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Original Research

Thermal Regions in Light of Contemporary Climate Change in Poland

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Abstract

Agroclimatic elaborations, including practical agricultural recommendations, are based on recent climate standards (30-year periods): 1881-1930, 1931-60, 1951-80, and 1961-90. The period 1971-2000 has just recently been included in climate studies. During the final two decades of the 20th century and in the beginning of the 21st century we have observed a clear and well documented increase in air temperature. In this article the authors compare the extent of thermal regions in Poland, which have been designated on the basis of effective temperature sums ≥10ºC for the period 1971-2000. It should be noted that at present this is the effective climatological standard and it was used to obtain regression equation data for 2000 and 2007. The results of this study indicate that the area of the temperate-cool region with effective temperature sums ≥10ºC in the range of 2,000-2,400ºC has been decreasing in subsequent time periods – 37%, 12%, and 3%, respectively. Meanwhile, the warm region characterized by effective temperature sums in the range 2,800-3,200ºC has increased its area from 3% in 2000 to 26% in 2007. It should be emphasized that the warm region has not been observed when we analyzed the 1971-2000 data. The originality of this article is outlined by the fact that it documents and characterizes contemporary climate changes, which are manifested through changes in the extent of thermal regions. In addition, this article attempts to depict a number of consequences of these changes by illustrating the possibility of expansion of the surface area of thermophilic plants.

Keywords: global warming, Poland, thermal regions

Introduction

When examing a number of elaborations pertaining to Polish climate and agroclimate it becomes evident that scientists did not pay much attention to risks associated with human impact on climate change. The aforementioned risks have recently been included by the World Meteorological Organization, which established a standard 30-year period to determine climate variations. This period has been updated roughly every 10 years. According to the above-mentioned procedure the Institute of Meteorology and Water Management in Poland publishes current monthly meteorological reports and over time replaces the discontinued standard period with a new one. For instance, in 1970 the obligatory climatological standard was the 1881-1930 period. In subsequent periods the following climatological standards have been utilized: for 1971-83 this standard was extended to the year 1960 (1881-1960), from 1984 until June of 1995, 1951-80 was used, and finally from July 1995, 1961-90 was used. The Bulletin of the National Hydrological and Meteorological Service, which has been published since 2003, is based on average temperature calculations in reference to the 1971-2000 period.

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Important Polish climate atlases that present air temperature graphs and maps use the following climatological standards: 1881-1930 [1] and 1931-60 [2]. The latter atlas also contained meteorological data for the following periods: 1881-1930, 1931-40, 1941-50, and 1951-60. Data for the period 1961-90 also have been published in the form of tables [3]. The most recent recommended climatological period (1971-2000) has been used to elaborate a new atlas of Polish climate [4], but there is a lack of tabular data. Apart from the mentioned climate atlases there have been many other valuable elaborations of Polish climate, which included various climate characteristics such as temperature and thermal indices. It should be noted, however, that these elaborations were based on different time periods that were usually shorter than 30 years. We should mention the works of Chomicz [5] and Koźminska and Michalska [6], to name a few. Additionally, comparison analyses have been published, which referred to different time periods or climatological standards, as well as characteristics of perennial temperature series [7, 8]. Despite the fact that subsequent characteristics of the Polish climate were based on new and effective standards, these time frame changes have not been related to climate change.

In the last two decades of the 20th century and in the beginning of the 21st century a visible and well documented increase in global temperature has been observed, including Poland [9-11]. During the last two decades of the 20th century the increase in mean annual temperature in Poland was estimated at 0.3ºC per decade [12, 13]. European climate models anticipate an increase in mean annual temperature in the years 2080-99 (in reference to the 1980-99 period), ranging from 2.3 to 5.3ºC [14]. The anticipated increase of mean annual temperature in Poland is estimated at 3.0-3.5ºC. Such large changes in air temperature will result in considerable changes in agriculture [15, 16]. Warmer temperatures will create better conditions for cultivation of thermophilic plants. It may also be possible that wine trails could become an additional tourist attraction as part of multi-functional development of rural areas. Having said that, it is crucial that we take into account the most up-to-date (or forecasted) temperature assessment to ascertain relations between cultivated crop and meteorological conditions suitable for a growing period, and when devising climatic and agroclimatic divisions of Polish climate. It should be emphasized that current climatological standards are practically treated as mean values from past climate periods and subsequently they are underestimated. Górski presents in his work the most updated attempt. The author evaluates the probability of corn maturation on the basis of temperature values forecasted for the years 2001-10 [17].

The goal of this article is to assess the changes in thermal characteristics of Polish climate that have been occurring during the last three decades of the 20th century and in the beginning of the 21st century. This task is carried out by comparing the total area of thermal regions, which have been calculated on the basis of updated climate data (1971-2000), as well as on the basis of values that have been derived from regression equations for the years 2000 and 2007. This work possesses not only a cognitive and utilitarian character, but also features methodological aspects. It presents some innovative and original contributions to recent climate and agroclimate studies. By showing the extent and differences within the surface of thermal regions in Poland, the authors have attempted to show that the standard climatic period (1971-2000) used thus far, depicts slightly underestimated values in relation to the actual temperature increase. The authors believe that for practical purposes we should use the values that have been extrapolated for either the present time period, or we may use the predicted values. The ongoing climate change is beneficial in terms of the growing season of thermophilic plants.

Materials and Methods

In this work the authors employed mean monthly air temperature data from the period 1971-2007 that has been published in the following sources: Monthly Agrometeorological Review, Decadal Agrometeorological Bulletin, and Bulletin of National Hydrology and Meteorology Service. The data has been collected from 21 meteorological stations evenly distributed over the entire country. Due to the insufficient number of meteorological stations in the mountains practically no analyses have been performed in this area.

A comparison of thermal regions has been performed for both the period 1971-2000 and temperature that has been calculated on the basis of regression equations (2000, 2007). It should be noted that in the latter case we obtain an image of increasing temperature at the end of this period (year 2000) as well as for the year 2007. Regression equations have been used because the authors wanted to eliminate random temperature values that result from natural climate variability. Subsequently the authors' intention was to rely on values that are directly associated with the observed increasing temperature trend. In order to designate thermal regions Daunbenmiere's method [18] has been employed in its slightly modified version [19]. In this particular method thermal conditions during the growing period are determined on the basis of effective temperature sums ≥10ºC. The above-mentioned period is referred to as the active period of plant development and is considered to be one of the most important periods in terms of the demand of agricultural production (besides economic period, growing season, and maturation period). The period designated by temperatures ≥10ºC is referred in agrometeorology as an active plant development period. Temperature sums ≥10ºC are frequently used to determine the heat capacity in both thermal and pluvio-thermal regionalizations of studied regions. The increase in temperature sums ≥10ºC within the period 1971-2007 is statistically significant at 0.05. It should be mentioned that for this particular purpose a linear function of temperature increase over time has been established. The estimated values for years 2000 and 2007 have been derived from the same equation as for the period 1971-2007. The areas of individual thermal regions have been determined by employing planimetrics.

Table 1. The area of designated thermal regions for mean values for the period 1971-2000, and for values that have been obtained from regression equations for 2000 and 2007 (given as % of the Poland area).

Thermal region	Effective temperature sum ≥10ºC	Mean 1971-2000	Calculated value for 2000	Calculated value for 2007
Cool	1600-2000	1		
Temperate-cool	2000-2400	37	12	3
Temperate-warm	2400-2800	62	85	71
Warm	2800-3200		3	26

Results and Discussion

In the period 1971-2000 the largest area (covering 62% of Poland) is occupied by a temperate-warm region with effective temperature sums ≥10ºC in the range 2,400-2,800ºC. This region encompasses central and southern parts of Poland, excluding the western part of Zachodniopomorskie Lakelands, Kielecko-Sandomierska, and the Lubelska Highlands, as well as lower parts of the Sudety and Carpathian Foothills. The temperate-cool region with effective temperature sums ≥10ºC in the range 2,000-2,400ºC covers about 37% of the country and includes the eastern part of Zachodniopomorskie Lakelands, Wschodniopomorskie and Mazurskie Lakelands, with the exception of Suwalskie Lakelands. The temperate-cool region also encompasses northern parts of Północnomazowiecka and Północnopodlaska Lowlands, as well as the Kielecko-Sandomierska and Lubelska Highlands. The cool region with effective temperature sums ≥10ºC in the range 1,600-2,000ºC encompasses the vicinity of Suwalskie Lakeland. It should be emphasized that this particular thermal region covers merely 1% of Poland (Table 1, Fig. 1).

It should be noted that for values that have been obtained based on regression equations (2000), we can detect a significant decrease of the temperate-cool area (from 37% to 12%) and a characteristic shift to the north, while the temperate-warm region expands to Kielecko-Sandomierska and Lubelskie Highlands. In addition, a new region appears on the agroclimatic map – with effective temperature sums ≥10ºC in the range 2,800-3,200ºC. This region covers about 3% of Poland's surface and is situated in the central Odra River Valley, i.e. in the vicinity of large cities (Opole and Wrocław). The remaining majority of Poland's area (85%) is occupied by the temperate-warm region with effective temperature sums ≥10ºC in the range 2,400-2,800ºC (Table 1 and Fig. 2).

For values that have been calculated for the year 2007 we can observe a further decrease in the surface of the temperate-cool region, which in this case covers only 3% of Poland (in the vicinity of Suwalskie Lakelands), while there is an increase in the surface of the warm region namely in southwestern Poland from 3 to 26% (Table 1 and Fig. 3).

The period 1971-2000 is characterized by a systematic temperature increase on all of the analyzed weather stations. The value of this increase during the growing period (April-October) is estimated to be 0.48ºC per decade, which is statistically significant (α=0.05). The largest increase was noted in April (0.71ºC per decade). Having said that, it is understandable that the images of thermal regions, which

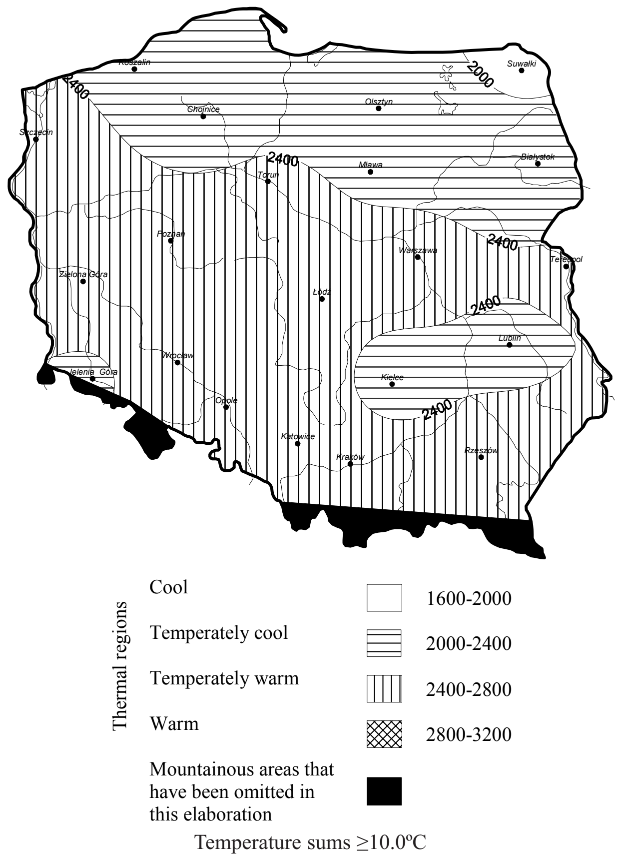

Fig. 1. Thermal regions in Poland, 1971-2000.

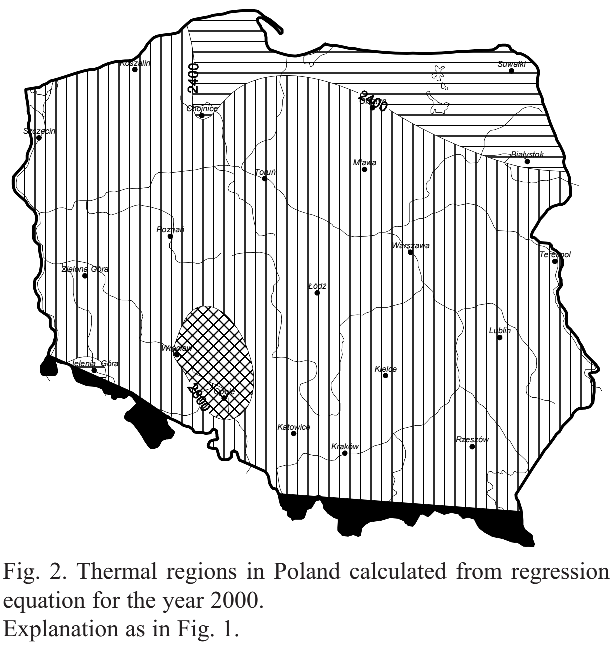

Fig. 2. Thermal regions in Poland calculated from regression equation for the year 2000.
Explanation as in Fig. 1.

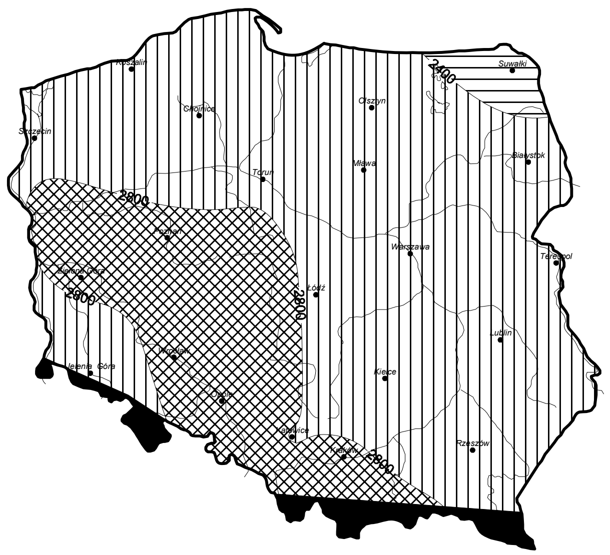

Fig. 3. Thermal regions in Poland calculated from regression equation for the year 2007.
Explanation as in Fig. 1.

have been determined for the period 1971-2000, and for values calculated from regression equations (2000 and 2007) vary rather significantly with increasing temperatures. When we take into account the anticipated increase in temperature (0.48ºC per decade) derived from calculation for the growing season, we can assume that 1ºC increase in temperature will occur in roughly 21 years (counted from the middle of the 1971-2000 period). This will occur in 2006. Therefore, we have to acknowledge that the present image of thermal regions in Poland is simultaneously a fulfilled scenario of 1ºC temperature increase in terms of the 1971-2000 mean.

Recent projects and economic investments, in which climate plays a major role, have been elaborated upon and realized on the basis of the stationary condition of climate phenomena. In light of climate change and subsequent increase of air temperature, it is fully justified that the principle of stationary conditions of climate phenomena should not be treated as a fundamental principle in determining the risks associated with practical meteorological applications. The reason for this is that we could encounter values of climate elements that have not occurred in previous meteorological observations.

A recent increase in air temperature will likely weaken thermal barriers for cultivation of maize in Poland [20] and will cause a termophilic plant zone to shift to the north [15, 17]. The forecasted increase in temperature due to climate change should in principal be favorable for agricultural production. Recent study emphasizes strong correlation between growing season temperature and higher yields of wheat, maize, and rice in China's provinces [21]. Generally, when temperature was higher during the growing season, higher yield of the above-mentioned plants was observed. According to the IPCC Report from 2007 by the end of the 21 century, the potential region of maize cultivation in northern Europe should increase by 30 to 50% [22]. It should be noted that higher agricultural productivity in this region is primarily caused by the extension of the growing season and decreased number of very cold days [23]. Many climatologists point out to a distinct warming of climate during spring months. For example, in the Great Plains earlier flowering of winter wheat in recent years is a sign of warmer spring [24]. Also, in Ireland it has been observed that the growing season started earlier in recent decades, and temperature increased significantly during spring months [25].

Another problem is the demand for quantitative assessment of the consequences of climate change that occur in the domain of water management resources [26], as well as the impact of climate change on water quality taking into account various precipitation change scenarios. Water resources and their variability is very important in terms of agriculture. It is evident that a warmer climate will exacerbate the frequency of drought and flood. According to one study, drought is the main component that leads to diversification of the amount of crop yield. Severe droughts that have occurred in the Czech Republic in the last 30 years have resulted in a significant decrease of wheat and rye yields [27]. In western Europe the frequency of occurrence of extreme precipitation events could lead to increased flood risk during winter, while decreased summer precipitation could result in decreased river discharge [28]. It is estimated that Hungary will experience a 30% decrease in river discharge, which could result in periodical occurrence of severe droughts. In southern Europe large water deficits could cause a decrease of crop yield in the range of 15 to 30% by 2100 [22].

The increase in temperature will not only result in acceleration of growing of a cultivable crop, but it will also lead to rapid infestation of weeds and pests, which will cause serious difficulties in agriculture [20]. It is estimated that a warmer climate will lead the increased area of pest appearance and intensification of pests. It is possible that pests may even begin to appear at high altitudes [29]. It is interesting to examine the total surface occupied by cultivated plants in Poland in the years 1970-2005. From this analysis we can clearly distinguish potential winners and losers. It becomes clear that the surface of potato growing regions has decreased in the years 1970, 1980, 1990, 2000, and 2005, from 2.7 million, 2.3 million, 1.8 million, and 1.3 million to 588,000 hectares, respectively [30]. It should be mentioned here that potatoes are the only cultivated plant whose yields indicated a negative trend in 1971-94 [6]. On the other hand the surface of corn cultivation has increased from 5,000, 16,000, 59,000, and 152,000 to 339 thousand hectares during the last 35 years. It is certain that all of the above-mentioned changes are not just the effect of climate change. The observed temperature increase will certainly result in expansion of the surface areas of C3 plants, unless restrictions are present. The above-mentioned restrictions could be inclement meteorological conditions that will affect the growing period. We can also anticipate that the frequency of frost occurrence will be gradually decreasing, although the drought frequency will most likely be higher. In the latter case, such a scenario is possible even if no change in precipitation due to increased evaporation is observed.

For the last couple of decades scientists in Poland have elaborated a methodology pertaining to certificates of energy needs for residential housing and public utilities, which is compatible with the European Parliament and European Council Directive (effective since December 16, 2002). This directive obliges members of the European Union to execute energy certificates for residential buildings and apartments that are finished, submitted to renovation works, and that are put to turnover on the real estate market. The methods pertaining to designation of energy demand used for heating and cooling require that valid climate data be submitted. This data usually pertains to air temperature, which is essential in locating the apartment [31]. A typical meteorological year used in energy analyses and simulations of housing includes data from a standard 30-year period, in this case 1971-2000. We can debate whether conclusions obtained on the basis of obsolete climate data (60 years in the past) will possess somewhat limited value in terms of the observed increase of temperature.

Conclusions

Based on the performed research we can formulate the following conclusions:

1. The observed temperature trend during the growing period (1971-2007), excluding territorial diversity and differences encountered in individual months, is about 0.48ºC per decade.
2. The image of thermal regions elaborated on the basis of mean values from the period 1971-2000 under increasing temperature scenario, differs from the image obtained for the values that have been calculated for the year 2000. This tendency is even more pronounced for values calculated for 2007. By examining the temperature trend we can assume that the scenario of 1ºC increase during the growing period (April-October) in reference to the 1971-2000 mean, has already been fulfilled in 2006.
3. Climatic and agroclimatic elaborations pertaining to the period of pronounced climate change should not be based on the principle of stationary conditions of climate phenomena because we may encounter values of meteorological elements that have not been observed in previous observations.
4. Climatic and agroclimatic elaborations, in which it is important to comprehend the variability of climate phenomena, should be based on updated climatological standards, but above all on the values obtained from regression equations, as well as forecasted meteorological values.

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