Climate of the Wielkopolski National Park in the period of 1848-2017

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Abstract: The aim of this study was to evaluate trends in changes of precipitation and air temperature and their cyclicity in the Wielkopolski National Forest Park during the period of 1848-2017. The Park is located in the middle segment of the Warta river basin, in the central part of the Wielkopol ska region, near the city of Poznań. The area is situated in the western part of the Wielkopol ska-Mazovian climatic region. The natural landscape is of the glacial type of Pleistocene and Holocene formation. Scots pine (Pinus sylvestris) is the dominant species, but also Common oak (Quercus robur), Silver birch (Betula pendula), Alder (Alnus glutinosa) and Red beech (Fagus sylvatica) are present there. The predominant habitats include fresh broadleaved forest, fresh mixed broadleaved forest and fresh mixed coniferous forest. Climate change in the Wielkopolski National Forest Park is distinguished by relatively significant stationarity expressed e.g. by parameters of air temperature and precipitation dynamics. The time series of mean air temperature for the investigated periods expressed statistically significant positive trend changes for March, April, May, August, November, December and all-year (at \( \alpha = 0.05 \)). Respectively, these trends are 0.010, 0.009, 0.008, 0.007, 0.012, 0.009 and 0.006 °C/year (Sens's slope). For the other months relevant trends are not statistically significant. The time series of air temperature is characterized by periodicity. The dominating cycles are 168.0-, 84.0-, 8.0-, 7.6- and 5.3-year long. For the period from 1848 to 2017 the directional changes of the precipitation time series were not indicated at the significance level of 0.05. The trends are statistically non-significant for each month of the year and all-year periods. However, periodicity of annual precipitation was observed. The dominating periods are 18.7-, 9.9-, 7.0-, 3.2- and 2.1-year long. In the Wielkopolski National Forest Park during the last 170 years the mean annual air temperature has increased by about 1°C. Total annual precipitation remains unchanged. The time series of mean annual air temperature is not homogeneous. In the last 20 years the trend towards rising air temperatures was 0.04 °C/year and it was about 6 times higher than the same trend for the whole investigation period. However, for the sum of annual precipitation the hypothesis that the time series is statistically homogeneous may not be rejected.

Key words: Wielkopolski National Park, trend and periodicity of air temperature and precipitation

INTRODUCTION

The status and variability of water relations in ecosystems are affected mainly by meteorological factors, i.e. precipitation and air temperature. Continuous increment in biomass depends on the amount of transpired water, which means that the condition of tree stands is determined by precipitation and thermal conditions (Miler 2008, Okoński and Miler 2012).

Climate change is assessed based on long series (30 years according to WMO and IPCC) of direct observations. Such series are not available for the Wielkopolski National Park (WNP). From the Ecological Station in Jeziory, located in the centre of the Park, the only available data come from the period of 2001-2017. However, data from a long observation period for air temperatures and precipitation are known for the city of Poznań (1848-2017, 170 years). It needs to be stressed here that for Poznań no complete and uniform data have been published on air temperature and precipitation starting from the beginning of their observations, i.e. 1848, in contrast to those available e.g. for Wrocław (the period of 1791-2007) described by Bryś and Bryś (2010), for Warszawa (1779-1998) elaborated by Lorenz (2000) or Kraków (1792-1995) presented by Trepnińska and Kownatz (1997).

The Jeziory Station is located approx. 20 km south of the meteorological station in Poznań-Lawica. Thus it was assumed that the missing weather data for the period of 1848-2000 will be supplemented based on the regression relationships for the period 2001-2017 between the stations in Jeziory and Poznań-Lawica, belonging to the Institute of Meteorology and Water Management - National Research Institute.

The Wielkopolski National Park (WNP), serving extensive recreation functions for the Poznań agglomeration, is located in the middle segment of the Warta river basin, in the central part of the Wielkopolska region, in the western part of the Wielkopol ska-Mazovian climatic region (Woś 1994). The natural landscape is of the postglacial type of Pleistocene and Holocene formation. Since 1996 the WNP area has been 7 584 ha.
and together with the protection zone it is 14 840 ha. The Park is situated approx. 15 km south of Poznań. Eighteen strict protection areas with the total area of 259 ha have been established (Nowak et al. 2000). These areas protect various landforms of the postglacial landscape and the most natural plant communities, as well as the related wildlife (Anders et al. 1999). The WNP also serves a very important recreation function for the inhabitants of the Poznań agglomeration (Miler and Krysztowiak 2003). Within the Park the predominant soils are grey brown podzolic (47%) and brown podzolic soils (30%), while the other soils include podzols (7%), proper brown soils (6%), alluvial soils (3%), deluvial soils (2%), anthropogenic soils (1%), arenosols (1%), muck soils (1%), black turf soils (1%) and brown acid soils (1%) (Nowak 1999). Scots pine (Pinus sylvestris) is the dominant species, accompanied by oak (Quercus robur), birch (Betula pendula), alder (Alnus glutinosa) and beech (Fagus sylvatica). Most of the WNP area is covered by forest sites representing 10 forest site types: fresh broadleaved forest (Lśw) 55%, fresh mixed broadleaved forest (LMśw) 24%, fresh mixed coniferous forest (Bśw) 13%, flood plain forest (Lś) 3%, fresh coniferous forest (Bśw) 3%, moist broadleaved forest (Lś) 1%, ash-alder swamp forest (Olj) 1%, and alder swamp forest (Oł) (Batazy 1994, Miler and Krysztowiak 2006).

The aim of the study was to assess trends for changes in precipitation and air temperatures as well as their cyclicity, taking place in the WNP in the last 170 years, i.e. between 1848 and 2017.

\[ x_j, x_k \] - values of data in time j and k,
\[ n \] - length (size) of the data set.

Values of data xi were compared in relation to all

MATERIAL AND METHODS

While mean monthly or annual air temperatures have the S1 (normal) distribution, mean monthly and annual precipitation totals have the A3 (Pearson type III) distribution (Kaczmarek 1970). Thus it is necessary to apply non-parametric tests in statistical analyses.

In order to assess time trends for changes in air temperatures and precipitation in Poznań the adopted methodology was based on the Mann-Kendall non-parametric test (Gilbert 1987), which is used e.g. to assess trends in hydrological and climatic parameters (Hirsch and Slack 1984, Chiew and McMahon 1993, Yue et al. 2002, Khambhammettu 2005, Banasik et al. 2013). Values of statistic S in the test were determined using the following formula:

\[
S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn (x_j - x_k)
\]

where: \( sgn (x_j - x_k) = \begin{cases} 
1 & \text{for } (x_j - x_k) > 0 \\
0 & \text{for } (x_j - x_k) = 0 \\
-1 & \text{for } (x_j - x_k) < 0 
\end{cases}
\)

successive data values. The initial value of Mann-Kendall statistic S was assumed as 0 (no trend). If the value of the next element in the series was greater that the preceding value, then S was increased by 1. On the other hand, if the value of the next element in the series was lower than the preceding value, then S was reduced by 1. As a result of these calculations the final value of S was obtained.

Calculations of variance S (Var(S)) were made taking into consideration adjustments concerning the number of data in the series over 40 with repeated values in the group of data (Gilbert 1987):

\[
Var(S) = \frac{n(n-1)(2n+5) - \sum_{p=1}^{g} t_p (t_p - 1)(2t_p - 5)}{18}
\]

where:
\[ n \] - length (size) of the data set,
\[ g \] - number of groups of data with repeated values,
\[ t_p \] - number of repeated values of data in the group.

Probability connected with test statistic Z was obtained using normalised test statistic Z calculated from equation:

\[
Z = \begin{cases} 
\frac{S - 1}{\sqrt{Var(S)}} & \text{for } S > 0 \\
0 & \text{for } S = 0 \\
\frac{S + 1}{\sqrt{Var(S)}} & \text{for } S < 0 
\end{cases}
\]

It is assumed that a trend is downward when Z is less than zero and probability is lower than the assumed significance level \( \alpha = 0.05 \). At the same time, a trend is considered to be upward when Z is greater than zero and probability is analogous as above.

The chronological sequence – time series F(t) for a given parameter (e.g. precipitation, air temperature) may be described as follows:

\[
F(t) = A_0 + A \cdot t + \sum_{i=1}^{n} (B_i \cdot \sin \left( \frac{2 \cdot \pi \cdot T_i}{T_i} \cdot t \right) + C_i \cdot \cos \left( \frac{2 \cdot \pi \cdot T_i}{T_i} \cdot t \right) + \epsilon(t)
\]

where: \( A_0 \) – constant value, \( A \) – trend for changes, \( t \) – time, \( B_i, C_i \) – amplitudes of harmonics, \( T_i \) – periods of harmonics.

Periodogram P(i) is defined as follows:

\[
P(i) = (B_i^2 + C_i^2) \cdot \frac{N}{2}
\]

where: \( B_i, C_i \) – as above, \( N \) – number of observations.

Function P(i) was used in this study to estimate periodicity of annual precipitation totals and mean annual air temperatures.
RESULTS
Correlation coefficients in the period of 2001-2017 for monthly values of air temperatures and precipitation at the meteorological stations in Jeziory and Poznań-Lawica are statistically highly significant (α<0.000 000 001) and amount to 0.999 and 0.783, respectively.

Thus it is justified to extrapolate air temperatures and precipitation calculated based on regression relationships with data for Poznan-Lawica to the years 1848-2000 for the station in Jeziory (the Wielkopolski National Park - WNP).

Calculations of trends for changes in air temperature and precipitation in WNP in the years 1848-2017 using the above-mentioned methodology (Mann-Kendall trend tests), i.e. hypotheses: H0: there is no trend in the series, and Ha: there is a trend in the series, for the significance level α=0.05, indicate significant trends for air temperatures for the months: III, IV, V, VIII, XI, XII, and the year (I-XII). This is 0.010, 0.009, 0.008, 0.007, 0.012, 0.009 and 0.006 °C/year (Sen’s slope). For the other months no statistically significant trends were found for air temperatures (Fig. 1).

In turn, for precipitation in WNP no significant trends were found either for individual months or the entire year (Fig. 2).

Thus in WNP in the period of the last 170 years mean annual air temperatures increased by approx. 1 °C, while annual precipitation totals remained unchanged.

These facts may be confirmed also by the results of studies on the homogeneity of time series for mean annual air temperatures and annual precipitation totals for WNP in the investigated period. Homogeneity of time series was analysed using the standard normal homogeneity test (SNHT) for the significance level α=0.05 using the XLSTAT package. Tests were conducted to verify hypotheses H0: the time series is statistically homogeneous, and Ha: there is statistical non-homogeneity of the time series. The test results indicate as follows:

- there is a statistical non-homogeneity of the time series for mean annual air temperatures. The last 20 years were markedly warmer than the previous years (Fig. 3),

![Fig. 3. Results of analysis on homogeneity of time series of mean yearly air temperature in the Wielkopolski National Forest Park (mu1, mu2 – means)](image_url)

- there are no grounds to reject the hypothesis that the time series for annual precipitation totals is statistically homogeneous (Fig. 4).

![Fig. 4. Results of study on homogeneity of time series of total yearly precipitation in the Wielkopolski National Forest Park (mu – mean)](image_url)

Analogous calculations using SNHT for individual months indicate:

- for months I, III, IV, V, VII, IX and XI, similarly as for years, there is a statistical non-homogeneity of the time series for mean monthly air temperatures. In turn, for months II, VI, VIII, X and XII there are no grounds to reject the hypothesis that the time series of mean monthly air temperatures is statistically homogeneous.

- For all months I-XII there are no grounds to reject the hypothesis that the time series for monthly precipitation totals is statistically homogeneous.

Figures 5 and 6 present periodograms of mean yearly air temperatures and annual precipitation totals in the Wielkopolski National Park.

Mean annual air temperatures show dominant 168.0-, 84.0-, 8.0-, 7.6- and 5.3-year periodicities. In turn,
dominant periodicities of annual precipitation totals are 18.7-, 9.9-, 7.0-, 3.2- and 2.1-year cycles.

Fig. 5. Periodogram of air temperature \( T(1) \) in the period of 1848-2017 in the Wielkopolski National Forest Park

Fig. 6. Periodogram of precipitation \( P(\) in the period of 1848-2017 in the Wielkopolski National Forest Park

DISCUSSION

The longest experimentally identified cycles of changes in air temperature on Earth are estimated at 100 000 years (Petit et al. 1999). Many researchers showed cyclicity of air temperatures to be several hundred years and resulting from natural causes (e.g. Boryczka and Stopa-Boryczka 2007b). Trends and cyclicities observed in shorter periods are similar to those found in this study. For example, comparable trends were shown in the case of annual temperature in Central and Western Europe for long measurement series (Jones and Mann 2004, Luterbacher et al. 2004, Boryczka and Stopa-Boryczka 2007a, Koźuchowski and Żmudzka 2001, Zawora 2005).

For precipitation no statistically significant changes were found in WNP for the entire multianual period of 1848–2017, as only cyclical changes were observed. A similar result was reported by Boryczka and Stopa-Boryczka (2004) and Żmudzka (2009), who analysed precipitation in Poland, and Pauling et al. (2005) for Central Europe in the case of long measurement series.

In the case of temperature and precipitation in WNP a considerable role is played by cycles with short periods, of maximum 10 years. The dominance of cycles with short periods for temperature in the temperate climate zone of Europe has been confirmed by numerous studies (Żmudzka 1995, Boryczka and Stopa-Boryczka 2004, Pałuś and Novotná 2006, Nicolay et al. 2009). In turn, cycles with short periods for precipitation were found e.g. Brázdil et al. (1985), Boryczka and Stopa-Boryczka (2004) as well as Paul and David (2006).

CONCLUDING REMARKS

Climate in the Wielkopolski National Park shows relatively high stationarity.

Air temperatures in the investigated period show positive, statistically significant (for the significance level \( \alpha=0.05 \)) time trends for March, April, May, August, November, December as well as the year. In contrast, for the other months the respective trends are not statistically significant. Mean annual air temperatures show marked multianual periodicities, with dominant 168.0-, 84.0-, 8.0-, 7.6- and 5.3-year periodicities.

Precipitation in the years 1848-2016 shows no statistically significant changes at \( \alpha=0.05 \) either for individual months I, II, ..., XII and the entire years. However, marked periodicities are observed for annual precipitation totals, with the dominant 18.7-, 9.9-, 7.0-, 3.2- and 2.1-year periodicities.

In the last 170 years in WNP mean annual air temperatures increased by approx. 1°C, while annual precipitation totals remained unchanged. The time series for mean annual air temperatures is non-homogeneous. In the last 20 years the upward trend for temperature was 0.04 °C/year and it was approx. 6-fold greater than the trend for the entire analysed period. In turn, for annual precipitation total there are grounds for the rejection of the hypothesis that the time series is statistically homogeneous.

REFERENCES


**For citations**