Resumen **Sobre la eficiencia de algunos métodos de inventariación forestal**

Se realizaron pruebas de comparación de la eficacia de diversos métodos de inventariación forestal, destinados a la planificación de la ordenación. Los datos para estudiar las variaciones de la masa fueron tomados en cinco superficies, de extensiones variables entre 20 y 900 ha. Las varianzas de los volúmenes de las parcelas fueron calculadas para la masa entera, y divididas después en estratos. Se tomaron varias muestras para inventariación sistemática con uso de computadores electrónicos, calculando la desviación media de los promedios. Las comparaciones realizadas indican que, en determinado número de parcelas, los resultados de los inventarios sistemáticos son por lo general tan exactos como los de inventarios por el método estratificado al azar que, a su vez, es claramente superior que el sistema de inventariación al azar. Se calculó una función de regresión para proporcionar un ejemplo del efecto ejercido por factores tales como el tamaño de la parcela, la distancia entre parcelas, la extensión de las parcelas de inventariación y el volumen medio sobre el error normal en inventarios uniformes por líneas de inventariación. La ecuación fue utilizada para calcular las cifras de las parcelas con determinados grados de precisión. Mediante estudios de tiempos se calculó la regresión del tiempo de conteo de árboles por parcela de prueba sobre diferentes variables. Se prestó también atención a otras fases del trabajo de inventariación. Combinando los resultados de los estudios de tiempo y variación se ha conseguido comparar la eficiencia de diversos métodos. La extensión óptima, en general, oscila alrededor de los 300 m². En muchos casos no existieron diferencias en el tiempo total empleado, al variar la extensión de las parcelas de prueba de 100 a 1.000 m². Se incluye también un estudio sobre el posible efecto de cambiar factores tales como el número de árboles, el tiempo requerido para la localización de la parcela o la medición por líneas. El sistema de parcelas variables de pequeño tamaño, con comprobación de árboles limítrofes de situación dudosa, parece ser por lo menos tan exacto como el de parcelas fijas.

Résumé **Sur l'efficacité de quelques méthodes d'inventaire forestier**

Des expériences ont été effectuées pour comparer l'efficacité en vue de l'aménagement de méthodes différentes d'inventaire forestier. Les données pour l'étude des variations du matériel sur pied furent recueillies sur cinq surfaces allant de 20 à 900 ha. Les variances des volumes par placettes furent calculées pour la totalité du peuplement et réparties entre les strates. Pour les inventaires systématiques plusieurs échantillons furent prélevés en utilisant un calculateur électronique, et l'écart-type de leur moyenne fut calculé. La comparaison indiqua, qu'avec un nombre donné de placettes, les résultats d'inventaires systématiques sont généralement au moins aussi bons que ceux des inventaires stratifiés au hasard, lesquels, à leur tour, sont évidemment meilleurs que ceux d'inventaires au hasard. Une fonction de régression fut calculée pour apporter un exemple de l'effet de facteurs, tels que la dimension et la distance des placettes, la superficie de l'unité à inventorier et le volume moyen, sur l'erreur-type dans un inventaire systématique avec placettes en ligne. Cette équation fut utilisée pour calculer le nombre de placettes pour un degré déterminé de précision. À partir de l'étude des temps d'exécution, on a calculé la régression sur différentes variables du temps nécessaire par placette pour inventorier les arbres. Il fut également porté attention aux autres phases du travail d'inventaire. La combinaison des études de variations et de temps d'exécution rendit possible la comparaison de l'efficacité des différentes méthodes. La dimension optimum variant autour de 300 m². Dans beaucoup de cas, il n'existait pas de différence majeure dans le temps total nécessaire, à l'intérieur d'un éventail de variation de 100 à 1.000 m² dans la dimension de la placette. On a également inclu une discussion sur l'effet des variations de facteurs tels que le nombre de tiges, le temps nécessaire pour asseoir la placette et le chaînage d'un cheminement. Les petites placettes de dimensions variables, dans l'hypothèse où un contrôle des arbres douteux de limite est effectué, ont paru être au moins aussi efficaces que les placettes correspondantes de surface fixe.

MINIMIZING EXPERIMENTAL ERROR IN THINNING RESEARCH

C. B. BRISCOE (U. S. A.)

Many diverse approaches have been made prescribing and evaluating thinnings on an objective basis (Assmann, 1961; Chisman *et al.*, 1940; Cooper, 1961; Craig, 1947; Crane, 1962; Czarnowski, 1961; Dawkins, 1960; Downs, 1946; Gentle *et al.*, 1962; Hiley *et al.*, 1955; Hummel, 1953; Petrescu, 1962; Sagreiya, 1963; Singh, 1960; Smith *et al.*, 1961; Tadaki, 1964; Zahner *et al.*, 1960; and others). For two helpful reviews, especially of the American and European works, see Braathe (1957) and Vézina (1963). None of the techniques proposed has been widely accepted. Indeed, none has been proven superior to the others, nor even widely applicable. There are at least two possible reasons for this: none of the techniques suggested is of any general utility, and/or experimental error (whether or not results are actually subjected to statistical analyses) is so large that real treatment effects are hidden.

No good idea among the many suggested may be considered unlikely. Not only are the techniques the result of a great deal of thought and work by well qualified men, but all are clearly related to established physiological principles. Furthermore, many have given statiscally significant results under certain circumstances. Excessive experimental error, the second reason suggested, seems a more likely explanation. Certainly error values are often high, which can easily obscure real and important differences. This paper reviews briefly some of the general methods of limiting experimental error and discusses one technique applicable specifically to thinning research.

GENERAL METHODS

Restriction to a simple comparison. Experimental designs, now widely understood, efficiently compare many levels of a variety of factors. These designs permit large savings in time and money for agricultural and short-term forestry studies. Unfortunately, long-term studies are subjected to so many random accidents and systematic influences not recognized before establishment that even a moderately complex plan becomes filled with missing plots and non-comparable comparisons. Minor variations accumulate through time into major differences completely unrelated to or — worse — confounded with planned treatments. Keep it simple.

Replication. In spite of the expense and difficulties involved some replication is simply indispensable. Not only to limit experimental error, but as Fisher (1951) pointed out (p. 60) «...its main purpose... is to supply an estimate of error» and (p. 34) «...it is all too frequent, for an experiment to be so conducted that no valid estimate of error is available. In such a case the experiment cannot be said, strictly, to be capable of proving anything.» Current literature indicates this view has not been completely accepted as yet. Replication of thinning research is often thought to be physically impossible; sufficiently large areas of uniform forest just do not exist. However, only one complete set of treatments — normally about four plots — need be installed at a single location; in fact, not even a single complete set of treatments at each location is essential, but complete sets are preferable. Other replications may be at other locations, and reliability of results is actually improved by doing so.

Accuracy. Whatever the degree of precision, measurements must be correct. If diameter is measured to the nearest millimeter, it should be correct to the nearest millimeter. If height is measured to the nearest two meters, it must be correct to the nearest two meters.

Minimum extraneous variation. In practice, this usually means select a site and stand that appear uniform, then use the smallest plots practical as close together as possible. Plots need not be the same size for all treatments; precision of plot values depends — almost invariably — on the number of trees per plot, not on area of plot.

Uniformity of treatment. Treating all plots the same, except for the variable under study, is extremely difficult to accomplish in practice, chiefly because of the difficulty of deciding what constitutes «the same». if 10 m^2 of basal area are cut per hectare on two different plots, is that equal treatment when original basal areas were 30 and 60 m^2 per ha? Is thinning to a spacing of 20 percent of top height a constant treatment whether original spacing is 5 percent or 15 percent? Obviously not. It is with one aspect of this problem that the remainder of this paper deals.

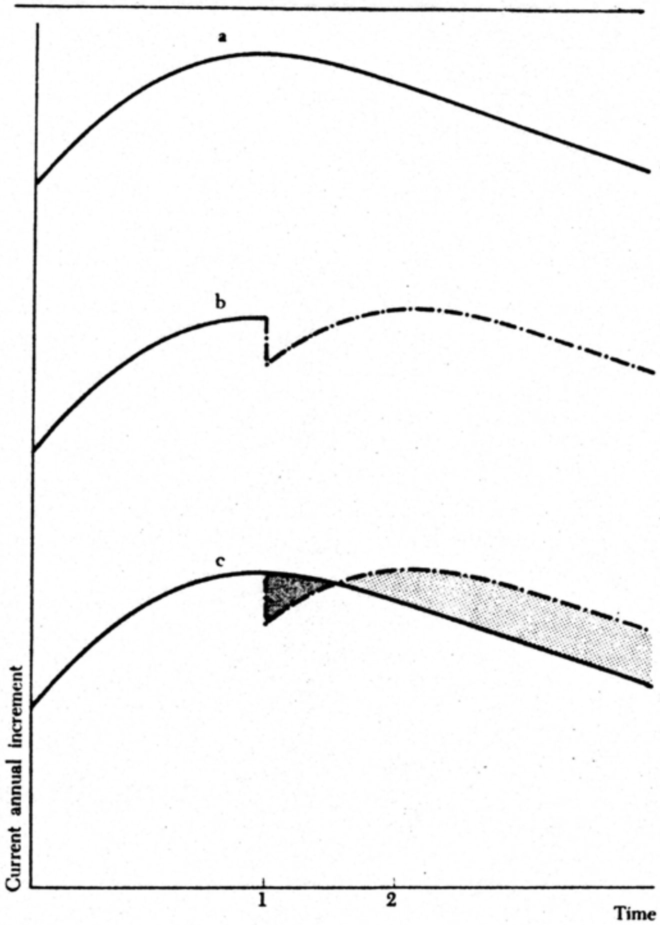
THINNING CYCLE

Johnston and Bradley (1963) made an important contribution to the scientific study of thinning effects by pointing out that «weight» (amount of stand removed) is quite distinct from «cycle» (number of years between thinnings), although the two are often combined as «intensity», i. e., weight divided by cycle. The inference is plain that weight and cycle must be controlled. But how? Virtually all thinning studies have treated cycle as a constant when all weights of thinning are made on a cycle of the same number of years. That is, if 10, 20, and 30 percent of basal area is cut at each thinning, cycle may be set at five years for all. The tacit assumption is that such a procedure constitutes equal treatment. In fact, it is grossly unequal.

Measuring cycle in years. The normal increment pattern of an undisturbed stand is shown in the upper curve of Figure 1 (McArdle *et al.*, 1949; Avanzo, 1963). The assumed effects of thinning the same stand are shown as the dashed portion of the middle curve, and the loss and the gain resulting from the thinning are shown in the lowest curve. It is apparent that regardless of the exact shape of the modified curve, assumed in Figure 1 to be identical to the undisturbed one, there will be a net loss in total increment if a second thinning is made before point 2 in time. Actually, the disturbed portion of the curve may well rise more slowly, peak at a lower absolute value, and fall more rapidly than the undisturbed curve, but such a response would simply accentuate loss resulting from too short a cycle.

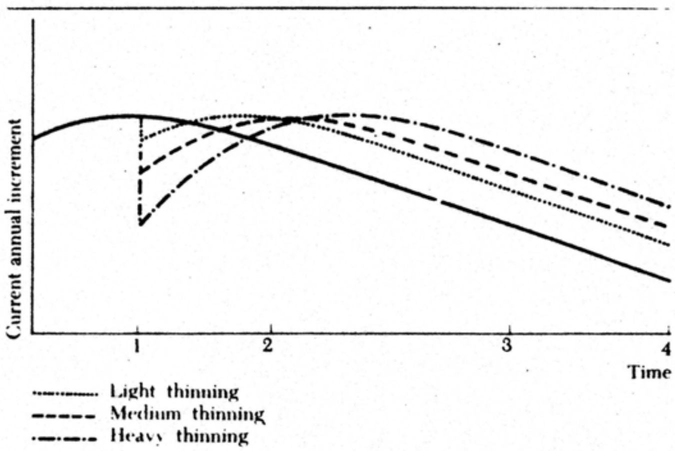
Figure 2 shows the effects of a light, medium, and heavy thinning, again assuming identical curve shape. A second thinning at point 2 in time would greatly favor the light thinning, since recovery is still not complete for the other two. A second thinning at point 3, however, would favor a medium thinning, and at point 4 would favor heavy thinning. Thus a study supposedly of weight of thinning could yield any of three mutually contradictory results, depending entirely on the cycle selected. The relatively short cycles selected for most

FIGURE 1. ASSUMED PATTERN OF FOREST INCREMENT.



a. Undisturbed stand.
b. Thinned stand.
c. Undisturbed and thinned stands, showing initial loss and increment resulting from thinning and subsequent gain.

FIGURE 2. INCREMENT PATTERN OF STAND IF UNDISTURBED, AND IF GIVEN A LIGHT, MEDIUM, OR HEAVY THINNING.



thinning studies may be the reason most have indicated light thinnings yield more. Similarly, a constant time cycle combined with a changing pattern of stand recovery may be why some thinning studies have shown one weight of thinning to yield most at first, to be supplanted by a different weight later. Finally, too short thinning cycles, before point 2 in Figure 1, may be why many studies have indicated that any thinning reduces total yield. It should be clear from the above that thinning cycle cannot be fixed in terms of years.

OTHER UNITS FOR MEASURING CYCLE. Only brief reflection is needed to see that a unit of height growth is equally unacceptable, since height growth is simply time corrected for site quality, and modified to an unknown extent by tree physiological age. A unit of diameter growth is somewhat better, since it is at least more closely related to growing conditions and vigor, but it is certainly not adequate. Shortest cycles would be applied to trees with no competition whatever, and which biologically least need release. On the other hand, dense stands badly in need of thinning may require years and years to complete a cycle based on diameter growth. Lexen's (1943) bole area, based on both height and diameter, may be found useful for a rule-of-thumb practical application, but appears to have no place in studying thinning cycle. The above discussion seems to point quite clearly to the curve of stand development as the logical means of determining thinning cycle, a technique first suggested to the writer by R. T. Bradley.[1] Increment in value, volume, basal area, diameter, or even bole area could be used as the dependent variable. The critical point is this: a separate curve must be determined for each thinning plot, and each plot must be thinned at the same point on its curve.

ADVANTAGE OF UNIFORM CYCLES. With thinning cycle actually equal for all weights of thinning, objective studies of the effects of varying weight should be possible. If sufficient accurate measurements are made, a single study could compare thinning weights and also compare methods of expressing the weight. Simple correlation analysis will determine empirically whether the currently popular spacing as a percentage of height (Brown, 1847; Hart, 1928; Becking, 1953) is in fact superior to average diameter (Warren, 1936; Mitchell, 1943; Sagreiya, 1946), number of stems (Reinecke, 1933; O'Connor, 1935; Witch, 1948), basal area directly (Joergensen, 1957), or indirectly (Assmann, 1961), crop tree release (Langsaeter, 1941; Staebler; 1956; MacDonald, 1962), or some other character or combination of characters. Although I believe Sakaguchi (1961) may have been too pessimistic in his conclusion that qualitative thinnings cannot be replicated or consistent, the most widely-used thinning grades in Europe certainly confound both weight and frequency with crown class and stem quality. Purely quantitative controls seem to offer more useful information until their effects are known.

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Resumen

Reducción del error experimental en investigaciones sobre aclareos

El error experimental puede reducirse simplificando el estudio, replicando, midiendo correctamente, usando parcelas pequeñas agrupadas lo más cerca posible y tratando igual todas las parcelas. Para conseguir esto último, debe establecerse un ciclo de aclareo para cada parcela, basado en su propia curva de desarrollo, ya que los ciclos de años iguales oscurecen o invierten los efectos verdaderos del peso variable de aclareo.

Résumé

Comment réduire l'erreur expérimentale dans la recherche sur les éclaircies

L'erreur expérimentale peut être réduite par la simplification de l'étude, par la répétition, par des mensurations correctes, en utilisant des petites parcelles étroitement groupées et en appliquant un traitement égal à toutes les parcelles. Pour mener à bonne fin cette dernière tâche, la période des éclaircies doit être établie pour chaque parcelle sur la base de sa courbe de développement, parce que des rotations égales peuvent masquer ou intervertir les effets réels de l'influence variable de l'éclaircie.

ECOLOGICAL RESEARCH IN CHANGING FORESTS OF WILDERNESS AREAS

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The trend of life in modern civilization has evolved to a stage where leisure time is available to most working classes. With more and more urbanization, man in increasing numbers is seeking the forests, lakes, and campsites for his recreation. Population increases make this exodus to the forest even greater. Consequently, recreational pressures on forested lands are growing at an alarming rate in many countries. Furthermore, modernized equipment has changed the modes of travel and camping, making it necessary to adapt the recrea-