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CURRENT AND FUTURE AGROCLIMATE CONDITIONS IN POLAND IN PERSPECTIVE OF CLIMATE CHANGE

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A b s t r a c t. The paper is a compilation of results, which indicate the scale of possible changes of agroclimate that will occur as a result of the ongoing global warming on Polish territory. Calculations on the future meteorological elements were performed using WGENK weather generator. The 300 variants were obtained of possible annual weather courses dating to the beginning of the second half of this century, and corresponding annual indices of the A1 scenario developed by the IPCC (The Intergovernmental Panel on Climate Change). According to the local climate-factors, obtained data indicate that there are possible situations satisfying assumptions A1 main scenario, exceeding the current climate indicators in terms of temperature, radiation and precipitation, both downward and upward. Apart from this it is possible to greatly expend of the growing season as well as a higher frequency of certain adverse events such as frosts and drought periods. Due to the inability to accurately predict the weather in the perspective of decades and because the main indicators of climate can be realized locally in the form of multiple variants of weather on an annual agricultural production results are difficult to unambiguously determine. Agricultural productivity will certainly significantly be changed, but regardless of global change will have important local factors.

K e y w o r d s: global warming, agroclimate, Poland

INTRODUCTION

The level of agricultural production in the future will mainly depend on technological progress, but you may find that the main factor determining the level of production will prove climatic conditions. In the nearest future, agriculture will evolve, adjusting to climate changes (Reddy and Hodges 2000, Olesna *et al.* 2011b, Mall *et al.* 2006, Trnka *et al.* 2011).

Technologies change very quickly but changes in agricultural management systems cannot be introduced day-to-day, it is necessary to carry out proactive operations based on predictions concerning climate changes using probable scenarios of future generated weather time series (Wilbanks 2003, Olesna *et al*. 2011).

Recently, climate change has become one of the major scientific problems now. Numerous research centres deal with forecasting climate changes and the collective results of those activities are reflected in IPCC periodical reports (Climate change, 2007). Based on scenario variants included in one such report (the fourth IPCC report), the scale of further warming can be estimated based on expert forecasts. Taking into consideration the fact that it is generally very difficult to construct a good global climate model, this type of estimation is valuable. Nevertheless, for the purposes of outlining perspectives for agriculture, it would be beneficial to know not only the perspective of climate changes, but also the type of weather patterns in a dozen or several dozen years (Smith and Pitts 1997).

This study follows the approach of applying climate change scenarios created as results produced by climate models, to generate weather data using a weather generator (Richardson 1985).

MATERIALS AND METHODS

The analysis performed was based on weather data generated for analyzed area for 2050 with the use of a WGENK generator (Kuchar 2005). Basic climatic characteristics obtained on the basis of data registered at the Hydrological-Weather Station around analyzed area between 1985 and 2005 provided the input material for the generator (Fig. 1, Tab. 1).

The climatic forecast is based on generated weather time series generated following scenario A1 according to IPCC Special Report on Emissions Scenarios (SRES, 2000) and the calculations were performed using models. On the other hand, climatic characteristics that provided patterns for constructing country, prospective weather scenarios for the weather data generator were composed of data concerning daily sums of total radiation (SR), minimum temperatures (T_{min}), maximum temperatures (T_{max}) and daily precipitation sums (P). Weather forecasts, as well as approximation of weather data, consisted in generating values for every day in a year, according to principles described by Kuchar and Kuchar (2005). On the basis of results produced by the generator, 300 annual generated weather time series scenarios were obtained (the cases investigated here have been rendered based on weather mechanisms functioning in the vicinity of analysed area, with the use of all possible deviations from the assumed norms), which may occur as a result of the assumed climate change variant. Three hundred generated weather time series variants were used as a basis to characterise possible situations. The criteria of minimum, maximum, mean value and median were applied for four meteorological elements calculated for the entire year, the vegetation period and the spring period. Additionally, the length of the vegetation period, the period of intensive vegetation with mean daily temperature above 10°C and the summer period with temperatures exceeding the threshold value of 15°C were calculated. The obtained data also made it possible to establish the scope of weather threats, such as precipitation-free periods exceeding 10 days and the number of ground frosts during the vegetation period.

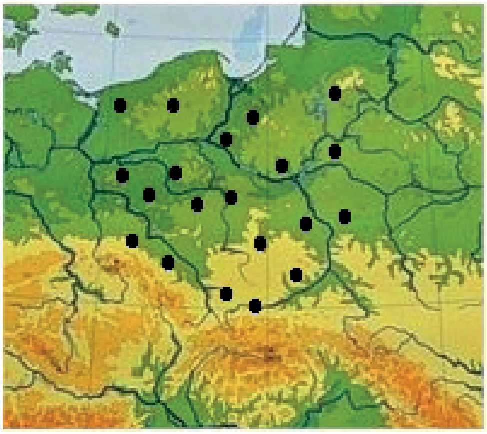


Fig. 1. The locations where meteorological data and data of yields of crops were obtained from

RESULTS AND DISCUSSION

Each generated weather time series analysed in this study satisfies one common condition, namely, the mean annual temperature is corresponding to the level determined by the assumed climatic scenario. The same value of the annual mean may, as it is known, be revealed in completely different patterns of other weather elements – and the results of the analyses presented below provide the answer to the question concerning the types of these elements.

The mean annual minimum temperature will probably range from 3.6 to 8.9°C (Tabs 1, 2, Fig. 2). Thus, generally, an decrease and increase in minimum temperature will amount respectively –1.4 and 3.9°C compared to the values currently recorded. This means very high growth, particularly in the extreme point of the range. The highest mean maximum temperatures will exceed the present maximum to a similar extent. With the mean from the multi-year period amounting to 12.9°C, the lowest maximum temperature could be lower than 1.2°C, while the highest maximum temperature might exceed the current value by 6.7°C (Tabs 1, 2, Fig. 3). For minimum and maximum mean temperatures, the differences between the state characterizing the years 1985-2005 and the forecast for 2050 are 1.2°C for the minimum and 3.9°C for the maximum. Thus, as it results from the entire analysis, the climate warming will probably occur symmetrically in the pattern of annual minimum and maximum temperatures. The median value of expected maximum and minimum temperatures is equal to their means.

Table 1. Climatic characteristics of analyzed area from the period 1985-2005

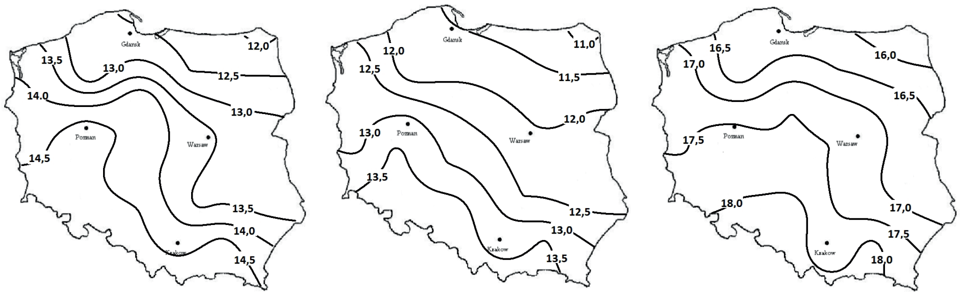
Months	Minimal temperature °C	Maximal temperature °C	Monthly precipitation mm	Solar radiation MJ m^{-2}
I	−2.3	1.5	31.6	62.9
II	−1.9	2.7	27.4	122.1
III	0.9	6.4	34.7	251.6
IV	3.4	12.8	34.0	389.4
V	7.6	19.9	56.6	574.9
VI	11.1	22.8	64.2	548
VII	14.4	24.9	75.8	577.3
VIII	13.8	24.8	61.7	482.5
IX	8.9	18.6	49.4	326
X	5.5	12.8	35.9	196
XI	1.2	5.8	38.6	72
XII	−2.4	2.3	37.5	44.5
Average – total annually	5.0	12.9	547.2	3647.2
Average for growing period	9.9	20.6	341.7	2898.1
Value for the period: March-May	4.0	13.0	125.3	1215.9

A – actual (mean 1985-2005) B – predicted minimal C – predicted maximal

Fig. 2. Spatial distribution of yearly mean minimal temperature in °C (without consideration foothill and mountain areas)

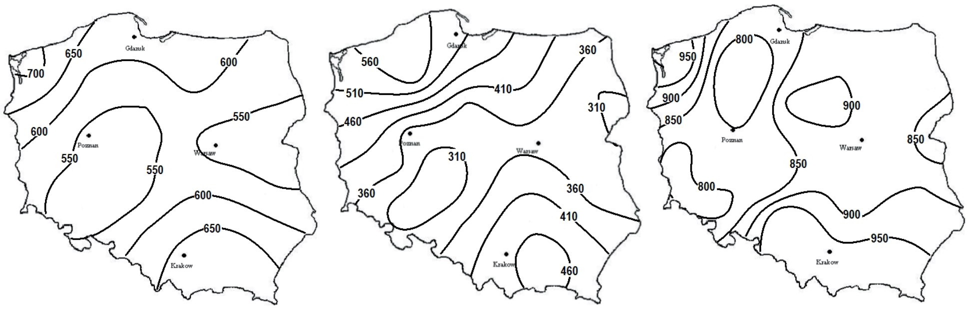
In the vegetation period, the minimum temperature could exceed the current value by 1.3 to 4.2°C, while the value of exceeding future maximum temperatures might range from 1.6 up to 7.3°C. Therefore, the possible values of excessive temperature extremes in the vegetation period were at the same level as in the yearly period. The mean minimum temperature of the vegetation period would be higher by 1.5°C and the maximum mean calculated from the generated data might exceed the current maximum mean from the multi-year period of 1985-2005 by 1.5°C.

Thus, similar changes concerning extreme temperatures as to their level and direction can also be expected in the future in the vegetation period, as well as the values calculated for the entire year.



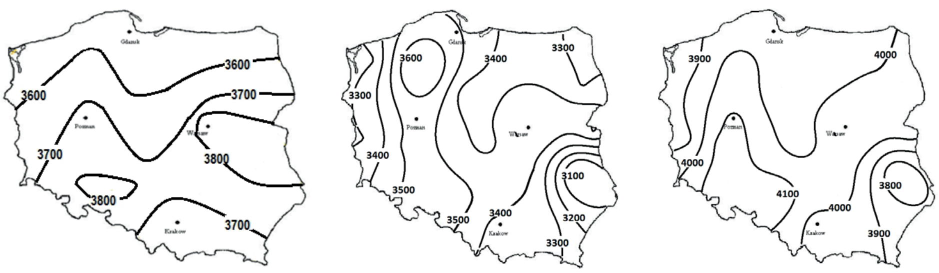
A – actual (mean 1985-2005)   B – predicted minimal   C – predicted maximal

Fig. 3. Spatial distribution of yearly mean maximal temperature in °C (without consideration foothill and mountain areas)



A – actual (mean 1985-2005)   B – predicted minimal   C – predicted maximal

Fig. 4. Spatial distribution of total yearly precipitation in mm (without consideration foothill and mountain areas)



A – actual (mean 1985-2005)   B – predicted minimal   C – predicted maximal

Fig. 5. Spatial distribution of total yearly radiation in (MJ m^{-2}) (without consideration foothill and mountain areas)

The specific spring period is the time which highly determines the future yielding of plants. At present, the low temperatures in the March-May period constitute a high yield factor for many thermophilic species (Atlas…, 2001). The expected warming should change this situation. The generated data show that minimum temperatures in this period could higher by 1.2°C compared to the present values, and the highest value exceeding the spring month minimum could even reach 9.3°C. This is a huge difference, indicating the possibilities of a significant increase in the production potential of plants. The maximum spring temperature will also increase, ranging from 2.3°C and 11.6°C, on average by 7.4°C. At such high spring temperatures, all previous thermal limitations will disappear, although new ones will probably emerge, so the growth in plant productivity will not be linear (McKeown *et al.* 2006).

It is obvious that changes in precipitation values do not follow the temperature changes (Tab. 2, Fig. 4). For this reason, the minimum annual precipitation in generated weather data series was lower than the contemporary mean by 94.4 mm. The maximum value of the 300-variant set proved obviously higher than the present mean, by up to 444.2 mm. A level so high above the current state – as predicted by the data generator based on current, regional weather schemes – is possible only on one of the lower levels of maximum temperatures. In the analysed future (2050), it is probable that vegetation periods will prove either drier than present, by up to 164.1 mm, or moister by 284.6 mm. The mean value of this parameter of 300 generated variants for 2050 is close to the mean value of the 1985-2005 multi-year period in the region. The data indicating a correlation between current and future values of precipitation sums in the March-May spring period display similar characteristics. The mean values of precipitation do not differ much, while the forecasts concerning the minimum and the maximum values indicate possible variants below or above the current sums. Therefore, the future of the agroclimate of the region, viewed from the perspective of water supply for plants, is not as explicit as in the case of established temperature changes.

The expected climate changes will be related to an increase in the accumulation of solar energy and with changes in the Sun's activity (Cowie 2007). This latter effect will probably have a lower impact on the changes occurring in the atmosphere. Consequently, the generated weather data series assume even the possibility of lower sums of solar radiation than contemporarily recorded, in each of the periods under analysis (Tab. 2, Fig. 5). Such a course of events results from weather patterns with high precipitation sums, which will involve a high degree of cloudiness.

Even the extreme values of the meteorological elements analysed above – as it can be presumed – will not pose a significant problem due to the high level of adaption of agricultural systems. For this reason, the present analysis also included, on the basis of the generated data, the frequency of some harmful weather phenomena, such as frost and non-precipitation periods.

The data presented in Table 3 show that it may be possible that none of these phenomena will occur. The maximum number of frost days is nine, *i.e.* even more than shown by the multi-year means for located in analyzed area – the Mazury Lake District (Szwejkowski *et al.* 2001). Near all frost days in the vegetation period will probably occur in the spring.

The maximum number of non-precipitation periods over 10 days may occur even in five cases during a year and in three cases during the vegetation period, in which most will take place in the crucial spring period, which means that the current norm will be preserved.

The final element of this analysis involves calculations concerning the expected length of periods important for plant vegetation. The current length of those specific periods determines the lower potential of agricultural production in the area under analysis. The situation will change due to the growth of mean temperatures (Tab. 4). As demonstrated by calculations, the expected minimum value of the period length may be close to the current one, but the expected maximum of its duration may exceed the present value by almost 3 to 4 months. The mean length of the vegetation period calculated based on the analysed weather variants for 2050 is 242 days, *i.e.* the same as the maximum in analyzed area in the second half of the 20^{th} century.

Exceeding the thermal threshold level of mean daily temperature of 10°C means a time of intensive plant growth, and its length is particularly important for thermophilic plants. Already at the expected minimum level, this period may last as long as close to six months, and at the maximum level – even as long as the present duration of the vegetation period in the region. This would open totally new quality perspectives for agricultural production. At the same time, summer temperatures above the daily mean of 15°C could last for three to six months.

The analysis of basic meteorological elements provides an overview of the future of weather conditions in about 40 years around analyzed area. The reliability of this analysis and its precision is difficult to establish at present, in spite of the fact that the operation of the WGENK generator has been positively verified several times on the basis of contemporary data (Kuchar 2005, Richardson 1985). Consequently, it does not constitute a specific type of weather forecast in such a long time perspective, since even short-term weather forecasts are still unreliable to a significant degree. The cognitive and partially practical value of the system consists in the fact that it presents an outline of possible weather patterns and derivative evaluations calculated on this basis, provided in the form of up to 300 variants, characterised in the present study as extreme ranges, means and medians.

Table 2. Cross-sectional values of meteorological elements from 300 weather data series on year 2050

Meteorological element	Values in time scale	Values in relation to the prediction set			
		minimal value	maximal value	average	mediana
Minimal temperature (°C)	annual value	3.6	8.9	6.2	6.2
	value for growing season	11.2	14.1	13.2	12.8
	value for the period: March-May	5.2	13.3	8.5	7.9
Maximal temperature (°C)	annual value	11.7	19.6	16.8	16.6
	value for growing season	22.2	27.9	22.1	22.8
	value for the period: March-May	15.3	24.6	20.4	20.6
Totals of precipitation (mm)	annual value	452.8	991.4	771.2	772.3
	value for growing season	177.6	626.3	401.7	399.2
	value for the period: March-May	52.8	333.3	191.9	191.8
Solar radiation (MJ m^{-2})	annual value	3227.3	4152.2	4001.4	3979.2
	value for growing season	2712.5	3289.1	2966.8	2952.8
	value for the period: March-May	732.1	1222.6	1033.1	1010.2

Table 3. Frequency of the weather harmful phenomena for farming determinated on the base of 300 weather data series for year 2050

Meteorological element	Values in time scale	Values in relation to the prediction set			
		minimal value	maximal value	average	mediana
Frost day events	Value for growing season	0.0	9.0	3.4	3.0
	Value for the period: March-May	0.0	7.0	3.8	3.0
Non precipitation periods over 10 days	Annual value	0.0	5.0	2.0	2.0
	Value for growing season	0.0	3.0	1.2	1.0
	Value for the period: March-May	0.0	1.0	0.5	0.0

Table 4. Number of days of meteorological periods determinate on the base of 300 weather data series for year 2050

Values in time scale	Values in relation to the prediction set			
	minimal value	maximal value	average	mediana
Length of growing period, t > 5°C	223	310	252	246
Length of intensive growing, t > 10°C	172	232	191	188
Length of a summer temperature period, t > 15°C	106	174	135	130

CONCLUSIONS

1. In perspective of year 2050 the lowest generated values of minimal temperatures will below the current minimum temperature by about 1,4°C, while the highest could exceed them by slightly above 3,9°C. The future maximal temperatures will be lower than current values of maximum temperatures by about 1.2 or higher 3,9°C. Absolutely the lowest and highest minimal and maximal temperature (from 300 generated patterns) shows that difference could be much higher. In the same perspective, the minimal temperature the vegetation period (growing season) may be higher than the contemporary values by 1.3°C, and the highest exceeding

of the minimum value for this period may amount as much as 4.2°C. The maximum spring temperature will also increase, ranging from 1.6 up to 7.3°C. The data generated on 2050 for the spring period (March-May) indicate that minimum temperatures may be higher than the contemporary values by 1.2°C, and the highest exceeding of the minimum value for spring months may amount even to 7.3°C. The maximum spring temperature will also increase, ranging from 2.3 up to 11.6°C.

2. The minimum annual precipitation in the generated weather data series proved lower than the contemporary mean by 94.4 mm. The maximum value from the 300-variant set obviously proved higher than the present mean, by as much as 444.2 mm.

3. In the forecast, the vegetation periods may prove either much drier than the current ones even by 164.1 mm, or wetter by 284.6 mm. The data indicating a correlation between the current and future values of precipitation sums in the March-May spring period show similar characteristics.

4. The obtained weather scenarios indicate a potential higher than the current sum of irradiation 354.2 MJ m^{-2}.

5. The maximum number of expected frosts is nine, and all of them will probably occur in the spring period.

6. The highest number of non-precipitation periods above 10 days can occur in five cases during a year and in three cases in the vegetation period, with most of them occurring in the spring period.

7. According to calculations, the shortest expected vegetation periods may last the same number of days as currently, while the maximum expected duration of the period may exceed the current state by almost four months.

REFERENCES

Climate Change, 2007. Synthesis Report. http://www.ipcc.ch/pdf/assessment report/ar4/syr/ ar4_syr_spm.pdf.

Cowie J., 2007. Climate change. Biological and Human Aspects. Cambridge University Press, 433.

IPCC Special Report on Emissions Scenarios. 2007. A Special Report of Working Group IV of the Intergovernmental Panel on Climate Change, 27.

Koźminski C. (ed.), 2001. Atlas of the climate risk of plant growing in Poland (in Polish). Wydawn. AR Szczecin.

Kuchar L., 2005. The Modified model WGENK for meteorological daily data generation for the purpose of agrometeorology (in Polish). Water, Rural Areas and Environment (Woda Środowisko Obszary Wiejskie), 5(14), 185-196.

Mall R.K., Ranjeet Singh, Aakhileskh Gupta, Srinivasan G., Rathore L.S., 2006. Impact of climate change on Indian agriculture: A review. Climatic Change, 78, 445-478.

McKeown A.W., Warland J., McDonald M.R., 2006. Long-term climate and weather patterns in relation to crop yield. Canadian Journal of Botany, 84(7), 1031-1037.

Olesena J.E., Trnkab M., Kersebaumc K.C., Skjelvagd A.O., Seguine B., Peltonen-Sainiof P., Rossig F., Kozyrah J., Micalei F., 2011. Agricultural impacts of climate change in Spain: developing tools for a spatial analysis. Europ. J. Agronomy, 34, 96-112

Reddy K.R., Hodges H.F., 2000. Climate Change and Global Crop Productivity: CABI Publishing, Wallingford, Oxon, UK, 488.
Richardson C,W., 1985. Weather simulation for crop management models. Trans. ASAE, 28,1602-1606.
Smith J.B., Pitts G.J., 1997. Regional climate change scenarios for vulnerability and adaptation assessments. Climatic Change, 36(1-2), 3-21
Szwejkowski Z., Nowicka A., Panfil M., 2001. Climate of the Mazury Lakes District (in Polish). Fragm. Agronom., 2(74), 307-316.
Trnka M., Eitzinger J., Semerádová D., Hlavinka P., Balek J., Dubrovský M., Kubu G.,Štepánek P., Thaler S., Možný M., Žalud Z., 2011. Expected changes in agroclimatic conditions in Central Europe. Climatic Change, 108, 261-289.
Wilbanks T.J., 2003. Integrating climate change and sustainable development n a place-based context. Climate Policy, 3(1), S147-S154

AKTUALNE I PRZYSZŁE WARUNKI AGROKLIMATYCZNE W POLSCE W PERSPEKTYWIE GLOBALNYCH ZMIAN KLIMATU

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S t r e s z c z e n i e. Przedstawione w artykule wyniki wskazują na skalę ewentualnych zmian agroklimatu w porównaniu ze stanem obecnym. Nastąpią one w efekcie trwającego globalnego ocieplenia na terytorium Polski. Obliczenia dotyczące przyszłych warunków meteorologicznych przeprowadzono przy użyciu generatora pogody WGENK. Pozyskano w ten sposób 300 wariantów możliwych rocznych przebiegów pogody datowanych na początek drugiej połowy aktualnego stulecia, przy przyjęciu wskaźnika ogólnego wzrostu temperatury według scenariusza A1 opracowanego przez IPCC (The Intergovernmental Panel on Climate Change). Zgodnie z lokalnymi uwarunkowaniami klimatycznymi uzyskane dane wskazują, że możliwe są bardzo różnorodne sytuacje pogodowe, spełniające ogólne założenia A1. Najbardziej prawdopodobne jest zatem wydłużenie wegetacji, jak i znaczne jej skrócenie, częstość zjawisk ekstremalnych może się zwiększyć, jak i obniżyć (np. mrozy, susze). Wskaźniki przyszłego klimatu mogą się spełnić lokalnie w postaci różnych wariantów pogody w układzie rocznym, kiedy w przyszłości temperatura globalna wzrośnie, to agroklimat lokalny może okazać się w tej samej mierze korzystny, jak i niekorzystny. Zatem trudno jednoznacznie przewidzieć przyszły stan agroklimatu i wynikający z tego poziom produkcji rolnej, gdyż niezależnie od tendencji globalnych, rola czynników lokalnych będzie znacząca.

S ł o w a k l u c z o w e: globalne ocieplenie, agroklimat, Polska