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Tools supporting planning and organizing rescue actions in state forests in Poland as an example of the practical implementation of scientific research

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Abstract

In terms of the average number of forest fires (7,188) in 2010-2019, Poland was third in Europe after Portugal (19,362) and Spain (11,860). The average burnt area, which is a kind of efficiency indicator for the forest fire protection system, in the analyzed period was 0.42 ha in Poland. The functioning fire protection system in the State Forests, which covers 76.9% of the forest area in the country, is constantly improved thanks to close cooperation with the Forest Research Institute. The results of the research conducted by the Institute are thus implemented in forestry practice, examples of which are presented in this article.

The basis for planning and organizing rescue operations is the assessment of potential forest fire risk, which is carried out using the method of classifying forest areas to the forest fire risk category. It is determined for the forest district (average area 17500 ha) for 10 years on the basis of the frequency of fires, forest stand, climatic and anthropogenic conditions according to the formulas developed for each of the factors. The category determines the distribution of funds for fire protection and the method of forest preparation in the event of a fire, concerning fire detection, communication and alarm systems, the density of fire access roads and water supply points, and fire extinguishing equipment. The macroscopic method of forest fire risk categorization is complemented by the method of forest stand flammability classes, which determines their susceptibility to fire due to the presence of flammable material. It is based on the forest habitat type and soil cover type and is determined at the level of separation (average area 3 ha), with the possibility of generalization to the division (20 ha) and forestry (1300 ha). Both methods are used to map the potential fire risk of forests in Poland. The method of determining the degree of forest fire risk on the basis of air temperature and relative humidity, precipitation and direct measurements of moisture content of pine litter (*Pinus sylvestris*) is used to assess the dynamic forest fire risk, shaped by weather conditions. Determining the degree of risk is performed from the 1st of March to the 30th of September, daily at 9.00 and 13.00 in 60 forecast zones with the use of an automated network of 145 meteorological measuring points. Information on the degree of risk determines the operational readiness of ground and air forces. In the event of a fire and determination of its forest address, we can download from the Information System of the State Forests, data on the flammability class of the forest stand and the characteristics of the flammable material (type, fuel load), using the developed fuel models for 7 types of soil cover, the fires of which constitute nearly 90 % of all events.

The possibility of a soil cover fire turning into a crown fire is determined based on the developed algorithms, taking into account the age of the forest stand, habitat and stand conditions, meteorological conditions and the duration of the fire. Organizing a firefighting action, including in particular having the right amount of forces and resources to extinguish a fire with the smallest possible area, can be supported by the application "Model of a forest fire", which the forest service has at its disposal. It was developed on the basis of laboratory and field research on the conditions of the emergence and spread of forest fires. The result of these works was the development of algorithms in the form of mathematical equations, enabling the calculation of the basic parameters of a forest fire (speed of the front, surface and perimeter of the fire) depending on the wind speed, moisture content of the flammable material, fuel load and the time of free fire development. Model calculations can be performed for forest bed, grass, heather and total fires. Early fire detection, reliable alarming and extinguishing action at the earliest possible stage of fire development, supported by the above-mentioned actions contribute to the effective protection of state forests in Poland. The examples cited and discussed above indicate a high level of usefulness, practical application and full implementation at the national level of the results of the research work of the Forest Research Institute in the structures of the functioning and constantly improved system of fire protection of the State Forests in Poland.

1. Introduction

According to EFFIS data {Forest fires in Europe, Middle East and North Africa 2020. JRC Technical Report. 2021], in Poland in the years 2010-2019, on average, 7188 forest fires occurred in Poland. More fires were recorded only in Portugal (19,362) and Spain (11,860). Taking into account the average burnt area, which can be treated as a kind of efficiency indicator for the organization of the forest fire protection system, in the analyzed period it amounted to 0.42 ha in Poland. For comparison, the average in Portugal and Spain was at a similar level, amounting to 7.13 and 7.97 ha per fire, respectively. The maximum average burnt area was in Croatia (56.48 ha), followed by Serbia (28.10 ha), Greece (25.60 ha) and North Macedonia (21.40 ha). The functioning fire protection system in the State Forests, which cover 76.9% of the forest area in the country, is constantly improved thanks to close cooperation with the Forest Research Institute. Thanks to this, the results of the conducted research are implemented in practice, and selected examples of them in the field of supporting the planning and organization of firefighting actions are presented in this article. Its beginning is the assessment of the potential and dynamic fire risk, then the acquisition of forest stand data from the place where the fire started from the IT system and finally forecasting the spread of the fire.

2. Assessment of the potential risk to the forest

The basis for the operational planning and organization of rescue activities is the assessment of the potential fire risk of forests. The analysis determining the forest susceptibility to fire is performed by determining the potential fire risk at the following levels: national - classification of the Regional State Forests Directorates, of regions (NUTS 2) and subregions (NUTS 3), regional - classification of forest districts and counties, and local - classification of stands. The method of classifying forest areas into the forest fire riskcategory {Szczygiel et al, 2020] and the method of forest fire risk classification according to flammability classes [Kaczmarowski et al, 2021], developed by the Forest Research Institute, are used to evaluate the fire risk. The forest fire risk category is determined on the basis of the frequency of fires, forest stand, climatic and anthropogenic conditions according to the formulas developed for each of the factors. It decides on the distribution of funds for fire protection and the method of forest preparation in case of fire, concerning fire detection, communication [Szczygiel et al, 2020] and alarm systems, the density of fire access roads and water supply points, and fire extinguishing equipment. The categorization of forest fire risk is made on a macroscopic scale, because the minimum area for which it is determined is the area of a forest district, amounting to an average of 17.5 thousand hectares. The macroscopic method of forest fire risk categorization is complemented by the method of forest stand flammability classes, which determine their susceptibility to fire due to the presence of combustible material. It is based on the forest habitat type and the type of soil cover and is determined at the level of separation (average area 3 ha), with the possibility of generalization to the compartment (20 ha) and forest range (1300 ha). The classification of forest stand flammability can be used: when carrying out rescue and extinguishing actions of small and medium forest fires (risk assessment at the level of sub-compartment), when planning the target network of fire access roads and water supply points, and conducting rescue and firefighting actions when extinguishing large fires (risk assessment at the level of sub-compartment, compartment) and in determining the location of observation points and equipment bases for extinguishing forest fires (risk assessment at the forest range level).

3. Assessment of dynamic forest fire risk

To assess the dynamic forest fire risk, shaped by weather conditions, the method of determining the degree of forest fire risk is used on the basis of air temperature and relative humidity, precipitation and pine litter moisture content (*Pinus sylvestris*) [Szczygiel et al, 2017]. The determination of the degree is performed from March 1 to September 30, daily at 9.00 am and 1.00 pm in 60 forecast zones with the use of an automated network of 145 meteorological measurement points, making measurements with a 10-minute frequency. Their distribution density depends on the forest fire risk category. The method makes it possible to determine the current degree of risk on the basis of the measurements made, and to calculate the projected degree 24 hours in advance. The projected degree of risk is calculated on the basis of the forecasted values of meteorological parameters obtained from the numerical weather model (COSMO) and the projected moisture content of pine litter, calculated on the basis of equations developed for this purpose. Information on the degree of risk provided to the forest service and fire brigade determines the operational readiness of the ground and air forces.

4. Determining the data on the place where a forest fire occurred

In the event of a fire and determination of its forest address, we have the option of downloading from the Information System of the State Forests, data about the stand (habitat type, species, age, type of soil cover), which allow to determine the flammability class of the forest stand and the characteristics of the combustible material. For the fire characteristics (eg type, fuel load), developed fuel models are used for 7 types of soil cover, where fires account for nearly 90% of all events [Kwiatkowski et al, 2016]. The main features that characterize the type of fuel (fuel model) were: fuel load (kg / m^2), moisture of combustible material (%), heat of combustion and calorific value (KJ / kg) and fuel volume density (kg / m^3). In order to facilitate the mapping of the existing types of combustible materials, a matrix of the occurrence of fuel models was developed depending on the habitat type of forest and the type of cover, which allows to generate a map for any forest area after collecting forest stand assessment data.
The typology of fuels enables the identification of the occurring fire risk and is used in the fire spread forecasts.

5. Modeling of fire spread

From the point of view of the person managing the rescue operation, the key information is the type of fire, the expected size and speed of fire spread, which affects the amount of forces and resources necessary to extinguish the fire. The "Forest Fire Model" application is used to forecast fire development, which was developed on the basis of laboratory and field research on the conditions of the formation and spread of forest fires. The result of these works was the development of algorithms in the form of mathematical equations, enabling the calculation of the basic parameters of a forest fire (speed of the front, surface and perimeter of the fire) depending on the wind speed, moisture content of the flammable material, fuel load and the time of free fire development (time from the start of the fire to the start of the extinguishing). The amount of extinguishing agents needed (water and foam) is also calculated for the three fire extinguishing variants (extinguishing the entire surface, extinguishing the edges or location with barrier zones). Model calculations can be performed for litter cover, grass, heather and total fires [Szczygiel 1991, Szczygiel et al, 2013]. The possibility of a soil cover fire turning into a crown fire is determined based on the developed algorithms, taking into account the age of the forest stand, habitat and stand conditions, meteorological conditions and the duration of the fire [Szczygiel 1991]. The use of the application for forecasting the development of a fire can be used by the commander of the firefighting operation, because all alarm and disposition points of forest districts are equipped with it. This application can also be used for post-fire analysis and training purposes.
The process of supporting planning and organizing firefighting actions discussed in this article is presented in figure 1.

6. Summary

The forest fire protection system operating in Poland is based on three principles: early fire detection, immediate alerting of the rescue forces and starting fire extinguishing at the earliest stage of its development. Rapid fire detection is ensured by a comprehensive forest fire detection system, consisting of 693 lookout towers, 7 patrol planes and 320 patrol and firefighting vehicles. Moreover, nearly 50% of forest fires are reported by outsiders. Quick alarming about a fire is possible thanks to the created network of communication and alerting the forest service and fire brigade, which means that the average time of starting fire extinguishing is from 30 to 45 minutes. IT tools supporting operational planning, from the assessment of potential forest fire risk, through the assessment of fire risk depending on meteorological conditions, have an impact on the readiness of rescue forces to act. Data on the place of the fire allow assessing the risk of fire spreading there and at the same time are used to forecast the basic parameters of the fire, which allows you to have the required amount of forces adequate to the local risk and fire situation. This procedure of actions undoubtedly has a decisive influence on the effectiveness of extinguishing actions, expressed in the average area burned, and consequently also on the amount of losses caused by fires in the forest.

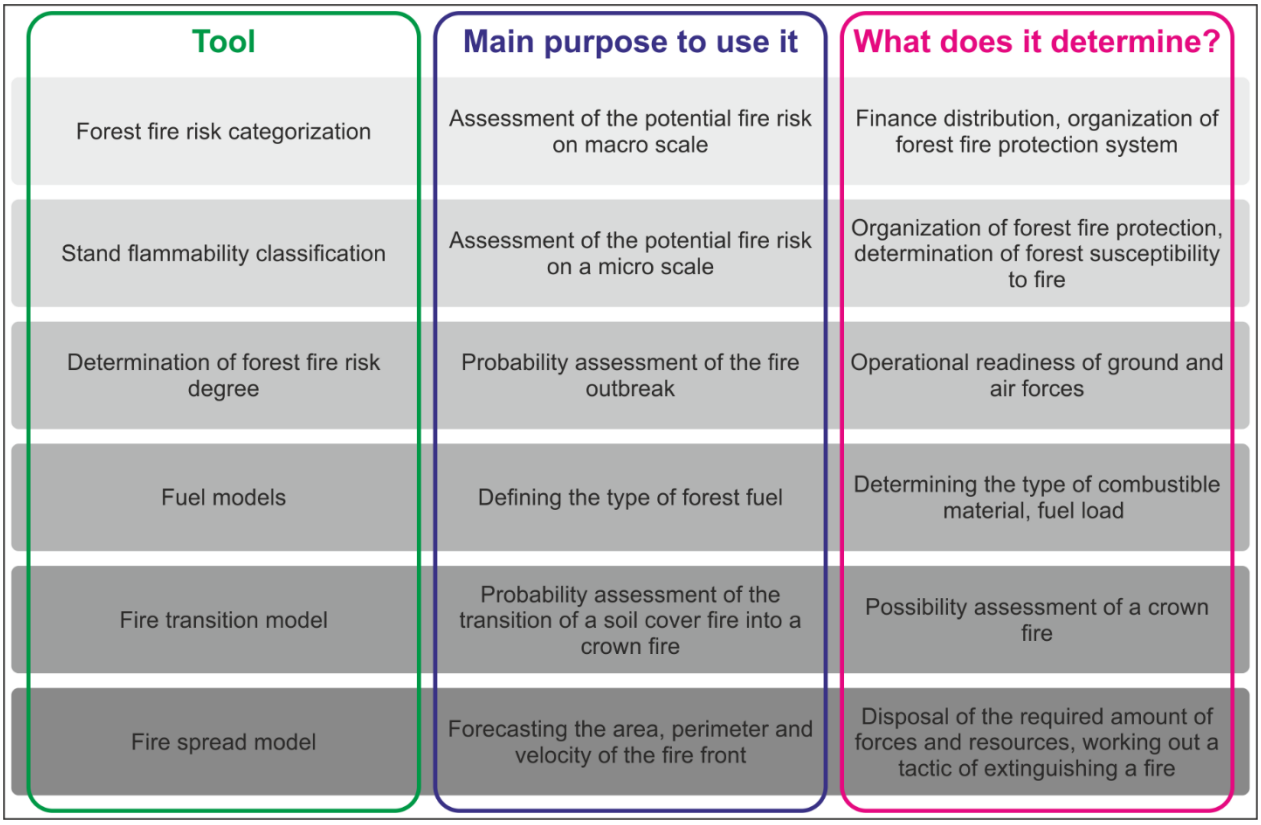

Figure 1. The process planning and organizing firefighting actions

7. Literature

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