COENOSES 12(1):33-41, 1997
© C.E.T.A., Gorizia, Italy

SPATIAL AND TEMPORAL CHANGES IN THE FREQUENCY OF CLIMATIC YEAR TYPES IN THE CARPATHIAN BASIN

B. Zólyomi[1*], M. Kéri[2] & F. Horváth[3]

1 Geographical Research Institute Hungarian Academy of Sciences, Andrássy út 62, H-1062 Budapest.
2 Hungarian Meteorological Service, Kitaibel P. u. 1, H-1024 Budapest.
3 Ecological and Botanical Research Institute, Hungarian Academy of Sciences, Vácrátót, H-2163 Hungary (address for reprint requests).

Keywords: Aridification, Climatic regions, Eco-climate, Europe, Köppen's climatic classification, Pontic, Submediterranean.

Abstract. The climatic description of the Carpathian Basin's typically transitional climate is approached through the concept of "climatic year types" for the years 1891-1990. With the help of the frequency of annual precipitation curve types, characteristic of the individual climates, major climate fluctuations are detected. An undoubted trend is the increasing frequency of "steppe years", i.e. definite aridification. European-Continental and Pontic-Mediterranean precipitation curve types spread at the expense of the Atlantic-Submediterranean types in the second half of this century. The growing frequency of Köppen's class C climate indicates amelioration.

Climate of the Carpathian Basin

The Carpathian Basin has a rather great variability of the climate. Over the long term this climate is expressly transitional, and as correctly defined by Bacsó (1959, 1961), also of a mixed character. The region is where three climatic influences of different quality collide which cannot average out: Atlantic, Submediterranean and Continental. From an ecological viewpoint of view, in this temperate basin of low altitude annual rhythm, the inclination to reduced precipitation has overwhelming significance.

It is well known that there lies a zone of transition between the Mediterranean winter precipitation maximum and the continental summer precipitation maximum, the so-called equinoctial zone. In this zone there are predominantly double, autumn and spring maxima of precipitation. The main peak is usually in autumn. Only on the Spanish Meseta, in parts of southern France and of the Po Plain and in Transdanubia, Hungary, it shifts to late spring (May). The precipitation map of Europe after Blüthgen (1958, Fig. 1) shows the southern and western boundaries of an expressed summer precipitation maximum and the northern limit of mid-summer Mediterranean aridity. Enclosed by these lines one can find the region of the transitional Submediterranean climatic influence and the Atlantic region to the west.

Jakucs (1961) published a map of the northern limit of European Submediterranean mixed forests (Orno-Cotinetalia). The coincidence with Blüthgen's climatic boundary is clear. Vegetation indicators further specify the limits of the Submediterranean climate, namely, to the Orsova and Visegrád gorges of the Danube, the Thermal Alpen relict island near Vienna, and the wine-growing areas of the Upper Rhine). It is known that the Submediterranean floristic elements advance more to the north in the Atlantic area than in the eastern Pontic region. As an example, the distribution of an Atlantic-Submediterranean floristic element, *Primula vulgaris*, is cited here (after Meusel, Jäger, Rauschert and Weinert 1978, Fig. 2). The core species has distribution including the environs of the Carpathian Basin, while to the east, its vicarious species occur. The similarity between the map of its geographic distribution and the climate map is impressive.

Precipitation curve types

The usual manipulations with long-term data series tend to obscure extreme fluctuations and other real events. This has to be considered particularly important when vegetation-climate relationships are studied. Novel approaches are needed. With this intention, Zólyomi (1958) identified types of the annual precipitation curve. In this he relied upon Köppen's (1918, 1931) modified climate classification, his definition of typical and transitional climates, and the climatic year concept of Russel (1934) which Berényi (1943) supported. It was unfortunate that this line of inquiry was not pursued, but rather as in Borhidi (1961), the Walter-Lieth climatic diagrams received main attention. We return in this paper to the Russel-Zólyomi line of inquiry and show the

* **Editor's note**: The sad news of the death of Academician Bálint Zólyomi reached us at *Coenoses* as the editing of this manuscript entered the final phase. We deeply mourn his passing and feel the void that he left in the scientific community. We bid farewell to a good friend and a deeply respected colleague. (L. Orlóci.)

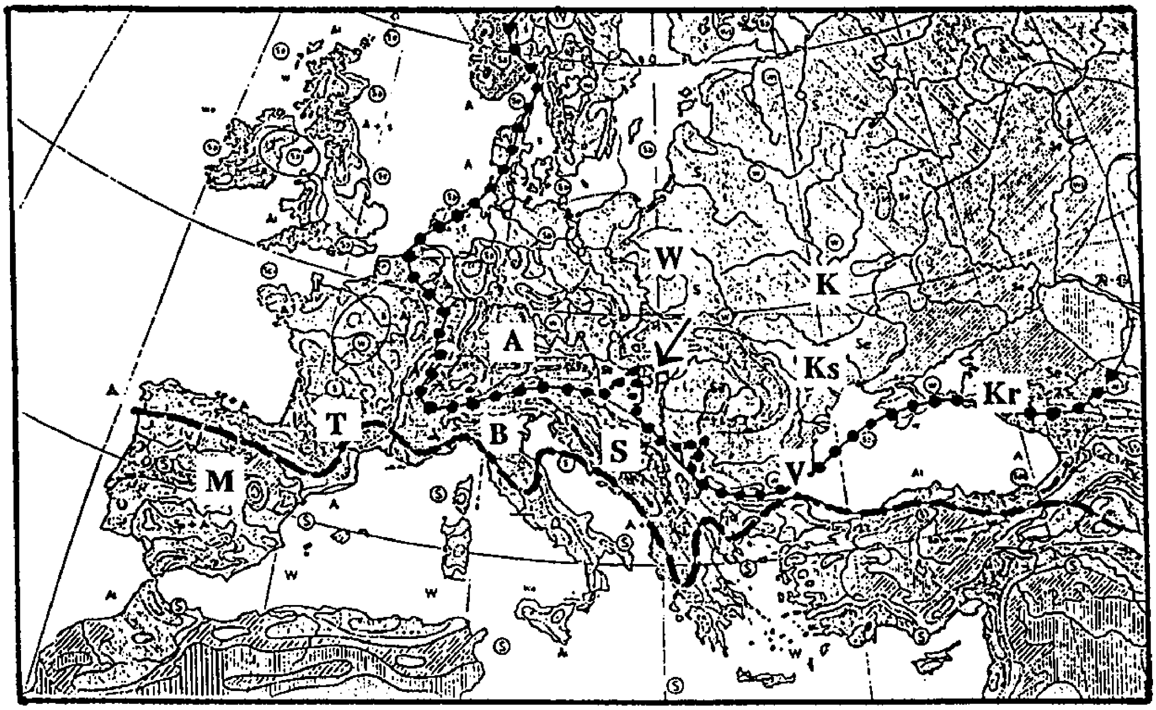


Figure 1. Precipitation map of Europe (Blüthgen 1958). Dashed line: N limit of Submediterranean mid-summer aridity; dotted line: S limit of mid-summer precipitation maximum.

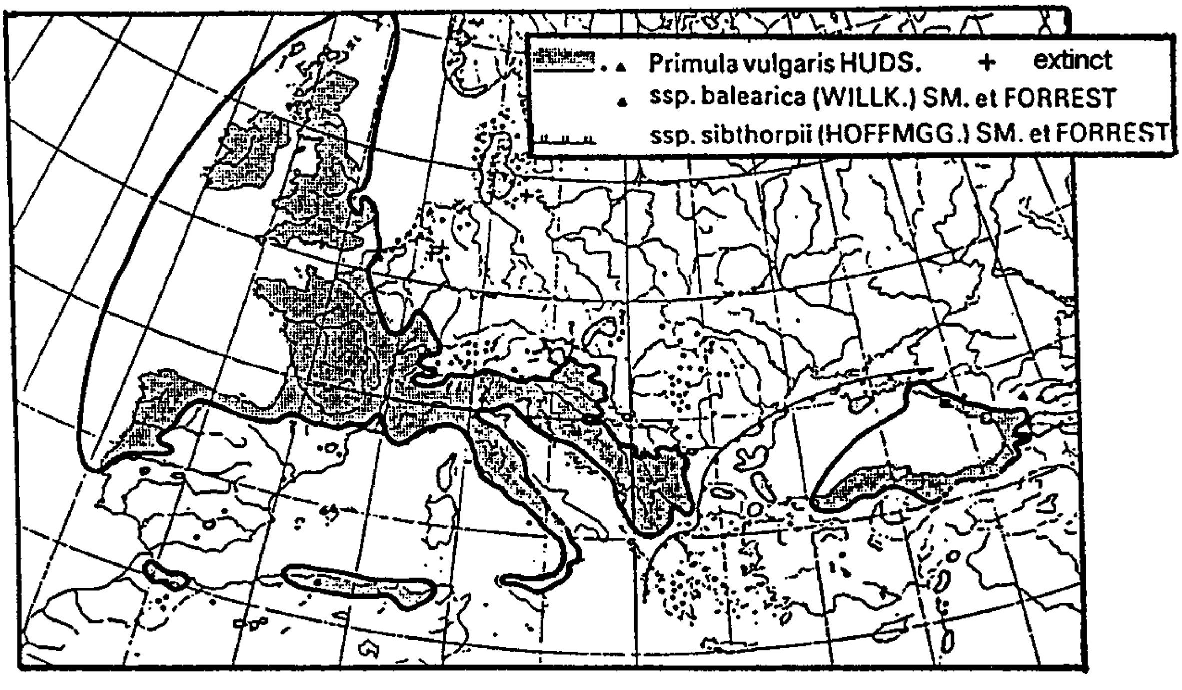


Figure 2. Map of Europe with the distribution of *Primula vulgaris*.

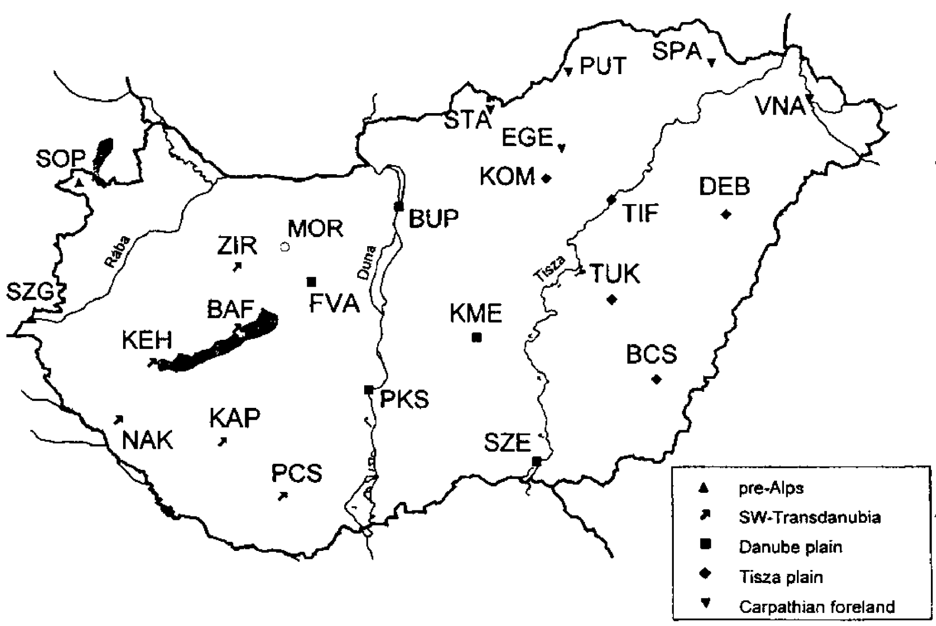


Figure 3. The climatic regions of the Hungarian portion of the Carpathian Basin and their representative stations. *Pre-Alps*: SZG: Szentgotthárd, SOP: Sopron; *SW-Transdanubia:* PCS: Pécs, KAP: Kaposvár, NAK: Nagykanizsa, KEH: Keszthely, BAF: Balatonfüred, ZIR: Zirc; *Danube Plain*: FVA: Székesfehérvár, BUP: Budapest, KME: Kecskemét, SZE: Szeged, PKS: Paks; *Tisza Plain:* BCS: Békéscsaba, TUK: Túrkeve, TIF: Tiszafüred, KOM: Kompolt, DEB: Debrecen; *Carpathian Pre-Carpathian Mountains:* STA: Salgótarján, EGE: Eger, PUT: Putnok, SPA: Sárospatak, VNA: Vásárosnamény (cf. Figure 6).

logic in the preference for the annual precipitation curve in characterisations of the local climate. As for the *modus operandi*, each year of a station is individually assessed and typified. The climate of a particular locality is then characterised by the frequency of an averaged precipitation curve type.

The climatic regions of the Hungarian portion of the Carpathian Basin are shown in Fig. 3 along with the stations representing them. It does not pose any difficulty to identify general climatic year types, since there are limit values fixed by Köppen. In contrast, the annual precipitation curve type can only be identified after careful consideration and through the analyses of reference stations (Figs 4-5). The station of reference shows the most common curve in the core area of the climate in question. Each year a stations' precipitation curve is compared to those of the reference stations. The local annual climate is typed such as that at the most similar reference station. The patterns so derived are not an artifact, but they occur regularly in nature.

Case example

In order to present an example, one of the stations in the Carpathian Basin with the least rainfall, Tiszafüred has been selected. The records indicate that the various climatic influences are not only peripheral to the region but may cover the whole basin.

1. *The Atlantic-Submediterranean influence.* Its precipitation curve type, x", was described by Köppen. (This type occurs with 29 per cent relative frequency in Budapest.) Our reference stations for x" are Toulouse and Bologna. When the monthly average precipitation values for these two stations are compared to x", no month shows a significant difference (cf. Zólyomi, Kéri and Horváth 1992a,b). In addition to precipitation maximum in May, characteristic primary or secondary Mediterranean maxima in autumn (mostly October) are present (Figs 4-5).

2. *Pontic-Mediterranean influence.* The curve type is xx". It can equally be regarded continental and Submediterranean in character with Varna as the reference station. The precipitation maximum in June is marked, the drought period shifts into late summer and September and there is a secondary maximum in November.

3. *European continental influence.* The summer precipitation maximum (climate f) is characteristic. The station of reference here is Kiev or rather Warsaw if January mean temperatures are also regarded. For the case of increased late autumn and December precipitation (variety fx), Krasnodar can be identified as reference.

Varieties of the above three types with similar but reduced annual curve are designated BSx", BSxx" and BSf with reference stations respectively: Madrid, Varna and Chisinau. For the identification of steppe climatic years, De Martonne's formula ($2x[t^o+14]$) is used. When the annual precipitation is less than this, the year can be regarded as a steppe year. Finally, there are two climatic year types with abundant precipitation: Alpic-Subatlantic influence (ff) and the Illyric (x"ff). The first (reference: Augsburg) only occurred at Tiszafüred in a single year and was, therefore, disregarded. The latter type (reference: Sarajevo) occurred on seven occasions in 100 years, although with moderate amounts of annual precipitation at this location.

Figure 4. Climatic year types and stations of reference, A.

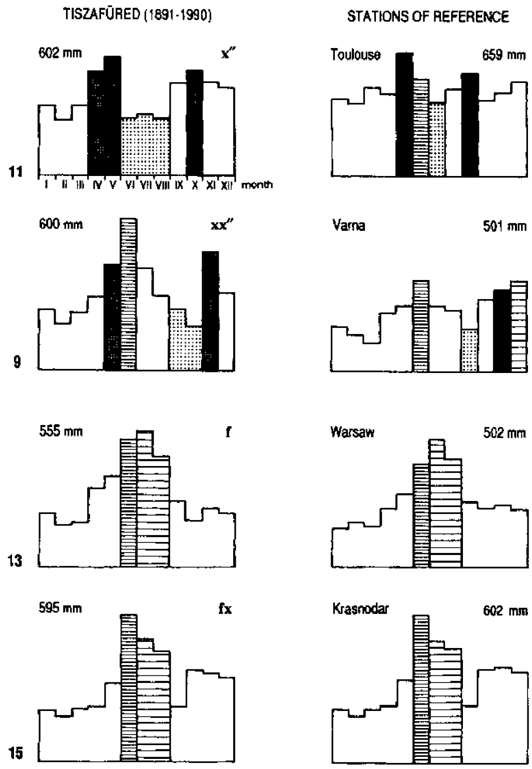
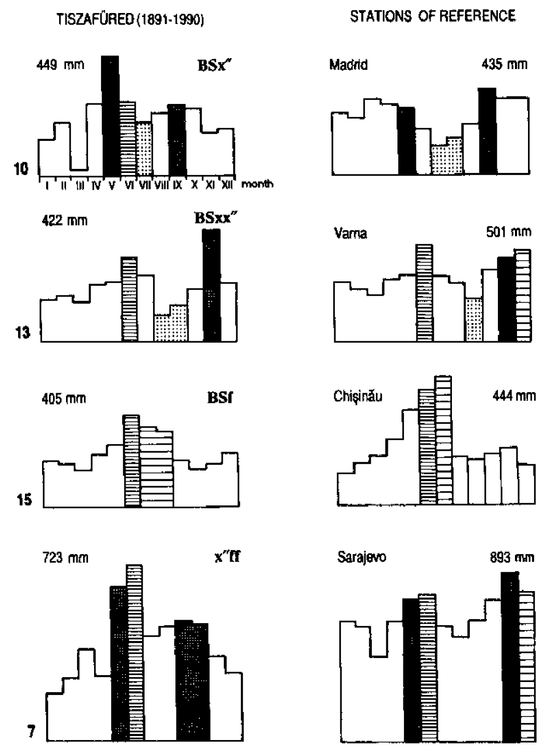


Figure 5. Climatic year types and stations of reference, B.



The Middle-Danubian floristic divide

The problem of the Middle-Danubian floristic divide was raised by Zólyomi (1942). He applied selected lists of floristic elements to show that the south-west wing of the phytogeographical 'Paleo-Mátra' (the Transdanubian Mountains) of a more equable climate is characterised by Mediterranean, or more precisely Submediterranean, Atlantic, Central European and Western Balkanic (Illyric) floristic elements. In contrast, on the north-west wing (North Hungarian Mountains and the Carpathian piemont) in a more continental climate, continental as well as eastern Balkanic, Moesian and Dacian, elements come to the fore. Based on the available climatic data (1901-1930), the divide has been climatically confirmed (Réthly 1933, 1935 and Hajósy 1935). The boundary lines in the distribution of floristic elements grow denser in the Visegrád Gorge area. This indicates abrupt change.

We re-examined the identification of the Middle-Danubian floristic divide on the basis of a 100-year (1891-1990) time series on a transect through 11 meteorological stations. The transect runs from the south-west to the north and north-east across Pécs, Kaposvár, Nagykanizsa, Keszthely, Balatonfüred, Mór, Budapest, Salgótarján, Putnok, Sárospatak and Vásárosnamény as seen in Fig. 6. Up to Budapest the types of Atlantic-Submediterranean annual precipitation curves are 50-60 percent frequent at the stations. Beyond Budapest to the northeast, their relative frequency falls below 30 per cent. Accordingly, the share of Continental and Pontic-Submediterranean climate types grows from ca 35 per cent in Transdanubia to 65 per cent in the northeast. Such an extent change must have demonstrable major ecological implications, leading to the development of a major floristic divide. The frequency distribution of the C/D boundary shows a similar pattern.

As it is known, in Transdanubia there is also a minor incursion of Atlantic and Illyric floristic elements such as, for instance, *Asphodelus albus, Lamium orvala* and *Ruscus aculeatus* (Jávorka 1940). The advance of these as far as Keszthely and the western Bakony Mountains is understandable on climatic grounds. Regarding the long boundary across the southern part of Europe (Fig. 1), the Middle-Danubian floristic divide is not a local phenomena but part of that south European boundary line.

Climate year curves in ecological typology

We hold that in the ecological typology of climatic years the precipitation curve is of decisive importance, because precipitation is a limiting factor for the development of major vegetation formations. The Carpathian Basin is no exception. The picture would not be complete, however, if relationships with temperature were not analysed. For this purpose, the annual temperature curve is compared with the climatic year types (Table 1). The annual temperature curve is constructed according to Köppen's criteria as Ca, Da, Cb and Db. In these symbol D stands for cold winter (January mean temperature below -3°C) and symbol "a" for hot sum-

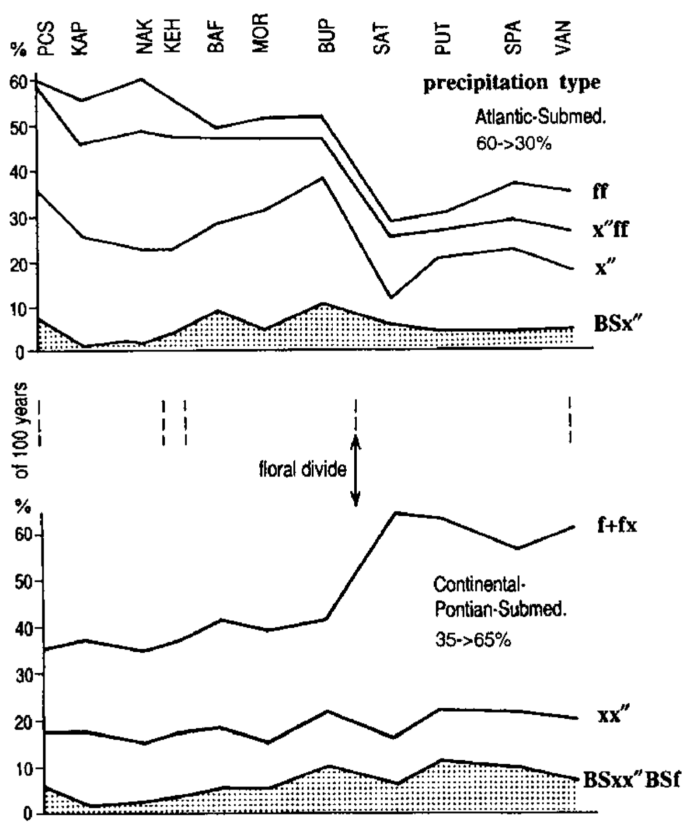


Figure 6. New findings in the climatic confirmation of the Middle-Danubian floristic divide. From Keszthely to Budapest: Transdanubian Mountains; from Salgótarján to Vásárosnamény: Carpathian Foreland (or North Hungarian Mountains and Northern Great Plain).

Table 1. Relationship between climatic year types and Köppen's classification in annual temperature features.

	Ca mild winter hot summer	**Da** cold winter hot summer	**Cb** mild winter warm summer	**Db** cold winter warm summer
sAA sub-Atlantic - Alp (ff), Illyrian (x"ff)	n.s. 5.7	− *** 16.6	+ * 8.8	n.s. 4.3
AsM Atlantic-sub-Mediterranean (x",BSx")	+ *** 48.2	+ *** 26.7	− *** 18.4	− *** 54.4
PsM Pontic-sub-Mediterranean (xx", BSxx")	− * 9.1	n.s. 6.8	n.s. 1.6	n.s. 4.1
EuK European-Continental (f, BSf, fx)	− * 10.0	− ** 13.2	n.s. 3.6	+ ** 13.0

Abbreviations: n.s.=not significant
* = significant at $p< 0.05$ (χ^2=8.7)
** = significant at $p< 0.01$ (χ^2=11.3)
*** = significant at $p< 0.001$ (χ^2=16.3)

Table 2. Relative frequency of the climatic year types by geographical regions in Hungary for a 100-year period (1891-1990).

	pre-Alp	**SW Trans-danubia**	Danube plain	Tisza plain	Carpathian foreland
ff	19	7	2	1	7
(Illyr) x"ff	20	26	11	8	9
subAtl-Alp	39	33	13	9	16
x"	16	21	21	15	15
BSx"	1	3	11	9	5
Atl-subMed	17	24	32	24	20
	56	**57**	**45**	**33**	**36**
f	21	13	11	15	19
BSf	1	2	7	11	5
fx	8	7	9	15	18
Eur-Cont.	30	22	27	41	42
xx"	8	12	11	12	12
BSxx"	0	2	11	8	5
Pont-subMed	8	14	22	20	17
	38	**36**	**49**	**61**	**59**
	6	7	6	6	5

mer (July mean temperature above 22°C). From the frequency data of joint occurrences 2x2 contingency tables were constructed and tested for independence by χ^2. The positive or negative deviations from expected values, the extent of significance and the computed χ^2 are given in Table 1.

In a considerable part of cases there are close and significant relationships which mostly derive from the reverse correlation between mid-summer (July) precipitation and hot weather. Subatlantic-Alpine (sAA) and Illyric years (ff, x"ff) are characterised by more equable temperature and this is indicated by a positive association with type Cb and strong negative association with type Da. Atlantic-Submediterranean (AsM) years (x", BSx") are in very close correlation with hot summers as a result of remarkable mid-summer heat. The warm and dry periods of the Pontic-Submediterranean (PsM) years (xx", BSxx") shift to late summer and early autumn. Therefore, no relationship is found with the typology reflecting heat in July, while the slight positive association with colder winters (Da and Db) computed individually does not reach the 5% significance level. The abundant mid-summer precipitation of European-Continental (EuK) years (f, BSf, fx) is accompanied by a cooler July, confirmed by significant positive and negative relationships (Table 2).

Climatic regions

We are considering the macro-regions of the Carpathian Basin. The data for the annual precipitation curves and the relative frequency of climatic year types are in Table 1. These are based upon the data series of 5 meteorological stations from each region, except 2 for the Pre-Alps. The deviations among the regions are so large that even without a formal test significant differences have to be assumed. Table 1 provides a comprehensive picture of the climatic regions. However, further explanation is required, considering that the 100-year period is very heterogeneous and divisible into distinct intervals. The spatial and temporal analysis reveals the following calendar intervals:

1. 37 years (1891-1927). The frequency of Atlantic-Submediterranean (x") and Continental (f+fx) climatic years is balanced.

2. 10 years (1928-1937). The Atlantic-Submediterranean x" climatic years dominate.

3. 15 years (1938-1952. The climate years are similar as in interval 1.

4. 30 years (1953-1982). The almost complete disappearance of Atlantic-Submediterranean years and the prevalence of continental and Pontic-Submediterranean (f+fx and xx") years are characteristic. Instead of BSx" steppe years, BSf and BSxx" climatic years are frequent.

5. Since 1983 the entire basin is affected by Atlantic-Submediterranean (x") with mid-summer (July) drought typical of the Mediterranean.

We can follow the changing relative frequencies in all regions at the same time but to various extents on the diagrams:

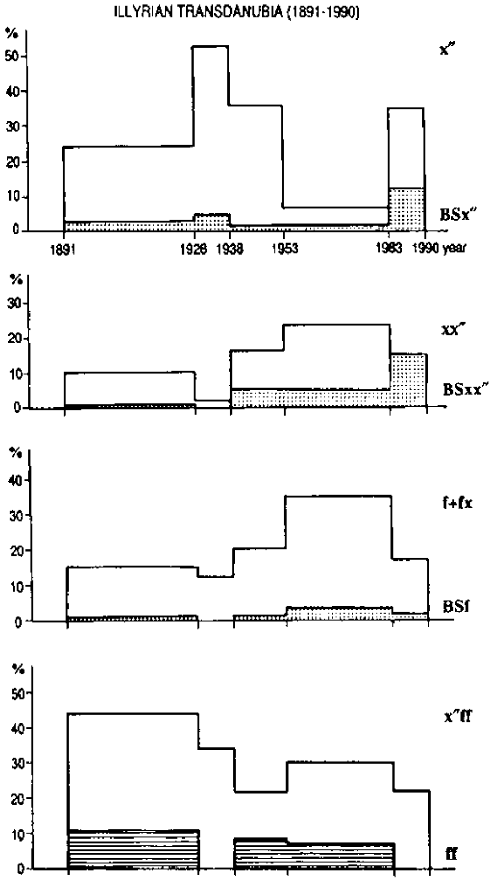


Figure 7. Southwest-Transdanubia, time sections of 100 years (1891-1990).

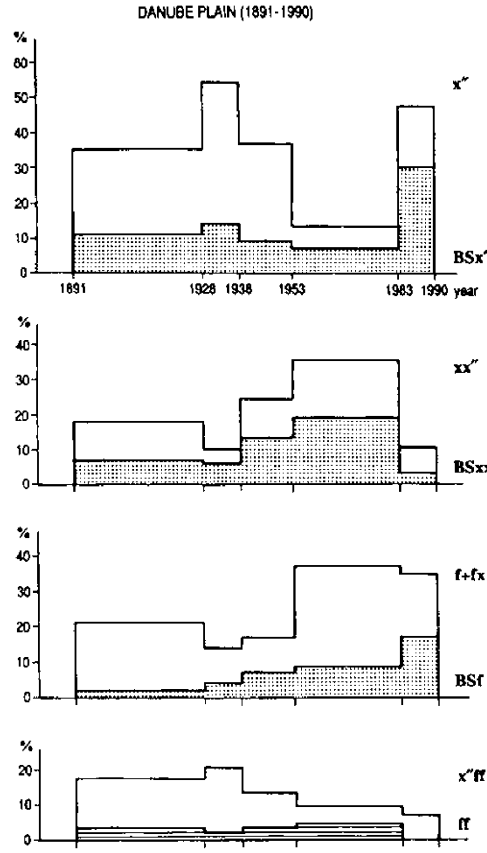


Figure 8. Danube Plain, time sections of 100 years (1891-1990).

Southwest-Transdanubia (Fig. 7). This is in the immediate neighbourhood of the western Balkanic Illyric area. Thus, the occurrence of Illyric x"ff climatic years is of relatively uniform distribution (20-35%) in all intervals. In interval 4, the Atlantic-Submediterranean x" type is drastically reduced (to 6%). It is replaced by the continental f+fx (30%) and Pontic-Submediterranean xx" (20%) climatic types. In other intervals the ratio of x" years approaches 50%.

Pre-Alps. The climate of this small region in Hungary is only represented by two meteorological stations. Its climatic diagram is not shown here. It is mostly of the Atlantic climate year type (ff: 27%), but in interval 4 here, too, European continental and Pontic-Submediterranean climatic years (f+fx and xx": 50%) became the most common.

The Danube Plain (Fig. 8). The most marked change occurs in interval 4. While in other intervals the high frequency of x" climate years (40%) is characteristic, here they fall back to a minimum (15%) and the continental f+fx and Pontic-Submediterranean xx" climatic year types dominate. The ratio of Illyric x"ff years approaches 20% in intervals 1 and 2. Noting that in in south-west Transdanubia BS steppe years appear sporadically, in the Danube Plain their share is high in all intervals. Their joint ratio (BSx", BSxx" and BSf) can reach 40%. The x" climate years are more frequent than 20%, while for the Illyric x"ff climate year type this is the maximum.

The Tisza Plain (Fig. 9). With the exception of interval 2, during all intervals European continental f+fx and Pontic-Submediterranean xx" years are jointly prevalent. During interval 4 their frequency rise to 80%. The frequency of three varieties of steppe years together may approach 40%.

The Pre-Carpathian Region (Fig. 10). In all intervals, European continental f+fx and Pontic-Submediterranean xx" climatic year types are predominant (around 40-50%). The frequency of x" and x"ff years is uniformly low. The total share of steppe years is reduced to 10-20%. The 10% ratio of Alpine-Atlantic ff years in intervals 3 and 5 indicates proximity to the Carpathian Mountains.

It is clear from the above that the climate of the Carpathian Basin has great temporal and geographic variability. Under this condition, the re-conceptual change of the climatic years approach is fully justified. We point also to the fact that the forest steppe of the Danube and Tisza Plains differs considerably from the Ukrainian and South-Russian steppe, exactly in accordance with frequent incursions of the Atlantic-Submediterranean x" climatic year type. The presence of Atlantic-Submediterranean floristic elements or

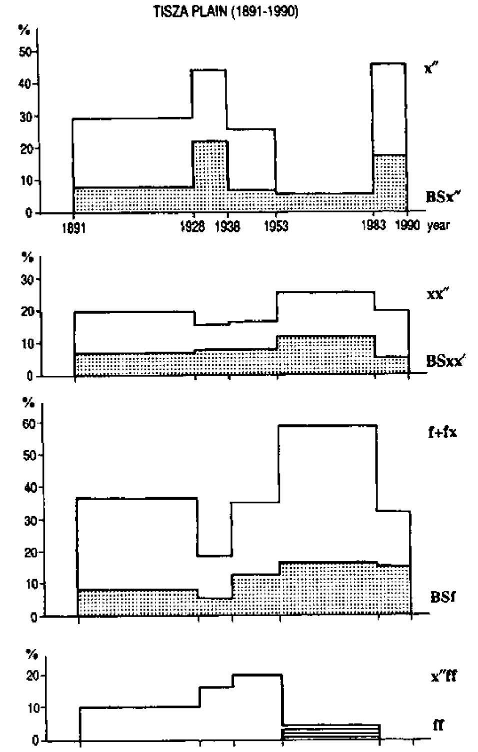


Figure 9. Tisza Plain, time sections of 100 years (1891-1990).

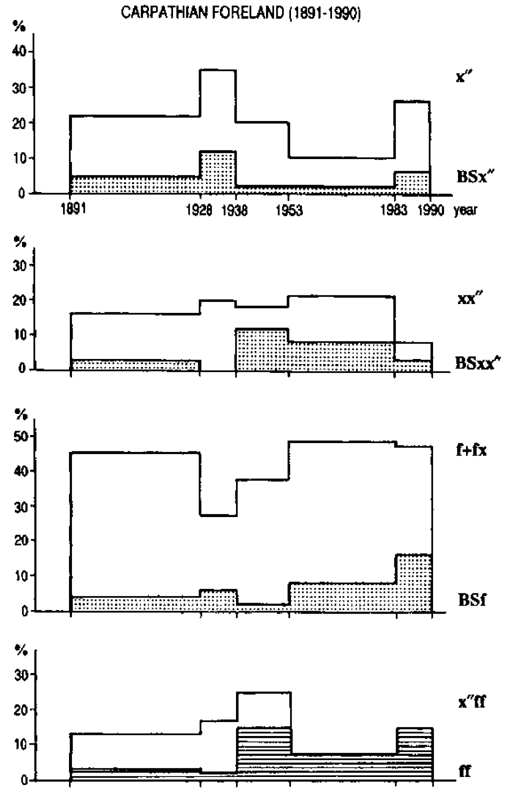


Figure 10. Carpathian Foreland, time sections of 100 years (1891-1990).

of hairy oak (*Quercus pubescens* s.l.) on the lowlands of the Carpathian Basin is an indication.

Warming and aridification

Frequency diagrams of Köppen's C and D climatic years and BSx" and BSxx" steppe years from the 150-year data series of Budapest (1841-1990) were published earlier (Zólyomi, Kéri and Horváth 1992) and reproduced here (Figs. 11-12) for further interpretations. Warming waves are evident in Fig. 11. Signs of aridification are clear in wave 3 in Fig. 12 in the abrupt increasing frequency of steppe climatic years. Whether these are periodic fluctuations or unidirectional changes can only be decided after the investigation of much longer time series.

Here a hint is made to the exemplary comprehensive study of the drought year of 1983 (Baráth, Győrffy and Harnos 1993). This year is an Atlantic-Submediterranean BSx" steppe climate year type. The 8 stations of the affected area had the following monthly mean precipitations: 22 mm, 40 mm, 29 mm, 24 mm, 47 mm, 51 mm, 24 mm, 40 mm, 46 mm, 30 mm, 29 mm, 10 mm. The annual precipitation was 411 mm. This precipitation curve is closest to that of the Madrid reference station (cf. Fig. 5). This was the end of a 30-year continental interval. The situation was aggravated by the fact

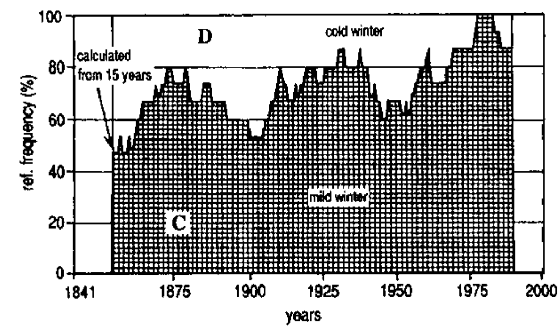


Figure 11. Budapest, 150 years (1841-1990), frequency of C and D.

that the last year of this continental interval was a continental steppe year.

Closing comments

It has to be mentioned that the overview of the data indicated a loose periodicity of 11 years in steppe or reduced precipitation years (BSxx", BSx", Bsf), which is, however,

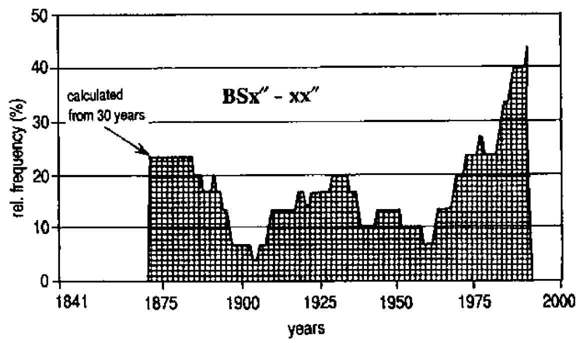


Figure 12. Budapest, 150 years (1841-1990), steppe years.

not so regular as the sun spot cycles. Comparing this with the curve of the recently published four solar cycles (1945-1983: solar cycles #18-21, Marik 1989), it is claimed that although the marked frequency of steppe years does not coincide with maximum solar activity, the intervals with abundant steppe years closely coincide with intervals of increased solar activity. Interestingly, drops in frequency are also coincident in the two phenomena. This relationship could not be found in the previous period but it is worth noting that solar activity was at a much lower level (almost half of its intensity) in the previous period. We believe that in a more quiet climate period the influence of increased solar intensity could induce a growing frequency of steppe years. In contrast, during larger scale climate fluctuation other factors hide or obliterate the assumed impact of solar cycle.

Bibliography

Bacsó, N. 1959. Climate of Hungary (in Hungarian). Akadémiai, Budapest.

Bacsó, N. 1961. Effect of the continental, atlantic and mediterranean climate characters on Hungarian agriculture (in Hungarian). Agrártud. Egyetem Mezőgazd. Kar Közl. 1:157-170.

Baráth, Cs., Győ rffy, B. & Harnos Zs. (eds.) 1993. Aszály. (in Hungarian) Kertészeti Egyetem Matematikai és Számítástechnikai Tanszéke, Budapest. pp. 174.

Berényi, D. 1943. Climate boundaries and their performances (in Hungarian). Földr. Közl. 71/4. 230-248.

Blüthgen, J. 1958. Allgemeine Klimageographie. Berlin.

Borhidi, A. 1961. Klimadiagramme und klimazonale Karte Ungarns. Annales Univ. Sci. Budapestiensis, Sect. Biol. 4:21-50.

Bryson, R.A. 1989. Late Quaternary Volcanic Modulation of Milankovitch Climate Forcing. Theor. Appl. Climatol. 39: 115-125.

Hajósi, F. 1935. Rainfall distribution in Hungary, 1901-1930 (in Hungarian). Meteorological and Geomagnetics Institute, 34 pp.

Hajósi, F., J. Kakas & M. Kéri 1975. Monthly and annual sums of precipitation in Hungary from the beginning of observations to 1970 (in Hungarian). Budapest

Horvat, I., V. Glavac & H. Ellenberg 1974. Vegetation Südosteuropas. G. Fischer, Jena,768 pp.

Houghton, G.J., G.J. Jenkins & JJ. Ephraums (eds.) 1991. Climate Change. The IPPCS Scientific Assessment. WMO, UNEP. Cambridge University Press, XI-XXXIX. 364 pp.

Jakucs, P. 1961. Die Phytozönologischen Verhältnisse der Flaumeichen Buschwälder Mitteleuropas. Akadémiai Kiadó, Budapest. 314 p.

Jávorka, S. 1940. Plant area boundaries in Transdanubia (in Hungarian). Mat. és Term. Tud. Ért. 59:967-997.

Kéri, M. 1952. Snow conditions of Hungary 1929/30-1943/44 (in Hungarian). Hungarian Meteorological Institute, Budapest. 75 pp.

Kéri, M. & Gy. Szakács 1954. Feststellung des Anteils von Aufgleit- und Schauernieder-schlägen an der beobachteten Niederschlagsumme, ohne Anwendung von Frontkalender oder Registrierinstrumenten. Időjárás 58:218-223.

Köppen, W. 1918. Klassifikation der Klimate. Petermanns Geogr. Mitteilungen, Gotha.

Köppen, W. 1923. Grundviss der Klimakunde. Walter de Gruyter, Berlin und Leipzig. 137 pp.

Köppen, W. 1929. Typische und Übergangs-Klimate. Meteorologische Zeitschrift, 45:121-126.

Kun, A. 1995. Rocky grasslands and steppe slopes in the region of the Middle-Danubian Boundary I. (in Hungarian). Bot. Közlem. 82 (in press).

Marik, M. (ed.) 1989. Astronomy (in Hungarian), Akadémiai, Budapest. pp. 867.

Meusel, H., E. Jäger, S. Rauschert & E. Weinert 1978. Vergleichende Chorologie der Zentraleuropäischen Flora 2. Jena

Országos Meteorológiai Szolgálat Közp. Meteorol. Int. (Hungarian Meteorological Service, Central Meteorological Institute). Yearbooks C-CXIV, Budapest. 1973-1985.

Réthly, A. 1933. Rainfall conditions of the Great Hungarian Plain (in Hungarian). In: Recent studies on irrigation. Publications of Ministry of Agriculture, Budapest. pp.148-177.

Réthly, A. 1935. The heaviest rainfalls in Hungary, 1901-1930 (in Hungarian). Földr. Közl. 63/9,10:246-252.

Russel, R.J. 1934. Climatic Years. The Geogr. Review 24:92-103.

Varga, Z. 1989. Die Waldsteppen des Pannonischen Raumes aus biogeographischer Sicht. Düsseldorfer Geobotanische Kolloquien, 6:35-50.

Wallen, C.C. (ed.) 1977. Climates of Central and Southern Europe. World Surveys of Climatology vol. 6. Elsevier, NY. pp. 248.

Zólyomi, B. 1942. A remarkable floristic boundary in the Danube Valley and the dolomite phenomenon. Bot. Közlem. 39:209-223.

Zólyomi, B. 1958. The natural vegetation of Budapest and its environs (in Hungarian). In: The Natural Environment of Budapest (Pécsi, M., S. Marosi and J. Szilárd eds.), Akadémiai Kiadó, Budapest. pp. 509-642.

Zólyomi, B., M. Kéri & F. Horváth 1992a. Changes and fluctuation of a zonal Submediterranean hairy oakwood and the Submediterranean climate in time and space in the Pannonian Basin. In: Teller, A., P. Mathy and J.N.R. Jeffers (eds.), Responses of forest ecosystems to environmental changes. Elsevier Applied Sciences. London, New York. pp. 582-585.

Zólyomi, B., M. Kéri & F. Horváth 1992b. Impacts od Submediterranean climatic influences on the composition of climatic zonal plant associations in the Carpathian Basin. (in Hungarian). Memorial volume to Kabos Hegyfoky. Debrecen-Túrkeve. 60-74.

Zólyomi, B. & G. Fekete 1994. The Pannonian loess steppe: differentiation in space and time. Abstr. Bot. 18: 29-41.