ValiDat.DSM, a new soil data validation dataset for Central Europe.

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Abstract

Digital soil maps are often derived using digital soil mapping tools, satellite imageries and digital terrain models as environmental covariates. Therefore several new datasets are raster based data representing soil classification categories, like WRB reference soil groups. Validating raster datasets with categorical data is not well researched and supported. No procedure and validation datasets exist that can take categorical diversity and similarity (taxonomic distance) into consideration. This approach would require an input validation dataset describing the categorical diversity of the spatial units to be validated. The aim of this study is to introduce a novel dataset developed for this purpose.

Keywords: ValiDat.DSM, soil validation, DSM, raster dataset, categorical data

Introduction

Digital soil mapping has become a very efficient tool in soil science, and several applications have been published (McBratney et al., 2003, Lagacherie et al. 2006). Many of these applications use environmental covariates like remotely sensed images and digital elevation models, which are raster based data sources with block support. Raster format is favoured by the many users as well. The majority of soil data users require data in raster format with values of certain properties, like pH, clay content or soil organic matter content. Qualitative data can be later classified and used as categorical data. The most typical categorical soil data is the soil type/classification category, like WRB (IUSS Working Group WRB. 2006.) or the national classification systems.
Pixels represent a homogeneous spatial object having only one descriptive value or class allocated to it. However the land surface area represented by a pixel has a more or less heterogeneous soil coverage. This heterogeneity is difficult to handle in a “one value environment”. The quantitative variables often use the average value, while the categorical variables use the dominant class of the pixel area. Both methods simplify the real heterogeneity of the area. Quantitative information can be further explained by descriptive statistics, like standard deviation, minimum, maximum, range etc. Explaining the diversity is more difficult for the categorical data. A potential way to characterize the pixel area is the fuzzy membership approach, when each potential class is represented by a corresponding layer representing the occurrence likelihood or spatial share of the given soil class within the pixel (A-Xing Zhua et al. 2010, De Gruijter and McBratney, 1988, McBratney and Odeh, 1997, McBratney et al., 1992, 2000). This is an appropriate way to keep the heterogeneity information, but user do not prefer this way of information presentation due to its data complexity. Fuzzy data sets are often simplified in the preprocessing steps by selecting the one with the highest share - namely the dominant class - and the rest of the information is lost.

The presentation and validation of the raster based, categorical soil data is not well developed. The e-SOTER project developed a novel approach to present categorical information on block support. The resulting dataset has several layers of occurrence probabilities of WRB diagnostic horizons/features/properties and an additional layer of the reference soil group (RSG) of the WRB system (IUSS Working Group WRB. 2007). However, no appropriate validation methodology and data exist so far.

This paper describes a novel approach for the development of a validation database, entitled as ValiDat.DSM and its potential use for validating digital soil mapping derived WRB reference soil groups and the occurrence probabilities of selected diagnostics. The sampling methodology combines an automated simple random sampling with slight adjustment for better accessibility and fit to the raster database and a systematic random sampling approach to populate the selected pixels with additional observations.

**Methods**

**Overall validation procedure**

An external validation dataset was developed for predicting the accuracy of categorical raster soil datasets. The ValiDat.DSM dataset has 114 validating sites from the four Visegrád countries, 17 from the Czech Republic, 58 from Hungary, 23 from Poland and 16 from Slovakia (Figure 1.). The sites/pixels for validation were randomly selected. All sites had 5 observations falling within a 450 by 450 meters pixel area. Having these 5 observations, proportions of the RSG within the pixel can be approximated with 20, 40, 60, 80 and 100 percent coverage.

The coordinates of the sites are given in WGS_1984_UTM_Zone_34N projection system (Projection: Transverse Mercator, False Easting: 500000, False Northing: 0, Central Meridian: 21, Scale Factor: 0.999600, Latitude of origin: 0, Linear Unit: Meter, Datum: D_WGS_1984).
Each sites had one profile opened in the centre of the selected pixel. This soil pit was described and all WRB diagnostic criteria, materials, horizons and features have been documented and the classification name was defined.

Chemical properties were identified using only field tools, like HCl 10 % solution for CaCO₃ content, pH indicators, alfa-alfa-dipiridil test for free iron detection. The interpretation and the translation of the results into quantitative information were done using expert knowledge and the soil description guidelines of the FAO (FAO 2006). Field work for the core set (65 profiles) was done by an international expert group representing all four countries.

Four additional augerings were deepened 100 meter North, East, South and West from the pit. The material taken out from the hole has been put into a 1 meter long tray keeping the original depth. By this way a disturbed profile has been created and was taken back to the pit, where all four were put next to each other in a clockwise order starting from North. Documenting photos were taken from the trays and the pit as well (Figure 2.). All four disturbed profiles have been described in the same way as the pit.
In some cases, where the disturbed material did not let us recognizing the diagnostic the features important for the classification (like the lamelles or clay coatings), the existence or lacking of them was assumed based on the pit description. At the end a table was compiled with five observations and all diagnostic properties, features, horizons and material have been listed for each of the observations (Table 1.).

Based on the five observations per site, a table with the RSG classes and diagnostics were listed with an appropriate proportion rounded up to 20 percents, like 20, 40, 60 80 and 100 percent (Table 2.). 100 percent was given for a certain diagnostic, when it could be found in all observations, while 40 percent was given when 2 out of the five showed the certain feature. The RSG column lists all RSG observed in the site having the proportion list as well, where the proportions are rounded in the same way as for the diagnostics and sums up to 100 percent to a site.

**Site selection methodology**

The sites have been selected randomly. These sites had to be moved to the closest pixel centres and checked for accessibility, potential disturbance or other restricting factors. The whole site optimization procedure was programmed in ArcGIS, no personal bias could have a significant impact on the site selection.

Required input data:
- randomly generated sampling points by ArcGIS random point generator
- the raster dataset to be validated (in this case the e-SOTER Central European window)
- vector-based GIS databases of the settlements, road and railroad networks, water bodies, nature conservation and other protected areas of the country

The site location optimization process

A 5 pixel circle shape neighbourhood around the selected point was selected as potential sampling pixels. Because neither the pits, nor the auger sites should be within settlements or on roads, railways, or any similar locations or even close to them, a 50 meter limit was set as minimum distance from the lines or polygons symbolizing them in the vector databases. This limit was increased to 150 meter because the auger sites are 100 meter far from the profile pit, so to keep the minimum 50 meter distance in the case of the auger sites, the pit should be at least 150 meter far from the excluded areas. Every points falling within a distance of 150 meter from roads, railways, or settlements were deleted from the possible sampling points, just like the points that were closer to the water bodies, or protected areas then this limit.

At the end an accessibility test was performed on the data. A 500 meter maximum allowed distance was set up from the closest road to make sure that the field sampling group does not have to spend too much time on approaching the points and transport the gears there. These two steps of filtering result a set of potentially selectable pixels. The closest to the original randomly selected point was selected as validation pixel.

Results and discussion

Validation of categorical information, like WRB RSG, is a complex problem. Congalton (1991) and Brus et al (2011) reviewed the most common tools and approaches. Taxonomic adjacency or genetic relationship within a certain set of soil forming factors makes a significant difference in the level of misclassification (Phillips, 2013). Misclassifying a pixel to a related RSG or to a “nonsense” RSG does not mean the same level of uncertainty. Minasny et al (2009) has published an approach to quantify the differences between the soil classes by estimating the taxonomic distances for the WRB RSG classes. This approach is very promising to solve the problem of taxonomic adjacency and quantify the taxonomic differences. However, the variables and their weights used to calculate the taxonomic distances are needed to be further refined for a more realistic picture.

Besides of the lack of an advanced procedure for validation, the most limiting factor is the lack of appropriate, unbiased datasets describing the within-pixel variability, that can be used as ground truth for the validation. The aim of the ValiDat.DSM is to support new initiatives to develop a more appropriate and standardisable way of categorical soil data validation.

The ValiDat.DSM dataset has three major forms of information. Table 1 shows the field recording sheet. It describes the profile physical and chemical properties needed for the WRB classification procedure and all diagnostics that was identified in the profile and the official WRB classification category. The second half of the table records all diagnostics for the four augerings done 100 meters North, East South and West from the profile and also the WRB classification names. This table can be used to understand the site when data used for scientific purposes. Table2. is derived from table 1 by interpreting the soil variability
expressed in a selected set of diagnostics important in Central Europe and by the WRB RSG (Dobos et al. 2013). The tabulated information is complemented with soil profile photos and photos on the landscape and the four auger sites in one picture. This latter one is a magnificent tool for soil diversity representation.

This information can be used as field/ground truth data for validating soil categorical information with estimated proportions or occurrence probabilities. Having information on the spatial share of the soil classes within the pixels, advanced techniques can be used to assess the real reliability of the datasets. The validation can be done considering the taxonomic adjacencies/distances (Phillips, 2013, Minasny and McBratney, 2007) between the WRB RSG classes and defining similarity factors to express their relationship in the quantification of the level of misclassification/uncertainty.

This dataset can be used for research purposes as well for soil variability studies within different soil forming environments important for soil mapping and for the definition of the minimum set of sampling sites for mapping and validation.

CONCLUSIONS

The ValiDat.DSM dataset has been initiated for Central Europe with the contribution of four countries, Czech Republic, Hungary, Poland and Slovakia. The dataset is freely available after registration in the project site (http://www.uni-miskolc.hu/~soil/index.html). Data is presented there in several ways, excel sheet format and the documenting sets of photos and in several kind of GIS environment for visualization helping the users understanding the spatial relationships.

The dataset is a good tool for validating DSM derived soil datasets and for scientific researches on soil variability within different soil forming conditions. At the end each validation sites – pixel area - have 5 observations. Therefore the overall purity - defined as the proportion of the mapped area covered by a certain soil class – can be predicted.

ACKNOWLEDGEMENT

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REFERENCES


Table 1. An example of the validation dataset

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Table 2. The interpreted validation dataset

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