Impact from global warming on the occurrence of forest fires in Poland

Ryszard Szczygieł, Barbara Ubysz, Józef Piwnicki[1]

Abstract

Trends for change in selected climate components (air temperature and atmospheric precipitation) in 1901–2005 are presented. It was fund, upon relevant data series collected by ten meteorological stations in Poland, which have the multi-year homogenous observation data series, that the multi-year tendencies in air temperature featured by constant upward trend in relation to that of early 20th Century. During the first half of the 20th Century, temperature deviations appeared more frequently towards cool years, whereas after 1967 towards warm ones. The recent 15–year period was the warmest one in the past Century. On the other hand, the analysis of the magnitude of atmospheric precipitation shows that the values of its decrement level vary between the 0.4 and 0.5 mm/year. These trends have grown particularly since 1982 and upheld by now. The longing series of dry and those of warm winters are mostly hazardous since they pose risks to forest fires. During warm winter periods, the number of days with the occurrence of snow cover declined, when compared to the multi-year mean, as did its thickness. The result is that water deficit which is caused by the summer droughts has not been made good by water from melting snow cover. Both the air temperature and atmospheric precipitation are the major decisive factors for the risks to occurrence of forest fires, since having effects on humidity level in the flammable material. Both the factors have just served as the background for the analysis of the occurrence of forest fires in Poland. The global scenarios of the further climate warming indicate the further rise in forest fire risks that requires counteracting on the global scale.

Keywords: climate, forest fire

[1]Forest Fire Protection Department, Forest Research Institute. Sękocin Stary, 3, Braci Leśnej Street, 05-090 Raszyn, Poland.

Introduction

The likelihood of a forest fire outbreak is determined primarily by weather conditions. The most important parameters which characterise these conditions are air temperature and precipitation. They are the basic factors which determine the possibility that a fire may break out, affecting the humidity of the fuel and its ignition susceptibility, depending on the energy stimuli which may emerge in a forest. In recent years, the problem of global warming became particularly significant, including climate variations and oscillations. The problem also affects the general trends in the emergence of forest fire danger in the world.

The WMO reports, prepared by the Intergovernmental Panel on Climate Change (IPCC), indicate that the greatest dangers to the natural environment of our planet also include acid rains, the processes of steppe development and desertification as well as the deletion of the ozone layer. These unfavourable effects emerge in a feedback relationship with forest fires breaking out on a global scale, the number of which and the related size of the area burnt are characterised by a growing trend.

Purpose of the study

The purpose of the study was to analyse the trends of change in selected elements of Poland's climate from 1901 to 2006 and their effect on forest fire outbreaks.

Method

The trends in climate change were determined for precipitation and air temperature on the basis of data from nine meteorological stations which have long-term homogeneous observation time series. Fig. 1 shows the situation of meteorological stations the data from which provided the basis for the analysis.

Figure 1—Poland's map illustrating the situation of meteorological.

A given year was evaluated in terms of precipitation, using the criterion of Kaczorowska (1962), who classified years in the following manner in respect of insufficient or excessive precipitation (Table 1).

Table 1—*Classification of years depending on the precipitation levels.*

Item	Characteristics of a year	Total precipitation as a percentage of the standard level
1.	Extremely dry	< 50%
2.	Very dry	50 – 74%
3.	Dry	75 – 89%
4.	Normal	90 – 110%
5.	Wet	111 – 125%
6.	Very wet	126 – 150%
7.	Extremely wet	> 150%

These criteria were applied to classify all the years for the meteorological stations considered in this study.

In turn, the classification of years classified depending on the mean annual temperature was carried out on the basis of the standard deviation (δ), according to the principles set out in Table 2.

Table 2— *Classification of years depending on the mean annual air temperatureSample table title style.*

Class No.	Name of class	Interval of standard deviation values (δ)
1.	An extremely hot year	> 2.5
2.	An anomalously hot year	$2.0 < t \leq 2.5$
3.	An extremely hot year	$1.5 < t \leq 2.0$
4.	A very hot year	$1.0 < t \leq 1.5$
5.	A hot year	$-1.0 < t \leq 1.0$
6.	A normal year	$-1.5 < t \leq -1.0$
7.	A cold year	$-2.0 < t \leq -1.5$
8.	An anomalously cold year	$-2.5 < t \leq -2.0$
9.	An extremely cold year	$t < -2.5$

For both meteorological parameters, statistical analyses of the trends in their change in a given period were carried out.

Against the background of changes in air temperature and precipitation, the number of forest fire outbreaks and their surface area in 1948 to 2006 were analysed (in view of the absence of earlier data), using statistical trend analyses, in the same manner as for the weather factors under study.

Study results

4.1. Precipitation

Table 3 shows the trend coefficients for total annual precipitation levels. Fig. 2 shows the variations in mean annual total precipitation levels with a trend line for which the value of the precipitation was -0.5006.

Table 3*—Trend coefficients for total precipitation levels and their annual.*

Name of meteorological station	Trend coefficients for a year	Annual standard values of precipitation levels [mm]
Koszalin	- 0.549	726
Cracow	- 0.935	669
Poznań	- 0.488	520
Słubice	+ 0.199	543
Szczecin	- 0.704	550
Mt. Śnieżka	+ 0.204	1253
Warsaw	+ 0.217	571
Wrocław	- 0.409	586
Zakopane	-1.017	1126

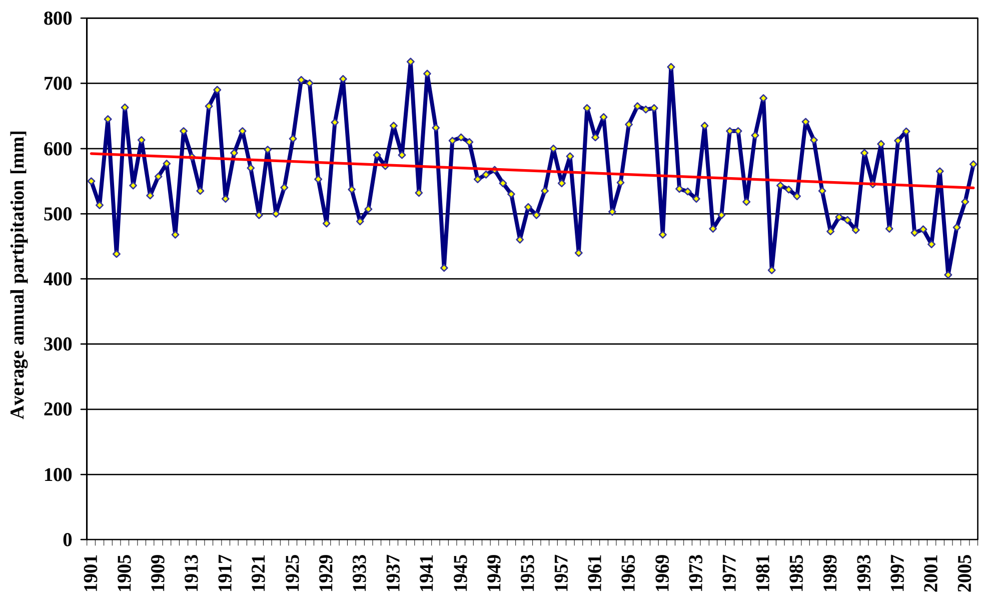

Figure 2—Variations in mean annual total precipitation levels in Poland from 1901 to 2006

Analysis of the results obtained indicates very large precipitation variations in particular years. Different directions and levels of trends can be observed in the particular regions of Poland. The annual trends were not always determined by the same season of the year. In general, it can be said that 66% of meteorological stations showed negative long-term annual precipitation trends. It is interesting to emphasise the fact that all the determined values of long-term trends are statistically insignificant at the level of 0.05, as also confirmed by the very low values of the correlation coefficient, i.e. less than 0.03. Therefore, an insignificant falling trend in precipitation levels can be observed; still, this does not exclude the possibility that such a trend was significant in certain shorter periods.

The classification of the particular years in terms of precipitation levels demonstrated that years with excessive precipitation represented 26.0%, of which:

- the number of wet years represented 18.3%,
- the number of very wet years represented 7.1%,
- the number of extremely wet years represented 0.6%.

Statistically, the years with excessive precipitation levels repeated every 3.5 – 4 years. The extremely wet years came in 1939, 1941 and 1970. From the beginning of the 20th century, the years with excessive precipitation levels occurred as follows:

- at the beginning of the century,
- in the second half of the 1920s,
- the turn of the 1930s and the 1940s,
- in the 1960s,
- in the second half of the 1970s,

at the beginning of the 1980s and in the years 1985 – 1987.

The years with insufficient precipitation levels represented 28%, of which:

- there were no extremely dry years,
- the number of very dry years represented 8%,
- the number of dry years represented 20%.

The most intensive droughts came in 1943, 1953 and 1982. Analyses indicate that years with insufficient precipitation levels tended to occur in series of years. Such series of dry years could be observed in the periods: 1904 – 1917, 1951 – 1959 and 1982 – 1992.

In conclusion, long-term data on precipitation levels indicate that years with standard precipitation levels represented 46%. The number of years with excessive precipitation levels represented 26%, whereas those with insufficient precipitation levels accounted for 28%. The mean precipitation loss was of the order of 0.4 – 0.5 mm/year. The wettest years came in the decade of 1961-1970. The drought in 1992 covered the largest part of the country. In the last twenty years, a series of dry years could be seen, with single-year periods with precipitation, breaking the series, failing to compensate for a shortage of precipitation.

4.2. Air temperature

Analysis of air temperature trends shows large variations in its annual values throughout Poland; this is a normal effect for its climate. Table 4 shows the air temperature trend coefficients. Fig. 3 shows the mean annual temperature changes with a trend line for which the value of the coefficient was 0.0038. The values of the trends turned out to be statistically significant at the level of 0.05 for half the number of meteorological stations and insignificant for the other half, irrespective of the region of Poland. Statistical trend analyses indicate that annual air temperature trends at all the meteorological stations demonstrated a growing trend. Detailed analysis demonstrates that in the last years of the period in question the recorded increase in the value of the trend was on average as much as 0.0015°C/year. The greatest positive deviation from the standard value could be seen in October, December, January, March and May. Overall, in the period under study, 24% to 35% of years were hot (depending on the region of the country), whereas 15% to 18% of years were cold. The other percentages of years were normal. The first half of the 20th century was characterised by the occurrence of a temperature deviation towards cold years, whereas after 1967 a deviation towards hot years could be seen. In addition, the deviations in the positive direction were greater than those in the negative direction. The last twenty years were the hottest in the entire period under study.

Table 4—*Air temperature trend coefficients in ℃/year at the meteorological stations considered.*

Name of a meteorological station	Air temperature trend coefficients
Koszalin	0.0084
Cracow	0.0142
Poznań	0.0091
Słubice	0.0037
Szczecin	0.0067
Mt. Śnieżka	0.0034
Warsaw	0.0036
Wrocław	0.0033
Zakopane	0.0077

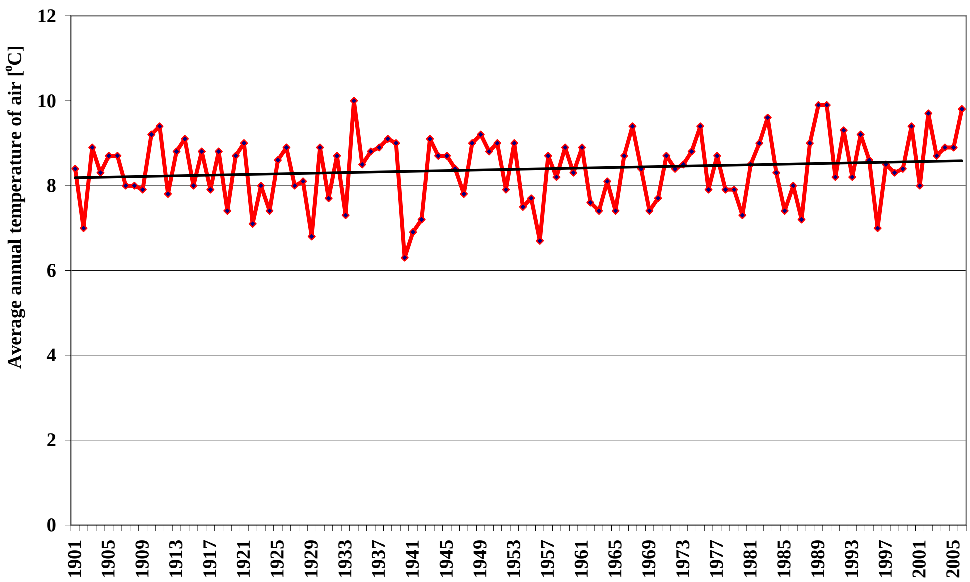

Figure 3—Variations in mean annual air temperature levels in Poland from 1901 to 2006

4.3. Forest fire outbreaks

Fig. 4 shows forest fire outbreaks in terms of their number and the related area burnt from 1948 to 2006, also indicating the trends which characterise them. The trend value for the number of fires was 139.62, whereas the one for the area burnt was 158.54. In turn, Fig. 5 shows together the curves of the trends of the examined meteorological parameters as well as the number of forest fire and the area burnt. From 1948 to 2006, a total of 232,320 fires broke out, covering forests with a surface area of 307,938 ha. The curves indicate that both the number of fire outbreaks and the area burnt showed a growing trend, with some deviations depending on the weather conditions. It should be noted that the growing trend in the number of fires was greater than the trend in the area burnt. This indicates the effectiveness of the organisation of the fire protection system in Poland, since – despite an increase in the number of fires – a steady decrease in the mean area of a single fire (0.75 ha) can be observed (in the years 2001 to 2006). For comparison, in 1948 to 1950 it was 3.25 ha; in 1951 to 1960, 2.35 ha; in 1961 to 1970, 1.78 ha; in 1971 to 1980, 1.43 ha; in 1981 to 1990, 1.41 ha; in 1991 to 2000, 1.30 ha.

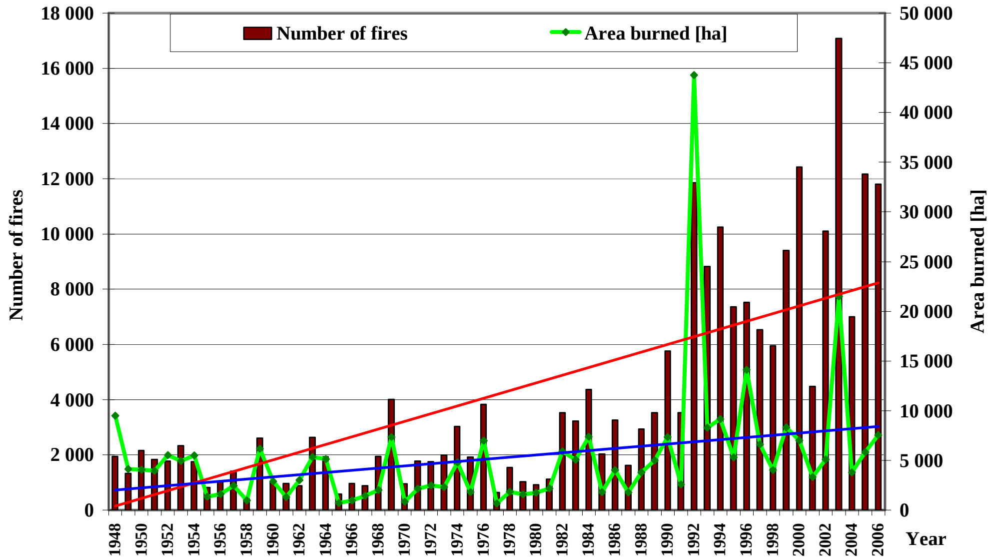

Figure 4—The number of forest fires and the area burnt in Poland from 1948 to 2006 and the trends which characterised them

Overall, it can be observed that the number of forest fires and the area burnt in the course of them increased with the falling precipitation levels and the steady climate warming in Poland. This growth was the greater the more the standard deviations of the examined meteorological parameters exceeded the standard values in the positive direction. This was the case in particular with the period of the last twenty years, which was the hottest period in the interval of years under study; especially, in the early 1990s, when extremely favourable weather conditions caused a sudden increase in the number of fires (in 1992). This trend became stronger in 2000 and 2003, when the maximum number of forest fires was recorded. It is interesting to note that the maximum area burnt in the entire period under study occurred in 1992, when several catastrophic forest fires broke out almost at the same time, affecting a surface area of more than 2,000 ha, including the largest fire after 1948 with a surface area of 9,060 ha. This can be explained by the fact that that year the National Fire fighting and Rescue System was established and it was only beginning to function.

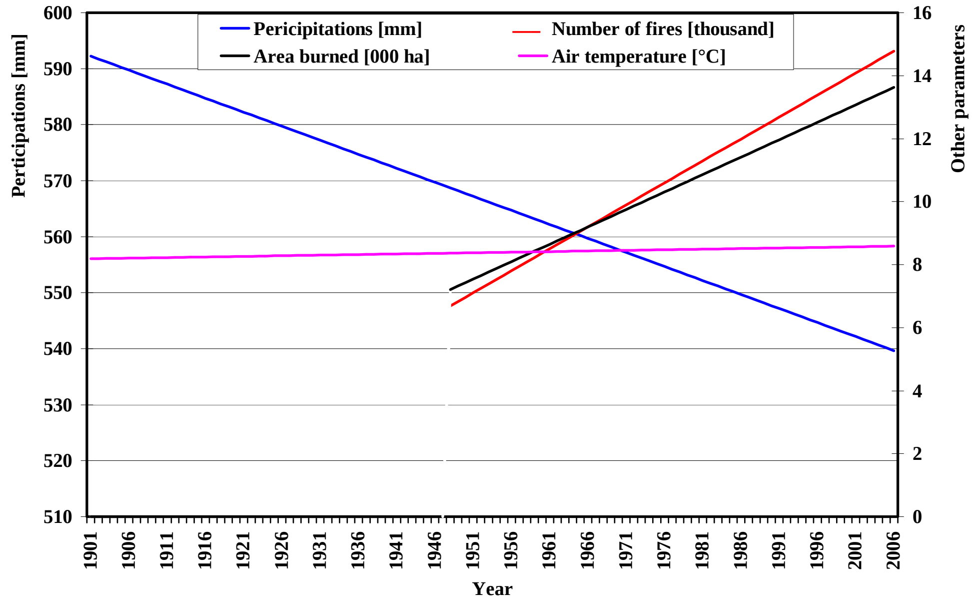

Figure 5—The trends of change in mean annual precipitation levels, air temperature levels, the number of forest fires and the area burnt in Poland from 1948 to 2006

The climate change in Poland, often characterised by the absence of snow cover and warm winters, caused an extension of the period exposed to forest fire danger to include the time which had not been considered earlier to be part of the fire season, i.e. the winter and autumn months. An example of this can be the situation in 1999, when the maximum number of fires came in September, amounting to 2,106 fires. For comparison, such numbers had been recorded as the total number of fires in the particular years.

Conclusions

Analysis of long-term time series of meteorological data indicates the existence of a growing air temperature trend and a falling precipitation trend since the beginning of the century in Poland's territory. These trends have become stronger, particularly since 1982, and have persisted to date. This situation has caused an increase in the number of fires and the area burnt in the course of them; this was most conspicuous in the 1990s.

Series of dry summers and series of warm winters were most dangerous in relation to the emergence of forest fire danger. As a result, water shortages caused by summer droughts were not compensated for by water resources from snow cover; and this increased the forest fire danger.

In connection with the prediction scenarios on the future climate on Earth and the farther warming, mainly caused by greenhouse gas emissions, a further increase in forest fire outbreaks, including those in Poland, can be expected.

References

Dunikowski S., Kwiatkowski M., Santorski Z. 2001, Fire danger monitoring. Sounding fire alarms. Characteristics of the hydrothermal conditions in certain regions of the country, based on the results of observations at forest-based meteorological stations [in Polish]. Report of the Forest Research Institute, Warsaw.

Environmental Protection 1980-2001, the series Statistical Information and Studies, GUS Warsaw.

Forestry 1980-2001, the series Statistical Information and Studies, GUS Warsaw.

Kaczorowska Z. 1962, Long-term analysis of precipitation in Poland [in Polish]. Prace Geograficzne, v. 33, Polish Academy of Science – Institute of Geography.

Kwiatkowski M., Ubysz B., 2004, Interdependence of meteorological conditions and large forest fires. In: Large-Area Forest Fires (eds. J. Piwnicki and B. Ubysz), Forest Research Institute, PROFOREST Centre Excellence, Warsaw, pp.11-12.

Large-area forest fires in Poland in the period of 1999-2003. In: Large-Area Forest Fires (ed. J. Piwnicki, B. Ubysz), Forest Research Institute, PROFOREST Centre Excellence, Warsaw 2004, p. 15-16.

Lorenc H., Bogucka M., Dołęga E., Mazur A. et al. 1995, Trends of change in selected elements of climate and groundwater in the last 30 years in Poland [in Polish]. Report of the Institute of Meteorology and Water Management, Warsaw.

Poland - chapter 4.4. in: Forest Fires Report in Europe 2004, Report No 5, European Communities 2005, p. 27-29, [Ubysz B., Piwnicki J.].

Reports on the condition of forests 1995-2001 [in Polish], Information Centre of State Forests, Warsaw.

Sakowska H. 2005, A method for assessing fire risk to Polish forests based on predicted change in litter humidity [in Polish], Ph. D. Thesis, Forest Research Institute, Warsaw.

Santorski Z., Ubysz B., Sakowska H., Kwiatkowski M. et al. 2001, Monitoring fire risk and sounding alarms of forest fires [in Polish], Forest Research Institute's Report, Warsaw.

Statistical tables on rescue operations in 1994, 1995, 1996, 1997, 1998, 1999, 2000 and 2001 [in Polish], National Headquarters of the State Fire Service, National Centre for the Co-ordination of Rescue and Civil Protection 1994-2001, prepared from data contained in the EWID-93 programme.

Szczygieł R. 1992, Influence of weather factors forest fire risk. Seminar on forest fire prevention, land use and people. ILO/ECE/FAO, Athens, Grecja 1991, published by Ministry of Agriculture Secretariat General Forests and Natural Environment Greece.

Szczygieł R., Ubysz B., Zawiła-Niedźwiecki T. 2006, Spatial and temporal trends in distribution of forest fires in Central and Eastern Europe. 22nd International Meeting for Specialists in Air Pollution Effects on Forest Ecosystems. IUFRO: Forests under Antropogenic Pressure - Effects of Air Pollution, Climate Change and Urban Development, Forestry 7.01 Symposium: Impacts of air pollution and climate change on forest ecosystems. Riverside, California, USA, 10-16 September 2006. W: "Wildland Fires and Air Pollution", A. Bytnerowicz, M. Arbaugh, C. Andersen and A. Riebau (editors), Elsevier Book Series "Developments in Environmental Science", Series Editor: Dr. S. V. Krupa, Elsevier (in the press).

Ubysz B., Szczygieł R. 2005, Occurence of the forest fire in 2004. In: Forest condition in Poland in 2004. Biblioteka Monitoringu Środowiska, Inspekcja Ochrony Środowiska, Warsaw , p. 37-38.

Ubysz B., Szczygieł R. 2002, Fire Situation in Poland. International Forest Fire News, No. 27 – July - December, UN ECE/FAO p. 38-64.

Ubysz B., Szczygieł R.2003, Pożary – przyczyna klęsk w lasach w Polsce i na świecie, Postępy Techniki w Leśnictwie r., nr 84, (Problematyka klęsk żywiołowych w lasach) s. 32-40.

Ubysz B. 2003, The influence factors on the forest fire danger in Poland. XII World Forestry Congress, Québec City, Canada, September 21 to 28, , Forests, Source of Live. Congress Proceedings, B – Forests for the Planet, p. 230.

Ubysz B. 2004, Forest fires in Poland in the period of 2002-2003. In: Large-Area Forest Fires (ed. J. Piwnicki, B. Ubysz), Forest Research Institute, PROFOREST Centre Excellence, Warsaw , p. 27-28.

Ubysz B., Kwiatkowski M., Piwnicki J., Szczygieł R. et al. 2004, Monitoring forest fire risk [in Polish], Forest Research Institute's Report, Warsaw.

Ubysz B., Szczygieł R. 2006, Ocena sytuacji pożarowej w polskich lasach. Notatnik Naukowy nr 5(73)/2006(XIV).

Ubysz B., Szczygieł R., Piwnicki J. 2006, Analysis of the trends in the forest fire risk for recent years in Poland against the background of long-term trends. Proceedings of the 5th International Conference on Forest Fire Research, 27 – 30 November, 2006, Figueira da Foz, Portugal, Edited by D.X.Viegas, ADAI/CEIF University of Coimbra, Portugal, ELSEVIER Amsterdam - Boston – Jena – London – New York – Oxford – Paris – Philadelphia – San Diego – St. Louis, Proceedings on the CD-rom, Abstracts in the Forest Ecology and Management Vol. 234, Supplement 1 (2006), 11 pp., index 245, S248.

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