647,025
1981-85	3	1,686	8,880	2,758	3,153	16,476	106,212	1,864,731	579,118	662,075	3,212,136
1986-90	2	1,352	7,121	2,212	2,528	13,213	73,009	1,281,788	398,077	455,101	2,207,974
1991-95	1	921	4,852	1,507	1,723	9,004	38,694	679,339	210,978	241,200	1,170,212
1996-00	0	458	2,410	749	856	4,472	-	-	-	-	-
		5,764	30,359	9,428	10,779	56,330	276,114	4,847,639	1,505,500	1,721,160	8,350,412

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NOTE: Volumes per ha for CTG have been taken to be one third of the other divisions

Plantation establishment
(1998 prices, USD, 1ha)

ANNEX 5

Normal yield Western Coastal areas, plants produced by FD
low transportation cost, no fencing

Establishment cost	Plant./ha	Unit price		
Plants	3460	$0.02	unit	76
Plantation		$0.02	unit	76
				0
Beating up 20%	plants	$0.02	unit	15
" plantation		$0.02	unit	15
Other (administration)		$5.00		5
Total establishment				188
Protection (1st year)		$10.00		10
Supervision (1st yr)		$10.00		10
Climber cutting (1 time)		$15.00		$15.00
Total maintenance				35
Total cost per ha				223

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FINANCIAL ANALYSIS	Sonneratia apetala				ANNEX 6
Normal yield Western Coastal areas, plants produced by FD low transportation cost, no fencing					
Variables					
Spacing		1.7	m x m	3460 trees/ha	
Establishment (from annex)		188	USD		
Harvesting costs		2	USD/m3		
Growth		9	m3/ha/yr		
Rotation length		12	years		
Sales price					
1st thinning		12	USD/m3		
2nd thinning or pulp		12	USD/m3		
Final cut (timber)		25	USD/m3		
Yield (% of potential)		85	%		
Distribution of yield in time:					
Period 1- 4. year		10	%		
Period 5-10. year		35	%		
Period 11- 15. year		55	%		
Quality					
Low quality (1st thinning)		15	%		
Medium (pulp/fuelw.)		30	%		
High quality (timber)		55	%		
Age from establishment	0	1-4	5-8	9-10	11-12
Yield					
Yield Low quality (1st thinning)		9			8
Yield Medium (pulp/fuelw.)			32		15
Yield High quality (timber)					28
Gross revenue		110	386		967
Harvest. costs		18	64		101
Net revenue		92	321		866
Total silv./maintenance cost	188	18	11	4	2
Net forest benefit	-188	74	311	-4	864
Discounted Net Benefits					
p=12%	-188	53	157	-1	222
NET PRESENT VALUE:					
Discount rate	NPV	NPV*T			
p=12%	**243**	**327**			

Note: T= (1+r)^n/(1+r)^n-1,where r=discount value, n=years discounted, representing infinite rotatio

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ANNEX 7

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