

BOREAL AND TEMPERATE FORESTS

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Keywords: biogeography, boreal forests, ecosystem function, forest biomes, forest ecology, forest history, forest management, global change, temperate forests.

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Summary

We review aspects of the ecology, biogeography, and management history of boreal and temperate forests with the aim of providing a basis for understanding their role as part of the earth's "life support system". Boreal and temperate forests together cover ~25% of the Earth's terrestrial land surface, mainly in the northern hemisphere in Eurasia and North America. Boreal forests are strongly affected by both extreme cold temperatures, and by frequent stand-replacing fires. Fire disturbance also plays an important role in many temperate forests, and natural fire disturbance cycles have figured prominently in recent efforts at "ecosystem management".

Boreal and temperate forest communities are mainly of recent origin, and were drastically affected by glaciation, glacial retreat, and climatic change during the Pleistocene. Most temperate forests and many boreal forests also show profound influences of forest utilization and management by humans. Temperate forests were heavily over-utilized in the 19th century, but have shown a global pattern of recovery in the latter part of the 20th century; extensive boreal forest utilization for pulp and paper is a more recent trend. Boreal and temperate forests are presently subject to a variety of human-caused environmental changes, including impacts of atmospheric pollutants, rising atmospheric CO₂, and climate change. Climate change effects are expected to be especially severe in northern temperate and boreal systems. Although boreal and temperate forests are among the best-studied terrestrial ecosystems, there remain

important aspects of uncertainty regarding the underlying mechanisms for the current distribution of forest types, the long-term sustainability of forest management practices, and impacts of global warming and other aspects of environmental change.

1. Introduction

The biogeography, ecology, and management history of boreal and temperate forests are central to understanding their role as part of the Earth's "life support system". Historically, research has focused solely on forests as a source of wood products, but increasing attention has been placed on understanding ecosystem processes associated with natural and human-influenced conditions. By "ecosystem processes", we refer specifically to forest structure and composition, stores and fluxes of water, carbon, plant mineral nutrients, and xenobiotics; soil structure and stability; surface and sub-surface hydrology; forest interactions with local and regional climate; and biotic and abiotic interactions that maintain and ultimately generate biodiversity at the genetic, phylogenetic, and ecological levels of integration.

Such processes are, to a great extent, synonymous with "environmental services", and have been accorded monetary value in explicit economic analyses. We consider an "Earth life support system" perspective to simply connote the integration of such processes and services over large spatial and temporal scales. Such a perspective does not imply any kind of self-regulation or other "super-organismic" attributes to ecological systems or the biosphere as a whole.

Temperate forests represent one of the best-researched ecosystems on the planet, and are, moreover, the historical birthplace of modern forestry (18th century Europe). Despite a much shorter legacy of large-scale human impact, boreal forests have also been heavily studied due to their economic significance in the last half of the 20th century. The literature on temperate and boreal forests is accordingly voluminous. No short review can do more than cover essential background information and illustrate a subset of recent conceptual and empirical advances.

From a comparative perspective, boreal and temperate forests show striking differences but also important similarities with tropical forests (*See Tropical and Subtropical Forests*). Temperate forests are generally much less biologically diverse than tropical forests; dominance by one or a few tree species is common in temperate forests and is the rule in the boreal. Temperate forest communities are of recent origin, having been drastically affected by recent cycles of glaciation, glacial retreat, and climatic change. Most temperate forests show profound influences of historical patterns of land use, often spanning a history of many centuries. Moreover, it is fair to say that all boreal and temperate forests have been influenced to some degree by recent anthropogenic impacts that include regional influences of atmospheric pollutants, and global impacts of rising atmospheric CO₂ and climate change. Humans and their multifarious effects are therefore integral to understanding temperate and boreal forests.

Our objective here is to provide an overview of boreal and temperate forests from an "Earth life support system" perspective, as defined above. Essentially, we wish to describe the major forces, both natural and human-related, that have and will in the

future act to determine the distribution and ecological status of boreal and temperate forests. We focus on several overarching themes, namely: (1) the underlying processes determining the distribution of boreal and temperate forests; (2) the importance of forest history, including both anthropogenic impacts and long-term geological and climatic processes such as glaciation; (3) natural disturbance regimes and stand dynamics in non-managed forests, and their relationship to forest management effects and objectives; (4) the evolution of objectives and conceptual foundations of forest management, and the emerging impacts of these changes on the forests themselves; and (5) boreal and temperate forests in relation to "unintentional" human impacts, including global change factors. For each of these themes we highlight what we consider the most important recent advances in both empirical data and conceptual understanding.

2. Definitions and Geographic Distribution of Boreal and Temperate Forests

Boreal and temperate forests cover ~25% of the land area of the Earth, comprising a broad band of forest vegetation extending across the northern hemisphere, with comparatively small and localized areas in the southern hemisphere (Figure 1). Political regions which hold the largest areas of boreal and temperate forests include the former Soviet Union, Canada, the United States, China, and eastern and western Europe. In the southern hemisphere, temperate forests occur in Australia, New Zealand, South Africa, Chile, and Argentina; there is no true southern analog to the extensive boreal forests of Eurasia and North America. In many temperate regions, areas formerly forested have largely been converted to agricultural land use. Large-scale anthropogenic impacts on boreal forests are of much more recent origin, and are mainly related to industrial pulpwood production. Historical declines in boreal and temperate forests have been particularly severe in southern Europe, North Africa, and the agricultural regions of China, Northern and Central Europe, and North America.

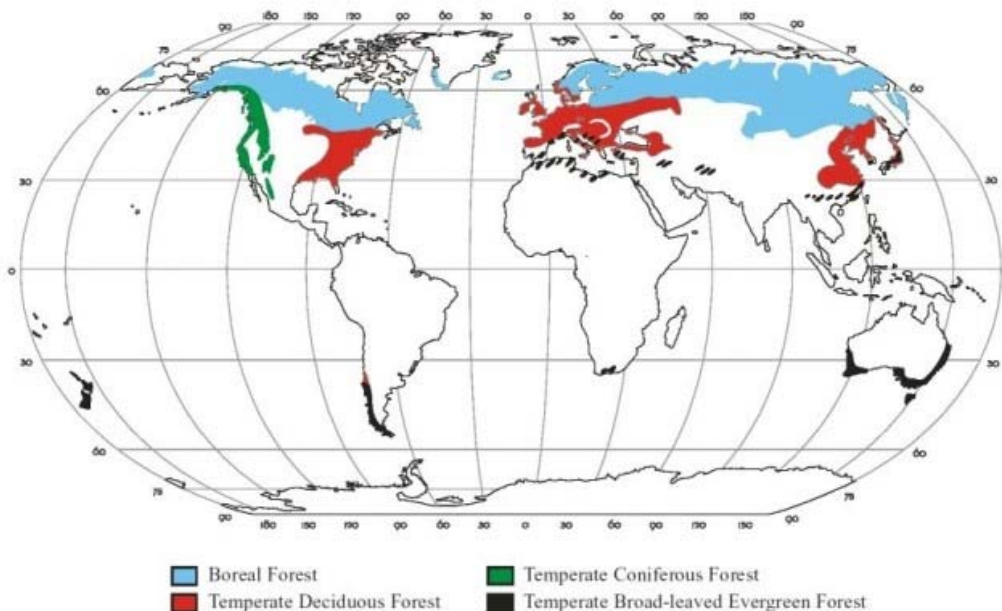


Figure 1. Global temperate and boreal vegetation zones; adapted from Rohrig and Ulrich, 1991, and various other sources.

"Temperate" climates are those occurring between the frigid and torrid zones, showing an intermediate long-term average temperature. Temperate regions generally also exhibit strong seasonality in temperature, and rainfall. The structure and ecosystem dynamics of temperate forests reflect this intermediate but seasonal climatic regime. Thus, the majority of temperate forests are dominated by winter deciduous trees, or by coniferous evergreen species that are physiologically dormant during winter months. However, evergreen temperate forests occur in areas with a strong maritime climatic influence. Important examples include most of the temperate forest areas of the southern hemisphere, and the temperate "rain forests" of the Pacific coast of North America, dominated by coniferous species that remain physiologically active year-round. Temperate evergreen broad-leaved forests also occur in such areas as New Zealand and parts of East Asia. Temperate forests span a very wide range of precipitation regimes, and much of the coarse-scale variation in the temperate forest ecology is related to differences in the overall amount and seasonality of rainfall, as modified by edaphic conditions.

The term "boreal" pertains to the north, from the etymological root Boreas, the cold north wind. Climatically, the boreal region is the northernmost section of the temperate zone before the arctic begins and is coincident with the limits of continuous forest cover in the northern hemisphere. While this "northern forest" is commonly referred to as "taiga", this term refers properly to northern coniferous forests alone. Although late-successional boreal forests are generally dominated by conifers, broad-leaved deciduous trees are also an important element, and may dominate under certain edaphic conditions or as a result of human activities. "Boreal" is thus a better description of the ecological zone as a whole.

Geographically, the boreal is the largest forest in the world covering ~25 million km² of land or 11% of the Earth's terrestrial surface, and representing about half of the world's remaining "frontier" or natural forests. This region stretches over northern Europe (~3 million km²), Siberia (~6 million km²) and North America (~5 million km²) in a belt up to 1000 km wide, or spanning ~10° of latitude. 95% of the world's boreal forest is contained within the political regions of Russia, China, Mongolia, the Baltic Republics, Fennoscandia, and Canada. High elevation forests within the temperate zone (including parts of the United States, Japan, Korea, Poland, Ukraine, Romania, Hungary, Slovakia, Czech Republic, Austria, Switzerland, Germany, as well as Chile and Argentina) are sometimes classified as "boreal" as well.

The transition between boreal and temperate forests is often gradual. For example, while spruce (*Picea*) species are often used as a proxy indicator of boreal forest extent, dominant *Picea* species in North America extend as far south as 40-45°N latitude, well into the temperate forest zone. Likewise, outlying populations of tree species characteristic of temperate forests can be found in the far north, particularly in sheltered microhabitats. The broad spatial distributions of boreal and temperate forests are also greatly complicated by climatic and biogeographical effects of mountains. Temperate montane forests are often considered analogs of northern boreal forests. However, while some boreal tree species do extend into high altitude regions in the temperate zone, in general other (related) species are dominant in montane forests. Montane forest species have specific adaptations to, for example, day length and CO₂ partial pressure, and so

are physiologically and ecologically distinct from boreal species. We thus cannot assume *a priori* that generalizations concerning structure, ecosystem processes, or responses to human impacts seen in the boreal proper will necessarily apply to montane forests, or vice-versa.

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Biographical Sketches

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James McClellan is a Ph.D. candidate in the University of Toronto's Faculty of Forestry, and recently hired as a member of the Sustainable Forest Management Research Group at University of British Columbia. He has work experience of more than 20 years in the Canadian boreal region, primarily related to fire protection, fire ecology, and operations research.