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CLIMATE ISSUES ON ARIDITY TRENDS OF SOUTHERN OLTENIA IN THE LAST FIVE DECADES

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Abstract

Climate aridity in Romania, in the context of global climate change, represent an actual issue at national level. The present study attempts to quantify the trend of climate aridisation of southern Oltenia in the last five decades (from 1961 to 2009) based on analysis of climate data on temperature, precipitations and potential evapotranspiration. These meteorological parameters were used to create specific climate indexes to assess the temporal trend of aridity (De Martonne Aridity Index, UNEP Aridity Index and Water Deficit Index), which are among the most representative of the analyzed phenomenon. The obtained results showed that during the five decades analyzed, the aridity trend is pronounced, occurring especially after 1980 year. This threshold of growing aridity phenomenon are mainly due to the changes of climatic parameters such as: the lowering of the average annual rainfall, the rising of mean annual temperatures and the increasing of potential evapotranspiration as a result of the annual thermal regime change after 1980 year.

Key Words: *Aridization, aridity indexes, southern Oltenia, climate changes.*

1. INTRODUCTION

According to the IPCC report (2007), scenarios on climate changes in Central Europe (which correspond for Romania), indicate dramatic changes in the evolution of averages temperatures and precipitations. It is expected that average annual rainfalls will increase in the winter season, but will decrease in summer season and average temperatures will increase in the summer, creating the potential to enhance the frequency and intensity of drought phenomenon. Also, the solid shape precipitation will decrease, shortening the season of snow and its average thickness. Due to the increase in average temperatures, the report draws attention to the changes of the balance of water from soil, with serious consequences in terms of climate, ecological and social.

In the context of the current policies of the European Union, Romania is classified as country with risk of desertification (*PDESP, 2009*). However, nationwide speciality studies often use the notion of aridity, considered to be more appropriate for the magnitude of the climate changes that affected the country to the actual state (*Păltineanu et al., 2007; 2009*). This aridity phenomenon from Romania was directly or indirectly extensively studied over the last decades in various specialized works (*Cernescu, 1961; Berbecel et al., 1970; Canarache, 1990; Păltineanu, 2005 et al.*).

Currently, the southern Oltenia is directly affected by climate changes, corresponding to an obvious trend of aridity (*Dumitraşcu, 2006; Vlăduţ, 2010; Achim et al., 2012*), along with other representative areas in Romania, as Bărăgan Plain and Dobrogea Plateau (*Păltineanu et al., 2009*).

The context of climatic changes, and local climatic peculiarities such as non-periodic variability of rainfalls, frequent advections of warm air, dry and drought frequents phenomena, are the main causes of climate aridisation of southern Oltenia.

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Also, political and social changes after 1990 year, led to important changes in the land use (destruction of irrigation systems, deforestation of forest ecosystems with consequences for the reactivation of deflation phenomenon, abandoning the agricultural lands, some of them with key role in maintaining moisture, such rice fields) are other associated causes with the amplification role of the studied phenomenon (*Dumitraşu, 2006; Prăvălie & Sîrodoev, 2013; Prăvălie, 2013*).

This paper aims to quantify the trend of climate aridity of southern Oltenia, based on temporal variation of meteorological parameters such as temperature, precipitations and potential evapotranspiration, these parameters being analyzed as De Martonne, UNEP aridity indexes, and Water Deficit Index.

2. DATA AND METHODS

To capture the quantification of the aridity trend, in a first stage were downloaded climate data (average annual temperature and precipitations) from the European Data Platform ECAD (European Climate Assessment & Dataset), for a period of 49 years (1961 - 2009).

For the analyzed territory, southern Oltenia (**Fig. 1**), were chosen the most representative weather stations, limited to available data: Drobeta Turnu Severin, Craiova and Turnu Măgurele (**Fig. 1**). Since meteorological station Craiova was the only with continuous string of data, eventual missing data from Drobeta Turnu Severin and Turnu Măgurele stations were obtained by linear regression using values from Craiova station. While there may be some differences in local climate influences in the three weather stations, overall, the geographical conditions in which they are located are relatively similar, issue confirmed by close correlation of linear regression (correlation coefficient r is approximately 0.9).

Mean annual values of potential evapotranspiration were obtained based on annual mean temperatures, using Thornthwaite methodology (*Thornthwaite, 1948*). While there are many methodologies for estimating potential evapotranspiration (*Bandoc, 2012*), the reasons for which this methodology was chosen are related to the fact that it is the most widely used and most representative for Romania (*Păltineanu et al., 2007*) and is relatively easy to calculate, based only on mean values of temperature. The calculation of potential evapotranspiration was based on Thorntwaite formula which expression is:

$$ETP = 16 * \left(\frac{10t}{I}\right)^{a} F(\lambda)$$

where: t - average monthly temperature (° C)

I - annual heat index calculated from the formula:

$$I = \sum_{n=1}^{12} \mathrm{i_n},\ \mathrm{i_n} = \left(\frac{\mathrm{t}}{5}\right)^{1.514}$$

$$a = 6{,}75 * 10^{-7} * I^3 - 7{,}71 * 10^{-5} * I^2 + 1{,}79 * 10^{-2} * I + 0{,}49$$

F (λ) – correction term depending on latitude and month of the year.

Received and processed data have been used in the development of specific aridity indexes namely de Martonne Aridity Index, UNEP Aridity Index and Water deficit index. De Martonne Aridity Index ($I_{ar\text{-}DM}$) was calculated using the connection formula between temperature and precipitations (De Martonne, 1926): $I_{ar\text{-}DM} = P / (T + 10)$, where P and T represent the rainfalls (mm) respectively mean annual temperatures (°C). UNEP Aridity Index ($I_{ar\text{-}P/PET}$), originally proposed in 1979 as UNESCO Aridity Index (which takes into account the relation between rainfalls and potential evpotranspiration calculated by Penman method) (*UNESCO, 1979*), was accepted in 1992 by the United Nations Environment Programme. It is calculated using the formula: $I_{ar\text{-}P/PET} = P / PET$, where P represents the average annual rainfalls (mm) and PET is potential evapotranspiration (mm), calculated based on Thornthwaite methodology (*UNEP, 1992*).

Water Deficit Index, calculated as the numerical difference between rainfalls amount and potential evapotranspiration, highlights synthetically the moisture balance and is commonly used in the specialty literature (*Păltineanu et al., 2007; Bussay et al., 2012*).

Finally, to confirm the effects of aridity trends on environment (hydrological component), a correlation was made between the obtained values of aridity indexes and hydrological data (mean annual flows) obtained from the Water Basin Jiu Administration. This is about average annual flows (1961-2009 period) of Desnăţui river, at Dragoia hydrological station (**Fig. 1**) correlated with the values of the three indexes of aridity obtained from Craiova meteorological station. These stations were considered representatives for the analysis of the correlation between climatic conditions and surface drainage, as they are located at close distances and hydrological data obtained cover the whole analyzed period of the last five decades.

3. RESULTS AND DISCUSSIONS

In the current stage, in Romania there are approximately 3.75 million hectares of lands affected by drought, the most affected regions being the Romanian Plain, the southern part of Moldavian Plateau and Dobrogea Plateau (**Fig. 1**).

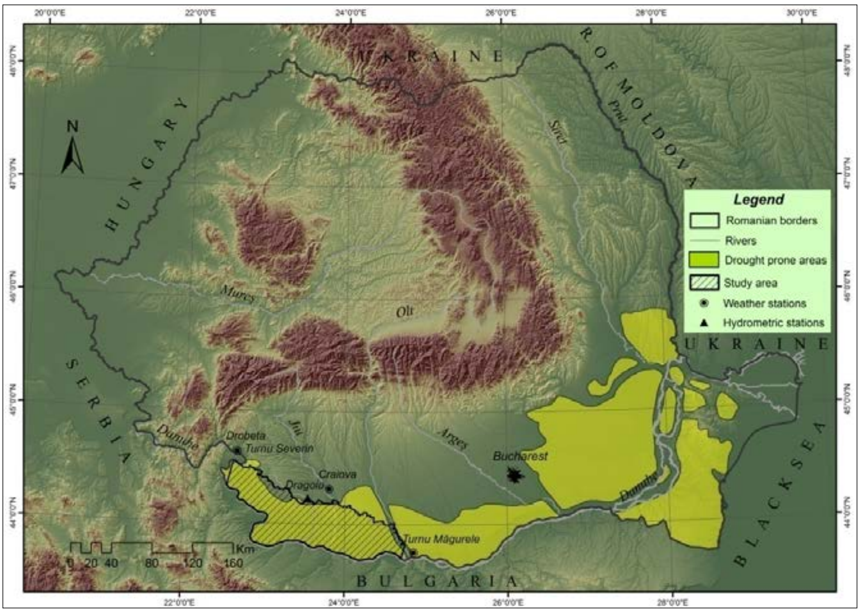

Fig. 1. The location of the study area and affected areas by drought in Romania. (adapted from *Achim et al., 2012*)

The drought plays an esential role in the increasing of intensity of aridity phenomenon, along with other important factors such as lands degradation, inappropriate land use (*Liu et al., 2008*), reduction of water resources (*Chamchati & Bahir, 2011*), etc. Southern Oltenia, delimited by administrative criteria (113 territorial-administrative units), corresponds in major part to Oltenia Plain and overlaps over 90% to areas affected by drought in Romania, areas delimited according to specialized studies (*Achim et al., 2012*) (**Fig. 1**).

The analysis of the aridity indexes De Martonne, UNEP and Water Deficit Index captures local climate changes, with the direct effects in increasing the aridity phenomenon in the last five decades. The aridity index De Martonne (**Fig. 2**) shows a significant variation in the analyzed period, its values having a clear trend of decreasing. According to the specialty literature (De Martonne, 1926), the more lower are the values, the more excessive is the aridization. The most obvious downward trend of De Martonne Index values in the analyzed period is recorded after 1982 year when the values start to oscillate frequently in the interval 15-20, interval that characterizes the dry steppe zone according to De Martonne classification. It is interesting to note that De Martonne Aridity Index recorded minimum values in 1992 year (11.7 mm/°C at Craiova station and 14.6 mm/°C at Turnu Măgurele station) and in 2000 when are recorded minimum record values (11.9 mm/ ºC at Craiova station, 12.2 mm/°C at Drobeta Turnu Severin station and 12 mm/°C at Turnu Măgurele) (**Fig. 2**), values were filled in the gap 10-15, corresponding to semi-arid regions.

In terms of trends, in the case of Drobeta Turnu Severin station it is observed the highest tendency of decreasing of De Martonne Index values (the a coefficient of the linear equation has the value -0.119 in comparison to -0.082 and -0.065 values of Craiova station and Turnu Măgurele station). Although the station has a high potential for precipitations due to local peculiarities (proximity to the mountains with the role of orographic barrier, slopes with southern orientation towards tropical air circulation) (*Vlăduţ, 2004*), the sharp decline in De Martonne Index values is due to changes encountered at the average annual temperatures level. In the three analyzed weather stations, the largest increase in average annual temperatures during 1961-2009 was recorded at Drobeta Turnu Severin station, with an a coefficient of the linear equation equal to 0.022 value, compared to Craiova and Turnu Măgurele stations where the coefficients reached the values of 0.021, respectively 0.016.

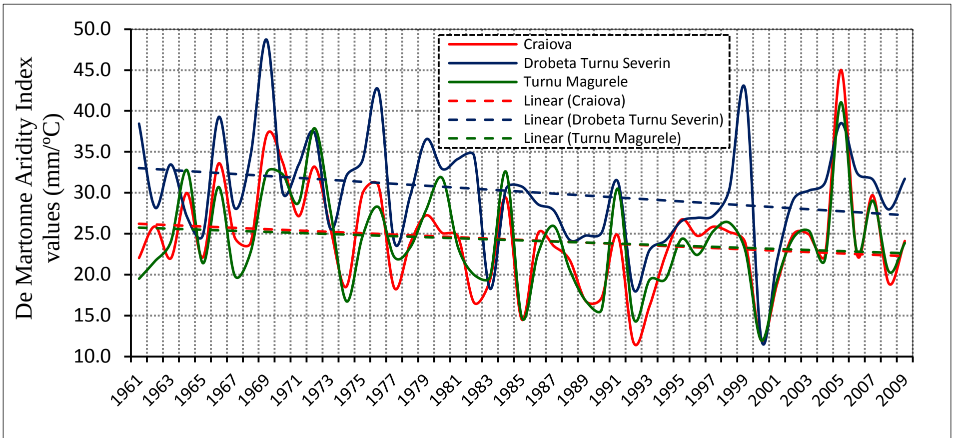

Fig. 2. The annual dynamics of De Martonne Aridity Index and linear trend at Craiova, Drobeta Turnu Severin and Turnu Măgurele meteorological stations (1961-2009).

De Martonne Index is very representative and for growing season period (*Dumitraşcu, 2006*). Thus, in seasonal conditions (April-October), the decreasing trends are significantly attenuated (**Fig. 3**) the a coefficient of the linear equation ranging from -0.026 (Drobeta Turnu Severin) to -0.001 for Turnu Măgurele and Craiova stations. The mean of the De Martonne Index values ranges from 14.1 mm/°C at Drobeta Turnu Severin to 12.3 mm/°C at Craiova station and 12 mm/°C at Turnu Măgurele station, which correspond to 10.1-15 gap, range which for the period of the growing season characterizes dry steppe zone (*Dumitraşcu, 2006, 156 p*). Interestingly, in the period 1980-2000 were frequently recorded values below 10 mm/°C (valid situation for all three stations), characteristic for a semi-arid areas.

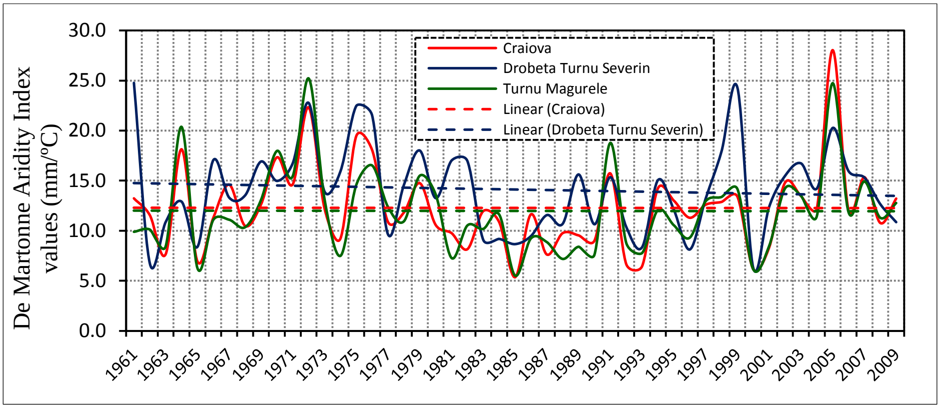

Fig. 3. The dynamics of De Martonne Aridity Index values during growing season period. (April-October) and linear trend from Craiova, Drobeta Turnu Severin and Turnu Măgurele meteorological stations (1961-2009).

UNEP Aridity Index case is similar, with clear trends of decreasing values (**Fig. 4**). In this case also, the climate is more arid with both values are lower. Thus, could be noticed that after 1985 year, the index values fluctuate frequently in the gap 0.2 - 0.5, the gap that, according to UNEP Index, characterizes the existence of a semiarid climate (*UNEP, 1992*).

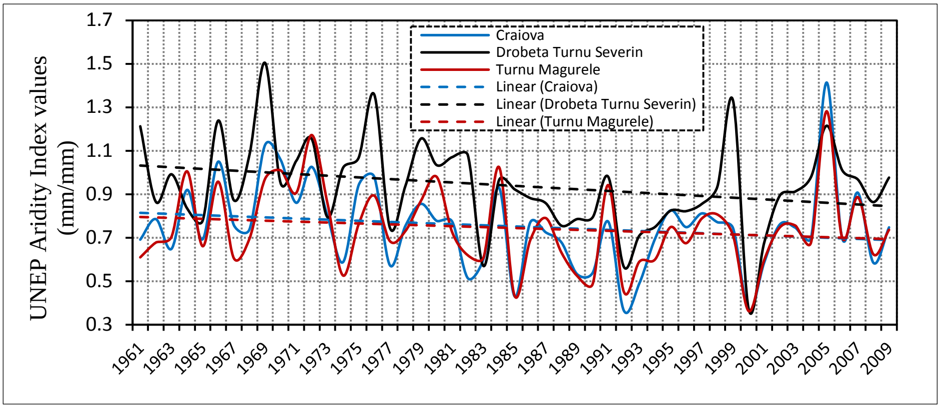

Fig. 4. The annual dynamics of UNEP Aridity Index and linear trend from Craiova, Drobeta Turnu Severin and Turnu Măgurele weather stations (1961-2009).

Minimum values were recorded in the same years, 1992 and 2000, when at the three stations were obtained values between 0.4 - 0.6 mm/mm. Downward trends recorded values of the a coefficient from -0.003 in the case of Drobeta Turnu Severin station to -0.002 for the other two stations.

In the growing season is observed also significant attenuations (**Fig. 5**), the a coefficient having values of -0.002 at Drobeta Turnu Severin station and -0.001 for Craiova and Turnu Măgurele stations. Minimum values correspond to the 1985 year (the minimum value of 0.2 mm/mm at Craiova and Turnu Măgurele stations), 1992 and 2000 years (values of 0.3 - 0.4 mm/mm at all three stations).

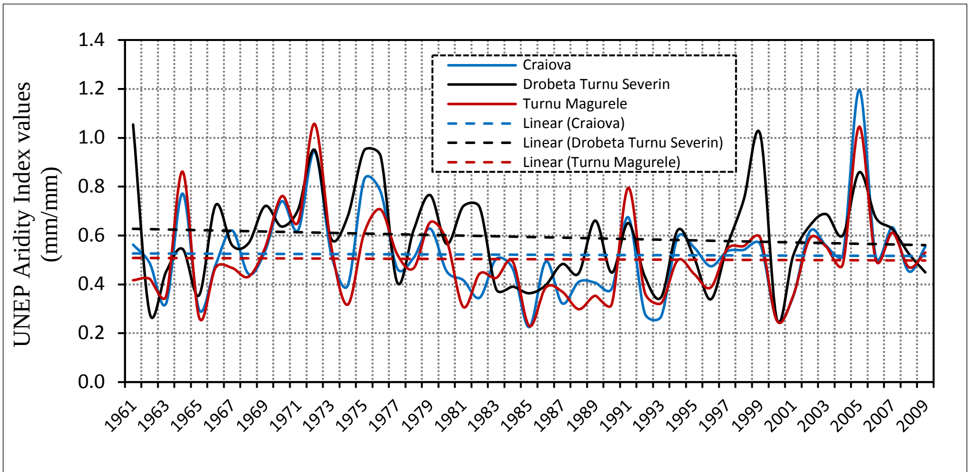

Fig. 5. The dynamics of UNEP Aridity Index values during the growing season period (April-October) and linear trend from Craiova, Drobeta Turnu Severin and Turnu Măgurele weather stations (1961-2009).

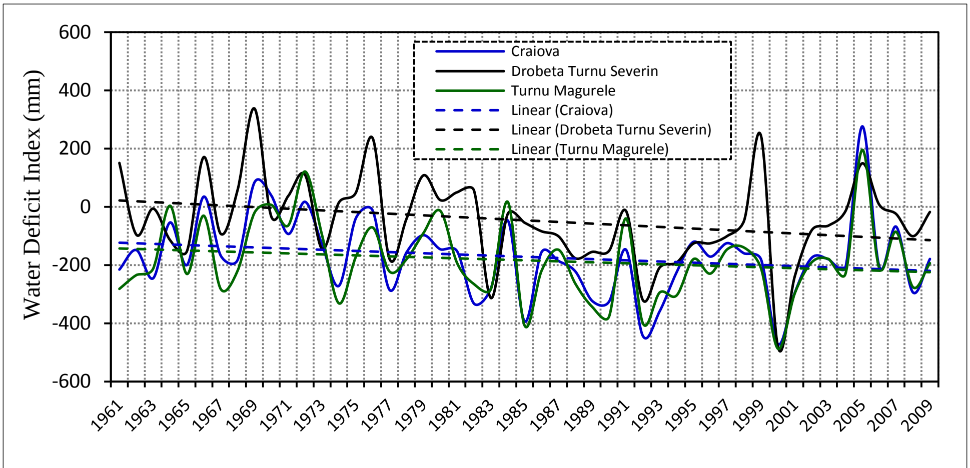

Fig. 6. The annual dynamics of Water Deficit Index and linear trend from Craiova, Drobeta Turnu Severin and Turnu Măgurele weather stations (1961-2009).

Water Deficit Index is another way of assessing synthetically the climatic conditions of a territory. The analysis of its variation in the three analyzed stations captures important temporal changes in both annual and seasonal regime.

In annual regime, the maximum values of moisture deficit were recorded in the years 1985 (-408 mm Turnu Măgurele, -393.5 mm Craiova), 1992 (-443.4 mm Craiova, -399.9 mm Turnu Măgurele, -320.3 mm Drobeta Turnu Severin) and 2000 (-487.4 mm Turnu Măgurele, -481.1 mm Drobeta Turnu Severin, -471.2 mm Craiova) (**Fig. 6**).

Downward trends during the analyzed period are evident for all three stations, existing small differences between Drobeta Turnu Severin station and Craiova and Turnu Măgurele stations(the a coefficient of linear equation being -2.853 for Drobeta Turnu Severin and -2.019, respectively -1.693 for Craiova and Turnu Măgurele stations).

The growing season period (Fig. 7) was marked by peaks value of moisture deficit, but in this case they were achieved in 1985 year (- 537.6 mm Turnu Măgurele, -521.4 mm Craiova) and 2000 (-541 mm Turnu Măgurele, -535.3 mm Drobeta Turnu Severin, -523.2 mm Craiova). Decreasing trends registered the values for the a coefficient of -1.226 (Drobeta Turnu Severin), -0.462 (Craiova) and -0.460 (Turnu Măgurele).

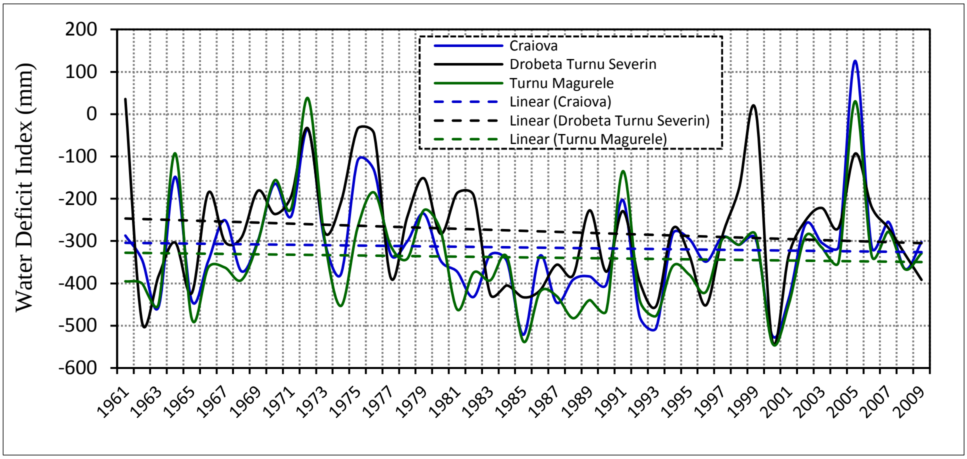

Fig. 7. Fig. 7 The dynamics of Water Deficit Index values during the growing season (April-October) and linear trend from Craiova, Drobeta Turnu Severin and Turnu Măgurele weather stations (1961-2009).

After analyzing temporal fluctuations of the three indexes it is observed that, during the analyzed period (1961-2009), there were at least three critical years in terms of severity of aridity of southern Oltenia: 1985, 1992 and 2000. These years correspond to periods of prolonged drought, periods characterized by high temperatures (in 2000 was recorded average annual temperature of 13.5 °C at Drobeta Turnu Severin station, 13.2 °C at Turnu Măgurele station and 12.7 °C at Craiova station) and high moisture deficit due to very low rainfalls (generally below 300 mm/year) and high evapotranspiration (usually over 700 mm potential evapotranspiration values).

It also should be noted that both in the case of Water Deficit Index, and in UNEP Aridity Index case, the results depend on potential evapotranspiration values, these values showing some disadvantages. Although Thorntwaite methodology for calculating potential evapotranspiration shows the major advantage of requiring minimal data and provide satisfactory results, the disadvantages are related to the fact that, according to the findings of the specialty literature, it underestimates the evapotranspiration in summer period and overestimate during winter period (*Carrega, 1994*). Also, evapotranspiration potential real fluctuations largely depend on other factors such as saturation deficit and wind speed, factors not considered. Therefore, the obtained results in annual and seasonal regime are influenced by these issues.

The aridization of southern Oltenia, amplified in the last two decades, caused major disruptions and to other environmental components. Among the most important direct effects is noticed the reduction of water resources at the local level, mainly due to changes of local rivers drain system (*Savin, 2008*). To capture the impact of aridisation on temporal variability of surface drainage, were corelated the obtained values of the three aridity indexes at Craiova meteorological station with average annual flows values at Dragoia hydrometric station on Desnăţui river. The obtained results showed that there is a connection between the two environment variables due to correlation coefficients of 0.61 and 0.62 (**Fig. 8**). So, during the last five decades, there is a direct connection between aridization of climatic conditions and diminushes the surface drain regime in southern Oltenia, at least in analyzed situation.

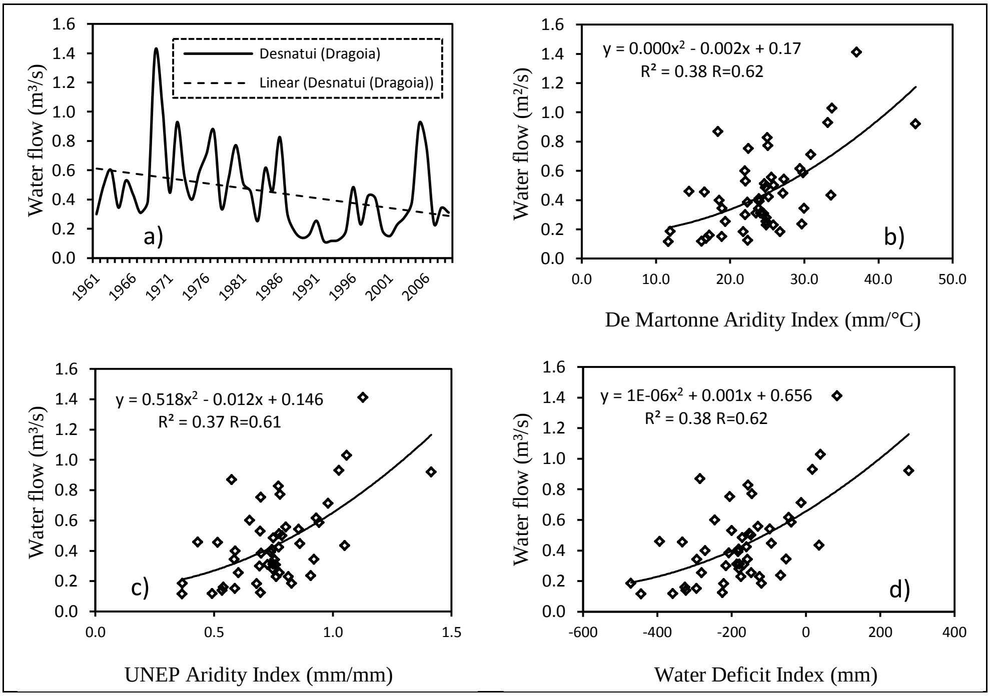

Fig. 8. The variation of average annual flows (1961-2009) at Dragoia hydrometric station on Desnăţui river(a). Polynomial correlations of second degree between average annual flows and annual values of indicators: De Martonne (b), UNEP (c) and Water Deficit Index (d).

4. CONCLUSIONS

The climatic factor is one of the most important components of the aridity phenomenon, but it should be noted that locally there are others essential factors with aridity amplifying role (dune landscape with wind deflation role, misuse of land use, the cutting of forest ecosystems etc.). So, synergistic context of severe weather conditions and of local narrowly factors represent the direct consequence of aridity phenomenon, a phenomenon amplified in a first stage after1980 year, concomitant with the tightening of climatic conditions in a global context, and in the second stage, after political transition 1990 year, when it appear a series of failures in the land use.

Aridity indexes are a good methodology for synthetic quantifying the severe climatic conditions of a territory. Thus, based on the analysis of the dynamics of the three indexes of aridity, it can be concluded that the year 1980 marks a turning point in the trend of aridity of southern Oltenia, after this time the installation of a semi-arid climate becomes increasingly more evident.

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