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THE INFLUENCE OF CLIMATIC CONDITIONS ON THE FOREST VEGETATION WITHIN THE GETIC SUBCARPATIANS – OLTENIA SECTOR

INFLUENȚA CONDIȚIILOR CLIMATICE ASUPRA VEGETAȚIEI FORESTIERE DIN SUBCARPAȚII GETICI – SECTORUL OLTEAN

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Abstract: The present paper aimed to render the correlation between the climatic conditions and forest vegetation within the Subcarpathian area, based on specific bioclimatic indices. In order to emphasize this correlation, there were analysed the spatial distribution and temporal variability of three indices - "De Martonne" aridity index (I_a), Ellenberg Quotient (EQ) and the forestry aridity index (FAI). The average monthly and annual temperature and precipitation data cover a period of 58 years (1961-2018). Based on the average values of the three indices it resulted that the central and eastern parts of the study area, with lower altitudes, is more suitable for the development of thermophilic species (oak, but also other deciduous species), while the western part, as well as at higher altitudes, beech (*Fagus silvatica*) and even coniferous species find proper conditions. The results indicate a good correlation among different bioclimatic indexes and between bioclimatic indexes and CLC 2018 classes of vegetation cover. In terms of temporal evolution, there Were not identified any statistically significant trends for the analyzed indices, mainly due to the fact that temperature increase in the area was also accompanied by the increase of the precipitation amount.

Key-words: *Getic Subcarpathians, "De Martonne" aridity index, Ellenberg Quotient, forestry aridity index, vegetation zones, beech*
Cuvinte-cheie: *Subcarpații Getici, indicele de ariditate de Martonne", Coeficientul Ellenberg, indicele forestier de ariditate, areale de vegetație, fag*

I. INTRODUCTION

The vegetation cover and composition is the result of the influence of the climate, an influence that is added to other factors, such as the relief (altitude, slope exposure) or pedological conditions. In its turn, vegetation influences climate, especially when it comes to forests. Air temperature and atmospheric precipitation are the most important climatic parameters that determine a certain distribution and the development of vegetation, which is thus seen as the result of the interaction

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between historical or recent natural factors and human disturbance factors (Hoersch et al., 2002). Consequently, any changes of the monthly and annual values or of the distribution pattern of the climate parameters greatly affect vegetation, especially if they occur rapidly (ANPM, 2007).

According to the IPCC evaluation report (2014), the global temperature (continental and oceanic surface) increased by 0.85°C between 1880 and 2012 and the period 1983-2012 was classified as the warmest in the last 800 years in the Northern hemisphere. Central and Eastern Europe registered the highest temperature values in 2019, but the years 2014, 2015, 2016 and 2018 were also very warm. In fact, 11 of the warmest 12 years in Europe were registered after 2000 (Copernicus Climate Change Service, 2019). In terms of precipitations, changes are expected to be less consistent and harder to be predicted (IPCC, 2013).

Thus, the main factor that may affect vegetation vertical and latitudinal distribution is temperature. Meier et al. (2012) considers that these so-called migration rates greatly depend on species, habitat configuration, competition, etc. besides the climatic conditions and that it is not sure if plants can adapt to these rapid climatic changes. This is also the opinion of other researchers, such as Malcolm et al. (2002), Neilson et al. (2005), who consider that the rate of future climate change will be higher than the migration rates of most plant species. In Central Europe, besides the shift of vegetation belts upwards (Bertrand et al., 2011), it is assumed that beech forests will reduce in surface and be replaced by thermophilous forests, while coniferous forests will be converted to deciduous forests (Garamvölgyi&Hufnagel, 2013).

The correlation between climate conditions and vegetation from different viewpoints was rendered in a series of regional studies covering Central Europe (Bálint et al., 2011; Hlásny et al., 2014; Spinoni et al., 2013), South-Eastern Europe (Páscoa et al., 2020), Serbia (Stojanović et al., 2012), Hungary (Führer et al., 2011; Mátyás et al., 2018), Romania (Budeanu et al., 2016; Vlăduț et al., 2017), etc. The aim of the present study is to emphasize this correlation based on certain bioclimatic indices within the Subcarpathians as this is the most important region if considering deciduous compact forest surfaces except for the mountain region from Oltenia.

II. DATA AND METHODS

The Getic Subcarpathians develop between the Southern Carpathians to the north and the Getic Plateau to the South and from the Dâmbovița Valley in the east to the Motru Valley in the west (Fig. 1). The studied area includes Oltenia Sector of the Getic Subcarpathians, the western limit of which is the Motru Valley that separates them from Mehedinți Plateau, while the eastern limit is marked by the Bistrița Vâlcii River, a tributary on the right of the Olt. In the north, there are Vâlcan, Parâng and Căpățânii Mountains, the limit between the two units being given by the alignment of the submontane depressions in which a series of localities developed, while in the south, the limit is less obvious, due to the close connection to the Getic Plateau (Geografia României, 1983).

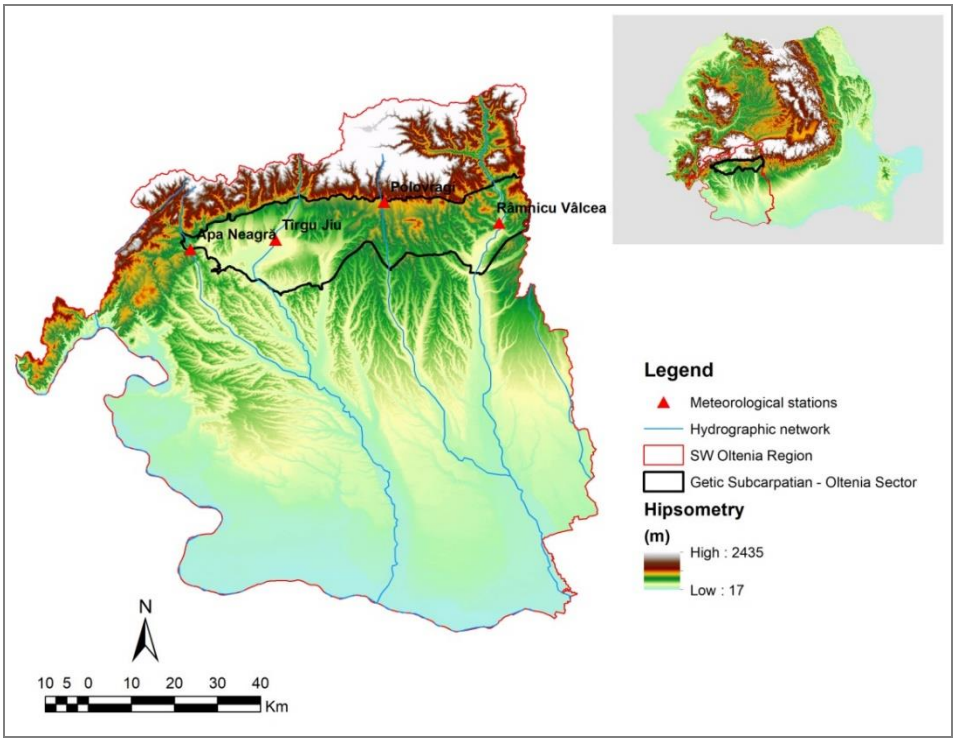

Fig. 1. Location of meteorological stations within the Getic Subcarpathians – Oltenia Sector

(Data source: http://www.geo-spatial.org/)

In this paper, there were used the average monthly and annual temperature and precipitation data for four meteorological stations located in the Getic Subcarpathians - Oltenia Sector for the period 1961 - 2018 (Table no. 1). The data for Târgu Jiu and Râmnicu Vâlcea meteorological stations come from Klein Tanket al., 2002 (Data and metadata available on line at http://www.ecad.eu), while for the other two stations the data were provided by the National Administration of Meteorology or taken from the annual reports elaborated by the Inspectorates for Emergency Situations.

There were analysed three indices - "De Martonne" aridity index (Ia), Ellenberg Quotient (EQ) and the forestry aridity index (FAI).

"De Martonne" aridity index (Ia) can be calculated for annual, seasonal and monthly values and it was introduced by De Martonne in 1926. The annual values of the index are calculated based on the following formula:

$$Ia = \frac{P}{T+10} \quad (1),$$

where P – the annual amount of precipitation, T – the mean annual temperature, 10 – a coefficient that is added in order to obtain positive values.

Table no. 1. Geographical coordinates of the considered meteorological stations

No.	Meteorological station	Altitude (m)	Latitude	Longitude
1	Apa Neagră	258	45°00’	22°52’
2	Târgu Jiu	203	45°02’	23°16’
3	Polovragi	5331	45°11’	23°49’
4	Râmnicu Vâlcea	237	45°06’	24°22’

(Source: Vlăduț et al., 2017)

In Romania, it is considered that Ia≤5 indicates arid areas, 5>Ia<10 steppe areas, 10>Ia<30 forest steppe and Ia≥40 forest areas (Table no. 2) (Gaceu, 2002, p. 69; Dumitrașcu, 2006, p. 156; Vlăduț, 2010, apud. Vlăduț et al., 2017).

Table no. 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 apud. Vlăduț et al., 2017)

The forestry aridity index (FAI) is characterized by Führer et al. (2011) as an index that renders the favourability of climatic conditions for the development of beech forests. It is calculated according to the formula:

$$FAI = 100 \frac{(T7-8)}{(P5-7+P7-8)} \quad (2),$$

where T7-8 is the mean temperature of July and August, P5-7 represents the precipitation amount of the period May-July and P7-8 is the precipitations of July and August. Führer (2010) and Führer et al. (2011) consider beech (*Fagus silvatica*) finds favourable conditions when FAI value is below the 4.75 threshold.

Ellenberg Quotient (EQ) was introduced by Ellenberg in 1988 and it also renders the correlation between beech and climate. It is calculated according to the formula:

$$EQ = \frac{Tw}{p} 1000 \quad (3),$$

where Tw is the temperature of the warmest month of the year, P = annual precipitation amount.

According to Ellenberg, when EQ values are lower than 20 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, apud. Vlăduț et al., 2017).

III. RESULTS AND DISCUSSIONS

Vegetation is influenced by a number of factors directly (ecological factors) or indirectly (such as relief, soil, climatic conditions) (Chiriță et al., 1977). If referring strictly to the relief, the influence exerted by it is determined by altitude, massiveness, slope, exposure, etc. (Săvulescu, 2014). Generally, the increase of the altitude determines the decrease of the temperature values and the increase of the precipitation amounts, which correlated with the edaphic conditions, in their turn, determine the distribution and composition of the vegetation. The minimum altitude in the Getic Subcarpathians - Oltenia Sector is registered within Târgu Jiu Depression (below 300 m), while at the contact with the mountain, there are high altitudes (over 900 m). The average altitude is 500-600 m, in the west being lower, between 400 and 500 m, and in the east higher, between 500 and 800 m (www.carpati.org).

Slope exposure imposes distinct climatic conditions even if the altitude is similar, due to the different amounts of heat received from the Sun. According to Constantinescu (1973), quoted by Săvulescu (2014), on a slope with a southern exposure, the amount of heat received per unit area is 1.6 to 2.3 times higher than that received by a slope with northern exposure.

As it can be seen in Fig. 2, there is an interesting proportionality in terms of exposure and orientation of the slopes within the study area, the largest share being that of flat surfaces - 37.8%. This type of surface is also the most favorable for the development of anthropogenic activities, and, consequently, there are located the considered meteorological stations. The sunny slopes, with southern and southwestern exposure, cover approximately 19% of Oltenia Subcarpathians, being favorable for the development of forest vegetation, while the shady slopes, with northern and northeastern exposure, with a share of approx. 11% are characterized by higher moisture throughout the entire year, which enables the processes of pluvio-denudation and solifluction and diminishes forest vegetation.

The Getic Subcarpathians display a temperate climate, characteristic to the hilly region, influenced by altitude and position in the south of the Southern Carpathians. The forest vegetation predominates and includes oak forests (up to 500 m), mixed forests of oak and beech (between 400 and 600 m) and beech forests

(on the highest hills). If taking into account only the altitudes of the considered unit, it results that the specific species is beech (Fig. 3).

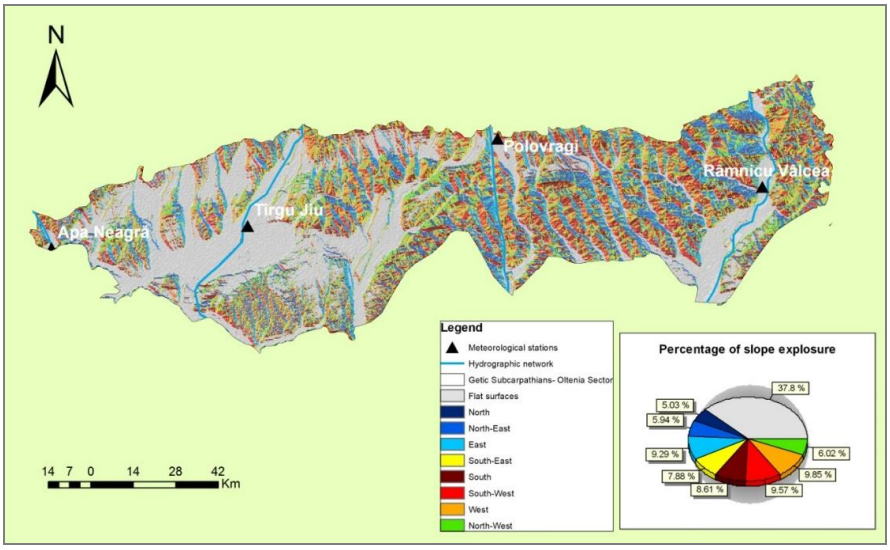

Fig. 2. Slope exposure within the Getic Subcarpathians – Oltenia Sector
(Data source: http://www.geo-spatial.org/)

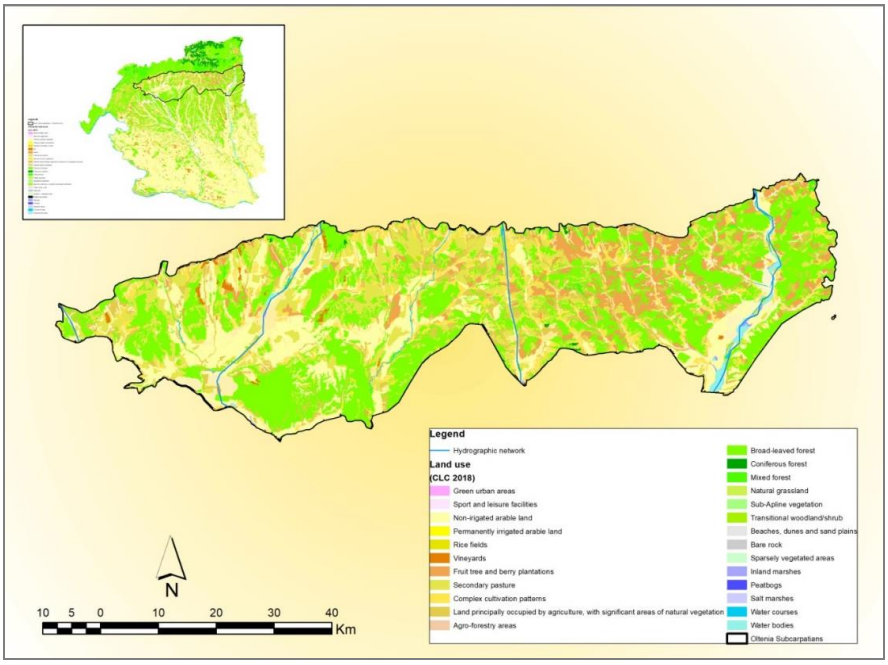

Fig. 3. Vegetation within the Getic Subcarpathians – Oltenia Sector
(Data Source: http://www.geo-spatial.org/)

At lower altitudes, especially in the depression of Târgu Jiu - Câmpu Mare and in the eastern sector of the region, thermophilous species develop better than beech. The vegetation of the Getic Subcarpathians - Oltenia Sector is quite transformed by anthropogenic activities, similarly to the vegetation from other regions of the country (www.oocities.org).

3.1 "De Martonne" aridity index (Ia)

It allows the determination of the degree of aridity of a region for a short period (month) or long period (year), being an expression of the restrictive character climate may impose on certain vegetal formations (Satmari, 2010).

The average values of Ia, calculated for the entire analysed interval, show a humid climate within the Subcarpathians (thresholds of 35-60ºC/mm), except for the eastern part (Râmnicu Vâlcea), where a semi-humid climate (25-35°C/mm) is characteristic (Table no. 3). From the point of view of the association with the vegetation formations, it resulted that in the wetter western area (Apa Neagră - 46.5ºC/mm), as well as in the immediate vicinity of the mountains (at higher altitude, Polovragi - 44.9ºC/mm) climatic conditions are favorable for the development of beech and coniferous forests. Within Târgu Jiu - Câmpu Mare Depression, where temperatures are higher and rainfall amount is lower, even if the climate is humid, Ia (38.3ºC/mm) marks a higher favorability for thermophilic oak species than for beech. In the eastern part, the values of the index show favorable conditions for the development of the forest-steppe (Râmnicu Vâlcea - 34.2ºC/mm).

Table no. 3 Type of climate and vegetation based on "De Martonne" aridity index (I_a)

No.	Meteorological station	I_a	Climate	Vegetation
1.	Apa Neagră	46.6	Humid	Coniferous forests
2.	Târgu Jiu	38.7	Humid	Oak forests
3.	Polovragi	45.0	Humid	Beech forests
4.	Râmnicu Vâlcea	33.9	Semi-humid	Forest steppe

With regard to the temporal evolution during the analysed interval, Ia indicates a high variability. In most cases when Ia displays low values, there is a generalized situation, drought being a phenomenon felt throughout the southern part of the country. When considering the highest values, the action of local factors gains in importance. Thus, the year 2000 presents the lowest Ia values corresponding to a semi-arid climate due to the extremely low precipitation amounts (Fig. 4, Fig. 5). It is the only year with such a character during the 58 years of the interval. Other dry years are 1992-1993, especially in lower areas (Mediterranean climate), but the most exposed station is Râmnicu Vâlcea, which registered 7 such years (1983, 1989, 1990, 1992, 1994, 2008, 2011).

The highest values, corresponding to the super-humid type in the west and north and to the humid type in the rest of Oltenia Subcarpathians, are registered in

2005 and 2014. Particular situations are specific mainly to the western sector (Apa Neagră), where the relief configuration plays an important role in the development of local cloud systems, which generate significant amounts of precipitation and high values of the "de Martonne" aridity index. One such example is 1999. In the western part of the Subcarpathians, 20 of the 58 years displayed values above 50ºC/mm, 6 of these years even above 60ºC/mm (super-humid climate). An almost similar situation has to be mentioned for Polovragi, with 18 very humid years, 3 of which being super-humid. On the contrary, in the central part, at Târgu Jiu, there are only 6 years with Ia above 50ºC/mm, while in the east, at Râmnicu Vâlcea, only 2 years.

The linear trend of the Ia is not statistically significant at any of the analysed stations (Fig. 4, Fig. 5). At Apa Neagră, Polovragi and Râmnicu Vâlcea the values are positive, but not significant. Târgu Jiu is the only station displaying a slightly negative trend (0.0048), indicating the reduction of Ia values.

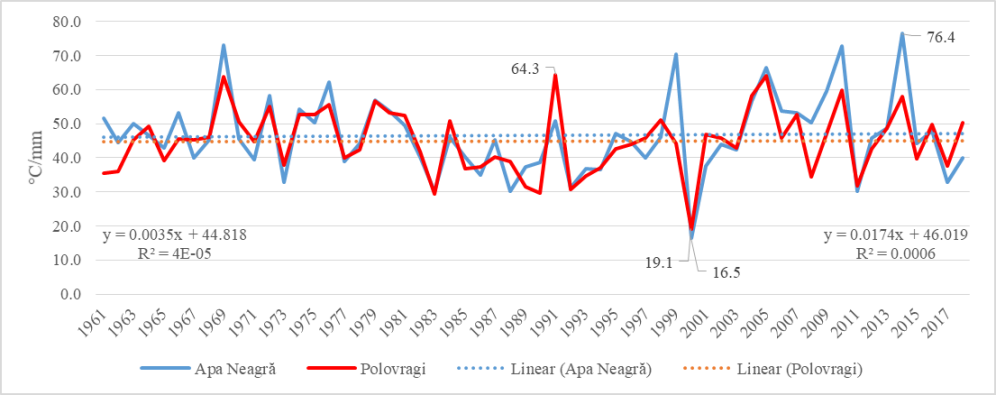

Fig. 4. Annual values of ”De Martonne” aridity index and its linear trend at Apa Neagră and Polovragi (1961-2018)

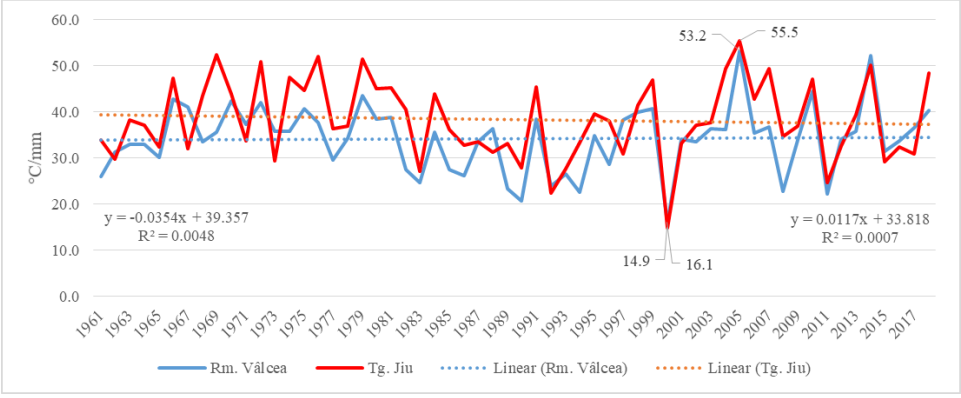

Fig. 5. Annual values of ”De Martonne” aridity index and its linear trend at Râmnicu Vâlcea and Târgu Jiu (1961-2018)

Thus, even if the temperature clearly increased in the last 20 years, at the same time, there was an increase in precipitation amounts, which led to relatively homogeneous values of the "de Martonne" aridity index.

3.2 The forestry aridity index (FAI) and **Ellenberg Quotient (EQ)**

These indices are used to determine the degree of the climate favourability for the development of beech forests. In Romania, beech as a species is important because our country represents the eastern development limit in optimal conditions. Beech requires precipitation amounts between 600 and 1,000 mm/year, but the species can easily adapt to lower amounts, even below 500 mm (Belmonte et al., 2008, quoted by Vlăduț et al., 2017). Air temperature is a restrictive factor in beech distribution because the optimum average annual temperature is between 4.5°C and 6°C, and the average temperature of the warmest month has to be between 13°C and 20°C (Pezzi et al., 2008; Vlăduț et al., 2017).

The average values of the two indices show that most of Oltenia Subcarpathian area is favorable for the development of beech forests, correlating with the values of the aridity index. At higher altitudes, in the northern part of analysed region, as well as in the western sector, beech has the most favorable development conditions (the values of Ellenberg coefficient are between 20 and 30, and those of the forest aridity index are less than 5). In the eastern part, however, climatic conditions are favorable for other deciduous species, with higher tolerance to high temperatures and lower precipitation amounts (Table 4).

Table no. 4 Different tree species favourability according to EQ and FAI

Meteorological station	Ellenberg Quotient (EQ)	Favourability	Forestry Aridity Index (FAI)	Favourability
Apa Neagră	22.7	Favourable to beech	4.75	Favourable to beech
Târgu Jiu	27.3	Favourable to beech	5.19	Moderately favourable for beech forests; Hornbeam, oak are dominant species
Polovragi	24.7	Favourable to beech	3.93	Favourable to beech
Râmnicu Vâlcea	30.2	Moderately favourable for beech forests; Hornbeam oak dominant species	5.02	Moderately favourable for beech forests; Hornbeam, oak are dominant species

During the analysed interval, FAI values are generally below 9.5 (which represents the double favorability threshold of 4.75) (Fig. 6). There are only certain years characterized by high values of this index, in general, those with high precipitation deficit and temperatures above normal. There is only one common year in the whole region, the year 2000, which also holds the record of the highest value of FAI, except for the eastern extremity, where the maximum value was recorded in 2015. On the whole, the number of years with FAI below 4.75 decreases from west to east (22 year at Apa Neagră – 19 at Râmnicu Vâlcea) and from north to south (38 year at Polovragi and 20 at Târgu Jiu). The interval between 1983 and 1997 was exceptionally dry and unfavourable to beech development as FAI values were below the threshold only in 1991 within the entire area, and in 1984, respectively 1986 at Polovragi. The analysis of the trendline revealed that the index values are slightly increasing both in the west and in the east, but not statistically significant.

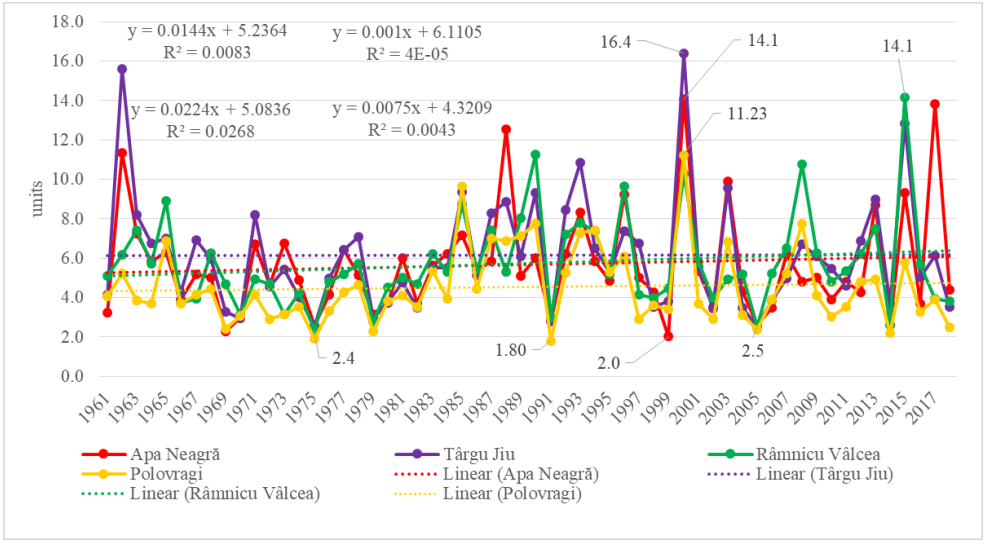

Fig. 6. Annual values of the forestry aridity index (FAI) and its linear trend within the Getic Subcarpathians – Oltenia Sector (1961-2018)

Ellenberg Quotient (EQ) shows the same situation as FAI, the favorable climatic conditions decreasing from west to east (Fig. 7). If in the western part only 8 years have values above the threshold of 30, at Târgu Jiu there are 25 years above this threshold, and at Râmnicu Vâlcea 31 years. Favourable conditions are also in the northern part of the region, at Polovragi, where there are only 11 years with values above 30. The most problematic year was also 2000, as EQ values corresponding to this year were between 55.1 and 73.4 units. The lowest values of EQ standing for greater favourability for beech development were registered in the rainiest years – 2005 and 2014, except for Târgu Jiu where the highest value