INFLUENCE OF CLIMATIC CONDITIONS ON THE TERRITORIAL DISTRIBUTION OF THE MAIN VEGETATION ZONES WITHIN OLTENIA REGION, ROMANIA

VLĂDUŢ Alina, NIKOLOVA Nina, LICURICI Mihaela

Abstract. In the context of present climate change, the assessment of vegetation and vegetation zones response greatly gained in importance. Within Oltenia region there is registered an obvious altitudinal zonation of the vegetation as altitudes increase from south (about 3 m) to north (2519 m), which means decrease of temperatures, and, to a certain extent, increase of the precipitation amounts. The assessment of the territorial distribution of the vegetation zones was made taking into account the values indicated by different bioclimatic indexes (the simple continentality index, annual ombrothermic index, compensated summer ombrothermic index, Mayr tetratherm, the sum of precipitation in the months when the mean temperature is higher than 10ºC, "De Martonne" aridity index, rain factor of Lang, Ellenberg quotient, forestry aridity index, Gams continentality index), the information rendered in specialized literature and Corine Land Cover (CLC 2012) reference database. "De Martonne" aridity index and the rain factor of Lang, for example, indicate the same types of bioclimate characteristic to the same areas (steppe/sub-humid dry; semi-humid/sub-humid moist; humid/humid; super-humid/perhumid). Ellenberg Quotient and forestry aridity index, both indicate the western and central Subcarpathian area as the area highly favourable to the development of beech forests, while in the eastern sector, the drier and warmer climate favours the development of hornbeam and other thermophilous deciduous species, which also cover the piedmont area and the northern extremity of Oltenia Plain. The areas mentioned above also appear in Corine Land Cover databaseas areas covered by deciduous or mixed forests, without specifying the species. Thus, the results indicate a good correlation among different bioclimatic indexes and between bioclimatic indexes and CLC 2012 classes of vegetation.

Keywords: Oltenia, climatic conditions, bioclimatic indexes, vegetation zones.

Rezumat. Influenţa condiţiilor climatice asupra distribuţiei teritoriale a principalelor zone de vegetație din Oltenia, România. În contextul schimbărilor climatice globale, evaluarea răspunsului speciilor de plante și a zonelor de vegetație a câștigat mult în importanță. În cadrul regiunii Oltenia, se înregistrează o zonare altitudinală evidentă a vegetației ca urmare a faptului că altitudinea creşte de la sud (circa 3 m) la nord (2519 m), ceea ce înseamnă scăderea temperaturilor, şi, într-o anumită măsură, creşterea cantităților de precipitații. Evaluarea distribuției teritoriale a zonelor de vegetație a fost făcută ținând cont de valorile indicate de către diferiți indici bioclimatici (indicele de continentalitate, indicele ombrotermic anual, indicele ombrotermic compensat de vară, tetraterma Mayr, suma precipitațiilor în lunile în care temperatura medie este mai mare decât 10ºC, indicele de ariditate "De Martonne", factorul de ploaie Lang, coeficientul Ellenberg, indicele forestier de ariditate, indicele Gams de continentalitate), informațiile redate în literatura de specialitate și Corine Land Cover (CLC 2012). Indicele de ariditate "De Martonne" şi factorul de ploaie Lang, de exemplu, indică aceleaşi tipuri de bioclimat caracteristic aceloraşi zone (de stepă / sub-umed uscat, semi-umed / sub-umed umed; umed / umed; super- umed / perumed). Coeficientul Ellenberg şi indicele forestier de ariditate indică zona subcarpatică vestică şi centrală ca zonă extrem de favorabilă dezvoltării pădurilor de fag, în timp ce în sectorul estic, climatul mai uscat şi mai cald favorizează dezvoltarea carpenului şi a altor specii de foioase termofile, care acoperă, de asemenea, zona piemontană şi extremitatea nordică a Câmpiei Olteniei. Zonele menționate apar, de asemenea, și în Baza de date Corine Land Cover ca zone acoperite de păduri de foioase sau de păduri mixte, fără a specifica însă specia. Astfel, rezultatele indică o bună corelare între diferiți indici bioclimatici şi între indicii bioclimatică şi clasele de vegetație evidențiate de CLC 2012.

Cuvinte cheie: Oltenia, condiţii climatice, indici bioclimatici, zone de vegetaţie.

INTRODUCTION

The distribution of vegetation is clearly dependent on climatic conditions, mainly temperature values and precipitation amounts, as well as on their pattern of distribution in time and space, if the global scale is taken into consideration. On a smaller scale, the role of other factors, secondary factors, such as altitude, exposure, soil cannot be ignored (WHITTAKER, 1975; WOODWARD, 1987; SALAMON-ALBERT et al., 2016). During time, there were used numerous simple climatic parameters in order to render the influence of climate on vegetation (GAMS, 1932; PRENTICE et al., 1992; BLASI et al., 1999), but the results were not always eloquent. Thus, different researchers elaborated phytoclimatic or bioclimatic indexes, which are based on relations between these simple climatic parameters, but better highlight the importance of climate on the development and distribution of vegetation. Presently, this relation is studied based on the bioclimatic classification, known as *Worldwide Bioclimatic Classification System* (WBCS), which was elaborated by RIVAS-MARTÍNEZ et al. (1999) and improved by RIVAS-MARTÍNEZ (2005; 2011).

In the present climatic context – temperature increase especially in colder regions (IPCC, 2012), reduction of precipitation amounts in many regions of the globe (IPCC, 2007a, b), increased frequency of different risk phenomena, among which drought is the one with great impact and considerable negative consequences on vegetation, it is no wonder researchers focused on the immediate or predicted response of vegetation. Thus, there were achieved numerous bioclimatic impact studies focusing on continental-scale effects of climate change (REHFELDT et al. 2003; OHLEMÜLLER et al. 2006), but also regional studies on the Swiss Alps (BOLLIGER et al., 2000), the British Isles (BERRY et al., 2002), the Iberian Peninsula (BENITO GARZÓN et al., 2008), Central Europe (LEUSINGER et el., 2005;

BÁLINT et al., 2011), or local studies, Germany (SCHARNWEBER et al., 2011), Serbia (STOJANOVIĆ et al., 2012), Hungary (FÜHRER, 2010; FÜHRER et al., 2011; MÓRICZ et al., 2013), Romania (BUDEANU et al., 2016).

Oltenia region is affected by climate change as well, which mainly corresponds to an obvious temperature increase (VLĂDUŢ & ONŢEL, 2013; VLĂDUŢ, 2016) together with the increase of the aridity (DUMITRAŞCU, 2006; VLĂDUŢ, 2010; ACHIM et al., 2012; PRĂVĂLIE, 2013; VLĂDUŢ et al., 2013). Thus, the present study aims to emphasize certain bioclimatic indexes within Oltenia region and correlate them with the characteristic vegetation zones (based on specialized literature and situation observed in the field), as well as to render the trend registered by certain indexes and the potential impact on vegetation.

MATERIAL AND METHODS

Study area and vegetation. Oltenia region is limited by the following geographical coordinates: 43°40' N lat in the south and 45°35' N lat in the north and 22° - 24°53' E long in the west, respectively east. From the altitudinal viewpoint, the range is quite high, 3 m in the Danube Alluvial Plain (at the confluence between the Olt and the Danube rivers) and 2519 m Parângul Mare Peak (Geografia României, 1983). Accordingly, Oltenia presents many latitudinal and altitudinal vegetation zones: southern forest steppe, sub-mesophilous – thermophilous oak species, sessile oak forests, beech forests, mixed beech and coniferous forests, spruce forests, subalpine and alpine vegetation (Figs. 1; 2).

Presently, steppe vegetation is highly altered due to the intensive human activities, and the initial species of *Festuca vallesiaca, Festuca sulcata, Stipa* sp. were replaced mainly by *Cynodon dactylon*, *Poa bulbosa, Andropogon ischaemum*, etc. There also appear some mesophilous Oak forests (*Quercus pedunculiflora, Q. pubescens*) or acacia (*Robinia pseudoacacia*) plantations (DRĂCEA, 2008). In the lower hilly area, there are Turkey oak (*Q. cerris*) and Hungarian oak (*Q. frainetto*) forests, the greatest percent of afforestation being met within the Olteţ Piedmont, in the eastern part of the Getic Piedmont. In the upper hilly area, the nemoral zone is represented by three sub-zones: sessile oak (*Quercus petraea*), beech (*Fagus sylvatica*), mixed deciduous and coniferous forests. Sessile oak develops between 300 and 600 m altitude, but, due to the milder climatic conditions, it grows even at 700 m, on the southern slopes of the mountains. Beech and mixed forests develop on a great altitudinal range, starting from 450-500 m up to 1400-1550 in Vâlcan and Mehedinţi Mountains (Geografia României, 1983). In the north of the region, we find the spruce forest zone (*Picea abies*), which develops between 1400 and 1750 m. However, the upper limit can go to 1850 in Parâng (the Sadu basin) (MUICĂ, 1995). The subalpine zone, 1750-2100 m, is characterized by the presence of *Pinus montana*, *Juniperus sibirica* and, sometimes *Rhododendron kotschyi,* and *Agrostis rupestris, Festuca ovina, Festuca supina*, which due to overgrazing tend to be replaced by *Nardus stricta*, an oligotrophic species. In the alpine zone, above 2100 m, there are meadows where the main species are *Agrostis rupestris, Carex curvula, Festuca rubra, Nardus stricta*, etc.

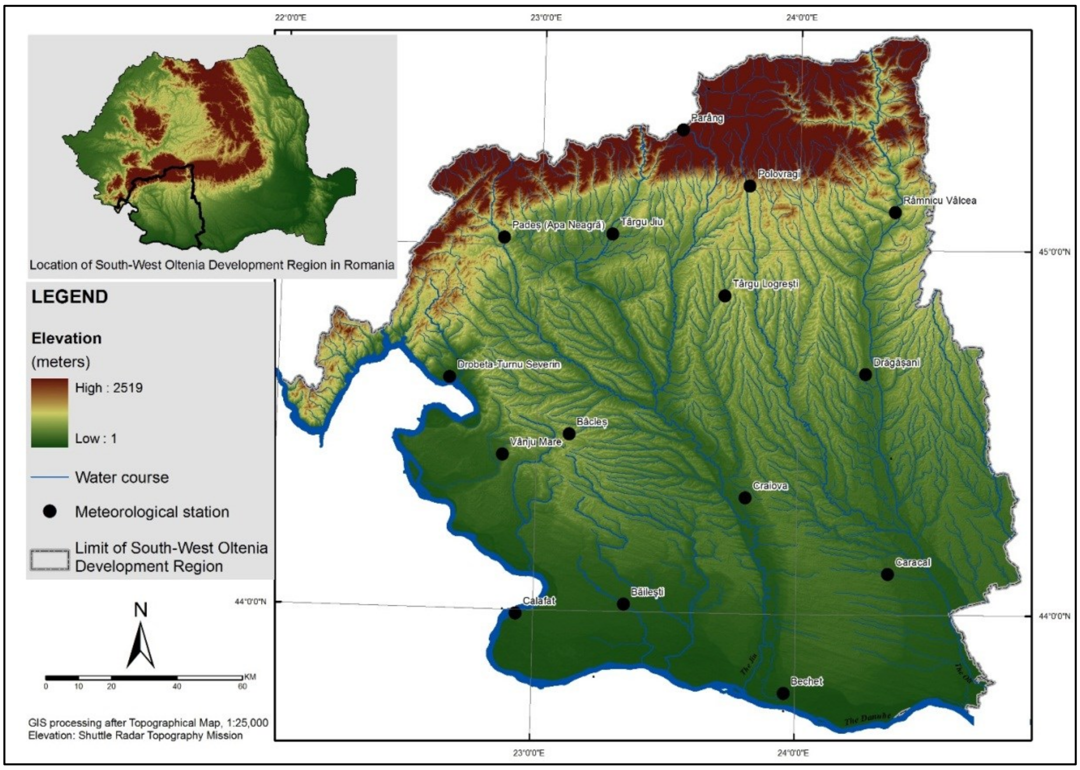

Figure 1. Location of the meteorological stations within Oltenia Region (original).

Data. There were used mean monthly temperature and precipitation data for 15 meteorological stations located within Oltenia Region (Fig. 2; Table 1). The data cover a mean period of fifty years (1961-2010), except for two stations, Vânju Mare and Parâng (1961-2002, respectively 1961-2005). For four of the stations (Drobeta Turnu Severin, Craiova, Târgu Jiu, Râmnicu Vâlcea) the data come from – Klein Tank, A.M.G. and co-authors, 2002. Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. Int. J. of Climatol., 22, 1441-1453 (Data and metadata available on line at http://www.ecad.eu), while for the other stations the data were partly provided by NAM or taken from the annual reports elaborated by PEAs or ESIs.

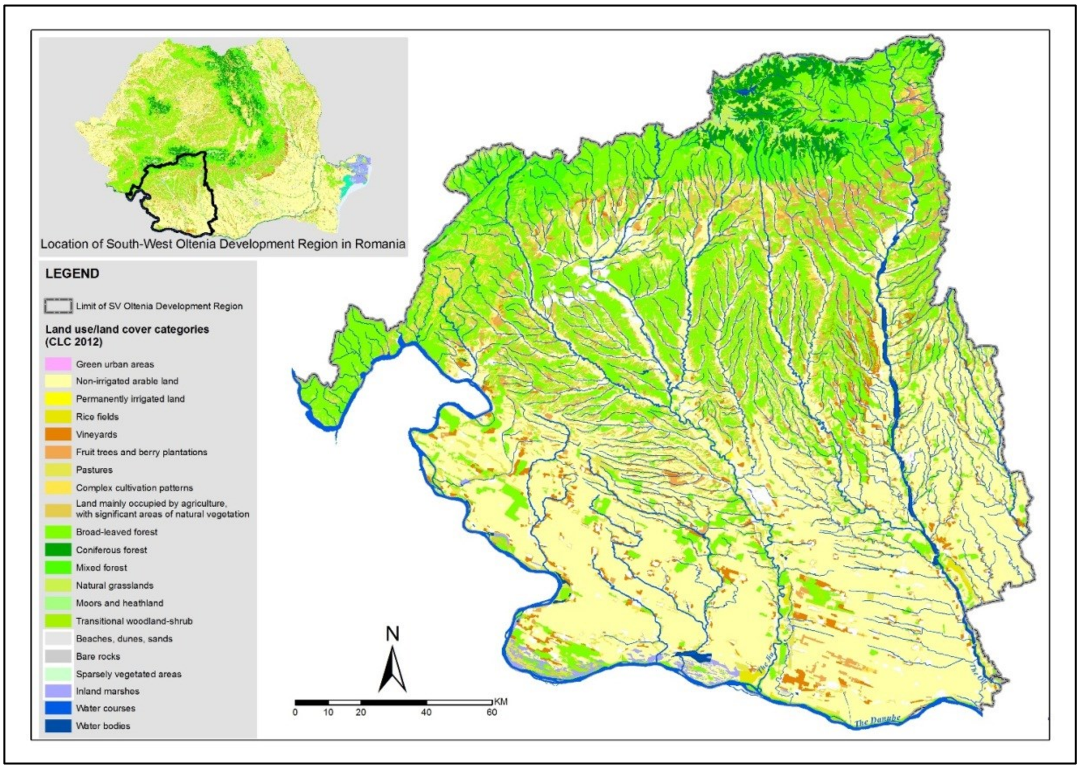

Figure 2. Main vegetal associations within Oltenia Region (original).

Table 1. Geographical coordinates of the considered meteorological stations.

No.	Meteorological station	Altitude (m)	Latitude	Longitude
1.	Calafat	61	43°59`	22°57`
2.	Bechet	36	43°47`	23°57`
3.	Băileşti	57	44°01`	23°20`
4.	Caracal	106	44°06`	24°22`
5.	Craiova	192	44°19`	23°52`
6.	Vânju Mare	86	44°26`	22°51`
7.	Dr. Turnu-Severin	77	44°38`	22°38`
8.	Bâcleş	313	44°29`	23°07`
9.	Drăgăşani	280	44°40`	24°17`
10.	Târgu Logreşti	265	44°53`	23°42`
11.	Apa Neagră	258	45°00`	22°52`
12.	Târgu Jiu	203	45°02`	23°16`
13.	Polovragi	531	45°11`	23°49`
14.	Râmnicu Vâlcea	237	45°06`	24°22`
15.	Parâng	1548	45°23`	23°28`

Methods. The *type of bioclimate* was established based on WBCS, taking into account two indexes - simple continentality index and annual ombrothermic index (http://www.globalbioclimatics.org/book/table_2016.htm). Additional information was also obtained based on the compensated summer ombrothermic index.

The simple continentality index represents the annual temperature range, meaning difference between mean maximum monthly temperature and mean minimum monthly temperature, as it follows:

$Ic = T_{max}-T_{min}$ (°C) (1)

Thus, according to the obtained values the climate can be: hyperoceanic (0-11) [extremely hyperoceanic (0-3), euhyperoceanic (3-7), barely hyperoceanic (7-11)], oceanic (11-21) [euoceanic (11-18), semicontinental (18-21)], and continental [subcontinental (21-28), eucontinental (28-45) and hypercontinental (45-65)].

The Annual ombrothermic index is calculated according to the formula:

$Io = \frac{Pp}{Tp}$ (2) where, Pp represents the sum of the precipitation amounts registered in all the months with positive temperatures and Tp represents the sum of the positive monthly temperatures (RIVAS-MARTÍNEZ, 1997; RIVAS-MARTÍNEZET al., 1999). The thresholds values for ombrotypes are: 0.1-0.3 hyperarid; 0.3-0.9 arid; 0.9-2.0 semiarid; 2.0-3.0 dry; 3.0-5.5 subhumid; 5.5-11 humid.

The Compensated Summer Ombrothermic index (CSOi) (RIVAS-MARTÍNEZET al., 1999 apud. SALAMON-ALBERT et al., 2016) is calculated by the formula:

$CSOi = \frac{(P5+P6+P7+P8)}{(T5+T6+T7+T8)}$(3), where P5 to P8 is the precipitation sum from May to August and T5 to T8 is the sum of temperature means from May to August (mm, °C).

In order to emphasize the influence of climatic factors on the territorial distribution of vegetation there were calculated several other bioclimatic indexes.

Mayr tetratherm (T_{Mayr}), introduced by Mayr in 1909, was calculated according to the following formula:

$T_{Mayr} = \frac{\sum(t_5 + t_6 + t_7 + t_8)}{4}$ (4), where t_5-t_8 represents the mean monthly values in the period May-August.

Summer temperature values represent a limiting factor of the timber-line and Mayr considered that the mean of the four warmest months highlight the influence of temperature on vegetation (DAHL, 1998). According to SATMARI (2010), values between 13 and 18°C indicate favourability for beech forests. Temperature values comprised between 10 and 14°C are favourable for coniferous forests (mainly, pine forests) (TYLKOWSKI, 2015).

The sum of precipitation in the months when the mean temperature is higher than 10ºC (P_{veg}) represents the total amount of precipitation registered mainly during the vegetation period.

"De Martonne" aridity index (I_a) (DE MARTONNE, 1926) can be calculated both for annual and monthly values. For annual values, it is used the following formula:

$I_a = \frac{P}{T+10}$ (5), where P – the annual amount of precipitation, T – the mean annual temperature, 10 – a coefficient that is added in order to obtain positive values.

Thus, hyper-arid areas display $I_a<3$, arid areas $3>I_a<8$ and semi-arid areas to $8>I_a<20$ (VERHEYE, 2009), while $20>I_a<30$ semi-humid areas and $I_a>30$ humid areas (IENCIU et al., 2015). For Romania, it was considered that $I_a \leq 5$ corresponds to desert areas, $5>I_a<10$ to the steppe areas, $10>I_a<30$ indicates forest steppe area and $I_a \geq 40$ forest areas (Table 2) (GACEU, 2002, p. 69; VLĂDUŢ, 2010; DUMITRAŞCU, 2006, p. 156).

Table 2. Numerical correlation between De Martonne index and the characteristic climate and vegetal association.

I_a	Climate	Vegetation
0-5	Hyper-arid	Desert – lack of vegetation
5-10	Arid	
15-20	Steppe (semi-arid, Mediterranean)	Dry steppe
20-25		Steppe with gramineous species
25-30	Semi-humid	Steppe with tall grass
30-35		Forest steppe
35-40	Humid	Oak forests
40-45		Beech forests
45-50		Coniferous forests
50-55		Sub-alpine
55-60		Alpine
>60	Super-humid	

Source: SATMARI, 2010

The rain factor of Lang (I), also called the pluvio-thermal index renders the atmospheric moisture, as well as its variation; this index is calculated on annual, summer or vernal basis (GACEU, 2002, p. 70; DUMITRAŞCU, 2006, p. 155). There was used the following formula:

$I = \frac{P}{t}$ (6), where *P* is the mean annual precipitation amount and *t* is the mean annual temperature. Lang defined the type of climate for positive mean annual temperatures as arid when I < 40, humid for 40-160 and perhumid when I > 160. According to AWASTHI (1995), arid climate corresponds to areas where I<17, semiarid climate to areas with 17>I<34, sub-humid dry areas to 34>I<50, sub-humid moist areas to 50>I<66, humid areas to 66>I<100, and perhumid areas to I>100. According to VERHEYE (2009), arid climate corresponds to areas where I<5, semiarid climate to areas with 5>I<35 and sub-humid areas to I>35. In Romania, it was used a different value system for this index: 0 > I < 20 arid climate, 20 > I < 40 Mediterranean climate, 40 < I < 70 semi-arid climate, 70 < I < 1000 humid climate (RUSĂNESCU, 2014; IENCIU et al., 2015).

Ellenberg Quotient (EQ), introduced by ELLENBERG in 1988, which renders beech (*Fagus silvatica*) favourability, was calculated according to the formula:

$EQ = \frac{Tw}{P} 1000$ (7), where Tw is the temperature of the warmest month of the year, P = annual precipitations. According to Ellenberg, when EQ values are lower than 20 (JAHN, 1991), they indicate areas of pure beech forests, values between 20 and 30 correspond to areas favourable to beech, while values higher than 40 mark the disappearance of the species (BUDEANU et al., 2016).

The Forestry Aridity Index (FAI) was used by FÜHRER et al. (2011) as an index also rendering the favourability of climatic conditions to beech forests. It was calculated according to the following formula:

$FAI = 100 \frac{(T7-8)}{(T5-7+P7-8)}$ (8), where T7-8 is the mean temperature of the July and August, P5-7 represents the precipitation sum of the period May-July and P7-8 is the precipitations of July and August. Führer (2010) and Führer et al. (2011) set the beech favourability threshold at a FAI value of less than 4.75.

Gams Continentality Index (GCI) also known as Fagus Favourability Index (FFI) (BUDEANU et al., 2016), was calculated according to the formula:

$GCI = \frac{P}{Alt}$ (9), where P is the annual precipitation amount and Alt the altitude. According to PACHE et al. (1999), this method eliminates the effects of altitude and, thus, the comparison of the degree of continentality of stations located at different altitude becomes possible. PACHE et al. (1999) also mention that this method is valid only in case of mountains, more precisely for altitudes between 900 m and 1600 m. MICHALET (1991) modified this formula and it became applicable for altitudes lower and higher than the aforementioned thresholds. However, in Romania, it was used this formula and values < 1 indicate favourability for coniferous species, values between 1 and 2 for the beech, and values > 2 for thermophilous species (LANG, 1920; SATMARI, 2010).

RESULTS

Oltenia region includes all major landforms, starting from low altitudes in the south, corresponding to the Danube alluvial plain, and reaching high altitudes in the north, where there are located the Carpathian Mountains (2519 m Parângul Mare Peak). Thus, all major climatic parameters are more or less influenced by altitude, slope exposure, topography particularities, etc., which, in their turn influence the type of vegetation associations and their distribution.

Type of bioclimate. Bioclimate is rendered by the correlation of two simple indexes, Ic and Io. If taking into account Ic, it results that there are two types of bioclimate – continental type for the entire region with the subcontinental sub-type, except for the mountain area, where the values indicate an oceanic bioclimate, respectively a semicontinental sub-type. Based on the values of Io, it resulted that the bioclimate is subhumid within most of the region. In the north, in the Subcarpathian (western extremity and at higher altitudes) and Carpathian region, the bioclimate is humid. The correlation of these two indexes indicates a temperate continental bioclimate, subcontinental and semicontinental (only in the mountain area) subtype. In the plain area, the level of sub-continentality is excessive, while in the hilly and mountain areas it is moderate (Table 3).

The Compensated Summer Ombrothermic index highlights the situation rendered by the annual ombrothermic index in terms of spatial distribution. However, when taking into account only the thermic and pluviometric values characteristic to the vegetation period, it results that the plain area has dry conditions, except for the northern extremity, at the contact with the plateau area, where the values indicate a subhumid bioclimate (Craiova). The hilly region, corresponding to the Getic Plateau and Subcarpathians presents subhumid conditions as well, while the in Carpathians, the conditions indicate a humid bioclimate.

Table 3. Type of bioclimate based on Ic and Io values, according to RIVAS-MARTINEZ et al. (2011).

No.	Meteorological station	Ic (°C)		Io		Bioclimate – type; subtype, level
1.	**Calafat**	24.1	C, Sbc	3.5	sH	**Tc, Sbc, E**
2.	**Bechet**	24.7	C, Sbc	3.6	sH	**Tc, Sbc, E**
3.	**Băileşti**	24.5	C, Sbc	3.9	sH	**Tc, Sbc, E**
4.	**Caracal**	24.9	C, Sbc	3.8	sH	**Tc, Sbc, E**
5.	**Craiova**	24.2	C, Sbc	4.2	sH	**Tc, Sbc, E**
6.	**Vânju Mare**	23.6	C, Sbc	3.7	sH	**Tc, Sbc, M**
7.	**Dr. Turnu-Severin**	23.5	C, Sbc	4.4	sH	**Tc, Sbc, M**
8.	**Bâcleş**	23.2	C, Sbc	4.2	sH	**Tc, Sbc, M**
9.	**Drăgăşani**	22.5	C, Sbc	4.3	sH	**Tc, Sbc, M**
10.	**Târgu Logreşti**	22.6	C, Sbc	4.3	sH	**Tc, Sbc, M**
11.	**Apa Neagră**	22.9	C, Sbc	6.0	H	**Tc, Sbc, M**
12.	**Târgu Jiu**	22.9	C, Sbc	5.4	sH	**Tc, Sbc, M**
13.	**Polovragi**	21.3	C, Sbc	6.2	H	**Tc, Sbc, M**
14.	**Râmnicu Vâlcea**	22.5	C, Sbc	5.1	sH	**Tc, Sbc, M**
15.	**Parâng**	**18.5**	**O, Sc**	**10.9**	**H**	**To, Sc, M**

O – oceanic; C – continental; sH – subhumid; H – humid; Tc - Temperate continental; To - Temperate oceanic; Sbc – subcontinental; Sc – semicontinental; M – moderate; E - excessive

Mayr tetratherm (TMayr) that was often used in studies regarding the timberline presents the highest values in the south, mainly within the Danube Alluvial Plain (> 21°C). Northwards, at the contact with the plateau, the values decrease to about 20°C, while in the hilly area to 19-20°C. Only at the contact with the mountains, at higher altitudes, TMayr is about 18°C (Polovragi and Apa Neagră). In the Carpathian Mountains (Parâng station), the registered difference of 5.2°C is imposed by altitude. Thus, in the south, there are conditions for the development of steppe vegetation (gramineous xerophilous species adapted to high temperatures and low humidity, especially during summer) and in the northern part of the plain and the southern part of the plateau for forest steppe and oak forests. Beech thermal favourability interval is between 13 and 18°C, which means that the optimum conditions are met in the northern part of the Subcarpathians and the southern slopes of the Carpathians. Coniferous forests develop at higher altitudes (generally 1500 m up to 1700 m), characterized by lower temperatures (mean annual temperature below 10°C and mean monthly maximum temperatures below 15°C) and larger precipitation amounts.

The sum of precipitation in the months when the mean temperature is higher than 10ºC **(P_{veg})** is very important for both agriculture and development of forest vegetation. Generally, the period with temperatures above the 10°C threshold covers seven months (April-October). Only in higher hilly or mountainous areas, the period gradually reduced as altitude increase (Apa Neagră, 6 months April-September; Polovragi, 5 months May-September; Parâng, 4 months June-September). The amounts registered during this period generally represents between 50 and 70% of the mean annual precipitation amount. Thus, in the plain area, there is an approximate difference of only about 50 mm between the lowest and the highest amounts (332.7 mm at Calafat and 385.6 mm at Craiova). However, in the western extremity, at Drobeta Turnu-Severin, it exceeds 400 mm (410.3 mm), due to the local particularities. Even at higher altitudes, in the piedmont area and the southern part of the Subcarpathians, the amounts are between 390 and 420 mm, while in the north, they are between 490 and 515 mm. Due to the shorter interval, at Polovragi and in the mountains, the amount is lower than in the Subcarpathian area, at lower altitudes. When correlating precipitation amounts with temperature values, it results that certain cultivated plants require supplementary water amounts in order to reach optimum conditions of development. For example, during the vegetation period, maize needs about 400 mm, sugar beat 400 - 600 mm (BÂLTEANU & BÂRNAURE, 1989). As for forest vegetation, oak species find suitable conditions within the piedmont and Subcarpathian areas, as most of the species are quite tolerant to temperatures and precipitation variations (even drought periods) (ANNIGHÖFER et. al, 2015), while beech forests develop better at higher altitudes due to temperature requirements.

"De Martonne" aridity index (I_a) was widely used to highlight both the correlation between the vegetation type and climate and aridity issues. When applied on multiannual mean values of temperature and precipitation, it results that there is a partial correlation with the situation illustrated by T_{Mayr}. More precisely, both indexes indicate the presence of steppe and drier bioclimate in the southern part of Oltenia Plain and of a semi-humid climate with steppe and forest steppe vegetation in its northern and western part. Within the entire area of Subcarpathians the climate is characterized as humid, except the eastern extremity where it is semi-humid, while in the mountains, at altitudes above 1500, it is super-humid. Consequently, oak forests find favourable conditions in the lower sectors of the Subcarpathians and in the piedmont, while beech forests at higher altitudes in the Subcarpathians (Polovragi) and low altitudinal levels of the mountains (Table 4). Based on I_a values, coniferous forests may appear even in the north-western sector of the Subcarpathians (Apa Neagră) as rainfall amounts are almost similar to those registered at much higher altitudes. Alpine vegetation is characteristic to super-humid climatic conditions, which can be found only at high altitudes in the Carpathians (more than 2000 m).

Table 4. Type of climate on "De Martonne" aridity index (I_a) and the rain factor of Lang (I) and vegetation based on "De Martonne" aridity index (I_a).

No.	Meteorological station	I_a	Climate	Vegetation	I	Climate
1.	**Calafat**	24.5	Steppe	Steppe with gramineous species	45.50	Sub-humid dry
2.	**Bechet**	24.5	Steppe	Steppe with gramineous species	46.06	Sub-humid dry
3.	**Băileşti**	26.5	Semi-humid	Steppe with tall grass	50.03	Sub-humid moist
4.	**Caracal**	26.3	Semi-humid	Steppe with tall grass	49.84	Sub-humid dry
5.	**Craiova**	28.6	Semi-humid	Steppe with tall grass	54.80	Sub-humid moist
6.	**Vânju Mare**	27.1	Semi-humid	Steppe with tall grass	51.24	Sub-humid moist
7.	**Dr. Turnu-Severin**	31.1	Semi-humid	Forest steppe	57.32	Sub-humid moist
8.	**Bâcleş**	29.8	Semi-humid	Steppe with tall grass	58.34	Sub-humid moist
9.	**Drăgăşani**	28.9	Semi-humid	Steppe with tall grass	55.51	Sub-humid moist
10.	**Târgu Logreşti**	32.0	Semi-humid	Forest steppe	64.87	Sub-humid moist
11.	**Apa Neagră**	46.6	Humid	Coniferous forests	94.90	Humid
12.	**Târgu Jiu**	38.7	Humid	Oak forests	75.70	Humid
13.	**Polovragi**	45.0	Humid	Beech forests	93.16	Humid
14.	**Râmnicu Vâlcea**	33.9	Semi-humid	Forest steppe	65.48	Sub-humid moist
15.	**Parâng**	62.4	Super-humid	Alpine	181.29	Perhumid

"De Martonne" aridity index shows a great variability during the analysed period. In order to assess the aridization tendency, indicated by decreasing values of the index, there were analysed the annual values for six meteorological stations, considered representative, located in different sectors of the analysed region. Thus, the period 1980-2000 is marked by the lowest values of I_a, which culminated with 1992, 1993 and 2000, when the values got below 20 mm/°C, thus corresponding to dry steppe climate even at the foot of the mountains (Caracal 12.46 mm/°C in 2000;

Craiova 13.62 mm/°C in 1992; Calafat 11.7 mm/°C in 2000; Apa Neagră 16.46 mm/°C, Târgu Jiu 14.85 mm/°C, Râmnicu Vâlcea 16.06 mm/°C, all in 2000) (Figs. 3; 4). However, in spite of extremely low values and obvious variability, when analysing the trend, we notice that in the plain area it is quite different: in the south-western part the tendency is linear (Calafat 0.0015 the coefficient of the linear equation), in the eastern sector, the values decrease indicating the aridization of the climate (Caracal-0.0628), while in the north, I_a values increase (Craiova 0.0665), indicating a moister climate. In the Subcarpathian area, the coefficient of the linear equation emphasizes that the upward or downward trend is not highly significant (0.0453 at Apa Neagră; -0.0091 at Târgu Jiu and -0.232 at Râmnicu Vâlcea), due to the stabilization of the pluviometric regime in the last decade of the analysed period.

The rain factor of Lang (I). When applying the classification proposed by Lang, it results that the entire hilly and plain areas of Oltenia present a humid climate, while in the mountains there is a perhumid climate. If applying the thresholds proposed by AWASTHI (1995), we may notice that the results are almost similar to those indicated by I_a (Table 4), namely a drier climate in the southern extremity of the plain and a sub-humid moist climate within the rest of the plain and the southern hilly region enabling the development of different forest types (the dominant species being *Quercus* spp.). In the Subcarpathians and at lower altitudes in the mountains (below 1000 m), the climate is humid, which indicates favourable conditions for beech forests, except for the northeastern sector (Râmnicu Vâlcea), while in the mountains (above 1000 m), the climate is perhumid, being favourable to coniferous forests, subalpine and alpine vegetation.

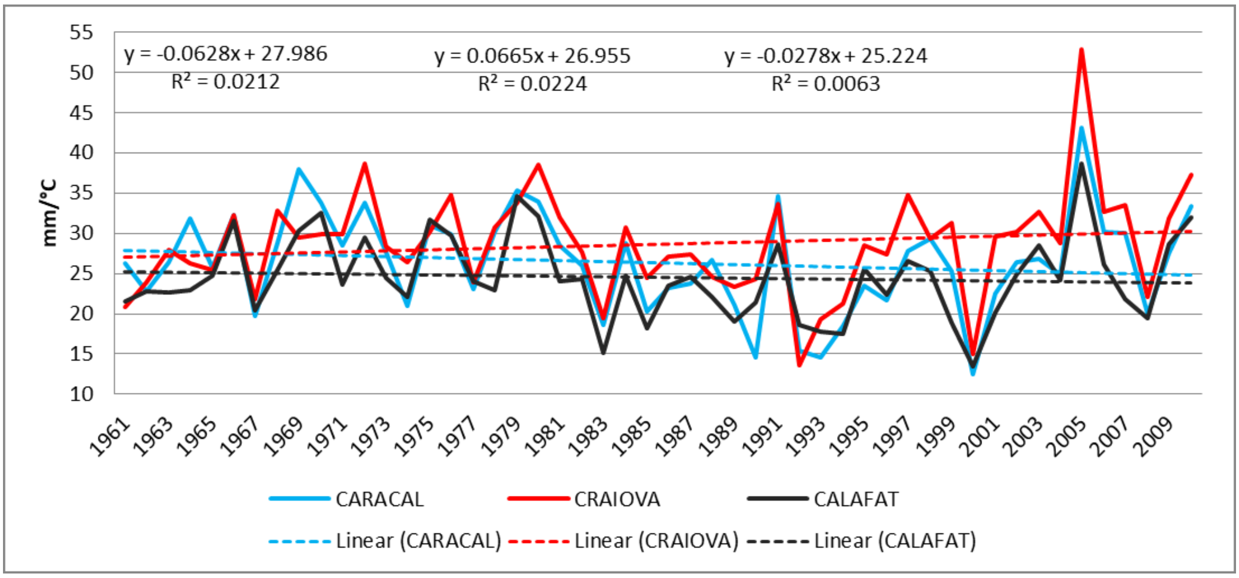

Figure 3. The annual dynamics of "De Martonne" Aridity Index and linear trend at the selected meteorological stations within Oltenia Plain (1961-2010).

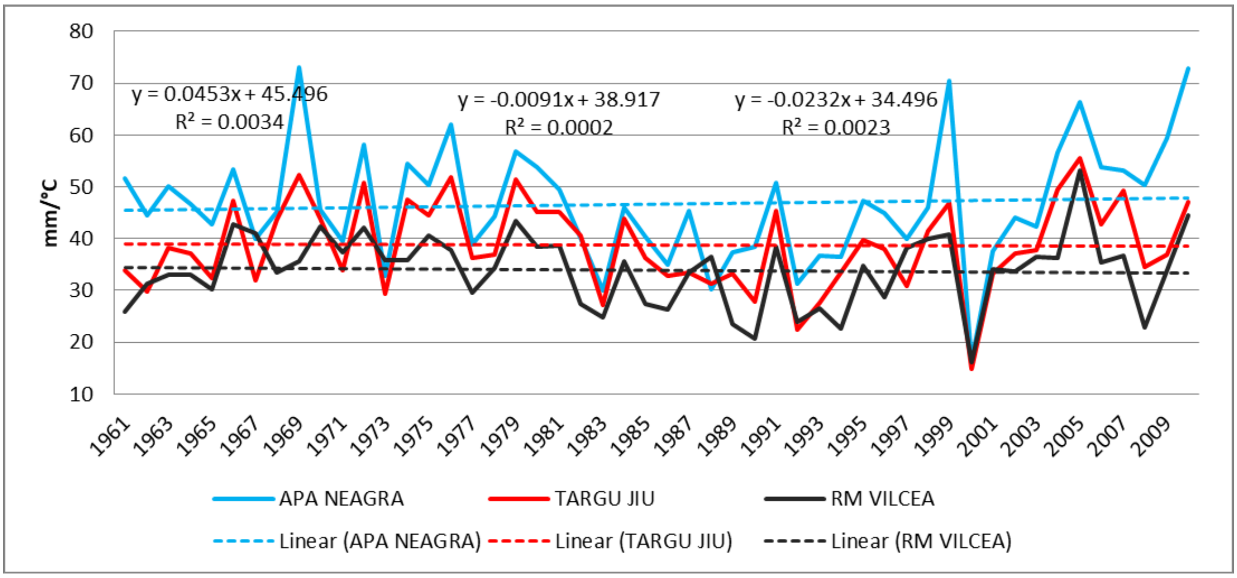

Figure 4. The annual dynamics of "De Martonne" Aridity Index and linear trend at the selected meteorological stations within the Getic Subcarpathians (1961-2010).

Ellenberg Quotient (EQ), Forestry Aridity Index (FAI), Gams Continentality Index (GCI)

The aforementioned indexes are greatly used in the assessment of the occurrence of different tree species, mainly beech, as one of the dominant tree species in western and central Europe. In Romania, beech occurrence is also important, as from the ecological point of view, it represents its eastern limit of development. According to BELMONTE et al. (2008), beech tree finds optimum conditions of development when the annual precipitation amount is between 600 and 1000 mm. However, it was documented that *Fagus sylvatica* can also adapt to lower precipitation amounts, namely to 500 mm. A more restrictive factor in its distribution is related to temperature requirements – mean annual temperature of 4.5-6°C and 13-20°C mean temperature of the warmest month (PEZZ et al., 2008), with the same mention, that in certain regions of Europe, it adapted to higher annual or monthly temperatures.

There is a good correlation between *EQ* and *FAI* as both indexes indicate the same distribution of the dominant species. Thus, in the plain area, the species that find suitable conditions are thermophilous mainly represented by *Quercus* spp. (EQ values between 40.67 and 44.26, an average of 42.5; FAI values above 7.25 - between 7.48 and 9.48, an average 8.14). In the northern part of the plain and the plateau area, the deciduous forests are mainly composed of sessile oak and Turkey oak (EQ values between 33.36 and 39.33, an average of 36.15; FAI values between 6 and 7.25, in the region between 6.32 and 7.13, an average 6.86). The area showing moderate favourability to beech tree develops in the southern and eastern parts of the Subcarpathian region, the dominant species being hornbeam oak (EQ values around 30; FAI values between 4.75 and 6, in the region between 5.03 and 5.12, an average 5.07). At higher altitudes, in the northern part of the Subcarpathians and on the southern slopes of the Carpathians, the dominant species is *Fagus sylvatica* (EQ values around between 20 and 30, and average of 24.3; FAI values < 4.75, in the region between 4.01 and 4.7, an average 4.35) (Table 5) (REHFELDT et al., 2003).

Based on GCI, the area favourable for beech forests is only partially highlighted by the other two indexes, namely the higher central part of the Subcarpathians (Polovragi). There also appears Bâcleş area as favourable, which is a piedmont area, mainly covered by mixed forests. Except for the mountains, where GCI indicates the favourability of coniferous species, the rest of the surface of the analysed region is favourable for thermophilous species.

Table 5. Different tree species favourability according to EQ, FAI and GCI.

No.	Meteorological station	EQ	FAI	GCI	Favourability
1.	Calafat	43.76	9.08	8.74	Favourable for
2.	Bechet	44.26	8.47	14.49	coniferous forests
3.	Băileşti	40.67	8.15	9.92	and alpine
4.	Caracal	41.28	7.48	5.26	vegetation
5.	Craiova	37.53	7.06	3.11	Highly favourable
6.	Vânju Mare	39.33	7.13	6.71	for beech forest
7.	Dr. Turnu-Severin	34.15	7.49	8.81	Moderately favourable for
8.	Bâcleş	35.90	6.98	1.95	beech forests; Hornbeam
9.	Drăgăşani	36.64	6.82	2.15	oak dominant species
10.	Târgu Logreşti	33.36	6.32	2.39	Sessile oak, Turkey oak
11.	Apa Neagră	22.50	4.70	3.56	forests
12.	Târgu Jiu	27.23	5.12	3.89	Thermophilous
13.	Polovragi	22.96	4.01	1.64	species (forest
14.	Râmnicu Vâlcea	30.45	5.03	2.96	steppe)
15.	Parâng	15.65	2.48	0.61	

CONCLUSIONS

The relation between climatic conditions and vegetations has been dealt with in numerous global and regional studies so far, mainly in the context of present climate change, which surely imposes certain modifications in zonal and altitudinal distribution of different species. As Oltenia region covers a great altitudinal range (3 to 2519 m), which determines distinct climatic conditions, there also succeed different vegetation zones from south to north, starting from the steppe to alpine vegetation. Thus, there were applied certain bioclimatic indexes in order to assess the favourability of the climatic conditions for the development of certain species, making reference especially to tree species, which are more sensitive to variations of temperature and precipitations.

In terms of type of bioclimate, calculated based on multiannual mean values, the region displays a temperate continental bioclimate, with two subtypes – subcontinental and semicontinental (only in the higher mountain area), the level being excessive in the plain and moderate in the hilly and mountain areas. However, during the vegetation period (considered the interval May-August), the plain area is characterized by a dry bioclimate, the hilly area by a subhumid bioclimate, and the mountain area by a humid bioclimate, which determine certain restrictions for tree species.

The steppe and forest steppe area, characteristic to the plain, is highly transformed due to intense agricultural use. As natural vegetation, there predominate gramineous xerophilous species adapted to high temperatures and low humidity, while tree species are mainly represented by thermophilous oak species. Thus, the presence of this type of vegetation is indicated by the values of the indexes – T_{Mayr}, P_{veg}, I_a, I, EQ, FAI, GCI. Sessile oak forests find suitable development conditions in the northern extremity of the plain area and the entire piedmont area, as indicated by T_{Mayr}, P_{veg}, EQ and FAI. However, according to I_a values, in this area there are registered adequate conditions for the development of forest steppe, while oak forests appear in the lower Subcarpathian area (Târgu Jiu). For beech forests, the best conditions are registered in the Subcarpathians area – the central sector with higher altitudes (Polovragi), as indicated by T_{Mayr}, P_{veg}, I_a, I, EQ, FAI, GCI. According to EQ, the beech favourability area extends within the entire Subcarpathian region, except for the eastern extremity, while according to FAI, only in the western sector (Apa Neagră), in the central (Târgu Jiu) and eastern sector, the dominant species being the hornbeam. The presence of thermophilous species is indicated in the eastern sector of the Subcarpathians also by I_a, I based on which the climate in the region is semi-humid, respectively sub-humid moist, compared to the rest of the area, where the climate is humid. Coniferous forests and alpine vegetation find suitable conditions in the mountain area, above 1500 m, characterized by lower temperatures (mean annual temperature below 10°C and mean monthly maximum temperatures below 15°C), as emphasized by T_{Mayr}, I_a, I, EQ, FAI, GCI (OHLEMÜLLER et al., 2006; CRĂCIUNESCU, 2007).

If analysing temperature and precipitation data for the period 1961-2010, there can be noticed a great variability and a succession of periods - dry and warm, moist and warm, moist and cool, etc. In order to assess the aridization tendency, as according to various studies Oltenia is a region highly susceptible to aridization processes, it was calculated "De Martonne" aridity index at annual level for some of the stations. In spite of the great variations, there is no statistical significant trend indicating the decrease of I_a values and, thus, a corresponding increase in the intensity of the aforementioned process.

When comparing the situation rendered by the bioclimatic indexes with the latest version of Corine Land Cover (2012), we notice a good correlation in terms of location and extension of the main vegetation types, with the specification that there appear only deciduous and mixed forests without specifying the tree species; in the plain area, except for small surfaces covered by such deciduous forests, there appear different types of arable lands, which means natural steppe vegetation is no longer present, as the area is entirely agriculturally used.

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Vlăduţ Alina
University of Craiova, Geography Department, Al. I.Cuza Str., No. 13, 200585 Craiova, Romania.
E-mail: vladut_alina2005@yahoo.com

Nikolova Nina
St. Kliment Ohridski University of Sofia, Bulgaria.
nina@gea.uni-sofia.bg

Licurici Mihaela
University of Craiova, Geography Department, Al. I.Cuza Str., No. 13, 200585 Craiova, Romania.
mihaela_licurici@yahoo.com

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