Approaches to the solution of a soil map of the Czech Republic at the scale 1:250 000 using SOTER methodology

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ABSTRACT

Soil map at the scale 1:250 000 was set up by means of transformation of the published and later digitised soil map of the Czech Republic. The legend to this map reflects a new classification system of Czech soils that can easily be correlated with the reference international classification system FAO-WRB. In the next step this map was converted into the SOTER system, which links the soil cover to the geomorphology. The modification of the original SOTER procedure consisted in the abandoning of the consequent hierarchy geomorphology – lithology – soil associations. Only in territories characterised by rather shallow transported slope deposits over compact or consolidated rocks was this principle observed in the SOTER unit delimitation. In flat landscapes covered with deep sediment deposits the prevailing soil cover (mosaics of taxonomic units and their parent materials) determines the borders of SOTER units. Ten major landscape units were delineated. They are based on relief intensity and hypsometry. The slope gradient map enables a detailed insight into the landscape geomorphology. 158 SOTER units are defined by the combination of 10 major landscape units, 21 grouped soil parent materials and 19 grouped soil units. The single factors and their combinations are reflected in GIS layers that can be matched with the map of soil associations. The major soil regions, which are conceptually close to the SOTER units, will be delimited as homogeneous mosaics of the individual SOTER units with respect to regionally integrating factors (climate, vegetation). The interconnection of the geometric and attribute data generates the soil information system. This system is anticipated to be used for the soil policy regulation both in the Czech Republic (PUGIS) and within the EU (EUSIS).

Keywords: soil map 1:250 000; SOTER system; SOTER units; soil GIS

The expanding focus on environmental issues and sustainable development of natural resources evokes the need for precise and quantified soil information in Europe at the scale 1:250 000. For the standardisation and permanent improvement of soil classification, which initially represented only soil map legends, a working group (IRB) and later a working commission was established. World reference base for soil resources (WRB 1998) was proposed. This soil classification is characterised by a limited hierarchy of taxonomic levels (three for medium scale maps). The American *Soil Taxonomy* (1975, 1999) also contributed to the unification of taxonomic classification at the world scale.

The delineated mapping units of large- and medium-scale soil maps display soil mosaics – soil associations of taxonomic units (and some additional information concerning texture classes, soil phases, slope phases). Unfortunately, the progress in soil taxonomic classification is not supported by unification of the systematics of soil associations. Many authors (Dudal et al. 1993) stress the fact that for non-specialised users soil maps should preferentially reflect the interrelations of soil unit distribution and landforms and landscape lithology. Soil maps should delineate the areas with a homogeneous set of soil and terrain features. The SOTER system was proposed by ISRIC (Engelen and Pulles 1991) to fulfil these needs. Soil and terrain units represent the unique combination of terrain and soil characteristics. SOTER is not only a mapping approach but also a land information system (Batjes and Engelen 1997), which involves both the spatial and attribute database. The original SOTER approach represents a descendent way of the delineation of areas – polygons made up of terrain and soil elements. The highest level of the procedure is defined by physiographic criteria, the lowest one by soil classification. SOTER units comprise: terrain units (physiography – major landforms, general lithology), terrain components (slope, mesorelief, soil parent materials) and soil components (soil associations, complexes). The above-mentioned original version of the SOTER system can be applied thoroughly in countries with limiting coverage by soil maps (especially at a large scale).

Based on the feasibility study on the creation of a soil map of Europe at a scale 1:250 000 the SOTER approaches were recommended (Dudal et al. 1993). Some modifications are admitted at larger scales, where the hierarchy terrain soil loses its importance gradually. The 1:250 000 georeferenced soil database of Europe should provide precise and internationally harmonised soil information for European organs (EC, EEA) and EU member states. The European Soil Bureau was charged with the implementation of this project. Two versions of the procedure

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manual for the elaboration of the above-mentioned soil database for Europe were set out (Finke et al. 2000).

MATERIAL AND METHODS

The creation of a soil map of the Czech Republic at a scale 1:250 000 in the SOTER system was derived from the map of soil associations at a scale 1:200 000 (Němeček et al. 1970–1973). This synthetic soil map of soils used both in agriculture and in forestry was published by the Ministry of the Environment in co-operation with the Ministry of Agriculture (Novák et al. 1989–1993). This map was digitised at the Department of Soil Science and Geology of the Czech University of Agriculture. Some maps of soil forming factors of other authors and maps of important soil properties (humus, base saturation) were also digitised for matching them with soil association distribution.

The mentioned soil map (at the level of subtypes and their parent material forms) was transformed into a module 1:250 000. The transformation consisted in the transfer of dominants, accompanying and accessory components of soil associations into a new taxonomic soil classification system (Němeček et al. 2001) that enables the more precise correlation with the WRB (1998) – the principal unifying element of the European project.

The SOTER system was modified for the use in a country which was surveyed at a large scale in the following way:

- combination of both descendent and ascendant procedures was applied
- in flat areas covered with deep sedimentary parent materials the SOTER units prefer soil taxonomic units including their parent material forms to relief features
- in lowlands, highlands and mountains with medium-deep sedimentary covers over compact and consolidated rocks the SOTER units reflect the original sequence: geomorphology, lithology, soils

A special problem of the creation of SOTER units was the classification of major landform units, taking into consideration the demands of the international SOTER methodology and satisfying the conditions of the Czech Republic.

The setting up of the SOTER map issued from the experience obtained in the course of the compilation of CZE-SOTER map at a scale 1:1 mil. for the international project SOVEUR (Kozák and Němeček 2000, Němeček et al. 2000).

RESULTS AND DISCUSSION

The SOTER system of the Czech Republic at a scale 1:250 000 consists of:

a) GIS layers
- of SOTER units
- of geomorphologic regions
- of soil associations (displayed are dominants with a possibility to identify also accompanying and accessory components)
- of slope gradients and relief intensity

b) database of soil profiles

We are dealing only with the geometric (polygon) data in this contribution. The above mentioned GIS layers were checked up and harmonised.

The background of the SOTER system is the map of soil associations.

For the processing of geomorphologic regions (major land forms) the following basic data were used: slope gradients, relief intensity, hypsometric levels. They were grouped into the following classes:

a) slope gradients in °: 0–1, 1–3, 3–5, 5–8, 8–15, 15–25, 25–35, > 35

b) relief intensity m/2 km: 0–30, 31–50, 51–75, 76–100, 101–150, 151–200, 201–300, 301–450, 451–600, > 600

c) hypsometric levels in m above sea level: 0–200, 201–450, 451–600, 601–750, 751–900, 901–1200, 1201–1600

The delineation and classification of geomorphologic regions (major landforms) was deduced on the basis of:

a) the combination and classification of all three above listed factors,

b) the combination of the relief intensity and hypsometric data

The combination of all factors that emphasised slope gradients results in 17 categories which could be reduced to seven classes. The second mentioned approach can be preferred due to the fact that ten continuous areas are delineated. It is reflected in the scheme in Table 1.

The codes have the following meanings:

P	plains
LL	level areas in lowlands
LF	flat lowlands
LF/LD	flat lowlands < 8°, dissected > 8°
LD	dissected lowlands
HL	level areas in highlands
HF	flat highlands
HD	dissected highlands
ML	level areas in mountains
MF	flat mountains
MD	dissected mountains

The main geomorphologic regions with similar names are also found in the classification of Demek (1965) and Kudrnovská and Kousal (1971), but they are based on another concept of combinations of relief intensity and hypsometry. The slope gradient becomes a separate GIS level in our second concept, which enables the more detailed insight into the land geomorphology and its correlation with the soil cover.

As was already stated, the linkage of geomorphology and soil cover (lithology is involved in the concept of soil forms) is carried out in different ways in two major mega-regions. Soil cover – mosaics of soil taxonomic units and their parent material forms is stressed in the flat relief with deep sediments. In lowlands, highlands and mountains with transported slope weathering products of compact and consolidated rocks the role of major landforms and parent materials prevails.

Table 1. Major landforms (geomorphologic regions)

Relief intensity in m/2 km	Major landform types					
0–30	PL	PL	LL	HL	HL	X	X
31–50	PL	PL	LL	HL	HL	ML	X
51–75	PL	PL	LL	HL	HL	ML	X
76–100	LF	LF	LF	HF	HF	MF	MF
101–150	LF	LF	LF	HF	HF	MF	MF
151–200	LF	LF/LD	LD	HD	HD	MD	MD
201–300	LF/LD	LD	LD	HD	HD	MD	MD
301–450	LD	LD	LD	HD	HD	MD	MD
451–600	X	LD	LD	HD	HD	MD	MD
> 600	X	X	LD	HD	HD	MD	MD
Hypsometry (m above sea level)	0–200	201–450	451–600	601–750	751–900	900–1 200	> 1 200

In the map of SOTER units generated by means of the computer technique from the soil map at a scale 1:250 000, the following indication was used:

a) for grouped soil parent materials
01 – gravelly sands, sandy gravels of terraces, eolian sediments over terraces, coarse textured deep deposits, 02 – loess and loesslike sediments, 03 – polygenetic and glacial loamy deposits, 04 – sandy clays, clayey sands, 05 – marls and clays, often with coarser textured covers, 06 – fluvial sediments, 07 – skeletal or shallow parent materials;
08–19 – transported weathering products of: 08 – granites and similar acid rocks, 09 – gneisses, 10 – micaceous schists and phyllites, 11 – neutrals rocks, 12 – basalts and similar rocks, 13 – mafic intrusives and metamorphites, 14 – limestones, 15 – carbonaceous and non-carbonaceous cretaceous and flysch slates, 16 – carbonaceous and non-carbonaceous sandstones, 17 – coarse textured sedimentary rocks, 18 – medium textured sedimentary rocks, 19 – fine textured sedimentary rocks, 20 – peats, 21 – anthropogenic parent materials

b) for grouped soils
f – fluvisols, r – arenosols, k – cambisols of terraces, c – chernozems and phaeozems, b – luvisols, l – albeluvisols, g – stagnosols, x – rendzinas, pararendzinas (rendzic leptosols), m – modal cambisols, t – eutrophic cambisols, d – dystric cambisols (hyperdystric), p – pelosols, s – podzols, cryptopodzols, o – histosols, q – gleysols, w – pelogleys, u, y, z – urban, dumpsite, cultizemic anthroposols

The following SOTER units were delineated in the territory of the Czech Republic.

A – in plains (and flat lowlands) covered with deep unconsolidated sediments (28 major units)

1. AV alluvial valleys
   - ○ parent materials: 06
   - ● soils: f, q, c
2. TE terrace plains
   - ○ parent materials: 01
   - ● soils: r, c, b, l, k, g, s
3. PA plains (flat lowlands) covered with eolian and polygenetic sediments
   - ○ parent materials: 02, 03
   - ● soils: c, b, l
4. PW plains (flat lowlands) covered with eolian and polygenetic sediments, with waterlogging
   - ○ parent materials: 02, 03, (04)
   - ● soils: g, c
5. PC plains and flat lowlands with marls or clays
   - ○ parent materials: 05
   - ● soils: c, p
6. CW plains and flat lowlands with clays, sandy clays and clayey sands or marls, with waterlogging
   - ○ parent materials: 04, 05
   - ● soils: w, p, c

B – on slope deposits of compact and consolidated rocks, often in more dissected regions of lowlands, highlands and mountains (124 major units)

7. PL plains
8. LL level areas in lowlands
9. LF flat lowlands
10. LD dissected lowlands
    - ○ parent materials: (03, 04), 08–19
    - ● soils: x, t, m
11. HL level areas in highlands
12. HF flat highlands
13. HD dissected highlands
    - ○ parent materials: (03, 04), 08–19
    - ● soils: x, t, d, s (from 16, 17)
14. ML level areas in mountains
15. MF flat mountains
16. MD dissected mountains
    - ○ parent materials
    - ● soils: t, d, s

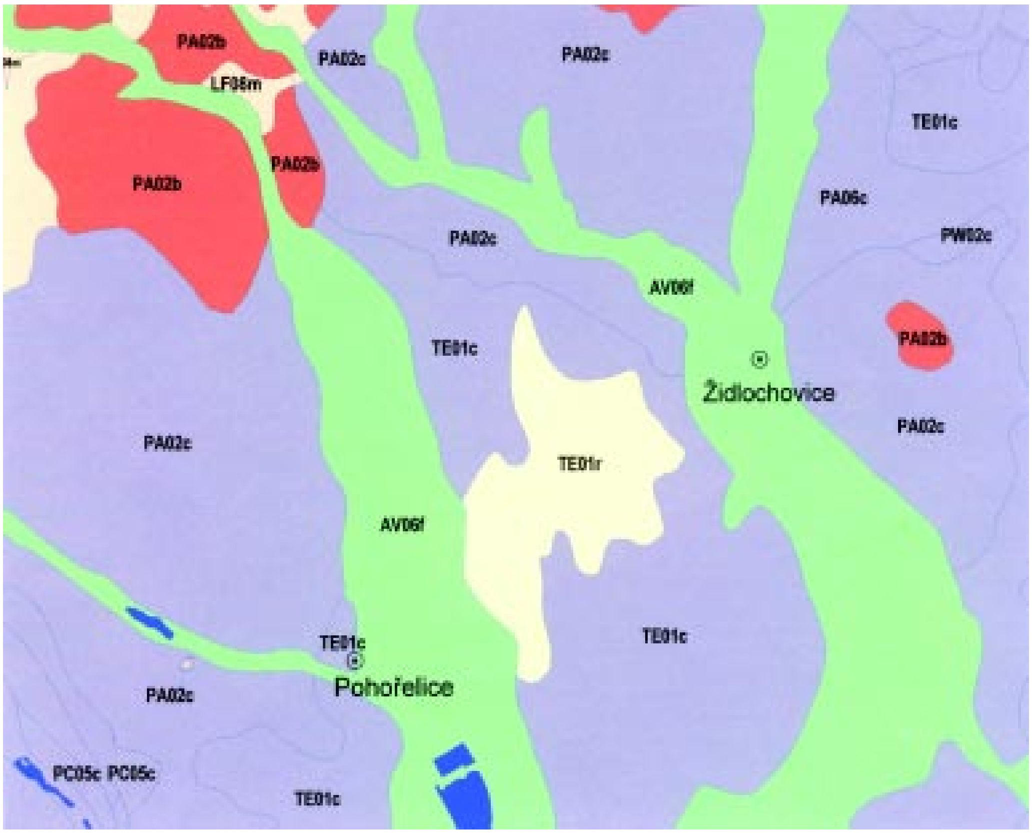

Figure 1. SOTER units of plains (alluvial valleys, terraces, eolian plains); soils are derived from deep quarternary deposits

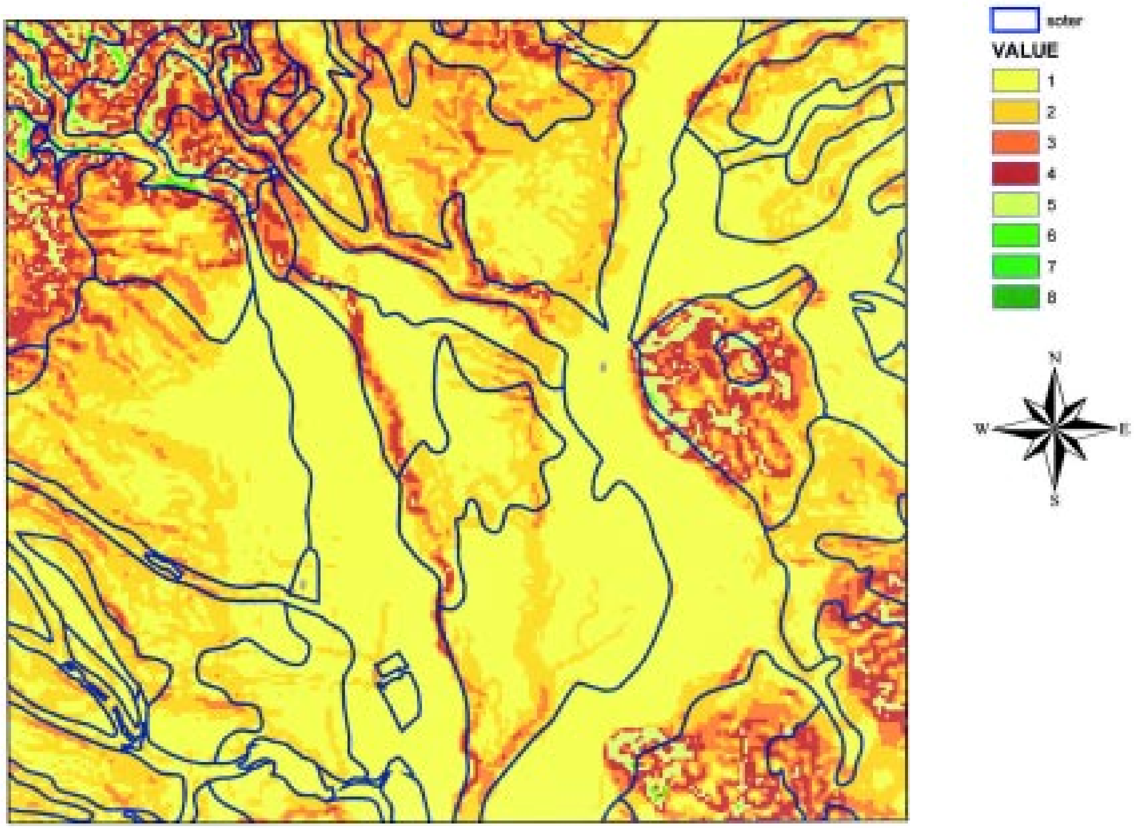

Figure 2. Slope gradients enable a more detailed insight into the local landscape features, especially in flat territories (1:0–1, 2:1–3, 3:3–5, 4:5–8, 5:8–15, 6:15–25, 7:25–35, 8: > 35; in °)

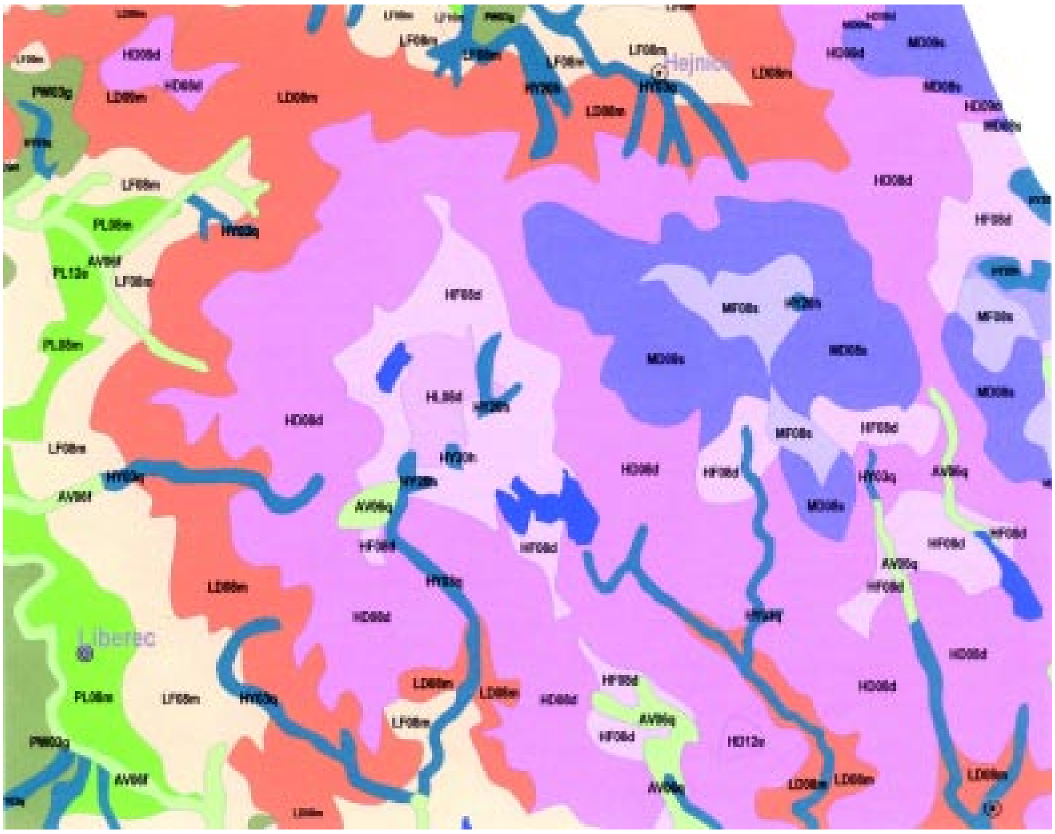

Figure 3. SOTER units in territories with soils from slope deposits of compact or consolidated rocks reflect the original SOTER concept of their delineation: geomorphology – lithology – soils

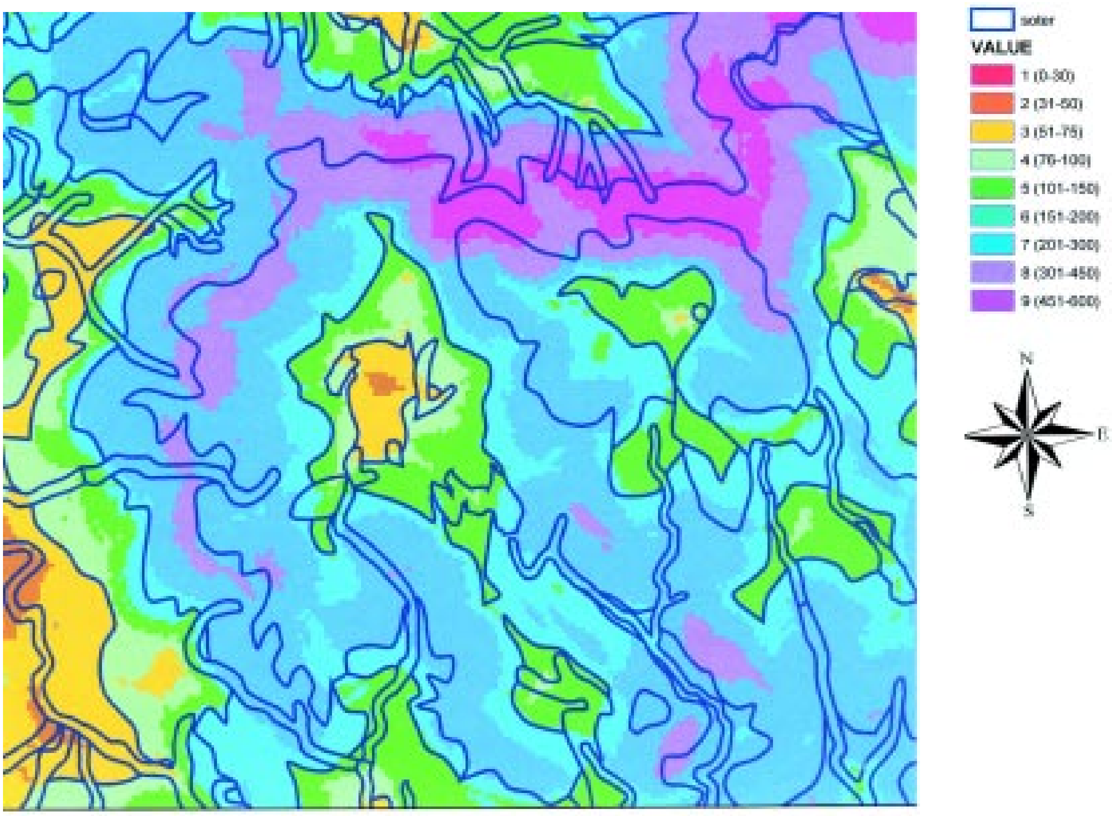

Figure 4. In dissected territories SOTER units conform distinctly with a relief intensity (m/2 km)

C – locally occurring soils

17. HY gleysols and histosols
    - ○ parent materials: 03, 04, 05, (18–19), 20
    - ● soils: q, o
18. AN anthroposols
    - ○ parent materials 21 (or 1–19 in case of z)
    - ● soils: u, y, z

SOTER units are indicated on soil maps in the SOTER system in the following way (see examples in Figures 1 and 2) e.g. TE 01 r terraces, sands, arenosols, PA 02 c plains covered with loess, chernozems.

Figure 1 demonstrates a soilscape that includes the alluvial valley, terraces and plains covered with loess. The role of soils and their parent materials in the diagnostics of SOTER units prevails in the mentioned flat landscapes. Figure 2, which displays the same territory as Figure 1, allows a more detailed insight into the landscape features. Figure 3 shows a predominantly dissected landscape where the geomorphology prevails in the identification of SOTER units. Their delineation conforms at the most with the relief intensity, presented in Figure 4.

The descendent approach proposed for the original compilation of the SOTER soil map at a scale 1:250 000 (Finke et al. 2000) starts from the major landform units and soil regions. We prefer the ascendent way to the original one. The SOTER units will be grouped into landscape megaregions. This kind of work requires some non-computerised effort. Soil regions delineated in the Czech Republic in the past (Němeček and Tomášek 1983, Němeček and Zuska 1989) will become the basis for the delineation of soil megaregions. Their concept will be harmonised with international proposals (Finke et al. 2000).

The soil map in the SOTER system was already used in the framework of the SOVEUR project, which is focused on the vulnerability of soils to contamination.

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ABSTRAKT

Přístup k řešení půdní mapy České republiky 1 : 250 000 v systému SOTER

Půdní mapa v měřítku 1 : 250 000 byla sestavena transformací publikované a později digitalizované syntetické půdní mapy ČR 1 : 200 000. V legendě této půdní mapy byl využit nový klasifikační systém českých půd, který lze snadno korelovat s mezinárodním referenčním klasifikačním systémem FAO-WRB. Dalším krokem byla transformace do systému SOTER, který propojuje půdní pokryv s geomorfologií. Modifikace originální metodologie SOTER se zakládá na opuštění důsledné hierarchie geomorfologie – litologie – půdní asociace. Pouze v oblastech charakterizovaných středně hlubokými svahovinami nad pevnými a zpevněnými horninami byl původní princip dodržen. V plochých územích s hlubokými pokryvy sedimentů určuje hranice jednotek SOTER půdní pokryv (mozaiky taxonomických jednotek a jejich substrátových forem). Bylo vymezeno 10 (po redukci 7) geomorfologických regionů na základě intenzity reliéfu a nadmořské výšky. Mapa svažitosti umožňuje podrobnější pohled na geomorfologii území. Jednotky SOTER jsou definovány kombinací 10 geomorfologických typologických celků, 21 seskupených substrátů a 19 seskupených půdních jednotek. Výsledkem je 158 jednotek SOTER.

Vrstvy GIS zachycují dílčí faktory geomorfologie, substrátů a jejich kombinací, které mohou být srovnávány s půdní mapou. Velké půdní regiony budou představovat mozaiky jednotlivých jednotek SOTER ve vztahu k regionálně integrujícím faktorům (klima, vegetace). Vztahy mezi geometrickými a atributovými údaji tvoří informační systém o půdě. Tento systém bude sloužit pro usměrňování půdní politiky v ČR (PUGIS) i v rámci EU (EUSIS).

Klíčová slova: půdní mapa 1 : 250 000; systém SOTER; jednotky SOTER; GIS o půdě

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