

Discrepancy in climatic zoning of the current soil productivity evaluation system

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Abstract: Pedologic-ecological estimation in the Czech Republic (Central Europe) means determination of land agronomic productivity and its economical pricing and is expressed as a five position numeral code and mapped as iso-lines. The first position of the code is the climatic region representing approximately the same conditions for agricultural plant growth and development. This climatic regionalization was based on the climatic data from 1901–1950. Currently, there is the need to update their existing zoning due to the technological progress of measurement and development of climate models including estimation of future climate. The aim of the paper is (i) to apply actual climatic data to climatic regionalization and (ii) to estimate what climatic conditions are relevant for actually valid climatic regions. The original methodology currently enables us to unequivocally classify only 17% of the entire territory of the Czech Republic (and 18% of Czech agricultural land). A substantial part of the territory does not fit neatly into individual climatic regions. Subsequently the actually valid ranges of climatic characteristics of individual climatic regions were determined. The GIS layers of individual climatic variables computed with data from 1961–2010 were one by one covered by GIS layers of individual climatic regions based on data from 1901–1950. Interval ranges of climatic region variables determined in this way are valid for the period 1961–2010. The upper limit of air temperature sum above 10 °C and annual air temperature in most of the climatic regions was significantly shifted up in 1961–2010. An increase in precipitation is noticeable in wet climatic regions. Moisture certainty in vegetation season and probability of dry vegetation are the most problematic in terms of Estimated Pedologic-Ecological Units (EPEU) climatic zoning. This should be taken into account when fixing the official soil price.

Key words: climatic data, the Czech Republic, production potential, soil climate development

1. Introduction

Production capacity of soils is influenced by many factors, such as arable cropping systems and crop rotation, substrate, forming the surface, etc. and is strongly influenced by the climate conditions (*Anaya-Romero et al., 2013*). Abiotic stress is a major cause of reduced yield in the case of healthy plants. In this context, many scientific research projects dealt with the impact of weather course and climate change on agricultural crops. They were primarily focused on the impact of stress evaluation – especially drought and air and soil temperature extremes. The main current problem is lack of soil water or soil drought and high air temperatures respectively. The increase in air temperature and precipitation extremity in the future across climatic conditions and types of landscapes in the Czech Republic was published by *Mužíková et al. (2011)*. The prolongation of the growing season by 15 to 25 days in the Central Europe in the last twenty years has also been proved. It is attended by an increasing risk of vegetation frost.

Production features of agricultural land in the Czech Republic and in Slovakia as well, are classified with a system of Estimated Pedologic-Ecological Units (EPEU, in Czech “BPEJ”) developed by *Mašát et al. (1974)* on the basis of a comprehensive survey of soil (CSS) carried out in the sixties. CSS was the first modern land survey for almost the whole country (except for instance Military training areas) and brought a complex genetic and agronomic classification of agricultural lands. Subsequent pedologic-ecological estimation means determination of land agronomic productivity and its economical pricing. Individual EPEU are expressed as a five position numeral code and mapped as iso-lines. A similar system is used in the Slovak Republic. The Slovak EPEU code has seven-digits and climatic region (00 to 10) occupies the first two positions (*Bielek et al., 2005*). Similarly in neighbouring countries such as Austria and Germany climatic conditions play one of the most important roles when official land prices are set (*Voltr, 2011*). EPEU is expressed with the following structure: In the first position is the climatic region (0–9) namely a region with approximately the same conditions for agricultural plant growth and development; the second and third positions indicate the main pedological unit (01–78) namely the purpose group of pedological forms with similar ecological features such as morfogetic type or subtype, pedological substrate, texture, significant slope, soil

profile depth, skeleton content and degree of hydromorphism; the fourth position characterizes land sloping and its exposition to the cardinal points; the fifth position characterizes depth of soil profile and skeleton content.

Initially the EPEU system was used mainly as a tool for rational utilization of agriculture land, optimal crop and variety location etc. After comprehensive economic evaluation of individual lands the EPEU code became a base for real estate tax. At present the EPEU system is legislatively provided under Regulation no 327/1998 Coll. and has been used for taxation purposes, estimation of official agricultural land price and taxes on the exemption of land from the agricultural land resources. In the framework of landscape management the EPEU is used for proposal of new plots and also for estimation of erosion risk. Land protection classes derived from EPEU pose a limit of local planning mainly for build-up area delimitation.

Basic climatic characteristics are thus among the parameters affecting the land prices. This climatic regionalization was based on the climatic data from the first half of 20th century 1901–1950. Employed basic climatic variables regarding the level of knowledge, technical and technological abilities of the time were: mean annual air temperature and precipitation total, mean air temperature and precipitation total in the growing season and mean annual air temperature sum above 10 °C (see Table 1).

The results of *Středová and Středa (2015)* assess changes in agroclimatic characteristics used to define climatic regions within the EPEU (averages of temperature sum above 10 °C, annual air temperature, moisture certainty in the growing season and probability of dry vegetation period) probably due to climate change and use of advanced methods for measuring meteorological elements as well as due to transition to an automatic system of measurement. The results suggest an increase of potential evapotranspiration and thus higher susceptibility of agricultural intense areas of southern and central Moravia and central Bohemia to dryness. It corresponded with the results of *Kohut et al. (2012)* which used some agroclimatic characteristics for evaluation of Czech climate development.

Anaya-Romero et al. (2015) analyzed the soils threats under climate change by using the agroecological decision support system (MicroLEIS DSS model) in the Andalusia region. Climate change is expected to impact crop growth and potential opportunity for reforestation in future climate scenarios. Soil contamination and erosion show only slight differences between the

current and future scenario of climate change.

The main aim of the paper is firstly to apply actual climatic data to the EPEU climatic regionalization and secondly to estimate what climatic conditions are relevant for actually valid climatic regions of the EPEU system.

2. Materials and methods

Climatic variables defining climatic regions of EPEU were calculated based on fifty-year climatic data from 1961 to 2010 represented by homogenous and fully completed technical series in 10 km grid based on data measured by the Czech Hydrometeorological Institute (*Štěpánek et al., 2013*). The results were spatially expressed as a map (software ArcGIS). Areas representing individual climatic regions and their total area were subsequently compared to the original map by *Mašát et al. (1974)* from 1901–1950 (Fig. 1).

Methodology (*Mašát et al., 1974*; details in *Středová and Chuchma, 2014*) defining climatic regions employed the basic climatic elements (air temperature and precipitation totals) to determine:

- Air temperature sum above 10°C (TS10) [°C];
- Mean annual air temperature (T_{AVG}) [°C];
- Mean annual precipitation total (P_{AVG}) [mm];
- Moisture certainty from April to September (MC_{IV-IX}) [mm];

Long-term mean annual MC is defined as a difference between an annual limit of drought and a long-term annual precipitation total divided by a long-term mean annual air temperature and is defined by a formula:

$$MC_{IV-IX} = \frac{P_{IV-IX} - \frac{P_{IV-IX} \cdot (3t + 21)}{P_a}}{t_{IV-IX}}, \quad (1)$$

where:

P_{IV-IX} – long-term mean precipitation total from April to September;

P_a – long-term annual precipitation total;

t – long-term mean annual air temperature;

t_{IV-IX} – long-term mean air temperature from April to September;

– *The probability of dry periods from April to September: DP_{IV–IX} [%];*
 is defined as per cent of years when the precipitation total from April to September is lower than the limit of drought from April to September (PIV–IX)

$$PIV-IX = \frac{P_{IV-IX} \cdot (3t + 21)}{P_a} \tag{2}$$

GIS layers of individual climatic variables computed with data from 1961–2010 were one by one covered by GIS layers of individual climatic region based on data from 1901–1950. Interval ranges of climatic region variables determined in this way are valid for the period 1961–2010.

Table 1. Intervals of climatic variables defining individual climatic regions (*Mašát et al., 1974*).

code	symbol	characteristic	TS10		T _{AVG}		P _{AVG}		DP _{IV–IX}		MC _{IV–IX}	
			min	max	min	max	min	max	min	max	min	max
0	VT	very warm, dry	2800	3100	9	10	500	600	30	50	0	3
1	T 1	warm, dry	2600	2800	8	9	500	600	40	60	0	2
2	T 2	warm, slightly dry	2600	2800	8	9	500	600	20	30	2	4
3	T 3	warm, slightly wet	2500	2800	(7) 8	9	550	650 (700)	10	20	4	7
4	MT 1	slightly warm, dry	2400	2600	7	8.5	450	550	30	40	0	4
5	MT 2	slightly warm, slightly wet	2200	2500	7	8	550	650 (700)	15	30	4	10
6	MT 3	slightly warm (to warm), wet	2500	2700	7.5	8.5	700	900	0	10	10	
7	MT 4	slightly warm, wet	2200	2400	6	7	650	750	5	15	10	
8	MCH	slightly cold, wet	2000	2200	5	6	700	800	0	5	10	
9	CH	cold, wet		2000		5	800		0		10	

3. Results

3.1. Application of actual climatic data to the EPEU climatic regionalization

Firstly the EPEU climatic characteristics for the period 1961–2010 were simply converted in accordance with the procedure set out in the original methodology for defining of climatic regions (*Mašát et al., 1974*). The impossibility of successful application of this procedure is demonstrated by

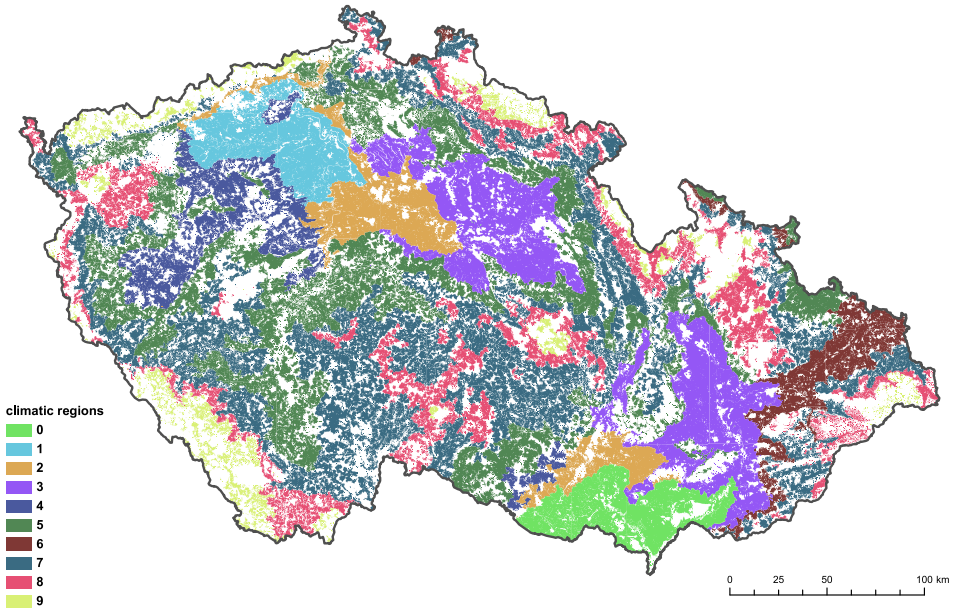


Fig. 1. Map of climatic regions defined by *Mašát et al. (1974)*.

Figs 2 to 5. Only 17% of the entire territory of the Czech Republic (Figs 2 and 3) and 18% of the agricultural land (Figs 4 and 5) can be unequivocally classified using the original methodology. A substantial part of the territory will not fit neatly into individual climatic regions, because sub intervals of climatic region characteristics overlap each other (see Table 1).

The analysis shows that in 1961–2010 some locations had to be classified for instance as “very warm, moderately dry” or “very warm, slightly wet”. Only these combinations of temperature and moisture conditions did not occur in 1901–1950 at all and thus are not included in the *Mašát et al. (1974)* methodology. The reason is probably the rising air temperature and practically unchanged precipitation totals in the updated period 1961–2010.

3.2. Definition of actually valid ranges of climatic characteristics of individual climatic regions

The upper limit of TS10 (Fig. 6) and T_{AVG} (Fig. 7) in most of climatic

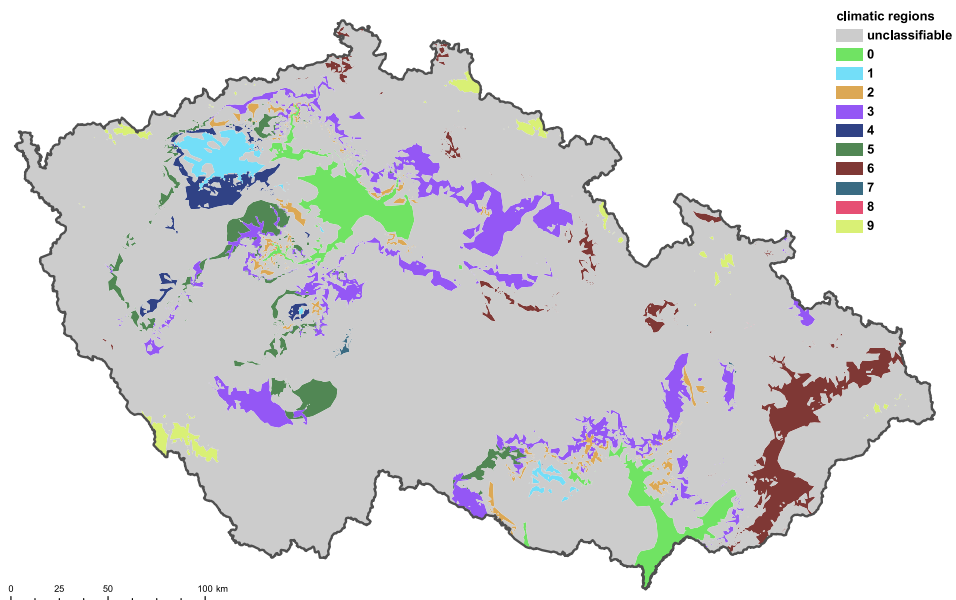


Fig. 2. Map of climatic regions based on *Mašát et al. (1974)* methodology and data from 1961–2010 for the entire Czech Republic.

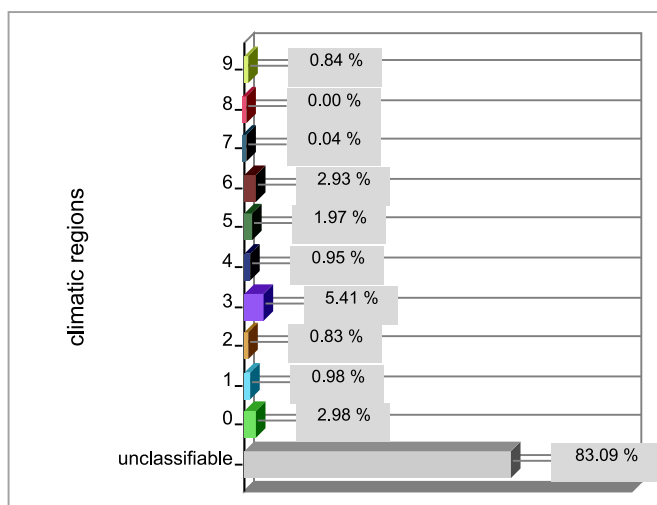


Fig. 3. Percentage of area unequivocally (un)classifiable as any climatic region based on *Mašát et al. (1974)* methodology and data from 1961–2010 for the entire Czech Republic.

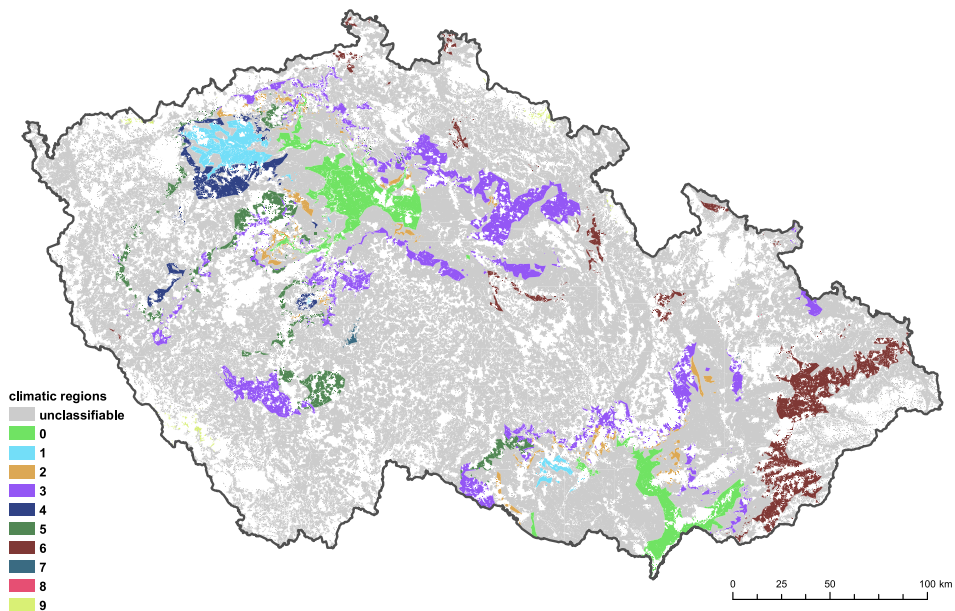


Fig. 4. Map of climatic regions based on *Mašát et al. (1974)* methodology and data from 1961–2010 for the agricultural land of the Czech Republic.

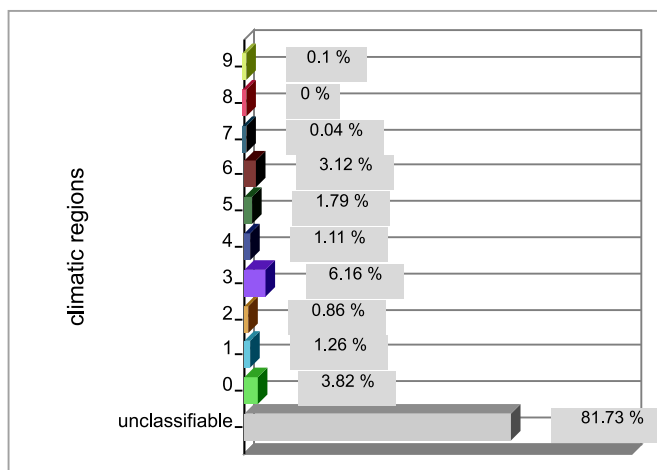


Fig. 5. Percentage of area unequivocally (un)classifiable as any climatic region based on *Mašát et al. (1974)* methodology and data from 1961–2010 for the agricultural land of the Czech Republic.

region was significantly shifted up in 1961–2010 compared to 1901–1950. An increase in precipitation (P_{AVG} , Fig. 8) is especially noticeable in the wet climatic regions 5, 7 and 8. Significant volatility of interval ranges was found in DP_{IV-IX} (Fig. 9). This parameter does not evince any unequivocal trend. The upper limit of MC_{IV-IX} (Fig. 10) for climatic regions 6–9 in the period 1901–1950 was not defined (this value was given only as greater than 10). The values found in the period 1961–2010, however, reach up to 70 (climatic region 9). Due to fluctuations in the real tens a limiting value of 10 is insufficiently precise. The above mentioned findings indicate that the particular values of MC_{IV-IX} and DP_{IV-IX} are the most problematic in terms of EPEU climatic zoning.

Evaluation based on long-term annual averages shows a shift of climatic regional boundaries compared to the values specified in the methodology *Mašát et al. (1974)*. Based on the analysis, we can state that areas representing individual climatic regions (see Fig. 1) are defined in the period 1961–2010 by climatic characteristics given in Table 2. To eliminate outliers the interval ranges were determined as 10th and 90th percentile.

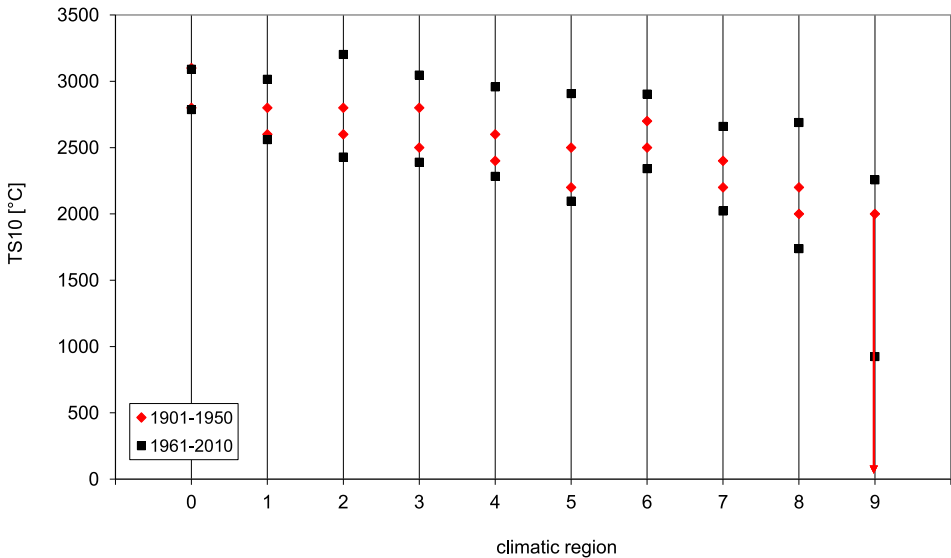


Fig. 6. Ranges of TS10 of individual climatic regions for two fifty-year periods 1901–1950 and 1961–2010.

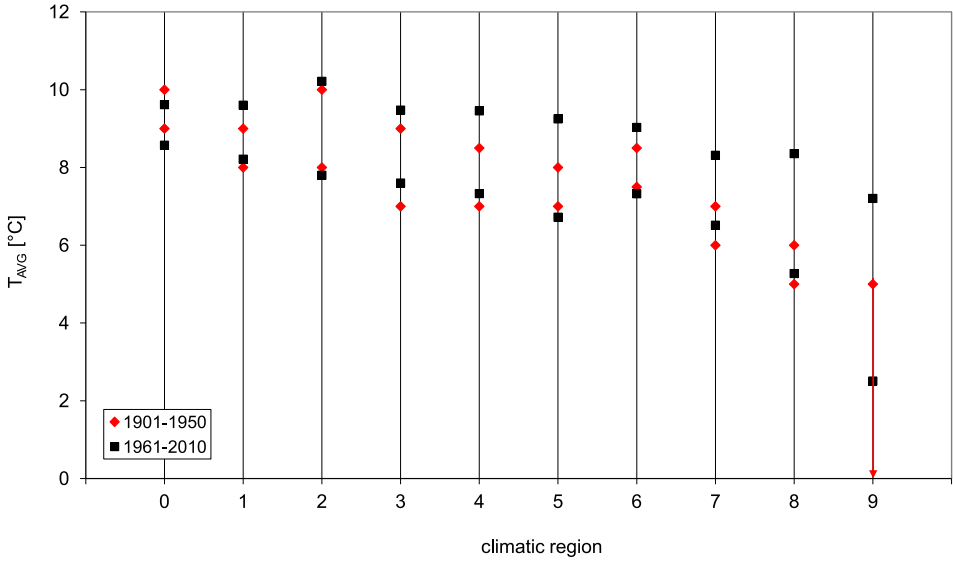


Fig. 7. Ranges of T_{AVG} of individual climatic regions for two fifty-year periods 1901–1950 and 1961–2010.

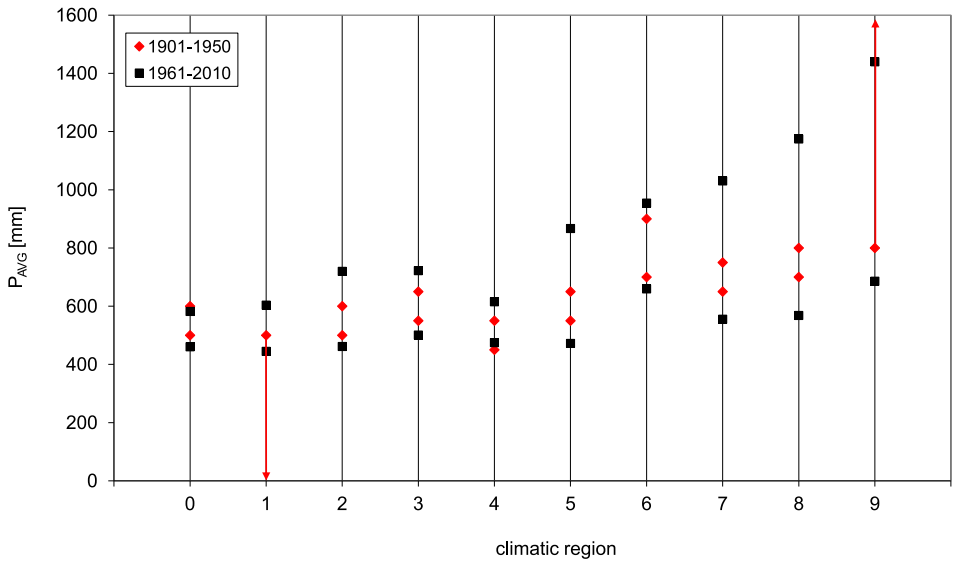


Fig. 8. Ranges of P_{AVG} of individual climatic regions for two fifty-year periods 1901–1950 and 1961–2010.

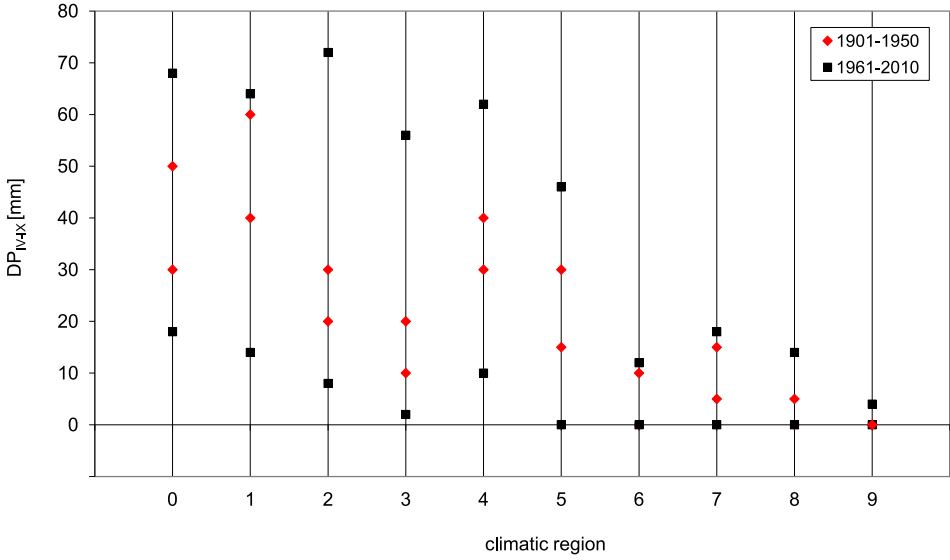


Fig. 9. Ranges of DP_{IV-IX} of individual climatic regions for two fifty-year periods 1901–1950 and 1961–2010.

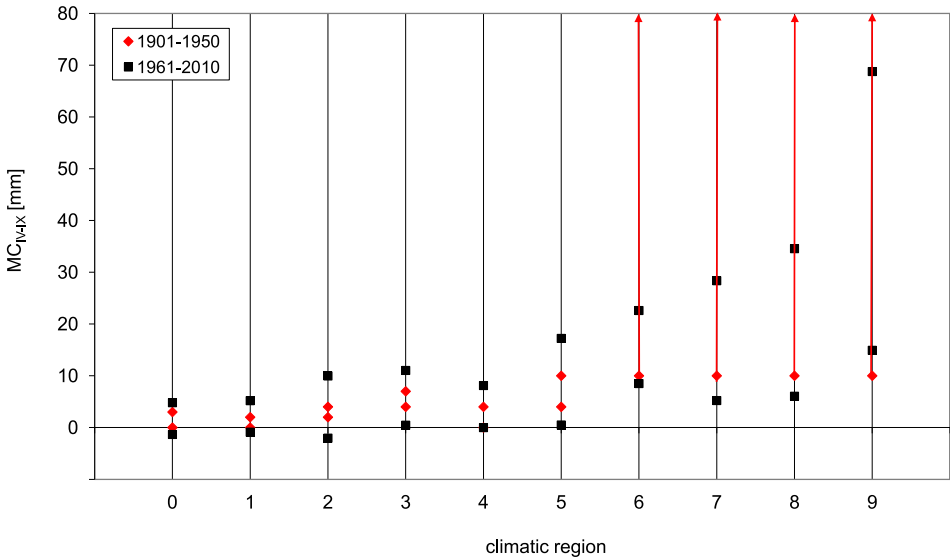


Fig. 10. Ranges of MC_{IV-IX} of individual climatic regions for two fifty-year periods 1901–1950 and 1961–2010.

Table 2. Intervals of climatic variables defining individual climatic regions based on data from 1961–2010 stated as values of 10th and 90th percentile.

code	symbol	characteristic	TS10*		T _{AVG}		P _{AVG} *		DP _{IV-IX} **		MC _{IV-IX}	
			10 th perc.	90 th perc.	10 th perc.	90 th perc.	10 th perc.	90 th perc.	10 th perc.	90 th perc.	10 th perc.	90 th perc.
0	VT	very warm, dry	2910	3070	9	10	480	560	0	65	-1	3
1	T 1	warm, dry	2610	2930	8	9	460	550	20	60	0	4
2	T 2	warm, slightly dry	2590	3000	8	9	480	620	20	55	0	6
3	T 3	warm, slightly wet	2610	2880	8	9	550	660	5	30	4	8
4	MT 1	slightly warm, dry	2400	2790	8	9	490	570	15	40	1	6
5	MT 2	slightly warm, slightly wet	2330	2720	7	8	540	690	0	20	4	11
6	MT 3	slightly warm (to warm), wet	2500	2830	8	9	660	840	0	10	9	18
7	MT 4	slightly warm, wet	2190	2500	7	8	600	810	0	10	8	18
8	MCH	slightly cold, wet	1900	2330	6	7	640	950	0	5	11	24
9	CH	cold, wet	1380	2110	4	7	760	1260	0	0	18	48

* rounded to nearest ten
 ** rounded to nearest five

4. Conclusion

Currently, approximately 60 years after the end of the reference period used for the climatic regions of the EPEU determination (1901–1950) it is necessary to update the existing zoning. A very important factor of actual discrepancy in this climatic zoning is climate change. Air temperature increase as well as changes in character of precipitation and its annual distribution have been globally recorded since the early 19th century. It is expected that this trend will continue. Weather fluctuations resulting in extreme weather events will become more frequent and intense with various impacts in different regions.

Further important reasons to update the EPEU climatic zoning include technical progress and technological development (improved measurement technology, automation of the measurement etc). Meteorological measurements are dependent on the knowledge of physics since devices often measures physical quantities and convert them into values of meteorological elements. Along with technical development the methodologies of meteoro-

logical measurements are changing. The network of climatological stations is also denser and data series are longer. Advanced climate models have been developed and enabled simulation of complex characteristics and estimation of future climate conditions using climate change scenarios and climate models. Currently it is possible to use homogenized technical data series in grid 10 km for the whole country. Comprehensive agroclimatic characteristics can be successfully modelled with various agro climatic models.

For these reasons, the comparisons carried out in this paper is not just expressions of changed climatic conditions due to climate change but rather the tool, which can help explain the causes of EPEU climatic zoning discrepancy in the present. Results show which climatic conditions actually correspond to individual climatic regions. In any case, we are not criticizing the previous evaluation, but pointing out that it is not really representative of the current conditions.

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