SOIL ORGANIC MATTER MAP OF HUNGARY DERIVED FROM DIGITAL ELEVATION MODEL AND SATELLITE DATA

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Introduction

One of the major stresses on the soil functions is the decline of soil organic matter (SOM) content. Soil Information and Monitoring Systems were setup to survey the recent situation and estimate the rate and trend of potential changes in different soil properties and components including SOM. These Monitoring systems are profile or point based networks with regular sampling periods, which can provide limited, often insignificant percentage of the country surface. The collected data need to be extrapolated to create continuous coverage of the land area of interest.

The SOM content of the soil is strongly related to the landuse, vegetation, climate and terrain features, which can be characterized with DEM and satellite data. Due to the limitation in the lenght of the paper, the authors could not give references for each of the methods and tools used for SOM estimation. Please refer to the paper of McBratney et al. (2003) for details on the use of statistical tools and digital data sources within this topic. In this paper a method to extrapolate point information based on integrated digital elevation model (DEM) and satellite (MODIS) data set and statistical-geostatistical tools to create a soil organic matter map of Hungary is demonstrated.

Materials and methods

The Satellite data

MODIS sensor data was used for the project (Salomonson et al. 2002). In order to represent different environmental conditions, two dates, May and September of year 2000 were selected. MODIS provides a lot of spectral bands for numeruous applications. In this study the 1-7 reflective bands (covering the visible, near and mid infrared spectra), the NDVI with 500 m resolution and one thermal infrared band (band 31) were used.

SRTM30 Global Elevation Data

SRTM30 database is an improved version of the GTOPO30 (Gesch et al., 1999). Its documentation can be read on the following homepage: *http://edcdaac.usgs.gov/gtopo30/README.asp#h10*. SRTM30 is a near-global digital elevation model, covering the Earth surface between the 60 degrees of the south and north latitudes. Its data is coming from the combination of the GTOPO30 and from the Shuttle Radar Topography Mission (Farr and Kolbrick, 2000), flown in 2000. The basic product has a resolution of 1 arc second, which was first generalized to 30 arc seconds (approximately 1 km). There are small gaps in the dataset due to the shadowing effect of the radar. These gaps were filled with data from the GTOPO30. It is approximately 0,15% of the dataset.

The data were transformed from geographical coordinates (latitude/longitude) to the standard Lambert Azimuthal Equal-Area projection. Numerous terrain derivatives were created and added to the database: Altitude, Specific catchment area (A), Profile, planar and complex convexity, Slope percentage (S), Tangens β, Potential drainage density (PDD), Aspect,

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Flowaccumulation, Relief intensity (focalmax-focalmin) and CTI (Compound Topographic Index: ln A/S).

The terrain dataset originally had a resolution of 1 km. In order to match the 500 m resolution of the MODIS, the terrain data layers were resampled to 500 meter using the bilinear function of Arc/Info.

Geographic position representing the climatic changes

Two artificial layers were created, an easting and a northing one to represent the geographic position.

Soil Monitoring System for Hungary (TIM)

TIM is part of the Hungarian Environmental Monitoring System created and maintained since 1995 (Várallyay et al., 1995). The TIM data provided the reference SOM information. It was calculated on a horizonal basis in t/ha, and the SOM contents of the horizons were summed up to derive the total SOM content of the area. The variables used to calculate the SOM content were the SOM %, bulk density and horizon depths.

Methods

Regression kriging was used to create the SOM content layer for Hungary. The procedure had four major steps, (1) the database construction, (2) the linear regression, (3) kriging of the regression error, and (4) summing up the regressed and krigged values to derive the final database.

The MODIS bands of the two dates provided 18 layers, representing 18 environmental variables. 10 layers of terrain variables were created as well. All together 30 independent variables were derived counting the easting and northing layers as well. In order to achieve normal or normal-like distribution for all the variables, logarithmic and square root data transformations were carried out where it was needed. Finally 45 layers (variables) were created. The average SOM content from the years of 1992 and 1998 – derived from the TIM - was used as dependent variable. All variable layers were sampled for the TIM points and an excel data sheet was created with 46 variables for the app. 1200 records. This database was used as input for the statistical package of SPSS 8 for linear regression. Kriging was done with the geostatistical package of ArcGIS.

Regression kriging

Forward regression was used to select the variables for the regression equation. With the use of the derived regression equation, a continuous layer of estimated SOM content was created. In the second step, the estimation errors were calculated for all the TIM points and were krigged to create a continuous layer. Finally, the regressed and krigged values were summed up and the final version of SOM map was completed.

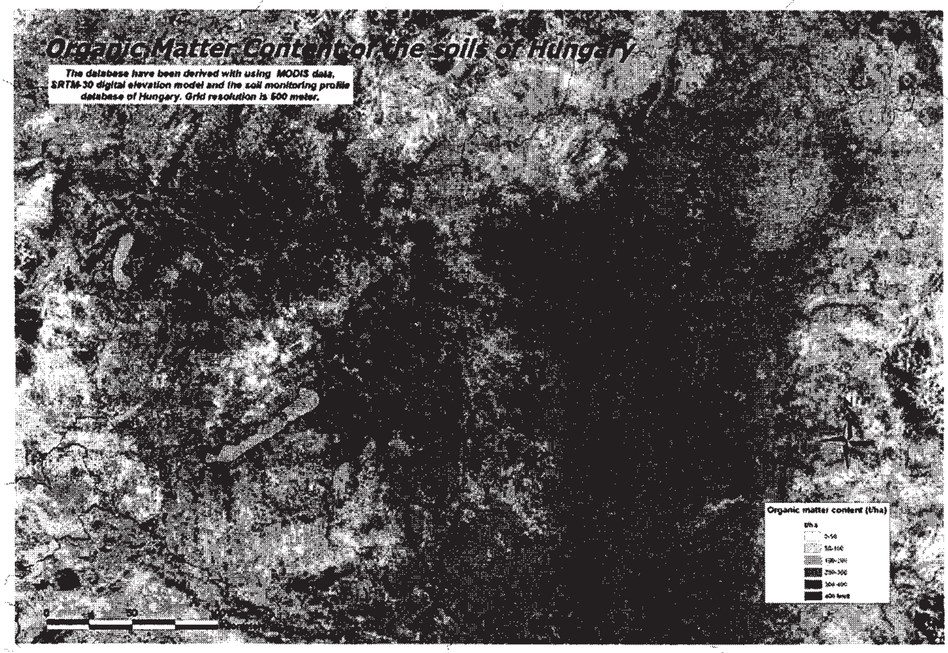

Figure 1. Organic matter content of the soils of Hungary derived from MODIS and SRTM30 data through regression kriging.

Summary and Conclusions

The final map of the SOM content is shown on Fig. 1. The forward regression has selected 12 variables and the following regression equation was set up:

SOM_g/m² = ([Square root transformed NDVI from Sept.] * **-1829.276)** - ([MODIS band 5, May] * **1.469)** - ([Square root transformed PDD] * **7626.015)** + ([PDD] * **1240.775**) - ([Logaritmic transformed altitude] * **12097.897)** + ([Relief Intensity] * **54.247**) + ([MODIS NDVI, May] * **105.134**) - ([MODIS band 3, May] * **33.099**) - ([Profile convexity] * **9179.56**) + ([Square root transformed MODIS band 1, May] * **2556.134)** - ([MODIS band 4, May] * **3.998**) - ([Aspect] * **10.738**) + **87921.241**

The adjusted R^2 was quite low, but significant, 0.238, meaning that there is significant correlation between the SOM content and terrain and spectral variables. Despite of the low statistical correlation, the overall look of the map looks promising. It coincides with our understanding about the spatial distribution of SOM content over Hungary, determined by the climatic, geologic, biotic and human impacts on the soil formation. The low R^2 value and the scatterplot intimate the complex nature of the SOM distribution, determined by important soil forming factors, which are not significantly represented by the satellite images or the terrain variables. The results and the descriptive statistics need more thorough interpretation of the soil specialistst.

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