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Past and present fire regimes in temperate forest zone of lowland Central Europe

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Abstract

Fires in Central European lowland forests are nowadays numerous but efficiently suppressed and hence usually very small. Poland is one of the countries with highest annual number of forest fires in the region, with as many as 9–10 000 individual fire events per year (with record of 17 000 fires in 2003), however of relatively limited size, with 0.5–0.95 ha being mean values of area burned in a single forest fire. Main fire season in Poland lasts from March to September and is driven largely by weather conditions and litter humidity, with people being the dominant source of ignition. Active forest fire prevention and suppression is carried both by the regular fire services and State Forest Administration – the main forest manager in Poland due to the ownership structure of forest land in the country (>80% state-owned). In Białowieża Forest, one of the best preserved lowland forest ecosystems in temperate Europe fires happen at present rather incidental, alike in the rest of the country are effectively controlled and thereby affect very small areas (0.5 ha). However numerous stands with fire scarred trees, stumps and snags, especially in the conifer dominated areas, can be found; indicating substantial fire presence in the past. The first tree ring fire history records from that area evidenced frequent fires in *Pinus sylvestris*-dominated forests during the 17th up to early 19th centuries, with dramatic decrease in fire presence over the last 150+ years, most likely linked to changes in human fire use and forest management. We conclude that there is a large need for fire history and fire ecology studies in Central Europe due to high population density and strong dominance of flammable conifers in forests of that region. Extended knowledge about past disturbance dynamics and reference conditions may be essential for future sustainable forest management and nature conservation throughout this part of European continent.

Keywords: annually burned area, Białowieża Forest, dendroecology, fire ecology, fire history, fire protection, fire scars, fire suppression, forest fires, forest fire statistics, mean annual number of fires, *Pinus sylvestris*, Poland, tree rings

1. Introduction

Fires in Central European lowland forests are nowadays numerous but efficiently suppressed and hence usually very small (Szczygieł *et al.* 2009a; Schmuck *et al.* 2011). However, that region has evidenced a significant rise in the number of forest fires in the recent decades (Szczygieł *et al.* 2008, 2009a,b), alike the whole European continent (Schelhaas *et al.* 2003).

Although fire has been proven to be one of the key elements of European lowland forest ecosystems during the Holocene (e.g. Hannon *et al.* 2000; Rösch 2000), the knowledge on fire ecology in that region is limited (Bradshaw *et al.* 1997; Hille 2006; Niklasson *et al.* 2010). Forest fires in that part of Europe are still associated with threat and large economic losses (Ubysz and Szczygieł 2002; Ubysz *et al.* 2006; Szczygieł *et al.* 2009a), which may impede the acceptance of fire as one of the important natural factors shaping forest structure and dynamics throughout the region (*cf.* Faliński 2001).

Given the significant share of fire-prone coniferous forests and the observed increase in fire activity throughout Central Europe, projected climate change and its possible influence on forest fire risk in

the near future (Badeck *et al.* 2003; Schelhaas *et al.* 2003, 2010; Szczygieł *et al.* 2008, 2009a; San-Miguel-Ayanz *et al.* 2011), extended knowledge on the ecological role of fire in forest ecosystems of that region is valuable.

Poland is one of the largest countries in Central-Eastern Europe (Szczygieł *et al.* 2009a), with the total country area of approx. 312.7 th. km² and total population of approx. 38.5 mill people, reflecting high population density of 123 people/km² (GUS 2014). Over 9 mill ha, accounting for ca. one third of the country area is covered by forests (San-Miguel-Ayanz *et al.* 2011; Zajączkowski *et al.* 2014), which locates Poland among the countries with substantial forest cover in the region (San-Miguel-Ayanz *et al.* 2011). Polish forests are largely dominated by coniferous forest habitats on sandy soils (51%) and coniferous stands (approx. 70% of the forest area), with *Pinus sylvestris* L. (Scots pine) being the dominant tree species (approx. 60%). Stands younger than 80 years cover approx. 70% of the forest area, with age class 41–60 yrs accounting for as much as 26.0%. Over 80% of forests in Poland is owned by the state (Zajączkowski *et al.* 2014).

Active forest fire prevention and suppression in Poland is carried both by the regular fire services and State Forest Administration (LP = Lasy Państwowe, State Forests National Forest Holding) – the main forest manager in the country, administrating 77.3% of the forest area (Zajączkowski *et al.* 2014), obliged to conduct forest fire prevention by the Forestry Act (1991).

In Białowieża Forest, one of the best preserved lowland forest ecosystems in temperate Europe (Faliński 1986; Peterken 1996) fires happen at present rather incidental, alike in the rest of Poland are effectively controlled and thereby affect very small areas (ca. 0.5 ha) (E. Zin and M. Niklasson, unpubl.). However numerous stands with fire scarred trees, stumps and snags, especially in the conifer dominated areas, can be found (e.g. Faliński 1986); indicating substantial fire presence in the past. This has been also confirmed by the first tree ring fire history reconstruction in that area (Niklasson *et al.* 2010).

To conclude on past and present fire regimes in temperate forest zone of lowland Central Europe we used Poland as a case study and applied both: (1) literature review (including actual fire inventory reports throughout the last decades) on current data concerning present fire activity in the country and (2) tree ring fire history record from two locations in Białowieża Forest, obtained by dendroecological analyses of tree ring samples from *Pinus sylvestris*, spanning over the period 1650–2010.

2. Methods

To achieve data on the present forest fire activity in Poland we did literature review. Additionally, selected actual fire inventory reports throughout the last decades were reviewed in the National Information System on Forest Fires database (available online at [https:// bazapozarow.ibles.pl/ ibl_ppoz/faces/index.jsp](https://bazapozarow.ibles.pl/ibl_ppoz/faces/index.jsp)). To summarize data on the annual number of forest fires, burnt area in forest fires and mean area burned in a single forest fire in Poland in 1990–2013, we used the following publications: Szczygieł and Piwnicki (2011); Piwnicki and Szczygieł (2011, 2012); Zajączkowski *et al.* (2014). The first one may be found in Schmuck *et al.* (2011). The three latter ones are available online at <http://www.gios.gov.pl/monlas/raporty.html> (Annual Reports: 2011, 2012) and at [http://www.lasy.gov.pl/informacje/publikacje/ informacje-statystyczne-i-raporty/raport-o-stanie-lasow/raport-o-stanie-lasow-2013/view](http://www.lasy.gov.pl/informacje/publikacje/informacje-statystyczne-i-raporty/raport-o-stanie-lasow/raport-o-stanie-lasow-2013/view) (Annual Report: 2013), respectively.

Tree ring fire history data from two locations in Białowieża Forest were obtained by dendroecological analyses of wood samples from *Pinus sylvestris*, spanning over the period 1650–2010. Exact fire dates were identified by cross dating of fire scars according to the standard dendrochronological techniques. Details on field and laboratory procedures are given in Niklasson *et al.* (2010).

3. Results and discussion

Present-day forest fire activity in Poland

Poland is one of the countries with the highest annual number of forest fires in Central-Eastern Europe (Szczygieł *et al.* 2009a), with as many as 9–10 000 individual fire events per year, however of relatively limited size, with 0.5–0.95 ha being mean values of area burned in a single forest fire in the recent decades (Tab. 1).

Although most of the burnt area occurs nowadays in the Mediterranean part of the European continent (Schmuck *et al.* 2011), Poland still has accounted for as much as 60% of all forest fires in Central-Eastern European countries in 1999–2001, with as many as approx. 240.5 th. fires which burned approx. 465 th. ha. In that period larger burnt area has been noted only once, in 1996, when the highest value has been recorded in the Ukraine (Szczygieł *et al.* 2009a). In the recent past (1990–2013) the highest number of forest fires in Poland occurred in 2003, with the record value of 17 088 fires. The largest area (43 755) burned in Polish forest fires in 1992 (Tab. 1). This has been a year with a disastrous fire situation (Szczygieł *et al.* 2008, 2009a), when the two largest, catastrophic forest fires in Poland in the recent history have occurred. In the Potrzebowice Forest District in north-western Poland more than 5 000 ha have burnt, whereas the Rudy Raciborskie fire in Upper Silesia (south-western Poland), being the largest forest fire in the country since 1948, has damaged over 9 000 ha in Forest Districts: Rudy Raciborskie, Rudziniec and Kędzierzyn (Hawryś *et al.* 1998, 2004; Dobrowolska 2008; Szczygieł *et al.* 2008).

As weather conditions and litter humidity are the main drivers of the fire risk in Poland (Ubysz *et al.* 2006; Szczygieł *et al.* 2009b) the anticipated changes in temperature and precipitation patterns may considerably increase the burning hazard in the near future (Schelhaas *et al.* 2010). In fact, a significant rise in the forest fire activity in Poland has been already observed over the last decades due to the increasing trend in temperature and decreasing precipitation (Ubysz *et al.* 2006; Szczygieł *et al.* 2008). Furthermore, mild winters and shortening of the snow cover period have prolonged fire season (Szczygieł *et al.* 2008), that nowadays lasts from March–April to September (Ubysz *et al.* 2006; Piwnicki and Szczygieł 2011, 2012; Szczygieł and Piwnicki 2011; Zajązkowski *et al.* 2014). In 2011–2012 the highest forest fire risk has been recorded in April, May and June (Piwnicki and Szczygieł 2011, 2012), whereas in the last year in April and July (Zajązkowski *et al.* 2014). Nevertheless the effective fire suppression system in Poland may successfully prevent the increase in annually burnt forest area (Szczygieł *et al.* 2008). Mean area of a single forest fire in 1990–2013 was 0.93 ha (Tab. 1) – a value considerably lower than the average for earlier periods, given by Szczygieł *et al.* (2008): 3.25 ha in 1948–1950, 2.35 ha in 1951–1960, 1.78 ha in 1961–1970, 1.43 ha in 1971–1980 and 1.41 ha in 1981–1990. However, extreme weather conditions in certain years (like e.g. 2003) may still significantly increase the forest fire activity and hence the mean forest fire size (Tab. 1).

The main cause of fires in Poland are people as natural, lightning-ignited fires account for about 1% only. It has been also observed, that the number of forest fire outbreaks has been larger on holidays than on workdays (Ubysz and Szczygieł 2006). Arson cases have represented as much as approx. 40% of forest fire causes throughout the recent past (Szczygieł *et al.* 2009a; Piwnicki and Szczygieł 2011, 2012; Szczygieł and Piwnicki 2011; Zajązkowski *et al.* 2014). Fire spreading from nonforest areas due to the burning of grasslands has been another important cause of forest fires in Poland (Rydzak and Trebecki 2009; Szczygieł *et al.* 2009a). This practice, although illegal according to Polish legislation (Nature Conservation Act 2004), has been traditionally aiming at improving grazing conditions by removal of old plant remains and post-fire fertilizing effect (Rydzak and Trebecki 2009; Szczygieł *et al.* 2009a). The decrease in number of fires caused by setting grasslands ablaze has been observed in the most recent years only (Rydzak and Trebecki 2009; Szczygieł and Piwnicki 2011; Zajązkowski *et al.* 2014), likely as an effect of educational campaigns by the State Forest

Administration (Rydzak and Trebecki 2009; Szczygieł and Piwnicki 2011) and/or of people's concern for EU-subsidies, that could have been eventually withdrawn (Szczygieł *et al.* 2009a).

*Table 1. Data on forest fires in Poland in 1990–2013 (Sources: Piwnicki and Szczygieł 2011, 2012; Szczygieł and Piwnicki 2011; Zajaczkowski *et al.* 2014).*

Year	No of forest fires	Burnt area (ha)	Mean fire area (ha)
1990	5 756	7 341	1.28
1991	3 528	2 567	0.73
1992	11 858	43 755	3.69
1993	8 821	8 290	0.94
1994	10 710	9 171	0.86
1995	7 681	5 306	0.69
1996	7 924	14 120	1.78
1997	6 818	6 598	0.97
1998	6 166	4 019	0.65
1999	9 820	8 307	0.85
2000	12 428	7 013	0.56
2001	4 480	3 429	0.77
2002	10 101	5 593	0.55
2003	17 088	28 554	1.67
2004	7 219	4 338	0.60
2005	12 803	7 387	0.58
2006	11 828	5 912	0.50
2007	8 302	2 841	0.34
2008	9 090	3 027	0.33
2009	9 161	4 400	0.48
2010	4 680	2 126	0.45
2011	9 220	2 850	0.31
2012	9 265	7 235	0.78
2013	4 883	1 289	0.26
Mean values for the periods			
1990–2013	8 735	8 145	0.93
1990–1999	7 908	10 947	1.38
2000–2013	9 325	6 142	0.66
1999–2003	10 783	10 579	0.98
2004–2008	9 848	4 701	0.48
2009–2013	7 442	3 580	0.48

Fire prevention together with creating and maintaining fire protection infrastructure are obligatory tasks of the Polish State Forest Administration (LP = Lasy Państwowe, State Forests National Forest Holding), as defined by the Forestry Act (1991). Current fire prevention and suppression measures applied by the State Forest Administration, besides education activities for the public, include construction of fuel- and fire breaks, silvicultural operations, fire observation system, communication

and alarm network, water supply points and professional fire suppression equipment (Szczygieł and Piwnicki 2011). All that has amounted to the total fire protection cost (incurred by the State Forest Administration) of 294 mill PLN (approx. 71 mill EUR) in 2003–2004 (Szczygieł *et al.* 2007) and of 63 mill PLN (approx. 15.2 mill EUR) in 2010 only (Szczygieł and Piwnicki 2011). According to the Polish law State Forest Administration is not obliged to conduct active fire suppression. Nevertheless it belongs to its important activities. In 2003–2004 fire suppression carried out by the State Forest Administration has accounted for 17.2% of the total fire protection cost incurred, corresponding to the cost of approx. 8–10 mill PLN (approx. 1.9–2.4 mill EUR) annually. As many as 9% of all forest fires in that period have been suppressed by the employees of the State Forest Administration alone, with no fire brigades involved (Szczygieł *et al.* 2007).

At present there is no prescribed burning practice in Polish forests as it is legally restricted (e.g. Forestry Act 1991; Nature Conservation Act 2004). In the other neighbouring countries in the temperate Europe fire use is still practiced at the experimental level only, for nature conservation and landscape management purposes (Goldammer and Bruce 2004).

Historical forest fire record from Białowieża

The first tree ring fire history records from two locations in Białowieża Forest evidenced frequent fires in *Pinus sylvestris*-dominated stands during the 17th up to early 19th centuries, with dramatic decrease in fire presence over the last 150+ years, most likely linked to changes in human fire use and forest management (Niklasson *et al.* 2010; Zin *et al.*, unpubl.).

Despite the considerable fire occurrence in Central-Eastern Europe nowadays (e.g. Szczygieł *et al.* 2009a; Schmuck *et al.* 2011), there are hardly any annually resolved data on fire activity in temperate European forests spanning over time periods longer than the 20th and the 21st centuries (*cf.* Niklasson *et al.* 2010). As main reasons for the lack of such research in that region Niklasson *et al.* (2010) gave both the traditional perspective on fire as less important disturbance agent in the vegetation dynamics of this biome (e.g. Ellenberg 1988; Vera 2000; Timbal *et al.* 2005) and the paucity of old-growth woodlands enabling dendrochronological analyses spanning over several centuries, mainly linked to the long history of forest use and management throughout this part of the European continent (e.g. Pyne 1997; Farrell *et al.* 2000).

Białowieża Forest however, a large woodland in the borderland between north-eastern Poland and western Belarus, offers an extraordinary value for dendroecological studies. Thanks to its status as a royal hunting area since the early 1400s (Samojlik 2007) it withstood deforestation and commercial timber exploitation that made thousands of hectares of old-growth woodlands all over the continent disappear and survived until today as one of the best preserved temperate lowland deciduous and mixed forests in Europe (Faliński 1986; Peterken 1996). Considering dendrochronological reconstructions, Białowieża Forest is most likely unique among other European lowland forests. Old-growth forest stands with deadwood continuity and numerous ancient, large-size trees that are still present in that area (Faliński 1986; Sokołowski 2004) deliver annually resolved tree ring record of past stand and forest dynamics.

The first tree ring fire history record from a site located in the Polish part of Białowieża Forest (Niklasson *et al.* 2010), being to our knowledge also the first dendrochronological fire history reconstruction from the temperate forests of lowland Central Europe, has evidenced fire as a factor of major importance for the past forest dynamics. It has been proven that historical fires were recurring at very short intervals (approx. 10 years on average) over the last 350+ years (1650–2007), which favoured *Pinus sylvestris*-dominated forest. However, significant temporal changes in the past fire frequencies have been recorded at the end of the 18th century, when fire intervals have significantly increased. The complete cessation of fire occurrence has been documented since 1920s. This change in historical fire regime has resulted in a remarkable shift in tree establishment patterns, towards the dominance of fire-sensitive, shade-tolerant Norway spruce (*Picea abies* (L.) Karst.) (Niklasson *et al.*

2010) – a phenomenon described also in boreal Europe (e.g. Linder 1998; Wallenius *et al.* 2004). Furthermore, substantial human impact on the reconstructed fire regime has been suggested (Niklasson *et al.* 2010), alike in other studies from Northern European locations (e.g. Niklasson and Granström 2000; Groven and Niklasson 2005; Storaunet *et al.* 2013).

Interestingly, the second tree ring fire history record from Białowieża Forest, coming from a study site located in the Belarusian section of that area (Zin *et al.*, unpubl.), brought similar information on the historical forest fire activity over the analogous period. That site, although separated in space, evidenced comparably high fire frequency between 1650s and the first decades of the 1800s, when the onset of fire decline appeared. Similarly to the Polish location, no fires were recorded since the first decades of the 20th century (Zin *et al.*, unpubl.).

4. Conclusions

We conclude that there is a large need for fire history and fire ecology studies in Central Europe due to high population density and strong dominance of flammable conifers in forests of that region. Extended knowledge about past disturbance dynamics and reference conditions may be essential for future sustainable forest management and nature conservation throughout this part of European continent.

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