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MONITORING OF THE THERMAL AND HYDRIC REGIME OF THE SOILS FROM THE SOMEȘAN PLATEAU

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Abstract

The purpose of monitoring the thermal and hydric regime of the soils from the Someşan Plateau is to set up the evolution tendency of pedoclimate parameters and to establish the agrotechnical measures in order to adapt agricultural technologies to climate changes. Romania is among the areas with the lowest capacity to adapt to existing climate changes and to those which are going to come and the Someşan Plateau is among the most affected areas due to the reduced degree of afforestation and the lack of forest curtains. Monitoring and variability of climate elements was achieved during 2013-2018, through a network of 10 HOBO microstations which stored soil temperature data electronically (at 10, 30, 50 cm deep) and air (at 1 m height), soil moisture (at 10 cm depth) and rain gauges. The thermal regime of the soils from the Someşan Plateau is mesic, with values of the annual average temperature of the soil 50 cm deep ranging between 8-15°C, and the differences between the average of summer temperatures and the average of winter temperatures are higher than 6°C at 50 cm depth (the difference ranging between 10.3-15.6°C). The annual values of the soil humidity ranged between 0.153-0.344 m^3/m^3. The annual average of the air temperature during 2013-2018 ranged between 9.21-11.03°C. The annual average of rainfall ranged between 476.3-879.4 mm/an.

Key words*: thermal and hydric regime of soils, the Someşan Plateau.*

INTRODUCTION

The Earth's climate is generated by factors like: insolation, excentricity of the Earth's orbit, the movement of earthly precession, obliqueness compared to the Sun, terrestrial albedo, anthropic factors, humidity etc., cannot remain constant as long as there are changes, evolution at the level of the earthly bark (Eastwood et al., 2006; Casas-Prat, 2012; Murante et al., 2020). Climate changes are currently a political issue worldwide (Ramirez-Villegas et al., 2012; Cattaneo et al., 2019).

Scientific evidence and explanations of climate changes have accumulated over decades, being integrated into strategies and adaptation policies (Fuhrer, 2003; Hemadi et al., 2011; Lereboullet et al., 2013; Clar and Steurer, 2019).

Changes in the rainfall regime at a European level show a higher temporal and spatial variability compared to temperatures, increasing in the areas from the north and nort-western Europe, but decreasing in the south of Europe. The majority of projections of climate models show a continuation of increased rainfall in the north of Europe and their decrease in the south of Europe (EEA, 2019).

The effects of climate changes in agriculture reflect in the expansion to the north of areas favorable for certain agricultural crops during blooming and harvesting of crops earlier than the usual ones, in the growth of irrigation need for the crops from the South and South-West of Europe, in the decrease of productivity in the case of certain crops due to heat waves and drought periods, mainly in central and southern Europe, instead there is an increase in productivity for crops from northern Europe, where the vegetation period of crops has been extended.

In terms of the soil humidity, there are no clear clues as to the tendencies of keeping water in the soil due to the lack of systematic and harmonized data. The projections suggest a reduction of the soil humidity in the greatest part of Europe, significant reductions in the mediterranian region and its growth in the North-East of Europe (Calanca et al., 2006; Sheffield et al., 2012).

The regional distribution of the impact of climate changes on agricultural production can vary a lot (Donatelli et al., 2012). Thus, the biggest drops in crops are forecast in the southern part of Europe, of approximately 25%, up to 2080 based on a temperature increase by 5.4°C (Ciscar et al., 2011). Under these conditions, Bindi and Olesen (2011) also estimate an increase of the risk of failure, especially in the case of summer crops which are not irrigated.

Romania is among the areas with the lowest capacity to adapt to the existing climate changes and to those which are going to come and the Someşan Plateau is among the most affected areas due to the reduced degree of afforestation and the lack of forest curtains. Right now and in perspective, a series of strategies and plans to fight climate changes are being proposed, but in order to put them into practice, a strict monitoring of the thermal and hydric regime of the area is needed in order to identify and implement the measures to adapt to the effects of climate changes.

The afforestation percentage of the current geographical space of Romania has slowly decreased from around 80%, which was in the recent past to 55-60% at the beginning of the XIXth century and to 23%, which is now. Therefore, a considerable damage of the environment has been produced, including an incredible narrowing of biodiversity at all levels (Baciu, 2006). The Someșan Plateau is a subdivision of the Transilvanian Basin together with the Transylvanian Plain and the Târnavelor Plateau. The Someșan Plateau is aproximately a quadrilateral, as a form, with a surface of approximately 510000 hectares, having around 100 km on the South-West : North-East direction, respectively 60 km on the North-West : South-East direction. In this region, high erosion is not only the result of combined processes of two neotectonic movements (the uplift of the hill compartment and local subsidence), but also the friability of geological formations. The Someșan Plateau is a “hilly complex” of plateaux and basins, with many corridors on the side and it is very fluctuant both in terms of relief and as lithological structure. The lithology from the Someşan Plateau is a dominant pedogenic factor, influencing the type of relief, the diversity and territorial distribution of soils. Its influence reflects in the texture, depth, fertility and humidity regime of soils, being at the same time the main cause of slope processes. The zonal soils are: phaeozems, preluvisols and luvisols, to which intrazonal lithomorph soils are added: rendzina, pseudorendzina, hydromorph, halomorph, less spread. Less developed soils like lithosols, regosols, alluvial soils and river deposits are also met. The analysis of crop structure from the Someșan Plateau shows a higher share and considers main agricultural plants: autumn wheat, triticale, maize, potato and clover.

The annual average temperature has values ranging between 6.5-9ºC, the lower value is very rarely reached in higher areas, and the higher value of 8.5-9ºC is rarely met, only during very hot years. The annual average rainfall has values ranging between 600-800 mm, rarely dropping or exceeding this limit.

The purpose of the paper is to monitor the thermal and hydric regime of the soils from the Someşan Plateau in order to set up the evolution tendency of the pedoclimate parameters and to set up the agrotechnical measures to adapt agricultural technologies to climate changes.

MATERIALS AND METHODS

Monitoring and variability of climate element from Someșan Plateau was achieved during 2013-2018, through a network of 10 HOBO-MAN-H21-002 (On-set Computer Corp., Bourne, MA, USA) stations, which store soil temperature data electronically (at 10, 30, 50 cm deep) and air (at 1 m height), soil moisture (at 10 cm depth) and rain gauges. HOBO Smart Temp (S-TMB-M002) temperature sensors and Decagon EC-5 (S-SMC-M005) moisture sensors were connected to HOBO Micro Stations. Additionally, tipping bucket rain gauges (RG3-M) were deployed to measure rainfall. Data was downloaded from the Micro

Stations every four months via laptop computer using HOBOware Pro Software Version 3.7.2. Soil types, land slope and exposition, altitude and geographic coordinates of the locations in which stations were set are shown in Table 1 (Duda, 2018).

Table 1. Configuration of stations in the Someșan Plateau

No. station	Location (County)	Altitude (m)	Soil type	Exposition	Slope, %
1	Cristorel (Cluj)	404	Preluvosol	N	8-10
2	Borșa (Cluj)	332	Faeoziom	S	2-3
3	Lelești (Bistrița-Năsăud)	606	Regosol	V	25-26
4	Șomcutu Mic (Cluj)	271	Aluviosol	S	2-3
5	Căprioara (Cluj)	416	Preluvosol	S	4-5
6	Almașu (Sălaj)	323	Aluviosol	S	8-10
7	Racâș (Sălaj)	253	Preluvosol	S-E	2-3
8	Șimișna (Sălaj)	256	Preluvosol	N-E	7-9
9	Ileanda (Sălaj)	225	Aluviosol	S	2-3
10	Bunești (Cluj)	209	Preluvosol	N	6-8

When calculating the average, minimum and maximum values of daily, monthly and annual temperatures from the soil and air, as well as the average, minimum and maximum values of humidity from the soil and rainfall, the initial data recorded by the HOBOware Pro Software Version 3.7.2 Program mentioned earlier shall be used, which is exported in Microsoft Excel table worksheets. Subsequently, the data is analyzed, it is graphically represented and statistically interpreted by using both functions specific for Microsoft Excel and specific statistic methods of interpreting data. Regression is used as the best interpolation method in order to spatialize climate information, taking into account the nature of the variable (continuous spatial character) and the time scale (monthly, annual and multiannual average values).

In order to estimate the evolution tendency of climate parameters we used the regression analysis which supposes quantifying relations from one (simple regression) or several (multiple regression) independent variables and a dependent variable (of reply), quantifying cause relations being made by linear equations (linear regression). The estimation of evolution tendencies was applied in the evolution analysis of climate parameters during 2013-2018, with regards to the soil temperature at the surface and 10 and 30 cm deep in the soil, the air temperature 1 m from the soil surface, the evolution of rainfall and soil humidity. The values of the correlation coefficients in relation to the tendencies of linear evolution of the calculated parameters were graphically represented for each of the parameters previously mentioned. The correlation analysis was used in order to measure the intensity among the variables by offering information regarding the existance, the sense, the form and the intensity of the connection among the variables analyzed.

For a synthetic image of the space-time variability of the variation of a meteorologic parameter, we used standard deviation (standard deviation), frequently used in climatology, an index with the same unit measure as that of the values from the data string used. The evolution of quantitative elements were shown by the graphical representation of standard deviations, for example, of the annual amount of rainfall compared to the multiannual average, which indicates the value of positive or negative deviations from each year compared to the multiannual average, also called normal, considered absolute zero arbitrary. For the calculation of rainfall, the HOBOware program allowed to record the events (daily counting of the number of tippings of the cup to collect rainfall), which were exported in their turn in Excel calculation sheets, where the monthly and annual amount of rainfall was calculated by multiplying the number of events by 0.2 (mm), a value which corresponds to each balance of the cup mechanism the rain gauge is equipped with.

RESULTS AND DISCUSSIONS

The thermal regime of the soil depends on a complex of factors, first on the intensity of solar radiation and its periodic variations in

time, to which physical properties of the soil, composition, structure, texture, degree of humidity or dryness of the soil, specific heat and thermal conductivity, orientation and slope inclination as well as nature and degree of covering soil surface with vegetation are added.
The soil surface receives a certain amount of energy which is converted into thermal energy, which subsequently propagates and/or it is taken over, then, by the soil layers through conduction.
The thermal regime of the soil influences in its turn the growth of plants, the biological activity and movement of water inside the soil. In evaluating the thermal regime of the soil, the multiannual average of temperature is the value mostly used.
The analysis of the thermal regime of the soils from the Someşan Plateau during 2013-2018 by indirect determination according to SRTS, 2012 (adding 2°C to the annual average temperature of the soil 50 cm deep from the surface) is not confirmed as, in the case of most stations from the Someşan Plateau, the temperature values 50 cm in the soil are higher than those of the air.
Figure 1 shows the multiannual average temperatures (2013-2018) of the temperatures in the soil, at 10 cm, 30 cm and 50 cm in the case of the 10 stations from the Someşan Plateau:

- the multiannual average of the soil temperature 10 cm deep ranged between 10.59°C at Cristorel station and 12.04°C at Căprioara station;
- the multiannual average of the soil temperature 30 cm deep ranged between: 10.62°C at Cristorel station and 11.98°C at Căprioara station;
- the multiannual average of the soil temperature 50 cm deep ranged between: 11.03°C at Almaşu station and 11.91°C at Căprioara station.

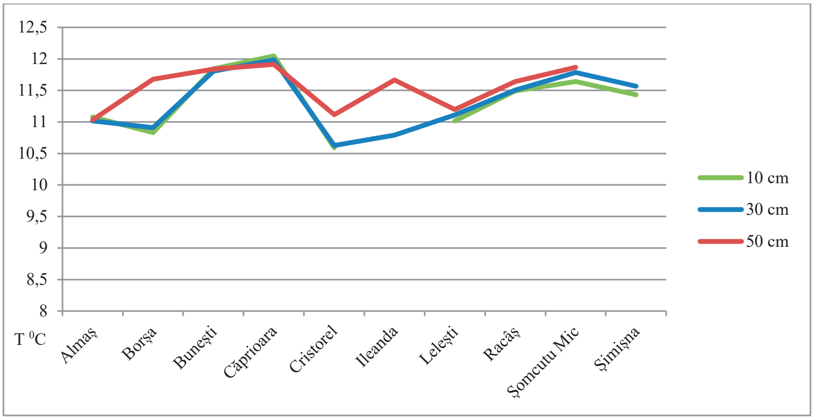

Figure 1. Multiannual average (2013-2018) of soil temperature in the Someşan Plateau

From the data recorded during 2013-2018, it results that the thermal regime of the soils from the Someşan Plateau is ***mesic***, with values of the annual average temperature of the soil, 50 cm deep, ranging between 8-15°C, and the differences between the average of summer temperatures and the average of winter temperatures are higher than 6°C at 50 cm deep. The annual average of the soil temperature has values ranging between 10.3°C and 15.6°C. In terms of the differences between the average of the summer and winter temperatures, 50 cm deep into the soil, they range between 12.07°C and 19.91°C. The differences between the annual average of the summer and winter temperatures, 50 cm deep into the soil, range between 12.07°C at Borşa, in 2015 and 19.19°C at Cristorel in 2017. The lowest differences of temperature were recorded at Borşa (12.07°C) and Almaşu (12.6°C) stations in 2015, and the highest differences of temperature were recorded at Cristorel in 2017 (19.19°C) and Şomcutu Mic in 2017 (18.91°C).
The soil humidity is one of the derived meteorological elements of atmosphere, with a

determining role, together with other factors, in the ongoing under the best conditions of the vegetation cycle of plants. The determination of the soil humidity was made with soil humidity sensors located 10 cm deep into the soil. The annual values of the soil humidity are presented in Figure 2, from which one can notice that the lowest annual values of the soil humidity are recorded at Cristorel station in 2016 of 0.153 m^3/m^3, in 2013 of 0.1762 m^3/m^3 and in 2018 of 0.176 m^3/m^3; followed by Căprioara station of 0.185 m^3/m^3 in 2017. The highest values were obtained in 2013 at Lelești station, of 0.344 m^3/m^3, followed by those at Șimișna station in 2018, of 0.327 m^3/m^3 and Ileanda in 2017, of 0.322 m^3/m^3.

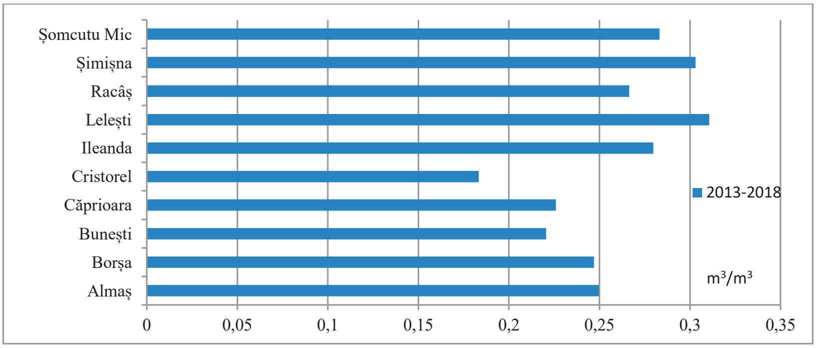

Figure 2. Multiannual averages of soil moisture in the Someșan Plateau

The air temperature was recorded at the stations which were equipped with rain gauge, 1 m high from the soil surface. The annual average of the air temperature during 2013-2018 ranges between 9.21°C at Cristorel station in 2017 and 11.03°C at Șomcutu Mic station in 2015. The lowest values of the annual average of air temperature during 2013-2018 were recorded at Cristorel and Șomcutu Mic stations and the highest values were recorded at Bunești and Almașu stations (Figure 3).

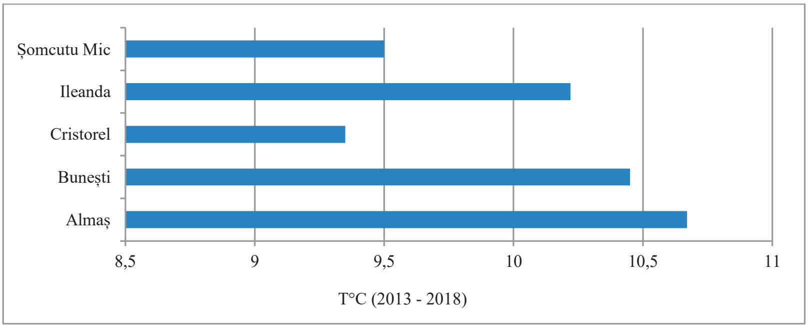

Figure 3. Multiannual averages of air temperature during 2013-2018

From the data recorded at the stations equipped with rain gauges, the highest amount of rainfall from the Someșan Plateau during 2013-2018 was recorded at Ileanda station in 2016 (879.4 mm/year), followed by the ones from Bunești station in 2016 (708.8 mm/year) (Figure 4).

In order to statistically analyze the general direction in time of the soil temperature, *the monthly rolling average for 12 months* was used of temperatures 10, 30 and 50 cm deep during 2013-2018. Then, *the linear tendency* was applied to the values of the rolling average based on the size of R^2 determination index and the correlation coefficients, the first 12 months of data was excluded from the graphs in order to allow the rolling average to accumulate all 12 months for which calculations are made and thus to become relevant for 1 year every month when it is calculated. Figure 5 shows the values of the correlation coefficients associated to the trend evolution of the annual average temperatures calculated by the average of temperatures at 10, 30 and 50 cm. The values range between 0.69 at Almaşu station and 0.19 at Buneşti station.

The average of the rolling temperatures is presented in Figure 6. Temperature values between 11.5 and 13.5°C can be noticed, the only exception is at Ileanda station, where on an average, 14.85°C was calculated.

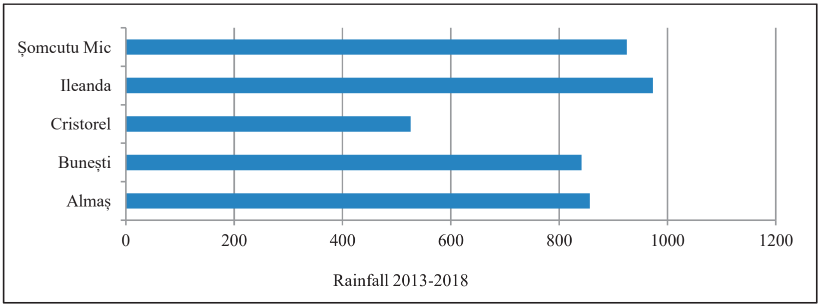

Figure 4. Multiannual rainfall the Someşan Plateau

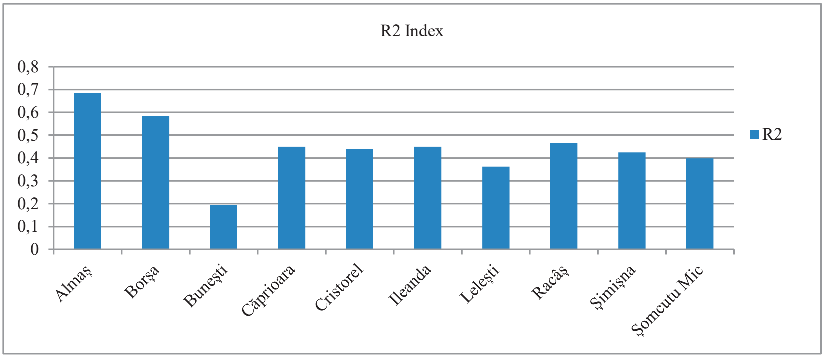

Figure 5. Values of correlation coefficient associated with trend evolution of annual average temperature averaged at 10, 30 and 50 cm

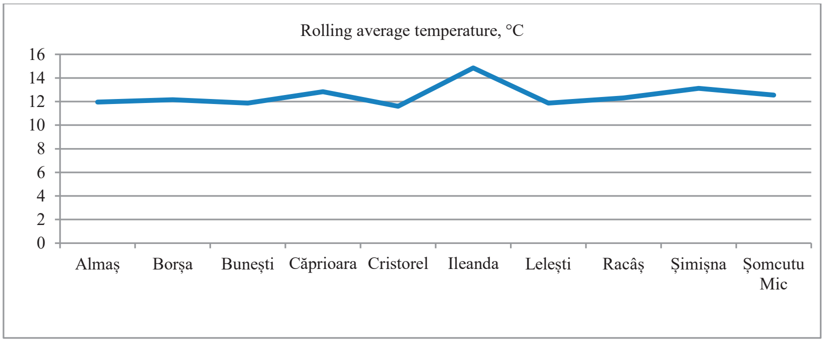

Figure 6. Temperature rolling average in the Someşan Plateau, 2013-2018

The values of the correlation coefficients associated to the evolution tendencies of the annual average temperatures calculated through the soil humidity are shown in Figure 7.

The values range between 0.6922 at Bunești station and 0.0097 at Șomcutu Mic station. The evolution tendencies of humidity are described in Figure 8.

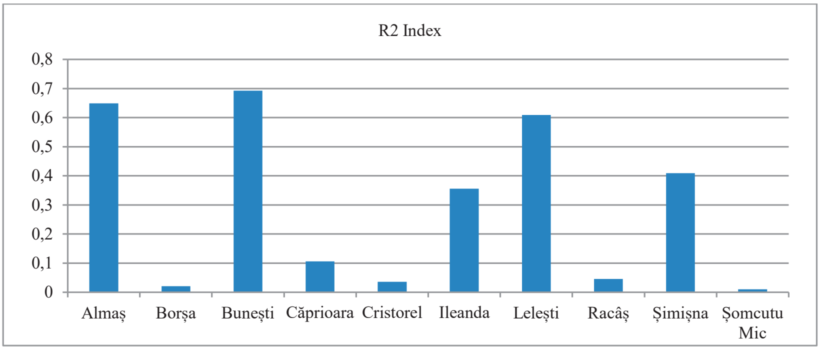

Figure 7. Values of the correlation coefficients between temperature and humidity, Someșan Plateau, 2013-2018

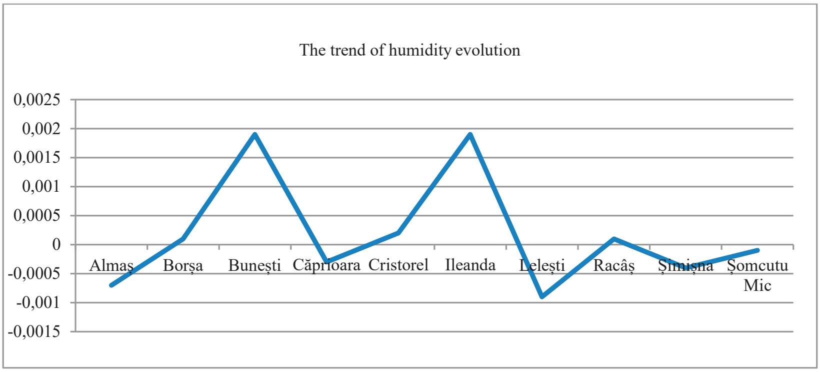

Figure 8. The trend of humidity evolution in Someșan Plateau, 2013-2018

At Bunești and Ileanda stations, tendencies of easy growth (0.002) of humidity were recorded, and at the other stations decreases or an almost constant evolution resulted. At Lelești, the highest decreasing tendency was recorded (-0.0009). The highest multiannual values of the rolling average (Figure 9) were calculated at Lelești and Șimișna stations (of over 0.3 m^3/m^3), and the stations with the lowest averages were Bunești and Cristorel - the only ones with values under 0.2 m^3/m^3 (0.173 and, respectively, 0.178 m^3/m^3).

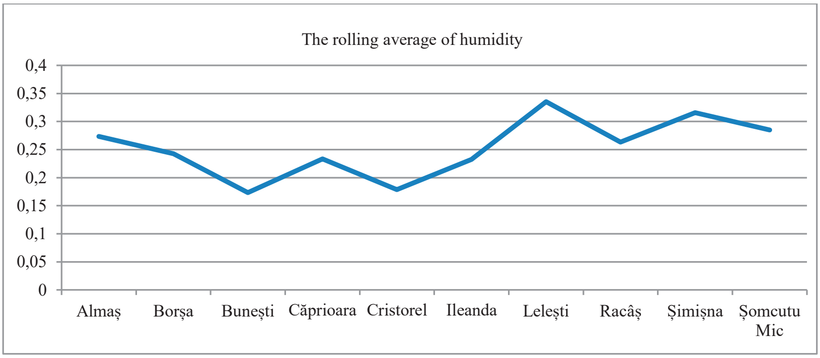

Figure 9. The rolling average of humidity in the Someșan Plateau, 2013-2018

For the stations equipped with rain gauge, the correlation index between the amount of rainfall and the soil humidity was calculated, too and its results are shown in Figure 10. Thus, a very high R^2 correlation index (0.8507) between the annual rainfall recorded at the stations with rain gauge and the records offered by the humidity sensors in the soil is confirmed.

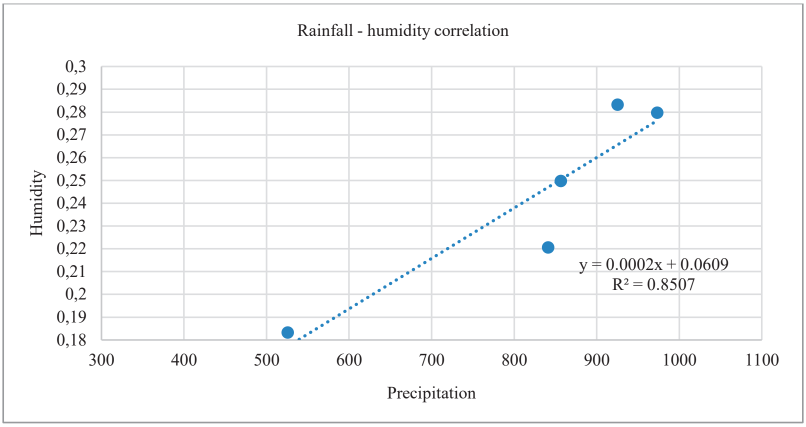

Figure 10. The correlation index between rainfall and soil moisture, Someșan Plateau, 2013-2018

CONCLUSIONS

The thermal regime of the soils from the Someșan Plateau resulted from the data analysis of soil temperature during 2013-2018, indicates a mesic-type regime, with values of the annual average temperature of soil at 50 cm deep ranging between 8 and 15°C, and the differences between the average of summer temperatures and winter temperatures are higher than 6°C at 50 cm into the soil. The differences between the annual average of summer temperatures and winter temperatures at 50 cm deep range between 12.07°C at Borșa, in 2015, and 19.19°C at Cristorel, in 2017. The lowest differences of temperature were recorded at Borșa (12.07°C) and Almașu stations (12.6°C), in 2015, and the highest differences of temperature at Cristorel, in 2017 (19.19°C) and Șomcutu Mic, in 2017 (18.91°C).
The evolution of temperatures at 10, 30 and 50 cm into the soil during 2013-2018, but also of the average of the 3 temperatures indicates evident decreasing trends of temperature in most of the stations. The coefficients of linear correlation among the data strings analyzed indicate a dropping synchronous evolution of the annual average temperature in the soil, with more evident tendencies at Almașu, Borșa and Cristorel (-3%), the only station which recorded an increase in temperature was Ileanda, by 4%. The R2 coefficients of linear correlation for the rolling average, calculated every month, of the average of temperatures range between 0.35 and 0.8 for all stations.
Following the analysis of evolution trends of annual average temperatures, based on the data recorded during 2013-2018 we can notice that the latter recorded decreases, even more important than those for the soil temperature. Drops of up to 10-15% of the rolling average of temperatures were recorded, the only station with a relatively constant evolution is Șomcutu Mic, with an unimportant decrease of -0.5%. The values of correlation coefficients associated with the evolution trends of annual average air temperature are lower than soil temperatures. An R2 index of 0.62 was calculated at Almașu and approximately 0.3 at the other stations.
From the data analysis regarding the amount of rainfall recorded, one can observe their linear falling trend, the highest values of the annual average are recorded in 2016, an average value of 616.9 mm, this year is considered a year with rainfall close to the normal of the area. The lowest amount of rainfall was recorded in 2017 (476.3 mm), a dry year from the point of view of rainfall. The value of the correlation

coefficient associated with the falling evolution trend of rainfall R2 is smaller, which expresses the unpredictable character of rainfall from the area.

Following the comparative analyses between the monthly average amount of rainfall during 2013-2018 and the monthly average amount of rainfall from the data series for 30 years and respectively 100 years, one can notice evident decreases of the average amount of rainfall, especially in critical periods, with high demands for water, mainly during the blooming and filling the seed/grain periods.

The evolution of soil humidity during 2013-2018, recorded at 10 cm deep indicates its general stagnation trend. The values of R2 correlation coefficients associated to the linear trends of soil humidity range between 0.35 at Ileanda and 0.69 at Bunești.

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