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INTERPRETATIONS OF SOIL PROPERTIES AND SOIL CLIMATE IN THE TRANSYLVANIAN PLAIN, ROMANIA

D.C. WEINDORF*, B. HAGGARD*, T. RUSU, M. SOPTEREAN**, H. CACOVEAN*****

*Louisiana State University AgCenter, Baton Rouge, LA, USA
**University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca
***Soil and Agrochemical Studies Office of Cluj-Napoca

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Abstract

The Transylvanian Plain is an important region for agronomic productivity. However, limited soils data and adoption of best management practices hinder land productivity. Soil temperatures of the Transylvanian Plain (TP) were evaluated using a set of 20 datalogging stations positioned throughout the plain. Soil temperatures were monitored at the surface and at depths of 10, 30, and 50 cm. Soil moisture was monitored at 10 cm. During soil pedogenesis, soil properties and features developed in response to differential lithology and macro/microrelief. Evaluated soils were found to largely be a complex mix of Cernisols, Luvisols, and Antrisols. Soil temperatures of the TP are mesic, with small differences between the northern and southern extents. Differences in seasonal warming and cooling trends across the plain were noted. Influences of slope aspect and inclination are suspected as a cause for local temperature variation on TP soils. Temperature variation has important implications for planting recommendations (i.e. germination temperature, maximum growing season, etc.).

INTRODUCTION

The Transylvanian Plain (TP), with an area of approximately 395,000 ha, is an important agricultural production area of Romania. Once forested, the area was cleared hundreds of years ago and is now used largely for agricultural production. Today, steppe vegetation is found in non-agricultural areas of the TP and few areas of virgin forest remain. The TP has generally fertile soils and is capable of large agronomic production (corn, sunflower, wheat, soybeans, potatoes) (Badea, 2009; Haggard et al., 2010). Contrary to its name, the TP is characterized by extensive rolling hills and is bounded by two main rivers, the Someş to the North and West, and the Mureş to the South and East. Elevation of the TP ranges from 231 to 662 m. Original geologic deposits in the area are Miocene, with contemporary hills largely derived from Pliocene and Quaternary materials [2].

Over time, the rugged terrain, deforestation, erosive slopes, and irrational agrotechnical practices for crop production have combined to degrade large areas of agricultural land, reducing its productivity. Within the TP, tens of thousands of hectares of land show signs of denudation or reduced productivity [9]. Furthermore, most of the land is non-irrigated, owing to a lack of available groundwater and limited access to surface waters in the central TP [8].

Climate of the TP is highly dynamic, with hot summers (high temperatures >25°C) and cold winters (lows ~-5°C) [3]. Moisture regimes of the TP are generally udic to ustic with moisture increasing slightly to the north [5]. Climatic research inside the Carpathian basin has identified an increase in mean air temperatures over the last 100 years of ~0.7°C [8]. Evidence of warming is further supported by the fact that six of the warmest years of the 20^{th} century were registered in the 1990's. However, long-term documentation of temperature and moisture data in soils of the Transylvanian Plain has never been established. Regimes currently set forth for the region are based on estimation or limited short-term observations of soil moisture and temperature. As such, this research on temperature, moisture, and precipitation of the Transylvanian Plain is a first for Romanian soil science.

The methods and analyses established by this study are instrumental in defining a rubric for future soil climatic studies throughout Romania. As such, the objectives of this study were to: 1) establish 20 datalogging stations for long term documentation of soil temperature and moisture on soils of the TP, 2) characterize the physicochemical soil properties and establish the taxonomic classification, moisture and temperature regimes of the studied soils, 3) determine the significant relationships between soil temperature/moisture and soil physicochemical properties, and 4) evaluate the influence of ancillary factors such as slope inclination and aspect on soil temperature/moisture.

MATERIAL AND METHODS

Twenty datalogging stations were deployed across the TP on divergent soil types, slopes, and aspects. The location of each site was recorded using a Garmin eTrex Vista (Olathe, KS, USA) handheld global positioning system unit. Ten datalogging stations were installed in March of 2008, with an additional ten stations installed in March of 2009. HOBO Smart Temp (S-TMB-M002) temperature sensors and Decagon EC-5 (S-SMC-M005) moisture sensors were connected to HOBO Micro Stations (H21-002) at each site (On-set Computer Corp., Bourne, MA, USA). 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) (Figure 1).

At sites with a tipping bucket rain gauge, the following data was recorded: soil temperature at depths of 10, 30, and 50 cm; soil moisture at 10 cm; surface air temperature; and precipitation. At sites without a tipping bucket rain gauge, the following data was recorded: soil temperature at 10 and 50 cm; soil moisture at 10 cm; and surface air temperature. 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).

Soils at each site were initially sampled and described to a depth of 50 cm. Field descriptions were made per the Soil Survey Staff (2002) as a collaborative effort between soil scientists from the University of Agricultural Sciences and Veterinary Medicine Cluj Napoca (USAMV Cluj Napoca), Soil and Agrochemical Studies Office Cluj Napoca (OSPA Cluj Napoca), and the Louisiana State University (LSU) AgCenter (Baton Rouge, LA, USA). Soils samples were processed at LSU AgCenter in Baton Rouge, LA. Prior to lab analysis, soils were oven dried at 40°C and ground to pass a 2 mm sieve. Particle size analysis was conducted via the pipette method (Gee and Bauder, 1986) with 24 h clay determinations. Sands were sieved with a 53 µm sieve. Soil pH and electrical conductivity were accomplished via saturated paste and read on an Orion 2-Star pH meter (Thermo Scientific, Waltham, MA, USA) and model 4063CC digital salinity bridge (Traceable Calibration Control Company, Friendswood, TX, USA) (Salinity Laboratory Staff, 1954; Soil Survey Staff, 2004). Organic matter was determined via loss on ignition testing at 400°C and converted to organic carbon following [10]. Elemental analysis was accomplished via Mehlich III digestion with quantification via a CIROS model inductively coupled plasma atomic emission spectrometer (Spectro Analytical Instruments, Marlboro, MA, USA).

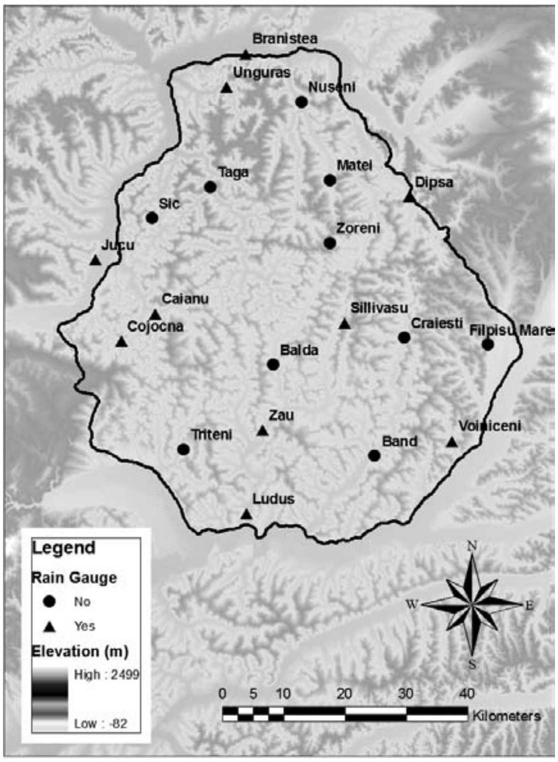

Fig. 1. Location, elevation, and configuration of soil temperature and moisture monitoring stations within the Transylvanian Plain, Romania

Data processing was accomplished with several software packages. Digitization of existing 1:200,000 scale soil maps of the TP was accomplished via ArcGIS 9.3 [4]. Inverse distance weighting and spline interpolations of soil temperature data were made with ArcGIS 9.3. Multiple regression analysis was accomplished using SAS 9.2 (SAS Institute, Cary, NC, USA).

RESULTS AND DISCUSSION

Soils of the TP were digitized and converted into the contemporary taxonomic system used in Romania [5]. A total of 1,472 polygons were digitized and classified by soil class, type, and subtype (Figure 2, Table 1).

Table 1

Total area and extent of soil classes for soils of the Transylvanian Plain, Romania derived from digitization of 1:200,000 scale soil maps

Class	Area (ha)	% of TP
Antrisoluri	58921	14.9%
Cambisoluri	35679	9.0%
Cernisoluri	200543	50.7%
Hidrisoluri	6816	1.7%
Luvisoluri	86410	21.8%
Pelisoluri	6737	1.7%
Protisoluri	154	0.0%
Salsodisoluri	356	0.1%
Total:	395616	100.0%

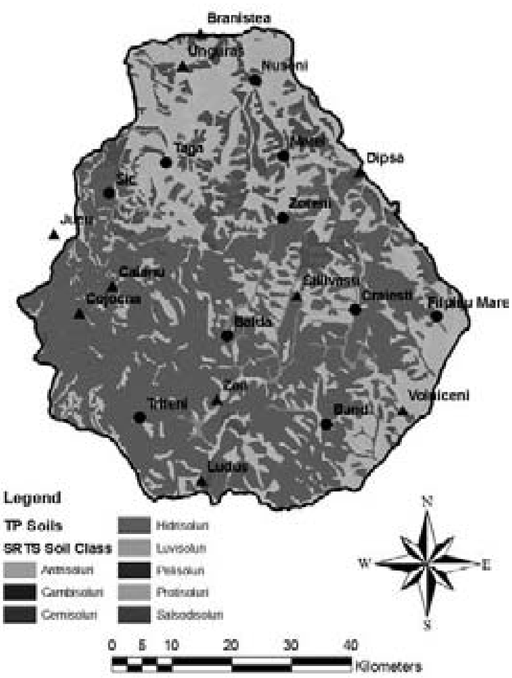

Fig. 2. Soil classes of the Transylvanian Plain, Romania derived from digititation of 1:200,000 scale soil maps

Calculation of soil temperature regime according to the Soil Survey Staff (2010) consists of averaging soil temperatures at 50 cm between summer (June, July, and August) and winter (December, January, and February). The Soil Survey Staff (2010) defines mesic soil temperature as a "mean annual soil temperature that is >8°C, but <15°C where the difference between mean summer and mean winter soil temperatures is more than 6°C at 50 cm or at a densic, lithic, or paralithic contact, whichever is shallower." Data from the monitoring sites clearly indicated that all sites have a mean annual soil temperature of ~10°C at 50 cm with more than 6°C variation between summer and winter. Thus, the soil temperature regime of the TP was determined to be mesic.

Although soil temperatures were mesic across the TP, differences were noted between the northern and southern extents. Taken as an annual average, temperatures at Cojocna, Caianu, Sic, Taga, Zoreni, Sillivaşu, and Nuşeni were noted to be 1-2°C cooler than temperatures at Filipişu Mare, Zau, Luduş, Voiniceni, and Dipşa (Figure 3). Possible reasons for the observed differences in temperature spatial variability include: distance to the Someş and Mureş Rivers, albedo effects imposed by humic substances common to Cernisoluri, slope inclination, and slope aspect. To evaluate these possibilities, a multiple regression model was created such that euclidean distance to the Mureş River and elevation (derived from a digital elevation model) were used as regressors to explain observed temperature. Soil temperature estimation at 10 cm was constructed using June, 2009 data. Temperature predictions align with drainage basins of the Someş and Mureş with surprising accuracy (r^2 = 0.5073). However, other months showed less robust prediction accuracy. To address these shortcomings, an exploratory factor analysis was established across 15 months and 20 sites. The months analyzed were: March 2009 - May 2010. Results of factor analysis showed that two factors substantially impact soil climate on the TP. Specifically, the factor analysis differentiated April-October (Factor 1) as being influenced dominantly by a separate factor from November-March (Factor 2). Factor 1 is associated with higher amounts of evapotranspiration, while factor 2 reflects moisture recharge, where evapotranspiration is less than the rainfall input [13].

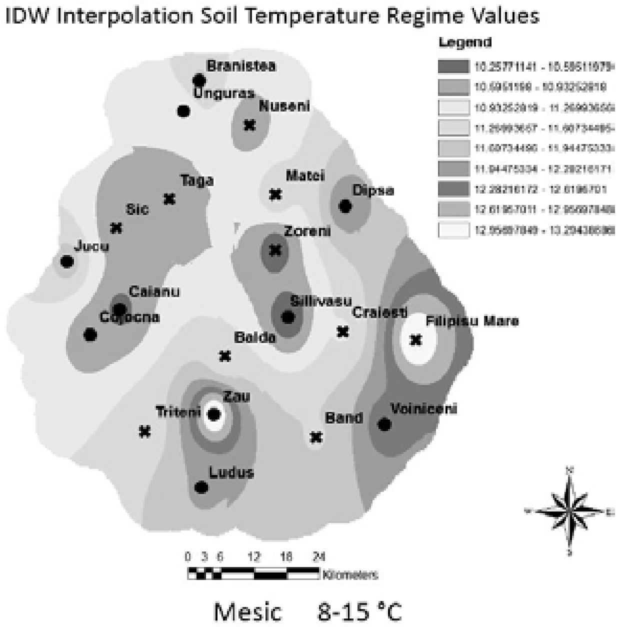

Fig. 3. Average annual soil temperatures (°C) at 50 cm across the Transylvanian Plain, Romania in 2009

Using data generated from this study, a land classification map was initially created with soil type and slope. The US equivalent of Mollisols were classed as 3, Alfisols, Alluvium, and Inceptisols were classed as 2, Spodosols, Histosols, and Entisols were classed as 1, and highly eroded soils, salt affected soils, and lithic soils were classed as 0. Slopes classes were established as follows: 0-0.5% slope (class 4), 0.5-5% (class 3), 5-15% slope (class 2), 15-25% slope (class 1), and >25% slope (class 0). Once complete, these two rankings were reclassified together, to produce a land classification map ranking the suitability of soils for production agriculture across the TP (Figure 4). Results indicate that superior agronomic soils are generally located in the southern TP, with less desirable soils located in the northern TP.

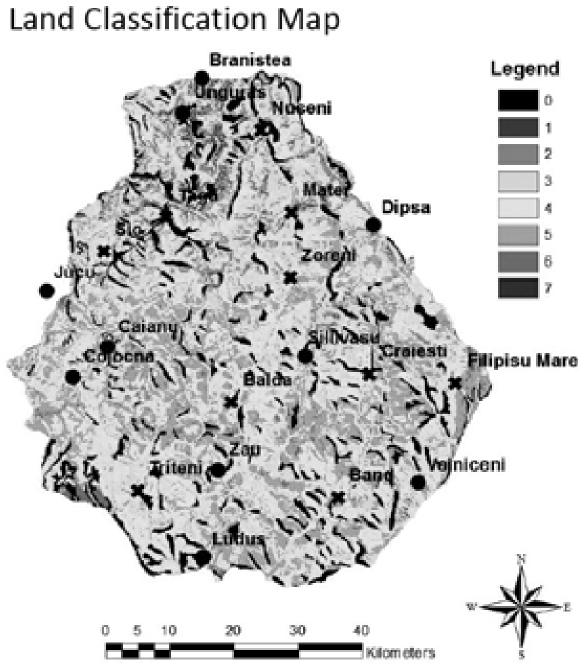

Fig. 4. Land classification map of soils of the Transylvanian Plain, Romania using soil type and slope inclination as inputs. Scale of 0 to 7 is a synthesis of land type and slope such that 7=best and 0=worst land for agronomic production

Results of soil physicochemical data across the plain were dynamic, though generally within the boundaries established by previous studies. Soil pH was generally moderately alkaline, with many soils exhibiting pH from 7.2 – 7.7. Isolated soils had pH values as high as 8.0. Soil textures were largely silty clay, clay, and clay loam. These textures have significance in the context of organic matter preservation across the TP. Soil organic matter is well protected by clays, where its macromolecular complexes become bound to the surfaces of electrostatically charged clays. Soil organic matter levels commonly ranged from 3-6%, though values as high as 8.6% were observed. Soil organic matter levels generally showed a decrease with depth, commonly observed in upland soils. The elemental range and mean of common exchange complex elements in the soils is given in Table 2. As expected, soil organic carbon levels aligned rather well with the spatial distribution of Cernisoluri (Figure 5).

Table 2

Mehlich III elemental concentrations in soils (0-50 cm depth) of the Transylvanian Plain, Romania

	P	K	Ca	Mg	Zn	Cu	Na	S	Fe	Al	Mn
	---mg kg^{-1}---										
Mean	224	780	5878	413	13	6	43	78	307	481	220
Minimum	5	106	1700	147	1	1	6	10	99	0	106
Maximum	1608	3492	11528	1090	143	12	194	223	476	1485	359

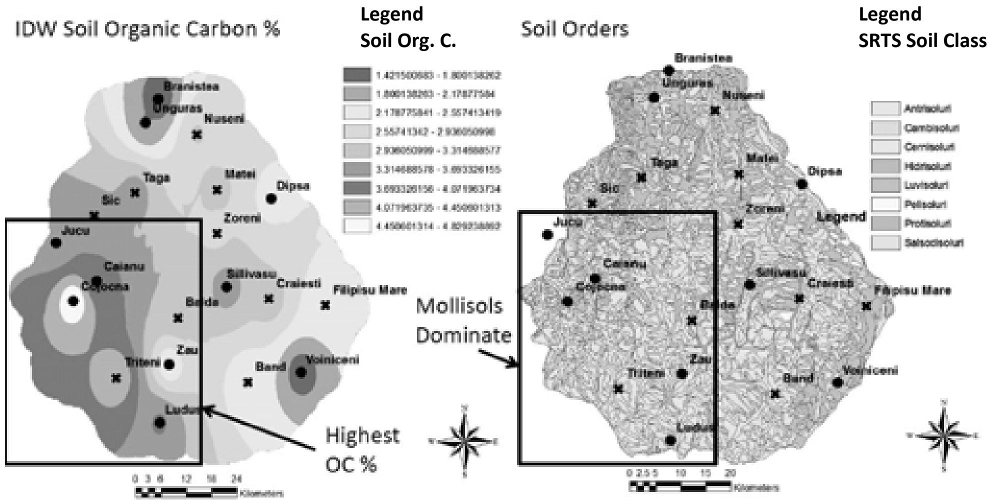

Fig. 5. Inverse distance weighted interpolation of soil organic carbon on the Transylvanian Plain, Romania and associated soil classes

The data collected to date notwithstanding, further study on the influence of soil slope and aspect are required for a better model of soil temperatures across the TP. As such, an array of 11 soil temperature/moisture monitoring stations was deployed in March, 2011 at Caianu, Romania to study aspect differences in temperature around a single hill as well as catena effects imposed by slope and elevation across a valley. Data will be collected from March through October, 2011 then analyzed for differences in soil temperature and moisture effects. Aspect and slope inclination effects will be incorporated into the data model for the entire TP to more accurately describe soil temperature and moisture dynamics.

CONCLUSIONS

1. Soil temperatures of the Transylvanian Plain, Romania were evaluated via 20 datalogging stations in 2009 and 2010.

2. Data from the loggers indicated that the soil temperature regime of the TP is mesic. More than 50% of the soils on the TP were Cernisoluri, followed by Luvisoluri (21.8%) and Antrisoluri (14.9%). Interpolations of soil organic carbon based upon levels documented at the research sites generally show association with Cernisoluri.
3. Soils across the TP were classified according to agronomic use with slope and soil type as input factors. Output from this map shows that superior agronomic lands are located in the southern portion of the TP. Distance to the Mureş River was shown to be a significant variable in explaining spatial temperature variation across the TP.
4. Two factors were differentiated within the data, indicating that the temperatures of winter months are related to a different factor than the remaining months.
5. Ongoing studies of the impact of slope aspect and inclination will allow for further refinement of the soil climate model for the entire TP.

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