TREE DOMESTICATION AND THE HISTORY OF PLANTATIONS

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Summary

Trees have been planted for thousands of years for food, wood, shelter, and religious purposes. The first woody plants to be cultivated were those yielding food, such as the olive. Trees were moved around the world by the Romans, Greeks, Chinese, and by others during military conquests. Voyages of discovery by European navigators to the

Americas and Asia provided new opportunities to transfer tree germplasm between distant countries. In contrast to most agricultural crops, the principal domestication of trees has occurred in the last one hundred years, and few species are significantly changed from their wild state. Intensive domestication programs have been applied only to eucalypts, pines, or other species with high value for products such as timber and paper. Shortages of timber stimulated tree planting in Western Europe after 1500.

The value of trees for landscape enhancement was appreciated in ancient times and was widely practiced by European noblemen who established parks and arboreta on their great estates in the eighteenth and nineteenth centuries. In the tropics, the earliest plantations were mainly teak and large-scale plantations of pines and eucalypts for industrial wood and were established after 1950. While many trees around the world are planted in industrial plantations to produce wood, the majority of plantations are for nonindustrial purposes of which protection forests are an important component.

Planting sand dunes prevents their spread, and many tree species have been used in temperate and tropical regions for shelterbelts to protect crops and livestock from wind. Forest practices changed little until after 1950 when labor shortages in developed countries stimulated mechanization of almost all operations. Global concerns about the biological, economic, and social sustainability of forests has resulted in changes in management practices in plantations. A challenge is to develop sustainable, productive plantations while taking a holistic view of ecosystem management.

1. Introduction

In the history of human development from the time of the earliest agricultural activities man has cleared the natural forests and woodlands to obtain building materials and fuelwood and to provide lands for domestic animals and crops (see *Forests and Grasslands as Cradles for Agriculture* and *History of Forestry*). The vast clearing of the tropical rainforests in Amazonia is principally to make way for cattle ranches, and in Asia the tropical forests are destroyed for palm oil and rubber plantations. In comparison, tree planting of cleared lands has been limited in extent and usually prompted by timber shortages after excessive clearing of natural forests. Nevertheless, trees have been planted for thousands of years for food, wood, shelter, and religious purposes. Domestication of plants goes back to the earliest days of settled agriculture. There has been a 4000-year history of selecting and breeding fruit trees and other nonwood products and transferring them around the globe.

Exotic forest species in the past 500 years have been used increasingly to provide a choice of fast-growing species to produce fuelwood, timber, or pulpwood. It is common practice to differentiate between “industrial plantations” established to produce wood for sawlogs, veneer logs, pulpwood, and mining timbers; and “nonindustrial” plantations established for fuelwood, wood for charcoal, wood for domestic consumption, nonwood products, and soil protection. In the process of plantation development the main species have been domesticated to varying degrees. Forest trees, however, are mostly wild populations little changed by the actions of people, and this provides the opportunity to exploit their genetic variability and make improvements.

Intensive selection and breeding have been applied to most major plantation species since about 1950.

This article describes the history of plantation development from the earliest plantations in Europe and Asia. It documents their development from the 1400s in Europe, through the period of colonial expansion from the sixteenth century to the nineteenth century, and describes the extent of the extensive industrial and protection forest resources developed around the world since 1900. A century of production forestry has resulted in an increasing intensity of management and greater mechanization of operations. There is an increasing trend toward "sustainable forest management" in which forests are managed as ecological systems with multiple economic benefits and environmental values, and with broad public participation in decisionmaking (see *History of Forestry*). Plantation ecosystem sustainability is considered in this context.

2. Origins of Planting

2.3. The Mediterranean Lands

The first woody plants to be cultivated were undoubtedly those yielding food or other nontimber products. The first selection and planting of a woody species may have been the olive (*Olea europea*), a thorny shrub growing near the Syrian and Anatolian coasts, as early as 4000 BC. Subsequently, selected varieties of olive were transported to the eastern Mediterranean where, for example, the cultivation has been known in Greece at least since the Minoan era (3000 BC). Discoveries in the graves and the palaces of Knossos and Phaestos on the island of Crete show that in the period from 2500 BC to 1500 BC the Minoans grew olives for food and olive oil fueled their small clay lamps. They also exported some of the oil to Egypt. The huge earthen olive jars in the Palaces of Knossos and Phaestos are evidence of the expansion of olive cultivation in the second millenium. From ancient Greece the olive tree was spread throughout the Mediterranean by the Phoenicians, the Greeks, and the Romans. The edible fig (*Ficus carica*) was also cultivated in the Mediterranean region as early as 4000 BC. The temple of Queen Hatshepsut, constructed in 1500 BC at Thebes in Egypt, has depictions of myrrh trees (*Commiphora myrrha*) introduced from Somalia being planted as sources of perfume. In the fourth century BC Theophrastus reports trees of frankincense (*Boswellia* spp.) and myrrh being planted on private estates in southern Arabia, and Aristotle established what was probably the first arboretum in Greece. Cato (234 BC) records the planting of willows (*Salix* spp.), and poplars (*Populus* spp.) and notes that a conifer was planted for ships' timbers. There are also several Biblical references to tree planting in the first millennium.

2.4. Asia

Tree planting was practiced in ancient times in Asia. The Chinese cultivated fruit trees from at least 2000 BC, and during the early part of the Chou Empire (circa 1100 BC to 256 BC) the Emperor established a forest service with the responsibility for preserving natural forest and reforesting denuded lands. Subsequent Han and Tang Dynasties (208 BC to 256 AD) encouraged people to plant trees important for both food and timber production. In the Sung Dynasty (420 AD to 589 AD) direct planting of tree seeds for

reforestation was widely practiced, and public land reforested by farmers became the property of the farmer. Monographs were also prepared describing methods of planting and protection of the tung tree (*Aleurites* sp.), bamboos, and other woody species. Historical records in Korea indicate that during the Shilla Kingdom starting in 57 BC trees were being planted around kings' tombs, in royal gardens, along roadsides, as shelterbelts, along rivers, and on the coast for erosion control. In Sri Lanka, during the reign of the Sinhalese King Vijaya (circa 543 BC), village communities planted home gardens with flowering and fruit-bearing trees, and under King Dutugemunu (161 BC to 137 BC) forest plantations were raised and rules for forest protection and use of forest products were promulgated.

3. Movement of Germplasm

The term "exotic" is applied to trees that are established in a locality in which they do not occur naturally. Exotic species are used to supplement or replace local indigenous trees or forests that cannot, or do not, provide the quality or quantity of forest products and services that are required. This may be because the local forests have been destroyed or simply that suitable trees are not present. Historically, exotics were used principally to increase the range and availability of fruits and nonwood products, but in the past 500 years they have been used increasingly to provide a choice of fast-growing species for fuelwood, timber, or pulpwood production. They have also been planted to rehabilitate severely degraded lands such as moving sand, severely eroded areas, and mine sites where the ecological conditions have been so changed that local species will no longer thrive. In many countries the indigenous species are relatively slow growing and cannot compete economically with selected exotic species that may grow many times faster.

Fast growth rates and the early availability of the desired products have been a major incentive to the establishment of plantations of exotic trees. While there has been a long history of successful movement of tree germplasm from North America to Europe, southern Africa, South America, and Australia, not many exotics have been found to be better than local species for commercial forestry in North America. Asian trees are commonly seen in ornamental plantings in Europe and North America but are not widely used in commercial plantations.

3.5. Evidence of Early Transfers

The movement of seeds, cuttings, and living plants has been practiced commonly since the earliest times of human settlement. The olive was transferred around the Mediterranean before 2000 BC, myrrh was introduced into Egypt in 1500 BC, and olives, walnuts, and almonds from the Middle East and western Asia were moved into China in the Han and Tang Dynasties (208 BC to 265 AD). The apple (*Malus pumila*) was cultivated for a few centuries BC by the Greeks and Romans, and it was spread throughout Europe and Asia as a result of their travels and military conquests. The Romans also introduced the edible, nut-bearing, sweet chestnut (*Castanea sativa*) into Britain.

The voyages of discovery by Columbus, Vasco da Gama, Magellan, and other European navigators to the Americas and Asia in the fifteenth and sixteenth centuries provided new opportunities for the transfer of tree germplasm between distant countries. In 1686 John Evelyn, famous for his treatise "Silva, or a Discourse of Forest Trees, and the Propagation of Timber in his Majesty's Dominions," gave the Secretary for the Admiralty in London a list of plants and instructions for their collection to be given to a ship's captain going to New England and Virginia (US). Species such as the tulip tree (*Liriodendron tulipifera*) and swamp cypress (*Taxodium distichum*) were early introductions from the US to Europe. Trade and commerce with the expanding empires of the European powers in England, France, The Netherlands, Spain, and Portugal resulted in a new, rich, landowning class who built great houses with spacious parks and gardens. These landowners sought exotic plants to enhance their estates, and plant collectors were dispatched to many countries. These collections were to provide the basis for the selection of trees for wood production in plantations. This was particularly the case in England where a passion for collecting exotic trees developed. As Sir John Stirling-Maxwell (1932) stated, "In a country of gardeners it is through the garden that new trees find their way to the woods . . . ."

3.6. Role of Botanic Gardens and Arboreta

Botanic gardens and arboreta were established in Europe to test new introductions. A tree collection was established in France as early as 1550 by Rene du Bellay, Bishop of Mans, who received seeds from Pierre Balon, a physician and traveler in western Asia. Two centuries later, Duhamel de Monceau, Head of the French navy, assembled a collection of more than 1000 European and American trees and shrubs on his estates and formed the first arboretum with a scientific purpose. He published a critical study of his collections in 1755. Another famous French arboretum was established in 1825 at Les Barres near Orleans by Pierre Philippe Andre de Vilmorin. It was here that he conducted his pioneering studies on the geographical variation of the principal timber trees of Europe. Kew Gardens was established in England as a national garden in 1841 and developed an extensive exotic tree collection. In The Netherlands botanic gardens in Leiden, Ghent, and Utrecht received many new species from Asia and elsewhere. Botanic gardens were established in the European colonies to assemble and test the suitability of economic plants. For example, in 1728 John Bertram set up a botanical garden in Philadelphia, and in 1817 Reinwardt established the famous Buitenzorg Botanic Garden at Bogor in Java. Such gardens became centers for the exchange of tree germplasm.

During the late eighteenth and nineteenth centuries further exploration resulted in the movement of many tree species to Europe. Archibald Menzies, a botanist with Captain Vancouver's expedition to the Pacific in 1792, introduced the Californian redwood (*Sequoia sempervirens*) and the Chilean monkey puzzle (*Araucaria araucana*) to Britain. David Douglas, a Scottish botanist, was sent several times by the Horticultural Society of London to British Columbia from 1823 to 1831, and he introduced several new conifers including the Sitka spruce (*Picea sitchensis*) and the lodgepole pine (*Pinus contorta*), both of which are now planted commercially in Western Europe on a significant scale. A body known as the Oregon Association established by a group of British landowners made further introductions including the western hemlock (*Tsuga*

heterophylla) from western North America. Trees from the West Coast of the US were introduced into countries with similar climates, such as Australia, New Zealand, South Africa, and Chile. One species in particular, *Pinus radiata*, would form the basis of substantial plantations for timber and pulpwood.

South America has provided some important trees for commercial plantations. Paramount is the latex-producing rubber tree (*Hevea brasiliensis*), which from being a wild tree in the Amazonian forests rapidly became an important plantation species in Southeast Asia, especially in Malaysia and Indonesia, the Indian subcontinent, and West Africa. In 1876 Sir Henry Wickham successfully took viable seeds to Kew Gardens in England, and the resulting seedlings were transported to several Asian botanical gardens, notably at Peradeniya in Sri Lanka and one in Singapore. First commercial plantings began in 1898 in Malaysia but accelerated greatly after 1910 such that by 1920 there was a substantial rubber industry in Southeast Asia. Extensive rubber plantations in Malaysia and Thailand have also yielded large amounts of industrial wood.

Few therapeutic agents of plant origin have had as great an impact as quinine, the main alkaloid and active principle of the bark of cinchona trees. The Spaniards recognized the medicinal value of the bark during their colonization of Peru and Bolivia, and by 1640 cinchona bark was being used in Europe to combat malaria (see *Herbs and Medicinal Plants*). Overexploitation of the natural forests resulted in a shortage of quinine in about 1850, and steps were taken to cultivate *Cinchona* in other parts of the world. Dutch and British expeditions to South America secured germplasm which was used to set up plantations in India and Indonesia. Selection and breeding by the Dutch of the high yielding *C. ledgeriana* from Bolivia resulted in Indonesia having a virtual monopoly in cinchona production until World War II. Large-scale felling during the Japanese occupation and changes in plantation ownership following independence from the Dutch reduced Indonesia's hold on the trade, and Zaire emerged as another important supplier.

3.7. Australian Tree Species and Their Transfer

In 1788 the British began the colonization of Australia where there was a unique and diverse woody flora dominated by many species of *Eucalyptus* and *Acacia*. Australian trees had a curiosity value in Europe and soon seeds were collected and propagated in botanic gardens and private arboreta. By 1830 at least 30 species of eucalypts were growing in England. In 1869 seeds of blue gum (*Eucalyptus globulus*) were given by the botanist Baron Ferdinand von Mueller to Archbishop Gould of Melbourne who passed them to Trappist monks at Tre Fontaine near Rome. The eucalypts grew rapidly and not only assisted the monks in drying out the Campagna marshes but also served to highlight the potential value of eucalypts. Many species were grown in France and Italy and the botanic gardens became secondary centers of dispersal to other parts of the world. In the latter part of the nineteenth century tree seed dispersal from Australia by travelers, traders, gold miners, soldiers, priests, and botanists spread eucalypts and other Australian species to all parts of the globe. The French took eucalypts to North Africa and Ethiopia, and the first eucalypts to be planted in China were introduced in the 1890s

through the Chinese Consul in Italy and French Jesuit priests working in southwestern China.

The fast growth and adaptability of some of the species from Australia stimulated interest in using them for commercial wood production, especially to provide fuel for the wood-burning railway engines. Private seed companies were set up in Australia to meet the increasing demands for eucalypt seed from around the world. The Australian eucalypts and acacias were to become some of the most successful exotics for plantation forestry in the twentieth century.

3.8. North Asia as a Rich Source

The movement of seed of ornamental Asian trees such as magnolias (e.g., *Magnolia kobos*, 1709) to Europe began early in the eighteenth century and was stimulated by Engelbert Kaempfer (1651–1716), a German physician who traveled in China and Japan and published his observations on Japanese trees between 1690 and 1692. He is credited with the "discovery" of the Japanese cypress or sugi, *Cryptomeria japonica.* Philipp Franz von Siebold (1796–1866) traveled officially for Holland in Japan and was responsible for sending the seeds of many Japanese trees to botanic gardens in Holland and Java (Indonesia). Large forest trees with potential for timber production such as *Cryptomeria japonica*, *Pinus densiflora*, and *Pinus thunbergii* were introduced to Holland in the 1840s and 1850s. More introductions of Japanese conifers were made to England by John Gould Veitch in 1861. One of his more important introductions from a forestry viewpoint was the Japanese larch (*Larix kaempferi*), which was subsequently planted extensively when the Duke of Atholl secured more substantial supplies of seed from Japan in 1883.

Excited by the botanical richness of China the Royal Horticultural Society in London sent Robert Fortune to China three times between 1843 and 1853 to collect garden flowers and ornamental and economic woody plants. Best known of the early collectors are the French missionaries Father Armand David who was active in China from 1860–1874 and Father Jean Marie Delavay who lived in China from 1867 to 1895. They sent seeds of trees and shrubs to French botanic gardens and to the garden of Maurice de Vilmorin. One of the greatest of all plant collectors in China and Japan was Ernest H. Wilson. He made four trips to China from 1899 to 1911, the first two for the English nursery firm of James Veitch and Sons and the others for Harvard University's Arnold Arboretum and for some private British sponsors. He was also active in Japan. He was responsible for introducing many trees and shrubs to Europe and the US including the beautiful dove tree (*Davidia involucrata*). Despite the intensive botanical exploration in Japan and China, few trees were well enough adapted as exotics to feature as major timber plantation species, although they undoubtedly enriched the parks and gardens in many countries.

4. Tree Domestication

It is not always easy to predict how a species will perform based on the ecological conditions in its natural habitat. Some species are adaptable and have the plasticity to grow under a wide range of conditions in new and different environments. Species

selection is complicated by the great genetic variability in some species, so a process of careful testing is an essential part of the domestication process of wild tree species. There are a number of ways to define "domestication" in relation to woody plants. Complete domestication involves the identification and characterization of germplasm resources; the capture, selection, and management of genetic resources; and the regeneration and cultivation of the species in managed ecosystems.

The concept of domesticating animals is widely accepted, but the domestication of plants is generally less well appreciated (see *History of Agriculture*). Nevertheless, the process of domesticating plants goes back to the earliest days of settled agriculture (see *Domestication and Development of Plant Cultivars*). Grain cultivars currently in use are the result of selection and breeding over many generations. Similarly there has been a history of selecting and breeding temperate and tropical fruit trees extending over 4000 years.

4.1. Domestication by Indigenous Peoples

Domestication of trees by indigenous people, especially fruit trees in the tropics, has been undertaken for centuries. At least a dozen Amazonian fruit species were partially or fully domesticated by indigenous people before European contact. The Brazil nut, *Bertholletia excelsa*, indigenous to southeastern Amazonia has been dispersed beyond its natural range and cultivated by farmers in swidden agriculture systems. In Southeast Asia there is a long history of cultivating mangosteen (*Garcinia mangostana*), durian (*Durio* spp.), and other fruit trees, and a similar situation exists in West Africa with species such as bush mango (*Irvingia gabonensis*) and kola (*Cola* spp.).

However, there are hundreds of lesser-known multipurpose tree species which could be used to improve the livelihoods of farmers through the production of nonindustrial products such as fuel, fodder, medicines, and posts and poles for local use. It is not economic or practical to apply intensive breeding and management in the domestication of these species that will be planted on a much smaller scale for a variety of products and services.

Domestication usually involves testing their performance in trials on small farms and developing simple nursery and establishment techniques. In many species it is possible to select genotypes that meet local needs and to use vegetative propagation to mass produce them. The degree of improvement in yields will not be as great as for the intensively selected industrial species but can be significant.

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Biographical Sketch

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