Increasing accuracy of a spatio-temporal soil information system by digital soil mapping and field GIS

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SUMMARY
Elaboration of a detailed, complex national spatial soil information system accompanied with its appropriate desktop and field reambulation are steps toward a spatio-temporal soil information system. Kreybig Digital Soil Information System (KDSIS) is a Hungarian spatial soil information system (SSIS) with a nominal spatial resolution of 1 :25,000. KDSIS is still under construction which process goes far further the simple digital reproduction of the information originating from Kreybig soil survey. Its compilation involves both its integration within appropriate spatial data infrastructure and updating with efficient field correlation, which make an inherent refinement and upgrading of the system possible. Desktop reambulation is carried out applying digital soil mapping toolsets. Field-based updating of KDSIS has been done using field GIS technology.

KEYWORDS: *spatio-temporal soil information system, reambulation, digital soil mapping, field GIS*

INTRODUCTION
Soil surveys, soil maps, spatial soil information systems, soil geographic databases, are all designed for fulfilling the requirements and demands of society, which increased dramatically in the last decades (Mermut & Eswaran, 2000). Traditional soil survey is time consuming and expensive, new conventional surveys in the near future are very unlike, consequently methods exploiting existing information are becoming increasingly important (Nachtergale and van Ranst, 2002). In the recent digital era spatial soil information systems (SSISs) are playing a more and more important role in this context (Lagacherie & McBratney, 2004; Rossiter,(2004).

A key issue of applicability of SSISs is their accuracy. Essentially, the main practical aim of soil surveys and soil maps is prediction (Leenhardt et al., 1994). It simply means that certain soil feature is estimated for a whole region based on available soil data collected at localized sample points. The traditional tool of this information extension is the classical soil map using soil mapping units. Crisp soil maps subdivide the region into disjunctive units in a way that within heterogeneity of soil properties is less than for the whole territory (Beckett and Webster, 1971). Numerous novel methods have been developed for producing more accurate soil maps; traditional crisp soil maps however are still extensively applied, since they offer the most easily interpretable results for the majority of users (Leenhardt et al., 1994). On the other hand accuracy of crisp soil maps can be increased in several ways: with the refinement of soil contours; with the subdivision of mapping units taking into consideration smaller within patch inhomogeneities; and with the refinement of attribute information (more recent data, more precise measurement, up-to-date methodology, more appropriate classification etc.).

Digital soil mapping (DSM) integrates the recent developments in numerical soil mapping techniques with the knowledge on soil cover which has been accumulated by soil surveyors. A body of research work in geographical information science heralds the evolution from classical raster or vector GIS tools limited to the collection and storage of all kinds of spatial data, to more sophisticated systems able to represent more complex spatial models, and to embed spatial reasoning procedures such as inductive learning, or hierarchical reasoning. The development of DSM methods has been a growing activity for the past decades. DSM with the computational power integrated into modernised GIS packages provides new solutions for the improvement of SSISs (http://www.digitalsoilmapping.org/).

HUNGARIAN SPATIAL SOIL INFORMATION

A great amount of soil information is available in Hungary due to former agrogeological surveys. The collected data are available in different scales: national, regional, micro-regional, farm and field level and generally they are related to maps (Várallyay, 2002). However, similarly to the great majority of the world, large scale, comprehensive new surveys cannot be expected in the immediate future. In the 1990s a great deal, dominantly the small-scale of these soil related data were converted into digital format and organized into SSISs (AgroTopo: Várallyay & Molnár, 1989; HunSOTER: Várallyay et al., 1994; MERA: Pásztor et al., 1998; SOVEUR: Várallyay et al., 2000). Nevertheless more detailed SSISs are strongly expected by numerous potential users (land users, planners, policy makers, legislative officers, engineers, scientists etc.). The next step in spatial resolution would be featured by a scale of 1:200,000 up to 1:20,000 (with a nominal spatial resolution of 40-400 m or 0.16-16 ha in territorial units) (Lagacherie & McBratney, 2004), also required by European Soil Protection Strategy (CEC, 2002) in accordance with INSPIRE principles (CEC, 2004), as it was discussed in details by Dusart (2004).

In Hungary, as primary importance, GIS adaptation and digital reambulation of the results of the practical 1:25,000 scale soil-mapping programme hallmarked by Kreybig is under construction (Szabó et al., 2000; Pásztor et al., 2002; Szabó et al., 2005; Pásztor & Szabó 2005a). There is much more utilizable information originating from this survey, than it was processed traditionally and published on the map series and in reports, and what is provided by simply archiving them digitally. The surplus information should be exploited by the new technologies provided by GIS and DSM. Furthermore a true SSIS can and should reach higher levels of digital processing.

In traditional soil survey representative soil profiles are commonly used for the linkage of detailed soil properties originating from soil profile description and analysis and the mapping units of crisp soil map representing the pedological variability of land (Leenhardt et al., 1994). There was a unique approach introduced by the Kreybig survey method, namely the application of the so-called non-representative soil profiles occurring within soil mapping units (Kreybig, 1937, 1938). Traditionally however this special feature could not have been totally utilized due to the limits of classical cartography. They just indicated the non-mappable (within soil unit) pedological heterogeneity of the area. New technologies however make the surplus information provided by this methodology exploitable, which can be incorporated into the compilation process of KDSIS.

REAMBULATION OF KDSIS

Integration of Kreybig Digital Soil Information System within appropriate spatial data infrastructure (SDI) and its updating with efficient field correlation make an inherent refinement and upgrading of the system possible as well as the estimation, measurement of the reliability of the system. As a result, the raw information processed using appropriate methods together with complementary spatial, digital, environmental data, a higher level, more accurate and consequently more reliable system could be developed. During its development different stages of KDSIS provides soil information on different level of accuracy. This kind of multilevel feature can be also preserved and even utilized.

KDSIS provides various opportunities for increasing its spatial and thematic accuracy on soil properties. Spatial refinement of mapping units is mainly based on DSM tools. Contours of soil patches can be reshaped using more detailed/recent/accurate/reliable indicator environmental covariables (DEM derived terrain features, remotely sensed spatial information, ancillary data collected with non-invasive soil sensors etc.). New soil patches can be deliniated integrating Kreybig profile methodology and SDI (figure 1).

Soil attribute information could be also updated with recent fieldwork and sampling which is supported by field GIS tools. This latter however can also be used for spatial refinement taking into consideration field experiences. In our paper we are going to present GIS based methods developed for the spatial and thematic refinement, improvement of Kreybig Digital Soil Information System.

Upgraded KDSIS makes the compilation of up-to-date (crisp) soil maps possible. Mapping units of the old and new maps may differ due to several reasons. There are reshaped contours, new soil patches, units with changed attributes on the the map presented in the bottom of figure 2 as compared to upper map. Accuracy and reliability of the upgraded map is significantly highher.

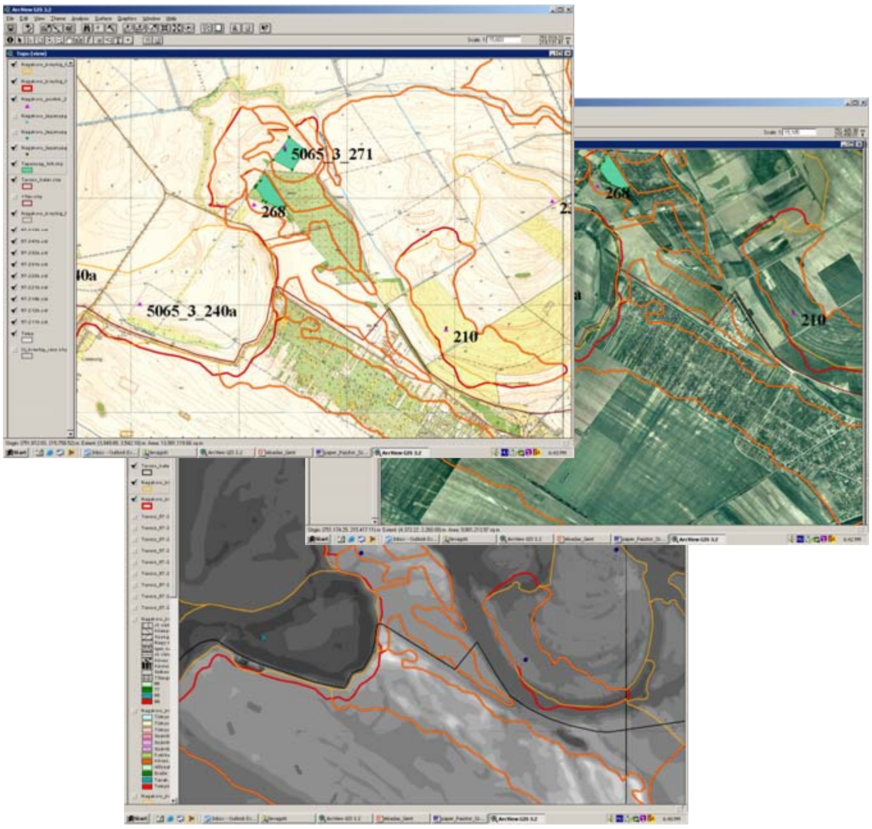

Figure 1: Reshaping soil contours and deliniation of new mapping units using environmental, covariable, spatial data.

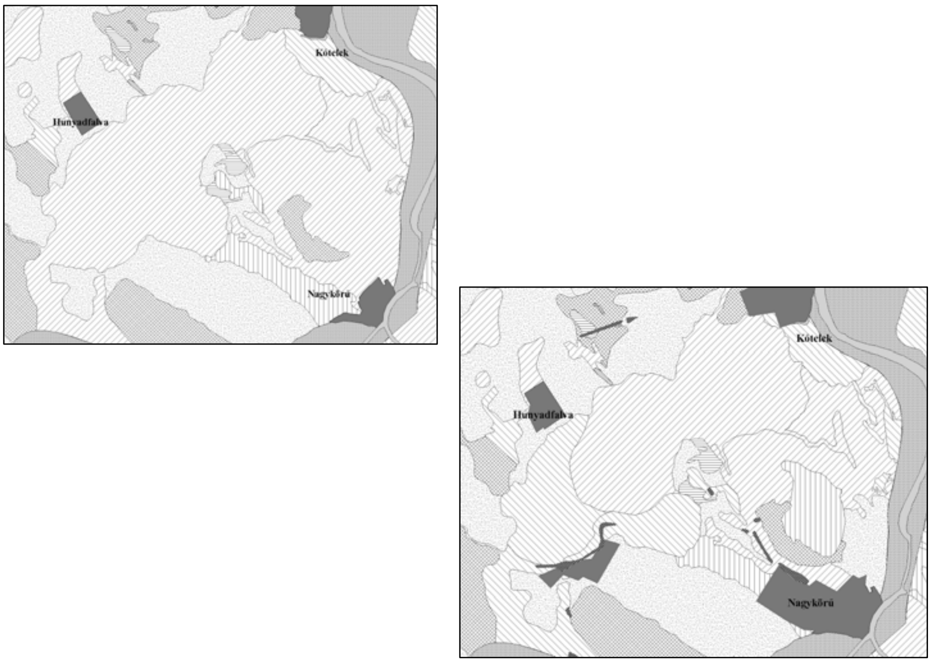

Figure 2: Map of chemical soil properties for Nagykörű pilot area based on KDSIS before reambulation using merely archived information and based on KDSIS integrating desktop and field reambulation results respectively.

APPLICABILITY OF REAMBULATED KDSIS

Implication of new sampling data collected at revisited sites makes the comparison of archived (and so far stored) and newly surveyed data possible. Thus changes in soil properties can be identified (as an example see figure 3). This in one hand should be recorded in the database thus updating it. On the other hand trends can be identified in soil characteristics and functions, degradation processes can be realized and/or forecasted. It can serve as reference to the study of anthropogenic effects. Joint management and application of multi-temporal spatial soil information within an appropriate relational database management system (RDBMS) and GIS environment makes KDSIS also a spatio-temporal soil information system (Pásztor & Szabó, 2005b).

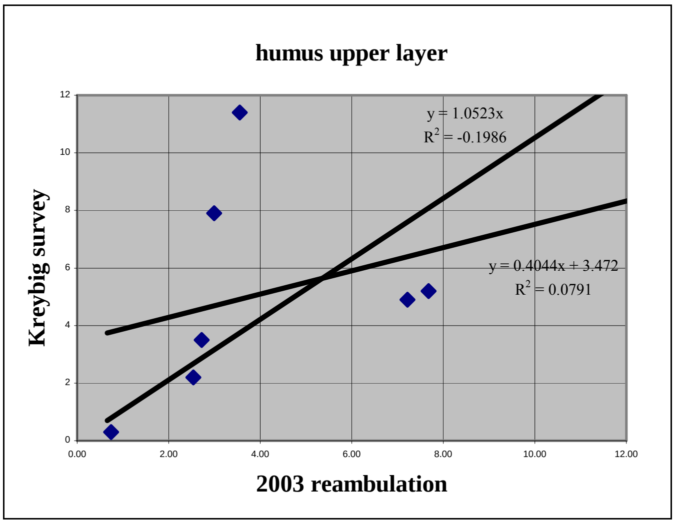

Figure 3: Changes in organic matter content.

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