BADANIA FIZJOGRAFICZNE
R. VIII – SERIA A – GEOGRAFIA FIZYCZNA (A68) str. 223–232

DOI 10.14746/bfg.2017.8.16

THE PERIOD OF INTENSE VEGETATION GROWTH AND MATURING OF PLANTS IN NORTH-WESTERN POLAND

ARKADIUSZ M. TOMCZYK, KATARZYNA SZYGA-PLUTA

Department of Climatology, Faculty of Geographical and Geological Sciences,
Adam Mickiewicz University in Poznań,
B. Krygowskiego 10, 61-680 Poznań

Abstract: The objective of the study consisted in determining the changeability of the dates of commencement and termination of the period of intense vegetation growth and the period of maturing of plants in north-western Poland, and also the respective durations thereof. Use was made of data concerning average monthly air temperatures for the years 1966–2015, which were obtained from the collections of the Institute of Meteorology and Water Management – National Research Institute. The period of intense vegetation growth has been defined as a period with average daily air temperature of $\geq 10^{o}$C, whereas the period of maturing of plants as one with an average daily air temperature of $\geq 15^{o}$C. The dates of commencement and termination of the aforementioned periods were determined using mathematical formulae proposed by Gumiński. On average, the period of intense vegetation growth commenced 3 days/10 years earlier and terminated 1 day/10 years later. In turn, the period of maturing of plants commenced on average 2 days/10 years earlier and terminated on average 2 days/10 years later. Research also revealed an increase in the duration of both the period of intense vegetation growth, and the period of maturing of plants in north-western Poland.

Keywords: period of intense vegetation growth, period of maturing of plants, north-western Poland

INTRODUCTION

The present-day warming of the climate is a phenomenon that cannot be called into question, and the first decade of the 21st century is commonly considered as the hottest since the commencement of instrumental measurements (IPCC, 2013). The increase in air temperature has led to a lengthening of the vegetation growth period in Europe, thus leading to a modification of the phenological phases of individual plants (Menzel & Fabian 1999; Chmielewski & Rötzer 2001; Chmielewski et al. 2004). Nieróbca et al. (2013) have indicated that by 2030, the vegetation growth period in central Poland may be 10–14 days longer than in the reference period of 1971–2000, and 18–27 days longer by 2050, whereas in south-western Poland it may be 11–17 days longer and 22–30 days longer, respectively.

A significant increase in temperature occurred among others in the warm part of the year, bringing about a lengthening of the period of intense vegetation growth and a considerable increase in thermal resources during the period of active growth of plants (Żmudzka 2012). The warming of the Polish climate

facilitates the development of stenothermal plant species. A particularly conducive factor is the longer duration of periods with temperatures over 10ºC, of periods of intense vegetation growth, and of plant maturing periods (Skowera & Kopeć 2008; Kopeć 2009). The length of the vegetation growth period is of fundamental importance for the selection of useful plants and the conditions for their development, and thus impacts the quantity of plant production (Mager & Kopeć 2010). The date of commencement of the vegetative growth season is to a large extent decisive for the course of the developmental phases of useful plants and the possibility of performing work in the field with optimal efficiency (Węgrzyn 2007). However, these changes in thermal conditions may also have undesirable effects for agriculture (Nieróbca 2009). A decrease in the productivity of certain crops may be the result of heat stress and a deterioration of the water balance. Furthermore, rising temperatures may be conducive to the development of stenothermal weeds, pests and new plant diseases.

The objective of the study consisted in determining the changeability of the dates of commencement and termination of the period of intense vegetation growth and the period of maturing of plants in north-western Poland in the years 1966–2015.

RESEARCH METHODS

Average monthly air temperature values for the years 1966–2015, obtained for 6 stations located in north-western Poland (Fig. 1, Tab. 1), formed the basis of the study. These data were made available by the Institute of Meteorology and Water Management – National Research Institute.

The aforementioned data were used to determine the dates of commencement and termination of the period of intense vegetation growth and the period of maturing of plants. The following definitions have been applied in the present study:

– period of intense vegetation growth – a period with an average daily air temperature of $\geq 10^{o}$C;
– period of maturation – a period with an average daily air temperature of $\geq 15^{o}$C.

These definitions had been commonly adopted in research conducted previously by other authors (Szwejkowski et al. 2008; Kopeć 2009; Żarski et al. 2012; Żmudzka 2012). In order to determine the dates of commencement and termination of the above periods, use was made of mathematical formulae proposed by Gumiński (1948). The following assumptions were adopted for this method: the average monthly temperature coincides with the 15th day of the month, each month has 30 days, while changes in temperature from month to month occur in a regular manner. The formulae used:

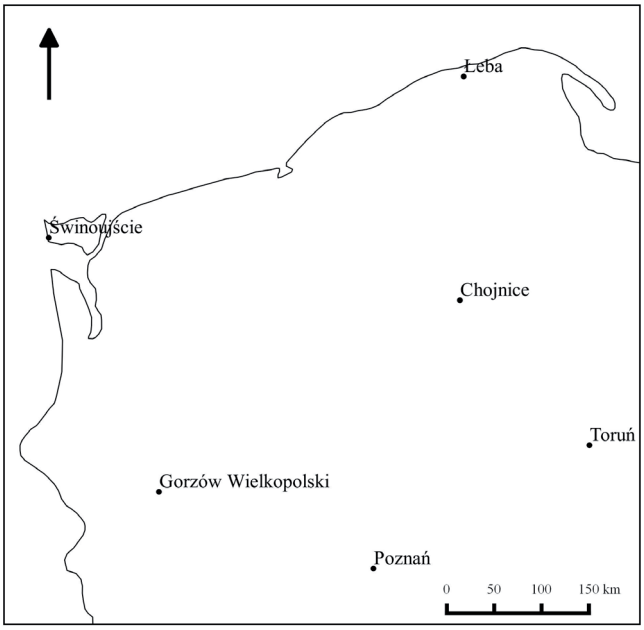

Fig. 1. Locations of the meteorological stations

Table 1. Locations of the meteorological stations

Station	Geographic coordinates		Altitude [m a.s.l.]
	Latitude (N)	Longitude (E)	
Chojnice	53.72°	17.55°	172
Gorzów Wielkopolski	52.75°	15.28°	73
Łeba	54.76°	17.53°	6
Poznań	52.42°	16.83°	86
Świnoujście	53.92°	14.23°	5
Toruń	53.05°	18.58°	72

$$x = 30\ [(tp - t_1)/(t_2 - t_1)]$$

$$x = 30\ [(t_1 - tp)/(t_1 - t_2)]$$

where:
tp – threshold temperature,
t_1 – average temperature in the month preceding the threshold temperature,
t_2 – average temperature in the month following the threshold temperature,
x – number of days separating the threshold temperature day and the 15th day of the preceding month.

The number of days calculated on the basis of the above formulae was added to the 15th day of the month preceding the threshold temperature. If the number sought was greater than 15, it was necessary to take into consideration the actual number of days in a given month when adding. The date obtained was that of the beginning or end of the period in question. It should be noted that this method is commonly used for determining thermic periods (Skowera & Kopeć 2008; Szyga-Pluta 2011a, b; Tomczyk 2013; Kępińska-Kasprzak & Mager 2015; Tomczyk & Szyga-Pluta 2016).

The next step consisted in calculating the length of these periods in individual years and the potential length for the examined multiannual period, that is the time between the earliest commencement and the latest termination of the said periods. Average values, the standard deviation and linear trends were then calculated for these parameters. In order to assess the nature of changes, use was made of the linear regression model, while an assessment of the statistical significance of the directional coefficient was performed on the basis of the *t*-Student test at the significance level $p < 0.05$.

RESULTS

Period of intense vegetation growth

In the years 1966–2015, the period of intense vegetation growth in north-western Poland commenced on average on 30 April and ended on 7 October. On average, the earliest commencement of the period of intense vegetation growth was observed in the south-western part of the analysed area (in Poznań – on 23 April, in Gorzów Wielkopolski – on 24 April), and the latest along the coastline (Świnoujście – 4 May, Łeba – 11 May) (Tab. 2). In turn, the earliest termination of the surveyed period was observed in the eastern part of the researched area (Chojnice – 1 October, Toruń – 6 October), and the latest in coastal stations (Łeba – 9 October, Świnoujście – 12 October). During the multiannual period under examination, the first day of the period of intense vegetation growth occurred earliest on 5 April 2009 in Gorzów Wielkopolski, whereas the latest last day – 29 October 2006 – was observed for Świnoujście. The above data show that the potential duration of the period of intense vegetation growth totalled 208 days. This period lasted under 200 days at coastal stations (Łeba – 195 days, Świnoujście – 199 days) and in Chojnice (195 days), whereas for the remainder of the area its term was 204 days.

It was observed for the years 1966–2015 that the period of intense vegetation growth commenced at steadily earlier dates. The greatest changes were noted in Gorzów Wielkopolski (3.5 days/10 years), and the smallest in Łeba (2.5 days/10 years) (Tab. 2). The changes noted were statistically significant.

In turn, the termination of the period of intense vegetation growth occurred at steadily later dates, however the rate of change was considerably slower than in the case of commencement. The greatest changes were observed in Chojnice (1.4 days/10 years), and the smallest in Świnoujście (0.6 day/10 years). The changes noted were not statistically significant.

Table 2. A numerical description of the period of intense vegetation growth in north-western Poland in the years 1966–2015

Station	Commencement of period			Termination of period			Potential period [days]
	average	changes [day(s)/ 10 years]	earliest	average	changes [day(s)/ 10 years]	latest	
Chojnice	02.05	**–3.0**	11.04.2000	01.10	1.4	22.10.2000	195
Gorzów Wielkopolski	24.04	**–3.5**	05.04.2009	09.10	1.0	25.10.2000 25.10.2006	204
Łeba	11.05	**–2.5**	16.04.2000	09.10	0.7	27.10.2006	195
Poznań	23.04	**–3.3**	06.04.2000 06.04.2009	08.10	0.9	26.10.2000	204
Świnoujście	04.05	**–3.1**	14.04.2000	12.10	0.6	29.10.2006	199
Toruń	27.04	**–2.7**	06.04.2000	06.10	1.2	26.10.2006	204

bold – statistically significant

In north-western Poland, the average duration of the period of intense vegetation growth was 161 days, varying from 152 days in Łeba to 169 days in Gorzów Wielkopolski and Poznań. The course of the seasonal duration of the analysed period underscores its considerable fluctuation from year to year, whereas this changeability is similar for the researched area, as evidenced by the value of the standard deviation, which apart from Świnoujście (12 days) totalled 13 days. During the examined multiannual period, the shortest periods lasted between 124 and 147 days, and were observed mainly in 1972, 1987, 1991, 1993, and 1999 (Fig. 2). In turn, the longest period for all stations occurred in 2000, ranging from 193 days in Łeba to 204 days in Poznań and Toruń. An equally long period was observed for the majority of stations in 2014. A statistically significant increase in the length of the period of intense vegetation growth was determined for the analysed multiannual period. The greatest changes were noted in Chojnice and Gorzów Wielkopolski (4.5 days/10 years), and the smallest in Łeba (2.5 days/10 years).

Fig. 2. The duration of the period of intense vegetation growth for selected stations in north-western Poland in the years 1966–2015

Plant maturing period

The plant maturation period, that is the period with an average daily air temperature of ≥ 15°C, commenced in the examined region on average on 6 June, and terminated on average on 3 September. It began earliest in the south west (Poznań – 27 May, Gorzów Wielkopolski – 28 May), and latest along the coast (Świnoujście – 12 June, Łeba – 22 June) (Tab. 3). In turn, the date of termination of the plant maturing period ranged from 28 August (Chojnice) to 6 September (Gorzów Wielkopolski, Poznań, Świnoujście). However, the earliest commencement of the analysed period was observed on 7 May 1993 (Poznań, Toruń), while the latest termination – on 29 September 2006 (Świnoujście). On the basis of the above data we may state that the potential duration, i.e. the time between the earliest start and the latest end, of the period of maturing of plants in north-western Poland was 146 days. For individual stations, it ranged in length from 117 days (Łeba) to 143 days (Gorzów Wielkopolski and Poznań).

It was observed for the analysed multiannual period that the plant maturation period commenced at steadily earlier dates, however statistically significant changes were noted only along the coast and in Chojnice. The rate of change ranged from 1.5 days/10 years in Toruń to 2.5 days/10 years in Łeba (Tab. 3). In turn, the termination of the plant maturing period occurred at steadily later dates, while the rate of these changes ranged from 1.8 days/10 years in Świnoujście to 2.6 days/10 years in Chojnice. The changes noted were statistically significant.

Table 3. A numerical description of the plant maturation period in north-western Poland in the years 1966–2015

Station	Commencement of period			Termination of period			Potential period [days]
	average	changes [day(s)/ 10 years]	earliest	average	changes [day(s)/ 10 years]	latest	
Chojnice	11.06	**–2.3**	12.05.2002	28.08	**2.6**	20.09.2006	132
Gorzów Wielkopolski	28.05	–1.9	09.05.1993	06.09	**2.1**	27.09.2006	143
Łeba	22.06	**–2.5**	01.06.2007	01.09	**2.4**	25.09.2006	117
Poznań	27.05	–1.9	07.05.1993	06.09	**2.1**	26.09.2006	143
Świnoujście	12.06	**–1.8**	25.05.2003 25.05.2007	06.09	**1.8**	29.09.2006	128
Toruń	29.05	–1.5	07.05.1993	04.09	**2.1**	22.09.1999 22.09.2006	139

bold – statistically significant

In north-western Poland, the average length of the plant maturation period was 90 days. Only in the south west did its duration exceed 100 days (Gorzów Wielkopolski – 102 days, Poznań – 103 days), while for the remaining stations it ranged between 71 days (Łeba) and 99 days (Toruń). Apart from two stations (Łeba, Chojnice), the standard deviation varied similarly and totalled 14–15 days, which clearly points to a comparable variability of the length of the analysed period throughout the major part of the area. The shortest plant maturing period was observed for 1984, 1987 and 1977, and the longest for 2006 and 2002 (Fig. 3). For the last 15 years, periods with a length of > 100 days were noted decidedly more frequently than in previous years. Research conducted for the purposes of the study revealed a statistically significant increase in the duration of the plant maturing period. The greatest changes were noted in Łeba and Chojnice (4.9 days/10 years), and the smallest in Toruń (3.5 days/10 years).

Fig. 3. The length of the plant maturing period for selected stations of north-western Poland in the years 1966–2015

SUMMARY AND DISCUSSION

In north-western Poland in the years 1966–2015, the period of intense vegetation growth lasted on average 161 days, that is from 30 April to 7 October. On average, the period of intense vegetation growth commenced 3 days earlier (per 10 years) and terminated 1 day later (per 10 years), whereas the period of maturing of plants commenced on average 2 days/10 years earlier and terminated on average 2 days/10 years later. The average length of the plant maturation period was 90 days, i.e. it lasted from 6 June to 3 September. The research disclosed an increase in the duration of both the period of intense vegetation growth and the period of maturing of plants in north-western Poland. The greatest changes were noted in Łeba and Chojnice (4.9 days/10 years), and the smallest in Toruń (3.5 days/10 years).

The lengthening of the period of intense vegetation growth in different regions of Poland was further confirmed by other authors. This extension of its duration

was caused first and foremost by the steadily earlier dates of commencement. Olechnowicz-Bobrowska and Wojkowski (2006) stated that the period of intense vegetation growth was 9–11 days longer in decade 1991–2000 in comparison with 1951–1980. According to Skowera and Kopeć (2008) the aforementioned periods start 2–6 days earlier in south-eastern Poland in years 1971–2000. According to Żmudzka (2012), there occurred a lengthening of the period of intense vegetation growth in the lowland part of the country, while the number of days with an average temperature of at least 5°C and 10°C increased at a rate of ~0.3 day per year. Krużel et al. (2015) stated that the on-average four-day increase in the duration of the vegetative period in Poland is the result of both its earlier commencement (by 2 days), and later termination (again by 2 days). Skowera and Kopeć (2008), in turn, are of the opinion that the vegetative period and the period of intense vegetation growth have become extended primarily due to their earlier commencement (by 2–6 days in the years 1971–2000 in comparison with the period 1951–1980). This has been confirmed by Bochenek et al. (2013), whose results show that in the years 2001–2011 the vegetative period in south-eastern Poland displayed a lengthening tendency, first and foremost due to its steadily earlier commencement date. Nieróbca at al. (2011), however, opined that due to transformations in the seasonal distribution of warming, the extension by approximately 8 days of the vegetative period in Poland in the last few years (2001–2009) in comparison with the multiannual period of 1971–2000 was primarily the result of the steadily later termination of this period. According to Węgrzyn (2007), the changeability of dates of commencement of the vegetative growth period points rather to a temporary differentiation that is typical of the climate.

In north-western Poland, we can observe a similar spatial differentiation of the commencement and termination dates for both periods of intense plant development. Such a distribution was previously demonstrated by Żmudzka (2012), Nieróbca et al. (2013), and Krużel et al. (2015). The earliest beginning of the intense plant development periods occurred in the south-western part of the analysed region, while the latest beginning was observed on the coast. Finally, the earliest termination was noted in its central and eastern part, and the latest in the south-western.

REFERENCES

Bochenek W., Dedo J., Marczewski W., 2013: *Zróżnicowanie długości i warunków termicznych okresu wegetacyjnego na obszarze Beskidów i Pogórzy w latach 2001–2011 na podstawie danych zgromadzonych w bazie GLDAS*, Monit. Środ. Przyr., 14, 79–85.

Chmielewski F.M., Muller A., Bruns E., 2004: *Climate changes and trends in phenology of fruit trees and field crops in Germany, 1961–2000*, Agricultural Forest Meteor., 121, 1–2, 69–78.

Chmielewski F.M., Rötzer T., 2001: *Response of tree phenology to climate change across Europe*, Agricultural Forest Meteor., 108, 101–112.

Gumiński R., 1948: *Próba wydzielenia dzielnic rolniczo-klimatycznych w Polsce*, Przegl. Meteor.-Hydrol., Warszawa.

IPCC, 2013: *Climate change: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel in Climate Change*, Cambridge Univ. Press, Cambridge.

Kępińska-Kasprzak M., Mager P., 2015: *Thermal growing season in Poland calculated by two different methods*, An. of Warsaw Univ. of Life Sciences-SGGW Land Reclamation, 47, 3, 261–273.

Kopeć B., 2009: *Uwarunkowania termiczne wegetacji winorośli na obszarze południowo-wschodniej Polski*, Infrastruktura i Ekol. Teren. Wiej., 4, 251–262.

Krużel J., Ziernicka-Wojtaszek A., Borek Ł., Ostrowski K., 2015: *Zmiany czasu trwania meteorologicznego okresu wegetacyjnego w Polsce w latach 1971–2000 oraz 1981–2010*, Inż. Ekol., 44, 47–52.

Mager P., Kopeć M., 2010: *Okres wegetacyjny w Polsce i w Europie w dobie obserwowanego ocieplenia*, [w:] E. Bednorz, L. Kolendowicz (red.), *Klimat Polski na tle klimatu Europy. Zmiany i ich konsekwencj*e, Bogucki Wyd. Nauk., Poznań, 49–63.

Menzel A., Fabian P., 1999: *Growing season extended in Europe*, Nature, 397, 659.

Nieróbca A., 2009: *Skutki zmian klimatycznych dla rolnictwa w Polsce – ocena zagrożeń*, [w:] J. Kozyra, A. Nieróbca, K. Mizak (red.), *Zmiany klimatyczne a rolnictwo w Polsce – ocena zagrożeń i sposoby adaptacji*, IUNG-PIB, Puławy.

Nieróbca A., Kozyra J., Mizak K., Pudełko R., 2011: *Zmiany długości okresu wegetacyjnego w Polsce i prognozy na lata 2011–2030*, Streszczenia prac. XXXV Ogólnopolski Zjazd Agroklimatologów i Klimatologów z udziałem gości zagranicznych, 7–10 września 2011, Wrocław–Pokrzywna k. Głuchołaz, UP, Wrocław, 38.

Nieróbca A., Kozyra J., Mizak K., Wróblewska E., 2013: *Zmiana długości okresu wegetacyjnego w Polsce*, Woda–Środowisko–Obszary Wiejskie, 13, 2(42), 81–94.

Olechnowicz-Bobrowska B., Wojkowski J., 2006: *Okresy termiczne w południowej części Wyżyny Krakowsko-Częstochowskiej (1991–2000)*, [w:] J. Trepińska, Z. Olecki (red.), *Klimatyczne aspekty środowiska geograficznego*, Inst. Geogr. i Gosp. Przestrz. UJ, Kraków, 51–61.

Skowera B., Kopeć B., 2008: *Okresy termiczne w Polsce południowo-wschodniej (1971–2000)*, Act. Agrophys., 12, 2, 517–526.

Szwejkowski Z., Dragańska E., Banaszkiewicz B., 2008: *Scenariusze warunków agroklimatycznych okolic Olsztyna w perspektywie spodziewanego globalnego ocieplenia w roku 2050*, Act. Agrophys., 12(2), 543–552.

Szyga-Pluta K., 2011a: *Termiczne pory roku w Poznaniu w latach 2001–2008*, Przegl. Geogr., 83, 1, 109–119.

Szyga-Pluta K., 2011b: *Zmienność termicznych pór roku w Poznaniu*, Bad. Fizjograf., 62, 181–195.

Tomczyk A., 2013: *Termiczne pory roku w stacji Svalbard Lufthavn (Longyearbyen)*, Bad. Fizjogr., 64, 281–286.

Tomczyk A.M., Szyga-Pluta K., 2016: *Okres wegetacyjny w Polsce w latach 1971–2010*, Przegl. Geogr., 88, 1, 75–86.

Węgrzyn A., 2007: *Ocena okresu wegetacyjnego na Lubelszczyźnie w latach 1951–1990*, An. Univ. Mariae Curie-Skłodowska Lublin – Polonia, 62, 1, 23–30.

Żarski J., Kuśmierek-Tomaszewska R., Dudek S., 2012: *Tendencje zmian termicznych okresów rolniczych w rejonie Bydgoszczy*, Infrastruktura i Ekol. Teren. Wiej., 3, I, 7–17.

Żmudzka E., 2012: *Wieloletnie zmiany zasobów termicznych w okresie wegetacyjnym i aktywnego wzrostu roślin w Polsce*, Woda–Środowisko–Obszary Wiejskie, 12, 2(38), 377–389.