INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

No IV/2/2017, POLISH ACADEMY OF SCIENCES, Cracow Branch, pp. 1563–1576
Commission of Technical Rural Infrastructure

DOI: http://dx.medra.org/10.14597/infraeco.2017.4.2.118

EFFECTIVENESS OF FOREST FIRE SECURITY SYSTEMS IN POLAND

Sylwester M. Grajewski
University of Life Sciences in Poznań

Abstract

It has been estimated that over 80% of forest areas in Poland is threatened with fire. Due to the number of fires and burned area, Poland is counted to the group of European countries where fires break out the most frequently. On average, each year and mostly because of human activity, almost 8.5 thousand fires break out resulting in over 7 thousand ha of burned forest area. Many scientists forecast that the climate warming, decline in precipitation amount and prolonging rainless periods will enhance fire risk in forests, which will translate itself not only into an increase in the number of fires, but also will favour their intensive spreading. The aim of presented paper is estimating the operational efficiency of the fire protection system in Polish forests and the effectiveness of fire extinguishing actions in forests, but also recognition of the effect of the forest area management type on fire statistics. Following data series were investigated: of the number of fires, the burned forest area and average fire area for the years 1990-2016 for the forests under the management of the State Forests National Forest Holding (State Forests NFH) and other managements. Determined trends were analysed by means of Mann-Kendall non-parametric test. A mean area of forest fire was assumed as the main measure of forest fire protection system effectiveness. The area was compared with the other European countries, Canada and the USA. Despite a lack of a tendency for decreasing number of fires in Poland, which is noted in Europe, taking into account a low value and a statistically significant downward trend for average fire area, forest protection and the effectiveness of extinguish-

This is an open access article under the Creative Commons BY-NC-ND license
(http://creativecommons.org/licences/by-nc-nd/4.0/)

ing actions in Polish forests should be regarded as very good. The exception are forests remaining beyond the management of the State Forests NFH, where the upward trend for the number of forest fires is alarming.

Keywords: forest fires, forest fire risk, forest fire protection, forest fire security, the State Forests National Forest Holding

INTRODUCTION

In Poland forests cover 9215 thousand ha (29.5%). Public forests prevail in the ownership structure (80.8%), including: forests under the management of the State Forests National Forest Holding (SF NFH) – 77.0%, national parks – 2%, municipalities ownership – 0.9% and other public property – 0.9%. The other forests are private property – 19.2% (Raport… 2016). Currently, forest areas occur mainly on the terrains with poorest soils, which is reflected in the arrangement of forest habitat types with dominant coniferous habitats (51%). The prevailing species is pine occupying 58.1% of the forest area of all ownership forms (Raport… 2016).

Forest fires usually cause highly negative changes in forest ecosystems, affecting many plant (Brown and Smith 2000) and animal groups (Smith *et al.* 2000, Butenko *et al.* 2000), at the same time deteriorating life quality of communities (Szczygieł 2012, Wiler 2016a). Fires also cause measurable economic losses (Piwnicki *et al.* 2005, Szczygieł *et al.* 2007). The negative outcomes of fires are mostly not without the effect on the atmospheric air (Sandberg *et al.* 2002). It is considered that recognizing the amount of gases and aerosols released with fires is a most urgent and important matter due to a major participation of these substances in the intensification of the greenhouse effect (Trofimova and Suchinin 2005).

It has been estimated that in Poland over 80% of forest areas is threatened with fires, in Europe over 60% and about 40% in the world (Zarzycki 2012). Considering the number of forest fires and burned forest area, Poland, Spain and Portugal are classified to the group of European countries where fires break out the most frequently (Kwiatkowski and Szczygieł 2013). Each year, on average close to 8.5 thousand fires break out in result of which over 7 thousand hectares of forest area is burned. In the vast majority of cases human activity is the main cause of fire.

Moreover, because of climate warming, decrease in precipitation and prolonging of rainless periods, it has been forecasted that fire risk in forests will be increasing in the future (*inter alia* Szczygieł *et al.* 2007, Grajewski 2010, Wąs and Grajewski 2011, Müller *et al.* 2015), which will affect not only the increase

in the number of fires, but will also favour their intensive spreading, i.e. large-scale fires formation (Goldammer and Nikolov 2009, Spracklen *et al.* 2009).

Therefore the causes of fire risk in forests are environmental and forest conditions, meteorological conditions changing in time and space, as well as human activity (Kwiatkowski and Szczygieł 2013). Efficient system of fire protection in forest should take into account these elements. Its basis is an analysis of potential and dynamic forest hazards. The result of potential hazard assessment is fundamental for the activities involved in forest areas preparation in case of fire, whereas the estimation of dynamic threat (daily forecasts considering current meteorological conditions) is the basis for undertaking the day-to-day activities by a given forest area administrator (Kwiatkowski and Szczygieł 2013).

Fire security of forests in Poland is adjusted to the categories and degrees of forest fire risk (Obwieszczenie… 2006, Rozporządzenie… 2006, Haze 2012). A forest fire danger category comprises forests with a similar level of susceptibility to fire, determined on the basis of the frequency of fire occurrence, climatic and tree stands conditions (the age, forest habitat type, tree species) and anthropogenic factors. A forest fire danger category is determined for each forest division in the forest management plans. There are three categories of forest fire danger:

I – high danger,
II – moderate danger,
III – low danger.

The forest fire risk is the level of probability of fire occurrence on a given day, depending on the dynamic weather changes and the forest floor moisture. Four degrees of forest fire risk have been adopted:

0. fire risk – no danger,
1. fire risk – low danger,
2. fire risk – moderate danger,
3. fire risk – high danger.

The degree of forest fire risk is determined twice daily at 9.00 and 13.00 for designated diagnostic zones covering the whole country area. For the forests classified to category III of forest fire risk, determination of fire risk is not required.

The owners, managers or users of the forests which independently or jointly form a forest complex with the total area of over 300 ha are obliged to (Rozporządzenie… 2006, 2010):

1. organize observation and patrolling of forests in order to detect fires and alarm about their outbreak,
2. ensure and maintain water sources for fire-fighting purposes,
3. maintain roads, so called fire access roads marked in the forest management plan,

4. mark the water intake points using signs in compliance with Polish Standards concerning safety symbols,
5. furnish and maintain bases of equipment for forest fire-fighting in the appointed places in agreement with the county (city) commandants of the State Fire Service appropriate for a given location,
6. coordinate forest management plans, simplified forest management plan and national park protection plan concerning the fire protection with the voivodship commandant of the State Fire Service appropriate for the locality, for the forests with fire risk categories I and II.

Organization of the fire protection system in the State Forests is regulated by the *Forest fire protection instruction*, latest version of which was implemented by the regulation of the General Director of the State Forests on 1 January 2012 (Haze 2012). The functioning of fire protection system in Poland was described in detail by Ubysz and Szczygieł (2002).

Fire protection in Polish forests comprises a number of various activities, such as:

1. fire prevention relying mainly on:
   - conducting informative and warning activities,
   - determining the rules of forest use, principles of behaviour in the forests and the use of open fire,
   - implementing the recommendations concerning forest breeding (among other intensive introducing of admixture and auxiliary species along roads and surface division lines) or undertaking typically economic activities to limit potential forest fire spreading (fire breaks),
2. developing and maintaining the observation and alarm system whose task is the fastest possible identification of fire in the forest area, its localization and alarming the forces and means for the fire-fighting;
3. preparation of the organizational and technical means making a fast access to the fire site and activities of the fire-fighting forces possible.

Observation and alarm system consists of:

1. constant terrestrial observing system,
2. fire patrols,
3. alert and disposition points,
4. alert and disposition telecommunication network.

A set of organizational and technical means is composed of:

1. access roads (fire access roads),
2. fire-fighting equipment bases,

3. water supply (including water intake points),
4. forest air bases and the other infrastructure,
5. instructions developed for individual forest complexes entitled: "Procedures for the Forest Directorate in case of forest fire outbreak".

Present paper aims to estimate the effectiveness of the fire security system in Poland against some other European countries, Canada, USA and comparing the effect of the kind of area manager (the State Forests National Forest Holding and the others) on fire statistics.

MATERIAL AND METHODS

The investigations used the data on forest fires number, burned forest area and mean area of a single fire for the years 1990-2016 concerning the forests under the management of the State Forests NFH and the others (Raport… 2016, Piwnicki and Szczygieł 2017, Raport… 2017). In comparative analyses the number of fires and burned area were referred to the forest area of a given country or management, and the fire statistics were converted into each 1000 ha of forest area. An average forest fire area was used as the measure of fire security system effectiveness (Kwiatkowski and Szczygieł 2013), which was compared with the data from other European countries, Canada and USA. The necessary information about forest fires in other countries was quoted after Grajewski (2017).

The trends for the available data were analyzed using Mann-Kendall non-parametric test (Hamed and Rao 1998, Węglarczyk 2010) accessible in the XLSTAT package. So far, the test has been successfully used for, among others, estimation of hydrological and climatic parameters trends (Yue *et al.* 2002, Yue and Wang 2004). Detailed description of the analysis using Mann Kendall test applied in the presented paper was given by Banasik *et al.* (2013) and Krysztofiak-Kaniewska *et al.* (2016).

RESULTS

In Poland, on average 8445 fires break out per year of which 3869 in the forests managed by the State Forests NFH and 4576 in the forests under other management (Fig. 1). Situation observed in the area managed by the State Forests NFH is much better, because four times less fires break out there per 1000 ha (Tab. 1). Generally, the number of fires in Poland does not show any trend, which is the consequence of averaging the decreasing number of fires in the forests under the National Forest Holding management and the growing number of fires in the forests under other management. Considering the number of fires, unfortunately

Poland belongs to the group of countries with the greatest number – the average is above the value determined for the other analysed countries (Fig. 2).

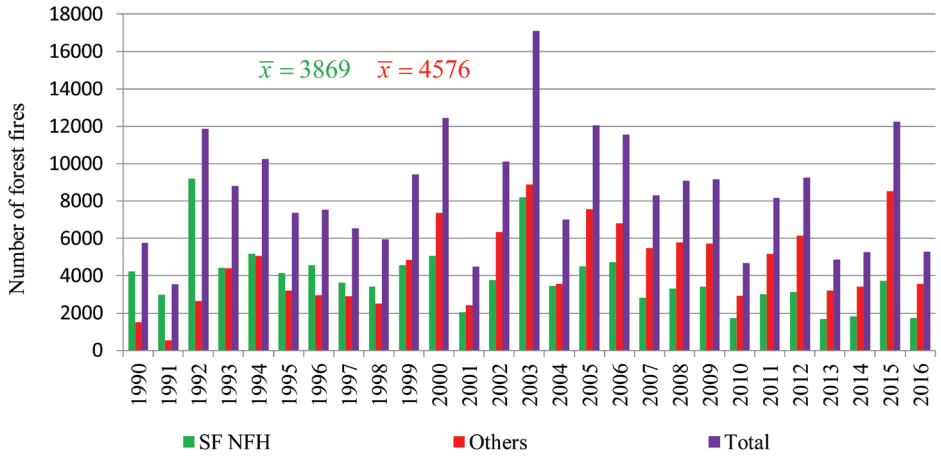

Figure 1. Number of fires in forests managed by the State Forests NFH (SF NFH) and in forests under different management in 1995-2016

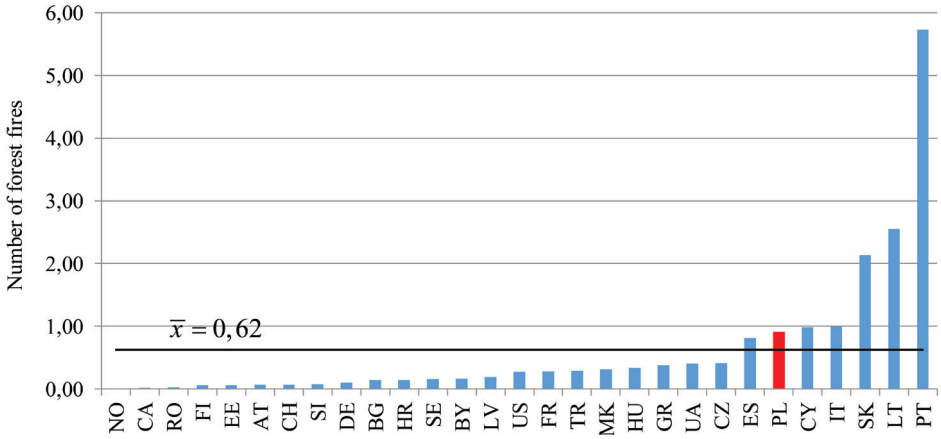

Figure 2. Number of forest fires in Poland against other European countries, Canada and USA per 1000 ha of burned forest area (AT – Austria, BG – Bulgaria, BY – Belarus, CA – Canada, CH – Switzerland, CY – Cyprus, CZ – Czech Republic, DE – Germany, EE – Estonia, ES – Spain, FI – Finland, FR – France, GR – Greece, HR – Croatia, HU – Hungary, IE – Ireland, IT – Italy, LT – Lithuania, LV – Latvia, MK – Macedonia, NO – Norway, PL – Poland, PT – Portugal, RO – Romania, SE – Sweden, SI – Slovenia, SK – Slovakia, TR – Turkey, UA – Ukraine, US – the United States)

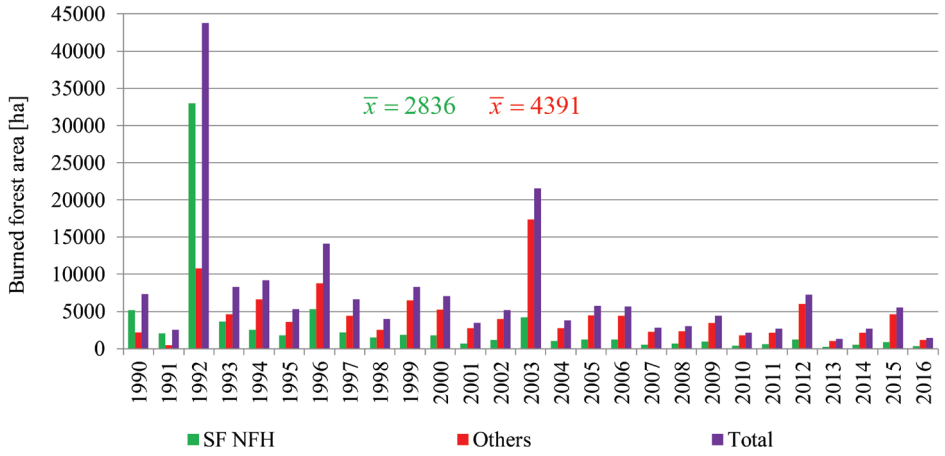

Figure 3. Burned area in forests managed by the State Forests NFH (SF NFH) and in forests under different management in 1995-2016

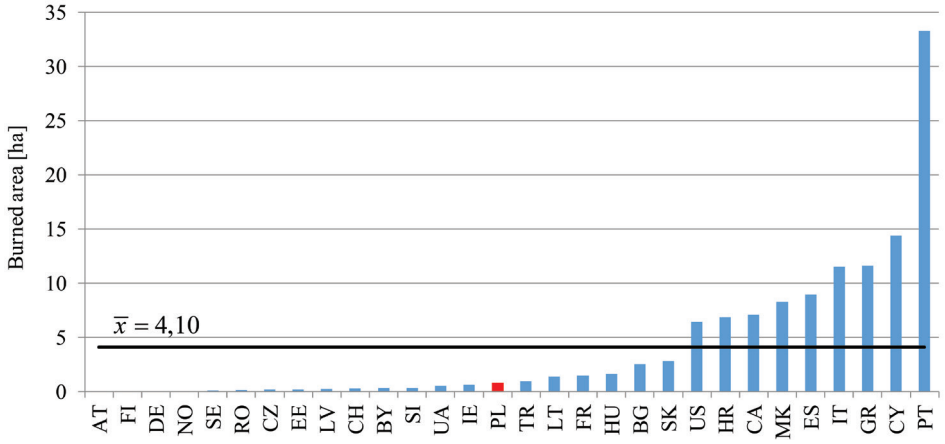

Figure 4. Area of burned forests in Poland against other European countries, Canada and USA per 1000 ha of forest area (symbols of countries as in Figure 2)

In the years 1990-2016 on average 7226 ha of Polish forests were burned. Like in the case of the fires number, definitely better situation was observed in the forests managed by the State Forest NFH (Fig. 3, Tab. 1). Average annual area of burned tree stands per 1000 ha of forests was here five times smaller in comparison to the forests under the other management. The trend of burned forest area, irrespective of the management, is downward and statistically proved

in each case. However, the downward trend of this feature in SF NFH forests is markedly stronger (Tab. 1). In terms of burned forest area, Poland looks much better in comparison with other countries than for the number of fires. With the mean burned area much below the average, we rank in the middle of investigated countries group.

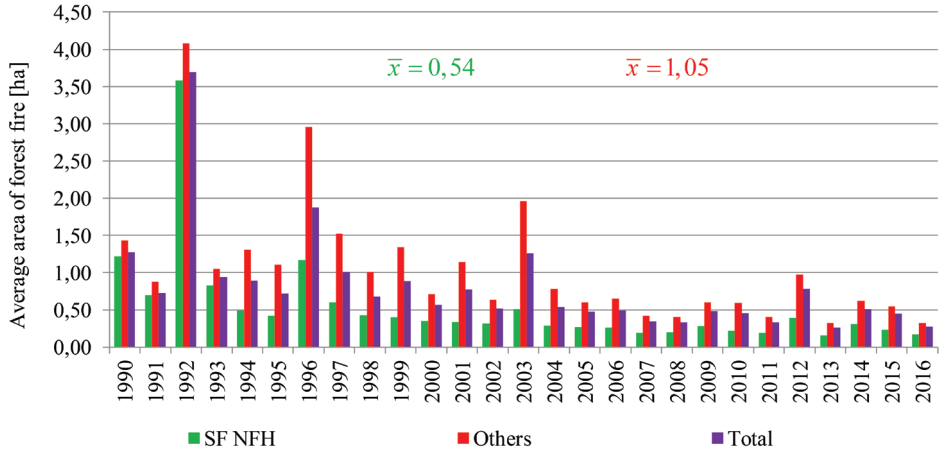

Figure 5. Average fire area in the forests managed by the State Forests NFH (SF NFH) and in the forests under different management in 1995-2016

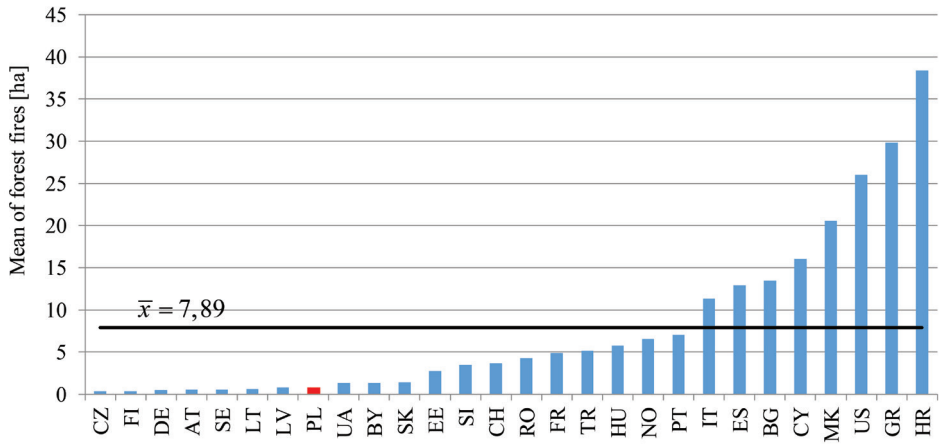

Figure 6. Average fire area in the forests in Poland against other European countries and USA (Canada was left out due to disproportionally high value of burned area – 317 ha) per 1000 ha of forest area (symbols of countries as in Figure 2)

The average area of fire in Poland is 0.80 ha and fluctuates from 0.26 to 3.7 ha (Tab. 1, Fig. 5). Also, in terms of this very important characteristics, forest managed by SF NFH look much better, as the average fire area there is almost twice smaller. Irrespective of the management, the trends are decreasing. This time a stronger decline characterizes the forests under different management, however (Tab. 1). In the compilation of countries concerning the average fire area, Poland looks even better (Fig. 6). Moreover, for Poland these values show a distinctive and statistically significant downward trend (Tab. 1).

Table 1. Results of the analysis of fires number and burned forest area (per 1000 ha of forests) and average fire area in Poland in the years 1990-2016 acc. to forest managements

Feature	Forest management	Range	$\bar{x}$	SD	SS	Z	p	Trend
Number of forest fires	SF NFH	0.2370 ÷ 1.2969	0.5452	0.2451	-0.0136	-3.0020	0.0013	↘ ***
	Others	0.2557 ÷ 4.1888	2.1590	1.0094	0.0435	2.1477	0.0159	↗ *
	Total	0.3829 ÷ 1.8543	0.9164	0.3407	-0.0012	0.0000	0.5000	–
Burned area [ha]	SF NFH	0.0368 ÷ 4.6428	0.3996	0.8706	-0.0144	-4.7948	0.0000	↘ ***
	Other	0.2251 ÷ 8.1951	2.0716	1.6558	-0.0543	-1.9596	0.0250	↘ *
	Total	0.1399 ÷ 4.7482	0.7842	0.9148	-0.0264	-3.1270	0.0009	↘ ***
Average fire area [ha]	SF NFH	0.1552 ÷ 3.5800	0.5378	0.6674	-0.0211	-5.2117	0.0000	↘ ***
	Others	0.3211 ÷ 4.0800	1.0509	0.8338	-0.0421	-4.3779	0.0000	↘ ***
	Total	0.2640 ÷ 3.6918	0.7976	0.6826	-0.0298	-4.6280	0.0000	↘ ***

$\bar{x}$ – mean, SD – standard deviation, SS – Sen's slope, Z – statistics *Z*, p – value *p*, ↗ or ↘ – upward or downward trend statistically significant on the level $\alpha = 0{,}05$ (*), $\alpha = 0{,}01$ (**) or $\alpha = 0{,}001$ (***)

DISCUSSION

Poland belongs to the group of European countries where the highest number of fires per 1000 ha of forest area break out each year. In this respect we occupy the sixth position in Europe after Portugal, Lithuania, Slovakia, Italy and Cyprus and just before Spain. The high number of forest fires in Poland is a consequence of a serious fire risk primarily due to unfavourable climatic and habitat conditions, age and species structure of Polish tree stands (Szczygieł 2012).

Despite a considerable and still not decreasing number of forest fires, we manage to limit the dimension of burned forest area (a statistically confirmed downward trend), which best proves that a good fire protection system exists in

forest areas. Beside Poland, also 21 other countries belong to the group, where a tendency to decrease the forest fire areas was noted and in 12 cases it was statistically proved (Grajewski 2017).

Our country belongs to the leading countries where fires are extinguished at the early phase of their development, thus minimizing both material and ecological losses. In this respect we are preceded by Czech Republic, Finland, Germany, Austria, Sweden, Lithuania and slightly by Latvia. Moreover, the values of average annual fire areas for Poland reveal statistically a significant downward trend, which allows to assume that the process of fire protection system for Polish forests has not been completed yet.

The effectiveness of firefighting actions allowing for so called extinguishing fires in the bud are the result of not only proper training of people provided with modern equipment, but also the efficiency of fire risk forecasting systems, early detection system of forming fires and disposing proper manpower and equipment which faultlessly reach the fire site in a short time. Early detection directly determines the fire losses and the costs of fire extinguishing actions and extinguishing of burned sites (Wiler 2016a). The conducted research allows for a most positive evaluation of the forest fire security system in Poland. However, it should be also mentioned that fire protection is visibly much poorer, except for the forests managed by SF NFH (Wiler 2016b). There is no doubt, that the main organizational and financial responsibility of fire security in Polish forests falls on the State Forests National Forest Holding (Szczygieł *et al.* 2007). In fact, forest fires break out for reasons independent of the forest (land) manager and do not result from the forest technologies applied by them (Wiler 2016c). Therefore, the occurrence and development of fires depend mainly on the fire protection infrastructure, construction of which in private forests has not even begun (Wiler 2016c). The situation looks different e.g. in Ireland where average burned area in private forests in the years 1987-2015 was by c.a. 21% smaller than in public forests (Irelands's Forests… 2016).

Forecasting fire outbreak in the coming decades will require, apart from climate research, also full knowledge about the socio-economic aspects affecting fires and their extinguishing (Arndt *et al.* 2013, Arpaci *et al.* 2014, Valese *et al.* 2014, Ruffault and Mouillot 2015). Moreover, in case of estimating future fire conditions one should consider ecological prognoses connected with the changes in forest structure and dominating tree species. Multilateralism of this problem emphasizes the importance of interdisciplinary research on forest fires (Venäläinen *et al.* 2014).

CONCLUSIONS

1. Effectiveness of fire security system in forest areas in Poland, described by a relatively low value of average forest fire area, should be regarded as very good.
2. The registered downward trend for average fire area allows to suppose that the process of fire security system improvement in Polish forests has not been completed yet.
3. A lack of an upward trend for the number and area of forest fires allows for the statement that in the area of Poland forecasted growing tendencies of these features associated with the consequences of climatic changes have not had place so far.
4. The most optimistic fire statistics apply to the forest areas managed by the State Forests National Forest Holding, therefore the forests under different management require greater attention. The statistically significant upward trend of the number of fires in these forests is particularly alarming.

REFERENCES

Arndt N., Vacik H., Koch V., Arpaci A., Gossow H. (2013). *Modeling human-caused forest fire ignition for assessing forest fire danger in Austria*. iForest. 6: 315-325

Arpaci A., Malowerschnig B., Sass O., Vacik H. (2014). *Using multi variate data mining techniques for estimating fire susceptibility of Tyrolean forests*. Appl. Geogr. 53: 258-270.

Banasik K., Hejduk L., Hejduk A., Kaznowska E., Banasik J., Byczkowski A. (2013). *Wieloletnia zmienność odpływu z małej zlewni rzecznej w regionie Puszczy Kozienickiej*. Sylwan, 157 (8): 578-586.

Brown J.K., Smith J.K., eds. (2000). *Wildland fire in ecosystems: effects of fire on flora*. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 1-257

Butenko K.O., Gongalsky K.B., Korobushkin D.I., Ekschmitt K., Zaitsev A.S. (2017): *Forest fires alter the trophic structure of soil nematode communities*. Soil Biology & Biochemistry, 109: 107-117

Goldammer J.G., Nikolov N. (2009). *Climate change and forest fires risk*. Proceedings of the European and Mediterranean Workshop, Climate change impact on water-related and marine risks, 26-27 October 2009, Murcia (Spain)

Grajewski S.M. (2010). *Potencjalny wpływ zmian klimatycznych na gospodarkę leśną centralnej Wielkopolski*. Infrastruktura i Ekologia Terenów Wiejskich, 14: 109-123

Grajewski S.M. (2017). *Long-term variability of forest fires in selected 28 European countries, Canada and the USA*. Safety & Fire Technique, 47 (3): 46-61

Hamed K.H., Rao A.R. (1998). *A modified Mann-Kendall trend test for autocorrelated data*. Journal of Hydrology, 204(1-4): 182-196

Haze M. (red.) (2012). *Instrukcja ochrony przeciwpożarowej lasu*. CILP, Warszawa (Załącznik do zarządzenia nr 54 Dyrektora Generalnego Lasów Państwowych z 21 listopada 2011 r. Obowiązuje w jednostkach Lasów Państwowych od 1 stycznia 2012 r.): 1-106

Ireland's Forests – Annual Statistics 2016 (2016). Annual Forest Sector Statistic. The Forest Service of the Department of Agriculture, Food and the Marine: 1-61

Krysztofiak-Kaniewska A., Miler A.T., Ziemblińska K., Wróbel M. (2016). *Trend analysis of changes in soil moisture from the different depths in the Martew Forestry*. Infrastruktura i Ekologia Terenów Wiejskich, IV(1): 1157-1167

Kwiatkowski M., Szczygieł R. (2013). *System zabezpieczenia przeciwpożarowego obszarów leśnych*. Zabezpieczenia, 4: 16-19

Obwieszczenie Prezesa Rady Ministrów z dnia 24 kwietnia 2006 r. o sprostowaniu błędu (Dz. U. z 2006 r., nr 82, poz. 573)

Piwnicki J., Szczygieł R. (2017). *Wpływ pożarów na lasy – Polska 2016 rok*. IBL, maszynopis: 1-9 (pobrano z https://www.ibles.pl/documents/17150/28287/pozary-2015-2016.pdf 4 sierpnia 2017 r.)

Piwnicki J., Szczygieł R., Ubysz B. (2005). *Analiza ekonomiczna funkcjonowania ochrony przeciwpożarowej lasu z podziałem na zadania obligatoryjne i dodatkowe (zalecenia dla praktyki leśnej)*. Warszawa: 1-24

Raport o stanie lasów w Polsce 2015 (2016). Centrum Informacyjne Lasów Państwowych, Państwowe Gospodarstwo Leśne Lasy Państwowe, Warszawa: 1-94

Raport o stanie lasów w Polsce 2016 (2017). Centrum Informacyjne Lasów Państwowych, Państwowe Gospodarstwo Leśne Lasy Państwowe, Warszawa, 1-97

Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 7 czerwca 2010 r. w sprawie ochrony przeciwpożarowej budynków, innych obiektów budowlanych i terenów (Dz. U. z 2010 r., nr 109, poz. 719)

Rozporządzenie Ministra Środowiska z 22 marca 2006 r. w sprawie szczegółowych zasad zabezpieczenia przeciwpożarowego lasów (Dz. U. z 2006 r., nr 58, poz. 405)

Ruffault J., Mouillot F. (2015). *How a new fire-suppression policy can abruptly reshape the fire-weather relationship*. Ecosphere, 6: art199

Sandberg D.V., Ottmar R.D. Peterson J.L. Core J. (2002). *Wildland fire on ecosystems: effects of fire on air*. Gen. Tech. Rep. RMRS-GTR-42-vol. 5. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 1-79

Smith J.K. (ed.), L. Lyon J.L., Huff M.H., Hooper R.G., Telfer E.S., Schreiner D.S. (2000). *Wildland fire in ecosystems: effects of fire on fauna*. Gen. Tech. Rep. RMRS-GTR-42-vol. 1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 1-83

Spracklen D.V., Mickley L.J., Logan J.A., Hudman R.C., Yevich R., Flannigan M.D., Westerling A.L. (2009). *Impacts of climate change from 2000 to 2050 on wildfire activity and carbonaceous aerosol concentrations in the Western United States*. Journal of Geophysical Research, 114: D2030

Szczygieł R. (2012). *Wielkoobszarowe pożary lasów w Polsce*. Bezpieczeństwo i Technika Pożarnicza, 1: 67-78

Szczygieł R., Piwnicki J., Ubysz B. (2007). *Analiza ekonomiczna funkcjonowania ochrony przeciwpożarowej lasu w Lasach Państwowych*. Leśne Prace Badawcze, 1: 27-50

Szczygieł R., Ubysz B., Piwnicki J. (2007). *Impact from global warming on the occurrence of forest fires in Poland*. Proceedings of the 4th International Wildland Fire Conference, 13-17 May 2007, Seville (Spain)

Trofimova N.V., Suchinin A.I. (2005). *Ocena zanieczyszczenia środowiska emisjami dymowymi z pożarów lasu na podstawie danych satelitarnych*. Leśne Prace Badawcze, 3: 7-15

Ubysz B., Szczygieł R. (2002). *Fire Situation in Poland*. IFFN, 27: 38-64

Valese E., Conedera M., Held A.C., Ascoli D. (2014). *Fire, humans and landscape in the European Alpine region during the Holocene*. Anthropocene, 6: 63-74

Venäläinen A., Korhonen N., Hyvärinen O., Koutsias N., Xystrakis F., Urbieta I.R., Moreno J.M. (2014). *Temporal variations and change in forest fire danger in Europe for 1960-2012*. Nat. Hazards Earth Syst. Sci. 14: 1477-1490

Wąs M., Grajewski S. (2011). *Zmienność parametrów klimatycznych i ich wpływ na gospodarkę leśną Nadleśnictwa Kaliska*. Zarządzanie Ochroną Przyrody w Lasach, V: 132-153

Węglarczyk S. (2010). *Statystyka w inżynierii środowiska*. Wydawnictwo PK, Kraków, 1-375

Wiler K. (2016a). *Prawa lasu* (cz. 3). Przegląd Pożarniczy, 8: 36-38

Wiler K. (2016b). *Prawa lasu* (cz. 1). Przegląd Pożarniczy, 6: 20-24

Wiler K. (2016c). *Prawa lasu* (cz. 2). Przegląd Pożarniczy, 7: 22-24

Yue S., Pilon P., Cavadias G. (2002). *Power of the Mann-Kendall and Spearman's rho tests for detecting monotonic trends in hydrological series*. Journal of Hydrology, 259 (1-4): 254-271

Yue S., Wang C.Y. (2004). *The Mann-Kendall test modified by effective sample size to detect trend in serially correlated hydrological series*. Water Resour. Manage. 18: 201-218

Zarzycki J. (2012). *Bezpieczeństwo pożarowe lasów w powiecie – cz. 1*. Przegląd Pożarniczy, 2: 26-29

Sylwester M. Grajewski PhD Eng.
University of Life Sciences in Poznań
Department of Forest Engineering
Wojska Polskiego 71C
60-625 Poznań
e-mail: sylgraj@up.poznan.pl

Received: 05.08.2017
Accepted: 26.10.2017