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Laboratory of Forest Fire Protection – 60 Years of Research in the Field of Forest Fire Protection

Łukasz Tyburski ✉, *Ryszard Szczygieł*, *Mirosław Kwiatkowski*, *Józef Piwnicki*

Forest Research Institute, Laboratory of Forest Fire Protection, Sękocin Stary, Braci Leśnej 3, 05-090 Raszyn, Poland, phone: +48 22 7150430, e-mail: l.tyburski@ibles.waw.pl

Abstract

On 1 April 1963, the Department of Forest Fire Protection was established at the Forest Research Institute, which resulted from the need to develop scientific and organisational bases for building a forest fire protection system that would effectively minimise the growing fire hazard of Polish forests. The Department began its activities by developing a programme that took into account both the immediate but urgent needs of the forestry and the anticipated directions of research. Over the course of 60 years, more than 350 research reports were produced. Among the achievements that have influenced the currently functioning forest fire protection system in Poland there are: the method of forest fire risk assessment, forest fire risk prediction, the creation of fire risk monitoring based on a network of forest meteorological measuring points, the development of forest fuel models, the extensive use of aircraft to detect and extinguish forest fires, the conduct of the first studies on the possibility of using television cameras to detect forest fires, the operation of the National Forest Fire Information System, the purpose of which is to collect data on forest fires and natural non-forest areas, the development of an application for forest fire models and the conduct of the first workshop on controlled heath burn in the country. Among the many projects completed, there were also those dealing with the evaluation and suitability of equipment and chemicals for extinguishing forest fires.

Key words

fire hazard, forest fire protection, forest fire research, fire protection management

Introduction

Fire has always accompanied human, and the first documented traces of its use come from the period 650–450,000 years B.C. (Sygit and Guzewski 2016). It was both helpful and dangerous when out of control. The lack of water has always been the cause of fires that destroy the natural environment and pose a threat to human safety.

There is currently a significant increase of fire risk in forest ecosystems in Poland, Europe and the world. The analysis of long-term time series of meteorological data shows that since the beginning of the century there has been a trend towards increasing air temperatures and decreasing precipitation on the territory of Poland. These trends have intensified, especially since 1982, and continue to this day. This situation has caused an increase in the number of fires and the area

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burnt in the course of time; this was most noticeable in the 1990s.

A series of dry summers and warm winters were most dangerous in terms of creating forest fire risk. As a result, the lack of water caused by the summer drought was not compensated by water resources from snow cover; and this increased the risk of forest fire. (Szczygieł et al. 2007).

In the post-war period, there were relatively many forest fires covering large areas, mainly due to the lack of appropriate equipment and means for extinguishing them, as well as the lack of proper organisation and management of forest fire protection. To address these deficiencies, it was decided in the 1960s to establish a scientific and research unit for the State Forests that would attempt to establish the organisational basis for a modern forest fire protection system that would ensure efficient and effective control of the existing fire hazard and minimise the production and non-production losses of the forests through adequate fire prevention.

On 1 April 1963, the Department of Forest Fire Protection was established at the Forest Research Institute (FRI), its organiser and first manager was Tytus Karlikowski, PhD. Together with his team, he was the author of the national forest fire protection system, which is still in operation and is constantly being improved and is considered one of the most effective systems in Europe. All its components have been developed at FRI and successfully implemented in the State Forests.

When it was established, the Department of Forest Fire Protection began its activities by developing a programme that took into account both the immediate but urgent needs of forestry and the anticipated directions of research. These were in the following three areas:

1. Research on fire prevention in forests.
2. Basic scientific and research works aimed at determining the impact and extent of the negative impact of fires on the forest environment.
3. Experimental technical work on the selection of methods and means to combat forest fires (Rozwój… 1981).

The aim of the research in the field of prevention was to develop criteria for assessing forest fire risk and indicators of flammability in different types of stands, taking into account natural and forest regions. These tasks were related to determining the optimal species composition of stands that reduce fire risk. Within the framework of this task group, design assumptions were also developed and field tests were carried out with mechanical devices that enable the implementation of preventive measures, for example for the construction of fire belts. The basic research concerned the effects of fires of different intensities on tree species, undergrowth vegetation and soil and addressed issues of soil degradation and vegetation regeneration processes.

The last thematic group dealt with the development of methods for fighting fires in the forest, the improvement of equipment and chemical extinguishing agents and the organisation of observations in endangered areas.

Research in the field of forest fire protection is interdisciplinary and therefore requires the support of specialists from other fields, such as meteorology, chemistry, soil science and firefighting (Rozwój… 1981).

Several administrative changes took place during the existence of the department, as a result of which the name of the Department of Forest Fire Protection was later changed to the Independent Workshop of Forest Fire Protection (in 2002) and the current (since 2014) name of the Laboratory of Forest Fire Protection (LFFP). Over the course of 60 years, more than 350 research and field reports were produced (an average of about 9 per year). During the period of the greatest development of the team and the need for practical solutions, two additional field stations were established in Krzystkowice (Regional Directorate of State Forests in Zielona Góra) and in Niedźwiady (Regional Directorate of State Forests in Szczecinek), where field research was conducted, for example equipment that could be used by fire brigades and in field conditions, the spread of forest fires was studied, and the proposed methods for their control were evaluated.

This article presents some selected issues that have had a significant influence on the creation of a forest fire protection system, its functioning and continuous improvement.

Selected aspects of the activity of the Department /Workshop/Laboratory of Forest Fire Protection

Forest fire prevention includes forest fire hazard forecasting. In Poland, interest in this issue began in the 1960s. Work in this field was started in the Forest Fire

Protection Department of the FRI. Initially, the aim was to analyse the possibility of applying the existing European methods of fire risk assessment in the conditions of Polish forests. These attempts ended with the rejection of this idea due to the unsatisfactory accuracy in determining the threat compared to the actual occurrence. Attempts were also made to establish meteorological criteria for assessing the potential forest fire hazard on humidity indices, which also did not yield the expected results. For these reasons, it was decided to develop a separate method for predicting fire hazard, which was developed during the years 1964 to 1976. As a result, a method for determining fire hazard was developed, the so-called FRI method (Karlikowski 1981). It was based on three factors: moisture of pine litter, relative air humidity and precipitation. The use of litter moisture to determine forest fire hazard required a quick and accurate method to measure it. In the first years, the so-called xylene method was used, in which water was distilled from a litter sample together with xylene. However, this method was harmful to the health of the people taking the measurement. In the following years, the dryer method was used, in which the litter sample was dried with an infrared radiator, and with the automation of the measurement of meteorological parameters, moisture analysers came into use. Depending on the value of litter moisture and relative air humidity, the degree of forest fire hazard was determined by means of a table or diagrams drawn up for two observation times – at 9.00 a.m. and 1.00 p.m. The method assumed that fires can occur up to a scattered humidity of 60% and a relative air humidity of 100%. Depending on the amount of atmospheric precipitation, adjustments were made to the determined hazard level for the forecast zone. In the first version of the FRI method, six degrees of forest fire hazard were distinguished. This method was implemented for use in the State Forests, which were divided into 34 prognostic zones. In each of these zones, there was one prognostic point for measuring litter moisture and two to five auxiliary points (depending on the size of the zone) where relative air humidity and precipitation were measured.

In 1993, the FRI method was modified by changing the threshold values for litter moisture and relative air humidity and distinguishing four degrees of forest fire hazard (0, I, II, III) (Santorski 1999). The most important change was the lowering of the moisture content of the litter, at which there is a fire hazard, to 40%, but only for the 1 p.m. observation. As a result of subsequent changes, the forest fire hazard is currently determined based on the following factors: air temperature and relative humidity, as well as daily precipitation and the moisture content of pine litter (due to the dominant share of pine in Polish forests), which is an indicator of combustible material. The level of forest fire hazard is determined for forecast zones, which comprised 33 in 1975, 34 in 1981, 42 in 2008 and the current number of 60 forecast zones since 2018. The forecast zones were classified on the basis of dense forest complexes, membership of natural and forest districts, homogeneity in terms of climate, habitat and tree stand conditions, frequency and size of forest fires, radiotelephone communication, administrative division of the State Forests and the presence of large urban agglomerations, industrial regions and areas with high tourist traffic. The forest district was chosen as the basic organisational unit. The degree of forest fire risk determines the tasks and organisational measures that should be undertaken by the forest service (Szczygieł 2017).

The data for determining the degree of fire hazard are obtained from meteorological measuring points whose task is to analyse the meteorological conditions in forest areas. They are located in such a way that they reflect the influence of the forest stand on the local climatic conditions. In Poland, the first 17 meteorological measuring points in forest areas were established around 1955 and monitored by the National Hydrological and Meteorological Institute. From 1966, they are placed under the FRI's Forest Fire Protection Department. In the following years, the network of meteorological points was expanded. At the beginning of the 1990s, attempts were made at the FRI to use modern equipment to measure meteorological parameters by installing two automatic stations in Sękocin and Krzystkowice. At the beginning of the current century, the first automatic measuring stations were set up in the Regional Directorate State Forest in Szczecin, in which representatives of the FRI were involved. Another important step towards automating the measurements of meteorological parameters used to determine the forest fires hazard fire hazard was Ordinance No. 7 of the Director General of State Forests of 11 Febru-

ary 2004 on the operation of the network of year-round forest meteorological stations in the State Forests, according to which at least one automatic meteorological station was to be established in each Regional Directorate State Forest by the end of 2006.

In the year 2007 to 2008, the network of automatic measuring stations developed most dynamically. The basic weather stations measure parameters for 365 days, every 10 minutes, such as: rainfall, wind speed and direction, air temperature at 2, 0.5 and 0.05 m height, ground temperature at 0.05, 0.1, 0.2 and 0.5 m depth, air humidity at 2 and 0.5 m height and solar radiation. In addition, during the period of fire hazard risk and field observations, the moisture content of the litter is measured for stands aged 41 to 60 years growing in fresh coniferous forests or fresh mixed coniferous forests. The moisture content of the top layer of pine litter is measured with a specially programmed dry weight scale, which automatically transfers the results to a special system IT.

Within the created network of 146 meteorological measuring points, a distinction is made between forecast and auxiliary points. At the forecast points, in addition to the meteorological measurements, litter moisture is measured obligatorily, at some auxiliary points it is measured optionally. Using the meteorological data, the current forest fire hazard level is determined on the basis of the data derived from the meteorological measuring points (Szczygieł et al. 2020).

An important and interesting result of the research was the creation of forest fuel models. Thus, five forest fuel models were developed for plant materials of ground cover (boggy soil, litter, mossy, herbaceous in coniferous forests and forest habitats), taking into account the different types of forest habitats. The formulas developed in the model allow the calculation of the fire load depending on the age of the stand, taking into account the boggy soil layer and the aboveground vegetation layer. Depending on the fire load, the dry calorific value of the combustible material and the volumetric density, which is an indicator of the spatial structure of the fuel, are calculated. It is also possible to calculate the boggy soil moisture and the aboveground fuel layer for each fuel model depending on the litter moisture and the number of days without precipitation once with less than 1 mm or 5 mm precipitation. The information obtained from the forest fuel model can be helpful in optimising the fire protection infrastructure, which in turn can increase the effectiveness of firefighting and direct prevention measures (Szczygieł et al. 2017).

Another issue that received much attention was the comprehensive use of aircraft to detect and extinguish forest fires. In 1967, the Fire Protection Department of the FRI began research to determine the suitability of aircraft and helicopters for fire detection and to analyse the technical and economic effectiveness of using aviation equipment for this purpose. The agricultural version of the PZL-101 'Gawron' aircraft was selected for the test. This aircraft was a high-wing with a 260 hp engine. Its top speed was 171 km/h and its range was 666 km. The surveys were conducted on the territory of the Regional Directorate of State Forests in Zielona Góra and Wrocław, in forest districts with and without radiotelephone communication. In the year 1968 to 1969, the PZL-104 'Wilga' aircraft, which had similar parameters to the PZL-101 'Gawron', was included in the research work. The advantage of the PZL-104 was its higher maximum speed of 200 km/h and a range of 700 km. During the tests, it turned out that the PZL-104 aircraft was better suited for detecting forest fires, as it could only be used for this purpose after attaching special mirrors for better observation. During the three-year research period, it was found, among other things, that the most favourable flight altitude is 400–500 m. Flying at this altitude makes it possible to observe a strip about 30-km wide. The flights were to take place between 10 a.m. and 5 p.m., and their routes were to be determined by the appropriate Regional Directorate of State Forests based on the current state of forest fire hazard. In the year 1967 to 1968, in cooperation with the Fire Brigade Headquarters in Wrocław, the usefulness of using the SM-1 helicopter to patrol forests was analysed. Patrol flights were conducted over an area of 150,000 ha of forest in the districts of: Bolesławiec, Zgorzelec, Żagań and Szprotawa in the period from 15 April to 15 September. The use of the helicopter was evaluated as positive and in the course of two years the first principles for the use of the helicopter for the detection of forest fires and cooperation with the ground fire protection of forest areas were developed (Karlikowski et al. 1979).

During the years 1977 to 1981, the Forest Fire Protection Department, together with the Mielec Trans-

port Equipment Factory (now Polish Aviation Company), investigated the suitability of the PZL-M18 'Dromader' with a built-in tank for liquid agents for forest fire protection. As a result of the tests, the functional characteristics were determined in flight and the extinguishing properties and basic principles of forest firefighting tactics were established with the help of an aircraft. From 11 June to 12 July 1981, field tests were conducted at the Regional Directorate of State Forests in Zielona Góra. The tests included both patrol flights with a load of extinguishing agent to make a drop on the detected fire and extinguishing flights carried out during firefighting at the request of the Alarm and Operations Centre Point (Santorski and Szczygieł 1981). Thanks to these tests, the Dromader aircrafts are still used to extinguish fires throughout the country and in many countries around the world, as the M-18 Dromader aircraft proved to be the export hit of WSK Mielec.

Currently, technologies for monitoring land through a camera system are becoming more common. In the area of State Forests, cameras are increasingly being used at observation points that enable rapid detection of smoke. The first studies on the possibility of using cameras to detect forest fires were carried out during the years 1967 to 1975. This work made it possible to determine which types of television equipment available at the time should be used and to develop technical and forestry requirements for this type of equipment. Based on these requirements, Warsaw Television Company manufactured and introduced into production a television set for domestic use, which was tested under field conditions. As a result of these studies, among other things, modifications were made to a hermetic casing by installing an electric heater that reduced evaporation of the outer glass, which improved the picture quality (Santorski et al. 1975).

One of the basic requirements for the proper organisation of forest fire protection, both in terms of prevention and in terms of organisational and technical preparation of forest areas in the event of a fire, is comprehensive information on fires, both at national and international levels. LFFP has been cooperating internationally for many years, for example within the framework of the Global Fire Monitoring Centre and the Joint Research Centre of the European Union in Ispra. According to the European Union Regulation No. 2152/2003 of 17 November 2003, concerning the monitoring of interactions between forests and the natural environment in the Community, Member States are obliged to maintain a database on forest fires. Since 2007, the National Forest Fire Information System has been in operation, the purpose of which is to collect data on forest fires and natural, non-forested – non-urbanised – land, regardless of its ownership. The LFFP deals with the management of the system, its modifications and the production of reports for the needs of national and European institutions. The database allows the collection of data from two different systems: the State Fire Service and the State Forests National Holding, and it also allows the input of data from the administration of national parks, which do not have a separate, unified system for registering fires. Part of the data is available for non-logged-in users on the website https://bazapozarow.ibles.pl (Piwnicki et al. 2007). The data are also transferred to the European Union, under which the European Forest Fire Information System is operated. As part of its engagement with the European Union, since 2004 LFFP staff have also been members of the Expert Group on Forest Fires, which operates within the European Commission.

An IT tool to optimise and streamline the response activities of rescue forces was the development of a forest fire model application. The 'Forest fire model' application was developed on the basis of laboratory and field research into the conditions for the development and spread of forest fires. The result of this work was the development of an algorithm in the form of mathematical equations that enables the calculation of basic fire parameters depending on the selected input data. Depending on the input data, such as wind speed, material moisture, fire load and fire-free duration, the most important parameters are calculated from the point of view of organising firefighting measures: wind front speed, fire area and fire perimeter. With the application you can also perform the following calculations: the time for moving the fire edge forward, to the sides and to the rear depending on the set distance, the calorific value of forest materials, the height of flames (average and maximum) in the case of a fire in the spreading cover and the amount of extinguishing agents required (water and foam) depending on three variants of carrying out firefighting measures (extinguishing the entire fire area,

extinguishing the edges and their location using barrier strips) (Szczygieł et al. 2013).

The implementation of various activities by the LFFP team also contributed to draw the attention of the scientific community and the public to the perception of fire, which can be used to protect natural habitats under certain conditions. On 18 March 2015, the country's first workshop on the controlled use of fire on heathland was held. The area to be burned was located within the boundaries of the Wrzosowiska Przemkowskie Natura 2000 site (PLH 020015) in the territory of the Przemków Forest District, whose object of protection are the natural habitats of *Calluna-Genistion*, *Pholio-Callunion* i *Calluno-Arctostaphylion*. The heath landscape has developed as a result of anthropogenic pressure at this site, which was a training ground actively used by the army in the past. As a result of economic transformations and changes in military infrastructure, the training ground was closed and the area transferred to the State Forests. When the strong human influence on this area ceased, the process of natural succession began, resulting in the emergence of pines and birches. Burning slowed down this process to a certain extent and renewed the heath fields. During the workshops, methods of burning were presented, the appropriate times and weather conditions for burning, as well as surface protection methods were discussed (Szczygieł et al. 2015). The next step was to conduct further practical training for state forest employees, for example in 2019 and 2022.

The activities of the LFFP also focused on analysing the effects of fire on the ecosystem. One of the studies was the application of the electrophysiological method to diagnose the condition of Scots pines (*Pinus sylvestris* L.) after a fire. The aim of this study was to test the electrophysiological method (measuring the bioelectrical resistance of trees) for predicting the survival rate of trees damaged by ground cover fires in pine stands. The research conducted aimed to determine the effects of fire on tree bioelectrical resistance values and its relationship to post-fire tree detachment processes, in order to use the results obtained for post-fire forest stand diagnosis. In one of the conclusions, it was pointed out that the increase in the value of the electrical resistance of the cambium of trees after fire and the asymmetry of its distribution on the circumference of the trunk compared to the corresponding control trees, even if this did not lead to the death of the trees, proved the negative effects of fire on the stand, which is a counter-argument to the notions of 'fire without damage'. The changes in the values indicated disturbances in the normal course of physiological processes in the tree, which affected the further condition of the tree (Ubysz et al. 1996).

The subject of the work was also a multi-faceted study on the negative effects of fires on the forest environment, which, among other things, dealt with methods of developing areas after fires in the 1980s, paying attention to issues related to methods of regeneration, the possibility of organic fertilisation and the technology of soil cultivation in fire zones. In one of the research reports, the final conclusions pointed out that when regeneration takes place in a fire zone, it is necessary to introduce a foliage mixture in a linear form (3 to 5 rows) according to the forest site type at the spatial dividing lines. Furthermore, the possibility of using the natural regeneration that has developed in the fire zones is pointed out (Karlikowski et al. 1982).

The abovementioned presents only selected, important studies that have a significant influence on the organisation and functioning of the fire protection system in the State Forests. Among the numerous projects carried out, there are other interesting and special projects, such as the assessment of the potential threat posed by a forest fire to a nuclear power plant to be built near the village of Skoki (Rzewuski et al. 1987a) or Klempicz (Rzewuski et al. 1987b) in the Wielkopolska Voivodeship. Staff from the laboratory took part in analyses dealing with the assessment of fire risk in areas affected by windbreaks (RDSF area in Toruń) or with the death of trees due to insect feeding, which took place, among others, in the Białowieża Forest, which is an internationally valuable stand (Szczygieł and Kwiatkowski 2018). The result of the latter work was the development of the 'Fire Protection Plan for the Protection and Extinguishing of Forest Fires for the Polish Part of the Białowieża Forest Transboundary Natural World Heritage Site'.

Many works and expert reports have been concerned with the evaluation and suitability of equipment for extinguishing forest fires. These include, among others:

1. Expert opinion related to the suitability of a fire-fighting vehicle on an all-terrain chassis, model Star

266, where the design and operational characteristics of the vehicle were evaluated under field conditions and during firefighting operations. The proposed modifications in the expert opinion include: in the installation of sprinklers and quick attack lines, the bumper structure, it was recommended to protect the lamps, the oil sump, to install a spare wheel, to reduce the efficiency of the water and foam cannon, it was recommended to equip the vehicle with firefighting equipment (Szczygieł 1982).

2. 1973 research on a trailer with a tanker that could be used on small fires and hitched to State Forest Service vehicles. The tests addressed issues related to technical solutions, operation of the equipment included in the kit and traction characteristics. During the field tests, the following needs were addressed:
   – replace the metal tank with a plastic tank, which would reduce the weight of the waggon by about 260 kg,
   – changes to various types of hooks, which did not ensure proper and safe installation of the equipment on the test model,
   – the installation of the foam generator,
   – changes to the undercarriage, which underwent permanent deformation during the tests, affecting the divergence of the wheels and the durability of the structure (Karlikowski 1973).
3. Research on a prototype forest firefighting trailer, which was equipped with the necessary equipment and could be useful in forest firefighting operations. It was found that the design solutions proposed in the prototype were suitable for conducting activities in forest conditions (Łonkiewicz and Pietraszkiewicz 1975). The tested solutions were not used on a large scale, but now attention is being drawn back to the need for mobile firefighting equipment, which the forest fire bases are equipped with.

The team's research has also been conducted for places such as military training areas, for which an alerting method has been developed to determine the forest fire hazard level, complementing the existing system for predicting fire hazard in the State Forests. The proposed method makes it possible to determine the level of danger at any time of the day. This level is determined at the initiative of the user of the training area and more accurately reflects the actual fire hazard, it is valid for 4 hours a day and is set in the evening (6.00–9.00 p.m.) – until 9.00 a.m. the next day, if not been previously defined again. In this way, the training of troops in the field can be made more effective and less costly. In addition, by rationally adapting the type of exercises conducted to the local fire hazard on the training ground, safety and environmental protection can be better ensured (Szczygieł et al. 2016).

The laboratory did most of the analyses and research for the State Forest units, but also conducted studies for national parks, the examples being 'Fire protection survey of the Kampinos National Park' (Rzewuski et al. 1996), 'Development of a categorisation of forest fire hazard in the Słowiński National Park' (Santorski et al. 1999), 'Development of a method for fire hazard assessment of non-forest ecosystems and fire protection rules for the Biebrza National Park' (Szczygieł et al. 2021) and 'Development of forest fire hazard categories, flammability classes of stands and non-forest ecosystems for the Drawieński National Park' (Kwiatkowski 2022).

After our country's accession to the European Union, the laboratory expanded its international cooperation by participating in 10 research projects funded by the EU Framework Programmes and INTERREG IVC. These include among others:

– An Innovative Approach of Integrated Wildland Fire Management Regulation the Wildfire Problem by the Wise Use of Fire – Solving the FIRE PARADOX – the project was carried out by an international consortium consisting of 30 European partners and 6 from other parts of the world. The main objective of the project was to reduce the damage and maximise the benefits of fire. The project created the scientific and technological basis for new practises and strategies for comprehensive protection against forest fires. As a result of the research to understand combustion mechanisms, a forest fire model and fire hazard assessment were developed to increase the effectiveness of fire protection.
– System for highly reliable, cost effective, early detection and accurate localisation of incipient forest fires (ForFire) – the project was carried out by 8 European partners. The project developed a new fire detection system and built a model of an integrated camera with image sensors that respond to

vacuum ultraviolet radiation emitted only by fire flames.

– Forest Fire Causes – the project was carried out by 8 European partners. The aim of the topic was to analyse the spatial and temporal distribution of forest fires and their causes, to identify the most important causal factors for the occurrence of fires in different regions of Europe and to develop a uniform method for their determination. A uniform system for classifying the causes of fires was introduced by the Member States of the European Community (including Poland) in 2014.
– European Forest Fire Monitoring System (EFFMIS) – a project carried out in the framework of interregional cooperation (INTERREG). The aim of the project was to learn about the best practises of the consortium partners regarding the systems of IT used for early detection of forest fires, organisation of firefighting measures, damage assessment and development of fire areas, as well as the development of regional action plans by all partners.
– European Forest Fire Networks (EUFOFINET) – the main objective of the project was to exchange experiences in the following areas: fire detection and fire prevention, firefighting strategies, fire hazard mapping, training and firefighting strategies, fire hazard mapping and training and strategies for the use of simulators. The outcome of the project was the development of training programs for the crews of light patrol and firefighting vehicles and for the representatives of forest inspectors (Arkuszewska et. al. 2015).

In addition to the research activities, a unique programme of postgraduate studies in the field of forest fire protection has been created within the framework of cooperation with the Main School of Fire Service in Warsaw, where, among other things, issues related to factors influencing fire, methods of conducting firefighting operations, firefighting infrastructures in forests and legal regulations.

The team members have also disseminated research results and actively participated in the creation of legal regulations in the field of forest fire protection, both in the form of laws, regulations, orders, decisions and instructions. Over the course of 60 years, they have been the authors of numerous scientific and popular publications as well as public and media appearances on various issues in the field of forest fire protection.

It should be remembered that during the operation of the Department/Workshop/Laboratory of Forest Fire Protection FRI, a total of 81 employees were involved in its activities (including 12 people at the Krzystkowice outstation and 4 people at the Niedźwiady station). Their leaders were successively: Prof. Tytus Karlikowski DSc (in this position for 36 years until 1999), Zygmunt Santorski PhD (1999 – 2002), Barbara Ubysz PhD (2002 – 2010), Ryszard Szczygieł DSc (since 2010). The team's achievements in 2013 were recognised, including LFFP's award of the Polish Forester's Cordelas (Kordelas Leśnika Polskiego). This award was given for the first time in the history of a department of the FRI. This is the highest award given for many years of work and special services to the development and protection of Polish forests. Another distinction was the award of the 'Gold Medal for Merits in Fire Fighting' ('Złoty Medal za Zasługi dla Pożarnictwa') by the Praesidium of the Main Board of the Association of Volunteer Fire Brigades of the Republic of Poland. The team's activities were also recognised with the Józef Tuliszkowski's Medal of Honour, by the commander-in-chief of the State Fire Service for outstanding contributions to the development of forest fire protection and for activities promoting fire safety.

Conclusion

Sixty years of activity of the Department/Workshop/Laboratory of Forest Fire Protection at the FRI have contributed to the fact that although Poland ranks third in the European Union in terms of the number of fires, it is also a country where the average fire area is one of the smallest, amounting to approximately 0.45 ha (Szczygieł, Kwiatkowski, Kołakowski 2020). This is related, among other things, not only to a well-organised system of fire protection infrastructure in the forests, which has developed under the significant influence of the research and analysis carried out by a team of FRI employees, but also thanks to the close cooperation with the State Forests teams, which have been involved in this process and today monitor the rapid detection and localisation of fires, attempting to

reduce the fire in the first moments and cooperating closely with firefighting units in fighting the fire.

Fire in the forest is and remains a dangerous phenomenon that should always be perceived as an element. Therefore, there is a constant need for research, for trying to understand the impact of fires on ecosystems and for improving existing methods aimed at reducing the risk of fires in forests and thus reducing material losses.

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