SILVA FENNICA 1983, vol. 17 n:o 1: 77—82

HEIGHT RELASCOPE FOR REGENERATION SURVEYS

LAPPI, J., SMOLANDER, H. & KOTISAARI, A.

Seloste

PITUUSRELASKOOPPI METSÄNUUDISTAMISEN INVENTOINNIN APUVÄLINEEKSI

Saapunut toimitukselle 15. 2. 1983

The choice of sampling method is of prime importance when seeking relevant information about the height distribution and spatial arrangement of seedlings in regeneration surveys. It is suggested that the size of sampling plots should depend on the height of the seedlings. Tall seedlings should be sampled from a larger area than short ones since tall seedlings are more important for the future development of the stand. We suggest principles for a technical development task to construct a device which is easy enough to use in practical regeneration surveys and by which sampling can be made proportional to plant height or any desired fuction of height.

1. INTRODUCTION

In forest inventory work the choice of sampling method is of prime importance when trying to increase accuracy and to decrease measurement costs. Estimation of the basal area of the stand by a relascope (Bitterlich 1948) is advantageous in both respects: the accuracy is increased as sampling probabilities are proportional to the basal area, and the measurement costs are decreased as only the number of stems is needed.

Several modifications of this simple method have been suggested (e.g. Bickerstaff 1961, Zöhrer 1978, Kuusela 1979) which attain more or less successfully these two conflicting goals. Most of the applications have been developed for estimating the characteristics of merchantable stands, e.g. volume and basal area. Bickerstaff (1961) describes a relascope technique for assesing the stocking of stands. In his method, sampling is proportional to the height of the seedlings. Most methods have been based on the utilization of critical angle, which determines whether a tree is selected for the sample or not.

In this paper the goals in the regeneration surveys are first briefly discussed. In cases where the height varies greatly it is proposed, that circular sample plots where the plot size is dependent on the height of the seedlings should be used. The criteria utilized in choosing the radius of the sample plot as a function of the seedling height are discussed. A technical development task is proposed to design and construct a device which would make the presented sampling method easy enough to use in practical regeneration surveys. Emphasis is mainly placed on surveys of naturally regenerated stands where the height of the seedlings varies greatly.

2. GOALS OF REGENERATION SURVEYS

The principal problem in forest regeneration surveys is that we are not directly interested in what is the total amount (number, volume, height, basal area) of the trees but rather what are the characteristics of the stand after it has evolved for several years in a process which is basically stochastic. The number of trees and the mean height can be highly misleading parameters if, for instance, many trees die before maturity as a result of having a suppressed position, cleaning, pests or other factors. The situation is less problematic in planted areas if the mature tree stock consists mainly of planted trees and the planting density is low and even.

In natural regeneration areas the height of a seedling as such, and in comparison to the height of nearby seedlings, is a useful indicator of the survival probability. Taller trees are more likely to survive because they have reached a more advanced developmental stage and are in a better competition position.

In practical regeneration surveys (e.g. Rautiainen and Räsänen 1980) the future development of the stand has been taken into account by classifying the seedlings into qualified and disqualified seedlings. The classification has the advantage of taking into account information about pests, diseases etc. However, such a classification is subjective, and not reliable.

The main goal of regeneration surveys is to obtain useful information about the height distribution and spatial arrangement of the seedlings. If sample trees are selected from fixed-area circular plots, then the sampling distribution corresponds to the height distribution of the whole stand. Zero-plot percentage is the most natural indicator of the adequacy of stocking. Plot counts can also be used in the calculation of different kinds of clustering indices (e.g. Ripley 1981).

Fixed area plots have drawbacks with respect to both height distribution and spatial arrangement. Firstly, the height distributions of trees on natural regeneration areas are skewed positively (Yli-Vakkuri et al. 1969). The density estimates of the tallest trees, which are the most important, are therefore the least reliable. Secondly, if the spatial arrangement is evaluated by fixed-area counts all the trees have unjustifiably an equal weight. Using the zero-plot percentage as an indicator of the coverage of the growing trees also ignores the basic fact that trees do not grow in the forest on fixed exclusive plots.

Distances from randomly selected points to the nearest trees, or from randomly selected trees to the nearest trees have been used in estimating tree density and spatial distribution (cf, e.g. Persson 1964). Point-to-tree distances can be used to calculate zero-plot percentages for each plot size (e.g. Pohtila 1980). However, if tree heights vary a lot and trees of different height are not considered equal, these methods can lead to erroneous conclusions. It seems to be difficult to incorporate the height aspect in these methods.

As taller trees are more important, variable size plots should be used in regeneration surveys so that the sampling probability is a function of height. However, what is the right function to map tree height to sample area, and what is the best way to carry out the sampling on the regeneration areas? Suggestions are given in the following.

3. HEIGHT RELASCOPE

The basic idea of the height relascope can be presented in a crude form as in Fig. 1. If a 360° sweep with a vertical angle and the center p is made to get circular plots, then the sampling will be proportional to the square of the height. However, this kind of sampling appears to lack a theoretical justification.

According to Bickerstaff (1961), a given vertical angle is moved along a baseline of fixed length so that the horizontal projection

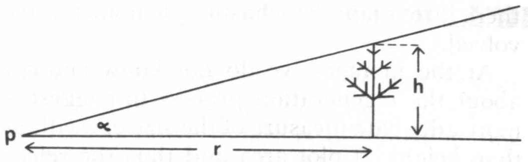

Fig. 1. Basic principle of the height relascope.

p is the starting point of the selection
α is the critical angle, all trees which subtend an angle greater or equal to α are selected for the sample.
r is the distance between the tree and point p.
h is the height of the tree, the tree being included in the sample if h> tan α·r.

of the angle is at right angles to the baseline. In this method sampling is proportional to the height. If a critical angle of 45° is used, then a tree is accepted in the sample if it is taller than its distance from the baseline.

The method of Bickerstaff can be criticized on both practical and theoretical grounds. Practically speaking it seems to be too complicated for use in large scale regeneration surveys. The ruggedness and the slope of the terrain also further complicate the sampling.

Utilization of the forest area can described by assuming that a tree of height h can utilize a circle of radius r(h). If all trees of height h are sampled from a circular plot with radius r(h) whether or not the center of the plot is utilized is known for certain. If the exact position of sampled trees is known then we know whether other points in the circle are utilized by sampled trees, but not whether they are utilized by trees outside the circle. However, the rectangular plots defined by Bickerstaff's sampling method do not indicate definitely whether any point is utilized or not. Thus zero-plot percentages calculated from circular plots give a better measure of the proportion of utilized points.

We thus propose a technical development project to design and construct a practical device for sampling and measuring seedlings in variable-size circular plots. The principle could be as described in Fig. 2. Technically the most difficult part is the realization of the sign C. Perhaps it can be made electrically combining simple calculator and lights. Even if the critical height should be easy to see approximately, numerical display can be used to check uncertain observations.

The proposed method avoids all the difficulties associated with slopes and ruggedness of the terrain. We think that it is possible to build a relatively cheap device according to the principles outlined above which would be practical enough for use in large scale regeneration surveys.

The most difficult theoretical problem is how to define critical height h as a function of the distance r from the plot center. Naturally, h(r) should be a bijection (one-to-one). Thus r can equivalently be seen as a function of h.

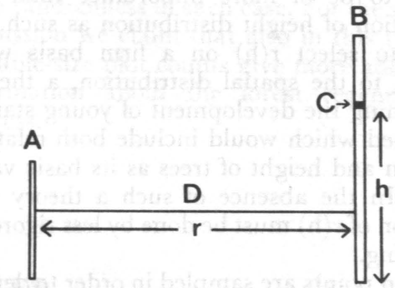

Fig. 2. Suggested principle of height relascope for regeneration surveys.

A is the center stick of the plot.
B is the measuring stick.
C is a moving sign, seedlings projecting above it are to be measured.
D is a rope or wire which will get longer or shorter as needed and which will always tighten horizontally.

4. RELATION BETWEEN PLOT SIZE AND PLANT HEIGHT

The function r(h) can be selected to provide the desired sampling distribution of plant heights. Suppose that the density function of the height distribution in the whole stand is f(h). The sampling distribution with the density function g(h) is required. Then r(h) can be derived as follows:

$$g(h) = b\pi r^2(h)\, f(h),$$

where b is a chosen scale factor. Thus

$$r(h) = \sqrt{g(h)/(f(h)\pi b)} \quad = b'\sqrt{g(h)/f(h)},$$

where $b' = \sqrt{1/\pi b}$.

The easiest way to fix the scale factor b is to select for height h_0 the corresponding $r(h_0)$. Then

$$b = g(h_0)/(\pi r^2(h_0)\ f(h_0)).$$

The selection of g(h) determines the accuracy to which the density in each height class can be estimated. If the sample plots and trees are randomly located and the sampled area is small compared to the total area, all density estimates are equally accurate for all height classes if g(h) is the density function of the uniform distribution, i.e. constant over the height range. In this case the area of the sample plot is inversely proportional to the density of the height class.

In practice the stand height distribution f(h) is not known, the goal is to estimate it. However, the general form of the observed height distributions can be used to guide the selection of r(h).

Description of the spatial arrangement seems to be of more importance than the estimation of height distribution as such. In order to select r(h) on a firm basis with respect to the spatial distribution, a theory concerning the development of young stands is needed which would include both relative location and height of trees as its basic variables. In the absence of such a theory the selection of r(h) must be done by less rigorous reasoning.

When points are sampled in order to determine their coverage or openess the main question is: which tree, if any, occupies a given point in the direct ecological sense or in the more economic sense that the space will be utilized later on when trees have a market value. Thus an adequate measure of seedling size is needed. It should be remembered of course that it is impossible to divide space up into conclusive domains of different seedlings and into unused space because the seedlings have gradually changing interactions and there are many stochastic phenomena involved.

At the moment we do not know enough about the regeneration process to suggest a more adequate measure of the size of seedling than height. If plot area and thus the selection probability is proportional to plant height then:

$$\pi r^2(h) = b\ h,$$

where b is a scale factor. Therefore

$$r(h) = \sqrt{b\ h/\pi},$$

or inversely

$$h(r) = \pi r^2/b.$$

Analogically to basal area estimation using a relascope, when the sampling is proportional to height the total height of the seedlings can be estimated by merely counting the qualified seedlings.

If there are several seedlings on the given plot, then the tallest one can be considered to be the seedling which qualifies as the basic tree for the future tree stock. When selecting basic, qualified trees from variable-size plots instead of fixed-area plots, the absurd situations in which a small tree lying just inside the fixed circle is chosen as the basic tree even if there are much taller trees very close to it, but just outside the circle, can be avoided.

There are two different strategies for handling the scale factor, the functional equivalent of the width of the notch in an ordinary relascope. The first possibility is to choose one universal scale factor to make direct comparison of different regeneration areas straightforward. The second is that the scale factor can be adjusted to the average age and density of the stand under survey so as to make the sampling more accurate with respect to the internal variability of the stand.

5. CONCLUDING REMARKS

Utilization of variable-size circular plots in surveys of the adequacy of stocking on naturally regenerated stands is proposed in this paper. Tall seedlings should be sampled from a larger area than smaller ones because tall seedlings fill a larger space, are usually growing further apart than smaller ones, are more important in the development of the stand, and are more likely to survive.

Circular plots have more intuitive appeal than the variable-size rectangular plots used by Bickerstaff (1961), because the existence of seedlings on a circular plot can be interpreted to mean that the center of the plot is stocked.

The height relascope might also be useful in energy wood inventories of forests. Energy wood plantations are probably too dense and even to gain by the height relascope. If the goal is to obtain good estimates of the tree volume, sampling should be proportional to the cube of height or to a more precise estimator of the volume.

If the heights of the sampled trees are measured, an estimate of the height distribution of the stand is obtained which is more reliable with respect to tall trees than would be the case with fixed-area plots. Estimates of the mean, median, percentiles, number of trees above a certain height etc. can be calculated directly from the estimated height distribution.

Sample plots can also be used to describe the spatial distribution of the trees. It would appear that the zero-plot percentage calculated from variable-size plots is a better indicator than if calculated from fixed-area plots. In addition it is more justifiable to select basic trees for the future tree stock from variable-size plots. How different tree species should be handled remains an open question.

If the trees of each height class are distributed randomly and independently of other height classes, then the plot counts are also Poisson-distributed as is the case with fixed-area plots. Thus the same clustering indices can be used for variable-size plots as for fixed-area plots. Of course, clustering indices will be sensitive to different kind of departure from randomness in each case. For the sake of discussion we claim that also in this respect variable-size plot counts give more adequate information about the forest regeneration process.

REFERENCES

BICKERSTAFF, A. 1961. A variable quadrat regeneration survey method. For. Chron. 37: 39–54.

BITTERLICH, W. 1948. Die Winkelzählprobe. Allg. Forst- u. Holzwirtsch. Ztg. 59: 4–5.

KUUSELA, K. 1979. Sampling of tree stock by angle gauge in proportion to tree characteristics. Seloste: Puuston arviointi kulmamittarilla suhteessa puun tunnuksiin. Commun. Inst. For. Fenn. 95 (7): 1–16.

PERSSON, O. 1964. Distance methods. The use of distance measurements in the estimation of seedling density and open space frequency. Stud. For. Suec. 15: 1–68.

POHTILA, E. 1980. Havaintoja taimikoiden ja nuorten metsiköiden tilajärjestyksen kehityksestä Lapissa. Summary: Spatial distribution development in young tree stands in Lapland. Commun. Inst. For. Fenn. 98 (1): 1–35 p.

RAUTIAINEN, O. & RÄSÄNEN, P. K. 1980. Männyn ja kuusen viljelytaimikkojen kehitys Itä-Savossa 1968–1976. Summary: Development of Scots pine and Norway spruce plantations in Itä-Savo in 1968–1976. Folia For. 426: 1–24.

RIPLEY, B. 1981. Spatial Statistics. John Wiley & Sons. 252 pp.

ZÖHRER, F. 1978. Fundamentale Stichprobenkonzepte der Forstinventur I. Allg. Forstztg. 89 (5): 180–185.

YLI-VAKKURI, P., RÄSÄNEN, P. & SOLIN, P. 1969. Metsän viljelyn antamista tuloksista Lounais-Suomen, Itä-Hämeen, Itä-Savon, Keski-Suomen ja Kainuun piirimetsälautakuntien alueella. Helsingin yliopiston metsänhoitotieteen laitoksen tiedonantoja 2: 1–92.

SELOSTE

PITUUSRELASKOOPPI METSÄNUUDISTAMISEN INVENTOINNIN APUVÄLINEEKSI

Metsänuudistamisen inventoinneissa otantamenetelmällä on keskeinen merkitys pyrittäessä saamaan luotettava ja informatiivinen kuva taimien pituus- ja tilajakaumasta. Kirjoituksessa esitetään, että koealan koon pitäisi riippua portaattomasti taimien pituudesta. Pitkät taimet tulisi valita otokseen laajemmalta alalta kuin lyhyet, sillä suurilla taimilla on keskeisempi merkitys metsikön vastaisessa kehityksessä. Jos otanta suoritetaan tavallista relaskooppiotantaa jäljitellen kiinteää pystysuoraa hyväksymiskulmaa käyttäen, kohdataan käytännöllisiä vaikeuksia. Lisäksi muutoin kätevillä ympyräkoealoilla päädyttäisiin otantaan suhteessa pituuden neliöön, mikä yleisesti ottaen ei liene perusteltua. Kirjoituksessa esitetään periaatteet sellaisen helppokäyttöisen mittakepin rakentamiseksi, jonka avulla otantatodennäköisyys saadaan verrannolliseksi pituuteen tai haluttuun pituuden funktioon. Mittakeppi saattaisi soveltua myös metsien energiapuuinventointeihin.