Yield Regulation and Forecasts of Production

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(Paper read at meeting of the British Association for the Advancement of Science at Dublin in September, 1957)

THE title of this paper 'Yield Regulation and Forecasts of Production' embraces a very wide subject but I propose to deal mainly, although not exclusively, with one aspect of it which is of special interest to foresters in Great Britain and Ireland at the present time. I refer to the question of forecasting the yield from thinnings in new forests. An exchange of experiences and views on this particular aspect of the subject should be to our mutual advantage and the present meeting of the British Association affords an exceptional opportunity for the purpose.

In countries where there has been afforestation on a large scale, the volume of forest produce available for marketing will increase rapidly and will change in quality. In particular, thinnings will yield large quantities of small sized produce for which there may be no established markets within easy reach. The establishment of new wood-using industries may be called for, but this needs to be carefully planned if the industries are to flourish while paying an adequate price for the raw material. The right type and size of plant must be selected and it must be put up at the right place and at the right time. This careful planning is only possible if reliable forecasts of production are available.

Although forestry conditions are, in many respects, similar in our two countries it may be useful to start by giving a very brief summary of our forestry position in Great Britain.

Our total forest area is 4,000,000 acres, or about 7% of the total land surface; 1,000,000 acres are managed by the State Forest Service while most of the other 3,000,000 acres are in private ownership. There are but few large tracts of forest and the greater part of our forest area is made up of many small woods which are widely dispersed throughout the country but readily accessible by road. Most of the State forests consist of forest crops less than 40 years old in which conifers predominate. The private woods, on the other hand, contain a large proportion of old stands, mainly broadleaved, and also large areas which are not fully productive as a result of war-time fellings. At present the State Forest Service plants between 50 and 60 thousand acres a year most of which is on land not previously under forest and consists of coniferous species, except in the relatively small areas where growth conditions for broadleaved species are favourable. Private owners, of whom there are about 40,000, are planting between 25 and 30 thousand acres per year

mainly on old woodland sites. Technical advice and financial assistance is made available by the State which, however, exercises some control over the level of fellings.

In both the State and private planting the most common species are Scots pine, Corsican pine, Sitka spruce, Norway spruce, Japanese larch, European larch and Douglas fir, but several other species such as *Tsuga heterophylla, Abies grandis* and *Pinus contorta* are gaining in popularity.

Generally speaking, there are three broad approaches to the preparation of production forecasts in forestry.

First, there is the felling plan which consists of a programme by which a certain volume of produce is felled each year. These volumes may be arrived at after considering the requirements of industries and silvicultural and other relevant factors, but the essential feature is that the actual volume that is to be felled is definitely prescribed. For a country as a whole this approach is only possible if the economy is strictly controlled. The Soviet Union has prepared production forecasts of this type.

The second possible approach is to forecast consumer demand. A forecast of this type, which takes into consideration such factors as probable changes in the size of population, in the standard of living, and of technical developments which may either lead to new uses for wood or to its substitution by other materials, has recently been prepared by the United States. This approach is particularly appropriate where the central forest authority exercises little or no control over the level of felling.

The third approach, and it is with this that we are primarily concerned in Great Britain, is to take as the starting point the silvicultural potential; that is to estimate the volumes that will be felled under a specific silvicultural treatment. The essential difference between this approach and the felling plan is that in this case the silvicultural treatment is prescribed and the yields that result from it are estimated, while in the felling plan, the volumes to be felled are prescribed and the silvicultural treatment may have to be adjusted accordingly.

In order to determine the silvicultural potential of a forest or a whole country it is necessary to have information on :—

1. Area, volume and increment; this implies a survey of the growing stock.
2. The silvicultural treatment.
3. Statistics of past yields.

The collection and assembly of this information is perhaps the most difficult and laborious part of preparing forecasts and must therefore be considered in some detail.

The first of these requirements presents no particular difficulty in either State or private forests provided that permission can be obtained to enter private property to collect the necessary data. Information on future silvicultural treatment and statistics on past yields, on the other hand, is often only available for the State forests. But if the information

on the growing stock is collected in the same way in all forests, irrespective of ownership, forecasts for the private woodlands may be made by using the State forests as a standard of comparison and as a guide. For this reason, our national forest survey covers both State and private forests.

Although there were some previous surveys, we may take as our starting point in the present context the complete census of all woodlands over 5 acres in extent which was carried out between 1947 and 1949 (Forestry Commission 1952). The first stage of the work was to visit all woods over 5 acres and to classify each stand in them according to crop type, age class, tree form, stocking and species. In order to provide adequate estimates of the total areas in each species and age category for the purpose of forecasting yields, a complete census of all woods was not necessary; a survey of a suitably selected 5 to 10 per cent. sample of the total area would have sufficed. The complete census was, however, carried out in order to enable us to implement the general policy of encouraging efficient forest management on private estates.

The second stage of the work was to provide estimates of volume. No attempt was made to estimate the standing volume of individual stands or even forests, but for each major region estimates based on sample enumerations were obtained, giving average volume per acre and total volumes by species and age classes. The sampling units were circular plots of 0.1 acre and there was one plot for every 200 acres giving a sampling fraction of 1 in 2,000. The sample was stratified by county, species and age class, but within each stratum the selection of the stands to be sampled and the allocation of plots within the stands was at random. The method of sampling was designed to give an unbiased estimate of adequate precision at minimum cost and an approximate estimate of that precision. A total of about 7,000 plots was measured.

The third stage was to arrive at an estimate of the current increment. No very precise estimate was considered necessary at the time, as the level of fellings and thinnings for many years to come would not be greatly influenced by the current increment. This is partially due to the very abnormal age class distribution of our forests and partially to the need, immediately after the war, of replenishing our sadly depleted stocks of standing timber by restricting fellings to a minimum irrespective of increment. The estimate of increment was based, not on measurements taken as part of the National Forest Survey, but on the data derived from our long term studies of growth and yield in the permanent sample plots of the Forestry Commission. In important species, for which insufficient permanent sample plot data were available, subsidiary information on the rate of growth was obtained by means of stem analyses on several hundred trees.

Long term studies of growth and yield are a field of work in which co-operation between neighbouring countries is likely to prove particularly useful. Co-operation leads to economy of effort and it

may save time. For example, the results of our studies in Great Britain of species such as Sitka spruce should serve as a useful preliminary indication of the growth potential of the young stands of this species in Ireland and as a starting point for more detailed local studies in that country; conversely we in Great Britain should be able to benefit greatly from Irish experience with lodgepole pine.

The census of 1947-1949, the cost of which worked out at slightly less than one shilling per acre, was followed in 1951 by a sampling survey of the small woods, hedgerow and park trees which, in Great Britain, account for over 20 per cent. of our total standing timber and form such a characteristic and pleasing feature of our landscape, particularly in the southern half of the country. A detailed report on the survey and the methods used has been published (Forestry Commission 1953).

The information on the area and volume of our woods is now being kept up to date by a system of continuous census revision whereby a few countries are re-surveyed each year. This revision started in 1953; it embraces hedgerow and park trees as well as the larger woods, State forests as well as privately owned woods. In the State forests, most of the information is available from management records, but we record the information in exactly the same way as for private woods because this facilitates forecasts of production in the private woods. The methods used in the census revision are very similar to those used in the original census except for some minor refinements and only one of these need be mentioned here.

In each plot in which the volume is measured the portion of that volume which could be removed in thinnings at the time of measuring is recorded; this is intended to assist in determining the thinning potential. The method has not been in use long enough to prove its worth in Great Britain but it has been found useful elsewhere, for example in Finland, Sweden and Cyprus, and little additional work is involved. The surveyors' judgement of how many and which trees could be removed is necessarily subjective, but some uniformity of standards is maintained by the fact that the surveyors all have experience in the measurement and thinning of the permanent research sample plots of the Forestry Commission.

We must now consider how, with a given growing stock, yields will be affected by silvicultural treatment. Taking a long term view, the yield of a forest will equal the increment; experience has shown that the silvicultural treatment has only a limited effect on total increment, although it greatly influences the type and size of produce, the time when it comes on the market and the relative proportion of yield from thinnings and final fellings. It follows that a more accurate knowledge of the proposed silvicultural treatment is needed if forecasts are to relate to thinnings alone instead of to total production and if the forecasts are short term rather than long term. Thinning yields are primarily affected by the grade and frequency of thinnings; and to a

lesser extent by the length of rotation.

In areas with large scale afforestation such as Great Britain, total yields from thinnings and fellings may also be greatly affected for a period by measures intended to improve the very abnormal age class distributions that may occur when a whole forest is planted in only a fraction of the intended rotation. The problem of how abnormal age class distributions may be improved with a view to securing a sustained yield has been discussed in two recent papers (Hummel 1956, Hummel and Grayson 1957).

There are five methods by which a transition towards sustained yield may be achieved :—Grouping, either temporarily or permanently, forests in the same neighbourhood to form a single felling series; underplanting or replacing plantations that are unsatisfactory or have failed; taking advantage of the fact that some species grow faster than others and that the rate of growth of any one species will vary according to the site; felling stands before or after they would normally be considered mature; and finally by varying the thinning treatment.

It was found that conversion to sustained yield presents no particular technical difficulties and little or no sacrifice in increment, provided it is planned in good time and an ample period of conversion is allowed. The main result of the investigation as far as forecasts of production are concerned, is that conversion usually entails some heavy thinnings and pre-rotation fellings; this means that a considerable volume of produce may be available for marketing earlier than without conversion.

While it is possible to prepare forecasts solely from a knowledge of the growing stock and future treatment, the reliability of any forecast is greatly increased if statistics of actual past yields are available as a guide. Early attention to the collection of felling statistics is therefore desirable in any large scale afforestation scheme, where the yields from the new plantations may be expected to differ considerably from old established forests. In collecting statistics on yield three points require particular attention.

First, the statistics must be as simple as possible. There is a great temptation, in an endeavour to achieve perfection, to devise too complicated a system of records which it is impracticable to maintain accurately; and inaccurate records may be worse than useless because they mislead. Secondly, the records must be consistent. Forestry is bedevilled by a multiplicity of units of measurement and conventions of measuring. Timber may be sold by volume or by weight, over bark or under bark; volumes may refer to "gross" volumes of a tree or to "net" volumes of what is regarded as merchantable under particular conditions. In Great Britain we have adopted stemwood over bark, measured to a top diameter of 3 inches, as the basis for our felling records and the volumes are expressed in "hoppus" feet, one hoppus foot being equal to 1.27 true cubic feet or 0.036 cubic metres. The archaic convention of hoppus measure can hardly be justified on rational grounds, but it is so widely used in practice that it was the obvious

choice as the standard unit. Thirdly, as has already been mentioned, it is desirable that the statistics for private woodlands should be comparable with those for the State forests. In Great Britain all major thinnings and fellings on private estates are licensed by the State so that adequate records present no difficulty.

When the available information on the growing stock, future treatment and past yields has been been assembled, the actual work of forecasting can begin.

In Great Britain, we have found it useful, in both State and private forests, to distinguish between long term forecasts covering periods of about 5 to 30 years, medium term forecasts for periods of 2 to 5 years and short term forecasts for the year immediately ahead.

When preparing long term forecasts for the State forests, the first step is to determine the gross area which is in the thinning stage at the time of the estimate and to calculate what this gross area will be after 5, 10, 15, 20 years and so forth. Within each forest, separate areas are calculated for the major species groups and site types, but it has been our experience that if this differentiation is carried too far, much work may be caused without any corresponding gain in the accuracy of the forecast. In order to arrive at the gross area it is necessary to know the average age at which thinnings commence: under our conditions this is usually between an age of 15 and 20 years. From the gross areas deductions must be made for areas in 'check' (i.e. where abnormally slow growth leads to a delay in the first thinning), as well as for possible losses, e.g. from wind and fire and, where old age classes are present, for final fellings according to the felling plan.

Having determined the net area for each species-site category, the next step is to determine the average annual thinning yield for it. Under our conditions this usually works out at somewhere between 45 and 80 hoppus feet per acre per year in the case of conifers and rather less than half that amount for broad-leaved species. This figure is usually estimated from past records in the forest concerned but, in recently planted forests where no such records are available, the estimate is based either on records from other forests which are comparable, or on an estimate of increment from yield tables. Although thinning yields differ somewhat with the age of a crop, we have found that to work out separate thinning yields for each age class does not appreciably improve the forecasts of total thinning volume although it facilitates a breakdown of this total into size or produce classes. Every five years the long term forecasts are extended by five years and the forecasts for the intervening period are revised.

The long term forecasts in private forests are prepared in a similar manner but in less detail. The 'gross areas' in the thinnings stage are determined from the census of woodlands but are computed for whole regions and not for individual forests. The necessary deductions for arriving at the 'net' areas are estimated from our experience in the State forests. The forecast of average annual thinning yield per acre is based

partially on our experience in the State forests which indicate the silvicultural potential and partially on records of thinning volumes on private estates which are available because, apart from some minor exceptions, whenever a private owner wishes to thin a plantation he must apply for a licence stating the volume to be thinned.

The medium term forecasts which cover a 2 to 5 year period are in some respects more difficult to prepare than the long term forecasts because yields may temporarily be either reduced or increased by relatively minor changes in silvicultural fashions or in economic climate. While the long term production is largely determined by the physical growth potential of a site, the amount that is felled during any short period of years can be varied greatly. Forecasting human behaviour thus plays an important part in medium and short term forecasts.

Reliable medium term forecasts are only possible where there are definite thinning plans such as we have in all State forests and some of the private estates. These thinning plans are based on a thinning cycle which is usually 3 to 4 years for young plantations and 6 to 8 years for older ones; they prescribe the area to be thinned each year and in some instances also the actual compartments in which these thinnings are to take place. It is particularly important to make provision for the areas which reach the stage of first thinning during the period. The area to be thinned is multiplied by the expected volume yield per acre which lies normally between 200 and 400 hoppus feet. This expected yield per acre is estimated either from past records or from an assessment of each individual stand. Except in special circumstances, estimates based on average past records for the forest as a whole have proved as reliable as the more detailed estimates compartment by compartment. For private woodlands, where thinning plans are either non-existent or unknown to the State forest authority, the medium term forecasts are prepared by taking the known yields of the previous year and the first year of the long term forecast, i.e. five years ahead, and interpolating for the years between, making any allowances that may appear desirable for expected changes in markets, e.g. the establishment of new wood-using industries, and other relevant factors. Each year the medium term forecasts are extended by one year and the forecasts for the intervening years are revised.

The short term forecasts for the year immediately ahead are prepared in great detail. For the State forests they are linked with the programme of work compartment by compartment and with the financial estimates for the year. In the private forests, where this is not possible, the results of the preceding year are taken as the starting point and adjusted to allow for expected changes in markets, etc.

Responsibility for preparing thinning forecasts in Great Britain rested originally with the Mensuration Section of the Research Branch; but gradually an increasing amount of this work has been passed to the territorial Conservators of Forests. This trend is likely to continue because the accuracy of locally made forecasts should steadily increase

as more information becomes available from local records of management in both State forests and on private estates.

The actual methods of forecasting which are in use in Great Britain are unlikely to be applicable elsewhere where conditions are different, but it may be useful to conclude this paper by mentioning a few general lessons we have learnt which may prove of interest to others. Most of these points have either been discussed or at least implied previously in this paper.

1. The best guide to all forecasts is past experience; for this to be available proper records are indispensable. Records of out-turn from forests are usually only reliable if they are simple and if the units of measurement (e.g. over bark or under bark) are uniform and clearly defined.

2. It is desirable to keep the broad framework of statistics for State forests and private woodlands on the same basis so that valid comparisons are possible and the maximum use can be made of the more detailed statistics available in the State forests for predicting yields in the private forests.

3. In long term forecasts it is usually best to adopt the analytical approach, i.e. to take whole forests or regions and total volumes as the basic units of estimate and to derive estimates for smaller areas or the volumes in particular species groups or produce classes by a breakdown of the totals. The same applies to medium term and short term forecasts where no detailed data or definite thinning plans are available. To oversimplify: if guesswork is necessary, one big guess is likely to be more accurate than the sum total of many little ones—and it is far less work.

The opposite approach of synthesis, i.e. of building up the total estimate compartment by compartment, species by species, and volume category by volume category causes much more work and will only give more reliable forecasts if all the relevant facts and records are available and there is a detailed programme of work such as is only practicable for a limited period. Management planning and proper record keeping necessarily precede accurate forecasting.

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