PROGNOSIS OF EMERGENCY SITUATIONS UNDER WILDLAND FIRES BASED ON VEGETATION FUEL MAPS

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ABSTRACT

One of the main problems is the strategic and operative prediction of wildland fire risks in Siberia. It requires the elaboration of a geoinformation expert system to predict emergency situations causing large wildland fires. The process for developing this system consists of the following tasks: 1) creation of the regional medium-scale vegetation fuel maps (VF maps) based on forest types and vegetation zones maps; 2) drawing large scale VF maps for the most fire dangerous areas taking into account the results of retrospective analysis; 3) realization of methods of operative (3 to 7 days), medium-term-period (1 month) and seasonal fire danger prediction. As a result, the GIS will create maps of different scales with evaluation of lands according to fire danger level risk.

INTRODUCTION

According to predictions, a rise in the average global temperature of 1^{o} to 2^{o} is expected by the middle of the 21st. century. This could lead to considerable changes in climate and reformation of the whole biota. Therefore, the UN Convention on Climate Change was accepted in June 1992. This Convention was ratified by Russian Federation in October 1994 and came into force. On the basis of this Convention, the Special Federal Program: “Prevention of dangerous climate changes and their negative consequences for the period till 2000” was created and accepted by the Russian Federal Government in June, 1996. Thus, global and regional changes of the environment and climate are not considered to be only the subject of pure theory.

It has been proven that climatic changes occur with extreme declination of seasonal weather variations and may cause large scale fire emergency situations (Stocks, 1993; Wein & Groot 1996; Fosberg et al. 1996). In recent years, climate changes are vividly seen southern Siberia and the Far East. They are the cause of intensified spring and summer droughts. Due to these droughts, emergency situations often occur when forest and steppe fires become dangerous for inhabited localities and even inflict casualties.

OBJECTIVES

This work analyses the peculiarities of the development of dangerous vegetation fires and the forecasting and possibilities of prevention of emergency situations based on vegetation fuel maps.

It is necessary to first consider the question of the way typical surface fires become a catastrophic phenomenon. Here a widespread opinion is: the more the stock of vegetation fuel is, the stronger fire will be. However, this is not quite true for two reasons. First, the main role in combustion belongs to the stock of vegetation fuel, which can be burnt down under the conditions of the definite fire. This stock is dynamic and can be a small part of the whole stock of vegetation fuels. Second, dangerous fire intensity depends on the mass of vegetation fuel burning down in flame regimes in time units per meter length (not per square meter!) of the fire’s edge. This mass depends on two factors:

a) the stock of vegetation fuel per unit area, and
b) the speed of the spread of the fire’s edge.

If the speed of spread is large, the intensity of the fire can be very high even with a small stock of vegetation fuel. This is characteristic of steppe fires. For example, in the Chita region in the spring of 1998, half of a large settlement was burnt because of a steppe fire in a strong wind. In Khakasia in 1999, steppe fires inflicted a large number of casualties to agricultural structures.

The presence of a large stock of vegetation fuel burning down in a smoldering regime (litter, peat, duff) decreases the intensity of flame burning, for hot gases rise from a wide strip of smoldering litter (peat) and make a shield against the wind behind the frontal fire edge. In Evenkia, according to this reason, forest fires have higher intensity at the beginning of summer than later in summer when the litter is dry.

Fires become high intensity and, therefore dangerous, if they reach the so-called 'phase of self development.' First, it happens at the expense of their speed increase under 'spotting" with throwing burning particles in front of the fire front. It is especially characteristic of 'explosive' fires. Under the 'explosive' fire a vertical stream of hot gases makes a hole in the lower part of troposphere. As a result of this, a gigantic 'ventilating pipe' arises. It sucks in air, smoke and burning particles at high speed. Then the burning particles fall upon the surrounding area. The stream with a 'plume' of smoke is like an 'atomic fungus', explaining the name of the fire. The 'explosive' fire develops in conditions where there is a high-altitude inversion of the wind, i.e. there is a strong wind below intensifying a fire and a weak wind above which does not destroy the stream (Valendik et al. 1979).

Second, fire intensity increases at the expense of increase of vegetation fuel stock, for instance, in the presence of coniferous reproduction, coniferous stand canopy. Moreover, especially favorable conditions for the preparation of vegetation fuel to burn are created within intensive flames. It is known that the quantity of formed energy under flaming burning is in proportion to the flame volume. Its radiant isolation is going on through the flame surface. The more the flame volume is, the less 'surface-volume ratio' it has and, therefore, the higher temperature is within a flame. Under these conditions the vegetation fuel which does not burn in typical fires begins to burn, i.e. the stock of burning vegetation fuel increases considerably.

It is known that there are catastrophic fires resembling 'fiery whirlwinds.' Their causes can be different. For example, the whirlwinds with a horizontal axis occur in front of thunderstorm front. This whirlwind can make a surface fire, then turn it into a crown fire and spread the flame over the tree crowns in the far distance.

In some cases the whirlwind with horizontal axis may occur in front of rectilinear front of a strong fire. But the direction of this whirlwind rotation will be opposite to the direction of thunderstorm whirlwind. The fire whirlwind below is directed to the fire and its stream above together with burning particles are directed from the fire. Under typical conditions the fire front is not rectilinear but has a convex shape. Nevertheless, when the wind direction changes 90^o, an extended fire flank can turn into a rectilinear front. The whirlwind spread of burning can arise on mountain slopes of steep hollows with young coniferous stands (Sofronov & Volokitina, 1990).

Ignitions of inhabited localities and industrial structures occur because of burning particles which are thrown in front of a strong forest or steppe fire front. This usually happens in dry windy weather. Therefore, the ignition of separate dwellings and industrial buildings can spread to other buildings and structures. Burning particles can spread to 500 meters distance and more. Due to this, strong vegetation fires can cross rivers, nonflammable bogs and other obstacles (Valendik et al. 1979).

The main way of protecting structures against an approaching strong fire is preliminary backfiring. But, it is necessary to know the technology of safe backfiring. Usually administrative officials do not decide to do preliminary backfires as they are afraid of the responsibility. Instead; they hope to stop the fire by means of wide, mineralized strips. The history of very large forest fires (for example, the fires in the Northern China in 1987) (Cahoon et al, 1994) shows that such fires are able to spread freely over the area for a long time destroying inhabited localities and crossing the rives and roads which could be the best initial line for preliminary backfires.

Thus, emergency situations connected with forest fires close to inhabited localities, agricultural and industrial structure can be prevented by means of forecasting the probable fire behavior and making appropriate preliminary arrangements.

METHODS

To avoid casualties in similar emergency situations the following list of tasks should be taken into account:

1) determining the inhabited localities and structures that can be damaged by vegetation fires (forest fires, steppe fires etc.);
2) elaborating preliminary arrangements for protection of such structures against vegetation fires;
3) forecasting the probable dangerous development of vegetation fires close to inhabited localities or industrial structures;
4) creating quick and safe fire stops with the least expense of means.

The first task is the most difficult. First, it is necessary to determine the complex of conditions (taking into account different variants) which can develop into emergency situations. Moreover, theoretical developments must be supplemented by a thorough study of real ignitions of inhabited localities, agricultural and industrial structures due to forest and steppe fires, and by the analysis of publications about similar cases and by making preliminary arrangements for protection of structures against fires.

The complex of conditions includes three groups of factors:

1) spatial placement of vegetation plots of different categories around inhabited localities and industrial structures and their pyrological characteristics as vegetation fuel complexes;
2) seasonal (phenological) vegetation state;
3) weather conditions: drought level, wind direction and wind speed.

The first group of factors is constant. It serves for determining the inhabited localities and industrial structures where emergency situations may occur because of forest and steppe fires.

Finding out these localities and structures must have two stages:

1. Preliminary examination - based on pyrological zoning and with space images or middle scale (1:1 000 000-1:500 000) vegetation fuel maps. (Middle scale vegetation fuel maps have been made for a part of Priangarie and the northern part of Lake Baikal Basin). The main criteria of emergency situations occurrence is the presence of forest and steppe areas at a distance of less than 500 m from inhabited localities and structures.
2. Final examination - with aerial imagery and large scale (1:25 000- 1:50 000) vegetation fuel maps made for the area around these localities and structures within a 5 km radius.

We have elaborated a simple and inexpensive technology for creating large-scale vegetation fuel maps (including automated method) according to forest inventory data (Volokitina et al. 1995). The most difficult element of this technology is characterizing taxonomic plots according to the types of prime conductors of burning (Volokitina & Sofronov, 1996).

These characteristics can be defined based on forest types defined in the characteristics of plots. Each natural region must have a table connecting the forest types with the types of prime conductors of burning using the existing descriptions of forest types and making them more accurate in practice.

The map shows only the main part of the information from the plots (the types of prime conductors of burning, the presence of young coniferous stands, coniferous reproduction). The full information is included in pyrological description of plots together with the map. All rivers, streams and other elements of pyrological area division are marked in vegetation fuel maps.

A special program is elaborated for the automated creation of large-scale vegetation fuel maps. The vegetation fuel maps of Bolshemurtinsky Leskhoz were made in the automated way based on our technology by the GIS group at the V. N. Sukachev Institute of Forest SB RAS (Vaganov et al., 1997).

The fact that a part of the forests close to inhabited localities may not be situated on State Forest Fund lands but instead on the territories of former collective farms or State farms makes the creation of vegetation fuel maps difficult.

Based on vegetation fuel maps, maps of natural fire danger are created. They show the likelihood of plots of the specific drought classes to ignite during a certain period of season. The creation of these maps is also automated.

As for the second task - elaborating preliminary arrangements for fire protection - it is necessary to have large-scale vegetation fuel maps indicating barriers and natural obstacles (rivers, streams, lakes, peat, roads, plowed fields, etc.). Additional barriers and obstacles must be suitable for the existing network.

The character of any vegetation fire (as well as forest fire) depends on the following factors:

1) the complexes of vegetation fuel and their spatial placement (in relief); the plots without VF (roads, rivers, streams, etc.) which make fire spread difficult, are of great importance;
2) the moisture content of VF depending on the type of VF, soil moisture regime, period of season, drought index and time;
3) weather conditions including wind, relative air moisture, cloudiness (Sofronov & Volokitina, 1990).

Therefore, the third task for forecasting fire behavior demands large scale vegetation fuel maps for the area close to inhabited localities or structures, meteorological data including detailed forecasts for the near future and a method of fire behavior prognosis. We are elaborating this method together with computer specialists.

And the fourth task on quick and safe fire stops demands development of general practical recommendations or instructions and projects for protection against fire for each marked structure. Corresponding organs of government should approve and document these recommendations and projects in order to perform their functions. Based on these documents, firefighting leaders must make take responsible decisions.

The practical recommendations should have regulation of conditions for carrying out effective and safe backfiring. The concrete boundaries of backfiring (as close to structures as possible) and optimal time of starting backfires according to the distance to the fire and the period of day and night are indicated in the projects.

CONCLUSIONS

Vegetation fuel maps help to forecast the fire spread speed, fire intensity and behavior and choosing an optimal method of fire protection. The expenses of these elaborations are less than the probable damage to inhabited localities and industrial structures after strong forest and steppe fires.

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