VOLUME 115 NUMBER 11

THE

INDIAN FORESTER

NOVEMBER, 1989

UTILITY-BASED PHYSICAL APPRAISAL OF *EUCALYPTUS* HYBRID PLANTATIONS IN INDIA UNDER THE RISK OF ILLICIT FELLING

S.N. TRIVEDI

Forest Research Officer, Bihar, Ranchi (Bihar)

Introduction

Physical outputs of plantation can be calculated with the help of yield tables and financial appraisals can be carried out after adding a risk premium to the risk-free discount rate. This technique leads to a reduction in the present value of future outputs, but does not provide a proper reasoning for it. The illicit felling reduces the wood output available to the authorised felling agency and it is desirable to make a direct attempt to assess the expected wood output under the incidence of illicit fellings In this paper an attempt is made to quantify expected physical output of *Eucalyptus* hybrid plantations in India under various assumptions about the nature of illicit felling.

Models to predict expected wood output

The expected output will depend on the rate of loss on account of illicit felling and the manner in which it occurs. There is no scientific or systematic study so far to throw light on these aspects.

Risk of illicit felling is generally quantified in terms such as "there is 10% loss per year on average". However, it is less commonly specified how such losses are made up. Are they scattered or concentrated spatially? Do they principally affect productive area, standing volume or crop increment? The manner of the loss has important implications for predicting wood output of plantations.

Three models (Trivedi, 1987) are discussed below to predict plantation yield under different assumptions about the way in which the loss due to illicit felling takes place In each model loss is assumed to occur according to an exponential rather than an arithmetic progression e.g. with a 10% loss per year, the remainder after two years is not 100%−2.(10%), but $(100\%-10\%)^2$.

Model I—Loss of area : This model treats illicit felling simply as a proportional loss of forest area. That is, each year a given proportion of remaining forest area is completely felled illicitly, thereby taking that land out of forest production. The volume obtainable at the end of the T^{th} year is given by

$$V_T = V.(1-f)^T \qquad (1)$$

where V is the volume obtainable in the absence of illicit felling and f is the annual loss of area expressed as a decimal.

Model 2—Loss of cumulative volume (increment unaffected) : This model treats illicit felling as a proportional loss of cumulative volume. That is, each year a given proportion of current standing volume is removed illicitly in scattered fellings. However, volume increment rate is treated as unaffected. This corresponds with the observation that authorized thinning does not, within wide limits of intensity, affect volume increment significantly. The volume obtainable at the end of the T^{th} year is given by

$$V_T = V_{T-1} + \triangle V_T - (V_{T-1} + \triangle V_T/2)\, f \quad (2)$$

where $\triangle V_T$ is the volume increment in the T^{th} year, V_{T-1} is the cumulative volume at the end of the $(T-1)^{th}$ year and f is the annual loss in cumulative volume expressed as a decimal. Increment rate dV/dT at any instant of time is treated simply as a function of the cumulative volume which would have existed at that instant in the absence of illicit felling

Model 3—Loss of cumulative volume (increment affected) : This model is similar to model 2 except that the rate of volume increment is treated as affected by the illicit felling The expression for volume obtainable in this model is the same as in model 2, but increment rate dV/dT is treated as a function of cumulative volume, which in turn is a function of number of trees remaining The assumption is made that each year a given proportion of remaining trees is removed illicitly; moreover, these trees are a proportional sample of the existing size class distribution. The number of trees at the end of the T^{th} year is given by

$$N_T = N\,(1-f)^T \quad (3)$$

where N stands for the initial plantation density and f is the annual loss of tree numbers expressed as a decimal.

Expected utility of a forest plantation

The expected utility of a forest plantation under the risk of illicit felling can be measured in terms of the expected crop value which is a function of the volume of wood and the crop diamater expected at a given crop age. The crop diameter variable can be ignored if biomass production is treated as a measure of utility. In such a case the discounted expected utility, for use in determining optimum rotation for the plantation, is obtained by discounting the volumes obtainable under the three models by the pure time-preference rate :

$$DEU = EU/1+r)^T \quad (4)$$

where DEU stands for discounted expected utility, EU stands for expected utility and r stands for pure time-preference rate This treatment has been adopted for the appraisal of *Eucalyptus* plantations in India by Trivedi and Price (1986).

Application of models to appraise *Eucalyptus* plantations in India

An attempt is made in this section to generate a yield-table for the *Eucalyptus* hybrid plantations in India under risk-free condition as well as under conditions of risk represented by the three models discussed earlier. A variable density yield equation, specified by Sharma (1978), is used as the basic equation and is reproduced below:

$$\log V = b_0 + b_1.(1/A) + b_2.S + b_3.(\log N) + b_4.(1/S) \quad (5)$$

where V is the yield in cubic metres per hectare, A is the age of the crop expressed in years, S is the site index specific to the quality class and N is the number of stems per hectare. The classification into three quality classes I, II and III (on the basis of top height) and the determination of the corresponding site indices and the values of the regression constants and coefficients by Sharma (1978) using data from 124 sample plots scattered all over India used in the present study. These values are reproduced in Tables 1 and 2.

Let us consider a *Eucalyptus* plantation with N=2500. This corresponds to a spacing of 2m×2m. Let us generate a yield table for the plantation age starting from year 1 to year 15 using the above equation (Sharma's tables contain an age-range of 4-14 years, but a little extrapolation does not matter for the aim is to illustrate the models). This gives risk-free volume. Yield tables are also generated using the three models already discussed. The rate of volume increment in model 2 is obtained by differentiating equation (5) with respect to T and is expressed as

$$\frac{dV^T}{dT} = = \frac{b1 - V_T}{T^{-2}} = - \frac{b1}{T^2} e^{[b_0 + b_1.(1/T) + b_2.S + b_3.\log N + b_4(1/S)]}$$

Table 1

Site indices for Eucalyptus hybrid plantation

Quality class	Top height at 8 years (m)			Site indices		
	Max.	Min.	Mean	Max.	Min.	Mean
I	26 6	20.2	23.4	24	18	21
II	20.2	13 8	17.5	18	12	15
III	13.8	7.4	10.6	12	6	9

Table 2

Regression constants and coefficients for equation

Quality class	b_0	b_1	b_2	b_3	b_4
I	3.08754	− 7.51748	0.022068	0 609979	−44 4264
II	−2.34040	−10.93654	0.264975	0.216846	31.0078
III	3.50694	−14.93375	−0.045310	0.622400	-29.5316

Extracted from 'Yield tables for *Eucalyptus* hybrid (plantation) for various levels of stocking' (Sharma, 1978).

Scanned by CamScanner

For model 3, dV_T/dt is evaluated by the same expression (6) except that N is replaced by N_T as given by equation (3). Introducing the concept of variable tree number during the life of the crop may not be compatible with the original assumptions behind equation (6), but this is being done to illustrate the models and no better equations are currently available. How much the estimated loss reflects the true quantum of loss in the field depends on how closely the models depict the individual field situations.

The value of f, i.e., the annual rate of loss of area in model 1 and the annual loss of cumulative volumes in models 2 and 3, has been taken as 0.1 (or 10%) in the present study. Loss from illicit felling does not occur as a single annual event, but may be scattered throughout the year. Accordingly, in models 2 and 3 the year is divided into 100 equal parts, in any of which illicit felling may take place. The mean rate of loss in each part is 0 105305%. Owing to the exponential nature of loss, this would result in a loss after one year of precisely 10% :

$$(100\%-0.105305\%)^{100}=90\%$$

In models 2 and 3, the net effect of volume increment and illicit removal is calculated at the mid-point of each period, and the remaining standing volume revised.

Expected volume under risk and discounted expected utility

The risk-free volume as well as the risk-incorporated volume under the three models have been tabulated in Table 3 for quality classes I II and III. Using biomass production as indicator of utility the estimated volumes are then discounted using a pure temporal discount rate of 10% (r=0.1) to indicate the discounted expected utility, and the results displayed in Table 4

As expected, Table 3 shows the risk-free volume increasing with age and a 15 year rotation giving higher yield than that for shorter rotations. The highest yields are 300 8, 106.6 and 40.1 cubic metres (m^3) for quality class I, II and III respectively and all these correspond to a 15 year rotation. On applying models 1, 2 and 3, however, the highest yield reduces to 83.5, 149 5 and 103 m^3 for quality class I, 25.8, 55 and 45 6 m^3 for quality class II and 8.8, 22 5 and 22.2 m^3 for quality class III respectively. These correspond to rotations of 8, 11 and 9 years for quality class I; 10, 14 and 13 years for quality class II and 12, 15 and 13 years for quality class III respectively. These reflect the optimum rotations and corresponding yield for the three models if time preference is nil.

If time preference is greater than 0, there will be further reductions in optimum rotations and yield Using a discount rate of 10% for time preference we get discounted yield Table 4, a glimpse of which gives an idea of the reduction in optimum rotations and yield for the three quality class. In the absence of illicit felling the greatest discounted volumes are 91.32, 28.66 and 9 97 m^3 for quality classes I, II and III respectively. These correspond to ages 9, 11 and 13 years respectively. Under the incidence of illicit felling, the maximum discounted yield for quality class I is 42.54, 66.12 and 49.89 m^3 for models 1, 2 and 3 respectively. The corresponding rotations are 6, 7 and 6 years.

Scanned by CamScanner

Table 3

Yield table for Eucalyptus hybrid plantation in India

Quality class & plants per ha.	Age (years)	Volume (without illicit felling) (m^3)	Volume under illicit felling		
			Model 1 (m^3)	Model 2 (m^3)	Model 3 (m^3)
I 2500	1	0.27	0.24	0.27	0.25
	2	11.57	9.37	11.14	10.03
	3	40.51	29.53	37.59	32.44
	4	75.80	49.73	67.34	55.93
	5	110.38	65.18	93.41	74.90
	6	141.82	75.37	113.87	88.35
	7	169.61	81.13	128.84	96.87
	8	193.98	83.50	139.06	101.46
	9	215.33	83.42	145.39	103.04
	10	234.09	81.62	148.64	102.39
	11	250.65	78.66	149.47	100.15
	12	265.34	74.94	148.45	96.79
	13	278.44	70.77	146.03	92.67
	14	290.18	66.38	142.56	88.08
	15	300.75	61.92	138.33	83.22
II 2500	1	0.00	0.00	0.00	0.00
	2	0.93	0.76	0.91	0.87
	3	5.77	4.21	5.44	5.15
	4	14.35	9.42	13.07	12.17
	5	24.80	14.64	21.68	19.90
	6	35.70	18.97	29.87	27.04
	7	46.32	22.16	36.96	33.02
	8	56.31	24.24	42.74	37.70
	9	65.55	25.40	47.22	41.15
	10	74.02	25.81	50.54	43.50
	11	81.76	25.66	52.82	44.92
	12	88.82	25.09	54.24	45.58
	13	95.27	24.22	54.93	45.62
	14	101.17	23.15	55.03	45.17
	15	106.58	21.94	54.66	44.33
III 2500	1	0.00	0.00	0.00	0.00
	2	0.06	0.05	0.06	0.05
	3	0.75	0.55	0.71	0.60
	4	2.60	1.70	2.41	1.94
	5	5.48	3.23	4.91	3.78
	6	9.01	4.79	7.78	5.74
	7	12.86	6.15	10.65	7.55
	8	16.79	7.23	13.32	9.08
	9	20.66	8.00	15.66	10.27
	10	24.39	8.50	17.63	11.14
	11	27.94	8.77	19.23	11.72
	12	31.28	8.84	20.48	12.04
	13	34.43	8.75	21.42	12.15
	14	37.37	8.55	22.07	12.09
	15	40.12	8.26	22.47	11.89

Scanned by CamScanner

Table 4

Discounted yield table for Eucalyptus plantation in India

Quality class & plants per ha	Age (years)	Discounted Volume (no illicit felling) (m^3)	Discounted Volume		
			Model 1 (m^3)	Model 2 (m^3)	Model 3 (m^3)
I 2500	1	0.25	0.22	0.24	0.23
	2	9.56	7.75	9.21	8.28
	3	30.44	22.19	28.24	24.37
	4	51.77	33.97	45.99	38.20
	5	68.54	40.47	58.00	46.51
	6	80.05	42.54	64.28	49.87
	7	87.04	41.63	66.11	49.71
	8	90.49	38.95	64.87	47.33
	9	91.32	35.38	61.66	43.70
	10	90.25	31.47	57.31	39.48
	11	87.85	27.57	52.39	35.10
	12	84.54	23.88	47.30	30.84
	13	80.65	20.50	42.30	26.84
	14	76.41	17.48	37.54	23.19
	15	72.00	14.82	33.12	19.92
II 2500	1	0.00	0.00	0.00	0.00
	2	0.77	0.62	0.75	0.72
	3	4.33	3.16	4.09	3.87
	4	9.80	6.43	8.93	8.31
	5	15.40	9.09	13.46	12.36
	6	20.15	10.71	16.86	15.26
	7	23.77	11.37	18.96	16.94
	8	26.27	11.31	19.94	17.59
	9	27.80	10.77	20.03	17.45
	10	28.54	9.95	19.48	16.77
	11	28.66	8.99	18.51	15.74
	12	28.30	7.99	17.28	14.52
	13	27.60	7.01	15.91	13.21
	14	26.64	6.09	14.49	11.89
	15	25.52	5.25	13.08	10.61
III 2500	1	0.00	0.00	0.00	0.00
	2	0.05	0.04	0.05	0.04
	3	0.56	0.41	0.54	0.45
	4	1.77	1.16	1.64	1.33
	5	3.40	2.01	3.05	2.35
	6	5.09	2.70	4.39	3.24
	7	6.60	3.16	5.47	3.83
	8	7.83	3.37	6.21	4.24
	9	8.76	3.39	6.64	4.36
	10	9.40	3.28	6.80	4.30
	11	9.79	3.07	6.74	4.11
	12	9.97	2.82	6.53	3.84
	13	9.97	2.53	6.20	3.52
	14	9.84	2.25	5.81	3.18
	15	9.61	1.98	5.38	2.85

Scanned by CamScanner

Table 5

Expected mean annual increment for Eucalyptus plantation

Quality class & plants per ha.	Age (years)	MAI (without illicit felling) (m³)	Expected MAI under illicit felling		
			Model 1 (m³)	Model 2 (m³)	Model 3 (m³)
I 2500	1	0.27	0.24	0.27	0.25
	2	5.79	4.69	5.57	5.01
	3	13.50	9.84	12.53	10.81
	4	18.95	12.43	16.83	13.98
	5	22.08	13.04	18.68	14.98
	6	23.64	12.56	18.98	14.72
	7	24.23	11.59	18.41	13.84
	8	24.25	10.44	17.38	12.68
	9	23.93	9.27	16.15	11.45
	10	23.41	8.16	14.86	10.24
	11	22.79	7.15	13.59	9.10
	12	22.11	6.74	12.37	8.07
	13	21.42	5.41	11.23	7.13
	14	20.73	4.74	10.18	6.29
	15	20.05	4.13	9.22	5.55
II 2500	1	0.00	0.00	0.00	0.00
	2	0.47	0.38	0.45	0.44
	3	1.92	1.40	1.81	1.72
	4	3.59	2.35	3.27	3.04
	5	4.96	2.93	4.34	3.98
	6	5.95	3.16	4.98	4.51
	7	6.62	3.17	5.28	4.72
	8	7.04	3.03	5.34	4.71
	9	7.28	2.82	5.25	4.57
	10	7.40	2.58	5.05	4.35
	11	7.43	2.36	4.80	4.08
	12	7.40	2.09	4.80	4.08
	13	7.33	1.86	4.23	3.51
	14	7.23	1.65	3.93	3.23
	15	7.11	1.46	3.64	2.96
III 2500	1	0.00	0.00	0.00	0.00
	2	0.03	0.03	0.03	0.03
	3	0.25	0.18	0.24	0.20
	4	0.65	0.43	0.60	0.49
	5	1.10	0.65	0.98	0.76
	6	1.50	1.80	1.30	0.96
	7	1.84	0.88	1.52	1.08
	8	2.10	0.90	1.66	1.13
	9	2.30	0.89	1.74	1.14
	10	2.44	0.85	1.76	1.11
	11	2.54	0.80	1.75	1.07
	12	2.61	0.74	1.71	1.00
	13	2.65	0.67	1.65	0.93
	14	2.67	0.61	1.58	0.86
	15	2.67	0.55	1.50	0.79

Scanned by CamScanner

For quality class II the maximum discounted yield is 11.37, 20.03 and 17 59 m³ for models 1, 2 and 3 respectively. These correspond to rotations of 7, 9 and 8 years respectively. For quality class III, the maximum discounted yield is 3.39, 6.80 and 4.36 m³ for models 1, 2 and 3 respectively. The corresponding rotations are 9, 10 and 9 years.

Expected mean annual increment as the indicator

Under the risk of illicit felling the expected yield at various ages is less than the ones obtainable in the absence of illicit felling. This leads to the reduction in the value of mean annual increment (MAI). This reduced value of MAI can be called the expected MAI to distinguish it from the normal MAI.

Table 5 gives the expected MAIs for various rotation ages of *Eucalyptus* hybrid plantation. Maximum MAIs in the absence of illicit felling are 24.25, 7.43 and 2.67 m³ for quality class I, II and III respectively. These correspond to the ages of 8 years, 11 years and 15 years respectively. Under the risk of illicit felling the maximum expected MAIs for quality class I are 13.04, 18.97 and 14.98 m³ for models 1, 2 and 3 respectively. These correspond to the ages of 5 years, 6 years and 5 years respectively. For quality class II the maximum expected MAIs are 3 17, 5.34 and 4.72 m³ for madels 1, 2 and 3 respectively. The correspond to the ages of 7 years, 8 y[illegible] and 7 years respectively. For quality cl[illegible] III the maximum expected MAIs are [illegible] 1.76 and 1.14 m³ for models 1, 2 and [illegible] respectively. These correspond to the a[illegible] of 8 years, 10 years and 9 years respectiv[illegible]

A significant point is that th[illegible] optimum rotations in the case of maxim[illegible] expected MAI are less than those in the ca[illegible] of maximum expected volume. Th[illegible] corresponds to the difference betwe[illegible] maximum NPV of one and an infinite seri[illegible] of rotations, and reflects the opportun[illegible] cost of land for successor rotations.

Conclusion

The problems raised by the risk [illegible] illicit felling in project appraisal can not [illegible] properly visualised without undertaking [illegible] physical appraisal to ascertain its impact [illegible] plantation output. The expected value [illegible] plantations depends on how losses occur.

Modelling of Indian *Eucalyp*[illegible] plantations shows that losses concentra[illegible] by area are more serious and shor[illegible] optimal rotations further than scatter[illegible] losses which remove the same proportion [illegible] the crop. Losses affecting increment shor[illegible] rotations more than those which do n[illegible] Study of pattern of losses is needed [illegible] decide the most appropriate model.

Acknowledgement

The models discussed in the paper were suggested by Dr. C. Price, Deptt. of Fore[illegible] & Wood Science, U.C.N.W., Bangor (U.K.). The author is grateful to him for h[illegible] suggestions. The assistance provided by Shri Ashim Kumar Das and Shri Shatrughan Pr[illegible] of Forest Research Division, Ranchi in typing the manuscript is also acknowledged.

Scanned by CamScanner

SUMMARY

This paper discusses three models to incoporate the risk of illicit felling and applies them to predict the yield from *Eucalyptus* hybrid plantations in India for a spacing of 2 m × 2 m. The optimum rotations for different quality classes are discussed. The paper shows that losses concentrated by area are more serious than those removing the same proportion of cumulative volume with or without affecting the increment.

भारत में अवैध पातन के खतरों को ध्यान में रखते हुए यूकेलिप्टस प्रजाति की रोपणियों की उपयोगिता का वास्तविक मूल्यांकन

एस०एन० त्रिवेदी

सारांश

इस निबन्ध में अवैध पातन का क्षतिभय दर्शाने वाली तीन प्रतिकृतियों पर विचार किया गया है और भारत मे 2 मी० × 2 मी० की दूरी पर किये जाने वाले यूकेलिप्टस हाइब्रिड वनरोपण से प्राप्ति के पूर्वानुमान मे व्यवहार मे लाया गया है। इसमे विभिन्न गुणवत्ता-वर्गों के लिए अनुकूलतम आवर्तन पर विचार किया गया है। यह निबन्ध दर्शाता है कि क्षेत्रफल के रूप में होने वाली क्षति उसी अनुपात में कुल आयतन में होने वाली क्षति आयतन वृद्धि-दर को प्रभावित करते या प्रभावित नहीं करते हुए, से ज्यादा गम्भीर होती है।

References

Sharma, R P. (1978). Yield tables for *Eucalyptus* hybrid (plantation) for various levels of stocking *Indian For.*, **104** (6) : 387-397.

Trivedi, S N and C Price (1986). *Risk of illicit felling in afforestation project appraisal : some models illustrated for Eucalyptus plantations in India.* Unpublished Paper. Deptt. of Forestry and Wood Science, UCNW, Bangor (U.K.)

Trivedi, S.N. (1987). *Utility-based social shadow-pricing and its comparison with other evaluation techniques : a cost-benefit of fuelwood plantations in Bihar, India.* Unpublished *Ph. D Thesis.* Deptt. of Forestry and Wood Science, UCNW, Bangor (U.K.).

Scanned by CamScanner