SUB-SURFACE PEAT FIRES

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Content

Summary

This article only considers sub-surface peat fires. A peatland fire is a type of landscape fire originating spontaneously or anthropogenically on the dried suface of bogs. Such fires are typical of the tundra, forest-tundra and taiga with peat beds and hillocks, and the depth of fire penetration can reach 3 or more meters. Peat fires are also quite common in some tropical peatlands. The area covered by peat fires is usually less impressive than that of grassland and forest fires, but its consequences, including the volume of carbon emission, are certainly comparable. Peatland fires most commonly occur in northern Eurasia (Sweden, Finland, Russia, China, etc.) and same tropical countries (Indonesia, Malaysia, Polynesia, Philippines, Papua New Guinea).

The origins of peatland fire are mainly due to human activity. In late summer and early autumn bogs are subject to increased urban and rural recreational impact.

In most of Europe, with a long practice of intensive drainage, practically every surviving bog has been given official protection. The exceptions are Sweden and Finland which have a total peatland territory amounting of 12% and 30% respectively. The peat bogs of Russia occupy a territory of 60 million ha, half of which is located in western Siberia. Large peatland areas are also present in Belorussia (10 million ha).

Surface fires normally cause very little damage to the plants and wildlife of natural bog ecosystems as the high water table limits the penetration of fire. Moreover bogs are often protected from forest fires by a wide surrounding belt of waterlogged land.

Since the start of intensive peat extraction in Russia (since the 1920s) the number of sub-surface fires in peat deposits has increased. The peak of fire frequency on bogs in Russia coincided with the highest rate of peat extraction in the 1960s and 1970s, and

with the start of the wide-scale drainage of forested bogs intended to increase yields of timber.

Since the 1980s there has been an increasing incidence of major fires in the peatswamp forests of south-east Asia. Just in Indonesia 1.45 million ha of peat wetlands have been damaged by fires.

The distinction between genuine peat and peaty soils is that the non-decomposed organic matter content of the former must exceed 15 to 29%. In extremely dry years the bog surface can be so dry that destructive processes dominate the process of peat growth. The margins of peat bogs may contract in dry phases of climatic cycles.

Bog ecosystems, like forest, steppe and tundra, are important as a carbon sink, helping to stabilize global climate. The rate of carbon deposition in bogs of the temperate zone is assessed as some millimeters annually, representing up to 10-15% of primary production of ecosystems. The contribution of tropical peat wetlands to the global carbon cycle is higher than those of most of the temperate zones: These tropical sites hold about 15% of the global peat wetland carbon.

Besides the carbon dioxide generated in the combustion of peat, other gases are also emitted in large quantities. These become components of the atmosphere and affect processes in its upper layers. These gases, principally CH_4, H_2S, H_2, N_2, are produced in the peat bed beneath the level of groundwater, under anaerobic conditions and exist in the form of bubbles which, from time to time break through to the surface of the bog. Fire facilitates the release of these greenhouse gases, with further affects on climate stability.

1. Introduction

Underground fire is a type of landscape fire originating spontaneously (as a result of self-inflammation or a forest fire) or from anthropogenic activity on bogs with a dried peat layer. They are more typical of the tundra, forest-tundra and taiga with peat beds and hillocks. The peat layer is normally more than 5 to 7 meters thick, and the fire usually penetrates to a depth of 3 or more meters. The speed of underground fire spread can reach several hundreds meters per day.

On drying or partly drained bogs, self-inflammation can arise as a result of overheating of the surface. Such fires are remarkable for their long continuation of burning, sometimes for several months or even years. Precipitation plays a determinative role in the intensity of combustion only at the initial stage or where the peat bed is of small *capacity*. If the fire has penetrated the peat bed, its spread can be limited only by the moisture content of the upper and lower layers of organic matter. The scale of coverage of peat fires is usually less impressive than that of grassland and forest fires, but their consequences, including the volume of carbon emitted, are certainly comparable. Extinguishing such fires is very difficult, potentially embarrassing, and in many cases, impossible. As a rule deep fires only affect peat bogs which have been altered by human drainage activity for purposes of peat extraction or melioration of boggy forest.

2. Surface fires as a factor of spread of peat fires

In the summer and autumn seasons of the boreal climate, the peat bogs of the tundra, forest tundra and taiga zones can be so dry that the inter-relation of the capillary level of bog water and the productive moss cover is destroyed. In other words, the plants receiving enough light are not receiving enough water, and vice versa. At these periods the bogs, initially their uppermost layer, and large tussocks, are very vulnerable to fire. The exposed parts of peat, on a bright sunny day, can be heated to temperature of more than 50 ^{o}C. The combination of dry reed *(Phragmites)*, woodreed *(Calamagrostis*), sedge *(Carex)*, and dry moss cover, provides favorable material for the spread of fire. The origin of fire is usually due to human activity, e.g. hunters, fishers, tourists, and mushroom and berry pickers, as the bogs are subject to increased urban and rural recreational impact in late summer and early autumn

Surface fires cannot do much damage to the plants and wildlife of natural bog ecosystems if they are protected by a moist surface layer pierced by fresh shoots and roots, and dead material, all conserving moisture. This factor stops fire spreading deep into a peat bed. In exposed places a surface fire driven by wind can rapidly spread, at a higher rate than that of forest fires. Fire partly destroys the dry above-ground parts of the reed, cotton-grass, dwarf shrubs and died-off moss. The trees, some of the dwarf shrubs and the vegetation of wet depressions are safe from the fire impact. Anthills inside moss tussocks are usually inaccessible to fire, and birds nesting on the bog surface are absolutely safe from fire as they finish nesting before the start of the dry season. As with forest fires, controlled fires of the bog surface can prevent the accumulation of inflammable material and hence protect the bog from disastrous fires, including underground ones.

This can be illustrated using an example from controlled fires on high bogs in Scotland. In order to provide more productive hunting ground the vegetation is burnt out in the form of patches and belts with an area of about 1 ha each (about 6 patches per 1 km^2). This results in increased foraging areas for red grouse and, accordingly, higher densities of birds during the subsequent shooting season.

Unlike forests, surface fires on bogs have a limited spread as they have a mosaic structure with permanently wet depressions and periodically dryer areas (e.g. tussocks, mounds and hillocks). Moreover many high and temporary bogs are protected from the spread of forest fire by surrounding areas with a high water table. The better drained and drier central parts of raised bogs are not accessible to surface fire.

At the same time a great number of small bogs (from 1 to 5 ha) are burnt out by surface fires. This has been demonstrated from analysis of peat accumulated during the Holocene “climatic optimum” (about 8000-5000 years ago). At that period, in conditions of dry and warm climate, intensive natural spread of forest had been taking place, following fires that destroyed the upper layers of peat beds. Their traces in the form of buried small pieces of charcoal, and scorched trunks and stumps, can be found deep in the peat beds.

The important feature of natural peat bogs is that fire does not spread down to the level of the “bog water” or the capillary level above it. The volume of peat accessible to fire in late summer increases in peat beds with varying water levels affected by the natural drainage conditions on adjacent areas (e.g. on the terraces of river valleys, and drained peat bogs). Accordingly these are the places where surface fire can be transformed into underground fire. Since the start of intensive peat extraction in Russia (about the 1920s) the number of underground fires in peat deposits has increased. The highest frequency of fires in bogs in Russia coincided with the peak period of peat extraction—the 1960s—and with the start of widespread drainage of forested bogs for increased timber production.

As a result the best conditions for transformation of surface fire into sub-surface peat fire are in reclaimed forested lands with modified drainage conditions, or where the reclamation system was not sustained. The area of lands of this type in Russia amounts to 3 000 000 ha, including 600 000 ha in Karelia, 600 000 ha in the Central Region (Moskovskaya, Tverskaya and Vladimirskaya oblasts), and more than 750 000 in the North-Western region (Leningradskaya, Novgorodskaya, Pskovskaya oblasts). These regions are often featuring in the news in Russia today, as they are subject to frequent peat fires, during the appropriate season.

Sub-surface fires present a particular problem, as traditional methods of extinguishing fire normally result in failure. Such fires often inflict casualties and economic losses. For example, in the vicinity of Moscow in 1972, there were recorded cases of fire emergency trucks falling down into burning peat beds, with the consequent death of the firemen. As a result of peat fires, the narrow-gauge railways built to transport peat and to deliver workers to the peat processing factories have been destroyed. Sometimes these mini-trains have been the cause of the fire. Normally, for confining and extinguishing a sub-surface fire it is best to dig a contour trench around the burning area, at least 1 meter wide and reaching down to the mineral layer, or at least to the water saturated layer.

It should be noted that peat fires have much in common with underground fires occurring in coal deposits, which may continue for many years. Possibly, ancient humans gained the idea of using the fossil fuel from observation of underground fires. They began to extract coal as well as peat for heating dwellings and cooking food. In the countries of western Europe the extensive peatlands had been largely drained by the Middle Ages, and the extracted peat had been used as fuel or fertilizer. In Russia peat extraction has been practiced up to the present although on a smaller scale than that in the 1920s and 1930s, when special peat-burning power plants had been built. Peat was also used as a fuel for locomotives, along with coal. In certain regions of European Russia, it is still possible to find local plants producing peat briquettes as an alternative fuel for local inhabitants.

3. The causes of peat fires

The calorific capacity of peat is higher than that of timber (see Table1). Its deeper layers in combustion produce more calories than the upper, which are less decayed. This accounts for the increasing component of humic acids and bitumen in the process of biolysis. A 10% increase of decay rate of peat provides a subsequent rise of calorific capacity by 100 to 400 calories. Accordingly, the better the drainage the higher the inflammability rate and heat emissions, because more of the decomposed peat is able to burn. The early stage of peat extraction is a dangerous time for fires, when the more decomposed material is exposed.

Type of organic matter	Composition, %			Calorific capacity of organic matter, cal
	carbon	hydrogen	oxygen and nitrogen	
Timber	50	60	44	4500
Peat -low level of decay	55	6	39	5000
Peat - high level of decay	60	5,5	34,5	5700
Brown coal	70	5	25	6200
Hard coal	83	5	12	7900
Anthracite coal	96	2	2	8400

Table 1. Calorific capacity of vegetation organic matter

At first site the words “bog” and “fire“ sound incompatible, but peatlands can serve as places of origin of large-scale fires inflicting huge damage to ecosystems and inhabitants all over the world. The damage is especially heavy in the vicinity of unique wetlands supporting rare and endangered species. In most of Europe, with a long practice of intensive drainage, practically every surviving peatland has been taken under protection. For example in France lowland peat bogs occupy only 0.1 to 0.2%, and in Italy, 0.2 to 0.3% of the national territory. The exceptions are Sweden and Finland with a total peatland area of 12% and 30% respectively. Russia occupies the first place in respect of absolute peatland area and peat deposits (see Table 2). Peat bogs occupy a territory of 60 000 000 ha, half of which is located in western Siberia, where the largest peatlands are located. There are also large peatlands in Belorussia, which has a total of 10 000 000 ha.

Country	Peat stocks, bln. t	Peat extraction, mln. t per year
Russia, Belorussia and other republics of the former USSR	162,5	about 90,0
Finland	25,0	about 1,0
Canada	23,0	about 1,0
US	13,8	0,3
Sweden	9,0	0,3
Poland	6,0	1,3
Ireland	5,0	about 5,0

Table 2. The stocks of peat and level of extraction in certain countries of Europe and North America (at the end of the 1980s and early 1990s)

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Biographical Sketch

Arkady Alexanrovich. Tishkov (born in 1950) is one of the leaders of modern biogeography and nature conservation in Moscow. In 1973, he graduated from the biological faculty of Moscow State University and since then he has been working in the Institute of Geography, Russian Academy of Sciences. Since 1990 he has been Head of Laboratory and a Professor at the International Independent University of Ecology and Politology.

In 1979 he obtained a scientific degree for his thesis entitled is "Bryophyte Communities in Tundra and Taiga Ecosystems", and in 1994 he was awarded Doctor of Sciences and Professor of Geography (his second thesis was entitled "Geographical Regularities of Natural and Anthropogenic Successions".

He has participated in many expeditions, e.g. the Taimyr peninsula, Magadan region, Kola peninsula, Spitsbergen (Norway), Uzbekistan, Ukraine, Hymalayas (China), and other regions.

He is scientific secretary of the editorial office of "Proceeding of Russian Academy of Sciences: Geographical Series", editor of "Problems of Regional Ecology", secretary of the section "Flora and Fauna Conservation" in the Higher Ecological Council under the State Parliament of Russia, a member of the Nature Protected Areas Commission of the Russian Academy of Sciences, a member of the Biogeography Commission of the International Geographical Union, and coordinator and Deputy Chief Editor of "First National Report: Biodiversity Conservation in Russia".

In recent years, he has supervised 12 PhD students in geography and published over 350 research papers and monographs including: *Geographical regularities of structure and functioning of ecosystems* (1986); *Geographical regularities of ecosystem dynamics* (1986); *The basis of modern biogeography* (1993,1995); *Ecological restoration of disturbed areas in the North* (1996); and *The future of steppes* (1997). His research interests are geography of biodiversity, succession, ecological restoration, and biodiversity conservation.

Current research projects for which he is acting as leader include: climatic fluctuations and successions of zonal vegetation (1993-1994), changes of biodiversity after invasions of exotic species (1993-1995), small watershed vegetation dynamics in southern taiga (1993-1994), biogeographical effects of alien species invasions (1995-1997), and biodiversity conservation, a GEF Project (1996-2001).