Boreal zone

8.1 Distribution

The Boreal zone is the only ecozone limited to the Northern Hemisphere. It is circumpolar with a north south extent of at least 700 km; in North America it reaches a maximum of 1,500 km and in Asia 2,000 km. On the east coast of the continents its southern boundary extends to 50°N but only 60°N on western coasts because of warm ocean currents, such as the Gulf Stream and the Kiroshio. Apart from some areas of tundra, Canada, Alaska, Scandinavia, northern Russia and Siberia belong entirely or in large part to the Boreal zone. The zone is bordered to the south by steppes in the center of the continent and elsewhere by the Temperate midlatitudes. The northern boundary coincides with the *polar treeline* at about 72°N in Russia and 69°N in Canada. It is the fourth largest ecozone with a total area of almost 20 million km^2 or about 13% of the land mass.

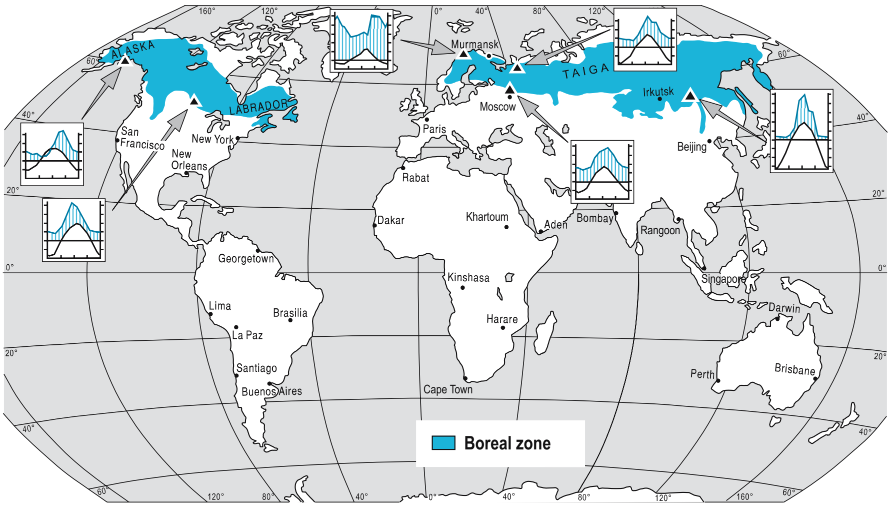


Fig. 8.1. Boreal zone

8.2 Climate

The Boreal zone has four to five, maximally six months with a mean monthly temperature of ≥ 5 °C. This is generally also the length of the *growing season*. Mean monthly temperatures of ≥ 10 °C occur in one to three, occasionally four months. In the interiors of continents the growing season can be as short as 2 to 3 months but in all of them the mean monthly temperature is > 10 °C.

The *boreal coniferous forest* is the characteristic plant formation for the zone. It is still relatively unexploited. To the south, where there is sufficient moisture and the growing season is at least 6 months and there are about 4 months in which the mean monthly temperature is ≥ 10 °C, the Boreal zone merges with the Temperate midlatitude zone. Elsewhere the steppes and semi-deserts of the Dry midlatitude zone form the boundary.

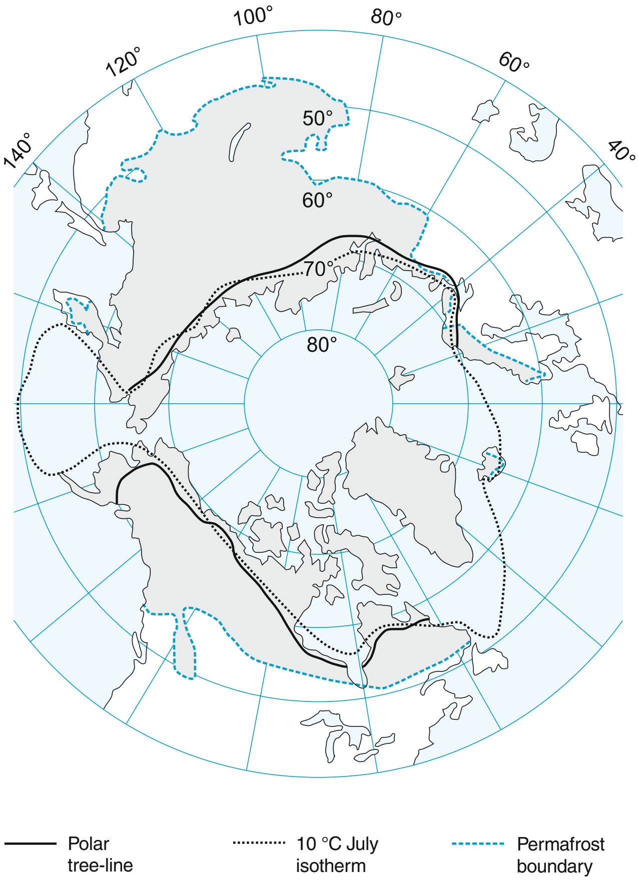


Fig. 8.2. 10 °C isotherm for July and the polar tree line in the Northern Hemisphere. Source: Stäblein 1987

To the north beyond the polar tree line, the tundra begins. The tree line lies very close to the 10 °C July isotherm (Fig. 8.2). The distribution of the permafrost and the tree line so not coincide.

The annual precipitation in the zone ranges from 250 to 500 mm, maximally up to 800 mm. Exceptions are the western and eastern coastal areas and islands of North America and Eurasia where precipitation totals can be considerably higher. Although higher than in the tundra, annual precipitation in the Boreal zone is relatively low compared to other humid zones. A large proportion of the precipitation falls as snow but the total is generally less than the total rainfall in the area. Winter snow cover ranges from 30 to 100 cm in depth, more than in the tundra, but of shorter duration, generally staying on the ground for only 6 to 7 months.

At the summer solstice there are at least 16 hours of daylight on the southern boundary of the zone and 24 hours in the most northerly areas. Similar to the tundra, the low intensity of radiation, is partially compensated for by longer hours of sunshine. The global radiation from May to July has a peak value of about 60×10^8 kJ ha^{-1} mon^{-1} or more, similar to climatic zones to the south during this period.

Air temperatures remain, however, low because a large proportion of the radiation is reflected by the extensive snow surface or transferred as latent heat by evaporating meltwater later in the season The period of higher radiation values and positive radiation balance is relatively short and the initially frozen and later, after thawing, saturated soil has a high heat capacity and conductivity and warms up only very slowly.

West east change in the degree of *continentality*, or distance from the oceans, is the reason for a regional climatic differentiation in Eurasia and, to a lesser extent, in North America. Temperature differences in both summer and winter are largely determined by the extent to which the equalizing influence of the oceans reaches into the continents. Extremes are shown in the climatic diagrams 1 and 2 in Fig. 8.3. The first showing data from a station in central

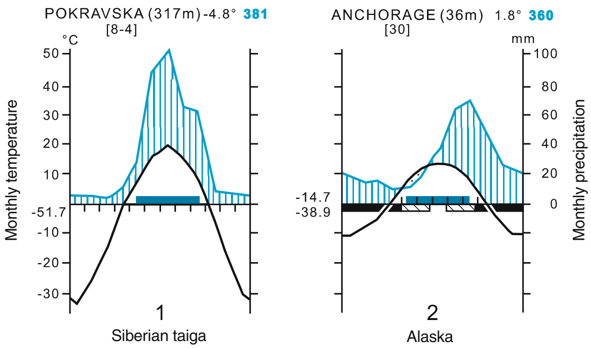


Fig. 8.3. Climates in the Boreal zone. 1. cold maritime climate 2. cold continental climate. Temperature amplitudes and the proportions of the total precipitation falling in summer increase with increasing continentality

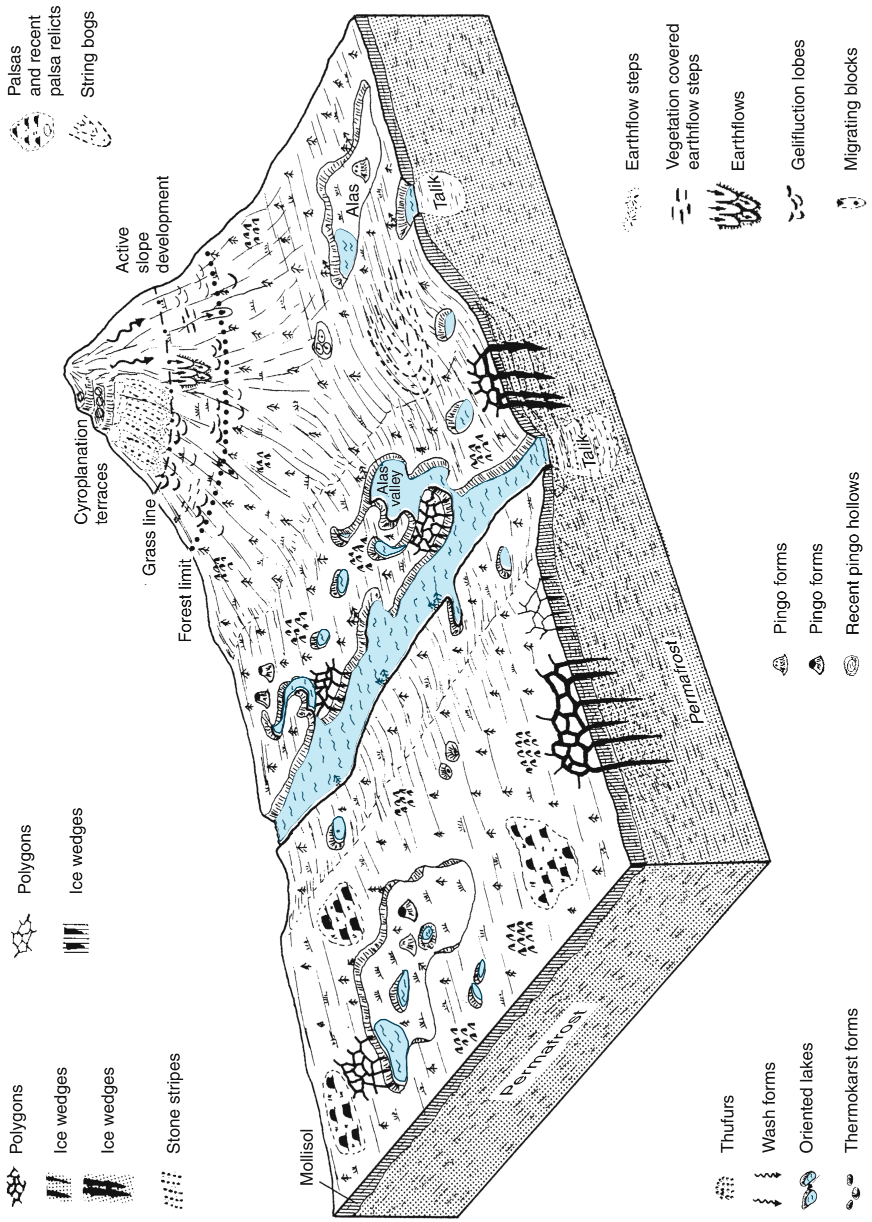


Fig. 8.4. Block diagram of landforms in a periglacial area of the Boreal zone. Source: Karte 1979

Siberia is an example of cold continental climate. Winters are very cold with absolute minima down to an extreme of −70 °C and summers warm but short with a maxima over 30 °C. The mean annual temperature is usually below −5 °C but the range of the temperatures is greater than in any other ecozone. Snowfall is low and below a certain depth the subsoil is permanently frozen.

Diagram 2 in Fig. 8.3, shows data from southern Alaska for a cold oceanic climate. Summers are cooler than further inland and winters considerably milder. The annual temperature range is consequently much smaller and the mean annual temperature higher at around 0 °C. Snow cover is deeper and permafrost is discontinuous or sporadic and in a few areas absent altogether.

8.3 Relief and drainage

Similarly to Polar subpolar ecozone, the Boreal zone was largely covered by the inland ice during the Pleistocene Ice Age. An exception was Siberia where only the central uplands and eastern mountain ranges were ice covered. The present landscape has developed, therefore, relatively recently and soils are maximally 12,000 years old. In contrast to the Temperate midlatitudes most of the Boreal zone lies in the center of the area covered by the Pleistocene ice mass. Glacial erosion processes have dominated leaving rock surfaces, roche moutonnees and rock basins, which now often form lakes. Glacial and fluvioglacial deposits are largely absent. Where they are present, they are related to material deposited as the ice retreated and melted.

As in the Polar subpolar zone, processes and forms resulting from *frost action* predominate. Large parts of the Boreal zone in Eurasia are in the area of *continuous permafrost*. In nearly all the remainder of the zone, particularly in North America, *sporadic permafrost* is widespread. String bogs, palsas, frost wedges and thermokarst are typical forms. *String bogs* develop on slopes as long narrow ridges of *peat bog* on which dwarf shrubs grow. They form a pattern of stripes or less often a network. The lower areas between the peat ridges

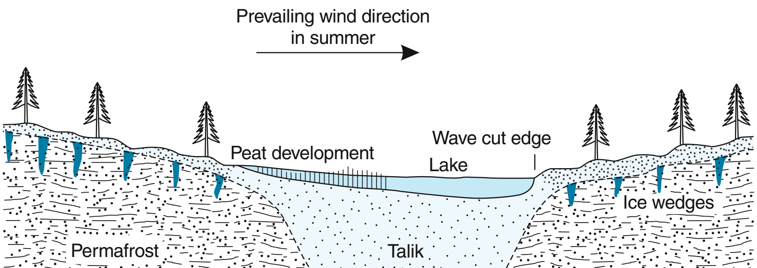


Fig. 8.5. Thermokarst lake. Subsidence at the surface is due to local more rapid thawing. Source: Butzer 1976

are usually water filled. String bogs run at right angles to the slope angle and are probably formed when the vegetation cover is torn over short stretches as a result of soil movement. Thermokarst forms extend as shallow hollows sometimes over many kilometers the result of local more intensive thawing of the permafrost, particularly if it contains a high proportion of ice, which causes loose material to collapse when water in the permafrost flows away after the ice thaws.

In sporadic or *discontinuous permafrost*, the thawing processes are frequently related to small areas of fossil permafrost. They can also occur in continuous permafrost after, for example, forest fires or clearing of the forest. Once the forest is removed the solar radiation is no longer absorbed on the crown but on the forest floor where warmer and dryer conditions are created. The permafrost thaws to a greater depth at these locations and, depending on the volume of ice in the soil, hollows form at the surface. The hollows fill with water which increases the absorption of radiation and heat flow in the soil. The thawing process is thereby accelerated and the hollows deepened. The process can be further intensified by the increased rate of decomposition of dead organic matter in the soil, formerly preserved in the permafrost. Several positive feedbacks take place in the interaction of these processes (Fig. 8.6).

If conditions are reversed lakes or ponds of this type are filled in and the newly developed vegetation cover has an insulating effect. The summer heat

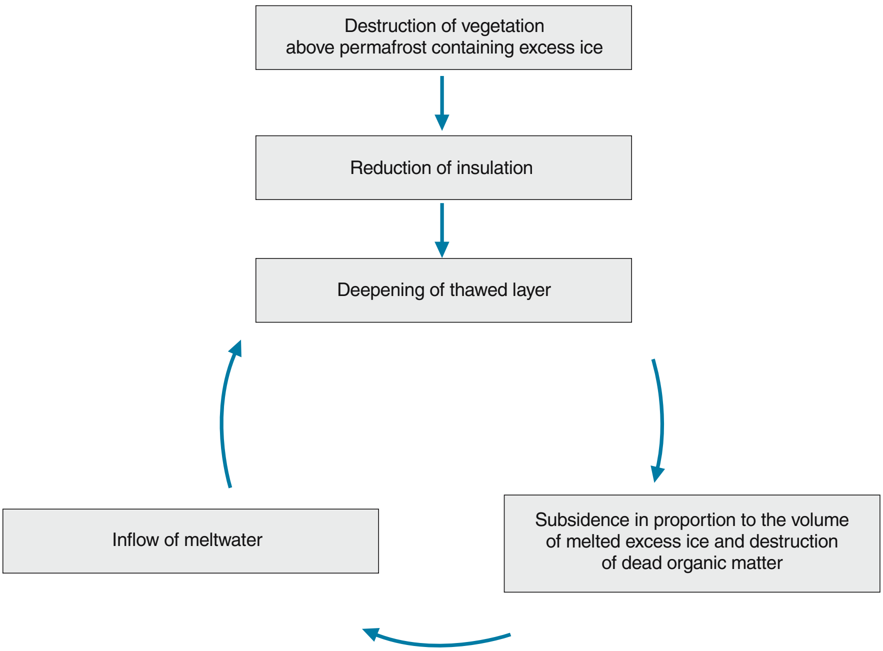


Fig. 8.6. Development of hollows following forest destruction.

flows in the soil are then reduced and large soil ice masses may develop which arch up the surface.

Stream flow in the Boreal zone is highly variable. In April or May the snow melts within a few weeks in entire stream basins, particularly if they are small, leading to extreme peaks as the streams flow simultaneously over the frozen surfaces. In the valleys, the spring meltwater flows over still frozen rivers, sometimes forming new channels. Braiding frequently follows.

After the snow melt, stream flow decreases rapidly. Summer rain, which is not large, does not contribute to groundwater storage because evaporation during the warmer months is more or less equal to precipitation. With the decrease in the air temperature and therefore also evaporation in the autumn, the surplus precipitation results in a small increase in the stream flow. As soon as the winter snow falls, this trend is reversed From now on, there is only groundwater storage flow which reaches its minimum before the snow melt in the following spring. In stream basins that lie entirely in areas of continuous permafrost, all flow ceases completely as soon as the summer thawed layer is refrozen.

8.4 Soils

Deep litter layers that are thicker than the underlying Ah horizon are characteristic of the soils in the Boreal zone. They are largely the consequence of the slow decomposition of the resinous conifer needles and the small hard leaves of many dwarf shrubs (Calluna, Vaccicium, Erica, Andromeda) in the cold and wet conditions that dominate for much of the year and which lead to the development of a highly acid litter and soil. *Peat* is present where there are stagnant conditions or the groundwater table is near the surface. Otherwise *raw humus* has developed. Both types of humus formation contain very low levels of nutrients because of the slow mineralization rates, and tend to lie at the surface, unmixed with the horizons beneath.

Podzols are widespread in the Boreal zone. They are the product of the podzolization process in which humins produced by decomposition in an acid environment are soluble and are carried down through the soil profile in seepage water to a lower level where they are precipitated out. In addition to the organic compounds, Al and Fe oxides (sesquioxides) produced by silicate weathering are also leached and deposited in the lower horizons.

With the removal of the humins and sesqioxides, a 20 to 60 cm ashy grey colored eluvial Ae or E horizon develops beneath the dark grey Ah horizon. Below the eluvial horizon is an illuvial horizon (Spodic B horizon) in which the dissolved material has been precipitated out.

The upper part of this horizon (Bh horizon) is dark brown in color because of the accumulation of humus colloids. Below, the sesquioxides give a more rusty brown color to the Bs horizon (Fig. 8.7).

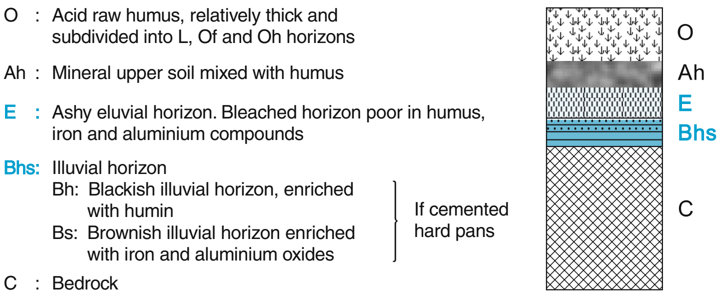


Fig. 8.7. Podzol profile

High concentrations of iron (Fe) can lead to the development of a hardened layer which usually contains a high proportion of large pores. Water can percolate in these conditions but root development may be limited. Acidity, low CEC and base saturation, coupled with a sandy A horizon in which there is little clay to prevent water percolating through and cementation in the B horizon, together underlie the low fertility of the podzols.

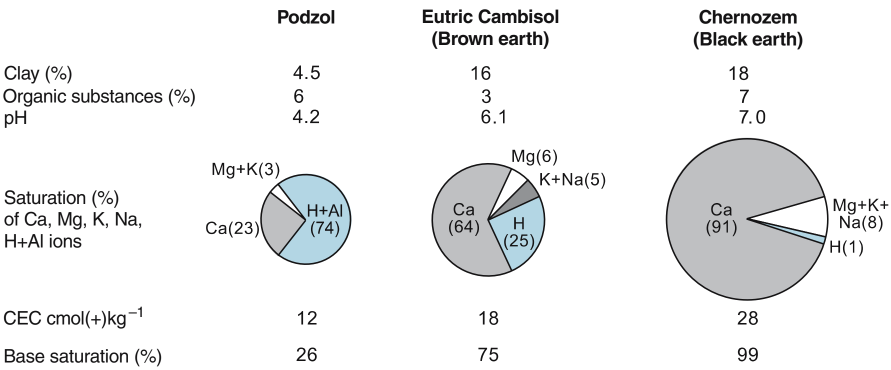


Fig. 8.8. Cation exchange capacity (CEC), cation composition and base saturation in a Podzol, a Eutric Cambisol (Brown earth) and a Chernozem (Black earth). The Podzol is the least favourable of the soils in all respects: its CEC is one-third smaller than that of the Cambisol and less than half that of the Chernozem; and only a quarter (26%) of the CEC is saturated with basic ions; i.e. in the Podzol only 3 cmol(+)kg^{-1} are attributed to nutrient ions. In the case of the Cambisol, this value amounts to 13.5 cmol(+)kg^{-1} (three-quarters of 18) and in the case of the Chernozem to 28 cmol(+)kg^{-1} (almost the entire CEC). Cambisols possess therefore four times as many and Chernozems nine times as many nutrient cations as the Podzols. If the soil depth and the root depth are taken into account, there is an even greater difference in the availability of nutrients. Despite the relatively high share of organic matter in Podzols, 6%, compared to 7% in Chernozems and 3% in Cambisols, it is composed largely of biologically inactive raw humus in which plant remains are hardly decomposed. Source: Schroeder and Blum 1992

Histosols have developed in the Boreal zone in areas of poor drainage in the extensive lowlands of western Siberia and parts of central Canada where deep horizons of peat have been formed. They have a depth of at least 40 cm, increasing to 60 cm if the proportion of peat mosses is high. Hydromorphic soils of this type belong to the Gelic Histosols or, if they lie outside the areas of permafrost, to the Fibric Histosols.

In the more pronounced continental areas of central and eastern Siberia and the Canadian Rockies, *Cambisols* dominate, either Gelic or Dystric or more seldom, Eutric Cambisols. Gelic Leptosols occur on steep slopes. Both Leptosols and Cambisols are relatively underdeveloped soils with only a Bw horizon or AC Profile. Similar to the Podzols, fertility is low because of high acidity, lack of plant nutrients and a disadvantageous environment.

8.5 Vegetation and animals

Despite the large extent of the Boreal zone, there are few regional variations in the vegetation. Over the entire area *coniferous forests* and occasional areas of mixed forests are separated by numerous, often partially filled in, lakes and oligotrophic peat bogs. In the north of the zone, the *forest tundra* forms a transition zone with the tundra. The total number of species in the boreal regions is small although larger than in the tundra.

8.5.1 Boreal coniferous forest

Spruce (Picea), pine (Pinus), larches (Larix) and firs (Abies) cover thousands of square kilometers in single species stands. Deciduous larches extend over large areas of the interior of Siberia and form the polar tree line for all of Siberia.

Conifers replace their needles over a period of several years so that their requirements for minerals is much lower than deciduous trees which renew their foliage each spring (Chap. 9.5.4). The continuous shedding of needles over a long period is, in effect, a reflection of the poverty of minerals in the soil, the limitations on root growth because of the permafrost, the winter cold and the absence of moisture due to frost. Lack of nutrients is also expressed in the sparse stands and, compared to the spruce and fir stands of the midlatitudes, slender growth.

Unlike coniferous forests in temperate zones, a cover of shrubs and herbs is well developed. Deciduous species such as birch (Betula), poplar (Populus), willow (Salix), alder (Alnus) and ash (Fraxinus) are frequent. The herb layer includes lichens and, where stands are denser, mosses. There is also a relatively high proportion of dwarf shrubs.

The large scale differentiation of forest cover reflects the north-south differences in climate. In Russia there are three zones, the northern, central and

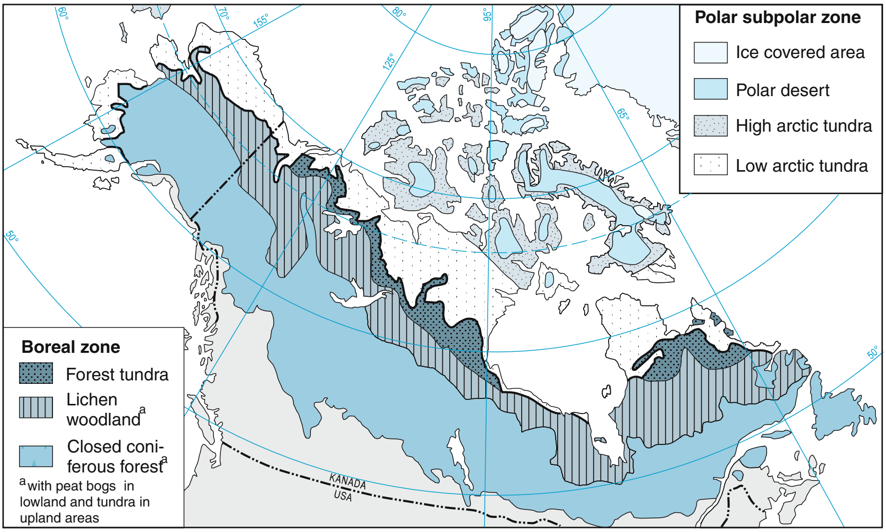


Fig. 8.9. Distribution and subdivisions of the Polar subpolar zone and Boreal zone in North America. Source: Elliot-Fisk 1989 and Bliss et al. 1981

southern *taiga*, and in North America, two: a northern area of open lichen woodland and a southern zone of closed stands of woodland (Fig. 8.9).

Small scale differentiation in the boreal forests can relate to variations in soil moisture or to exposure to solar radiation but more commonly it represents different stages of regeneration. The renewed growth in woodlands that follows events such as local forest fires, damage by insects, wind destruction or flooding results in a physiognomic and to some extent also floral mosaic composed of rejuvenation, mature and aging phases. A steady state in the sense of a forest preserved over a long period does not occur. While the stands of different age constantly change their position within the vegetation mosaic, the overall ecosystem remains stable for thousands of years. Age related changes in plant cover take place rapidly at the beginning of a regeneration period but then slow down so that the later stages of plant cover tend to be dominant in a forest mosaic.

8.5.2 Peat bogs

Peat bog covers at least 10% of the surface in most parts of the Boreal zone and in a few areas a considerably higher proportion. Trees are absent and plant life is confined to a very few species of moss, sedges (Carex, Eriophorum) herbs and dwarf shrubs. The ability of sphagnum mosses, the main component of peat, to store water allows the bog to develop above the original stagnant water level. Deposition from the atmosphere is the only source of minerals in a peat bog. Bog convexity increases with the favorability of conditions for peat bog development. Maritime climatic conditions are more suitable than the interiors of continents where in general summers are too warm and dry.

The accumulation of *carbon* stored in the post Ice Age boreal and subarctic bogs has been estimated at 455 Gt which is approximately one quarter of world wide organic carbon (Gorham 1991). This is based on a total peat area of 3.42 million km^2, a mean peat thickness of 2.3 m, a density of 0.122 $g\,cm^{-1}$ and a carbon content of 51.7%. The mean growth rate in the post Ice Age period, the *net sink*, has been estimated at 0.096 Gt^{-1}. At the present time the growth rate is estimated to be 0.076 $Gt\,a^{-1}$, or 23 $g\,a^{-1}$ per square meter of peat bog, an annual growth of peat (dry weight) of approximately 0.5 t per hectare (Fig. 8.13).

8.5.3 Forest tundra, polar and forest tree lines

Forest tundra is a transition area between tundra and boreal coniferous forest that ranges in width from 10 to 50 km, maximally 300 km (Fig. 8.9). Trees are sparsely distributed or, more typically, there is a mix of tundra and forest in which the areas of tundra increase towards the pole and of forest southwards (Fig. 8.10).

The *polar tree line* (Fig. 8.2) links the most northerly occurrence of individual or small stands of trees. Usually only trees of at least 5 meters in height are

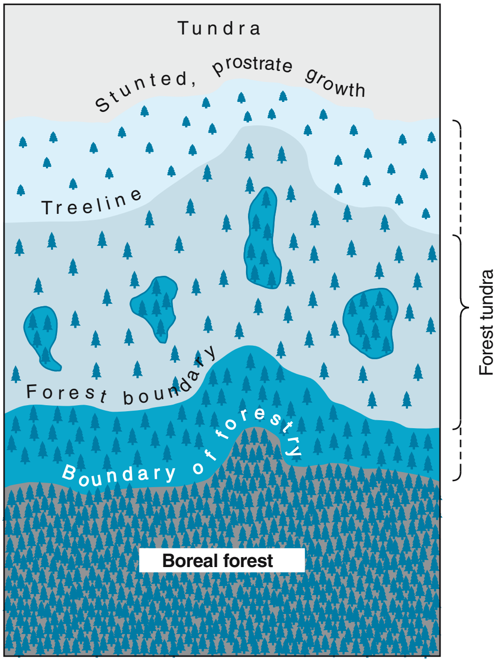


Fig. 8.10. Forest and treeline in the transition area between boreal coniferous forest and tundra. Source: Hustich 1966

included. The *forest line* is the northern boundary of areas of more or less continuous forest cover. Conifers dominate everywhere except in the maritime areas of Scandinavia, Greenland and Kamchatka where there are also stands of birch. Larsen (1981) defines the forest tundra as beginning where the forest cover falls below 75%. Areas that are treeless because of the soil conditions are not included in the estimate.

The location of the polar tree line is determined by the duration and extent of the summer warm period. If the growing season has a mean of $t_{mon} \geq 5\,°C$ over less than 4 months, or a diurnal mean of $\geq 5\,°C$ over less than 105–110 days, or no month with more than $t_{mon} \geq 10\,°C$, or the sum of all diurnal means $> 0\,°C$ is less than 600, trees cannot develop cold new shoots and assimilation organs to the point where they will be able to withstand the cold, dry winter to come. In addition, the ability of trees to produce seeds or of seeds to germinate is limited to summers or a series of summers in which the temperature lies considerably above the mean, or when the minimum temperature for germination, especially in the soil, is exceeded. Towards the tree line the frequency of exceptionally warm summers falls to near zero. Most trees in the forest tundra tend to belong, therefore, to one of the few years in which conditions were suitable for germination. A consequence of this is that stands of similar age are characteristic of the forest tundra.

8.5.4 Biomass and primary production

The *biomass* of a mature boreal coniferous forest ranges from about 150 $t\,ha^{-1}$ in the north of the ecozone to about double this quantity in the south. The increase in height of the trees and densities of the stands from north to south reflects the progressively more favorable climatic conditions for growth.

Primary production of the plant cover is limited everywhere in the zone by climatic factors and the lack of mineral nutrients. The mean annual production of biomass is little more than 4 to 8 $t\,ha^{-1}$, whereby the larger amounts are attained only on the nutrient richer, warmer soils of south facing slopes in the southern taiga.

8.5.5 Decomposition, organic soil matter and mineral reserves

The *decomposition rate* of organic waste is very low, much lower than in a deciduous forest of the midlatitudes (see also Chap. 9.5.4). *Fire* plays an important role in decomposition. The mean reoccurrence interval of forest fires is only 50 to 100 years. Lightening is the most common cause, in contrast to the savanna and tropical rainforest where fires are usually started by man. Forest growth on the burnt over areas benefits from the increased supply of minerals available following burning as well as the lowering of the permafrost table and increased decomposition rates that result from the soil being heated to a higher temperature and greater depth by the fire. In the first stages of

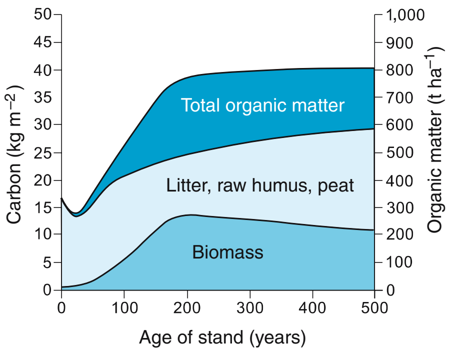


Fig. 8.11. Changes in biomass and soil organic matter in relation to the ages of stands in boreal coniferous forest. Because of its very low rate of decomposition, organic carbon in the soil might increase for several hundred years before there is an equilibrium between delivery of organic matter and decomposition. In Fig. 8.11 this has not ocurred after 500 years and the forest remains a net sink for carbon. The biomass does not increase after 200 years, reaching a level of about 300 t ha^{-1}. It then declines slowly. Source: Kasischke et al. 1995

regeneration after a fire, a cover of shrubs develops in which more demanding broadleaved species such as poplar and birch dominate. There is also a greater variety of fauna.

The greater the amount of dead organic matter in the soil, the longer the period since the last forest fire. After a long absence of forest fires, the layer of litter on the ground in old stands can reach up to 1,000 t ha^{-1}, far exceeding the quantity of living organic matter in the vegetation (Fig. 8.11).

Large amounts of carbon and mineral nutrients are bound in the dead organic matter; with the development of peat, some minerals are even lost from the cycle for ever, particularly the available stocks of nitrogen, calcium and to a lesser extent, potassium. Shortages that result from insufficient nitrogen recycling are partly compensated for by retranslocation from needles and leaves which covers 30% to 40% of nitrogen requirements, also by a very high nitrogen use efficiency of over 200 and by the N_2 fixation by blue-green algae which contributes considerably to the supply of anorganic nitrogen (ammonium).

The volume of soil affected by decomposition and the rate of decomposition depend on the depth of the summer thawed layer (active layer) and the extent to which it is heated. Because of the large quantities of humus stored in the Boreal zone soils, it is likely that changes in the climate will have a major effect on the release or binding of carbon, and consequently the CO_2 balance in the atmosphere. The *global warming* that is believed to be taking place is, in large part, thought to be caused by the measurable increase in CO_2 in the atmosphere (Fig. 8.13). Should this be correct, an increase in the amount of carbon released in northern areas would help to accelerate global warming, which, in turn, could further increase the rate of carbon release.

It is questionable whether such positive feedbacks would develop. If a long lasting warming of the climate occurs, it is probable that the production capacity and area of the boreal forest and tundra would also increase and the forest boundary move closer to the poles. An increase in the amount of organic bound carbon in the biomass would also then follow and the former net release from dead organic soil matter possibly compensated for (Kolchugina and Vinson 1993 and Shaver et al. 1992).

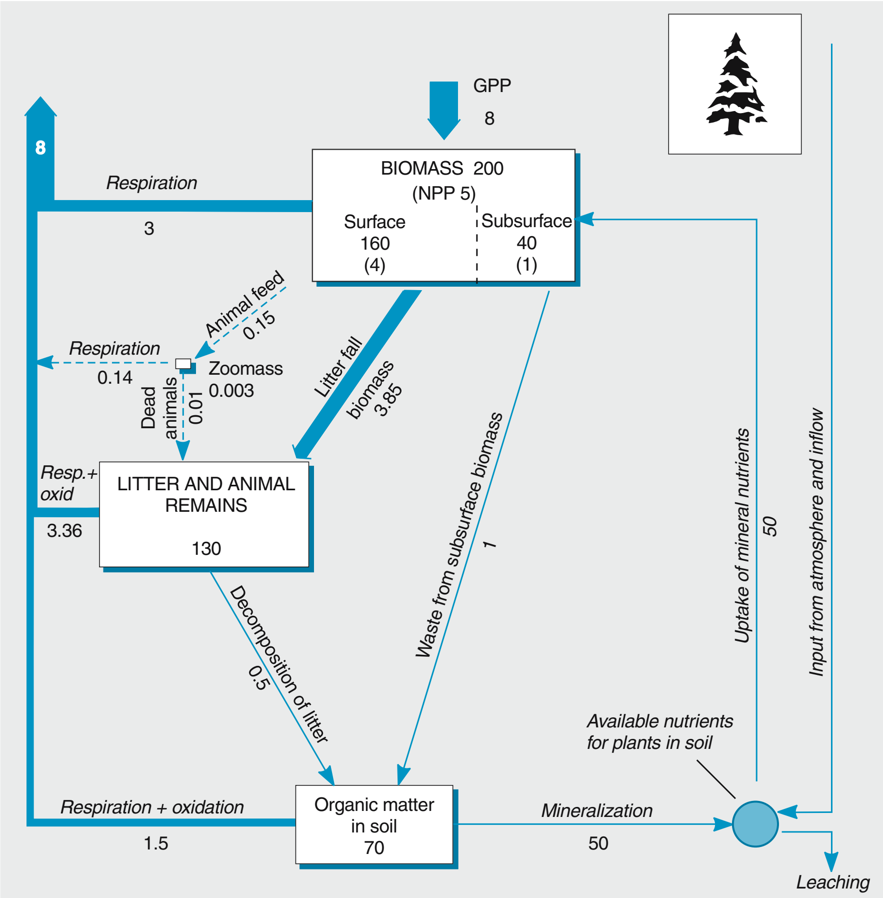


Fig. 8.12. Model of ecosystem of a boreal coniferous forest. Characteristic for these forests is that the large supply of dead organic matter, litter and humus in and on the soil, is approximately equal to the supply of living matter. Two-thirds is litter, which is decomposed at a rate of only 3% per year. There are few animals. Fire is more important for nutrient recycling than animal feeding. The supply of minerals available to plants in the soil is small. Width of arrows, areas of circles and boxes are approximately in proportion to the volumes involved. Organic substances in $t\,ha^{-1}$ or $ha^{-1}\,a^{-1}$, minerals $kg\,ha^{-1}\,a^{-1}$. Source: Persson 1980, Shugart et al. 1992

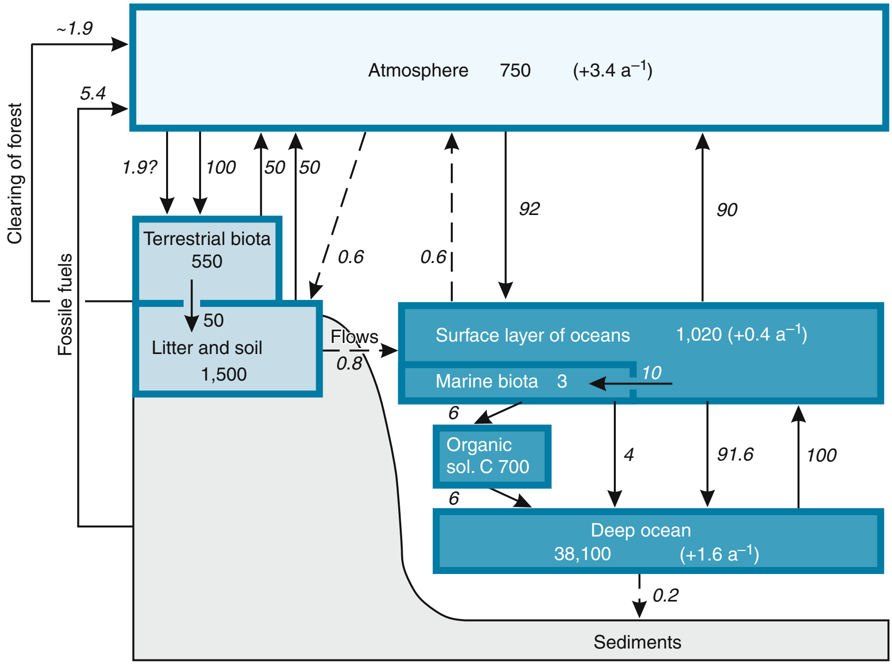


Fig. 8.13. Global carbon circulation. Gt C = 10^{15} g C. Data is for the period 1980–1989. The man-made emissions of carbon dioxide, largely the result of the burning of fossil fuels (5.4 Gt) and the clearing and burning of tropical forests (1.9 Gt) amount to an estimated 7.0 ± 1.1 Gt C a^{-1}. About 3.4 Gt is taken up by the atmosphere, in which carbon dioxide is increasing. About 2.0 Gt ± 0.6 are absorbed by the ocean, mostly the deep oceans. The remaining 1.9 Gt is not fully accounted for. Some may be taken up by the boreal forests and peat bogs and in the tundra. Probably CO_2 released by burning is less than estimated, with some of the amount going into an increasing biomass, the result of the improved CO_2 supply in the primary production, larger supplies of nitrogen oxide from the atmosphere and higher applications of fertilizer. Also, in North America, fire protection measures and reaforestation have resulted in an increase in the wood mass. The missing sink would probably be equal to the CO_2 stored by the boreal and subpolar ecosystems, estimates for which range from 0.5–0.8 Gt. Source: Siegenthaler and Sarmeinto 1993

Because of the greater nitrogen supply from the atmosphere, the growth in biomass will probably be reinforced, if it has not already occurred since man has largely been the cause of the increase by burning, cultivating legumes and fertilizing his fields. The estimated amount of biologically usable nitrogen (nitric oxide, ammonium) induced by man world wide ranges from 132 to 153 million t a^{-1}, compared to the 140 million t a^{-1} that are created naturally (Vitousek et al. 1997). The mean supply of nitrogen to plants has almost doubled in recent decades. Regionally, this has been concentrated in northern and central Europe.

8.5.6 Boreal coniferous forest ecosystems

The model in Fig. 8.12 attempts to show the mean supplies and turnovers of boreal coniferous forest ecosystems in conditions of steady state. The assumptions in the model are, in fact, unrealistic since both the tundra (Fig. 7.18) and the boreal forests and peat bogs are exceptional among ecosystems in that they probably continuously produce a surplus of organic material (Apps and Price 1996, see also Fig. 8.11). All other ecozones show a balance in the medium term. Bird et al. (1996) have confirmed this supposition on the basis of C^{13} and C^{14} measurements. Apps et al. (1993) estimate the annual storage of org. C at 0.7 Gt in the Boreal zone and 0.17Gt in the tundra.

These estimates would indicate that in the Boreal zone and the tundra over 400 Gt (Waelbroeck (1993) or possibly even 700 Gt (Apps et al.(1993) of carbon are bound in the organic soil material in the form of litter, humus or peat. A very large amount when compared to the estimated 1,500 Gt supply of org. C in soil worldwide and the current approximate 750 Gt of anorg. C (as CO_2) in the atmosphere (Fig. 8.13).

Price and Apps (1995) and Waelbroeck have also estimated about 100 Gt for carbon stored in the vegetation (standing biomass) in both ecosystems. If it is assumed that the tundra and boreal forests cover about 25 million km^2 and that 1 g org. C corresponds to a 2.2 g of dry matter in a biomass, a total of 100 t of biomass per hectare results. This value is certainly below the actual value for forests, but when approximately 10 million km^2 of biomass poor tundra are taken into account, the 100 Gt is probably a realistic estimate.

The stored carbon in the soils and biomass of the high latitudes total about one-third of the available supplies on the landmasses of the world although the boreal forests and tundra cover only one-sixth of the total area. On the basis of these data, it would appear that the protection of the boreal forests is of similar importance to the protection of tropical rainforests.

8.6 Land use

Although rich in mineral resources, the Boreal zone coniferous forests are one of the least densely populated regions of the world, with fewer than 5 inhabitants per km^2 in most areas. It is also one of the regions least affected by man. The felling of timber, peat cutting, as well as traditional hunting for furs and the collecting of berries are the main economic activities. Agriculture is unimportant but it is hoped that the management of game and tourism have a future.

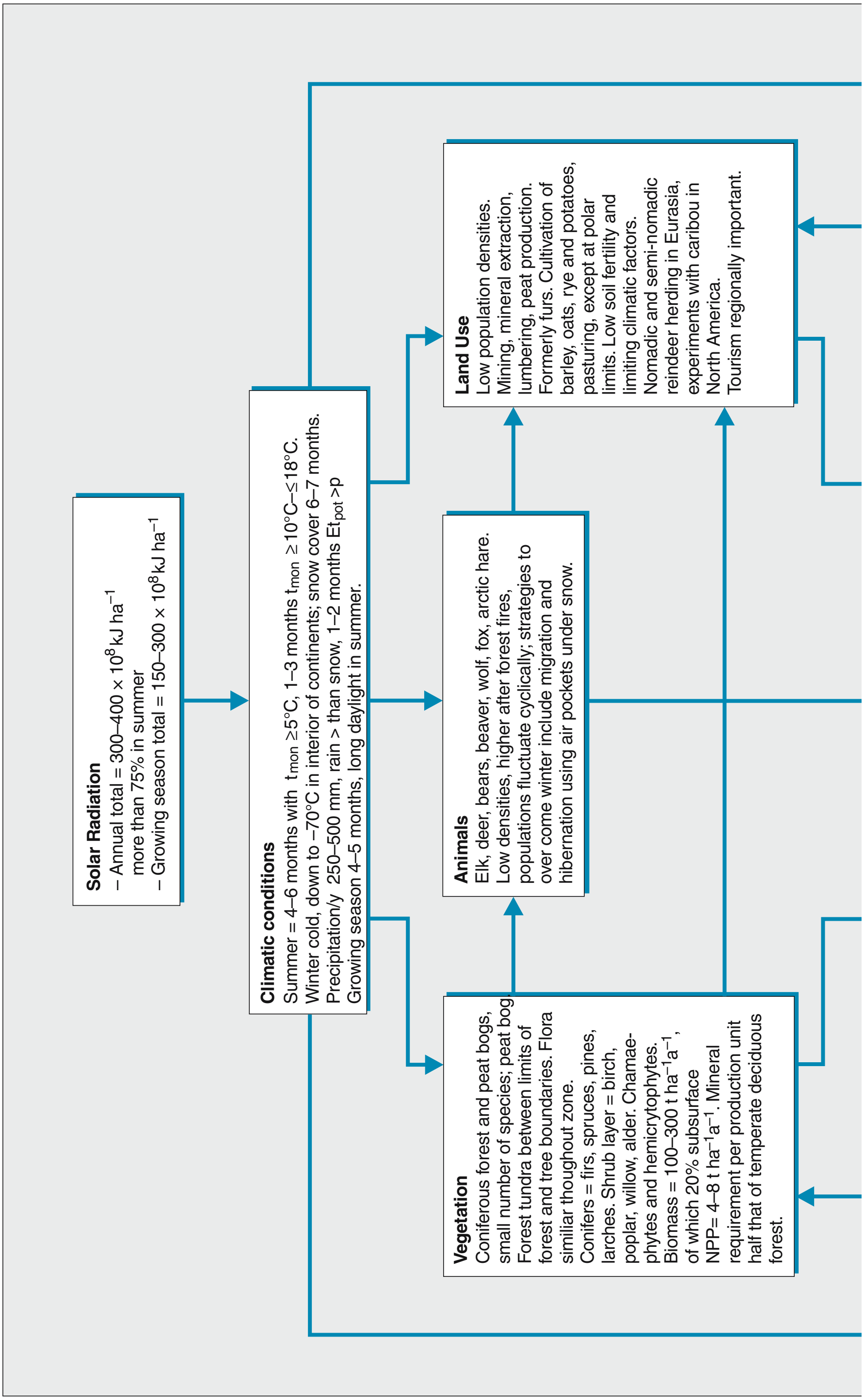
The production of timber covers 90% of the world's requirements for paper and saw timber. These volumes must be seen in relation to the vast area covered by forest. The actual area affected by forestry is small. It is estimated that the boreal forests contain three-quarters of the world's reserves of softwoods.

The problems related to commercial forest increase from south to north, included are

1. Distance and consequently long transportation routes to manufacture and consumption centers. Rivers flow northwards and cannot, as elsewhere, be used for timber transport. Few people are available to work in the forests.
2. Low temperatures and deep snow in winter.
3. Low usable quantities of timber per surface area, low quality of timber, stands are not dense, trees are not tall.
4. Low growth capacity. Regeneration of the forest or reaforestation require longer periods than in the midlatitudes before timber can be cut again. In order to retain reserves of timber, it is essential not just to exploit forests, as has usually occurred, but for there to be simultaneous reaforestation.

The working of peat is particularly important in the Eurasian part of the Boreal zone (Paavilainen and Päivänen 1995). In the area of the former Soviet Union reserves are estimated at 200 to 250 billion tons, 66% of the world total (Gore 1983). Worldwide 170 million tons were produced in 1984 and 217 million in 1989. About 90% was used to improve soil for cultivation and the remainder as fuel in power plants or for heating buildings in remote settlements.

Agriculture is possible in permafrost areas if the depth of thaw in summer is at least one meter. The polar limit for cultivation lies about 5° to 10° latitude south of the forest boundary Spring barley is the northernmost cereal crop, maturing in 90 to 95 days, with a limit of cultivation in northern Europe of about 70°N. Spring oats and rye are grown further south. Both are less demanding on the soil and can be grown on nutrient poor Podzols. Potatoes are the most northerly root crop and are also grown up to 70°N in Scandinavia. Most northern forest areas in Eurasia are used as pasture for reindeer. In North America these areas are unusable for most forms of agriculture. Because of the limited agricultural potential of the Boreal zone, other forms of animal husbandry such as a controlled use of the undomesticated caribou and the management of moose and American elk are being examined.


Solar Radiation
– Annual total = 300–400 × 10^8 kJ ha^{-1} more than 75% in summer
– Growing season total = 150–300 × 10^8 kJ ha^{-1}
Climatic conditions
Summer = 4–6 months with t_{mon} ≥5°C, 1–3 months t_{mon} ≥10°C–≤18°C.
Winter cold, down to –70°C in interior of continents; snow cover 6–7 months.
Precipitation/y 250–500 mm, rain > than snow, 1–2 months Et_{pot} >p
Growing season 4–5 months, long daylight in summer.
Land Use
Low population densities.
Mining, mineral extraction, lumbering, peat production.
Formerly furs. Cultivation of barley, oats, rye and potatoes, pasturing, except at polar limits. Low soil fertility and limiting climatic factors.
Nomadic and semi-nomadic reindeer herding in Eurasia, experiments with caribou in North America.
Tourism regionally important.
Animals
Elk, deer, bears, beaver, wolf, fox, arctic hare.
Low densities, higher after forest fires, populations fluctuate cyclically; strategies to over come winter include migration and hibernation using air pockets under snow.
Vegetation
Coniferous forest and peat bogs, small number of species; peat bog Forest tundra between limits of forest and tree boundaries. Flora similiar thoughout zone.
Conifers = firs, spruces, pines, larches. Shrub layer = birch, poplar, willow, alder. Chamaephytes and hemicrytophytes.
Biomass = 100–300 t $ha^{-1}a^{-1}$, of which 20% subsurface
NPP= 4–8 t $ha^{-1}a^{-1}$. Mineral requirement per production unit half that of temperate deciduous forest.

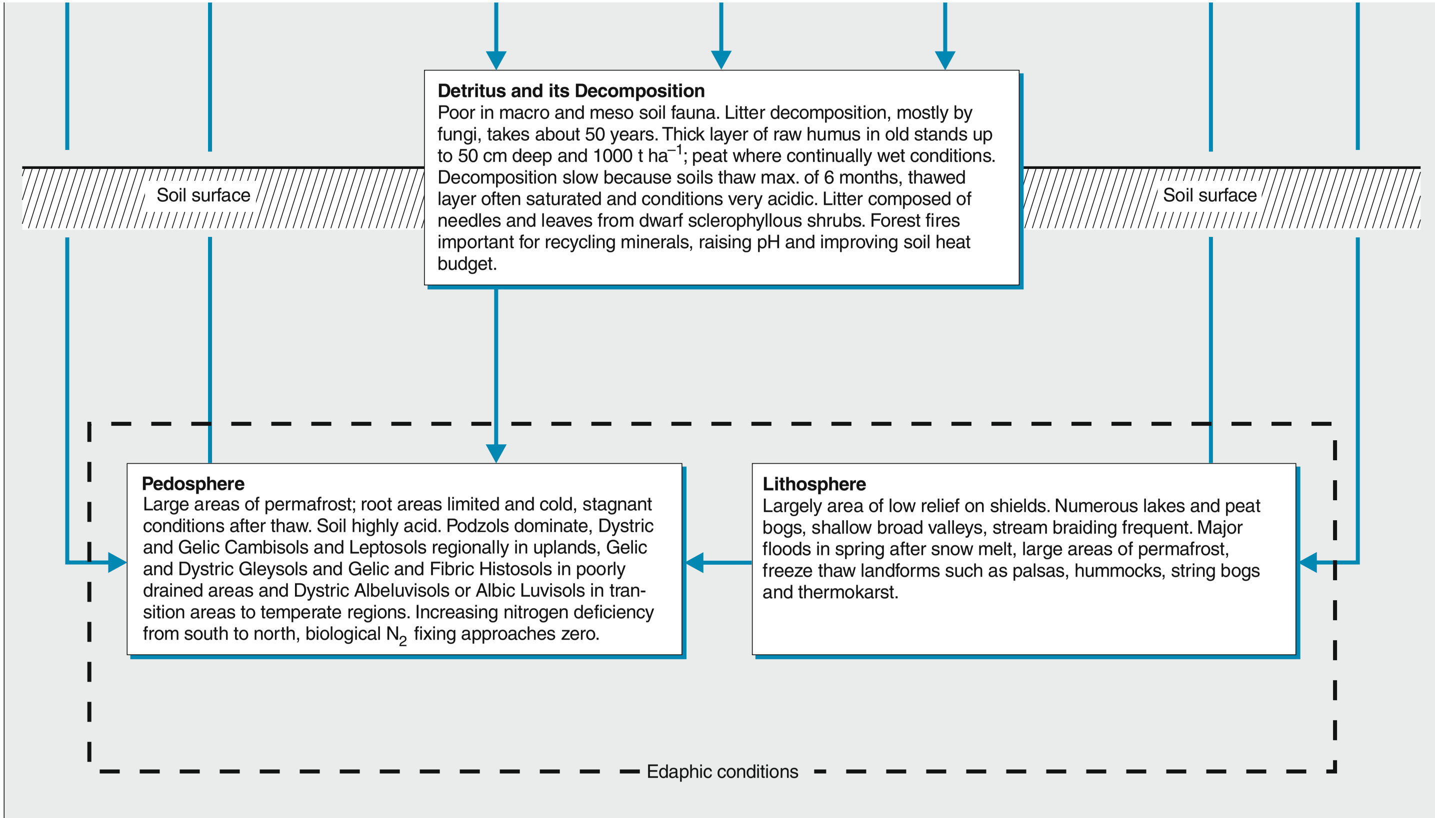


Fig. 8.14. Synoptic diagram for the Boreal zone