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YIELD FROM *ACACIA AURICULIFORMIS* PLANTATIONS IN KERALA

K. Jayaraman
A.R. Rajan

KERALA FOREST RESEARCH INSTITUTE
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ABSTRACT

The growing stock of *Acacia auriculiformis* plantations raised under the Social Forestry Scheme in Kerala till the year 1986 has been estimated through a stratified two-stage sampling procedure. The first-stage units were plantations whereas rectangular plots formed the second-stage units. Strata were formed based on age (4 to 8 years), species planted (pure and mixture plantations of *Acacia auriculiformis)* and type of plantation (block, strip and avenue). About 10 percent of the existing plantations were covered with proportional allocation of the sampling units among the strata.

Commercial volume (wood $>$ 10 cm girth over bark) of plantations above 4 years of age was estimated to be 0.284 million m^3. Fresh weight of the commercial volume worked out to be 0.296 million t. Air-dry weight of the material which will come to nearly 60 percent of this amount works out to 0.178 million t. Age-class distribution of the growing stock was found uneven.

Provisional volume table and variable density yield table have been prepared for the species. The mean annual volume increment has been found to be maximum at 7 years for all site quality levels within the range of data suggesting a 7 year rotation of maximum volume production. Diameter-height relationship at the tree level has also been established. Stacked wood of 2 m^3 has been found to have a fresh weight of 1.2663 t and an air-dry weight of 0.7598 t after 120 days.

Regional differences in productivity could not be detected due to large within region variation. However, Central Region including Ernakulam, Trichur and Palghat Districts has relatively lesser stocking in terms of volume per unit area.

INTRODUCTION

Acacia auriculiformis A. Cunn. ex Benth. is a leguminuous, nitrogen-fixing tree of the subfamily Mimosoideae. It is a fast growing exotic, adaptable to a variety of environments. It is an ideal firewood and is planted for this purpose in China, India and other parts of Asia. Charcoal is not too heavy and glows well with no smoke or sparks. The species is valued also for its timber and high quality chemical pulp (Turnbull, 1986).

Acacia auriculiformis entered as a major component in Social Forestry Programmes in Kerala since 1980's. The Kerala State which is situated on the South Western part of India has an equable climate with day temperature ranging from 2O^{o}C to 35^{O}C. The mean annual rainfall is about 3,000 mm. Plantations of *Acacia auriculiformis* were raised through out the State both in forest and nonforest environments. A critical appraisal of the current status of these plantations was felt necessary and the present project was primarily formulated with that objective. Very few studies were found reported on biometricaf aspects of the species and the additional objectives complied with the same. A separate section on review of literature is not included here but past works are referred to in appropriate places in the text.

MATERIALS AND METHODS

GROWING STOCK

Data were gathered during January to March 1991 through a stratified two-stage sampling. The list of plantations of *Acacia auriculiformis* and *Acacia auriculiformis* mixed with other species, supplied by the Forest Department formed the sampling frame. Stratification was based on age (4 to 8 years) , species mix (*Acacia auriculiformis* and *Acacia auriculiformis* mixed with other species) and type of plantation (block,strip and avenue). Region was excluded from the stratification scheme since the number of plantations in many strata was less. Instead, species mix was considered for stratification since large differences in stocking were expected due to this factor. 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, 45 m x available width in the case of strips and 300 m in length for avenue plantations. Slight adjustments had to be made in plot size depending upon the local conditions. A sample size of 100 plantations was fixed (roughly 10 percent of the total number of plantations in Kerala) and the same was distributed to the different strata approximately in proportion to the area available in each stratum. 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.

Girth at breast-height (1.37 m from ground level) was recorded for each tree in a plot. Standard rules governing breast-height measurement were followed while making the measurements (Chaturvedi and Khanna, 1982). Observations on site features included nearness to water (near = within 50 m, distant = more than 50 m), nearness to habitation (near = within 1 km, distant = more than 1 km), aspect, slope, soil erosion, illicit felling and pruning.

Felling of sample trees was undertaken in a subset of the plots covering different age groups and types of plantations. The height (total 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 as 10 cm girth over bark. Total fresh weight of billets from each tree was also noted. Material below 10 cm girth including leaves were collectively weighed and later fresh weight of leaves was determined after removing them from the branches.

The estimates of growing stock were developed by first predicting volume and weight of individual trees using diameter at breast-height (see section Allometric Relations), aggregating at the plot level and further using the plot level estimates in the formulae for stratified two-stage sampling involving ratio estimator (Sukhatme and Sukhatme, 1970) . Plot area formed the auxillary variate in the ratio estimator. The prediction error at the plot level has been ignored while working out the variances. In plots where high pruning is carried out for safety reasons such as to avoid trees touching electric wires, the mainstem is usually found cut back to 2 m high stump. Separate equations were run to predict volume and weight of such stumps.

ALLOMETRIC RELATIONS

Different allometric relations at the tree level were established using regression functions. Each of these equations was based on a sample size of 36 trees felled from different parts of Kerala. The equations involved diameter at breast-height (dbh) computed from measurements of girth at breast-height and total height as predictor variables. The range of dbh was from 0.0318 m to 0.4838 m. Total height ranged from 4.9 m to 18 m. Individual tree volume was obtained by aggregating the volume of billets from the tree. Billet volume was calculated using Newton's formula (Chaturvedi and Khanna, 1982) . 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.

Complete felling was undertaken in a plot of size 20 m x 20 m in a block plantation of age 5.5 years at Nilambur. This was done mainly to work out the volume-weight relation and to check the validity of volume table to be prepared. Though the trees were planted at an espacement of 1.5 m x 1.5 m the plot had only 100 trees at the time of felling. The wood above 10 cm of girth over bark was stacked in open in 2 m^3 units. After taking the fresh weight, periodical measurements on weight loss were made restacking the material every time. The observations covered a period of 79 days from 28 February 1991 during which dry season prevailed with negligible rainfall at the site.

YIELD TABLE

The data used for constructing variable density yield table was restricted to those of pure Acacia *auriculiformis* stands from block type of plantations. There were 17 temporary plots which belonged to different age groups and productivity levels.

Crop volume table was established using the following equation (Clutter et al., 1983).

$$E(\ln V) = a + bS + cA^{-1} + d \ln B \tag{1}$$

where V = Volume ($m^3\ ha^{-1}$)

S = Site index with base age of 8 years (m)

A = Stand age (years)

B = Basal area ($m^2\ ha^{-1}$)

E stands for expectation

Site index curves were of anamorphic type using Schumacher functions (Clutter et al., 1983).

$$E(\ln H) = a + bA^{-1} \tag{2}$$

$$\ln S = \ln H + \hat{b}(A^{-1} - A_0^{-1}) \tag{3}$$

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).

$$E(V) = a + bX + cX^2 \tag{4}$$

$$\text{where } X = \frac{H N^{(1/6)}}{10}$$

N = Number of trees (number ha^{-1})

At any age, top height was predicted through equation (3) for a given site index and the expected yield for that age worked out using 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 characterised through the following equation.

$$E(\ln d) = a + b \ln H + c \ln N$$

where d = crop diameter (m)

H, N as defined earlier

Prediction of crop diameter for any given age under a particular site quality and stocking level can be achieved using equations (3) and (5).

FACTORS AFFECTING STOCKING

Factors affecting yield and regional variation in performance were investigated through analysis of covariance. Five broad geographical regions, three types of plantations and four levels of mixed plantations including pure *Acacia auriculiformis* stands were identified as factors. Detailed description of the factors is furnished in Table 1. Regions 1 to 5 go from South to North and their centres are separated roughly by one degree latitude. Plantation age and initial number of seedlings planted in the plot formed the covariates. Both factors and covariates were included concurrently in the analysis and thus the effect of each component is adjusted for the effect of others in the set. Effects of these factors on the commercial volume per unit area were studied. The dependent variable was transformed to square root scale before the analysis (Montgomery and Peck, 1982).

RESULTS AND DISCUSSION

GROWING STOCK

The growing stock in terms of commercial volume (wood $>$ 10 cm girth over bark) of *Acacia auriculiformis* plantations above 4 years of age in Kerala has been estimated to be 2,84,264 m^3. The age-class distribution of the growing stock is reported in Table 2. Largest portion of the total growing stock is available under 4.5 years of age and much lesser portion in other age-classes. Ideally increasing growing stock with increasing age would be preferable for sustainable production. Freshweight of the commercial volume worked out to be 2,96,159 t. Airdry weight of the material which will come to nearly 60 percent of this amount works out to 1,77,695 t. Estimate of the fresh weight of the material less than 10 cm girth over bark including leaves came to 1,59,162 t. Airdry weight of this portion is not relevant because it is usually left at the site to be degraded. The corresponding confidence intervals (CI) are also reported in Table 2. The volume and weight equations used are given under section Allometric Relations. List of plantations selected for the survey is given in Appendix 2 along with certain observations made.

ALLOMETRIC RELATIONS

The equations fitted are reported below. Figures in brackets are standard errors of the estimates. The mean square error (MSE) obtained are given in Appendix 1.

$$\begin{array}{llllll}
\ln V & = & 1.0683 + & 0.8680 \ln D - & 0.3699 (\ln D)^2 & (6) \\
 & & (0.3721) & (0.3460) & (0.0769) & (\text{Adj. } R^2 = 0.9813) \\
\ln W1 & = & 1.1153 + & 0.7880 \ln D & - 0.4053 (\ln D)^2 & (7) \\
 & & (0.4436) & (0.4124) & (0.0917) & (\text{Adj. } R^2 \quad 0.9752)
\end{array}$$

$$\ln W2 = 0.8162 + 1.9535 \ln D \qquad (8)$$
$$(0.2235) \quad (0.0923) \qquad (\text{Adj. } R^2 = 0.9274)$$

$$\ln h = 2.6160 - 0.4007 \ln D - 0.1978 (\ln D)^2 \qquad (9)$$
$$(0.1903) \quad (0.1769) \quad (0.0393) \qquad (\text{Adj. } R^2 = 0.8866)$$

$$\ln V = -1.5898 + 1.9213 \ln D + 1.2317 \ln h \qquad (10)$$
$$(0.9064) \quad (0.1352) \quad (0.2558) \qquad (\text{Adj. } R^2 = 0.9814)$$

where V = Commercial volume of tree (m^3)

W1 = Freshweight of commercial volume (t)

W2 = Fresh weight of wood less than 10 cm girth over bark including leaves (t)

D = Diameter at breast height (m)

h = Total height of tree (m)

The coefficient of In D in the heightdiameter relation is negative because diameter is expressed in meters and so are fractions within the range considered. Equation (6) can be used to predict individual tree volume and thereby stand volume by aggregation. Equation (10) can be used for the Same purpose when measurements on both dbh and height are available on individual trees. The output of equation (6) is given in Table 3. Scatter diagram of tree volume v. gbh is given in Figure 1 along with the graph of the fitted equation.

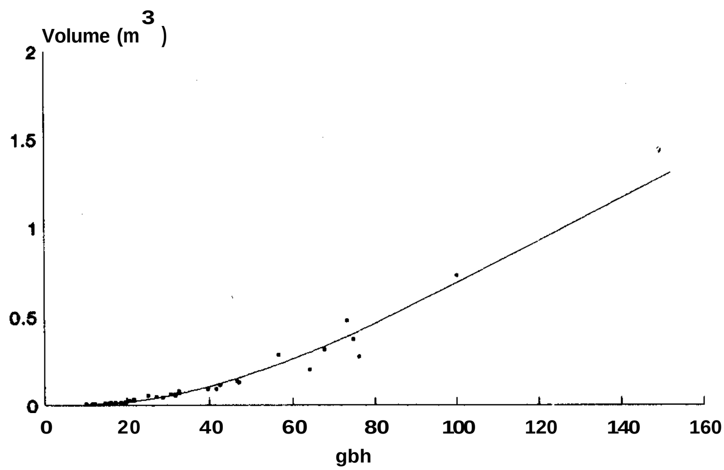

Figure 1. Relation between tree volume and gbh

Results of clear felling undertaken in a plot at Nilambur are given in Table 4. The stacked volume of the wood above 10 cm girth over bark was 7.14 m^3. Thus the conversion factor from stacked volume to solid volume comes to 0.6049. The volume-weight relation works out to be the following.

2 m^3 stacked volume = 1.2663 t (fresh weight)

2 m^3 stacked volume = 0.7598 t (air-dry weight)

The equation leading to air-dry weight was of the following form

$$Y_T = \underset{(0.0320)}{2.7622} + \underset{(0.0287)}{1.7471} \exp(-\underset{(0.0011)}{0.0255}\,T) \quad (11)$$

(Adj. R^2=0.9993)

where Y_T = weight of the stack at time T (t)

T = time elapsed (days)

Adj. R^2 for equation (11) was computed using residuals of the nonlinear regression equation fitted. Equation (11) was established using data from Nilambur and regional variation is expected for the estimates. It can be deduced using equation (11) that it takes about 4 months for a fresh stack of wood to reach air-dry weight. The change in weight of stacked wood over time is depicted in Figure 2.

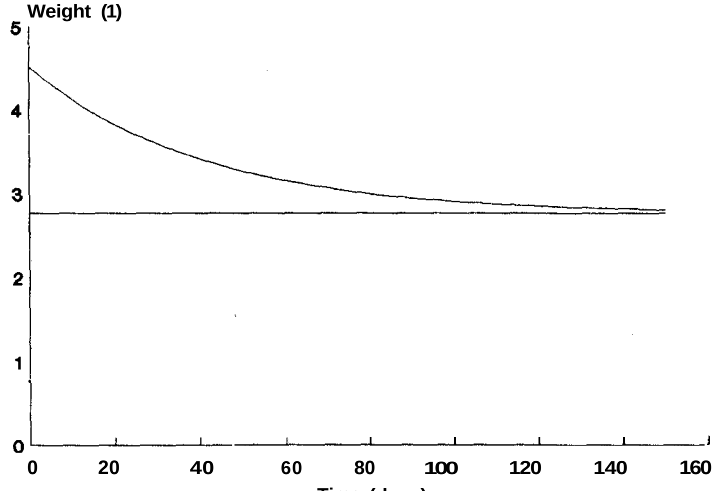

Figure 2. Change in weight stacked wood over time

YIELD TABLE

Site index equations were the following

$$\ln H = 2.8624 - 1.6140\, A^{-1} \qquad (12)$$

$$(0.0978) \quad (0.5144) \qquad (\text{Adj. } R^2 = 0.3560)$$

$$\ln S = \ln H + 1.6140\, (A^{-1} - A_0^{-1}) \qquad (13)$$

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 (12) and (13) can be used to arrive at the expected top height at different years under different site quality levels. Table 5 gives such an output. A graphical display of the contents of Table 5 is given in Figure 3. The site index ranges for the different site quality levels are indicated below. Site index here refers to the expected top height at 8 years.

Site quality	Site index (m)
I	16-t8
II	14 - 16
III	12 - 14

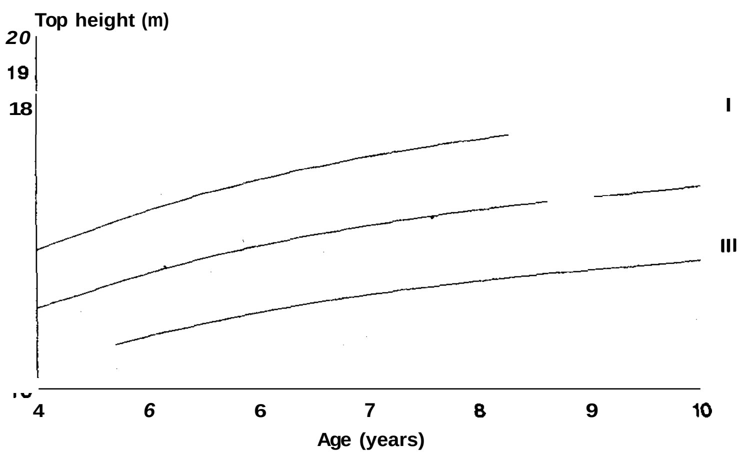

Figure 3 .Top height over age under different site

The equation leading to the crop volume table was the following.

$$\ln V = 0.8029 + 0.1273\ S - 2.9539\ A^{-1} + 0.9082 \ln B \qquad (14)$$
$$(0.1428)\ (0.0093)\ (0.2638)\ (0.0209)$$
$$(\text{Adj. } R^2 = 0.9933)$$

where V = Commercial volume ($m^3\ ha^{-1}$)

B = Basal area ($m^2\ ha^{-1}$)

S, A as defined earlier

Equation **(14)** can be used for explicit prediction of current yield for given site index, age and stand basal area. The output of equation **(14)** is given in Table 6.

For practical purposes stand density is preferable to be expressed in number of trees and *so* an alternative method was followed for constructing yield table. The equation fitted was

$$V = 537.2984 - 275.8150\ X + 38.2018\ X^2 \qquad (15)$$
$$(335.6904)\ (148.5408)\ (16.3270)\ (\text{Adj. } R^2 = 0.7730)$$

where $X = \dfrac{H\ N^{(1/6)}}{10}$

H = Top height (m)

N = Number of trees (number ha^{-1})

The expected yield under different site qualities for different number of trees existing in the stand with varying age are reported in Table **7.** Table **7** has to be used in conjunction with Table 5 where expected top height is reported for different site quality levels with varying age. Mean Annual increment (MAI) curves for different stocking levels are given in Figures **4** to **9** along with the corresponding Current Annual Increment (CAI) curves. The trend in the interval of **4** to **10** years is shown in an expanded scale. Information on the pattern below **4** years is lacking. A typical set of curves for the case of *Cedrus deodara* is shown in Figure **10** for the purpose of reference (Mathur and Ranganathan, **1968).**

Table **7** shows that mean annual volume increment reaches maximum or near maximum at **7** years for all site quality levels and numbers of trees per hectare reported. In certain cases the maximum is attained at **8** years but the successive increments are less than 0.1 m^3 thus not suggestive of a longer rotation age. Figures 4 to **9** confirm this where MAI and CAI curves are seen to meet between 7 and **8** years for the cases considered. This indicates that a rotation age of 7 years is adoptable for the above site quality levels. Gerkens and Kasali **(1988)** had found **7** years as optimum exploitation age for *Acacia auriculiformis* in Bateke Plateau of Zaire.

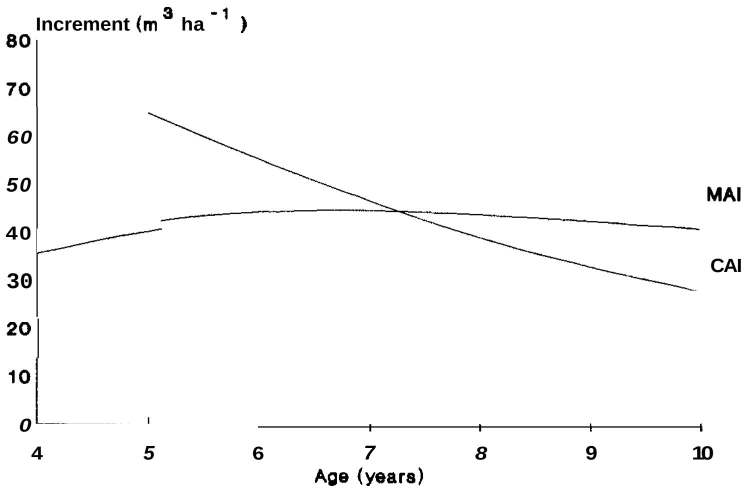

Figure 4. MAI and CAI of commercial volume under site quality I for stand density of 3000 trees/ha

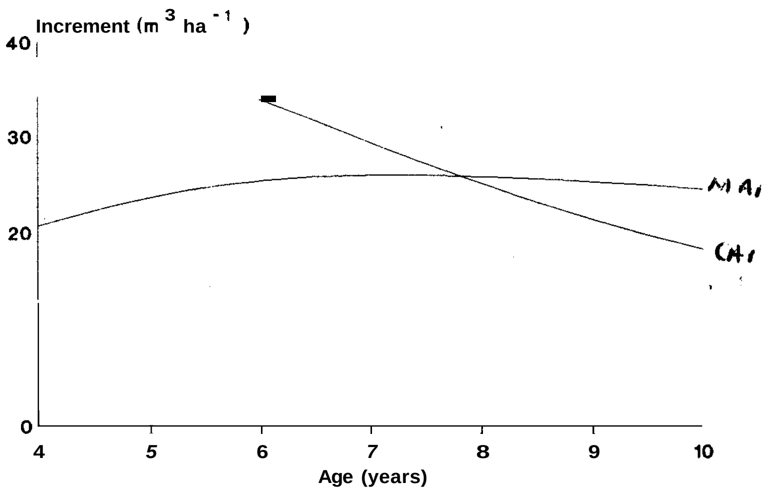

Figure 5. MAI and CAI of commercial volume under site quality II lor stand density of 3000 trees/ha

Figure 6. MAI and *CAI* of commercial volume under site quality III for stand density of 3000 trees/ha

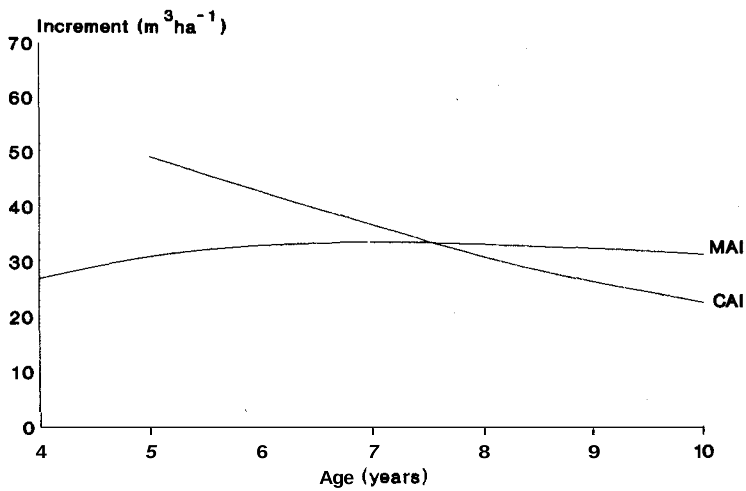

Figure 7. MAI and *CAI* of commercial volume under site quality I for stand density of 2000 trees/ha

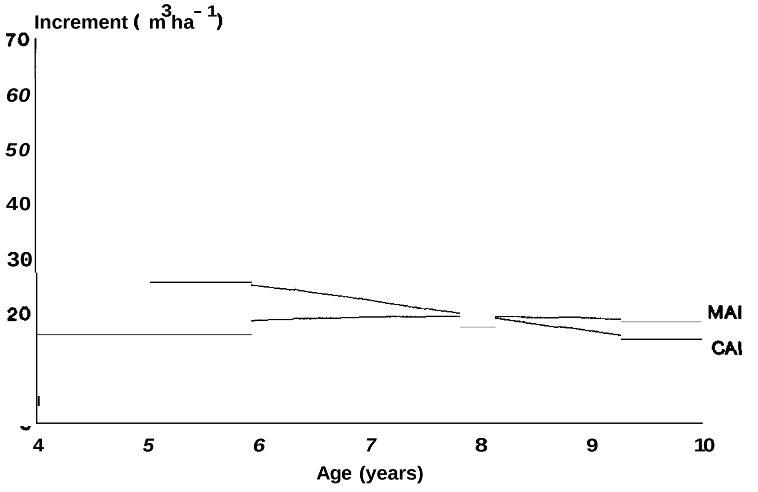

Figure 8. MAI and CAI of commercial volume under site quality II for stand density of 2000 trees/ha

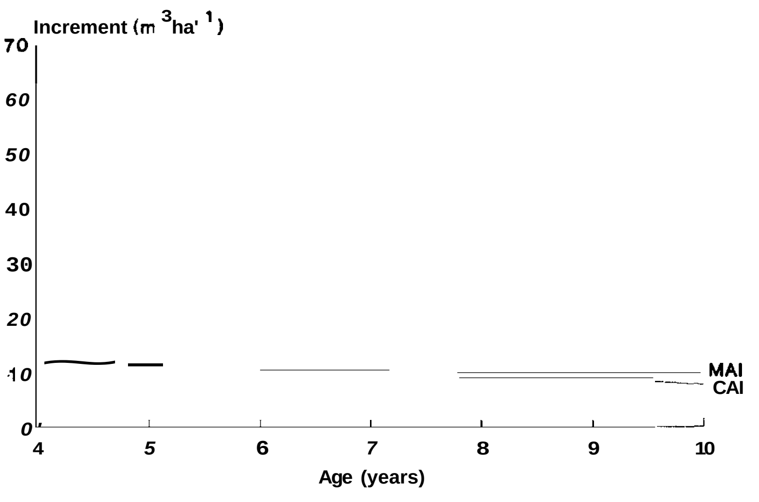

Figure 9. MAI and CAI of commercial volume under site quality III for stand density of 2000 trees/ha

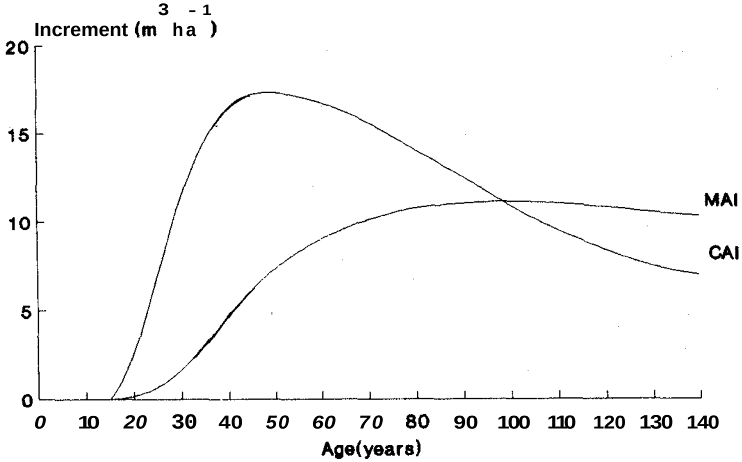

Figure 10. MAI and CAI of stem timber volume under site quality III and C grade thinning for *Cedrus deodara*

Comparison of MAI obtained here with those of other places are not possible in many cases because of the differences in espacement, and utilization limits. Wiersum and Ramlan (1982) reported that on relatively fertile Javanese soils receiving over 2000 mm rainfall, MAI of 15-20 m^3 ha^{-1} is possible but on less fertile or highly eroded sites the increment is reduced to 8-12 m^3 ha^{-1}. The expected MAI at 7 years with 2000 trees per ha at harvest ranges from 10 to 34 m^3 ha^{-1} over poor to good sites in Kerala.

Estimates of parameters in equation (5) were as follows.

$$\ln d = -6.4500 + \underset{(0.2339)}{1.9904} \ln H - \underset{(0.0297)}{0.1572} \ln N \qquad (16)$$

$$(0.7496) \qquad (\text{Adj. } R^2 = 0.9323)$$

where d, H, N are as defined in equation (5).

Expected crop diameter for different age, site quality and stocking levels are reported in Table 7. Diameter growth observed under site quality II with 2000 trees per ha compares well with those reported from Karnataka State with similar stocking levels (Kushalappa, 1991).

FACTORS AFFECTING STOCKING

Variation in performance of a species over different regions or due to differences in site features is usually ascertained through well controlled experiments repeated in different locations. However certain indications on this aspect can be obtained from survey data as well. Some results obtained in this respect under the present study are detailed below.

Effects of the factors considered on the commercial volume per unit area are discernible from Tables 8 and 9. Only a small portion (11.26%) of the total variance is explained by the factors and covariates. The only effect that has turned out significant is number of species planted. The large error component has masked the effect of even the covariates. However an examination of Table 9 shows certain trends. Region 3 which includes dry areas of Palghat District has relatively lesser stocking in terms of commercial volume per unit area. Block plantations in general have larger stocking compared to strips and avenues in spite of the downward adjustment through analysis of covariance of the larger number of trees planted in block type of plantations. Commercial volume of *Acacia auriculiformis* per unit area in mixed plantations is on par with those of pure *Acacia auriculiformis* stands, except when *Acacia auriculiformis* is planted with three or more other species. This is largely due to failure of other species when planted with *Acacia auriculiformis* and subsequent replanting or gapfilling with *Acacia auriculiformis.* Care should be exercised while interpreting the values given in Table 9. For instance a value of 71.284 m3 ha-1 for Region 1 is not to be taken as an indication of the current status of Region 1. It only shows that if Region 2 had 68.277 m^3 ha^{-1} then Region 1 will have 71.284 m^3 ha^{-1}. In other words the values are relative and not absolute. Also such comparisons should be restricted to levels of a single factor and not those of different factors. The adjusted means for levels of any factor in Table 9 is applicable to an average age of 5.8 years with 3800 trees planted initially and averaged over the levels of other factors in the set.

Similar analysis done to find out the effect of certain site features like elevation, nearness to water and habitation, aspect, slope, rainfall, illicit felling and pruning did not lead to any definite conclusions. This has probably occurred since the site features included in the analysis were not exhaustive. Stocking is found affected by many more factors like fire, cattle damage, damage by elephants, soil conditions, application of fertilizers etc. proper recording of which were difficult in practice.

CONCLUSIONS

The age-class distribution of the growing stock of *Acacia auriculiformis* plantations in Kerala is found uneven mostly due to the unequal extent of area planted in different years. If sustainability is intended the distribution is to be brought to normal form with due weightage given to the variation in productivity over sites.

The expected range of MAI as per the observations made which is 10-34 m3 ha^{-1} of commercial volume at 7 years for 2000 trees per ha at harvest gives an impression that Acacia auriculiformis has performed well in Kerala yielding as high or higher when compared to many other parts of the country or the continent

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Table 1. **Levels of factors included in the analysis of covariance**

Factor	Level	Description
Region	1	Trivandrum, Quilon
	2	Alleppey, Pathanamthitta, Kottayam, Idukki
	3	Ernakulam, Trichur, Palghat
	4	Malappuram, Calicut, Wynad
	5	Kasaragod, Cannanore
Type	SB	Small block plantations less than 5 ha of area in social environments
	LB	Large block plantations greater than 5 ha of area in forest environments
	SA	Strip and avenue type of plantations along road-sides
Species	1	Pure acacia stands
	2	Acacia mixed with another species
	3	Acacia mixed with two other species
	4	Acacia mixed with three or more other species

Table 2. **Growing stock of *Acacia auriculiformis* plantations in Kerala**

Age (years)	V (m3)	w1 (t)	w2 (t)
4.5	185,471 (21,097)	190,854 (21,853)	112,588 (12,277)
5.5	38,215 (3,185)	40,255 (3,316)	20,319 (1,820)
6.5	21,295 (10,954)	23,005 (12,640)	8,832 (2,687)
7.5	13,851 (1,966)	14,730 (2,100)	6,389 (928)
8.5	25,432 (1,533)	27,316 (1,656)	11,034 (662)
Total	284,264	296,159	159,162
95 % Confidence Interval on Total			
Lower limit	**236,037**	**244,954**	**133,661**
Upper limit	**332,491**	**347,363**	**184,662**

Note: V = Commercial volume (wood > 10 cm girth over bark)

W1 = Fresh weight of commercial volume

W2 = Fresh weight of wood < than 10 cm girth over bark including leaves

(Figures in brackets are standard errors)

Table 3. Provisional tree volume table for *Acacia auriculiformis*

Gbh (cm)	Volume (m^3)	Gbh (cm)	Volume (m^3)
15	0.006962	90	0.566768
20	0.016558	95	0.623778
25	0.031086	100	0.681790
30	0.050606	105	0.740633
35	0.074956	110	0.800147
40	0.103854	115	0.860191
45	0.136955	120	0.920635
50	0.173894	125	0.981362
55	0.214303	130	1.042265
60	0.257823	135	1.103250
65	0.304113	140	1.164229
70	0.352857	145	1.225125
75	0.403755	150	1.285866
80	0.456537	155	1.346389
85	0.510951	160	1.406637

Note: Use equation (6) for intermediate values with correction factor given in Appendix 1. Predictions of volume outside the range of 15 cm to 152 cm of gbh are extrapolated.

Table 4. Volume and weight of wood from the sample plot at Nilambur

Sl. No.	Characteristic	Actual	Predicted	Equation used
1.	Commercial volume (m3)	4.3192	3.8306	(6)
2.	Fresh weight of commercial volume (t)	4.5210	4.2721	(7)
3.	Fresh weight of wood less than 10 cm girth over bark including leaves (t)	2.1787	2.0005	(8)

Table 5. Top height for dlffrrent age classes of *Acacia auriculiformis*

Site quality	Age (years)	Top height (m)
I	4	13.94
	5	15.11
	6	15.94
	7	16.57
	8	17.05
	9	17.44
	10	17.76
II	4	12.30
	5	13.33
	6	14.07
	7	14.62
	8	15.05
	9	15.39
	10	15.67
III	4	10.66
	5	11.55
	6	12.19
	7	12.67
	8	13.04
	9	13.34
	10	13.58

Table 6. Provisional crop volume table for *Acacia auriculiformis*

Basal area (m^2 ha^{-1})	Site quality	Age (years)	Volume (m^3 ha^{-1})
5	I	4	40.068
		5	46.445
		6	51.251
		7	54.986
		a	57.964
		9	60.391
		10	62.406
5	II	4	31.064
		5	36.008
		6	39.734
		7	42.629
		a	44.938
		9	46.820
		10	48.382
5	III	4	24.083
		5	27.916
		6	30.804
		7	33.049
		8	34.839
		9	36.298
		10	37.509
10	I	4	75.197
		5	87.166
		6	96.185
		7	103.193
		8	108.782
		9	113.338
		10	117.119
10	II	4	58.298
		5	67.577
		6	74.569
		7	80.003
		8	84.336
		9	87.868
		10	90.800
10	III	4	45.197
		5	52.391
		6	57.812
		7	62.024
		a	65.383
		9	68.122
		10	70.394

Basal area (m^2 ha^{-1})	Site quality	Age (years)	Volume (m^3 ha^{-1})
15	I	4	108.676
		5	125.972
		6	139.007
		7	149.135
		8	157.213
		9	163.796
		10	169.262
15	II	4	84.253
		5	97.663
		6	107.768
		7	115.620
		8	121.883
		9	126.987
		10	131.224
15	III	4	65.319
		5	75.715
		6	83.550
		7	89.637
		8	94.492
		9	98.450
		10	101.734
20	I	4	141.125
		5	163.586
		6	180.513
		7	193.665
		8	204.155
		9	212.704
		10	219.801
20	II	4	109.410
		5	126.824
		6	139.947
		7	150.143
		8	158.276
		9	164.904
		10	170.406
20	III	4	84.823
		5	98.323
		6	108.497
		7	116.402
		8	122.707
		9	127.846
		10	132.111

Note: Use equation (14) for intermediate values with correction factor given in Appendix 1. Prediction of volume may be restricted to basal area between 5 to 20 m^2 ha^{-1} and age between 4 to 8 years.

Table 7. Provisional yield table for *Acacia auriculiformis*

Number of trees ha-1	Site quality	Age (years)	Volume (m3 ha-1)	MAI of volume (m3 ha-1)	Crop diameter (cm)
2000	I	4	107.855	26.964	9.1
		5	156.901	31.380	10.7
		6	199.684*	33.281	11.9
		7	236.585*	33.798	12.8
		8	267.265*	33.408	13.6
		9	293.825*	32.647	14.2
		10	316.712*	31.671	14.7
2000	II	4	61.287	15.322	7.1
		5	87.510	17.502	8.3
		6	112.654	18.776	9.3
		7	134.756	19.251	10.0
		8	154.065	19.258	10.6
		9	170.593*	18.955	11.1
		10	185.039*	18.504	11.5
2000	III	4	40.610*	10.153	5.3
		5	48.618	9.724	6.3
		6	59.091	9.848	7.0
		7	69.532	9.933	7.5
		8	79.094	9.887	8.0
		9	87.814	9.757	8.3
		10	95.415	9.541	8.6
3000	I	4	147.793	36.948	8.5
		5	212.505*	42.501	10.0
		6	267.558*	44.593	11.1
		7	314.412*	44.916	12.0
		8	353.046*	44.131	12.7
		9	386.306*	42.923	13.3
		10	414.849*	41.485	13.8
3000	II	4	82.477	20.619	6.6
		5	120.037	24.007	7.8
		6	154.238	25.706	8.7
		7	183.567*	26.224	9.4
		8	208.819*	26.102	9.9
		9	230.228*	25.581	10.4
		10	248.816*	24.882	10.8
3000	III	4	46.797	11.699	5.0
		5	62.482	12.496	5.9
		6	79.156	13.193	6.5
		7	94.623	13.518	7.1
		8	108.279	13.535	7.5
		9	120.459	13.384	7.8
		10	130.916	13.092	8.1

*Prediction outside the range of data

Note: For a given stand, site quality is to be determined based on top height and age using Table **5.** For a given number of trees per ha, assumed or estimated, the volume can be read out from Table **7.** For intermediate values use of equation (15) is suggested. Prediction of volume or crop diameter may preferably be restricted to a stocking range of 2000 to 3000 trees per ha and age between **4** to years.

Table 8. Results of analysis of covariance on commercial volume per unit area (square root scale)

Source	df	SS	MSS	F value
Region	4	55.576	13.894	0.962 (ns)
Type	2	37.778	18.889	1.309 (ns)
Species	3	132.916	44.305	3.070*
Age (covariate)	1	0.023	0.023	0.002 (ns)
NTP (covariate)	1	4.574	4.574	0.317 (ns)
Residual	115	1659.599	14.431	--
Total	126	1870.218	--	--

Note: NTP = Number of seedlings planted
ns = nonsignificant
*indicates significance at P = 0.05

Table 9. Adjusted means for levels of different factors indicating relative values

Factor	Level	Commercial volume (m^3 ha^{-1})
Region	1	71.284
	2	68.277
	3	51.739
	4	63.091
	5	90.307
Type	SB	95.121
	LB	73.668
	SA	47.790
Species	1	69.606
	2	
	3	63.409
	4	28.334

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

Equation number	MSE
(6)	0.05381
(7)	0.07649
(8)	0.13232
(9)	0.01407
(10)	0.05363
(12)	0.00632
(13)	0.00632
(14)	0.00165
(16)	0.00584

Note: **A** correction factor of MSE/2 has to 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.** List **of** plantations selected **for** the survey along with the status

Sl. No.	Division	Range	Plantation	Year of planting	Species	Crop diameter (cm)	No. of plots selected
1	Alleppey	Alleppey	Steel Industries Cherthala	1984	AC	6.9	1
2	Alleppey	Chengannur	Krishnapuram-Kareelakkulangara	1983	MX	27.3	1
3	Alleppey	Chengannur	Railway Land Pln. Cheriyanad	1984	MX	9.1	2
4	Alleppey	Chengannur	IEC Plantation Kollakadavu	1984	AC	12.5	1
5	Calicut	Calicut	Payyoli Court Compound	1986	MX	8.8	1
6	Cannanore	Cannanore	Veliambra	1986	AC	7.8	3
7	Ernakulam	Ernakulam	Thevakkal	1985	MX	21.2	1
8	Ernakulam	Ernakulam	Indian Aluminium Company Eloor	1985	AC	11.4	1
9	Ernakulam	Ernakulam	Veettoor	1986	AC	5.6	2
10	Idukki	Thodupuzha	Pln. at Uloopni Peerumedu	1985	MX	6.3	2
11	Kasaragod	Hosdurg	Nedumkanda Shoping Complex	1985	MX	5.5	2
12	Kasaragod	Hosdurg	Nedumkanda Stove Junction	1985	MX	6.4	2
13	Kasaragod	Hosdurg	Moolakandam-Chalengal	1986	MX	6.6	2
14	Konni(T)	Naduvathum	Manneera	1984	MX	14.7	2
15	Konni(T)	Naduvathum	Neeramkulam	1984	MX	11 9	2
16	Konni(T)	Naduvathum	Appooppanthode	1985	MX	103	2
17	Kottayam	Kottayam	Vaikom Railway Station	1986	MX	6.3	2
18	Malappuram	Malappuram	KSRTC Compound Edappal	1986	AC	5.4	2
19	Malappuram	Malappuram	GLPS Vellila	1986	MX	8.7	1
20	Malappuram	Malappuram	Mankada Govt Hospital	1986	MX	11.6	2
21	Malappuram	Malappuram	GHS Tirur	1986	MX	12.7	1
22	Malappuram	Malappuram	Govt Hospital Purhakkattiri	1986	MX	13.2	1
23	Malappuram	Malappuram	GDHS Tanur	1985	MX	19.0	1
24	Malappuram	Nilambur	MES College Mampad	1982	MX	22.5	1
25	Malappuram	Nilambur	Veliyanthode	1985	MX	8.5	1
26	Nilambur(T)	Karulai	Pulimunda	1985	MX	11.9	3
27	Palghat	Agali	BommiampadiBit No 1 No 2	1986	MX	4.0	4
28	Pathanamthitta	Pathanamthitta	Govt Girls HS Adoor	1986	MX	8.8	1
29	Pathanamthitta	Pathanamthitta	Kulanada (Panchayath Landj	1984	MX	17.8	1
30	Pathanamthitta	Pathanamthitta	Govt LPS Edamuri	1986	AC	11.1	1
31	Quilon	Quilon	Kundara Ceramics Ltd	1984	MX	4.5	2
32	Quilon	Quilon	TS Canal Bank Kochuplammude	1983	MX	19.1	1
33	Quilon	Quilon	Titanium Compound Chavara	1986	MX	7.5	3
34	Quilon	Quilon	Railway Area Mayyanad	1982	AC	0.0	1
35	Quilon	Quiion	Neendakara	1985	AC	8.0	1
36	Quilon	Quilon	TB Hosoital Nedumoana	1986	MX	6.6	3

Cont ...

Sl. No.	Division	Range	Plantation	Year of planting	Species	Crop dia-meter (cm)	No. of plots selected
37	Quilon	Quilon	Fishing Harb. Sakthikulangara	1982	AC	9.1	2
38	Quilon	Quilon	DB College Sasthamkottah	1983	AC	11.2	2
39	Quilon	Quilon	Fishing Area Sakthikulangara	1984	MX	15.4	1
40	Trichur	Chalakkudy	Kannamkuzhy Plantation	1986	AC	6.5	3
41	Trichur	Chalakkudy	Village Ext. Office Amballur	1985	MX	13.4	1
42	Trichur	Trichur	Ollukkara Block Office	1985	AC	6.6	1
43	Trichur	Wadakkanchery	Talikkulam Beach	1986	MX	0.0	1
44	Trichur	Wadakkanchery	Vaniampara Mannuthy II	1983	AC	23.1	3
45	Trichur	Wadakkanchery	Chettupuzha Bridge	1985	AC	13.5	1
46	Trichur	Trichur	Trichur-Nellikkunnu Road	1984	AC	0.0	1
47	Trichur	Wadakkanchery	Wadakkanchery Shornur Road	1983	AC	22.1	1
48	Trichur	Wadakkanchery	Vettikkattiri Mulloorkara	1986	MX	4.4	2
49	Trichur	Chalakkudy	AEO Office Chalakkudy	1985	AC	6.4	1
50	Trichur	Chalakkudy	Chettikkulam Degraded Fórest	1984	AC	8.6	3
51	Trichur	Chalakkudy	Kavanad Plantation	1986	AC	6.5	3
52	Trichur	Chalakkudy	Panampilly College	1983	AC	11.4	2
53	Trichur	Chalakkudy	Vallakkunnu-Nellai Road	1985	MX	21.8	1
54	Trichur	Wadakkanchery	Vaniampara-Mannuthy I	1983	AC	22.2	1
55	Trichur	Wadakkanchery	Trichur-Shornur Road	1983	AC	13.2	1
56	Trichur	Chalakkudy	Appolo Tyres Perambra	1984	AC	11.0	1
57	Trichur	Trichur	Perumkunnu	1986	AC	5.7	2
58	Trichur	Trichur	KAP Cantonment Ramavarmapuram	1985	MX	6.8	2
59	Trichur	Trichur	Children School Ramavarmapuram	1983	MX	9.2	2
60	Trichur(T)	Trichur	Aroormuzhy	1983	MX	15.6	2
61	Trichur(T)	Pattikkad	Moolamkode-Ninnukuzhy	1985	MX	0.0	1
62	Trichur(T)	Trichur	Naduppakkundu	1986	MX	6.5	2
63	Trichur(T)	Peechi	Kuthiran-Anavari	1985	MX	7.6	3
64	Trivandrum	Trivandrum	Pallippuram NH	1984	MX	9.7	2
65	Trivandrum	Trivandrum	RFP Area VSSC Veli	1986	MX	5.3	3
66	Trivandrum	Trivandrum	VSSC Pln. at Rocket Store	1982	MX	5.1	2
67	Trivandrum	Neyyaattinkara	Poovachal HS	1986	AC	4.1	1
68	Trivandrum	Trivandrum	Staff Quarters Kariavattom	1984	MX	5.5	2
69	Trivandrum	Trivandrum	Railway Station Nemom	1983	MX	12.1	3
70	Trivandrum	Trivandrum	Railway Station Kazhakkoottam	1982	MX	10.6	2
71	Trivandrum	Neyyaattinkara	Thannivila Plantation	1986	MX	6.9	2
72	Trivandrum	Attingal	TS Canal Bank Varkala	1983	MX	9.3	2
73	Trivandrum	Trivandrum	Nemom to Amaravila	1983	MX	0.0	1
74	Wynad	Sultan Battery	Karapuzha	1986	AC	7.1	3

Note: AC Acacia auriculiformis MX: Acacia auriculiformis mixed with others