FORESTS AND FOREST PLANTS

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Summary

Only in the later part of the twentieth century has the role of forests in the global environment become appreciated fully. Forests are crucial to the conservation of soil, and to the provision of clean water. They are the richest reservoir of terrestrial biodiversity. They link the land and the atmosphere, and so affect global climate. They are also an important economic resource, providing food, forage, firewood, medicines, recreational activities, water catchment protection, and consumables such as paper and building timber. This chapter covers the forest resource base: different types of forest; their extent and management; important tree species; the goods and services that trees and forests provide; and tree and forest improvement and regeneration. Contributions have come from many countries of the world, tropical and temperate, developing and industrialized.

1. The Forest Resource Base

According to the UN *Global Forest Resource Assessment* (FRA 2000) the world has about 3,500 million ha of forest, or 0.6 ha per head of population. About half of the world's forest area is located in the tropical and sub-tropical regions, predominantly in developing countries. The other half is in the temperate and boreal regions, mostly in industrialized countries. Africa, Asia, and North and Central America each have about 500 million ha. Europe (including the Russian Federation) and South America have considerably more, and Oceania has less. The four countries with the largest forest area are the Russian Federation, Brazil, Canada, and the USA. Together, they account for half the world's forests.

Forests cover 27 percent of the world's total land area, but their distribution among countries and regions is highly variable. Europe and South America have almost half their areas under forest, whereas Africa, Asia, and Oceania have less than one-fifth. Seventy-eight countries and other reporting areas, mainly in Asia and Africa, have less than 10 percent of their land area forested. Seven countries (Brazil, Finland, Gabon, Indonesia, Japan, Papua New Guinea, and Sweden) have forest on more than 60 percent of their land area. French Guyana, Guyana, and Surinam reported more than 90 percent of their land under forest.

According to FRA 2000, the world's tropical forests were lost at a rate of about 8.6 million ha annually in the 1990s, compared to a rate of around 9.2 million ha per year during the previous decade. During the same period, the annual rate of loss of closed forests decreased from 8 million ha in the 1980s to 7.1 million ha in the 1990s. The rate of change in forest area in most industrialized temperate and boreal countries is low. In Europe, the area of forest expanded, while that of "other wooded land" decreased, for a net expansion of forest and other wooded land of 0.3 million ha per year. In the USA, the forest area also expanded while other wooded land decreased, for a net increase of 0.4 million ha per year. Much of this was due to the natural transition, and reclassification, of other wooded land to forest. Most countries of the former USSR reported increases for both forest and other wooded land, giving a net increase of 1.2 million ha per year for the region.

Concerns for the environment, set against the need for continuing economic development, led to the United Nations Conference on Environment and Development, in 1992. This, in turn, led to the various international conventions and agreements calling for global information on the world's forest resources. National inventories and global resource assessments provide basic data for the developing sustainable management plans.

Global forest data are derived from forest resource assessments conducted by the United Nations, and assessments of forest cover generally produced by national and international space agencies. These two assessments compliment each other. The former is best suited for providing data on forest landuse and production; the latter provide data on the extent and changes of forest cover.

2. Important Tree Species

There are almost unlimited numbers of definitions of a tree, and little general agreement about them. Generally speaking, they are plants with a woody stem several meters in height, with a crown of branches and leaves at the top. They are our largest and oldest living things, and may be classified by various means. In this theme we emphasize commercially important forest trees, but do not exclude those of less commercial importance. They may have an equal importance in the ecology of the forest, through habitat formation, climate moderation, maintenance of our atmosphere, and for their aesthetic value. Common classifications may separate evergreen and deciduous species, but in this essay we use a slightly more botanical classification. This recognizes the hardwoods, separated into temperate and tropical, conifers, and the bamboos and rattans. The latter two are not always considered as trees because they are small and shrub-like, or grow as vines. However, they are very important in tropical regions.

Hardwoods are generally broadleaved, evergreen, or deciduous flowering (angiosperm) trees, although the flowers are often small and inconspicuous. The softwoods include the conifers, only a few of which are broadleaved. Most have needle-like or scale-like leaves, and are evergreen. They lack true flowers, but instead bear cones (strobili) on which the seeds are more exposed, thus the name gymnosperm (naked-seeded). Hardwoods bear fruits, many of which are edible; in some cases, attractive flowers also lead to selection by humans. The terms hardwood and softwood can lead to confusion because certain conifers have much harder (denser) wood than some flowering trees. The terms arose more due to differences in the anatomical makeup of the wood (xylem) than in its true hardness. Conifer wood is made up primarily of long water-conducting and supporting cells (tracheids), whereas the hardwoods have a greater variety of these, including tracheids and vessels. Common conifers are pine, spruce, firs, and larches, all species characteristic of north temperate forests. Common hardwood species differ greatly from temperate (for example, birch, alder, maple) to tropical regions (for example, eucalyptus, rosewood, coconut). Some genera (like oak and pine) extend from temperate to tropical regions, but this is rare.

All tree species have played, and continue to play, important roles in our lives. The diversity of the hardwoods is tremendous; that of the conifers, by comparison, is very limited. A walk in a tropical and a temperate forest will clearly demonstrate this. In the temperate coniferous forest a one-hectare area may contain only five conifer species, each represented 100 times: in a similar area in the tropical hardwood forest you may encounter 100 species, each represented five times. The economic value of hardwoods in the tropics is very high, because of their great diversity and the high quality lumber they produce, whereas conifers are most important in temperate and boreal regions because of their vast distribution. Commercial use of trees has greatly influenced exploration and colonization in many regions of the world.

2.1. Coniferous Species

There are only 630 extant species of conifers. They are divided into sixty-eight genera, thirty of which have but a single species and thirty-nine are considered endemic. Conifers arose about 300 million years ago and flourished during the Mesozoic; these trees are the remnants of a once-diverse group of plants that dominated the forests for millions of years. Today their economic and ecological importance is far greater than their limited diversity indicates. They dominate temperate and boreal regions, but are very limited in distribution in the tropics. Commercial exploitation, forest degradation, and destruction of habitat have caused about 25 percent of conifer species diversity to become threatened with extinction. There is cause for concern about preserving the limited conifer biodiversity that remains, and measures must be taken to protect habitats in which threatened conifers grow.

2.2. Temperate and Tropical Hardwoods

The term hardwood refers to the flowering, or angiosperm, trees. Their wood is usually denser, harder, and heavier than that of conifers. Temperate hardwoods of North America, north-eastern Asia, and Europe grow in environments with well-defined seasons, and distinct winters. In more tropical countries, temperate regions' location is dictated by altitude, rather than latitude. Important temperate hardwoods include the maples (*Acer*), alders (*Alnus*), birches (*Betula*), hickories (*Carya*), chestnuts (*Castanea*), beeches (*Fagus*), ashes (*Fraxinus*), oaks (*Quercus*), and poplars (*Populus*), to mention only a few of the commercially important genera. Many have been exploited for centuries on account of their valuable wood products. Many have also been used as ornamental species, and others domesticated and developed for fruits and nuts. Many are now used in plantation forestry and grown far from their original source. Some have been over-exploited, or are threatened by disease and urban development.

Tropical hardwoods are found around the equator, between the Tropic of Cancer and the Tropic of Capricorn. They are found on the southeast coast of Brazil, the Guinea Coast, the Zaire Basin, and eastern Madagascar. In Asia, they are found in southeastern India, Malaysia, Indonesia, Thailand, and New Guinea. There is a narrow, discontinuous strip along the northeastern coast of Australia. The forests are very diverse, and vary from lush green rainforests to dry savannas. Thousands of species of plants and animals, often displaying unique diversity, are found there. For example, in Amazonian Ecuador, 473 trees per hectare were counted, and each tree was found to harbor hundreds of species of insects and other invertebrates. Tropical forests also have a high degree of endemism. Tropical hardwood forests have high economic value for wood and non-timber forest products (NTFPs); they also have a moderating effect on climate, and prevent floods and soil erosion. Tropical hardwood types include multipurpose, moist deciduous, littoral and swamp dry deciduous, wet evergreen, and arid and semi-arid hardwoods. They have many uses, including as fuel and food, as fodder, for ornamental purposes, and as sources of industrial raw material.

2.3. Use of Tree Species in Reclamation

Over the past fifty years, about 2,000 million ha of land worldwide have become degraded through wind and water erosion, and physical and chemical deterioration of the soil. Most of this degradation is human-induced, through intensification of agriculture and mining practices, and destruction of forest ecosystems. Added to this is the fact that many soils are naturally infertile or difficult to cultivate.

There are two main types of soil degradation: acid and saline. Degraded soils occur over several billion hectares of land worldwide. When suitable tree species and appropriate land management practices are used, however, many of these soils can support sustainable tree growth. Some types of soil degradation, such as that caused by excess salt, require careful choices of species and provenances, proper planting methods, and maintenance of root-zone salinity at desired levels. Excessively high water tables can be lowered by strategically placed trees, planted with careful regard to the soil texture, depth and salinity of the groundwater, and density of tree planting. Selection of tree species is mainly dictated by the extent and rate of root growth. If fast-growing plantation species are to be grown on acid soils then not only is selection of appropriate tree species important, but also selection of suitable root symbionts, mycorrhiza, and rhizobia. Fertilizer, lime, and organic matter must be applied to manage levels of soil phosphorus, aluminum, and nitrogen. Existing evidence suggests that growing trees in acid soils will increase, rather than decrease soil acidity, but the elemental composition of leaves may ameliorate acidity. Reclamation of degraded land is often attempted with fast-growing exotic trees, but more emphasis should be given to indigenous species.

2.4. Tree Species in Arid Zones

Arid zones account for about 19 percent of the land area of the world on all continents: of this area, Africa has about 46 percent, and Asia 36 percent. Water is the scarcest commodity in these areas, and most rainfall is lost to evaporation. Vegetation is sparse, and there are few perennial woody tree species. In these zones the major cause of land degradation is soil erosion. Sixty percent of this is caused by wind, and the remainder by water, over-grazing, agriculture, overexploitation of vegetation for domestic use, and inappropriate land use. A prime example is the hot arid zone of the western Indian desert, better known as Thar, which accounts for about 90 percent of the arid land area of India. Climatically and edaphically Thar is inhospitable, yet it is the most densely populated arid zone in the world. It has a population density of 101 persons per square kilometer, whereas other arid zones of the world support only six to eight. It is also the most vegetated arid zone in the world, and farmers grow arable crops in association with trees. The drought-resistant trees provide fuel, fodder, fruits, and many other products, and are an important component of the life support system of the region. Because Thar has been inhabited for a very long time, it is one of the most studied and best-understood arid zones in the world.

Thar is classified as a tropical thorn forest, where the hostile environment does not support much natural regeneration and growth of native plants. Of the 682 plant species, only 9.4 percent are endemic. There are relatively few tree species (forty-nine), mostly introduced from other arid zones in the world. Most are multipurpose species, providing numerous products. They are often grown in association with other crop plants, as part of vegetation complexes in the form of agroforests. Tree species are selected for several reasons. They can utilize incoming solar radiation throughout the year; enrich micro-sites by depositing litter in topsoil, which can then be utilized by shallow-rooted agricultural crops; modify microclimate; and generally bring about favorable effects on the soil and associated plant species.

3. Forest Products

Traditionally, the foremost economic function of forests is considered to be their use as a regenerative source of timber, and of other products such as resin, cork, mushrooms, and berries. This is known as the *raw-material function* of forests. A wide variety of non-timber forest products (NTFPs) are collected or cultivated by local populations, underlining their economic and life support importance, especially for indigenous people.

This topic is divided into articles dealing with production and processing of timber for construction, cellulose, and pulp, along with other uses as food, forage, medicinal and resin products, ecotourism and wildlife, along with products from unique forest plants—the bamboos and rattans.

Global demand for forest products has increased with population. Over the last fifty years, world population has increased from 2.7 billion to 6 billion and there is no sign of this slowing. At the same time, wood production to meet human needs has more than doubled, and per capita consumption has increased from 0.54 to 0.58 m^2 per year. The variety of wood products has greatly increased: production figures are discussed for industrial roundwood, sawlogs and veneer logs, pulpwood and particles, paper and paperboard, sawnwood, and wood-based panels. Recently, plantations have played an important role in increasing the area and productivity of forests. Trade in forest products was estimated to have reached $135,000 million in 1997, and has increased further since that time.

In this post-industrialized era we must consider all possible forest products, and their social and environmental, as well as their economic, needs. Rising economic levels and expectations only increase demand for the broad range of forest products. We face the dilemma of increasing harvesting to meet social and economic needs, or withholding harvesting to sustain the resource and protect the environment. Developed and developing countries differ in their production and consumption of forest products. Industrialized countries produce and consume 70 percent of all industrialized wood products, whereas developing countries produce and consume 90 percent of their wood as fuelwood and charcoal.

NTFPs, reflecting one of the oldest uses of forests by indigenous peoples, are receiving increased attention. Forest-based communities depend upon the whole range of products the forests can yield. Although their market value is more difficult to measure, the value of NTFPs is impressive, especially in regions such as Asia. They include a wide variety of food, forage, and medicinal uses, especially by indigenous peoples, and the products of resin processing. Ecotourism and exploitable wildlife resources may also be economically significant NFTPs.

3.1. Wood Products

Wood has been important for shelter, tools, and goods for daily living, from the earliest civilizations to present times. The structure of wood and its fibrous nature are key attributes, and its mechanical properties are important in its various structural applications. As wood is converted to a variety of products, it enters a manufacturing stream in many different forms, ranging from individual fibers to logs. Traditionally, round timbers (in the form of piles, poles, and ties) and sawn lumber (in the form of boards) have been used widely for structural applications. Composites are made from wood in many forms (lumber, veneer, chips, flakes, strands, sawdust, fibers) to take advantage of the properties of each material, and to meet specific needs. Glued, laminated structural members can be designed to meet exacting engineering specifications for specific architectural needs. Consumer needs can be met using modern technology, and the variety of wood products now available. Wood has been essential to human life throughout history, but its use has evolved from a simple, readily available natural commodity, to a modern industrial and engineering material.

3.2. Cellulose and Pulp

Cellulose is found abundantly in wood. It has largely been derived from wood since an extraction process using caustic soda was developed in England in 1851. Cellulose is a long-chain polymer, consisting of 3,000 to 15,000 anhydroglucose units held together with hydrogen bonds, and containing both crystalline and amorphous structures. Cellulose in most wood has about 10,000 units. Due to the high degree of polymerization, and its partially crystalline structure, cellulose can only be dissolved in certain chemicals. Cellulose esters and ethers are two of the most important derivatives, with a wide range of applications. Products produced at least in part from derivatives are discussed here. Those from esters include materials such as plastics, lacquers, adhesives, films, fibers, and explosives; those from ethers that are soluble in water, and have adhesive qualities, are used in cosmetics, pharmaceuticals, foods, plastics, glues, paper, textiles, cement, and concrete. There has been rapid development of new cellulosic products in recent years, and cellulose has been chemically synthesized. It is hard to imagine a more versatile and useful natural forest product.

Pulp is a heterogeneous product of cellulosic and non-cellulosic impurities, including hemicelluloses, lignin, resin, and many inorganic compounds. The manufacture of pulp, using chemical, semi-chemical, and physical processes, is described, as well as its fiber makeup, optical, and strength properties. The two primary end products are paper and board, but it can also be converted to cellulose. Hundreds of other products are produced, including many kinds of papers, textiles, plastics, and lacquers. Newsprint is the largest category of paper converted from pulp. The global production of paper pulp and certain other products is presented graphically; annual world consumption of pulp is predicted to rise at 2.8 percent annually. At present 75 percent of this is produced in industrialized countries, but Asian and South American countries are beginning to gain a bigger share.

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Bibliography

Baharuddin, H. G. 1995. Timber Certification: an Overview. *Unasylva*, Vol. 46, No, 183, pp. 18–24. [This presents a comprehensive discussion of timber certification.]

Balick, M. J.; Cox, C. J. 1997. *Plants, People and Culture: The Science of Ethnobotany*. New York, Scientific American Library. 256 pp. [A general text on ethnobotany, citing numerous examples of forest plant species that have been prominent in human cultures, past and present.]

Bruijnzeel, L. A. 2000. Forest Hydrology. In: J. Evans (ed.) *The Forests Handbook*, Vol. 1, pp. 301–43. Oxford, Blackwell. [A state-of-the-art review of knowledge of forest hydrology, and the impacts of management on forest hydrology.]

Bryant, D.; Nielsen, D.; Tangley, L. 1997. *The Last Frontier Forests: Ecosystems and Economies of the Edge*. Washington D.C., World Research Institute. 42 pp. [Overview of world deforestation patterns, including useful maps of remaining “ Frontier Forests” areas.]

CAB International 2000. *Forestry Compendium: Global Module*. Wallingford, UK, CAB International. [A CD containing comprehensive information on the geographical distribution, taxonomy, morphology, and economic importance of about 1,200 trees and shrubs of importance to forestry and agroforestry.]

Calder, I. R. 1999. *The Blue Revolution: Land Use and Integrated Water Resources Management.* London, Earthscan. 192 pp. [This account explodes several myths associated with the relationship between forestry and the hydrological cycle.]

Casey, J. P. (ed.) 1980. *Pulp and Paper Chemistry and Chemical Technology*. 3rd edn., Vols 1 and 2. New Jersey, John Wiley. [Part of a classic textbook in the field of pulp and paper technology.]

Coppen, J. J. W. 1995. *Gums, Resins and Latexes of Plant Origin. Non-Wood Forest Products #6.* Rome, Food and Agriculture Organization of the United Nations. 142 pp. [Global overview of plant resin.]

Dregne, H.; Kassas, M.; Razanov, B. 1991. A New Assessment of the World Status of Desertification. *Desertification Control Bulletin (United Nations Environment Programme)*, No. 20, pp. 6–18. [This article provides a good overview of land degradation worldwide.]

Edmonds, R. L.; Agee, J. K.; Gara, R. I. 2000. *Forest Health and Protection.* New York, McGraw-Hill. 630 pp. [First comprehensive text to integrate fire, insect, and disease management into an ecologically-based approach to forest health.]

Evans, J. 1992. *Plantation Forestry in the Tropics*. New York, Oxford University Press. 403 pp. [Text on silvicultural systems used for plantation forestry in the tropics.]

——. 1999. *Sustainability of Forest Plantations: the Evidence.* Issues Paper, UK Department for International Development (DFID). 64 pp. [A review of data and experience from many plantations about sustainability of yield in successive rotations, impacts on site and soil, risk of pest and disease problems, and likely future developments. All evidence suggests plantation forestry is sustainable provided good silviculture is carried out.]

Farjon, A. 1998. *World Checklist and Bibliography of Conifers*. Kew, UK, Royal Botanic Gardens. 298 pp. [The most comprehensive list of all species and synonyms currently available, with additional information on distribution and conservation status for each of 630 accepted species, and 170 accepted subspecies and varieties.]

Food and Agriculture Organization of the United Nations. 1985. *Arid Zone Forestry. FAO conservation guide No. 20*. Rome, Food and Agriculture Organization of the United Nations. 143 pp. [A simplified and concise book on arid zone forestry.]

——. 2000. *FAOSTAT database*. http://apps.fao.org/ lim500/Agr_db.pl. [Provides the most comprehensive data on production, imports, exports, and trade in wood.]

——. *Results of the Global Forest Resources Assessment 2000*. http://www.fao.org/docrep/meeting/003/X9591e.htm. [Provides latest statistical data regarding the world's forest resource base.]

Haygreen, J. G.; Bowyer, J. L. 1996. *Forest Products and Wood Science*. Ames, Iowa, Iowa State University Press. 484 pp. [A comprehensive text on the nature of wood, its processing, and wood products.]

Grayson A. J. (ed.) 1997. *The World's Forests: International Initiatives since Rio*. Oxford, Commonwealth Forestry Association. 72 pp. [Summarizes international efforts to encourage sustainable management of forests.]

Heywood, V. H. (ed.) 1995. *Global Biodiversity Assessment. UNEP*. Cambridge, Cambridge University Press. 1140 pp. [This is a volume written by many authors, with a great deal of information about all levels of biodiversity throughout the globe.]

Howard, J. A.; Mitchell, C. W. 1985. *Phytogeomorphology*. New York, Wiley. 222 pp. [Covers vegetal and climatic classifications within a more complex subject that involves geomorphology].

IPCC. 1997. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* [J. T. Houghton; L. G. Meira Filho; B. Lim; K. Tréanton; I. Mamaty; Y. Bonduki; D. J. Griggs; B. A. Callander (eds.)]. Intergovernmental Panel on Climate Change, Meteorological Office, Bracknell, United Kingdom. Vol. 1: Greenhouse Gas Inventory Reporting Instructions, 130 pp. Vol. 2: Greenhouse Gas Inventory Workbook, 346 pp. Vol. 3: Greenhouse Gas Inventory Reference Manual, 482 pp.

Kimmins, J. P. 1997. *Forest Ecology. A Foundation of Sustainable Forest Management*. 2nd edn. Upper Saddle River, N.J., Prentice Hall. 596 pp. [A comprehensive standard textbook on forest ecology.]

Kozlowski, T. T.; Pallardy, G. S. 1997. *Physiology of Woody Plants*. New York, Academic Press. 411 pp. [A modern advanced text on tree physiology, structure, development, and reproduction.]

Landis, T. D.; Tinus, R. W.; McDonald, S. E.; Barnett, J. P. 1990. *The Container Nursery Manual*. Vols 1–5. Agriculture Handbook (Washington) No. 674. Washington D.C., USDA Forest Service. [An overview of various aspects of seedling production in containers, and the management of container nurseries.]

Langholz, J.; Lassoie, J.; Schelhas, J. 2000. Incentives for Biodiversity Conservation: Lessons from Costa Rica's Private Wildlife Refuge Program. *Conservation Biology*, No. 14, pp. 1735–43. [This article provides the most detailed analysis yet of a government policy designed to promote conservation on private lands in a tropical country.]

Leopold, A. 1949/1989. *A Sand County Almanac, and Sketches Here and There*. New York : Oxford University Press. 228 p. [There have been several editions of this classic since it was first written.]

Miller, R. W. 1997. *Urban Forestry: Planning and Managing Urban Greenspaces*. Upper Saddle River, N.J., Prentice-Hall. 502 pp. [Textbook on urban forestry.]

Nair, P. K. R. 1993. *An Introduction to Agroforestry*. Dordrecht, Netherlands, Kluwer Academic. 499 pp. [This book covers the history, classification, and use of agroforestry, dealing with research and socio-economic aspects.]

Namkoong, G.; Kang, H. C.; Brouard, J. S. 1998. *Tree breeding: Principles and Strategies*. New York, Springer. 180 pp. [A well known textbook on tree breeding theory and strategies suitable for forest genetics.]

Nylund, R. D. 1996. *Silviculture Concepts and Applications*. New York, McGraw-Hill. 633 pp. [Provides context and descriptions of silviculture systems and their application.]

Panshin, A. J.; Harrar, S. E.; Bethel., J. S.; Bakar, W. J. 1962. *Forest Products: Their Sources, Production and Utilization*. New York, McGraw Hill. 538 pp. [A general test on wood products.]

Rao, R. V.; Rao, A. N. (eds.) 1995. *Bamboo and Rattan Genetic Resources and Use*. Italy, International Plant Genetic Resource Institute. 77 pp. [Proceedings of the first International Network for Bamboo and Rattan (INBAR) on biodiversity, genetic resources, and conservation workshop, providing relevant information on bamboos and rattans].

Rowe, R.; Sharma, N.; Browder, J. 1992. Deforestation: Problems, Causes and Concerns. In: N. P. Sharma (ed.), *Managing the World's Forests: Looking for Balance Between Conservation and Development*, pp. 33–45. Iowa, Kendall/Hunt. [More of an ethical and philosophical work than a technical analysis of safe and sustainable ways to manage the world's forests.]

Tisdell, C. 2001. *Tourism Economics, the Environment and Development: Analysis and policy*. Cheltenham, UK, Edward Elgar. 371 pp. [Analyzes market and political failures in relation to tourism development and environment].

Valverde, T.; Silvertown, J. 1998. Variation in the Demography of a Woodland Understorey Herb (*Primula vulgaris*) Along the Forest Regeneration Cycle: Projection Matrix Analysis. *Journal of Ecology*, No. 86, pp. 545–62. [This is an important case study demonstrating the effects of temporal variation within a forest on the population dynamics of a forest herb. There need to be more studies like this for important understory species.]

Waring R. H.; Running, S. W. 1998. *Forest Ecosystems: Analysis at Multiple Scales*. 2nd edn. San Diego, Calif., Academic Press. 370 pp. [This edition emphasizes the modeling and monitoring of forest ecosystem function, and its response to climate change and disturbance.]

Zobel, B.; Talbert, J. 1984. *Applied Forest Tree Improvement*. New York, Wiley. 505 pp. [A basic textbook on the principles and techniques used in forest tree improvement programs.]

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