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Climatic conditions of semi-natural habitats in Belső-Somogy, Külső-Somogy and Zselic regions I. Climatic surface and climatic envelope of woodlands

Éva Salamon-Albert[1]*, Adrienne Ortmann-Ajkai[2], Ferenc Horváth[3], Tamás Morschhauser[1]

[1]University of Pécs, Biological Institute, Department of Systematic and Ecological Botany
H-7624 Pécs, Ifjúság útja 6., Hungary, *e-mail: albert@gamma.ttk.pte.hu, morsi@gamma.ttk.pte.hu
[2]University of Pécs, Biological Institute, Department of Ecology and Hydrobiology
H-7624 Pécs, Ifjúság útja 6., Hungary, email: aadrienn@gamma.ttk.pte.hu
[3]Institute of Ecology and Botany of the Hungarian Academy of Sciences
H-2163 Vácrátót, Alkotmány utca 4., Hungary, e-mail: horvfe@botanika.hu

Salamon-Albert, É., Ortmann-Ajkai, A., Horváth, F., Morschhauser, T.: *Climatic conditions and habitats in Belső-Somogy, Külső-Somogy and Zselic as vegetation-based landscape regions I. Climatic surface and climatic envelope of woodlands.*
Abstract: In our study bioclimatic variables calculated from long-term temperature and precipitation data (1960-1990) were applied in order to define climatic surfaces and climatic envelope of significant woody habitat types in three vegetation-based hilly landscape of South Transdanubia (Belső-Somogy, Külső-Somogy, Zselic). Certain differencies can be observed in the climatic surface of the regions. Külső-Somogy is the most extreme region by all the bioclimatic indeces, Zselic is the most balanced by precipitation and Belső-Somogy is similar by the temperature indeces. Climatic envelopes of main woody habitat types (J – riverine and swamp woodlands, K – mesic deciduous woodlands, L – dry closed deciduous woodlands, R – other tree dominated habitats) are considerably overlapping by the selected bioclimatic variables. Precipitation must be a significant role in the existence of woody habitat types according to the landscape region. Values of temperature are valid in a narrower range without any differentiation by the habitats or landscapes.

Keywords: climatic envelope, climatic surface, GIS database, MÉTA habitats, landscape ecology

Introduction

Bioclimatic indeces connected to vegetation data are widely used for interpretation of species or habitat distribution or suitability in vegetation science under past, current and future climate scenarios (Hossell et al. 2003, Beaumont et al. 2005, Attorre et al. 2007). They were derived from the monthly temperature and precipitation data in order to generate more biologically meaningful variables, representing annual trends, seasonality and extreme or limiting environmental factors (Hijmans et al. 2005). Climate has been shown to be a dominant element of the environment in determining vegetation distributions and classification for European scales in different vegetation types. It is important that we can confidently describe current habitat distribution according to cli-

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matic surface and quantify their climatic envelope. It will be beneficially used for predicting future distribution patterns, to be able to understand the impacts of a continuous climate change.

In the three selected vegetation-based landscape regions semi-natural and managed woodland vegetation types are frequent. The western part of Külső-Somogy is a potential woodland landscape, especially including semi-natural mesophilous woodland communities or other tree-dominated woodlands originated from any kind of natural forest stands. Eastern part of Külső-Somogy is rich in semi-dry and closed oak woodlands, the south part of the region is poor in any kind of woodlands. Belső-Somogy is a diverse landscape. There are several types of mesophilous woodlands in its western part, riverine swamps and oak-elm-ash woodlands in the eastern part. Zselic is the most forested landscape in South Transdanubia. Woodlands are very diverse ranging from submontaneous mesophilous beech forests to dry closed and open woodland patches. The most frequent woody habitat types are alder and ash swamp woodlands, riverine ash-alder woodlands, lowland pedunculate oak-hornbeam woodlands, sessile oak-hornbeam woodlands, turkey oak-sessile oak woodlands, uncharacteristic softwood forests and plantations and uncharacteristic hardwood forests and plantations in the regions (Lehmann 1976, Borhidi 1984, Salamon-Albert and Horváth 2008, Király et al 2008).

Our aim was to answer 1) what the regional ranges of bioclimatic variables as a ‘climatic surface’ that could determine distribution of woodland habitats are, 2) what the ’climatic envelope’ of significant woody habitat types occurring in the regions and their differences are.

Material and method

Study sites

The studied area are Külső-Somogy (abbr: KS), Belső-Somogy (abbr: BS) and Zselic (abbr: ZS) as vegetation-based landscape regions, situated in the South-Transdanubia geographical region of Hungary, covering about 5705 km^2 (570500 ha) in total. Their borders are newly defined on the basis of present zonal or dominant extrazonal or edaphic vegetation by the knowledge of local expert botanists (Molnár et al. 2008). This new division differs in shape features from the currently used, country-wide, flora- or geography-based landscape divisions (e.g. Marosi & Somogyi 1990).

Elevation varies in a moderate range above sea level from lowlands (96 m) to hills (300 m), average altitude is 161 m. Long-term annual precipitation varies between 562 and 753 mm, the average was 674 mm, the annual temperature varied between 8.4 °C and 11.4 °C, the average was 10.9 °C. Studied regions are at the intersection of three climatic areas: from West as the Atlantic, from East as the Continental and from South as the Mediterranean, that can influence the general climatic pattern. According to the main geobotanical division of Europe, they are clustered into the submountaneous oak-hornbeam woodlands and thermophilous oak woodlands with open steppe oak woodlands and riparian vegetation (Ozenda and Borel 2000).

BIOCLIM variables

For calculation of BIOCLIM variables, monthly averages of climatic data, measured at weather stations on global and local scales were used. Temperature data are from WorldClim database (http://www.worldclim.org/, Hijmans et al 2005), precipitation data are from the local weather stations of Hungarian Meteorological Service (http://vissycd.

glia.hu/atlasz.html, MERSICH et al 2001). Set of calculated variables are reported as the regional climatic surface, BIOCLIM 1 to 11 from the temperature data, BIOCLIM 12 to 19 from the precipitation data, considering the elevation correction. Calculation of bioclimatic variables was carried out by the Institute of Ecology and Botany of the Hungarian Academy of Sciences (CZÚCZ et al 2007). Table 1 reports main descriptive statistics for the analysed temperature and precipitation data as bioclimatic variables for the vegetation-based regions. Meaning of variables: BIOCLIM 1 = Annual mean temperature, BIOCLIM 2 = Mean diurnal range of temperature, BIOCLIM 3 = Isothermality, BIOCLIM 4 = Temperature seasonality as standard deviation × 100, BIOCLIM 5 = Maximum temperature of Warmest Month, BIOCLIM 6 = Minimum temperature of Coldest Month, BIOCLIM 7 = Temperature annual range, BIOCLIM 8 = Mean temperature of Wettest Quarter, BIOCLIM 9 = Mean temperature of Driest Quarter, BIOCLIM 10 = Mean temperature of Warmest Quarter, BIOCLIM 11 = Mean temperature of Coldest Quarter, BIOCLIM 12 = Annual mean precipitation, BIOCLIM 13 = Precipitation of Wettest Month, BIOCLIM 14 = Precipitation of Driest Month, BIOCLIM 15 = Precipitation seasonality as coefficient of variation, BIOCLIM 16 = Precipitation of Wettest Quarter, BIOCLIM 17 = Precipitation of Driest Quarter, BIOCLIM 18 = Precipitation of Warmest Quarter, BIOCLIM 19 = Precipitation of Coldest Quarter. A quarter is a period of three months, ¼ of the year. Among them BIOCLIM 1 and 12 represent annual trends, BIOCLIM 2, 3, 4, 7 and 15 represent any kind of seasonality, BIOCLIM 5, 6, 8, 9, 10, 11, 13, 14, 16, 17, 18, 19 represent extreme or limiting environmental factors for vegetation distribution.

MÉTA habitats

MÉTA project (2002-2006) was a systematic habitat mapping of the Hungarian vegetation on landscape scale integrated with spatial and geographical information (MOLNÁR et al 2007). MÉTA quadrates (35 km^2) are the organisational and constructing units, divided into hexagons (35 ha) per each for higher resolution, as the basic units of MÉTA tables and databases. In our study, habitat types and bioclimatic variables were assigned to finer spatial scale for cc 16300 hexagons of 163 quadrates.

In total 57 MÉTA habitat types were identified in the three regions, including woody and non-woody habitats with natural, semi-natural and managed status. They represent more than half of the total number of habitats listed for Hungary (66.3%). In our study we focused only on significant woody habitat types, occurring at least 5 percent of hexagons. Binary data of habitat occurrence were used for the analyses. Significant woody habitat types in the regions are: riverine and swamp woodlands signed by J, mesic deciduous woodlands signed by K, closed dry and deciduous woodlands signed by L and other tree dominated habitats signed by R. P = bush vegetation, woodland margins, wooded pastures, sweet chesnut forests and extensive orchards. English nomenclature of habitats by MOLNÁR et al (2008), Hungarian names are by BÖLÖNI et al (2003).

Regarding woody vegetation types (Fig.1), riverine and swamp woodlands (J) are abundant only in Belső-Somogy, mostly streamside alder groves (J5, 8.7%) and, in a lesser extent, alder swamps (J2, 2.4%). Mesic deciduous woodlands are the most widespread as the original zonal vegetation in out study area, preserved best in Zselic (14%), half of it in the other two regions. In Belső-Somogy dominate hornbeam-pedunculate oak forests (K1a, 8%), in Külső-Somogy and Zselic hornbeam-sessile oak forest (K2, 4.3% and 8.1%, accordingly); in Zselic beech forests (K5) are also important (5.4%). Closed dry deciduous forests (L) are in a marginal zonal position in Külső-Somogy, but most of them are disappeared, their actual coverage is about 3%. Secondary woody types

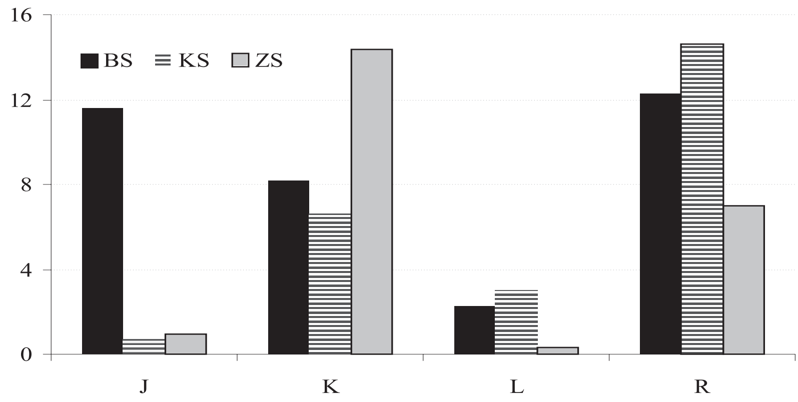

Fig. 1: Relative distribution of woody habitat occurrence in vegetation-based landscape regions. (Abbreviations see in Material and methods)

(R), mostly plantations dominate in Belső- and Külső-Somogy (12%, 14%), far less widespread in Zselic (7%). Woody pastures (P45), characteristic and spectacular remnants of former traditional landuse, in Belső-Somogy cover (partly degraded) 5440 ha (0.6%).

Results

Climatic surface of the regions

Climatic surface is a realized range of climatic variables that could effect pattern and distribution of vegetation types potentially in geographical or natural landscape areas. In Table 1 basic statistics of 19 calculated bioclimatic variables, as minimum, maximum, mean values and their ranges are given for the studied regions. Referring to general climatic position the most relevant indexes are the annual mean of temperature (BIOCLIM 1) and the annual precipitation (BIOCLIM 12). The annual mean temperature varies between 9.8 °C and 11.3 °C, its maximum range is 1.5 °C in Külső-Somogy. Maximum and mean values and the range are the lowest in Belső-Somogy region. Annual mean precipitation (BIOCLIM 12) varies between 562 to 753 mm per year. Minimum, maximum and mean of this variable occur with the highest values in Belső-Somogy region, maximum range occurs in Külső-Somogy region.

Bioclimatic indexes according to a short period (e.g. a month or a quarter) could have a hard climatic limitation for the vegetation. Mean values in maximum temperature of warmest month (BIOCLIM 5) are quite similar in the regions, but the minimum values and the range significantly differs in Külső-Somogy and Belső-Somogy region with its extremities. Among values in minimum temperature of coldest month (BIOCLIM 6), the highest maximums of minimum, maximum and mean values can be observed in Belső-Somogy, range is the biggest in Külső-Somogy region. Minimum value in Zselic, maximum value and mean in Belső-Somogy, and the range in Külső-Somogy is the highest by precipitation of wettest month (BIOCLIM 13). In values by precipitation of driest month (BIOCLIM 14) can be seen similar distribution among the regions. Generalized variable of temperature seasonality (BIOCLIM 4) has the highest values in Belső-Somogy and Külső-Somogy regions, as also the maximum values of precipitation sea-

Table 1: Climatic surface by BIOCLIM variables for vegetation-based landscape regions. Highest values are signed by bold, lowest values are signed by dashed.

(Abbreviations and variables see in Material and methods)

Variable	Minimum			Maximum			Mean			Range (Max - Min)		
	BS	KS	ZS	BS	KS	ZS	BS	KS	ZS	BS	KS	ZS
BIOCLIM 1	**10.3**	*9.8*	10.2	*11.1*	11.3	11.3	*10.7*	10.8	10.8	*0.8*	**1.5**	1.1
BIOCLIM 2	**9.4**	*9.0*	9.1	**9.7**	9.6	9.6	9.5	9.2	**9.3**	*0.3*	**0.6**	0.5
BIOCLIM 3	**30.2**	*29.1*	29.2	**31.9**	*31.3*	*31.3*	**31.1**	*29.8*	30.2	*1.7*	**2.1**	**2.1**
BIOCLIM 4	73.8	**74.9**	**74.9**	*76.7*	78.6	**78.7**	*75.1*	**77.3**	76.5	*2.9*	3.7	**3.8**
BIOCLIM 5	**26.4**	*25.8*	26.1	*27.3*	**27.6**	**27.6**	26.9	26.9	26.9	*0.9*	**1.8**	1.5
BIOCLIM 6	**-4.2**	-4.8	*-4.5*	**-3.2**	*-3.5*	*-3.5*	**-3.8**	*-4.1*	-4.0	*1.0*	**1.3**	1.0
BIOCLIM 7	30.4	**30.5**	30.4	*31.1*	**31.5**	**31.5**	*30.7*	**31.0**	30.9	*0.7*	1.0	**1.1**
BIOCLIM 8	**18.4**	18.0	*17.9*	*20.4*	**20.6**	20.5	19.8	19.4	*18.8*	*2.0*	**2.6**	**2.6**
BIOCLIM 9	**1.9**	*1.1*	1.6	**2.9**	2.7	2.7	**2.3**	*2.0*	2.1	*1.0*	**1.6**	1.1
BIOCLIM 10	**19.5**	*19.1*	19.4	*20.4*	**20.8**	**20.8**	20.0	**20.2**	20.1	*0.9*	**1.7**	1.4
BIOCLIM 11	**0.2**	*-0.5*	-0.1	**1.2**	0.9	0.9	**0.6**	*0.3*	0.4	1.0	**1.4**	1.0
BIOCLIM 12	**643**	*562*	631	**753**	*708*	720	**715**	*639*	691	110	**146**	*89*
BIOCLIM 13	75	*69*	**78**	**91**	*87*	*87*	**86**	*78*	85	16	**18**	*9*
BIOCLIM 14	34	*32*	**35**	**42**	*39*	40	**40**	*36*	39	**8**	7	*5*
BIOCLIM 15	24	24	24	**29**	28	*26*	25	**26**	25	**5**	4	*2*
BIOCLIM 16	**216**	*188*	209	**245**	*230*	235	**233**	*215*	227	29	**42**	*26*
BIOCLIM 17	111	*100*	**115**	**134**	*131*	*131*	**127**	*114*	126	23	**31**	*16*
BIOCLIM 18	**216**	*188*	209	**245**	*230*	235	**233**	*215*	227	29	**42**	*26*
BIOCLIM 19	115	*109*	**125**	**143**	*140*	*140*	**136**	*124*	135	28	**31**	*15*

sonality (BIOCLIM 15). Bioclimatic variables for a quarter are different in their values and in the regions. Mean temperature of the quarters (BIOCLIM 8,9,10,11) show the highest minimum, maximum and mean values in Belső-Somogy region, their range is the highest in Külső-Somogy. By precipitation of the quarters (BIOCLIM 16,17,18,19) Belső-Somogy shows the highest maximum and mean, Külső-Somogy shows the lowest minimum, maximum and mean values. Zselic is a special region with its lowest precipitation range.

In general minimum, maximum and mean values of bioclimatic variables are the lowest in Külső-Somogy region, they are the highest in Belső-Somogy region. Value ranges are the widest in Külső-Somogy region in both temperature and precipitation bioclimatic variables at most cases, so that this region occurs as the climatic extremity among three vegetation-based landscape regions. According to temperature variables Belső-Somogy is the less climate moderated, according to precipitation variables Zselic is the most climate moderated landscape region.

Among bioclimatic indexes having strongly different minimum, maximum and mean values and showing a wider range, are appropriate for calculating and comparing climatic envelope of woody habitat types in the regions by BIOCLIM 12 to 1, 17 to 9 and 18 to 10.

Climatic envelope of habitats in the regions

According to selected bioclimatic pairs, main woody habitat types are characterized by a variable calculated from a pair of precipitation and temperature data. The first pair is BIOCLIM 12 as the mean annual precipitation to BIOCLIM 1 as mean annual tem-

Table 2: Climatic envelope of woodland habitats in the regions for selected bioclimatic variables (Abbreviations and variables see in Material and methods)

J habitats	BS				KS				ZS			
	Min	Mean	Max	Range	Min	Mean	Max	Range	Min	Mean	Max	Range
BIOCLIM1	10.3	10.7	11.1	0.8	10.1	10.7	11.0	0.9	10.4	10.8	11.1	0.7
BIOCLIM9	1.9	2.3	2.8	0.9	1.4	2.0	2.3	0.9	1.8	2.2	2.7	0.9
BIOCLIM10	19.5	20.0	20.3	0.8	19.5	20.0	20.5	1.0	19.7	20.1	20.4	0.7
BIOCLIM12	644	721	753	109	576	662	703	127	640	705	720	80
BIOCLIM17	113	128	134	21	103	117	125	22	117	128	131	14
BIOCLIM18	216	235	245	29	194	222	230	36	212	231	235	23

K habitats	BS				KS				ZS			
	Min	Mean	Max	Range	Min	Mean	Max	Range	Min	Mean	Max	Range
BIOCLIM1	10.4	10.7	11.1	0.7	9.8	10.5	11.2	1.3	10.2	10.7	11.3	1.1
BIOCLIM9	1.9	2.3	2.8	0.9	1.2	1.8	2.3	1.1	1.6	2.0	2.6	1.0
BIOCLIM10	19.6	19.9	20.3	0.7	19.1	19.9	20.6	1.5	19.4	20.1	20.8	1.4
BIOCLIM12	656	721	752	96	579	658	699	120	636	690	719	83
BIOCLIM17	113	128	134	21	102	117	125	23	116	126	131	15
BIOCLIM18	222	235	245	23	195	221	230	35	211	226	235	24

L habitats	BS				KS				ZS			
	Min	Mean	Max	Range	Min	Mean	Max	Range	Min	Mean	Max	Range
BIOCLIM1	10.4	10.7	11.0	0.6	9.9	10.6	11.1	1.2	10.2	10.6	11.2	1.0
BIOCLIM9	1.9	2.3	2.8	0.9	1.3	1.8	2.3	1.0	1.7	2.0	2.5	0.8
BIOCLIM10	19.6	19.9	20.3	0.7	19.2	20.0	20.6	1.4	19.5	19.9	20.7	1.2
BIOCLIM12	660	722	750	90	572	639	696	124	640	696	711	71
BIOCLIM17	116	129	134	18	102	114	125	23	117	127	129	12
BIOCLIM18	222	235	244	22	192	215	229	37	212	228	234	22

R habitats	BS				KS				ZS			
	Min	Mean	Max	Range	Min	Mean	Max	Range	Min	Mean	Max	Range
BIOCLIM1	10.4	10.8	11.1	0.7	9.8	10.6	11.3	1.5	10.2	10.7	11.3	1.1
BIOCLIM9	2.0	2.4	2.9	0.9	1.2	1.9	2.4	1.2	1.6	2.1	2.7	1.1
BIOCLIM10	19.6	20.0	20.4	0.8	19.1	20.1	20.8	1.7	19.5	20.1	20.8	1.3
BIOCLIM12	646	713	750	104	566	645	702	136	632	689	719	87
BIOCLIM17	112	128	134	22	100	115	125	25	115	126	131	16
BIOCLIM18	217	232	242	25	190	217	230	40	210	226	235	25

perature reflecting to main character of the climate by a long-term average dataset (Table 2, Fig 2). Occurrence all of woody habitat types is characteristic in a wide range of precipitation, and a narrow range of temperature in the regions. Range of climatic envelope by BIOCLIM 12 is the widest in Külső-Somogy region, the narrowest in Zselic region in all the case of woody habitats. Range of climatic envelope by BIOCLIM 1 as the mean temperature is also the widest in Külső-Somogy region, the narrowest is in Belső-Somogy region. Habitats are well-ordered by an increasing precipitation gradient from Külső-Somogy, through Zselic to Belső-Somogy under similar range of temperature variable. Between these bioclimatic indexes, BIOCLIM 12 proved to be the most effective variable for regional differentiation. Among habitat types, all of woodlands exist in a wide range of annual precipitation, K and R habitats are under a wide range, J and L habitats are under a narrow range of annual temperature as the climatic envelope.

The second selected pair among bioclimatic variables is BIOCLIM 17 as the precipitation of driest quarter to BIOCLIM 9 as mean temperature of driest quarter, reflecting to quarterly climatic extremities of a short term outside the regular vegetation period (Table 2, Fig 3). The driest quarter could cause an environmental limitation in starting of vegetation period. Occurrence all of woody habitat types is characteristic in a wide range of quarterly precipitation, and a regionally differentiated narrow range of temperature. Range of climatic envelope by BIOCLIM 17 is the widest in Külső-Somogy region, the narrowest in Zselic region in all the case of woody habitats. Range of climatic envelope by BIOCLIM 9 as the mean temperature of driest quarter is also the widest in Külső-Somogy region, the narrowest is in Belső-Somogy region. Habitats are well-ordered by an increasing precipitation gradient from Külső-Somogy, through Zselic to Külső-Somogy under continuously increasing temperature variable. Between these two bioclimatic indexes, both BIOCLIM 17 and BIOCLIM 9 proved to be effective for regional differentiation, but not for the habitat types. Among habitat types, all of woodlands exist in a wide range of temperature and precipitation as well. The widest range of temperature and precipitation in driest quarter is effective as the climatic envelope in Belső-Somogy region, the narrowest range of them is in Zselic region. Range of climatic variables is in proportion to the case number of habitat occurrence.

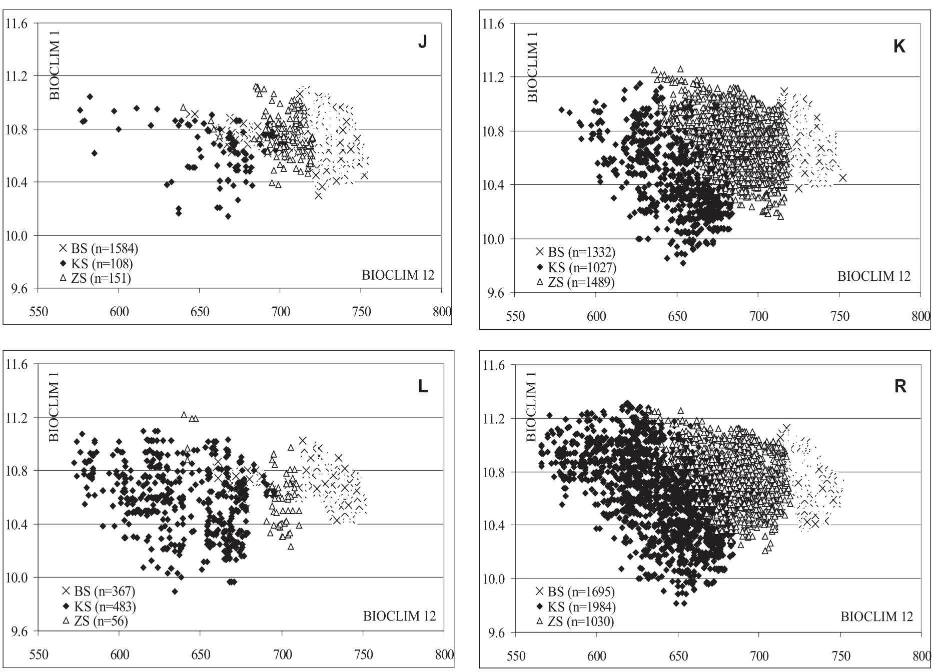

Fig. 2: Climatic envelope by mean annual precipitation (BIOCLIM 12) to mean annual temperature (BIOCLIM 1) for woodland habitats.

(Abbreviations and variables see in Material and methods)

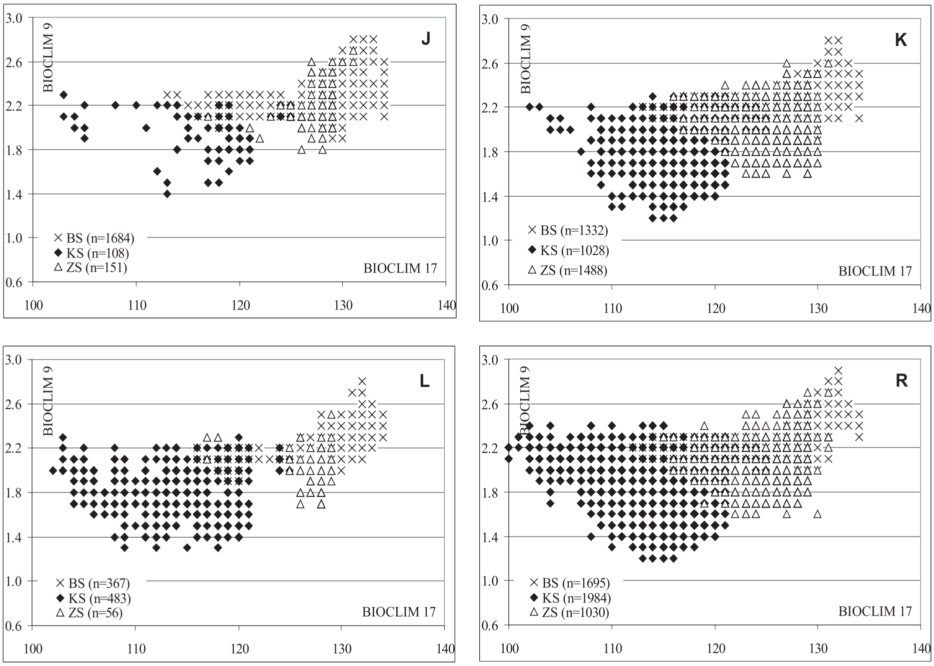

Fig. 3. Climatic envelope by precipitation (BIOCLIM 17) to mean temperature (BIOCLIM 9) of driest quarter for woodland habitats
(Abbreviations and variables see in Material and method)

The third selected pair among bioclimatic variables is BIOCLIM 18 as the precipitation of warmest quarter to BIOCLIM 10 as mean temperature of warmest quarter, reflecting to quarterly climatic optimum of a short term inside the regular vegetation period (Table 2, Fig 4). The warmest quarter could result an environmental optimum period for vegetation existence. Occurrence all of woody habitat types is characteristic in a wide range of quarterly precipitation, and a regionally differentiated narrow range of temperature. Range of climatic envelope by BIOCLIM 18 is the widest in Külső-Somogy region, the narrowest in Zselic or Belső-Somogy region. Range of climatic envelope by BIOCLIM 10 as the mean temperature of warmest quarter is also the widest in Külső-Somogy region, the narrowest is in Belső-Somogy region. Habitats are well-ordered by an increasing precipitation gradient, but decreasing and tightening temperature range from Külső-Somogy, through Zselic to Belső-Somogy. Between these two bioclimatic indexes, both BIOCLIM 17 and BIOCLIM 9 proved to be effective for regional and habitat differentiation. Among habitat types, R and L woodlands exist in a wide range of temperature and precipitation, J habitats are under wide range of precipitation but a narrow range of temperature, and K habitats are under a narrower range of precipitation and a wide range of temperature in the warmest quarter.

Discussion

There were differences among climatic surfaces of the regions by all the bioclimatic variables. Vegetation-based landscape regions along a rough east-west gradient were ordered by bioclimatic indices originated from precipitation data in each habitat, similarly to other South Transdanuian small regions (ORTMANN-AJKAI and HORVÁTH 2009). This trend was not revealed by bioclimatic indices calculated by temperature data. In spite of differences in climatic variance, woodland habitats occurred under similar bioclimatic conditions.

Riverine and swamp woodlands (J habitats) have high water demand, so they occur mostly in the wetter part of the climatic envelope. Their occurrences in climatically drier areas – especially in Külső-Somogy – shows that they are edafic communities. Mesic woodlands (K habitats) in drier Külső-Somogy are more constrained to areas of lower temperature index, showing their marginal phytogeographical position. Contrasting to that dry woodlands (L habitats) occur dominantly in Külső-Somogy, in the whole temperature range, showing that this region is close to their phytogeographical optimum. Secondary forests (R habitats) cover climatic envelope of both mesic and dry forests, because they were planted to the place of both of them (see Fig.4). Variable case number of any woody habitat types in the regions cannot be explained by climatic conditions only, it could be interpreted by land use and management data also.

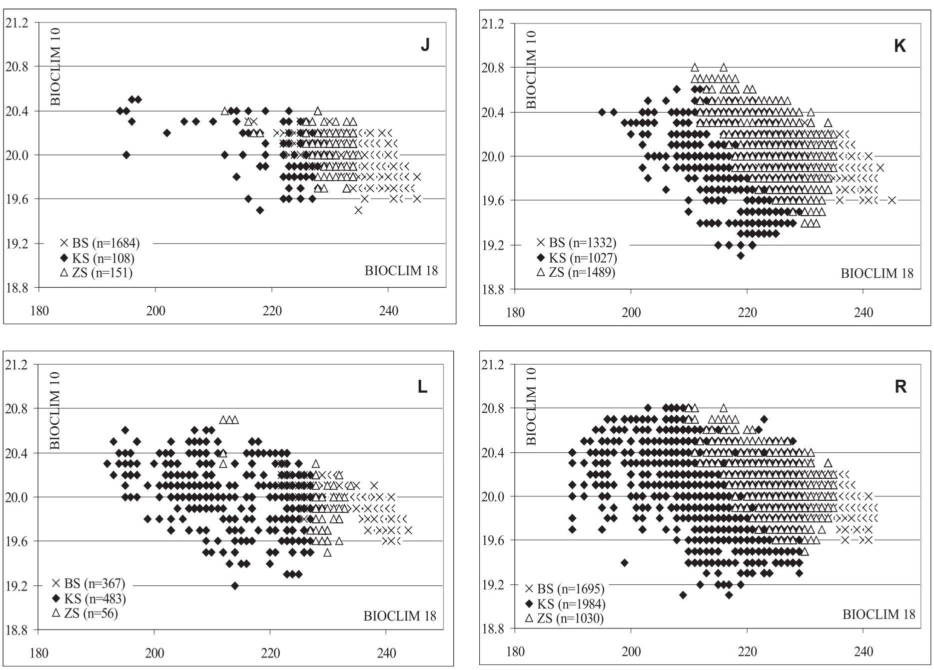

Fig. 4: Climatic envelope by precipitation (BIOCLIM 18) to mean temperature (BIOCLIM 10) of warmest quarter for woodland habitats

(Abbreviations and variables see in Material and method)

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