FIRE STATIONS IN THE FORESTRY AROUND THE WORLD: DATA, INFRASTRUCTURE AND FEATURES TO MANAGE FOREST FIRES

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Abstract
Paper gives an overview of forestry regulations and forest fire stations features in a number of countries including Russia, the Republic of Belarus, European countries, Canada, USA, China, Finland, Australia, and Turkey. Stations in the forestry worldwide have a history dated back to the centuries. Forest fire stations provide tools, vehicles and work forces to manage wildfires by reaching them by roads. Modern system of stations varies from country to country, they are managed by administrative units or regions and have federal governance in all these countries. There is a common feature of their classification in Russia and Belarus. Publicly available data on the forest fire stations are very limited, a search is needed by addressing the government organizations on coutry basis or the forestry researchers. Based on the reviewed papers the most frequent methodology to evaluate forest fire stations layout is implementation of spatial and network analysis in GIS-software.

Key words: *Forestry, Forest Fire stations, Infrastructure, GIS.*

INTRODUCTION

There is a series of researches on the location and optimal distribution of urban fire stations within towns and cities (Aleisa, 2018; Rokde et al., 2019; Bispo et al., 2023), some works address links between fire stations and population (Echeverria et al., 2018), discuss decision support tool to locate fire stations in a a small European country like Belgium (Chevalier et al., 2012); others cover city's extent and describe spatial planning of forest fire stations based on the location-assignment model including response time, construction cost, and coverage area (Yang et al., 2023).

Over the last decades, research community has shown the great interest in studying forest fires (Martynyuk et al., 2016; Loupian et al., 2017; Sakellariou et al., 2020; Tarko et al., 2021; Tyukavina et al., 2022; Ciesielski et al., 2022; Kotelnikov et al., 2023), covering methods of remote sensing implementation, statistics and prognosis for the future. Key role in the emergency response to access forest fires by ground means belongs to the infrastructure, settlements and roads, fire stations. Settlements are the logistics centers of work forces and equipment to manage forest fires. Trunk roads varying in classification from country to country, as well as temporary logging roads, which include branches and forest roads, are used all year round to extinguish forest fires.

For the present moment we state a lack of investigations in the forestry domain where fire stations usually located and managed at the regional extent (Akay et al., 2018; Podolskaia et al., 2020a, 2020b, 2020c; Podolskaia, 2021; Akay et al., 2022). In order to continue and extend the topic of fire stations in the forestry covered in the paper (Podolskaia, 2022) we discuss their datasets, infrastructure and features at global scale in the countries with developed forestry practive like Russia, the Republic of Belarus, European countries, Canada, USA, China, Finland, Australia, and Turkey.

Stations in the forestry worldwide

As we know from the history research (Fedotova, 2014), the first forestry stations as experiment were established in Europenian countries in XIX century (1860–1870s). Russian Federation was also a part of it. The main initial idea of forestry stations was studing soil, its dynamics under the forest canopy. Leading forestry experts from Forestry Society of St. Petersburg supported by Forestry Department made a proposal of the stations. That was the first time of stations appearance as centers of forest monitoring, then forest have a meaning of meteoropological monitoring and measuring.

Now data on the meteorological stations could be obtained from different countries, for example, from Natural Resources Canada (NRCan) via Open Government Portal.

In some countries like Australia, Belarus, United States, and Turkey (Bugday, 2019) we can find examples of fire lookout trees and fire lookout towers (or forest fire watch-towers) located on the mountain summits or on any other point with elevation which is enough to viewing long distances around. For instance, Forestry Ministry of the Republic of Belarus have under its responsibility about hundreds of fire observation towers and masts equipped with video surveillance systems (https://www.mlh.by/news/6652/). There is a type of weather station used to prevent and to monitor forest fires (https://www.renkeer.com/weather-station-aids-prevent-forest-fire/).

In the present research by forest fire station we mean a logistical center or equipment store to access forest fire (wildfire, bushfire, or wildland fire) by ground means (heavy trucks with equipment and trained work force). Fire stations are the main territorial and forest structural units on the forest lands in areas where ground forces and fire extinguishing equipment are used.

Their definition varies from country to counry, in Russia fire stations are called fire-chemical stations, in others – fire stations that deal with wildfires management and are being the logistical centers of regional firefighting activities. Some of them have publicly and more or less actively updated datasets on the fire stations location. This paper is an overview of forest fire stations infrastructure, their spatial extent and features; could be of interest for the researchers in search of fire stations data in the forestry. Review on the fire stations-related research was made based on the currently available papers from ResearchGate (https://www.researchgate.net/), electronic libraries e-library (https://www.elibrary.ru), Cyberleninka (https://cyberleninka.ru/) and publicly available information from the Internet (as of May 2024).

Forestry regulations and forest fire stations by country

In Russia

Fire-chemical stations (FCS – in Russian forestry terminology) are specialized divisions of forest fund owners (forestry enterprises, reserves, national natural parks, educational, forestry and experimental forestry enterprises, collective farms, state farms and other agricultural formations carrying out forestry management). They work with the aim of forest fires timely elimination (https://xn--b1ae4ad.xn--p1ai/enc/pozharno-khimicheskie-stantsii-pkhs; https://mchs.gov.ru/ministerstvo/o-ministerstve/terminy-mchs-rossii/term/221) taking into account official document (Methodological recommendations…, 2014).

FCS plays a role of forestry division equipped with fire fighting equipment, means of transport and communication, fire extinguishing chemicals, and intended for the prevention and extinguishing of forest fires **(**Tjurin et al., 2019). FCS are organized in the forest fund where forests of I-III classes of fire danger predominate, within the areas of forest ground protection (Forest Encyclopedia, 1985). There are three types of PCS (Order of Rosleskhoz dated December 19, 1997 N 167) depending on the purpose, equipment, and structure.

PHS-I (first type) is organized mainly in forest districts whose forests have high natural fire hazard. Fire stations of I type manage two simultaneous fires per day; they also participate together with other units in extinguishing the spread of forest fires within serviced area. They have specialized forest fire equipment, extinguishing means, transport, communications; function as a rule for the fire season.

PHS-II (second type) is organized mainly in the central estates of forestry enterprises (national parks, state nature reserves), within the forests of high natural fire danger. They provide elimination of up to four simultaneously active fires per day, participate together with other formations in extinguishing the spread of fires in the serviced territory. They are equipped with more diverse and larger quantities than PHS-I, specialized forest fire extinguishing equipment, transport, communications. They also responsible for carrying out preventive measures and explanatory work among the population. PHS-II team is organized as a permanent or seasonal formation.

PHS-III (third type) manage areas whose forests have very high natural fire hazard, long fire season and are the most flammable in the region. It is formed within the forestry enterprises (national parks, state nature reserves) located in the center of a fire-hazardous zone to eliminate large forest fires that create emergency situations, as a special inter-district forest fire service of forestry management bodies in Russian regions. They are equipped with powerful tools, heavy

transport for prompt work force delivery to the fires, fire extinguishing equipment, communication means. They can create reserve warehouses. A PHS-III team is organized as a permanent (year-round) formation.

Forest fire stations, as a rule, are placed in the settlements of a forestry unit depending on the regulatory requirements for the service area. Project of fire station location should be created in accordance to the requirements of Russian Forest Code (Forest Code of the Russian Federation, 2006), to the Federal Law on the fire safety and to the Fire Safety Rules for the forest areas (Rulev, Matveeva, 2016). Fire stations are the important infrastructural facility in the system of forest protection (Kovalev et al., 2021)**.** Forest plan of administrative unit serves as a base to organize a fire station, decision of the regional executive authorities of the Russian Federation could also play a role.

In the Republic of Belarus

Ministry of Forestry (https://www.mlh.by/), its relevant structural divisions and entities involved in the forestry in cooperation with emergency departments of the Ministry of Emergency Situations are in charge of forest protection at the level of country and its regions (Usenya, 2023). State Forest Protection Service (SFPS) was created in the Republic of Belarus to ensure forests conservation and protection, to exercise control in their use and reproduction. The main units of forest fire services in the Republic of Belarus include fire-chemical stations of various types. Structure of fire stations is similar to the Russian system and includes PHS of I and II types, in addition to them there are the stores of fire equipment.

In Europe

EFFIS (https://forest-fire.emergency.copernicus.eu/) - European Forest Fire Information System - supports the services in charge of the protection of forests against fires in the EU and neighbor countries and provides the European Commission services and the European Parliament with updated and reliable information on wildfires in Europe (San-Miguel-Ayanz et al., 2012). Currently, the EFFIS network is constituted by countries, including EU Member States, European non-EU countries and 4 countries (Algeria, Lebanon, Morocco and Tunisia). According to the information received from the European Commission - Joint Research Centre, nowdays fire management is a competence of the EU Member States, every country has its own system and datasets on the forest fire stations.

Main source of data is (https://forest-fire.emergency.copernicus.eu/; https://forest-fire.emergency.copernicus.eu/applications). There is an updated set of forest fires maps at https://forest-fire.emergency.copernicus.eu/reports-and-publications/countryregional-wildfire-maps with unified styled maps for the regions in Europe, North Africa and Middle East with burnt areas and number of fires, but no fire stations indicated. There is also a set of annual fire reports on the region and country basis (https://forest-fire.emergency.copernicus.eu/reports-and-publications/annual-fire-reports). From Data and Services section (https://forest-fire.emergency.copernicus.eu/applications/data-and-services) we can access to real-time updated Burnt Areas database in shp-file ans SpatiaLite formats. Layer with settlements could be of use to plan or to model a layout of fire stations as they often located within the settlements.

Research activities on the evaluation of fire stations layouts are presented by country scale, an example is shown in the paper for the management of forest fires in the province of Spain (de Domingo et al., 2021).

In Canada

Fire management in Canada is a responsibility of autonomous provinces and territories. Research activities are being undertaken at the federal level. Provincial governments are the key management units to react for the forest fires (Copes-Gerbitz et al., 2022), they have a system of three tiers including a headquarter, fire centers in the regions, and district offices. Information accessible via the Ministry of Natural Resources and Forestry (https://www.ontario.ca/page/fire-management-offices#section-2). Some Canadian provinces have special firefighting teams to handle forest fires.

The Canadian Wildland Fire Information System (CWFIS) produces daily fire weather and fire behavior maps year-round and hot spot maps throughout the forest fire season, generally between May and September (https://cwfis.cfs.nrcan.gc.ca/home). Canadian geospatial data could be found at (https://natural-resources.canada.ca/science-and-data/data-and-analysis/geoca/).

In USA

Forest management is a key responsibility of a number of state agencies in US, they are the USDA Forest Service, the Bureau of Land Management, the National Park Service, and the Department of Defense **(**Vatandaslarb, 2024**).** USDA

Forest Service used its current fire management strategy (https://www.fs.usda.gov/managing-land/fire). The history of fire lookout towers is linked to the United States Forest Service (USFS) which is an agency within the U.S. Department of Agriculture. Many townships, private lumber companies, and State Forestry organizations managed fire lookout towers on their own. Research work is being conducted since 1905 (https://www.fs.usda.gov/research/).

As example we note the California Department of Forestry and Fire Protection (CAL FIRE), fire department of the California Natural Resources Agency in the State of California (https://data.cnra.ca.gov/dataset/cal-fire-facilities-for-wildland-fire-protection) which is responsible for fire protection in various forest and wildland areas. A statewide agency Connecticut DEEP Forest Fire Service share responsibility to fight forest fires with the local departments, for instance they have 9 fire stations (https://fire.fandom.com/wiki/Connecticut_Forest_Fire_Service#Station_Map).

In China

The National Forestry and Grassland Administration of China fonctions presently as the National Park Administration and supervises and manages fires in the forests among grasslands, wetlands, and deserts. National Science Foundation of China (wellknown globally as NSFC) is one of the major organizations to support scientific and technological innovation of forest fire safety. At the national level in China there is the State Key Laboratory of Fire Science (SKLFS) for the basic forest fire research.

In China, like in other big countries, there is a practice of using weather stations. A network of weather stations is used for the forest fires anticipation and firefighting; it includes two groups and subgroups (Bangyu, Xiaozhong, 1996).

In Finland

Extinguishing fires, including forest fires, is under responsibility of Rescue Services of the Ministry of the Inrerior (https://intermin.fi/en/ministry), there are few dozens of main firefighting stations throughout the country. They are equipped to manage different fires and are provided with the professional staff. They also lead the mobilization of volunteer firefighters on the ground. Some related to the forest fires research is being conducted by Finnish Meteorological Institute.

In Australia

Australasian Fire and Emergency Service Authorities Council (AFAC) is the official organization for fire, land management and emergency service organisations in Australia and New Zealand (https://www.afac.com.au/).

Firefighting against forest fires is a responsibility of each state or Territory. There are three types of firefighting organizations, one of them is in change of government managed public land including forestfighting. Each state in Australia has its own website, for instance bushfire-related datasets at (https://www.seed.nsw.gov.au/need-help/finding-data-on-dataset-catalogue/bushfire-related-datasets). Forestry maps could be found at https://www.agriculture.gov.au/abares/forestsaustralia/forest-data-maps-and-tools/forest-maps#australias-forestry-industry-map).

In Turkey

Majourity of the forest lands in Turkey are government-owned and managed by the General Directorate of Forestry (GDF) connected to the Ministry of Agriculture and Forestry (https://www.tarimorman.gov.tr/). GDF plays a key role in firefighting and includes 28 district offices, 243 forestry departments, and 1403 forest sub-district directorates (Elvan et al., 2021). Like in other countries constantly dealing with forest fires, detection and control of forest fires is one of national priorities in the forestry sector. Turkey uses three main strategies to fight against forest fires: prevention – extinguishing – restoration (Palenova et al., 2023). There is a set of researches covering forest fires management and published recently (Demir et al., 2019; Vatandaslarb, 2024; Gultekin, Y.S., Gultekin, P., 2024).

Apart from mentioned countries we have found few papers mentioning forest fire stations: one for Central Nepal (Ranabhat et al., 2022) describing how to evaluate forest fire risks and place fire stations according to them and one paper (Lemessa, Perault, 2001) about the state of forestry in Ephiopia where there is a need to create firebreaks and fire towers in the absence of regulation and fire management from the state.

Datasets available on the forest fire stations and software to be used with

We have searched for the data on the forest fire stations in GIS- and non-GIS formats. ArcGIS Online has a collection of data for the forestry, available formats are Feature and Map Services, all dated of 2022-2023.

US datasets formats varies from DOC-files to the APIs (they are CSV, HTML, ArcGIS GeoServices REST API, JSON and GeoJSON, ZIP, KML, XML). The Forest Service uses ArcGIS Online and Open Data. Description of some available US-examples covering fire stations of general use is presented in the Table.

Table 1. US-data sources for the fire stations (including forest fire stations)

Management unit	**Web-link, data description, attributes**	**Format if information available**	**Publications/ Updates**
ArcGIS HUB	***Fire stations in the United States*** https://hub.arcgis.com/datasets/6ac2adfd51414a28b30841bbdd912db1/about the oldest record dates from 01/03/2005 and the newest record dates from 01/11/2010	CSV	2019/2024
The US Forest Service	***Fire stations*** https://usfs.maps.arcgis.com/apps/mapviewer/index.html?layers=8589a27ad1ff4b688c60024f33f831fe address, telephone number, geographical coordinates, type of operation (fire and rescue service)	Map Viewer	2017
The US Forest Service	***STATION FIRE PERIMETER*** https://usfs.maps.arcgis.com/apps/mapviewer/index.html?layers=2fee421dd6dc4c788edfbbd3cf70af50 area, perimeter	Map Viewer	2009/2016
Common-wealth of Massachusetts	***MASSGIS DATA: FIRE STATIONS*** Fire Stations layer shows the point locations of 771 Fire stations https://www.mass.gov/info-details/massgis-data-fire-stations#downloads-	SHP, LYR-symbology	2022
California Department of Forestry and Fire Protection	***FACILITIES FOR WILDLAND FIRE PROTECTION*** https://gis.data.cnra.ca.gov/maps/CALFIRE-Forestry::facilities-for-wildland-fire-protection/about; https://www.arcgis.com/home/item.html?id=8e72bb9b01954c83bf910cef4174bb3a; https://egis.fire.ca.gov/arcgis/rest/services/FRAP/Facilities/FeatureServer address, geographical coordinates *Dataset includes state and local funded fire stations, stations providing wildland firefighting services*	Feature Service	2021/2023
Arkansas GIS Office, State of Arkansas	***FIRE STATIONS TGS (HISTORICAL)*** HTTPS://GIS.ARKANSAS.GOV/PRODUCT/FIRE-STATION-POINT/; https://gis.arkansas.gov/arcgis/rest/services/FEATURESERVICES/Structure/FeatureServer/; publisher – Techni Graphic Systems, Inc.	Feature Service	2010/2014

There is a set of software, spatial and non-spatial like in the paper (Tjurin et al., 2019), that deals with the fires stations and their modeling. We can definitevly state ArcGIS from ESRI, QGIS as an Open Source software, special modeling

packages like AnyLogic (https://anylogic.help/anylogic/gis/index.html). For the last tens of years researchers use these GIS-softwares for the modeling projects, for instance (Akay et al., 2018; Sokolovic et al., 2022; Awad et al., 2024).

Search with QuickMapServices plug-in (https://plugins.qgis.org/plugins/quick_map_services/) to QGIS shows no datasets or services on the forestry fire stations. Extended search in the content of QGIS-plug-ins library (https://plugins.qgis.org/) has shown no variants to find these forestry data. Search for the fire stations at (https://data.world/datasets/fire-station) gave one result of a dataset for the Fire and Emergency Medical Services Department in US updated in 2019. Search in the Kaggle database for Machine Learning (https://www.kaggle.com/datasets) resulted in several datasets, there is spatial database of wildfires that occurred in the United States from 1992 to 2015(1.88 Million US Wildfires (FPA_FOD_20170508.sqlite). It is in the public domain and available at (https://www.kaggle.com/datasets/rtatman/188-million-us-wildfires). In that database there is an attribute of 'complex name' which is a name of the complex under which the fire was ultimately managed, when discernible. For US there is a set of reports coming prom Forest Service Research Data Archive, for example (Short, 2017).

CONCLUSIONS AND FUTURE RESEARCH

Conclusions of paper are determined by data and materials that could be found in the public domain. Coutries manage forest fires at the federal and regional level, so layouts of forest fire stations are organizied at different spatial extents.

Majourity of reviewed papers with reference of forest fire stations have used GIS-methods like spatial and network analysis to evaluate existing and possible locations of fire stations, to make maps of their actual and prospective location. Accessibility of fires from fire stations remains an actual research topic linked to up-to-date data on the road networks and settlements. There is a certain luck of publicly available data on the forest fire stations, some attributes linked to them are included in the GIS-datasets but require a deep investigation.

There is still no global research on the special location (layout) of forest fire stations and we have to seach for their geodata if we know government organization or by coutry basis. Useful help could be found asking researchers on the forest fires management directly by their published e-mail contacts.

To extend the review we could consider an idea to make one database of forest fire stations, to merge spatially already available data and to enrich it with additional information. Attributes and geometry of a global layer with fire stations could help in evaluation forest fires suppression activities, forestry management, modeling transport accessibility of forest fires in the countries and in their bordering regions. This database as a file of global coverage could be a constantly updated product available for the researchers in the forestry domain.

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REFERENCES

Akay A. E., Karas I. R., Kahraman I. Determining the locations of potential firefighting teams by using GIS techniques. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2018. International Conference on Geomatics and Geospatial Technology (GGT 2018), 3–5 September 2018, Kuala Lumpur, Malaysia. XLII-4/W9. P. 83-88. https://doi.org/10.5194/isprs-archives-XLII-4-W9-83-2018

Akay A. E., Podolskaia E. S., Aricak B. Spatial modeling of transport and resources accessibility for protecting forest ecosystems against forest fires. In: Suratman, M.N. (eds). Concepts and Applications of Remote Sensing in Forestry. 2022. Springer, Singapore. P. 99-114. https://doi.org/10.1007/978-981-19-4200-6_5

Aleisa E. The fire station location problem: a literature survey. Int. J. Emerg. Manag. 2018. 14 (3). P. 291-302. https://doi.org/10.1504/IJEM.2018.094239

Awad A. M. M., Wikantika K., Ali H., Abujayyab S. K. M., Hashempour J. Optimization of new fire department location using an improved GIS algorithm for firefighters travel time estimation. International Journal of Emergency Services. 2024. Vol. 13 No. 1. P. 80-97. https://doi.org/10.1108/IJES-04-2023-0011

Bangyu C., Xiaozhong J. Managing forest fires: an automatic fire weather station network in China. In: El-Sabh, M.I., Venkatesh, S., Denis, H., Murty, T.S. (eds) Land-Based and Marine Hazards. Advances in Natural and Technological Hazards Research. 1996. Vol 7. Springer. Dordrecht. P. 287-293. https://doi.org/10.1007/978-94-009-0273-2_21

Bispo R., Vieira F. G., Yokochi C., Marques F. J., Espadinha-Cruz P., Penha A., Grilo A. Using spatial point process models, clustering and space partitioning to reconfigure fire stations layout. Int J Data Sci Anal. 2023. P. 1-11. https://doi.org/10.1007/s41060-023-00455-z

Bugday E. Evaluation of forest fire watch-towers location. International Congress on Engineering and Life Science. 2019. ICELIS. P. 518-522.

Ciesielski M., Balazy R., Borkowski B., Szczesny W., Zasada M., Kaczmarowski J., Kwiatkowski M., Szczygiel R., Milanovic S. Contribution of anthropogenic, vegetation, and topographic features to forest fire occurrence in Poland. iForest. 2022. 15. P. 307-314. doi: https://doi.org/10.3832/ifor4052-015

Chevalier P., Thomas I., Geraets D., Goetghebeur E., Janssens O., Peeters D., Plastria F. Locating fire stations: an integrated approach for Belgium. Socio-Econ. Plan. Sci. 2012. 46(2). P. 173-182. https://doi.org/10.1016/j.seps.2012.02.003

Copes-Gerbitz K., Hagerman S. M., Daniels L. D. Transforming fre governance in British Columbia, Canada: an emerging vision for coexisting with fire. Regional Environmental Change. 2022. 22. P. 1-15. https://doi.org/10.1007/s10113-022-01895-2

Demir H. I., Nur M., Kokcam A. H., Erden C. Determination of new proper fire station location using TOPSIS and AHP techniques: a case study from Turkey. Proceedings of 10th International Symposium on Intelligent Manufacturing and Service Systems (IMSS'19). Sakarya University - Sakarya/Turkey, 9-11 September 2019, P. 153-162.

de Domingo M., Ortigosa N., Sevilla J., Roger S. Cluster-based relocation of stations for efficient forest fire Management in the Province of Valencia (Spain). Sensors. 2021. 21. P. 797. https://doi.org/10.3390/s21030797

Echeverria F., Abrego A., de Audicana M.G., Lopez-Maestresalas A., Arazuri S., Ciriza R., Jaren C. Analysis of fire services coverage in Spain, Dyna 93. 2018. P. 247-251.

Elvan O. D., Birben U., Ozkan U. Y., Yidirim H. T., Turker Y. O. Forest fire and law: an analysis of Turkish forest fire legislation based on Food and Agriculture Organization criteria. Fire ecology. 2021. 17. 12. P. 1-15. https://doi.org/10.1186/s42408-021-00102-7

Fedotova A. Forestry experimental stations: Russian proposals of the 1870s. Centaurus. 2014. Vol. 56. P. 254-274; doi:10.1111/1600-0498.12070

Forest Code of the Russian Federation of 04.12.2006 N 200-Federal Law (edited 04.08.2023) (in force with additions since 01.01.2024). Accessed on 08/05/2024 at https://www.consultant.ru/document/cons_doc_LAW_64299/

Forest Encyclopedia: In 2 volumes. Chief ed. Vorobyov G.I.; Editorial team: Anuchin N.A., Atrokhin V.G., Vinogradov V.N. and others - M.: Sov. Encyclopedia, 1985. 563 p.

Gultekin Y.S., Gultekin P. Forest Fire Risk Management at the Country Scale: The Case of Turkey. In: Rodrigo-Comino, J., Salvati, L. (eds) Fire Hazards: Socio-economic and Regional Issues. 2024. Springer. P. 43-52. Cham. https://doi.org/10.1007/978-3-031-50446-4_4

Kotelnikov R. V., Loupian E. A., Balashov I. V. 2023. Preliminary analysis of forest fires in the Russian Federation in the 2023 fire season based on remote monitoring data. Modern problems of remote sensing from the Earth from space. 2023. 20(5). P. 327-334. DOI: 10.21046/2070-7401-2023-20-5-327-334

Kovalev R., Enaleeva-Bandura I., Baranov A., Grigoreva O., Grigorev I. Mathematical model for determining the optimal location of forest fire and chemical stations taking into account the level of development of transportation networks on the territory of the forest fund. Resources and Technology. 2021. 18 (4). P. 77-92, 2021. DOI: 10.15393/j2.art.2021.5963

Lemessa D., Perault M. Forest fires in Ethiopia: Reflections on socio-economic and environmental effects of the fires in 2000. UNDP emergencies for Ethiopia. 2001. accessed on 09/05/2024 at https://reliefweb.int/report/ethiopia/forest-fires-ethiopia-reflections-socio-economic-and-environmental-effects-fires

Loupian E. A., Bartalev S. A., Balashov I. V., Egorov V. A., Ershov D. V., Kobets D. A., Senko K. S., Stytsenko F. V., Sychugov I. G. Satellite monitoring of forest fires in the 21st century in the territory of the Russian Federation (facts and figures based on active fires detection). Modern problems of remote sensing of the Earth from space. 2017. 14(6). P. 158-175. DOI:10.21046/2070-7401-2017-14-6-158-175

Martynyuk A. A., Sidorenkov V. M., Doroshchenkova E. V., Sidorenkova E. M., Zakharov Yu. G. Zoning of the Russian Federation territory based on forest management and forest use intensity. Siberian Journal of Forest Science. 2016. 1. P. 3-12. DOI: 10.15372/SJFS20160101

Methodological recommendations on the use of forces and means to extinguish forest fires (approved by the Ministry of Emergency Situations of Russia on 07/16/2014 No. 2-4-87-9-18). http://legalacts.ru/doc/metodicheskie-rekomendatsii-po-primeneniiu-sil-i-sredstv-dlja-tushenija/ (accessed on 09/05/2024).

Order of Rosleskhoz dated December 19, 1997 N 167 “On approval of the regulations on fire-chemical stations”. https://aviales.ru/files/documents/2015/lps.npa/lps_36.pdf

Palenova M., Yugov A., Filipchuk A., Zolina T. Forestry in the Republic of Turkey: Overview. Forestry information. 2023. N 1. P. 68–83. DOI 10.24419/LHI.2304-3083.2023.1.06

Podolskaia E. S. Analysis of infrastructural forest data with GIS-tools. Abstr. Int. Cartogr. Assoc. 2021. 3. P. 243. https://doi.org/10.5194/ica-abs-3-243-2021

Podolskaia E. S. Fire stations: modern standards and infrastructural features in the Russian forestry. Complex problems of technosphere security. Proceedings of VII International Scientific and Practical Conference. 2022. Voronezh State technical University, Voronezh, 1. P. 491-499.

Podolskaia E., Ershov D., Kovganko K. Automated construction of ground access routes for the management of regional forest fires. J. For. Sci. 2020a. 66. P. 329-338. https://doi.org/10.17221/59/2020-JFS

Podolskaia E., Kovganko K., Ershov D. Regional geoinformation modeling of ground access to the forest fires in Russia. In: Popovich V., Thill JC., Schrenk M., Claramunt C. (eds) Information Fusion and Intelligent Geographic Information Systems. Advances in Geographic Information Science. Springer. 2020b. P. 155-165. Cham. https://doi.org/10.1007/978-3-030-31608-2_11

Podolskaia E., Ershov D., Kovganko K. GIS-Approach to estimate ground transport accessibility of forest resources (case study: Novosibirsk Region, Siberian Federal District, Russia). Journal of Geographic Information System. 2020c. 12. P. 451-469. 10.4236/jgis.2020.125027

Ranabhat S., Pokhrel A., Neupane A., Singh B., Gahatraj S. Forest fire risk assessment and proposal for fire stations in different geographical regions of Central Nepal. Journal of Forest and Livelihood. 2022. 21 (1). P. 46-59.

Rokde P., Valdes-Vasquez R., Mosier R. The Green Status of Fire Stations in the United States: an Analysis of Leed-nc V3. Journal of Green Building. 2019. 14 (2). P. 137-153. https://doi.org/10.3992/1943-4618.14.2.137

Rulev A. S., Matveeva A. A. Ecological and economic aspects to design a regional network of fire stations for the regulation of fire hazardous situation. Bulletin of agriculture and industry of Stavropol region. Ecology. 2016. N 3(23). P. 251-255.

Sakellariou S., Sfougaris A., Christopolou O. Location planning of fire service fleet based on forest fire susceptibility. WSEAS Transactions on Environment and Development. 2020. 16. P. 643-648. DOI: 10.37394/232015.2020.16.66.

San-Miguel-Ayanz J., Schulte E., Schmuck G., Camia A., Strobl P., Liberta G., Giovando C., Boca R., Sedano F., Kempeneers P., McInerney D., Withmore C., Santos de Oliveira S., Rodrigues M., Durrant T., Corti P., Oehler F., Vilar L., Amatulli G. Comprehensive monitoring of wildfires in Europe: the European Forest Fire Information System (EFFIS), in John Tiefenbacher (Ed.), Approaches to Managing Disaster - Assessing Hazards, Emergencies and Disaster Impacts. 2012. P. 87-105.

Short K. C. Spatial wildfire occurrence data for the United States. 1992-2015. 4th Edition. Fort Collins, CO: Forest Service Research Data Archive. 2017. https://doi.org/10.2737/RDS-2013-0009.4

Sokolovic D., Bajric M., Akay A. E. Using GIS-based network analysis to evaluate the accessible forest areas considering forest fires: the case of Sarajevo. European Journal of Forest Engineering. 2022. 8(2). P. 93–99.

Tarko A. M., Kurbatova A. I., Grigorets E. A. System analysis of forest fires in the Russian Federation. Geographical Environment and Living Systems. 2021. 1. P. 17–41. DOI: 10.18384/2712-7621-2021-1-17-41

Tjurin N. A., Gromskaya L. Ya., Antonova T. S., Zubova O. V., Siletskiy V. V. Optimization location of forest fire stations. Bulletin of St.-Petersburg Forestry Academy. 2019. 227. P. 224–235 DOI: 10.21266/2079-4304.2019.227.224-235

Tyukavina A., Potapov P., Hansen M. C., Pickens A. H., Stehman S. V., Turubanova S., Parker D., Zalles V., Lima A., Kommareddy I., Song X-P., Wang L., Harris N. Global trends of forest loss due to fire from 2001 to 2019. Front. Remote Sens. 2022. 3:825190.P. 1-20. doi: 10.3389/frsen.2022.825190

Vatandaslarb C. Comparative analysis of forestry systems in the United States and Türkiye: Practices, technologies, and challenges. Eurasian Journal of Forest Science. 2024. 12(1). P. 19-45. DOI: 10.31195/ejejfs.1413359

Yang J., Guo K., Dai Y., Tian S., Wang W., Jiang Z., Dai Z. Spatial layout siting method for fire stations based on comprehensive forest fire risk distribution. Case Studies in Thermal Engineering. 2023. Vol. 49. P. 1-13. DOI:10.1016/j.csite.2023.103243

Usenya V. V. Protection of forests from fires in the Republic of Belarus: status and ways for improvement. Sib. J. For. Sci., 2023. N 6. P. 141-154.

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