Natural Habitats & Ecosystems

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First Edition, 2012

ISBN 978-81-323-4192-5

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Published by:
White Word Publications
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
Email: info@wtbooks.com

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WORLD TECHNOLOGIES

Chapter 1

Ecological Succession

Succession after disturbance: a boreal forest one (left) and two years (right) after a wildfire.

Ecological succession, a fundamental concept in ecology, refers to more or less predictable and orderly changes in the composition or structure of an ecological community. Succession may be initiated either by formation of new, unoccupied habitat (*e.g.*, a lava flow or a severe landslide) or by some form of disturbance (*e.g.* fire, severe windthrow, logging) of an existing community. Succession that begins in areas where no soil is initially present is called primary succession, whereas succession that begins in areas where soil is already present is called secondary succession.

The trajectory of ecological change can be influenced by site conditions, by the interactions of the species present, and by more stochastic factors such as availability of colonists or seeds, or weather conditions at the time of disturbance. Some of these factors contribute to predictability of succession dynamics; others add more probabilistic elements. In general, communities in early succession will be dominated by fast-growing, well-dispersed species (opportunist, fugitive, or r-selected life-histories). As succession proceeds, these species will tend to be replaced by more competitive (k-selected) species.

Trends in ecosystem and community properties in succession have been suggested, but few appear to be general. For example, species diversity almost necessarily increases during early succession as new species arrive, but may decline in later succession as competition eliminates opportunistic species and leads to dominance by locally superior competitors. Net Primary Productivity, biomass, and trophic level properties all show variable patterns over succession, depending on the particular system and site.

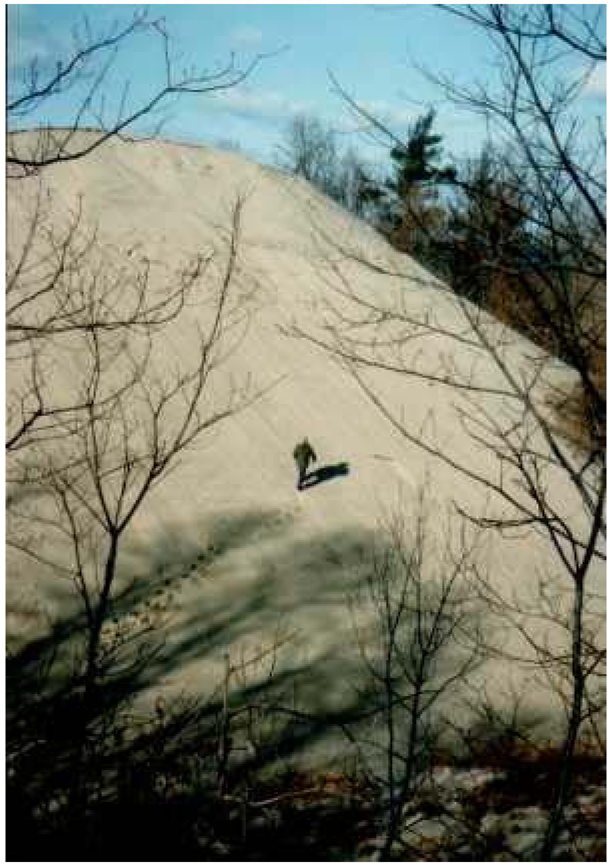
Ecological succession was formerly seen as having a stable end-stage called the climax, sometimes referred to as the 'potential vegetation' of a site, shaped primarily by the local climate. This idea has been largely abandoned by modern ecologists in favor of nonequilibrium ideas of how ecosystems function. Most natural ecosystems experience disturbance at a rate that makes a "climax" community unattainable. Climate change often occurs at a rate and frequency sufficient to prevent arrival at a climax state. Additions to available species pools through range expansions and introductions can also continually reshape communities.

The development of some ecosystem attributes, such as pedogenesis and nutrient cycles, are both influenced by community properties, and, in turn, influence further community development. This process may occur only over centuries or millennia. Coupled with the stochastic nature of disturbance events and other long-term (e.g., climatic) changes, such dynamics make it doubtful whether the 'climax' concept ever applies or is particularly useful in considering actual vegetation.

History of the theory

The idea of ecological succession goes back to the 14th century. The French naturalist Adolphe Dureau de la Malle was the first to make use of the word *succession* about the vegetation development after forest clear-felling. In 1859 Henry David Thoreau wrote an address called "The Succession of Forest Trees" in which he described succession in an Oak-Pine forest.

Henry Chandler Cowles, at the University of Chicago, developed a more formal concept of succession. Inspired by the studies of Danish dunes done by Eugen Warming, Cowles studied vegetation development on sand dunes on the shores of Lake Michigan (the Indiana Dunes). He recognized that vegetation on sand-dunes of different ages might be interpreted as different stages of a general trend of vegetation development on dunes, and used his observations to propose a particular sequence (sere) and process of primary succession. His paper, "The ecological relations of the vegetation of the sand dunes of Lake Michigan" in 1899 in the Botanical Gazette is one of the classic publications in the history of the field of ecology.



The Indiana Dunes on Lake Michigan, which stimulated Cowles' development of his theories of ecological succession.

Understanding of succession was long dominated by the theories of Frederic Clements, a contemporary of Cowles, who held that successional sequences of communities (*seres*), were highly predictable and culminated in a climatically determined stable climax. Clements and his followers developed a complex taxonomy of communities and successional pathways.

A contrasting view, the Gleasonian framework, is more complex, with three items: invoking interactions between the physical environment, population-level interactions between species, and disturbance regimes, in determining the composition and spatial distribution of species. It differs most fundamentally from the Clementsian view in suggesting a much greater role of chance factors and in denying the existence of coherent, sharply bounded community types. Gleason's ideas, first published in the early 20th century, were more consistent with Cowles' thinking, and were ultimately largely vindicated. However, they were largely ignored from their publication until the 1950s.

About Frederic Clements' distinction between primary succession and secondary succession, Cowles wrote (1911):

This classification seems not to be of fundamental value, since it separates such closely related phenomena as those of erosion and deposition, and it places together such unlike things as human agencies and the subsidence of land.

Beginning with the work of Robert Whittaker and John Curtis in the 1950s and 1960s, models of succession have gradually changed and become more complex. In modern times, among North American ecologists, less stress has been placed on the idea of a single climax vegetation, and more study has gone into the role of contingency in the actual development of communities.

Types of succession

Primary and secondary succession

If the development begins on an area that has not been previously occupied by a community, such as a newly exposed rock or sand surface, a lava flow, glacial tills, or a newly formed lake, the process is known as primary succession.

Secondary succession: trees are colonizing uncultivated fields and meadows.

If the community development is proceeding in an area from which a community was removed it is called secondary succession. Secondary succession arises on sites where the vegetation cover has been disturbed by humans or animals (an abandoned crop field or cut-over forest, or natural forces such as water , wind storms, and floods.) Secondary succession is usually more rapid as the colonizing area is rich in leftover soil, organic matter and seeds of the previous vegetation, whereas in primary succession the soil itself must be formed, and seeds and other living things must come from outside the area.

Seasonal and cyclic succession

Unlike secondary succession, these types of vegetation change are not dependent on disturbance but are periodic changes arising from fluctuating species interactions or recurring events. These models propose a modification to the climax concept towards one of dynamic states.

Causes of plant succession

Autogenic succession can be brought by changes in the soil caused by the organisms there. These changes include accumulation of organic matter in litter or humic layer, alteration of soil nutrients, change in pH of soil by plants growing there. The structure of the plants themselves can also alter the community. For example, when larger species like trees mature, they produce shade on to the developing forest floor that tends to exclude light-requiring species. Shade-tolerant species will invade the area.

Allogenic succession is caused by external environmental influences and not by the vegetation. For example soil changes due to erosion, leaching or the deposition of silt and clays can alter the nutrient content and water relationships in the ecosystems. Animals also play an important role in allogenic changes as they are pollinators, seed dispersers and herbivores. They can also increase nutrient content of the soil in certain areas, or shift soil about (as termites, ants, and moles do) creating patches in the habitat. This may create regeneration sites that favor certain species.

Climatic factors may be very important, but on a much longer time-scale than any other. Changes in temperature and rainfall patterns will promote changes in communities. As the climate warmed at the end of each ice age, great successional changes took place. The tundra vegetation and bare glacial till deposits underwent succession to mixed deciduous forest. The greenhouse effect resulting in increase in temperature is likely to bring profound Allogenic changes in the next century. Geological and climatic catastrophes such as volcanic eruptions, earthquakes, avalanches, meteors, floods, fires, and high wind also bring allogenic changes.

Clement's theory of succession/Mechanisms of succession

F.E. Clement (1916) developed a descriptive theory of succession and advanced it as a general ecological concept. His theory of succession had a powerful influence on ecological thought. Clement's concept is usually termed classical ecological theory. According to Clement, succession is a process involving several phases:

1. **Nudation**: Succession begins with the development of a bare site, called Nudation (disturbance).

2. **Migration**: It refers to arrival of propagules.
3. **Ecesis**: It involves establishment and initial growth of vegetation.
4. **Competition**: As vegetation became well established, grew, and spread, various species began to compete for space, light and nutrients. This phase is called competition.
5. **Reaction**: During this phase autogenic changes affect the habitat resulting in replacement of one plant community by another.
6. **Stabilization**: Reaction phase leads to development of a climax community.

Seral communities

A seral community is an intermediate stage found in an ecosystem advancing towards its climax community. In many cases more than one seral stage evolves until climax conditions are attained. A *prisere* is a collection of seres making up the development of an area from non-vegetated surfaces to a climax community. Depending on the substratum and climate, a seral community can be one of the following:

A hydrosere community.

Hydrosere
: Community in freshwater

Lithosere
: Community on rock

Psammosere
: Community on sand

Xerosere
: Community in dry area

Halosere
: Community in saline body (e.g. a marsh)

Changes in animal life

Animal life also exhibit changes with changing communities. In lichen stage the fauna is sparse. It comprises few mites, ants and spiders living in the cracks and crevices. The fauna undergoes a qualitative increase during herb grass stage. The animals found during this stage include nematodes, insects larvae, ants, spiders, mites, etc. The animal population increases and diversifies with the development of forest climax community. The fauna consists of invertebrates like slugs, snails, worms, millipedes, centipedes, ants, bugs; and vertebrates such as squirrels, foxes, mouse, moles, snakes, various birds, salamanders and frogs.

Microsuccession/Serule

Succession of microorganisms like fungi, bacteria, etc occurring within a microhabitat is known as microsuccession or serule. This type of succession occurs within communities, for example in dead trees, animal droppings, etc.

The climax concept

According to classical ecological theory, succession stops when the sere has arrived at an equilibrium or steady state with the physical and biotic environment. Barring major disturbances, it will persist indefinitely. This end point of succession is called climax.

Climax community

The final or stable community in a sere is the *climax community* or *climatic vegetation*. It is self-perpetuating and in equilibrium with the physical habitat. There is no net annual accumulation of organic matter in a climax community mostly. The annual production and use of energy is balanced in such a community.

Characteristics of climax

- The vegetation is tolerant of environmental conditions.
- It has a wide diversity of species, a well-drained spatial structure, and complex food chains.
- The climax ecosystem is balanced. There is equilibrium between gross primary production and total respiration, between energy used from sunlight and energy released by decomposition, between uptake of nutrients from the soil and the return of nutrient by littefall to the soil.
- Individuals in the climax stage are replaced by others of the same kind. Thus the species composition maintains equilibrium.
- It is an index of the climate of the area. The life or growth forms indicate the climatic type.

Types of climax

Climatic Climax

If there is only a single climax and the development of climax community is controlled by the climate of the region, it is termed as climatic climax. For example, development of Maple-beech climax community over moist soil. Climatic climax is theoretical and develops where physical conditions of the substrate are not so extreme as to modify the effects of the prevailing regional climate.

Edaphic Climax

When there are more than one climax communities in the region, modified by local conditions of the substrate such as soil moisture, soil nutrients, topography, slope exposure, fire, and animal activity, it is called *edaphic climax*. Succession ends in an edaphic climax where topography, soil, water, fire, or other disturbances are such that a climatic climax cannot develop.

Catastrophic Climax

Climax vegetation vulnerable to a catastrophic event such as a wildfire. For example, in California, chaparral vegetation is the final vegetation. The wildfire removes the mature vegetation and decomposers. A rapid development of herbaceous vegetation follows until the shrub dominance is re-established. This is known as catastrophic climax.

Disclimax

When a stable community, which is not the climatic or edaphic climax for the given site, is maintained by man or his domestic animals, it is designated as Disclimax (disturbance climax) or anthropogenic subclimax (man-generated). For example, overgrazing by stock may produce a desert community of bushes and cacti where the local climate actually would allow grassland to maintain itself.

Subclimax

The prolonged stage in succession just preceding the climatic climax is *subclimax*.

Preclimax and Postclimax

In certain areas different climax communities develop under similar climatic conditions. If the community has life forms lower than those in the expected climatic climax, it is called *preclimax*; a community that has life forms higher than those in the expected climatic climax is *postclimax*. Preclimax strips develop in less moist and hotter areas, whereas Postclimax strands develop in more moist and cooler areas than that of surrounding climate.

Theories regarding nature of climax

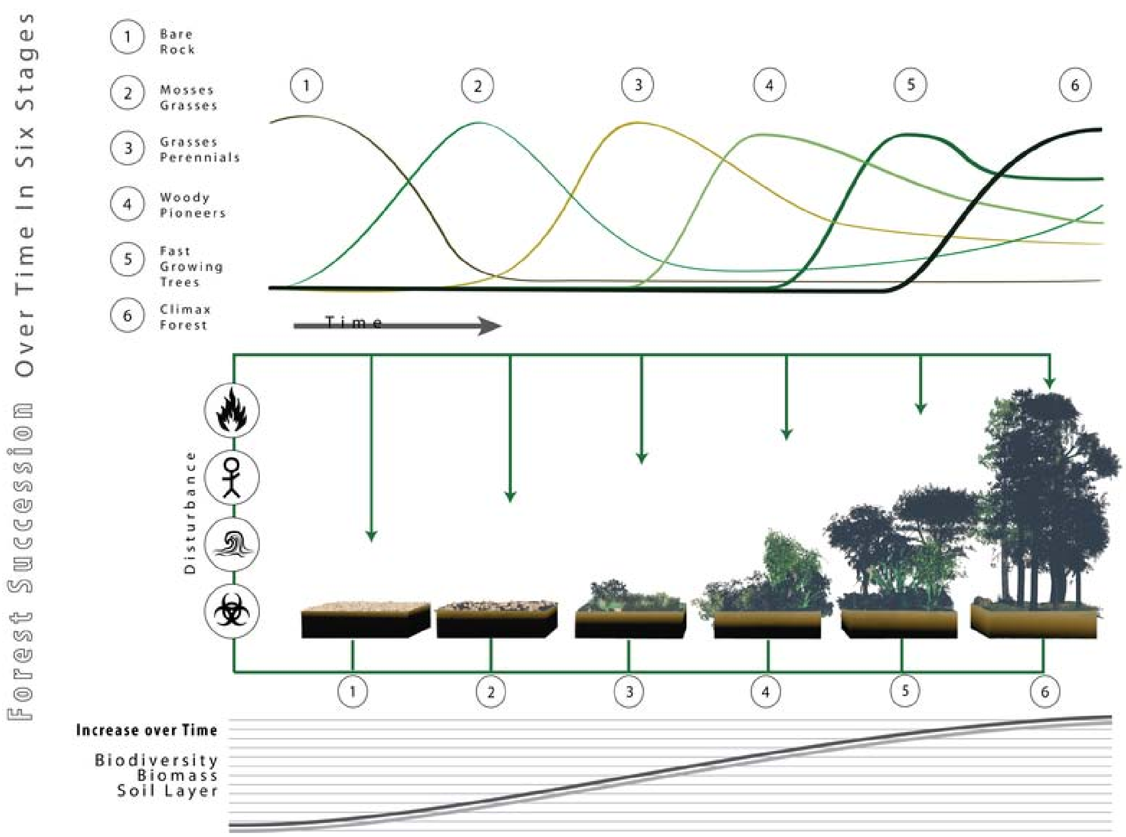
There are three schools of interpretations explaining the climax concept:

- **Monoclimax** or **Climatic Climax Theory** was advanced by Clements (1916) and recognizes only one climax whose characteristics are determined solely by climate (climatic climax). The processes of succession and modification of environment overcome the effects of differences in topography, parent material of the soil, and other factors. The whole area would be covered with uniform plant community. Communities other than the climax are related to it, and are recognized as subclimax, postclimax and disclimax.

- **Polyclimax Theory** was advanced by Tansley (1935). It proposes that the climax vegetation of a region consists of more than one vegetation climaxes are controlled by soil moisture, soil nutrients, topography, slope exposure, fire, and animal activity.
- **Climax Pattern Theory** was proposed by Whittaker (1953). The climax pattern theory recognizes a variety of climaxes governed by responses of species populations to biotic and abiotic conditions. According to this theory the total environment of the ecosystem determines the composition, species structure, and balance of a climax community. The environment includes the species responses to moisture, temperature, and nutrients, their biotic relationships, availability of flora and fauna to colonize the area, chance dispersal of seeds and animals, soils, climate, and disturbance such as fire and wind. The nature of climax vegetation will change as the environment changes. The climax community represents a pattern of populations that corresponds to and changes with the pattern of environment. The central and most widespread community is the climatic climax.

More recently another possible idea has been put forward called the theory of alternative stable states which suggests that there is not one end point but many which transition between each other over ecological time.

Forest succession



The forests, being an ecological system are subject to the species succession process . There are "opportunistic" or **"pioneer"** species that produce great quantity of seeds that are disseminated by the wind, and therefore can colonize big empty extensions, and they are capable to germinate and grow under direct sun exposition. Once they have produced a closed canopy, the lack of direct sun radiation at soil makes it difficult for their own seedlings to develop. It is then the opportunity for shade **"tolerant"** species to get established under the protection of pioneer. When these pioneers will die, the shade tolerants will replace them. The shade tolerant species are capable of growing under the canopy, and therefore, in the absence of catastrophes, will stay. For this reason it is said than the stand has reached its **climax**. When an important catastrophe will arrive, the opportunity for the pioneers will be open again, provided they are not absent at a reasonable range.

An example of pioneer species, in forests of northeastern North America are *Betula alleghaniensis* (Yellow birch) and *Prunus serotina* (Black cherry), that are particularly well-adapted to exploit large gaps in forest canopies, but are intolerant of shade and are eventually replaced by other (shade-tolerant) species in the absence of disturbances that create such gaps.

Things in nature are usually nor white neither black, and there are **intermediates**. It is therefore normal that between the two extremes light/shade there is a gradation, and there are species that may act as pioneer or tolerant, depending on circumstances. It is of paramount importance to know the tolerance of species in order to practice an effective silviculture.

Chapter 2

Biome

The planet Earth.

Biomes are climatically and geographically defined as similar climatic conditions on the Earth, such as communities of plants, animals, and soil organisms, and are often referred to as ecosystems. Some parts of the earth have more or less the same kind of abiotic and biotic factors spread over a large area creating a typical ecosystem over that area. Such major ecosystems are termed as biomes. Biomes are defined by factors such as plant structures (such as trees, shrubs, and grasses), leaf types (such as broadleaf and needleleaf), plant spacing (forest, woodland, savanna), and climate. Unlike ecozones, biomes are not defined by genetic, taxonomic, or historical similarities. Biomes are often identified with particular patterns of ecological succession and climax vegetation (quasi-equilibrium state of the local ecosystem). An ecosystem has many biotopes and a biome is a major habitat type. A major habitat type, however, is a compromise, as it has an intrinsic inhomogeneity.

The biodiversity characteristic of each biome, especially the diversity of fauna and subdominant plant forms, is a function of abiotic factors and the biomass productivity of the dominant vegetation. In terrestrial biomes, species diversity tends to correlate positively with net primary productivity, moisture availability, and temperature.

Ecoregions are grouped into both biomes and ecozones.

A fundamental classification of biomes is:

1. Terrestrial (land) biomes
2. Aquatic biomes (including Freshwater biomes and Marine biomes)

Biomes are often known in English by local names. For example, a temperate grassland or shrubland biome is known commonly as *steppe* in central Asia, *prairie* in North America, and *pampas* in South America. Tropical grasslands are known as *savanna* in Australia, whereas in Southern Africa it is known as *veldt* (from Afrikaans).

Sometimes an entire biome may be targeted for protection, especially under an individual nation's Biodiversity Action Plan.

Climate is a major factor determining the distribution of terrestrial biomes. Among the important climatic factors are:

- latitude: Arctic, boreal, temperate, subtropical, tropical.
- humidity: humid, semi-humid, semi-arid, and arid.
    - seasonal variation: Rainfall may be distributed evenly throughout the year or be marked by seasonal variations.
    - dry summer, wet winter: Most regions of the earth receive most of their rainfall during the summer months; Mediterranean climate regions receive their rainfall during the winter months.
- elevation: Increasing elevation causes a distribution of habitat types similar to that of increasing latitude.

The most widely used systems of classifying biomes correspond to latitude (or temperature zoning) and humidity. Biodiversity generally increases away from the poles towards the equator and increases with humidity.

Biome Classification Schemes

Biome classification schemes seek to define biomes using climatic measurements. Particularly in the 1970s and 1980s there was a significant push to understand the relationships between these measurements and properties of ecosystem energetics because such discoveries would enable the prediction of rates of energy capture and transfer among components within ecosystems. Such a study was conducted by Sims et al. (1978) on North American grasslands. The study found a positive logistic correlation between evapotranspiration in mm/yr and above ground net primary production in g/m^2/yr. More general results from the study were that precipitation and water use lead to aboveground primary production, solar radiation and temperature lead to belowground primary production (roots), and temperature and water lead to cool and warm season growth habit. These findings help explain the categories used in Holdridge's bioclassification scheme, which were then later simplified in Whittaker's. The number of classification schemes and the variety of determinants used in those schemes, however, should be taken as a strong indicator that biomes do not all fit perfectly into the classification schemes created.

Holdridge Scheme

The Holdridge classification scheme was developed by L. R. Holdridge, a botanist. It maps climates based on four categories:

- Average total precipitation (cm) on a logarithmic scale
- Potential evapotranspiration ratio: the potential evapotranspiration divided by the precipitation; the ratio increases from humid to arid regions.
- Potential evapotranspiration
- Mean annual biotemperature (°C): calculated from monthly mean temperatures after converting any mean temperature to 0°C, based on the assumption that temperatures at or below freezing all have the same effect on plants, and delineating between -10°C and -30°C would yield unrealistic results.

In this scheme, climates are classified based on the biological effects of temperature and rainfall on vegetation under the assumption that these two abiotic factors are the largest determinants of the type of vegetation found in an area. Holdridge uses the 4 axis to define 30 so called "humidity provinces," which are clearly visible in the Holdridge diagram. While the scheme largely ignores soil and sun exposure, Holdridge did acknowledge that these, too, were important factors in biome determination.

Whittaker's Biome-type Classification Scheme

Whittaker appreciated biome-types as a representation of the great diversity of the living world, and saw the need to establish a simple way to classify these biome-types. Whittaker based his classification scheme on two abiotic factors: Precipitation and Temperature. His scheme can be seen as a simplification of Holdridge's, one more readily accessible, but perhaps missing the greater specificity that Holdrige's provides.

Whittaker based his representation of global biomes on both previous theoretical assertions as well as an ever increasing empirical sampling of global ecosystems. Whittaker was in a unique position to make such a holistic assertion as he had previously compiled a review of biome classification.

The Whittaker Classification Scheme can be viewed at the following address: here

Key definitions for understanding Whittaker's Scheme

- **physiognomy**: The apparent characteristics, outward features, or appearance of ecological communities or species.
- **biome**: a grouping terrestrial ecosystems on a given continent that are similar in vegetation structure, physiognomy, features of the environment and characteristics of their animal communities
- **formation**: a major kind of community of plants on a given continent
- **biome-type**: grouping of convergent biomes or formations of different continents; defined by physiognomy
- **formation-type**: grouping of convergent formations

Whittaker's distinction between biome and formation can be simplified: formation is used when applied to plant communities only, while biome is used when concerned with both plants and animals. Whittaker's convention of biome-type or formation-type is simply a broader method to categorize similar communities. The world biome-types, as displayed on a world map, can be viewed at the following link: here

Whittaker's parameters for classifying biome-types

Whittaker, seeing the need for a simpler way to express the relationship of community structure to the environment, used what he called "gradient analysis" of ecocline patterns to relate communities to climate on a worldwide scale. Whittaker considered four main ecoclines in the terrestrial realm.

1. Intertidal levels: The wetness gradient of areas that are exposed to alternating water and dryness with intensities that vary by location from high to low tide
2. climatic moisture gradient
3. temperature gradient by altitude
4. temperature gradient by latitude

Along these gradients, Whittaker noted several trends that allow him to qualitatively establish biome-types.

- The gradient runs from favorable to extreme with corresponding changes in productivity.
- Changes in physiognomic complexity vary with the favorability of the environment (decreasing community structure and reduction of stratal differentiation as the environment becomes less favorable).
- Trends in diversity of structure follow trends in species diversity; alpha and beta species diversities decrease from favorable to extreme environments.
- Each growth-form (i.e. grasses, shrubs, etc.) has its characteristic place of maximum importance along the ecoclines.
- The same growth forms may be dominant in similar environments in widely different parts of the world.

Whittaker summed the effects of gradients (3) and (4), to get an overall temperature gradient and combined this with gradient (2), the moisture gradient, to express the above conclusions in what is known as the Whittaker Classification Scheme. The scheme graphs average annual precipitation (x-axis) versus average annual temperature (y-axis) to classify biome-types.

Walter System

The Heinrich Walter classification scheme was developed by Heinrich Walter, a German ecologist. It differs from both the Whittaker and Holdridge schemes because it takes into account the seasonality of temperature and precipitation. The system, also based on precipitation and temperature, finds 9 major biomes, with the important climate traits and vegetation types summarized in the accompanying table. The boundaries of each biome correlate to the conditions of moisture and cold stress that are strong determinants of plant form, and therefore the vegetation that defines the region.

- I: Equatorial
    - Always moist and lacking temperature seasonality
    - Evergreen tropical rain forest
- II: Tropical
    - Summer rainy season and cooler “winter” dry season
    - Seasonal forest, scrub, or savanna
- III: Subtropical
    - Highly seasonal, arid climate
    - Desert vegetation with considerable exposed surface
- IV: Mediterranean
    - Winter rainy season and summer drought
    - Sclerophyllous (drought-adapted), frost-sensitive shrublands and woodlands
- V: Warm temperate
    - Occasional frost, often with summer rainfall maximum

    - Temperate evergreen forest, somewhat frost-sensitive
- VI: Nemoral
    - Moderate climate with winter freezing
    - Frost-resistant, deciduous, temperate forest
- VII: Continental
    - Arid, with warm or hot summers and cold winters
    - Grasslands and temperate deserts
- VIII: Boreal
    - Cold temperate with cool summers and long winters
    - Evergreen, frost-hardy needle-leaved forest (taiga)
- IX: Polar
    - Very short, cool summers and long, very cold winters
    - Low, evergreen vegetation, without trees, growing over permanently frozen soils

Bailey System

Robert G. Bailey almost developed a biogeographical classification system for the United States in a map published in 1976. Bailey subsequently expanded the system to include the rest of South America in 1981 and the world in 1989. The Bailey system is based on climate and is divided into seven domains (Polar, Humid Temperate, Dry, Human, and Humid Tropical), with further divisions based on other climate characteristics (subarctic, warm temperate, hot temperate, and subtropical; marine and continental; lowland and mountain).

- **100 Polar Domain**
    - 120 Tundra Division
    - M120 Tundra Division - Mountain Provinces
    - 130 Subarctic Division
    - M130 Subarctic Division - Mountain Provinces
- **200 Humid Temperate Domain**
    - 210 Warm Continental Division
    - M210 Warm Continental Division - Mountain Provinces
    - 220 Hot Continental Division
    - M220 Hot Continental Division - Mountain Provinces
    - 230 Subtropical Division
    - M230 Subtropical Division - Mountain Provinces
    - 240 Marine Division
    - M240 Marine Division - Mountain Provinces
    - 250 Prairie Division
    - 260 Mediterranean Division
    - M260 Mediterranean Division - Mountain Provinces
- **300 Dry Domain**
    - 310 Tropical/Subtropical Steppe Division
    - M310 Tropical/Subtropical Steppe Division - Mountain Provinces

WWF system

A team of biologists convened by the World Wide Fund for Nature (WWF) developed an ecological land classification system that identified fourteen biomes, called **major habitat types**, and further divided the world's land area into 867 terrestrial ecoregions. Each terrestrial Ecoregion has a specific EcoID, fomat XXnnNN (XX is the Ecozone, nn is the Biome number, NN is the individual number). This classification is used to define the Global 200 list of ecoregions identified by the WWF as priorities for conservation. The WWF major habitat types are:

- 01 Tropical and subtropical moist broadleaf forests (tropical and subtropical, humid)
- 02 Tropical and subtropical dry broadleaf forests (tropical and subtropical, semi-humid)
- 03 Tropical and subtropical coniferous forests (tropical and subtropical, semi-humid)
- 04 Temperate broadleaf and mixed forests (temperate, humid)
- 05 Temperate coniferous forests (temperate, humid to semi-humid)
- 06 Boreal forests/taiga (subarctic, humid)
- 07 Tropical and subtropical grasslands, savannas, and shrublands (tropical and subtropical, semi-arid)
- 08 Temperate grasslands, savannas, and shrublands (temperate, semi-arid)
- 09 Flooded grasslands and savannas (temperate to tropical, fresh or brackish water inundated)
- 10 Montane grasslands and shrublands (alpine or montane climate)
- 11 Tundra (Arctic)
- 12 Mediterranean forests, woodlands, and scrub or Sclerophyll forests (temperate warm, semi-humid to semi-arid with winter rainfall)
- 13 Deserts and xeric shrublands (temperate to tropical, arid)
- 14 Mangrove (subtropical and tropical, salt water inundated)

Freshwater biomes

According to the World Wildlife Fund, the following are classified as freshwater biomes:

- Large lakes
- Large river deltas
- Polar freshwaters
- Montane freshwaters
- Temperate coastal rivers
- Temperate floodplain rivers and wetlands
- Temperate upland rivers
- Tropical and subtropical coastal rivers
- Tropical and subtropical floodplain rivers and wetlands
- Tropical and subtropical upland rivers
- Xeric freshwaters and endorheic basins
- Oceanic islands

Realms or Ecozones (terrestrial and freshwater, WWF)

- NA Nearctic
- PA Palearctic
- AT Afrotropic
- IM Indomalaya
- AA Australasia
- NT Neotropic
- OC Oceania
- AN Antarctic

Marine biomes

Marine biomes (H) (major habitat types), Global 200 (WWF)

Biomes of the coastal & continental shelf areas (Neritic zone - List of ecoregions (WWF))

- Polar
- Temperate shelves and sea
- Temperate upwelling
- Tropical upwelling
- Tropical coral

Realms or Ecozones (marine, WWF)

- North Temperate Atlantic
- Eastern Tropical Atlantic
- Western Tropical Atlantic
- South Temperate Atlantic
- North Temperate Indo-Pacific
- Central Indo-Pacific
- Eastern Indo-Pacific
- Western Indo-Pacific
- South Temperate Indo-Pacific
- Southern Ocean
- Antarctic
- Arctic
- Mediterranean

Other marine habitat types

- Hydrothermal vents
- Cold seeps
- Benthic zone
- Pelagic zone (trades and westerlies)
- Abyssal
- Hadal (ocean trench)

Major Habitats, Non Global 200 (WWF)

- Littoral/Intertidal zone
- Kelp forest
- Pack ice

Summary - Ecological taxonomy (WWF)

- Biosphere (List of ecoregions)
    - Ecozones or Realms (8)
        - Terrestrial Biomes (Major Habitat Types, 14)
            - Ecoregions (867)
                - Ecosystems (Biotopes)
        - Freshwater Biomes (Major Habitat Types, 12)
            - Ecoregions (426)
                - Ecosystems (Biotopes)
    - Marine Ecozones or Realms (13)
        - Continental Shelf Biomes (Major Habitat Types, 5)
            - (Marine Provinces) (62)
                - Ecoregions (232)
                    - Ecosystems (Biotopes)
        - Open & Deep Sea Biomes (Major Habitat Types)
    - Endolithic Biome

Example

- Biosphere
    - Ecozone: Palearctic ecozone
        - Terrestrial Biome: Temperate Broadleaf and Mixed Forests
            - Ecoregion: Dinaric Mountains mixed forests (PA0418)
                - Ecosystem: Orjen, vegetation belt between 1,100-1,450 m, Oromediterranean zone, Nemoral zone (temperate zone)
                    - Biotope: *Oreoherzogio-Abietetum illyricae* Fuk. (Plant list)
                        - Plant: Silver fir (*Abies alba*)

Anthropogenic biomes

Humans have fundamentally altered global patterns of biodiversity and ecosystem processes. As a result, vegetation forms predicted by conventional biome systems are rarely observed across most of Earth's land surface. Anthropogenic biomes provide an alternative view of the terrestrial biosphere based on global patterns of sustained direct human interaction with ecosystems, including agriculture, human settlements, urbanization, forestry and other uses of land. Anthropogenic biomes offer a new way forward in ecology and conservation by recognizing the irreversible coupling of human and ecological systems at global scales and moving us toward an understanding how best to live in and manage our biosphere and the anthropogenic biosphere we live in. The main biomes in the world are freshwater, marine, coniferous, deciduous, ice, mountains, boreal, grasslands, tundra, and rainforests.

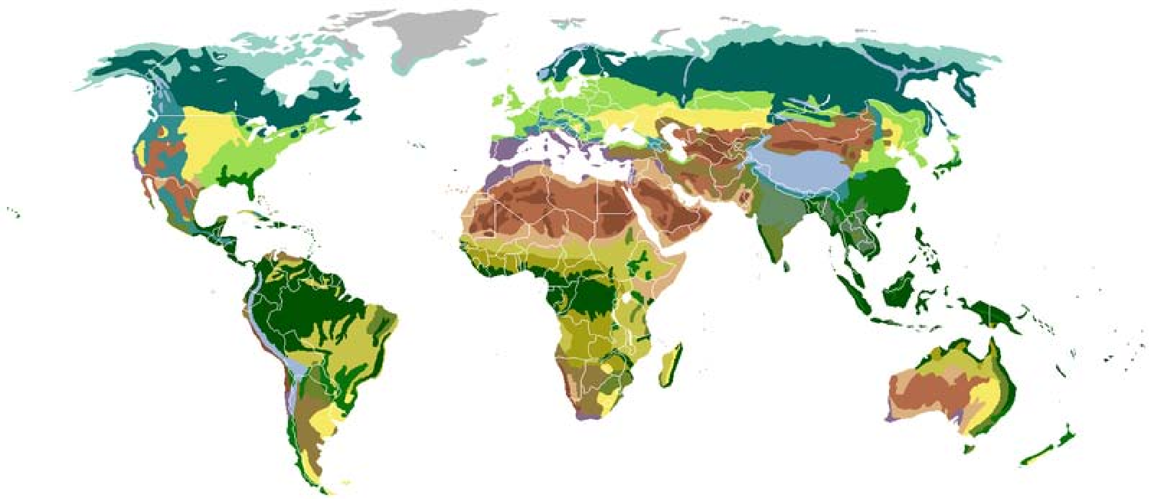
Major Anthropogenic Biomes

- Dense Settlements
- Villages
- Croplands
- Rangelands
- Forested

Other biomes

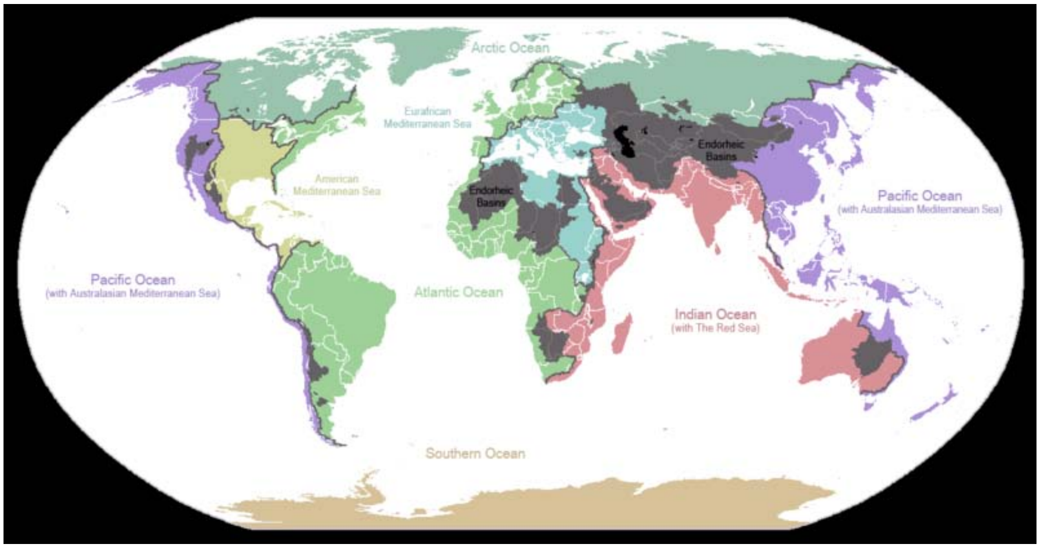
The Endolithic biome, consisting entirely of microscopic life in rock pores and cracks, kilometers beneath the surface, has only recently been discovered and does not fit well into most classification schemes.

Map of Biomes



ice sheet & polar desert tundra taiga temperate broadleaf forest	temperate steppe subtropical rainforest Mediterranean vegetation monsoon forest	arid desert xeric shrubland dry steppe semiarid desert	grass savanna tree savanna subtropical dry forest tropical rainforest	alpine tundra montane forest

Freshwater Biomes



Drainage basins of the principal oceans and seas of the world. Grey areas are endorheic basins that do not drain to the ocean.

Chapter 3

Cloud Forest

Tree ferns in cloud forest on Mount Kinabalu, Borneo

A **cloud forest**, also called a **fog forest**, is a generally tropical or subtropical evergreen montane moist forest characterized by a persistent, frequent or seasonal low-level cloud cover, usually at the canopy level. Cloud forests often exhibit an abundance of mosses covering the ground and vegetation, in which case they are also referred to as **mossy**

forests. Mossy forests usually develop on the saddles of mountains, where moisture introduced by settling clouds is more effectively retained.

Distribution and climate

One of the hanging bridges of the Sky walk in Santa Elena, Costa Rica disappearing into the clouds

Dependent on local climate, which is affected by the distance to the sea, the exposition and the latitude, the altitude varies from 500 m to 4000 m above sea level. Typically, there is a relatively small band of altitude in which the atmospheric environment is suitable for cloud forest development. This is characterized by persistent mist or clouds at the vegetation level, resulting in the reduction of direct sunlight and thus of evapotranspiration. Within cloud forests, much of the precipitation is in the form of fog drip, where fog condenses on tree leaves and then drips onto the ground below.

Tropical cloud forests extend from 23°N to 25°S latitudes and occur in a relatively narrow altitudinal zone with a special atmospheric environment which is characterized by at the vegetation level. Annual rainfall can range from 500 to 10000 mm/year and mean temperature between 8 to 20°C.

While cloud forest today is the most widely used term, in some regions these ecosystems or special types of cloud forests are called mossy forest, elfin forest, montane thicket, dwarf cloud forest, nuboselva, bosque montano nebuloso, selva de neblina, bosque nuboso, bosque de ceja, selva sublada, nebelwald, wolkenwald, forêt néphéliphile, forêt de nuage, unmu-rin, bosque anao, foresta nebular, mata nebular, matinha nebular, floresta fe neblina, floresta nuvigena, mata de neblina, matinha de altitude, floresta nublada, and floresta pluvial montana e/ou alto montana.

The definition of cloud forest can be ambiguous, with many countries not using the term (preferring such terms as Afromontane forest and upper montane rain forest, or more localised terms such as the Bolivian yungas, and the laurisilva of the Atlantic Islands) , and occasionally subtropical and even temperate forests in which similar meteorological conditions occur are considered to be cloud forests.

Only 1% of the global woodland is covered by cloud forests.

Important areas of cloud forest are in Central- and South America, East- and Central Africa, Indonesia, Malaysia, at the Philippines, Papua-New Guinea and in the Caribbean.

Tropical and subtropical cloud forests exist in the following countries:

- Angola
- Argentina
- Australia
- Bangladesh
- Belize
- Bolivia
- Brazil
- Brunei
- Burundi
- Cambodia
- Cameroon
- China
- Colombia
- Costa Rica
- Democratic Republic of Congo
- Dominica
- Ecuador
- El Salvador
- Fiji
- Gabon
- Guatemala
- Guyana (Pakaraima Mountains)
- Hispaniola (Massif de la Hotte)
- Honduras
- India
- Indonesia
- Jamaica (Blue and John Crow Mountains National Park)

- Kenya
- La Réunion (France)
- Madagascar
- Malaysia
- Mexico
- Federated States of Micronesia
- Mozambique
- Myanmar
- Nicaragua
- Oman
- Pakistan
- Panama
- Papua New Guinea
- Peru
- Philippines
- Portugal (Madeira)
- Rwanda
- Samoa
- Spain (Canary Islands)
- Sri Lanka
- Tanzania
- Trinidad and Tobago
- United States (Hawaiʻi and Puerto Rico)
- Venezuela
- Vietnam

Temperate cloud forests

Although far from being universally accepted as true cloud forests, several forests in temperate regions have strong similarities with tropical cloud forests. The term is further confused by occasional reference to cloud forests in tropical countries as "temperate" due to the cooler climate associated with these misty forests.

Temperate cloud forest on La Palma, Canary Islands

Distribution of temperate cloud forests

- Argentina - Catamarca and Tucumán
- Australia - Lamington National Park (Queensland)
- Chile (Bosque de Fray Jorge National Park)
- People's Republic of China - Yunnan Plateau, mountains of southern and eastern China
- Japan - parts of Yakushima Island
- New Zealand - parts of Fiordland, Mount Taranaki and Mount Cargill, near Dunedin.
- Portugal - Azores and Madeira
- South Africa
- Spain - Canary Islands (laurisilva)
- Taiwan
- United States - Redwood Coast

Characteristics

Hanging moss in a Cool Temperate Rainforest at Budawang National Park, Australia

In comparison with lower tropical moist forests, cloud forests show a reduced tree stature combined with increased stem density and generally the lower diversity of woody plants. Trees in these regions are generally shorter and more heavily stemmed than in lower altitude forests in the same regions, often with gnarled trunks and branches, forming dense, compact crowns. Their leaves become smaller, thicker and harder with increasing altitude. The high moisture promotes the development of a high biomass and biodiversity of epiphyte, particularly bryophytes, lichens, ferns (including filmy ferns), bromeliads and orchids. The number of endemic plants can be very high.

An important feature of cloud forests is that the tree crowns can intercept the wind-driven cloud moisture, part of which drips to the ground. This water stripped from the clouds is termed horizontal or occult (because it is not recorded with normal rainfall measurement) precipitation, and can be an important contribution to the hydrologic cycle.

Due to the high water content of the soil, the reduced solar radiation and the low rates of decomposition and mineralization, the soil acidity is very high, with mor humus and peat often forming the upper soil layer.

Stadtmüller (1987) distinguishes two general types of tropical montane cloud forests:

- Areas with a high annual precipitation due to a frequent cloud cover in combination with heavy and sometimes persistent orographic rainfall; such forests have a perceptible canopy strata, a high number of epiphytes and a thick peat layer which has a high storage capacity for water and control the runoff;
- In drier areas with mainly seasonal rainfall cloud stripping can amount to a large proportion of the annual precipitation.

Importance of cloud forests

At the edge of the Panamanian side of the Parque Internacional la Amistad

- Watershed function. Because of the cloud stripping strategy the effective rainfall can be doubled in dry seasons and increase the wet season rainfall by about 10 percent. Experiments of Costin and Wimbush (1961) showed that the tree canopies of non-cloud forests intercept and evaporate 20 percent more of the precipitation than cloud forests, which means a loss to the land component of the hydrological cycle.

- Vegetation. Tropical montane cloud forests are not as species-rich as tropical lowland forests but they provide the habitats for many species that are found nowhere else. For example, the Cerro de la Neblina, a cloud covered mountain in the south of Venezuela accommodates many shrubs, orchids and insectivorous plants which are restricted to this mountain only.
- Fauna. The endemism in animals is also very high. In Peru, more than one third of the 270 endemic birds, mammals and frogs are found in cloud forests. One of the best known cloud forest mammal is the Mountain Gorilla (*Gorilla b. beringei*). Many of those endemic animals have important functions such as seed dispersal and forest dynamics in this ecosystems.

Current situation

The cloud forest of Monteverde, Costa Rica

In 1970, the original extent of cloud forests was around 50 million hectares. Population growth, poverty and uncontrolled land use have contributed to the loss of cloud forests. The 1990 Global Forest Survey found that 1.1% of tropical mountain and highland forests were lost each year, which was higher than in any other tropical forests. In

Colombia, one of the countries with the largest area of cloud forests, only 10-20% of the initial cloud forest cover remains. Significant areas have been converted to plantations, or for use in agriculture and pasture. Important crops in montane forest zones are tea and coffee, but also logging special species such as Podocarpus causes changes to forest structure.

Currently, one third of all cloud forests are protected.

Impact of climate change on cloud forests

Because of their delicate dependency on local climate, cloud forests will be strongly affected by global climate change. A number of climate models suggest that the low-altitude cloudiness will be reduced, which means that the optimum climate for many cloud forest habitats will increase in altitude. Linked to the reduction of cloud moisture immersion and increasing temperature, the hydrological cycle will change with the consequence that the system will dry out. This can result in the wilting and the death of epiphytes, which rely on high humidity. Frogs and lizards are expected to suffer from increased drought. In addition, climate changes can result in a higher amount of hurricanes, which may increase damage to tropical montane cloud forests. All in all the results of the climate change will be a loss in biodiversity, altitude shifts in species ranges and community reshuffling and, in some areas, complete loss of cloud forests.

Chapter 4

Conservation Grazing

Conservation grazing is the use of semi-feral or domesticated grazing livestock to maintain and increase the biodiversity of natural or semi-natural grasslands, heathlands, wood pasture, wetlands and many other habitats.

Conservation grazing is generally less intensive than practices such as prescribed burning, but still needs to be managed to ensure that overgrazing does not occur. The practice has proven to be beneficial in moderation in restoring and maintaining grassland and heathland ecosystems. The optimal level of grazing will depend on the goal of conservation, and different levels of grazing, alongside other conservation practices, can be used to induce the desired results.

History

For historic grasslands, grazing animals, herbivores, were a crucial part of the ecosystem. When grazers are removed, historically grazed lands may show a decline in both the density and the diversity of the vegetation. The history of the land may help ecologists and conservationists determine the best approach to a conservation project.

Historic threats to grasslands primarily began with land conversion to crop fields. However, this threat shifted to improper land management techniques and more recently to the expansion of woody species of plants due to a lack of management, and to climate change. These threats hinder the ecological importance of grassland communities. Grasslands are a carbon sink, and benefit livestock. Ecologically, if managed properly, conservation grazing can help to restore these historic ecological assets. However, if the grazing levels reach too high, shrubs will persist over grassland.

In 1985, the US established the Conservation Reserve Program (CRP), which gave money to farmers to leave land fallow, instead of using it for crops or grazing. It was argued that exclusion or use of moderate grazing would be an important factor in future decisions as to what to do with the land that was a part of the CRP program. The land could have varied uses in the future. The minimization of the effects of climate change has a lot to do with the sequestering of carbon, and expansive grasslands may play an essential role in this process. But also it could be used for the rotation of crops to the benefit of wildlife populations.

Conservation grazing in practice

The use of conservation grazing is dependent on what type of ecosystem, habitat, and plant community are desired to be maintained or restored. Grazing is a beneficial tool used to create a grass and small shrub dominated area. *Tasker and Bradstock* found that grazed areas returned a lower vegetation complexity score than ungrazed, however this was mainly because tree species and shrubs produce higher complexity scores than grasses – the grazed areas were composed primarily of bunch grasses and the ungrazed were dominated by shrub species. Certain areas that have been, historically, woody forest, may be chosen to be restored back to historical conditions, thus *Tasker's and Bradstock's* study would imply that wooded areas should remain ungrazed by livestock such as cattle.

Conservation practices such as grazing need to be monitored closely. If they are not, the practice can become overused and have an opposite effect than intended. Overgrazing may cause erosion, habitat destruction, soil compaction, or reduced biodiversity (species richness).

One issue of controversy with grazing is whether conservation grazing is in fact beneficial to a grassland community and what intensity of grazing management needs to be taken. *Rambo and Faeth* found that the use of vertebrates for grazing of an area would increase the species richness of plants by decreasing the abundance of dominant species and increasing the richness of rarer species. The decrease in abundance may lead to a more open forest canopy and more room for other plant species to emerge.

Grazing restoration effect dependent on grazer species

Different grazing species have different effects. For example, elk and horses have a similar grazing frequency to cattle but tend to spread their zone of grazing to cover a greater area, producing a smaller effect on a given area than cattle would. Similarly, cattle have been found to be more useful in the restoration of pastures with low species richness, and sheep were found useful for the re-establishment of neglected fields. The type of area that needs to be restored or maintained will determine the species of grazer ideal for conservation grazing. *Dumont et al.* found in the use of varied breeds of steers that "traditional breeds appeared slightly less selective than commercial breeds", but did not make a significant difference in biodiversity. In this particular study biodiversity was maintained by the same amount by both breed types.

Effects on native and non-native plant species

Conservation grazing is a tool used for conserving biodiversity. However, one danger in grazing is the potential for invasive species to be enhanced as well as the native biodiversity. A study by *Loeser et al.* showed that areas of high intensity grazing and grazer removal increased the biomass of nonnative introduced species. Both showed that an intermediate approach is the best method. The nonnatives did demonstrate that they were not as well adapted to the disturbances, such as drought. This indicated that implementing controlled grazing methods would decrease the abundance of nonnatives in those plots that had not been properly managed.

Effects of grazing can also depend on the individual plant species and its response to grazing. Plants that are adapted to extensive grazing (such as that done by cattle) will respond quicker and more effectively to grazing than native species that have not had to cope with intense grazing pressure in the past. An experiment done by *Kimball and Schiffman* showed that grazing increased the cover of some native species but did not decrease the cover of nonnative species. The species diversity of the native plants was able to respond to the grazing and increase diversity. The community would become denser than originally with the increased biodiversity. (However, this may have been simply variance in plots due to the fact that the native and nonnative compositions were of different species between the grazed and ungrazed plots.)

Effects on non-plant species

Insects and butterflies

Degree of grazing has a significant effect on the species richness and abundance of insects in grasslands. Land management in the form of grazing tends to decrease diversity with increased intensity. *Kruess and Tscharntke* attribute this difference to the increased height of grasses in the ungrazed areas. The study showed that the abundance and diversity of insects (such as butterfly adults, trap-nesting bees and wasps) were increased by increased grass height. However, other insects such as grasshoppers responded better to heterogeneity of the vegetation.

Vertebrates

Grazing can have varied effects on vertebrates. *Kuhnert et al.* observed that different bird species react in different ways to changes in grazing intensity. Grazing has also been thought to decrease the abundance of vertebrates, such as the Prairie Dog and the Desert Tortoise. However, *Kazmaier et al.* found that the effect of moderate grazing on the Texas Tortoise did not show a significant difference when comparing grazed and ungrazed plots.

Rabbits have been widely discussed due to their influences on land composition. *Bell and Watson* found that rabbits show grazing preference for different plant species. This preference can alter the composition of a plant community. In some cases, if the preference is for a non-native, invasive plant, rabbit grazing may benefit the community by reducing non-native abundance and creating room for the native plant species to fill. When rabbits graze in moderation they can create a more complex ecosystem, by creating more variable environments that will allow for more predator-competitor relationships between the various organisms. However, besides the effect on wild vegetation, rabbits destroy crops, compete with other herbivores, and can result in extreme ecological damage. Competition can be direct or indirect. The rabbits may specifically eat the competitions target food or it may inhibit the growth of grasses that other species eat. For example, rabbit grazing in the Netherlands inhibits tall grasses from becoming dominant. This in turn enhances the suitability of the pasture for Brent Goose. However, they may benefit predators that do better in open areas, because the rabbits reduce the amount of vegetation making it easier for those predators to spot their prey.

Effect on ephemeral wetland ecosystems

Ephemeral wetlands degradation and loss of biodiversity had, at one point in time, been blamed on mismanaged grazing of both native and non-native ungulates and other grazers. A study done by Jaymee Marty of The Nature Conservancy examined the effects on the vernal pools formed in California when grazers were removed. The results of the short study showed that areas where grazers were removed had a lower diversity of native grasses, invertebrates and vertebrates in the pools, with an increase in non-native grass abundance and distribution in the area. The study also demonstrated reduced reproduction success of individual species in the area, such as the Western Spadefoot Toad and California Tiger Salamander. Marty argues that this decrease is due to ecosystems adapting to historical changes in grazers and the effects they have. In other words, the historic ecosystem, theoretically, would have responded positively to the removal of cattle grazing, however, the system has adapted to the European introduced species and require now may require them for maintained diversity. In another study performed by *Pyke and Marty*, measurements showed that on average, vernal ponds on grazed land pooled longer than ungrazed areas and soil was more resistant to water absorption in the grazed areas.

Chapter 5

Forest

A conifer forest in the Swiss Alps (National Park).

Mixed deciduous forest in Stara Planina, Serbia.

A **forest**, also referred to as a **wood** or the **woods** and less often as a "wold" (or "weald"), "holt", or "frith" (or "firth"), is an area with a high density of trees. There are many definitions for forest, based on the various criteria. These plant communities cover approximately 9.4% of the Earth's surface (or 30% of total land area), though they once covered much more (about 50% of total land area), in many different regions and function as habitats for organisms, hydrologic flow modulators, and soil conservers, constituting one of the most important aspects of the Earth's biosphere. Although a forest is classified primarily by trees a forest ecosystem is defined intrinsically with additional species such as fungi.

A typical forest is composed of the overstory (or upper tree layer of the canopy) and the understory. The understory is further subdivided into the shrub layer, herb layer, and sometimes also moss layer. In some complex forests, there is also a well-defined lower tree layer.

Etymology

The word "forest" comes from Middle English *forest*, from Old French *forest* (also *forès*) "forest, vast expanse covered by trees", believed to be a borrowing (probably via Frankish or Old High German) of the Medieval Latin word *foresta* "open wood". *Foresta* was first used by Carolingian scribes in the Capitularies of Charlemagne to refer specifically to the king's royal hunting grounds. The term was not endemic to Romance languages (e.g. native words for "forest" in the Romance languages evolved out of the Latin word *silva* "forest, wood"; cf. Italian, Spanish, Portuguese *selva*; Romanian *silvă*; Old French *selve*); and cognates in Romance languages, such as Italian *foresta*, Spanish and Portuguese *floresta*, etc. are all ultimately borrowings of the French word. The exact origin of Medieval Latin *foresta* is obscure. Some authorities claim the word derives from the Late Latin phrase *forestam silvam*, meaning "the outer wood"; others claim the term is a latinisation of the Frankish word **forhist* "forest, wooded country", assimilated to *forestam silvam* (a common practise among Frankish scribes). Frankish **forhist* is attested by Old High German *forst* "forest", Middle Low German *vorst* "forest", Old English *fyrhþ* "forest, woodland, game preserve, hunting ground", and Old Norse *fýri* "coniferous forest", all of which derive from Proto-Germanic **furχísa-*, **furχíþja-* "a fir-wood, coniferous forest", from Proto-Indo-European **perkʷu-* "a coniferous or mountain forest, wooded height". Uses of the word "forest" in English to denote any uninhabited area of non-enclosure are now considered archaic. The word was introduced by the Norman rulers of England as a legal term (appearing in Latin texts like the Magna Carta) denoting an uncultivated area legally set aside for hunting by feudal nobility. These hunting forests were not necessarily wooded much, if at all. However, as hunting forests did often include considerable areas of woodland, the word "forest" eventually came to mean wooded land more generally. By the start of the fourteenth century the word appeared in English texts, indicating all three senses: the most common one, the legal term and the archaic usage.

Forest near Rajgir, Bihar, India

Other terms used to mean "an area with a high density of trees" are *wood, woodland, wold, weald, holt, frith* and *firth*. Unlike *forest*, these are all derived from Old English and were not borrowed from another language. Some classifications now reserve the term *woodland* for an area with more open space between trees and distinguish among woodlands, *open forests*, and *closed forests* based on crown cover.

Distribution

Amazon Rainforest in Brazil.

Rainforest in Tasmania's Hellyer Gorge.

Forests can be found in all regions capable of sustaining tree growth, at altitudes up to the tree line, except where natural fire frequency or other disturbance is too high, or where the environment has been altered by human activity.

The latitudes 10° north and south of the Equator are mostly covered in tropical rainforest, and the latitudes between 53°N and 67°N have boreal forest. As a general rule, forests dominated by angiosperms (*broadleaf forests*) are more species-rich than those dominated by gymnosperms (*conifer*, *montane*, or *needleleaf forests*), although exceptions exist.

Forests sometimes contain many tree species only within a small area (as in tropical rain and temperate deciduous forests), or relatively few species over large areas (e.g., taiga and arid montane coniferous forests). Forests are often home to many animal and plant species, and biomass per unit area is high compared to other vegetation communities. Much of this biomass occurs below ground in the root systems and as partially decomposed plant detritus. The woody component of a forest contains lignin, which is relatively slow to decompose compared with other organic materials such as cellulose or carbohydrate.

Forests are differentiated from woodlands by the extent of canopy coverage: in a forest, the branches and the foliage of separate trees often meet or interlock, although there can be gaps of varying sizes within an area referred to as forest. A woodland has a more continuously open canopy, with trees spaced further apart, which allows more sunlight to penetrate to the ground between them (also see: savanna).

Among the major forested biomes are:

- rain forest (tropical and temperate)
- taiga
- temperate hardwood forest
- tropical dry forest

Classification

Biogradska forest in Montenegro

Spiny forest at Ifaty, Madagascar, featuring various Adansonia (baobab) species, Alluaudia procera (Madagascar ocotillo) and other vegetation.

Even, dense old-growth stand of beech trees (*Fagus sylvatica*) prepared to be regenerated by their saplings in the understory, in the Brussels part of the Sonian Forest.

Trees on a mountain in northern Utah during early autumn.

Forests can be classified in different ways and to different degrees of specificity. One such way is in terms of the "biome" in which they exist, combined with leaf longevity of the dominant species (whether they are evergreen or deciduous). Another distinction is whether the forests composed predominantly of broadleaf trees, coniferous (needle-leaved) trees, or mixed.

- Boreal forests occupy the subarctic zone and are generally evergreen and coniferous.
- Temperate zones support both broadleaf deciduous forests (*e.g.*, temperate deciduous forest) and evergreen coniferous forests (*e.g.*, Temperate coniferous forests and Temperate rainforests). Warm temperate zones support broadleaf evergreen forests, including laurel forests.
- Tropical and subtropical forests include tropical and subtropical moist forests, tropical and subtropical dry forests, and tropical and subtropical coniferous forests.
- Physiognomy classifies forests based on their overall physical structure or developmental stage (e.g. old growth vs. second growth).
- Forests can also be classified more specifically based on the climate and the dominant tree species present, resulting in numerous different forest types (e.g., ponderosa pine/Douglas-fir forest).

A number of global forest classification systems have been proposed, but none has gained universal acceptance. UNEP-WCMC's forest category classification system is a simplification of other more complex systems (e.g. UNESCO's forest and woodland 'subformations'). This system divides the world's forests into 26 major types, which reflect climatic zones as well as the principal types of trees. These 26 major types can be reclassified into 6 broader categories: temperate needleleaf; temperate broadleaf and mixed; tropical moist; tropical dry; sparse trees and parkland; and forest plantations. Each category is described as a separate section below.

Temperate needleleaf

Temperate needleleaf forests mostly occupy the higher latitude regions of the northern hemisphere, as well as high altitude zones and some warm temperate areas, especially on nutrient-poor or otherwise unfavourable soils. These forests are composed entirely, or nearly so, of coniferous species (Coniferophyta). In the Northern Hemisphere pines Pinus, spruces Picea, larches Larix, silver firs Abies, Douglas firs Pseudotsuga and hemlocks Tsuga, make up the canopy, but other taxa are also important. In the Southern Hemisphere, most coniferous trees (members of the Araucariaceae and Podocarpaceae) occur in mixtures with broadleaf species that are classed as broadleaf and mixed forests.

Temperate broadleaf and mixed

Temperate broadleaf and mixed forests include a substantial component of trees in the Anthophyta. They are generally characteristic of the warmer temperate latitudes, but extend to cool temperate ones, particularly in the southern hemisphere. They include such forest types as the mixed deciduous forests of the United States and their counterparts in China and Japan, the broadleaf evergreen rain forests of Japan, Chile and Tasmania, the sclerophyllous forests of Australia, Central Chile, the Mediterranean and California, and the southern beech Nothofagus forests of Chile and New Zealand.

Tropical moist

Tropical moist forests include many different forest types. The best known and most extensive are the lowland evergreen broadleaf rainforests include, for example: the seasonally inundated várzea and igapó forests and the terra firma forests of the Amazon Basin; the peat swamp forests and moist dipterocarp forests of Southeast Asia; and the high forests of the Congo Basin. The forests of tropical mountains are also included in this broad category, generally divided into upper and lower montane formations on the basis of their physiognomy, which varies with altitude. The montane forests include cloud forest, those forests at middle to high altitude, which derive a significant part of their water budget from cloud, and support a rich abundance of vascular and nonvascular epiphytes. Mangrove forests also fall within this broad category, as do most of the tropical coniferous forests of Central America.

Tropical dry

Tropical dry forests are characteristic of areas in the tropics affected by seasonal drought. The seasonality of rainfall is usually reflected in the deciduousness of the forest canopy, with most trees being leafless for several months of the year. However, under some conditions, e.g. less fertile soils or less predictable drought regimes, the proportion of evergreen species increases and the forests are characterised as "sclerophyllous". Thorn forest, a dense forest of low stature with a high frequency of thorny or spiny species, is found where drought is prolonged, and especially where grazing animals are plentiful. On very poor soils, and especially where fire is a recurrent phenomenon, woody savannas develop.

Sparse trees and parkland

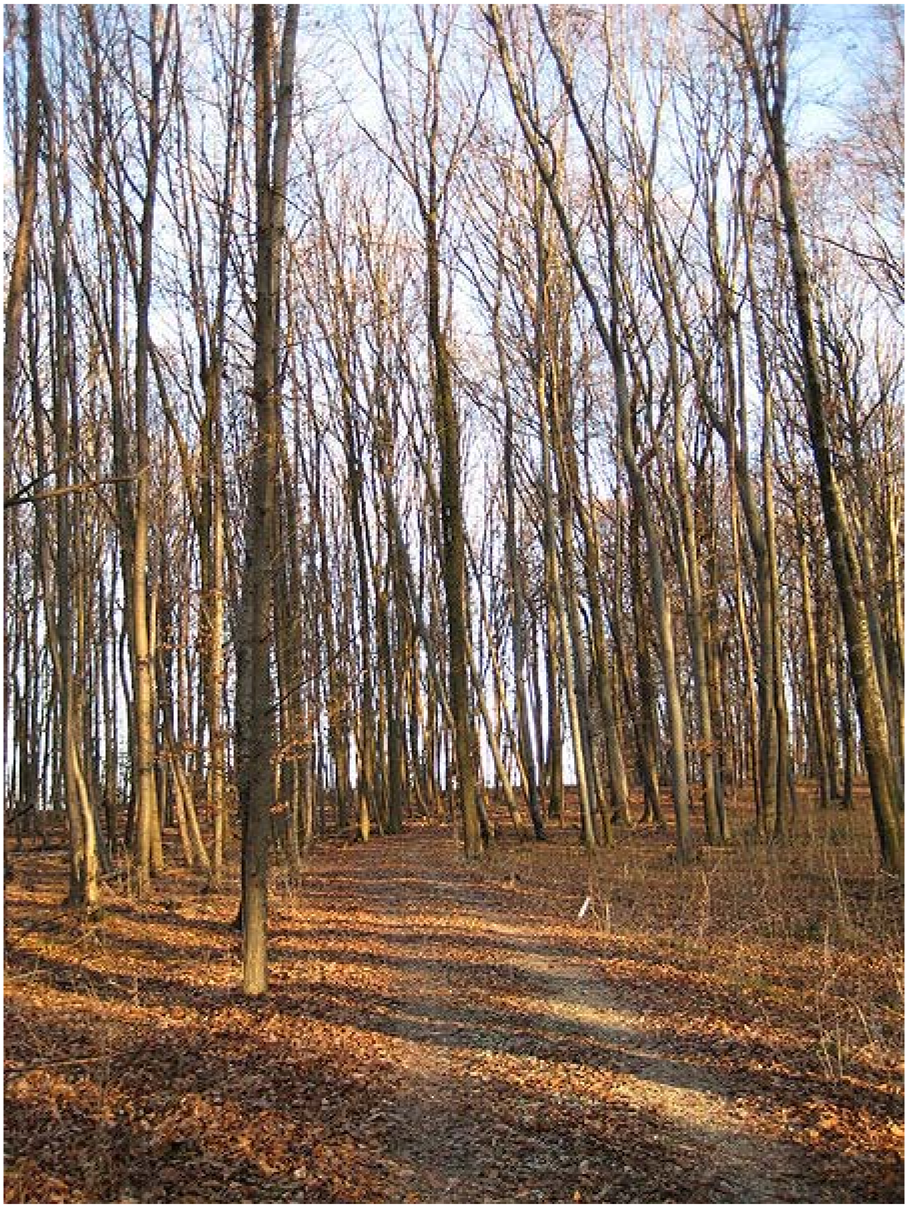
Taiga forest near Saranpaul in the northeast Ural Mountains, Khanty-Mansi Autonomous Okrug — Yugra, Russia. Trees include Picea obovata (dominant on right bank), Larix sibirica, Pinus sibirica, and Betula pendula.

Sparse trees and parkland are forests with open canopies of 10-30% crown cover. They occur principally in areas of transition from forested to non-forested landscapes. The two major zones in which these ecosystems occur are in the boreal region and in the seasonally dry tropics. At high latitudes, north of the main zone of boreal forest or taiga, growing conditions are not adequate to maintain a continuous closed forest cover, so tree cover is both sparse and discontinuous. This vegetation is variously called open taiga, open lichen woodland, and forest tundra. It is species-poor, has high bryophyte cover, and is frequently affected by fire.

Forest plantations

Forest plantations, generally intended for the production of timber and pulpwood increase the total area of forest worldwide. Commonly mono-specific and/or composed of introduced tree species, these ecosystems are not generally important as habitat for native biodiversity. However, they can be managed in ways that enhance their biodiversity protection functions and they are important providers of ecosystem services such as maintaining nutrient capital, protecting watersheds and soil structure as well as storing carbon. They may also play an important role in alleviating pressure on natural forests for timber and fuelwood production.

Forest categories



A temperate deciduous broadleaf forest, the *Hasenholz*, southeast of Kirchheim unter Teck, Baden-Württemberg, Germany.

Redwoods in old growth forest in Muir Woods National Monument, Marin County, California.

28 forest categories are used to enable the translation of forest types from national and regional classification systems to a harmonised global one:

Temperate and boreal forest types

1. Evergreen needleleaf forest - Natural forest with > 30% canopy cover, in which the canopy is predominantly (> 75%) needleleaf and evergreen.
2. Deciduous needleleaf forests - Natural forests with > 30% canopy cover, in which the canopy is predominantly (> 75%) needleleaf and deciduous.

3. Mixed broadleaf/needleleaf forest - Natural forest with > 30% canopy cover, in which the canopy is composed of a more or less even mixture of needleleaf and broadleaf crowns (between 50:50% and 25:75%).
4. Broadleaf evergreen forest - Natural forests with > 30% canopy cover, the canopy being > 75% evergreen and broadleaf.
5. Deciduous broadleaf forest - Natural forests with > 30% canopy cover, in which > 75% of the canopy is deciduous and broadleaves predominate (> 75% of canopy cover).
6. Freshwater swamp forest - Natural forests with > 30% canopy cover, composed of trees with any mixture of leaf type and seasonality, but in which the predominant environmental characteristic is a waterlogged soil.
7. Sclerophyllous dry forest - Natural forest with > 30% canopy cover, in which the canopy is mainly composed of sclerophyllous broadleaves and is > 75% evergreen.
8. Disturbed natural forest - Any forest type above that has in its interior significant areas of disturbance by people, including clearing, felling for wood extraction, anthropogenic fires, road construction, etc.
9. Sparse trees and parkland - Natural forests in which the tree canopy cover is between 10-30%, such as in the steppe regions of the world. Trees of any type (e.g., needleleaf, broadleaf, palms).
10. Exotic species plantation - Intensively managed forests with > 30% canopy cover, which have been planted by people with species not naturally occurring in that country.
11. Native species plantation - Intensively managed forests with > 30% canopy cover, which have been planted by people with species that occur naturally in that country.
12. *Unspecified forest plantation - Forest plantations showing extent only with no further information about their type, This data currently only refers to the Ukraine.
13. *Unclassified forest data - Forest data showing forest extent only with no further information about their type.

Those marked * have been created as a result of data holdings which do not specify the forest type, hence 26 categories are quoted, not 28 shown here.

Tropical forest types

The Fatu Hiva rainforest in Polynesia.

1. Lowland evergreen broadleaf rain forest - Natural forests with > 30% canopy cover, below 1,200 m (3,937 ft) altitude that display little or no seasonality, the canopy being >75% evergreen broadleaf.
2. Lower montane forest - Natural forests with > 30% canopy cover, between 1200–1800 m altitude, with any seasonality regime and leaf type mixture.
3. Upper montane forest - Natural forests with > 30% canopy cover, above 1,800 m (5,906 ft) altitude, with any seasonality regime and leaf type mixture.
4. Freshwater swamp forest - Natural forests with > 30% canopy cover, below 1,200 m (3,937 ft) altitude, composed of trees with any mixture of leaf type and seasonality, but in which the predominant environmental characteristic is a waterlogged soil.
5. Semi-evergreen moist broadleaf forest - Natural forests with > 30% canopy cover, below 1,200 m (3,937 ft) altitude in which between 50-75% of the canopy is evergreen, > 75% are broadleaves, and the trees display seasonality of flowering and fruiting.
6. Mixed broadleaf/needleleaf forest - Natural forests with > 30% canopy cover, below 1,200 m (3,937 ft) altitude, in which the canopy is composed of a more or

less even mixture of needleleaf and broadleaf crowns (between 50:50% and 25:75%).

7. Needleleaf forest - Natural forest with > 30% canopy cover, below 1,200 m (3,937 ft) altitude, in which the canopy is predominantly (> 75%) needleleaf.
8. Mangroves - Natural forests with > 30% canopy cover, composed of species of mangrove tree, generally along coasts in or near brackish or seawater.
9. Disturbed natural forest - Any forest type above that has in its interior significant areas of disturbance by people, including clearing, felling for wood extraction, anthropogenic fires, road construction, etc.
10. Deciduous/semi-deciduous broadleaf forest - Natural forests with > 30% canopy cover, below 1,200 m (3,937 ft) altitude in which between 50-100% of the canopy is deciduous and broadleaves predominate (> 75% of canopy cover).
11. Sclerophyllous dry forest - Natural forests with > 30% canopy cover, below 1,200 m (3,937 ft) altitude, in which the canopy is mainly composed of sclerophyllous broadleaves and is > 75% evergreen.
12. Thorn forest - Natural forests with > 30% canopy cover, below 1,200 m (3,937 ft) altitude, in which the canopy is mainly composed of deciduous trees with thorns and succulent phanerophytes with thorns may be frequent.
13. Sparse trees and parkland - Natural forests in which the tree canopy cover is between 10-30%, such as in the savannah regions of the world. Trees of any type (e.g., needleleaf, broadleaf, palms).
14. Exotic species plantation - Intensively managed forests with > 30% canopy cover, which have been planted by people with species not naturally occurring in that country.
15. Native species plantation - Intensively managed forests with > 30% canopy cover, which have been planted by people with species that occur naturally in that country.

Forest loss and management

Coastal Douglas fir woodland in northwest Oregon.

Redwood tree in northern California redwood forest, where many redwood trees are managed for preservation and longevity, rather than being harvested for wood production.

The scientific study of forest species and their interaction with the environment is referred to as forest ecology, while the management of forests is often referred to as forestry. Forest management has changed considerably over the last few centuries, with rapid changes from the 1980s onwards culminating in a practice now referred to as sustainable forest management. Forest ecologists concentrate on forest patterns and processes, usually with the aim of elucidating cause and effect relationships. Foresters who practice sustainable forest management focus on the integration of ecological, social and economic values, often in consultation with local communities and other stakeholders.

Anthropogenic factors that can affect forests include logging, urban sprawl, human-caused forest fires, acid rain, invasive species, and the slash and burn practices of swidden agriculture or shifting cultivation. The loss and re-growth of forest leads to a distinction between two broad types of forest, primary or old-growth forest and secondary forest. There are also many natural factors that can cause changes in forests over time including forest fires, insects, diseases, weather, competition between species, etc. In 1997, the World Resources Institute recorded that only 20% of the world's original forests remained in large intact tracts of undisturbed forest. More than 75% of these intact forests lie in three countries - the Boreal forests of Russia and Canada and the rainforest of Brazil. In 2006 this information on intact forests was updated using latest available satellite imagery.

Canada has about 4,020,000 square kilometres (1,550,000 sq mi) of forest land. More than 90% of forest land is publicly owned and about 50% of the total forest area is allocated for harvesting. These allocated areas are managed using the principles of sustainable forest management, which includes extensive consultation with local stakeholders. About eight percent of Canada's forest is legally protected from resource development (Global Forest Watch Canada)(Natural Resources Canada). Much more forest land — about 40 percent of the total forest land base — is subject to varying degrees of protection through processes such as integrated land use planning or defined management areas such as certified forests (Natural Resources Canada).

These maps represent only virgin forest lost. Some regrowth has occurred but not to the age, size or extent of 1620 due to population increases and food cultivation. *From William B. Greeley's, The Relation of Geography to Timber Supply, Economic Geography, 1925, vol. 1, p. 1-11. Source of "Today" map: compiled by George Draffan from roadless area map in The Big Outside: A Descriptive Inventory of the Big Wilderness Areas of the United States, by Dave Foreman and Howie Wolke (Harmony Books, 1992).]]*

By December 2006, over 1,237,000 square kilometers of forest land in Canada (about half the global total) had been certified as being sustainably managed (Canadian Sustainable Forestry Certification Coalition). Clearcutting, first used in the latter half of the 20th century, is less expensive, but devastating to the environment and companies are required by law to ensure that harvested areas are adequately regenerated. Most Canadian provinces have regulations limiting the size of clearcuts, although some older clearcuts can range upwards of 110 square kilometres (27,000 acres) in size which were cut over several years. China instituted a ban on logging, beginning in 1998, due to the destruction caused by clearcutting. Selective cutting avoids the erosion, and flooding, that result from clearcutting.

In the United States, most forests have historically been affected by humans to some degree, though in recent years improved forestry practices has helped regulate or moderate large scale or severe impacts. However, the United States Forest Service estimates a net loss of about 2 million hectares (4,942,000 acres) between 1997 and 2020; this estimate includes conversion of forest land to other uses, including urban and suburban development, as well as afforestation and natural reversion of abandoned crop and pasture land to forest. However, in many areas of the United States, the area of forest is stable or increasing, particularly in many northern states. The opposite problem from flooding has plagued national forests, with loggers complaining that a lack of thinning and proper forest management has resulted in large forest fires.

Old-growth forest contains mainly natural patterns of biodiversity in established seral patterns, and they contain mainly species native to the region and habitat. The natural formations and processes have not been affected by humans with a frequency or intensity to change the natural structure and components of the habitat. Secondary forest contains significant elements of species which were originally from other regions or habitats.

Smaller areas of woodland in cities may be managed as Urban forestry, sometimes within public parks. These are often created for human benefits; Attention Restoration Theory argues that spending time in nature reduces stress and improves health, while forest schools and kindergartens help young people to develop social as well as scientific skills in forests. These typically need to be close to where the children live, for practical logistics.

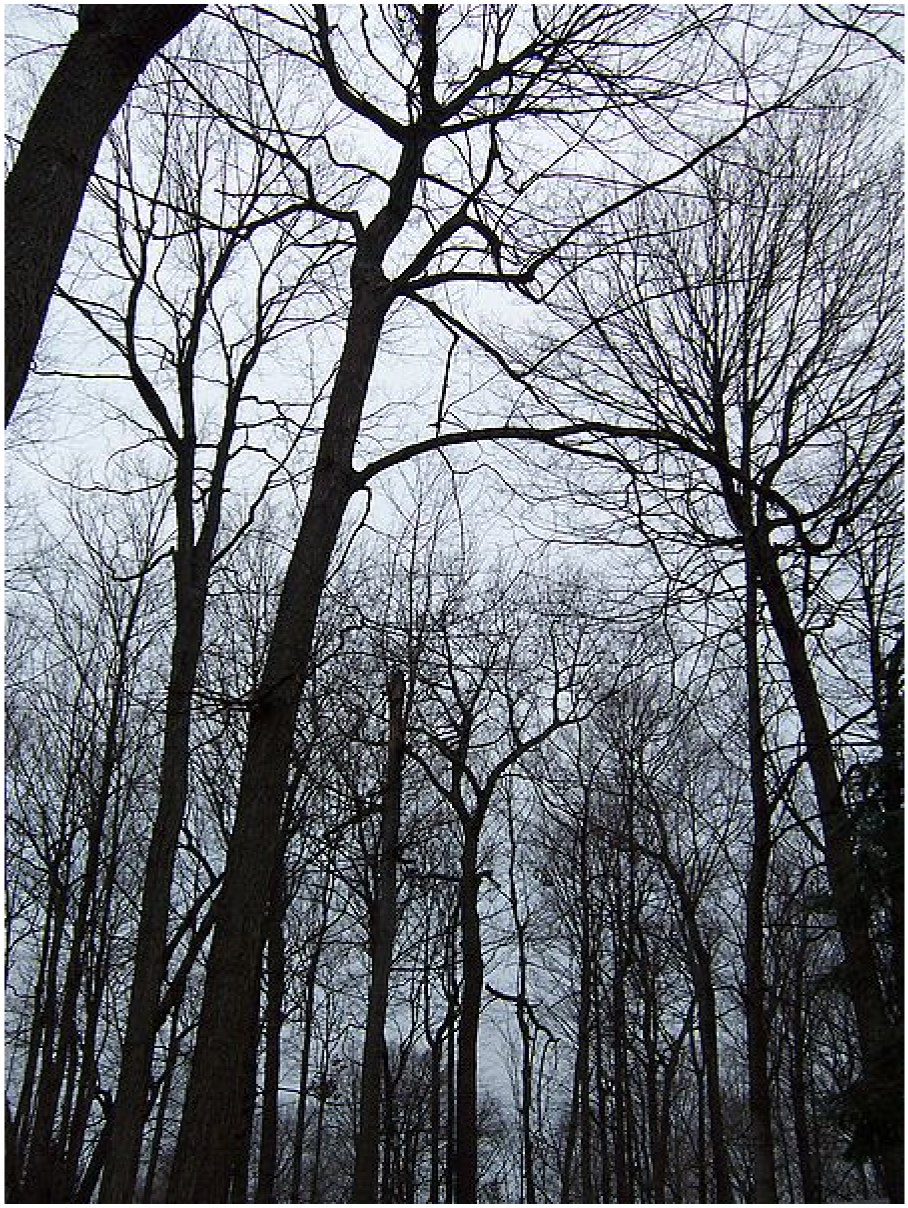
Typical forest in the south east side of Norway.

A deciduous broadleaf (Beech) forest in Slovenia.

The Foloi oak forest in southewestern Greece, is a deciduous, broadleaf forest.

A forest on San Juan Island in Washington.

Ueckermünder Heide (Puszcza Wkrzańska), Germany/Poland



Maple and Oak (broadleaf, deciduous) forest in Wisconsin during winter.

A forest in Osaka, Japan.

Forest in Alsace, France.

Drawa National Park, Poland

Pinus banksiana forest

A forest in the northeast of Turkey

Piñones State Forest in Isla Verde, Puerto Rico

Chapter 6

Habitat Corridor

A **habitat corridor** is a strip of land that aids in the movement of species between disconnected areas of their natural habitat. An animal's natural habitat would typically include a number of areas necessary to thrive, such as wetlands, burrowing sites, food, and breeding grounds. Urbanization can split up such areas, causing animals to lose both their natural habitat and the ability to move between regions to use all of the resources they need to survive.

Habitat fragmentation due to human development is an ever-increasing threat to biodiversity, and habitat corridors are a possible solution. There are many things to look at before considering a corridor, such as the goal trying to be achieved, if the land is suitable, what type would be implemented, and the positive and negative aspects.

Goals

The main goal of implementing habitat corridors is to increase biodiversity. When areas of land are broken up by human interference, population numbers become unstable and many animal and plant species become endangered. By re-connecting the fragments, the population fluctuations can decrease dramatically. Corridors can contribute to three factors that stabilize a population:

- **Colonization**—animals are able to move and occupy new areas when food sources or other natural resources are lacking in their core habitat.
- **Migration**—species that relocate seasonally can do so more safely and effectively when it does not interfere with human development barriers.
- **Interbreeding**—animals can find new mates in neighboring regions so that genetic diversity can increase and thus have a positive impact on the overall population.

Although corridors have been implemented with the assumption that they will increase biodiversity, not enough research has been done to come to a solid conclusion. The case for corridors has been built more on intuition and much less on empirical evidence (Tewksbury et al. 2002). Another factor that needs to be taken into account is what species the corridor is intended for. Some species have reacted more positively to corridors than others.

Users

Species can be categorized in one of two groups (1) passage users and (2) corridor dweller.

Passage users occupy corridors for brief periods of time. These animals use corridors for such events as seasonal migration, dispersal of a juvenile, or moving between parts of a large home range. Usually large herbivores, medium to large carnivores, and migratory species are passage users (Beier & Loe 1992). One common misconception is that the corridor only needs to be wide enough for the passage users to get through. However, the corridor still must be wide enough to be safe and also encourage the animals to use it, even though they do not live out their entire lives in it.

The second type of corridor user is a “corridor dweller,” which can occupy the passage anywhere from several days to several years. Species such as plants, reptiles, amphibians, birds, insects, and small mammals can spend their entire lives in linear habitats. In this case, the corridor must include everything that a species needs to live and breed, such as soil for germination, burrowing areas, and multiple other breeding adults (Beier & Loe 1992).

When/Where Necessary

A habitat corridor could be considered as a possible solution in an area where destruction of a natural area has greatly affected its native species. Development such as roads, buildings, and farms can interrupt plants and animals in the region being destroyed. Furthermore, natural disasters such as wildfires and floods can leave animals with no choice but to evacuate. If the habitat is not connected to a safer one, it will ultimately lead to death. A remaining portion of natural habitat is called a remnant, and such portions need to be connected, because when migration decreases, extinction increases (Fleury 1997).

Corridors can be made in two distinct areas—either water or land. Water corridors are called riparian ribbons and usually come in the form of rivers and streams. Land corridors come on a scale as large as wooded strips connecting larger woodland areas. However, they can also be as simple as a line of shrubs along a sidewalk (Fleury 1997). Such areas can facilitate the movement of small animals, especially birds, from tree to tree, until they find a safe habitat to nest in. Not only do minimal corridors aid in the movement of animals, they are also aesthetically pleasing, which can sometimes encourage the community to accept and support them.

Types

Habitat corridors can be categorized according to their width. Typically the wider the corridor, the more use it will get from species. However, the width to length ratio, as well as design and quality play just as important of a role in creating the perfect corridor (Fleury 1997). The strip of land will suffer less from edge effects such as weeds, predators, and chemicals if it is constructed properly. The following are three divisions in corridor widths:

- **Regional** – (>500m wide); connect major ecological gradients such as migratory pathways.
- **Sub-regional** – (>300m wide); connect larger vegetated landscape features such as ridgelines and valley floors.
- **Local** – (some <50m); connect remnant patches of gullies, wetlands, ridgelines, etc.

Habitat corridors can also be divided according to their continuity. Continuous corridors are strips that are not broken up, while "stepping stone" corridors are small patches of suitable habitat. When stepping stones are arranged in a line, they form a strip of land connecting two areas, just like a continuous corridor would. Both kinds provide linkages between protected core areas and stimulate or allow species to migrate.

Finally, corridors can come in the form of underpasses or overpasses, which can be very safe for both animals and humans. Many busy highways cross through natural habitats that native species occupy, as well. Large animals such as deer become a hazard when they cross in front of traffic and get hit. An overpass or an underpass serves as a bridge to facilitate the movement of animals across a busy road. Observations have shown that underpasses are actually more successful then overpasses because many times animals are too timid to cross over a bridge in front of traffic and would prefer to be more hidden (Dole et al. 2003).

Overpasses such as this one allow for traffic to continue for human convenience, while allowing wildlife to pass unharmed beneath from place to place.

Costs

Corridors can be expensive to plan out and put into action. For example, Daniel Simberloff et al. states that “a bridge that would maintain a riparian corridor costs about 13 times as much per lane-mile as would a road that would sever the corridor.” He also states that maintenance of a corridor would be much more costly than refuges for endangered species. It would simply be easier to move animals between refuges than to buy land, install a corridor, and maintain it. However, where the goal is not just to preserve a few large animal species but to protect biodiversity among all plants and animals, then habitat corridors may be the only option. Corridors are going to be expensive to implement no matter what, but it does depend on the type, location, and size, which can all vary to a great degree. With the lack of field data on the effectiveness, many agencies are not willing to consider putting in corridors.

Monitoring Use

It is extremely important for researchers to pay attention to the population changes in animals after a corridor has been implemented to ensure that there are no harmful effects. Researchers can use both mark-recapture techniques and evaluate genetic flow in order to observe how much a corridor is being used. Marking and recapturing animals is more useful when keeping a close eye on individual movement (Mech & Hallet 2001). The only problem is that tagging animals and watching them does not tell anyone whether the migrating individuals are successfully mating with other populations in connected areas of land. On the other hand, genetic techniques can be more effective in evaluating migration and mating patterns.

One of the most important goals of developing a corridor is to increase migration in certain animal species. By looking at a population's gene flow, researchers can understand the genetic consequences of corridors (Mech & Hallett 2001). The migration patterns of an entire population are much more important than the movements of a few individuals. From these techniques, researchers will better understand whether or not habitat corridors are increasing biodiversity.

Stephen Mech and James Hallett introduce an additional reason genetic techniques are more useful; they "measure average migration rates over time, which reveals the effects of fragmentation of several generations and is not as sensitive to current population sizes as mark-recapture studies are." For example, when a population is extremely small, mark-recapture is almost impossible. Clearly, genetic analysis of a species is the best way to determine if animals are actually using corridors to move and reproduce.

Negatives

A major downfall to habitat corridors is that not much information has been gathered about their success. Due to the lack of positive data, many agencies will not allow corridors to be established because they are unsure of their effectiveness. Another problem with corridors is that they are not as useful as simply preserving land so that it cannot be fragmented. However, it is becoming very difficult to set aside land for nature reserves when road-building, industry, and urban sprawl are all competing for space.

Even if corridors are sought as a solution, it does not necessarily mean that animals will use them. Especially in the case of overpasses, research shows that animals do not like to use them to get to another remnant area of land. Usually overpasses are built over busy highways, and many species are too timid to expose themselves in front of all of the traffic. As more roads and buildings arise, there becomes less space to try and preserve.

Habitat corridors need to be species-specific (not every kind of animal will use every kind of corridor) and corridors can be barriers to some species. For instance plants may use road verges as corridors however some mammals will not cross roads to reach a suitable habitat.

When a corridor is implemented, many times development is so close by, that it becomes difficult to build a wide enough passage. There is usually a very limited amount of space available for corridors, so buffers are not usually added in (Rosenberg 1997). Without a buffer zone, corridors become susceptible to harmful outside factors from city streets, suburbdevelopment, rural homes, forestry, cropland, and feedlots.

Unfortunately, another limiting factor to the implementation of corridors is money. With such inconclusive data about the effectiveness of connecting land, it is difficult to get the proper funding. Those who would be in charge of the corridor design and construction would ask such questions as "what if the corridors affect species negatively" and "what if they actually aid in the spread of disease and catastrophic events?" Furthermore, there is a possibility that corridors could not only aid in the dispersal of native organisms, but invasive ones, as well (Beier & Loe 1998). If invasive species take over an area they could potentially threaten another species, even to the point of extinction.

Positives

Habitat corridors may be defenseless against a number of outside influences, but they are still an efficient way of increasing biodiversity. Strips of land aid in the movement of various animal species and pollen and seed dispersal, which is an added benefit to the intended one (M. 2002). For example, when insects carrying pollen or birds carrying seeds travel to another area, plant species effectively get transported, as well.

Another positive aspect of corridors is that they allow both animals and humans to occupy virtually the same areas of land without interfering as much. Large animals such as bears can be attracted to residential areas in search of food due to lack of natural resources because of habitat fragmentation. A corridor would provide a passage for the bears to find food in other locations, so that they would not pose as much of a threat to humans.

Prime Examples of Success

Both the safety of animals and humans can be achieved through the creation of corridors. For example, deer commonly cross roads in order to get to other grazing land. When they are faced with a car coming at them, they freeze; this puts both the deer and the human's life in danger. In Alberta, Canada, an overpass was constructed to keep animals off of the busy highway; the area is part of a national park, so many different creatures roam the area. The top of the bridge is covered in the native grass of the area so that it blends in better and animals will not know the difference. Gates were also put of on either side of the overpass to help guide animals in the right direction (Semrad 2007).

In Southern California, 15 underpasses and drainage culverts were observed to see how many animals used them as corridors. They proved to be especially effective on wide-ranging species such as carnivores, mule deer, small mammals, and reptiles, even though the corridors were not intended specifically for animals. Researchers also learned that factors such as surrounding habitat, underpass dimensions, and human activity also played a role in how much use they got. From this experiment, much was learned about what would constitute a successful habitat corridor (Dole et al. 2003).

In South Carolina, five remnant areas of land were monitored; one was put in the center and four were surrounding it. Then, a corridor was put between one of the remnants and the center. Butterflies that were placed in the center habitat were two to four times more likely to move to the connected remnant rather than the disconnected ones. Furthermore, male holly plants were placed in the center region, and female holly plants in the connected region increased by 70 percent in seed production compared to those plants in the disconnected region. The most impressive dispersal into the connected region, though, was through bird droppings. Far more plant seeds were dispersed through bird droppings in the corridor-connected patch of land (M. 2002).

There have also been positive effects on the rates of transfer and interbreeding in vole populations. A control population in which voles were confined to their core habitat with no corridor was compared to a treatment population in their core habitat with passages that they could use to move to other regions. Females typically stayed and mated within their founder population, but the rate of transfer through corridors in the males was very high. Researchers are not sure why the females did not move about as much, but it is apparent that the corridor effectively transferred at least some of the species to another location for breeding (Aars 1999).

Are Corridors the Solution?

Some animal species are much more apt to use habitat corridors than others depending on what their migration and mating patterns are like. For example, many cases of birds and butterflies successfully using corridors have been observed. Less success stories have come out of mammals such as deer. How effective a corridor is may simply rely on what species it is directed towards (Tewskbury 2002). Corridors created with birds in mind may be more successful because they are highly migratory to begin with.

Human interference is almost inevitable with the quickly increasing population. The goal behind habitat corridors shows the most hope for solving habitat fragmentation and restoring biodiversity as much as possible. Although there are many positives and negatives, there may be enough positives to continue studying and improving corridors. It is truly difficult to say whether corridors are the solution to increasing biodiversity, because each one must be judged on its own. Each corridor has its own set of standards and goals that may set it apart from another one.

Chapter 7

Heath

Heathland at Woodbury Common, Devon (England). Purple flowers of *Calluna vulgaris* and yellow flowers of *Ulex gallii*

Alpine Heathland at High Shelf Camp near Mount Anne

A **heath** or **heathland** is a dwarf-shrub habitat found on mainly infertile acidic soils, characterised by open, low growing woody vegetation, often dominated by plants of the Ericaceae. There is no clear difference between *heath* and *moorland* but *moorland* is generally related to high-ground heaths with — especially in Great Britain — a cooler and damper climate.

Heaths are widespread worldwide. They form extensive and highly diverse communities across Australia in humid and sub-humid areas. Fire regimes with recurring burning are required for the maintenance of the heathlands. Even more diverse though less widespread heath communities occur in Southern Africa. Extensive heath communities can also be found in California-chaparral, New Caledonia, central Chile and along the shores of the Mediterranean Sea. In addition to these extensive heath areas, the vegetation type is also found in scattered locations across all continents, except Antarctica.

Characteristics

Fynbos Heathland, South Africa.

Heathland is favoured where climatic conditions are typically warm and dry, particularly in summer, and soils acidic, of low fertility, and often sandy and very free-draining; bogs do occur where drainage is poor, but are usually only small in extent. Heaths are dominated by low shrubs, 0.2–2 m tall.

Heath vegetation is extremely plant-species rich, and heathlands of Australia are home to some 3,700 endemic or typical species in addition to numerous less restricted species. The fynbos heathlands of South Africa are second only to tropical rainforests in plant biodiversity with over 7,000 species. In marked contrast the tiny pockets of heathland in Europe are extremely depauperate with a flora consisting primarily of heather (*Calluna vulgaris*), heath (*Erica* species) and gorse (*Ulex* species).

The bird fauna of heathlands are usually cosmopolitan species of the region. In the depauperate heathlands of Europe bird species tend to be more characteristic of the community and include Montagu's Harrier, and the Tree Pipit. In Australia the heathland avian fauna is dominated by nectar feeding birds such as Honey-eaters and lorikeets although numerous other birds from emus to eagles are also common Australian heathlands. Australian heathlands are also home to the world's only nectar feeding terrestrial mammal: the Honey Possum. The bird fauna of the South African fynbos includes sunbirds warblers and siskins. Heathlands are also an excellent habitat for insects including ants, moths, butterflies and wasps with many species being restricted entirely to it.

Anthropogenic heaths

Lüneburg Heath, an anthropogenic heath

Anthropogenic heaths habitats are a cultural landscape that can be found worldwide in locations as diverse as northern and western Europe, the Americas, Australia, New Zealand, Madagascar and New Guinea.

These heaths were originally created or expanded by centuries of human clearance of the natural forest and woodland vegetation, by grazing and burning. In some cases this clearance went so far that parts of the heathland have given way to open spots of pure sand and sand dunes, with a very local desert climate that, even in Europe can create local temperatures of 50 degrees Celsius in summer, drying the sand spot bordering the heathland and further raising its vulnerability for wildfires. Referring to heathland in England, Rackham says, "Heaths are clearly the product of human activities and need to be managed as heathland; if neglected they turn into woodland".

In recent years the conservation value of even these man-made heaths has become much more appreciated, and consequently most heathlands are protected. However they are also threatened by tree incursion because of the discontinuation of traditional management techniques such as grazing and burning that mediated the landscapes. Some are also threatened by urban sprawl. Anthropogenic heathlands are maintained artificially by a combination of grazing and periodic burning (known as Swailing), or (rarely) mowing; if not so maintained, they are rapidly re-colonised by forest or woodland. The re-colonising tree species will depend on what is available as the local seed source, and thus it may not reflect the natural vegetation before the heathland became established.

Chapter 8

Intact Forest Landscape

An **Intact Forest Landscape—IFL** is an unbroken natural landscape of a forest ecosystem and its habitat—plant community components, in a current extant forest zone. It is a natural environment with no signs of significant human activity or habitat fragmentation, and of sufficient size to contain, support, and maintain the complex of indigenous biodiversity of viable populations of a wide-range of biota genera and species, and their ecological effects.

History

The Intact Forest Landscape term and concept developed by a group of NGO—non-governmental environmental organizations, including Greenpeace, World Resources Institute, Biodiversity Conservation Center, International Socio-Ecological Union, and Transparent World. The **IFL** concept has since been used both in regional and global forest monitoring projects, such as Intact-Forests.org, and in scientific forest ecology research projects.

Definition

The concept of an **Intact Forest Landscape (IFL)** and its technical definition were developed to help create, implement, and monitor policies concerning the human impact on forest landscapes at the regional or country levels.

Technically, an **IFL** is defined as a territory within today's global extent of forest cover which contains forest and non-forest ecosystems minimally influenced by human economic activity, with an area of at least 500 km^2 (50,000 ha) and a minimal width of 10 km (measured as the diameter of a circle that is entirely inscribed within the boundaries of the territory).

Areas with evidence of certain types of human influence are considered disturbed and consequently not eligible for inclusion in an **IFL**:

- Settlements (including a buffer zone of one km);
- Infrastructure used for transportation between settlements or for industrial development of natural resources, including roads (except unpaved trails), railways, navigable waterways (including seashore), pipelines, and power transmission lines (including in all cases a buffer zone of one km on either side);
- Agriculture and timber production;
- Industrial activities during the last 30–70 years, such as logging, mining, oil and gas exploration and extraction, peat extraction.

Areas with evidence of low intensity and old disturbances are treated as subject to "background" influence and are eligible for inclusion in an **IFL**. Sources of background influence include local shifting cultivation activities, diffuse grazing by domesticated animals, low-intensity selective logging and hunting.

This definition builds on and refines the concept of a frontier forest that was developed by the World Resources Institute.

Conservation value

Most of the world's original forests have either been lost to conversion or altered by logging and forest management. Forests that still combine large size with insignificant human influence are becoming increasingly important as their global extent continues to shrink.

Ecosystems are generally better able to support their natural biological diversity and ecological processes the lower their exposure to humans and the greater their area. They are also better able to absorb and recover from disturbance (resistance and resilience).

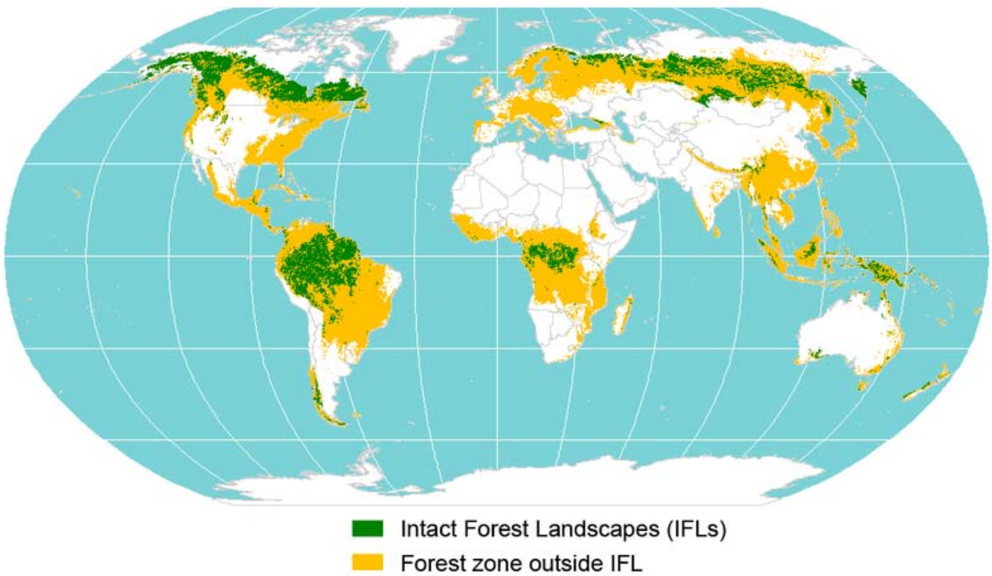
Fragmentation and loss of natural habitats are the main factors threatening plant and animal species with extinction. Forest biodiversity largely depends on intact forest landscapes. Large, roaming animals (such as forest elephants, great apes, bears, wolfs, tigers, jaguars, eagles, deer etc.) especially require that intact forest landscapes be preserved. Loss of natural habitat can occur through introduction of forest monoculture or by even aged timber management, which are also destructive of biodiversity and wildlife abundance. For example, many wildlife species such as the Wild turkey depend upon variegation of tree ages and sizes for its optimal sub-canopy flight; forests that have been managed for even aged composition fail to achieve abundance values of the Wild turkey and many other organisms.

Large natural forest areas are also important for maintaining ecological processes and supplying ecosystem services like water and air purification, nutrient cycling, carbon sequestration, erosion and flood control.

The conservation value of forest landscapes that are free from human disturbance is therefore high, although it varies among regions. At the same time the cost of conserving large unpopulated areas is often low. The same factors that have kept them from being developed, such as remoteness and low economic value, also help to reduce the cost of protecting them.

Several international initiatives to protect forest biodiversity (CBD), to reduce carbon emissions from deforestation and forest degradation (IGBP, REDD), and to stimulate use of sustainable forest management practices (FSC) require that large natural forest areas be preserved. Mapping, conservation and monitoring of **Intact Forest Landscapes** is a therefore a task of great global significance.

IFL mapping initiatives



The World's Intact Forest Landscapes (IFLs)

Several attempts have been made since the mid-to-late 1990s to map the remaining extent of large natural forests. At the global level, these include: Wilderness Areas map by McCloskey and Spalding, Human Footprint map by Sanderson et al.; and Frontier Forests map by Bryant et al. These efforts have generally combined already existing maps and information to identify areas of low human impact at a coarse scale, typically no finer than 1:16 million.

The **IFL** mapping initiatives differ from these by using the **IFL** definition mentioned above, by using information from satellites in addition to other sources, and by producing results at a much finer scale, approximately 1:1 million.

The first regional **IFL** map was presented by Greenpeace Russia in 2001, covering Northern European Russia. The report also contains a complete description of the **IFL** concept and mapping algorithm.

A number of regional IFL maps were presented in 2002–2006, using similar methods, by a group of scientists and environmental non-governmental organizations under the framework of Global Forest Watch - an initiative of the World Resources Institute.

Still using the same method, a global **IFL** map was prepared in 2005–2006 under the leadership of Greenpeace, with contributions from: Biodiversity Conservation Center, International Socio-Ecological Union, and Transparent World (Russia), Luonto Liitto (Finnish Nature League), Forest Watch Indonesia, and Global Forest Watch, a network initiated by the World Resources Institute.

The global IFL map relies on publicly available high spatial resolution satellite imagery (provided by GLCF and USGS) and on a simple and consistent set of criteria.

Within today's global extent of forest ecosystems, **IFLs** are estimated to cover 23% (13.1 million km^2). Two [biomes] hold almost all of these **IFLs**: dense tropical and subtropical forests (45%) and boreal forests (44%), while the proportion of **IFLs** in temperate broadleaf and mixed forests is very small. **IFLs** remain in 66 of the 149 countries that that could potentially have them. Three of these countries — Canada, Russia, and Brazil — contain 64% of the total **IFL** area. 19% of the global **IFL** area is under some form of protection, but only 10% is strictly protected, i.e., belongs to IUCN protected areas categories I–III.

Practical implementation of the IFL concept

The concept of an **Intact Forest Landscape** is a useful tool for making, implementation, and monitoring of policy in the realms of sustainable forest management, conservation and climate, as shown by the following examples.

Forest degradation can be assessed through IFL monitoring.

The distinction between intact and non-intact forest landscapes can be used to account for losses of carbon from forest degradation, as proposed by Mollicone et al. The global **IFL** map provides a geographically explicit baseline with several advantages:

- it provides a globally consistent and highly detailed snapshot of the ecological integrity of the world's forest biomes at the beginning of the new millennium (approximately year 2000);
- the method that was used to create the map can easily be adapted into a monitoring method that uses high spatial resolution satellite images;
- its high precision and fine scale make it a meaningful baseline for assessment of small-scale disturbances that can be detected by remotely sensed data.

Nature conservation strategies can be formulated using IFL maps.

Conservation of large IFLs is a robust and cost-effective way to protect biodiversity and maintain ecological integrity and should therefore be an important component of a global conservation strategy. The remoteness and large size of these areas provide the best guarantee for their continued intactness. Withdrawing remaining intact areas from the production base would lead to small or negligible economic loss.

Russian NGOs have, for example, used IFL maps to argue that the most valuable of the remaining intact natural landscapes of Northern European Russia and Far East be preserved, and to propose several new national parks: Kutsa and Hibiny (Murmansk Region), Kalevalsky (Karelia Republic) and Onezhskoye Pomorye (Arkhangelsk Region).

Sustainable forest management can be underpinned by IFL maps.

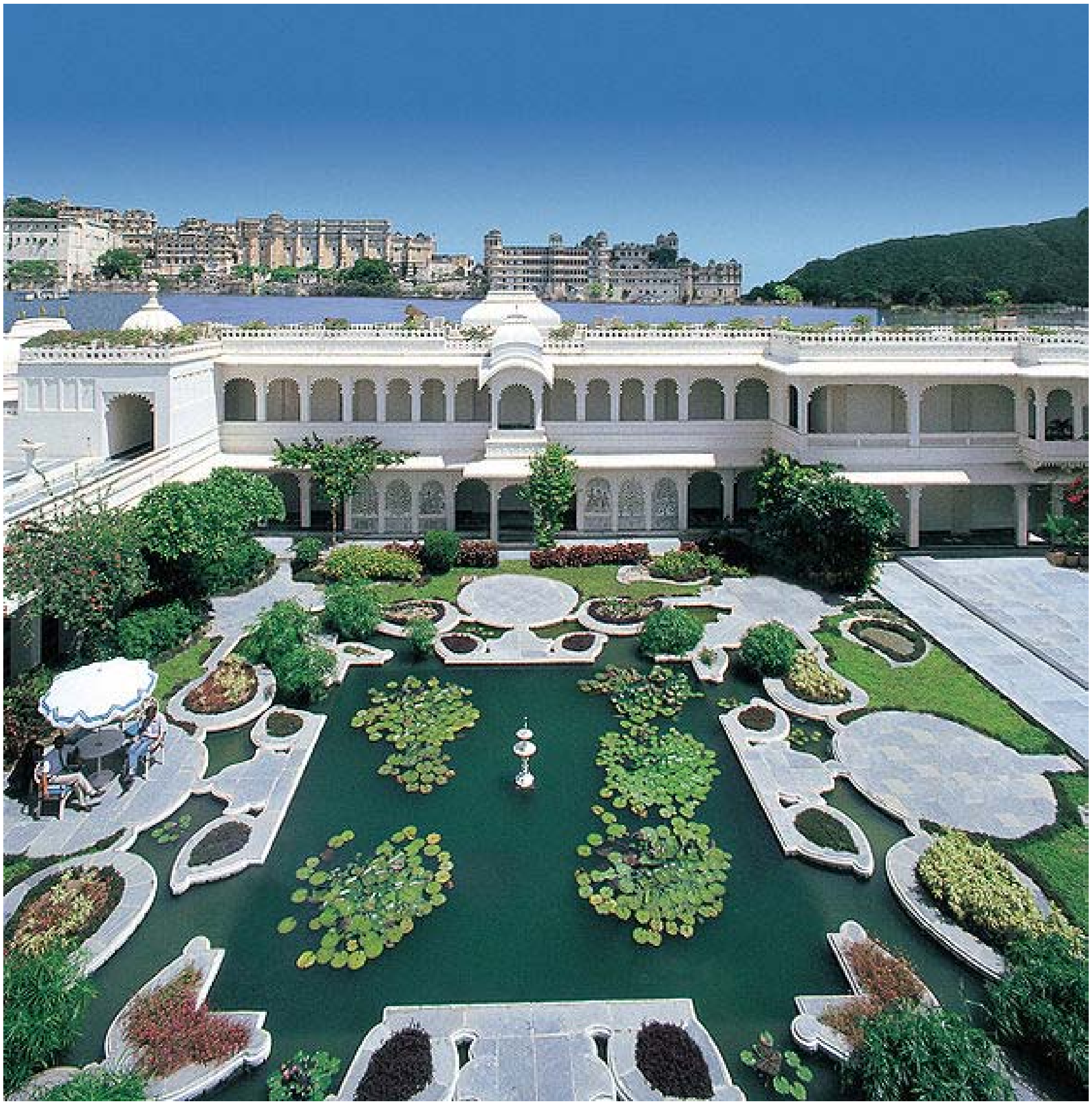
Several boreal countries are using the **IFL** concept in the context of forest certification. One of the categories of High Conservation Value Forest used by the Forest Stewardship Council is analogous to that of **IFLs**. The formulation used in the Canadian and Russian national FSC standards - globally, nationally, or regionally significant forest landscapes, un-fragmented by permanent infrastructure and of a size to maintain viable populations of most species - calls for IFL maps for implementation. IFLs are directly mentioned among other categories of High Conservation Value Forest in the FSC Controlled Wood standard.

Several forest products retailers have committed not to use wood from **IFLs** unless intactness values are preserved, e.g., IKEA and Lowe's, or to invest only in companies that maintain such values, e.g., Bank of America. The companies use regional **IFL** maps to implement these policies.

Chapter 9

Pond

A pond in Swarzynice, Poland



A small man-made garden pond at the Taj Lake Palace in Udaipur, India

Formal rock garden pond with waterfall.

Pond in winter

338 acre Long Pond in the Saint Regis Canoe Area in the Adirondack Mountains

A **pond** is a body of standing water, either natural or man-made, that is usually smaller than a lake. A wide variety of man-made bodies of water are classified as ponds, including water gardens, water features and koi ponds; all designed for aesthetic ornamentation as landscape or architectural features, while fish ponds are designed for commercial fish breeding, and solar ponds designed to store thermal energy.

Standing bodies of water such as puddles, ponds and lakes are distinguished from a water course, such as a brook, creek or stream via current speed. While currents in streams are easily observed, ponds and lakes possess thermally driven microcurrents and moderate wind driven currents. These features distinguish a pond from many other aquatic terrain features, such as stream pools and tide pools.

Some mills use the kinetic energy of the moving water in the pond to generate electricity.

Technical definitions

The technical distinction between a pond and a lake has not been universally standardized. Limnologists and freshwater biologists have proposed formal definitions for *pond*, in part to include 'bodies of water where light penetrates to the bottom of the waterbody,' 'bodies of water shallow enough for rooted water plants to grow throughout,' and 'bodies of water which lack wave action on the shoreline.' Each of these definitions have met with resistance or disapproval, as the defining characteristics are each difficult to measure or verify. Accordingly, some organizations and researchers have settled on technical definitions of *pond* and *lake* which rely on size alone.

Even among organizations and researchers who distinguish lakes from ponds by size alone, there is no universally recognised standard for the maximum size of a pond. The international Ramsar wetland convention sets the upper limit for pond size as 8 hectares (19.768 acres), but biologists have not universally adopted this convention. Researchers for the British charity Pond Conservation have defined a *pond* to be 'a man-made or natural waterbody which is between 1 m^2 and 20,000 m^2 in area (~2 ha or ~5 acres), which holds water for four months of the year or more.' Other European biologists have set the upper size limit at 5 ha (12.355 acres). In North America, even larger bodies of water have been called ponds; for example, Walden Pond in Concord, Massachusetts measures 61 acres (~25 ha).

Formation

Ponds can result from a wide range of natural processes, although in many parts of the world these are now severely constrained by human activity. Any depression in the ground which collects and retains a sufficient amount of precipitation can be considered a pond, and such depressions can be formed by a variety of geological and ecological events.

Nomenclature

In origin, pond is a variant form of the word pound, meaning a confining enclosure. As straying cattle are enclosed in a pound so water is enclosed in a pond. In earlier times, ponds were man-made and utilitarian; as stew ponds, mill ponds and so on. The significance of this feature seems, in some cases, to have been lost when the word was carried abroad with emigrants. In the United States, natural pools are often called ponds.

A pond is sometimes characterized as being a small body of water that is shallow enough for sunlight to reach the bottom, permitting the growth of rooted plants at its deepest point.

Pond usually implies a quite small body of water, generally smaller than one would require a boat to cross. Another definition is that a pond is a body of water where even its deepest areas are reached by sunlight or where a human can walk across the entire body of water without being submerged. In some dialects of English, pond normally refers to small artificially created bodies of water.

Some regions of the United States define a pond as a body of water with a surface area of less than 10 acres (40,000 m^2).

Regional differences include the use of the word pond in New England, and Maine in particular, for relatively large water bodies. For example a Great Pond in Maine is considered to be at least 10 acres (41,240 m^2) in area.

In areas which were covered by glaciers in the past, some ponds were created when the glaciers retreated. These ponds are known as kettle ponds. Walden Pond in Concord, Massachusetts, is a well known example. Kettle ponds are usually quite deep and clean because they are fed by underground aquifers rather than surface streams.

The term is also used for temporary accumulation of water from surface runoff (*ponded* water).

There are various regional names for naturally occurring ponds. In Scotland, one of the terms is lochan, which may also apply to a large body of water such as a lake.

The word "pond" is sometimes also used to refer to the Atlantic Ocean in the expression "across the pond", and the expression "big pond" similarly is sometimes used for the Pacific. These uses are deliberate idiomatic understatements.

Ponds' calm waters are ideal for insects and other water dwelling invertebrates. This includes the pondskater, the water boatman, the diving beetle, the whirligig beetle and the water scorpion.

Characteristics

Some ponds have no surface outflow draining off water and ponds are often spring-fed. Hence, because of the closed environment of ponds, such small bodies of water normally develop self contained ecosystems.

Uses

In the Indian subcontinent, Hindu temples usually have a pond nearby so that pilgrims can take baths. These ponds are considered sacred. In medieval times in Europe, it was typical for many monastery and castles (small, partly self-sufficient communities) to have fish ponds. These are still common in Europe and in East Asia (notably Japan), where koi may be kept.

Another use is in agriculture. In agriculture, treatment ponds combined with irrigation reservoirs are used as a self-purifying irrigation reservoir to allow irrigation at times of drought.

Tobha is Punjabi name for village pond. Every village in Punjab (India) essentially has a pond, into which the drainage of village is forced. Buffalos and other village animals take bath in village pond during summers. Tobha is really an object of entertainment for village people, where children also learn to swim and play.

The small pond in (bog) or mountain is called "池塘" (chitōʾ) in [Japan] and is discriminate from the pond in the plain and widely recognized by mountaineers.

Examples

Thousands of examples worldwide are available to illustrate the pond; a few of these are:

- Antonelli Pond, California, USA
- Big Pond, Nova Scotia
- Bullough's Pond, Massachusetts, USA
- Christian Pond, Wyoming, USA
- Hampstead Ponds, England
- Milicz Ponds, Poland
- Oguni-numa Pond, Japan
- Pete's Pond, Botswana
- Rožmberk Pond, Czech Republic

Chapter 10

Puddle

A seep puddle in a forest clearing

A **puddle** is a small accumulation of liquid, usually water, on a surface. It can form either by pooling in a depression on the surface, or by surface tension upon a flat surface. They are often formed anywhere from rain water, in gardens from irrigation, and on municipal streets from urban runoff.

A puddle is generally small enough for an adult to step over, shallow enough to walk through, and too small to traverse in a boat or raft. Puddles can be a source of fascination for children, as well as attracting other small wildlife.

Natural puddles and wildlife

A water puddle on a beach in Denmark

A water puddle following a thunderstorm in Sheffield, UK, 2010

Puddles in natural landscapes and habitats, when not precipitation sourced, can indicate the presence of a seep or spring. They can provide essential moisture for small wildlife, such as birds and insects. Many butterfly (*Lepidoptera*) species need puddles for mud-puddling to obtain nutrients such as salts and amino acids, including some types that are endemic endangered species.

Swallows use the damp loam which gathers in puddles as a form of cement to help to build their nests. The reduction in the number of puddles in the countryside due to intensive farming, urban sprawl, and climate change is partially the cause of a decrease in the swallow population.

Wildlife uses puddles as a drinking source, a bath such as bathing birds, or in the case of some smaller forms such as tadpoles or mosquito larvae, an entire habitat. Raised constructed puddles, bird baths, are a part of domestic and wildlife gardens as a garden ornament and "micro-habitat" restoration.

Small seasonal riparian plants, grasses, and wildflowers germinate with the ephemeral "head start" of moisture.

Artificial puddles and transportation

A small road puddle with reflections of buildings

Puddles commonly form during rainstorms, and can cause problems for transport, especially when combined with cold conditions to form patches of ice, which are highly slippery and difficult to see. Due to the angle of the road, puddles tend to be forced by gravity to gather on the edge of the road. This causes the notorious 'splash' as cars drive quickly through the puddle, which causes water to be sprayed onto pedestrians on the adjacent pavement. Sometimes, irresponsible drivers do this deliberately, which, in some countries, can lead to prosecution for careless driving.

Puddles commonly form in potholes in a dirt road, or in any other space with a shallow depression and dirt. In such cases, these are sometimes referred to as *mud puddles*, because mud tends to form in the bottoms, resulting in dirtied wheels or boots when disturbed.

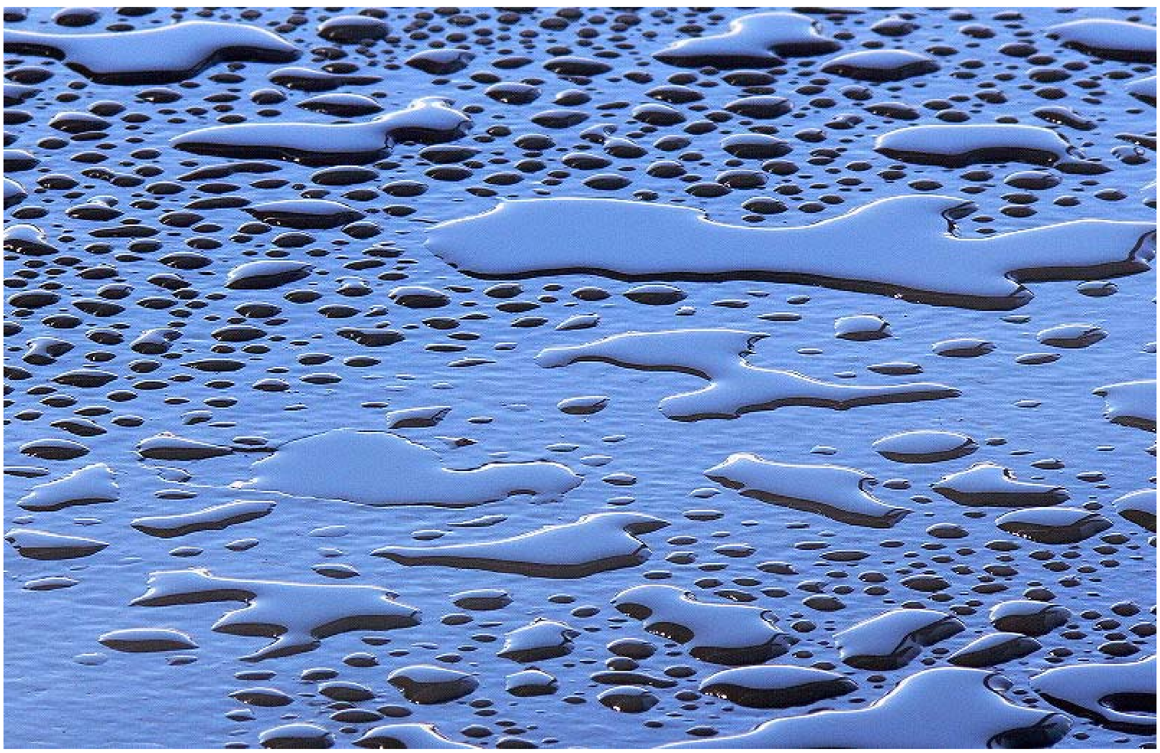
Puddle management

Puddles tend to evaporate quickly due to the high surface area-to-volume ratio, allowing a large number of molecules to be vaporised at once, and as such tend to be short lived. However, due to this property, puddles of chemicals such as bromine, which produce highly toxic vapour, are highly dangerous and spills such as this must be dealt with immediately, with emergency evacuation as a common step.

In order to deal with puddles, roads and pavements are often built with a camber (technically called 'crowning'), being slightly convex in nature, to force puddles to drain into the gutter, which has storm drain grates to allow the water to drain into the sewers. In addition to this, some surfaces are made to be porous, allowing the water to drain straight through the surface to the aquifer below.

Puddles which do not evaporate quickly can become standing water, which can become polluted by decaying organisms and are often home to breeding mosquitos, which can act as vectors for diseases such as malaria and of more recent concern in certain areas of the world, West Nile Virus.

Physics



Small puddles of water on a smooth clean surface have perceptible thickness.

Child with a puddle

In the physics context puddles may refer to where a liquid forms into patches on top of a surface of a solid material.

History

Medieval legend spoke of one man who was desperate to find building materials for his house, so he stole cobblestones from the road surface. The remaining hole filled with water and a horseman who later walked through the 'puddle' actually found himself drowning. A similar legend, of a young boy drowning in a puddle that formed in a chuckhole in a major street in the early years of Seattle, Washington, is told as part of the Seattle Underground Tour.

When Walter Raleigh met Queen Elizabeth I, Raleigh is reputed to have thrown his coat over a muddy puddle to allow the Queen to cross without getting her feet wet. Such activities were once part of chivalry, but are less common nowadays.

The "oldest puddle"

The Oxfordshire town of Wallingford is home to England’s oldest recorded puddle. There has been a puddle on the pavement at a intersection since April 1976. The puddle’s longevity is in large part due to the disrepair of pavement not resurfaced since 1973. The puddle was initially a source of frustration for local residents who lobbied to have it resurfaced. However South Oxfordshire District Council and Oxfordshire County Council insist repaving is the responsibility of the other. Subsequently the puddle itself has become an ironic tourist attraction and is now the starting point for a local pub crawl, the “Wally Run”.

Military

In military terminology, puddles are "liquid terrain obstacles deprived of tactical importance". In military slang, "the Puddle" may also refer to the Pacific Ocean, much as the Atlantic Ocean is referred to as "the Pond".

The Newest Puddle

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"Is being created in a rain storm ... RIGHT NOW"-Shelby Dodson
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Recreation

Puddles are often a source of recreation by children, who regard jumping in puddles as an "up-side" to rain. A children's nursery rhyme records the story of Doctor Foster and his encounter with a puddle in Gloucester.

Chapter 11

Shrubland

Low shrubland in Hawaii

Scrub vegetation in the Texas Hill Country

Shrubland, **scrubland**, **scrub** or **brush** is a plant community characterized by vegetation dominated by shrubs, often also including grasses, herbs, and geophytes. Shrubland may either occur naturally or be the result of human activity. It may be the mature vegetation type in a particular region and remain stable over time, or a transitional community that occurs temporarily as the result of a disturbance, such as fire. A stable state may be maintained by regular natural disturbance such as fire or browsing. Shrubland may be unsuitable for human habitation because of the danger of fire. The term "shrubland" was first coined in 1903.

Shrubland as a botanical structural form

In botany and ecology a shrub is defined as a much-branched woody plant less than 8 m high and usually with many stems. Tall shrubs are mostly 2–8 m high; small shrubs 1–2 m high: subshrubs less than 1 m high.

A descriptive system widely adopted in Australia to describe different types of vegetation is based on structural characteristics based on plant life-form, plus the height and foliage cover of the tallest stratum or dominant species.

Prince Edward County bird observatory shrubland.

For shrubs 2–8 m high the following structural forms result:

- dense foliage cover (70–100%) — **closed-scrub**
- mid-dense foliage cover (30–70%) — **open-scrub**
- sparse foliage cover (10–30%) — **tall shrubland**
- very sparse foliage cover (<10%) — **tall open shrubland**

For shrubs <2 m high the following structural forms result:

- dense foliage cover (70–100%) — **closed-heath**
- mid-dense foliage cover (30–70%) — **open-heath**
- sparse foliage cover (10–30%) — **low shrubland**
- very sparse foliage cover (<10%) — **low open shrubland**

Shrubland as a biome plant group

Fynbos in South Africa

Similarly, shrubland is a category used to describe a type of biome plant group. In this context, shrublands are dense thickets of evergreen sclerophyll shrubs and small trees, called:

- Chaparral in California
- Matorral in Chile and Spain
- Maquis in France and elsewhere around the Mediterranean
- Macchia in Italy
- Fynbos in South Africa
- Kwongan in Southwest Australia

In some places shrubland is the mature vegetation type, and in other places the result of degradation of former forest or woodland by logging or overgrazing, or disturbance by major fires.

A number of World Wildlife Fund biomes are characterized as shrublands. These biomes are reviewed, below.

Desert scrublands

The Nullarbor plain in Australia

Xeric or *desert scrublands* occur in the world's deserts and xeric shrublands ecoregions, or in areas of fast-draining sandy soils in more humid regions. These scrublands are characterized by plants with adaptations to the dry climate, which include small leaves to limit water loss, thorns to protect them from grazing animals, succulent leaves or stems, storage organs to store water, and long taproots to reach groundwater.

Mediterranean scrublands

Mediterranean scrublands occur naturally in the Mediterranean forests, woodlands, and scrub biomes, located in the five Mediterranean climate regions of the world. Scrublands are most common near the seacoast, and have often adapted to the wind and salt air of the ocean. Low, soft-leaved scrublands around the Mediterranean Basin are known as *garrigue* in France, *phrygana* in Greece, *tomillares* in Spain, and *batha* in Israel. Northern coastal scrub and coastal sage scrub occur along the California coast, strandveld in the Western Cape of South Africa, coastal matorral in central Chile, and sand-heath and kwongan in Southwest Australia.

Interior scrublands

Interior scrublands occur naturally in semi-arid areas where soils are nutrient-poor, such as on the matas of Portugal which are underlain by Cambrian and Silurian schists. Florida scrub is another example of interior scrublands.

Dwarf shrubs

Moorland on Kilimanjaro

Some vegetation types are formed of *dwarf-shrubs*: low-growing or creeping shrubs. These include the maquis of Mediterranean climates, and the acid-loving dwarf shrubs of heathland and moorland.

Other scrub

Scrub vegetation also occurs as part of other habitats, such as grasslands, heathlands and dune vegetation.

Chapter 12

Temperate Deciduous Forest

Temperate forest in Germany

A **temperate deciduous forest**, more precisely termed **temperate broadleaf forest** or **temperate broadleaved forest**, is a biome found in the eastern and western United States, Canada, central Mexico, southern South America, Europe, West Asia, China, Japan, North Korea, South Korea and parts of Russia. A temperate deciduous forest consists of trees that lose their leaves every year. Examples include oak, maple, beech, and elm.

Organisms and their adaptations

Many well-known animals live in this kind of forest. Some examples are the Eastern Gray Squirrel, bears, beavers, foxes, deer, rats, snakes, mice, wolves, raccoons, and large birds of prey like red-tailed hawks. These animals have unique adaptations suited for seasonal life. For example, some rodents store up fat, then hibernate during cold winters. Birds include the bald eagle, nightingale, cardinals, hawks, and the snowy owl.

The plants are adapted to survive in these conditions. For example, trees like the palm, white spruce, and the elm have leaves that absorb water and sunlight. The soaring branches do more than just provide shade for other creatures of this biome; they also provide nutrients necessary for the tree to live. Another example of adaptation: these trees shed their leaves in the winter. By shedding their leaves, they cannot transpire. Consequently, they are able to retain water for the winter. Plants also soak up nutrients from the soil. These plants shed their leaves in fall.

Climate

The temperate deciduous forest has a temperate climate, with summer highs of around 80 to 90° Fahrenheit (27 to 32° Celsius). Winter highs are around 30 to 55° Fahrenheit (-1 to 15° Celsius). Temperate forests get about 35 to 60 inches (900 to 1500 millimeters) of precipitation per year. Precipitation is spread out relatively evenly throughout the year. Snowfall amounts vary widely, from none to very little to 30 inches (75 centimeters) per year.

Human effects

Humans have often colonized areas in the temperate deciduous forest. They have also harvested wood for timber. As a result, less than one quarter of original forests remain. Temperate forests have also been used for farming.

A forest of beech trees

Trees in a temperate deciduous forest lose their leaves during months, as shown here.

A mature elm tree

Young deciduous forest

Chapter 13

Temperate Rainforest

Temperate rainforests are coniferous or broadleaf forests that occur in the temperate zone and receive high rainfall.

Humid temperate rain forest in Gīlān Province, northern Iran

Definition

The vegetation behind Marriott Falls, Mount Field National Park, Tasmania, Australia

For temperate rain forests of North America, Alaback's definition is widely recognized:

1. Annual precipitation 200–400 cm
2. Mean annual temperature between 4°C and 12°C. (39° and 54°Fahrenheit)

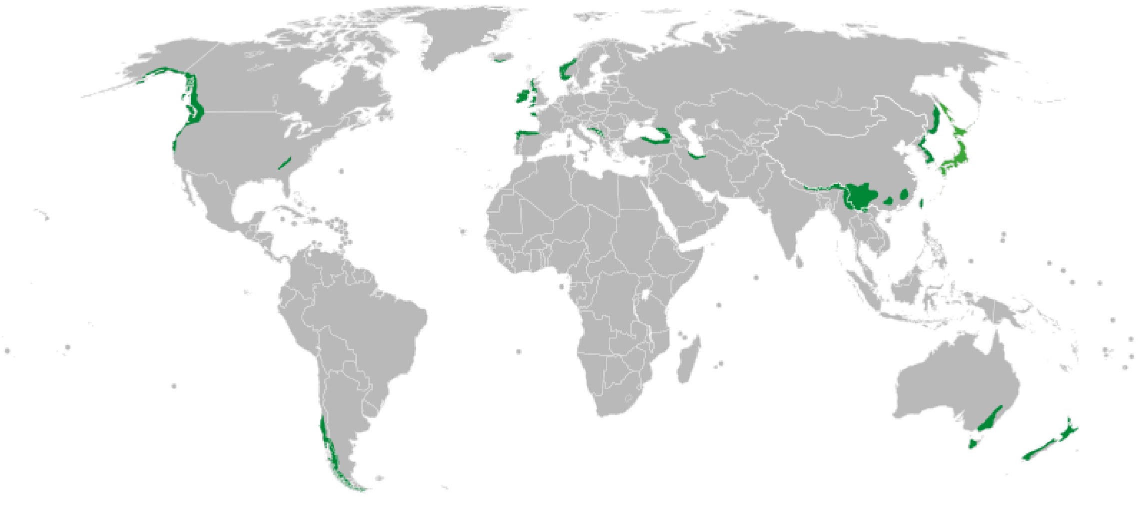
Hiker in the Queets Rain forest on the Olympic Peninsula of Washington, USA.

However, required annual precipitation depends on factors such as distribution of rainfall over the year, temperatures over the year and fog presence, and definitions in other countries differ considerably. For example, Australian definitions are ecological-structural rather than climatic:

1. Closed canopy of trees excludes at least 70% of the sky
2. Forest is composed mainly of tree species which do not require fire for r

egeneration, but with seedlings able to regenerate under shade and in natural openings The latter would, for example, exclude a part of the temperate rain forests of western North America , as Coast Douglas-fir, one of its dominant tree species, requires stand-destroying disturbance to initiate a new cohort of seedlings. The North American definition would in turn exclude a part of temperate rain forests in other countries.

Global distribution



A map showing the areas of temperate rain forest

Temperate forests cover a large part of the globe, but temperate rain forests only occur in few regions around the world. Most of these occur in Oceanic-Moist Climates: the Pacific temperate rain forests in Western North America (Southeastern Alaska to Central California), the Valdivian and Magellanic temperate rain forests of southwestern South America (Southern Chile and adjacent Argentina), pockets of rain forest in northwest Europe (southern Norway to northern Spain) and Portugal, temperate rain forests of southeastern Australia (Tasmania and Victoria) and the New Zealand temperate rain forests (South Island's west coast).

Others occur in Subtropical-Moist Climates: South Africa's Knysna-Amatole coastal forests, the Colchian rain forests of the eastern Black Sea region (Turkey and Georgia), the Caspian temperate rain forests of Iran and Azerbaijan, the mountain temperate rain forests along eastern Taiwan's Pacific Coast, southwest Japan's Taiheiyo forests, Australia's coastal New South Wales and New Zealand's North Island.

Some areas, however, such as the Rocky Mountains of British Columbia, northern Idaho and northwestern Montana, Rocky Mountain Trench in BC and Montana, and the Russian Far East (Ussuri, Manchuria, Sakhalin) in Asia have more of continental climate but get enough precipitation in both rain and snow to harbor significant pockets of temperate rain forest.

Scattered small pockets of temperate rain forest also exist along the Appalachian Mountains from northern Georgia to New England. The mountainous coniferous forests of the Changbai Mountains bordering China and North Korea are a good example contain some of the richest high-elevation coniferous evergreen forests in East Asia.

Temperate rain forest regions

Coast Redwood forest in Redwood National Park

Pacific temperate rain forests of western North America

Temperate rain forest in the Mount Hood Wilderness, Oregon, USA. This area, on the west side of the mountain, receives over 2.5 meters of rain per year.

A portion of the temperate rain forest region of North America, the largest area of temperate zone rain forests on the planet, is the Pacific temperate rain forests ecoregion which occur on west-facing coastal mountains along the Pacific coast of North America, from Kodiak Island in Alaska to northern California, and are part of the Nearctic ecozone. In the different system established by the Commission for Environmental Cooperation, this same general region is classed as the Pacific Maritime Ecozone by Environment Canada and as the Marine West Coast Forest and Northwestern Forested Mountains Level II ecoregions by the United States Environmental Protection Agency. In terms of the floristic province system used by botany, the bulk of the region is the Rocky Mountain Floristic Region but a small southern portion is part of the California Floristic Province.

Sub-ecoregions of the Pacific temperate rain forest ecoregion as defined by the WWF include the Northern Pacific coastal forests, Queen Charlotte Islands ecoregion, Vancouver Island ecoregion, British Columbia mainland coastal forests, Central Pacific coastal forests, Southern Cascades forests ecoregion, Klamath-Siskiyou coastal forests, and Northern California coastal forests ecoregions. They vary in their species composition, but are all predominantly coniferous, sometimes with an understory of broadleaved trees and shrubs. Most of the precipation occurs in winter but summer fogs moisture is extracted by the trees and produces a fog drip keeping the forest moist. The Northern California coastal forests are home to the Coast Redwood (*Sequoia sempervirens*), the world's tallest tree. In the other ecoregions, Coast Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*), Sitka Spruce (*Picea sitchensis*), Western Hemlock (*Tsuga heterophylla*) and Western redcedar (*Thuja plicata*) are the most important tree species. A common feature of Pacific temperate rain forests of North America is the Nurse log, a fallen tree which as it decays, provides ecological facilitation to seedlings.

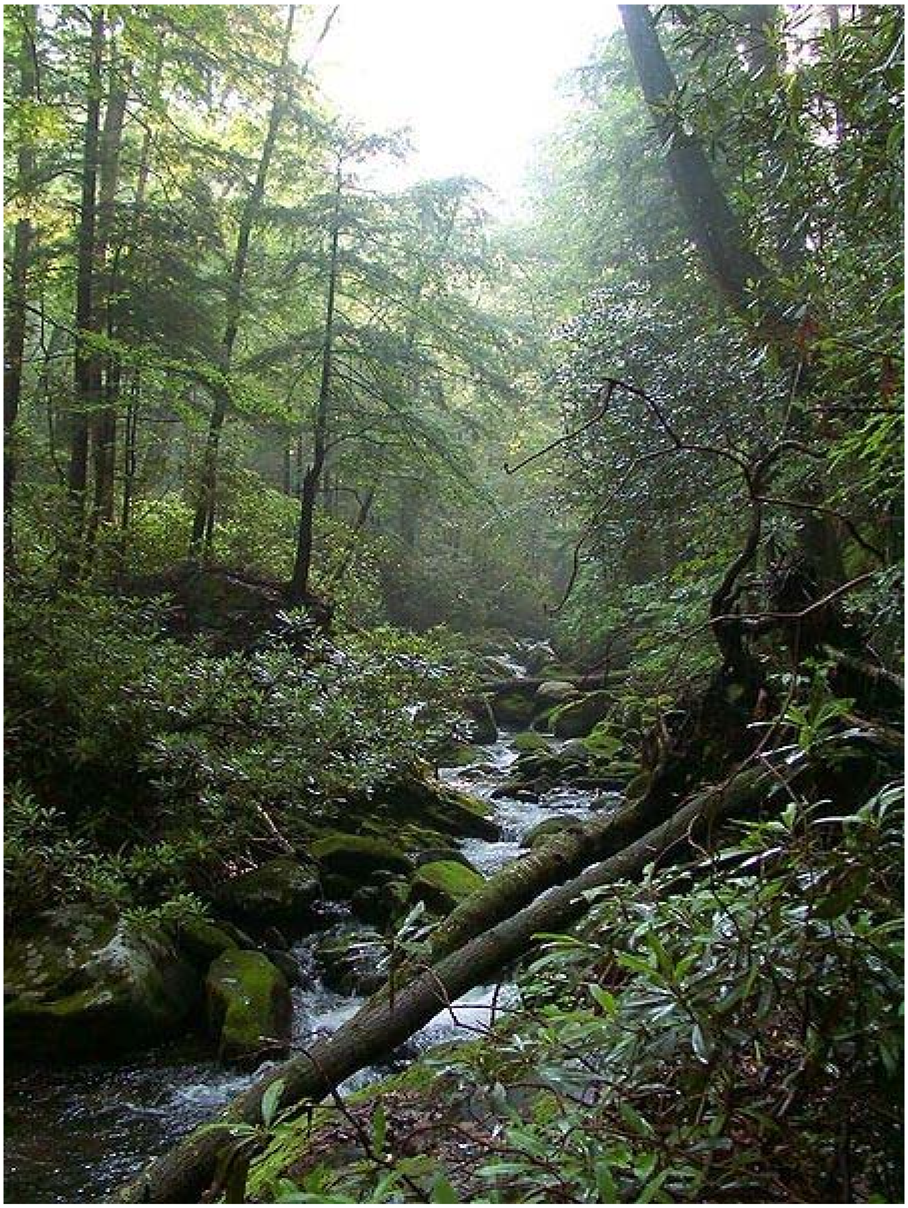
Temperate rain forest seen from Capilano Suspension Bridge in British Columbia, Canada.

Some of the largest expanses of oldgrowth are found in Olympic National Park, Mount Rainier National Park, Tongass National Forest, Mount St. Helens National Monument, Redwood National Park, and throughout British Columbia (including British Columbia's Coastal Mountain Ranges), with the coastal Great Bear Rainforest containing the largest expanses of oldgrowth temperate rainforest found in the world.

British Columbia's Rocky Mountains, Cariboo Mountains, Rocky Mountain Trench (east of Prince George) and the Columbia Mountains of Southeastern British Columbia (west of the Canadian Rocky Mountains that extend into parts of Idaho and Northwestern

Montana in the USA), which include the Selkirk Mountains, Monashee Mountains, and the Purcell Mountains, have the largest stretch of interior temperate coniferous rain forests. These inland rainforests have more continental climate with a large proportion of the precipitation falling as snow. Being closer to the Rocky Mountains, there is more of a diverse mammalian fauna. Some of the best interior rain forests are found in Mount Revelstoke National Park and Glacier National Park (Canada) in the Columbia Mountains.

Appalachian temperate rain forests of the eastern USA



Temperate rain forest in the Great Smoky Mountains National Park, part of the Appalachian Mountains.

Temperate rain forests in the eastern USA are limited to areas in the southern Appalachian Mountains where orographic precipitation causes weather systems coming from the west and from the Gulf of Mexico to drop more precipitation than in surrounding areas. The largest of these forest blocks are located in western North Carolina, northern Georgia, and far eastern Tennessee, largely in the Pisgah, Nantahala, Chattahoochee National Forests and nearby Gorges State Park. In addition, small areas in the highest elevations of the Great Smoky Mountains also receive substantial rainfall, with Clingmans Dome, for example, collecting about 2000 mm of precipitation per year. Although the highest summits of the Green Mountains of Vermont, the White Mountains of New Hampshire, and Mount Katahdin in Maine receive over 2000 mm of precipitation per year, some of these locations have alpine environments and whether or not temperate rain forests exist in these regions is subject to debate. It is possible for small blocks of temperate rainforest to exist along the slopes of these mountain ranges below the tree line where annual precipitation is sufficient for such forests to thrive.

Valdivian and Magellanic temperate rainforests of South America

Aextoxicon punctatum forest in Bosque de Fray Jorge National Park

The temperate rain forests of South America are located on the Pacific coast of southern Chile, on the west-facing slopes of the southern Chilean coast range, and the Andes Mountains in both Chile and Argentina down to the southern tip of South America, and are part of the Neotropic ecozone. The Valdivian rainforests are home to a variety of broadleaf evergreen trees, like *Aextoxicon punctatum*, *Eucryphia cordifolia*, and southern beech (*Nothofagus*), but include many conifers as well, notably Alerce (*Fitzroya cupressoides*), one of the largest tree species of the world. The Valdivian rainforests occur in the Valdivian temperate rain forests and Magellanic subpolar forests ecoregions.

The Valdivian and Magellanic temperate rainforest's are the only temperate rain forests in South America. Together they are the second largest in the world, after the Pacific temperate rain forests of North America. The Valdivian forests are a refuge for the Antarctic flora, and share many plant families and genera with the temperate rainforest's of New Zealand, Tasmania, and Australia. Fully half the species of woody plants are endemic to this ecoregion.

In the Valdivian region the Andean Cordillera intercepts moist westerly winds along the Pacific coast during winter and summer months; these winds cool as they ascend the mountains, creating heavy rainfall on the mountains' west-facing slopes. The northward-flowing oceanic Humboldt Current creates humid and foggy conditions near the coast. The tree line is at about 2,400 m in the northern part of the ecoregion (35° S), and descends to 1,000 m in the south of the Valdivian region. In the summer the temperature can climb to 62 degrees Fahrenheit (16.5 °C), while during winter the temperature can drop below 45 °F (7 °C).

South Africa's Knysna-Amatole coastal rain forests

Knysna Forest Biome near Nature's Valley, in the Tsitsikamma, South Africa

The temperate rain forests of South Africa are part of the Knysna-Amatole forests that are located along South Africa's Garden Route between Cape Town and Durban on the south-facing slopes of South Africa's Drakensberg Mountains facing the Indian Ocean. There are several coniferous podocarps that grow here. This forest receives a lot of moisture as fog from the Indian Ocean, and resembles not only other temperate rain forests worldwide, but also the montane evergreen Afromontane forests that occur at higher elevations in southern and eastern Africa. A fine example of this forest is in South Africa's Tsitsikamma National Park.

Northwest Europe

Temperate rainforest occurs in fragments across the west of Britain, Ireland, southern Norway and northern Spain.

Britain

The woodlands are variously referred to in Britain as Upland Oakwoods, Atlantic Oakwoods, Western Oakwoods or Temperate Rainforest. They are also listed in the British National Vegetation Classification as British NVC community W11 and British NVC community W17 depending on the ground flora. In England many steep sided valleys in Devon and Cornwall harbour the rainforest with notable examples being the Fowey valley in Cornwall and the valley of the river Dart which, flowing off Dartmoor, has rainfall in excess of 2 metres per year.

Colchian rain forests of Turkey and Georgia

The Colchian rainforests are found around the southeast corner of the Black Sea in Turkey and Georgia and are part of the Euxine-Colchic deciduous forests ecoregion, together with the drier Euxine forests further west. The Colchian rain forests are mixed, with deciduous Black Alder *(Alnus glutinosa)*, hornbeam (*Carpinus betulus* and *C. orientalis*), Oriental Beech (*Fagus orientalis*), and Sweet Chestnut *(Castanea sativa)* together with evergreen Nordmann Fir (*Abies nordmanniana*, the tallest tree in Europe at 78m), Caucasian Spruce (*Picea orientalis*) and Scots Pine (*Pinus sylvestris*).

Temperate rain forests of Iran and Azerbaijan

The Caspian Hyrcanian mixed forests ecoregion in northern Iran contains a jungle in the form of a rain forest which stretches from the east in the Khorasan province to the west in the Ardebil province, covering the other provinces of Gilan, Mazandaran, and Golestan. The Elburz or Alborz mountain range is the highest mountain range in the Middle East which captures the moisture of the Caspian Sea to its north and forms subtropical and temperate rain forests in the northern part of Iran. The Iranians call this forest and region *Shomal* which means *north* in Persian.

In southeast Azerbaijan, this ecoregion includes the Lankaran Lowland and the Talysh Mountains, the latter being evenly divided with Iran to the south.

They are deciduous forests containing tree species such as Black Alder (*Alnus glutinosa* subsp. *barbata*), hornbeam (*Carpinus betulus* and *C. orientalis*), Caucasian wingnut (*Pterocarya fraxinifolia*), chestnut-leaved oak (*Quercus castaneifolia*), Caucasian oak (*Quercus macranthera*), oriental beech (*Fagus orientalis*), Persian ironwood (*Parrotia persica*) and Persian silk tree (*Albizia julibrissin*).

The existing protected areas in Azerbaijan include:

- Gizil-Agach State Reserve – 88.4 square kilometres (34.1 sq mi)
- Hirkan National Park - 214 square kilometres (83 sq mi)
- Zuvand National Park - 15 square kilometres (5.8 sq mi)
- Girkan State Reserve – 3 square kilometres (1.2 sq mi)

Taiwan's mountain rain forests

These forests are found in eastern Taiwan and Taiwan's Central Mountain Ranges, part of the Taiwan subtropical evergreen forest region covering the higher elevations. Most of the lower elevations are covered by subtropical broadleaf evergreen forests, dominated by Chinese Cryptocarya (*Cryptocarya chinensis*), *Castanopsis hystrix* and Japanese Blue Oak (*Quercus glauca*). Higher elevations give way to temperate forests with large stands of old growth Taiwan Cypress (*Chamaecyparis taiwanensis*), Camphor tree (*Cinnamomum camphora*), maple (*Acer* spp.), Chinese yew (*Taxus chinensis*), Taiwan Hemlock (*Tsuga chinensis*), and Taiwan Douglas-fir (*Pseudotsuga sinensis var. wilsoniana*). These higher elevation forests include also giant conifers Formosan Cypress (*Chamaecyparis formosensis*) and Taiwania (*Taiwania cryptomerioides*) Some fine examples of forests are found in Yushan (Jade Mountain) National Park and Alishan.

Japan's Taiheiyo (Pacific) rain forests

Jōmon Sugi, the largest specimen of Japanese Cedar (*Cryptomeria japonica*), on Yakushima, Japan

Southwestern Japan's Taiheiyo evergreen forests region covers much of Shikoku and Kyūshū Islands, and the Southern/Pacific Ocean-facing side of Honshu ("Taiheiyo" is the Pacific Ocean, in Japanese). Here the natural forests are mainly broadleaf evergreen in lower elevations and deciduous in higher elevations. The limit occurs at 500–1000 metres depending on latitude. The main tree species are members of beech family (Fagaceae). In lower altitudes these include evergreen oaks (*Quercus* spp.), Japanese Chinquapin (*Castanopsis cuspidata*) and Japanese Stone Oak (*Lithocarpus edulis*), and in higher altitudes Japanese Blue Beech (*Fagus japonica*) and Siebold's beech (*Fagus crenata*).

Some of the best preserved examples of forest are found in Kirishima-Yaku National Park on the Island of Yakushima off of Kyūshū in a very wet climate (the annual rainfall is 4,000 to 10,000 mm depending on altitude). Because of relatively infertile soils on granite, Yakushima's forests in higher elevations are dominated by a giant conifer species, Japanese Cedar (*Cryptomeria japonica*), rather than deciduous forests typical of the mainland. Other areas include Mount Kirishima near Kagoshima in southern Kyūshū. On Southern Honshū, there is a splendid forest with the beautiful Nachi Falls located in Yoshino-Kumano National Park. This particular area of Honshū has been described as one of the rainiest spots in Japan.

Temperate rainforest in Great Otway National Park, Victoria, Australia.

Subtropical rainforest in Border Ranges National Park, New South Wales, Australia.

Australian temperate rainforests

In Australia rainforests occur near the mainland east coast and in Tasmania. There are warm-temperate and cool-temperate rainforests. They are broadleaf evergreen forests with the exception of montane rainforests of Tasmania. Eucalypt forests are not classified as rainforests although some eucalypt forest types receive high annual rainfall (to over 2000 mm in Tasmania), and in the absence of fire they may develop to rainforest. If these widespread wet sclerophyll forests were considered rainforests, the total area of rainforest in Australia would be much larger.

Warm-temperate rainforest replaces subtropical rainforest on poorer soils or with increasing altitude and latitude in New South Wales and Victoria. Cool-temperate rainforests are widespread in Tasmania (Tasmanian temperate rain forests ecoregion) and they can be found scattered from the World Heritage listed Border Ranges National Park and Lamington National Park on the NSW/Queensland border to Otway Ranges, Strzelecki Ranges, Dandenong Ranges and Tarra Bulga in Victoria. In the northern NSW they are usually dominated by Antarctic Beech (*Nothofagus moorei*), in the southern NSW by Pinkwood (*Eucryphia moorei*) and Coachwood (*Ceratopetalum apetalum*) and in Victoria and Tasmania by Myrtle Beech (*Nothofagus cunninghamii*), Southern Sassafras (*Atherosperma moschatum*) and Mountain Ash (*Eucalyptus regnans*). The montane rainforests of Tasmania are dominated by tasmanian endemic conifers (mainly *Athrotaxis* spp.). They are dominated by Ferns. i.e. Cyathea cooperiCyathea australisDicksonia antarcticaCyathea cunninghamii Cyathea leichhardtiana

Fiordland National Park near Te Anau, New Zealand

New Zealand temperate rain forests

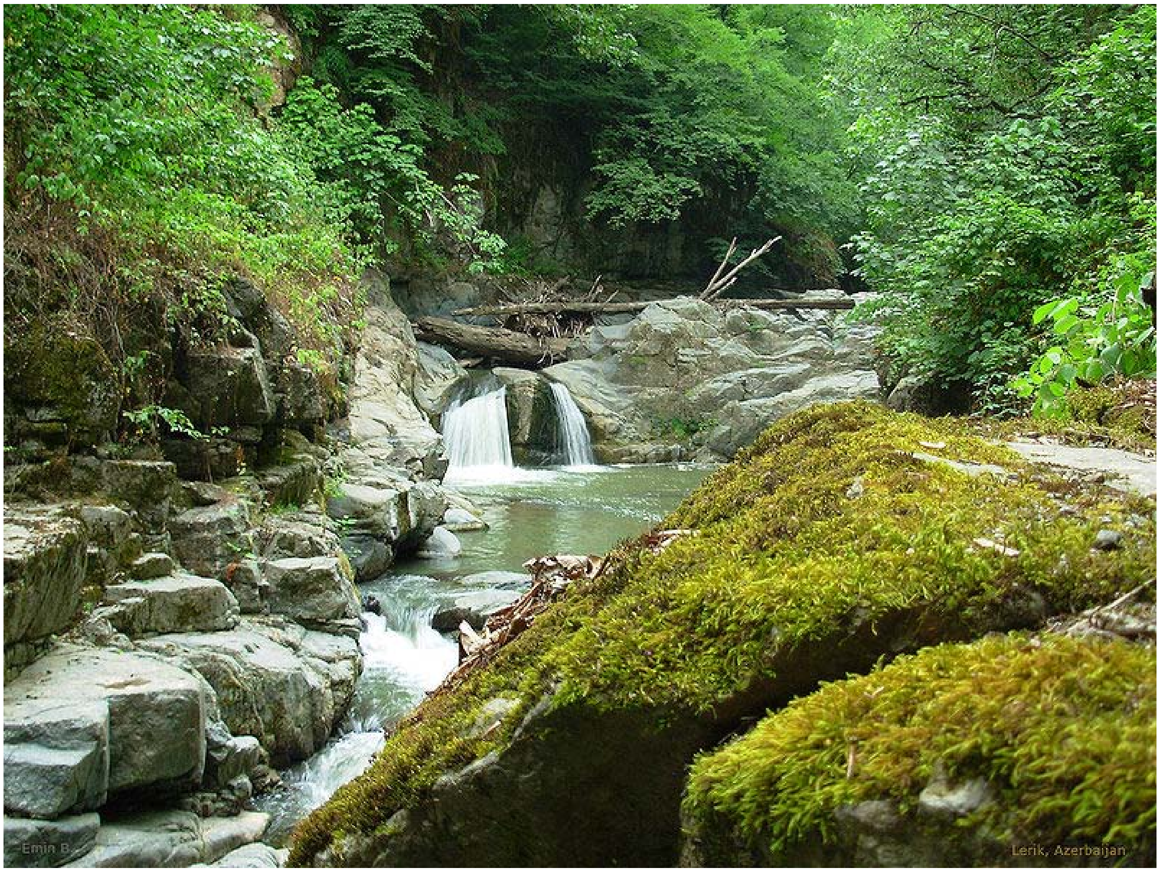
The temperate rain forests of New Zealand occur on the western shore of New Zealand's South Island and on New Zealand's North Island. The forests are made up of coniferous podocarps and broadleaf evergreen trees; the podocarps are abundant at lower elevations, while southern beech (*Nothofagus*) can be found on higher slopes and in the cooler southernmost rain forests. Ecoregions include the Fiordland temperate forests and Westland temperate forests.

Southern ocean island temperate rain forests

The islands of the Tristan da Cunha group and New Zealand's southern outlying islands of the Antipodes Islands, Auckland Islands, and Campbell Island group all host temperate rain forests. Annual rainfall totals are high due to the lack of landmass in their latitudes. Some areas of these islands are too windy for forests, but those areas that are not as windy are capable of growing temperate rain forests.

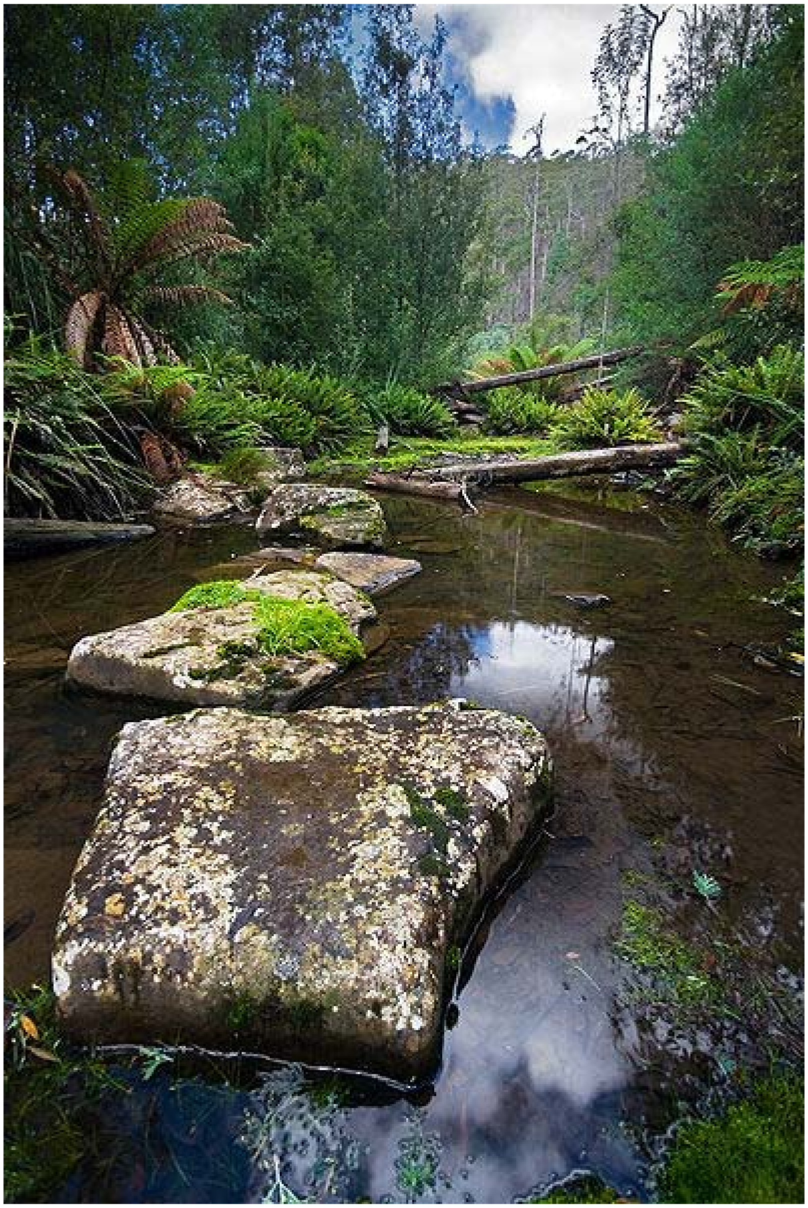
Valdivian forest in the west of Chiloé Island, Chile.

Lophosoria quadripinnata ferns in the Valdivian temperate rainforest of Southern Chile.



Caspian Hyrcanian mixed forests in Lerik Region of Azerbaijan

Jungles of Iran, Northern Iran.



The Sandspit River in a cool temperate rainforest area of Wielangta forest, Tasmania.

Chapter 14

Old-Growth Forest

Coast Redwoods in old-growth forest in Muir Woods National Monument, Marin County, California.

An **old-growth forest** (also termed **primary forest**, **ancient forest**, **virgin forest**, **primeval forest**, **frontier forest** or in Britain, **ancient woodland**) is a forest that has attained great age (and associated structural features), and thereby exhibits unique ecological features.

Old-growth forests typically contain large and old live trees, large dead trees (sometimes called "snags"), and large logs. Individual tree mortality creates gaps in the main canopy layer, allowing light to penetrate the main canopy and create favorable conditions for photosynthesis in the understory (which is why old-growth understory is more developed than in immature stands).

Forest regenerated after a severe disruption, such as clearcutting or fire, is often called second-growth or *regeneration* until enough time passes for the effects of the disturbance to be no longer evident. Depending on the forest, this may take anywhere from a century to several millennia. Hardwood forests of the eastern United States can develop old-growth characteristics in one or two generations of trees, or 150–500 years.

Many old-growth forest stands are threatened by habitat destruction through excessive logging. This destruction reduces biodiversity, affecting not only the old-growth forest itself, but also indigenous species that rely upon old-growth forest habitat.

Old-growth forests are often home to rare species, threatened species, and endangered species of plants and animals, making them ecologically significant. One example of a rare species reliant upon old-growth forest is the Northern Spotted Owl. Levels of biodiversity may be higher or lower in old-growth forests compared to that in second-growth forests, depending on specific circumstances, environmental variables and geographic variables. Logging in old-growth forests is a contentious issue in many parts of the world.

Definitions

Old-growth European Beech forest in Biogradska Gora National Park, Montenegro.

Tongass National Forest, Alaska

Yakushima cedar *(Yakusugi)* tend to have longer lives, and many larger trees have been around for more than 2,000 years.

Redwood tree in northern California redwood forest, where 45 percent of remaining old-growth redwood trees are park managed. According to the National Park Service "96 percent of the original old-growth coast redwoods have been logged."

Distinguishing characteristics of old-growth forest fall into three major categories: ecological, social, and economic.

Ecological definitions

Definition by forest characteristics

Most definitions use various forest characteristics to define old-growth forest. Usually the characteristics include presence of old trees, dead standing snags, a multilayered canopy dominated by large overstory trees, and accumulations of large dead woody material.

Stand dynamics definition

From stand dynamics perspective, old-growth forest is a forest in a stage that follows Understory Reinitiation stage. A review of the stages helps to understand the concept:

1. Stand-replacing: disturbance hits the forest and kills most of the living trees.
2. Stand-initiation: population of new trees becomes established.
3. Stem-exclusion: trees grow higher and enlarge their canopy, thus competing for the light with neighbors. Light competition mortality kills slowly growing trees

and reduces forest density. This allows surviving trees to increase in size. Eventually the canopies of neighboring trees touch each other and drastically lowers amount of light that reaches lower layers. Due to that, the understory dies and only very shade-tolerant species survive.

4. Understory reinitiation: trees die from low level mortality, such as windthrow and diseases. Individual canopy gaps start to appear and more light can reach forest floor. Hence, shade-tolerant species can establish in the understory.
5. Old-growth: Main canopy trees become older and more of them die, creating even more gaps. Since the gaps appear at different times, the understory trees will be at different growth stages. Furthermore, the amount of light that reaches each understory tree depends on its position relative to the gap. Thus, each understory tree grows at a different speed. The difference in establishment timing and in growth speed create a population of understory trees that are variable in size. Eventually, some understory trees grow to become as tall as the main canopy trees, thereby filling the gap. This perpetuation process is typical for the old-growth stage. This, however, does not mean that the forest will be old-growth forever. Generally there are three possible futures for old-growth stage forest: a)The forest will be hit by a new stand-replacing disturbance and most of the trees will die. b)The tree community will eventually create unfavorable conditions for new trees to regenerate. In this case, the old trees will die and smaller plants will create woodland. c)The regenerating understory trees are different species than the main canopy trees. In this case, the forest will switch back to Stem-Exclusion stage, but with different tree species. The forest in old-growth stage can be stable for centuries but the length of this stage depends on the forest's tree composition and climate of the area. For example, frequent natural fires do not allow boreal forests to be as old as coastal forests of western North America.

It is important to note that while the stand switches from one tree community to another, the stand will not necessarily go through old-growth stage between those stages. Some tree species have relatively open canopy. That allows more shade-tolerant tree species to establish below even before Understory Reinitiation stage. The shade-tolerant trees will eventually out-compete the main canopy trees in stem-exclusion stage. Therefore, the dominant tree species will change, but the forest will still be in Stem-Exclusion stage.

Stand age definition

Stand age can also be used to categorize forest as old-growth. For each geographical area, there is an average time since disturbance when the forest will reach old-growth stage. This method is useful, because it allows quick and objective determination of forest stage. However, this definition does not provide explanation about forest function. It just gives a useful number to measure. Due to that fact, some forests may be excluded from being categorized as old-growth even if they have old-growth attributes just because they are too young. Also, older forests can lack some old-growth attributes and be categorized as old-growth just because they are so old. The idea of using age is also problematic, because human activities can influence the forest in varied ways. For example, after logging of 30% of the trees, we can wait less time for old-growth to come back than after removal of 80% of the trees.

Social definitions

Common cultural definitions and common denominators regarding what comprises old-growth forest, and of the variables that define, constitute and embody old-growth forests include:

- The forest habitat possesses relatively mature, old trees;
- The old-growth trees have long continuity on the same site;
- The forest itself has not been subjected to significant inhabitation by mankind that has altered the appearance of the landscape and its ecosystems, has not been subjected to logging, and has inherently progressed per natural tendencies.

"Ancient woodland" is a term used in the United Kingdom to refer specifically to woodland dating back to 1600 or before (in England and Wales) or 1750 (in Scotland). Before this, planting of new woodland was uncommon, so a wood present at these dates was likely to have developed naturally. By this definition Ancient Woodland may have been affected by human management, and may have no very ancient trees: the important characteristic is long continuity of woodland on the land.

In North America, the term "old growth" is often (but not always) used to characterize a forest that has experienced little direct disruption or disturbance by humans during contemporary historical epochs, although sometimes determining the long-term history of human land management can be difficult. Additionally, because landscapes are naturally dynamic and continue to change as time progresses, it is difficult to ascertain hypothetical old-growth forest characteristics that may have come into fruition had humans not destroyed such a great deal of old-growth forests.

The role of natural disturbances in defining old-growth is more ambiguous. For example some definitions exclude recently burned forests, even where fire has been part of the natural forest dynamics for millennia. In other cases such natural disturbance is incorporated in the old-growth concept. However, it is sometimes difficult to distinguish the ecological effects of natural disruption from human-caused disruption. Furthermore, many forests that have never experienced direct manipulation by humans have been subjected to indirect effects in the form of invasive species, removal of native species (including megafauna), climate change, and regional modifications of ecological disturbance regimes (e.g., fire suppression).

Economic definitions

Characteristics

Down wood decaying.

Many botanists specifically define old-growth in terms of meeting several criteria, under which system forests with sufficient age and minimal disturbance are considered old growth. Typical characteristics of old-growth forest include presence of older trees, minimal signs of human disturbance, mixed-age stands, presence of canopy openings due to tree falls, pit-and-mound topography, fallen timber in various stages of decay, standing snags (dead trees), multi-layered canopies, intact soils, a healthy fungal ecosystem, and presence of indicator species.

Mixed age

A forest in old-growth stage has a mix of tree ages, due to a distinct regeneration pattern for this stage. New trees regenerate at different times from each other, because each one of them has different spatial location relative to the main canopy and hence each one receives a different amount of light. This regeneration pattern is different from the regeneration of trees after a major disturbance, when trees regenerate on the site in relatively similar time. In younger forests trees have similar ages, because they all started to grow at the same time, after the old forest stand was killed.

Canopy openings

Forest canopy gaps are essential in creating and maintaining mixed-age stands. Also, some herbaceous plants only become established in canopy openings, but persist beneath an understory. Openings are a result of tree death due to small impact disturbances such as wind, low-intensity fires and tree diseases.

Old-growth forests are unique, usually having multiple horizontal layers of vegetation representing a variety of tree species, age classes, and sizes, as well as "pit and mound" soil shape with well-established fungal nets. Because old-growth forest is structurally diverse it provides higher-diversity habitat than forests in other stages. Thus, sometimes higher biological diversity can be sustained in old-growth forest, or at least a biodiversity that is different from other forest stages.

Topography

Fungus on a broken tree in the Białowieża Forest, one of the last largely intact primeval forests in Central Europe.

The characteristic topography of much old-growth forest consists of pits and mounds. Mounds are caused by decaying fallen trees, and pits (tree throws) by the roots pulled out of the ground when trees fall due to natural causes, including being pushed over by animals. Pits expose humus-poor, mineral-rich soil and often collect moisture and fallen leaves, forming a thick organic layer that is able to nurture certain types of organisms. Mounds provide a place free of leaf inundation and saturation, where other types of organisms thrive.

Standing snags

Standing snags provide food sources and habitat for many types of organisms. In particular, many species of dead-wood predators such as woodpeckers must have standing snags available for feeding. In North America the spotted owl is well-known for needing standing snags for nesting habitat.

Decaying ground layer

Fallen timber, or coarse woody debris, contributes carbon-rich organic matter directly to the soil, thus providing a substrate for mosses, fungi and for seedlings, and in creating microhabitats by creating relief on the forest floor. In some ecosystems, such as the temperate rain forest of the North American Pacific coast, fallen timber may become nurse logs, providing a substrate for seedling trees.

Soil

Intact soils harbor many life-forms and usually have well-defined soil profiles. Different organisms may need different soil profiles to adapt to the forest, while many trees need well-structured soils free of disturbance. Some herbaceous plants in northern hardwood forests need thick duff layers (which are part of the soil profile). Fungal ecosystems are essential for efficient *in-situ* recycling of nutrients back into the entire ecosystem.

Importance

- Old-growth forests often contain rich communities of plants and animals within the habitat due to the long period of forest stability. These varied and sometimes rare species may depend on the unique environmental conditions created by these forests.

- Old-growth forest serves as a reservoir for species which cannot thrive or easily regenerate in younger forest, and so can be used as a baseline for research.

- Plant species that are native to old-growth forests may someday prove to be invaluable towards curing various human ailments, as has been realized in numerous plants in tropical rainforests.

- Old-growth forests also store large amounts of carbon above and below the ground (either as humus, or in wet soils as peat). They collectively represent a very significant store of carbon. Destruction of these forests releases this carbon as greenhouse gases, and may increase the risk of global climate change.

Logging

Northern Spotted Owl, Six Rivers National Forest, NW California

The large trees in old-growth forests are often economically valuable, so these forests have been subjected to aggressive logging around the world. This has led to much controversy between logging companies and environmental groups. An example of this was that over Spotted Owls in the 1980s and 1990s.

In Australia, the regional forest agreement (RFA) attempted to prevent the clearfelling of defined "Old Growth Forests". This led to struggles over what constitutes "Old Growth". For example in Western Australia, the timber industry tried to limit the area of Old Growth in the karri forests of the Southern Forests Region; this led to the creation of the

Western Australian Forests Alliance, the splitting of the Liberal Government of Western Australia and the election of the Gallop Labor Government. Old Growth Forests in this region have now been placed inside National Parks. A small proportion of Old Growth Forest also exists in South-West Australia, and is protected by a Federal laws from logging, which hasn't occurred there for more than twenty years.

Locations of remaining tracts

In 2006 Greenpeace identified that the world's remaining intact forest landscapes are distributed among the continents as follows:

- 35% in Latin America. The Amazon rainforest is mainly located in Brazil, which clears a larger area of forest annually than any other country in the world.
- 28% in North America. North America harvests 10,000 square kilometres of ancient forests every year. Many of the fragmented forests of southern Canada and the US lack adequate animal travel corridors and functioning ecosystems for large mammals.
- 19% in Northern Asia. Northern Asia is home to the largest boreal forest in the world. The Siberian tiger once roamed across huge areas of Northern Asia but today can only be found in a small area of intact forest near the Sea of Japan. Only about 400 remain in the wild and 800 in zoos.
- 8% in Africa. Africa has lost most of its intact forest landscapes in the last 30 years. The timber industry is responsible for destroying huge areas of intact forest landscapes and continues to be the single largest threat to these areas.
- 7% in South Asia Pacific. The Paradise Forests of Asia Pacific are being destroyed faster than any other forest on Earth. Much of the large intact forest landscapes have already been cut down, 72% in Indonesia and 60% in Papua New Guinea.
- Less than 3% in Europe. In Europe, more than 150 square kilometres of intact forest landscapes are cleared every year and the last areas of the region’s intact forest landscapes in European Russia are shrinking rapidly.

Effect on climate change

Old-growth forests store large amounts of carbon, which is stored in wood, soil humus and peat. When forests are cut, the trees' wood, soil humus and peat all decay, releasing the carbon as carbon dioxide or methane. Logging practices often include burning of the logged area, releasing further CO_2.

While old-growth forests are often perceived to be in equilibrium — releasing as much carbon dioxide as they capture; or even in a state of decay, studies of soils in undisturbed tropical rain forests, Siberian woods and in German national parks have found that soils contain enormous amounts of carbon derived from fallen leaves, twigs and buried roots that can bind to soil particles and remain for 1,000 years or more. Replacing old-growth forests with plantations is counter-productive from a carbon-storage view, as the new forest may take centuries to recapture the carbon lost. Further, the loss of biodiversity in a plantation monoculture lessens the performance of ecosystems regarding biomass production, nutrient retention and carbon dioxide absorption.