FIXING ROTATION OF MAXIMUM VOLUME PRODUCTION FOR CHIR PINE (PINUS ROXBURGHII) FORESTS OF MURREE

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Introduction

Tree species in a forest exhibit different patterns of growth. Some species may show rapid growth in early life but slow down later while others may follow a reverse pattern. Besides intrinsic growth character of the species, soil, geology, gradient, microclimate etc. and management practices applied to the forest are some of the factors which influence the growth design. Different species thus depict different pattern of growth during their life cycle and as such would need different management approaches and decisions including the fixation of rotation age. Fixation of the felling age of a tree species is primarily a managerial decision depending upon the evaluation of several criteria and options consistent with the prevalent policy. Thus for some species there could be different ages (rotations) at which trees may be felled for specific management objective.

Objective of the Study

To determine the rotation of maximum volume production for chir pine, which is the age at which both CAI and MAI become at par.

Data Collection

Data were collected from 5 mature chir trees scattered in the forests of Murree. Diameter breast height and total height of each tree was measured in the field. Increment cores were taken at breast height from each tree and bark thickness at breast height was determined. The annual growth rings were counted on the increment cores starting from pith outwards. Rings for each decade were grouped and marked on the extracted core. Measurements from pith to successive decades were taken and recorded. Twice these widths provided diameters under bark for 10, 20, 30 years ages. Multiplying these diameters with factor of 1.16 derived for this species (13) diameters over bark were obtained. After plotting diameter breast height over bark against age in years at breast height a smooth and harmonised curve was drawn to fit the data as shown in Fig. I.

Methodology

a. CAI, MAI and Volume equation

The age at which both CAI and MAI become equal is the age for maximum volume pro-uction. At this age the site is being utilized most efficiently. This age is, therefore, impor-

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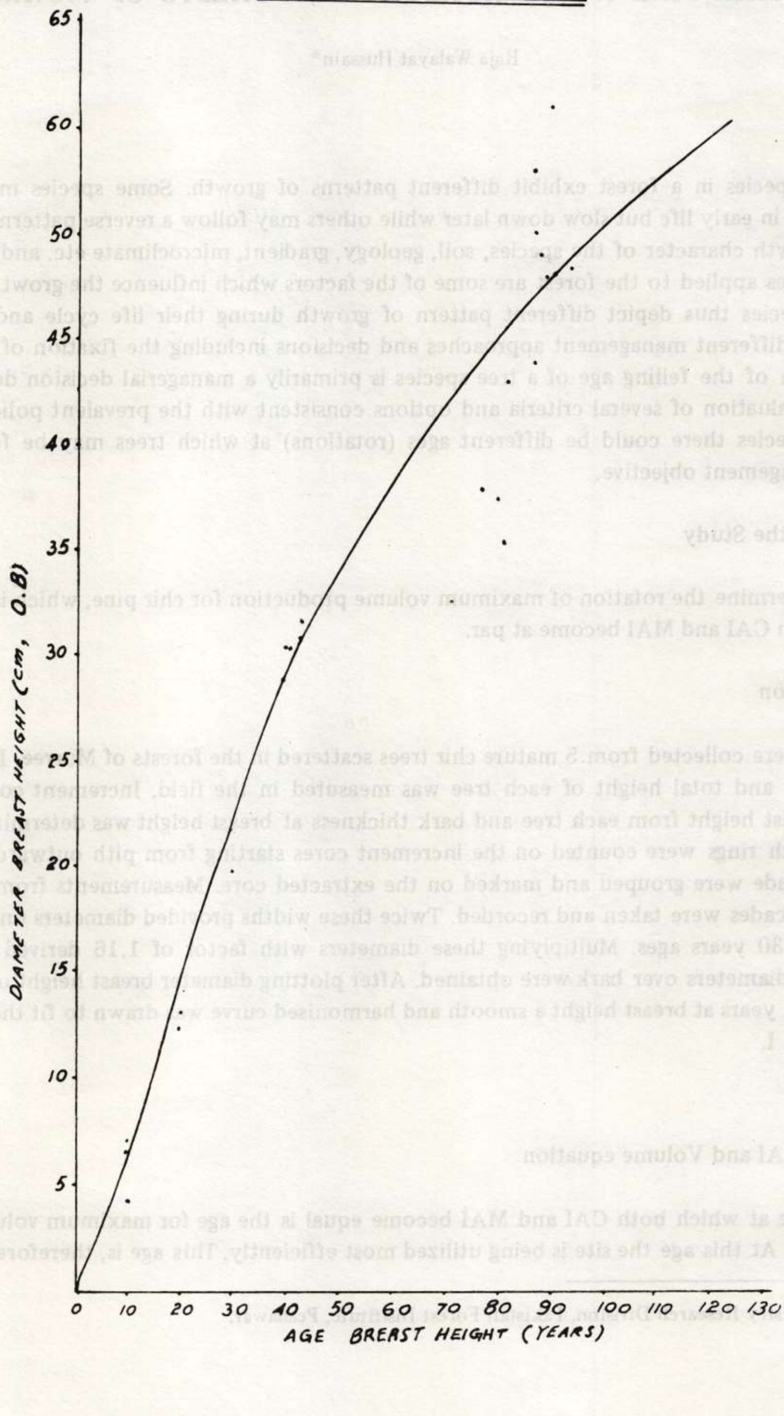
FIG.1 - MURREE CHIR



tant from management point of view. CAI being growth at a particular point of time is obtained by differentiating volume (V) with respect to age (t) and symbolised as $\frac{dV}{dt}$ Whereas MAI is botained by dividing total volume by total age at that point of time and is represented as V/t.

For maximum volume production:

$$\frac{dV}{dt} \text{ (CAI) } = \frac{V}{t} \text{ (MAI)}$$

Mathematical models can be fitted relating volume with age keeping other variables constant (3). To find out which type of mathematical model can best depict the underlying phenomenon of growth following reasoning is given for selection of the best model for estimating volume:

(i) First degree curve can be used i.e. $V = a + bt$ where V is the volume of a tree, t is age, 'a' is Y — intercept when $t = 0$ and 'b' is the slope of the line. The model represents a straight line which obviously does not conform to the law of growth.

(ii) Second degree curve viz; $V = a + bt + ct^2$ can be fitted. Since CAI is its first derivative with respect to t therefore $\frac{dV}{dt} = b + 2\,ct$. The derivative gives equation of a straight line which does not correspond to growth pattern depicted by CAI curve.

(iii) From third degree polynomial of $V = a + bt + ct^2 + dt^3$, CAI will be $\frac{dV}{dt} = b + 2\,ct + 3\,dt^2$. This represents a parabola of second degree and is symmetrical on both sides of the maximum value. CAI curve does not follow this trend of the parabola as it is not symmetrical due to fluctuations in its values.

(iv) A fourth degree polynomial of the form $V = a + bt + ct^2 + dt^3 + et^4$ seems to exhibit the underlying growth phenomenon realistically. However, if 'a' is kept in this equation it means that volume is 'a' when to = 0 which is not in conformity with the law of growth. Therefore removal of 'a' from the equation yields $V = bt + ct^2 + dt^3 + et^4$. Differentiating this with respect to 't' we get CAI = $\frac{dV}{dt} = b + 2ct + 3dt^2 + 4et^3$. Putting $t = 0$, CAI equals 'b' which is not correct. Hence removal of term containing 'b' i.e. bt from the above equation gives $V = ct^2 + dt^3 + et^4$ This equation satisfies all the above criteria and hence is selected for determination of age for maximum volume production.

(b) Determination of rotation for maximum volume production.

The rotation is to be fixed at an age when CAI = MAI. From the above selected equation $V = ct^2 + dt^3 + et^4$ we get CAI = $\frac{dV}{dt} = 2\,ct + 3dt^2 + 4et^3$ and MAI = $V/t = ct + dt^2 + et^3$. Equating CAI and MAI we have $2ct + 3dt^2 + 4et^3 = ct + dt^2 + et^3$ which on simplification gives: $3et^2 + 2dt + c = 0$. This is a quadratic equation giving:

$$t = \frac{-d \pm \sqrt{d^2 - 3ce}}{3e}$$

Value of t can be determind if values of c, d and e are known.

(c) Determination of values of c, d and e.

To find the values of three unknowns i.e. c, d and e three equations are required. Consulting Figure I, diameter breast height are read against age 30, 60 and 90 years. Using local volume table of the species (2) following figures were obtained:

Age (Years)	DBH (cm)	Volume (m^3)
30	22	0.226
60	38	0.975
90	48	1.763

Referring back to selected volume equation i.e. $V = ct^2 + dt^3 + et^4$ we can form three equations by substituting volumes (V) against corresponding ages (t). The equation are:

$$0.226 = c\,(30)^2 + d\,(30)^3 + e\,(30)^4$$

$$0.975 = c\,(60)^2 + d\,(60)^3 + e\,(60)^4$$

$$1.763 = c\,(90)^2 + d\,(90)^3 + e\,(90)^4$$

Solving these equations simultaneously

$$c = 15.84 \times 10^{-5}$$

$$d = 43.02 \times 10^{-7} \quad \text{and}$$

$$e = -0.41 \times 10^{-7}$$

Substituting these values in the above quadratic equation:

$$t = \frac{-d \pm \sqrt{d^2 - 3ce}}{3e} \quad \text{we get}$$

t = −15.1 and 85.9. Ignoring minus value, the age of maximum volume production equals 86 years at breast height. Giving an allowance of 5 − 10 years for the sapling to attain breast height according to site quality the rotation comes to 90 − 95 years.

Working plan officers, researchers and others have drawn similar conclusion regarding reduction in rotation but with different considerations:

(i) Khan (9) critically reviewed the present management of the coniferous forests and recommended reduction on the basis of the production of medium sized industrial wood in a minimum possible time.

(ii) Khan (8) recommended a rotation of 90 years for chir pine on the basis of suitability of 50 cm (20″) DBH.

(iii) Khan (7) recommended an adjustment period of 80 years for chir pine which may be taken as rotation for the present.

(iv) Lerche and Khan (11), on the basis of financial maturity, recommended a rotation of 50 years for chir pine.

(v) Ahmad (1) in consideration of good quality wood of chir pine indicated the best rotation of 90 to 120 years as it attains maximum trachied length during this period.

(vi) Hussain et al. (4,5), in connection with yield table formulation, found 95−100 years as the age for maximum volume production for site quality I and 100−105 years for site quality II for chir pine forests. By this time the trees will attain an average breast height diameter of 48 cm and 50 cm respectively.

Conclusion and Recommendation

Culmination of volume production occurs at the breast height age of 86 years, as shown in Table 1, when both CAI and MAI are equal. After giving allowance for saplings to grow upto breast height the rotation age comes to 90−95 years. By this age the diameter at breast height would be about 50 cm (20″). This age/diameter is most suitable for many purposes/considerations and may be adopted as rotation age for chir pine.

Table 1: Volume (m^3) represented by volume, CAI and MAI equations at different ages of chir pine

Age (years)	Total volume[1] (V) m^3 (10^{-2})	Current Annual[2] Increment (CAI) m^3 (10^{-3})	Mean Annual[3] Increment (MAI) m^3 (10^{-3})
10	1.97	4.30	1.97
15	4.81	7.11	3.21
20	9.13	10.21	4.57
25	15.05	13.46	6.02
30	22.60	16.75	7.53
35	31.78	19.96	9.08
40	42.53	22.96	10.06
45	54.69	25.64	12.15
50	68.09	27.87	13.62
55	82.46	29.53	14.99
60	97.50	30.49	16.25
65	112.82	30.65	17.36
70	127.99	29.87	18.28
75	142.51	28.03	19.00
80	155.83	23.02	19.48
85	167.32	20.71	19.68
86[4]	169.34	19.68	19.69
90	176.30	14.98	19.59
95	182.04	7.71	19.16
100	183.73		18.37

1. $V = 1.584881 \times 10^{-4}\ t^2 + 4.302450 \times 10^{-6}\ t^3 - 4.050055 \times 10^{-8}\ t^4$

2. $\frac{dV}{dt} = 3.169762 \times 10^{-4}\ t + 12.907350 \times 10^{-6}\ t^2 - 16.200220 \times 10^{-8}\ t^3$

3. $\frac{V}{t} = 1.584881 \times 10^{-4}\ t + 4.302450 \times 10^{-6}\ t^2 - 4.050055 \times 10^{-8}\ t^3$

4. **Point of intersection of CAI and MAI is at this age.**

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