USE OF ENUMERATION DATA AND YIELD TABLES TO CALCULATE THE INCREMENT OF A FOREST WITH A VIEW TO FIX ITS YIELD

BY R. SAHAI, I.F.S.

Chief Conservator of Forests, Uttar Pradesh, Naini Tal

Let I denote the number of trees per acre above the exploitable limit, II the number per acre in the next lower diameter class and so on. The number of II class trees per acre which pass into I class in f years is obtained from the formula :

$$x = \frac{f}{II^{t}I} \times II\left(1-\frac{z}{II}\right)$$

where f = felling cycle in years

$II^{t}I$ = years taken for II class trees to pass up into I class.

$\frac{z}{II}$ = fraction of II class trees that die or do not pass up in $II^{t}I$ years.

2. If the forest is normal, i.e., if the younger and middle-aged diameter classes are properly represented and the basic object of management is to ensure as large a sustained yield of trees above the exploitable diameter as possible there will be no drop in yield of trees above the exploitable diameter during the next felling cycle if the number of III class trees per acre that pass into II class during the felling cycle is equal to the number of II class trees per acre that pass into I class during the felling cycle plus the mortality in the II class trees during the same period. This can be represented algebraically as follows :—

$$\frac{f}{t_{III\,II}} \times III\left(1-\frac{z}{III}\right) = \frac{f}{t_{II\,I}} \times II\left(1-\frac{z}{II}\right) + \frac{f}{t_{II\,I}} \cdot II\cdot\frac{z}{II}$$

$$= \frac{f}{t_{II\,I}} \cdot II$$

$$\therefore \quad \frac{III}{II} = \frac{III^{t}II}{II^{t}I} \times \frac{I}{\left(1-\frac{z}{III}\right)}$$

If this condition is fulfilled there will be no drop in yield, X, during the next felling cycle.

If the conditions given in this para are fulfilled this formula can also be used to estimate trees of any diameter class which is not enumerated provided the values of 't' & 'z' are known.

3. This yield, X, can be expressed as a percentage (p) of the number (N) per acre of I class trees present at the time of marking.

$$\text{Thus, } p = \frac{X}{N} \times 100$$

4. Let I represent the number of I class trees per acre at the beginning of the cycle ; the number at the end will be I + X, so the average number

$$= \tfrac{1}{2} \times \{ I + (I+X) \}$$
$$= I + \frac{X}{2}.$$

5. N can be replaced without introducing any serious error by the average number of I class trees, i.e., $I + \frac{X}{2}$ in the above formula ; thus,

$$p = \frac{X}{\left(I + \frac{X}{2}\right)} \times 100 = \frac{1}{\left(\frac{I}{X} + \frac{1}{2}\right)} \times 100.$$

6. The above formulæ can be used to calculate the yield for those species for which I, II and III class trees have been enumerated and for which the values of t and z are known (from yield tables, etc.).

7. It should be noted that the value of 'p' can be calculated from the formula given in para 5, only, if I is within certain limits and not in general. Thus if $I=0$, $p=200$, which is absurd. Similarly, if the value of I is comparatively very high that of 'p' will be very small. On the other hand a little consideration will show that if the value of I is very large these trees will be deteriorating and so it should be permissible to remove a large percentage of these. If $I = \frac{X}{2}$, $p = 100$. It is thus clear that it is not possible to apply the above formula unless I is equal to or greater than $\frac{X}{2}$.

8. In practice the percentage of trees given by the above formula cannot be applied in the forests rigidly as the removal of I class trees has to be governed by silvicultural availability. As an example the formula may give the value of $p = 50$, but unless adequate regeneration is present it may not be permissible to remove any mature trees.

9. If the condition in para 2 is not fulfilled, the percentage 'p' will have to be reduced or increased according as the recruitment from III class to II class is less or more than the recruitment from II class to I class plus mortality in II class. Similarly, the percentage 'p' will have to be increased if the number of I class trees is comparatively very large and these trees are deteriorating. Again, 'p' may have to be reduced if the trees are silviculturally not available. The formula, as applied in practice, thus becomes :

$$p = \left(\frac{X}{I + \frac{X}{2}} \times 100 \right) \pm A$$

where A is an arbitrary adjustment to be made to cover all other factors influencing the yield.

10. It would be thus seen that before applying Smythies' formula it is essential to verify that the forest is normal. For this purpose it is necessary to know the number per acre of I, II and III class trees to ensure, as has been done in para 2, that there is no drop in yield during the next felling cycle. This means that enumerations should be done for two diameter classes below the exploitable diameter. Further, before calculating the percentage 'p', it should be verified that I is equal to or greater than $\frac{X}{2}$ (see para 7).

11. The method to be described can be used for calculating the yield of forest where the exploitable species have been enumerated and yield tables exist for those species. This

method uses the principle that the maximum yield that can be removed from a forest without depleting the existing stock is its Current Annual Increment. Enumeration data give the number of trees per acre of the various diameter classes while the yield tables give the volume of the mean tree and its Periodic Current Annual Increment for the various diameter classes.

12. The following example of yield calculation for the Sal Conversion Working Circle in the Working Plan for Dehra Dun Forest Division (1949–58) will illustrate the method. The area of this working circle is 68,500 acres. Sal (*Shorea robusta*) constitutes more than 90 per cent of the main crop and is of III quality.

13. Columns (1) to (4) of the following table are obtained by using the figures in Col. 1, 2, 5 and 10 of Table 6 given on pages 226–29 of the Yield and Stand Tables for sal (*Shorea robusta*, Gaertn. f.) High Forest, by A. L. Griffith and Bakshi Sant Ram, *Indian Forest Record* (New Series) Silviculture, Vol. 4-A, No. 4, 1943. The figures in columns (5) and (6) are respectively obtained by dividing the figures in columns 10 and 26 by the corresponding figures in column 5 of that table.

Crop age	Average diameter in inches	No. of trees	Standing volume (stem timber and smallwood) in c. ft.	Volume of mean tree	C.A.I. of the mean tree
(1)	(2)	(3)	(4)	(5)	(6)
65	10·2	138	2,050	14·86	0·7391
100	14·3	74	2,560	34·59	0·8110
145	18·3	45	3,390	75·34	0·8889

14. Taking only the fit sal, enumeration result gives the following distribution per acre in various diameter classes.

Diameter classes in inches

12″–16″ (III class)	16″–20″ (II class)	Over 20″ (I class)
9·81	4·94	2·01

15. The number of sal trees in the IV class, i.e., 8–12 inches diameter class can be estimated by the formula given at the end of para 2, viz.

$$\frac{IV}{III} = \frac{IV^{t}III}{III^{t}II} \times \frac{1}{1-\frac{z}{IV}}$$

$$\text{or } IV = \frac{III\ IV^{t}III}{III^{t}II} \times \frac{1}{1-\frac{z}{IV}}$$

16. *Value of t and z*—No data are available for t and z for irregular forests. Their calculated values according to the existing working plan procedure, but based on the new sal yield tables, are as follows :—

Quality class	Diameter class (inches)	Age	No. of trees per acre	Total disappearance No. of trees	z (per cent)	t (years)
II/III	8–12	43	201	...	...	...
	12–16	71	117	84	42	28
	16–20	104	68	49	42	33
	20–24	144	43	25	37	40
III	8–12	48	193	...	...	...
	12–16	79	104	89	46	31
	16–20	118	59	45	43	39

17. As the values of t and z for II class (16″–20″) diameter trees are not available for III quality, the corresponding values for II/III quality class will be used. Applying these values of 't' and 'z' and III (from the enumeration result given in para 14) in the formula given in para 15,

$$IV = III \frac{IV^{t}III}{III^{t}II} \times \frac{1}{1-z_{IV}}$$

$$\therefore \quad IV = \frac{9 \cdot 81 \times 28}{33} \times \frac{1}{1-0 \cdot 42}$$

$$= 14 \cdot 35.$$

18. Columns (2) of the following table was obtained by using the figures of para (14). The figures in columns (5) and (6) of the table in para 13 were respectively plotted against the corresponding figures in Col. (2) and smooth curves were drawn to get the figures in columns (3) to (5) of the table :—

Diameter class (inches)	No. of trees per acre in the diameter class	Average diameter of mean tree	Volume of mean tree in c. ft.	C.A.I. of the mean tree in c. ft.	C.A.I. of the diameter class in c. ft.
(1)	(2)	(3)	(4)	(5)	(6)
8–12	14·35	10·0	14·10	0·7260	10·420
12–16	9·81	14·0	32·15	0·8450	8·290
16–20	4·94	18·0	71·50	0·8918	4·406
Over 20	2·01	...	...	...	...
Total ...	...	...	...	...	23·116

19. This shows that the C.A.I. per acre is 23·116 c. ft. So, the C.A.I. for the whole working circle :

$$= 68{,}500 \times 23\cdot116$$
$$= 15{,}83{,}000 \text{ c. ft.}$$

20. The actual C.A.I. will be slightly more than 15,83,000 c. ft., as in the above calculation the C.A.I. of unfit trees and those of trees below 8 inches diameter is not taken into account. This is the maximum annual yield that can be removed from the forest without depleting the existing stock.

21. This method is eminently suitable for fixing the yield for irregular forest under a system of conversion to uniform with periodic blocks. In such cases the yield is calculated for the whole working circle by the above method. This yield will be taken out of the various periodic blocks, viz., main fellings in P.B.I., removal of standards in young P.Bs., removal of mature trees and thinnings in intermediate P.Bs. and thinning in old P.Bs. (other than P.B.I.).

22. The following illustration shows how the yield can be calculated independently by the Smythies' formula and the C.A.I. method. The figures used below are those for the Sal Selection Working Circle given in the author's Working Plan for the Dehra Dun Forest Division, Uttar Pradesh, for 1949-50 to 1958-59.

23. *Enumeration data*—Neglecting unfit sal trees enumeration results give the following distribution per acre :

Diameter class	12″-16″ III class	16″-20″ II class	Over 20″ I class
Number of trees per acre	5,891	3,615	1,787

24. *Values of 't' and 'z'* - These are given in para 16.
f = 10, I'II = 40, z_{II} = 0·37, II'III = 33, z_{III} = 0·42.

25. *Yield by Smythies' formula*—

$$X = \frac{f}{t}\, II \left(1 - z_{II} \right)$$
$$= \frac{10}{40} \times 3\cdot615 \times (1 - 0\cdot37)$$
$$= 0\cdot5693$$

$$I + \frac{X}{2} = 1\cdot787 + 0\cdot2846$$
$$= 2\cdot0716$$

$$p = \frac{X}{1 + \frac{X}{2}} \times 100$$
$$= \frac{0\cdot5693}{2\cdot0716} \times 100$$
$$= 27\cdot48 \text{ or say } 27 \text{ p.c.}$$

26. Applying Smythies' formula to II and III class trees :—

$$X = \frac{f}{\text{III}'\text{II}} \, \text{III} \left(1 - \underset{\text{III}}{z} \right)$$

$$= \frac{10}{33} \times 5{\cdot}891 \times (1 - 0{\cdot}42)$$

$$= \frac{10}{33} \times 5{\cdot}891 \times 0{\cdot}58 = 1{\cdot}035.$$

27. This shows that recruitment from III to II class is nearly double the loss among II class trees due to II class trees passing into I class. So, there will be no drop in yield after the present felling cycle of 10 years is over. For the same reason it is permissible to remove a larger percentage of I class trees than 27 (see para 25).

28. *Yield by the C.A.I. method*—The following table is based on the result of enumeration and the yield tables (see para 18).

Diameter class in inches	No. of trees per acre	Average diameter in inches	Volume of mean tree in c. ft.	C.A.I. of mean tree in c. ft.	C.A.I. of the diameter class in c. ft.
12–16	5·891	14·0	32·15	0·8450	4·978
16–20	3·615	18·0	71·50	0·8918	3·224
Over 20	1·787	...	...	...	...
TOTAL ...	...	...	...	...	8·202

N.B.—The C.A.I. of trees over 20 inches is not available in the sal yield tables and so is disregarded as trees of that diameter do not put appreciable increment.

29. This shows that the C.A.I. per acre is 8·202 c. ft. and corresponds to 0·2551 trees of 12–16 inches class of which the volume is 32·15 c. ft. As the volume of trees over 20 inches diameter is about 3 times that of 12–16 inches class, the C.A.I. corresponds to 0·0850 trees of 20 inches and over diameter.

The above yield is conservative as in this calculation the C.A.I. of unfit trees and all trees up to 12 inches and over 20 inches diameter has been disregarded.

30. As the felling cycle is 10 years the C.A.I. of 10 acres can be removed annually from each acre. So, the number of selection trees (over 20 inches diameter) which can be removed per acre is 0·850. The average number of these trees per acre is 2·0716 (see para 25). So, the percentage 'p', that can be removed comes to

$$p = \frac{0{\cdot}850}{2{\cdot}0716} \times 100$$

$$= 41{\cdot}03 \text{ or say } 40.$$

31. The percentage according to Smythies' formula came to 27 (para 25). In view of what is stated in para 27 it would be safe to remove 40 per cent of the selection trees. As this yield has been calculated by two independent methods it can safely be prescribed.

REFERENCES

1. Smythies, E. A. (1933). The safeguarding formula for selection fellings. *Indian For.* pp. 659–664.
2. Sahai, R. (1948). Use of enumeration data and yield tables to calculate the C.A.I. of a forest with a view to fix its yield. *Indian. For.* pp. 13–15.

NEWS AND NOTES

Society of American Foresters

TWO EMINENT FORESTERS RECEIVE RESEARCH AWARDS

Two awards for outstanding achievement in biological research contributing to the advancement of forestry were made on November 13, 1957, at the annual meeting of the Society of American Foresters, in Syracuse, N.Y. They were presented by President De Witt Nelson of Sacramento, Calif.

Each award consisted of an engraved plaque and a cash payment. One went to a well-known American silviculturist and forestry educator; the other, to a world-famous Danish forest geneticist.

Dr. Harold J. Lutz of New Haven, Conn., the American recipient, is professor of silviculture in the faculty of the Yale University School of Forestry and Director of the Yale program of research in forest biology. Among his notable contributions to forest science is a technical publication on the ecological effects of forest fire in interior Alaska.

Dr. C. Syrach Larsen of Denmark is head of the Danish National Arboretum. He is the author of several highly regarded books and numerous scientific papers on the subject of forest tree improvement through genetics. His award was made *in absentia* to his friend and colleague, Dr. Erik Homsgaard, Director of the Danish Forest Experiment Station.

* * * *

PINCHOT MEDAL AWARD TO SAF EXECUTIVE SECRETARY

Henry Clepper, executive secretary of the Society of American Foresters and managing editor of the Journal of Forestry, was awarded the Gifford Pinchot Medal for outstanding service to forestry on November 13, 1957, at the annual meeting of the Society in Syracuse, N.Y. It was presented by President De Witt Nelson of Sacramento, Calif.

More than one thousand professional foresters from the United States and Canada attended this fifty-seventh anniversary meeting. Seventy scientific and technical papers were read during the three days of sessions.