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IMPACT OF CLIMATE CHANGE ON AGRO-CLIMATIC INDICATORS AND AGRICULTURAL LANDS IN THE TRANSYLVANIAN PLAIN BETWEEN 2008-2014

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Abstract: Integrated conservation and management of agricultural areas affected by the current global warming represents a priority at international level following the implementation of the principles of sustainable agriculture and adaptation measures. Transylvanian Plain (TP), with an area of 395,616 ha is of great agricultural importance for Romania, but with an afforestation degree of only 6.8% and numerous degradation phenomena of farmland, it has the lowest degree of sustainability to climate change. Monitoring of agro-climatic indicators and their evolution in between 2008-2014 and the analysis of the obtained data underlie the technological development of recommendations tailored to current favorable conditions for the main crops. Results obtained show that: the thermal regime of the soils in TP is of mesic type and the hydric regime is ustic; multiannual average of temperature in soil at 10 cm depth is 11.40ºC, respectively at 50 cm depth is 10.24ºC; the average yearly air temperature is 11.17ºC; multiannual average of soil moisture is 0.227 m^3/m^3; Multiannual average value of precipitation is 466.52 mm. During the studied period, compared with data series available (1961-1990; 1901-2000), clear decrease of the average quantities of rainfall especially during critical periods for crops, and increases in average temperatures for the entire year can be noticed. Between June and August the highest temperature difference were recorded, differences of +3.09°C to +3.65°C. There is an increase phenomenon of drought and heat; determined indicators show that most values, 61.11%, are commensurate with a semiarid climate. Aggression peaks are in February-April, July, and October-November, and for the whole period, in 19.43% of the cases are favorable and very favorable conditions for triggering erosion. Recommended agro-technical measures to limit and counteract the effects of drought, as a climatic phenomenon with major risk to agriculture in TP, refer to: i) use of a biological material resistant to water stress and heat; ii) use of management practices favorable for accumulation of, conservation and the efficient use of water from rainfall; iii) operating a system of conservation agriculture based on soil protection and desertification avoidance.

Keywords: climate change, adaptation technologies, Transylvanian Plain.

1. INTRODUCTION

Extensive research carried out on climate change, highlighted based on observational data and projections made for long periods of time, show that the changes in the evolution of climate, global, regional and local levels is an undeniable fact, and have a negative impact on maintaining the right balance in the relationship between society and the environment (Szajdak et al., 2003; Keskitalo et al., 2015; Rusu & Moraru, 2015; Niacsu et al., 2015).

Global average temperatures, calculated for the period 1880-2012 show an increasing trend with 0.85ºC (0.65-1.6ºC) for several series of independent data, with great interannual and decadal variability (Haylock et al., 2008; Casas-Prat & Sierra, 2012; Lereboullet et al., 2013). At European level, decade average temperature calculated for the period 2002-2011 is 1.3ºC ± 0.11ºC higher than the average of the period 1850 to 1899, since 1950 frequent increasing extreme high temperatures being registered (EEA, 2012; IPCC, 2014a; Luo et al., 2016).

The average temperature at ground level in Europe increased by 1.3°C over the period 2002 to 2011, making it the warmest decade on record, with the assumption of an increase between 2.5°C and 4°C during 2071-2100 (EEA, 2012).

In terms of rainfall, at European level, since 1950, the annual amounts of precipitation in northern Europe rose by more than 70 mm per decade and fell in some parts of the South (Haylock et al., 2008; IPCC, 2014a).

Regarding soil moisture, there are no clear indications of trends in soil water retention due to lack of systematic and harmonized data. Projections suggest a reduction in soil moisture in most of Europe, significant reductions in the Mediterranean and a slight increase in its northeastern Europe (EEA, 2012; Vidojevic et al., 2015). Heinrich & Gobiet (2012) stated that the soil moisture index shows a significant variation due to climate change, starting from drought conditions in southern Europe, underlined to wet conditions in northern Europe, in all seasons.

Regarding the causes of climate change is considered that more than half the temperature increases observed globally are the result of anthropogenic influences, mainly due to rising concentrations of greenhouse gas emissions, but also the action of other anthropogenic factors, of natural causes or a combinations thereof (IPCC, 2014a; Perry, 2015; Purton et al., 2015).

While agriculture is affected by climate change, in turn, agriculture contributes with 13.5% of the total greenhouse gas emissions (GGE). Of GGE emissions at European level, those from agriculture have a share of between 2-26% with an average of about 14% of the total (FAO, 2009).

Climate change and its effects are currently the focus many scientific research. Conservation and management of integrated agricultural areas affected by global warming is a current priority at international and national level among current concerns surrounding the implementation of the principles of sustainable agriculture and adaptation measures (IPCC, 2014b; Lavorel et al., 2015; Coyle et al., 2016). The question that arises most frequently with regard to climate change refers to its impact in local, regional or even global agriculture. Although there is some knowledge on climate change and its related areas, it is appropriate to pay particular attention to research on climate change and its impact assessment (Dong et al., 2013). According to the evaluation report - AR5, PCC, 2014, climate projections for the period 2016-2035 show an increase in global air temperature with 0.3-0.7ºC compared to the reference period 1985-2005, this warming having such as emissions resulting from human activity and natural climate variability.

Transylvanian Plain (TP) is regarded as an area with a low capacity to adapt to climate change so that in these conditions, climate monitoring and implementation of adaptation measures to such conditions are essential for the development of sustainable agricultural technologies.

Research conducted aimed at evaluating the dynamics of climate variability, soil temperature and moisture, and the calculation of specific agro-climatic indices (climatic and technological characterization of the land) in relation to the main crops recommended for TP. Research objectives consist in monitoring agro-climatic factors and trends, analysis of data obtained in relation to the principles of soil conservation and climate adaptation measures phenomena. Evolution of TP climatic characterization indices underly the development of recommended technological practices adapted to current suitability for main crops.

2. MATERIALS AND METHODS

2.1. Natural environment of the research

TP with an area of 395,616 ha, is an important agricultural production area of Romania. Transylvanian Plain together with Someş Plateau and Târnave Plateau represent the main unit of Transylvania Plateau, forming the Transylvanian Depression. TP is characterized by absolute altitudes between 250-500 m, with gentle "disordered hills", often separated by narrow valleys with excess moisture, with cuestas on southern slopes and slope processes on the nordic ones. Average yearly temperature is 8-9^{0}C and average multiannual rainfall of 500-600 mm (Geography of Romania, 1987). Starting from a partially woody vegetation, but overlooking a grassy meadow vegetation, the parent materials is rich in clay and calcium carbonate, and there is an annual rainfall deficiency, specific to steppes, between -50 to - 100 mm in interaction with other solification factors, favored domination of bioaccumulation, forming in this area mollisols or soils with a mollic horizon.

Rainfall is characterized by a large temporary spatial variability being largely responsible for the onset and subsequent development of the geomorphological processes. When torrential short duration and high intensity rainfall occurs, conditions are created for developing soil erosion through deployment and transportation of soil particles from the surface.

In the last two hundred years TP has suffered considerable anthropogenic impact, now being a hilly area with serious sustainability problems of soils, scarce water, rainfall deficit, and an extremely low afforestation degree of 6.8% (Rusu et al., 2014).

TP includes areas of three counties in Romania (Cluj: CJ, Bistrița-Năsăud: BN and Mures: MS), main crops being: winter wheat, corn, sunflower, soybean and sugar beet, holding the largest share of the total cultivated areas (INS, 2014).

2.2. Field experiment and data collection

Monitoring and variability of climatic elements was achieved during 2008 (March) -2014, through a network of 10 stations type HOBO-MAN-H21-002 (On-set Computer Corp., Bourne, MA, USA) which store soil temperature data electronically (at 10, 30, 50 cm deep) and air (at 1 m hight), soil moisture (at 10 cm depth) and all the stations are equipped with 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 precipitation. Data was downloaded from the Micro Stations every four months via laptop computer using HOBOware Pro Software Version 2.3.0.

Soil types, land slope and exposition, altitude and geographic coordinates of the locations in which stations were set are shown in Table 1 (Haggard et al., 2010) and figure 1. Majority of soils have a loam-clay texture, pH between 6 to 8.69 and humus content of 2.5 and 4.15 in the first 20 cm (Rusu et al., 2014).

2.3. Data processing and determined indicators

Thermal regime of the soil 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). Classification of soil temperature and water regime was made after the Romanian System of Soil Taxonomy (Florea & Munteanu, 2012).

Methodology used to highlight the evolution of climatic parameters and their characterization of climatic variables from TP is the one of specific climate indices (Domuță, 2009): Lang rain factor, arid Martonne index, Gaussen xerothermal index and Gams index. Erodability index of soils (Stanescu et al., 1969), Fournier index (Fournier, 1960) and the pluviometric Angot indexare used to assess the erosion potential of the land on which the stations are located.

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%).

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: $K_p = p^2/Pm$.

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 resultsis: 0 <L< 20 arid, 20 < L < 40 mediterranean, 40< L <70 semi-arid, 70< L <100 humid.

Table 1. Analytical data on location of measuring stations

No	*Station (County)*	*Soil Type and Subtype**	*Latitude*	*Longitude*	*Elevation, m*	*Slope, %*	*Exposition*
1	Caianu (CJ)	Cernoziom calcaric	46º79'	23º52'	469	17	SE
2	Mociu (CJ)	Cernoziom argiloiluvial	46º47'	24º04'	435	5	V
3	Taga (CJ)	Preluvosol tipic	46º97'	24º01'	469	17	N
4	Branistea (BN)	Eutricambosol tipic	47º17'	23º47'	266	1	V
5	Dipsa (BN)	Faeoziom tipic	46º96'	24º26'	356	3	E
6	Zoreni (BN)	Preluvosol tipic	46º89'	24º16'	445	17	NV
7	Silivasu de Campie (BN)	Eutricambosol molic	46º78'	24º18'	463	7	NV
8	Filpisu Mare (MS)	Districambosol tipic	46º74'	24º35'	375	19	S
9	Band (MS)	Faeoziom argic	46º58'	24º22'	318	1	SE
10	Triteni (CJ)	Faeoziom vertic	46º59'	24º00'	342	10	N

SE = southeast; V = west; N = north; E = east; NV = northwest; S = south; * Florea & Munteanu, 2012

CJ = Cluj county; BN = Bistri□a-Năsăud county; MS = Mure□ County

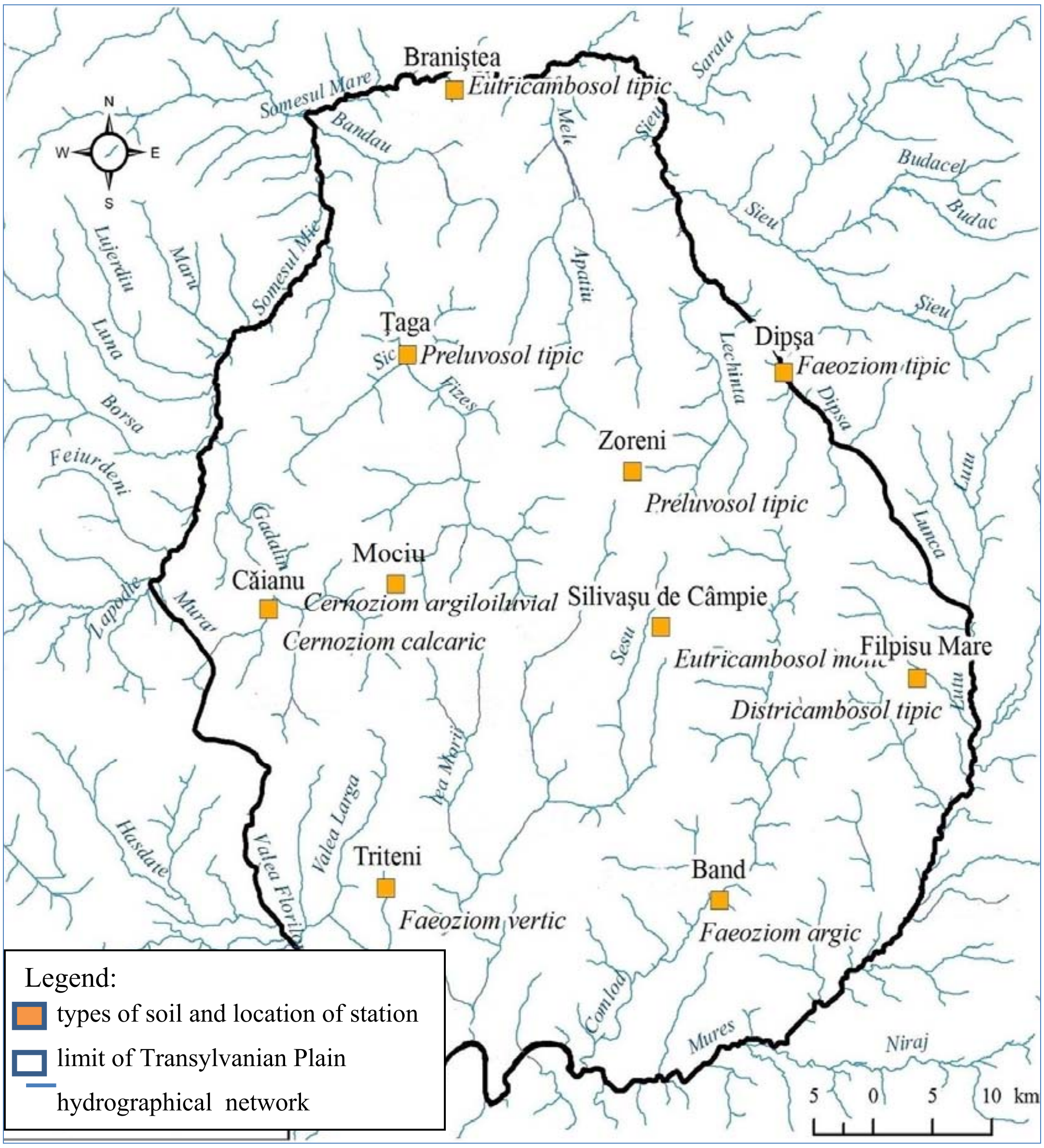

Figure 1. Types of soil and location of station in Transylvanian Plain

Aridity index De Martonneis (I_{ar-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-DM} = P/Ta+10; interpretation of results is: 0 <I_{ar-DM}< 5 arid, 5 <I_{ar-DM}< 20 semi-arid, 20< I_{ar-DM}<30 semi-humid, 30< I_{ar-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).

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.

In order to estimate trends in climate parameters regression analysis was used, quantifying causal relationships being achieved by linear equations. To analyze variability of meteorological parameters spatiotemporal standard deviation was used (frequently used in climatology), graphical format highlighting the quantitative development of studied elements.

Correlation analysis was used to measure the intensity of the relationship between variables, providing information on the existence, meanings, and link between analyzed variables. The data collected and processed represented theme of three Ph.D Theses: Haggard, 2012; Sopterean, 2012; Coste, 2015.

3. Results and Discussion

3.1. The thermal regime of the soil

The thermal regime of the soil depends on a number of factors, primarily on the intensity of the solar radiation and its variations over time, plus the physical properties of the soil, the composition, structure, texture, the moisture content or dry soil specific heat and thermal conductivity, orientation and tilt of the slopes, and the nature and coverage of the soil surface vegetation. The soil surface receives a certain amount of energy that is converted into heat that subsequently spreads and/or is taken then by soil layers through conduction.

The thermal regime of the soil in turn affects plant growth, water movement, and biological activity in soil. In evaluating the thermal regime of the soil, the annual average temperature (at 50 cm depth) is the value used in this study, being used as recommended by Florea & Munteanu, (2012). TP thermal regime of the soil is **mesic**, with average annual temperaturesat 50 cm soil depth of 8-15°C, with a difference between average summer temperatures and average winter temperatures of more than 6°C. Annual averages soil temperatures have ranged between 10.58-13.72°C and the difference between average summer temperatures and average winter temperatures are between 12.81-20.01°C. The multiannual average analysis of soil and air temperatures for the period 2009-2014 in TP, shows that the highest values were recorded at Filpisu station and the lowest at Triteni, Caianu, and Silivasu stations (Fig. 2).

Correlation coefficient values associated to evolutionary trends of mean annual temperature at 10 cm depth indicate an obvious trend in growth trends for the stations Branistea (0.82), Dipsa (0.73), and Zoreni (0.72) followedby Filpisu (0.63) (Fig. 3). The same linear trend in evolution of temperature rise in annual average temperatures was recorded at 30 cm soil depth, except for Silivasu station for which the trend indicates a decrease in average annual temperatures.

Following the analysis of evolving trends in mean annual air temperatures, based on data for the period 2009-2014 is found that for Dipsa, Silivasu and Branistea stations values are increasing and for Caianu station, trend of annual average temperature is droping.

3.2. Evolution of rainfall

From the analysis of data on TP rainfall recorded in the period 2009-2014 there is a linear trend in decline from the highest values of annual average recorded in 2010, with an average of 631 mm, 2010 being considered a year of normal rainfall for this area. Lowest rainfall amounts were recorded in 2012 (358.62 mm), which was considered a dry year in terms of recorded rainfall (Fig. 4). Multiannual average (2009-2014) of rainfall in the Transylvanian Plain is 466.52 mm being below the lower limit of the zone (500-600 mm/year).

For comparative analysis of the evolution of the average monthly rainfall amounts recorded in 2009-2014 for the the TP stations were used two data series, over a period of 30 years (1961-1990, stations Cluj-Napoca, Targu-Mures and Bistrita, taken from the National Meteorological Administration: NMA, 2014), respectively 100 years (from 1901 to 2000, stations Cluj-Napoca and Targu Mures taken from the Statistical Yearbook of the National Statistical Institute: INS, 2014).

Data analysis reveals clear decrease of monthly rainfall, particularly in the interval between April and September and decreases that are maintained during the autumn months (Fig. 5). There is a clear decrease of the average quantities of rainfall especially during critical periods for crops with high demands for water, especially during flowering and grain filling periods.

Ombrotermic diagram for TP allows visualization of changes in temperature and precipitation patterns comparative for the period 2009-2014 compared to the period 1901-2000 (Fig. 6). Monthly average temperatures of 1901-2000 time frame reveals increases in average temperatures for the entire year, compared to 2009-2014, mainly during April (+3.1°C) and June through August when are registered the greatest differences in temperature between the rows of the analyzed values, of + 3.09°C to + 3.65°C. The smallest temperature differences were recorded for October (+ 0.8°C), December (+ 1.02°C) and March (+ 1.5°C).

Significant decreases of rainfall between June and August associated with higher temperatures of 32ºC which is a factor for heat stress during the growing season of crops especially during critical peak demand for temperature and humidity for the main crops of TP, productivity prompted major declines affecting especially physiologically optimal growth and development of wheat and maize plants.

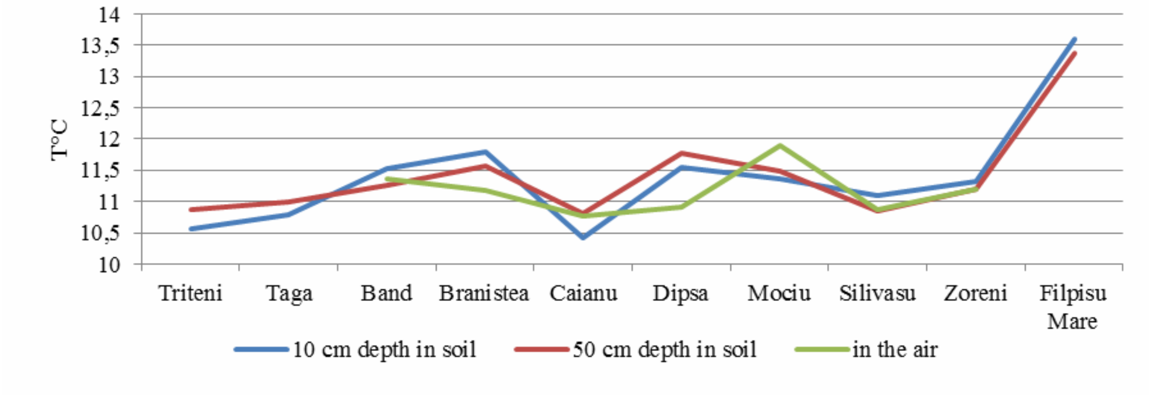

Figure 2. Multiannual average (2009 - 2014) of soil and air temperature in Transylvanian Plain

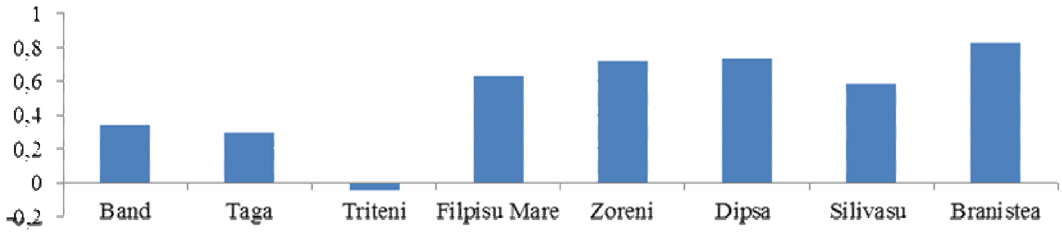

Figure 3. Values of correlation coefficient associated with trend of annual average temperature at 10 cm soil depth

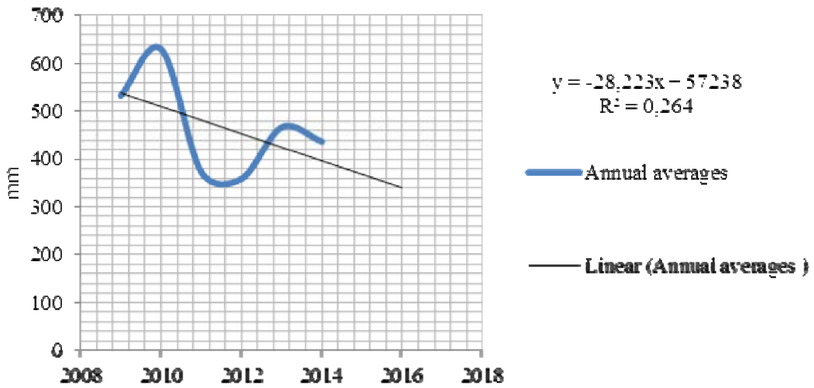

Figure 4. Linear trend of rainfall evolution in Transylvanian Plain during 2009-2014

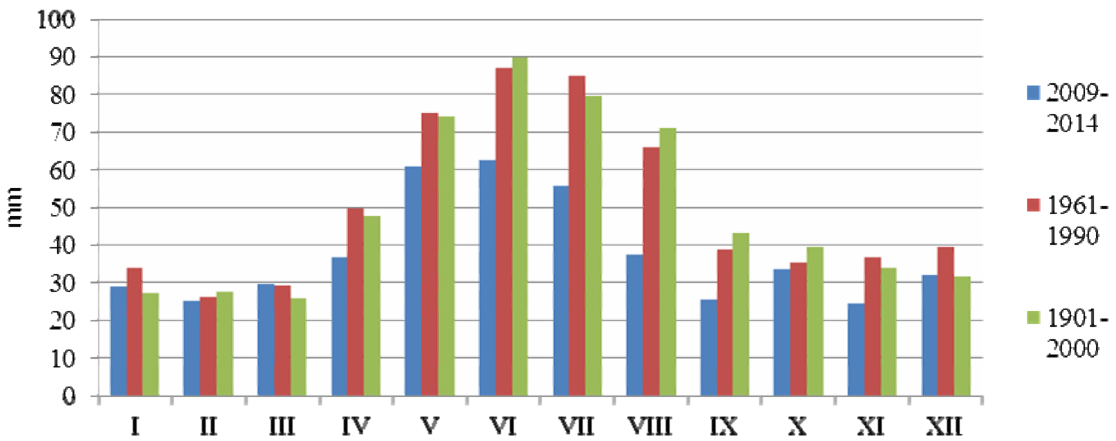

Figure 5. Evolution of monthly rainfall averages in Transylvanian Plain during 2009-2014 in comparision with monthly rainfall averages for periods1901-2000 and 1961-1990

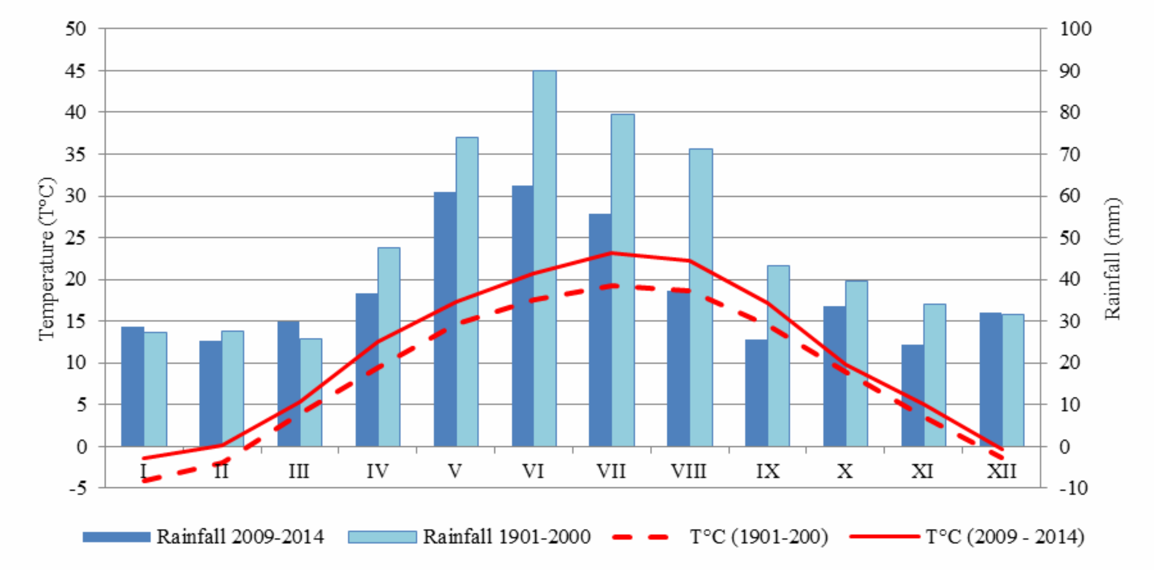

Figure 6. Thermal and rainfall variation in Transylvanian Plain for periods 2009-2014 and 1901-2000

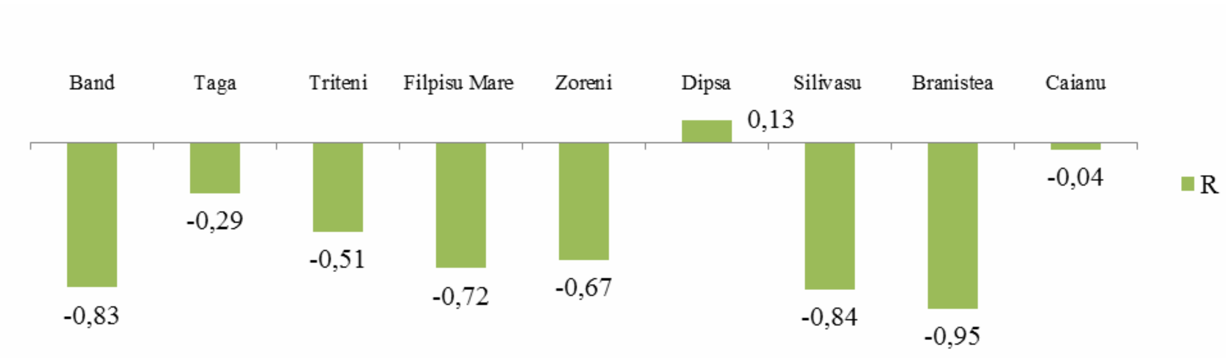

Figure 7. Values of correlation coefficient associated with trend of annual average soil moisture in Transylvanian Plain

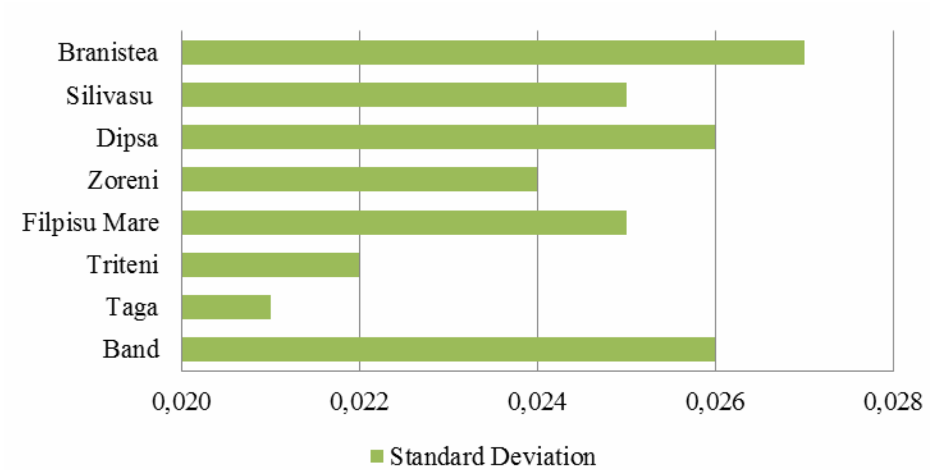

Figure 8. Standard deviation of annual value of soil moisture (m^3/m^3)

3.3. Evolution of soil moisture

The analysis of annual mean soil moisture values recorded at a depth of 10 cm, 2009-2014 in TP indicate a general downward trend in most stations except Dipsa station (where the groundwater is within 1-1.5 m). It is observed that the most high values of annual averages were recorded in 2010 being 0.309 m^3/m^3 at the station Caianu followed by Triteni with 0.288 m^3/m^3, and Silivasu with 0.280 m^3/m^3, while the lowest recording was at the Band station in 2014 with a value of 0.162 m^3/m^3 and 2013 of 0.177 m^3/m^3, respectively in 2012 of 0.176 m^3/m^3.

The correlation coefficients of linear trends associated with declining soil moisture, shown in Figure 7 have values ranging from -0.95 to -0.04 at Branistea and Caianu stations. Negative values and ones close to zero of correlation coefficients of Caianu and Taga stations (-0.13) indicate slight decrease, almost insignificant to null soil moisture.Positive value close to zero of the correlation coefficient for Dipsa station (0.13) indicates an almost insignificant increase in soil moisture. Analyzing the standard deviation calculated for each station shows that soil moisture varies with 0.021 m^3/m^3 to 0.027 m^3/m^3 from the annual average for each station analyzed (Fig. 8).

The correlation coefficient calculated in order to analyze the relationship between precipitation and soil moisture at 10 cm depth has a value of r=0.92 which indicates a very strong direct causal relationship, positive and significant between the two parameters (Fig. 9).

The correlation coefficient indicates a very good association between the two parameters, and the value of R^2 indicates that 84% of humidity variation can be explained by the linear relationship with precipitation.

Analyzing recorded data shows that the soil moisture regime of TP is anustic hydric regime. This means that, in normal years, control section of humidity is dry in parts or in whole for/or more than 90 cumulative days, but it is dry in all parts for more than 45 days cumulatively (when the temperature of soil at 50 cm deep is higher than 6^0C; Florea & Munteanu, 2012).

3.4. Indicators of technological characterization of the land

Index of erodability (S, Table 2) of the soils on which the stations were placed has the highest value at the station Zoreni (0.939), where there is a slope of 17% and the soil typeis a typical preluvosol and the lowest index of erodability is found at Dipsa (0.522), which has a 3% slope and a typical faeoziom soil type.

*Pluvial aggression index*shows how destructive action of rainfall during the year is. Pluvial aggression peaks are February-April, July and October-November. This requires special measures for soil conservation in autumn and early spring.

Annual amounts of *Fournier index* (IF) show high values for the period 2009-2014, between 21-60, especially in 2011, at Dipsa (45.75), Silivasu (47.34) and Caianu (52.87) stations, that fall within soils relevant in class 3 with a moderate pluvial erosion potential risk (risk of loss of soil erosion involving 12-50 t/ha/year; Oduro-Afriyie, 1996). IF values between 20-40 which framesoils in class 2, are subject to a low risk of pluvial erosion, with losses of soil between 5-12 t/ha/year were obtained at the station Silivasu (34.78) in 2009 and Branistea (32.45) in 2011, respectively at Dipsa (25.72) in 2012 and 2010 with a value of 20.89 (Fig. 10).

The multianual average of IF for the period 2009-2014 which is 21.47 TP that falls within in Class 2 of soils with low risk forpluvial erosion in TP, with losses of soil between 5-12 t/ha/year. Percentage analysis of IF values reveals that 70.83% of soils fall in Class 1 with very low risk of pluvial erosion, a percentage of 16.66% fall within soils in Class 2 with low risk of pluvial erosion, and 12.5% of soils TP are subject to a moderate risk of pluvial erosion is classified as Class 3 erosion that is soil loss are between 12-15 t/ha/year.

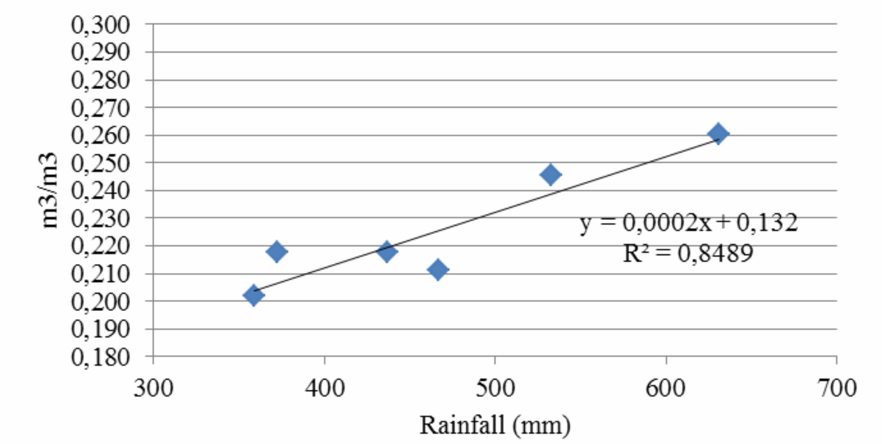

Figure 9. Correlation between annual value of soil moisture and rainfall during the period 2009-2014

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

No	Station	Soil Type and Subtype (Florea & Munteanu, 2012)	Clay(<0.002mm), %	Humus, %	Bulk density, g/cm^3	Erodability index (S)	Slope, %
1	Caianu	Cernoziom calcaric	40.01	2.85	1.2	0.729	17
2	Mociu	Cernoziom argiloiluvial	51.8	3.15	1.23	0.580	12
3	Taga	Preluvosol tipic	47.25	3.69	1.23	0.652	17
4	Branistea	Eutricambosol tipic	51.14	2.19	1.22	0.645	1
5	Dipsa	Faeoziom tipic	58.19	3.56	1.26	0.522	3
6	Zoreni	Preluvosol tipic	35.05	2.16	1.22	0.939	17
7	Silivasu de Campie	Eutricambosol molic	52.37	2.64	1.35	0.587	7
8	Filpisu Mare	Districambosol tipic	49.67	2.68	1.22	0.654	19
9	Band	Faeoziom argic	45.63	3.11	1.3	0.683	1
10	Triteni	Faeoziom vertic	49.34	4.15	1.2	0.602	10

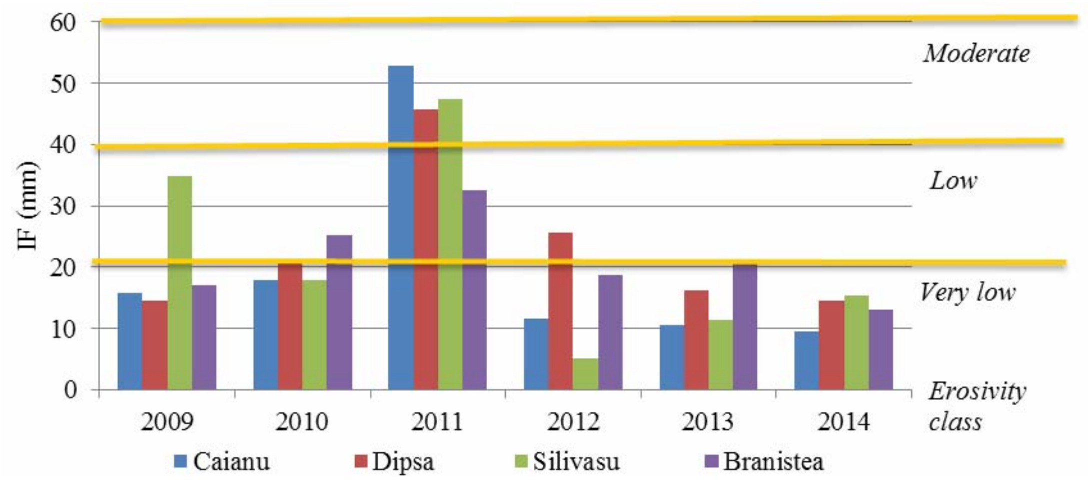

Figure 10. Fournier index values of annual pluvial and erosion risk in the period 2009-2014

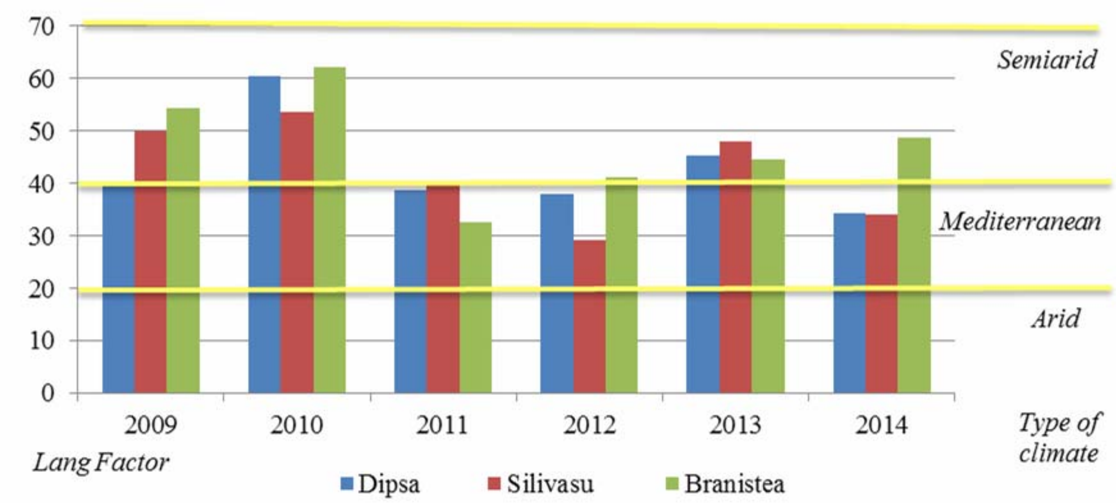

Figure 11. Lang factor values for the period 2009-2014 in Transylvanian Plain

Similar results are noticed for the *Angot rainfall index*, respectively in terms of the proportion predisposed totrigger slope linear processes and erosion is found that for 55.55% of cases there is no risk of pluvial erosion, in 25% of cases there is a small and very small predisposition, in 16.66% of the cases there are favorable conditions for triggering erosion, and up to 2.77% of cases created very favorable conditions for pluvial linear erosion.

Annual values calculated for the *Lang factor* for the period 2009-2014 reveals that 38.88% of the values are in the range of 20-40 which corresponds to a Mediterranean climate, and most values, 61.11% are in the range of 40-70 value corresponding to a semiarid climate type (Fig. 11). Lang multiannual factor value calculated for TP, for the period 2009-2014 is 44.2 which is within a semiarid climate, with multiannual values ranging between 42.5-47.3.

The share of types of climate associated with the monthly averages of the *Martonne index* in TP in the period 2009-2014 reveals a predominance of semiarid/mediterranean climate type for 47.2% of the analyzed values followed by semi-wet and wet climates characteristic values in equal proportions, but also values of arid and semiarid climate characteristic recorded in periods of high demands for water, especially during critical periods (June to August) for spring crops (Fig. 12).

Annual values are between 0.55-2.18 for *Gams index*. The relationship between altitude and multiannual values of the Gams index for the analyzed stations show a strong indirect and negative correlation, with a correlation coefficient r =-0.89, which shows that with increasing altitude, the index Gams decreases and the coefficient of determination $R^2 = 0.8$, and that, in this case, 80% of Gams index values are explained in relation to altitude (Fig. 13).

Xerothermal Gaussen Index shows that drought is a very common phenomenon in TP. This may occur in March, with higher frequency in April, then June to July, but installs every year from August to October.

4. CONCLUSIONS

TP thermal regime of the soil is of mesic type and hydric regime of the soil is of ustic type.In TP the multiannual average of temperature in soil, recorded during 2009-2014, at 10 cm depth is 11.40ºC, respectively at 50 cm depth is 10.24ºC. Multiannual average of air temperature for the same period is 11.17ºC.The multiannual average of soil moisture recorded in the same period is 0.227 m^3/m^3. The multiannual average value of precipitation is 466.52 mm.

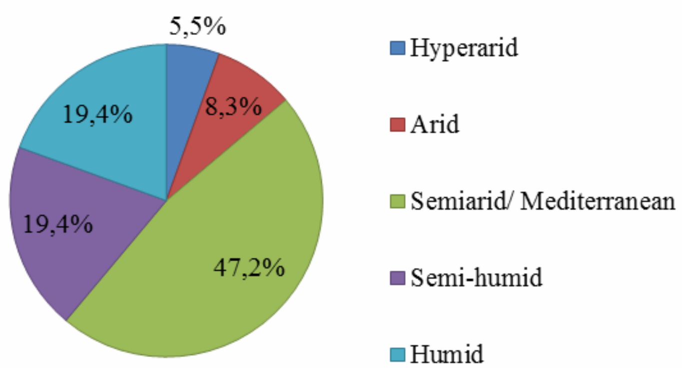

Figure 12. Share of types of climate associated with the monthly averages of the Martonne index in Transylvanian Plain (2009-2014)

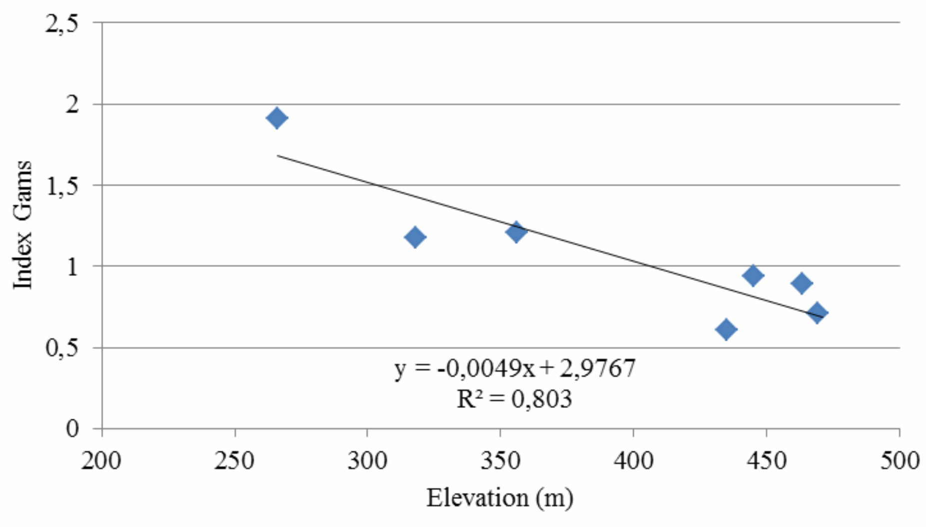

Figure 13. Correlation between elevation and multiannual value of Gams index

From the analysis of indicators for assessing the aggressiveness of rain on the soil it is shown that periodically it creates favorable conditions for occurrence and manifestation of pluvial erosion, its effect being much stronger when occurring after a period of prolonged drought, especially during March - April, July and August or in some cases from October to November.

From the analysis of parameters on soil temperature, soil moisture and precipitation trends we advocate applying technological measures that will help reduce water loss from the soil to maintain and increase soil water reserve.

Measures to limit and counteract the effects of drought as a climatic phenomenon with major risk to agriculture inTP refers both to the use of biological material resistant to water and heat stress and the use of management practices favorable to accumulation, conservation and the efficient use water from precipitation, using a system of conservation agriculture based on soil protection and avoid desertification.

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REFERENCES

Casas-Prat, M. & Sierra, J. P., 2012. *Trend analysis of wave direction and associated impacts on the Catalan coast.* Climatic Change, 115, 3-4, 667-691.

Coste, C. L, 2015. *The evolution of agroclimatic indicators and potential impact of climate change on Agricultural Land of Transylvanian Plain.* Ph.D. Thesis, UASMV Cluj-Napoca.

Coyle, C., Creamer R. E., Schulte R. P. O., O`Sullivan, L. & Jordan, P., 2016. *A Functional Land Management conceptual framework under soil drainage and land use scenarios.* Environmental Science & Policy, 56, 39–48, doi:10.1016/j.envsci.2015.10.012.

Domuţă, C., 2009**.** *Crop irigation*. Editura University of Oradea, p. 380.

Dong, W., Ren, F., Huang, J. & Guo, Y., 2013. *The Atlasof Climate Change: based on SEAP-CMIP5 - Super-Ensemble Projectionand Attribution (SEAP) of Climate Change.* Springerearth system sciences, DOI 10.1007/978-3-642-31773-6_1, ©Springer-Verlag Berlin Heidelberg.

Florea, N. & Munteanu, I. 2012. *Romanian System of Soil Taxonomy*. Ed. Estfalia, Bucharest, pp. 182.

Fournier, F., 1960. *Climat et erosion*. Editura Presses Universitarires de France, Paris.

Haggard, B., 2012. *Soil climate and pedology of the Transylvanian Plain, Romania*. Ph.D. Thesis, Louisiana State University, USA.

Haggard, B., Rusu, T., Weindorf, D., Cacovean, H., Moraru, P. & Sopterean, M., 2010. *Spatial soil temperature and moisture monitoring across the Transylvanian Plain in Romania*. Bulletin UASVM Agriculture, 67, 1, 130-137.

Haylock, M. R., Hofstra, N., Klein Tank, A. M. G., Klok, E. J., Jones, P. D. & New, M., 2008. *A European daily high-resolution gridded data set of surface temperature and precipitation for 1950-2006.* Journal of Geophysical Research, 113(D20), D20119, doi:10.1029/2008JD010201.

Heinrich, G. & Gobiet, A., 2012. *The future of dry and wet spells in Europe: a comprehensive study based on the ENSEMBLES regional climate models*. International Journal of Climatology, 32, 1951-1970.

Keskitalo, E. C. H., Legay, M., Marchetti, M., Nocentini, S. & Spathelf, P., 2015. *The Role of Forestry in National Climate Change Adaptation Policy: Cases from Sweden, Germany, France and Italy.* International Forestry Review, 17, 1, 30-42.

Lavorel, S., Colloff, M. J., Mcintyre, S., Doherty, M. D., Murphy, H. T., Metcalfe, D. J., Dunlop, M., Williams, R. J., Wise, R. M. & Williams, K. J., 2015. *Ecological mechanisms underpinning climate adaptation services.* Glob Change Biol, 21, 12-31. doi:10.1111/gcb.12689.

Lereboullet, A. L., Beltrando, G. & Bardsley, D. K., 2013. *Socio-ecological adaptation to climate change: A comparative case study from the Mediterranean wine industry in France and Australia.* Agriculture, Ecosystems & Environment, 164, 273-285.

Luo, Z., Wang, E. & Rossel, R. A. V., 2016. *Can the sequestered carbon in agricultural soil be maintained with changes in management, temperature and rainfall? A sensitivity assessment*. Geoderma, 268, 22-28. doi:10.1016/j.geoderma.2016.01.015.

Niacsu, L., Ionita, I. & Curea, D., 2015. *Optimum agricultural land use in the hilly area of eastern Romania, case study: Pereschiv catchment*. Carpathian Journal of Earth and Environmental Sciences, 10, 1, 183-192.

Oduro-Afriyie, K., 1996. *Rainfall erosivity map for Ghana.* Geoderma, 74, 161–166.

Perry, J., 2015. *Climate change adaptation in the world's best places: A wicked problem in need of immediate attention.* Landscape and Urban Planning, 133, 1-11.

Purton, K., Pennock, D., Leinweber, P. & Walley, F.,

2015. *Will changes in climate and land use affect soil organic matter composition? Evidence from an ecotonal climosequence*. Geoderma, 253-254, 48-60. doi:10.1016/j.geoderma.2015.04.007.

Rusu, T. & Moraru, P. I., 2015. *Impact of climate change on crop land and technological recommendations for the main crops in Transylvanian Plain, Romania.* Romanian Agricultural Research, 32, 1-9, DII 2067-5720 RAR 2015-89.

Rusu, T., Moraru, P. I., Coste, C. L., Cacovean, H., Chetan, F. & Chetan, C., 2014. *Impact of climate change on climatic indicators in Transylvanian Plain, Romania.* Journal of Food, Agriculture & Environment, 12, 1, 469-473.

Sopterean, M. L., 2012. *Monitorization of the thermic and hydric regime of the Transylvanian Plain and technological characterization of lands for the main crops.* Ph.D. Thesis, UASMV Cluj-Napoca.

Stanescu, P., Taloiescu, I., Gragan, L., 1969. *Contributions to the study of evaluation indicators of pluvial erosion*. ICPA Anuar, vol. 11 (XXXVI), Bucharest.

Szajdak, L., Zyczynska-Baloniak, I. & Jaskulska, R., 2003. *Impact of Afforestation on the Limitation of the Spread of the Pollutions in Ground Water and in Soils.* Polish Journal of Environmental Studies, 12, 4, 453-459.

Vidojevic, D., Manojlovic, M., Dordevic, A., Nesic, L. & Dimic, B., 2015. *Organic carbon stocks in the soils of Serbia*. Carpathian Journal of Earth and Environmental Sciences, 10, 4, 75-83.

*****NMA,** 2014. National Meteorology Administration, http://www.meteoromania.ro.

*****EEA,** 2012. *Climate change, impacts and vulnerability in Europe*, An indicator – based report, Summary, European Environment Agency, doi:10.2800/66071.

*****FAO,** 2009. *Profile for Climate Change* - Food and Agriculture Organization of the United Nations, Roma.

*****Geography of Romania**, 1987. *Romanian Carpathians and the Transylvanian Depression*, Coordinator: Badea Lucian, Vol. III., Ed. Socialist Republic of Romania.

*****INS**, 2014. *Romanian Statistical Yearbook* - National Statistics Institute.

*****IPCC**, 2014a. *Climate Change 2014*: *Synthesis Report.* Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 151.

*****IPCC**, 2014b. *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken,P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 688.

*****On-set Computer Corp., Bourne, MA, USA**. http://www.onsetcomp.com/products/data-loggers/h21-002.

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