TROPICAL AND SUBTROPICAL FORESTS

Irene Seling
Fachhochschule Furtwangen, University of Applied Sciences Furtwangen, Germany

Peter Spathelf
State Forest Administration of Baden-Wrttemberg at Tubingen,Germany

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Contents

Summary

Firstly, ecological characteristics, traditional land use practices and important tree families and species in forests in the different ecozones of the tropics and subtropics are described. Next, some socioeconomic factors that influence forest management and conservation are discussed with a focus on deforestation and its main causes. Substitution and transformation systems are then introduced as the main silvicultural systems in tropical forests. Some examples of natural forest management systems such as Centrum voor Landbouwkundig Onderzoek in Surinam (CELOS—Center for Agricultural Research in Suriname) and the Selective Systems of Malaysia and Indonesia are described with respect to technical criteria for goal-diameter and cutting cycles. The role of non-timber forest products (NTFPs) is outlined in the context of the multiple use of forest ecosystems. A high variety of products are collected or cultivated by the local population, which underlines their economic importance, especially for indigenous people. Plantation forestry is then described in all its aspects (areas, species, and increments), with special emphasis on its role as a raw material base for wood industries. Plantation forestry also reduces the pressure on native forest exploration. Special attention is next given to agroforestry, discussing its benefits for developing rural areas in the tropics, and describing the technical details of the different types of agroforestry systems. Forest conservation aspects are discussed in the framework of the combination of conservation and economic goals. At a local level, the participation of the local people has to be guaranteed. On a national level, sound and coherent land-use policies and conservation units are required. Both approaches have to be combined with an international concerted action to preserve the world's tropical forests. Certification of forest enterprises is described as a chance to introduce sustainable management practices in tropical forests. Finally, the role of tropical forests as carbon sinks, and strategies for achieving this goal are summarized in a discussion of so-called "carbon forestry."

1. Introduction: Definition and Geographical Localization of the Tropics and Subtropics

In general the tropics encompass the area between the Tropics of Cancer and Capricorn (23°27′ latitude north and south). Furthermore, the 20 °C isotherm, i.e., the area approximately between 30° latitude north and 26° latitude south can be used to distinguish the tropics from other ecozones of the world.

Because of the disadvantages of the above-mentioned definitions, e.g., they are not valid for mountainous regions, the following definition, which considers the climatic periodicity of the region is currently in use: in the tropics the daily thermal oscillation is greater than the annual thermal oscillation. In other words, the tropical zone shows an oscillation between the length of days and nights of between 10.5 and 13.5 hours. Therefore, the tropical boundary lies where an equilibrium between the daily and annual oscillation exists. In terms of ecozones the tropics comprise the seasonal tropics (savanna zone) and the humid tropics. The subtropics are delimitated from the tropics by thermal criteria, i.e., the frost limit or the +18°C isotherm of the coldest months in the lowlands. The subtropics consist of the subtropical (tropical) arid lands, the Mediterranean subtropics and the humid subtropics.

2. Phytogeographical Units, Forest Ecology and Land Use

2.1 Tropical and Subtropical Arid Lands

A high net radiation, low air humidity, and great differences between day and night temperatures characterize the tropical/subtropical arid lands. These comprise about 20% of the earth's landmass, limited from the seasonal tropics and arid mid-latitudes by the following humidity boundary: one humid month (desert) to 4.5–5 humid months (dry savanna).

The vegetation encompasses all transitional forms from pure grassland to tree stands (tropical thorn savanna, subtropical thorn steppes and grassland). Plants are adapted to dryness (leaf fall, reduction until drying out of foliage mass, formation of thorns, succulence, and barrel-shaped trees of the *Adansonia* type). The tropical dry regions lie beyond the agronomic humid-arid boundary, and in them, enormous human pressure often leads to a more or less pronounced desertification process.

Traditional land use is nomadic herding in the form of transhumance, where the women live near water places all year round with modest agriculture, whereas the men follow prescribed routes with their livestock, moving in the rainy season from the highlands to the lowlands. Modern irrigated farming plays an important role in intensive agriculture. Forestry activity is restricted to the cultivation of fodder trees and shrubs.

2.2 Mediterranean-Type Subtropics

This ecozone occurs in narrow coastal strips in California, Central Chile, the Cape region, Southeast Brazil, South Australia, on the western side of the continents, and in the Mediterranean zone of Europe.

Tree growth is restricted because of the subtropical winter climate which has a winter rainy season (at least 5 humid months with precipitation between 600 and 900 mm) and hot summers. Evergreen sclerophyllous shrub formations (*Quercus ilex*, *Olea europea*) dominate the vegetation, local names for which include garrigue, maquis (France) or jarral (Chile). The scleromorphic adaptations of succulence, thick bark or cork layers and dark leaf color are important.

Some economically important tree species originate from this ecozone, e.g., *Pinus radiata* as an extraordinarily important plantation species in Chile and New Zealand, or *Pinus halepensis* and *Quercus ilex*. Net primary production in the Mediterranean subtropics is as high as in the boreal forest but significantly lower than in the tropics. Land use comprises rain-fed agriculture in winter, irrigated crops, and pastorals. Because these regions have been settled for a long time—at least around the Mediterranean Sea—they have suffered and still suffer a high human impact (e.g., fire).

2.3 Humid Subtropics

The individual regions within the humid subtropics are distributed over the eastern parts of five continents: southeast Brazil, the southeastern part of South Africa, southeast

China, Australia, south Japan and the US. There is an east-west asymmetry due to monsoon effects with a large humidity in summer near the coast.

The vegetation is either luxurious evergreen rainforests, followed to the west by semideciduous and deciduous dry forests (laurel forests), sometimes mixed with conifers, such as *Araucaria* and *Podocarpus* (e.g., coastal mountainous rainforest in south Brazil). *Eucalyptus* species dominate the humid subtropics in Australia.

Resulting from dense population and industrialization, large forest areas have been lost and substituted by agriculture. There are excellent growth conditions for all kinds of annual and even perennial thermophilous crops such as citrus, tea and tobacco because summers are warm and humid and the winters with possible light frosts are not so strong. Many areas are characterized by large forest plantation activity (the southeastern US, southern Brazil).

2.4 Seasonal Tropics

The seasonal tropics generally are known as savanna zones and occur in Brazil (campos cerrados), in Venezuela (llanos), south Saharan Africa, Mexico, Costa Rica, the western part of the Indian subcontinent, Thailand and Indochina, and northeastern Australia.

Common features in this zone are the grass layer and a more or less continuous tree layer, and a strict seasonality. Trade wind (monsoon) related dry periods occur in winter (2.5–7.5 months). There is a doubled rainy season with 1000–1500 mm precipitation. Depending on relief and land use, an increasing surface runoff from the humid to the seasonal tropics, and within the seasonal tropics from the humid to the arid savanna, can be observed.

The vegetation is adapted to the water deficit (leaf shedding due to dry (cold) periods, reduced plant sizes, death of aboveground parts of the plants during the dry period, thick bark, xeromorphic leaves). Predominant tree types are the “umbrella” and the “bottle” type. Where groundwater contact is available, luxurious vegetation can also be observed. There is no well-established vertical stratification in the forest stands (mostly only two layers occur).

Soil fertility varies significantly and determines the shape of the different forest types in the seasonal tropics. There is a high turnover of organic matter (decomposition). Biomass production, net primary production, and therefore wood production, are lower than in the humid tropics.

Plant biodiversity also is lower in comparison with the humid tropics, but the seasonal tropics are very rich in macrofauna (with significant differences between the continents).

Forests suffer from high human pressure (fuelwood collecting, cattle grazing, traditional burning). Thus, many adjacent or close forest areas are involved in the so-called process of savannification.

The seasonal tropics provide valuable land for rain-fed annual agriculture (semi-permanent cultivation) and pasture because of the more fertile soil than in the humid tropics. Permanent cultures such as coffee need higher elevations in order to obtain orographic rains within the dry period. More intensive agriculture without fallow is now promoted because of a clear population increase in these areas (e.g., in the state of Mato Grosso, Brazil).

2.5 Humid Tropics

The forests of the humid tropics are distributed over the Amazon Basin, isthmus of Panama, Congo Basin, southeastern fringe of West Africa, southeast coast of India, Sri Lanka, the Malaysian Peninsula, the Indonesian archipelago and a small strip on the northeastern coast of Australia.

In the humid tropics, a thermal and solar day climate prevails. Mean daily temperatures lie between 25 and 27°C. There are no strikingly different seasons. Annual precipitation frequently attains 2000–3000 mm. There is nowhere more than two months with rainfall lower than potential evapotranspiration.

The zonal formation in the humid tropics is the evergreen tropical lowland forest, also called hylea. Around 70% of the species are moisture-loving evergreen trees (hygrophytes) with the exception of canopy trees (in which water stress leads to sclerophyllous adaptations). There is no (seasonal) periodicity (phenology).

The highest aboveground biomass of all forest ecosystems in the world is found in the humid tropics (luxuriance of vegetation). Net primary production is high but no correlation occurs between net primary production and the fertility of soils. A large amount of nutrients circulate in the biomass, leading to an extremely short mineral cycle. Due to a high amount of litter fall, wood production is not much higher than in other forest ecosystems (see *Forest Ecology*).

The forests are composed out of several stories with a rapid decline of light (and also of photosynthetically available radiation, PAR) available in the lower stories and the forest floor (nearly no herbaceous layer occurs on the forest floor); leaf area index is high.

There is high plant species diversity, as well as high animal diversity, especially of birds and insects, in the humid tropical forests. The highest tree biodiversity is found in the neotropics. Eastern tropical forests have more conifers, while the Indonesian archipelago is characterized by dipterocarps, and in Africa species of the Meliaceae dominate. Lianas and epiphytes grow in abundance. Some tree species on special seasonally influenced sites (e.g., inundation areas) show annual growth rings. Pollination by animals prevails.

The humid tropics are also characterized by lacking large-scale perturbations. They represent highly resilient ecosystems, but are not very stable; no clearly directed succession occurs.

Many authors have stated the disadvantages in terms of soils concerning land use in the humid tropics. Slash-and-burn agriculture (shifting cultivation), which is very land and labor consuming, and paddy rice farming, represent the traditional land uses. Ecologically adapted cultivation methods (ecofarming) with improved crop rotation in multistoried systems, the maintenance of a permanent plant cover, and the replacement of uncontrolled fallow by productive fallow could be a way out of the dilemma of sites of low fertility which are endangered by degradation when put under agriculture.

Special ecological factors determine the shape and function of azonal forest ecosystems such as mountainous forests (temperature and radiation gradient, fog), inundation forests (inundation), gallery (riparian) forests (contact with groundwater level), peat swamp forests (hydromorphic soils) and mangroves (tidal influence, saltwater).

3. Important Tree Families

3.1 Conifer Trees

3.1.1 *Pinus*

Originating from Mexico, the Caribbean and Southeast Asia (Northern Hemisphere) *Pinus* species (30–40 tropical species) are used because of their growth potential, site adaptability (pioneer species) and good wood characteristics. Pine species are a major component of plantation forests all over the tropics and subtropics (management with rotations of 20–30 years and one to four thinnings). The important role of fire in large parts of Central America, which saves the pioneer stage of these forest "pyroclimax" species, has to be emphasized. Important species (with origin) are:

- *Pinus caribaea*, *P. oocarpa*, *P. patula* (Caribbean).
- *Pinus elliottii* (southeastern US).
- *Pinus radiata* (California), largely extended as a plantation species in Chile and New Zealand.
- *Pinus merkusii* (the most "tropical" pine, from Southeast Asia).

3.1.2 *Podocarpus* and *Araucaria*

Podocarpus (>100 species) and *Araucaria* (14 species) are two shade-tolerant conifer genera which occur at the border of the tropics and subtropics of the Southern Hemisphere of South America and Southeast Asia/Australia. The genera occur in more cold climates with frosts or in mountainous forests. Important species are *Araucaria angustifolia* and *Podocarpus lambertii* (humid subtropics of Brazil) or *Araucaria hunsteinii* and *A. cunninghamii* (New Guinea) and *Podocarpus rospgliosii* (Venezuela), mostly making pure stands in the upper story with a high variety of broadleaved stands in the lower story. There are first experiences with plantations with these species (see *Coniferous Trees*).

3.2 Broadleaved Trees

3.2.1 Meliaceae

The Meliaceae comprise some of the species with the most precious wood in the world (see *Important Tree Species* and *Tropical Hardwoods*). In general these are late-successional pioneer species with a certain shade-bearing capacity in the juvenile phase. Pure plantations are frequently endangered by the shoot borer (*Hypsipyla*), so that other silvicultural techniques (e.g., enrichment planting) are more appropriate in forest management of these species. Note that the term mahogany often is used in a broad sense for wood from diverse tropical tree species, and not just for mahogany per se (*Swietenia*). Important species (with popular names) are:

- *Khaya* (kaya mahogany, acajou)
- *Swietenia* (American or true mahogany)
- *Cedrela* (cedro, but also Australian cedar/mahogany)

3.2.2 Leguminosae

The genus *Acacia* comprises a high variety of species in the tropical but also in the subtropical zone of the old and new worlds (it is a pantropical genus), as exemplified by *Acacia albida* (syn. *Faidherbia albida*) which has a large distribution in the African Sahel. These are pioneer species adapted to difficult sites, nitrogen-fixing species chosen for afforestation in semiarid areas and for agrosilvopastoral systems (supplying fuelwood, fodder, fruits, e.g., the genus *Leucaena*), especially in Africa. With the exception of *Acacia nilotica*, these species are not appropriate for timber production. A special case with regional economic relevance is tannin production from *Acacia mearnsii* in South Africa and South Brazil. Other important genera are *Albizia* and *Dalbergia* (Indian rosewood).

3.2.3 Dipterocarpaceae

Dipterocarp forests with about 400 species can be found both in tropical dry caducifolious forests and tropical humid evergreen forests in South and Southeast Asia. Dipterocarps form nearly pure stands within the emergent tree stratum, with a high share of basal area or stock at the total stand level. The most important genus is *Shorea* (with a more or less uniform wood called meranti). Dipterocarps occupy all types of soils from dry sandy soils to peat swamps (*Shorea albida*) and regenerate easily (see Section 5 on silvicultural systems). Therefore, these forests show very good potential for transformation into sustainable managed forests.

3.2.4 Myrtaceae

Several of the approximately 600 evergreen species of *Eucalyptus* with Australian origin (which occur in different forest types—open savannas, dry forests and humid forests in mixture with *Acacia* species) were introduced into many areas of the world (e.g., to the Mediterranean zone in 1857, to Brazil in 1910). *Eucalyptus* species are used especially for industrial plantations. The different species are suitable for a variety of

site conditions. Propagation in tree nurseries, and management, are easy. In most cases clear cutting with coppicing is practiced after a rotation period of 7 to 12 years. Wood can be used for pulp and cellulose as well as for sawnwood and veneer. Genetic improvement helps to increase growth and yield and to consider special production goals (e.g., maximization of cellulose content for pulp, or maximization of lignin content for charcoal production). Important species for plantation forestry are *Eucalyptus grandis*, *E. saligna*, *E. urophylla*, *E. dunnii*, and *E. deglupta*, among others (see *Cellulose and Pulp*).

3.2.5 Verbenaceae

A very important and promising tree species within the Verbenaceae is teak (*Tectona grandis*) with a natural occurrence in South and Southeast Asia. It is a leaf-shedding tree species with excellent wood characteristics, which is managed in plantations with a 20 to 50 years rotation. *Tectona grandis* was the classical species of the taungya agrosilvicultural system. *Gmelina arborea* is another leaf-shedding, extremely light demanding and fast growing tree within the Verbenaceae, frequently occurring with teak, dipterocarps and bamboos. Thus, it is also a very good plantation tree species (as exemplified in the Jari project in the Amazon basin of the Brazilian state of Pará, where *Gmelina* is managed with a rotation age of 6 years (for pulpwood) or 10 years (for clearwood).

Many of the pantropical palm species have significant economic relevance in the tropics and subtropics. They provide a variety of non-timber forest products, such as fruits, alcoholic drinks, fibers, and products to cover roofs (see Section 6, Non-Timber Forest Products).

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Biographical Sketches

Irene Seling: born 1966, has studied Forestry Sciences at the University of Freiburg, Germany. She made her Ph.D. in Forest Economics in 1997 also at the University of Freiburg. In 1998-1999 she was Visiting Scholar and in 1999-2001 Visiting Professor at the Federal University of Santa Maria, Rio Grande do Sul, Brazil. In 2001 she had a teaching appointment at the University of Applied Sciences in Rottenburg, University of Forestry, and is now working at the University of Applied Sciences Furtwangen as Deputy Director of the International Office. Her publications comprise analyses about the transformation from even-aged to uneven-aged forests, socio-historical studies of enterprise philosophies in Forestry Sciences as well as socio-economical research projects about the Amazon forest and plantation forestry in Brazil.

Peter Spathelf: born 1963, has studied Forestry Sciences at the University of Freiburg, Germany. He made his Ph.D. in Forest Growth in 1997 (University of Freiburg) and was Visiting Professor in 1998-2001 at the Federal University of Santa Maria, Rio Grande do Sul, Brazil. He is currently working with the state forest administration of Baden-Württemberg at Tübingen, Germany. His publications comprise analyses about the transformation from even-aged to uneven-aged forests in temperate zones, the transformation of tropical secondary forests as well as plantation forestry, among others.