Impact of Climate Change on Climatic Indicators and Technological Recommendations in Transylvanian Plain, Romania

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Abstract— Monitoring of the soil thermal and hydric regime, of the air temperature and rainfall in the Transylvanian Plain aims to establish the impact of climate changes on the climatic indicators which characterize the area and to identify the causes of land degradation. Thermal and hydric regime monitoring is necessary in order to identify and implement measures of adaptation to climate change. Soil moisture and temperature regimes were evaluated using a set of 20 data logging stations positioned throughout the plain. Each station stores electronic data of ground temperature at 3 depths (10, 30, 50 cm), the humidity at the depth of 10 cm, the air temperature (at 1 m) and precipitations. Climate change in the past few years have significantly altered the climatic indicators of the Transylvanian Plain. Precipitations, although deficient in terms of annual amounts, through their regime, have a negative influence on the plant carpet. 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. Climatic indicators determined for the period 2008-2012 point out, in Transylvanian Plain, 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.

Index Terms— Climate change, climatic indicators, technological recommendations, Transylvanian Plain.

1 Introduction

The vegetation type of a region is determined by its position on the globe, by local orographic, pedoclimatic, ecological and anthropogenic factors. Ligneous vegetation generally reflects the complex of macroclimatic factors and the herbaceous vegetation significantly reacts to the action of microclimatic factors (Cacovean, 2005; Bucur et al., 2011; Faramarzi et al., 2013).

Geographical distribution of soil, plants and of the connections established between the environmental components and the natural or cultivated vegetation, changes over the time, together with modifications in the environment that contribute to this distribution (Coman and Rusu, 2010; Hartmann et al., 2013). Each plant species has physiological characteristics that allow it to live in a certain range of temperature, humidity, acidity etc. The relationships between the environmental components and the biotic covering of a territory are interdependent connections between these and the vital needs of the organisms. The favourability and evolution of the climatic potential can be traced in time by analysing climatic indicators and cosmo-atmospheric environment factors (Zoccatelli et al., 2010; Wang et al., 2013).

The effects of climate change are currently a pressing issue in the scientific community (Fuhrer, 2003; Eastwood et al., 2006; Casas-Prat and Sierra, 2012). Monitoring of the affected environment proves therefore necessary, setting out directions of evolution and adaptation measures (Fowler et al., 2007; Hemadi et al., 2011; Ramirez-Villegas et al., 2012; Lereboullet et al., 2013; Beck, 2013). Transylvanian Plain (TP), with an area of 395,616 hectares, is an important agricultural production area of Romania, being characterised by a specific climate, extremely diverse and fickle, due to the fact it is a plain type climate, and, from the orographic point of view, it's a hilly relief (Baciu 2006).

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 (Sun et al., 2012; Oury et al., 2012).

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 (Bogdan and Niculescu, 1999; Moraru and 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 (Rusu, 2005; Ranta et al., 2008). 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 (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^{0}C 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).

Climate change in the past few years have significantly altered the climatic indicators of the TP. Monitoring of the soil thermal and hydric regime, of the air temperature and rainfall in the TP aims to establish the impact of climate changes on the climatic indicators which characterize the area and to identify the causes of land degradation. Results show that 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.

2 Materials and Methods

Transylvanian Plain, located in the central part of the Transylvanian Basin, is characterized by absolute altitudes ranging between 250-500 m, with "irregular knolls", separated by narrow valleys, often with excessive humidity, with south-facing ridges, with soft slopes and ascent processes on north-facing slopes. Partly ligneous vegetation, but dominated by a herbaceous vegetation of hayfields on parental clay materials, rich in calcium carbonate and an annual deficit of precipitation, typical of forest steppe, from 50 up to 100 mm, in interaction with other soil formation factors which have favoured the powerful lying fallow and bioaccumulation domination, thus forming in this areal the molisoils or the soils with a molic A horizon.

The thermal and hydric regime monitoring of the TP (soil temperature and humidity, air temperature and precipitations) 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. 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 has 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 (Weindorf et al., 2009; Haggard et al., 2010).

The first objectives of this research are: technological characterisation of the land (erodibility index of soils; Stanescu, 1980); pluvial aggressiveness index (Fournier, 1960) and determination of the climatic indicators (Fitiu, 2003) which characterize the TP: rain factor Lang, aridity index De Martonne, xerothermic index Gaussen, continentally index Gams, Angot index. The second objectives consists on monitoring of the soil thermal and hydric regime, air temperature and rainfall in the TP is to determine the impact of climate change, characterise the agrotechnical properties of soils, understand crop responce and identify specific and technological adaptation measures.

Erodibility index (S) has been calculated on the basis of soil analytical data at each station, namely: clay percentage, humus content and bulk density. Determination of soil properties was performed by the pipette method for Clay (C, %), Walkley-Black method for humus (H, %) and by volumetric ring method using the volume of a ring 100 cm^3 for bulk density (BD, g/cm^3). Equation used is: S= (100-C)/(C+NxH)BD; where N = 15-C (when C= 12-32%), N = 10-C (when C= 33-45%) and N = 5-C (when C= >45%).

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	Filpisu 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

Pluvial aggressiveness index (K_p) was calculated for each month on the basis of the total amount of precipitation recorded in the rainiest day (p) and total quantity registered in the respective month (Pm). Equation used is: $K_p = p^2/Pm$.

The rain index Lang (L) was calculated as the ratio between the annual quantity of rainfall (P) and average annual temperature (Ta), but can also be calculated for the average monthly temperature and rainfall values during the growing season. Equation used is: L = P/Ta; interpretation of results is: 0 < L < 20 arid, 20 < L < 40 mediterranean, 40< L <70 semi-arid, 70< L <100 humid.

Aridity index De Martonneis ($I_{ar\text{-}DM}$) a very important indicator in order to characterize the aridity, it's calculated based on the amount of annual rainfall (P) and average annual temperatures (Ta). Equation used is: $I_{ar\text{-}DM} = P/Ta+10$; interpretation of results is: $0 < I_{ar\text{-}DM} < 5$ arid, $5 < I_{ar\text{-}DM} < 20$ semi-arid, $20< I_{ar\text{-}DM} <30$ semi-humid, $30< I_{ar\text{-}DM} <55$ humid.

According to the xerothermic index (Gaussen), the drought phenomenon occurs when twice the monthly average temperature (°C) is higher than the monthly rainfall (mm).

The continentality index Gams (I_G) represents the ratio between the amount of annual rainfall (P) and altitude (A). Equation used is: $I_G = P/A$.

Angot's pluviometric index (k), is used to highlight the annual variation characteristics of atmospheric rainfall and in particular, to determine the types of their variation during the year. Thus, rainy intervals (k>1) and dry intervals (k<1) are being emphasized. This also represents the ratio of the average between the daily volume of precipitation in a month (q) and the amount that would be returned in case of a uniform distribution of the annual rainfall amount in all days of the year (Q). Equation used is: k = 365 x q/Q x n; where n is number of days in the respective month.

3 Results and Discussion

Land degradation in TP and its effects should be viewed through the prism of local physical-geographical conditions, to which extreme climatic conditions can be added. These conditions generally create a propitious framework of deployment of morphogenetic processes triggered by human activity, as well as triggered by natural mechanisms, increasing both the rhythm and their territorial expansion. In this sense, precipitations are first being observed, which although in terms of annual amounts are deficient, through their regime they exercise a negative influence on the plant carpet. 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.

Relief is also susceptible, together with the rainfall, through accentuated fragmentation degree and by slope tilting, particularly in case of southern ridges, vegetation with cultivated plants predominance and through advanced stage of degradation of vegetal associations on the grasslands, especially on slopes with southern exhibition, then the lithology by study friable stones predominance (sands, marls, grits etc.). This situation is shown by the index of erodibility (table 2). The highest value of the index is recorded at Zoreni, of 0.939, where we have a 17% slope and the soil is typical preluvosol, followed by the value of 0.818, from Zau de Campie, with a 12% slope and the soil type is of typically eutriccambisoil. The smallest value of the erodibility index is registered at Dipsa, 0.522, 3% slope and faeosiom type of soil, followed by the Jucu station, 0.533, with 17% slope (fallow ground), and the type of soil is argic faeoziom.

Pluvial aggressiveness index shows us how destructive is the action of precipitations during the year. The pluvial aggressiveness records, for the research period, several aggression peaks, very important to the establishment of agricultural technologies. Thus, the first peak of the pluvial aggression emerges in February-April, then in July and in autumn, the months of October-November. This requires special strategies for soil conservation both during the fall and early spring, being recommended soil tillage systems that ensure the presence of plant debris and vegetation from early spring, but especially in summer and autumn. Pluvial aggressiveness index differs depending on the climatic year, thus in 2010, a normal year in terms of recorded quantity of precipitation, we have the first peak of pluvial aggressiveness of recorded precipitations during the winter months, as a result of abundant quantities of this period, and then in the summer and reduced aggression in autumn. In 2009 and 2011, drought years, present a shifting of the pluvial aggressiveness peaks, for the summer and autumn periods, winter being with low precipitation.

Table 2. Erodability index of soil (S) in Transylvanian Plain

No.	Station	Soil type	Clay, %	Humus, %	Bulk density, g/cm^3	Erodability index (S)	Slope, %
1.	Balda	Faeoziom cambic	51.8	3.15	1.23	0.580	12
2.	Band	Faeoziom argic	45.63	3.11	1.3	0.683	1
3.	Craiesti	Faeoziom tipic	45.27	3.11	1.2	0.749	1
4.	Taga	Preluvosol tipic	47.25	3.69	1.23	0.652	17
5.	Triteni	Faeoziom vertic	49.34	4.15	1.2	0.602	10
6.	Filpisu Mare	Districambosol tipic	49.67	2.68	1.22	0.654	19
7.	Matei	Eutricambosol tipic	29.2	3.51	1.22	0.709	3
8.	Nuseni	Preluvosol tipic	51.14	2.19	1.22	0.645	30
9.	Sic	Preluvosol tipic	51.1	3.10	1.22	0.601	25
10.	Zoreni	Preluvosol tipic	35.05	2.16	1.22	0.939	17
11.	Caianu	Cernoziom calcaric	40.01	2.85	1.2	0.729	17
12.	Dipsa	Faeoziom tipic	58.19	3.56	1.26	0.522	3
13.	Jucu	Faeoziom argic	55.55	2.65	1.21	0.533	17
14.	Ludus	Faeoziom tipic	40.01	3.15	1.23	0.682	3
15.	Silivasu de Campie	Eutricambosol molic	52.37	2.64	1.35	0.587	7
16.	Branistea	Eutricambosol tipic	51.14	2.19	1.22	0.645	1
17.	Cojocna	Faeoziom argic	51.68	3.99	1.22	0.552	12
18.	Unguras	Eutricambosol tipic	45.99	2.05	1.22	0.787	12
19.	Voiniceni	Faeoziom gleic	47.69	2.21	1.22	0.729	1
20.	Zau de Campie	Eutricambosol tipic	43.81	2.5	1.22	0.818	12

The rain factor Lang (table 3), has values between 20-40 at Caianu and Zau de Campie stations, values that correspond to a Mediterranean climate. At all other stations, this index values ranges between 40-70, which indicate a semi-arid climate.

Table 3. Rain factor Lang (L) determined in the period 2009-2011, in Transylvanian Plain

Year / Station	Caianu	Dipsa	Jucu	Silivasu de Campie	Branistea	Unguras	Voiniceni	Zau de Campie
2009	16.17	39.58	39.08	49.99	5433	51.39	42.73	28.70
2010	61.44	6055	45.67	53.58	62.16	61.19	61.47	46.26
2011	37.92	3870	40.30	40.06	32.70	-	-	-
Multiannual average	38.51	46.27	41.68	47.87	49.73	56.29	52.1	37.48
Interpretation	M	SA	SA	SA	SA	SA	SA	M

M-Mediterranean, SA-Semiarid

De Martonne index (table 4), characterizes the aridity and allows us to divide the wet or dry climates, as well as those semi-wet or semi-arid. Multi-annual averages of De Martonne index have values between 20-30 and we can assert that, according to this index, we have a semi-wet climate in TP. Analysing the values on the stations per year, we have, in 2009, values under 20, namely a semi-arid climate at Zau de Campie really and Caianu stations (Southern TP) and 2011 is all included in under 20-values, a semi-arid climate.

Table 4. The aridity index de Martonne (I_{ar-DM}),, annual average recorded in 2009-2011 and multiannual average, in Transylvanian Plain

Year / Station	Caianu	Dipsa	Jucu	Silivasu de Campie	Branistea	Unguras	Voiniceni	Zau de Campie
2009	16.13	21.39	21.38	26.87	29.66	28.05	22.83	15.99
2010	31.87	30.84	23.50	27.42	32.27	31.11	31.47	24.57
2011	18.69	19.57	19.86	19.80	16.53	-	-	-
Multiannual average	22.23	23.93	21.58	28.03	26.15	29.58	27.15	20.28
Interpretation	SH	SH	SH	SH	SH	SH	SH	SH

SH - Semi-Humid

Drought is a very common phenomenon in TP, it may occur in March, with higher frequency in April, then June-July, but installs every year in August-October, a fact demonstrated by the xerothermic index (Gaussen). In 2009, the values of this index point that the months of April, July, August and September are all dry months at most stations. In 2010, August is a dry month at all stations. The year 2011 is recognized as an extremely dry year, a fact that is revealed by the data analysis with the help of the xerothermic indicator, being dry at the beginning of the year, from March to May, then August, September, October, at all stations.

According to the Gams index, the distribution of rainfall is realized according to altitude. In our case, in 2009, this index values are between 0.74-2.45; the smallest value corresponds to the Caianu station which is located at an altitude of 469 m, respectively the value of 2.45 corresponding to Braniste station, which is located at an altitude of 266 m. In 2010 is a year with a larger amount of precipitations, and the Gams index ranges from 1.21-2.52, the minimum index belonging to Silivasu de Campie station and the maximum index being recorded at Branistea station.

The pluviometric index of Angot points at all stations (except for Caianu station– 2009) that recorded values are all subunitary, namely annual rates ranging between 0.97-0.99. Data analysis oneach yearly month, shows subunitary values (dry months) during the period September to March (fall-winter-spring), and supraunitary values (rainy months) for the summer months (April-July) when pluvial aggressiveness is maximum.

4 Conclusions

The recorded data confirm 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, because of their seasonal distributions, have a negative influence on the plant carpet. 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.

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.

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