FOLIA POMERANAE UNIVERSITATIS TECHNOLOGIAE STETINENSIS
Folia Pomer. Univ. Technol. Stetin., Agric., Aliment., Pisc., Zootech. 2014, 312(31), 133–142

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HYDROTHERMAL CHARACTERISTICS OF VEGETATION PERIOD IN CENTRAL--EASTERN POLAND IN YEARS 1971–2005

HYDROTERMICZNA CHARAKTERYSTYKA OKRESU WEGETACYJNEGO W ŚRODKOWOWSCHODNIEJ POLSCE W LATACH 1971–2005

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Streszczenie. Jedną z miar wykorzystywanych do oceny kształtowania się warunków hydrotermicznych danego obszaru jest współczynnik Sielianinowa. W pracy wykorzystano dane z 9 stacji IMGW z rejonu środkowowschodniej Polski, zarejestrowane w latach 1971–2005. Na podstawie współczynnika Sielianinowa określono częstość występowania w okresie wegetacyjnym miesięcy w klasach wilgotności wg kryterium Skowery i Puły (2004). Przedstawiono rozkład przestrzenny wartości współczynnika Sielianinowa we wszystkich miesiącach okresu wegetacyjnego na badanym obszarze. Wieloletnie zmiany współczynnika Sielianinowa oceniono za pomocą współczynnika regresji trendu liniowego oraz współczynnika zmienności. Najmniejsze średnie wartości współczynnika Sielianinowa we wszystkich miesiącach okresu wegetacyjnego notowano w zachodniej i południowo-zachodniej części badanego obszaru. Część północno--wschodnia charakteryzowała się najkorzystniejszymi warunkami hydrotermicznymi. Kwiecień w badanym regionie był miesiącem najczęściej skrajnie wilgotnym lub optymalnym. W maju, czerwcu i sierpniu okresy suche występowały dwa razy częściej niż wilgotne. Istotne zmniejszanie się wartości współczynnika Sielianinowa w okresie wegetacyjnym analizowanego wielolecia świadczy o zwiększaniu się intensywności posuch.

Key words: central-eastern Poland, climate changes, Sielianinow's coefficient, spatial distribution, vegetation season.
Słowa kluczowe: okres wegetacyjny, Polska środkowowschodnia, rozkład przestrzenny, współczynnik Sielianinowa, zmiany klimatu.

INTRODUCTION

The main meteorological factors shaping the living conditions of organisms are precipitation and thermal conditions. These two meteorological (and in multiyear – climatic) parameters are so important because they condition water circulation as well as mineral and organic substances circulation in the environment (Bochenek 2012). In terms of agriculture the analysis of meteorological elements course during vegetation season is very important because they are recognized as the essential yield components. From the agrometeorology

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point of view the characteristics of atmospheric droughts is also relevant as they are often the cause of soil drought which results in underdevelopment of plants thus in the reduction of crop yields. Sielianinow's hydrothermal coefficient is useful for determining water relations in the environment (Kapuściński and Nowak 2003; Bartoszek and Banasiewicz 2007; Hutorowicz et al. 2008). It is important that development and yielding crops relations with hydrothermal conditions of vegetation season were based on the current or foreseen temperature and precipitation (Ziernicka-Wojtaszek 2009).

This paper is an attempt to determinate the variability of thermal and pluviometrical conditions in the multiyear 1971–2005 based on Sielianinow's hydrothermal coefficient.

MATERIAL AND METHODS

Data used in this paper regard average daily air temperature values and daily sums of precipitation, they come from nine IMGW stations from the area of central-eastern Poland between the years 1971–2005 (Table 1). Hydrothermal conditions of the area examined were evaluated on the basis of Sielianinow's hydrothermal coefficient which is a measurement of precipitation effectiveness in a particular month. The months were classified according to the following Skowera and Puła (2004) criteria:

- extremely dry – $k < 0,40$,
- very dry – $0,41 < k < 0,70$,
- dry – $0,71 < k < 1,0$,
- rather dry – $1,01 < k < 1,30$,
- optimal – $1,31 < k < 1,60$,
- rather humid – $1,61 < k < 2,0$,
- humid – $2,01 < k < 2,5$,
- very humid – $2,51 < k < 3,0$,
- extremely humid – $k > 3,01$.

Table 1. Geographic coordinates of synoptic and climatic IMGW stations in central-eastern Poland
Tabela 1. Współrzędne geograficzne stacji synoptycznych i klimatycznych IMGW w środkowowschodniej Polsce

Station – Stacja	Geographic coordinates Współrzędne geograficzne		H_s [m n.p.m.]
	φ°	λ°	
Ostrołęka	53 ° 05’	21 ° 34’	95
Białowieża	52 ° 42’	23 ° 51’	164
Włodawa	51 ° 33’	23 ° 32’	163
Szepietowo	52 ° 51’	22 ° 33’	150
Legionowo	52 ° 24’	20 ° 58’	93
Biała Podlaska	52 ° 02’	23 ° 05’	133
Sobieszyn	51 ° 37’	22 ° 09’	135
Pułtusk	52 ° 44’	21 ° 06’	95
Siedlce	52 ° 11’	22 ° 16’	146

Explanations – Objaśnienia: φ° – geographic latitude – szerokość geograficzna, λ° – geographic longitude – długość geograficzna, H_s – elevation above sea level – wysokość n.p.m.

The frequency of occurrence of humidity classes was determined in particular months of the vegetation season in nine stations of central-eastern Poland. In order to visualize the dynamics of changes of the examined parameter, the coefficient of variation was calculated.

The direction and significance of changes tendency was determined on the basis of linear trend equations. The significance of the regression coefficient of the trend was calculated with t-Student test where $\alpha = 0,05$.

RESULTS AND DISCUSSION

In Poland, there are significant and deepening water shortages. An important issue is therefore hydrothermal conditions study for the needs of the agricultural economy. The transitional climate of Poland is manifested in high variation of particular climate elements values, including air temperature and precipitation. Probable changes in temperature and precipitation will vary in different regions. Żmudzka (2004) and Michalska and Kalbarczyk (2005) point out statistical increase in temperature in Poland, especially visible during winter and spring seasons. Whereas the precipitation course analysis in the multiyear confirm lack of noticeable trend in precipitation for the region of Poland (Górski 2002; Żmudzka 2004). The analysis made within the project Adaptation of sensitive sectors… (2013) indicates the increase in winter precipitation of up to about 15% in northern part of the country in years 2021–2050 and up to above 20% in eastern part in years 2071–2100. Moreover it is clearly visible the reduction of precipitation at the end of century in summertime, the highest in the southern east. Spring precipitation in the first period is slightly decreasing in western part of the country, while in the second period considered approximately 10% increase is noticeable in the whole Poland. As for autumn the tendencies are the weakest, a slight decrease in the northern regions of the country.

On the basis of the analysis of average values of Sielianinow's coefficients during vegetation season (IV–IX) in central-eastern Poland it can be stated that north-eastern part of the area examined was characterized by the most favourable hydrothermal conditions comparing to the whole region of the study. The highest average value of this parameter during vegetation season was noted in Biała Podlaska (1.68), Białowieża (1.63) and Szepietowo (1.48). While in all of the vegetation season's months in western and north--western part this coefficient values were the lowest (Fig. 1). Average values (IV–IX) spread from 1.38 (Pułtusk) to 1.46 (Legionowo). In April north-eastern part was classified as very humid while central-western part as rather humid. In May and August in south-western part of the region examined it was rather dry. While the optimal hydrothermal conditions in central-eastern Poland were characteristics of June, July and September.

As Kalbarczyk research (2003) shows the average national value of hydrothermal coefficient in vegetation season from April till September varies from 1.29 to 1.67, wherein on average the lowest coefficient's values take place in September and the highest in April. Skowera and Puła (2004) analyzing extreme pluviothermal conditions during springtime in Poland between the years 1971–2000 presented the distribution of average Sielianinow's coefficient values and highlighted its regional diversity across the whole country.

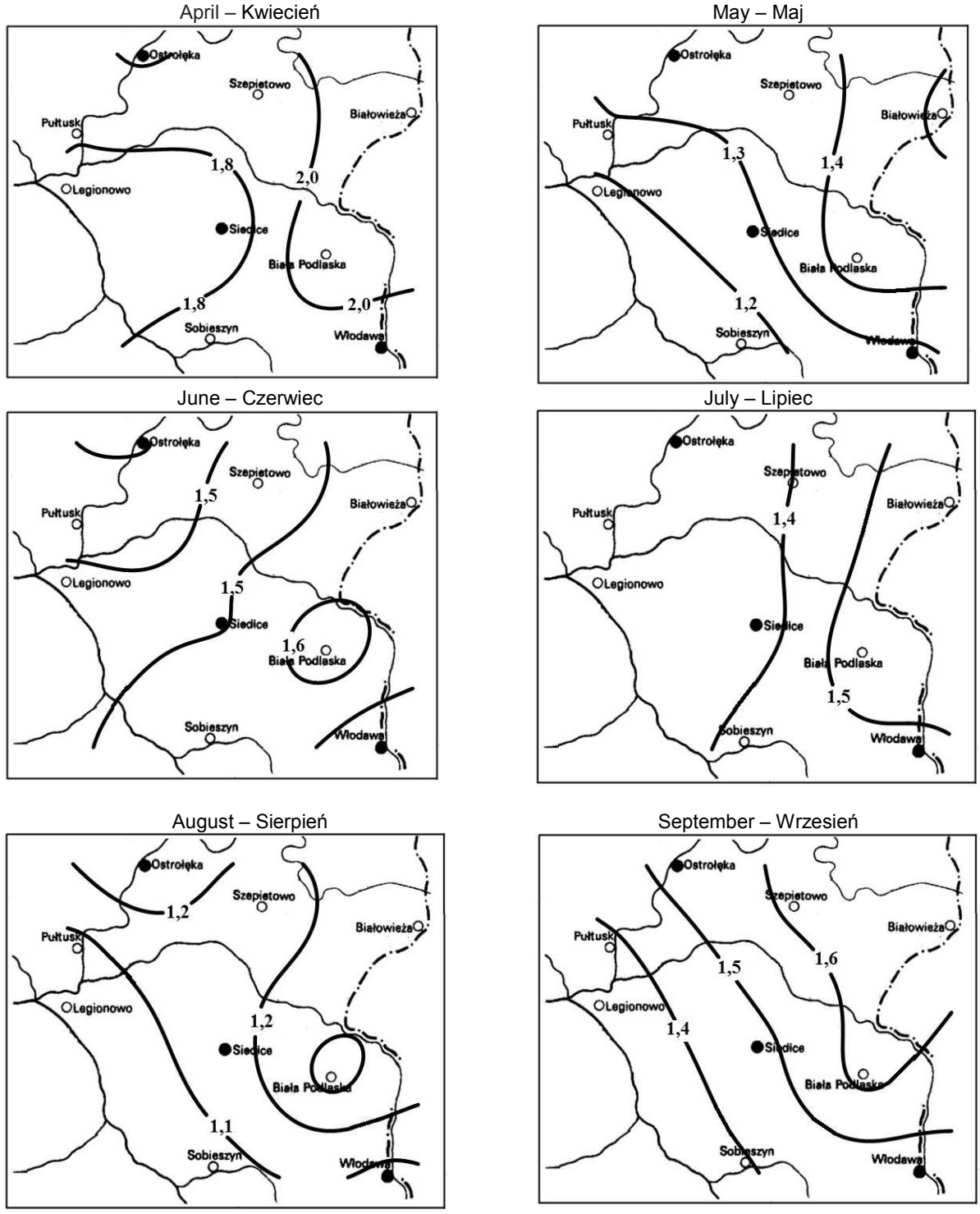

Fig. 1. Spatial distribution of average values of Sielianinow's coefficient in particular months of the vegetation season (IV–IX) in central-eastern Poland between the years 1971–2005
Ryc. 1. Rozkład przestrzenny średnich wartości współczynnika Sielianinowa w poszczególnych miesiącach okresu wegetacyjnego (IV–IX) w środkowowschodniej Polsce w latach 1971–2005

The most humid regions in April were southern and northern parts of the country. In the central part the conditions were optimal. According to average Sielianinow's coefficient values in May in Poland on the substantial area occur rather dry conditions, while optimal

conditions have much lower range. Only in southern part of the country occur rather humid and humid conditions. In June optimal conditions dominate, rather humid and humid conditions occur in northern, north-eastern and southern part.

In central-eastern Poland the least rarely in all of the stations and vegetation season's months occurred extremely dry, extremely humid and very humid months. Extremely humid months were the most often noted in Biała Podlaska, and extremely dry in Legionowo (Fig. 2). Very dry vegetation seasons were the most frequently noted in Sobieszyn and Siedlce, and the least rarely in Włodawa and Białowieża.

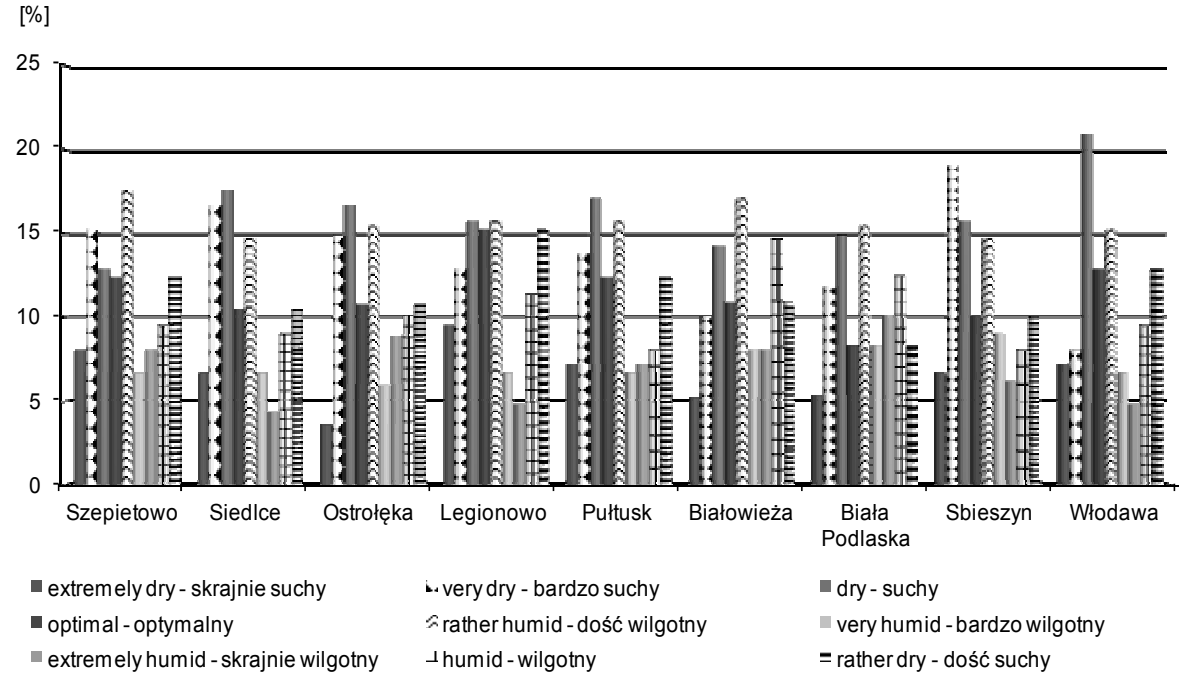

Fig. 2. The frequency of occurrence of months in adopted humidity classes during the vegetation season (IV–IX) in stations of central-eastern Poland between the years 1971–2005
Ryc. 2. Częstość występowania miesięcy w przyjętych klasach wilgotności w okresie wegetacyjnym (IV–IX) w stacjach środkowowschodniej Polski w latach 1971–2005

In the multiyear analyzed, taking into consideration the mean from nine stations, the most frequently were noted dry and optimal vegetation seasons (Table 2). Months classified as extremely dry during vegetation season appeared with similar frequency (6–8%). April was the most frequently optimal and extremely humid month, while May was dry or optimal. June and August were the most frequently dry, whereas July was characterized by optimal moisture.

Table 2. The frequency [%] of occurrence of months in adopted humidity classes during the vegetation season (IV–IX) in central-eastern Poland between the years 1971–2005. Mean value from 9 stations
Tabela 2. Częstość [%] występowania miesięcy w przyjętych klasach wilgotności w okresie wegetacyjnym (IV–IX) w środkowowschodniej Polsce w latach 1971–2005. Średnia z 9 stacji

Humidity class Klasa wilgotności	IV	V	VI	VII	VIII	IX	IV–IX
Extremely dry Skrajnie suchy	6	6	6	6	7	8	7
Very dry Bardzo suchy	10	13	8	10	20	16	13
Suchy Dry	10	20	20	17	21	16	17
Rather dry Dość suchy	10	12	16	13	10	9	12
Optimal Optymalny	15	19	15	19	14	12	16
Rather humid Dość wilgotny	12	15	11	13	12	11	12
Humid Wilgotny	11	10	11	9	7	13	10
Very humid Bardzo wilgotny	11	4	7	7	5	9	7
Extremely humid Skrajnie wilgotny	15	1	6	6	4	6	6

Variation in average Sielianinow's coefficient values during vegetation season (IV–IX) ranged from 17% (Włodawa) to 23% (Szepietowo, Legionowo, Biała Podlaska) – Table 3.

Table 3. The parameters of regression equation of the linear trend of Sielianinow's coefficient during the vegetation season (IV–IX) in central-eastern Poland between the years 1971–2005
Tabela. 3. Parametry równania regresji trendu liniowego współczynnika Sielianinowa w okresie wegetacyjnym (IV–X) w środkowowschodniej Polsce w latach 1971–2005

Station Stacja	Regression coefficient of the trend Współczynnik regresji trendu	Intercept Wyraz wolny	Coefficient of determination Współczynnik determinacji	Coefficient of variation Współczynnik zmienności [%]
Ostrołęka	–0,01	31,31	0,10	20
Białowieża	–0,03*	53,13	0,30	23
Włodawa	–0,01*	18,34	0,09	17
Szepietowo	–0,02*	38,36	0,19	23
Legionowo	–0,02*	38,36	0,19	23
Biała Podlaska	–0,03*	66,93	0,30	23
Sobieszyn	–0,01	29,72	0,14	22
Pułtusk	–0,01	16,39	0,05	20
Siedlce	–0,01*	16,39	0,05	20

* Significant α = 0.05 – Istotne przy α = 0,05.

On the basis of the analysis of regression coefficients of the trend values it can be stated that average k coefficient values during vegetation season (IV–IX) in most of the stations were significantly decreasing, in Siedlce and Włodawa of 0.1 in 10 years, in Szepietowo and Legionowo of 0.2 in 10 years, and in Biała Podlaska and Białowieża of 0.3 in 10 years.

Change of values of 0.3 results in a change of classification by one humidity class. In all of the vegetation season's months regression coefficients were negative and statistically significant (except for April and May). Sielianinow's coefficient values were significantly decreasing of 0.1 in 10 years in July and of 0.2 in 10 years in June, August and September (Table 4).

Table 4. The parameters of regression equation of the linear trend of Sielianinow's coefficient in particular months of the vegetation season (IV–IX) in central-eastern Poland between the years 1971–2005. Mean value from 9 stations
Tabela. 4. Parametry równania regresji trendu liniowego współczynnika Sielianinowa w poszczególnych miesiącach okresu wegetacyjnego (IV–X) w środkowowschodniej Polsce w latach 1971–2005. Średnia z 9 stacji

Parameter Parametr	IV	V	VI	VII	VIII	IX
Regression coefficient of the trend Współczynnik regresji trendu	–0,01	–0,01	–0,02*	–0,01*	–0,02*	–0,02*
Intercept Wyraz wolny	24,38	9,10	44,78	20,55	43,02	34,84
Coefficient of determination Współczynnik determinacji	0,01	0,01	0,06	0,01	0,07	0,03

* Significant α = 0.05 – Istotne przy α = 0,05

Statistically significant trend of Sielianinow's hydrothermal coefficient in the multiyear 1965–1995 proved also Kalbarczyk (2003) analyzing the influence of precipitation-thermal conditions on potato yielding in Poland. In May this trend was negative, while in September positive. Also Ziernicka and others (2000 / 2001) based on the analysis of Sielianinow's coefficient values point out the increase in climate dryness in vegetation season in south-eastern Poland.

CONCLUSIONS

1. The variability of hydrothermal conditions, determined on the basis of coefficient of variation during the vegetation season in all of the analyzed stations from central-eastern Poland, remained at a similar level.
2. The lowest average Sielianinow's coefficient values in all of the vegetation season's months were noted in western and south-western part of the area examined (Pułtusk, Legionowo and Sobieszyn). While north-eastern part was characterized by the most favourable hydrothermal conditions (Biała Podlaska, Białowieża and Szepietowo).
3. Between the years 1971–2005 April was the most frequently extremely humid or optimal month. Whereas in May, June and August dry months occurred two times more frequently than humid ones, and in July and August dry and humid months occurred with similar frequency.
4. Significant decrease of Sielianinow's coefficient values during vegetation season is an evidence of deterioration of water conditions in the environment. Changing hydrothermal conditions should be the cause for determining better water management methods in agricultural production.

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Abstract. One of the measures used to evaluate the hydrothermal conditions development of a particular area is called Sielianinow's coefficient. Data used in this paper come from nine IMGW stations from central-eastern region of Poland, and they were registered between the years 1971–2005. On the basis of Sielianinow's coefficient it was determined within the vegetation season the frequency of occurrence of months in humidity classes according to Skowera and Puła criterion (2004). The paper also describes spatial distribution of Sielianinow's coefficient values in all of the vegetation season months in the area examined. Long-term changes of Sielianinow's coefficient were evaluated using regression coefficient of the linear trend and coefficient of variation. The lowest average values of Sielianinow's coefficient in all

of the months of vegetation season have been noted in western and south-western parts of the area examined. Whereas the north-eastern part has been characterized by the most favorable hydrothermal conditions. In the area examined, April was generally extremely humid or optimal month. While in May, June and August the dry months have occurred two times more often than the humid months. The significant decreasing of Sielianinow's coefficient values during the vegetation season in the years analyzed proves the increase of intensity of drought.