THE PRACTICE OF UNEVEN-AGED SILVICULTURE

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ABSTRACT

The need to choose an appropriate silviculture system for a given set of management goals often poses problems. System selection should be influenced by ecological and silvicultural characteristics of species and forest types, plus site conditions.

Uneven-aged silviculture may be defined as the manipulation of a stand to maintain a continuous high forest cover, provide for regeneration of desired species and the production of timber together with other forest products and benefits. It is based largely on the philosophy that silviculture is dependent on a continuous input of biological knowledge and empirical judgement.

Stands with an all-aged structure and tolerant species composition are suited to uneven-aged silviculture. A diameter distribution goal, residual stocking level and maximum retainable tree size need to be set before uneven-aged silviculture can be practised. It is more complex than is even-aged silviculture. Much of the decision making is intuitive and difficulties have often been encountered. Its use is not an easy solution to forest resource conflicts.

INTRODUCTION

Foresters are, and will continue to be, confronted with the dilemma of choosing between different silvicultural and management systems to achieve various mixes of products and benefits on specific forest areas. Such choices have to be made because no single silvicultural or management system is ideal for all situations.

For several centuries numerous versions of two systems, even and uneven-aged management, have been applied to forests throughout the world. Both systems, whilst based upon silvicultural principles, have been expanded to include forest management aims, although in the pure sense silviculture and management are recognised as separate but related disciplines. Silviculture is the process whereby forests are tended, harvested and replaced. Management focuses on decision making, organisation, administration and planning (Gibbs, 1976).

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Silviculture is an ever-evolving activity. It is becoming more varied, more complex and more responsive to forest resource needs and conditions as more knowledge about the characteristics and cultural requirements of species and forest types is acquired (Chavasse, 1978).

HISTORICAL PERSPECTIVE

It has been suggested that silviculture had its beginning when thought was first given to reproducing trees. Accepting this view, it may be assumed that silviculture had its origin not when God put man in the Garden of Eden but when he kicked him out of paradise and told him to cultivate the ground (*Genesis*, 2:3). Up until that time Adam had only been concerned with harvesting the old crop.

More conventionally, history indicates that silvicultural systems usually evolved when a country or region was confronted with a diminished or depleted wood resource as a result of forest exploitation (Smith, 1972). The initial reaction was to protect what resource remained and to begin a reafforestation programme. A host of recorded events, laws, ordinances and regulations, from biblical times in the Middle East, China in the 12th century B.C., the era of the Roman Empire, and the medieval period of Europe, have been cited as being the stages or reference points in the development of the classical silvicultural systems (Fernow, 1911; Troup, 1952; Meyer *et al.*, 1961). Some of the more complete accounts of the chronological sequence of events from exploitation to the development of management systems for sustained yield timber production are those associated with the evolution of silviculture in Europe, particularly Germany.

Early work showed that economic and practical considerations favoured the use of few species and even-aged techniques. In the Austrian Forest Ordinance of 1786, even-aged techniques prevailed. In Prussia, a 1787 ordinance provided that even-aged stands should be grown and the Darmstadt Ordinance of 1776 prohibited use of the uneven-aged selection system (Heske, 1938). However, after several rotations, on some sites, growth began to decline, windthrow occurred and pathological disorders became evident. Timber yield and quality diminished. During the 19th century European foresters began to further examine uneven-aged silvicultural systems.

The Baden Forest Law of 1833 actually prohibited clearfelling. Later in the 19th century Karl Gayer led a back-to-nature movement that called for natural regeneration instead of clearfelling with replanting and uneven-aged forest structures rather than ones composed of schematically arranged even-aged stands. The Dauerwald (continuous forest) system was revived and management in many areas of Germany and Prussia shifted to single tree selection (Larsen, 1924).

PHILOSOPHICAL AND OTHER DIFFERENCES BETWEEN SILVICULTURAL SYSTEMS

Uneven-aged silviculture may be defined as manipulation of the forest to maintain a continuous high forest cover, provide for regeneration of desired species and controlled growth and development of trees through a range of diameter classes (Meyer *et al.*, 1961). Managed uneven-aged forests are characterised by trees of all size classes intermingled singly or in groups. Trees are cut individually or in very small groups and the process of regeneration of desired species occurs either continuously or at each harvest. Each cutting cycle may include thinning and other cultural treatments designed to promote growth and to maintain or enhance stand structure.

The philosophy of uneven-aged management is based upon the concept that forest management is more dependent on a continuous input of biological knowledge, experience and silvicultural judgement. This doctrine embodies the maintenance of a stable forest environment, the guarantee of forest perpetuation and the production of timber together with other forest products and benefits.

The philosophy of even-aged management is based upon the conviction that forest management is primarily based upon mensurational and financial formulas. The concepts of the fully regulated or normal forest and the doctrine of soil rent are examples of this form of ideology. Other examples include the range of methods used for determining rotation length and allowable cut levels (Knuchel, 1953).

The basis of even-aged management is area control aided by mean tree size (rotation age). Harvesting techniques generate new even-aged stands either naturally or by artificial means. By contrast, forests subjected to uneven-aged management are segregated into recognisable relocateable units on some basis other than age class. Stand differentiation usually utilises an expression related to density such as stocking, basal area, volume or structural considerations. Appropriate cutting methods are those which develop or perpetuate given stand structures and stocking levels. Traditionally the selection system of harvesting has been associated with uneven-aged management.

Stands with an all-aged structure and tolerant species composition are well suited to uneven-aged silviculture. Even-aged silviculture is more appropriate in single-aged stands of intolerant species.

The selection of a system for any particular stand or forest should have regard for species' ecological and silvicultural characteristics, site conditions, forest policies and management goals.

Several practical considerations lead many foresters to feel that even-aged management systems are easier to plan and implement than uneven-aged ones. Some aspects which enhance the desirability of using even-aged techniques are: greater opportunities exist for using larger sophisticated labour-saving equipment in clearfelling settings; the opportunity exists for introducing genetically improved tree stocks; and administrative and record keeping procedures are relatively straightforward.

Forest management in the western United States of America generally follows the even-aged ideology. In addition to the above this policy can be attributed to:

(1) The attractiveness of even-aged management as an effective means of converting areas composed of decadent individuals of inferior species to quality, regulated forest.
(2) The current trend toward management intensification which has resulted in the need for more efficient means of administrative control.
(3) The ease of implementing even-aged silvicultural prescriptions.
(4) The historic dearth of uneven-aged techniques for large forest areas (Hann and Bare, 1979).

ENVIRONMENTAL CONSIDERATIONS

An increasing awareness of environmental values has become evident in recent years. In developed countries publicly owned indigenous forests are recognised as important natural ecosystems. However, modern lifestyles have meant that these areas have been caught in a crossfire of increasing demand and use. A competitive interaction exists between recreational demands, commodity use of physical resources, and protection needs of a myriad of intangible amenities.

Management of publicly owned indigenous forests must reflect and respond to predominant public opinion and needs. In New Zealand recent debate has focused on the harvesting of timber and the impact of this activity on the quality of non-wood resources. This issue has resulted in considerable areas of forest being classified so that timber production is prohibited. In North America similar trends have resulted in large portions of production forest being zoned for "modified handling". Timber harvesting in these areas must often use partial cutting methods. These techniques, in many cases, follow uneven-aged silviculture principles thus avoiding the visual impact of clearfelling (logging disturbance is screened beneath the residual forest canopy).

In today's environmentally conscious climate, uneven-aged silviculture is well suited to aesthetic and recreational zones, areas with high soil and water conservation values, and wildlife habitat areas, particularly for fauna requiring high forest cover and vertical diversity of vegetation.

THE UNEVEN-AGED FOREST CONDITION

Unmodified forest tracts often appear to display almost infinite variation in stocking, structure, composition and quality. The theory of population dynamics indicates that a population subjected to a consistent schedule of birth and mortality will eventually develop a stable age distribution. In a constant environment, a situation which usually applies to trees, the population generally becomes stationary or constant (Keyfitz, 1968). This static age class distribution formed when the progress of a large number of seedlings is plotted against time until all are gone typifies the uneven-aged stand condition. Constant or sustainable size (rather than age) distributions can be derived for a variety of different densities and structural forest types .

Timber harvesting may be viewed as simply another form of mortality. Therefore the concept of a stationary age or size distribution also applies to managed stands. If a consistent cutting policy is adopted the stand, following a period of post-logging adjustment, will settle down to a constant structure and growth increment. Sustained yield and a balanced stand structure* are achieved at this point.

The French forester de Liocourt found that a balanced, or sustainable diameter distribution is characterised by a constant quotient (called "*q*") between the number of trees in successive

* The term "stand structure" usually implies a relationship between the numerical stocking and diameter class (diameter distribution). A given diameter distribution determines stand basal area and relates closely to other measurements of density or stocking. Furthermore size distribution also implies, sometimes imperfectly, an underlying age distribution. (This is important because most of the underlying theory of population structure is based on age.)

diameter classes (Meyer, 1943, 1952). This relationship generates a geometric series of the form:

$a, aq, aq^2\ aq^3 \ldots$

where a = number of stems in the largest diameter class

q = the ratio of the geometric series

When plotted this series forms the well-known inverse J-shaped curve. The ratio "q" expressing the increase in the number of stems as diameter decreases, is a fundamental characteristic of the uneven-aged condition and it provides the basis for the concept of uneven-aged normality (see Fig. 1).

Values for "q" ranging between 1.3 and 2.0 (for 5 cm diameter classes) have been recommended for various management situations. A high "q" ratio indicates a rapid decrease in the number of trees with increasing diameter and hence a relatively small

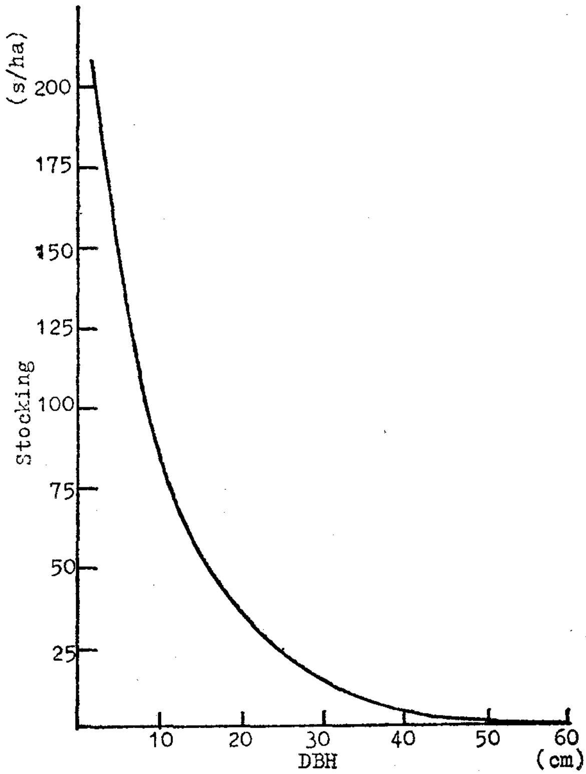

FIG. 1: *Diameter distribution for a "q" value of 1.3, maximum tree size of 60 cm and residual stocking level of 14 m²/ha*

proportion of large diameter trees. A smaller value for *"q"* signifies a slower decrease in the number of trees with declining diameter and hence a relatively high proportion of trees in the larger diameter classes. This situation generally results in a larger and more valuable yield. However, the maintenance of a low *"q"* value usually means that the excess numbers of small stems that develop must be removed periodically. For example, consider the number of stems that are retained if *"q"* equals 1.3 versus the number that remain at a *"q"* value of 2.0 (see Table 1).

TABLE 1: STAND STRUCTURE GOALS FOR VARIOUS *"q" VALUES*

		"q" Value (for 5 cm classes)	
	1.3	*1.6*	*2.0*
Diameter Class (2 cm classes)		*Average Stand Diameter (cm)*	
	22.9	15.7	11.2
	Stocking stems/ha		
2-14	200	531	1003
16-28	103	163	274
30-42	62	54	52
44-56	32	15	7
Total	397	763	1336
	Basal Area (m^2/ha)		
2-14	0.96	2.23	2.78
16-28	3.26	4.87	5.83
30-42	5.42	4.68	3.56
44-56	6.68	2.91	1.15
Total	16.32	14.69	13.32

Obviously many of the additional small stems present would have to be eliminated under a 1.3 *"q"* regime. Comparing the basal area in the upper diameter classes, there is much more growing space devoted to larger trees when *"q"* is low.

To facilitate the use of uneven-aged silviculture, the following three requirements need to be set:

(1) A residual stocking goal, expressed by number of stems and basal area by diameter class that must be maintained to provide acceptable growth and yield.

(2) A diameter distribution goal that will provide for regeneration, survival and development of replacement trees.

(3) A maximum tree size goal.

The setting of appropriate residual stocking levels is an important requirement. Since total productivity for a particular stand does not differ greatly over a range of stocking levels, residual stocking goals set near the lower limit concentrate increment on the fewest possible stems, so reducing the time required to grow individual trees to a specific size.

Management guides have been developed for uneven-aged stands. Generally they have been developed by subjective interpretation of forest studies. With relatively recent advances in forest growth modelling and mathematical programming techniques it is possible to derive optional stocking and structural guides for stands. Recently developed, relatively simple growth models (Mosen, 1973; Ek, 1974; Adams and Ek, 1974; Enright and Ogden, 1979; Buongiorno and Michie, 1980) explicitly consider the interdependence of stems and provide a means of predicting the response of stand growth components to variation in structure and other stand parameters brought about either by natural stand development or silvicultural tending and harvesting.

THE INFLUENCE OF SPECIES TOLERANCE VARIATION

Uneven-aged silviculture, involving the cutting of individual stems or small groups of trees, simulates natural disturbances such as might result from the death or windthrow of larger trees. Regeneration must become established under the partial shade of the overstorey and survive for lengthy periods in this situation. Uneven-aged silvicultural techniques are therefore suited as a regeneration cutting method for tolerant species and some species with intermediate tolerance.

Successional vegetation patterns indicate species' tolerance levels. Climax or equilibrium associations are usually composed of slower growing tolerant species. Seral stages are dominated by intolerant species which, to be renewed, need to be managed using even-aged techniques.

If single-tree selection techniques are applied to stands containing intolerant species, the composition of the forest will gradually change as the more tolerant species establish and grow (Trimble, 1965, 1970). However, if harvesting produces small openings in the canopy, as would be the case when a cluster of two or three trees are removed, a significant amount of the subsequent regeneration is likely to be of species with intermediate tolerance (Leak and Filip, 1975). By comparison, small patch clearfelling facilitates the establishment of some intolerant species (see Table 2).

TABLE 2: SPECIES COMPOSITION* BASED ON THE TALLEST TREE PER 4 m^2 PLOT†

Cutting Method	Species Tolerant	Composition Intermediate	(%) Intolerant
Single-tree selection	81-92	7-18	1
Single-tree selection with small openings (*ca.* 40 m^2)	68-80	18-31	1-2
Patch clearfelling (400-2500 m^2)	62-77	7-34	4-16

*Tolerant species are beech (*Fagus grandifolia*) sugar maple (*Acer saccharum*) eastern hemlock (*Tsuga canadensis*) and red spruce (*Picea rubens*). Intermediate are yellow birch (*Betula alleghaniensis*) white ash (*Fraxinus americana*) and red maple (*Acer rubrum*).
†Leak and Wilson, 1958; Marquis, 1965.

Although the intensity of cutting and the size of canopy gaps have an important influence on the proportion of tolerant, intermediate and intolerant species regenerating, site factors, harvesting method and other cultural work will influence the establishment and survival of species and tolerance groups.

Because uneven-aged silviculture is most suited to the management of tolerant species, there must be commercially acceptable tolerant or semi-tolerant species present or selection cutting should not be used. In some areas it is possible to expand the conventional single-tree selection system to include treatments which promote regeneration of intermediate and intolerant species. Group selection (small canopy openings) diversifies species composition. It also maintains stocking and structural conditions similar to those advocated for single-tree selection. It seems feasible to use a combination of group and single-tree selection as an option for managing some forest types. Group selection can be used to remove groups of mature and overmature trees and to maintain a mix of intermediate and some intolerant species. Single-tree selection can be applied between groups to remove malformed, defective or overmature trees and to shape stand structure as desired (Leak and Filip, 1977).

COMPLEXITIES OF UNEVEN-AGED SYSTEM

Most foresters would agree that the implementation of uneven-aged management systems is more complex than is the case for even-aged systems. Much of the decision making is intuitive, relying on ecological knowledge and practical experience.

The choice of harvesting systems compatible with residual stand structure goals must be considered as must other aspects of harvesting such as yield, costs and cutting cycle length. Harvesting must not injure residual stems but promote suitable conditions for the regeneration of desired species.

Various difficulties have been encountered when endeavouring to practise uneven-aged silviculture. In recent times environmental constraints have forced foresters to adopt uneven-aged regimes when even-aged techniques appear to be more appropriate for a particular situation. The lesson learnt has been that uneven-aged silviculture should not be seen as an easy solution to forest resource conflicts.

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