Focused sunlight factor of forest fire danger assessment using Web-GIS and RS technologies

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ABSTRACT

Timiryazevskiy forestry of Tomsk region (Siberia, Russia) is a study area elaborated in current research. Forest fire danger assessment is based on unique technology using probabilistic criterion, statistical data on forest fires, meteorological conditions, forest sites classification and remote sensing data. MODIS products are used for estimating some meteorological conditions and current forest fire situation. Geonformation technologies are used for geospatial analysis of forest fire danger situation on controlled forested territories. GIS-engine provides opportunities to construct electronic maps with different levels of forest fire probability and support raster layer for satellite remote sensing data on current forest fires. Web-interface is used for data loading on specific web-site and for forest fire danger data representation via World Wide Web. Special web-forms provide interface for choosing of relevant input data in order to process the forest fire danger data and assess the forest fire probability.

Keywords: sunlight, forest fire, danger, assessment, remote sensing, web-GIS

1. Introduction

Forecasting is important problem of forest fires prevention on large forested territories [1]. Now, the empirical and statistical methods of forest fire danger estimation are used in the various countries [2-4]. However, in recent years, the deterministic-probabilistic method of the forest fire danger forecast had intensive development [5,6]. Modern computing and information technologies of electronic maps are used for practical realization of this approach [7,8]. Moreover, technologies of consumer access to prognostic information have important value. It is an optimum variant to use web technologies to organize the interaction between consumers and information and computing system of the forest fire danger forecast [9,10].

Satellite sounding technologies of a terrestrial vegetative cover are applicable for estimating the current fire-dangerous situation on large forested territories [11]. MOD products from MODIS Terra/Aqua [12] are most applicable for the analysis of thermal anomalies.

Article purpose is to develop the web-oriented geoinformation system for estimating the forest fire danger using modern information and computing technologies and remote sensing data of the Earth from space.

2. Problem Description

At present, the most famous GIS-systems are as follows:

1. The Information System of Forest Fire Remote Monitoring of the Federal Forestry Agency (ISDM-Rosleskhoz) (Russia) [13]. It estimates the current fire danger relying on the Nesterov index without any physical basis. A separate meteorological station is responsible for the minimal territory. Thanks to the scientists from the National Research Tomsk Polytechnic University, this system acquired the probability criterion to estimate the forest fire danger with regard to the thunderstorm activity and human factor. It disregards the forest fires caused by a focused solar radiation effect. It uses the remote sensing data.

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2. The Canadian Forest Fire Danger Rating System CFFDRS (Canada) and the National Fire Danger Rating System NFDRS (USA) [2,3]. It estimates the forest fire danger relying on the statistical analysis of large data files about the large forested territories. It considers the anthropogenic impact and thunderstorm activity as the reasons for forest fires to occur. It disregards the factor of the focused solar radiation effect. It uses the remote sensing data.
3. The European Forest Fire Information System EFFIS (Europe) [14]. The most progressive component of this system repeats the subsystem of the Canadian Forest Fire Danger Rating System. It has the same characteristics and uses the remote sensing data.
4. GIS of the National Research Tomsk State University (Russia) [15]. It considers a mathematical model of drying the forest fuel layer. It disregards the ignition processes. The minimal territory is a stratum. It regards the factor of the focused solar radiation effect on the level of statistical estimates (but the forestry management lacks such statistics). It fails to use the remote sensing data.
5. The Virtual Fire System (Greece) [16]. It uses the web-services that reflect the information. It estimates the forest fire danger relying on meteorological data analysis. No data are available about the minimal territory. It disregards the factor of the focused solar radiation effect. It is possible to forecast the forest fire spread process. It fails to use the remote sensing data.

The Timiryazevsky Mechanized Forestry of the Tomsk Forest Administration is located in the interfluve between two big rivers, the Ob River and the Tom River, on the territory of three administrative districts of Tomsk region – Tomsky, Shegarsky and Kozhevnikovsky districts. The length of the forestry territory from the North to the South is 50 km. The Timiryazevsky forestry was founded in 1966 based on the order of the Ministry of Forestry Management of the Russian Soviet Federated Socialistic Republic dated 08.07-1966 No. 261. The forestry forests are represented mainly by the uniform forest area, except for the isolated cedar forests near Zorkoltsevo, Nizhne Sechenovo and Gubino settlements.

By forest and vegetation regionalization of the Western Siberia, the territory of the Timiryazevsky Forestry falls into the Southern Taiga zone (of the Obsko-Tomsky cedar and pine forest district). The forestry territory refers to the mild-humid region according to the agroclimatological zoning of Tomsk region, accepted by the Tomsk Department of the Siberian Institute for the Design of Metallurgical Factories (Sibgipromez). The duration of vegetation period is 120 days.

On the forestry territory, the most spread soils are: podzolic and derno-podzolic soils (58%). The prevailing species is pine which occupies 39,6%; aspen is 26,2% and birch is 21,2%; cedar, larch, spruce and silver fir are 13%.

3. Technological solutions

The geographical information system planned to use the Earth remote sensing data from the space. The MxD14 product (Thermal Anomalies/Fire) is one of the real-time resources about the spots of possible thermal anomalies. It is obtained when processing the data from the MODIS sensor aboard the TERRA/AQUA satellites (the MOD14 and MYD14 products correspondingly). These products are made relying on the real-time data obtained in the ranges of 4 micrometers (the MODIS 21 and 22 channels) and 11 micrometers (the MODIS 31 channel). To mask the cloud cover, we use the 1 and 2 channels with resolution of 250 meters (ranges are 0.65 and 0.68 micrometers), as well as the 7 and 32 channels (the spatial resolution of the 7 channel is 500 meters, the range is 2.1 micrometers, the 32 channel has the spatial resolution of 1 km., the range is 12 micrometers). The product documentation [12] and a number of articles [17] describe the detection algorithm in detail. Besides, some fire products of the MODIS sensor have the products that inform about the fire location, the emitted energy, relation of ignition and smoldering, as well as some estimate of the outburned area.

The clouds are detected by a method, based on the technology, used when obtaining the global fire product with the help of AVHRR during the International Geo-sphere Biosphere Program (IGBP).

The work [18] used the high resolution data (18 ASTER scenes) for validating the MODIS Thermal Anomalies product over Southern Africa. The ASTER instrument is also located on the Terra satellite platform and allows making investigations, which coincide with MODIS investigations in space and in time. Combination of these data allowed checking the validity of investigation over the active fires. The investigation area was only the Southern Africa territory, but we continue the work to validate the MODIS Thermal Anomalies product on the global level. With the MODIS products, we can have a probability estimate of the cloud cover parameters over the controlled territory. These four conditions specify the cloud cover: clear, may be clear, indefinitely and cloudy. In principle, it is enough to operatively monitor the forest fire danger under the focused solar radiation effect. Figure 1 shows a typical satellite image with cloud mask.

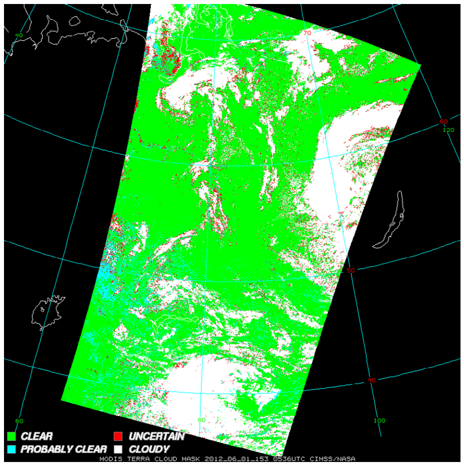

Figure 1. Typical satellite image with cloud mask

Figure 2 represents interface of the web-oriented system for an estimation of forest fire danger.

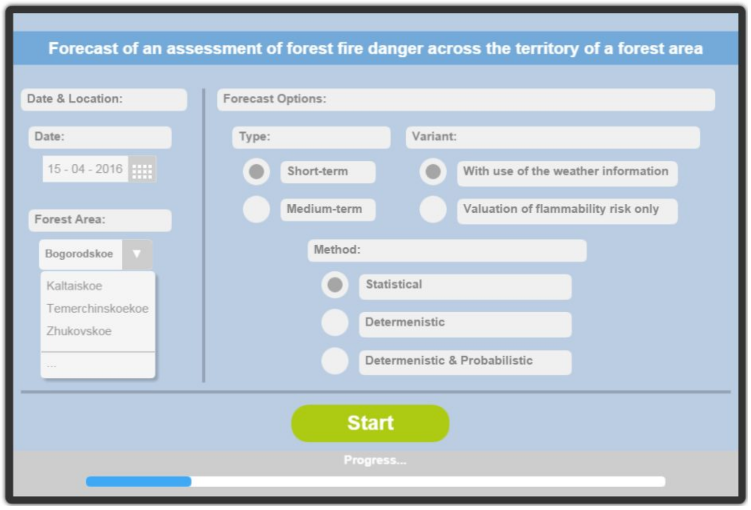

Figure 2. Interface of the web-oriented system for an estimation of forest fire danger

The web-oriented information-cartographical system uses classical iterative client-server architecture. Interaction between user web-browser and the web-application occurs under HTTP protocol. The Web-application is responsible for formation of the user interface of information-cartographical system and a cartographical substrate, due to the interaction with known suppliers of free cartographical data. Thus, the web-application is not engaged in any data processing. All inquiries for data processing are transferred from the web-application under SOAP protocol to the specialized web-service implementing all business logic of system.

Web-service possesses a wide set of the methods, allowing us to solve some or other user problems: to give numerical data on forest fire conditions, to generate a thematic layer for displaying on a web-application map etc. In its turn, the web-service addresses for its calculations to the data stored on a server or in separate DBMS. The service oriented architecture with the use of template MVC (Model-View-Controller) has been accepted as a basis for designing the web-application.

Model EDM ADO.NET was used to access the data. This model has generated all necessary essences from the base in the form of classes (the class, containing methods to access the data was designed, too). The basis of the web-application structure consists of five controllers: «Account» - for realization of authorization logic, «Home» - for the data control, «User» - accessible for an authorized user (in the role «user» or «admin»), «LayerController» - ApiController, responsible for addition, removal and editing of data about layers, «ObjectController» - ApiController, responsible for addition, removal and editing of data about objects.

In order to store the information, it was necessary to choose a control system of databases. Microsoft SQL Server has the leading positions in the market among DBMS. The market share of Microsoft SQL Server, according to the data from Gartner, is 46,8%, the rest market part belongs to Oracle and IBM DB2, a relatively small market part is occupied by DBMS Open Source, such as Postgre and Firebird. Among mentioned DBMS, each possesses sufficient functionality to solve the set task, therefore, the main criteria, when choosing, became the presence of the established software and experience of work with concrete DBMS. Due to the facts mentioned above, MS SQL Server was chosen as DBMS.
The library with an open initial code Leaflet will be used as a technology for visualizing the card on the web-page. The main peculiarities of the library are as follows: possibility to work both in browsers of mobile devices, and in browsers of desktop PC; small size of the library itself — 33 kb; availability of well documented API; functionality can be broadened, at the expense of connecting the additional plugins. The library is widely used on the sites Flickr, Foursquare, Craigslist, Data.gov, IGN, projects Wikimedia, Meetup, OpenStreetMap, WSJ, MapBox, CloudMade, CartoDB and others.

4. Results and Discussion

There are reasons of forest fire occurrence which have the mixed character. Forest fuel ignition is possible as a result of the focused sunlight action. Earlier theoretically and experimentally it is shown that forest fuel ignition is possible in the conditions of concentrated solar energy influence at level 15-17 times from natural value. Glass jags, their splinters and large drops of pitch can serve as energy concentrators. Physically proved method for an estimation of forest fire danger in the conditions of the focused sunlight action has been developed. Now it is necessity to develop the technology for forestry needs on the basis of this method of fire danger assessment on large forests.

The probabilistic criterion of the forest fire danger estimation is shown below [10]:

$$\left[P(A)P(A_j / A)P(FF / A, A_j) + P(L)P(D / L)P(FF / L, D)\right]P(N) \quad (1)$$

Where

P(A) - probability of anthropogenous loading in the territory,

$P(A_j/A)$ - probability of presence of fire sources on a defined week day under condition of anthropogenous loading in the territory,

$P(FF/A, A_j)$ - conditional probability of forest fire for the anthropogenous reason,

P(L) - probability of storm activity in the territory,

P(D/L) - probability of a cloud-to-ground lightning discharge under condition of storm activity in the territory,

P(FF/L, D) - conditional probability of forest fire on storm activity,

P(N) - probability of predisposition of territory and favorable meteorological conditions for occurrence of forest fires.

Probabilistic parts in the formula (1) are defined as follows [10]:

$$P(A) = \frac{N_A}{N_{TS}}, \qquad P(A_j / A) = \frac{N_D}{N_W}, \qquad P(FF / A, A_j) = \frac{N_{FA}}{N_{TF}}, \quad (2)$$

$$P(L) = \frac{N_L}{N_{TS}}, \qquad P(D / L) = \frac{N_{DH}}{N_{DD}}, \qquad P(FF / L, D) = \frac{N_{FL}}{N_{TF}}, \quad (3)$$

Where

N_A - quantity of days with anthropogenous loading in the territory,

N_L - quantity of days with thunder-storms in the territory,

N_{TS} - total of days for fire-dangerous season,

N_D - number of fires on a defined day of week,

N_W - number of fires within a week,

N_{DH} - quantity of cloud-to-ground lightning discharges at a defined hour of a day,

N_{DD} - quantity of cloud-to-ground lightning discharges for a day,

N_{FA} - quantity of forest fires for the anthropogenous reason,

N_{FL} - quantity of forest fires on storm activity,

N_{TF} - total of forest fires

Figure 3 represents the electronic map of forest fire danger on territory of the Timiryazevskiy forestry of Tomsk region. The analysis of results has shown that high level of forest fire danger is characteristic for small quantity of forest sites of the Timiryazevskiy forestry of Tomsk region. It allows developing the selective monitoring strategy for especially fire-dangerous sites in the controllable forested territory. The main part of fire-dangerous sites is concentrated in a vicinity of Timiryazevskiy settlement. In total about 10% of territory represents extreme fire danger level. It is expedient to organize video observation for the specified forest sites by means of video cameras and GSM-modems for remote access using a cellular communication network.

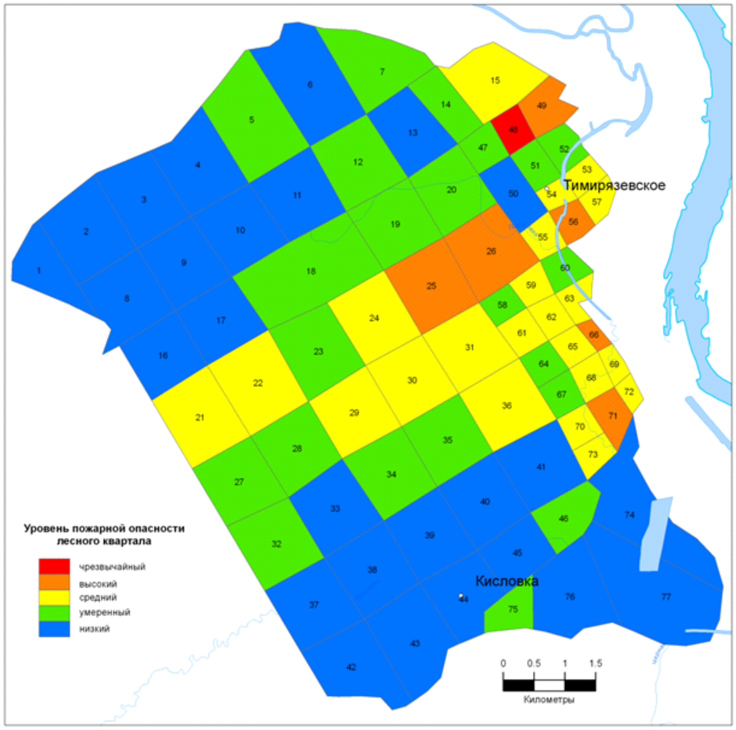

Figure 3. Electronic map of forest fire danger on territory of the Timiryazevskiy forestry of Tomsk region

Figure 4 represents a diagram which shows distribution of sites on forest fire danger levels.

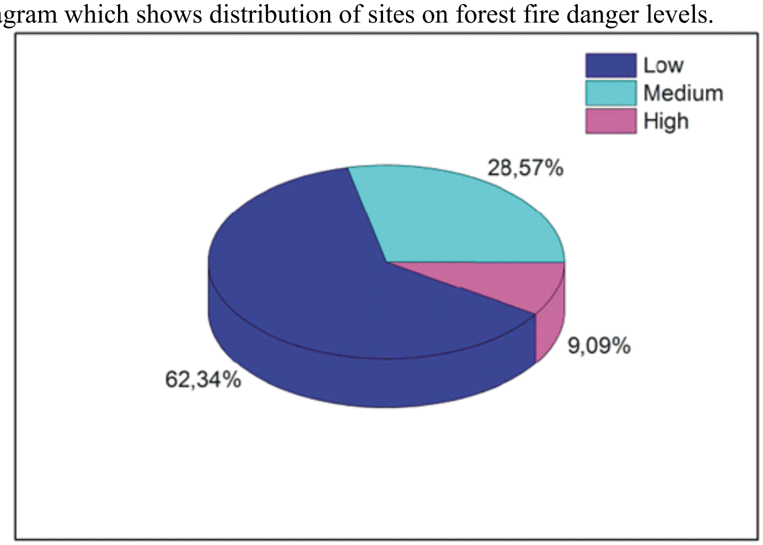

Figure 4. Distribution of forest sites on forest fire danger levels

5. Conclusion

The study represents the description of the web-oriented geoinformation system prototype for forest fire danger estimation taking into account the factor of the focused sunlight. System approbation was implemented in the territory of the Timiryazevskiy forestry of Tomsk region (Russia). The analysis of results allows us to conclude that the critical level of forest fire danger is characteristic only for a small number of forest sites in the controllable territory. It is possible to install the system of video observation with GSM-access in order to control such territories. The prognostic and estimated information is processed on a server, access to which is carried out through Internet. Development of the given system has prospects for creation of physically proved technologies of monitoring, estimating and forecasting of forest fire danger.

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