ASSESSMENT OF CLIMATIC RESOURCES AND RECOMMENDED AGROTECHNICS PRACTICES IN THE TRANSYLVANIAN PLAIN, ROMANIA

Teodor RUSU[1], Ileana BOGDAN[1], Paula Ioana MORARU[1], Adrian Ioan POP[1], Camelia COSTE[1], Bogdan DUDA[1]

e-mail: trusu@usamvcluj.ro

Abstract

The Transylvanian Plain (TP), with an area of 395,616 hectares is an important agricultural production area of Romania. During the last two hundred years, TP has been undergoing considerable anthropic impact, currently being a hilly area with serious issues of sustainability of soils, scarce in water resources, with deficient rainfall and an extremely low degree of afforestation: 6.8%. Monitoring the thermal and hydric regime of the area is essential in order to identify and implement sets of measures of adjustment to the impact of climatic changes. Soil moisture and temperature regimes have been evaluated on a basis of a set of 20 data logging stations positioned throughout the plain. Each station stores electronic data of ground temperature on 3 different levels of depth (10, 30 and 50 cm), of soil humidity at a depth of 10 cm, of the air temperature at 1 meter and of precipitation. The multiannual average air temperature situates between 9.35-12.04^{0}C and grow in the soil with increasing depth to 9.89-12.82°C – at 10 cm; 10.05-12.85°C – at 30 cm; 10.03-12.86°C – at 50 cm. The multiannual average air temperatures during the period 2008-2012 increased with 0.15(north) - 2.84(south) C as compared to the multiannual average temperature of the area (9.2°C). The thermal regime of the ground is of the mesic type, multiannual average soil temperature at 50 cm depth situating between 10.03-12.86°C and the differences between the average summer temperatures and average winter temperatures range between 11.35-17.72°C. Monitoring the hydric regime of the soils in TP demonstrate that the moisture regime is of the ustic type for the northern and north-western part, whereas for the southern and south-eastern part the hydric regime is of the xeric type; the soil being dry over 45 consecutive days following the summer solstice. The analysis of recorded data results in a situation similar to the southern, south-eastern and eastern slopes- lower rainfall with approx. 43.8 mm, higher temperatures with 0.37^{0}C in air, with 1.91^{0}C at 10 cm, with 2.22^{0}C at 20 cm and with 2.43^{0}C at 30 cm in soil, compared to northern, north-western and western slopes. These issues, supplemented by those of slope require special agrotechnical measures generated by TP relief.

Key words: soil temperature, soil moisture, precipitation, Transylvanian Plain.

Since the Earth's climate is being generated by certain factors, such as: solarisation, the eccentricity of the terrestrial orbit, the Earth's precession movement, obliquity in relation to the Sun, the terrestrial albedo, anthropogenic factors, moisture, terrestrial surface, it cannot remain constant as long as changes occur and an evolution at the terrestrial crust takes place (O. Bogdan and E. Niculescu, 1999; K. Brysse et al., 2013). Solar radiation is the main source of heat, its average value at the Earth level is 0.8-1.5 calories/cm^2/min (T. Rusu, 2005; M. Coman and T. Rusu, 2010). The solar radiation that reaches the Earth is reflected back into space. Part of these radiations is retransmitted towards the Earth's surface by a layer of "greenhouse gases", leading to an increase of the temperature in the atmosphere. The appearance of life on the planet is possible due to the natural greenhouse effect, which increases with 33^{0}C the average global temperature atthe Earth's surface as compared with the possibility in which these greenhouse gases wouldn't exist. This layer determines the average temperature of the Earth surface of 15^{0}C, its absence would lead to a temperature of -18^{0}C. This natural warming is a condition of the presence of water, in its liquid form, on the terrestrial surface, which is the basis of biological existence. A larger amount of energy, which occurs as a result of the intensification of the greenhouse gases, which have been emitted anthropically during the last 50 years, may result into a new climate (O. Ranta et al., 2008; K. Hemadi et al., 2011; J. Ramirez-Villegas et al., 2012; A. L. Lereboullet et al., 2013).

According to the climatologists who have reconstructed temperatures, the last decade of the

[1] University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5, Manastur street, 400372, Cluj-Napoca, Romania

twentieth century and early twenty-first century is the warmest period of the past 2000 years (C. M. Raymond and G. M. Robinson, 2013; V. Srinivasan et al., 2013). The risks brought about by climate changes are real and their impact has already become perceptible, and the fact that presently have been recorded the highest levels of CO_2 and CH_4 has been demonstrated by researchers (J. Fuhrer, 2003; W. J. Eastwood et al., 2006; H. J. Fowler et al., 2007; M. Casas-Prat and J. P. Sierra, 2012). Climate changes represent a problem of global policy. Scientific evidence and explanations of climate change have been accumulated over several decades, being integrated into strategies and policies of adaptation (EEA, 2009; A. Aaheim et al., 2012; J. Beck, 2013).

Romania is classified among the areas with the lowest capacity to adapt to existent climate change and to those likely to generate, and the Transylvanian Plain (TP) is one of the most affected areas (ESPON, 2011). Currently, and in the future, a series of strategies and plans to counter climate change are being put forward, but their implementation requires a strict monitoring of the area's thermal and hydric regime, in order to identify and implement the measures for adaptation to the impact of climate change.

In Romania, there has been a significant increase in the average annual temperature. Over the last century, this growth has been around 0.5^0C. Thermal growth accentuated during the last decades, beginning with the second half of the twentieth century, reaching values 0.8^0C - 1^0C on extended areas in Romania. Concerning the precipitations, a slight reduction in the rainfall amount on an annual basis at the level of the entire country has been reported during 1901-2007, being decreased to 50 mm (NMA, 2011).

National Meteorological Agency (NMA, 2011) forecasts for Romania, as compared to the period 1980-1990, an average annual warming as the one projected for Europe, namely an increase of the temperatures: between 0.5-1.5°C for the period 2020-2029; between 2.0- 5.0°C for 2090-2099. For the period 2090-2099, scientists estimate a pluviometric deficit during summer (10-30%) and an increase in rainfall during the winter (5-10%). Because the scarcity of water will be more and more accentuated, agriculture will be greatly affected, but at the same time the population will suffer from hardly adapting to extreme temperatures very likely manifest several days consecutively (P. Moraru and T. Rusu, 2010).

Latest research on the evolution of the climate within the Carpathian Basin, pointed out an increase of the air temperature during the last one hundred years of about 0.7°C. This reality is also supported by the fact that six of the warmest years of the 20th century were registered in the 1990's. Contrary to its name, the TP is not a geographically flat plain, but rather a collection of rolling hills, approximately 300 m to 450 m above the sea level in the south, and 550 to 600 m above the sea level in the north (N. Baciu, 2006). The climate of the TP is highly dynamic, ranging from hot summers with high temperatures of >30°C to very cold winters with lower temperatures approximately -10°C (Climate Charts, 2007).

For the period 1967-2000, the TP is characterized by multiannual average temperatures of 9.2°C in the south (Turda station) and 9.1^0C in the north (Targu Mures station) and the average multiannual precipitations being of 510 mm/year in the south (Turda station) and 567 mm/year in the north (Targu Mures station). In these circumstances, the purpose of the research conducted is to monitor climate, thermal and hydric regime of the soils in TP and to elaborate measures of adaptation to climate change. The TP, with an area of 395,616 hectares, is an important agricultural production area of Romania.

MATERIAL AND METHOD

Transylvanian Plain is a subunit of the Transylvanian Basin, along with Tarnavelor Plateau and Somesan Plateau. The Transylvania Basin is a "natural fortress" which communicates with the extracarpathical areathrough "gates" which have emerged from tectonic fragmentation, and, through these connections, the western air masses, wetter and hotter, penetrate. The name of TP is not in accord with its structural elements, but it is used due to its climate, to anthropic activity, and especially due to the methods of using the land for agriculture. Although it looks just like a constant and uniform relief, of the hilly type, some differences arise which require the division of the TP. In specialty literature, there has been attempted a regionalisation of the TP, so as to be better characterized by the name it bears, over the years being recorded by different terminology (H. Cacovean, 2005): The Someselor and The Mures Plains, or the Transylvanian High Hills Plain and the Transylvanian Low Hills Plain.

The thermal and hydric regime monitoring of the TP (soil temperature and humidity, air temperature and precipitations, *fig. 1*) has been achieved during the period 2008-2012. Twenty datalogging HOBO Micro Stations (H21-002, On-set Computer Corp., Bourne, MA, USA) have been deployed across the TP on divergent soil types, slopes, and aspects *(fig. 2).* Soil types where the stations were located: chernozem (Caianu), Phaeozem (Balda, Band, Craiesti, Triteni, Dipsa, Jucu, Ludus, Cojocna, Voiniceni), eutricambosoil (Matei, Silivasu de Campie, Branistea, Unguras, Zau de Campie), districambosoil (Filpisu Mare), preluvosoils (Taga, Nuseni, Sic, Zoreni). The majority have a loam-clay texture, pH between 6 to 8.69 and humus content of 2.5 and 4.15 in the 0-20 cm horizon. The stations were placed so as to cover the three subunits of TP: Low Hills Plain, High Hills Plain and Bistrita-Sieu Hills Plain. HOBO Smart Temp (S-TMB-M002) temperature sensors and Decagon EC-5 (S-SMC-M005) moisture sensors were connected to HOBO Micro Stations. Additionally, at 10 of the 20 sites, tipping bucket rain gauges (RG3-M) were deployed to measure precipitation (On-set Computer Corp., Bourne, MA, USA). Each station stores electronic data of ground temperature on 3 depths (10, 30, 50 cm), the humidity at the depth of 10 cm, the air temperature (1 m) and precipitations. Data was downloaded from the Micro Stations every two months via laptop computer using HOBOware Pro Software Version 2.3.0 (On-set Computer Corp., Bourne, MA, USA). *Table 1* shows the stations' configuration (B. Haggard et al., 2010).

The soil thermal regime was determined directly from the data recordedat a depth of 50 cm, with temperatures averaging in summer months (June, July, August) and winter (November, December, January). In order to determinate the hydric regime, the moisture levels have been calculated at 10 cm depth. Classification of thermal and hydric regime has been calculated according to the Romanian System of Soil Taxonomy (SRTS, 2003).

Table 1

Stations' configuration in the Transylvanian Plain

Station number	Station name	Latitude	Elevation, m / Exposition	Rain gauge
1	Balda (MS)	46.717002	360 / NE	No
2	Triteni (CJ)	46.59116	342 / NE	No
3	Ludus (MS)	46.497812	293 / NE	Yes
4	Band (MS)	46.584881	318 / SE	No
5	Jucu (CJ)	46.868676	325 / V	Yes
6	Craiesti (MS)	46.758798	375 / N	No
7	Sillivasu de Campie (BN)	46.781705	463 / NV	Yes
8	Dipsa (BN)	46.966299	356 / E	Yes
9	Taga (CJ)	46.975769	316 / N	No
10	Caianu (CJ)	46.790873	469 / SE	Yes
11	Cojocna (CJ)	46.748059	604 / N	Yes
12	Unguras (CJ)	47.120853	318 / SV	Yes
13	Branistea (BN)	47.17046	291 / V	Yes
14	Voiniceni (MS)	46.60518	377 / SE	Yes
15	Zau de Campie (MS)	46.61924	350 / S	Yes
16	Sic (CJ)	46.92737	397 / SE	No
17	Nuseni (BN)	47.09947	324 / SE	No
18	Matei (BN)	46.984869	352 / NE	No
19	Zoreni (BN)	46.893457	487 / NV	No
20	Filpișu Mare (MS)	46.746178	410 / S	No

NE = northeast; SE = southeast; V = west; N = north;
NV = northwest; E = east; SV = southwest; S = south
MS = Mures county; CJ = Cluj county;
BN = Bistrita-Nasaud county

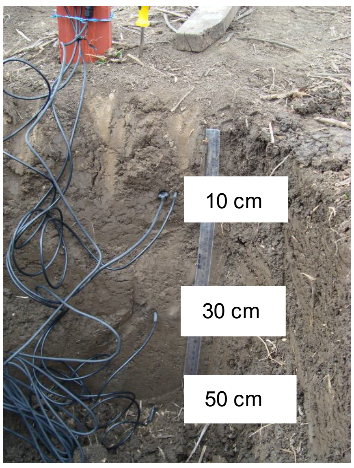

Figure 1. **Depth sensor location and data collection**

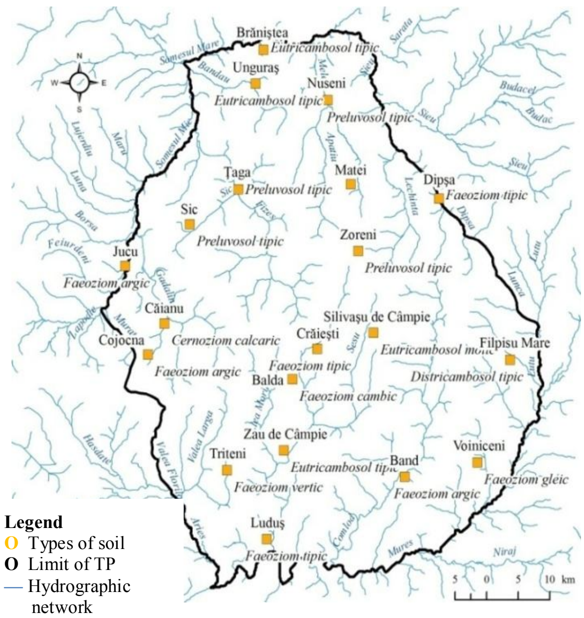

Figure 2. **Types of soil where the stations were placed in Transylvanian Plain**

RESULTS AND DISCUSSIONS

The location of the stations is thus established in order to conduct research specific pedoclimates and so as to include the main soil types of the area. In TP we discover a mosaic of soils (*fig. 3*) with an asymmetric territorial distribution. The most common soils in the TP being faeosioms (30.2%), chernozemic soils (20.5%), antrosoils (14.9%), luvosoils (13.4%), eutricambosoils (9%) and preluvosoils (8.4%). Cernisoils occupy the southern and southwestern sector of TP and are characterized by a high fertility, average on permeability and heavy structurally. In the north and north-east we come mostly across preluvosoils, luvosoils and eutricambosoils, potentially fertile soils, structurally heavy and sometimes prone to erosion. Antrosoils have a uniform distribution.

The typology of vegetation in the TP is extremely varied due to the monoclonal relief, to its exposition, to the altitude of the escarpments, and also due to climate characteristics. The TP territory reveals a deceptive and apparent feeling of uniformity and monotonicity in terms of vegetation. The percentage of current afforestation of Romanian geographic space gradually decreased from about 80%, as it was in the distant past, to about 55-60% at the beginning of the 19th century and down to 27% till present day. Consequently, a considerable damage to the environment has been inflicted, including an incredible diminution of biodiversity at all levels. The denomination of Transylvania Basin derives from the Latin "silva" meaning “forest”, but forests barely cover todayan average of 6.8% of TP land area. Since the Middle Ages, hydrological facilities have been implemented in the TP (especially reservoirs) in order to supply the area with water. For centuries, the region was the “granary” of Transylvania, hence the name of "Bread Plain" the name under which it appears in the XVIIth-XVIIIth centuries documents. Deforestations which have been carried out were not only a consequence of the need for arable land, but also occurred as a result of the technologies of extraction and processing of the materials, and particularly salt extraction, which led to an utter need for wood. During the last two hundred years, TP has suffered a considerable anthropic impact, despite the apparently insignificant pressure and of predomination of reduced population villages.

The quantity and quality of underground water in the TP are problems that have conditioned economic and social development of rural habitats and have determined the development and anthropic maintenance of the lakes naturally created. In the TP situation, the underground waters are ranged at different depths, due to the uneven relief and their feeding is attained directly from precipitations, through rivers network or by leakage from the escarpments. Phreatic water insufficiency is due to the presence of impermeable surface structure that determines the outpouring of water to the detriment of its infiltration but also as a result of the lack of vegetation and erosion.

TP climate is known to this day as one of the moderate continental type, with differences between north and south due to the presence of the Mountains, in the north-western part the foehnic influences of the Meses Mountains emerge, as well as a series of topoclimates specific to areas with wide valleys. Air temperature also varies slightly between the north and the south. Given the fact that the north is characterized by higher peaks, the temperature here is lower by nearly one degree from the south side, where the annual average is about 9^0C.

The TP detains a special situation linked to the hydrographical network and the multiannual deficient rainfall. A feature of TP is that, although an area lower than the surroundings, none of the main river valleys, nor large roads converge to its central part, but surround it at the periphery. Therefore, it is a poor area in water supplies, bypassed by the main flow and this is a reason for its partly rural character and disposition of the cities on the edges. Precipitations, generally deficient in TP, record, for the most part of the area, values of 500-600 mm/year, and the frequency of rainfall fall on the type of north-western and western flow. Winds have increased in intensity and enrol in the condition of the general flow of air masses in this part of Romania, so that the dominant ones are from the north-west and west.

Awareness of the relationship between air and soil temperature becomes essential in the analysis of the relationship between plant and soil, which is also due to the fact that the soil temperature is different from one pedogenetic horizon to another. As a conclusion, for the period 2008-2012, the differences in temperature recorded at the 20 stations depending on the location of the sensors is as follows (*fig. 4*): multi-annual average air temperature range between 9.35-12.04^{0}C; multi-annual average soil temperatures at a depth of 10 cm range between 9.89-12.82^{0}C; multi-annual average soil temperatures at a depth of 30 cm range between 10.05-12.85^{0}C; whereas multi-annual average soil temperatures at a depth of 50 cm range between 10.03-12.86^{0}C.

At most stations (with the exception of Caianu station – northern slope and Branistea – meadow) multiannual average temperatures of air are lower, growing up with 0.01 (Nuseni) to 2.04^{0}C (Matei) at the depth of 10 cm and to 0.15 (Nuseni) – 1.36^{0}C (Voinicieni) at the depth of 50 cm, as compared to the average multiannual air temperatures. The average air temperature from the monitored period is abovethe multiannual average of the area, which has significantly influenced the optimal sowing period and the amount of biologically active temperature degrees during the growing season.

The average rainfall recorded during 2009-2012 (*fig. 5*) is 498.97 mm/year, being below the multi-annual average of the area (538 mm). The year 2009 has registered an average of 503.84 mm being recorded at the inferior limit of the area, followed by the year of 2010, with an annual average of 607.84 mm, the year with precipitations closest to normal figure of the area. 2011 and 2012 are extremely droughty, with an average of 376.56 mm, respectively 394.45 mm. This situation of rainfall can be found in the humidity values recorded at the depth of 10 cm in the ground (*fig. 6*), in which case we have an average range of 0.249 m^3/m^3. Reduced quantities of rainfall, but especially their poor distribution throughout the growing season of crops, is aggravated by the scarcity of water resources of the area.

The soil thermal regime is closely related to the vegetation covering it, slope, exposition and human interference with it. Recorded data show that the thermal regime of the soils in the TP is of the "mesic thermic regime" type – "average annual soil temperature is equal or above 8^{0}C degrees, but less than 15^{0}C, and the difference between the average summer soil temperatures and winter average soil temperatures is above 6^{0}C, at the depth of 50 cm in the ground" (SRTS, 2003). The average multiannual soil temperature at 50 cm depth range between 10.03-12.86^{0}C, data comprised within the specified limits of 8-15^{0}C. The differences between the average summer temperatures and winter average temperatures are above 6^{0}C (*fig. 7*), the biggest value of the difference was recorded at Taga, in 2011, namely 17.72^{0}C followed by the de value of 16.48^{0}C, recorded at Caianu in 2010. The smallest value of this differenceis to be found in Matei, in 2009 and that is 11.35^{0}C, followed by Silivasu de Campie, in the same year, with a value of 11.55ºC.

The thermal regime of the soil, and the differences between the average summer and winter months acknowledge the micro areas of the TP, as well as the differences in the agro technical characterization of the lands resulted fromthe demarcation of the High Hills Plain of Transylvania - denomination given to the northern part of the plain with a higher relief, respectively the Low Hills Plain of Transylvania - the southern part, with lower altitudes.

An analysis of the recorded data

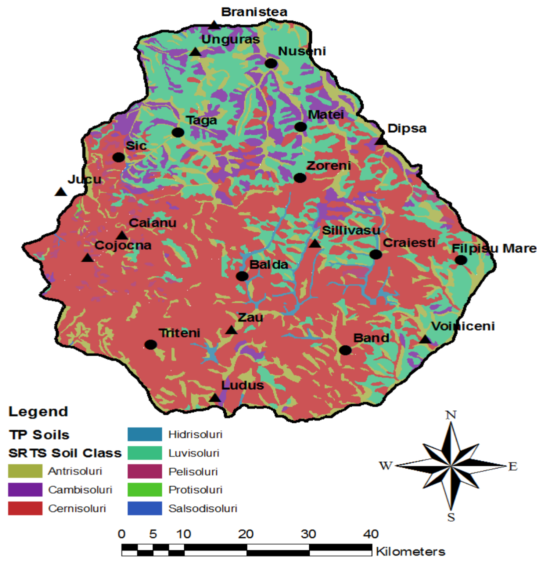

Figure 3. **Soil classes of the Transylvanian Plain derived from digititation of 1:200,000 scale soil maps (D. Weindorf et al. 2009)**

demonstrates that the humidity regime of the TP is of the "hydric ustic" type, consequently the average annual soil temperature is less than 22^{0}C (multiannual average soil temperatures at 50 cm depth ranging between 10.03-12.86^{0}C) and average summer temperatures and average winter temperatures differ with 6^{0}C or more at the depth of 50 cm (annual averages of the differences between the average summer and average winter months being between 11.35 (Matei) – 17.72^{0}C (Ţaga). In normal years, the moisture control section is dry in some parts or in totality for 90 cumulative days or more, but it is not dry in all parts for more than 45 cumulative days when the soil temperature at 50 cm depth is above 6^{0}C (SRTS, 2003). Many soils, particularly those in the southern part of the Plain, particularly for southern or south-eastern expositions, the soil is dry over 45 consecutive days following the summer solstice, which designates a "xeric hydric regime" for these areas. Data recorded confirms the condition of land degradation in TP and its effects, being the result of local extreme physical-geographical conditions, susceptible to degradation (evidenced by the erodibility index), which overlap the extreme climatic conditions. Precipitations, although deficient in terms of annual amounts, through their regime, have a negative influence on the plant carpet.

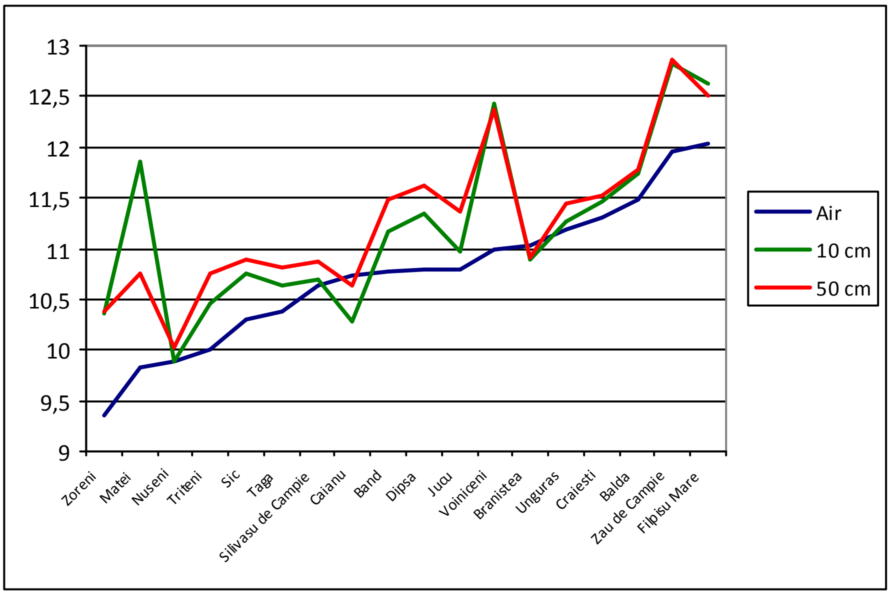

Figure 4. **Multiannual averages (2009-2012) of air and soil temperatures (T, ^{0}C) to 10 cm, 50 cm, in the Transylvanian Plain**

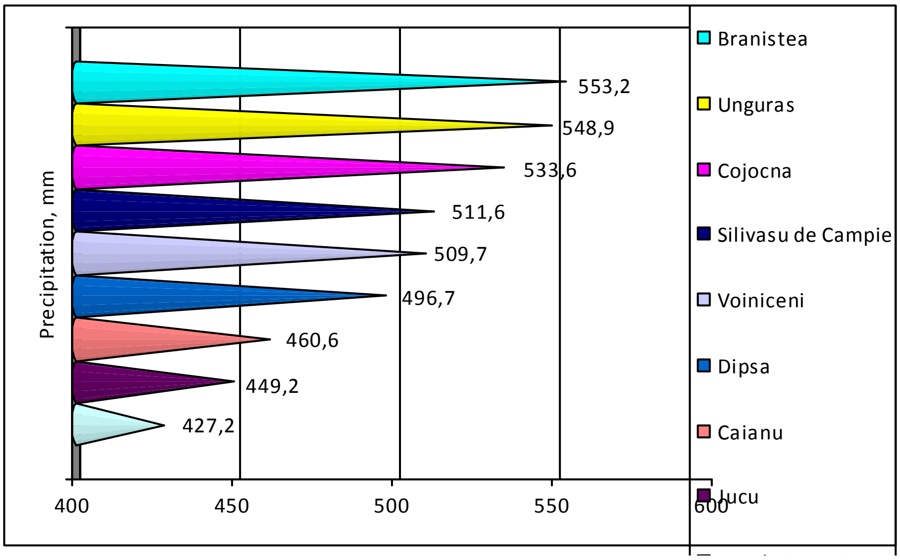

Figure 5. **Multiannual average of precipitations (2009-2012), in Transylvanian Plain**

This is due to the fact that, on the one hand, in the period from March to November, when soil, is always aired through agricultural tillage, the amount of rainfall discharging down the slopes is relatively high (40-50% of the total rainfall), and, on the other hand, torrential rains have increased pluvial aggressiveness. Pluvial aggressiveness index reveals, for the research period, a first peak of pluvial aggressiveness during the months of February-April, then in July and in autumn, the months of October-November. This requires special measures for soil conservation, both in autumn and early spring, soil tillage measures being recommended which ensure the presence of plant debris and vegetation in early spring but especially in summer and autumn.

Due to the hilly terrain of the TP, we have slopes with different degrees of inclination and exhibitions, and on their surface erosion may occur, requiring technological differentiation measures To determine the influence of climatic factors on agrotechnic characterization of land, depending on slope morphology, were placed 11 stations, from April to October 2011, in Caianu on slopes with different altitudes and exhibitions (*fig. 8*). The analysis of recorded data results in a situation similar to the southern, south-eastern and eastern slopes- lower rainfall with approx. 43.8 mm, higher temperatures with 0.37^{0}C in air, with 1.91^{0}C at 10 cm, with 2.22^{0}C at 20 cm and with 2.43^{0}C at 30 cm in soil, compared to northern, north-western and western slopes. These issues, supplemented by those of slope require special agrotechnical measures generated by TP relief. Seeding will be done on the southern slopes of approx. 3 days earlier and the maximum depth, from the range recommended for each crop to catch optimum germination temperature and humidity. Crop density will be lower on the southern slopes, given the more pronounced deficit of precipitation. Climatic indicators determined for the period 2008-2012 point out, in TP, a semi-arid Mediterranean climate through the rain factor Lang, respectively semi-arid (in the South) – semi-wet (in the North) according to the De Martonne index. This climatic characterization requires special technological measures for soil conservation.

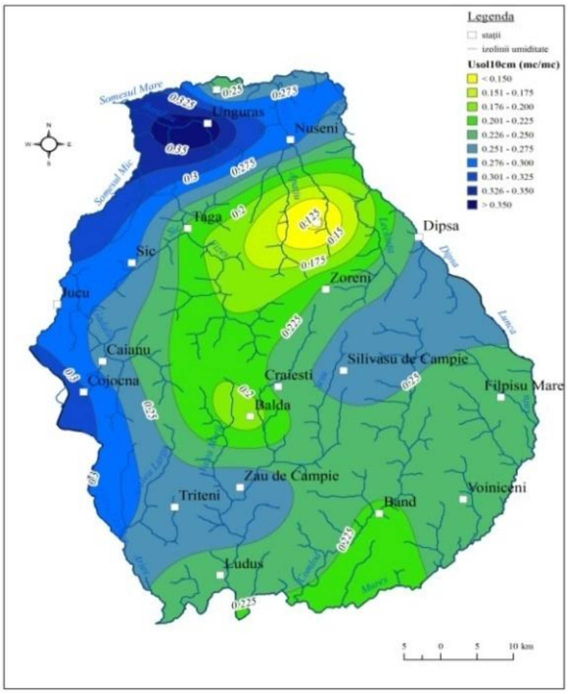

Figure 6. **Multiannual average humidity (2009-2012) at depth of 10 cm in the soil, in**

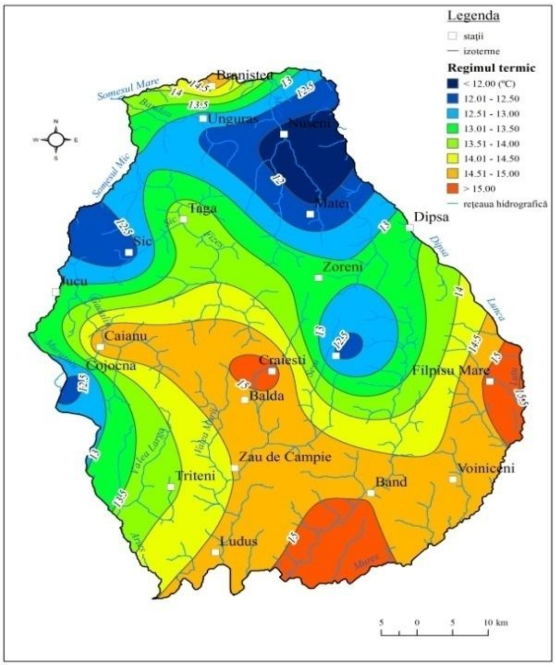

Figure 7. **Multiannual averages (2008-2012) between differences of the summer and winter average soil temperatures, in**

CONCLUSIONS

The risks brought about by climate changes are real, and their impact is already perceived on large areas of Europe. TP is one of the most affected areas, and European programs range it among the areas with the lowest capacity to adapt to climate change, and with the highest negative impact from the point of view of potential vulnerability. Monitoring the thermal and hydric regime of the area comes as a dire necessity, as a basis for scientific measures of adaptation and strategies to counter the effects of climate change. The multiannual averages of air temperature range between 9.35-12.04^{0}C and grow in soil with increasing depth to la 9.89-12.82^{0}C – 10 cm; 10.05-12.85^{0}C – 30 cm; 10.03-12.86^{0}C – 50 cm. The multiannual average air temperatures during 2009-2012, are with 0.15(north) - 2.84^{0}C (south) higher than the multiannual average of the area.

Monitoring the soil thermal regime in the TP during 2008-2012 with the help of 20 HOBO stations, demonstrates that the soil thermal regime is mesic (average multiannual soil temperature at 50 cm depth ranging between 10.03-12.86^{0}C and differences between the average summer temperatures and winter average temperatures are between 11.35-17.72^{0}C).

Monitoring the soil hydric regime of the TP reveals a humidity regime of the ustic type for the northern and the north western type and of the xeric type for the south and south eastern part, the soil being dry for over 45 consecutive days following the summer solstice.

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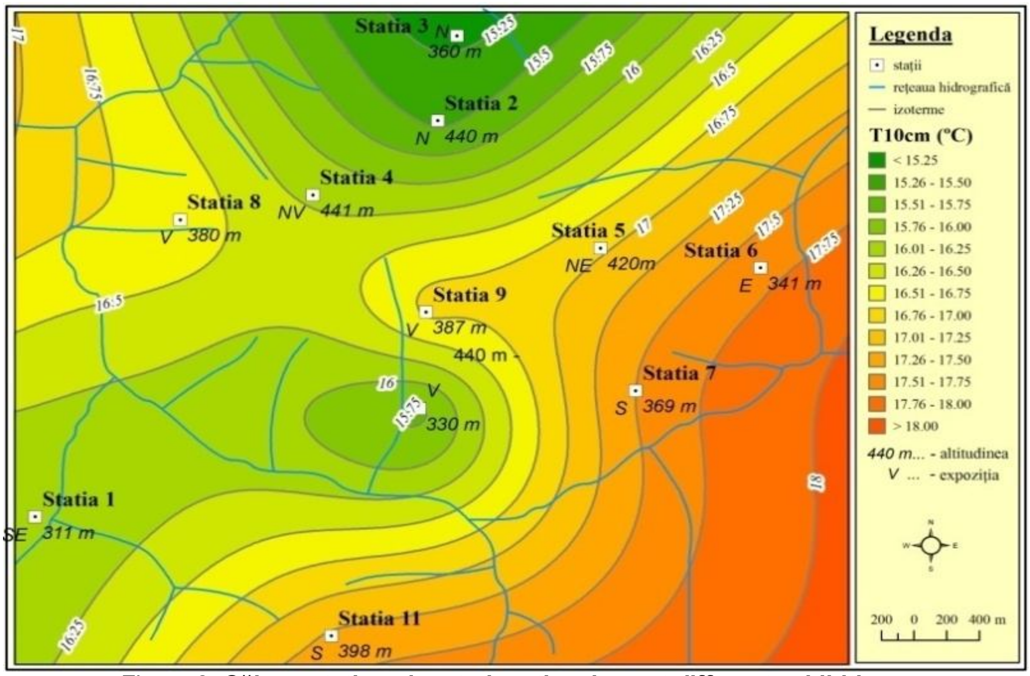

Figure 8. **Căianu stations located on the slope at different exhibitions**

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