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EVALUATION OF SOCIAL FORESTRY PLANTATIONS RAISED UNDER THE WORLD BANK SCHEME IN KERALA

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ABSTRACT

The plantations raised by the Social Forestry Wing of the Kerala Forest Department from 1985 to 1990 in Kerala under the World Bank Scheme were assessed for survival through a stratified two-stage sampling plan. Strata were formed based on year of planting and type of plantation. The first-stage units were plantations and second-stage units were small rectangular plots. About 27 per cent of the existing plantations were covered with proportional allocation of the sampling units among the strata. Survival rates were found to vary with type of plantation and year of planting. Survival shifted from 80 per cent in younger years to around 60 per cent in later years.

Productivity of four important species included in the planting programme was assessed through mean tree method. The species were *Acacia auriculiformis* , *Casuarina equisetifolia*, *Eucalyptus grandis* and *Grevillea* robusta. All the above species except *Grevillea* robusta exhibited high potential productivity to the order of 12 to 20 t ha $^{-1}$ yr^{-1} of woody biomass in 5.5 to 7.5 years. The average productivity of *Acacia auriculiformis* and *Casuarina equisetifolia* in different parts of the Stete was also investigated through allometric method. The biomass of all the components of the tree put together averaged out to 101 t ha^{-1} for *Acacia auriculiformis* and 56 t ha^{-1} for *Casuarina equisetifolia* in terms of dry weight at 6.5 years age. Strip and

small block plantations in general fared better than large block plantations with respect to the total biomass.

Moisture content on dry Weight basis of different components of trees was worked out for the four important species mentioned above through mean tree method and for two of the species through allometric method. The overall moisture content of trees of *Acacia auriculiformis* varied from 103 per cent at 3.5 years to **96** per cent at 6.5 years. Phyllodes showed maximum moisture content followed by bark, branches and bole. Trees of *Casuarina equisetifolia* showed an overall moisture content of 94 per cent at 3.5 years which decreased to 82 per cent at 6.5 years. Needles showed highest moisture content followed by bark, branches and bole. In the case of *Eucalyptus grandis* moisture content of trees decreased from 163 per cent at 5.5 years to **106** per cent at 7.5 years as observed thrcugh mean tree method. Bark carried the highest moisture level for trees at 5.5 years, 6.5 years and 7.5 years taken for the study. Leaves slsc contained higher levels of mcisture when compared to bole and branches. *Grevillea robusta* showed an overall moisture content of 92 per cent for trees at 3.5 pears and **98** per cent for trees at 4.5 years through mean tree method. Bark had higher levels of moisture when compared to leaves, branches and bole for this species.

Plantations have been raised over an area of 20,408 ha till 1990-91 under the World Bank Scheme in Kersla. Major portion of this area falls under 'large block' category. As many as 70 species are found planted in these plantations more important of which are the species mentioned above. There has been a shift in the choice of species planted over the years. The emphasis was on fast growing exotics in the initial years but more of indigenous species have been planted in recent years.

Rotation age which changes with the objects of management vary with the species. A 7-year rotation was propssed for *Acacia auriculiformis* based on a previous study by the Institute. The present study has indicated the need for thinning for *Casuarina equisetifolia* at the end of 4 years in good quality sites. Harvesting age could be extended to 7th or 8th year for the same species in poor quality sites. Average site index for plantations of *Acacia auriculiformis* and *Casuarina equisetifolia* raised under the World Bank, Scheme have been worked out which along with the other parameters like rotation age and stocking level at harvest is useful for working out the annual out-turn from the plantations. Provisional volume table and variable density yield table prepared for *Casuarina equisetifolia* are additional outputs of the present study.

1. INTRODUCTION

In Kerala, social forestry activities were initiated in 1980-81 through Rural Fuelwood Scheme sponsored by the Government of India. This was followed by National Rural Employment Scheme and Rural Land1ess Employment Guarantee Programme. A massive programme, namely the World Bank Aided Social Forestry Project with an estimated outlay of about Rs 600 million for a period of 6 years was started in 1984 (Basha, 1991). This gave a big boost to the social forestry activities in the State. Plantations raised under this scheme since 1985 were covered under the present study.

Plantations have been raised on available lands which are often in small patches. The lands belong to the Government or Quasi-Government bodies and the tree planting activities have been carried out not only to provide fuel, fodder, small timber and green manure but also to clothe the barren areas for ecological advantages. The plantations are of three types viz., large block, small block and strip type. Large block plantations are those raised inside Reserved Forest area where soil is highly degraded and eroded with scanty or no vegetation. Trees are often planted under close spacing of 1.5 m x 1.5 m. Large block plantations are also raised in areas where original plsntations have failed and in grasslands of lower elevaticns. Small block plantations are the ones raised in lands belonging to the Government or Quasi-Government organizations like Revenue lands or Panchayat lands. Since the plantations were raised on marginal fallow lands they have more of an ecological role to play than providing materials for human requirements. Strip plantations are also small block plantations and are raised in the form of strips along road-sides, canal banks, bunds, sides of railway lines, coastal belts and so on. The lands belong to National Highways, State Public Works Department, Minor Irrigation Department, Railways, Port, etc. Trees were often planted at close spacing of 1.5 m x 1.5 m in multiple rows but sometimes at larger espacements of 5 m to 10 m as avenue plants.

This part of the report is concerned with the assessment of survival and productivity of plantations raised under the World Bank Scheme since 1985 excluding avenue plantations. Survival assessment has been done through a stratified two-stage sampling, details of which follow. Productivity has been assessed in terms of biomass pruduction per unit area. Only four species viz., *Acacia auriculiformis Casuarina equisetifolia, Eucalyptus grandis* and *Grevillea robusta* could be covered in this respect. Certain aspects with regard to the productivity of *Acacia auriculiformis* in Kerala were dealt with in an earlier report (Jayarman and Rajan, 1991). No attempt is made to reproduce the same here butareappropriately referred to.

2. MATERIALS AND METHODS

2.1. Survival

Data were gathered during the period November 1991 to February 1992 through a stratified two-stage sampling. The list of plantations obtained from the forest Department formed the sampling frame. Stratification was based on year of planting (1985 to 1990) and type of plantation (large block, small block, strip). The first-stage units were plantations and the second-stage units were square or rectangular plots depending on the type of plantation. The plots were of size 15 m x 15 m in the case of block plantations and 45 m x available width in the case of strips. Slight adjustments had to be made in plot size depending upon the local conditions. Roughly 27 per cent of the total number of plantations in Kerala raised under the World Bank Scheme was selected for enumerations and the same was distributed to the different strata approximately in proportion to the area available in each stratum. The sample size in terms of total number of plots worked out to 955 plots. A minimum sample size of two plantations within strata was fixed to ensure variance estimation within any strata. Plantations for observation were selected through simple random sampling without replacement from each stratum and the plots within the plantations were selected by systematic sampling. In the case of block plantations, plots were taken along a single transect running through the centre of the plantation. The plots were separated by

100 m in most of the cases except when the plantation is too large where interval between plots was increased to reduce the number of plots. In the case of strips, small sections were selected systematically for taking observations. The interval between sampling units was adjusted according to the nature of the plantations. Number of surviving plants was noted in all the cases. Girth at breast-height (1.37m from ground level) was recorded for trees qualifying for such a measurement.

Estimates of survival at the State level were made by first estimating the stocking and then dividing by the initial number planted. Formulae used for estimating stocking conformed to that of stratified two-stage sampling involving ratio estimator (Sukhatme and Sukhatme, 1970). Size of the plot formed the auxiliary variable in the ratio estimation. Survival rates for individual species could not be computed because separate records of number of plants planted for different species are not kept in the case of mixture plantations. Replanting is understood to have been carried out in certain plantations after the first year. It was difficult to distinguish plants of different years in the field clearly. As such, the survival rates are with reference to the existing number of plants in the field at the time of observation.

2.2. Productivity

Four important species were chosen for assessment of productivity. The species were *Acacia auriculiformis, Casuarina equisetifolia Eucaliptus grandis* and *Grevillea robusta.* Mean tree method was followed for getting estimates of biomass. Combinations of the above species were found missing in the field because of the fact that individual species are often planted in separate patches in 'mixed' plantations. Sometimes mixed planting is done at the tree level but no particular pattern is found followed. Casualty replacement with a different species makes the pattern further disordered. Fcr instance many species planted with *Acacia auriculiformis* fail and such plantations become indistinguishable with pure acacia plantations after casualty replacement with *Acacia auriculiformsis.* For two of the above species viz., *Acacia auriculiformis* and Casuarina *equisetifolia,* biomass estimates could be developed through allometric method. Details of the above two methods are given below.

2.2.1. Mean tree method

Sample plots of size 15 m x 15 m were laid out and girth at bresst-height (gbh) of all trees in the plot was recorded. Slight variations were made in the plot size depending on the nature of the site. The tree having dbh nearest to the quadratic mean diameter of the stand was identified as 'mean tree'. The 'mean tree' was felled and green weight' of bole, branches and leaves was recorded. The tip end girth of the bole was fixed as 10 cm over bark. The branches included current year twigs as well with leaves separated. Representative samples from each of these portions were taken for finding the oven-dry weight. Bole was sampled by taking 5 cm wide discs from the base, middle and top of the bole. Dry weight of the discs was obtained after debarking. The component bark refers to the bark of the bole. Bark was not removed from the branches. The samples taken from branches and leaves amounted to 100 g by green weight. The samples were dried to constant weight at $103 \pm 2\,^{o}C$. Dry weight of the different components of the trees was estimated by applying the ratio of green weight to dry weight of the samples to green weight of the corresponding components. The estimates were later converted to per hectare basis taking into account the number of stems in the plot and size of the plot. Moisture content of the different components of the trees was expressed on dry weight basis.

2.2.2. Allometric method

Here, the ides was to develop prediction equations for predicting biomass of different components of trees through an easily measurable characteristic like dbh of trees. These equations can then be applied to develop estimates of stand level biomass for a number of stands for which such measurements are available. The sample plots selected for survival assessment through stratified two-stage sampling formed the database for the assessment of productivity as well. However the was restricted to pure stands of *Acacia auriculiformis* and *Casuarina equisetifolia* because biomass equations could be developed only for these two species. Further, stands having age of 3.5 years and above were only included since a large number of plants below this age may not qualify for measurement of dbh. Separate equations were run for each component of the tree relating them to the dbh. The following family of equations were tried in this respect.

$$E(Y) = a + bD + cD^2 \quad (1)$$

$$E(Y) = a + bD + cD^{-1} \quad (2)$$

$$E(Y^{0.5}) = a + bD + cD^2 \quad (3)$$

$$E(Y^{0.5}) = a + bD + cD^{-1} \quad (4)$$

$$E(\ln Y) = a + b\ln D + c(\ln D)^2 \quad (5)$$

$$E(\ln Y) = a + b\ln D + c(\ln D)^{-1} \quad (6)$$

$$E(YD^{-1}) = a + bD + cD^{-1} \quad (7)$$

$$E(YD^{-2}) = a + bD^{-1} + cD^{-2} \quad (8)$$

where Y = Biomass of tree component (t)

D = Diameter at breast-height (m)

E stands for expectation

The best fitting model in each case was selected using adjusted R^2, Furnival index and characteristics of residuals. Nonsignificant terms were eliminated while fitting the models. ?he equaticns for *Acacia auriculiformis* were based on a sample cf sixteen trees felled from different parts of the State. The correspoding number in the case of *Casuarina equisetifolia* was eighteen. Estimates of biomass of different component parts of the trees at the plot level were made by aggregating the predicted values for each tree in the plot. Eark content was obtained through the difference of the predicted values for the weight of the bole with and without bark. Later, conversions were made to the hectare level taking into account the size of the plot. Separate equations were run for predicting the dry weight and green weight of the different components of trees. Moisture content was expressed on dry weight basis.

In order to see whether productivity differed with respect to the different types of plantations, the sample plots were categorised into two broad groups viz., large block and other types of plantstions. Analysis of covariance was done on total biomass, current stocking and crop diameter keeping the number of seedlings planted initially as covariate. Additional sources of variation considered were age and its interaction with type of plantation. The dependent variables were transformed to square root scale befcre the analysis to meet the assumptions involved in the anslysis (Montgomery and Peck, 1982).

2.2.3. Mean tree method versus allometric method

In order to see the extent of difference between estimates obtained through the two methods at the plot level, estimates of biomass were worked out using allmetric method for plots which were selected for applying mean tree method. This could be done for the two species *Acacia auriculiformis* and *Casuarina equisetifolia* for which prediction equations were available.

2.3. Management

2.3.1. General features

Reliable information about the units to be managed is very critical for successful management of the system comprising these units. A list of plantations raised under the World Bank Scheme in Kerala from, 1985 to 1990, with essential details regarding location, extent, species planted, etc. was obtained from the office of the Principal Chief Conservator of Forests (Social Forestry and Projects). During the above survey an attempt was made to verify the correctness of the entries in the list by comparing it with the Plantation Journals maintained at the Range Offices. This was met with limited success as Plantation Journals are found not maintained properly for many plantations. Corrections were done to the extent possible. Based on the above list several types of tabulations were done and are reported under section 3.3. These include age-class distribution of the area under plantations, size-class distribution of the plantations, classification by the species planted, list of species planted, etc.

2.3.2. Rotation

Fixing up proper rotation is an important function involved in plantation management. The rotation besides depending on the silvicultural requirement of the species also depends on the object of management as it is necessary that the forest should yield the most suitable type of material. In some cases the management may desire to realize indirect results, such as the protection of mountain slopes, in which case high rotation may indicated; in another, consideration may go to the economic aspect of forestry such as the production of the greatest quantity or highest quality of timber in which case a shorter rotation may suffice. Here the major species of concern are *Acacia auriculiformis* and *Casuarina equisetifolia* which are primarily grown for firewood. Economic rotation is often hard to fix because of fluctuations in the price of products. An alternative is the rotation of maximum volume production which yields the greatest annual quantity of material. It coincides with the age at Which the MAI reaches the maximum value. It is also the point where the MAI and CAI curves meet. Based on the work carried out under the present prcject, rotation of maximum volume production could be fixed for *Casuarina equisetifolia.* For the species *Acacia auriculiformis* rotation was fixed as 7 years based on earlier work (Jayaraman and Rajan, 1991). Though an extended data set is available nor; for this species, a revision of the yield table will be undertaken only after validation of the existing one, which is currently going on. As such the recommendation on rotation age for *Acacia auriculiformis* stands at 7 years. Other than these two species, *Eucalyptus* spp. and *Grevillea robusta* ere also grown widely under the Social Forestry Programme. Species of *Eucalyptus* are mainly intended for pulpwood and the current rotation age adopted by the Forest Department is around 8 years. *Grevillea robusta* is used for timber as well as firewood. Hosts of other species are also found planted under the Social Forestry Programme recently, which are either timber yielding or of multipurpose in nature. Rotation age for these species naturally has to be very long.

The details of the method followed for finding rotation age for *Casuarina equisetifolia* are as follows.

As a first step, equations for predicting total height and commercial volume of individual trees from dbh were developed for the species. The trees conformed to those selected for developing equations for predicting biomass for the species. The height of trees was measured after felling. The felled trees were cut into 1 m billets and basal, middle and tip girth were recorded for each billet. The lower limit of commercial volume was fixed at 10 cm girth over bark. Billet volume was calculated using Newton's formula (Chaturvedi and Khanna, **1982).** Individual tree volume was obtained by aggregating the volume of billets from the tree. Dbh of the trees ranged from 4.9 cm to 15.4 cm, total height from 9.45 m to 22.15 m and volume from 0.0092 m^3 to 0.18805 m^3 Different regression functions were tried and the best fitting model in each case was selected using adjusted R^2, Furnival index and Characteristics of residuals. The models tried conformed to those given in equations (1) to (8). The selected equations were applied to dbh measurements on trees, available from a number of plots and total stand volume was computed for each plot. These plots were the same set of sample plots selected for the assessment of productivity of *Casuarina equisetifolia* through allometric method. Top height for each plot was also computed using the relation between dbh and height (Chaturvedi and Khanna, 1932). Site index curves were developed using Schumacher functions (Clutter et *al.,* 1983).

$$E(\ln H) = a + b A^{-1} \tag{9}$$

$$\ln S = \ln H + \hat{b}(A^{-1} - A_0^{-1}) \tag{10}$$

where A_0 = 8 years

H = Top height (m) which is the height corresponding to the quadratic mean diameter of the largest 250 diameters per ha as read from a height diameter curve.

$\hat{b}$ = an estimate of b

Further yield table based on number of trees per ha and top height was derived through the following equation (Pande, 1978).

$$E(\ln V) = a + b \ln x + c (\ln x)^2 \tag{11}$$

where $x = \dfrac{H N^{1/6}}{10}$

N = Number of trees (no. ha^{-1})

H as defined earlier

At any age top height was predicted through equation (10) for a given site index and the expected yield for that age was worked out using the predicted top height for a given number of trees. Changes in the crop diameter with varying stand age for different stocking and site productivity levels were characterized through the following equation.

$$E(d) = a + bH + cN + dH^2 + cN^2 + fHN \qquad (12)$$

where d = crop diameter (m)

H, N as defined earlier.

Equation (12) was subjected to stepwise regression to remove irrelevant variables. Prediction of crop diameter for any given age under a particular site quality and stocking level can be achieved using equations (10) and (12).

Mean Annual Increment (MAI) and Current Annual Increment (CAI) at any age were worked out based on the corresponding predicted volume. The rotation age was taken at the point where MAI and CAI curves meet. Changes in MAI near this point were also taken into account for the purpose.

2.3.3. Annual out-turn

Working out the annual out-turn of products from the units managed is of interest from the point of view of sustained yield principle in forestry. This will indicate the level at which a product can be supplied regularly over time. Information on the area under different species is essential in arriving at such an estimate. Unfortunately this information is lacking with respect to the Social Forestry plantations in Kerala for want of proper records. The problem lies with the category of mixed plantations for which only the total area is recorded and not its split-up as to the component species. Keeping aside this fact, an attempt has been msde here to provide the necessary ancillary information required to calculate the annual out-turn from plantations of *Acacia auriculiformis* and *Casuarina equisetifolia* raised under the World Bank Scheme in Kerala. This could be utilized when the said information becomes available at a later stage.

The three parameters involved in the prediction of yield are the rotation age, stocking level at harvest and the site quality/index. A discussion on these aspects is made for each of the two species separately in the following.

2.3.3.1. *Acacia auriculiformis*

Rotation age for *Acacia auriculiformis* has been found to be 7 years in a previous study (Jayaraman and Rajan, 1991). The overall survival rate in plantations has been found to stabilize at 60 per cent in around 7 years under the present study (Table 1). This is applicable to *Acacia auriculiformis* a major component of the Social Forestry Programme. *Acacia auriculiformis* is usually planted at a spacing of 1.5 m x 1.5 m. This gives an expected stocking level of 2667 trees ha^{-1} at 7 pears. The next parameter required for working out the annual out-turn is the average site index for plantations of the species in the State. The site index conformed to that of equations (2) and (3) in Jayaraman and Rajan (1991).

The site indices computed for the sample plcts carrying pure stands of *Acacia auriculiformis* were used for arriving at the mean site index. The plots were the same as those used for the assessment cf productivity of *Acacia auriculiformis* thrcugh allometric method.

2.3.3.2. *Casuarina equisetifolia*

Rotation age for *Casuarina equisetifolia* is found to vary with stocking level and site quality. Hence rotation age is to be fixed in consonance with the latter factors mentioned. The species is usually planted at 1 m x 1 m of spacement and the expected stocking after the third year of planting is 6000 trees ha^{-1}. The mean site index was worked out from predicted site index values from plots carrying pure stands of *Casuarina equisetifolia.* The plots were the same as those used for assessment of productivity of *Casuarina equisetifolia* through allometric method. Equation (10) was used for predicting the site index of individual plots.

2.3.4. Recent productivity estimates against projections of the World Bank

As per the terms of reference for the present project it was required to compare the estimates of the productivity developed through this project with the projections given in Anonymous (1984). The projections on productivity of different species reported in Anonymous (1984) are in terms of commercial volume rather than biomass units. Yield table with respect to commercial volume have been prepared for two species, *Acacia auriculiformis* and *Casuarina equisetifolia*, by this Institute. The tables for the latter species have been included in the present report. The projections can be compared to values of the yield table against average site index for the State and stocking level at the rotation age specified. Estimates of average productivity in terms of above-ground biomass were also worked out for these two species as requested by the Social Forestry Wing. The projections on productivity were to be converted to dry woody biomass before comparing with the recent estimates, using the following relations.

Acacia auriculiformis

1 m^3 green volume = 0.5449 t oven-dry weight

Casuraina equisetifolia

1 m^3 green volume = 0.6393 t oven-dry weight

These were worked out using the sample discs collected from different parts of the trees used for developing allometric relations.

No comparison was undertaken for the rest of the species since average values for the State were not available for the plantations concerned.

3. RESULTS AND DISCUSSION

3.1. Survival

The estimates of the survival rates for the Social Forestry plantations raised under the World Bank Scheme in Kerala from 1985 to 1990 are given in Table 1. All these plantstions were assessed for survival around the beginning of 1992. Survival rates are found to vary from year to year and with the type of plantation. These variations could have been induced by the climatic conditions prevailed in the planting season and afterwards in different years and also by the type of land where plantations have been raised. Sometimes the quality of the seedlings also matters in this respect. Survival rates are expected to be higher in younger plantations and are expected to stabilize over years. This is seen with the marginal figures against the years of Table 1 where the survival shifts from 80 per cent at 1.5 years to around 60 per cent in later years. Survival rate in general did not differ with the type of plantation. One has also to note that replanting was done in many plantations where high levels of casualty occurred. Though the survival rates reported are

Table 1. Survival rates of Social Forestry plantations raised in different years under the World Bank Scheme in Kerala

Year of planting	Age (yr)	Survival (x) Large block	Small block	Strip	Overall
1985	6.5	64.36 (10.43)	62.62 (9.18)	73.72 (7.95)	64.64 (9.22)
1986	5.5	57.56 (5.32)	52.38 (6.62)	37.73 (2.01)	56.63 (4.78)
1987	4.5	64.21 (4.12)	50.55 (21.65)	63.92 (22.69)	61.96 (4.92)
1988	3.5	52.64 (5.53)	80.67 (7.48)	32.66 (10.12)	54.40 (4.86)
1989	2.5	56.81 (3.81)	71.62 (14.34)	70.42 (12.78)	60.20 (3.78)
1990	1.5	82.43 (5.48)	60.23 (33.76)	61.64 (14.63)	80.19 (5.63)
Overall	-	60.56 (2.53)	62.46 (7.38)	54.51 (5.18)	60.54 (2.31)

Note: Figures in brackets are standard errors inclusive of such attempts for plantation establishment, the number of seedlings replanted could not be taken into account for lack of sufficient data on the same. Also to be noted is that the mean survival rate and its standard error in any stratum need not directly indicate the extend of variation at the level of individual plantations, as influenced by the varying espacements and local conditions existed in the different plantations.

Estimates of growing stock in terms of number of trees ha^{-1} as existed at enumeration are reported in Table 2. No systematic differences could be seen between the types of plantations with respect to the number of trees ha^{-1} in different years although differences do exist. The stocking levels are lower in recently raised plantations when compared to older plantations. This might be due to the larger spacing given to indigenous species planted in recent years compared to the close spacing given to fast growing exotics planted in early years of the planting programme.

The number of plantations surveyed in relation to the number of plantations available in different strata is given in Table 3 reference as to the sampling intensity that could be achieved in the survey.

Table 2. Stocking level of Social Forestry plantations raised in different years under the World Bank Scheme in Kerala

Year of planting	Age (yr)	Stocking (trees ha^{-1}) Large block	Small block	Strip	Overall
1985	6.5	2851 (462)	2483 (364)	3008 (324)	2828 (404)
1986	5.5	2740 (253)	2702 (341)	2258 (120)	2727 (230)
1987	4.5	2628 (168)	2860 (1225)	2788 (990)	2659 (211)
1988	3.5	2181 (229)	3702 (343)	2193 (680)	2311 (206)
1989	2.5	1523 (102)	1847 (370)	1698 (308)	1589 (100)
1990	1.5	1622 (108)	1177 (660)	2488 (590)	1595 (112)
Overall	-	2241 (93)	2482 (293)	2145 (204)	2262 (86)

Note: figures in brackets are standard errors

Table 3. Number of plantations surveyed under the different strata

Year of planting	Age (yr)	Type of plantation Large block	Small block	Strip	Total
1985	6.5	8	14	10	32
		(40)	(56)	(51)	(147)
		(20)	(25)	(20)	(22)
1986	5.5	23	22	4	49
		(86)	(103)	(19)	(208)
		(27)	(21)	(21)	(24)
1987	4.5	29	15	4	48
		(78)	(77)	(20)	(175)
		(37)	(19)	(20)	(27)
1988	3.5	39	14	4	57
		(92)	(52)	(8)	(152)
		(42)	(27)	(50)	(38)
1989	2.5	23	20	10	53
		(76)	(84)	(50)	(210)
		(30)	(24)	(20)	(25)
1990	1.5	21	7	2	30
		(62)	(34)	(3)	(99)
		(34)	(21)	(67)	(30)
Total	-	143	92	34	269
		(434)	(406)	(151)	(991)
		(33)	(23)	(23)	(27)

Note: Figures in brackets give the total number of plantations in the strata and the corresponding percentage of sampling intensity.

3.2. Productivity

Productivity of forests can be measured in terms of volume or weight. Conventional forestry practice is to express the yield in terms of commercial volume which ignores components of the tree other then commercial wood. Rather than volume, dry matter estimates of all the parts of the tree are required to convert wood production into energy units as wood density varies according to species. These data are also necessary to evaluate the effects of a whole tree harvest on the mineral equilibrium of the ecosystem. The recent trend is to express the yield in terms of biomass which is the amount of living matter accumulation on a unit area at specified point in time (Newbould, 1967). Biomass estimates for forests are generally expressed on oven-dry weight basis per unit of land area. Biomass estimates obtained for the four important species planted under the Social Forestry Programme in Kerala are reported here.

3.2.1. Mean tree method

Estimates of biomass of various components of the tree converted to hectare levels for different species are given in Tables 4 to 7. Since the stands selected were of fairly high stocking, the estimates reflect the potential yield rather than actual yield realized over vast areas. The latter aspect is dealt with in the next section. The 'potential' does not refer to hypothetical figures but that of fairly good grown stands. The results in general are erratic. The spatial

Table 4. Biomass of various tree components of *Acacia auriculiformis* through mean tree method

Characterstic	Details			
Location	Wadakkan-cherry	Cheppila-kkode	Chembikkunnu	Chettikulam
Forest Range	Wadakkan-cherry	Wadakkan-cherry	Wadakkan-cherry	Chalakkudy
Forest Division	Trichur	Trichur	Trichur	Trichur
Type of plantation	Strip	Large block	Large block	Large block
Age (yr)	3.5	3.5	5.5	6.5
Stocking (no. ha^{-1})				
Initial	4444	4444	4444	4444
At felling	2083	3644	3333	3244
Crop dimeter (cm)	8 . 9	6.5	7.0	8.4
Dry weight (t ha^{-1})				
Bole	43.140	32.252	44.954	79.412
Bark	4.799	5.118	6.402	13.285
Branches	11.216	9.787	15.134	19.005
phyllodes	4.303	3.805	4.015	4.785
Total	63.458	50.962	70.515	116.490

Cont..

Dry weight (%)				
Bole	67.982	63.286	63.765	68.170
Bark	7.562	10.043	9.079	11.405
Branches	17.675	19.205	21.462	16.315
Phyllodes	6.731	7.466	5.694	4.110
Total	100.000	100.000	100.000	100.000
Green weight ($t\ ha^{-1}$)				
Bole	77.302	62.326	7 7.200	142.522
Bark	11.026	10.840	14.382	24.874
Branches	19.999	18.655	26.984	34.418
Phyllodes	14.166	10.452	12.265	14.862
Total	122.493	102.283	130.831	216.676
Moisture content (%)				
Bole	79. 189	93.247	71.693	79.472
Bark	129.756	111.801	124.649	87. 234
Branches	78.308	90.712	78.301	81.100
Phyllodes	229.212	174.691	205.479	210.401
Total	93.030	100.704	35.536	86.004

Table 5. Biomass of various tree components of *Casuarina equisetifolia* through mean tree method

Characteristic	Details	
Location	Kazhimbram	Kothakkulam
Forest Range	Chalakudy	Chalakudy
Forest Division	Trichur	Trichur
Type of plantation	Strip	Strip
Age (yr)	4.5	5.5
Stocking (no. ha^{-1})		
Initial	10000	10000
At felling	7333	8083
Crop diameter (cm)	7.5	7.2
Dry weight (t ha^{-1})		
Bole	104.475	92.970
Bark	9.240	8.415
Branches	32.019	18.518
Needles	9.683	11.654
Total	155.417	131.557

Table 5 cont...

Dry weight (%)		
Bole	67.222	70.669
Bark	5.946	6.396
Branches	20.602	14.076
Needles	6.230	8.859
Total	100.000	100.000
Green weight (t ha^{-1}		
Bole	182.412	179.427
Eark	22.494	19.473
Branches	58.760	35.700
Need1es	33.147	34.000
Total	296.813	268. 600
Moisture content (%)		
Bole	74.599	92.995
Bark	143.442	131.408
Branches	83.516	92.785
Needles	242.322	191.745
	90. 978	104.170

Table 6. Biomass of various tree components of *Eucalyptus grandis* through mean tree method

Characteristic	Details		
Location	Idalimotta	Idalimotta	South machiplavu
Forest range	Munnar	Munnar	Munnar
Forest Division	Idukki	Idukki	Idukki
Type of plantation	Large block	Large block	Large block
Age (yr)	5.5	6.5	7.5
Stocking (no. ha^{-1})			
Initial	4444	2500	2500
At felling	3200	2250	1775
Crop diameter(cm)	8.1	11.1	13.2
Dry weight (t ha^{-1})			
Bole	32.179	68.720	76.467
Bark	6.222	9.377	11.444
Branches	6.017	14.884	9.404
Leaves	3.831	7.235	4.304
Total	48.249	100.216	101

Cont..

Dry weight (%)			
Bole	66.694	68.572	75.249
Bark	12.395	9.357	11.262
Branches	12.471	14.852	9.254
Leaves	7.940	7.219	4.235
Total	100.000	100.000	100.000
Green weight (t ha^{-1})			
Bole	80.352	122.421	150.084
Bark	21.398	30.129	28.481
Branches	14.079	27.900	20.235
Leaves	10.879	16.650	10.650
Total	126.708	197.100	209.450
Moisture content (%)			
Bole	149.703	78.145	95.273
Bark	243.909	221.307	148.873
Branches	133.987	87.450	115.174
Leaves	183.973	130.131	147.444
Total	162.613	96.675	106.113

Table 7. Biomass of various tree components of *Grevillea robusta* through mean tree method

Characteristic	Details	
Location	Palakkal	Vattachira
Forest Range	Calicut	Calicut
Forest Division	Calicut	Calicut
Type of plantation	Large block	Large block
Age (yr)	3.5	4.5
Stocking (no. ha^{-1})		
Initial	2500	2500
At felling	2050	1950
Crop diameter (cm)	3.0	5.1
Dry weight (t ha^{-1})		
Bole	2.729	8.522
Bark	0.458	1.423
Branches	2.563	3.160
Leaves	1.754	2.536
Total	7.504	15.741

Cont...

Table 7 cont...

Dry weight (%)		
Bole	36.367	54.774
Bark	6.103	9.040
Branches	34.155	20.075
Leaves	23.375	16.111
Total	100.000	100.000
Green weight ($t\ ha^{-1}$)		
Bole	5.005	16.326
Bark	1.040	3.034
Branches	5.115	7 040
Leaves	3.255	4.844
Total	14.415	31.244
Moisture content (%)		
Bole	83.401	89.353
Bark	127.074	113.212
Branches	99.571	122.785
Leaves	85.576	91.009
Total	92.098	98.488

variation in growth is considerable. However certain general trends are discernible.

Acacia auriculiformis isfound to accumulate as much as 117 t ha^{-1} of dry matter in 6.5 years (Table 4). The strip plantation has yielded better than the large block plantation of comparable age. Bole with bark constituted major portion of the above ground biomass showing slight increase in its content over years. The overall moisture ccntent is as much as as 100 per cent on dry weight basis showing slight decrease with increasing age. The phyllodes showed maximum moisture content followed by bark, branches and bole.

The yield of *Casuarina equisetifolia* on dry matter basis is found much better in the cases considered here (Table 5). This is mostly due to the closer spacing and nearness to sea. These were strip plantstions raised along the sea shore. Bole with bark constituted nearly 75 per cent of the above ground biomass. The overall moisture ccntent varied from 90 to 104 per cent. Needles and branches showed higher moisture content compared to bole and bark.

Eucalyptus grandis has performed well in Munnar, a high elevation area with as much as 100 t ha^{-1} of biomass in 6 to 7 years (Table 6). The crop diameter is higher in these stands because of the lower stocking. Bole without berk constituted 75 per cent of the biomass at 7.5 years. The overall moisture content decreased from 163 per cent at

5.5 years to 106 per cent in 7.5 years. Bark carried the highest moisture level at all ages. Leaves also contained higher levels of moisture when compared to bole and branches. *Grevillea rubusta* is comparatively a slow grower among the above four species (Table 7). The dry matter accumulation is only 16 t ha^{-1} at 4.5 years. Since most of the *Grevillea robusta* plantations raised under the World Bank Scheme in Kerala are of younger age group, older plantations were not available for sampling. The content of bole with bark is lesser in this case because of the younger age of the stands sampled. The overall moisture content varied in the range of 92 to 99 per cent. Bark and branches carried higher levels of moisture than bole and leaves.

Because of the variation in stocking and management over different locations it is not possible to make direct comparisons of the productivity of the above stands with those obtained in other States or Countries. However a global standard may be useful for assessing the performance. Cannel and Smith (1980) have shown that mean annual increments (MAT) in dry matter woody biomass (stem branches) of the order of 10-12 t ha^{-1} yr^{-1} would correspond to high productivity values. The potential productivity indicated by the above stands of *Acacia auriculiformis* (17.185 t ha^{-1} at 6.5 years), *Casuarina equisetifolia* (21.801 t ha^{-1} at 5.5 years), *Eucalyptus grandis*

(12.975 t ha^{-1} at 7.5 years) would fall under the highly productive category.

3.2.2. Allometric method

As mentioned earlier, only two species could be covered under this method. Unlike in the case of mean tree method, the estimates reflect average performance of the species over a wide region and are not specific to any particular location. This could be achieved becsuse measurements on dbh of trees were available from sample plots laid out in a number of places. Estimates of biomass could be developed fcr predicting the biomass of different components of trees. These equations are reported first for each species followed by the estimates of biomass.

3.2.2.1. *Acacia auriculiformis*

The best fitting equations for predicting the dry weight of the different components of the tree are given below. Figures in brackets are standard errors of the estimates. The mean square error (MSE) cbtsined are given in Appendix 1.

$$\ln W1 = \underset{(0.1499)}{0.4515} \ln D - \underset{(0.0574)}{0.4573} (\ln D)^2 \quad (\text{Adj. } R^2 = 0.9982) \tag{13}$$

$$\ln W2 = \underset{(0.1581)}{0.4891} \ln D - \underset{(0.0605)}{0.4663} (\ln D)^2 \quad (\text{Adj. } R^2 = 0.9981) \tag{14}$$

$$\ln W3 = \underset{(0.0269)}{2.1214} \ln D \quad (\text{Adj. } R^2 = 0.9974) \tag{15}$$

$$\ln W4 = \underset{(0.3504)}{3.4440} \ln D + \underset{(0.1342)}{0.3370} (\ln D)^2 \quad (\text{Adj. } R^2 = 0.9959) \tag{16}$$

where w_1 = Cry weight of bole with bark (t)

w_2 = Cry weight of bole without bark (t)

w_3 = Cry weight of branches (t)

w_4 = Cry weight of phyllodes (t)

D = Diameter at bresst-height (m)

The corresponding set of equations fur predicting the green weight of the different components of trees is as follows.

$$\ln w_1 = - 0.5296 (\ln D)^2 \quad (17)$$
(0.0053) (Adj. R^2 = 0.9984)

$$\ln w_2 = - 0.5574 (\ln D)^2 \quad (18)$$
(0.0057) (Adj. R^3 = 0.9984)

$$\ln w_3 = 1.8526 \ln D \quad (19)$$
(0.0305) (Adj. R^2 = 0.9957)

$$\ln w_4 = 2.1340 \ln D \quad (20)$$
(0.0386) (Adj. R^2 = 0.9348)

where w_1 = Green weight of bole with bark (t)

w_2 = Green weight of bole without bark (t)

w_3 = Green Weight of branches (t)

w_4 = Green weight of phyllodes (t)

D as defined earlier

Scatter diagrams of the biomass components versus gbh are given in Figures 1 to 4 along with the graphs of the fitted equations.

Estimates of biomass obtained through allometric method for large block plantations are given in Table 8, for other type of plantations in Table 9 and for the combined set in Table 10. The estimates of

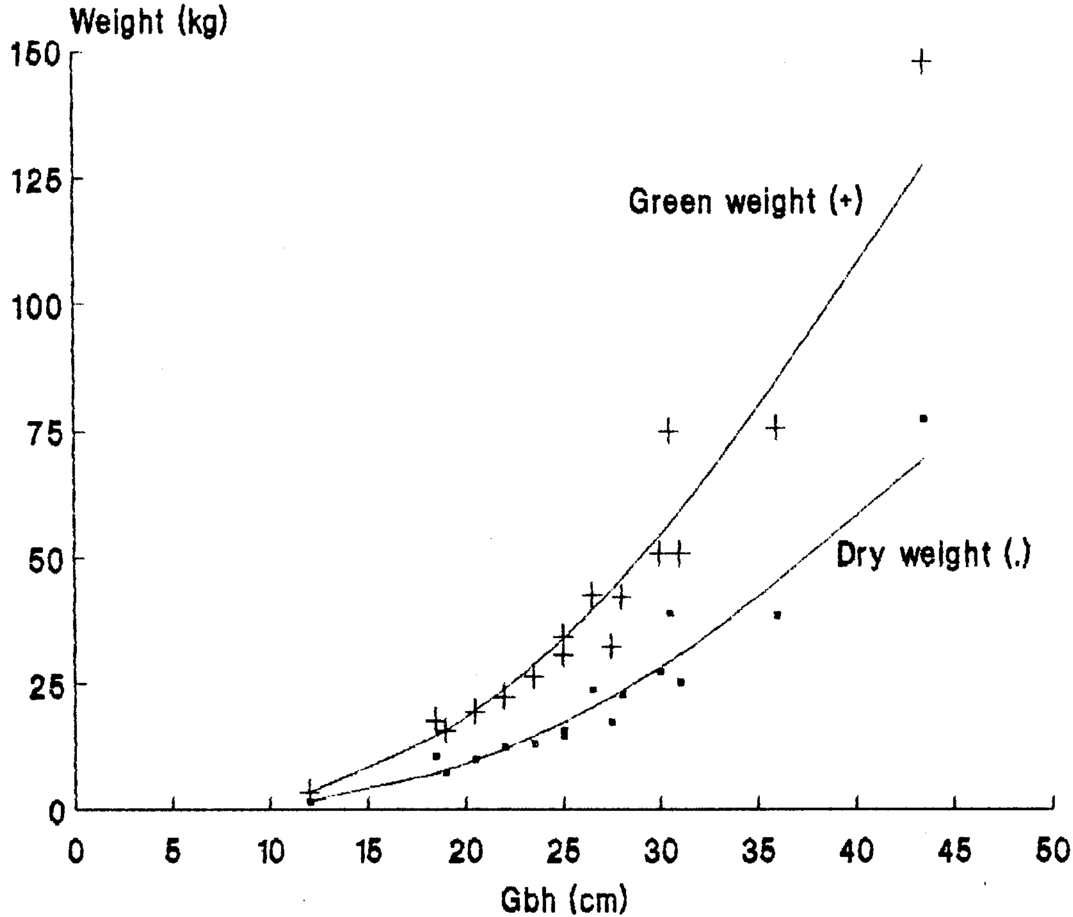

Figure 1. Relation between weight of bole with bark and gbh of *Acacia auriculiformis*

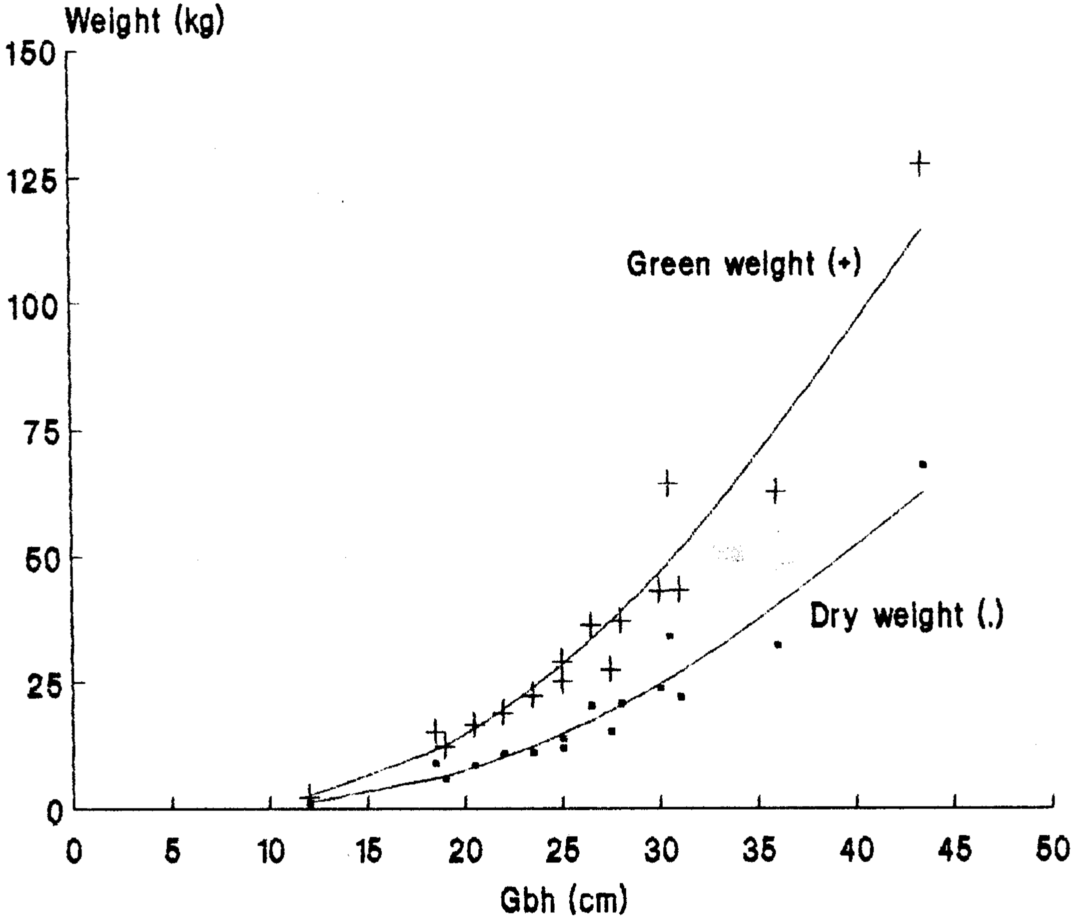

Figure 2. Relation between weight of bole without bark and gbh of *Acacia auriculiformis*

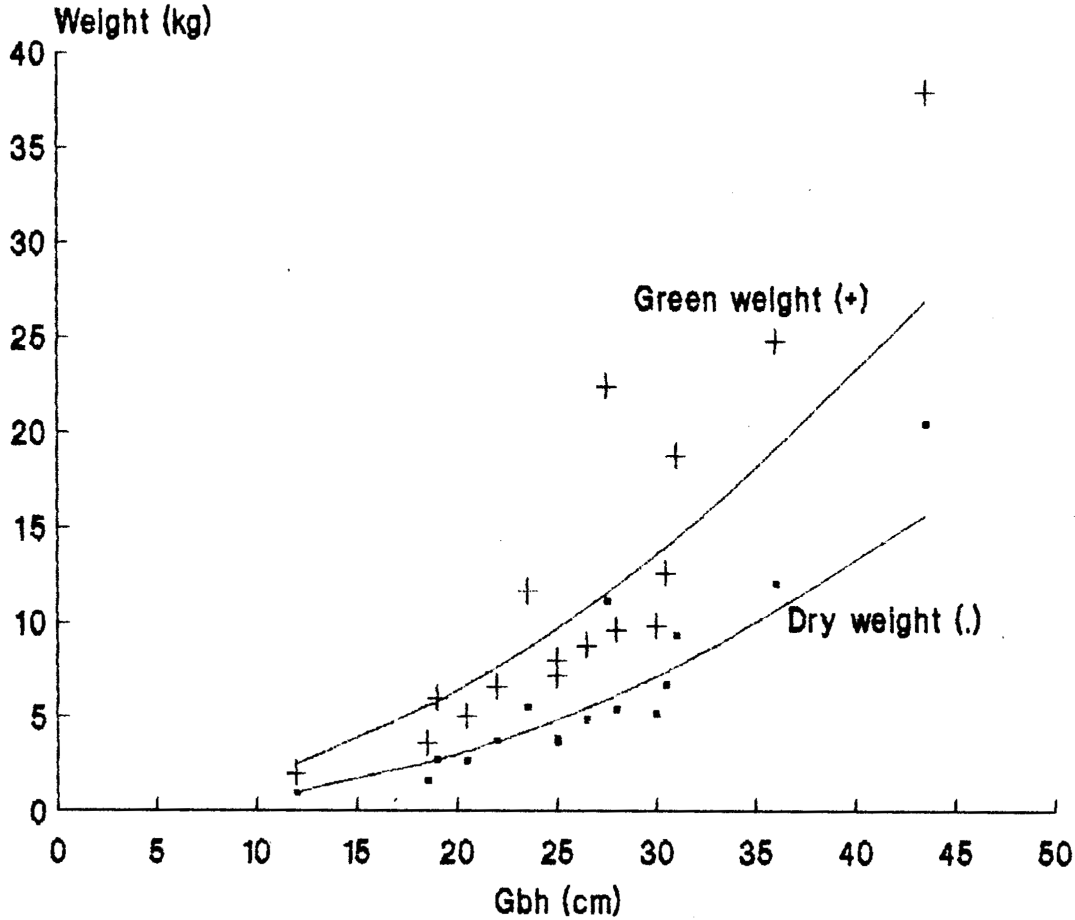

Figure 3. Relation between weight of branches and gbh of *Acacia auriculiformis*

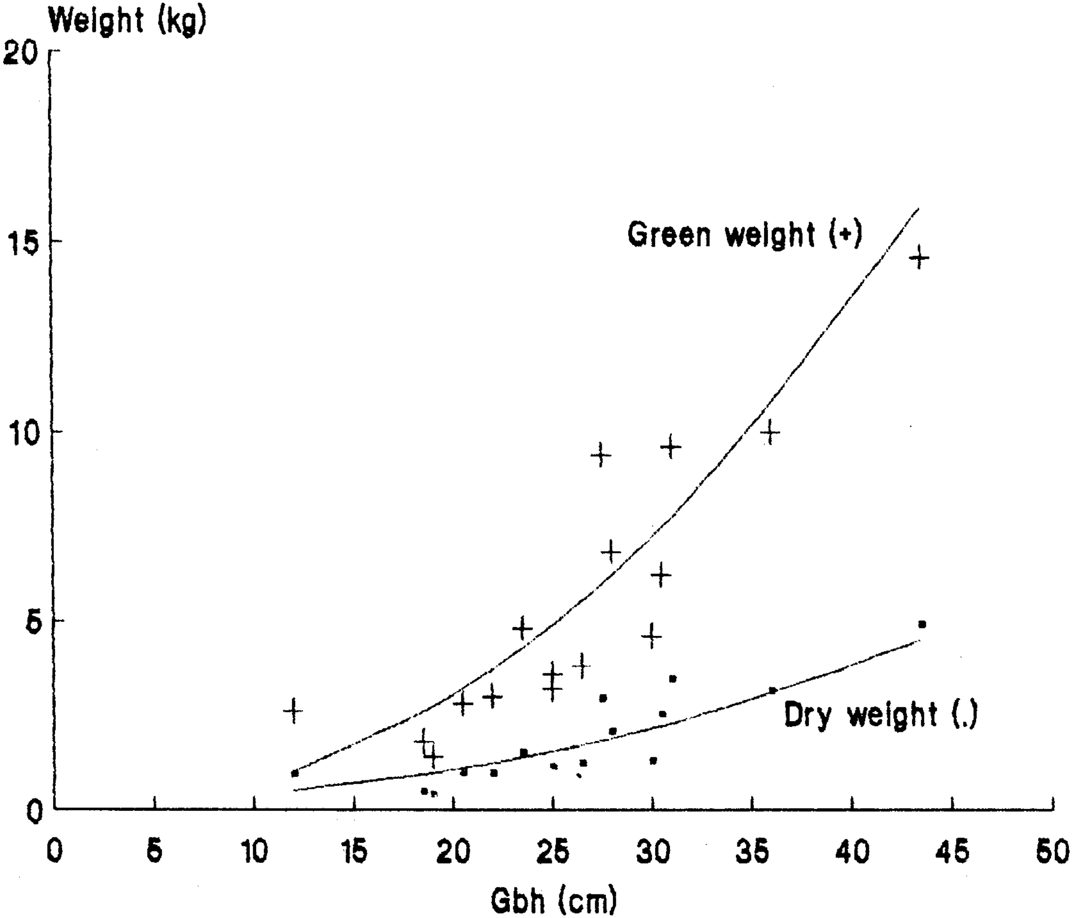

Figure 4. Relation between weight of phyllodes and gbh of *Acacia auriculiformis*

Table 8. Biomass of various tree components of Acacia *auriculiformis* through allometric method (large block plantations) (Average for the State)

Characteristic	Details			
Age (yr)	3.5	4.5	5.5	6.5
Number of plots	28	71	40	18
Crop diameter (cm)	4.5	6.0	7.4	9.0
Dry weight (t ha^{-1})				
Bole	11.321	26.139	36.340	69.279
Bark	2.131	4.490	5.600	9.360
Branches	4.939	9.651	11.632	19.838
Phyllodes	2.035	3.485	3.816	6.143
Total	20.426	43.765	57.388	104.620
Dry weight (%)				
Bole	55.424	59.726	63.323	66.220
Bark	10.433	10.259	9.758	8.947
Branches	24.180	22.052	20.269	18.962
Phyllodes	9.963	7.963	6.650	
Total	100.000	100.000	100.000	100.000

Cont...

Table 8 cont...

Green weight ($t\ ha^{-1}$)				
Bole	21.511	49.705	68.685	128.984
Bark	5.154	10.426	12.326	19.191
Branches	10.874	20.157	23.001	37.028
Phyllodes	4.958	9.712	11.735	20.065
Total	42.497	90.000	115.747	205.268
Moisture content (%)				
Bole	90.010	90.155	89.007	86.181
Bark	141.858	132.205	120.107	105.032
Branches	120.166	109.859	97.739	276.377
Phyllodes	143.636	171.793	207.521	226.632
Total	108.053	105.544	101.692	95 203

Table 9. Biomass of various tree components of *Acacia auriculiformis* through allometric method(small block and strip plantations) (Average for the State)

Characteristic	Details			
Age (yr)	3.5	4.5	5.5	6.5
Number of plots	15	25	20	24
Crop diameter(cm)	6.4	7.4	8.5	8.5
Dry weight ($t\ ha^{-1}$)				
Bole	37.933	35.707	56.178	64.200
Bark	5.610	5.578	7.674	8.826
Branches	12.126	11.572	16.179	18.877
Phyllodes	4.083	3.813	5.008	5.941
Total	59.752	56.670	85.039	97.844
Dry weight (%)				
Bole	63.484	63.009	66.062	65.615
Bark	9.389	9.843	9.024	9.020
Branches	20.294	20. 420	19.025	19.293
Phyllodes	6.833	6.728	5.889	6.072
	100.000	100.000	100.000	100.000

Cont...

Green weight (t ha^{-1})				
Bole	71.026	67.580	104.748	119.429
Bark	12.125	12.369	15.840	18.339
Branches	23.864	23.002	30.294	35.568
Phyllodes	12.237	11.671	16.361	19.086
Total	119.252	114.622	167.243	192.422
Moisture content (%)				
Bole	87.241	89.268	86.457	86.026
Bark	116.132	121.746	106.411	107.784
Branches	96.800	98.773	87.243	88.420
Phyllodes	199.106	206.084	226.697	221.259
Total.	99.578	102.262	96.666	96.669

Table 10. Biomass of various tree components of *Acacia auriculiformis* through allometric method (large block, small block and strip plantations)

(Average for the State)

Characteristics	Details			
Age (yr)	3.5	4.5	5.5	6.5
Number of plots	43	96	60	42
Crop diameter (cm)	5.2	6.3	7.9	8.7
Dry weight ($t\ ha^{-1}$)				
Bole	20.604	28.631	42.953	66.377
Bark	3.345	4.774	6.291	9.055
Branches	7.446	10.151	13.145	19.289
Phyllodes	2.749	3.571	4.213	6.027
Total	34. ?44	47.127	65.605	100.748
Dry weight (%)				
Bole	60.344	60. 753	64.489	65.884
Bark	9.797	10.130	9.445	8.988
Branches	21.808	21.539	19.740	19.146
Phyllodes	8.051		6.. 326	5.952
Total	100.000	100.000	100.000	100.000

Cont...

Green weight (t ha-1)				
Bole	38.784	54.360	80.706	123.524
Bark	7.586	10.932	13.498	18.704
Branches	15.406	20.898	25.432	36.194
Phyllodes	7.498	10.222	13.277	19.506
Total	69.274	96.412	132.913	197.928
Moisture content (%)				
Bole	88.235	89.864	87.894	86.095
Bark	126.786	128.990	114.560	106.560
Branches	106.903	105.87 1	93.429	87.641
Phyllodes	172.754	186.250	215.144	223.644
Total	102.882	104.579	102.557	96.458

biomass obtained through allometric method (Table 10) are comparable with those obtained through mean tree method (Table 4). However the former has shown slightly lower value as they are based on a larger set of stands scattered over a wide area. The extent of this variation clearer from Table 11 where the range of estimates of biomass is shown. There are stands with expected biomass as low as 19.177 t ha^{-1} and stands with as high as 205.202 t ha^{-1} at 6.5 years of age. A comparison of the performance of large block and other types of plantations requires adjustment for the variation in the number of seedlings planted initially. This is achieved through the analysis of covariance reported in Table 12. After the adjustment, large block and other type of plantations seem to be different with respect to the biomass. The interaction between type of plantation and age is also significant indicating that the difference between the levels of type of plantetion did not remain the same over years. The small block and strip. type of plantations fared better or were as good as large block plantations over the different age groups considered. Corresponding effects are found with respect to crop diameter. However there was no significant difference between the types of plantations with respect to stocking indicsting that the differences in the growth were not traceable to the differences in the survival rates. Large block plantstions seem to have a poorer environment probably due to the degraded condition of the land where they are raised.

Table 11. Range of bimass estimates for the different species obtained through allometric method

	Biomass (t ha^{-1})			
Acacia auriculiformis				
Age	Dry weight		Green weight	
(yr)	Min.	Max.	Min.	Max.
3.5	0.841	160.642	1.682	311.247
4.5	8.686	106. 171	18.254	212.697
5.5	4.045	197. 693	8. 171	381. 883
6.5	19.171	205.202	39.784	382.342
Casuarina equisetifolia				
3.5	0.100	82.294	0.272	157.057
4.5	3.739	163.401	8.348	293.395
5.5	2.488	206. 166	5.664	375.378
6.5	4.244	123.491	8.935	215.626

Table 12. Analysis of covariance on different stand attributes of *Acacia auriculiformis* (square root scale)

Source	df	F value		
		Stocking	Crop diameter	Biomass
		$no.^{0.5} ha^{-1}$	$cm^{0.5}$	$t^{0.5} ha^{-1}$
Initial stocking	1	3.3 (ns)	0.4 (ns)	2.7 (ns)
Type of plantation	1	2.4 (ns)	37.3 *	18.8 *
Age	3	3.1 *	48.5 *	37.7 *
Type of plantation x Age	3	1.2 (ns)	8.1 *	5.5 *
Residual		-	-	-

*Significant at P = 0.05, ns = nonsignificant

Biomass estimates in general increased with age. Bole with bark constituted major portion of biomass and its content showed slight increase over years. The overall moisture content decreased with increase in age in the case of large block plantation. The trend is not very clear in the case of small block and strip plantation. For the combined set of plantations it decreased from 102.882 percent at 3.5 years to 96.458 per cent at 6.5 years. The phyllodes had the highest moisture content and this showed an increasing trend with age. Bark ranked second in moisture content which showed a decreasing trend with age. Branches showed an erratic behaviour over different ages with respect to moisture content. The pattern showed by the bole was more or less stable over ages. Exceptions from the general trend are due to the fact that predictions of dry weight and green weight are bssically made using measurements of dbh of trees. Moisture content which depends on these predicted values will vary as per the variation in dbh of trees for a given age.

3.2.2.2. *Casuarina equisetifolia*

The equstions fitted for predicting the biomass of the different components of the tree are reported below. The mean square error (MSE) obtained are given in Appendix 1.

$$\ln W1 = 3.1268 + 2.8043 \ln D \quad (21)$$
$$(0.3789) \; (0.1559) \quad (Adj.R^2=0.9499)$$

$$\ln W2 = 3.0319 + 2.8010 \ln D \quad (22)$$
$$(0.3796) \; (0.1562) \quad (Adj.R^2=0.9497)$$

$$\ln W3 = 2.1214 \ln D \quad (23)$$
$$(0.0287) \qquad (\text{Adj. } R^2 = 0.9967)$$

$$\ln W4 = 2.5513 \ln D \quad (24)$$
$$(0.0474) \qquad (\text{Adj. } R^2 = 0.9938)$$

where w1 = Dry weight of bole with bark (t)

W2 = Dry weight of bole without bark (t)

W3 = Dry weight of branches (t)

W4 = Dry weight of needles (t)

D = Diameter at breast-height (m)

The corresponding equations for green weight are given below.

$$\ln W1 = 3.3263 + 2.6454 \ln D \quad (25)$$
$$(0.2811) \quad (0.1166) \qquad (\text{Adj. } R^2 = 0.9661)$$

$$\ln W2 = 3.2767 + 2.6713 \ln D \quad (26)$$
$$(0.2852) \quad (0.1183) \qquad (\text{Adj. } R^2 = 0.9658)$$

$$\ln W3 = 1.8803 \ln D \quad (27)$$
$$(0.0253) \qquad (\text{Adj. } R^2 = 0.9966)$$

$$\ln W4 = 2.1663 \ln D \quad (28)$$
$$(0.0480) \qquad (\text{Adj. } R^2 = 0.9908)$$

where W1 = Green weight of bole with bark (t)

W2 = Green weight of bole without bark (t)

W3 = Green weight of branches (t)

W4 = Green weight of needles (t)

D as defined earlier

Scatter diagrams of the biomass components *versus* gbh are given in 5 to 8 along with the graphs of the fitted equations.

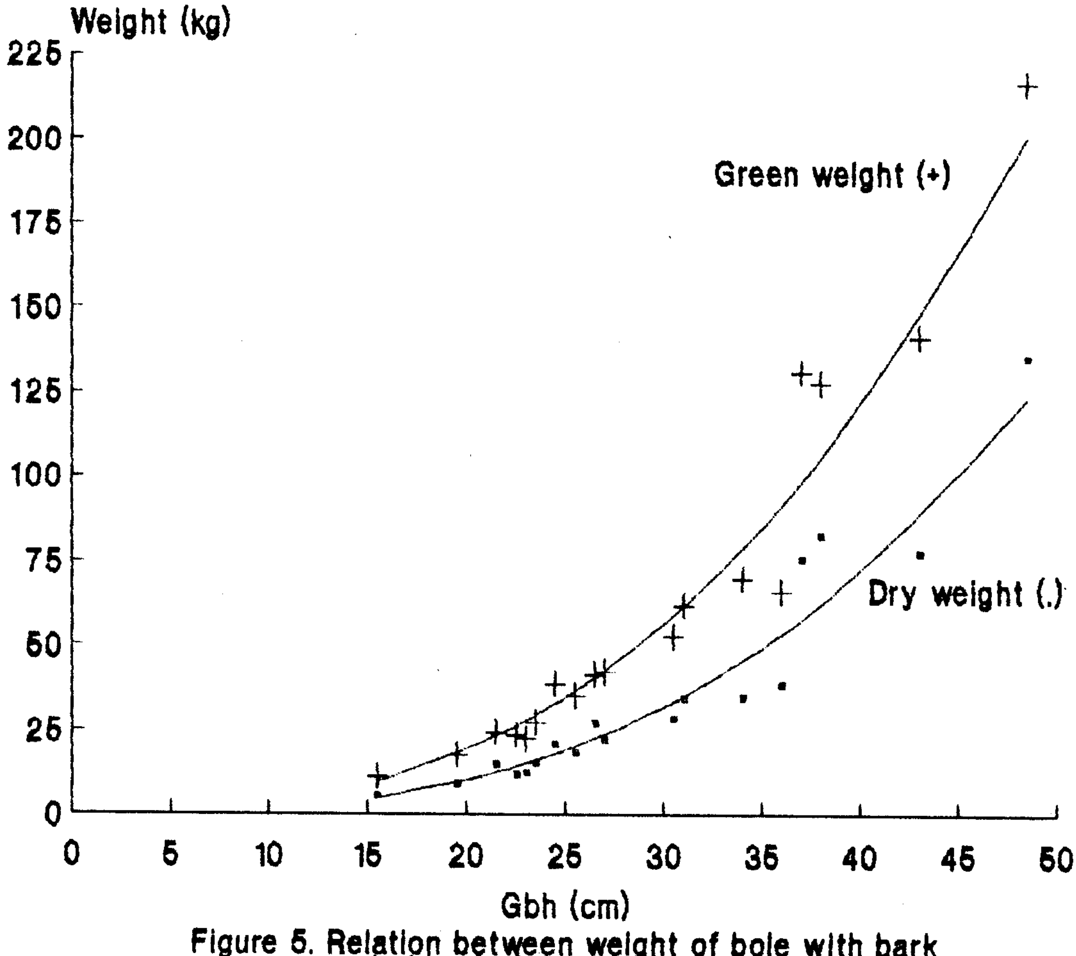

Figure 5. Relation between weight of bole with bark and gbh of *Casuarina equisetifolia*

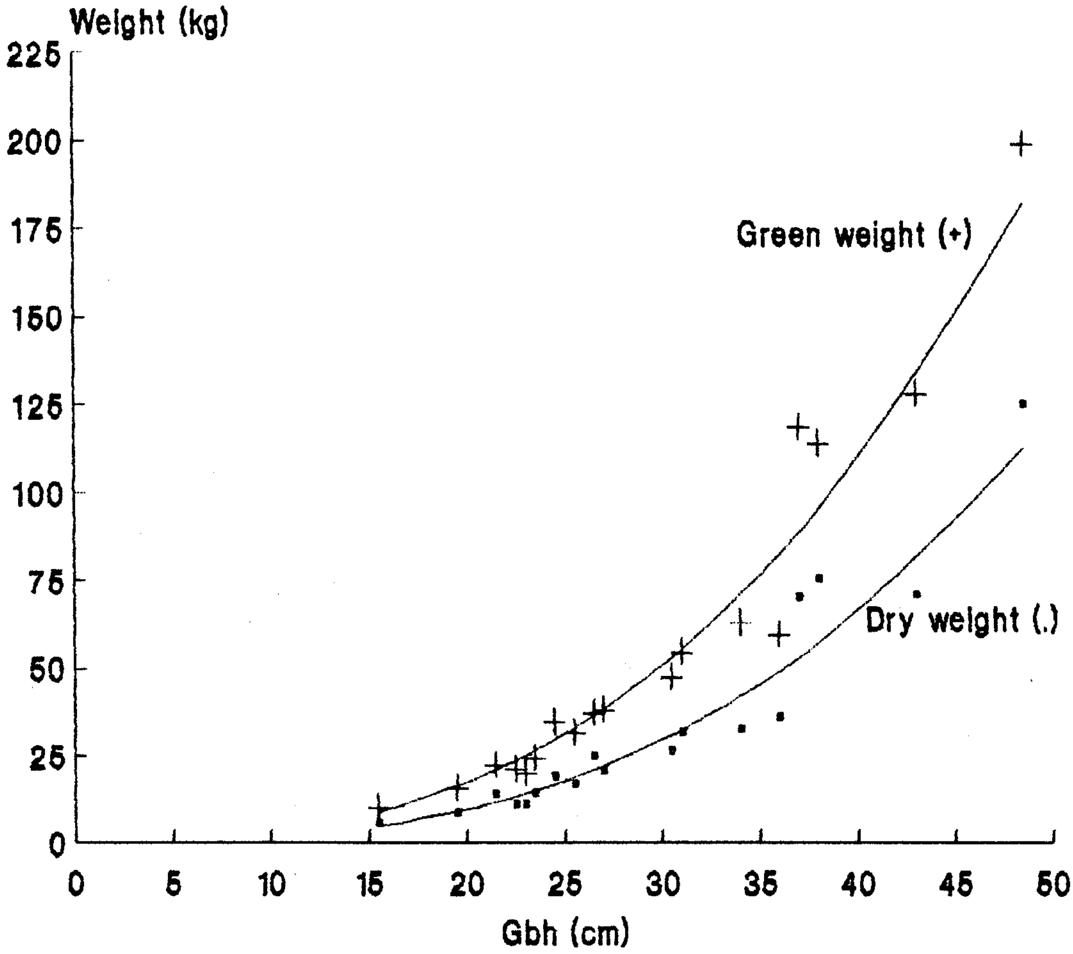

Figure 6. Relation between weight of bole without bark and gbh of *Casuarina equisetifolia*

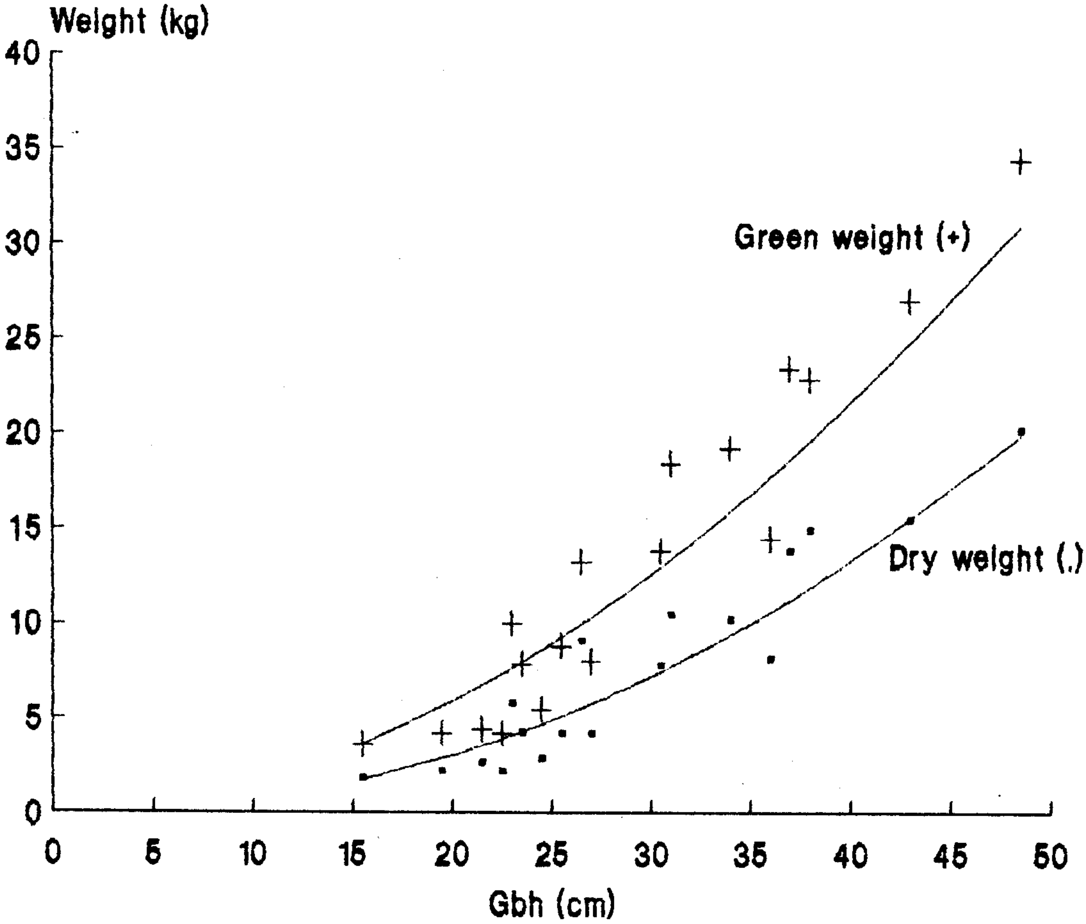

Figure 7. Relation between weight of branches and gbh of *Casuarina equisetifolia*

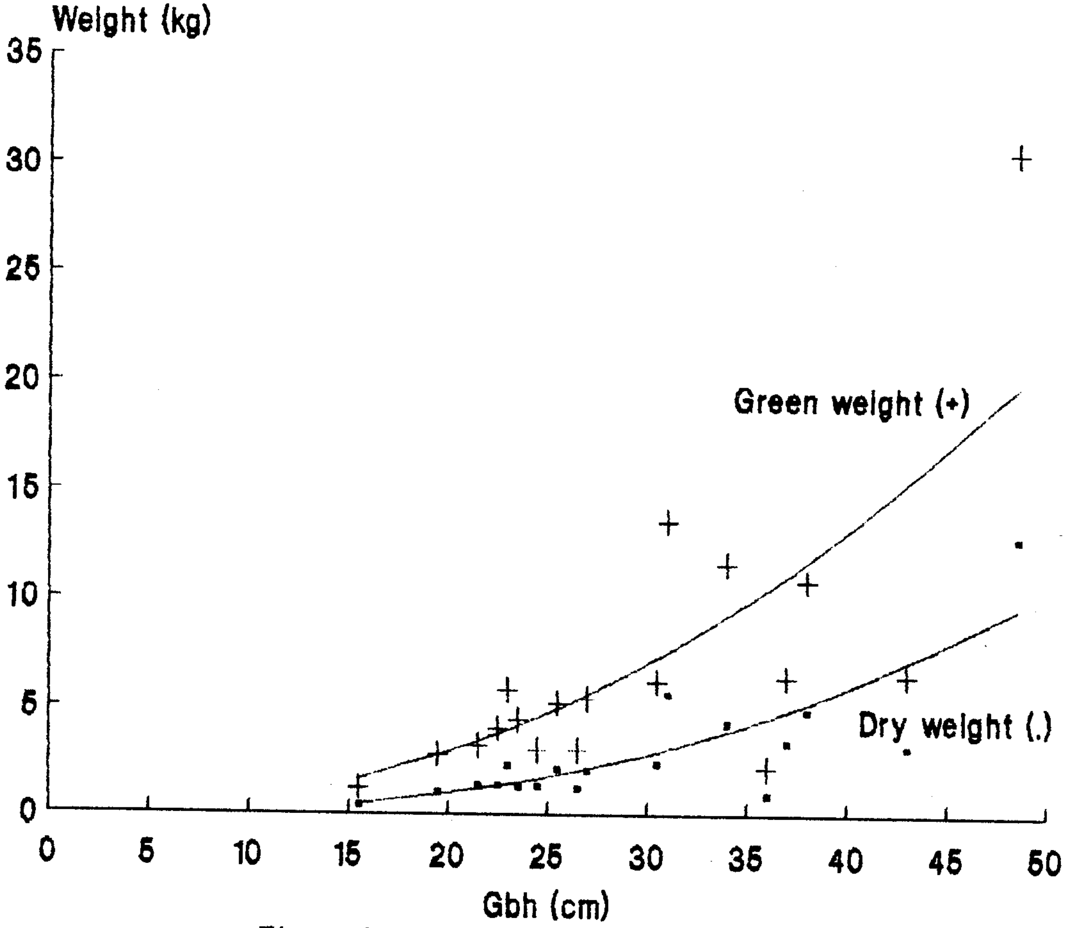

Figure 8. Relation between weight of needles and gbh of *Casuarina equisetifolia*

Estimates of biomass obtained through allometric method are given in Tables 13, 14 and 15. Separation as of large block and other types of plantations was not very effective because of the smaller sample size. The total biomass as seen from Table 15 is nearly half of that reported through mean tree method. This is because as mentioned earlier, the sample plots have come from. widely different regions as against selected stands in the case of mean tree method. The percentage breakup of the different components has however not changed much. The total biomass is found to increase with the age reaching a plateau around 7 years.

Analysis of covariance showed significant effects for the sources type of plantation, age group and their interaction, with respect to the total biomass and crop diameter (Table 16). Like in the case of *Acacia auriculiformis* strips and small block plantations were fcund to be better than large block plantations with respect to the size of trees and yield. Plantation types were found to be different with respect to stocking levels as well. Differences in the initial stocking were found to influence the current stocking level and crop diameter.

The overall moisture content showed a decreasing trend with increasing age. For the combined set of plantations it decressed from 93.939 per cent at 3.5 years to 82.223 per cent at 6.5 years. Needles

Table 13. Biomass of various tree components of *Casuarina equisetifolia* through allmetric method (large block plantations) (Average for the State)

Characteristic	Details			
Age (yr)	3.5	4.5	5.5	6.5
Number of plots	5	9	14	4
Crop diameter (cm)	2.6	4.3	3.0	5.0
Dry weight (t ha^{-1})				
Bole	5.007	13.448	7.661	28.957
Bark	0.439	1.205	0.681	2.611
Branches	2.488	4.656	3.164	8.970
Needles	0.620	1.454	0.884	3.013
Total	8.554	20.763	12.390	43.551
Dry weight (%)				
Bole	58.534	64.769	61.832	66.490
Bark	5.132	5.804	5.496	5.995
Branches	29.086	22.424	25.537	20.597
Needles	7.248	7.003	7.135	6.918
Total	100.000	100.000	100.000	100.000

Cont...

Table 13 cont...

Green weight (t ha-1)				
Bole	9.833	24.590	14.496	51.924
Bark	1.429	3.200	1.993	6.528
Branches	5.672	9.393	6. 796	17.317
Needles	2.318	4.441	2.903	8.624
Total	19.252	41.624	26.268	84.393
Moisture content (%)				
Bole	95.385	82.852	89.218	79.314
Bark	225.513	165.560	192.658	150.010
Branches	127.974	101.740	114.791	93.055
Needles	273.873	205.433	237.443	185.226
Total	125.054	100.472	112.010	

Table 14. Biomass of various tree components of *Casusrina equisetifolia* through allometric method (strip and small block plantations) (Average for the State)

Characteristic	Details			
Age (yr)	3.5	4.5	5.5	6.5
Number of plots	20	20	15	11
Crop diameter (cm)	5.4	6.3	7.5	7.9
Dry weight (t ha^{-1})				
Bole	22.633	37.337	67.340	42.579
Bark	2.045	3.382	6.144	3.899
Branches	6.800	10.657	17.090	10.133
Needles	2.331	3.775	6.512	4.024
Total	33.809	55.151	97.086	60.635
Dry weight (%)				
Bole	66.943	67.700	69.361	70.222
Bark	6.049	6.132	6.328	5.430
Branches	20.113	19.323	17.603	16.712
Needles	6.895	6.845	6.708	6.636
Total	100.000	100.000	100.000	100.000

Cont...

Table 14 cont...

Green weight (t ha-1)				
Bole	40.370	65.967	116.248	72.637
Bark	5.029	8.079	13.642	8.330
Branches	12.952	19.911	30.703	17.781
Needles	6.552	10.304	16.647	9.913
Total	64.903	104.261	177.240	108.661
Moisture content (%)				
Bole	78.368	76.680	72.628	70.593
Bark	145.917	138.882	122.038	113.645
Branches	90.471	86.835	79.655	75.476
Needles	181.081	172.954	155.636	145.347
Total	91.970	89.045	82.560	79.205

Table 15. Biomass of various tree components of *Casuarina equisetifolia* through allometric method (large block, small block and strip plantations)

(Average for the State)

Characteristic	Details			
Age (yr)	3.5	4.5	5.5	6.5
Number of plots	25	29	29	15
Crop diameter (cm)	4.8	5.8	5.6	7.0
Dry weight (t ha-1)				
Bole	19.108	29.923	38.529	38.946
Bark	1.724	2.707	3.506	3.556
Branches	5.938	3.795	10.367	9.823
Needles	1.988	3.054	3.795	3.754
Total	28.758	44.479	56.197	56.079
Dry weight (%)				
Bole	66.444	67.275	69.561	69.449
Bark	5.995	6.086	5.239	6.341
Branches	20.648	19.773	18.447	17.516
Needles	6.913	6.866	6.753	5.694
Total	100.000	100.000	100.000	100.000

Cont...

Green weight (t ha^{-1})				
Bole	34.263	53.126	67.127	67.114
Bark	4.309	6.565	8.019	7.849
Branches	11.496	16.647	19.161	17.657
Needles	5.705	8.485	10.051	9.569
Total	55.773	84.823	104.358	102.189
Moisture content (%)				
Bole	79.312	77.542	74.225	72.326
Bark	149.942	142.519	128.722	120.726
Branches	93.601	89.278	54.827	79.752
Needles	186.972	177.832	164.848	154.901
Total	93.939	90.703	85.700	82.223

Table 16. Analysis of covariance on different stand attributes of *Casuarina equisetifolia* (square root scale)

Source	df	F value		
		Stocking	Crop diameter	Biomass
		$no.^{0.5} ha^{-1}$	$cm^{0.5}$	$t^{0.5} ha^{-1}$
Initial stocking	1	26.1 *	4.9 *	0.6 (ns)
Type of plantation	1	8.8 *	50.9 *	34.8 *
Age	3	1.8 (ns)	6.8 *	5.7 *
Type of plantation x Age	3	1.7 (ns)	4.3 *	4.3 *
Residual	89	-	-	-

*Significant at P = 0.05, ns =

carried the highest level of moisture which also showed decreasing trend with increase in age. Bark ranked second in moisture content followed by branches and bole. These three components also showed decreasing levels of moisture with increasing age of trees though rates of decrease were different. Certain exceptions from the general trends could be seen in specific cases which is attributable to the variation in dbh of trees belonging to a particular age group.

3.2.3, Mean tree method versus allometric method

The estimates of biomass obtained through the two methods for plot: selected for applying mean tree method are given in Table 17 and 18. The estimates given by the two methods in genera? are comparable though in certain cases the deviations are more Both positive and negative deviations appear and such differences are expected to cancel out over a large number of plots. Sometimes mean tree method may give slightly lower or higher estimates depending on whether the tree selected for felling had a dbh lower or higher to the mean diameter of the stand.

Mean tree method is one which is applied in restrictive cases like permanent sample plots or experimental plots where the number of plots is few it is inapplicable in the case of a survey to find the overall performance of a species over a vast area based on large number of plots. For instance, to develop estimates using mean tree method from

Table 17. Comparison of estimates obtained through mean tree method and allometric method for *Acacia auriculiformis.*

Location	Characteristic	Biomass ($t\ ha^{-1}$) Mean tree method (E1)	Allometric method (E2)	Deviation per cent $\frac{(E2-E1)x100}{E2}$
Wsdakka-nchery	Dry weight of bole	43.140	44.344	2.7
	Dry weight of bark	4.799	6.238	23.1
	Dry weight of branches	11.216	12.899	13.0
	Dry weight of phyllodes	4.303	3.994	-7.7
	Total dry weight	63.458	67.475	6.0
	Green weight of bole	77.302	83.169	7.1
	Green weight of bark	11.026	13.047	15.5
	Green weight of branches	19.999	24.406	18.1
	Green weight of phyllodes	14.166	13.039	-8.6
	Total green weight	122.493	133.662	8.4
Cheppil-skkode	Dry weight of bole	32.252	32.943	2.1
	Dry weight of bark	5.118	5.548	7.8
	Dry weight of branches	9.787	11.639	15.9
	Dry weight of phyllodes	3.805	4.053	6.1
	Total dry weight	50.962	54.183	5.9
	Green weight of bole	62.326	62.714	0.6
	Green weight of bark	10.840	12.751	15.0
	Green weight of branches	18.565	23.947	22.1
	Green weight of phyllodes	10.452	11.717	10.8
	Total green weight	102.283	111.130	8.0

Cont...

	Dry weight of bole	44.964	44.485	−1.1
kkunnu	Dry weight of bark	6.402	7.255	11.8
	Dry weight of branches	15.134	15.054	−0.5
	Dry weight of phyllodes	4.015	5.074	20.9
	Total dry weight	70.515	71.868	1.9
	Green weight of bole	77.200	84.536	8.7
	Green weight of bark	14.382	16.418	12.4
	Green weight of branches	26.984	30.466	11.4
	Green weight of phyllodes	12.265	15.169	19.1
	Total green weight	130.831	146.589	10.7
Chetti-kkulam	Dry weight of bole	79.412	71.563	−11.0
	Dry weight of bark	13.285	10.323	−28.7
	Dry weight of branches	19.005	21.371	11.1
	Dry weight of phyllodes	4.788	6.728	28.8
	Total dry weight	116.490	109.996	−5.9
	Green weight of bole	142.522	134.507	−6.0
	Green weight of bark	24.874	21.934	−13.4
	Green weight of branches	34.418	40.972	
	Green weight of phyllodes	14.862	21.596	31.2
	Total green weight	216.676	219.009	1.1

Table 18. Comparison of estimates obtained through mean tree method and allometric method for *Casuarina equisetifolia.*

Location	Characteristic	Biomass ($t\ ha^{-1}$) Mean tree method (E1)	Allometric method (E2)	Deviation per cent $\frac{(E2-EI)x100}{E2}$
Kazhimbram	Dry weight of bole	104.475	132.959	21.4
	Dry weight of bark	9.240	11.780	21.6
	Dry weight of branches	32.019	32.912	2.7
	Dry weight of needles	9.683	12.726	23.9
	Total dry weight	155.417	190.397	18.4
	Green weight of bole	102.412	228.084	20.0
	Green weight of bark	22.494	26.551	15.3
	Green weight of branches	58.760	58.611	-0.3
	Green weight of needles	33.147	32.105	-3.2
	Total green weight	296.813	345.351	14.1
Kothakulam	Dry weight of bole	92.970	129.162	28.0
	Dry weight of bark	8.415	11.449	26.5
	Dry weight of branches	18.518	32.954	43.8
	Dry weight cf needles	11.654	12.474	6.6
	Total dry weight	131.557	186.040	29.3
	Green weight of bole	179.427	222.544	19.4
	Green weight of bark	19.473	26.150	25.5
	Green weight of branches	35.700	59.536	40.0
	Green weight of needles	34.000	32.071	-6.0
	Total green weight	268.600	340.300	21.1

the 241 plots used for *Acacia auriculiformis* and 98 plots used for *Casuarina equisetifolia* here, that many trees will be have to be felled. In contrast the allometric method requires only dbh measurement from the plots provided an unbiased prediction model is available to predict the characteristic of interest. Validation of both the methods will be possible only when actuals are available through felling of all trees in a plot.

3.3. Management

3.3.1. General features

Planting under the World Bank Scheme in Kerala seems to have been initiated in 1983 with a small block plantation of 0.09 ha (Table 19). Over the years the movement caught up and currently around 2500 to 3000 ha are brought under plantations under the programme. The total extent covered till 1990-91 bythe Social Forestry Wing alone is 15186.62 ha a major portion of which is of large block plantaticns. The total area put under plantation inclusive of those planted by the Territorial Divisions availing funds from the Social Forestry Wing comes to 20,408 ha. The distinction made by the Forest Department as large block and small block is not strictly based on the size cf the plantation as seen from Table 20. The size-class distribution of the plantations shows that there is considerable overlap between large and small blcck plantations. Large block plantations are in general those raised in Reserve Forests. There are 1024 plantations in total

Table 19. Area under different types of plantations raised in different years under the World Bank Scheme in Kerala by the Social Forestry Wing.*

Year of planting	Area (ha) Large block	Small block	Strip	Total
1983	0.00	0.09	0.00	0.09
1984	88.20	55.58	0.00	144.78
1985	1427.53	136.80	75.85	1640.19
1985	2422.55	208.31	54.61	2685.47
1987	2138.80	310.24	40.88	2489.92
1988	2889.80	278.08	85.22	3253.10
1989	1949.14	391.95	249.25	2590.34
1990	2160.25	194.99	27.49	2382.73
Total	13076.27	1577.04	533.31	15186.62

* Plantations raised by the Territorial divisions availing funds from World Bank Scheme have not been included. The total area of plantations including the ones raised by Territorial divisions works out to 20,408 ha.

Table 20. Size class distribution of the plantations raised under the World Bank Scheme in Kerala

Size class (ha)	Frequency Large block	Small block	Strip	Total	Percentage
0 – 1	8	163	67	238	23.24
1 – 2	7	91	19	117	11.42
2 – 3	8	51	20	79	7.71
3 – 4	8	33	9	50	4.88
4 – 5	8	11	7	26	2.53
5 - 15	122	60	23	205	20.01
15 - 25	84	15	3	102	9.96
25 - 35	51	5	3	59	5.76
35 - 45	38	2	1	41	4.00
45 - 55	41	1	0	42	4.10
55 - 65	25	1	0	26	2.53
65 - 75	9	0	0	9	0.87
75 - 85	8	0	0	8	0.18
85 - 95	3	1	0	4	0.39
> 95	18	0	0	18	1.75
Total	438	434	152	1024	100.00

identified as distinct units with individual names. Nearly 80 per cent of these units have area less than 25 ha individually.

The species composition of the above plantations is indicated in Appendix 2. Though many are shown, as mixed plantations, planting is usually done in separate patches within a 'mixed' plantation. Acacia tops the list with 3185 ha in pure plantations. Though *Acacia auriculiformis* is the most common species planted, other species of acacia are also found in these plantations. The other more important species are *Casuarina equisetifolia, Eucalyptus grandis and Grevillea robusta*. A host of other species are also raised which are used for timber, fruits and other products. A complete list of the species is given in Table 21. There are as many as 70 species planted under the World Bank Bank Schemd. Out of this only a mfew have been raised as plantations.

Area coverage of plantations under the World Bank Scheme in different Social Forestry Divisions in Kerala is reported in Table 22. Maximum area is in Idukki (4593 ha) followed by Trichur (2159 ha). The Divisions differ also with respect to the species planted as seen from Table 23. *Acacia auriculiformis* is planted in almost all districts. *Casuarina equisetifolia* is grown extensively in districts having long coastal lines. Eucalypt plantations are predominant in Southern districts especially in high ranges and conspicuously absent in

Table 21. List of species raised in Social Forestry plantations raised under the World Bank Scheme in Kerala

Sl.no.	Common name		Botanical name
1.	Acacia	*	*Acacia auriculiformis*
2.	Acacia	t	*Acacia dealbata*
3.	Acacia	*	*Acacia ferruginea*
4.	Acacia	*	*Acacia leucophloea*
5.	Acacia	*	*Acacia mangium*
6.	Acacia	*	*Acacia mearnsii*
7.	Acacia	*	*Acacia nilotica*
8.	Kurangatti	*	*Acrocarpus fraxinifolius*
9.	Matti	*	*Ailanthus triphysa*
10.	Albizia	*	*Albizia falcataria*
11.	Vaka	*	*Albizia lebbeck*
12.	Cashew	*	*Anacardium occidentale*
13.	Jack	*	*Artocarpus heterophyllus*
14.	Anjily	*	*Artocarpus hirsutus*
15.	Neem	*	*Azadirachta indica*
16.	Bamboo		*Bambusa bambos*
17.	Mandararn		*Bauhinia racemosa*
18.	Bauhinia		*Bauhinia spp.*
19.	Poola(Elavu)	*	*Bombax ceibe*
20.	Kulamavu		*Buchanania axillaris*
21.	Cane	*	*Calamus spp.*
22.	Bottle brush		*callistemon citrinus*
23.	Kanikonna		*cassia fistula*
24.	Yellow cassia		*Cassia siamea*
25.	Casuarina	*	*Casuarina equisetifolia*
26.	Neermathalam		*Crateva magna*
27.	Veeti(Rose wood)	*	*Dalbergia latifolia*
28.	Sissu	*	*Dalbergia sissoo*
29.	Delonix		*Delonix regia*
30.	Beedi leaf		*Disospyros melanoxylon*
31.	Nelli	*	*Emblica officinalis*
32.	Eucalyptus	*	*Eucalyptus globulus*
33.	Eucalyptus	*	*Eucalyptus grandis*
34.	Eucalyptus	*	*Eucalyptus tereticornis*
35.	Kanala	*	*Evodia lunu-ankenda*
36.	Kumbil	*	*Gmelina arborea*
37.	Silver oak	*	*Grevillea robusta*

38.	Pongu	*	*Hopea glabra*
39.	Jacaranda		*Jacaranda mimosifolia*
40.	Senteak	*	*Lagerstroemia microcarpa*
41.	Manimaruthu/ Pomaruthu		*Lagerstroemia reginae*
42.	Subabul	*	*Leucaena leucocephalla*
43.	Mango	*	*Mangifera indica*
44.	Elengi		*Mimusops elengi*
45.	Mulberry	*	*Morus alba*
46.	Pandanus		*Pandanus tectorius*
47.	Peltophorum		*Peltophorum pterocarpum*
48.	Pepper	*	*Piper nigrum*
49.	Ungu		*Pongamia pinnata*
50.	Pera		*Psidium guajava*
51.	Venga	*	*Pterocarpus marsupium*
52.	Red sandal	*	*Pterocarpus santalinus*
53.	Rain tree		*Samanea saman*
54.	Ashokam		*Saraca asoca*
55.	Spathodea		*Spathodea companulata*
56.	Mahogany	*	*Swietenia macrophylla*
57.	Njaval	*	*syzygium cumini*
58.	Tamarind	*	*Tamarindus indica*
59.	Tecoma		*Tecoma stans*
60.	Teak	*	*Tectona grandis*
61.	Thanni	*	*Terminalia bellirica*
62.	Badam		*Terminalia catappa*
63.	Thembavu		*Terminalia crenulata*
64.	Maruthu	*	*Terminalia paniculata*
65.	Mathagirivembu/ Chandanavembu	*	*Toona ciliata*
66.	Vellappine	*	*Vateria indica*
67.	Irul	*	*Xylia xylocarpa*
68.	Medicinal plants		

Note: * denotes species used more frequently in plantation scale.

Table 22. Area coverage of plantations raised under the World Bank Scheme in different Social Forestry Divisions in Kerala

Division	Area (ha)			
	Large block	Small block	Strip	Total
Kasaragod	917.79	114.19	4.80	1036.78
Cannanore	244.15	128.46	71.61	444.22
Calicut	113.79	72.09	2.89	188.77
Malappuram	78.18	92.41	5.08	175.67
Wynad	1417.67	23.80	0.00	1441.47
Trichur	2013.22	93.09	52.98	2159.29
Palghat	847.36	233.42	4.12	1084.90
Ernakulum	476.51	112.52	26. 90	615.93
Alleppey	0.00	32.12	48.76	80.88
Kottayam	535.73	51.40	1.63	76
Idukki	4370. 08	222.59	0.00	4592.67
Pathanamthitta	672.10	25.75	16.83	714.68
Quilon	959.05	80.06	284.69	1323.80
Trivandrum	430.64	295.14	13.02	738.80
Total	13076.27	1577.04	533.31	15186.62

Table 23. Major species combinations planted in different Social Forestry Divisions in Kerala under the World Bank Scheme

Division	Major species combinations	Area (ha)	Area (%)*
Trivandrum	Acacia,Eucalyptus	132.42	
	Acacia,Casusrina,Silver oak	104.92	
	Misc.,Poomaruthu,Thanni,Thembavu	60.00	
	Poomaruthu,Thanni,Thembavu	58.70	
	Acacia,Anjily ,Casuarina	57.80	
	Acacia,Cashew	50.35	
	Acacia,Casuarina	34.50	
	Acacia,Eucalyptus,Mahogany,Misc.	31.11	
	Acacia,Misc.	23.85	
	Acacia,Anjily ,Cashew,Mahogany ,Thanni	22.72	78
Quilon	Anjily,Irul,Manimaruthu,Thanni	230.00	
	Eucalyptus	173.00	
	Acacia	101.10	
	Cashew,Casuarina,Mahogany	100.50	
	Acacia,Eucalyptus	88.81	
	Anjily,Misc.,Thanni	57.75	
	Acacia,Cashew,Mahogany	56.50	
	Misc.,Thanni	49.00	
	Anjily,Bamboo,Jack,Mahogany,Matti	48.50	
	Anjily,Mahogany,Misc.	45.00	
	Casuarina,Mahogany,Matti	40.00	
	Acacia,Eucalyptus,Silver oak	38.00	
	Casusrina,Pandanus	30.00	80
Pathanamthitta	Acacia,Mahogany	204.43	
	Acacia,Silver oak	97.94	
	Eucalyptus	94.48	
	Anjily,Mahogany,Matt	77.95	
	Anjily,Elavu,Mahogany,Matti,Thanni, Vellappine,venteak	75.00	76

* Percentage of area occupied by the major species combinations out of the area planted in the District

Idukki	Acacia,Silver oak	1041.91	
	Acacia,Chandanavembu,Silver oak	589.99	
	Acacia	519.60	
	Acacia,Kurangatti,Silver oak	297.62	
	Acacia,Eucalyptus	251.68	
	Acacia,Eucalyptus,Silver oak	232.17	
	Eucalyptus	215.33	
	Acacia,Casuarina,Eucalyptus,Silver oak	192.10	
	Acscia,Anjily,Mathagirivembu, Silver oak	150.00	76
Kottayam	A1bizia,Mahogsny,Matti ,Teak	134.00	
	Mahogany,Silver oak ,Venga	129.92	
	Kana1a,Kulamavu , Mulberry,Venga	101.99	
	Acacia	67.44	
	Jack,Kanala,Thembavu	64.36	85
Alleppey	Acacia,Casuarina	35.50	
	Acacia,Casuarina,Eucalyptus	15.50	
	Casuarins	4.52	
	Casuarina,Eucalyptus	4.40	
	Acacia,Casuarina,Mshogsny	4.35	79
Ernakulam	Acacia	283.32	
	Acacia,Eucalyptus,Mahogsny,Sissu	75.00	
	Acacia,Mahogany,Manimaruthu	63.36	
	Albizia,Bamboo,Silver oak,Vellappine	59.45	78
Trichur	Acacia	1412.03	
	Acacia,Mahogany	167.20	
	Casuarina	99.43	78
Pa1ghat	Acacia	174.55	
	Acacia,Neem,Tamarind	110.00	
	Acacia,Subsbul	106.15	
	Mahogany,Misc.,Silver oak	00	
	Acacia,Neem,Tamarind,Misc.	54.42	
	Eucalyptus	50.00	
	Acacia,Albizia,Cashew,Jack	50.00	
	Acacia,Silver oak	45.90	
	Acacia,Cashew,Misc.	34.31	
	Acacia,Misc.	30.22	
	Acacia,Beedileaf,Neem,Tamarind	30.00	
	Acacia ,Tamarind	29.50	

	Acacia, Jack ,Misc. ,Subabul	28.69	
	Acacia,Neem	26.80	
	Acacia,Ashokam,Delonix,Misc.,Neem	24.92	
	Acacia,Casuarina,Subabul	22.23	81
Malappuram	Acacia,Mahogsny	35.10	
	Casuarina	19.20	
	Karimaruthu,Manimaruthu	16.77	
	Cashew,Mahogany,Nelli,Tesk,Vaka,Venga	15.40	
	Acacia, Karimaruthu, Mahogany, Manimaruthu,Thanni	13.00	
	Acacia,Casuarina,Kumbil	9.22	
	Acacia,Casuarina,Mahogany	8.80	
	Acacia,Casuarina,Eucalyptus,Mahogany	8.79	
	Acacia,Casuarina	8.02	76
Calicut	Acacia	91.17	
	Acacia,Casuarina,Matti	26.47	
	Casuarina	21.18	
	Acacia,Cashew,Jack,Matti,Nelli	13.64	
	Pepper	13.60	89
Cannanore	Cssusrina	127.02	
	Mahogany,Silver oak	90.20	
	Acacia,Mahogany,Silver oak	67.60	
	Acscia	61.85	78
Kassragode	Acacia,Casuarina		
	Casuarina	269.72	96
Wynad	Silver oak	627.79	
	Acacia	458.16	75

Northern and Central districts. *Grevillea robusta* is found in Southern, Central and Northern parts of the State but is more frequent in Wynad and Idukki Districts. Miscellaneous species like poomaruthu, thanni, thembavu, anjily, cashew, mahogany and jack are more prevalent in Trivandrum and Quilon Districts. Neem and tamarind are more common in Palghat District.

There has also been a shift in the species chosen for planting over the years as seen from Table 24. In the initial years of the planting programme the stress was on *Acacia auriculiformis, Casuarina equisetifolia, Eucalyptus* spp. and *Grevillea robusta* . Over the years the choice of species shifted to a large variety of timber yielding and fruit bearing indigenous species.

3.3.2. Rotation

The different allometric relations established at the tree level for *Casuarina equisetifolia* are given below.

$$\ln h = -0.1906 \ln D - 5.1588 (\ln D)^{-1} \quad (29)$$

(0.0557) (0.3138) (Adj. R^2 = 0.9972)

$$\ln V = 1.9505 \ln D - 3.6137 (\ln D)^{-1} \quad (30)$$

(0.0543) (0.3060) (Adj. R^2 = 0.9982)

where h = Total height of tree (m)

V = Commercial volume of tree (m^3)

= Diameter at breast-height (m)

Table 24. Major species combinations planted in different years under the World Bank Scheme in Kerala

Year	Major species combinations	Area (ha)	Area (%)*
1983	Acacia,Casuarina,Peltophorum	0.09	100
1984	Eucalyptus	38.00	
	Casuarina	33.70	
	Acacia	29.20	
	Acacia,Casuarina,Matti	13.00	79
1985	Acacia	483.56	
	Acacia,Casuarina	263.25	
	Acacia, Eucalyptus	208.25	
	Acacia,Casuarina,Eucalyptus,Silver oak	186.70	
	Eucalyptus	90.01	75
1986	Acacia	1290.16	
	Acacia,Casuarina	464.11	
	Acacia,Silver oak	198.20	
	Acacia,Mahogany	132.14	
	Acacia,Eucalyptus,Silver oak	109.00	
	Acacia,Casuarina,Silver oak	104.92	82
1987	Acacia	800.65	
	Acacia,Silver oak	313.94	
	Casuarina	191.15	
	Acacia,Casuarina	143.38	
	Albizia,Mahogany,Matti,Teak	134.00	
	Acacia,Eucalyptus,Silver oak	123.17	
	Acacia, Eucalyptus	107.88	
	Mabogany,Silver oak	82.20	
	Acacia,Mahogany	81.59	79
1988	Acacia,Chandanavembu,Silver oak	507.12	
	Acacia	489.92	
	Acacia,Silver oak	306.00	
	Casuarina	192.40	
	Acacia,Anjily,Mathagirivembu,Silver oak	150.00	

* Percentage of area occupied by the major species combinations out of the area planted in the year

	Acacia,Chandanavembu,Misc.,Silver oak	130.48	
	Mahogany,Silver oak,Venga	129.92	
	Acacia,Mahogany	109.23	
	Silver oak	83.04	
	Acacia,Neem,Tamarind	83.00	
	Acacia,Eucalyptus,Mahogany,Sissu	75.00	
	Mahogany,Misc.,Silver oak	60.00	
	Acacia,Mahogany,Silver oak	57.50	
	Mahogany,Nelli,Rose wood,Thanni	56.30	
	Anjily,Mathagirivembu,Silver oak	56.00	
	Acacia,Neem,Tamarind,Misc.	54.42	
	Acacia,Albizia,Cashew,Jack	50.00	
	Acacia,Eucalyptus,Silver oak	38.00	
	Casuarina,Mahogsny,Silver oak	36.16	
	Acacia,Cashew,Misc.	34.31	82
1989	Acacia,Silver oak	576.06	
	Silver oak	280.47	
	Acacia,Kurangatti,Silver oak	197.62	
	Eucalyptus	173.00	
	Acacia,Mathagirivembu,Silver Oak	132.31	
	Cashew,Casuarina,Mahogany	125.62	
	Acacia,Albizia,Mahogany,Teak	86.19	
	Acacia,Mahogany	67.84	
	Jack,Kanala,Thembavu	64.36	
	Anjily,Bamboo,Jack,Mahogany,Matti	48.50	
	Acacia,Albizia,Kumbil,Mahogany,Thembavu	45.10	
	Anjily,Mahogany,Misc.	45.09	
	Casuarina,Mahogany,Matti	42.68	
	Acacia,Eucalyptus,Kurangatti,Silver oak	41.70	
	Acacia	41.55	
	Acacia,Cashew	36.65	
	Acacia,Anjily,Mahogany,Nelli	31.64	
	Acacia,Tamarind	29.59	
	Acacia,Neem,Tamarind	27.00	81
1999	Silver oak	290.13	
	Anjily,Irul,Manimaruthu,Thanni	230.00	
	Eucalyptus	194.30	
	Acacia,Subabul	106.15	
	Kurangatti,Silver oak	103.73	
	Kanala,Kulmavu,Mulberry,venga	101.99	
	Acacia,Kurangatti,Silver oak	100.00	
	Anjily,Mahogany,Matti	77.95	
	Acacia,Eucalyptus	76.00	

Anjily,Elavu,Mahogany,Matti,Thanni, Ve11appine ,Ventesk	75.00
Kurangatti,Silver oak,Thanni	68.67
Misc.,Poomaruthu,Thanni,Thembavu	60.00
Albizia,Bamboo,Silver oak,Vellappine	59.45
Poomaruthu ,Thanni ,Thembavu	58.70
Anjily,, Misc.,Thanni	57.75
Acacia	50.10
Misc.,Thanni	49.00
Casusrin a	46.33
Acacia,Chandanavembu,Kurangatti, Silver oak	43.50
Mahogany,Misc.,Nelli	43.00
Njava1,Silver oak	40.00
Mahogany,Matti,Nelli,Thanni,Thembavu	35.00
Acacia,Maruthu,Mathagirivembu	32. 00
Kumbil,Mahogany,Matti,Nelli,Thanni	31.60
Acacia,Misc.	30.22
Acscis,Jack,Misc.,Subabul	28.69
Casuarina,Mahogany,Nelli	26.50

The output of equation (30) is given in Table (25). Scatter diagram of volume against gbh is given in Figure 9.

The site index equations were the following

$$\ln H = 3.0132 - 1.9016 \quad A^{-1} \qquad (31)$$
$$(0.1010) \quad (0.4701) \qquad (\text{Adj. } R2 = 0.1178)$$

$$\ln S = \ln H + 1.9016 \quad (A^{-1} - A_0^{-1}) \qquad (32)$$

where H = Top height of the stand (m)

A = Stand age (years)

A_0= Base age taken as 8 years

S = Site index (m)

Equations (31) and (32) were used to arrive at the expected top height at different years under different site quality levels. Table 26 gives such an output. A graphical display of the contents of Table 26 is given in Figure 10. The site index ranges for the different site quality levels are indicated below.

Site quality	Site index (m)
I	28 - 22
II	22 - 16
III	16 - 10

The yield table function fitted was

$$\ln V = -11.6206 + 14.3439 \quad \ln X - 3.0283 \ (\ln X)^2 \qquad (33)$$
$$(0.8560) \quad (1.0302) \quad (0.3043) \qquad (\text{Adj. } R2 = 0.9291)$$

where V, X as defined earlier.

Table 25. Provisional tree volume table for *Casuarina equisetifolia*

Gbh (cm)	Height (m)	Volume (m^3)
15	9.3	0.008779
16	10.1	0.010215
17	10.3	0.011789
18	10.6	0.013514
19	10.8	0.015385
20	11.1	0.017415
21	11.4	0.019617
22	11.7	0.021985
23	12.0	0.024535
24	12.3	0.027272
25	12.6	0.030216
26	12.9	0.033357
27	13.2	0.036711
28	13.5	0.040301
29	13.9	0.044112
30	14.2	0.048167
31	14.6	0.052489
32	14.9	0.057061
33	15.3	0.061910
34	15.7	0.067061
35	16.1	0.072496
36	16.5	0.078243
37	16.9	0.084315
38	17.4	0.090746
39	17.3	0.097510
40	18.3	0.104643
41	18.3	0.112182
42	19.2	0.120099
43	19.7	0.128431
44	20.3	0.137226
45	20.8	0.145447
46	21.4	0.156138
47	21.9	0.166354
48	22.5	0.177051
49	23.1	0.133233
50	23.7	0.200070

Note: Use equations (29) and (30) for intermediate values with correction factor given in Appendix 1. The column 'height' gives the total height fcr the corresponding gbh and the column 'volume' for the corresponding gbh of trees

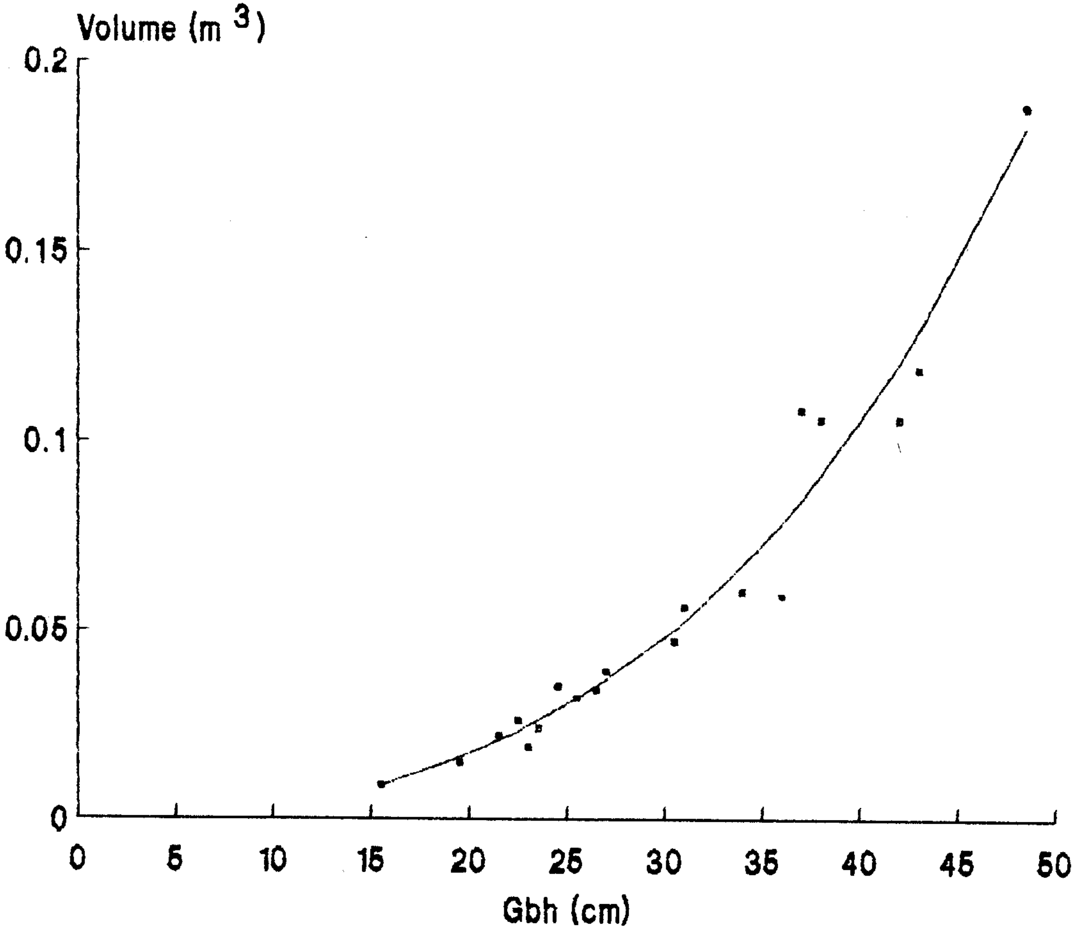

Figure 9. Relation between tree volume and gbh of *Casuarina equisetifolia*

Table 26. Top height for different age-classes of *Casuarina equisetifolia*

Site quality	Age (yr)	Top height (m)
I	3	16.82
	4	19.71
	5	21.68
	6	23.10
	7	24.17
	8	25.00
	9	25.67
	10	26.22
II	3	12.78
	4	14.98
	5	16.47
	6	17.55
	7	18.37
	8	19.00
	9	19.51
	10	19.93
III	3	8.75
	4	10.25
	5	11.27
	6	12.01
	7	12.57
	8	13.00
	9	13.35
	10	13.63

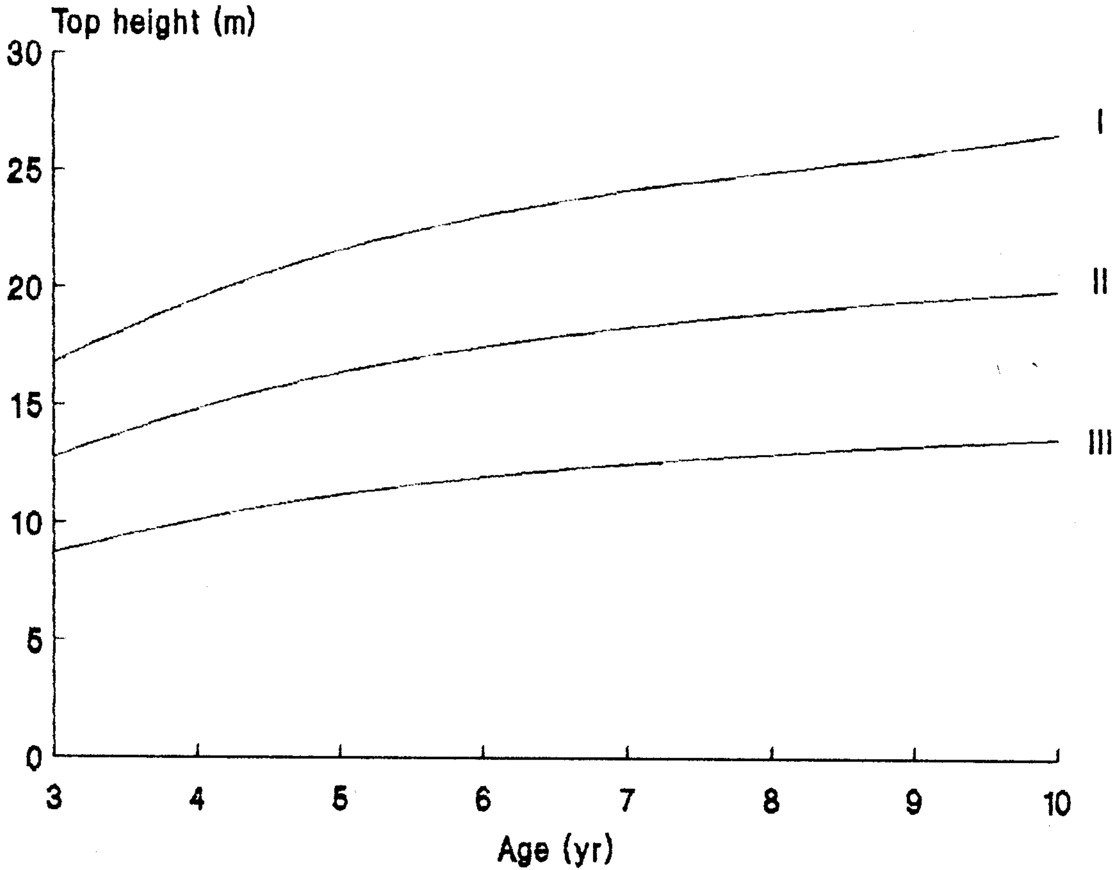

Figure 10. Top height over age under different site qualities of *Casuarina equisetifolia*

The expected yield under different site qualities for different number of trees existing in the stand with varying age are reported in Table 27. Table 27 is to be used in conjunction with Table 26 where expected top height is reported for different site quality levels with varying age. MAI curves for different stocking levels are given in Figure 11 to 19 along with the corresponding CAI curves.

The age at which the MAI reaches maximum or near maximum for different site quality and stocking levels was found out from Table 27 and is reported in Table 28. The general trend is that for a given site quality, rotation age lowers down with increase in stocking and for a given stocking level, rotation age increases with lowering site quality levels.For site quality I rotation age comes out as 4 years. This is indicative of a thinning required at the end of 4 years in very good sites in the absence of which the stand growth is likely to be affected. In poor sites the growth is slower and the rotation age is reached only by 7 or 8 years depending on the stocking.

The differences between yield levels for different site quality levels are drastic because of the large class interval given for these classes with respect to the site index . The site index range for each of these classes is fixed as 6 m equivalent to that of teak. For the same reason the expected MAI shows a wide range. For instance the MAI varied from 5.062 m^3 ha^{-1} for site quality III to 47.759^3 ha^{-1} for

Table 27. Provisional yield table for *Casuarina equisetifolia*

Number of trees ha^{-1}	Site quality	Age (yr)	Volume (m^3 ha^{-1})	MAT of volume (m^3 ha^{-1})	Crop diameter (cm)
2000		3	31.670	27.223	3.25
2000		4	132.237	33.072	9.58
2000		5	154.269	32.854	10.20
2000	I	6	134.052	30.675	10.50
2000		7	196.659	23.094	10.65
2000		8	204.957	25.620	10.72
2000		9	210.679	23.409	10.74
2000		10	214.724	21.472	10.74
2000		3	24.699	3.233	5.56
2000		4	52.145	13.036	7.15
2000		5	75.733	15.148	8.06
2000	II	6	94.336	15.723	8.64
2000		7	108.810	15.544	9.03
2000		8	119.931	14.991	9.30
2000		9	123.835	14.315	9.51
2000		10	136.052	13.605	9.66
2000		3	2.243	0.748	1.90
2000		4	6.790	1.698	3.38
2000		5	12.267	2.453	4.30
2000	III	6	17. 687	2.943	4.94
2000		7	22.648	3.235	5.39
2000		8	26.961	3.370	5.73
2000		9	30.793	3.421	6.00
2000		10	34.061	2.406	6.21

Note: For a given stand, site quality is to be determined based on top height and age using Table 26 . For a given number of trees per ha, assumed or estimated, the volume can be read out from Table 27. For intermediate values use of equation (33) is suggested. Prediction of volume or crop diameter may preferably be restricted to a stocking range of 2000 to 6000 trees per ha and age between 4 to 8 years.

Cont...

Number of trees ha-1	Site quality	Age (yr)	Volume $(m^3\ ha^{-1})$	MAI of volume $(m^3\ ha^{-1})$	Crop diameter (cm)
4000		3	117.819	39.273	7.33
4000		4	170.796	42.699	8.45
4000		5	198.415	39.683	8.92
4000	I	6	212.657	35.443	9.12
4000		7	220.137	31.448	9.19
4000		8	224.067	28.008	9.20
4000		9	226.102	25.122	9.20
4000		10	227.051	22.705	9.20
4000		3	43.182	14.394	4.94
4000		4	81.575	20.394	6.36
4000		5	110.881	22.176	7.16
4000	II	6	132.101	22.017	7.66
4000		7	147.582	21.083	7.99
4000		8	158. 872	19.859	8.22
4000		9	167.530	18.614	8.39
4000		10	174.297	17.430	8.51
4000		3	5.111	1.704	1.57
4000		4	13.852	3.463	2.94
4000		5	23.418	4.694	3.79
4000	III	6	32.297	5.383	4.37
4000		7	40.056	5.722	4.79
4000		8	46.578	5.822	5.09
4000		9	52.216	5.802	5.33
4000		10	56.924	5.692	5.52

Cont..

Table 27 cont...

Number of trees ha^{-1}	Site quality	Age (yr)	Volume (m^3 ha^{-1})	MAI of volume (m^3 ha^{-1})	Crop diameter (cm)
6000		3	140.613	46.871	6.84
6000		4	191.036	47.759	7.75
6000		5	213.439	42.688	8.08
6000	I	6	222.898	37.150	8.17
6000		7	226.501	32.357	8.17
6000		8	227.381	28.423	8.17
6000		9	226.975	25.219	8.17
6000		10	225.958	22.596	8.17
6000		3	57.671	19.224	4.74
6000		4	102.088	25.522	6.01
6000		5	133.477	26.695	6.70
6000	II	6	154.945	25.824	7.12
6000		7	169.894	24.271	7.39
6000		8	180.385	22.548	7.57
6000		9	188.167	20.907	7.70
6000		10	194.069	19.407	7.79
6000		3	7.971	2.657	1.67
6000		4	20.248	5.062	2.93
6000		5	32.927	6.585	3.71
6000	III	6	44.243	7.374	4.23
6000		7	53.859	7.694	4.61
6000		8	61.770	7.721	4.88
6000		9	68.501	7.611	5.10
6000		10	74.046	7.405	5.27

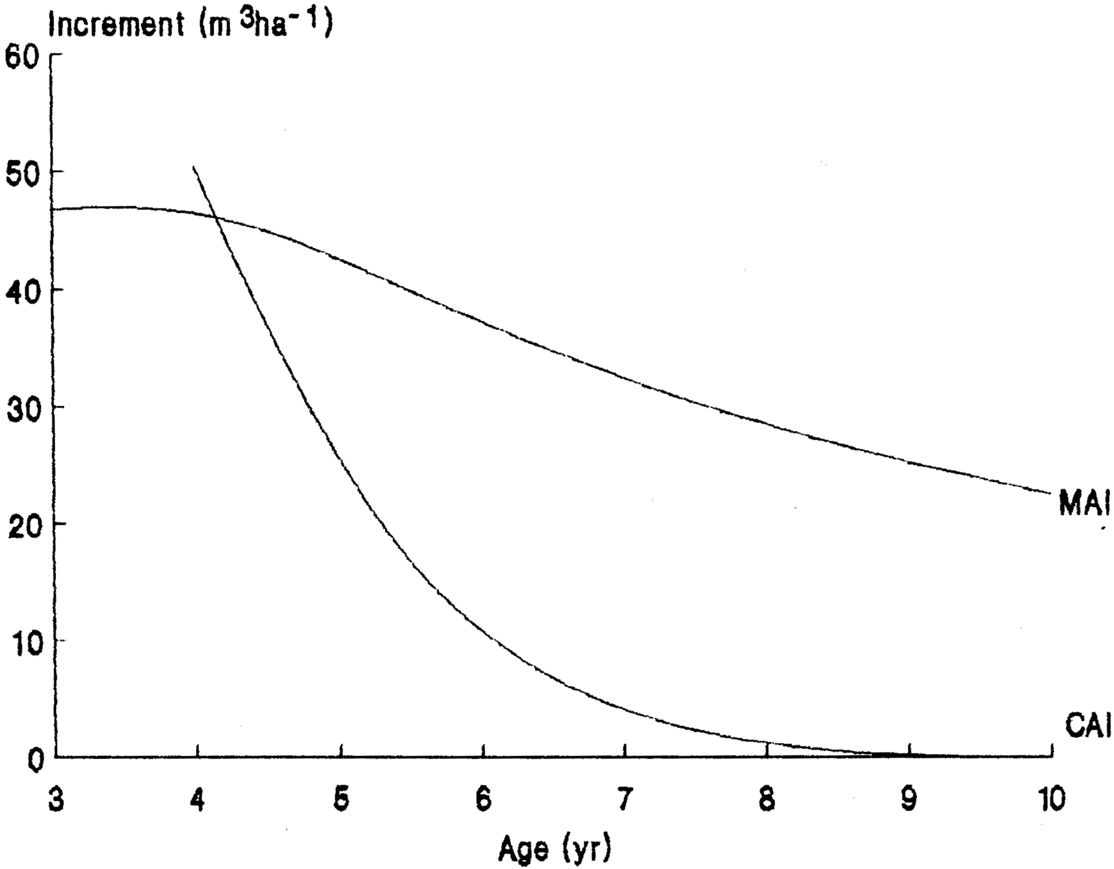

Figure 11. MAI and CAI of commercial volume under site quality I with 6000 trees/ha for *Casuarina equisetifolia*

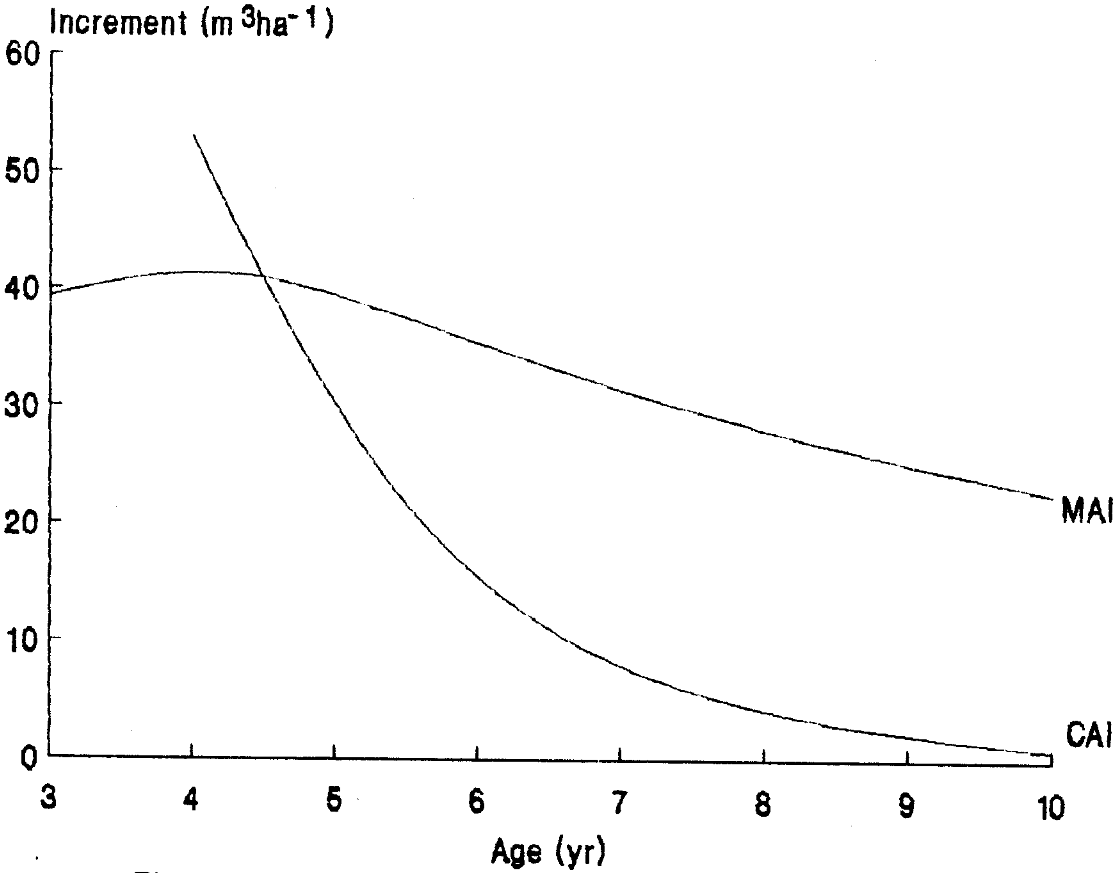

Figure 12. MAI and CAI of commercial volume under site quality I with 4000 trees/ha for *Casuarina equisetifolia*

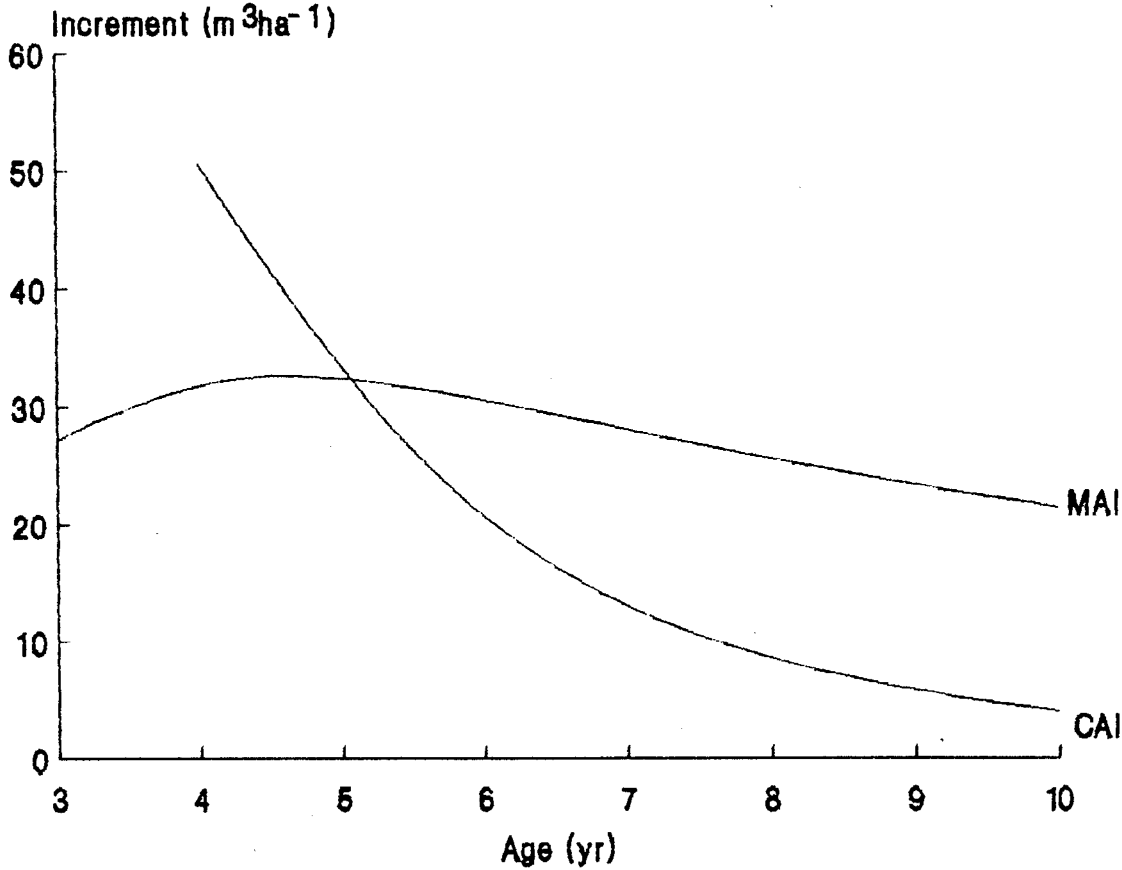

Figure 13. MAI and CAI of commercial volume under site quality I with 2000 trees/ha for *Casuarina equisetifolia*

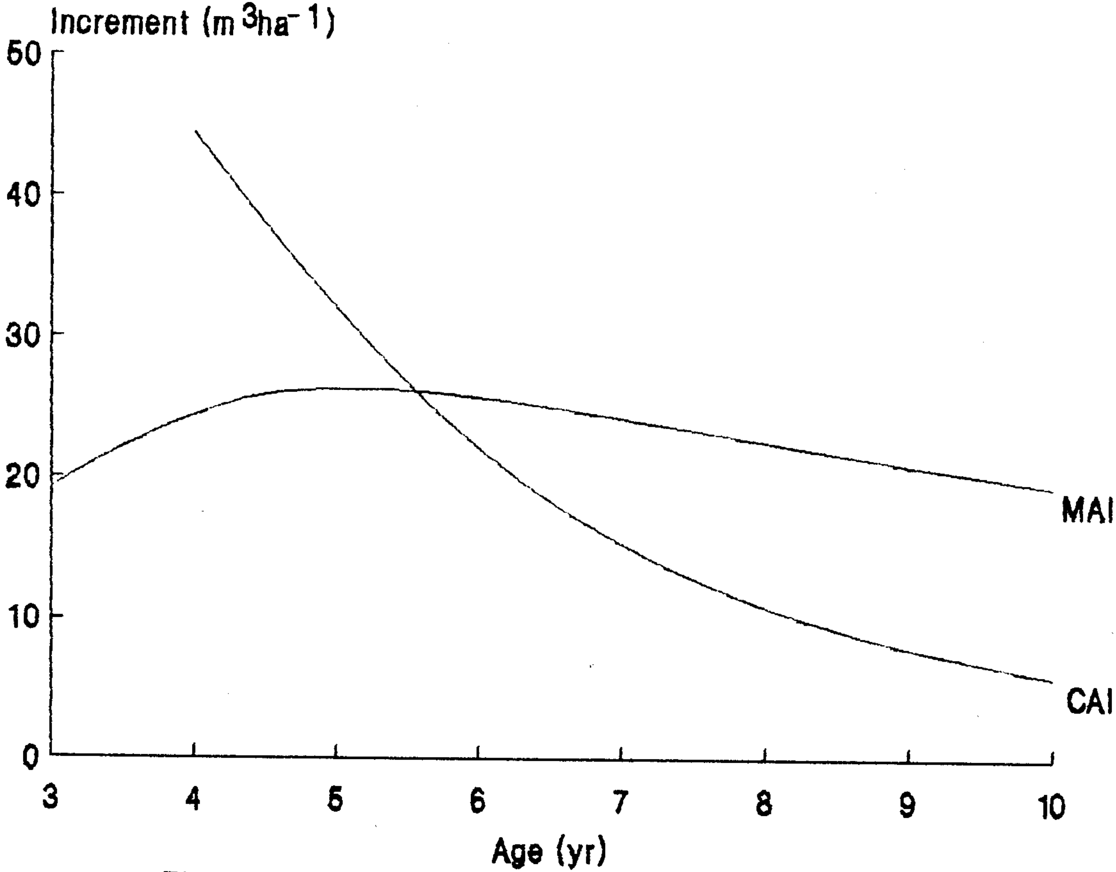

Figure 14. MAI and CAI of commercial volume under site quality II with 6000 trees/ha for *Casuarina equisetifolia*

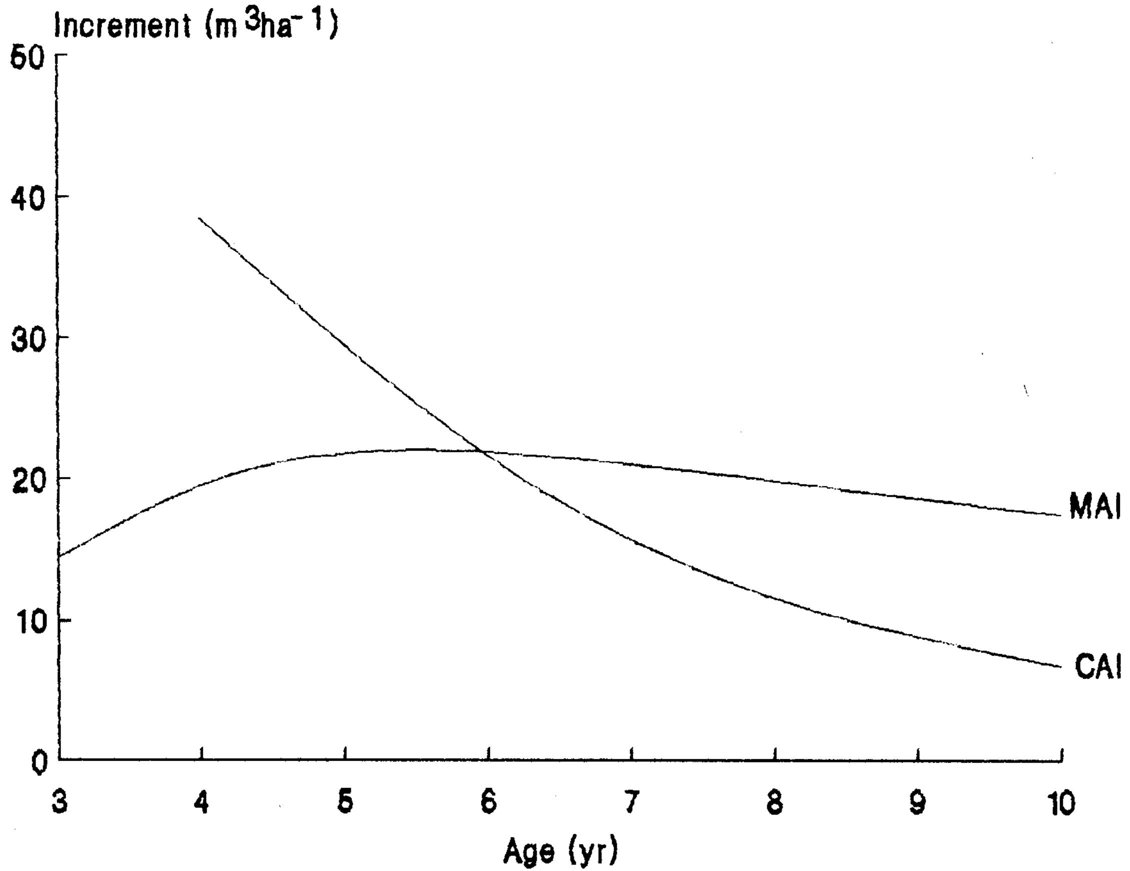

Figure 15. MAI and CAI of commercial volume under site quality II with 4000 trees/ha for *Casuarina equisetifolia*

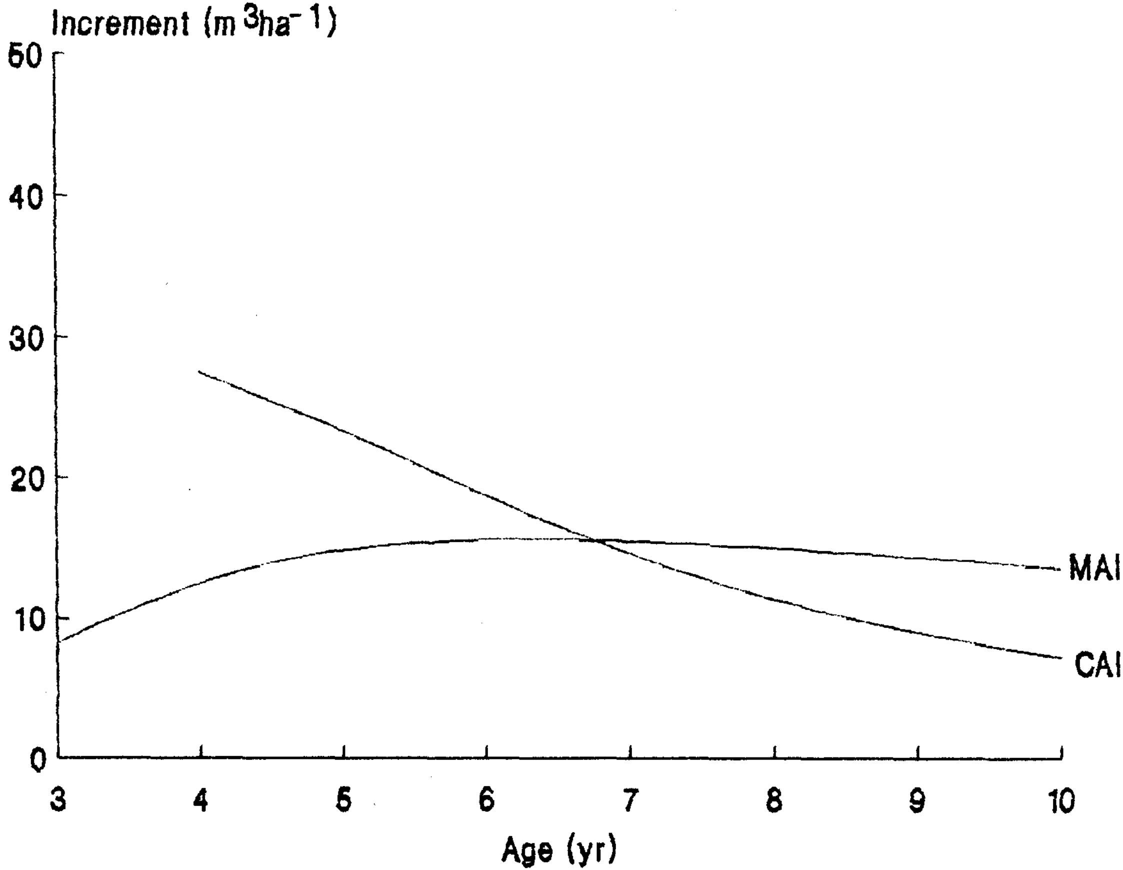

Figure 16. MAI and CAI of commercial volume under site quality II with 2000 trees/ha for *Casuarina equisetifolia*

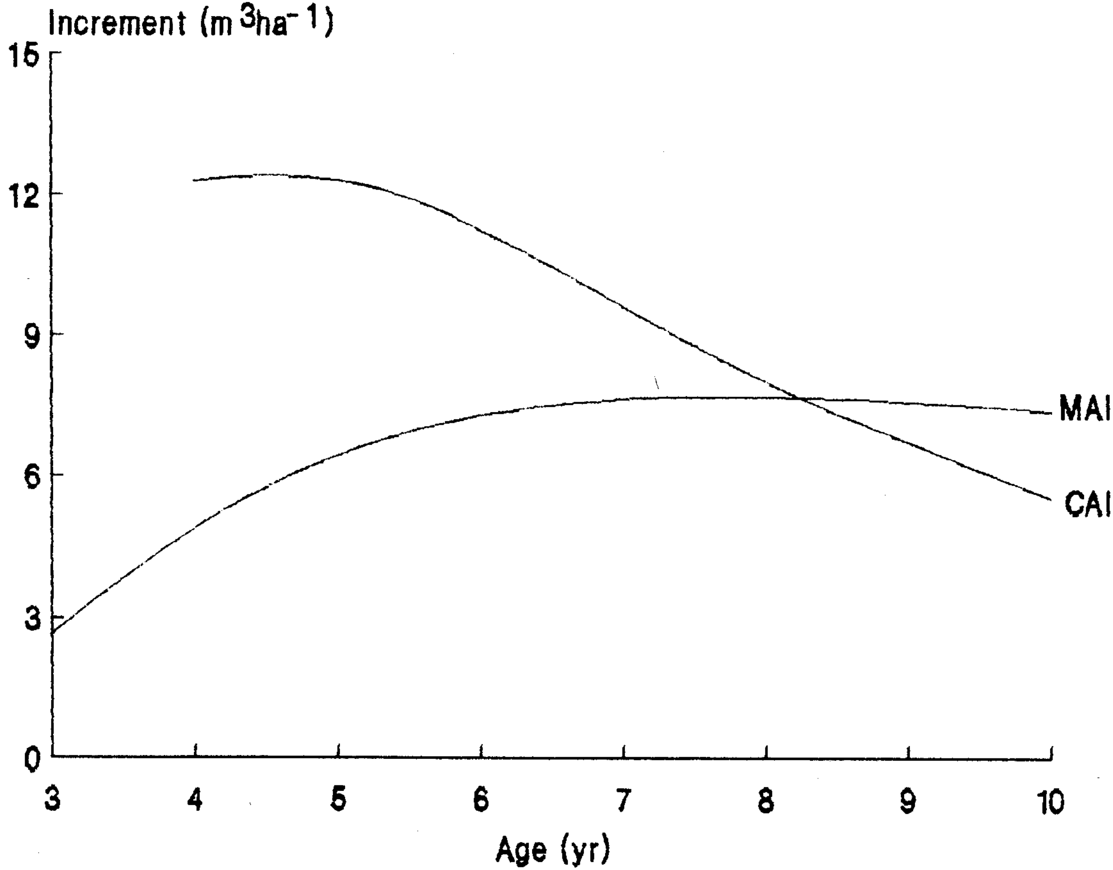

Figure 17. MAI and CAI of commercial volume under site quality III with 6000 trees/ha for *Casuarina equisetifolia*

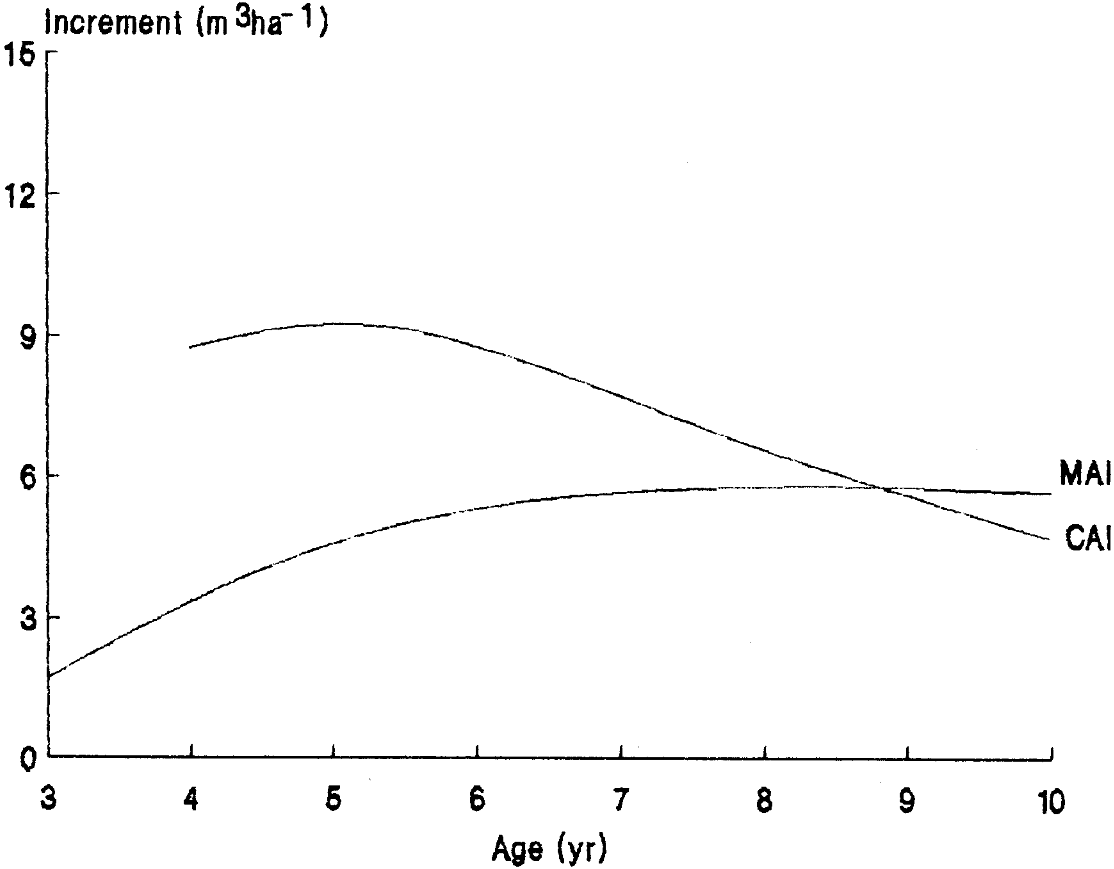

Figure 18. MAI and CAI of commercial volume under site quality III with 4000 trees/ha for *Casuarina equisetifolia*

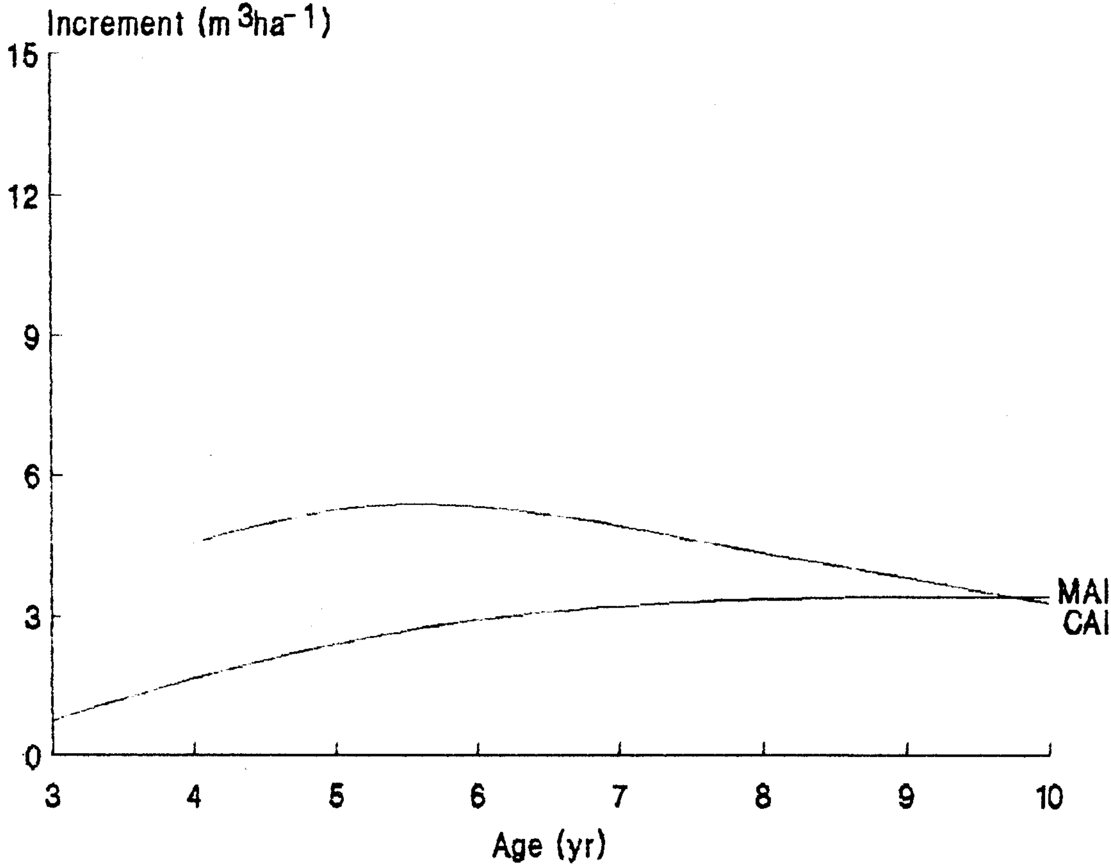

Figure 19. MAI and CAI of commercial volume under site quality III with 2000 trees/ha for *Casuarina equisetifolia*

Table 28. Rotation age for different stocking levels and site quality classes for *Casuarina equisetifolia*

Stocking (trees ha^{-1})	Rotation age (yr) Site quality class		
	I	II	III
2000	4	6	8
4000	4	5	8
6000	4	5	7

site quality I at 4 years with 6000 trees ha^{-1} in the stand.

The relation between crop diameter, top height and stocking level turned out to be following.

$$d = -9.2689 + 1.6254\ H - 1.6 \times 10^{-4}\ N$$
$$(0.7650) \quad (0.0938) \quad (1.4 \times 10^{-4})$$

$$- 0.0299\ H^2 - 5.4 \times 10^{-8}\ N^2 - 3.7 \times 10^{-5}\ H\text{-}N \qquad (34)$$
$$(3.0 \times 10^{-3}) \quad (1.4 \times 10^{8}) \quad (7.0 \times 10)$$

(Adj. R^2 = 0.9372)

where d = crop diameter (m)

H,N as defined earlier

The expected crop diameter for different age, site quality and stocking levels are reported in Table 27. Average size of trees as indicated by crop diameter increases as site quality improves, for a given level of stocking. The same is found to decrease with increase in the stocking level for a given site quality.

3.3.3. Annual out-turn

3.3.3.1. *Acacia auriculiformis*

The site index equations were the following.

$$\ln H = 2.8524 - 1.6140\ A^{-1} \qquad (35)$$
$$(0.0978) \quad (0.5144)$$

(Adj. R^2 = 9.3560)

$$\ln S = \ln H + 1.6140\ (A^{-1} - A0^{-1}) \qquad (36)$$

The frequency distribution of the site index is shown in Figure 20. The mean site index worked out to 14.484 m. The yield corresponding to rotation age of 7 years, stocking level of 2667 trees ha^{-1} and site index of 34.484 m, using the models developed by Jayaraman and Rajan

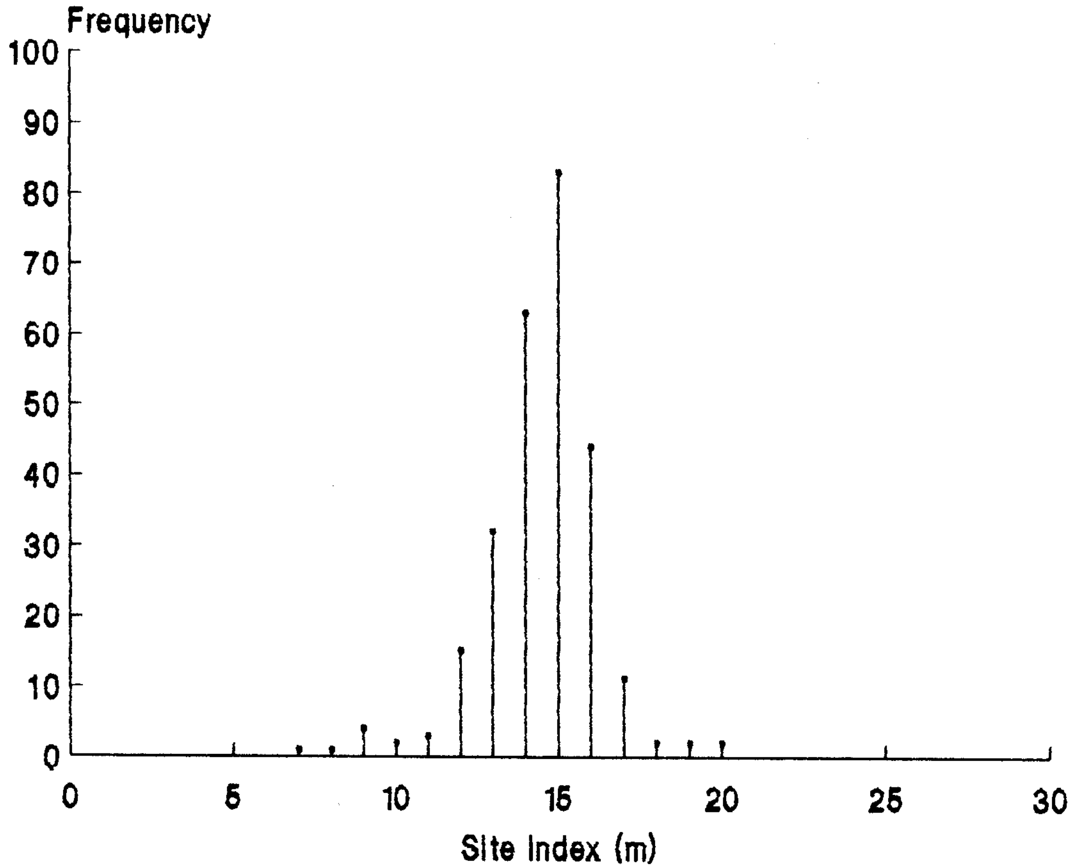

Figure 20. Frequency distribution of site index of *Acacia auriculiformis*

(1991) comes to 160.808 m^3 ha^{-1}. Multiplying this value with the area available annually for harvest will lead to the annual out-turn. If for instance 7000 ha is the total area under *Acacia auriculiformis*, 1000 ha will be available for harvest annually at a rotation age of 7 years.

3.3.3.2. *Casuarina equisetifolia*

The frequency distribution of the site index is shown in Figure 21. The mean site index worked out to be 16.112 m. With 6000 trees ha^{-1} at harvest and a mean site index of about 16 m the rotation age is likely to be around 6 years as per Table 27. The expected yield against these parameters as per equations (32) and (33) is 100.073 m^3 ha^{-1}. Multiplying this value with the area available for harvest annually would lead to an overall estimate of the annual out-turn from the plantations of the species.

3.3.4. Recent productivity estimates against projections of the World Bank

For *Acacia auriculiformis*, the projections on productivity given in Anonymous (1984) are the following.

MAI of 10 m^3 ha^{-1} yr^{-1} fcr small block plantstions

MAI of 12 m^3 ha^{-1} yr^{-1} for mid country plantations

MAI of 10 m^3 ha^{-1} yr^{-1} for coastal strip plantations

It is also stated that 'when watered adequately during the first year, growth is impressive, it produces a large number of branches, reaching uptu six feet in height. If the tree maintains such vigour, a

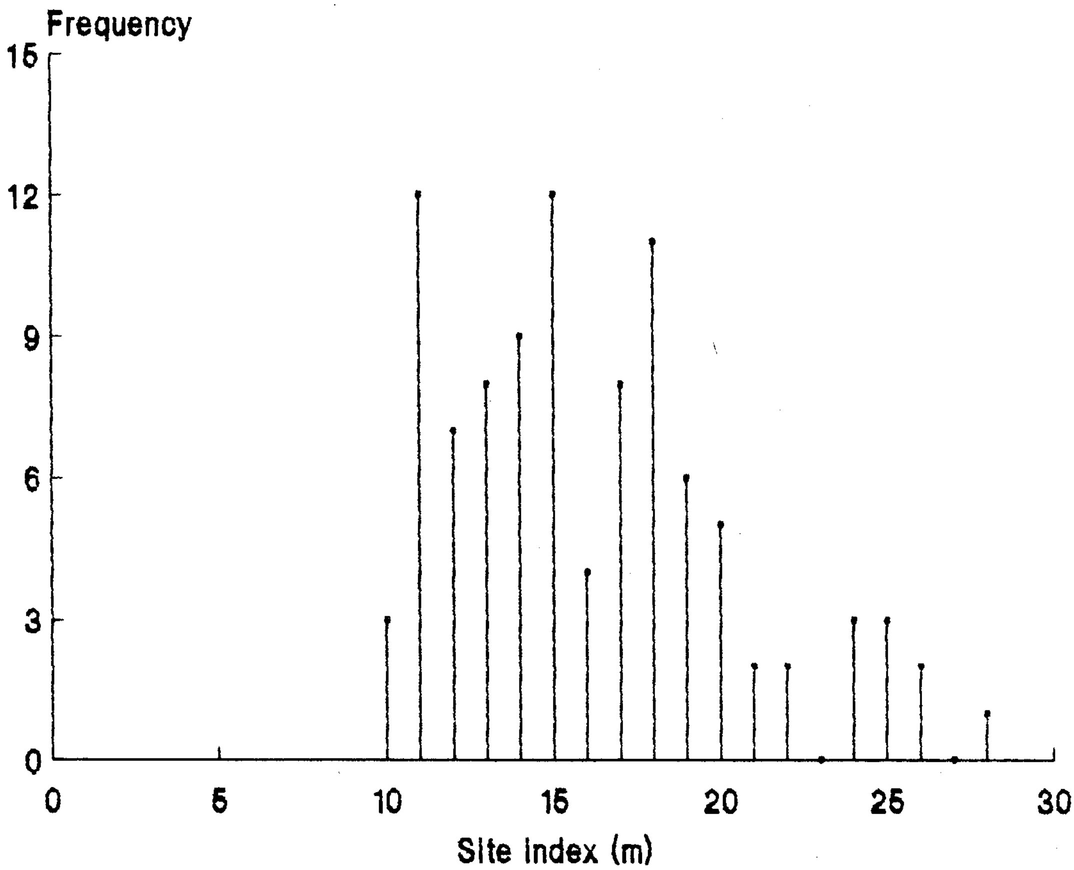

Figure 21. Frequency distribution of site index of *Casuarina equisetifolia*

MAI of 15 to 20 m^3 ha^{-1} yr^{-1} over a rotation period of 6 to 10 years should easily be obtained'.

The yield table prepared for the species (Jayaraman and Rajan, 1991) does not differentiate plantations with respect to type of plantation but with respect to site quality. The average productivity of *Acacia auriculiformis* as per the results given in section 3.3.3.1. of this report worked out using the above yield table is 23 m^3 ha^{-1} yr^{-1} at **7** years. This is well above the projections mentioned above. It 'has to be noted that the mean site index was obtained by taking into ccnsideraticn all plantations of the species included in the sample, with age greater than or equal to 3.5 years.

The higher levels of productivity exhibited by the small block and strip plantations in relation tc large block plantations are brought out in secticn 3.2.2.1.

The MAT of dry woody biomass based on average yield at 6.5 years for *Acacia auriculiformis* (Table 10) worked out to 14.6 t ha-1 yr^{-1}. This is much above the maximum of 10.9 t ha^{-1} yr^{-1} corresponding to 20 m^3 ha^{-1} yr^{-1} reported in Anonymous (1984).

For *Casuarina equisetifolia,* the projection is 8 to 9 m^3 ha^{-1} yr^{-1} at 15 years as per the World Bank report. Section 3.3.3.2. of this report puts the MAI to an expected value of 16.7 m^3 ha^{-1} yr^{-1} at years. The mean site index was obtained from plantations of the species included in the sample units with age greater than or equal to 3.5 years.

The MAI of dry woody biomass based on average yield at 6.5 years for *Casuarina equisetifolia* (Table 15) worked out to 8 t ha^{-1} yr^{-1}. This is much above 5.7 t ha^{-1} yr^{-1} corresponding to 9 m^3 ha^{-1} yr^{-1} reported Anonymous (1984).

4. CONCLUSIONS

The Social Forestry plantations raised under the World Bank Scheme in Kerala during the period 1985 to 1990 exhibited a varying survival rate ranging from 60 to 80 per cent. The potential productivity of *Acacia auriculiformis*, *Casuarina equisetifolia* and *Eucalyptus grandis* was to the order of 12 to 20 t ha^{-1} yr^{-1} of woody biomass. The *species Acacia auriculiformis* and *Casuarina equisetifolia* were also found promising with respect to their average productivity over different parts of the State. The recent output estimates for these species were found higher than the projections made in the proposal for the Kerala Social Forestry Project by the World Bank. Plantations have been raised by the Social Forestry Wing over an area of 15,187 ha till 1990–91 under the World Bank Scheme in Kerala. The emphasis given initially on fast growing exotic species useful for fuelwood and paper making has now changed towards indigenous multipurpose species. The present study has indicated the need for thinning the plantstions of *Casuarina equisetifolia* at the end of 4 years in good quality sites. Harvesting could be delayed till 7th or 8th year for the *species* in poor quality sites.

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APPENDICES

Appendix 1. Mean square error (MSE) for the equations fitted

Equation number	MSE
(13)	0.03197
(14)	0.03558
(15)	0.07492
(16)	0.17470
(17)	0.01979
(18)	0.02269
(19)	0.09602
(20)	0.15420
(21)	0.03585
(22)	0.03597
(23)	0.08744
(24)	0.23894
(25)	0.02214
(26)	0.02279
(27)	0.07093
(28)	0.25416
(29)	0.02013
(30)	0.01915
(31)	0.06553
(33)	0.12401
(35)	0.00632

Note: A correcticn factor of MSE/2 has tc be added to the predicted value before transforming to the original units in the case of equations involving dependent variable in logarithmic scale.

Appendix 2. Area under different species classes of Social Forestry plantations raised under the World Bank Scheme in Kerala

Sl. no.	Species	Area (ha)	Length (km)	No.of plns.
1.	Acacia	3185.14	6.50	189
2.	Acacia,Silver oak	1436.90	0.00	39
3.	Acacia,Casuarina	937.31	12.00	125
4.	Silver oak	657.24	0.00	29
5.	Acacia,Chandanavembu,Silver oak	589.99	0.00	12
6.	Eucalyptus	564.81	0.00	11
7.	Casuarina	557.29	0.00	103
8.	Acacia,Eucalyptus	477.41	0.00	15
9.	Acacia,Mahogany	448.54	0.00	29
10.	Acacia,Kurangatti,Silver oak	297.62	0.00	15
11.	Acacia,Eucalyptus,Silver oak	270.17	0.00	6
12.	Anjily,Irul,Manimaruthu,Thanni	230.00	0.00	3
13.	Acacia,Casuarina,Eucalyptus,Silver oak	192.70	0.00	4
14.	Acacia,Anjily,Mathagirivembu,Silver oak	150.00	0.00	2
15.	Albizia,Mahogany,Matti,Teak	134.00	0.00	1
16.	Acacia,Mathagirivembu,Silver oak	132.31	0.00	3
17.	Acacia,Chandanavembu,Misc.,Silver oak	130.48	0.00	1
18.	Mahogany,Silver oak,Venga	129.92	0.00	2
19.	Cashew,Casuarina,Mahogany	125.62	0.00	10
20.	Acacia,Neem,Tamarind	110.00	0.00	6
21.	Mahogany,Silver oak	107.20	0.00	5
22.	Acacia,Subabul	106.37	0.00	3
23.	Acacia,Casuarina,Silver oak	104.92	0.00	3
24.	Kurangatti,Silver oak	103.73	0.00	5
25.	Kanala,Kulamavu,Mulberry,Venga	101.99	0.00	2
26.	Acacia,Albizia,Mahogany,Teak	88.19	0.00	2
27.	Acacia,Cashew,Mahogany	80.50	0.00	4
28.	Acacia,Mahogany,Silver oak	79.20	0.00	5
29.	Anjily,Mahogany,Matti	77.95	0.00	3
30	Acacia,Eucalyptus,Mahogany,Sissu	75.00	0.00	2
31	Anjily,Elavu,Mahogany,Matti,Thanni, Vellappine,Venteak	75.00	0.00	1
32.	Acacia,Misc.	72.97	0.00	7
33.	Acacia,Mahogany,Manimaruthu	72.36	0.00	2
34.	Kurangatti,Silver oak,Thanni	68.57	0.00	2
35	Acacia,Albizia,Silver oak	64.50	0.00	2
36.	Jack,Kanala,Thembavu	64.36	0.00	2
37.	Acacia,Albizia,Casuarina,Mahogany, Silver oak,Subabul	63.30	0.00	1
38.	Mahogany,Misc.,Silver oak	60.00	0.00	1

39. Acacia,Albizia,Mahogany,Silver oak	60.00	**0.00**	2
40. Misc.,Poomaruthu,Thanni,Thembavu	60.00	**0.00**	1
41. Albizia,Bamboo,Silver oak,Vellappine	59.45	0.00	1
42. Poomaruthu,Thanni,Thembavu	58.70	**0.00**	1
43. Acacia,Cashew	58.35	**0.00**	**9**
44. Acacia,Anjily,Casuarina	57.80	**0.00**	2
45. Anjily,Misc.,Thanni	57.75	0.00	1
46. Mahogany,Nelli,Rose wood,Thanni	56.30	**0.00**	1
47. Anjily,Mathagirivembu,Silver oak	56.00	**0.00**	1
48. Acacia,Neem,Tamarind,Misc.	54.42	**0.00**	1
49. Acacia,Albizia,Cashew,Jack	50.00	**0.00**	1
50. Acacia,Tamarind	49.94	**0.00**	3
51. Acacia,Eucalyptus,Mahogany	49.21	**0.00**	2
52. Misc.,Thanni	49.00	**0.00**	1
53. Anjily,Bamboo,Jack,Mahogany,Matti	48.50	**0.00**	1
54. Acacia,Albizia,Kumbil,Mahogany,Thembavu	45.10	**0.00**	1
55. Anjily,Mahogany,Misc.	45.00	**0.00**	1
56. Acacia,Chandanavembu,Kurangatti,Silver oak	43.50	**0.00**	1
57. Mahogany,Misc.,Nelli	43.00	**0.00**	1
58. Acacia,Casuarina,Eucalyptus	42.85	**0.00**	13
59. Casuarina,Mahogany,Matti	42.68	**0.00**	6
60. Acacia,Eucalyptus,Kurangatti,Silver oak	41.70	**0.00**	1
61. Njaval,Silver oak	40.00	**0.00**	1
62. Casuarina,Silver oak	39.82	**0.00**	1
63. Casuarina,Mahogany,Silver oak	36.16	**0.00**	3
64. Mahogany,Matti,Nelli,Thanni,Thembavu	35.00	**0.00**	1
65. Acacia,Cashew,Misc.	34.31	**0.00**	1
66. Matti	32.60	**0.00**	4
67. Acacia,Maruthu,Mathagirivembu	32.00	**0.00**	1
68. Acacia,Anjily,Mahogany,Nelli	31.54	**0.00**	1
69. Kumbil,Mahogany,Matti,Nelli,Thanni	31.60	**0.00**	1
70. Acacia,Casuarina,Subabul	31.55	**0.00**	4
71. Acacia,Eucalyptus,Mahogany,Misc.	31.11	**0.00**	1
72. Casuarina,Pandanus	30. 00	**0.00**	1
73. Acacia,Beedileaf,Neem,Tamarind	30.00	**0.00**	1
74. Acacia,Casuarina,Mahogany	29.72	**0.00**	20
75. Acacia,Jack,Misc.,Subabul	28.69	**0.00**	2
76. Acacia,Neem	26.80	**0.00**	2
77. Casuarina,Mahogany,Nelli	26.50	**0.00**	1
78. Acacia,Casuarina,Matti	26.47	**0.00**	5
79. Acacia,Misc.,Silver oak	25.44	**0.00**	3
80. Acacia,Albizia,Bamboo,Sissu,Teak	25.00	**0.00**	1
81. Acacia,Cashew,Subabul	25.00	**0.00**	1
82. Acacia,Ashokam,Delonix,Misc.,Neem	24.92	**0.00**	2
83. Acacia,Cashew,Casuarina,Mahogany	24.00	**0.00**	1
84. Karimaruthu,Mahogany,Matti,Nelli,Thembavu	23.80	**0.00**	1

85.	Acacia,Anjily,Cashew,Mahogany,Thanni	22.72	0.00	1
86.	Eucalyptus,Silver oak	22.50	0.00	3
87.	Acacia,Badam,Bamboo	22.00	0.00	1
88.	Cashew,Casuarina	21.47	0.00	2
89.	Medicinal plants	20.48	0.00	1
90	Casuarina,Mahogany,Matti,Nelli,Thanni	20.30	0.00	1
91.	Albizia,Anjily,Subabul,Misc.	20.25	0.00	1
92.	Acacia,Manimaruthu,Njaval,Ungu	20.00	0.00	1
93.	Cashew	19.63	0.00	9
94.	Acacia,Albizia,Bamboo,Mahogany	19.00	0.00	1
95.	Acacia,Mahogany,Nelli,Rose wood,Thanni	19.00	0.00	2
96	Albizia,Cashew,Mahogany,Matti	18.63	0.00	2
97.	Cashew,Casuarina,Matti	18.50	0.00	2
98.	Acacia,Jack,Silver oak	18.40	0.00	1
99	Cashew,Jack,Karimaruthu	18.10	0.00	1
100.	Acacia,Cashew,Casuarina	17.80	0.00	3
101.	Misc.	17.16	0.00	6
102.	Pepper	16.85	0.00	3
103.	Karimaruthu,Manimaruthu	16.77	0.00	4
104.	Bamboo,Casuarina	16.63	0.00	4
105.	Acacia,Manimaruthu,Misc.	16.42	0.00	1
106.	Acacia,Mahogany,Matti,Silver oak,Sissu	16.10	0.00	1
107.	Acacia,Bamboo	16.00	0.00	1
108.	Acacia,Albizia,Bamboo,Irul,Mahogany	16.00	0.00	1
109.	Acacia,Mahogany,Nelli,Sissu	15.94	0.00	1
110	Cashew,Mahogany,Nelli,Teak,Vaka,Venga	15.40	0.00	2
111.	Acacia,Bamboo,Mahogany	15.20	0.00	2
112.	Acacia,Mahogany,Misc.,Silver oak	15.00	0.00	1
113.	Acacia,Bauhinia,Neem,Subabul	15.00	0.00	1
114.	Acacia,Eucalyptus,Neem	15.00	0.00	1
115.	Acacia,Casuarina,Eucalyptus,Misc., Silver oak	15.00	0.00	1
116.	Acacia,Mango,Neem	15.00	0.00	3
117	Cashew,Casuarina,Jack,Mahogany,Matti	15.00	0.00	1
118.	Acacia,Cashew,Jack,Matti,Nelli	13.64	0.00	1
119.	Acacia,Casuarina,Mahogany,Nelli	13.40	0.00	1
120.	Acacia,Karimaruthu,Mahogany,Manimaruthu, Thanni	13.00	0.00	1
121.	Albizia,Casuarina,Mahogany,Matti	12.50	0.00	1
122.	Cashew,Casuarina,Mahogany,Matti	12.00	0.00	2
123.	Mahogany,Matti,Nelli,Njaval	11.00	0.00	1
124.	Acacia,Subabul,Tamarind	10.48	0.00	1
125.	Cashew,Manimaruthu,Matti	10.00	0.00	1
126.	Misc.,Silver oak	10.00	0.00	1
127.	Acacia,Albizia,Eucalyptus,Jack,Mahogany, Mango,Teak	10.00	0.00	1

128.	Matti,Subabul	9.50	0.00	1
129.	Casuarina,Mahogany,Teak	9.50	0.00	1
130.	Cashew,Kanikonna	9.50	0.00	1
131.	Acacia,Casuarina,Kumbil	9.22	0.00	1
132.	Chandanavembu,Silver oak	9.10	0.00	1
133.	Jack,Mahogany	9.00	0.00	1
134.	Bamboo,Misc.	9.00	0.00	1
135.	Acacia,Cashew,Sissu	9.00	0.00	1
136.	Acacia,Casuarina,Eucalyptus,Mahogany	8.79	0.00	3
137.	Mulberry	8.73	0.00	3
138.	Matti,Neem,Sissu	8.50	0.00	1
139.	Acacia,Casuarina,Misc.	8.41	0.00	4
140.	Matti,Spathodea,Teak	8.00	0.00	1
141.	Casuarina,Jack,Matti,Tamarind	7.50	0.00	1
142.	Mahcgany	7.31	1.10	9
143.	Casuarina,Mahogany,Neem	7.00	0.00	1
144.	Mahogany,Misc. ,Teak	7.00	0.00	1
145.	Badam,Bamboo,Mahogany	7.00	0.00	1
146.	Silver oak,Subabul	6.50	0.00	?
147.	Casuarina,Matti	6.43	0.00	1
148.	Albizia	6.00	0.00	1
149.	Acacia,Casuarina,Poomaruthu	5.75	0.00	2
150.	Acacia,Casuarina,Rain tree	5.75	0.00	3
151.	Acacia,Teak	5.52	0.00	1
152.	Albizia,Casuarina,Matti	5.50	0.00	3
153.	Acacia,Casuarina,Kanikonna	5.50	0.00	1
154.	Beedileaf	5.50	0.00	2
155.	Acacia,Bamboo,Pera	5.45	0.00	1
156.	Acacia,Anjily,Cashew,Casuarina	5.40	0.00	1
157.	Subabul	5.15	0.00	3
158.	Casuarina,Mahogany	5. 10	0.00	7
159.	Casuarina,Fruit Bearing trees,Mahogony	5.00	0.00	1
160.	Acacia,Mahogany,Thanni	4.82	0.00	2
161 .	Mahogany ,Neem, Vaka	4. 60	0.00	1
162.	Bamboo,Cane	4.50	0.00	1
163.	Acacia,Jack,Mahogany,Matti	4.50	0.00	1
164.	Casuarina,Jack,Mahogany,Tamarind,Thanni	4. 50	0.00	1
155.	Casuarina,Eucalyptus	4.40	0.00	4
166.	Acacia,Karimaruthu,Mahogany,Manimaruthu	4.08	0.00	1
167.	Acacia,Anjily,Irul,Mahogany,Thanni	4.00	0.00	1
168.	Acacia,Albizia,Mahogany	4.00	0.00	2
169.	Anjily,Mahogany,Thanni	4.00	0.00	1
170.	Acacia,Delonix,Mahogany,Subabul	3.69	0.00	1
171.	Acacia,Cashew,Jack,Neem	3.61	0.00	1
172.	Mahogany,Matti	3.52	0.00	2
173.	Acacia,Casuarina,Mahogany,Neem	3.50	0.00	1

174. Albizia,Cashew	3.50	0.00	1
175. Acacia,Anjily,Sissu,Venga	3.50	0.00	3
176. Acacia,Casuarina,Mahogany,Matti	3.50	0.00	1
177. Karimaruthu,Mahogany,Thanni	3.48	0.00	1
178. Anjily,Cashew,Delonix	3.44	0.00	1
179. Fruit Bearing trees	3.36	0.00	1
180. Acacia,Albizia,Casuarina	3.27	0.00	2
181. Acacia,Mahogany,Misc.,Pongu,Thanni	3.25	0.00	1
182. Badam,Delonix,Mahogany	3.25	0.00	3
183. Albizia,Matti	3.20	0.00	1
184. Mahogany,Misc.,Poomaruthu	3.12	0.00	1
185. Teak	3.11	0.00	3
186. Elavu,Misc.,Tamarind	3.00	0.00	1
187. Acacia,Anjily,Delonix,Jack	3.00	0.00	1
188. Acacia,Sissu	3.00	0.00	1
189. Acacia,Cashew,Tamarind	3.00	0.00	1
190. Acacia,Delonix,Peltophorum	2.80	0.00	1
191. Matti,Misc.,Poomaruthu	2.72	0.00	1
192. Acacia,Casuarina,Mahogany,Peltophorum, Spathodea	2.50	0.00	1
193. Acacia,Delonix	2.25	0.00	3
194. Acacia,Mahogany,Misc.	2.11	0.00	1
195. Acacia,Delonix,Mahogany	2.10	0.00	2
196. Acacia,Badam,Cashew,Casuarina	2.07	0.00	1
197. Acacia,Casuarina,Delonix,Mahogany	2.00	0.00	1
198. Anjily,Delonix,Poomaruthu	2.00	0.00	1
199. Albizia,Cashew,Mango,Matti	2.00	0.00	1
200. Casuarina,Eucalyptus,Manimaruthu	2.00	0.00	1
201. Bamboo,Cashew,Casuarina	2.00	0.00	1
202. Cashew,Matti	2.00	0.00	1
203. Anjily,Casuarina,Mahogany,Nelli,Thanni	1.60	0.00	1
204. Acacia,Albizia,Casuarina,Mahogany,Neem	1.56	0.00	2
205. Delonix,Rain tree,Spathodea	1.50	0.00	1
206. Badam,Sissu,Vellappine	1.50	0.00	1
207. Acacia,Delonix,Njaval,Tamarind	1.50	0.00	1
208. Acacia,Misc.,Neem,Poomaruthu	1.50	0.00	1
209. Albizia,Mahogany,Sissu	1.50	0.00	2
210. Eucalyptus,Teak	1.50	0.00	1
211. Manimaruthu,Spathodea	1.41	0.00	1
212. Delonix,Mahogany	1.36	0.00	3
213. Mahogany,Rain tree	1.28	0.00	1
214. Acacia,Karimaruthu,Manimaruthu	1.20	0.00	1
215. Casuarina,Neem	1.00	0.00	1
216. Jack,Mango,Misc.,Neermathalam,Nelli,Pera	1.00	0.00	1
217. Acacia,Cashew,Casuarina,Mahogany,Nelli	1.00	0.00	1
218. Acacia,Mahogany,Matti	1.00	0.00	1

219.	Delonix,Mahogany,Misc.,Rain tree	1.00	0.00	1
220.	Acacia,Casuarina,Mahogany,Peltophorum	1.00	0.00	1
221.	Casuarina,Poomaruthu	0.95	0.00	3
222.	Acacia,Jack	0.80	0.00	2
223.	Acacia,Cashew,Delonix,Jack,Peltophorum, Tamarind	0.76	0.00	1
224.	Anjily,Cashew,Mahogany	0.71	0.00	1
225.	Mahogany,Misc.,Neem,Poomaruthu	0.60	0.00	1
226.	Delonix,Jack,Maruthu,Matti,Misc.,Tamarind	0.60	0.00	1
227.	Acacia,Delonix,Jack,Misc.	0.60	0.00	1
228.	Casuarina,Delonix	0.56	0.00	1
229.	Rose wood	0.54	0.00	1
230.	Poola,Veeti	0.54	0.00	1
231.	Casuarina,Matti,Neem	0.52	0.00	2
232.	Badam,Mahogany,Peltophorum	0.50	0.00	1
233.	Acacia,Mahogany,Poomaruthu	0.50	0.00	1
234.	Acacia,Delonix,Jack,Mango,Tamarind	0.50	0.00	1
235.	Casuarina,Peltophorum	0.50	0.00	1
236.	Albizia,Casuarina,Poomaruthu	0.50	0.00	1
237.	Mahogany,Rain tree,Sissu,Vellappine	0.50	0.00	1
238.	Acacia,Casuarina,Delonix,Jack,Mandaram, Manimaruthu	0.40	0.00	1
239.	Acacia,Delonix,Jack,Mango	0.30	0.00	1
240.	Delonix,Mahogany,Rain tree	0.30	0.00	1
241.	Delonix,Neem	0.25	0.00	1
242.	Acacia,Casuarina,Delonix,Jack	0.25	0.00	1
243.	Acacia,Casuarina,Jack,Mahogany	0.25	0.00	1
244.	Peltophorum,Teak	0.25	0.00	1
245.	Acacia,Casuarina,Jack	0.25	0.00	1
246.	Acacia,Delonix,Jack	0.25	0.00	1
247.	Mahogany,Sissu,Vellappine	0.25	0.00	1
248.	Casuarina,Manimaruthu	0.25	0.00	1
249	.Casuarina,Jack,Mahogany	0.23	0.00	1
250.	Acacia,Anjily,Mahogany	0.20	0.00	1
251.	Jack,Mango,Maruthu,Matti,Tamarind	0.20	0.00	1
252.	Acacia,Mahogany,Venga	0.20	0.00	1
253.	Casuarina,Rain tree	0.20	0.00	1
254.	Albizia,Anjily,Matti	0.20	0.00	1
255.	Acacia,Cashew,Delonix,Jack	0.20	0.00	1
256.	Mahogany,Neem,Peltophorum	0.20	0.00	1
257.	Acacia,Cashew,Casuarina,Jack	0.18	0.00	1
258.	Acacia,Albizia,Subabul	0.11	0.00	1
259.	Casuarina,Matti,Thanni	0.10	0.00	1
260.	Badam,Casuarina,Mahogany	0.10	0.00	1
261.	Cashew,Jack,Mango,Nelli	0.10	0.00	1
262.	Acacia,Casuarina,Peltophorum	0.09	0.00	1

263.	Casuarina,Poomaruthu,Thanni	0.05	0.00	1
264.	Cashew,Jack,Mango	0.00	0.00	1
265.	Badam,Jack,Mahogany	0.00	8.00	1
266.	Badam,Rain tree	0.00	0.50	1
267.	Jack,Mahogany,Mango	0.00	2.00	2
268.	Acacia,Mango	0.00	12.00	1
269.	Casuarina,Delonix,Peltophorum	0.00	1.50	1
270.	Acacia,Mahogany,Teak	0.00	0.00	1
271.	Cashew,Delonix,Jack,Peltophorum,Tamarind	0.00	4.00	1
272.	Anjily,Mahogany,Red sandal	0.00	0.00	1
273.	Bottle brush,Manimaruthu	0.00	3.00	1
274.	Delonix,Kanikonna	0.00	0.00	1
275.	Delonix,Jack,Mango	0.00	5.00	2
276.	Delonix,Jack,Mango,Manimaruthu,Tamarind	0.00	4.00	1
277.	Delonix,Jack,Mango,Maruthu	0.00	8.00	1
278.	Acacia,Casuarina,Neem,Vaka	0.00	2.00	1
279.	Delonix,Mahogany,Peltophorum	0.00	0.00	1
280.	Delonix,Mango,Manimaruthu,Tamarind	0.00	5.00	1
281.	Delonix,Mango,Rain tree	0.00	19.70	5
282.	Sarpagandhi	0.00	1.00	1
283.	Delonix,Neem,Peltophorum	0.00	12.50	5
284.	Badam,Jack,Mahogany,Mango,Misc.,Neem	0.00	10.00	1
285.	Acacia,Albizia,Jacaranda	0.00	20.00	1
286.	Acacia,Albizia,Elengi,Mahogany	0.00	1.10	1
287.	Acacia,Albizia,Delonix,Mahogany	0.00	0.00	1
288.	Yellow cassia,Mahogany,Poomaruthu	0.00	2.50	1

Appendix 3. Socio-economic aspects

Contents

Abstract

A survey was conducted among the people who live near the plantations to know their response regarding the species selection. About 80 to 85 per cent of the people who psrticipsted in the survey informed that the species selected conformed to their needs.

1. Introduction

The failure of traditional forest management to meet the growing demands for forest products especially fuelwood, small timber, and fodder resulted in the introduction of Social Forestry Programme in Kerala. Social Forestry is the creation of sustainable forest resources far the people, by the people, with Government support

(Tewari, 1991). In this scheme, trees are grown mostly in degraded forest areas and on lands outside forest areas. Hence, It is an effort to take forestry out of Forest Department to the people and therefore, it solicits active participation of the people. The participation of the people in Social Forestry Programme can be obtained only if it fulfills its objective of meeting the basic needs of the people. In this context, selection of species plays a very importent role. An attempt is made in this section to examine whether the species selected for block plantations conform to the needs of the people. Similar study in respect of farm forestry aspects is not inclcded in the term of reference and hence not attempted.

2. Materials and methods

Rapid appraisal, one of the recent methods in analyzing socio-economic problems in forestry, is used to assess whether the species selected conform to the needs of the people. One advantage of this method is that it can generate quantitative data in a shcrt period. The following tools of rapid appraisal were used to gather data.

i. Questionnaire interviews of individuals and households near the plantations

ii. Group interview among the people living near the plantations

iii. Direct observations at site level

iv. Use of secondary data

The plantings were made under the Social Forestry Programme in all the 14 Districts in the State. Broadly, the block plantations can be grouped into large block plantations in degraded forest areas and failed plantations, small block plantations in Institutional lands and strip plantations along canal banks, railway line sides, Coastal areas facing the sea and road-sides. The district-wise lists of plantations were prepared from the records of Social Forestry Department which formed the basis of selection of plantations for site observation and questicnnaire survey In each district, one each of large block plantation, small block plantation and strip plantation was selected at random and people living nearby were interviewed. Using questionnaire, information regarding species conformity to the needs of the people was gathered from **20** persons from each district.

Group interview among the people living near the plantations was anothar toel We used to gather data. The data generated in the group interview scpplemented that of questionnaire survey. Each group consisted of **20-25** persons and about **20** group interviews, at least one in each district in the State, had been carried out.

3. Results and discussion

3.1. Selection of species

Since 1980, Kerala has been faced with severe shortage of fuel wood and timber which are required both by households and industries, partly because of increase of demand and partly due to decline of supply of timber from forests (Muraleedharan *et al., 1984).* The stoppage of clearfelling during early 1980's and subsequent ban on selection felling announced by the Government still reduced its supply. Although the Social Forestry Programme has a number of objectives, the overriding one is that of production of fuelwood and small timber within a short time spsn. Thus, people preferred species which produce more biomass, and are relatively fast growing with multiple uses.

Initially, the Forest Department raised and supplied the seedlings of more than 70 species for raising plantations under Sccial Forestry Scheme and later they restricted this to around 20 species. Table 29 gives information regarding the percentage distribution of the saplings of different species from 1986-87 to 1989-90. One important point to be mentioned here is that, during the early years of the programme, eucalypts were planted very extensively in Kerala. Considering the criticism raised by the environmentalists, the planting of eucalypts and *Acacia auriculiformis* was restricted recently in the State. However, these formd two of the fccr major species that have been planted in Kerala, the others being *Casuarina equisetifolia* and *Grevillea robusta.* The discussions on whether the species selected conform to the needs of the people is confined to above four species.

Table 29. Percentage distribution of saplings of different species under Social Forestry Programme in Kerala

Name of species	1986-87	1987-88	1988-89	1989-90
Ailanthus triphysa	25.10	24.52	28.43	21.50
Casuarina equisetifolia	20.00	6.66	7.07	8.80
Acacia auriculiformis	10.00	8.58	0.76	-
Eucalyptus spp. (*E.grandis and E.tereticornis*)	2.00	1.54	0.14	-
Tectona grandis	5.00	3.54	6.03	19.70
Leucaena leucocephala	3.00	2.60	1.78	0.90
Swietenia macrophylla	3.00	4.38	7.03	8.80
Grevillea robusta	4.00	7.19	14.54	23.10
Fruit bearing species	6.00	5.41	12.69	9.50
Flowering and other miscellaneous species	21.90	35.57	21.52	7.70
Total	100.00	100.00	100.00	100.00
Total saplings distributed (10^6 nos.)	126.84	91.29	107.75	17.73

Source: (Basha , 1991)

Acacia auriculiformis, commonly known as wattle, is a fast growing and drought resistant species with a fairly deep and spreading root system. The heart wood is hard and durable and is used for a variety of purposes such as agricultural implements, construction of small houses, etc. It is extensively used as fuelwood. The calorific value of the wood ranges from 4800 to 4900 kcal kg^{-1} (Turnbull (1986)).

Casuarina equisetifolia, is generally planted in coastal areas. Under favourable conditions, the tree attains a height of 30 m and a girth of 1.5 m. It is extensively cultivated for fuel and the calorific value of the wood is estimated to be 4950 kcal kg^{-1}. The wood is utilized for a variety of purposes.

Eucalyptus grandis is a fast growing species and can be harvested in a period of 7 to 8 years. It is a fairly hardy species and is grown under adverse weather conditicns. The wood is used for making pulp and paper. This species, with a calorific value of 4814 kcal kg^{-1}, is also treated as a good fuelwood.

Grevillea robusta is a native of Australia. It is propagated through seeds, grows fairly faster in apprcpriate sites. It is resistant to drought and is suitable for degraded areas. Grevillea is a good fuelwood with a calorific value 4914 kcal kg^{-1}. This species is reported to be suitable for packing heavy mechineries, construction and pulp and paper. The leaves of the tree are good as manure.

There are certain common features to the above mentioned species. They are exotic, fast growing and drought resistant with fairly deep root systems. Their wood is useful as small timber, fuelwood and pulpwood. The leaves of some of these species are also valued as green manure. Further the plantations of these species are found to be a success in Kerala as the survival rate is as high as 80 per cent in the initial years and potential productivity of these species, except *Grevillea robusta,* ranges from 12 to 20 t ha^{-1} yr^{-1} in 5.5 to 7.5 years.

One of the assumptions of the Social Forestry Programme is that the villagers at the micro level would be consulted to get a true picture of their requirements at the time of implementation of the project. But this is rarely practiced in Kerala. Generally, the species selected are planted by the Forest Department, in the case of block plantations and common people have no say in it except for working as labourers. An attempt is made here to examine whether people feel that the species selected conform to their needs.

3.2. Socio-economic conditions of the informants

The selected plantations were mostly located in village and semi urban areas and therefore, the informants were mostly from such areas. The percentage distribution of informants acccrding to socio-economic conditions is presented in Table **30.** The selected informants could be grouped into (i) Backward cammunities (54 per cent), (ii) Christian

Table 30. Percentage distribution of informants according to Socio-economic conditions (Questionnaire survey and group interview)

Item	Percentage
Caste status	
Backward	54
Christian	15
Muslim	22
Caste Hindus	9
Monthly income (family)	
< 1000	38
1000-2000	42
2000-3000	20
Education	
Primary	30
Middle	42
Secondary	10
College	18
Occupation	
Wage labour	57
Self employment	28
Other (including Govt.service)	15
Type of fuel used for cooking	
Fuelwood	84
Fuelwood + LPG	16
Source of fuelwood	
House compounds	38
Forests	15
Social Forestry Plantations	20
Market	27

(15 per cent), (iii)Muslim (?? per cent) and (iv) Caste Hindus (9 per cent). Wage labour is the main source of income of the majority of the people (57 per cent). About 38 per cent of the informants had a family income less than Rs 1000 per month, 42 per cent between Rs 1000 and **2000** per month, and the rest had more than Rs 2000 per month. While 84 per cent of the informants used fuelwood including coconut waste for cocking and heating, the rest used LPG, in addition to fuelwood. House compound is the major source of fuelwood to 38 per cent of the informants, and Social Forestry plantations and forest provided firewood to 20 per cent and 15 per cent respectively. The rest purchased firewood from the market.

3.3. Distribution of benefits

The plantations raised under the Social Forestry Programme in Kerala are yet to attain full growth for harvesting. However, pruning and thinning have been carried cut in many places in the State. The State Forest Department and the donor agency have framed norms and procedures for distribution of products of the Social Forestry plantations. Those who have income below Rs 1000 per annum are selected as the beneficiaries for receiving fuelwood and other materials from pruning at free of cost. The products from thinning and harvesting will be distributed as per the following procedure (Basha, 1991).

i. All poles and 75 per cent of the fuelwood will be sold in public suction.

ii. The balance 25 per cent of the fuelwood will be sold to the local people at 75 per cent of the auctioned price.

iii. The lops and other left over materials will be distributed ta the beneficiaries at free of cost.

The selected informants are not aware of these norms procedures of distribution of benefits cf the Social Forestry plantations. However, they believe that the SocialForestry Programme would benefit them as it would provide employment to the people and augment the supply of timber resources in the State.

3.4. Species conformity : people's response

Deforestation hss been a regular phenomenon in Kerala for the last many decades· The annual rate of deforestation in the State, for instance, was estimated at about 15,000 ha during 1970's (State Planning Board,1989). Partly because of deforestation and partly due to large scale extraction of timber from, house compounds in the previous years, the inflow of timber and firewood now to the market has significantly declined. The people who participated in the interview and group discussion informed that the price of firewood has almost doubled during the last five years. Exploitation of trees from the hill slopes and from,house compounds in the highland areas of the State has brcught about a variety of ecological problems such as loss of top soil, greater surface evaporation, reduced moisture contents in the soil and poor recycling of soil nutrients (Nair, 1988). The species conformity has beer: evaluated on this background.

What,is the response of the people towards species selection? **Do** they think that the species selected conform to their needs ? Interestingly, all informants supported the Social Forestry Programmes. But they differed in their species choice. Broadly, they could be grouped into two. While the first group which constituted about 85 per cent of the informants think that the species selected conform to the needs of the people, the second group argues for planting of conventional tree crops. The major arguments of these two sets of people can be summarized in the following.

Group

i Major species planted are fast growing and early maturina with multiple uses such as small timber, firewood and leaves for green manure. The fast growing species are essential for augmenting the supply of fuelwood within a short period.

ii. Harvesting of Social Forestry plantations would increse the supply of fuelwood and timber thereby lowering the price now prevailing in the market.

iii Species such as *Acacia auriculiformis* and *Casuarina equisetifolia* are deep rooted and therefore help to prevent soil erosion, especially in the hilly tracts.

Group II

i. The planting of conventional tree crops such as mango, jack, etc. would give more income, fuelwood and timber in the long run.

ii. Such species do not pose any environmental problems or health hazards as in the case of exotics. Further, they are more suited to our ecological and climatic conditions.

As mentioned earlier, group discussions were carried out in many parts of the State. Arguments raised in the questionnaire interview were put for group discussion. About 70 to 80 per cent of the people who participated in the discussion informed that the fuelwood crisis in the State could be solved only by planting more fast growing species. Thus, the resultof the group discussions matches with that of the questionnaire survey. Field observations in the Socia1 Forestry plantations raised in denuded areas had clearly indicated that the plantings had enhanced moisture and nutrient level of the soil. The farmers living near the plantations informed that availability of green manure has increased in their localities due to the Social Forestry plantations. Thus, 70 to 80 per cent of the people consider that the species selected in the Social Forestry Programme conform to their needs.

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Appendix 4. Utilization aspects

Contents

Abstract

Sawn timber output of 7-year-old *Acacia auriculiformis* was determined. It increased from 36.4 per cent for smaller girth (30-45 cm at breast-height) trees, to 43.3 per cent for medium girth (45-60 cm) trees and 48.1 per cent for bigger girth (> 60 cm) trees. The average sawn timber volume of a bigger girth tree (0.124 m^3) was nearly twice that of a medium girth tree (0.066 m^3) and nearly four times that of a smaller girth tree (0.034 m^3).

Strength values of 7-year-old *Acacia auriculiformis* were very low compared to that of 9- and 14-year-old material reported earlier. As

age plays an important role , if strength is a criterion one should choose wood from at least 10-year-old trees.

1 . Introduction

Out of about 70 species planted under the Social Forestry Programme, the major species are *Acacia auriculiformis, Eucalyptus* spp. , *Grevillea robusta* and *Casuarina equisetifolia.* Adequate information on the uti lization aspects is available i n the literature on the above speciesexcept for *Acacia auriculiformis.* As per the terms of reference, this study was limited to only *Acacia auriculiformis*

As *Acacia auriculiformis* fixes nitrogen, it is able to thrive even on infertile soils. Becuase cf this, it is generally included in the afforestaticn and fuelwood production programmes in many countries. Besides firewood, this species is cpable of producing a large quantity of litter. One study indicated that annual fall of leaves, twigs and branches can amount to 4 tc 6 t ha^{-1} (NAS, 1983). A detailed study carried cut in the Institute has shown, that the annual litterfall alone amounted to 9.3, 11.0, 12.0 and 12.0 t ha^{-1} (oven-dry weight basis) at 3, 4, 5 and 5 years of age respectively (Sankaran *et al.,* 1992). A major part of it supplements the fuel needs of the households near these plantations. Estimates of dry matter obtained from other parts of the tree at these ages have been given in earlier sections of this report.

Studies conducted elsewhere have shown that it has potential for a wide range of uses. Rajan *et al.* (1979) tried the wood of *Acacia auriculiformis* for carving and lacquer work for toys and found it to be suitable and that it could replace *Wrightia tinctoria* for the purpose. Keating and Bolza (1982) also found that it was easy to work and finished well. This could be attributed to its medium to fine texture and straight grain (Chomcharn, et **al.**, 1986; Keating and Bolza, 1982).

Kumar *et al.* **(1982)** evaluated the physical and mechanical properties of 14-year-old Karnataka-grown trees. They classified *Acacia auriculiformis* as very heavy extremely strong, moderately tough and extremely hard. The results of their study indicated that the wood was suitable for turnery, furniture, joinery, flooring, construction timber and tool handles. This agrees with the potential uses of *Acacia auriculiformis* arrived by Chomcharn *et al.* (1986) for 13-year-old plantation-grown trees in Thailand.

Shukla *et al.* (1990) tested the wood from 9-year-old trees raised as plantation in Bihar for physical and strength properties. In general, wood from Bihar had lower strength values in comparison to that of Karnataka. This could be attributed to the difference in age of the tree.

The kiln drying schedule of acacia wood has been worked out by Ananthanarayana *et al.* (1988). Keating and Bolza (1982) noted that the wood must be dried with csre and that the boards tended to split when sawn. Chomcharn et *al.* (1986) determined the extent cf defects like bow, spring and split during drying.

In Kerala, the rotation age of *Acacia auriculiformis* has been proposed as seven years, mainly to meet the needs of fuelwood requirement. No report is available in the literature as to the suitability of wood from 7-year-old trees for other uses for which rood from older trees (13- or 14-year-old) have been found suitable, like turnery, furniture, joinery, etc.

Also no work has been reported in the litereture on the sawn timber output one could get **out** of *Acacia auriculiformis.* In general, this species has a crooked stem form and one is interested to know how this sffects the sawn timber output. This study was taken up with the view to determine sawn timber cutput of stem (non-firewood) portion of *Acacia acriculiformis* and also to generate data on strength properties to arrive at the utilisation potential of rood from 7-year-old trees.

2. Materiel and methods

2.1. Sawn timber output

A representative 7-year-old large block plantation at Chettikulam of Chalakudy Forest Range, Trichur Forest Division was chosen for the study. The plantations had about 75 per cent stocking. As there was wide variation in the girth of the trees, trees were cstegorised into three classes: smsller girth (30-45 cm at breast-height); medium girth (45-60 cm) and bigger girth (>SO cm). More or less straight-boled trees were chosen and nine trees under each girth class were felled. Only round wood (upto minimum girth of **20** cm) was taken for the study. The stem was cross-cut to convenient lengths so as to minimise crooks in the bole. Length and mid-girth of these legs were measured to get the round wood volume.

The logs were sawn in such a way to get maximum amount of 50 mm thick scantlings of variable widths and then 25 mm thick planks. These two thicknesses were chosen because of their maximum utility in joinery and furniture. The sawn sizes were measured and volume determined. Sawn timber output was determined as the ratio of sawn timber volume to round wood volume.

2.2. Strength properties

About 0.5 m long billets were taken fromthe butt logs. As the growth rate of the trees varied widely, as reflected in girth, it was decided to include trees of all the girth classes. The butt logs of 10 trees were sawn to get samples of 30 mm x 30 mm cross-section from, the outer zone, close to the bark. After air-drying the samples to about 12 per cent moisture content, the sampleswere sized to **20** mm x

20 mm. Clear specimens (cne from each log) of 300 mm length for bending test and of 80 mm length for compression test were taken. Strength tests were carried out in a 'Amster' Universal Testing Machine as per the Indian Standard IS: 1708(Bureau of Indian Standards,1986).

2.3. Workability

It was decided to see whether the wood from 7-year-old trees was suitable for turnery, furniture, joinery, etc. Wood has been kept for air-drying. Once it is properly dried, attempts will be made to make different items of furniture and joinery. For want of time, this was not possible during the project period.

3. Results and discussion

3.1. Sawn timber output

Data on girth, round wood length and volume, sawn timber volume and output of smaller, medium and bigger girth trees are giver: in Tables 31, 32 and 33 respectively.

Round wood bole length varied from 5.55 m ts 14.65 m. Top height of 7-year-old trees, of site quality I,II and III, as reported by Jayaraman and Rajan (1991) was 16.53 m, 14.62 m and 12.67 m respectively. The average round wood length of all the three girth classes did not vary much - it ranged from 9.84 to 10.47 m.

In general, sawn timber output increased with the girth class.

Table 31. Sawn timber output data of smaller girth (30-45 cm) trees

Tree no.	Gbh (cm)	Length of round wood (m)	Round wood volume (m^3)	Sawn timber volume (m)	Sawn timber output (%)
12	39.0	9.60	0.0807	0.0238	29.5
15	34.5	8.55	0.0684	0.0301	44.0
16	40.5	11.05	0.1028	0.0417	40.6
18	40.5	10.80	0.0948	0.0441	46.5
19	35.0	9.15	0.0683	0.0244	35.7
23	34.0	7.60	0.0637	0.0184	28.8
24	40.0	11.45	0.1139	0.0397	34.8
26	41.0	12.80	0.1032	0.0378	36.6
27	40.0	13.25	0.1313	0.0415	31
Mean	38.3	10.47	0.0919	0.0335	36.4

Table 32. Sawn timber output data of medium girth (45-60 cm) trees

Tree no.	Gbh (cm)	Length of round wood (m)	Round wood volume (m^3)	Sawn timber volume (m^3)	Sawn timber output (%)
02	53.5	14.65	0.2250	0.0934	41.5
03	51.0	10.45	0.1616	0.0608	37.6
28	56.0	10.15	0.1564	0.0791	50.5
29	48.0	9.00	0.1237	0.0557	45.0
30	53.5	10.65	0.1829	0.0657	35.9
31	51.5	10.55	0.1164	0.0536	46.0
32	55.0	10.15	0.1695	0.0641	37.8
40	59.5	7.45	0.1289	0.0640	49.7
42	59.0	5.55	0.1133	0.0601	53.0
Mean	54.1	9.84	0.1531	0.0663	43.3

Table 33. Sawn timber output data of bigger girth (>60 cm) timber

Tree no.	Gbh (cm)	Length of round wood (m)	Round wood volume (m)	Sawn timber volume (m3)	Sawn timber output (%)
22	68.0	10.00	0.2456	0.1052	42.8
33	61.0	13.15	0.2728	0.1192	43.7
35	66.5	5.85	0.1511	0.0750	49.6
38	79.0	9.45	0.3378	0.1714	50.7
41	76.5	9.25	0.2390	0.1226	51.3
45	72.0	10.80	0.2774	0.1459	52.6
46	66.5	10.05	0.2269	0.1038	45.8
47	78.0	10.65	0.3056	0.1422	46.5
48	67.5	9.75	0.2605	0.1288	49.4
Mean	70.6	9.88	0.2574	0.	48.1

Sawn timber output of smaller girth trees was only 36.4 per cent. It increased to 43.3 per cent for medium girth trees and to 48.1 per cent for bigger girth trees. Each group differed from each other in sawn timber output significsntly.

The smsller girth trees had large number of knots compared to that of other girth classes. Even though sawn timber output is 36.4per cent, useful timber will be much less.

Sawn timber volume out of a tree varied from 0.018 to 0.044 m^3 for smaller girth trees, from 0.054 to 0.093 m^3 for medium girth trees and from 0.035 to 0.171 m^3 for bigger girth trees.As most of the trees in the plantation are of more crooked bole in comparison to the sampled trees, sawn timber output will be less. Because of this, projection of sawn timber output that can be expected from 1 ha plantation was not attempted.

The average sawn timber volume of a bigger girth tree is nearly twice that of a medium girth tree and nearly four times that of a smaller girth tree. For utilization as sawn timber, the trees should be allowed to attain maximum girth possible. Silvicultural operation like selective thinning should be practiced so that maximum girth can be obtained. If needed, selected trees should be allowed to stand for a longer period, like 10 to 15 years or

3.2. Strength properties

The data on fibre stress at limit of proportionality (FSLP), **modulus** of rupture (MOR), modulus of elasticity (MOE) and maximum crushing stress (MCS) are given in Table 34. The mean values are 30.5 N mm^{-2}, 81.4 N mm^{-2}, 7.99 KN mm^2 snd 44.7 N mm^2 respectively. These values are very low compared to that of 9-year-old material (Shukla *et* al., 1990) and 14-year-old material (Kumar et al., 1987) as shown in Table 35. This indicates that age plays an important role in the strength of *Acacia auriculiformis* Seven-year-old *Acacia auriculiformis* may have adequate strength for furniture but not load-bearing components. If strength is a critericn, one should choose wood from at least 10-year-old trees.

Higher strength and higher sawn timber output can be expected only from older trees. The border trees in a plantation should be allowed to stand for 10-15 years so that the wood could be used for furniture or joinery. The study has shown that Iower age material is weak in strength

Table 34. Strength properties of 7-year-old *Acacia auriculiformis*

No.	Specimen no.	Fibre stress at limit of proportionality N mm^{-2}	Modulus of rupture N mm^{-2}	Modulus of elasticity kN mm^{-2}	Maximum crushing stress N mm^{-2}
1	02. 1	33 3	86.7	6.59	40.40
2	07. 1	25.8	83.9	8.64	44.94
3	15	36.6	77.2	6.52	42.86
4	19	27.5	96.1	11 -78	47.05
5	22-1	26.7	76.8	7.01	44.78
6	24	39.4	54.8	7-31	.04
7	27. 1	31.5	94.5	9. 13	44.41
8	28.1	25.6	61.8	7.05	42.28
9	30. 1	39.0	97.5	6.35	45.64
10	31-1	30.2	84.6	7.55	43.39
Mean		30.5	81.4	7.79	44.68

Table 35. Comparison of strength properties of *Acacia auriculiformis* of different age material

Grown in	Age (yr)	FSLP $N\ mm^{-2}$	MOR $N\ mm^{-2}$	MOE $KN\ mm^{-2}$	MCS $N\ mm^{-2}$	Reference
Kerala	7	30.5	81.4	7.79	44.7	Present study
Bihar	9.5	60.3	94.6	9.72	61.3	Shukla et al. (1990)
Karnataka	14	95.1	144.4	15.74	72.2	Kumar et al.

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