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AN EVALUATION OF CHANGES IN THE BIOCLIMATE OF ŁÓDŹ IN THE LIGHT OF THE TOURISM CLIMATE INDEX

Abstract: The paper presents basic information concerning bioclimatic conditions in Łódź based on the Tourism Climate Index (TCI). The index makes it possible to assess in a comprehensive manner, based on specified meteorological parameters, the climatic conditions affecting the development of tourism. The study uses measurements from the weather station, Łódź-Lublinek, taken in the years 1966-2014. The TCI values have a distinct annual pattern with the highest values recorded in summer. The summer season has the highest frequency of days with 'very good' or 'excellent' conditions for tourism. An assessment of the variability of bioclimatic conditions indicates an increase in the number of days with high TCI values pointing to 'very good' or 'excellent' conditions for tourism and recreation.

Keywords: urban bioclimate, tourism climate index (TCI), climate change.

1. INTRODUCTION

Tourism and recreation, while constituting one of the components of human life, are also an important sector of the economies of many countries, including Poland. The development of tourism and recreation is affected by a number of factors, and one of them is the weather. This especially concerns forms of recreation associated with outdoor activities where the weather and climate are a natural resource which significantly affects the development of tourism and recreation in a given location.

The issue of the effect of weather and climate is addressed by bioclimatology which investigates the impact of weather conditions on the human body. To this end, various bioclimatic indicators are used whose design enables a comprehensive consideration of the impact of selected elements of the weather on people (BŁAŻEJCZYK 2004, p. 70, KOZŁOWSKA-SZCZĘSNA 1997, p. 39). An analysis of the results, based on a longer-term series of measurements, allows a description of the bioclimate of a certain location, and of its changes. There are a number of studies which, based on bioclimatic indicators, take into consideration the sensible temperature (MARUSIK 1977, MĄKOSZA & MICHALSKA 2010, OWCZAREK 2011), air-cooling values (GURBA 1961, GREGORCZUK 1976, SZYGA-PLUTA 2011), and the sultriness of the air (CHEŁCHOWSKI 1965, KOŹMIŃSKI & MICHALSKA 2010, WIĘCŁAW & OKONIEWSKA 2015). A broad spectrum of bioclimatic indicators have also been used in defining the bioclimatic characteristics of Łódź (KŁYSIK *et al.*, 1995, KOŻUCHOWSKI 2003, PAPIERNIK 2004, PIOTROWSKI 2008, PODSTAWCZYŃSKA 2004, TARAJKOWSKA & ZYCH 1959) and the Łódź Voivodeship (region) (DUBANIEWICZ *et al.* 1971).

Due to the fact that the impact of climate on tourism is rather complex, an integrated indicator, i.e. the so-called Tourism Climate Index (TCI) proposed by Z. MIECZKOWSKI (1985), has been used, among others, in the analysis of this issue. The index includes selected climatic parameters, significant from the point of view of tourist activity, e.g. air temperature, sunshine duration, wind and precipitation conditions, as well as humidity. They are assessed on a point scoring system, depending on their suitability for tourism and recreation. Despite its high level of subjectivity, the index is widely used in the assessment of climatic conditions and their impact. For example, it allows a comparison of summer season conditions at various locations targeted by tourists (MORGAN *et al.*, 2000), their spatial and temporal variability in different countries (MATZARAKIS 2006, 2007) and in selected regions of Europe (PERCH-NIELSEN *et al.* 2010).

Another trend in research conducted using the TCI is an attempt to assess the impact of climate change on the development of tourism. Predicted changes in climatic conditions can have a significant impact on the tourism sector in many regions of Europe (PERCH-NIELSEN *et al.* 2010, STANKIEWICZ 2010) and North America (SCOTT *et al.* 2004). For example, an increase in the summer TCI in the period between 2011 and 2030 is forecast for Poland, which may result in a 0.53% increase in revenue from tourism (KLIMAT 2010 Project).

The main aim of this paper is to present the characteristics of climatic conditions in Łódź and their variability from the point of view of the development of tourism and recreation. In furtherance of this purpose, the classical form of TCI is used, and its annual variability, the frequency of climatic conditions suitable for tourism, and their variability in the analyzed period, are presented. At the same time, it should be noted that the indicator used makes it possible to provide a general description of climatic conditions from the point of view of a number outdoor recreation activities including (but not limited to) hiking, visiting architectural sites, organizing or participating in a variety of outdoor events. It must be kept in mind that every form of tourism requires different climatic conditions and therefore either a wide range of bioclimatic indicators are used or the index has to be adjusted.

Previous studies concerning the evaluation of climatic and bioclimatic conditions in Łódź chiefly focused on classical bioclimatic indicators, such as sunshine duration, equivalent temperature, wind chill index, physiological need, etc. (PAPIERNIK 2004, PIOTROWSKI 2008, PODSTAWCZYŃSKA 2004). On the other hand, the application of TCI is quite rarely used in the Polish literature, and therefore the results of this study may be conducive to drawing more detailed conclusions concerning its subject.

2. DATA AND METHODS

The Tourism Climate Index (TCI), based on a series of measurements of selected meteorological parameters recorded in Łódź in the years 1966-2014, was used in the study to assess the climate advantages of Łódź with a view to tourism and recreation. TCI values were based on the following formula (BŁAŻEJCZYK 2004):

$$TCI=2(4 \cdot Cld + Cla + 2RR + 2 \cdot SD + Wv)$$

where:

Cld – daytime thermal comfort index,
Cla – daily thermal comfort index,
RR – precipitation rate,
SD – sunshine duration index,
Wv – wind velocity index.

The individual elements of climate taken into account in the calculation of TCI are rated on a scale of 0 to 5 (for thermal characteristics, and –3 to 5) in terms of impact on tourism (a detailed discussion of this issue in K. BŁAŻEJCZYK 2004, pp. 95-98). The higher the TCI values, the better the suitability of climatic conditions for tourism. The classification of TCI values in terms of suitability is shown in Table 1.

Table 1. TCI rating scale of climatic conditions suitable for tourism

TCI	Rating of climate suitability for tourism
More than 90	ideal
80-90	excellent
70 -80	very good
60-70	good
50-60	favourable
40-50	not very favourable
30-40	unfavourable
20-30	very unfavourable
10-20	extremely unfavourable
Less than 10	tourist activity impossible

Source: K. BŁAŻEJCZYK (2004).

Daily TCI values were used to present the basic characteristics of the issue through presentations of their averages in individual months, their variability, their maximum and minimum values, the frequency of days with 'favourable' and 'unfavourable' climatic conditions, as well as and their variability in the studied period.

3. RESULTS

TCI values have a distinct pattern over the year. Its lowest values are characteristic of the winter period when the monthly average values of the tourism and climate index are 35 in January and 39 in February (Fig. 1a). Furthermore, the lowest absolute TCI values (16-22) also occurred in this season, while the absolute maxima ranged only between 54 and 64. Winter is also characterized by a relative stability in weather conditions which is important for tourism and recreation. The TCI standard deviation values are lowest and vary from 5 to 7, this result being influenced mainly by the design of the index itself. For sub-zero days and under thaw conditions, the components of the thermal comfort evaluation in Equation 1 will assume low values.

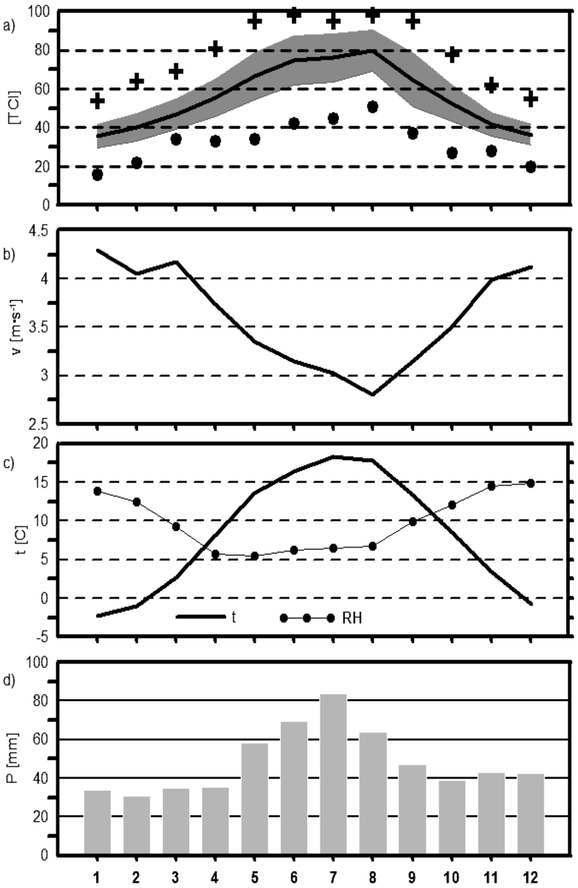

Fig. 1. Monthly statistics of meteorological parameters *P* – precipitation, *v* – wind velocity, *t* – air temperature, *RH* - relative humidity and the TCI in Łódź in the years 1966-2014: solid line – monthly averages, shaded area – ± standard deviation, symbol (+) – absolute maximum values of TCI, symbol (–) – absolute minimum values of TCI

In addition, the winter period is characterized by low values of sunshine duration and precipitation totals. In spring, TCI values rise steadily with monthly averages increasing from 46 and 66. With improving weather conditions, favourable for tourism, an increase in the variability becomes noticeable and standard deviation values rise from 8 to 12. In summer, TCI values are the highest. The average monthly values show 'very good' conditions (Table 1) for tourism and recreation, and maximum values over 90 (i.e. excellent). In autumn, a gradual deterioration is observed from 64 to 41.

An analysis of average values allows the presentation of an annual trend in weather conditions favourable for tourism and recreation. From the point of view of planning those tourism activities which are affected by weather, much more useful information is provided by an analysis of the probability of days favourable (or not) for such activities. In general, based on the annual average, 'unfavourable' (23%) and 'not very favourable' conditions (20% of the total) in terms of tourism development prevail (Fig. 2). Conditions described as 'very good', i.e. TCI > (70-80) or ideal (TCI > 90) have a much lower probability of occurrence and account for just 10% and 4% of the number of days in a year, respectively.

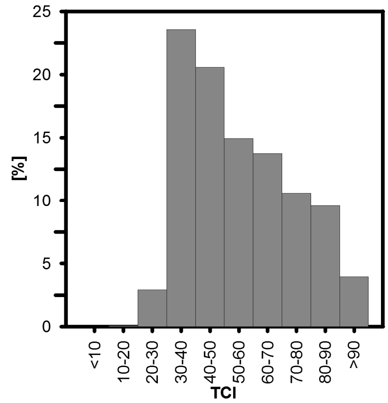

Fig. 2. TCI frequency distribution in Łódź in the years 1966-2014

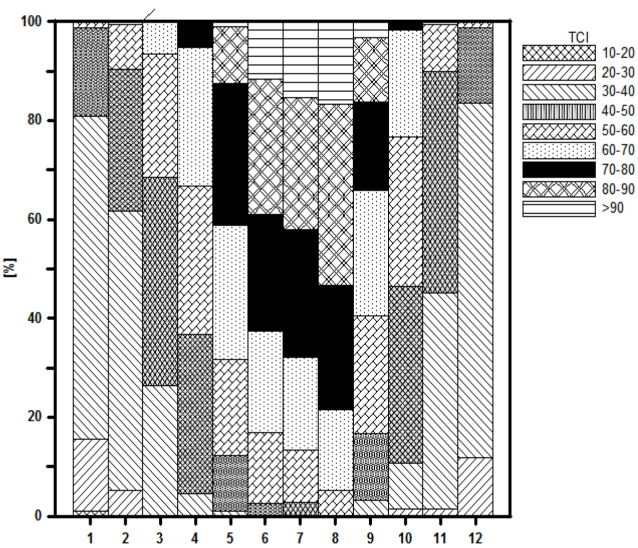

Fig. 3. TCI frequency distribution in individual months based on the period 1966-2014

Better conditions occur during the summer season, which is confirmed by the frequency pattern of TCI values in individual months (Fig. 3). In practice, it is only in summer that there are days with meteorological conditions referred to as 'ideal' for use in tourism (11%-16%), and the percentage of days described as 'good', 'very good' or 'excellent' is more than 50%. From June to August, there are no days with poor conditions (unfavourable, very unfavourable, etc.) for tourism and recreation. In spring and autumn, the climatic conditions are less favourable, and, while comparing the frequency distribution for May and September, the beginning of autumn has slightly better conditions than the end of spring. In September, a greater number of days occur with excellent (13%)

and ideal (3%) conditions, while in May these percentages are 11% and 1%, respectively. The winter period has the highest frequency of days with not very favourable and 'unfavourable' conditions. It is only in February and November that cases occur (0.6% in each) with TCI values ranging between 60 and 70 (referred to as 'good').

As a research objective, an assessment was also made of the variability of TCI in the analyzed period. In the first place (Fig. 4), the variability of monthly averages (January and July) of TCI values (presented as anomalies from the long-term monthly average) was investigated. In the pattern of average monthly values, both for summer (Fig. 4b) and winter (Fig. 4a), the occurrence of short periods of several years with higher or lower TCI values is characteristic. However, it is difficult to identify periods when in individual months, higher or lower values than the average prevailed. On the other hand, an analysis of the linear trend of monthly averages for all months (not shown in this paper) showed an upward trend in the average values of TCI.

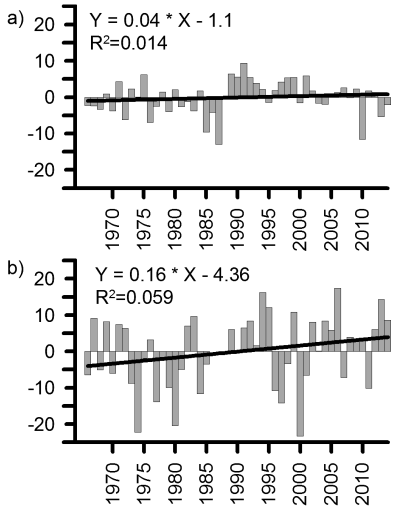

Fig. 4. Pattern of monthly anomalies for January (a) and July (b) of TCI values, linear trend in the years 1966-2014, and the value of coefficient of determination R^2

Of course, more important information about changes in climatic conditions affecting tourism and recreation, in addition to average values, is included in changes to the number of days with favourable conditions or not. In the analyzed period, days with TCI values below 30 (indicating 'unfavourable' and 'very unfavourable' conditions) were very rare and therefore their variability is not shown. Elsewhere, the variability year-on-year was at a similar level (between 10% and 15%), while, as in the anomaly pattern of monthly TCI values, it is difficult to distinguish periods with a greater or lesser frequency of days with specified values.

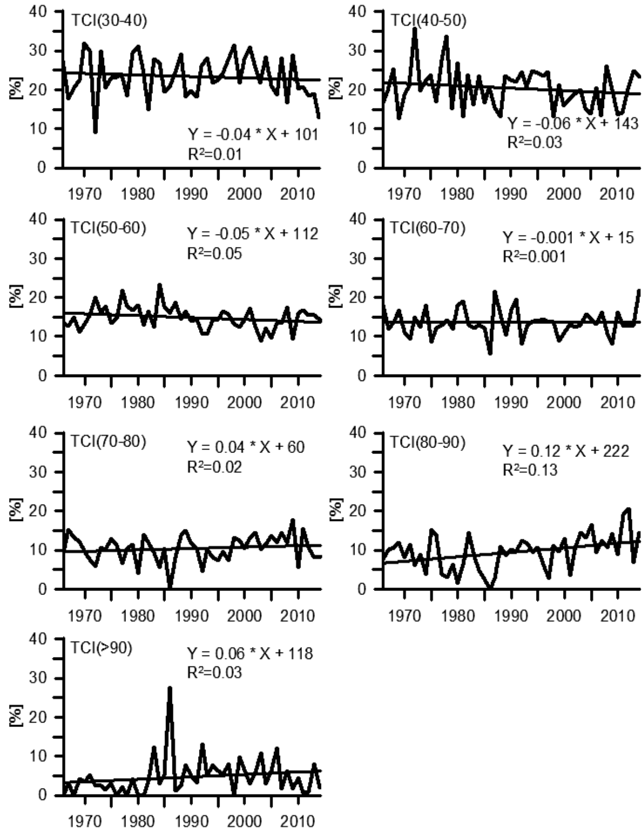

Fig. 5. TCI value frequency pattern in the period 1966-2014 in the assessment intervals of climatic conditions for tourism and recreation (linear trend and value of coefficient of determination R^2 are shown)

However, a systematic change in the frequency of days with specified TCI values is clearly visible. In the case of low TCI values (30-40, 40-50, 50-60), a decrease in the number of days with weather conditions less favourable for tourism and recreation is observed. The systematic increase in TCI value, shown in the analysis of the monthly anomalies (Fig. 4), is mainly due to an increase in the frequency of days with higher TCI values (Fig. 5). The strongest growth was recorded for days with excellent conditions (TCI values of 80-90).

4. SUMMARY

The best conditions for tourism and recreation in Łódź, based on the tourism climate index (TCI), occur in summer. In the summer season, the highest monthly TCI averages are recorded, and the highest number of days with 'very good' and 'excellent' conditions (TCI values above 80) occur as well. Moreover, over the entire period no unfavourable conditions appeared. In spring and autumn, TCI values are lower, the frequency of days with excellent conditions for tourism decreases and at the same time the percentage of days with unfavourable conditions increases. A comparison of the frequency distribution of TCI values for September and May shows that slightly more favourable conditions for tourism are characteristic for the beginning of autumn as compared with the end of spring. The annual TCI pattern is very similar to results obtained for cities in Central and Northern Europe (BŁAŻEJCZYK & KUNERT 2011). Some differences concern the level of TCI average values in individual months. However, the annual pattern of TCI values, e.g. for Prague, Debrecen or Szeged, has a bimodal arrangement with the highest TCI values being for April, May and September (KOVACS & UNGER 2014). The summer period in this region is characterized by slightly worse conditions for tourism and recreation with hot weather (so-called heat waves), generating a considerable strain on the human body. This type of phenomenon is more common in southern parts of Europe which leads to differences in the TCI characteristics of Łódź and those cities.

The evaluation of changes in TCI values over the long-term period 1966-2014 shows a positive trend in the analyzed index. It is characterized by an increase in the frequency of days with high TCI values and a decrease in the number of days with less favourable conditions from the point of view of tourism and recreation.

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