Forest Management

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Overview

Global variation in forests and in human cultures means that a single method for managing forests is not possible. However, forest management everywhere shares some common principles because it is rooted in physical and biological sciences like chemistry and genetics. Ecological forest management is an approach that combines an understanding of universal processes with site-specific, local knowledge to sustain forest ecosystems and to provide what people want from them. In places as diverse as the equatorial tropics and the boreal north, people use forests in different ways. Sometimes the prize sought is food; at other times it is building materials, medicine, or bird-watching. The plants and animals available and the ways people use them depend on the condition of the forest itself.

Ecological forest management is based on knowledge of a specific forest – with its unique mix of climate, trees and other plants, wildlife, and human uses – plus a desire to sustain the protective, productive, and social functions it provides. Ecological forest management requires understanding the features common to all forests and using this knowledge to manage specific forests in ways that are adapted to their unique attributes. Individual tree growth, for example, always involves photosynthesis and cell division, but the outcome of the growth processes differs between a sal tree (*Shorea robusta*) in India and a corkbark oak (*Quercus suber*) in Spain. Communities of trees, or forests, also tend to follow similar growth patterns, although the rate with which the process unfolds depends on the species in the community, their individual life histories and competitive dynamics, and the amount of water, light, and nutrients that are available. This means that although the structure and composition of forests vary around the globe, common processes of how they grow, die, and regenerate can be studied and the results distilled into guidelines for managing them.

Origins

People have been using forests for millennia, but not until the nineteenth century did forest science emerge as a discipline. It developed in Europe in response to concerns about wood shortages and has helped turn human use of forests from exploitative to regenerative. The early interest in sustaining yields of wood led to decades of scholarly research on the growth requirements of selected tree species and the development of silvicultural systems to regenerate them after harvest. As human demands on forests expand to include consumptive and nonconsumptive uses of many goods and services, forest science continues to inform management practices, and vice versa. This mutual influence is revealed in the various terms, like ecological forest management, that have arisen over time and in different places to describe a science-based approach to managing forests. The terms may change, but this essence remains.

Challenges

Prices for forest products have historically reflected the cost of obtaining them, rather than the costs of growing them. Harvesting systems, therefore, typically emphasize operational efficiencies to keep extraction costs low and to reduce prices for consumers. These costs influence how trees are used, how they are removed from a forest, and consequently, the impacts on forests themselves. Competitive markets, with their emphasis on reducing costs, tend to simplify forest structure and increase the size of harvest blocks and road networks. Such efficiencies can reduce the costs of production but may not support management objectives that emphasize maintaining complexity in forest ecosystems. This distinction is important because human demands on forests also include sustaining their biological diversity (biodiversity). A challenge of ecological forest management lies in maintaining greater complexity cost effectively. Methods to value the expanding array of goods and services that humans derive from forests are being developed in ecological economics and other fields. These methods in turn create pressure to price products more accurately, to compensate landowners for forest services, and to match site conditions with harvest and regeneration systems. This is a continuous process, with adjustments made as observations of responses occur.

Contemporary Concerns

The fears of scarcity and depletion of forest resources that gave rise to forest science are cyclical. They also vary geographically and culturally. In affluent countries, some people are as concerned about nonconsumptive resources, like landscape aesthetics and biodiversity, as they are with wood supplies. Scotland's first national park (see Case study 1) offers a case of a visual forest management objective and its effect on silvicultural and harvest

Case Study 1 Loch Lomond and the Trossachs National Park, Scotland

Scotland's first national park was officially opened by Princess Anne in July 2002. The Loch Lomond and the Trossachs National Park encompasses around 1865 km^2 of some of the finest scenery in Scotland. More than 70% of Scotland's population lives less than an hour's travel time from the park. It is estimated that 3.2 million people visit the park every year, and 15 600 live within the park boundary, so managing the forested landscape for aesthetic views (see Figure 1) and recreation is a priority.

Figure 1 Scottish landscape showing diversity of vegetation patterns.

Within the park, the Cowal and Trossachs Forest District occupies an area of 66 000 ha. This part of west-central Scotland has a predominately temperate climate, receiving annual rates of precipitation of between 3600 mm in the west and 1520 mm in the east, with mean annual temperatures of 8.5 °C. Most of the natural oak woodland vegetation has been replaced with plantations of commercially managed conifer forests, which contain both native (i.e., *Pinus sylvestris*) and non-native tree species (e.g., *Picea sitchensis, Pseudotsuga menziesii, Larix decidua*). Most plantations were established between 1942 and 1971, following a time of intense forest depletion from the late 1800s through World War I.

Within the Cowal and Trossachs Forest District, the Achray forest is dominated by European larch (*Larix deciduas*). Most were planted around 1939. It has been managed by using a low-thinning management regime typically practiced from age 20 years onward. This involves removing 70% of the tree maximum annual increment at 5–7 year intervals. Timber production is the main management objective for these stands, but since they lie within the park landscape, visual maintenance and the quality of visitor experience are also important. The Achray forest is visited by 140 000 visitors per year, according to the David Marshal Lodge visitor center. This stimulated a move away from the traditional silvicultural system of clearcutting stands at optimum age, toward a system that will maintain a continuous cover of trees in the landscape. Managers are now trying to use systems that mimic ecological forest processes of stand disturbance and natural recruitment of seedlings.

Forest soils in the area are nutrient rich, well-drained upland brown earths, which support vegetation-rich swards where light levels permit. This sward develops beneath the larch stands and then becomes one of the main barriers to natural recruitment of seedlings. Slopes are relatively steep and preclude the use of machinery for harvesting and extraction; manually felling with chain saws and cable crane extraction are the preferred operation. All management operations conform to the United Kingdom Woodland Assurance Scheme (UKWAS) standard and are Forest Stewardship Council (FSC) certified (see Case study 3 for details on the FSC).

Most large dimension timber goes to local sawmills within an 80.47 km radius of the forest. Smaller material is used for pallet production and is taken to a medium-density fiberboard mill within 40.23 km. Local markets place a financial penalty on noncertified timber.

By Colin Edwards

systems. Elsewhere in Europe and North America, single-species forests are being converted to species mixtures and managed for the structural or compositional diversity associated with naturally regenerated forests. Various terms are used to describe this trend, including continuous-cover forestry, ecosystem management, and close-to-nature forestry. In less-affluent countries, many people still use wood for cooking and heating and rely on both natural and planted forests for food, fuelwood, and construction materials. Planted forests, or plantations, also yield wood for industrial use and international trade. The contribution of plantations to the social, ecological, and economic conditions of a site are subject to ongoing study and debate. Some cultures rely on forests to yield nuts, resins, latex, sap, poisons, cork, fiber, fungi, fruits, spices, honey, herbs, drugs, dyes, tannins, bamboo, and rattan (see Figure 2). The study of how humans use plants is the focus of economic botany or ethnobotany.

There is growing global awareness that our human population is increasing and many resources, like fossil fuels, are limited. Forests have a finite ability to meet competing demands placed upon them, but many forest resources are renewable, as long as soil fertility is not depleted or conversion to another land use does not occur. Indeed, as a case study of the Warm Springs Indian Reservation illustrates (see Case study 2) many attributes of forests are available for use in perpetuity if the basis for their existence is not jeopardized, either by the methods used to extract them or the amount that is removed.

Humans benefit from forests on scales ranging from global (carbon and oxygen cycles) to local (hunting and recreation). The goods and services people want from forests vary by culture and demand for them varies with population density, per capita income and wealth distribution, and access to land. The reasons for managing forests change, and the pool of knowledge and types of technology with which to do so accumulate over time. However, the basic management techniques change little; they always involve securing the conditions in which a tree seedling can grow.

Figure 2 Nontimber forest products for sale in a market on Pulau Laut, an island southeast of Indonesian Borneo.

Forest Dynamics

Trees are the dominant and distinguishing life form of forests; they create the structures that make forests unique. Not surprisingly then, the knowledge gained from studying trees is fundamental to ecological forest management. This knowledge must be understood and applied at larger spatial scales, however, because managing individual trees is not practical. This need forges a link with community and landscape ecology, which study the patterns and processes of forest growth and the interactive effects of competition, succession, and disturbance dynamics.

Reproduction and Establishment

Information about how different tree species reproduce is chief among the needs for managing forests in ways that sustain them and the people who rely upon them. Different tree species have different reproductive strategies. Some species sprout from existing root systems, others rely on birds and other animals to disperse their seeds, still others evolve seed dispersal strategies that require fire, wind, or some other disturbance. The different strategies confer different abilities to establish and grow in a particular set of conditions. Trees that reproduce vegetatively can have an advantage over trees that reproduce via seed on flooded or burned sites. In contrast, seeds that remain viable in soil over decades can ensure survival of early colonizers that get shaded out during long intervals without disturbance. Species life histories offer clues to the conditions under which different trees evolved and provide guidance for managing forests to favor some species over others. Soil conditions, including structure and fertility, are vital for seedling establishment and growth.

Productivity

The combination of site fertility, climate, and species composition influences forest productivity. Productivity is a measure of potential energy of a site and can be divided into either gross productivity, which includes all production, or net productivity which excludes production used in respiration. A group of trees growing together on a site of similar soil and climate and having similar structure is called a stand. Individual tree growth can be thought of as annual growth increment, whereas stand growth is the total sum of all trees in an area. Some

Case Study 2 Warm Springs Indian Reservation, USA

An integrated approach to resource planning and management on the Confederated Tribes of the Warm Springs Indian Reservation is mandated by current tribal law and inspired by the beliefs and practices of generations. This approach requires that all resources be considered when setting objectives and envisions the coexistence of a self-reliant society and a healthy environment in perpetuity. The management plan for the forested area of the reservation provides guidelines for the stewardship of all forest resources so that future generations have the same range of options that are available today.

The Warm Springs Indian Reservation is located in north-central Oregon, USA. Approximately 50% of the 259 000 ha reservation is forest land. It is home to the Warm Springs, Wasco, and Paiute tribes. Most of the 4000 members of the Confederated Tribes of Warm Springs live on the reservation, of which less than 2% is in non-Indian ownership.

The crest of the Cascade Range forms the western boundary of the reservation; the slopes are covered with mixed-conifer forests (including *Tsuga mertensiana, Abies procera, Pseudotsuga menziesii, Pinus ponderosa, Abies grandis*) that gradually descend into pine-dominated forests (*Pinus ponderosa, Pinus contorta*) and extend east into high desert communities of bunchgrasses and juniper (*Juniperus occidentalis*). Geologically, most of the forested area is tied to the formation of the Cascades, which were created by uplift during the Pliocene. The deep valleys and long, gentle to steep slopes and dissected ridges of the area reveal subsequent glacial melt and volcanic activity, which deposited andesites overlaid with pumice and ash. Deep soils typically occur at mid to lower slope positions, whereas upper slopes often have shallow, gravelly soil.

The mixed-conifer forests are managed to provide an array of commercial, subsistence, and ceremonial products, including timber, deer (*Odocoileus* spp.), and huckleberries (*Vaccinium* spp.). Conditional use areas on the reservation are designated to protect cultural resources. The tribal forest management plan has been certified by the Forest Stewardship Council (FSC) (see Case study 3 for details on the FSC).

Mixed-severity fire regimes with return intervals of 30–200 years interact with root disease and defoliating insects to create a patchy landscape comprised of multi-aged stands. One aim of ecological forest management is to use silvicultural and harvesting systems that match site conditions and forest dynamics. Accordingly, shelterwood systems, variable-intensity thinning, and aggregate retention clearcuts are favored on the reservation. Depending on slope, harvest systems include ground-based and cable operations.

Warm Springs Forest Products Industries, a tribal industry, operates an FSC-certified mill on the reservation, so most logs are hauled there over a network of local, state, and federal roads. The mill produces framing and industrial lumber, mostly from Douglas fir, white fir, and ponderosa pine; logs of other species are sometimes sold off the reservation to maximize income. An important objective of Warm Springs Forest Products Industries is to provide jobs to tribal members (see Figure 3), and its mission is to maximize the value of the forest resource for the Confederated Tribes of the Warm Springs.

Figure 3 Sawmill operations on the Warm Springs Indian Reservation, Oregon USA.

The mill can produce FSC-certified kiln-dried lumber and currently operates a 3 MW biomass power generation facility. It uses an on-site boiler to generate steam energy from mill residues. A proposed biomass energy plant might be co-located at the mill site.

By S. Hummel

evidence exists that forest productivity can increase with species mixtures because of the different ways resources are exploited and space is shared. At different levels of competition, a tradeoff exists between individual tree growth and the growth of a stand, as illustrated by Figure 4.

Development

In some forest stands, development begins with a severe disturbance; hence, the developing plant community is generally even-aged. When less-severe disturbances affect forests, the result is often mixtures of age classes

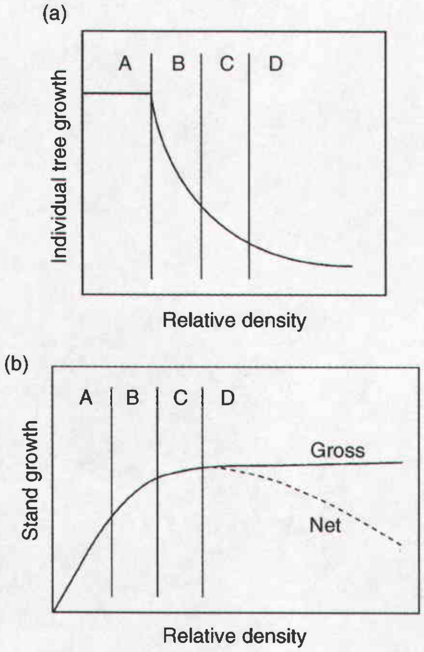

Figure 4 Tradeoff between tree growth and stand density as compared to stand growth and density. Both cannot be maximized at the same time in a single even-aged stand. Reproduced from Long JN, Dean TJ, and Roberts SD (2004) Linkages between silviculture and ecology: Examination of several important conceptual models. *Forest Ecology and Management* 200: 249–261, with permission.

Figure 5 Mixed-conifer forest in the Jack Creek watershed of the central Oregon Cascades USA.

that may be intermingled spatially or dispersed in clumps (see Figure 5).These uneven-aged or multi-aged stands are often more complex than even-aged stands because rates of growth affecting each age class differ. Similarities include the processes of trees getting larger, but declining in numbers, and continual competition for resources or growing space.

Stages of stand development can be classified by key stand structures and processes typical of each stage

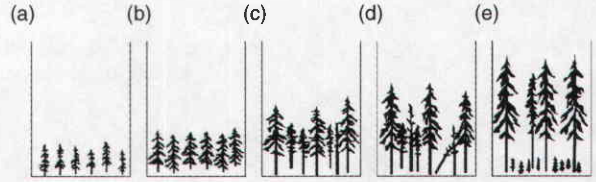

Figure 6 Schematic representation of stand development from a regenerating even-aged stand (a), through a series of competitive stages (b and c), to mortality (d), and regeneration of a second cohort (e). Reproduced from Long JN, Dean TJ, and Roberts SD (2004) Linkages between silviculture and ecology: Examination of several important conceptual models. *Forest Ecology and Management* 200: 249–261, with permission.

(as illustrated in Figure 6), although patterns of stand development vary by species and site. Stand structure includes the horizontal and vertical distribution of forest elements, including the heights and diameters of live and dead trees and the arrangement of foliage, crown layers, shrubs, herbs, and down wood. Although such classification methods can help link ecosystem processes and stand development, they also have limitations because they group continuous variables like diameter and foliage distribution, light conditions, and inter- and intraspecific competition into categories. Patterns of development are discernable in forests of all latitudes, but the rate of change varies with available resources and along gradients of temperature and moisture.

Disturbances redistribute carbon in a system and influence resource availability. They can occur at the scale of an individual tree or be much larger. Understanding the disturbance regime under which a forest evolved can provide important information on the possible continuum of intensity, frequency, and severity of management treatments. Scientific debate exists on the relation between disturbance frequency and biodiversity. A contemporary proposition is that silvicultural practices patterned on natural disturbance dynamics may conserve biodiversity in managed landscapes.

Silvicultural Principles

Silviculture applies theories and models from population ecology and biometrics to predict forest development. Two predominate. Size–density theory implies that in plant populations – such as a stand of trees – growth reaches a point where for some trees to get bigger, others must die to make resources available. Figure 7 represents a conceptual self-thinning trajectory of an even-aged stand undergoing density-dependent mortality over time. Whereas size–density theory relates to the trees per unit area of an average size, growth–growing stock relations describe the expected rate of growth .for any number of trees per unit area and stage of stand

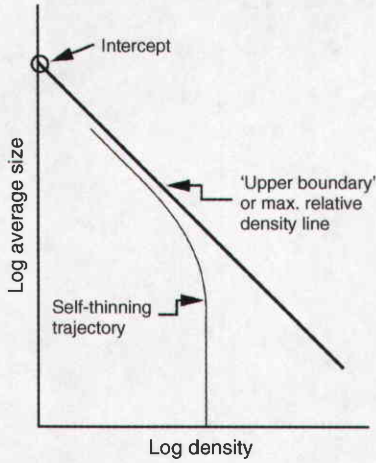

Figure 7 Self-thinning trajectory of an even-aged stand in relation to an upper boundary or maximum relative density line. In theory, any combination of tree size and density is possible below the upper boundary, but not above it. Reproduced from Jack SB and Long JN (1996) Linkages between silviculture and ecology: An analysis of density mangement diagrams. *Forest Ecology and Management* 83: 1–3, with permission.

development. Understanding how individual tree species respond to density is essential for ecological forest management.

Silvicultural Guidelines

Research has extended the principle of size–density relations to forest management by developing guidelines that avoid the subjectivity and site-dependent nature of absolute measures of density (trees per unit area, for example) and instead use mean size parameters such as quadratic mean diameter. Density management diagrams are based on theories of self-thinning populations and forest production and thus link forest ecology and management. They have been constructed for dozens of temperate species and a handful of tropical and boreal ones. Such diagrams illustrate volume and diameters associated with different levels of trees per area and help managers recognize how a stand is stocked relative to a maximum density. Thinning schedules can then be designed to achieve desired objectives, such as timber production or habitat structure. The diagrams are species specific and derived primarily from research in even-age, single-species stands.

Similar tools are generally not as developed for more-complex stand structures. Better knowledge is needed about the dynamics of mixed-species or uneven-aged stands and the response of such stands to specific treatments before such tools can be developed. For example, data on the effects of residual trees on the growth and yield of regeneration are limited, as is information about maximum density in mixed-species stands. Recent research in this area is linking more fundamental concepts related to stand productivity with management. For example, stand productivity is a function of photosynthesis which, in turn, is closely related to the amount of leaves in a stand. The amount of leaves is often represented by a leaf area index which is equal to the average number of layers of foliage projected to the ground. This information is useful because it is related to light reflectance, water usage, interception of precipitation, and productivity. Silviculturists are developing ways to use this as a stocking tool that links to other uses of this information. A multi-aged stand might have leaf area index divided by age class as a basis for stocking control. Similarly, a mixed-species stand could have its leaf area divided by species to determine proportions of different species.

Implementing Ecological Forest Management

A variety of methods to harvest and regenerate trees have been developed for forests of different types. Some have been studied experimentally and benefit from knowledge gained over decades, whereas others are still being developed and adapted. The methods rely on information about ecological and economic conditions of a site, including soil characteristics and life-history requirements of plants and animals, plus human cultural practices which favor the establishment and growth of some species over others. In implementing ecological forest management, the focus is on sustaining and developing the forms and functions of specific forest types. In some places, conditions favor stands comprised of few species and age classes, whereas in others the interaction of resource availability, species life histories, and disturbance patterns give rise to complex structures and composition.

Silvicultural Systems

In simple terms, silviculture manages the growing space of individual trees through treatments that regenerate and space trees. Trees can be spaced farther apart to create open stands that favor more understory plant development and larger trees with large branches, or they can be spaced closer together to create dense stands with little understory and smaller trees with smaller branches, but more overall tree volume production. Spacing can be managed when seedlings first establish or over time with intermediate thinning treatments.

A silvicultural system is a series of treatments applied to a forest stand to create target conditions. A given stand can be directed on many pathways, depending on management objectives. This is accomplished by altering the timing and intensity of silvicultural treatments to control light conditions and species composition. Traditional silvicultural systems represent a gradient of tree removal; the heaviest removals typically promote development of structurally and compositionally uniform conditions while the lightest removals may have little effect on diversity. Treatments between these extremes often promote the most complexity.

Even-aged silvicultural systems produce a single cohort of regeneration, which means the newly establishing trees are close in age. Clearcutting is an even-aged system that removes almost all trees, creating a fully exposed site. It is sometimes referred to as a monocyclic system, particularly in tropical forests. Seed tree systems also result in a single age class of regeneration. In this system, almost all trees are removed at harvest, but a few are retained so their seeds can produce the next generation. In contrast, a shelterwood system regenerates a stand with two age classes. It is distinguished from a seed tree system by using shade intentionally to give the seedlings of desired species a competitive advantage over other vegetation during their germination and early growth. If the shelter trees are removed after regeneration, the stand is even-aged.

Uneven-aged silvicultural systems regenerate a stand with three or more age classes. The objective is a forest with trees of different ages or sizes intermingled, typically accomplished with some form of selection system. In these systems, mature and immature trees are felled to create or maintain uneven-aged stands. Single-tree selection fells individual trees and generally tends to increase the proportion of shade-tolerant species in mixed-species stands. Group selection creates small openings and, therefore, maintains a higher proportion of shade-intolerant species in mixed species stands than does single-tree selection. Partial cutting is a general term denoting something other than a clearcut and can include selection systems. In tropical regions, selection systems are also referred to as polycyclic systems.

The methods used to manage structural and compositional diversity depend on site-specific conditions as well as on management objectives. For example, thinning is one silvicultural technique applied in various ways and for various objectives. It is a treatment to reduce tree density and alter spacing. Thinning can also be used to modify the stand structure to achieve greater vertical structural diversity, modify species composition, or encourage the development of new cohorts of trees or other plants. Precommercial thinning implies that trees cut are not merchantable, whereas in commercial thinning the trees are valuable enough to recover some of the costs of their harvest. When trees are cut from the lower crown classes to favor those in the upper classes, the term used is thinning from below. In contrast, thinning from above involves cutting dominant and co-dominant trees to favor the best trees of these classes. By targeting specific diameter classes or strata, thinning can be used to alter wildfire behavior, to recruit specific understory plants, to provide thermal and hiding cover for animals, and to grow trees with specific characteristics for wildlife habitat. For example, spatial patterns of residual trees can be altered to leave random or clumpy patterns depending on management objectives (see Figure 8). Although contemporary practices like variable density thinning do not have the benefit of long-term data supporting their intensity or design, they do rely on established theories of plant density and tree growth. Further, extensive silvical information on the shade tolerance and growth form of various species can be used to predict responses of mixed-species stands to various types and intensities of thinning.

Figure 8 Variable retention harvesting in Pacific Northwest of North America. Some trees are left within the cutting unit in clumps.

Harvest Systems

What occurs during and after intermediate treatments and final harvest determines whether and how a forest will be renewed, and its future composition. Chief among the effects are the condition of the soil and the condition of any advanced regeneration and its composition. Because harvest systems alter forest canopy and structure, it is important to control the removal of products in ways that site microclimate and soil are sufficient to regenerate desired tree species. This involves simultaneous consideration of the forest itself and available labor and machinery. Designing a harvest system involves weighing biotic and abiotic factors of forest inventory and topography. Minimizing damage to residual trees, other plants, animals, and soil is possible by the methods chosen and the timing of forest operations. The same property that makes wood so useful, lightness relative to strength, also makes it bulky in relation to its weight; so harvesting and transportation can be expensive. Harvest systems, which include falling, skidding, and hauling, are an important part of harvest planning. These systems include ground-based, cable, and helicopter; they differ in the amount of associated soil disturbance and in their cost. System selection considers factors like slope, value and size of trees removed, equipment availability, and site objectives. Helicopter logging disturbs soil and site

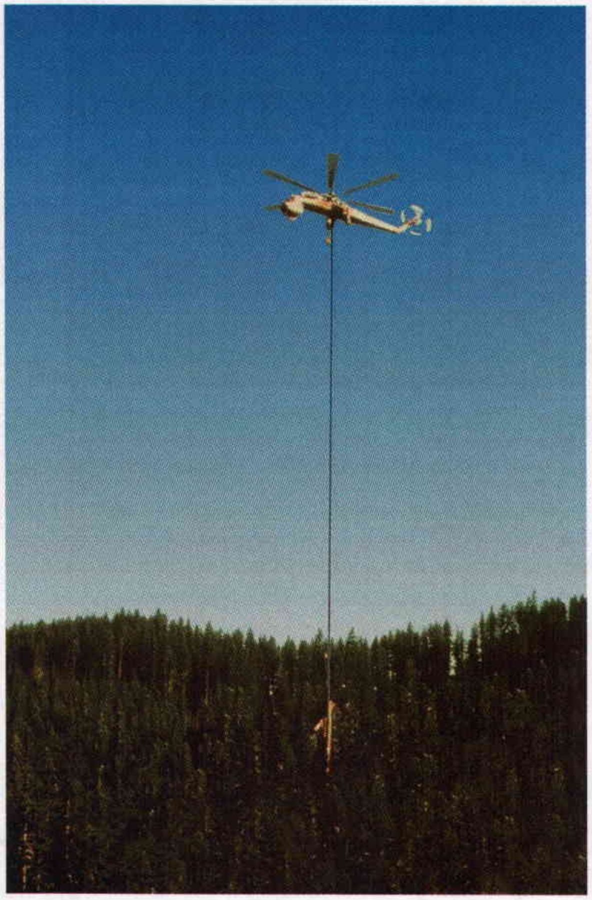

Figure 9 Helicopters can be used to harvest timber from areas where road construction and skidding of logs over the terrain would potentially cause severe erosion. The helicopter shown here is a heavy-lift machine capable of lifting an external load of about 11.3 t under optimal conditions.

vegetation the least (see Figure 9), but it is the most expensive system. In contrast, ground-based systems are less costly, but affect a larger area. The systems all rely on equipment to cut trees and remove logs to an area where they can be loaded on trucks or other transportation. At its simplest, this could include using a handsaw to fell trees and delimb them, then attaching ropes or cables to drag, or skid, them from a site with a tractor or animal.

Increased mechanization can occur at each step. Specialized machines have been invented for use on a range of terrain and in a variety of forest conditions. In tropical forests, where ground-based systems predominate, reduced-impact logging (RIL) emphasizes minimizing damage to the residual stand with preharvest planning and postharvest assessments. It includes designing roads to provide access to a harvest unit, while minimizing soil disturbance and protecting streams, using directional felling of trees, winching logs to planned skid trails, and using yarding systems that protect soils and residual vegetation. A case study from the Republic of Congo (see Case study 3) illustrates the value of harvest planning. In some tropical forests, cutting vines in advance of falling operations is necessary to avoid pulling down neighboring trees during harvest, which can endanger workers and create large gaps.

By limiting the season of harvest operations and the type of equipment used, it is possible to moderate immediate disturbances to nesting and breeding animals and soil structure. On sites with heavy rainfall and soils with high-erosion potential, operations can aim to maintain some canopy cover. Similarly, on sites where shrubs, herbs, or non-native plants are a concern, reducing their competitive advantage by keeping them in shade can be a useful practice. Postharvest effects such as erosion can be anticipated by installing water bars and culverts in roads.

Regeneration

Postharvest regeneration of trees is essential. Preharvest planning can promote favorable conditions for seedling establishment or continued growth of advance regeneration following harvest operations. On some sites or for some objectives, seedlings might be planted rather than naturally regenerated. This could be done to offset expected mortality on harsh sites, to increase the proportion of a particular species, or to regulate spacing. Advances in seedling production and nursery operations are occurring around the world.

Limits on Ecological Forest Management

Ecological forest management is not yet practiced everywhere in the world and limitations to its widespread application remain. Limitations include incomplete knowledge of the: effects of climate change on terrestrial ecosystem; life histories of previously noncommercial tree species and other plants and animals; the competition–density dynamics of mixed-species forests; and the appropriate scale at which to measure ecosystem responses to silvicultural treatments. Also lacking is economic knowledge about the total value of benefits derived from forests and about ways to evaluate tradeoffs among various goods and services.

Barriers also limit the application of existing knowledge. For example, the technology to apply variable-density silvicultural treatments could exist yet be cost-prohibitive for a site. Depending on product markets, for example, in the temperate rainforest of North America, Douglas fir trees can be harvested from steep slopes using helicopter systems, but not western hemlock. The reason is not technological but financial; products from hemlock are not sufficiently valuable to offset the costs of a helicopter system. The potential effect of wood prices on

Case Study 3 Société Congolaise Industrielle des Bois, Republic of Congo

In *No Timber without Trees* (Poore *et al.*) the authors concluded that fewer than 1% of tropical forests were being managed sustainably and that most were not being managed at all. They argued that sustainable management of tropical forests for timber production is essential because tropical countries often lack the budget, political will, and logistical means to protect forests from colonization. Concession holders have a strong motivation to provide such protection to defend their investments. The Forest Stewardship Council (FSC), an agency based in Bonn, Germany, that fosters the certification of forests as sustainably managed, developed from this concept. To date, FSC certification has been achieved in many temperate forests, but only a relatively small area of tropical forests has been certified, especially in Africa.

One timber company in Africa that has taken the long, but ultimately successful road toward FSC certification is CIB, the Société Congolaise Industrielle des Bois, located in Pokola, Republic of Congo. CIB holds three large, contiguous timber concessions in the northern part of Congo near the country's borders with Cameroon and the Central African Republic. The concessions were granted to CIB by the Government of Congo for the purpose of managing the forest to produce timber, develop and operate manufacturing facilities, provide housing, schools, hospitals, and other amenities for workers and residents of the area (see Figure 10), and of course to provide revenues to the government through royalties paid on the timber harvested. CIB is a subsidiary of the Swiss-based company tt Timber Group, which was acquired in 2006 by DLH Nordisk, a large manufacturer of tropical hardwood products based in Denmark. Most of the wood products from the CIB concessions are bound for Europe, a market that is particularly sensitive to the need for certified wood products. Thus, in 2001 CIB began evaluating options to have its forests certified as sustainably managed.

Figure 10 Employee housing at one of CIB's logging camps. Ecological forest management requires sustainable forest communities and, in addition to housing, the company provides schools, stores, hospitals, and other amenities such as farm plots and fish ponds to provide protein as an alternative to the traditional bushmeat.

The first step in the certification process was to establish and implement detailed policies on CIB's harvesting operations, which open up large areas of forest and can negatively impact residual trees, soil, water, wildlife, and other resources. This was regarded as an especially important step for CIB because the company's concessions border the Nouabalé-Ndoki National Park, an important reserve for lowland gorillas, forest elephants, and other wildlife. As a result, the company decided to formally adopt RIL on all of its operations. RIL comprises a set of technologies designed to reduce impacts associated with harvesting operations (see Figure 11). The most important of these technologies is comprehensive planning, based on a thorough preharvest inventory, to minimize disturbance to the forest while permitting access to trees that are available for commercial utilization.

Figure 11 CIB's logging operations all utilize ground skidding equipment such as this rubber-tired skidder, shown here delivering a tropical hardwood log to a roadside landing where it will be loaded onto a logging truck for transport to the company's sawmill.

(*Continued*)

Case Study 3 (*Continued*)

During the planning effort, CIB foresters realized that an area of about 250 km^2 within the Kabo concession and adjacent to the national park represented a serious impediment to certification. First, because of the flat terrain and high water table, it would be very difficult to harvest timber from the area without causing significant environmental impacts. Second, the area was shown through surveys to be an important refuge for lowland gorillas, chimpanzees, and forest elephants. As a result of negotiations involving the Government of Congo and the Wildlife Conservation Society (WCS), CIB was able to dedicate this entire area, known as the Gualogo Triangle, to wildlife conservation. It is now managed by WCS as a separate entity and is no longer part of CIB's timber concessions.

Because of the abundance of wildlife on its timber concessions, CIB was forced to confront the issue of illegal hunting. Opening of forest areas with logging roads provides potential access to hunters as well as to logging crews. The company began building gates and blocking unused roads, sometimes removing bridges and culverts to prevent access to vehicles. The company also worked with the government to create a cadre of paramilitary game wardens who inspect all vehicles, including logging trucks, moving in and out of the forest. Heavy fines and mandatory expulsion from the forest area are imposed on all violators. At the same time, the company began a program of farm and fisheries development at its headquarters in Pokola as a way of providing protein to village residents as a substitute for bushmeat.

In May 2006, the Forest Stewardship Council announced that CIB's Kabo concession had achieved full certification as a sustainably managed forest. It now represents one of the largest contiguous areas of certified tropical forest in the world.

By Dennis P. Dykstra

management options is illustrated by red alder, a deciduous tree in these predominantly coniferous forests. For decades, alder was not favored by forest management objectives that emphasized softwood production and so it was eradicated. But alder confers ecological benefits to a site because it has specialized roots that render atmospheric nitrogen available to other plants. In ecological forest management, alder retention also contributes structural and compositional diversity that is now valued for bird and other wildlife habitat. As markets for its wood have been developed, more options exist for maintaining it in a forest.

Other barriers to application can be political, social, and financial. Lack of forest land ownership, property rights, and tenure laws can discourage management planning that extends over decades and centuries. Politicians, not foresters, set policies that directly or indirectly affect forest management, and political time horizons are commonly shorter than ecological ones. Further, tax policies affect forest management by influencing investments. Incentives that favor investment in regeneration and harvesting phases over intermediate treatments can make ecological forest management difficult to accomplish. Global and regional cycles of prosperity and poverty, peacetime and war influence priorities for ecological forest management and the resources dedicated to it.

See also: Biodiversity; Carbon Cycle; Climate Change 1: Short-Term Dynamics; Climate Change 2: Long-Term Dynamics.

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