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Fire in Ecosystems of Boreal Eurasia: Ecological Impacts and Links to the Global System

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1. Introduction

The circumpolar belt of the boreal zone stretches in two broad trans-continental bands across North America and Eurasia. The northern boundary of the zone corresponds to the July 13°C isotherm, while the southern boundary is limited by the July 18°C isotherm (Kuusela 1990). The boreal zone has been classified into three sub-zones, the maritime, continental and high-continental sub-zones. The maritime sub-zone has mean summer temperatures of 10-15°C, winter temperatures of 2-3°C, and annual precipitation of 400 to 800 mm. The continental sub-zone has long, cold winters with mean temperatures from -20 to -40°C, and summer mean temperatures from 10 to 20°C. The growing season is between 100 and 150 days, and annual precipitation ranges between 400 and 600 mm. The high continental sub-zone covers the largest portion of the boreal zone and is characterized by more extreme winters and milder summers. In Europe, the influence of maritime airmasses decreases from west to east, reaching West Siberia as far as the Yenisei river. East Siberia and the Far East are characterized by high-continental climate.

The definition of the boundaries of the boreal zone is often considered synonymous with the occurrence of northern coniferous forests. However, the northern forest limit which exceeds 70°N latitude only in Eurasia, in fact, is a broad forest-tundra ecotone characterized by the transition between tundra associations and discontinuous forest cover (Treter 1993). The southern limit of the boreal forest zone is at ca. 45°N. As a consequence of geography (size of the continent, orography, oceanic and atmospheric circulation) ca. 40% of the North American boreal forest is between 45 and 55°N, much further south than in Eurasia's boreal forests which are mainly north of 55°N latitude (cf map on p. 496).

The distinct climatic seasonality with a short vegetation period and low average temperatures facilitates the accumulation of organic layers and widespread permafrost soils in the boreal zone. Together with topography both features critically determine species composition and dynamics of the forest landscapes in which bogs and grasslands are intermixed (Shugart et al. 1992; Treter 1993).

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The ecologically and economically most important coniferous tree species are pine (*Pinus* spp.), larch (*Larix* spp.), spruce (*Picea* spp.), and fir (*Abies* spp.); the main broadleaf tree species are birch (*Betula* spp.), poplar (*Populus* spp.), and alder (*Alnus* spp.) (Nikolov and Helmisaari 1992).

Boreal forests cover ca. 1.2×10^9 ha, of which 920×10^6 ha are closed forest. The latter number corresponds to ca. 29% of the world's total forest area and to 73% of its coniferous forest area (ECE/FAO 1985). About 800×10^6 ha of boreal forests with a total growing stock (over bark) of ca. 95 billion m^3 are exploitable (41% and 45% respectively of the world total). The export value of forest products from boreal forests is ca. 47% of the world total (Kuusela 1990).

The carbon stored in boreal ecosystems corresponds to ca. 37% of the total terrestrial global carbon pool (plant biomass and soil carbon) (Apps et al. 1993). Thus, the magnitude of the boreal forest area suggests that it may play a critical role in the global carbon budget and its influence on the climate system of the earth (potential sink or source of atmospheric carbon).

More than seventy percent of the global boreal forest cover is in Eurasia, mainly in the Russian Federation, and represent the largest unbroken forested area of the globe; the remainder is in Canada and Alaska, and relatively small areas of boreal forests are found in the North East of China and in the Nordic countries (Fennoscandia).

The total area of the Russian Forest Fund comprises ca. $1,181 \times 10^6$ ha, of which 886×10^6 ha (= 75,0%) are forested and 763×10^6 ha (= 64%) are stocked (Federal Forest Service of Russia 1994). The Federal Forest Service of Russia exercises control over 94% of the total Forest Fund area and 91% of the total growing stock of Russia. Depending on the criteria used to define "boreal forest", the area of closed boreal forest in the Russian Federation varies from 400 to 600×10^6 ha (Pisarenko and Strakhov 1993). These numbers correspond to a 43-65% share of the world's closed boreal forest.

2. Disturbances in Boreal Ecosystems

Over evolutionary time periods boreal ecosystems have been subjected to climate changes, and species were forced to migrate in accordance with advancing and retreating glacial land ice cover. At the end of the last glacial (Weichselian) major parts of Eurasia's present forests and wetlands were still covered by inland freshwater lakes (Grosswald 1980). During the present interglacial - starting ca. 10,000 years ago - the boreal forest biome has been subjected to inter- and intra-annual climate variability associated with multi-year drought periods and extreme dry years (cf Schweingruber, this volume), which in turn are associated with insect outbreaks (cf Holling 1992) and lightning fires (FIRESCAN Science Team 1996; Clark and Richard, this volume).

Among these natural disturbances, lightning-ignited fire is the most important factor controlling forest age structure, species composition and physiognomy, shaping landscape diversity, and influencing energy flows and biogeochemical cycles.

Small and large fires of varying intensity have different effects on the ecosystem. High-intensity fires lead to the replacement of forest stands by new successional sequences, offering a rich variety of floristic and faunistic habitats. Low-intensity surface fires favor the selection of fire-tolerant trees such as pines (*Pinus* spp.) and larches (*Larix* spp.) and may repeatedly occur within the lifespan of a forest stand.