Elaboration of digital soil map products for the support of terroir mapping

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Abstract

A "terroir-based approach" is needed for the characterization of viticultural land and the survey of the state of the vineyards. Soil plays dominant role determining the viticultural potential and terroir delineation. Relevant soil property map products can be created by the application of digital soil mapping (DSM) methods. DSM methods use spatially exhaustive, environmental auxiliary variables related to soil forming processes for spatial inference., which should be in direct or indirect relation with the target soil property and should provide full coverage for the target area. The soil-landscape relation can be modelled by geostatistical and data-mining methods. In this study regression kriging and classification trees methods were used to predict the target soil properties.

The summary of the project workflow – the design of sampling strategy, field survey, digital soil mapping process – and some examples of the resulting soil property maps indicating their applicability in terroir delineation will be presented.
Keywords: digital soil mapping, terroir mapping, regression kriging, classification trees

1 Introduction

Terroir is a homogeneous area that relates to both environmental and cultural factors, that influence the grape and wine quality. Soil plays dominant role in terroir determination and delineation. According to viticultural experts, the most relevant soil properties are drainage, water holding capacity, soil depth and pH. Not all of these soil characteristics can be directly measured, therefore the synthesis of observed soil properties is needed to satisfy the requirements of terroir mapping.

2 Data and methods

2.1 Study area

Our study area is located in Hungary, in the Tokaj Wine Region, which is a historical region for botrityzed dessert wine making. Tokaj Mountains was formed mostly by Miocene volcanic activity, where andesite, rhyolite lavas and tuffs are characteristic and loess cover also occurs in some regions (Zelenka et al., 2012). The various geology and morphology of this area result diversity in soil types and soil properties as well.

2.2 Data

The soil sampling strategy was designed to be representative to the combinations of basic environmental factors (slope, aspect and geology) which determine the main soil properties of the study area. Field survey was carried on 2 levels. At first soil samples were collected from 200 sites to obtain a general pedological view of the area. In the second stage the sampling strategy was designed based on spatial simulated annealing technique (van Groenigen et al., 1999) taking into consideration the results of the preliminary survey and the local characteristics of the area and further 650 samples were collected. The data collection regarded soil type, soil depth, parent material, rate of erosion, organic matter content and further physical and chemical soil properties which support the inference of the proper soil parameters.

The applied environmental auxiliary data were selected based on the soil forming factors, which determine and/or indicate the local soil properties (Table 1).

Table 1: Summary of the environmental auxiliary variables used in this study.

Environmental auxiliary variables	Nr. of derivated layers	Datasource, reference
Terrain	18	LiDAR (Tomor, 2010)
Geology	16	1:100,000 Geological Map of Hungary (Gyalog & Síkhegyi, 2005)
Climate	2	(Szentimrey and Bihari, 2010)
Landcover	5	hyperspectral aerial imagery (Bekő et al., 2015)
Spectral response	15	Landsat imagery (spectral indices, band reflections)

2.3 Data preprocessing

The environmental covariable maps with different spatial resolution were resampled into a common reference system with a 25 m spatial resolution. The categorical data (land cover and geology) were used in indicator form.

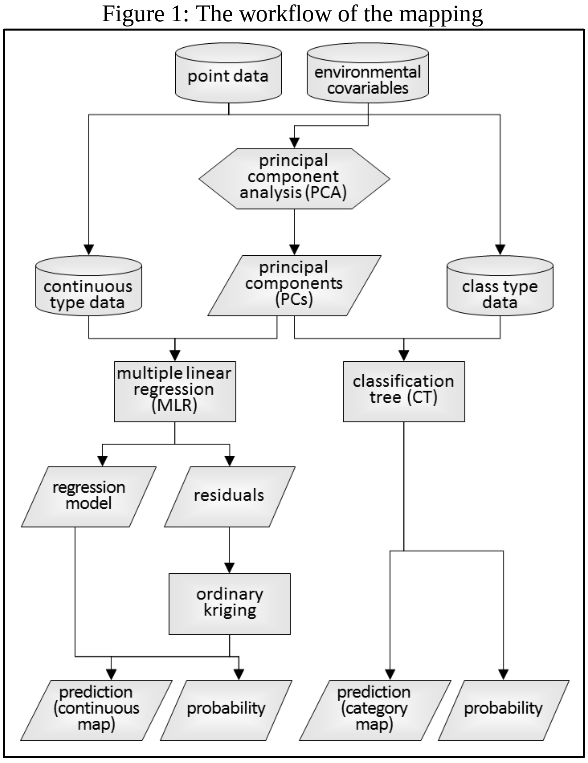
The final set of environmental covariables has consisted of more than 50 layers. In order to decrease the number of predictor variables and to avoid their multicollinearity principal component analysis (PCA) was carried out at first. In the further analysis the first principal components, which explained together the 99% of the variance, were used.

2.4 Method

The spatial extension of soil survey data was performed by two, different spatial prediction methods, which are widely applied in DSM (Fig. 1).

Regression kriging (RK) (Odeh et al., 1995; Hengl et al., 2007) was used for creating continuous soil property maps. RK combines multiple linear regression (MLR) of the dependent variable on auxiliary variables with kriging of the regression residuals. The result of the estimation is the sum of the regression model and the interpolated residuals. In this case the target variables were the viticulturally relevant soil properties. At first they were modelled by the MLR of the environmental covariables, which represent the relevant soil forming factors. Then the difference between the modelled results and reference data were spatially extended by ordinary kriging. The final result of each target soil property prediction is the sum of the regression model and the kriged residuals.

Figure 1: The workflow of the mapping



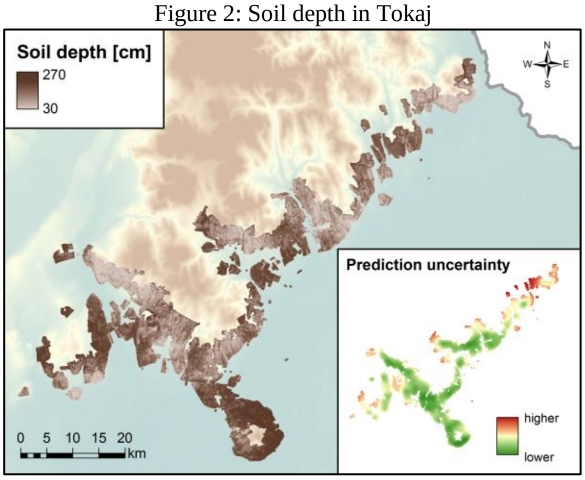
Category type soil maps were compiled by classification and regression trees (CART) method (Brienman et al., 1984; Behrens & Scholten, 2006). CARTs recursively partition the data space to get maximum homogeneity measured by different entropic indices, such as Gini or Shannon index. The rules for each partition can be combined from the initial criterion through the nodes to the final classification in proper SQL sentences. The relationships, which are represented by the rules of the CARTs, together with high resolution environmental covariables allow the creation of high resolution category type soil maps.

Accuracy assessment (included in the applied methods) was also provided for all of the soil map products.

3 Results and discussion

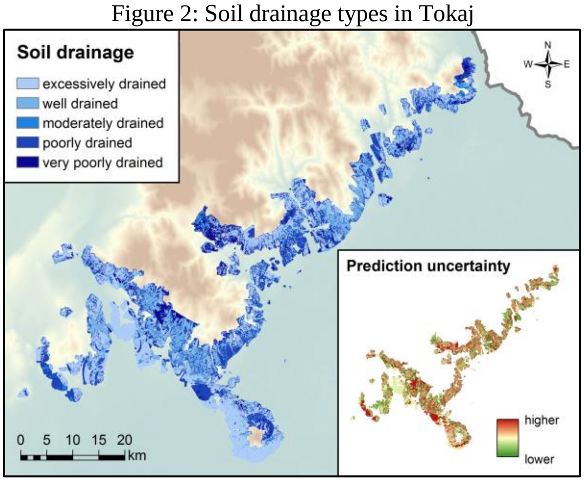
In the framework of the recent project a total number of 33 primary and secondary soil property, soil class and soil function maps were compiled. At first primary soil property maps, such as soil depth, pH, organic content etc. were created (Fig. 2). Based

Figure 2: Soil depth in Tokaj



on primary map further products were compiled characterizing complex soil properties and soil functions (Fig. 3).

Figure 2: Soil drainage types in Tokaj



A set of the resulting maps were created to meet the demands of the Hungarian standard viticultural potential assessment, while the majority of the maps were intended to be applied for terroir delineation. Some of these latter products were used to predict specific climatological parameters (e. g. the frequency of frost damage) and agronomic properties (as potential growth rate, earliness, stock selection). The soil maps together with the climatological, terrain and agronomic map products enable the terroir delineation in the area.

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