GLOBAL SYMPOSIUM ON SOIL ORGANIC CARBON, Rome, Italy, 21-23 March 2017

Turkey's National Geospatial Soil Organic Carbon Information System

Bulent SONMEZ[1] *Aynur OZBAHCE*[2] *Mehmet KECECI*[2] *Suat AKGUL*[2]
Ece AKSOY[3] *Sevinc MADENOGLU*[1]*(*)* *Armagan KARABULUT ALOE*[2]
Vecihe INCIRKUS[2] *Ceren GORGISEN*[2] *Tulay TUNCAY*[2]
Ines BEERNAERTS[4] *Ronald VARGAS*[5]

[1] General Directorate of Agricultural Research and Policies, Ankara-Turkey
[2]Soil Fertilizer and Water Resources Central Research Institute, Ankara-Turkey
[3]European Topic Center, Malaga University, Malaga-Spain
[4]FAO Sub Regional Office for Central Asia, Ankara-Turkey
[5] FAO Headquarters, Rome –Italy
*Presenting author

Abstract
Soil organic carbon, the major component of soil organic matter, an important indicator for the soil fertility, is not only extremely important in soil processes but also highly related to the climate change, soil/land degradation and soil ecosystem services. Spatially explicit soil organic carbon information system was a great need for Turkeys' soils. This study aimed at developing a territorial national geographical database for soil organic carbon of top soils (0-30 cm) in Turkey. In the first stage of project, 7742 top soil samples provided from different research projects for the period of 2008-2009 that represent the national territory and different land uses were analyzed to determine carbon content of soils. In the second stage, digital soil mapping methodology that applies geostatistical processes of geoferenced soil data has been used to produce maps of soil organic carbon. We expect that Geospatial Soil Organic Carbon Information System can serve as an important spatially explicit base and may guide for the climate change adaptation strategies, achieving of land degradation neutrality, agricultural carbon footprint, rural development and conservation of biodiversity.

Key words: soil organic carbon, regression kriging, digital soil mapping, geodatabase, Turkey

INTRODUCTION

Soil organic carbon is an important parameter that should be known for the studies on climate change, soil fertility and soil water storage capacity. Soils are one of the main reservoirs of carbon together with oceans, lithosphere, atmosphere and terrestrial biomass (Batjes and Sombroek, 1997). Soils have substantial dynamics of carbon sequestration that accumulate approximately %75 of carbon in the terrestrial ecosystems. Carbon stocks in soils depends on many variables interlinked with many other soil properties, particularly soil organic matter and characteristics of biomes and the responses to different land uses and management systems (Batjes, 1998).

The distribution of soil organic carbon (SOC) is under the impact of some subsidiary variables and these variables can be used to better explain the underlying causes of SOC distribution. Some or all of the variables or a single variable could be significant for changing the SOC content of the soils depending on the characteristics of the region. It is widely reported in the literature that the most significant factor affecting the distribution of SOC for the surface layer (down to 30 cm) of the soil was climate, being broadly precipitation and temperature (Jenny, 1980; Bui et al., 2009; Minasny et al., 2013; Viscarra-Rossel et al., 2014; Hobley et al., 2015). It can be concluded from the literature that there is less consistency regarding the relative influence attributed to factors like land use/management, parent material (including lithology and clay content), and topography (including slope and aspect). The relative influence of some factors varies with scale such as land use and topography, which appear to increase in importance at more localized scales (Minasny et al., 2013). There is a global need for spatially quantitative soil information for agricultural and environmental researches and policy making. Digital soil mapping, where soil maps are produced digitally based on different variables such soil properties, climate, organisms, parent materials, age, elevation and spatial position, is one of the solution to this demand (McBratney et al., 2003). Spatially explicit soil organic carbon information system was a great need for Turkeys' soils. Therefore, the main objective of this study was establishing a Turkey's Topsoil Soil Organic Carbon (SOC) Geospatial Database using representative soil samples, available spatial input data sets and reliable scientific methodology.

METHODOLOGY

Soil sampling and analyses

Soil Sampling strategy was established by interpreting spatially explicit a number of characteristics together such as soil properties, land use, land use capability classes, poorly drained alluvial soils with high water table, geothermal sites etc. using different base maps such as CORINE land use, geological maps, digital elevation models, 1/25 000 scale digital soil maps. 7742 top soil samples (0-30 cm) provided from different research projects for the period of 2008-2009 that represent the national territory and different land uses were analysed to determine carbon content of soils. Soil carbon analyse was performed using TOC device. Figure 1 shows spatial distribution of soil samples.

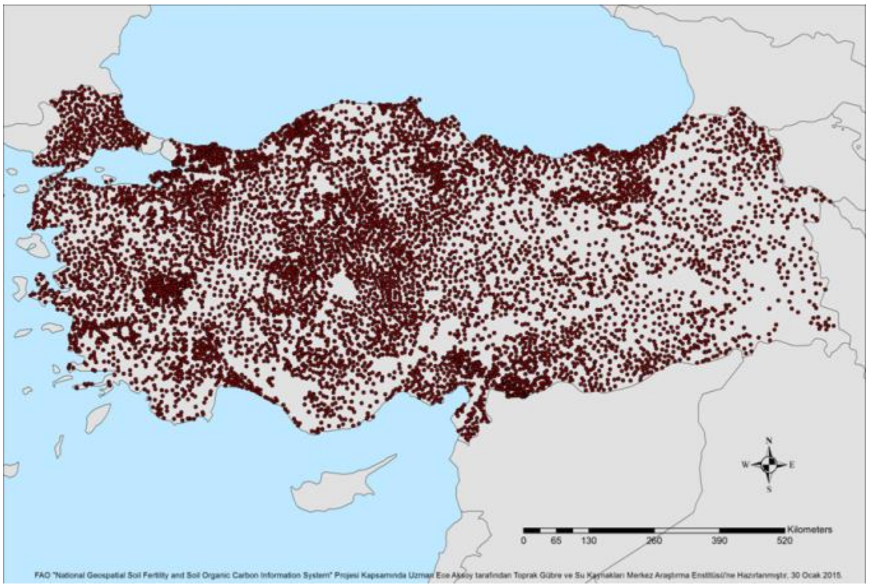

Figure 1: Spatial distribution of soil samples

Auxiliary dataset

In this study, climate (temperature, precipitation, compound topographic index, evaporation), topography (slope, aspect, elevation, etc.), soil texture, parent material, geology, vegetation (minimum, maximum and average data of NDVI) and land use types were used as environmental covariates for predicting soil organic carbon content. Both continuous (slope, aspect, temperature, precipitation) and categorical (elevation, geology, land-cover map, soil map) factors at different scales were used as subsidiary variables to map the distribution of SOC throughout the country.

Data Preparation and Processing

All input data were prepared before executing geostatistical analysis; all input data were prepared using transformations for compliant projection and coordinate system and were resampled to the same resolution (50 m) for ensuring compatible data structure. All covariates were normalized before executing the model. Most of the continuous covariates (slope, temperature, precipitation, etc.) were normalized by using Z-score normalization technique.

Digital Soil Mapping

Digital soil mapping (DSM) Digital soil mapping is an approach to find out relations between known soil data and environmental parameters to produce soil maps. Regression kriging (RK) method as one of the widely used geostatistical techniques has been used for producing of soil property maps (Odeh et al., 1995; McBratney et al. 2000). RK is a hybrid method that combines either a simple or a multiple-linear regression model with ordinary, or simple, kriging of the regression residuals.Multiple linear Regression-Kriging geostatistical technique was applied to estimate regression coefficients, calculate residuals and determine significant predictors for soil assessing and producing a continuous covers for soil organic carbon modelling in Turkey scale. After deriving significant predictors, regression model can be determined to predict target variable (soil organic carbon) with the help of those estimated regression coefficients. Residuals are interpolated by ordinary kriging technique. For final output, regression model of the significant predictors and interpolated residuals were summed up.

RESULTS

The geostatistical analysis using regression kriging method has been performed to determine spatial variability of soil organic carbon content in Turkey. Table 1 illustrates the regression coefficient, standard error of regression, and Root Mean Square Error (RMSE) of regression kriging method. Table 2 demonstrates the regression equation and subsidiary parameters used to calculate soil organic carbon. Statistically significant predictors of the models that were best explained by these covariates were determined in the Table 2 for soil organic carbon.

Table 1. Regression results, Standard error of regression, Root Mean Square Error (RMSE) of residuals and Mean of soil properties in National scale (Aksoy, 2014).

Soil Properties	**R^2**	**Standard Error**	**RMSE**	**Mean of soil property**
Soil Organic Carbon (%)	0.324	0.439	0.422	0,89

Table 2. Regression equations for calculations of soil organic carbon (Aksoy, 2014)

Soil Organic Carbon =
(1.075 +(0.022 *"nkirec")- (0.136*"nkum") - (0.092* "nkil")+ (0.162 *"neto")+ (0.173 *"nkuraklik")+(0.119 *"nndviave")+ (0.941*"nmintemp")+ (0.594* "nmaxtemp")- (1.778*"navtemp")- (0.108* "navprec") + (0.011* "ncti")+ (0.026* "nslope") - (0.101*"cor5") - (0.083* "cor3") - (0.145 *"cor2") - (0.061*"geo5") - (0.084* "geo4") - (0.052* "geo2") - (0.062* "geo1") - (0.218 *"Lpe"))

Semivariograms of the residuals and Q-Q Plots for soil organic carbon are shown in Figure 2.

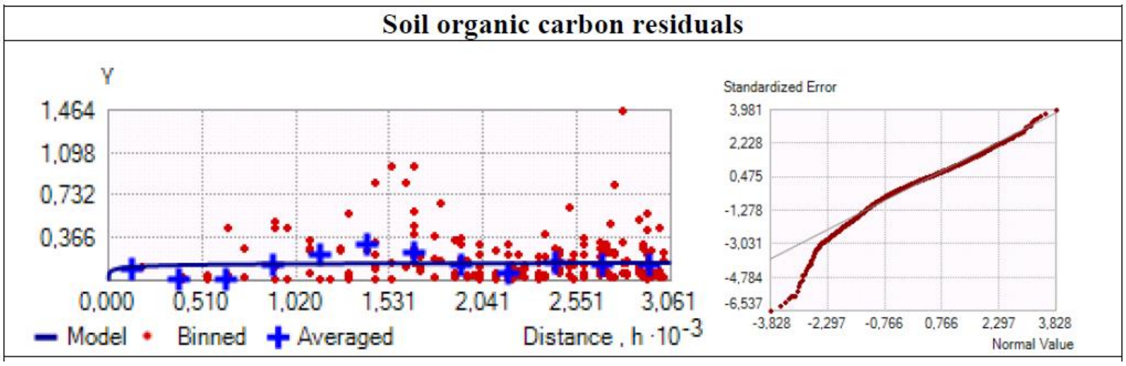

Figure 2: Semivariogram of the residuals and Q-Q Plot for soil organic carbon (Aksoy, 2014).

Significant covariates were selected by “Akaike information criterion (AIC)” in R. The AIC, which is a measure of the relative quality of a statistical model for a given set of data, is used to select a best model for our study. The chosen model is the one that minimizes the Kullback-Leibler distance between the model and the truth. AIC deals with the trade-offs between the goodness of fit of the model and the complexity of the model (Aksoy, 2014). For validation of the model, “repeated random sub-sampling validation” model was used by taking averages of the values comes from 25% validation datasets. The validation result was calculated using R by taking the averages of the results comes from 25% validation datasets. Predicted data were evaluated with repeated random sub-sampling validation datasets and average R^2 and RMSE were found for soil organic carbon.

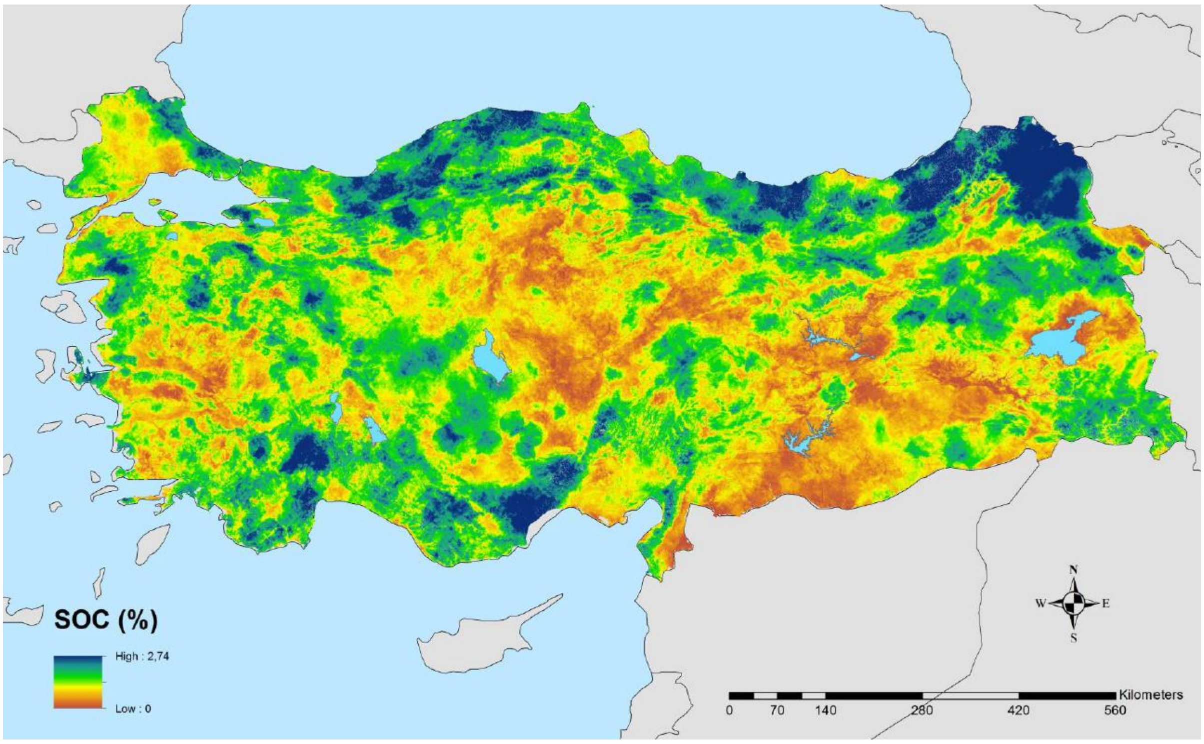

Figure 3: Turkey’s soil organic carbon map (Aksoy, 2014).

The Central Anatolia, South-eastern part of Turkey and Central part of Aegean have the lowest soil organic carbon content. Considering that these regions are the main agricultural lands in Turkey we may conclude that the agricultural practices should be tackled in order to avoid carbon emission from those areas. Those areas located in the Black sea region and other forest areas has the higher soil organic carbon content (Figure 3).

DISCUSSION

The geospatial Soil Organic Carbon (SOC) content of Turkey's soils which is necessary for both agricultural and environmental studies will fill up the gaps in the current national soil database of Turkey. Soil organic carbon content in Turkey scale were successfully modelled and mapped using digital soil mapping techniques with technical assistance provided by FAO. The soil carbon maps obtained by this study have the intention to meet one of the important needs of the relevant Institutions, Universities and disciplines in Turkey. These maps can be used as efficient sub-information for the related researches and studies.

CONCLUSION

Soil organic carbon (%) and soil carbon stock were modelled and mapped by digital soil mapping techniques for Turkey. This study is performed with a limited number of soil sample dataset. Despite the fact that the number of the soil samples was not sufficient to represent all land use types, except for agricultural areas, this study is a first attempt at national scale to be updated and improved with incoming works. Therefore, a second complementary project has been performed focusing on improving the geo-database of this project including soil fertility parameters and soil toxic elements (in total 53 soil characteristics) with additional soil samples. The first version of the soil organic carbon map is being updated under this second complementary project.

Acknowledge

This study is part of a national project supported by FAO and Ministry of Food Agriculture and Livestock which performed by Soil Fertilizer and Water Resources Central Research Institute. The authors thank to all researchers of the Institute, FAO-SEC and TAGEM due to their great contributions to the project.

References:

Aksoy, E. 2014.Technical Report to FAO-MoFAL, on National Geospatial Soil Fertility and Soil Organic Carbon Information System (UTF/TUR/057/TUR).

Batjes, N. H. 1998. Mitigation of atmospheric CO2 concentrations by increased carbon sequestration in the soil, Biology and Fertility of Soils, 27, 230-235.

Batjes, N. H., Sombroek, W.G. 1997. Possibilities for carbon sequestration in tropical and subtropical soils, Global Change Biology, 3: 161-173. Doi:10.1046/j.1365-2486.1997.0002.

Bui, E., Henderson, B., and Viergever, K. 2009. Using knowledge discovery with data mining from the australian soil resource information system database to inform soil carbon mapping in Australia, Global Biogeochem. Cy., 23, GB4033, doi:10.1029/2009GB003506, 2009.

Hobley, E., B. Wilson, A. Wilkie, J. Gray, and T. Koen. 2015. Drivers of soil organic carbon storage and vertical distribution in Eastern Australia. Plant and Soil 390:111–127.

Jeny, H. 1980. The soil resource, Origin and behaviour, Springer, New York.

McBratney, A.B., Odeh, I.O.A., Bishop, T.F.A., Dunbar, M.S., Chatar, T.M., 2000. An overview of the pedometric techniques for use in soil survey.Geoderma 97.293-327.

McBratney, A.B., M.L. Mendonça Santos, and B. Minasny. 2003. On digital soil mapping. Geoderma 117:3–52. doi:10.1016/S0016-7061(03)00223-4.

Minasny, B., McBratney, A.B., Malone, B.P. & Wheeler, I. 2013.Digital Mapping of Soil Carbon.Advances in Agronomy, Volume 118.Academic Press, Newark, NJ.

Odeh, I.O.A., McBratney, A.B., Chittleborough, D.J., 1994. Spatial prediction of soil properties from landform attributes derived from a Digital Elevation Model. Geoderma 63 .197-214.

Viscarra Rossel, R.A., Webster, R., Bui, E.N., and Baldock, J.A. (2014).Baseline map of organic carbon in Australian soil to support national carbon accounting and monitoring under climate change. Global Change Biology. 20(9):2953-2970.