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NORTH ATLANTIC OSCILLATION (NAO) AND INSECT DAMAGE IN SERBIAN FORESTS

V. DUCIĆ[1], JELENA LUKOVIĆ[1], M. MILENKOVIĆ[2], and NINA ĆURČIĆ[3]

[1] *Faculty of Geography, University of Belgrade,* 11000 Belgrade, Serbia
[2] *Faculty of Forestry, University of Belgrade,* 11000 Belgrade, Serbia
[3] *Institute of Geography "Jovan Cvijić", SANU,* 11000 Belgrade, Serbia

Abstract - This paper examines the relationship between North Atlantic Oscillation (NAO) and damage made by insects in Serbian forests. The damage has been separated into three groups: bark beetles, gypsy moth and damage made by other insects. For North Atlantic Oscillation the NAO index is used. The period of investigation was 1969-2001. Data were studied on an annual scale as well as with five-year moving averages. Analysis showed a statistically significant correlation for NAO index and gypsy moth.

Key words: NAO, gypsy moth, forests, Serbia

INTRODUCTION

North Atlantic Oscillation (NAO) is one of the dominant modes of global climate. The term itself was introduced by Walker (1924). It is defined as the sea-level pressure difference between the subtropical anticyclone over the Azores and the subpolar depression over Iceland. It has significant influence on winter weather conditions in Europe and parts of the North America. This is considered as the normal condition, which becomes more intensive during winter. There are positive and negative phases of NAO. During the positive phase, winters in North Europe are warmer and wetter with less rainfall than usually. A negative phase is followed by colder winters in North Europe and higher precipitation in the southern parts of Europe (Hurell and Van Loon, 1997).

The relationship between the population dynamics of living organisms and indicators of atmospheric circulation has been the subject of many papers, with regard to North Atlantic Oscillation.

Schmidt et al. (2004) investigated the impact of agriculture, predators and climate on the population dynamics of the European brown hare in Denmark. The influence of the NAO on winter temperatures, precipitation and wind is particularly detected in Northern Europe. The authors confirmed the impact of investigated phenomena on the population dynamics of the brown hare. Briers et al. (2004) found NAO impact on the growth and phenology of stream insects. Jonas and Joern (2007) state that there is a significant correlation between the NAO and the mean annual frequency of grasshopper populations in the North American prairies. Lima et al. (2008) stated that using a simple logical model that uses weather condition can help in predicting the green spruce aphid outbreaks in the UK. These models, using climatic variables like the NAO, also show geographical aspects. Knape and de Valpine (2010) have analyzed the relationship between weather and climate indices, and the number of time series of mammals, birds and insects. The authors believe that the NAO is a less reliable predictor of population dynamics than local weather vari-

ables. Data on insects are usually less predictable than those on birds or mammals.

NAO impact is found in marine organisms. Piontkovski et al. (2006) have found a positive correlation between copepod abundance in the northern Adriatic Sea and the NAO, with a 0- to 1-year time lag.

The NAO index and ENSO (El Nino Southern Oscillation) have been studied in terms of their relationship with precipitation in Serbia (Ducic et al., 2006) in the period 1951-2000. Precipitation data from 20 meteorological stations were analyzed. A statistically significant decadal trend has been calculated for two stations. Using cluster analysis, all the stations are grouped into three categories. Correlation analysis was performed for each cluster with ENSO and NAO indices. The statistically significant results could be possibly explained by an indirect mechanism of ENSO impact on the NAO index (Harrison and Larkin, 1998).

The main hypothesis in this paper is the existence of a relationship between the NAO as an indicator of atmospheric circulation and damage from insects in Serbian forestry.

DATA AND METHODOLOGY

Data on damage in forests caused by insects were taken from the series of Bulletins "Forestry in the Republic of Serbia", published by the Republic Statistical Office. These damages are separated into three groups: bark beetles, gypsy moth and other insects.

Bark beetles are of greater significance to coniferous forests than to deciduous forests. In Serbia, the bark beetles of pine, spruce and fir are of particular importance.

Gypsy moth (*Lymantria dispar* L.) (Lepidoptera: Lymantriidae) has a tendency to over-reproduce, resulting in the caterpillars of this species causing defoliation over large areas of forest, crops and urban greenery.

Other insects present a particular group which consists primarily of Coleoptera and Lepidoptera species.

Data on total damages are available for the period 1969-2001, and include damage structure. Data on structure since 2002 are missing, so the period 1969-2001 has been used for analysis.

Annual losses in wood mass expressed in m^3 were used as an indicator of the damage caused by insects in the forests of Serbia. These data are considered to be a more accurate indicator than those concerning the area of damage, because the area of damage does not include the quantity of biomass, which describes the intensity of degradation.

Data on air temperature, rainfall amount and cloud cover were taken from the Hydrometeorological Service of Serbia.

Data for the NAO index were obtained from the internet site (www.cru.uea.ac.uk/ftpdata/nao.dat).

As regards the methodology of the investigation, statistical tools such as coefficient of contingency and correlation coefficient were used. Data series were tested to determine distribution. As some series did not show normal distribution (Gaussian), Spearman's test of correlation coefficient was applied. In order to clearly isolate possible NAO signals on the damage caused by insects in Serbian forests, the period of five-year moving averages was used.

RESULTS AND DISCUSSION

During the investigated period (1969-2001), 82% of the damage was made by bark beetles, 6.1% by gypsy moth, and the remaining 11.9% by other insects. Bark beetles in 10 out of the 33 years participated 100%. Other insects were the absolute majority in 3 years and the gypsy moth in 1 year (1997 with 66.8%).

Spearman's rank correlation showed a statistically significant result for the annual NAO index and damage done by insects at the probability level

Table 1. Annual and five-year moving averages data series for NAO Index and losses in wood mass (m^3) caused by the gypsy moth.

Annual values						Five -year moving averages					
Years	Gypsy moth	NAO	Years	Gypsy moth	NAO	Pentads	Gypsy moth	NAO	Pentads	Gypsy moth	NAO
1969	434	-0.44	1986	0	0.56	1969/1973	110.8	-0.19	1984/1988	27	-0.10
1970	100	0.18	1987	135	-0.51	1970/1974	24	0.02	1985/1989	27	-0.04
1971	0	-0.55	1988	0	-0.32	1971/1975	4	-0.01	1986/1990	27	0.30
1972	20	-0.04	1989	0	0.57	1972/1976	4	0.09	1987/1991	27	0.26
1973	0	-0.09	1990	0	1.23	1973/1977	0	0.06	1988/1992	0	0.58
1974	0	0.59	1991	0	0.34	1974/1978	0	0.11	1989/1993	0	0.67
1975	0	0.05	1992	0	1.11	1975/1979	0	0.03	1990/1994	0	0.66
1976	0	-0.07	1993	0	0.12	1976/1980	0	-0.05	1991/1995	131.2	0.29
1977	0	-0.21	1994	0	0.51	1977/1981	0	-0.06	1992/1996	1102	0.02
1978	0	0.21	1995	656	-0.61	1978/1982	0	0.12	1993/1997	1947.2	-0.23
1979	0	0.19	1996	4854	-1.01	1979/1983	0	0.15	1994/1998	1957.2	-0.21
1980	0	-0.37	1997	4226	-0.18	1980/1984	0	0.16	1995/1999	2058.8	-0.30
1981	0	-0.09	1998	50	0.26	1981/1985	0	0.14	1996/2000	1927.6	-0.17
1982	0	0.67	1999	508	0.05	1982/1986	0	0.27	1997/2001	1395.8	-0.06
1983	0	0.34	2000	0	0.04	1983/1987	27	0.04	-	-	-
1984	0	0.26	2001	2195	-0.45	-	-	-	-	-	-
1985	0	-0.47	-	-	-	-	-	-	-	-	-

r = 0.05, only for the gypsy moth (R = -0.49). Therefore, further analysis included damage done by gypsy moth alone (Table 1)

Correlations were calculated between the damage done by gypsy moths and annual temperature, precipitation and cloud cover variability for six stations located in the north (Palic), southwest (Sjenica), southeast (Vranje), east (Negotin) and two central positions (Belgrade and Krusevac) (Fig. 1). There were no statistically significant correlations calculated at any of meteorological stations. This may contribute to the primary hypothesis about NAO impact on gypsy moth population dynamics. Atmospheric circulation (NAO) is a clear indicator of climate phenomena in the habitat and therefore the obtained relationship was to be expected.

Between the NAO index and the damage caused by gypsy moth using a period of five-year moving averages, the correlation was R = -0.61 (significant at the level of r = 0.05). Fig. 2 clearly shows an opposite relationship. The lowest pentad of the NAO index

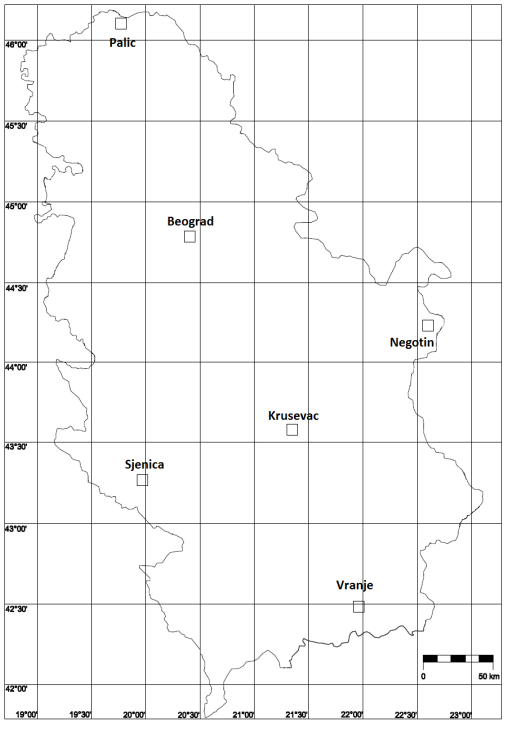

Fig. 1. Map showing locations of meteorological stations examined in this paper

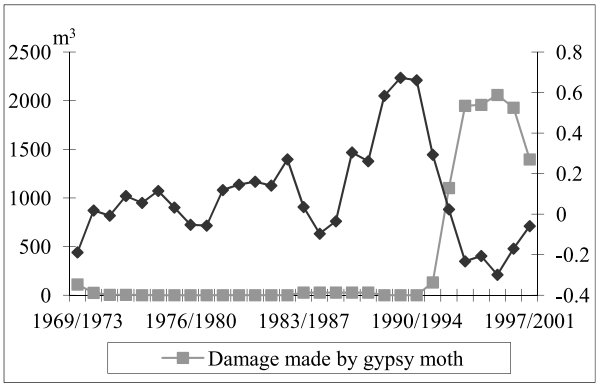

Fig. 2. Five-year moving averages of NAO Index and Gypsy moth (1969/1973-1997/2001)

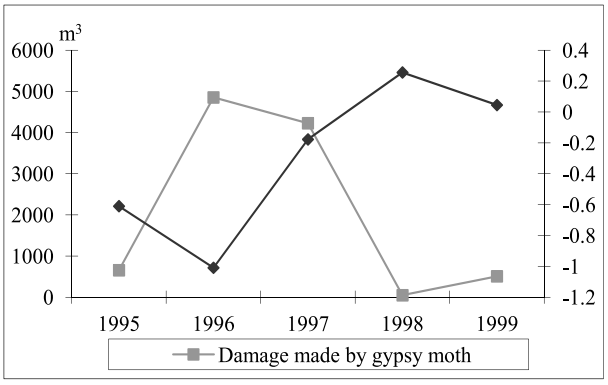

Fig. 3. NAO Index and gypsy moth for period 1995-1999 in which most of the damage done by Gypsy moth occurred.

(1995-1999) fully coincides with the largest average pentad of gypsy moth damage.

For one outbreak (1995-1999) with most of the damage done by gypsy moths, the contingency coefficient was (-1), which confirms the opposite relation (Fig. 3). The year with the greatest damage done by gypsy moth (1996 - 4854 m^3), corresponds to the lowest values of the NAO index. The least damage was in 1998 (50 m^3), when the NAO index had the highest value.

Although results for meteorological elements did not show any statistically significant correlations, the relationship between gypsy moth outbreaks and meteorological factors should not be ignored, using other insects as well. This is evident from the results given by Stige et al. (2007), who investigated the relationship between the annual abundance of the oriental migratory locust *Locusta migratoria manilensis* in China with temperature and precipitation reconstructions for the period 957-1956. The authors found that decadal mean locust abundance was highest during cold and wet periods. These periods coincide with the above-average frequencies of both floods and droughts in the lower Yangtze River, phenomena that are associated with locust outbreaks.

The results determined that the relationship between the NAO and the extent of the damage done by gypsy moths could be explained by the influence of solar activity in both investigated elements. Boberg and Lundstedt (2002) have correlated solar wind and the NAO, while the influence of solar flux at 2.8 GHz on the population dynamics of insects was found by Izmaylov et al. (2005), Kravchenko et al. (2006), Jovanović et al. (2006) and Milenković et al. (2010), where the last authors studied gypsy moth outbreaks in Serbia.

The NAO index, as well as indicators of solar activity in the future, could be the basis on which to forecast gypsy moth population dynamics. However, research is necessary for more accurate forecasting further.

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