BASIC PRINCIPLES OF BOREAL FOREST FIRE PROTECTION IN EURASIA

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ABSTRACT

Current forest protection strategy in Russia is based on a policy of suppressing all forest fires. However, both economic constraints and ecological concerns about the potential effects of fire exclusion necessitate reassessment of this approach. Fire in Siberian forests is a natural process that occurs in varying spatial and temporal patterns in different regions and forest types. Two dominant factors that affect current fire regimes in Russia are the occurrence of periodic severe droughts and anthropogenic influences. Depending on vegetation and burning conditions, the ecosystem effects of forest fires also vary widely. Average fire-return interval ranges from 7 to 14 years in southern pine stands to 58 to 110 years in central taiga larch stands. There is also great regional variation in the influence of lightning on fire ignitions. Forest fire protection strategies must take into account regional differences in dynamics of forests in response to fire and should be based on the long-term ecological and economic effects of fires. Because fires on newly harvested sites often prevent successful regeneration, approaches are needed to ensure adequate fire prevention measures in logging areas. In regions where fire exclusion has been attempted there appears to be a shift from lower intensity easily controlled fires to large fires that occur under the most severe conditions. Recommendations include: recognizing the ecological benefits of fire, developing a fire management system that varies in protection level with the value of the resources at risk, and introducing a prescribed fire policy for hazard reduction near high value areas and on recently harvested sites.

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INTRODUCTION

The most urgent issue of the boreal forest fire problem in Eurasia is how to organize effective fire protection of vast forest areas in Siberia and the Far East with very small amounts of funding coming from the State. The current forest protection strategy is based on a policy of fighting all forest fires. However, new directions that are being developed in the Russian economy necessitate a search for cost-saving approaches to the forest fire protection system, which in turn requires reviewing the question of whether fires are desirable or undesirable for both the environment and people.

Strategic planning should be based on the concept that fire in forests is a natural process occurring on large spatial and temporal scales. This process largely determines vegetation type, forest community dynamics, and the scale of environmental fire effects. Fire occurrence and spread are in turn influenced by climatic, physical, geographical, and biotic factors. Every woody species is known to have its specific fire regime characterized by a certain fire behavior, intensity, maximum size, interval, and periodicity, as well as postfire forest regeneration dynamics.

Biologists and ecologists have been concerned for a long time about the ecological outcome of the total fire exclusion policy in boreal forests (Kellehouse 1978, Mutch 1970). In their view, this policy leads to the predominance of dark coniferous stands (dominated by generally shade-tolerant short-needled conifers, such as *Abies* and *Picea* species), which take many years to return to conifer dominance after fires, and also shortens early successional stages and decreases biodiversity. With full exclusion of fire in normal years, uncontrolled fires will then occur only in years of exceptional fire hazard. These fires will burn freely, cover big areas, and kill primarily dark coniferous stands where large fuel amounts have accumulated.

MAJOR FIRE REGIMES IN SIBERIA

Comprehensive large forest fire studies conducted in Siberia have allowed researchers to determine spatial and temporal patterns of the variability of conditions conducive to occurrence and spread of large fires (Valendik 1995). For the area in question, two radically different fire regimes can be identified, which are determined by different regional environmental conditions. One is characteristic of the Western Siberian taiga forests and the other of the forests of Eastern Siberia. Low fire periodicity is the main feature of the fire regime in the swampy forests of Western Siberia, whereas the light coniferous forests (dominated by shade-intolerant *Pinus* species) of Eastern Siberia are remarkable for their high annual fire coverage and fire frequency. The current vegetation landscape of Siberia is thus the result of an interaction between the spatiotemporal dynamics of large fires and the physical, geographic, and climatic features of the region.

It should be mentioned that, in Siberia and the Far East, forest fire occurrence patterns are of local character (Valendik 1990), since the biggest number of fires occur in the regions where a high frequency of dry years is combined with severe anthropogenic stress. High numbers of fires are observed in several regions: the Trans-Ural region, the northwestern and eastern parts of the West-Siberian plain, the Angara basin, southwestern Yakutia, and the Trans-Baikal region; in the Far East: the southern part of the Amur and Khabarovsk regions, and the whole of Primorsky region; and the southeastern and northeastern parts of Magadan region. In those regions, light coniferous forests account for the biggest number of fires, with the exception of the Far East regions, where fires occur and burn primarily in hardwood stands in spring and autumn.

Effects of forest fires, like conditions of their occurrence, are extremely diverse and often unpredictable (Sannikov 1973, Furyaev and Zlobina 1981). Both short-term (a few years) and long-term (several decades) fire effects are important to consider. Short-term effects are well studied and predicted, while long-term effects are difficult to predict, because, depending on fire intensity, the state of whole natural complexes may change. For example, changes can occur in hydrological regime, soil and microclimatic conditions, and in the resistance of regenerating communities to repeated fires. These processes can induce changes in ecological regimes of vegetation communities and determine forest formation trends.

Forest fire protection strategy can become more effective and economical if one takes into account the dynamics of the forest as an object of burning. In addition, the climatic factors controlling fire occurrence, and the interactions between forest dynamic processes and climate patterns, determine both fire effects and trends in forest formation. Criteria of the fire protection system in a particular region should be based on long-term ecological, economic, and forestry effects of fires.

Fires that occur in normal years typically result in no long-term ecosystem damage and in some cases are even desirable for forest management: they can decrease fire danger by removing built up fuel, prevent insect outbreaks, and so on. However, fires that occur after long droughts can be quite destructive to the environment. In this respect, predictions of long-term spatial and temporal patterns of extreme fire season occurrence acquire the highest importance in strategic forest protection planning (Valendik et al. 1979).

Extreme Fire Seasons

The periodicity of extreme fire seasons in Siberia varies widely in both time and space (Valendik and Ivanova 1987). They can occur every few years and can continue for several years in succession. In the southeastern part of Western Siberia, their periodicity varies over time from 16–18, 9–11, or 3–6 years, largely in response to climatic fluctuations. In most parts of Eastern Siberia, extreme fire seasons occur every 3–4 years and sometimes are observed during two successive years.

When making scientifically founded long-term predictions of extreme fire seasons, the main problem is a lack of long-term weather information, as well as data on actual annual fire coverage for an area. One approach to reconstruction and prediction of extreme fire seasons is based on analyzing fire history through dendrochronological information. Comparison of dendrochronological records with the actual fire coverage in some regions of Siberia has proved such an approach to be reasonable (Ivanova 1995).

Reconstruction of fire frequency and climate in Central Siberian forests covering the past 400 years indicates that large fires occurred 4–5 times a century up to 1800 in the central and southern parts and up to 1900 in the northern part, after which severe fire seasons began to occur once a decade or more. This can be attributed to the fact that people started to settle in the central part in the1800's, while to the south of the area they came a bit later, and the northern part began to be populated in the 1930's. This increased the number of ignition agents. In presettlement time, the majority of fires were lightning fires, and as populations increased, human-caused fires began to prevail.

In Central Siberia, extreme fire seasons were found to occur in a certain sequence, proceeding from south to north. Between 50 and 55 degrees N, large forest fires can occur in April and early May, whereas they occur in May-June between 55 and 60 degrees N, and, further to the north, they are observed in June, with their maximum in July. During spring and summer, such fires occur usually after some 10 and 30 rainless days, respectively (Valendik 1990).

Average fire periodicity was established to be as follows in Central Siberia: 7–14 years in southern pine stands, 25–29 years in mixed forests of the central part, 42–50 years in the central taiga pine forests on permafrost, 58–110 years in the central taiga larch stands, and 37–102 years in the southern mountain hardwood forests.

So, studies of long-term spatial and temporal dynamics of extreme fire seasons and large fire recurrence provide an objective tool for classifying forest lands with regard to the level of protection needed. This forest fire-related evaluation of the area is of as fundamental importance for all levels of the forest fire protection system as the information on stand growth dynamics is for forest management planning.

Effects of Lightning on Fire Regimes

Summer storms accompanied by lightning are one of the determining factors of forest fire occurrence. Storm activity is known to increase from north to south. For example, the number of days with storms does not exceed 11 during the fire season at 66 degrees N, whereas storm days increase in number to 35 in the season at 50 degrees N. In the central and northern parts of Central Siberia, there are several areas remarkable for high storm activity, namely, the Yenisei plain, especially its Kas-Sym forest province; the watershed between Nizhnaya Tunguska and Podakamenaya Tunguska rivers; and the Angara river basin (Filipov 1974).

Although the region of mountain dark coniferous forests of southern Siberia is characterized by high storm activity, lightning fires occur during extreme fire seasons only once a decade. In normal years, however, because of high precipitation and grass species covering large areas, fires do not occur in the mountain forests, except for the southern forested slopes where fires are observed in early spring. When fires do occur they are typically stand-replacement fires. Initial postfire vegetation tends to be dominated by deciduous tree species, such as birches and poplars, and the succession back to conifer dominance is a slow process that may take 75 years or more.

In the northern regions, however, where storm activity is two to three times less than that in the south and storms occur only two to three times a decade, lightning fires are much more frequent. Their effects are not as destructive though, since those regions are dominated by highly fire-resistant light coniferous forests. Even under long droughts, stands situated in river valleys, around bogs, and in microdepressions remain virtually undamaged by fire.

THE FIRE ENVIRONMENT

In general, a biogeocoenosis, as a natural system, tends toward self-maintenance, such that succession after disturbance follows more or less predictable patterns of return to the prefire condition. These patterns, of course, depend greatly on the fire regime, which is the time interval between fires and fire severity across the landscape. Even extreme weather conditions do not disturb the "merciful" fire regime of areas where intervals between fires are dominated by low-intensity surface fires. This regime is characterized by long drought intervals and high stand adaptation to frequent fires. And of course, the southern taiga hardwood forests of Siberia are of fire origin, and are maintained by fire. If it were not for fires, the area would have been covered by dark conifers. Strategic planning should consider the specific fire regime features of the forest area.

Combinations of natural factors that create the fire environment, such as air masses, fuel complex, and relief, have a critical role in fire occurrence and spread (Countryman 1957). The fire environment is never constant; it changes in both time and space. The fire environment varies in size depending on the behavior and size of a fire itself. When it is a small fire, its environment, vertically and horizontally, is measured in meters. A large fire environment can be many kilometers wide and hundreds of meters high. The environmental factors are interrelated, that is to say that changes in some factors lead to changes in other. For example, relief can influence local weather. Fuels (ground cover) can modify these changes. Weather conditions can in turn influence active fuel type, amount, and moisture content. To track the dynamics of these factors is possible only through fire monitoring from space. Satellite monitoring of forest fires and their effects is especially important for the northern forests, which now are almost unprotected.

FIRE MONITORING WITH REMOTE SENSING

The analysis of the existing satellite systems has revealed that U.S. National Oceanographic and Atmospheric Administration (NOAA) satellites can best monitor forest fires. The satellite data allow us to estimate weather conditions and to detect large fires. The satellites can also monitor the same area 4 times in 24 hours. Thanks to the recent establishment of a satellite downlink station in collaboration with the U.S. National Aviation and Space Administration (NASA), the technology of forest fire monitoring in Central Siberia based on operating NOAA satellites is being developed at the Institute of Forests in Krasnoyarsk. The technology requires the development of a Geographic Information System (GIS) to resolve fire management problems. The most urgent information needed is: (1) forest fire danger rating within landscapes, (2) fire detection in vast areas, (3) storm detection, (4) tracking spatial and temporal dynamics of fires outside the zone of aerial protection, (5) monitoring of forest fire emissions, and (6) analysis and mapping of large fires and burned areas.

Satellite observations of occurring forest fires, of course, are not accurate enough to completely replace conventional methods of monitoring (e.g., with airborne pilot-observers), but they are relatively inexpensive and quick in providing operational information, which is critically important for controlling fires in unprotected regions of the central and northern taiga forests. Development of such a remote-sensing based forest monitoring system is very promising and, in order to guarantee its effective use in forest fire protection, a special service program should be established.

PROPOSED FOREST FIRE PROTECTION SYSTEM

Based on information from forest inventories, understanding of the ecological consequences of fires in particular areas, and analysis of the potential economic impacts and damage from fire in different areas, I suggest development of a system of fire protection that assigns different types and levels of protection depending on ecological and economic effects of fires. In this system there would be four possible levels of fire protection for forest areas:

Level 1—Increased protection. This level of protection is needed where forest fires potentially threaten economic or military objects, that is where potential fire damage to man-made structures, land developments, and human institutions is the highest;

Level 2—Constant protection. This would cover intensively cultivated areas including those of historic and cultural value (national parks and nature reserves);

Level 3—Limited protection. This should be used for the reserve forest fund and suggests increased protection of areas having especially valuable resources (oil wells, etc.);

Level 4—Episodic protection. This level would be used only during extreme fire seasons.

The four levels should differ in funding, technical facilities, staff number and level of qualification, and other economic and professional factors.

Fire Protection in Harvested Areas

Harvesting presents a particular problem for forest fire protection in Siberia, because of the greatly increased danger of fire on logged sites. Current practice includes little or no treatment of logging slash, resulting in heavy fuels on recently logged sites. Cut areas increase year by year, which means that territories of high fire danger grow larger, and, as a consequence, potential protection costs also increase. This is especially true with the mountain dark conifer-dominated regions, where cutting leads to replacement of the usual vegetation cover by grasses, and fires in cut areas can occur right after snowmelt. Also, in cut areas where fire prevention measures are disregarded, forest regeneration is not guaranteed. This is now becoming a very serious problem, since, under the Forest Rent Act, many people with businesses in wood extraction and trade are becoming more and more active.

A way out of this situation is the development of fire certificates for the forest areas that are cut regularly. This is a strategic question. Forest fire certificates will help develop technologies and establish standard costs of protection of various forest areas, thereby preventing potential fire damage and providing maintenance of young coniferous stands in the Russian forest fund in general. A forest fire certificate, as a legal document, would include:

- Evaluation of fire potential for the area, including forest fire danger rating;
- Estimation of potential forest fire damage;
- Recommended fire prevention measures for the area;
- Potential fire fighting guidelines and calculation of human resources and equipment needed to control fires under specific conditions.

Major advantages of this process are that fire certificates would make it possible for:

- People renting forest areas to organize appropriate fire protection at optimal costs;
- Administrative institutions to operationally control the realization of the plan of forest fire prevention measures;
- Insurance services to get realistic information about the objects to be insured.

The main advantage of such a process is that, because fire prevention measures will be paid for by those who are leasing the forest areas, logging slash will not be left on cut areas and healthy tree regrowth will be promoted. Putting this into practice will require that a forest fire certificate be a necessary component of the application process that gives people permission to rent forest areas for harvesting and subsequent management.

PRESCRIBED FIRE

Currently in Russia, the only approved use of intentional burning on forest lands is for burning out as a part of fire suppression actions. Because this practice is used extensively, many firefighters have substantial experience with the use of fire, which would be applicable as well to development of programs using prescribed fire for economic, ecologic, and stand management purposes. There are many situations in which it appears that application of prescribed fire might be of great benefit, especially for hazard reduction around communities, and for decreasing the risk of intense wildfires in some types of vegetation. Prescribed fire also would appear a promising approach for reducing the hazard of accidental burns in recently cutover areas. Currently, harvested areas are at a high risk of fire because of the large amounts of logging slash left behind. These fires often eliminate regeneration and can seriously delay establishment of new forest stands. Use of prescribed fires in these situations may be extremely beneficial, as it has been shown to be in other countries. Research on the uses and effects of prescribed slash fires and broadcast burns is just beginning in Siberia. Because current laws prohibit intentional burning for management purposes, extensive use of prescribed fire will require new laws to be passed, as mentioned above.

MOVING FROM FIRE SUPPRESSION TO FIRE MANAGEMENT

Forest fire experts have recognized for a long time that fire cannot be excluded from the boreal forest. On the one hand, no amount of money and fire suppression resources would be sufficient to achieve complete fire exclusion. On the other hand, where a policy of fire exclusion has been undertaken, it resulted in a shift in occurrence of uncontrolled fires to periods of extreme fire seasons. The result was very big mass fires whose control was extremely difficult and sometimes impossible.

In the 1980's, many countries in the northern hemisphere have turned from fire control to fire management. Fire management policy considers fire to be not only a negative but in some cases a positive factor of postfire ecosystem development. Practically, in order to maintain forest resources and increase biodiversity in the forests of Siberia, it is necessary to work on the following strategic issues:

- Move away from the current fire exclusion policy and recognize that fire is a natural and often beneficial process in boreal ecosystems of Eurasia;
- Inventory postfire forest parameters in taiga regions and analyze postfire ecosystem dynamics when fires are allowed to burn. This will help identify conditions under which fire has positive effects;
- Classify the State forest lands based on ecological

and economic consequences of fire, taking into account trends in forest development;
- Develop a multilevel forest fire protection system as described above;
- Introduce a system of certification of the forest areas involved in economic activity. The system is intended to help in developing optimal fire management that will prevent disturbances of biodiversity and forest regeneration process.
- Adopt a Federal Act regulating prescribed burning of forest areas, with the aim of reducing the risk of intense wildfires (near settlements and valuable forest stands), and also prescribed fires in cut areas aimed at promoting forest regeneration.

The above recommendations will allow us to significantly reduce the costs of forest fire protection and increase its effectiveness.

RESEARCH NEEDS

In the context of long-term fire effects prediction, the most urgent scientific question is how fires influence the ecosystem life cycle. To answer this question, we should thoroughly study:

- Influence of fire, as a constant environmental factor, on major ecosystems and their resources;
- Long-term changes of vegetation communities under fires of varying intensities;
- Relationship of major taiga forest vegetation species with fire, as well as the regeneration capabilities of trees, shrubs and grasses, and the ability of seeds to survive high temperatures;
- Influence of fire on soils and permafrost, with a special emphasis on long- and short-term fire effects on the depths of soil melting in different permafrost regions;
- Fire influence on hydrology, river floods, soil erosion and sediment movement, as well as fire-induced lake sediments;
- Influences of fire on wildlife including large and small mammals, birds, insects, and fish.

It should be noted that many studies on these topics are now underway in a number of countries, but most of these are not well coordinated with similar research in other areas. In Russia, very few specialists engage in them. These studies are vitally important for Siberia. Moreover, investigations of long-term fire effects on biological resources of this region should be approached systematically. This will allow us to make optimal decisions on forest resource use and protection and to apply fire as a tool for managing those resources.

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