Development of the prototype of a geo-information web system for dynamic visualization of forest fire hazard

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Abstract. The article examines the prototype of an interactive system to display fire hazard in the forest during the fire season, prototype’s main characteristics and development methods of web GIS technologies. The proposed approach tracks changes in a special web map showing the state of fire danger in the forest based on the daily calculation of the fire hazard class under the current weather conditions. The analysis of data on forest types and frequency of fires proves that the calculations should include an increase in the natural fire hazard class concerning grass allotments in spring and autumn, as compared with summer. Changes in the weather conditions over time cause the map of a given area at a given point and time to change in accordance with the fire threats for these allotments. The developed interface for displaying the fire hazard data allows one to select the area under study and time range, as well as configure the data presentation template. The technological means used were the methods of Internet systems and geportals producing geographic information, modern web technologies, libraries and services, including tools for dynamic representation of data of screen forms in web templates.

1. Introduction
Timely information about fire hazard (hereinafter referred to as “FH”) in the forest and the impact of meteorological conditions on it is the basis for making correct decisions and rational use of forces and necessary means. An underdeveloped road network and scattered meteorological stations contribute to fire hazard as well.

Large resources of different services are used for processing, evaluation and analysis of all factors influencing the creation of conditions that add to the fire exposure of a given territory. The need for timely information is growing, also, reliable and rapid assessment of natural fire hazard is a prerequisite for working with the forest resources.

In Russia, they have been working on ordering of information on combustible materials, their classification and mapping since 1950s [1-2]. Methods for local scales of FH [3], scales for different regions of Siberia [4-5] have been developed. Foreign methods have been analyzed in different countries and there have been made numerous attempts to improve them [6-7].

The most convenient form for displaying data and working with them is cartographic information. All agencies related to the forest fund and firefighting services work on the basis of maps. Modern information processing tools enable quick and informative visualization of information flows for users.
of all levels in a clearly arranged form [8-10]. Forest services work with “ISDM-Rosleskhoz” (Information System for Remote Monitoring of Forest Fires of the Federal Forestry Agency of the Russian Federation) or software products based on it. The main advantage of “ISDM-Rosleskhoz” is that it collects information from various sources, including data on forest fires (meteorological information; data on ground and aviation monitoring of results from regional forest fire departments; space monitoring data). This system provides the user with data in an enlarged form, without taking into account the characteristics of vegetation on the ground.

For the majority of those who work in forests the more useful information is which zones within their working area represent the greatest fire hazard in current weather conditions.

The main task of our work was to connect the static forestry map with the forest fire characteristics of the forest lands and current weather changes in order to obtain timely graphical information about fire exposure of individual plots, as well as the maximum information available through the web interface.

As an example of a web dynamic visualization system, we chose the data on the experimental farm “Pogorelsky Bor” (Sukachev Institute of Forest, Federal Research Center «Krasnoyarsk Science Center of the SB RAS»).

2. Research objects and methodology

The study area is located 5 km east to the settlement of Ustyug in Yemelyanovsky district of the Krasnoyarsk Krai and represents a section of the island forest-steppe of the Krasnoyarsk Krai. Geographical coordinates: 56°22′07.48″N 92°57′17.95″E. Coverage area: 1992 ha.

Prevailing types of plants are pine and birch trees, they make up 88.9% of the area of Pogorelsky Bor, while meadows and felling sites amount to 8%. The most fire hazardous types of vegetation are herbaceous, which reach the highest maximum in spring.

The actual fire hazardous season lasts from April to September. The earliest fires are registered as early as in the first decade of April. The number of days in a fire hazardous season varies considerably depending on the year – from 33 to 154 days. May is the most dangerous month, both in terms of the number of forest fires – 62% of all recorded fires, and the area burned by fire – 56% of all registered fires from 2006 to 2015.

The most frequent are ground fires of weak power – 54 % from the total amount. At the same time herbal types of forest account for 96% of the total area affected by fire. The most part of fires registered represent III class of fire danger, i.e. 45 % of fires for 10 years.

The main causes of fires (49.3%) in forests are fires caused by the local population who started agricultural burning.

2.1. Evaluation of fire hazard

Classification of classes of fire hazard in forests depending on the weather conditions determines the degree of probability of occurrence and spread of forest fires on the respective territory. The meteorological conditions strongly affect the fire hazard of forests.

The formula for calculation of the natural fire hazard class in the forests depending on the weather conditions is the air temperature multiplied by the difference between air temperature and dew point for the number of days without rain. If we take the day with more than 3 mm precipitation as the first day of the rain-free period, we get the following:

$$
K \Pi = \sum_{n}^{1} \left[ t^o(t^o - t_d) \right]
$$

where

t° – temperature at 13:00 local time, °C;
t_d – dew point at 13:00 local time, °C;
n – number of days without precipitation.
Meteorological data for calculations were obtained from the nearest weather station in Sukhobuzimskoe settlement.

The class of natural fire hazard of forests was determined in accordance with the annex of the order of the Federal Forestry Agency (Rosleskhoz) with the provision that in the spring and autumn this class shall be increased by two steps for herbal types of forests, while pastures and meadows displayed I class of FH for this period.

To determine the fire hazard class, the five-class scale shown in table 1 was used.

| PV-1         | Class of FH | Degree of FH | Colour on the map |
|--------------|-------------|--------------|-------------------|
| 1-300        | I           | absent       |                   |
| 301-1000     | II          | low          |                   |
| 1001-4000    | III         | medium       |                   |
| 4001-10000   | IV          | high         |                   |
| Over 10000   | V           | extraordinary|                   |
|              | –           | non-burnable |                   |

In table 1, the non-burnable areas are those with roads and water bodies.

2.2. Geoportal technologies

The technical solutions proposed for the implementation of the present task of displaying changes in the state of fire hazard in time during the fire season imply the development of a set of special software tools based on geoportal technologies.

The task of displaying changes in the state of fire hazard in time, which is the focus of the present article, is based on the geoportal software of the Institute of Computational Modelling SB RAS. This software consists of a large set of tightly interconnected software modules, including PostgreSQL database management system with PostGIS extension; Apache web-server; Mapserver/Mapscript geoinformation platform providing for geospatial data rasterization and cartographic web services; a subsystem of spatial information caching based on GeoWebCache, which significantly increases the speed of the web interface; client software for cartographic web visualization, developed on the basis of the OpenLayers library and a number of other components.

Several subsystems have been specially developed for the geoportal of the Institute of Computational Modelling SB RAS, namely web content management system for thematic sections of the geoportal (publications, articles) based on Drupal web site creation software, web application of the geoportal administrator “Data Management”, style editor for thematic layers and maps GeoExpress (for Windows and web version), web application for searching geoportal resources by metadata – “Resource Catalog”, subsystem of cartographic web visualization (for standard browser). There is also a set of software and user interfaces: access to file archive via secure SFTP protocol; operational monitoring module – collection of data coming from different detectors and sensors. Thematic layers and maps manager of the geoportal provides access rights to geodata via web-interface, direct access protocols of the Open Geospatial Data Consortium (OGC).

The geoportal has its own basic information resources. In order to enhance informativeness of the generated cartographic images there was created a set of cartographic bases (substrates) for different purposes. This set contains mosaics of Sentinel and Landsat satellite images for different years, relief colour maps with shading techniques, several versions of multiscale topographic base for universal purposes. The access to the prepared data is organized through web-interface or OGC WMS/WMTS cartographic services. The geoportal also gives the possibility of using third-party online services – about 20 different substrates based on OpenStreetMap data, 3-4 substrates from Google, Yandex, Bing, Rosreestr (The Federal Service for State Registration, Cadastre and Cartography), GeoMixer, ArcGIS; maps schemes from 2GIS, Geocentre-Consulting. The list of available substrates currently contains several dozens of titles.
The developed software tools of the geoportal enable viewing the information in a pop-up window in HTML-format when clicking on a web map. One can obtain information on the objects in a single layer or a group of layers, depending on current settings of layer visualization in the map legend.

There are several modes of attribute data visualization. The basic mechanism presupposes the use of a universal form of informational pop-up window, where all attributive information on a selected layer of the object is displayed in the form of a usual table regardless of its content. An alternative method uses a system of templates and external services. To activate it, one has to specify the need to use a template or an external service in the layer or map metadata, configure the corresponding parameters, create and save the template being used to the metadata. The software implementation of the template subsystem is based on the TWIG open source which compiles templates and provides an efficient combination of static HTML code and dynamic content. Templates allow one to change the order and form of attribute data output on objects in the map layers, including different style, color, font parameters, etc.

The listed geoportal technologies made up the software and technology basis for solving the task of displaying changes in the fire hazard state.

3. Results and discussion

As part of this work, a geospatial database was formed, which contains information on the degree of fire hazard of certain forest areas for the period from April 18 to September 17, 2017 (five months total). The mentioned database was registered on the geoportal, after that a thematic map with classification by fire hazard degree was created; the geoportal interface displays this map now (figure 1). One of the parameters of the thematic layer is the date, when the geodata thematic layer with the indicated class of fire hazard is created. In the process of performing this work, we considered various options for building a user interface to select a date for displaying the thematic layer.

It is assumed that the thematic coloring of fire hazard classes remains unchanged when one changes the date for the thematic map. Clicking on the map opens an informational pop-up window with information about the selected object. By default, this window displays a table with values of fire hazard class for the specified forest allotment by days (figure 1). At the same time, to make the data presentation more illustrative, the system has an option to customize the information display design; for this purpose, a set of HTML templates of the thematic layer has been developed, which provide for showing the same information in the form of charts or histograms. In particular, there has been introduced a template, which demonstrates data on fire hazard class for a selected forest allotment in the form of a histogram by months (figure 2).

The subsystem of data visualization based on templates uses HTML language extensions. As a result, the web pages created by the system administrator look like a specialized program that supports dynamic construction and formatting of text with information on the map objects.

The approach to building user interfaces seems promising due to the large number of freely available HTML/CSS and JavaScript libraries of visual graphics in the source codes, which can be embedded into templates and used for data visualization. It is also worth paying attention to the service-oriented architecture of the system, owing to which there is a great potential for functional extension of the presented development. For example, it is possible to obtain cadastral information, actual meteorological data and weather forecasts, to create and show photo and video information on objects in the investigated area through web-based application services. Another advanced task is to create a mobile application for a smartphone, which displays all the data under consideration.

The proposed concept of the web-interface organization can form the basis of a real-time automated system for displaying information about the state of fire hazard and changes that occurred during the period chosen by the user. The necessary condition for the performance of this system is the availability of operational and reliable meteorological data.
Figure 1. Fire hazard degree for the specified fire hazard class on the geoportal.

Figure 2. Template for displaying monthly dynamics of fire hazard.
4. Conclusions
The created system allows the user to receive timely information about the most dangerous areas as regards fire exposure and to respond adequately to the situation.

This system, as well as any GIS-system, enables creating additional layers with the necessary information for the user, which, in turn, unlocks unlimited potential for expanding the opportunities for its use.

The proposed and implemented mechanism for presenting thematic information based on HTML-templates with the option to connect third-party libraries and information web services provides a flexible configuration of data display, with possible upgrading the user interface in the process of operation.

The main problem facing the functioning of this web system may be the obsolete materials of the forest monitoring systems. Reliability of displayed information depends on their relevance. This problem can be solved by timely introduction of changes occurring on the territory of this forest area by trained specialists.

Another problem is the lack of meteorological information with good spatial resolution due to the extremely sparse network of weather stations in Siberia. A possible direction of work in this regard is the development of methods for calculation of meteorological parameters for a given location based on spatial interpolation of data from available weather stations, as well as operational information based on climatic models built in Russian and foreign weather data processing centers.

References
[1] Vonsky S, Zhdanko V, Korbut V, Semenov M, Tetyusheva L and Zavgorodnaya L 1981 Determination of a natural fire hazard in a forest Methodical recommendations (Leningrad: Forestry Research Institute) p 52 (in Russian)
[2] Abroskina A, Volokitina A and Korets M 2012 Mapping of the natural fire hazard according to the forest inventory materials Bulletin of Krasnoyarsk State Agrarian University 7 60 (in Russian)
[3] Kurbatsky N 1954 Methodological guidelines for test development of local fire hazard scales (Leningrad: Central Forestry Research Institute) p 33 (in Russian)
[4] Valendik E 1963 Scales of fire hazard for forests of the Krasnoyarsk Krai and Tuva ASSR Forest fires and fight against them (Moscow: USSR Academy of Sciences) p 31-57 (in Russian)
[5] Furyaev V 1963 Scales of fire hazard for forests of Transbaikalia Forest fires and fight against them (Moscow: USSR Academy of Sciences) 76-107 (in Russian)
[6] Sofronova T, Volokitina A and Sofronov M 2007 Improvement of fire hazard assessment by weather conditions in the mountain forests of Southern Baikal Region (Krasnoyarsk: Sukachev Institute of Forest SB RAS, KSPU named after V.P. Astafyev) p 236 (in Russian)
[7] Volokitina A, Sofronova T and Korets M 2017 Regional scales of fire hazard assessment in the forest: improved methods of making scales Siberian Forest Journal 2 52 (in Russian)
[8] Yakubailik O, Kadochnikov A and Tokarev A. 2018 WEB Geographic Information System and the Hardware and Software Ensuring Rapid Assessment of Air Pollution Optoelectronics Instrumentation and Data Processing 54 243
[9] Yakubailik O, Kadochnikov A and Tokarev A. 2019 Software for data visualization in the system of real-time satellite monitoring E3S Web of Conferences 75 03004
[10] Kadochnikov A, Shaparev N, Tokarev A and Yakubailik O 2019 Software tools for web mapping systems IOP Conference Series: Materials Science and Engineering 516(1) 012007