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ORIGINAL PAPER

Climate change in Hungary during the twentieth century according to Feddema

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Abstract Climate change in Hungary during the twentieth century is analyzed using Feddema's original scheme suitable for global scale applications (F-GS) and Feddema's fine-tuned scheme designed for Hungarian applications (F-HU). Input data of precipitation (P) and air temperature (T) are taken from the Climatic Research Unit (CRU) TS 1.2 database constructing P-T data referring to three 30-year periods (1901–1930, 1941–1970, 1971–2000) and two 50-year periods (1901–1950, 1951–2000). The method and data organizational effects are compared using these schemes and data sets. The results show that the evaluation of the climate change process depends much more on the methodological rather than on data organizational effects. Methodical fine-tuning effects considerably improved the spatial distribution, while the organization of data improved the insight into the dynamic of the processes. According to F-GS, there is no climate change on 76.7 % of Hungarian territory. According to F-HU, such areas amount to only 38.5 %. The main climate change process for F-GS is drying, while for F-HU drying and warming beside either drying or warming. For both models, the most climate change affected areas are characterized by higher altitudes, such as in the Mecsek and Villány Mountains (geographical region Transdanubia), in the Bükk Mountains (geographical region North Hungarian Mountains), and in the region of the so-called Danube Bend. The spatially most realistic climate description is obtained by using F-HU and the 30-year data sets. It is to be noted that Köppen's, Holdridge's, and Thornthwaite's methods are less suitable than F-HU for representing the process of climate change in Hungary in the twentieth century.

1 Introduction

Today, there is an abundance of studies considering climate change in the Carpathian Basin based on measurements. Many of them deal only with some selected elements, such as, for instance, precipitation (P) and air temperature (T) using non-homogenized (e.g., Domonkos and Zoboki 2000) and homogenized (e.g., Lakatos et al. 2013) data time series. However, climate change could not be well described by discussing only the time tendencies of a number of important elements. The description should be performed rather by applying biophysical climate classifications because of the strong connection between vegetation and climate (Gates 1993).

For Hungary, the first state of the art attempt using Köppen's method (Köppen 1923) was made by Fábián and Matyasovszky (2010). They considered the 1971–2060 period using monthly values of Climatic Research Unit (CRU) TS 1.2 (Mitchell et al. 2004) and TYN SC 1.0 data (Mitchell et al. 2004) in the spatial resolution of 1/6° × 1/6°. They showed an increase in the inter-annual variability and a decrease in the spatial variability of climate formulae. Climate change in the last century is also analyzed by Holdridge's method (Holdridge 1947), e.g., by Ács and Breuer (2013) and Szelepcsényi et al. (2014).

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CRU TS 1.2 precipitation and air temperature data were used in the spatial resolution of 1/6° × 1/6°. Both drying and warming processes are detected. The drying process occurred via transformation of cool-temperate moist forest to cool-temperate steppe, while the warming process via cool-temperate moist forest to warm-temperate dry forest transformation. Similarly to Holdridge's (1947) method, the climate change process is also detected by Thornthwaite's (1948) method analyzing the annual water and heat availability. The Carpathian Basin is considered in the period 1951–2100 using ensemble averaged P-T results of different regional climate models run in the resolution of 25 km × 25 km supposing A1B CO_2 emission scenario in the scope of ENSEMBLES project (van der Linden and Mitchell 2009). The climate change is analyzed for HIRHAM (HIRLAM (High Resolution Limited Area Model) + ECHAM (ECMWF, Hamburg)) and ARPEGE (Action de Recherche Petite Echelle Grande Echelle) model runs. According to Thornthwaite (1948), the drying process is reflected via dry, subhumid (symbol C1) to semiarid (symbol D) transformation in the Great Hungarian Plain, while the warming process via mesothermal B1' (potential evapotranspiration (PET) ranges between 570 and 712 mm) to mesothermal B2' (PET ranges between 712 and 855 mm) transformation on the whole territory.

In this work, Feddema's (2005) method as a simplified Thornthwaite's (1948) method for classroom applications is used. The analysis of climate change in Hungary during the twentieth century is performed by using Feddema's original model suitable for global scale applications (F-GS) as well as by its fine-tuned (Ács et al. 2015) version designed for Hungarian applications (F-HU). Precipitation (P) and temperature (T) data are taken from the CRU TS 1.2 database generated by the Climatic Research Unit (Mitchell et al. 2004). The analysis is performed using data of three 30-year periods (1901–1930, 1941–1970, 1971–2000) and two 50-year periods (1901–1950, 1951–2000). Our goal is to present the main results comparing the model and data organizational effects.

2 Method and data

The climate change process is investigated by comparing climate types referring to 30- and 50-year periods. The beginning (1901–1930), the middle (1941–1970), and the end (1971–2000) of the century could be treated using 30-year periods. When averaging data over 50-year periods, the treatment referring to the middle period is implicitly lacking. For reasons of simplicity, the treatment is illustrated

Table 1 The climate and the possible climate change types in Hungary during the twentieth century according to Feddema's (Ács et al. 2015) original scheme

Period	1971–2000				
	Type	Cool, dry, extreme T fl.	Cool, dry, high T fl.	Cool, moist, high T fl.	Cool, moist, high P and T fl.
1901–1930	Cool, dry, extreme T	No change	Decrease of seasonal ch.	- Wetting - Decrease of seasonal ch.	- Wetting - Decrease of seasonal ch. - T → (P and T)
	Cool, dry, high T	Increase of seasonal ch.	No change	Wetting	- wetting - T → (P and T)
	Cool, moist, extreme T	Drying	- Drying - Decrease of seasonal ch.	Decrease of seasonal ch.	- Decrease of seasonal ch. - T → (P and T)
	Cool, moist, high T	- Drying - Increase of seasonal ch.	Drying	No change	- T → (P and T)
	Cold, moist, high T	- Warming - Drying - Increase of seasonal ch.	- Warming - Drying	Warming	- Warming - T → (P and T)

ch. change, *fl.* fluctuation

brief only for the periods 1901–1930 and 1971–2000 for both the original and fine-tuned model versions.

2.1 Feddema—original scheme

The climate and the possible climate change types in Hungary during the twentieth century according to F-GS (Feddema 2005) are presented in Table 1. The climate type cool and dry with extreme seasonality of T can transform into three climate types of different annual and/or seasonal characteristics. The greatest climate change type is described in the last column; it is represented by wetting and by a decrease in the magnitude of the seasonal variability of T as well as by the change of the type of seasonality (not only T but also P and T possess seasonal variability). Similar changes could be seen for climate type cool and dry with high seasonality of T. Climate change types of drying refer to climate types cool and moist with extreme or high seasonality of T. In these cases, the magnitude of seasonal variability of T can increase as well as decrease. Climate type cold and moist with high seasonality of T can transform into four climate types. Here, the greatest possible climate change type is represented via warming and drying with an increasing seasonal variability of T.

2.2 Feddema—fine-tuned scheme

There is an abundance of climate types according to Feddema's (Ács et al. 2015) fine-tuned scheme during the twentieth century. Consequently, there is also an abundance of possible climate change types during the course of the twentieth century. Their review cannot be carried out as simply as in the previous section. Therefore, the annual and the seasonal characteristics of climate and climate change types will be considered separately.

2.2.1 Annual characteristics

Annual characteristics of the climate types and the possible climate change types in Hungary during the twentieth century according to Feddema's (Ács et al. 2015) fine-tuned scheme are presented in Table 2. Two basic parts can be distinguished. In each of them, there are so-called "single" changes, as, e.g., warming or cooling and drying or wetting.

Table 2 Annual characteristics of the climate and the possible climate change types in Hungary during the twentieth century according to Feddema's (Ács et al. 2015) fine-tuned scheme

Period	1971–2000								
	Type	mC, D	mC, mD	mC, mM	mC, M	C, D	C, mD	C, mM	C, M
1901–1930	m cool, dry	–	M+	M+	M+	T–	T– M+	T– M+	T– M+
	m cool, m dry	M–	–	M+	M+	T– M–	T–	T– M+	T– M+
	m cool, m moist	M–	M–	–	M+	T– M–	T– M–	T–	T– M+
	m cool, moist	M–	M–	M–	–	T– M–	T– M–	T– M–	T–
	cool, dry	T+	T+ M+	T+ M+	T+ M+	–	M+	M+	M+
	cool, m dry	T+ M–	T+	T+ M+	T+ M+	M–	–	M+	M+
	cool, m moist	T+ M–	T+ M–	T+	T+ M+	M–	M–	–	M+
	cool, moist	T+ M–	T+ M–	T+ M–	T+	M–	M–	M–	–
	cold, m moist	T+ M–	T+ M–	T+	T+ M–	T+ M–	T+ M–	T+	T+ M+

m moderately, *C* cool, *D* dry, *M* moist, *T+* warming, *T–* cooling, *M+* wetting, *M–* drying

Similarly, the so-called "double" changes are, e.g., warming and drying (in brief warming/drying) or warming/wetting. In the upper left part of Table 2, the typical possible single change type is drying, while in the lower left part, the typical possible double change type is warming/drying. Note that the double change type warming/wetting is in the left, central part of Table 2. The right part of Table 2 can be treated analogously. In its upper, right part, the double change type cooling/wetting is prevailing. Progressing downwards this double change type transforms into single change type wetting. Note that double change type cooling/drying can also be found in the right, central part of Table 2.

2.2.2 Seasonal characteristics

The seasonal characteristics of climate and the possible climate change types related to seasonal characteristics in Hungary during the twentieth century according to Feddema's (Ács et al. 2015) fine-tuned model version are presented in Table 3.

Similarly to annual characteristics, there are also so-called "single" and "double" seasonal changes. There are three single seasonal change types in total: decrease of the magnitude of seasonal variability, increase of the magnitude of seasonal variability, and the transformation of the seasonality of T into the seasonality of P and T. The only double seasonal change type is characterized by transformation of the seasonality of T into the seasonality of P and T when the seasonal change of T decreases. All possible climate change types could be obtained by multiplying annual (9 cases) and seasonal (4 cases) change types, this is 36 in total.

2.3 Data

Monthly mean temperature and monthly precipitation data are used from the Climatic Research Unit (CRU), the well-known climate data center of the University of East Anglia. Data refer to the period 1901–2000, the spatial resolution used is $10' \times 10'$ ($\approx 18 \times 18$ km^2), as part of the CRU TS 1.2 database (Mitchell et al. 2004). Each grid point represents 2400 monthly data. The region studied is Hungary together with neighboring countries located between the 16°–23° E/45.17°–49° N longitude/latitude lines. It contains 1032 grid points. The region, Hungary, and its main geographical regions and mountains are presented in Fig. 1.

3 Results

3.1 Climate change in Hungary—original model version

3.1.1 Thirty-year periods

The spatial distribution of climate change types in Hungary in the twentieth century (period between 1901–1930 and 1971–2000) according to Feddema's (2005) original scheme is presented in Fig. 2.

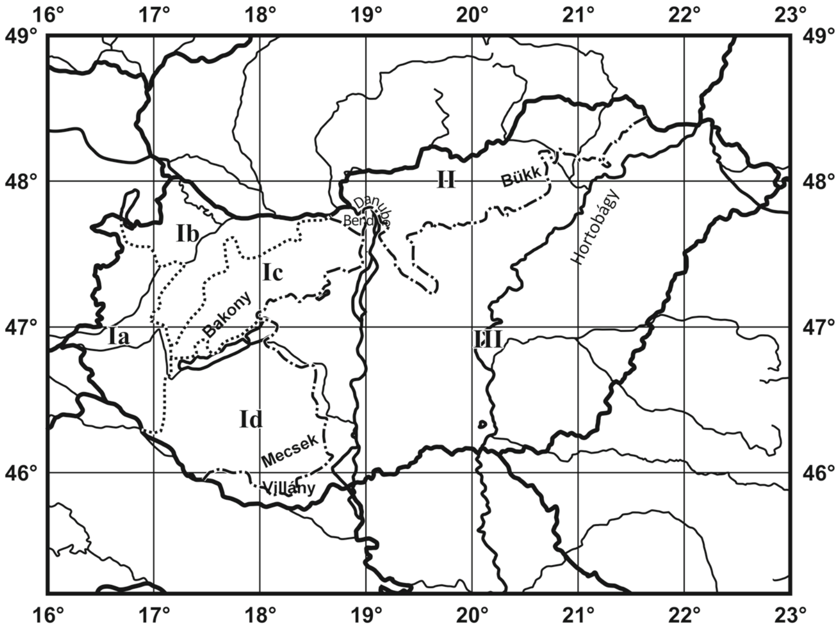
Over large areas (Great Hungarian Plain, Little Hungarian Plain), on precisely 76.7 % of Hungarian territory, there is

Table 3 Seasonal characteristics of the climate and the possible climate change types related to seasonal characteristics in Hungary during the twentieth century according to Feddema's (Ács et al. 2015) fine-tuned scheme

Period	1971–2000					
	Type	Extreme T fl.	Close to extreme T fl.	Very high T fl.	High T fl.	High P and T fl.
1901–1930	Extreme T	–	decr. of seasonal ch.	decr. of seasonal ch.	decr. of seasonal ch.	decr. of seasonal ch. T → (P and T)
	Close to extreme T	incr. of seasonal ch.	–	decr. of seasonal ch.	decr. of seasonal ch.	- decr. of seasonal ch. - T → (P and T)
	Very high T	incr. of seasonal ch.	incr. of seasonal ch.	–	decr. of seasonal ch.	- decr. of seasonal ch. - T → (P and T)
	High T	incr. of seasonal ch.	incr. of seasonal ch.	incr. of seasonal ch.	–	T → (P and T)

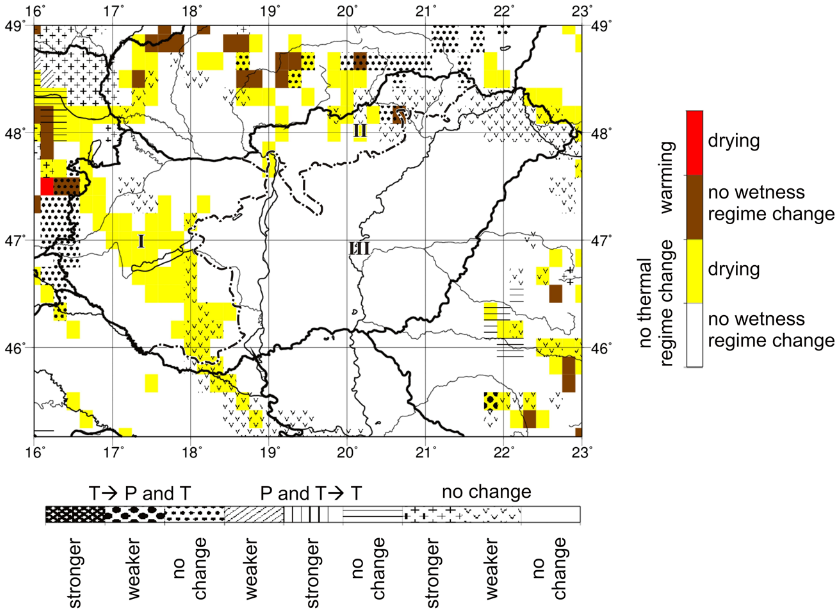
ch. change, *fl.* fluctuation, *incr.* increase, *decr.* decrease

Fig. 1 The region considered and Hungary with its main geographical regions and mountains. *I* Transdanubia (subregions: *Ia* Alpokalja region, *Ib* Little Hungarian Plain, *Ic* Transdanubian Mountains, *Id* Transdanubian Hills), *II* North Hungarian Mountains, and *III* Great Hungarian Plain. The main mountains are denoted on the map



no climate change at all. The climate change is characterized by its annual and seasonal characteristics. The main annual characteristic is drying with no changes in thermal regime. These areas amount to about 13 % of the country. This process is dominant in some parts of the North Hungarian Mountains, in the Danube Bend region (border between the geographical regions of Transdanubia and the North Hungarian Mountains), in the Bakony and Mecsek Mountains as well as in the region of the Transdanubian Hills. There is only one pixel (0.2 % of Hungarian territory) in the North Hungarian Mountains where the climate is becoming warmer without changes in the wetness regime. The seasonality of climate has also changed in some parts of country. Its type remained unchanged but its strength weakened (legend: small “v”) in about 11 % of Hungarian territory; this occurred in large parts of the Bükk Mountains, in the northeastern parts of the country near to the Ukraine boarder, in the Mecsek Mountains, and in the southern parts of the Little Hungarian Plain. Note that in some parts of the Bükk Mountains, the type of seasonality also changed (Fig. 1, two pixels). In two pixels, the seasonality of T changed to the seasonality of P and T (legend: black dots). This change could be observed not only at the border with Slovakia but also at the

Fig. 2 The spatial distribution of climate change types in Hungary in the twentieth century based on 30-year datasets (period between 1901–1930 and 1971–2000) according to Feddema’s original scheme



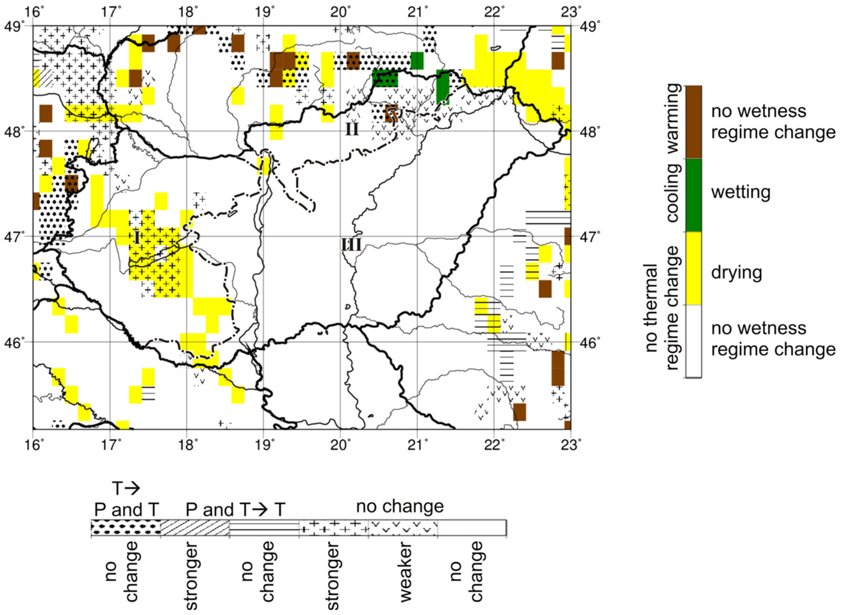


Fig. 3 The spatial distribution of climate change types in Hungary at the beginning (period between 1901–1930 and 1941–1970) of the twentieth century according to Feddema's original scheme

border with Austria as a larger homogeneous area. It is to be noted that there are no large areas (only about 3–4 %) where the climate change is characterized by change in both annual and seasonal characteristics. These areas can be found mostly in Transdanubia, in the Mecsek and Villány Mountains, and at the borders with Slovakia and Ukraine.

Figure 2, by its nature, cannot show anything about the dynamic of the changes. Some insight about the dynamic of the changes is given by Figs. 3 and 4. Figure 3 represents climate change in the first half, while Fig. 4 in the second half of the century. The results unequivocally suggest that the climate change was greater in the first half of the century than in the second. It is obvious that Figs. 2 and 3 are very similar. Beside the similarities, there are two important differences. Around Lake Balaton, the seasonal variability is becoming stronger (legend: symbol "+"), while in some areas of the North Hungarian Mountains, the climate is becoming wetter. In the second half of the century (Fig. 4), the process of drying proceeds but with less intensity. Note that at the border of Hungary and Slovakia, there were also areas where the process of wetting was registered.

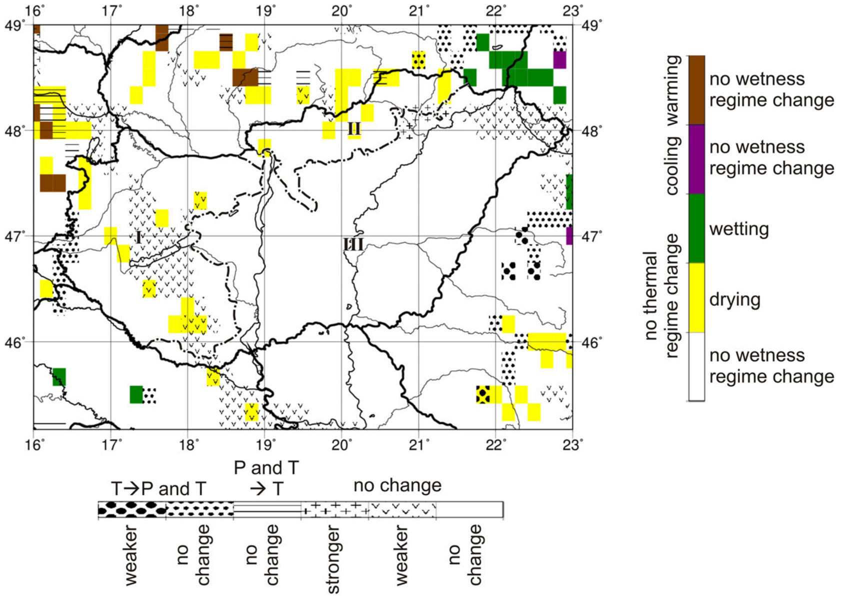


Fig. 4 The spatial distribution of climate change types in Hungary at the end of the twentieth century (period between 1941–1970 and 1971–2000) according to Feddema's original scheme

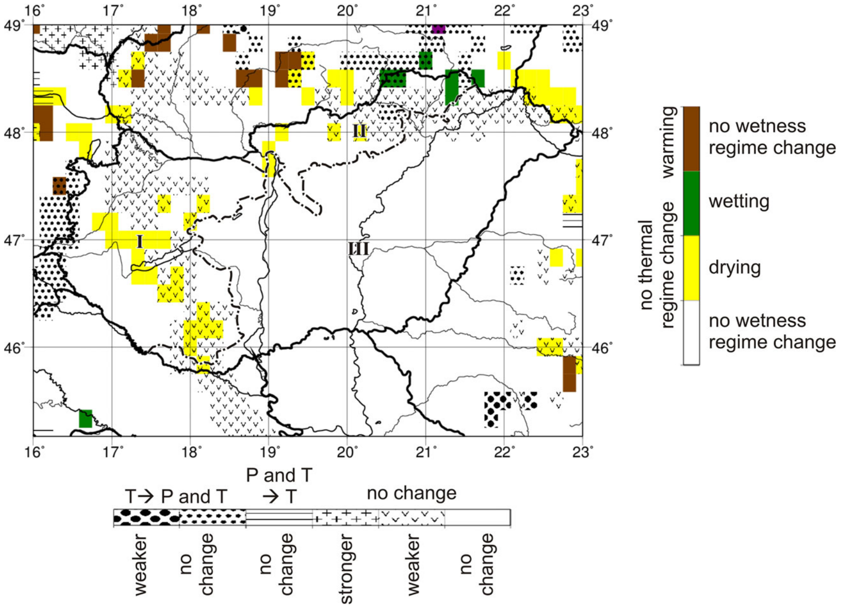


Fig. 5 The spatial distribution of climate change types in Hungary in the twentieth century based on 50-year datasets (periods between 1901–1950 and 1951–2000) according to Feddema's original scheme

3.1.2 Fifty-year periods

The spatial distribution of climate change types in Hungary in the twentieth century based on 50-year datasets (periods between 1901–1950 and 1951–2000) according to Feddema's original scheme is presented in Fig. 5.

Setting aside differences in the seasonal variability, Fig. 5 is very similar to Fig. 3. In other words, in the region of the Transdanubian Mountains and Hills, drying is the typical process, while in the region of the North Hungarian Mountains, both the processes of drying and wetting could be registered. In the majority of areas, the magnitude of the seasonal variability decreased, similarly to Fig. 2.

3.2 Climate change in Hungary fine-tuned model version

3.2.1 Thirty-year periods

The spatial distribution of climate change types in Hungary in the twentieth century (periods between 1901–1930 and 1971–2000) according to Feddema's (Ács et al. 2015) fine-tuned scheme is presented in Fig. 6.

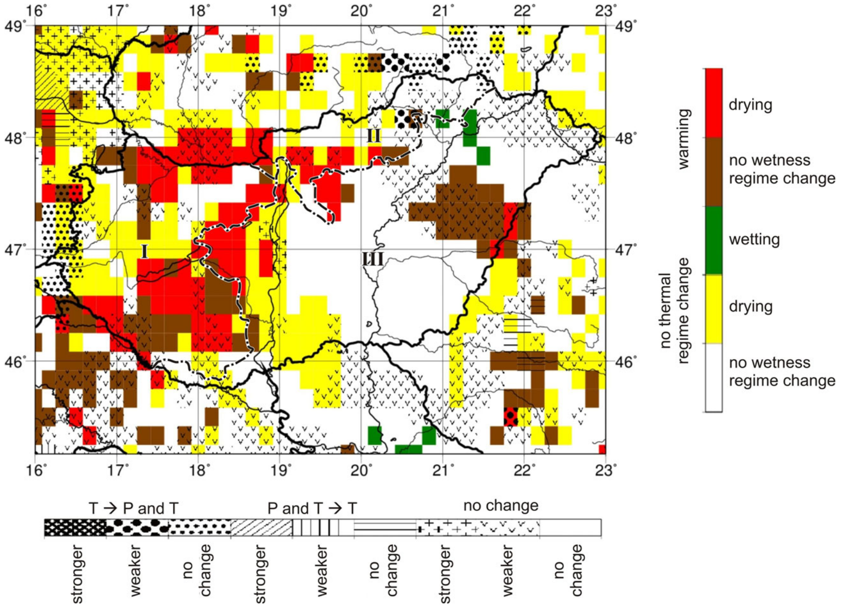
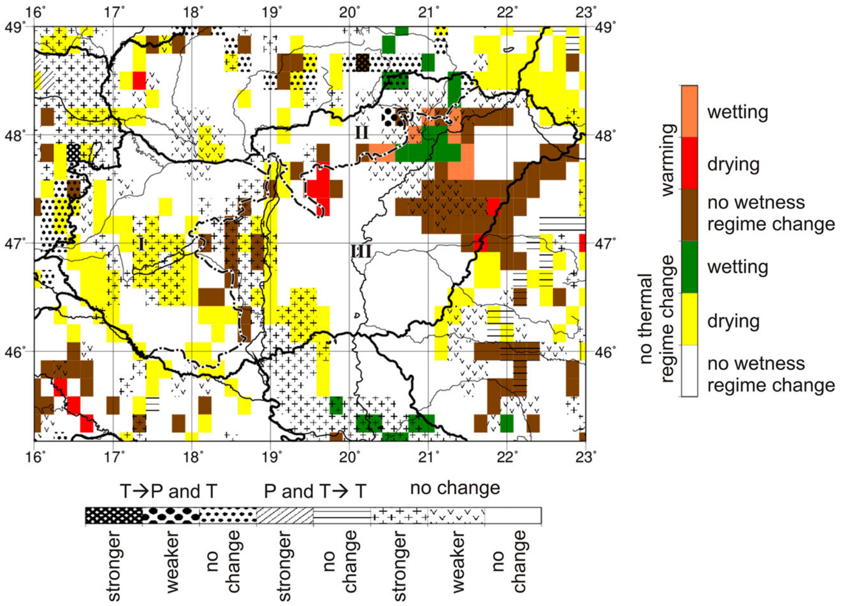


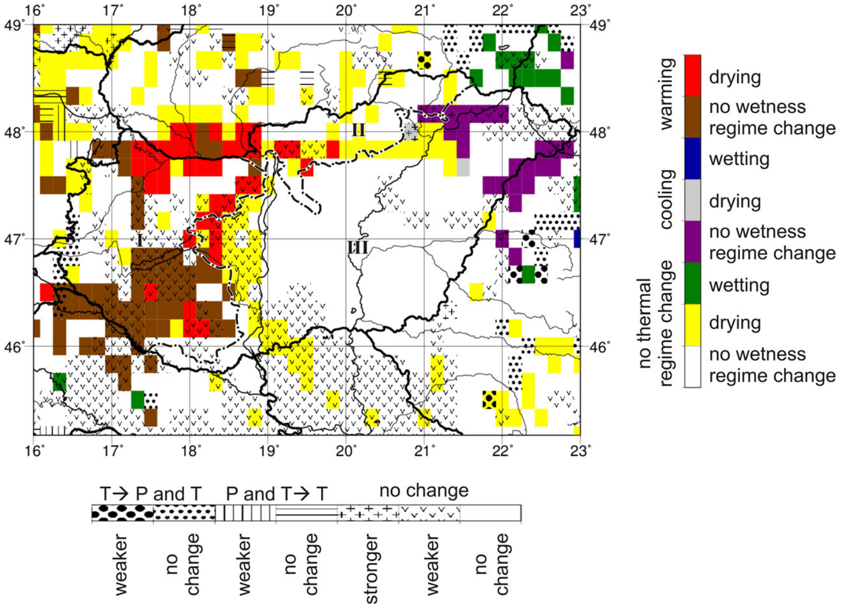
Fig. 6 The spatial distribution of climate change types in Hungary in the twentieth century based on 30-year datasets (periods between 1901–1930 and 1971–2000) according to Feddema's fine-tuned scheme

Fig. 7 The spatial distribution of climate change types in Hungary at the beginning (period between 1901–1930 and 1941–1970) of the twentieth century according to Feddema's fine-tuned scheme



The changes show a much more complicated structure than for Feddema's original scheme. There are no changes on relatively large, central and northeastern areas of the Great Hungarian Plain (about 38 % of the Hungarian territory). However, warming without wetness regime changes is observable in large parts of the Hortobágy region, in the Bükk Mountains, in the northern parts of the Mecsek Mountains, in the Transdanubian Hills, and in some areas close to the Austrian and Croatian borders. Drying without thermal regime changes is also noticeable. This is registered at the border with Ukraine, in the North Hungarian Mountains, along the Danube river, in the Transdanubian Mountains, and in the Alpokalja region. The largest changes (12–13 % of Hungarian territory), warming and drying together, occurred in some areas on the border with Romania, in central parts of Transdanubia, in the Little Hungarian Plain extending up to the Danube Bend region, and along the Drava River on the Croatian border. The seasonal characteristics of climate also changed; however, the territory of these changes is smaller than the territory of changes of annual characteristics. In most cases, the type of seasonality remained unchanged, while its strength became weaker. This could be observed in eastern and northeastern parts of the country as well as in central and southern regions of Transdanubia. Note that the strength of seasonality has been stronger in some areas along the Danube. It is also to be

Fig. 8 The spatial distribution of climate change types in Hungary at the end of the twentieth century (period between 1941–1970 and 1971–2000) according to Feddema's fine-tuned scheme



noted that there are areas where the strength of seasonality is unchanged but its type did change. This occurred in the Alpokalja region and at the border with Slovakia, where the seasonality of T changed to the seasonality of both T and P (legend: small dots). The largest changes (type and strength) in the seasonality (legend: large dots) were in the Bükk Mountains. Summarizing, the largest changes were registered in northern parts of the Mecsek Mountains and in the Villány Mountains close to the Croatian border, along the Danube River in the Little Hungarian Plain and on eastern areas close to the Romanian border.

Figure 6, similarly to Fig. 2, does not say anything about the dynamic of the changes. Some basic information concerning this can be obtained by inspecting Figs. 7 and 8. Figure 7 refers to the first half of the century, while Fig. 8 to the second.

Comparing Figs. 7 and 8, it is salient that drying and warming of the Little Hungarian Plain was an intense process as it supervened in the second half of the century. Warming in the region of the Transdanubian Hills occurred also in the second half of the century, in spite of this, warming in the Hortobágy region (east Hungary) and drying in the region of the Transdanubian Mountains and Hills as well as in the Alpokalja region happened in the first part of century. Beside the similarities of Figs. 6 and 8, there is also a noticeable difference between them. According to Fig. 8, a cooling process occurred in some eastern, northeastern parts of the Great Hungarian Plain. At the same time, according to Fig. 6, this cooling process does not exist. The magnitude of seasonal variability changes during the twentieth century. In the first part of the century, seasonal variations became stronger in the central part, but weaker in the eastern, northeastern parts of the country. In the second part of the century, the magnitude of seasonal variability decreased in the whole country.

3.2.2 Fifty-year periods

The spatial distribution of climate change types in Hungary in the twentieth century based on 50-year datasets (periods between 1901–1950 and 1951–2000) according to Feddema's fine-tuned scheme is presented in Fig. 9.

The difference between Figs. 9 and 6 is large. The areas affected by the climate change are smaller, at the same time the heterogeneity of climate change types is unequivocally larger in Fig. 9 than in Fig. 6. In Fig. 9, almost all "single" and "double" type changes could be observed: among "single" type processes drying and warming in the region of Transdanubia, wetting and cooling in the region of the North Hungarian Mountains and in the northeastern parts of the Great Hungarian Plain. Among "double" type processes, the process of drying plus warming occurred not only in Transdanubia but also in the region of the North Hungarian Mountains or in its vicinity. Concerning seasonal variability, there are no basic differences between Figs. 9 and 6.

4 Future tendencies and consequences

The main climate change processes in Hungary during the twentieth century are drying and warming. Both are typical in the Transdanubian region but they are also observable in some areas of the Great Hungarian Plain and the North Hungarian Mountains. Drying and warming will continue in the twenty-first century (Bartholy 2006; Belda et al. 2015),

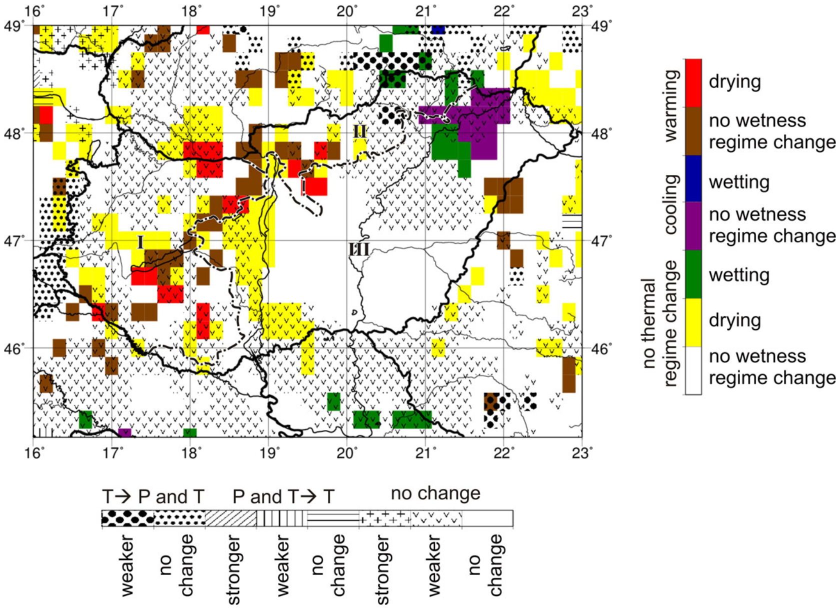


Fig. 9 The spatial distribution of climate change types in Hungary in the twentieth century based on 50-year datasets (periods between 1901–1950 and 1951–2000) according to Feddema's fine-tuned scheme

and the consequences induced will be pronounced not only in the ecosystem (e.g., considerable reduction of forests) but also in human society (e.g., mortality rate, agriculture). To be able to overcome destructive effects, adaptation is needed on both the individual and societal levels. This includes a range of adaptations; without being exhaustive, we will mention only some of the most important of these.

Water management has to be improved to mitigate fairly frequent drought and flood effects. For instance, the concept of "fighting the flood" should be replaced with "living with the flood," that is, as much water should be stored as possible (construction of flood plains, small and medium size water reservoirs; preferring cost-efficient, ecologically based land use strategies). This new program is under implementation by the Government entitled the Vásárhelyi Plan (Harkányi 2010). In the agricultural sector, drought-tolerant crop varieties should be preferred by using water preserving tillage technologies (for instance, mulching and appropriate stubble-field management). Plant breeding is to be expected to be the basic tool in achieving the threefold demand: grain quality, quantity, and yield stability (Jolánkai 2010). Irrigation as the best means for reducing drought damage should be more often used, especially for corn and sunflower areas (about 50–60 % of the total agricultural area) in the middle summer time period. Varietal structure changes in viticulture are also to be expected because of the warming. After Mesterházy et al. (2014), white wine grapes will likely lose their dominance over red wine grapes and the probability of the ripening of late-ripening and very late-ripening varieties will increase. Consequently, wine processing and storage procedures will be also gradually change. The largest changes are expected in the composition and productivity of the forests, since warming and drying effect are the strongest even in the period of the main growth cycle. This is showed and analyzed for the Transdanubian region in terms of forestry climate categories by Führer et al. (2013) using different climate data. A similar analysis, but in a broader context, was also performed by Führer et al. (2011). Czúcz et al. (2011) also showed that based on climate model results, the bioclimatic conditions will decrease dramatically the suitable areas for beech and sessile oak forests. The expected losses in productivity cannot be avoided, only mitigated by supporting forest activities that enhance the fixation of atmospheric carbon dioxide. Last but not least, some extreme weather events related to warming could have detrimental effect on public health. Heat waves and high summer temperatures contribute to a statistically significant increase in the mortality rate of all ages (e.g., Páldy et al. 2005). In this case, and in many other cases, adaptation on the individual level is also needed.

5 Concluding remarks

The climate change process in Hungary during the twentieth century is analyzed by using Feddema's (2005) original scheme suitable for global scale applications and Feddema's (Ács et al. 2015) fine-tuned scheme designed for Hungarian applications. P-T data are taken from the CRU TS 1.2 database generated by the Climatic Research Unit (Mitchell et al. 2004). The analysis is presented using data of three 30-year periods (1901–1930, 1941–1970, 1971–2000) and two 50-year periods (1901–1950, 1951–2000). So, it was possible to compare the methodological and the data organizational effects.

The main outcomes are as follows:

- In case of Hungary, the picture of the climate change process depends much more on the methodological than on data organizational effects. Methodical effects considerably improved the spatial distribution, while the organization of data improved the insight into the dynamic of the processes.
- According to F-GS, the climate remained unchanged on 76.7 % of the Hungarian territory (practically the entire Great Hungarian Plain), while according to F-HU on 38.5 %. The main climate change process for F-GS is drying, while for F-HU drying and warming beside either drying or warming. Beside the differences, there are also important agreements. For both methods, the most intense climate change areas are in the Mecsek and Villány Mountains (geographical region Transdanubia), in the Bükk Mountains (geographical region North Hungarian Mountains), and in the region of the so-called Danube Bend.
- F-HU showed greater sensitivity to data organization than F-GS. F-HU registered processes of wetting and cooling beside processes of drying and warming. This could be observed in the northeastern parts of the Great Hungarian Plain and in some eastern areas of the North Hungarian Mountains (Figs. 8 and 9). According to F-HU and 30-year data, warming of the Little Hungarian Plain occurred during second half of the century.
- Summarizing: The most realistic regional climate characteristics are obtained by using F-HU and 30-year data sets. We suggest at least three periods representing the beginning, the middle, and the end of the century.

It is to be noted that the results of F-HU possess greater spatial variability than the results obtained by other well-known methods (Ács and Breuer 2013). Most precisely, Köppen's, Holdridge's, and Thornthwaite's methods are less suitable than F-HU for representing the process of climate change in Hungary in the twentieth century.

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