Unit 1.01.00 - Temperate and boreal silviculture

State of Knowledge

Boreal and Temperate Forests

Boreal and temperate forests are the forests of the northern latitudes and the middle latitudes in both the northern and southern hemispheres. The boreal coniferous forest is limited to and dominates the northern latitudes where it comprises the largest forest area of the world. The middle latitudes outside of the tropical zone have four major natural temperate forest types, the broadleaf evergreen, broadleaf deciduous, middle latitude coniferous, and the schlerophyll forests. Human activity has impacted species composition and vegetation structure in the regions, including clearing for agriculture and pasture but the conversion of forest habitat to other uses has occurred at different rates and different times in history. For example, most of Europe and Asia were settled millennia ago, while human occupation of the Americas began only about 15,000 to 20,000 years ago. Nevertheless, the transformation of land use is not unidirectional; wars, plagues, population movement and fluctuations, and climate changes cause agricultural abandonment and reversion to forests. Despite widespread human activity, old forests remnants can be found in Europe, Asia, Australia and New Zealand, and the Americas. Significant changes have occurred within the last 200 years as industrialized nations shifted from a biomass energy economy to fossil fuels. Further changes are likely in the industrialized nations of the temperate and boreal zones, as changing policies for agriculture and nature conservation provide incentives for land use shifts from agriculture to forest.

Silviculture

The IUFRO definition of silviculture (IUFRO 2005) is as follows: "*Silviculture is the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis."* Silvicultural systems focus on controlling species composition and stand structure (which includes spacing and competition), emphasizing the vigor of desirable individual trees. Thus, two concerns differentiate silvicultural systems: how a stand is regenerated and the structure that is sought or maintained. The practical application of silviculture within forestry is greatly diversified by various silvicultural practises and traditions depending on country, ownership, and many other aspects including the experience of individual silviculturists. Johnson et al. (2002 p. 5-6) have elegantly described silviculture as a discipline of applied ecology but integrated within social realm: "*Silviculture consequently depends on linking knowledge and theories across many disciplines, both scientific and non-scientific...*"

A number of silvicultural systems have been developed and described in silvicultural textbooks and taught in forestry colleges (e.g. Matthews 1997). Although the following definitions are somewhat old and possibly outdated, nevertheless they are widely used.

- Clear-cutting system – the mature stand or part of it is cleared in one operation and typically the area is replanted. Advance natural regeneration, re-sprouts, natural regeneration, direct seeding, or a combined effort may also be used for the regeneration of the cleared area.
- Uniform shelterwood systems – the mature crop is typically a uniform single-species stand that is gradually and uniformly opened by successive fellings (regeneration fellings), often to facilitate the establishment and growth of evenly distributed natural regeneration. Artificial

regeneration may also be used, for example if natural regeneration fails or lacks desirable species.

- Group systems – are like the uniform system used in uniform stands and aim at producing even-age natural regeneration when they reach the pole-stage. Artificial regeneration may be used as well. At the initial stages gaps are cut in the mature stand leaving space for groups of regeneration to establish or be established. These groups gradually expand with the enlargement of the gaps to finally form completely regenerated areas.
- Irregular shelterwood systems – involve longer and less uniform regeneration periods and patterns. The goal is not even-age successive stands but rather an uneven-age future forest, often with an ambition to mimic the processes and patterns of the "natural forest."
- Strip systems – the mature crop is cleared in successive and narrow strips (approximately half the height of the old trees) to achieve side protection and sidelight for the natural or artificial regeneration in the strips.
- Selection systems – the felling of single trees or small groups of trees are not linked to particular areas or parts of the forest. The regeneration is predominantly natural and the harvested trees are often selected by criteria such as target-diameter limits or other measures of identifying harvestable trees. The system is often installed to facilitate an uneven-age type of forest.
- Group selection systems – this system is close to the (single-tree) selection system but with more emphasis on producing larger gaps and regeneration groups to facilitate the structural diversity of the forest.

More systems could be mentioned including various coppice and agro-forestry systems. Recent overviews of silvicultural systems can be found in Smith et al. (1997) and Nyland (1996). A more fundamental approach, such as that of Oliver and Larson (1996), focuses on the way stands develop following disturbances or silvicultural interventions. Additionally, there are many more "sub-systems," national and even "personal" systems developed and described by well-respected specialists in different countries or regions. Some of the systems are easily identified and described in both theory and practise. Other systems have always posed a challenge for even the trained observer to accurately identify because of overlapping definitions and appearance in the field.

Historical Development

Historically, silviculture developed because of real or imagined scarcity of timber resources. Thus, from its earliest stages silviculture has had an underlying and often unmentioned aim to produce wood products, in order to satisfy basic human needs for building materials, firewood, or pulp. Nonetheless, other forestry goals have always been a focus of silviculturists too such as protection forests, grazed forests, etc. From the beginning there has been a widespread desire among the most devoted silviculturists to mimic "natural" forest types in terms of forest structure, species composition, and stand dynamics. Popular ingredients have included continuous cover, uneven-age structures, mixed-species stands, and natural regeneration. The underlying aim was still wood production, but with an attempt to improve forest stability, production, and profitability relative to the simpler structures of plantation forestry.

Interestingly, the silvicultural system or the forest structure itself tended in some contexts to become the goal. During the last century, particularly the last two decades, interest has increased in incorporating natural disturbances into forest management as social preferences have shifted toward greater emphasis on forests providing goods and services other than wood products. In Europe, this "nature-based" forestry developed from German forestry traditions beginning in the 19th Century, with a first peak of interest in 1920s called the Dauerwald-movement. The main paradigm for

nature-based forestry is *"…. to follow and support Nature in her performance.*" As such it includes the various silvicultural systems, often with preferences for the various continuous-cover and mixed-species systems. In North America, a similar trend with an additional focus on management at broad geographic scale has been called ecosystem management. Systems mimicking small-scale-disturbances and gap-phase regeneration have gained popularity, such as irregular shelterwood and group selections systems.

Plantation silvicultural systems are often more intensive than classical systems. Decisions made at the outset will have long-term consequences for the plantation, and timing of treatments may have narrow windows to be successful. Costs of crop establishment and tending should be carefully balanced against returns, leading to an optimum harvest age just before interest charges overwhelm any returns from further growth. For example, a typical rotation of radiata pine *(Pinus radiata)* grown for clearwood in New Zealand would involve decisions about species and tree breed selection to match species and breed characteristics with site and product requirements. Plants would have to be propagated in a cost-effective manner. Site preparation methods would have to be chosen to provide a suitable environment for the young seedling and to provide access to manage the environment when trees are small, as well as to minimize impacts on the site that would lower productive capacity. Besides planting or sowing of tree stocks, vegetation management might be needed to favor the crop species. As the stand develops, pruning and thinnning may be required to optimize size and quality (amount of clearwood) of crop trees. These actions would have to be balanced against the cost of pruning in terms of tree growth and the cost of thinning in terms of growth per hectare. A final crop tree stocking would have to be selected, one that provides maximum growth for pruned trees at some cost in growth per hectare. Finally, the rotation length must be determined to guide the harvesting of trees at an age when they are big enough to provide enough clearwood to pay for pruning without waiting so long that interest on the establishment, pruning and thinning investments overwhelms the returns from clearwood.

The silviculturist's task for a plantation is similar to that for a natural forest managed for wood production: creation or maintenance of desired forest structure, composition, stand density and stocking, stem quality, and rotation length, while protecting both the crop and the site. In practice it is best to plan operations at the end of the rotation and work backwards, so that decisions about crop establishment are made only after the rest of the regime has been designed. The silviculturist must predict gains and losses of proposed actions from ecological, social and economic points of view in order to design management regimes for stands which satisfy human desires. The technology of plantation establishment and tending is well-developed for a few species and the approach is being adapted for other species and toward multiple goals, possibly but not always including wood production. Methods are being developed for establishing complex plantations of multiple species, especially in afforestation programs aimed at increasing biological diversity.

Current Knowledge and Future Challenges

Generalizations about the current state of knowledge and future challenges for silviculture in the boreal and temperate zones cannot adequately describe regional complexities and as such the condition is similar to challenges in tropical regions. Nevertheless, three general trends are affecting the practice of silviculture: a better understanding of the role of disturbance, effects of globalization of trade particularly changing market forces and the spread of invasive exotic species, and changing social preferences and expectations toward sustainability and provision of non-market goods and services from forests. In the industrialized nations, the response to these driving forces has been a

shift toward more complex structural goals, away from complete overstory removal (clearcut or clearfell operations) in managing existing forests, and the expansion of forest area using artificial regeneration and mostly simple structures (i.e., plantations). In the industrializing nations, the response has been protection of remnant natural forests and increasing forest area by establishing plantations. In some countries, unsustainable practices such as illegal logging, high-grading, and conversion of natural forests to plantations of exotic (non-native) species have occurred.

The focus of silviculture to adapt management of the existing forest estate to address new social objectives and reduce the negative effects of disturbance varies by region. In all countries, large-scale industrially-oriented forestry practices increasingly are challenged by the public on the basis of aesthetic and environmental concerns. In Europe many forests were established or regenerated into plantations, usually of non-native species that were ill-adapted to site conditions or subject to damage from wind disturbance. In North America, decades of fire suppression (along with other factors) have increased the risk of catastrophic wildfires. Throughout the boreal and temperate zones, new silvicultural approaches are required to manage existing forests to provide a wide-range of ecosystem services, including carbon sequestration and biodiversity, as well as roundwood production. Such approaches are often based, in part, on emulating natural disturbance regimes. Afforestation is undertaken to meet a variety of social objectives including reducing pressure on native forests, protecting water resources, carbon sequestration, and expanding production of roundwood and bioenergy feedstocks.

Selected Literature

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