Landform mapping for SOTER at scale 1:1 million using SRTM-DEM

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Abstract
A digital soil mapping based procedure has been developed and tested to support the SOTER (SOil and TERrain) digital database development. This quantitative procedure was aimed to maintain the original mapping concept and create a database analogue to the “manually” created, existing SOTER databases. The SOTER mapping unit delineation is based on physiographic criteria, namely slope, relief intensity, hypsometry and dissection. These terrain features were derived from an SRTM digital elevation model. The SRTM data were processed to remove the forest-generated elevation distortion and to create an artefact-free SRTM-DEM. Several GIS techniques were employed to translate the SOTER mapping concept. The traditional – manual – delineations and the quantitative procedure results have been compared and evaluated, and found to be significantly dissimilar. In order to explain the differences, the traditional SOTER delineations were tested against the SRTM based terrain features, like slope percentage and relief intensity. These tests showed significant discrepancy between the corresponding terrain feature classes and the SRTM overlays. The results proved that the manual SOTER unit delineations often do not represent the corresponding terrain features in majority. Therefore, the traditional and the quantitative manners of soil unit delineations are by their nature not comparable.

Key Words
Digital soil mapping, small scale databases, SOTER, SRTM, digital terrain modelling.

Introduction
Until recently, only manual methods were used to delineate SOTER (SOil and TERrain Digital Database) Units (ISRIC 1993). The aim of the present study was to develop a quantitative method to derive terrain classes that maintain the SOTER mapping concept and test the feasibility of reproducing existing, manually created database using Digital Soil Mapping (DSM) tools and environmental covariates.

Materials and methods
The procedure to generate the terrain units was developed by Dobos *et al.* (2007). This procedure was applied in this study with slight modifications. The aim was to develop a quantitative method to derive terrain classes corresponding to the SOTER concept (ISRIC 1993) using Shuttle Radar Topography Mission (SRTM) data. The SRTM data was pre-processed to remove the artefacts and the elevation distortion due to the forest cover using the procedures developed by Köthe and Bock (2009). According to the manual, four terrain attributes are used to define the SOTER Terrain Unit: hypsometry (elevation), slope percentage, relief intensity and dissection. The GIS layers of these attributes were derived from the SRTM digital elevation model by translating and reformatting the terrain class characteristics given by the SOTER manual. These four layers are combined to produce the complex landform classification. This combined layer was then vectorized, and finally generalized to achieve the polygon size limit appropriate for the 1:1 and 1:5 million scales of the database to be produced. The original procedure has been slightly modified. The PDD layers were calculated only for the areas with a relief intensity higher than 50 meters/ km^2.

The polygon system derived through the quantitative procedure has been compared with the existing, hand drawn SOTER polygon system of the SOVEUR database (Batjes 2000). However, no quality measure for the SOVEUR database was available. Therefore, the existing, traditional SOTER polygon system was tested against the SRTM derived terrain parameters. Two terrain parameters, the slope and the relief were chosen for the test and were derived from the SRTM DEM. The traditional SOTER unit system and the continuous slope and relief layers were overlaid, and descriptive statistics were calculated to characterize the area under the SOTER polygon having the same geomorphological classes.

Results and discussion

The polygon system derived by the procedure follows the main geomorphological trends, and identifies terrain units according to the scale (Figure 1). As a result of the rigorous, quantitative procedure, the polygons represent relatively homogeneous units as far as the four terrain parameters are considered. In order to test the resulting database a comparison with the traditional, manually delineated polygon system of the SOVEUR was performed. The overlay of the two datasets is shown in Figure 1. The SOVEUR database is compiled from manually delineated polygons, produced by the participating countries individually. Therefore, the national windows may have different approaches and interpretations of the SOTER manual and the national diversity of mapped physiographic and soil features. The quantitative SOTER is fully SRTM based, following the procedure described above, theoretically representing the SOTER concept. However, when the two polygon systems are overlaid, no clear similarity can be identified between them. The SRTM-based system has higher polygon density and a better match with the background SRTM image, from which it has been derived. It has to be noted here that the SOVEUR polygons already contain the parent material information as well, and the scale of that is also a little bit coarser, 1:2.5M, while the SRTM-derived one is 1:1M, which may explain some of the discrepancies. Despite of these differences, the major lines should have some similarity, which is not the case here. Based on this experience, we may conclude, that the digital procedure failed to reproduce the same database. However, the differences may have resulted from the non-rigorous application of the SOTER manual as well when it was used in a traditional way. Therefore, a quality check of the traditional database was performed using the SOVEUR database. Two terrain parameter layers, the slope and the relief intensity, were calculated from the SRTM database, classified into the SOTER classes and were used as ground truth information. The SOVEUR polygons classified into the same geomorphologic units – having defined slope and relief intensity classes - were selected and were used to overlay/mask the classified slope and relief images. In theory, the majority of the slope and relief layer pixels should match with the correlating polygon classes. The results of this test did not confirm this hypothesis.

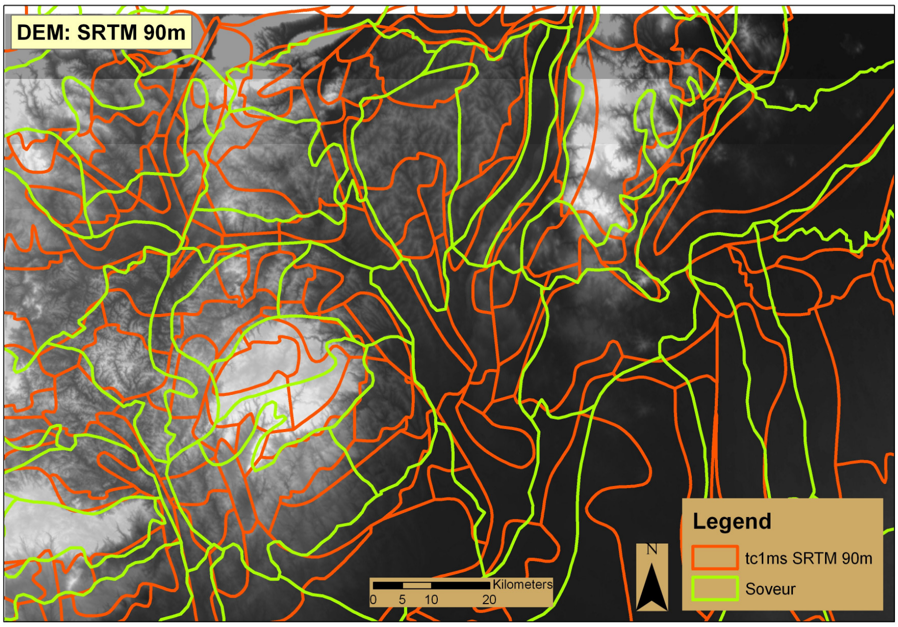

Figure 1. The overlay of the traditional (SOVEUR) and SRTM-derived (tcm1s SRTM 90 m) polygon systems.

The databases of six countries (Hungary, Slovakia, Czech, Romania, Ukraine and Poland) were tested, but only the Hungarian results are presented here which shows the main trends of all databases (Tables 1 and 2). The results show very distinctive trends, namely the higher the relief and the slope the lower the match between the traditional SOTER and the SRTM-derived terrain parameters. The traditional mappers tended to overestimate the slope and the relief classes when allocating the attribute information to the polygons. Therefore, the low relief classes lost some of their members while the remaining area showed a clear and pure membership of the corresponding class. However, the areas with overestimated relief and slope have only a small portion of the real members, complemented with the areas having lower values in reality, but being misclassified and shifted to the higher relief/slope areas. The differences are often shocking, like in the relief intensity class for medium gradient mountain case, where not even one pixel matches to the corresponding polygon. Only one-fourth of the area of the polygons having higher than 50m/km^2 relief intensity assigned to them matches to the corresponding SRTM pixel class (Table 2). The same trends occur in the higher slope classes as well (dissected plain, valley, medium gradient escarpment) (Table 1).

Table 1. The validation of the slope classes of the SOVEUR database using the SRTM-derived data.

Landform classes of the SOVEUR with the corresponding slope class	Total number of SRTM pixels within the corresponding polygons	The number of SRTM pixels matching the polygon class	Percent of matching SRTM pixel classes
low-gradient foot slope, 0-8%	874532	812925	92,9
valley floor, 0-8%	586637	550996	93,9
plain, 0-8%	9867338	9834630	99,7
plateau, 0-8%	149332	133084	89,1
dissected plain, 8-30%	851363	37907	4,4
medium-gradient hill, 8-30%	2527481	500463	19,8
Ridges, 8-30%	46944	9860	21,0
valley, >8%	490751	45657	9,3
Narrow plateau, >8%	287686	43245	15,0
Medium-gradient mnt. 15-30%	621468	97943	15,7
medium-gradient escarpment zone 15-30%	62838	3964	6,3

Table 2. The validation of the relief intensity classes of the SOVEUR database using the SRTM-derived data.

Landform classes of the SOVEUR with the corresponding relief intensity class	Total number of SRTM pixels within the corresponding polygons	The number of SRTM pixels matching the polygon class	Percent of matching SRTM pixel classes
low-gradient foot slope, 0-100 m/km^2	875214	862084	98,50
valley floor, 0-100 m/km^2	587187	579422	98,68
plain, 0-100 m/km^2	9869464	9866850	99,97
plateau, 0-100 m/km^2	149332	146632	98,19
medium gradient escarpment zone, <600m/2km	62838	62838	100,00
dissected plain, <50m/slope unit	853038	803471	94,19
medium gradient hill, >50m/slope unit	2529428	661159	26,14
Ridges, >50m/slope unit	46944	12930	27,54
medium-gradient mnts >600 m/2km	621468	0	0,00

Conclusions

The original aim of this study was to develop a quantitative procedure to speed up the database development and make use of the emerging technology and digital data sources, such as Digital Elevation Models. The SOTER manual describing the database development procedure was published in 1993. Since then, a significant portion of the World has been covered with SOTER databases. In the last decade Digital Soil Mapping (DSM) techniques and the supporting digital databases have changed the way of mapping and database development. These techniques have been adapted by this group and a quantitative procedure was developed to replace the traditional methodology of SOTER development. A rigorous procedure to maintain the original mapping concept was introduced and tested here. The comparison of the traditional and the quantitative procedure showed major discrepancies, which were difficult to explain. Therefore, a quality check on the SOVEUR database was performed using SRTM-derived terrain parameters as ground truth information. The results demonstrated that the thematic content of the traditional databases do not always match with the corresponding/assigned information. The characteristics/quality of a database depends on the procedure, the input data sources and the interpreter of the procedure. Even having a more or less clearly defined procedure with quantitative classes, a manually made database often introduces much shift from the original content. Therefore, translating a manual procedure to a quantitative one to reproduce a map or a database raises some important questions among which the first is: how to maintain the original mapping concept and conform to the original methodology defined by the manual of mapping procedures? However, the traditional maps have a great portion of subjectivity which may result from different interpretations when the procedure is used by different experts. This factor also has a significant impact on the final product. The final dilemma that remains on the table is what to reproduce, the procedure or the map? The new environmental covariates and the new DSM tools represent a different developing environment, and that necessarily means different products. Maintaining the linkage between the traditional and the quantitative products is not always possible and not always necessary either.

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