DOI:10.24394/NatSom.2013.23.75

Natura Somogyiensis	**23**	75-88	Kaposvár, 2013

Climatic conditions and habitats in Belső-Somogy, Külső-Somogy and Zselic as vegetation-based landscape regions IV. Precipitation envelopes of mesic deciduous woodlands

Salamon-Albert Éva

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

Salamon-Albert, É.: *Climatic conditions and habitats in Belső-Somogy, Külső-Somogy and Zselic as vegetation-based landscape regions IV. Precipitation envelopes of mesic deciduous woodlands.*
Abstract: In our study precipitation response of mesic deciduous woodlands (lowland pedunculate and sessile oak-hornbeam woodland, beech woodland) are discussed in the vegetation based landscape regions of South Transdanubia, including Belső-Somogy, Külső-Somogy and Zselic at landscape scale. Long term precipitation variables from BIOCLIM series as potential ecological predictors are used to characterize and compare climate envelopes of selected mesic woodlands. Non-parametric Gaussian probability estimation detailed with kernel densities as a potential series of ecological niches were computed for yearly, quarterly and some short time range or deviation of precipitation representing annual trends, seasonality and extreme or limiting environmental factors in order to get more extensive knowledge about macro-ecological responses leading to environmental adaptation. Precipitation envelopes of the woodlands as the whole and the habitats in each are nearly integrated into the regional range according to their summarized densities on relative frequency. Precipitation response of beech woodlands shows significant difference to semi-natural habitats by all variables consequently but to habitat group of mesic woodlands only in some case (e.g. annual sum of precipitation). Climate envelope of pedunculate oak-hornbeam woodlands and sessile oak-hornbeam woodlands significantly differ from semi-natural habitats response by precipitation of wettest and coldest quarter, especially. Among studied variables the annual sum and one of the warmest quarter turned to be the most effective in climatic niche differentiation in habitat group of woodlands as a whole as well as in mesic habitat types in each. In contrast to the above mentioned, fall sum of wettest month and precipitation seasonality is verified to provide the most slight niche segregation effort. The two latter ecological phenomena is suitable to discover the most significant macro-ecological factors to enchance functional diversity [BIOCLIM-12, -18] or variables to confirm a nearly uniform precipitation performance [BIOCLIM-13, -14] in submontaine mesic woodlands as the main macro-ecological predictors for water input.

Keywords: climate envelope model, mesic deciduous woodlands, niche segregation, MÉTA habitats, South Transdanubian Region

Introduction

Examining vegetation environment relationships based on relevant ecological data supported by a theoretical model and management applications is forming current hot spot questions and answers, and can be discussed both from ecological and environmen-

ISSN 1587-1908 (Print); ISSN 2062-9990 (Online)

tal point of view. Climate classification of the vegetation is mainly computed at different spatial scales, according to bioms, continents, countries and regions leading to be constructed spatial or ecological patterns and distributions (Ozenda and Borel 2000, Hossel et al. 2003, Piovesan et al 2005, Thompson et al 2005, Attore et al. 2007). Requirements for small-scale studies are discussed and demonstrated by more and more authors nowadays (e.g. Lindner et al. 2010), but their conclusions as the scientific results have to be applied with caution.

Quantifying significant ecological factors influencing range and threshold values of species or habitat existence or distribution is an ongoing challenge for scientists nowadays, especially under current changing climate conditions (Guisan and Thuiller 2005, Colwell and Rangel 2009). A lot of measures have been used to quantify distribution characteristics leading to construct environmental niches and analyse their overlap (e.g. Fitzpatrick et al. 2008; Peterson and Nakazawa 2008), differences in niches using observed occurrences of the objects can reflect to their unknown conjunction (Soberón 2007, Colwell and Rangel 2009). Ecologically appropriate subset of environmental conditions that is actually occupied by the species or habitats corresponds to the realized niche (Hutchinson 1957). Long term climatic conditions resulting the realized environmental envelopes described by a set of geographically referenced variables come from the widely used, systematic climatic databases (Hossell et al. 2003, Beaumont et al. 2005, Hijmans et al. 2005, Attorre et al. 2007, Czúcz et al. 2009). Novel analyses connecting distribution models with other ecological phenomena can provide novel capacities for understanding specific and general drivers of occurrence and distribution.

Transdanubia of Hungary is one of the most significant regions for lowland and colline mesic woodlands under high level of climatic and geographic variability (Molnár Zs. et al. 2008, www.met.hu). For this reason the region can be a suitable object for ecological modelling and passing out spatial studies at regional scale. Bioclimatic variables as the adequate macro-ecological environmental predictors representing annual trends, short or long term extreme or limiting abiotic factors of the sorrounding, therefore they are more suitable for studying climatic niches and interactions among them (e.g. Hijmans et al. 2005). These ecological phenomena, especially the precipitation components do play a significant role in the long term existence of mesic woodlands that are consensually regarded to be a macro-climate adapted vegetation in Europe, even though of their geographical or regional diversity (e.g. Marinsek et al. 2013).

The aims of our study is 1) to characterize and compare climate envelopes of mesic deciduous woodlands by mean, minimum, maximum and range of monthly, quarterly and yearly precipitation variables, 2) to analyse relationships between climatic niches of mesic woodland habitats by summarized and multipeak distributions and comparing to semi-natural habitats furtherly, and 3) to detect bioclimatic variable(s) that could be the most significant for niche segregation providing an essential contribution to quantify precipitation performance of mesic woodlands in the studied regions.

Material and method

Study area

The study area is Külső-Somogy, Belső-Somogy and Zselic as the three significant vegetation based landscape regions of South Transdanubia in Hungary, defined on their actual macro-climatic, dominant extrazonal or edaphic vegetation types (Molnár Cs. et al. 2008). Elevation varies in a moderate range from lowlands (96 m a.s.l.) to hills (300 m a.s.l.), the average is 161 m a.s.l. 30 year annual temperature varies between 9,8 °C and 11,3 °C, the average is 10,8 °C (SALAMON-ALBERT et al. 2011). Studied regions are positioned in the intersection of three macro-climatic zone: from west the atlantic, from east the continental and from south the mediterranean one, that can highly influence the climatic surface. According to the newest climatic map of Europe constructed by the categories of Köppen-Geiger climate classification system (PEEL et al. 2007) there is a humid cold continental climate in the region on global scale. Regarding to a district scale climate classification (PÉCZELY 1963, 2006, www.met.hu/) moderately warm - moderately dry and moderately warm - moderately wet climate types dominate and furtherly, six ones occur in the region among twelve regional climate types of Hungary configuring a climatically diversed sample area for a high resoluted climate based landscape ecological investigation. Regarding to the large scale climate classification mid-latitude grasslands, broadleaf deciduous forests and woodlands but rarely some mixed evergreen and broadleaf forests can be dominated in the vegetation potentially fitted into the zone of submontaneous oak-hornbeam woodlands as mesic woody habitats and thermophilous oak woodlands with open steppe oak woodlands and riparian vegetation at European scale (OZENDA and BOREL 2000).

BIOCLIM variables

Yearly, quarterly and monthly sum or deviation in precipitation as bioclimatic variables [from BIOCLIM 12 to 19] were used calculated from meteorological data measured by the local weather stations of the Hungarian Meteorological Service (http://vissycd.glia.hu/atlasz.html, MERSICH et al. 2001). They are also integrated into the WorldClim database for further applications (http://www.worldclim.org). Spatially interpolated variables are applied recalculated for the regional surface at fine resoluted hexagon scale of MÉTA database by the Institute of Ecology of the Hungarian Academy of Sciences (CZÚCZ et al. 2007). Bioclimatic variables are developed in order to generate more biologically meaningful ecological predictors and are often used in ecological niche computation as bioclimate envelope model.

Precipitation variables for the analyses are BIOCLIM-12 the mean annual sum, BIOCLIM-13 the mean sum of wettest month, BIOCLIM-14 the sum of driest month, BIOCLIM-15 the annual seasonality calculated as standard deviation of monthly means, BIOCLIM-16 the sum of wettest quarter, BIOCLIM-17 the sum of driest quarter, BIOCLIM-18 the sum of warmest quarter and BIOCLIM-19 the sum of coldest quarter. Annual data refer to monthly averages from January to De-cember, wettest quarter refers means from June to August, driest quarter refer means from January to March, warmest quarter refer means from June to August, coldest quarter refer means from December to February as the periods of three months, ¼ of a year.

Habitats of mesic deciduous woodlands

MÉTA habitat and mapping project (2002-2006) was a systematic survey of the Hungarian semi-natural vegetation on landscape scale connected with spatial and geographical information (BÖLÖNI et al 2007, MOLNÁR et al 2007, HORVÁTH et al. 2008). Data collecting in the field were carried out at high resoluted hexagon scale (35 ha) as basic units, and they were integrated into quadrats for landscape mapping (35 km^2), both were added to the so called MÉTA database (HORVÁTH and POLGÁR 2008). In our study mesic woody habitats connected with precipitation variables from BIOCLIM series were assigned for 16300 hexagons of 163 MÉTA quadrats of the three landscape regions.

Totally, 5 MÉTA habitat types of mesic woodlands in the associated habitat group (K) were identified in South Transdanubia, including K1a the lowland pedunculate oak-hornbeam woodlands, K2 the sessile oak-hornbeam woodlands, K5 the beech woodlands, K7a the acidofrequent beech woodlands and K7b the acidofrequent oak-hornbeam woodlands (MOLNÁR et al. 2008, SALAMON-ALBERT et al. 2008, 2010, 2011). In our paper we focus on significant mesic woodlands having sufficient sample size for the analysis as K1a (n=1792), K2 (n=2042), K5 (n=926), the associated habitat group of K (n=3848) and moreover, with high attention on totality of natural habitats as ÁNÉR (n=9187) using presence-absence data of occurrence.

Sessile oak hornbeam woodlands (K2) are the most abundant in the regions as well as in Hungary. They mostly occur in submontane and colline elevation, usually on deep soils and dominated by *Quercus petraea, Carpinus betulus* and *Fagus sylvatica*. In Belső-Somogy, this habitat type is replaced by lowland pedunculate oak-hornbeam woodlands, according to geographical distribution and connected to cool-humid climate suitable and available. It occurs on all types of (but mainly on solid) bedrock, it can rather be found on loess or loess-like sediments and misses on sand, and occurs on clay, where it forms mosaic with lowland oak-hornbeam woodlands in the hilly regions.

Pedunculate oak-hornbeam woodlands (K1a) are the next by their abundance among mesic woodland habitat types in the regions. Shadowed and mesic forests of lowlands and hilly landscapes with *Quercus robur* and *Carpinus betulus* in the tree layer. The centre of the distribution is in the western part of Transdanubia: with greatest area in Belső-Somogy (14000 ha) and in Dráva-sík (6000 ha) connected to. Apart from lowland of Drava (Dráva-sík), it can be found only at the edges of the Great Plain (Alföld), with the greatest extension in lowland of Szatmár-Beregi sík (1500 ha). It occurs on incoherent sedimentary rocks, especially on sand and clay, mainly on the humid parts of the regions. Along the rivers it appears typically in high floodplains formated by river and stream valleys in the hilly regions of Hungary. This habitat type frequently occurs together and forms mosaic with sessile oak-hornbeam woodlands (K2).

Submontaneous beech woodlands (K5) are high growing, closed mesic forests, connected to cool and humid climate with (mono)dominance of European beech (*Fagus sylvatica*). Habitat occurs in the Északi-középhegység macroregion with the greatest extension (45000 ha). In certain parts of Transdanubia there is 12500 ha of beech woodlands, especially in Zselic and Mecsek with the larger extension, and in Külső- and Belső-Somogy sporadically due to less favourable abiotic conditions (e.g. low precipitation) and several types of human impact and the high disturbance regime.

Nomenclature of the habitats is by MOLNÁR ZS. et al (2008), habitat description is by BÖLÖNI et al. (2008).

Data analyses

By the set of precipitation variables climate envelopes of semi-natural habitats are reported (Á-NÉR) as the basic, and ones of associated group of mesic deciduous woodlands and the types disposing statistically appropriate plot number (K, K1a, K2, K5). In the first step, scatterplots of relative distribution (%) were calculated for the total area covered by any semi-natural vegetation as the regional habitat envelope (Á-NÉR) and on woodland types as woodland envelope according to temperature variables. Data originated from the associated dataset of habitat occurrence and climatic variables, were sorted for the analyses representing all of the sampling points (MÉTA hexagons). In second step, area version of Gaussian probability curve as a nonlinear multipeak analysis was executed on the scatterplots, computing Levenberg-Marquardt algorithm as an iterative procedure using a smooth approximation. Gaussian model of climate envelope can be described as a non-parametric probability density function computed as a summarized series of normal distributions called kernel densities as realized precipitation niches. Gaussian curves as a result of integrated kernels were compared by a non-parametric measure of variance (Kruskal-Wallis ANOVA), pairwise significant differences were counted by Fischer LSD post hoc test and signed if $p<0.05$. Kernel densities of climate envelopes can be associated into functional groups, especially. To create functional groups hierarchical cluster analysis combined with an explanatory optimization process based on a ranking method was carried out on the standardized data of kernel distributions in the program Syn-Tax 5.0 (PODANI 1998). Analysing number and components of clusters, quantitative climatic trait of studied mesic woodlands can be revealed. Poorly grouped distributions are interpreted as a climatic gradient function, ones that are associated to each other form one or more climatic functional group (e.g. F1).

Results

Climate envelope is the current range of suitable environmental conditions described by significant variables referred to pattern and distribution of the habitat in a studied geographical area. Basic statistics of eight precipitation variables as minimum, maximum, mean values and the range of the habitats are given for the studied regions (Table 1). Referring to general and long term water input relations annual sum of precipitation [BIOCLIM 12] is the most relevant index. It varies between 566 and 753 mm exhibiting the widest range for semi-natural habitats [Á-NÉR] in the region. Climate envelope by the yearly sum of mesic woodland habitats (K) is a little bit narrowest with a little bit higher minumum and maximum values compared to semi-natural habitats. Among woodland habitat types different ranges of BIOCLIM-12 with the highest value in pedunculate oak-hornbeam woodlands (171 mm), with medium value in sessile oak hornbeam woodlands (154 mm) and the lowest range in beech woodlands (125 mm) can be demonstrated. Bioclimatic variables referring to a shorter period (e.g. a month or a quarter) or indicate environmental extremities could present some climate limitation for the distribution. According to precipitation of wettest month [BIOCLIM 13] whole range of semi-natural vegetation is completed by mesic woodland types, but the narrowest range of beech woodlands (K5) as well as by precipitation of the driest month [BIOCLIM 14]. Precipitation seasonality [BIOCLIM 15] provides the worst differentiation among the habitat types because of its extremely narrow range in all cases. On the precipitation of the wettest quarter [BIOCLIM 16] as well as the next three variables as one of the driest [BIOCLIM 17], the warmest [BIOCLIM 18] and the coldest quarter [BIOCLIM 19] habitats are exhibited in a decreasing order by their precipitation envelope from pedunculate oak-hornbeam woodlands (K1a) to beech woodlands (K5).

According to minimum value of yearly precipitation envelope [BIOCLIM 12] pedunculate oak-hornbeam woodlands can exist under the lowest (K1a, 579 mm), sessile oak hornbeam woodlands can grow under the medium (K2, 598 mm) and beech woodlands are positioned at the highest (K5, 612 mm) values as well as to minimum of all quarterly variables. Minimum of monthly variables [BIOCLIM 13 and 14] and precipitation seasonality [BIOCLIM 15] turns to have a weak dividing function among mesic woodland habitats. On the maximum values of BIOCLIM 12 climate envelopes pedunculate (K1a, 750 mm) and sessile oak hornbeam woodlands (K2, 752 mm) have quite similar threshold values, opposite to beech woodlands (K5, 737 mm) that are positioned under significantly lower maximum threshold. Regarding to monthly, quarterly and seasonality [BIOCLIM 13 to 19] precipitation maximums woodland habitas types can be poorly differentiated. By the mean of annual precipitation [BIOCLIM 12] sessile oak hornbeam

Table 1. Basic statistics of precipitation envelopes for semi-natural habitats as a whole (Á-NÉR), mesic deciduous woodlands (K), lowland pedunculate oak-hornbeam woodlands (K1a), sessile oak-hornbeam woodlands (K2), and beech woodlands (K5) in the landscape regions

Á-NÉR		min	mean	std	max	range
BIOCLIM-12	Annual mean precipitation	566	682	41	753	187
BIOCLIM-13	Precipitation of Wettest Month	69	83	5	91	22
BIOCLIM-14	Precipitation of Driest Month	32	38	2	42	10
BIOCLIM-15	Precipitation seasonality	24	26	1	29	5
BIOCLIM-16	Precipitation of Wettest Quarter	190	225	11	245	55
BIOCLIM-17	Precipitation of Driest Quarter	100	122	8	134	34
BIOCLIM-18	Precipitation of Warmest Quarter	190	225	11	245	55
BIOCLIM-19	Precipitation of Coldest Quarter	110	131	8	143	33

K		min	mean	std	max	range
BIOCLIM-12	Annual mean precipitation	579	692	31	752	173
BIOCLIM-13	Precipitation of Wettest Month	71	84	4	91	20
BIOCLIM-14	Precipitation of Driest Month	33	39	2	42	9
BIOCLIM-15	Precipitation seasonality	24	25	1	28	4
BIOCLIM-16	Precipitation of Wettest Quarter	195	228	8	245	50
BIOCLIM-17	Precipitation of Driest Quarter	102	125	6	134	32
BIOCLIM-18	Precipitation of Warmest Quarter	195	228	8	245	50
BIOCLIM-19	Precipitation of Coldest Quarter	112	134	6	143	31

K1a		min	mean	std	max	range
BIOCLIM-12	Annual mean precipitation	579	710	28	750	171
BIOCLIM-13	Precipitation of Wettest Month	71	85	3	90	19
BIOCLIM-14	Precipitation of Driest Month	33	39	2	42	9
BIOCLIM-15	Precipitation seasonality	24	25	1	28	4
BIOCLIM-16	Precipitation of Wettest Quarter	195	232	7	243	48
BIOCLIM-17	Precipitation of Driest Quarter	102	127	5	134	32
BIOCLIM-18	Precipitation of Warmest Quarter	195	232	7	243	48
BIOCLIM-19	Precipitation of Coldest Quarter	112	135	6	143	31

K2		min	mean	std	max	range
BIOCLIM-12	Annual mean precipitation	598	676	24	752	154
BIOCLIM-13	Precipitation of Wettest Month	73	83	4	91	18
BIOCLIM-14	Precipitation of Driest Month	34	38	1	42	8
BIOCLIM-15	Precipitation seasonality	24	25	1	28	4
BIOCLIM-16	Precipitation of Wettest Quarter	201	224	6	245	44
BIOCLIM-17	Precipitation of Driest Quarter	106	123	5	134	28
BIOCLIM-18	Precipitation of Warmest Quarter	201	224	6	245	44
BIOCLIM-19	Precipitation of Coldest Quarter	117	132	5	140	23

K5		min	mean	std	max	range
BIOCLIM-12	Annual mean precipitation	612	689	16	737	125
BIOCLIM-13	Precipitation of Wettest Month	73	85	2	89	16
BIOCLIM-14	Precipitation of Driest Month	34	39	1	41	7
BIOCLIM-15	Precipitation seasonality	24	25	1	27	3
BIOCLIM-16	Precipitation of Wettest Quarter	208	226	4	240	32
BIOCLIM-17	Precipitation of Driest Quarter	107	126	3	130	23
BIOCLIM-18	Precipitation of Warmest Quarter	208	226	4	240	32
BIOCLIM-19	Precipitation of Coldest Quarter	116	135	3	140	24

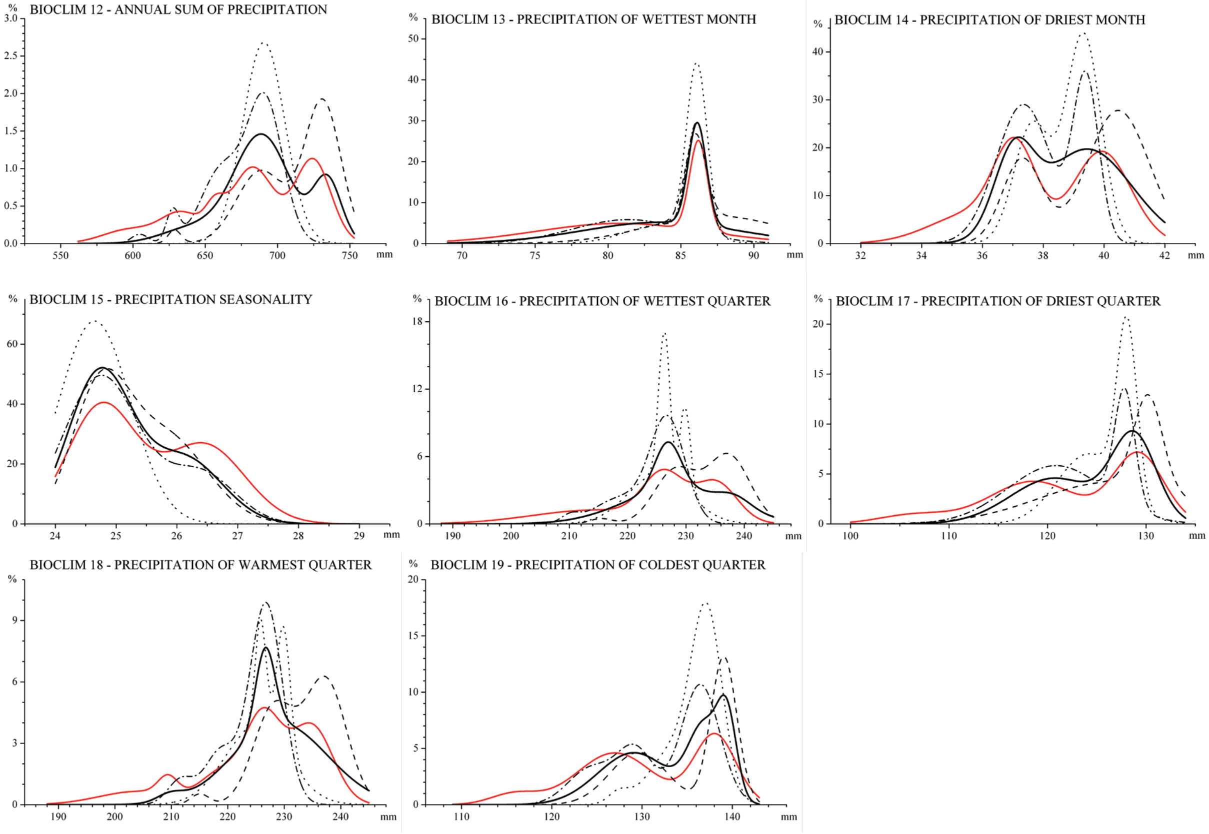

Fig 1. Summarized density function of precipitation variables for mesic deciduous woodlands in the landscape regions. Signs: — semi-natural habitats (Á-NÉR), — mesic deciduous woodlands (K), - -lowland pedunculate oak-hornbeam woodlands (K1a), –·– sessile oak-hornbeam woodlands (K2), ··· beech woodlands (K5).

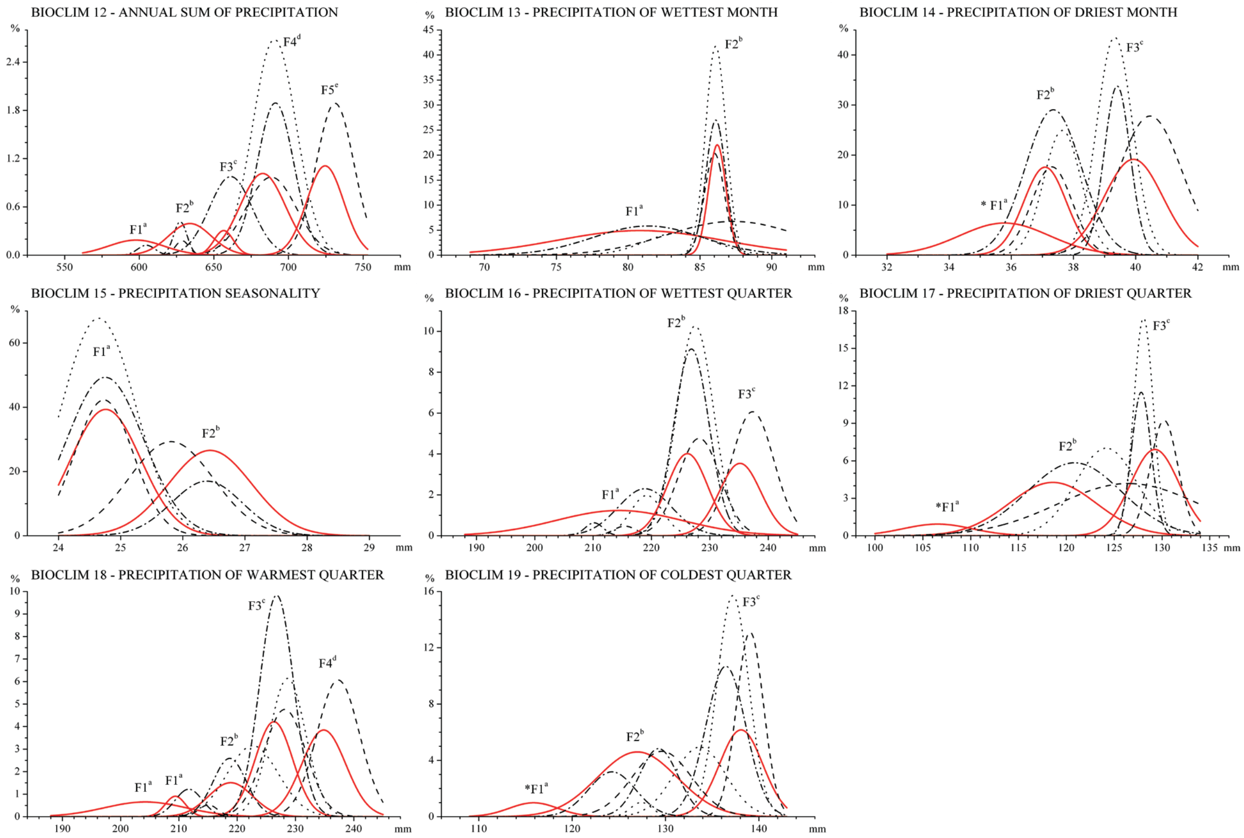

Fig 2. Gaussian multipeaks as kernel density function by precipitation variables for mesic deciduous woodlands in the landscape regions. Signs: — semi-natural habitats (Á-NÉR), - - lowland pedunculate oak-hornbeam woodlands (K1a), –·– sessile oak-hornbeam woodlands (K2), ··· beech woodlands (K5). Functional groups are indicated with capital F combined by number (e.g. F1), optimized differencies are signed with small letters, empty kernels of semi-natural habitats are indicated by asterisk (*).

Table 2. Pairwise differencies between summarized precipitation density of semi-natural habitats (Á-NÉR), mesic deciduous woodlands (K), lowland pedunculate oak-hornbeam woodlands (K1a), sessile oak-hornbeam woodlands (K2) and beech woodlands (K5) in the landscape regions. Probability level is indicated at three levels as p<0.001, p<0.01, p<0.05, ns = no significance based on Kruskal-Wallis ANOVA. For further abbreviations see Material and Method.

BIOCLIM-12	Á-NÉR	K	K1A	K2
K	ns			
K1a	ns	ns		
K2	ns	ns	ns	
K5	p<0.01	p<0.05	ns	ns

BIOCLIM-13	Á-NÉR	K	K1A	K2
K	ns			
K1a	ns	ns		
K2	ns	ns	ns	
K5	p<0.001	p<0.01	ns	p<0.01

BIOCLIM-15	Á-NÉR	K	K1A	K2
K	ns			
K1a	ns	ns		
K2	ns	ns	ns	
K5	p<0.05	ns	ns	ns

BIOCLIM-16	Á-NÉR	K	K1A	K2
K	ns			
K1a	p<0.05	ns		
K2	p<0.05	ns	ns	
K5	p<0.01	ns	ns	ns

BIOCLIM-17	Á-NÉR	K	K1A	K2
K	ns			
K1a	ns	ns		
K2	ns	ns	ns	
K5	p<0.01	ns	ns	ns

BIOCLIM-18	Á-NÉR	K	K1A	K2
K	ns			
K1a	ns	ns		
K2	p<0.05	ns	ns	
K5	p<0.001	p<0.01	ns	ns

BIOCLIM-19	Á-NÉR	K	K1A	K2
K	ns			
K1a	ns	ns		
K2	ns	ns	ns	
K5	p<0.01	ns	ns	ns

woodlands (K2, 676 mm) have the lowest, beech woodlands (K5, 689 mm) have the medium and pedunculate oak-hornbeam woodlands (K1a, 710 mm) have the highest values as well as by the quarterly variables [BIOCLIM 16 to 19]. Monthly mean precipitation and seasonality [BIOCLIM 13 to 15] are even less suitable for habitat differentiation.

Comparing mesic woodland habitats by their precipitation envelopes and their threshold values first and last, pedunculate oak-hornbeam woodlands show the lowest minimum, highest maximum and widest range opposite to beech woodlands with their highest minimum, lowest maximum and narrowest range, sessile oak hornbeam woodlands are positioned between the two mesic woodland habitats by the yearly and quarterly indices. Types of these woodlands are definitely ordered by the range of precipitation variables in each, as pedunculate oak-hornbeam woodlands are the most multifarious, sessile oak hornbeam woodlands have a medium precipitation variability and beech woodlands are represented on the lowest level of variability.

Generally, there was a high level of superimposition between the summarized precipitation density of semi-natural habitats (Á-NÉR) and mesic deciduous woodlands (K) or habitat types (K1a, K2, K5) in each as it was verified by the lack of dissimilarity (see Fig. 1). More detailed differences in precipitation envelopes can be anticipated by the analysis of kernel densities as functional differentiation in climate surface and niche segregation of semi-natural habitats as a whole and each (Fig. 2). Results are introduced as ecological suitabilities or unconveniencies of semi-natural habitats (Á-NÉR) and precipitation traits of the habitats (K1a, K2, K5).

Number of peaks as the kernel function of precipitation can be characterized with one to five Gaussian distributions per variable. Climate envelope of semi-natural habitats as a whole (Á-NÉR) is supremely divided by five kernels on annual sum of precipitation [BIOCLIM 12] and precipitation of warmest quarter [BIOCLIM 18]. Average segregation of ecological niches by three kernels are detected on precipitation of driest month [BIOCLIM 14], precipitation of wettest [BIOCLIM 16] and coldest quarter [BIOCLIM 19]. The least effective variable in density functions by two kernels is the precipitation of wettest month [BIOCLIM 13] and the seasonality [BIOCLIM 15]. Climate envelope of pedunculate oak-hornbeam woodlands (K1a) as a whole is divided into three kernels on annual sum of precipitation [BIOCLIM 12] and precipitation of wettest [BIOCLIM 16] and warmest quarter [BIOCLIM 18] done into two kernels by the others [BIOCLIM 13, 14, 15, 17, 19]. Climate envelope of sessile oak-hornbeam woodlands (K2) as a whole is divided into four kernels on annual sum of precipitation [BIOCLIM 12], it is done into three kernels on precipitation of warmest [BIOCLIM 18] and coldest quarter [BIOCLIM 19]. It is segragated into two kernels on precipitation of wettest [BIOCLIM 13] and driest month [BIOCLIM 14], seasonality [BIOCLIM 15] and precipitation of wettest [BIOCLIM 16] and driest quarter [BIOCLIM 17]. There are three kernel density functions of variable in that an empty habitat kernel as a non-competitive precipitation niche for any mesic woodland is appeared at the lowest values, namely the precipitation of the driest month [BIOCLIM 14], the driest quarter [BIOCLIM 16] and the coldest quarter [BIOCLIM 19].

Discussion

Previous analyses have resulted that precipitation variables could generally play a more significant role for mesic woody habitats distribution in the landscape region than temperature ones, but the exception of mean diurnal temperature range [BIOCLIM-2] for sessile oak hornbeam woodlands and mean tempreraturе of coldest quarter [BIOCLIM-11] for the beech woodlands (Salamon-Albert et al. 2010a,b, 2011, 2012). Among the eight studied precipitation variables all of them turned to be distinctive for the beech woodlands distribution having significant difference to semi-natural habitats (Á-NÉR). According to annual precipitation [BIOCLIM-12], precipitation of wettest month [BIOCLIM-13] and precipitation of warmest quarter [BIOCLIM-18] beech woodlands are diverged from the totality of mesic deciduous woodlands (K) owing to their narrowest precipitation envelopes (see Fig. 3). A strong climate envelope differentiation with the sessile oak hornbeam woodlands (K2) was investigated by the precipitation of wettest month [BIOCLIM-13] only.

Evaluating climate preference of beech woodlands (K5) described by the precipitation envelopes, all of variables become relevant for differentiation to semi-natural habitats as a whole (Á-NÉR), owing to their narrow range. A strong separation with mesic deciduous woodlands as a whole (K) was revealed by the annual precipitation and the precipitation of wettest month as July. A strong and sharp differentiation with sessile oak hornbeam woodlands (K2) was detected by the precipitation of wettest month as July. Distinction of beech woodland habitats with pedunculate oak-hornbeam woodlands (K1a) was not established in any case of precipitation envelopes. Precipitation preference of sessile oak hornbeam woodlands (K2) was exhibited by precipitation of wettest and warmest quarter, and of pedunculate oak hornbeam woodlands (K1a) was manifested by precipitation of wettest quarter merely. As the result of climate envelope analysis, beech woodland habitats turned to have the most restricted distribution among studied mesic woody habitats by all of precipitation variables. Sessile and pedunculate oak-hornbeam woodlands are climatically defined in the landscape by the precipitation of July. Regarding to functional group analysis, annual sum [BIOCLIM-12] and precipitation of warmest quarter [BIOCLIM-18] turned to be the most effective for niche segregation of mesic deciduous woodlands as a whole and the woody habitats each. In contrast with the latter, niche aggregation of mesic woody habitats leading to unity of climate specification was highly supported by the precipitation of wettest month [BIOCLIM-13] and the seasonality [BIOCLIM-15].

Acknowledgements

Vegetation and climatic data were available as requested by MÉTA workgroup, Institute of Ecology and Botany of the Hungarian Academy of Sciences (Vácrátót, Hungary). Research was financially supported by OM-NKFP/2002: „Magyarország természetes növényzeti örökségének felmérése és összehasonlító értékelése". Field data were kindly contributed by Bauer N., Bódis J., Botta-Dukát Z., Börcsök Z., Csiky J., Dávid J., Filotás Z., Fridrich Á., Hegedős L., Horváth A., Juhász M., Kádár G., Király G., Kovács T., Lelkes A., Lőrincz P., Mányoki G., Pándi I., Pfeiffer N., Szabó A., Szalóky I., Szeglet P., Toldi M., Varga A., Wágner L., Zsidákovits J. Climate envelope analysis was sponsored by „TÁMOP 4.2.2.A-11/1/ KONV-2012-0004" research grant.

References

ATTORRE, F., ALFO, M., DE SANCTIS, M., FRANCESCONI, F., BRUNO, F. 2007: Comparison of interpolation method for mapping climatic and bioclimatic variables at regional scale. – International Journal of Climatology 27: 1825-1843.

BEAUMONT, L.J., HUGHES, L., POULSEN, M. 2005: Predicting species distributions: use of climatic parameters in BIOCLIM and its impact on predictions of species current and future distribution. – Ecological Modelling 186: 250-269.

BÖLÖNI, J., MOLNÁR, ZS., ILLYÉS, E. and KUN, A. 2007: A new habitat classification and manual for standardized habitat mapping. − Annali di Botanica (nuova serie) 7: 55-76.

COLWELL R.K, RANGEL T.F. 2009: Hutchinson's duality: the once and future niche. – Proceedings of the National Academy of Sciences USA 106: 19651–19658.

CZÚCZ, B., KRÖEL-DULAY, GY., RÉDEI, T., BOTTA-DUKÁT, Z., MOLNÁR, ZS. (eds) 2007: Éghajlatváltozás és biológiai sokféleség. Elemzések az adaptációs stratégia tudományos megalapozásához. Kutatási jelentés, [Climate change and biological diversity – explorative analysis for a more effective adaptation strategy in Hunga-ry" - in Hungarian with English summary], Institute of Ecology and Botany of the Hungarian Academy of Sciences, Vácrátót, Hungary, Available: http://www.botanika.hu/download-01/NES

CZÚCZ B., TORDA G., MOLNÁR ZS., HORVÁTH F., BOTTA-DUKÁT Z., KRÖEL-DULAY GY. 2009: A spatially explicit, indicator-based methodology for quantifying the vulnerability and adaptability of natural ecosystems. In: Leal Filho, W. & Mannke, F.: Interdisciplinary Aspects of Climate Change. Peter Lang International Verlag der Wissenschaften, Frankfurt am Main, p. 209-227.

FITZPATRICK M.C., DUNN R.R., SANDERS N.J. 2008: Data sets matter, but so do evolution and ecology. – Global Ecology and Biogeography 17: 562–565.

GUISAN A., THUILLER W. 2005: Predicting species distribution: offering more than simple habitat models. – Ecology Letters 8: 993–1009.

HIJMANS, R.J., CAMERON, S.E., PARRA, J.L., JONES, P.G., JARVIS, A. 2005: Very high resolution interpolated climate surfaces for global land areas. – International Journal of Climatology 25: 1965-1978.

HORVÁTH F., POLGÁR L. 2008: MÉTA SQL expert interface and access service. − Acta Botanica Hungarica 50 (Suppl.): 35-45.

HOSSELL, J.E., RIDING, A.E., BROWN, I. 2003: The creation and characterization of a bioclimatic classification for Britain and Ireland. – Journal for Nature Conservation 11: 5-13.

HUTCHINSON G.E. 1957: Population studies – animal ecology and demography – concluding remarks. – Cold Spring Harbor Symposia on Quantitative Biology 22: 415–427.

LINDNER M., MAROSCHEK M., NETHERER S., KREMER A., BARATI A., GARCIA-GONZALO J., SEIDL R, DELZON S., CORONA P., KOLSTRÖM M., LEXER M.J., MARCHETTI M. 2010: Climate change impacts, adaptive capacity and vulnerability of European forest ecosystems. − Forest Ecology and Management 259: 698-709.

MARINŠEK A., ŠILC U., ČARNI A. 2013: Geographical and ecological differentiation of Fagus forest vegetation in SE Europe. − Applied Vegetation Science 16: 131-147.

MERSICH, I., PRÁGER, T., AMBRÓZY, P., HUNKÁR, M., DUNKEL, Z. (eds) 2001: Magyarország éghajlati atlasza. [Climate atlas of Hungary]. OMSZ [Hungarian Meteorological Service], Budapest.

MOLNÁR, CS., MOLNÁR, ZS., BARINA, Z., BAUER, N., BIRÓ, M., BODONCZI L., CSATHÓ, A.I., CSIKY, J., DEÁK, J.Á., FEKETE, G., HARMOS, K., HORVÁTH, A., ISÉPY, I., JUHÁSZ, M., KÁLLAYNÉ SZERÉNYI, J., KIRÁLY, G., MAGOS, G., MÁTÉ, I., MESTERHÁZY, A., MOLNÁR, A., NAGY, J., ÓVÁRI, M., PURGER D., SCHMIDT, D., SRAMKÓ, G., SZÉNÁSI, V., SZMORAD, F., SZOLLÁTH GY., TÓTH, T., VIDRA, T. AND VIRÓK, V. 2008: Vegetation-based landscape regions of Hungary. – Acta Botanica Hungarica 50. (Suppl): 47–58.

MOLNÁR ZS., BARTHA S., SEREGÉLYES T., ILLYÉS E., BOTTA-DUKÁT Z., TÍMÁR G., HORVÁTH F., RÉVÉSZ A., KUN A., BÖLÖNI J., BÍRÓ M., BODONCZI L., DEÁK J. Á., FOGARASI P., HORVÁTH A., ISÉPY I., KARAS L., KECSKÉS F., MOLNÁR CS., ORTMANN-NÉ AJKAI A. AND RÉV SZ. 2007: A grid-based, satellite-image supported, multi-attributed vegetation mapping method (MÉTA). − Folia Geobotanica 42: 225-247.

MOLNÁR, ZS., BIRÓ, M. BÖLÖNI, J. 2008: Appendix. English names of the Á-NÉR habitat types. – Acta Botanica Hungarica 50 Suppl: 249-255.

OZENDA P., BOREL J.L. 2000: An ecological map of Europe: why and how? – C.R. Academie Science Paris, Life Sciences 323: 983-994.

PEEL M.C., FINLAYSON B.L., MCMAHON T.A. 2007: Updated world map of the Köppen-Geiger climate classification. − Hydrology and Earth System Sciences 11: 1633–1644.

PETERSON A.T., NAKAZAWA Y. 2008: Environmental data sets matter in ecological niche modelling: an example with Solenopsis invicta and Solenopsis richteri. – Global Ecology and Biogeography 17: 135–144.

Péczely Gy. 1963: A helyi éghajlati zónák kijelölésének néhány kérdése. [Some issues of delineating local climatic zones (in Hungarian)]. Időjárás 67. 6: 346-351.

Péczely Gy. 2006: Éghajlattan [Climatology - in Hungarian]. Nemzeti Tankönyvkiadó Zrt., Budapest. pp. 336. ISBN 9789631939385

Piovesan G., Biondi F., Bernabei M., Di Filippo A., Schirone B. 2005: Spatial and altitudinal bioclimatic zones of the Italian peninsula identified from a beech (Fagus sylvatica L.) tree-ring network. − Acta Oecologica 27: 197-210.

Podani J. 1998: Explanatory variables in classifications and the detection of the optimum number of clusters. In: Hayashi C., Ohsumi N., Yajima K., Tanaka Y., Bock H.-H., Baba Y. (eds): Data Science. Classification and related methods. Springer Verlag, Tokyo. p.p. 125-132.

Salamon-Albert É., Horváth F. 2008: Vegetation of Külső-Somogy in Hungary I. Regional diversity and pattern of woody habitats at landscape scale. (Külső-Somogy vegetációja I. Fás élőhelyek diverzitása és tájmintázata). − Natura Somogyiensis 12: 5-15.

Salamon-Albert É., Ortmann-Ajkai A., Horváth F., Morschhauser T. 2010a: Climatic conditions of semi-natural habitats in Belső-Somogy, Külső-Somogy and Zselic regions I. Climatic surface and climatic envelope of woodlands. − Natura Somogyiensis 17: 53-64.

Salamon-Albert É., Ortmann-Ajkai A., Horváth F., Morschhauser T. 2010b: Bioclimatic interpretation of habitat distribution in a hilly landscape of the Pannonian Ecoregion. In: Botta-Dukát Z. and Salamon-Albert É. (eds): Book of Abstracts Flora, vegetation, environment and land use at large scale. 19th International Workshop of European Vegetation Survey, Pécs, Hungary 2010.04.29 – 05.02. Abstracts p. 21.

Salamon-Albert É., Ortmann-Ajkai A., Horváth F. 2011: Climatic conditions of semi-natural habitats in Belső-Somogy, Külső-Somogy and Zselic regions II. Temperature and precipitation sensitivity of woodlands. − Natura Somogyiensis 19: 51-66.

Salamon-Albert É. 2012: Climatic conditions of semi-natural habitats in Belső-Somogy, Külső-Somogy and Zselic regions III. Temperature envelopes of mesic deciduous woodlands. − Natura Somogyiensis 22: 27-38.

Soberón J. 2007: Grinnellian and Eltonian niches and geographic distributions of species. – Ecology Letters 10: 1115–1123.

Thompson R.S., Shafer S.L., Anderson K.H., Strickland L.E., Pelltier R., Bartlein P.J., Kerwin M. 2005: Topographic, bioclimatic and vegetation characteristics of three ecoregion classification systems in North America: Comparisons along continent-wide transects. − Environmental Management 34.1.: 125-148.