Integration of Soil Information Systems. BIS and SOTER Perspectives – a Review

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Abstract: The article presents an overview and brief characteristics of the selected soil information systems in the Czech Republic. It suggests synchronisation of their development, particularly some convergence of the Land Evaluation Information System and Soil and Terrain Digital Database. In the pilot area of Litoměřice district, it demonstrates the application of the SOTER methodology for the construction of middle- and detail-scale soil maps, using the data from the General survey of agricultural soils. It not only shows the variety of the district soil conditions, but it also supplements them with the data gathered in the 2006 soil survey.

Keywords: soil information systems; soil maps and survey; BIS; SOTER

Land is the only essential factor of production that is not renewable. It is thus necessary to develop and implement such procedures which would treat land in a way not endangering its versatile usability. At present, however, both the quality and quantity of the soil are decreasing (e.g. Janeček *et al*. 2002). That hat can help to stop and change this tendency is an up-to-date soil information database, easily accessible to everyone. The article lists several information systems built in the CR as well as a number of projects incorporating the Czech Republic into the existing international information systems (IS). It is crucial to synchronise the development of these systems not only in order to minimise the costs by using the GIS tools (especially in the long-term perspective), but also to reduce the distances between branches and to implement the idea of:

– integration (symbolised by e.g.: the European Union, the Taxonomic Soil Classification System of the CR, the Synthetic Soil Map);
– a single standardised default data layer (the only source of information) for:
  - recording – Land Registry,
  - soil maps,
  - integration of databases;
– „user-friendly GIS" – a wide range of possibilities for using GIS;
– universal accessibility of the data to a wide range of users, aiming at a prompter up-dating and a competent decision-making at all levels.

The common interest in the soil protection is a significant reason for the cooperation between various organisations and branches in the IS development. All the projects mentioned below (Table 1) link up well with the SOTER international system (Soil and

Terrain Digital Database), in particular through the utilisation of land (in SOTER definition) and future social-economic databases (in SOTER objectives).

MATERIAL AND METHODS

Soil information systems

Soil information systems in the Czech Republic (Table 1)

Land Registry of the Czech Republic

The administration of the Land Registry is entrusted to the Czech Office for Surveying, Mapping, and Cadastre (COSMC). Cadastral documents vary greatly in the map scales, in the range of coordinate systems as well as in the types of processing. The only way to unite this collection of non-homogenous maps is a hybrid cadastral map combining the vector cadastral maps with the hand-drawn raster images (Macoun 2004a).

In 1998, the digitisation of descriptive information from the Land Registry was finished (almost 80 million database clauses in total), and in 2001 the Land Registry Information system was implemented, which changed the database structure – some data previously kept in separate clauses were merged into a single clause.

Since July 2001, the Land Registry digital data have been accessible online; the number of accounts opened for external users has been increasing rapidly (Jirman 2004).

Land Fund of the Czech Republic (LF CR)

The Land Fund of the CR administrates the state-owned land, which accounts for more than 1 million properties with the total area of about 750 000 ha. The hybrid cadastral map processed for the graphic part of the information system of the Land Fund of the Czech Republic is, for the time being, the only map covering the total area of the Czech Republic, namely by maps with the scale of 1:1 000, precisely 1:2 880, transformed into the JTSK system of coordinates.

The maps in the system are arranged by individual districts. Cadastral region is the basic information unit; plot of ground is the smallest information unit in the system. The map layer is supplemented with vectorised cadastre border lines. The stock of the Land Registry cadastral maps is supplemented with the former land registry maps. In order to simplify the identification of the individual plots of ground in both the current Land Registry and the former land registry maps, the plot numbers have been vectorised in most districts. The map information is complemented with black-and-white aerial photographs, which are gradually being replaced by orthophotographic maps in colour.

The system contains also other types of graphic information, e.g. the territorial plan, the layouts of

Table 1. An overview of the soil information systems in the CR

Information systems in the CR		
Soil registration	Land Registry of the CR	COSMC
	Land Fund of the CR (LF CR)	LF CR
	Land Parcel Identification System (LPIS)	MoA CR
Professionally oriented mapping of soil	Map collection of environmental geofactors	MoE CR
	Soil Geographic Information System (PUGIS)	CULS Prague
Economic land evaluation	Land Evaluation Information System (BIS)	RISWC
	Determining less favoured areas (LFA)	MoA CR
Projects incorporating the CR into international IS		
Image & CORINE – Land Cover (I & CLC)		MoE CR
EUSIS and SOTER		CULS Prague
Integrated Administrative and Control System (IACS)		MoA CR

COSMC –Czech Office for Surveying, Mapping, and Cadastre; MoA CR –Ministry of Agriculture of the Czech Republic; MoE CR – Ministry of the Environment of the Czech Republic; CULS Prague – Czech University of Life Sciences in Prague; RISWC – Research Institute for Soil and Water Conservation vineyard tracks, hunting grounds, deposit reservations, etc. The vectorised plot numbers serve as the reference points (i.e. identifiers), which link the graphic part of the information system with the text databases of the Land Registry and the administrative databases of the Land Fund. Among other data attached, there are data on the areas and zones of national parks and landscape preserves as well as smaller protected areas, provided by organisations under the Ministry of the Environment of the Czech Republic (MoE CR); information on the mining areas and deposit reservations, provided by the Czech Mining Office (CMO). The Land Fund GIS comprises also a visualisation of the administrative districts. Together with GPS Trimble GeoXT system, it is possible to transfer the points from the system to the field as well as easily complement the system with the measured data.

The digital maps and text databases of the COSMC are updated quarterly. The geographic system is now being adjusted so that it can be linked up with the information system of the Ministry of Agriculture of the Czech Republic (MoA CR) – IACS (Integrated Administrative and Control System) – and thus it can be accessed via the state administration intranet (Macoun 2004a, b).

Land Parcel Identification System (LPIS)

The European Union obliges all member states to build an explicit system for registering the payment of subsidies, based on truly cultivated areas, established by aerial photographs. Since the Land Registry data cannot be an appropriate source material for the administration of such a volume of subsidies, in 1999 the MoA commissioned a pilot project for the solution of a new system of agricultural land registration. In June 2003, an amendment to the Agricultural Act came into effect (Act No. 128/2003 Coll.), adjusting the procedural rules for updating this registration system, termed LPIS.

Farmers can apply for informational statements and map sets with the scale of 1:10 000 at any regional office of the MoA CR. Besides helping with the processing of the application for the agricultural land grants, LPIS provides farmers with information on the farming restrictions resulting from the Nitrate Block Regulation and with information on the executed agrochemical testing of soils. At present, a project making the LPIS data accessible online to farmers is being implemented. It is expected that in the near future the comprehensive territorial information system, LPIS, will be of use also in others spheres of the state administration which do not work solely with agricultural land, e.g. in the land evaluation – Land Evaluation Information System (BIS in Czech) – or in determining the LFA (less favoured areas) restricting factors (SINE 2004).

Map collection of environmental geofactors

In connection with the sustainable development policy, ever greater demands arise on up-to-datedness of the cartographic projections of information on soil unit structure, mainly in middle- and large-scale as well as detailed maps.

Especially important from the point of view of the methodical principles for the construction of soil maps with the scale of 1:50 000 is the interconnection of the Czech soil classification system – TKSP CR (Němeček *et al.* 2001) with the classification systems which served as the basis for the systematic agricultural land survey and for the pedological part of the forest-typological survey and its compatibility with the classification systems regarded as international standards.

The processing of 107 map sheets of the soil map of the Czech Republic with the scale of 1:50 000 is a significant step towards the creation of a complex digital map with all relevant elements, covering the total area of the Czech Republic. Within the Integrated Environment Information System which is now being built, these maps would represent an essential source of spatial-related data of the soil information system (Janderková *et al.* 2004).

Soil Geographic Information System

The geographic soil information system of the CR (PUGIS in Czech), developed at the Czech University of Life Sciences (CULS) in Prague, is able to store, search, process, synthesise, and present the spatial soil information (areas of soil associations and parent materials, geomorphological maps, layers of other soil-forming and site-influencing factors, land use and interpretation layers), to connect them with the non-spatial information (characteristics of pedons, soil associations, regions, interpretations for practical purposes), and to interpret these syntheses (Kozák & Němeček 2002).

The aim of PUGIS is the creation of a data model, which will make geographical information about soil in the CR and about pedology-related topics accessible to all users. The content and structure of the data should facilitate a wide range of spatial analyses, their visualisation and presentation. This model should serve not only the research and teaching at CULS, but could also assist in the decision-making in other branches, on the regional as well as global scales. The complete PUGIS should include: digitised information from the soil and environmental maps, especially on geomorphology and slopes; soil characteristics (profile data, data from inventorying research); environment characteristics; data from the monitored research fields; information on soil utilisation, formation, degradation, contamination etc.; attributes of heterogeneity of the soil cover; criteria of data evaluation; pedotransfer models; models of transformation and models of pollutant transport and transfer processes between soil and hydrosphere, biosphere, atmosphere, and food chain; information about natural and anthropogenetic factors, concerning the environment (Kozák *et al.* 1996).

By now, the maps of the entire CR with the scales of 1:1 000 000, 1:500 000, and 1:250 000 have been digitised, and the maps with the scale of 1:50 000 are being processed (Kozák 1999; Kozák & Němeček 2002).

The PUGIS database consists of an alphanumeric part and a related localisation of the pits. The alphanumeric part is divided by districts, every district being represented by a separate table containing analytical data on individual soil pits; namely the data of geographic character (pit identification, climate, coordinates, location, altitude, parent material) and the data of generally pedological character (horizons identification, particles size, humus content, carbonates, soil reaction, cation exchange capacity, adsorbing complex saturation, P_2O_5 and K_2O content). The database can be enlarged with new information whenever needed (Janků & Němeček 1999).

Land Evaluation Information System

The Land Evaluation Information System collects the resulting materials of the agricultural land evaluation (e.g. Němec 2001; Mašát *et al.* 2002). The land evaluation data are available for three non-commercial research institutes – Institute of Agricultural Economics and Information (IAEI) – formerly Research Institute of Agricultural Economics (RIAE), Research Institute for Soil and Water Conservation (RISWC) and Crop Research Institute (CRI).

The basic structure of the Land Evaluation Information System is the following:

The soil-cartographic IS contains around 27 200 map sheets, where each mapped locality is marked with a five-digit number code, acreage, and serial number.

The land evaluation numeric database includes an agro-ecological and an economic block.

The administrator responsible for the soil-cartographic IS and the agro-ecological block of the database is SWCRI in Prague (Mašát *et al.* 2002), the administrator responsible for the economic block of the database is IAEI.

As the soil production ability has undergone considerable changes since the 1970s (among others because of recultivation and erosion) and the initial detail of the land evaluation mapping (minimum acreage of a locality was 3 hectares with the non-contrast and 0.5 hectare with the contrast soils) has proved insufficient in the conditions requiring each plot of ground to be assigned an evaluated soil-ecological unit (BPEJ in Czech) (changed land ownership distribution, the need for land conversion), the land revaluation and updating is taking place today. The revaluation and updating are executed by RISWC and employees of relevant departments of individual county offices; the whole process is supervised by the Central Land Registry of the Ministry of Agriculture of the CR (CLR MoA CR). The maps of BPEJ are therefore available not only in the RISWC archive, but partly also at the county offices (mostly in analogue form) and land registries (digital form).

In accordance with the EU requirements, the government ordered the BPEJ code introduction into the cadastre in 1992 (Resolution No. 177/1992 of the Czech government). The BPEJ code thus determines the amount of real-estate transfer tax. If the plot of land in question has not been evaluated yet, its price is determined by the average official price in the given cadastral region (MoA regulation No. 463/2002), which is also updated on the basis of the land reconnaissance results.

The results of the land evaluation survey are used mainly to determine the agricultural land productivity (100-point scale), to determine the official price of the agricultural land, to categorise the agricultural area (e.g. LFA), and to secure the protection (terms of exemption) of the agricultural land fund.

Determining less favoured areas (LFA)

For the purpose of administration, especially in connection with the grants and subsidies from the European Union funds, the agricultural areas are demarcated according to the unified criteria in the new member states. The agricultural areas are divided into these basic groups: favoured areas, less favoured areas (LFA), and ecologically restricted agricultural areas (E). LFA include: highland areas (H), other less favoured areas LFA (O), and specifically restricted areas (S).

Together with the categorisation of the agricultural areas, the classification of territorial statistic units CZ – NUTS (La nomenclature des Unités Territoriales Statistiques) was established in the Czech Republic; the classification was developed in accordance with the principles set by the European Community Statistical Office.

Projects incorporating the CR into international information systems

Image & CORINE – Land Cover (I & CLC)

In 2004, the European Commission passed a Proposal for a Directive establishing the infrastructure for spatial information in Europe (INSPIRE). INSPIRE will assist in making the spatial and geographical information accessible and universal to a wide extent of intentions supporting sustainable development. The proposal focuses specifically on the information needed to monitor and improve the environment, which needs to be backed up by multi-purpose spatial data. Land cover has been identified as one of the annex II data sets of the proposal for INSPIRE (SINE 2005).

CORINE (Coordinate Information on the Environment) – Land Cover 2000 (CLC 2000) is an international programme of EU countries mapping the land use and its changes with the help of multi-spectral satellite images resulting from the satellite imaging programme, IMAGE 2000.

CLC 2000 programme is produced by the EEA (European Environment Agency). IMAGE 2000 programme was carried out by EEA jointly with JRC EC (Joint Research Centre of the EU Commission).

Today, CLC is recognised by the decision-makers as a fundamental thematic reference data set for spatial and territorial analyses. However, at the end of the 1990s, several users at the national and European levels expressed a need for its updating. The aim of the updated version was to create a CLC2000 database and a CLC database mapping the changes in the land cover between the years 1990 and 2000 (SINE 2005).

In 1994 and 1995, as a part of the above-mentioned international project CORINE – Land Cover, the entire area of the Czech and Slovak Republics was processed on the 1:100 000 scale. These data were later modified for 1997 by the Help Service Company as a source material for GIS creation at the MoE CR. These source materials are continuously upgraded.

EUSIS and SOTER

EUSIS

EUSIS (European Soil Information System) is an information system about soil, which is maintained and developed jointly by the EU countries. One of the key activities inside EUSIS is the creation of the soil map of Europe as a part of the soil map of the world.

The soil map of the world is a suitable symbol of the international collaboration with both its positive and negative aspects. The form of the map as well as the way of its upgrading exemplifies the general transition from the analogue forms to the digital ones.

The development of the world soil map is coordinated by ISRIC (International Soil Reference and Information Centre), which works with three main databases:

(1) ISIS (International Soil Information System) – a database of soil monoliths, samples, and associated information,
(2) SOTER – see description below,
(3) WISE (World Inventory of Soil Emission) – a database of soil profiles (Batjes 2002).

The first draft of the world soil map (FAO/UNESCO) was – in the analogue form – presented as early as in 1968. Since 1986 its legend (FAO) has been regularly updated in a SOTER programme. The legend of the world soil map was been further developed into an internationally acceptable reference soil classification system – WRB (King *et al.* 1994; Nachtergaele 2003).

SOTER

SOTER represents not only an approach to the soil maps construction (e.g. Sládková & Kozák 2004; Sládková 2007), but also an information system about soil and landscape (the EUROSOILS section).

It is a relational database of the land resources with specific information on geomorphology, terrain, and soil components, which may be complemented with the land-related characteristics such as the land use, natural vegetation, and climate (SINE 1995, 1997; Batjes & van Engelen 2000).

SOTER is a joint project of ISSS (International Society of Soil Science), FAO and LRRC (Land Resources Research Centre) in Canada, and is developed and coordinated by ISRIC according to requirements of UNEP (United Nations Environment Programme).

Objectives:
– to establish a world database containing digitised map units and to provide related descriptive information needed for the progressive thematic mapping, monitoring, and modelling of local and global changes in the world soil and terrain resources,
– to store data on various scales in an easily accessible format, which can be easily upgraded,
– to provide a wide range of information accurately, in time and to an extensive group of people,
– to create a link with global databases covering other environmental resources.

Integrated Administrative and Control System (IACS)

Information systems of individual departments dealing with GIS (forest management, water management, land registries, and IACS) are now relatively independent, being designed and operated by subordinated units and controlled by relevant MoA's departments; in the past, they were not subjected to any co-ordination, with the exception of IACS system, which had been designed as the central solution.

IACS system, designed primarily to support the European Union subsidies administration, incorporates an extensive database based on GIS. It contains a seamless orthophotographic map of the Czech Republic, the registers of the agricultural plots of lands, animals and farmers, and other specialised registers. Financed mostly by means of PHARE projects, the system is a set of hardware and software, including primary data (Pechr 2002).

IACS is a system for monitoring subsidies in general; at the same time, it is a very detailed system for monitoring agricultural subsidies in particular – it provides the identification and registration up to the level of individual sowing, crop, and animal, and it is supplemented with other supportive programmes. IACS may also serve as a potent information system as well as a base for other activities in agricultural sector, such as the determination of the extent of subsidies, production quotas, yield prognosis, and action management.

IACS comprises seven basic registers (LPIS being the primary one), a number of sub-registers, and a multi-level control system. IACS also includes the classification of natural and unfavourable farming factors for the purpose of differentiated granting of subsidies to farmers in the EU system of supportive and compensation programmes (Knob 2002) – see LPIS and LFA.

Methodology of SOTER maps on an overview scale

The Standard SOTER

SOTER methodology is standardised in accordance with the soil profile description regulation (SINE 1990b) and with the legend of the world soil map (SINE 1988, 1990a), but it is open to the data from the national soil classifications. GIS makes it possible to link the database content with the units on the world soil map through the codes in its legend.

In SOTER, the main differentiating criteria for establishing the map units are applied gradually – the definition of the investigated area is more precise in every step. The main criteria are: terrain – geomorphology, lithology; terrain components – surface forms, degrees of slope, micro-relief, texture, class of parent materials; soil components – soil characteristics (SINE 1995, 1997; Batjes & van Engelen 2000). It is thus geomorphology which is emphasised most in the original SOTER methodology. Its criteria, however, have not been clearly defined yet.

Geomorphology – on the basis of the slope and relief intensity – identifies and quantifies the landforms. These may, in combination with the absolute altitude intervals and with the factor defining the degree of resolution, characterise extensive regions definable on the map and serve, as a reference for the first and the second terrain levels, characterised by main surface forms (SINE 1995b, 1997; Batjes & van Engelen 2000).

Therefore, three levels of terrain (individual combinations of landforms and lithology) may be distinguished:

a layer of geomorphology – main surface forms (landforms) – relief (e.g. plain)
+ a layer of lithology => local surface forms arise – meso-relief (e.g. dissected)

+ a layer of slope => micro-relief arise (e.g. grooves)

The regions characterised by terrain involve one or more typical combinations of the surface form, micro-relief, parent material, and soil, which form a functional transition to other subdivisions of terrain – to terrain components and soil components.

Czech SOTER (CZESOTER)

Němeček and Kozák (2003a, b) believe that the creation of the first Czech version of the 1:250 000 soil map in SOTER was stimulated by the proposal for a project of a Europe-wide map. The original SOTER hierarchy is slightly modified in the Czech version. The changes result from the geomorphological and lithological variety of the CR and from the fact that the agricultural and forest funds of the CR have been reconnoitred pedologically in detail.

Standard vs. Czech SOTER:

Standard SOTER

(a) units definition
- geomorphology
- lithology (grouped parent materials)
- soil associations (grouped soils)

(b) outlook

The system will be developed continuously in order to involve:
- a database of topography, soils, climate, vegetation, and land use including compatible socio-economic databases,
- models of agricultural crop yields for any combination of soil, climate, and management,
- models of environmental influences, enabling e.g. the calculation of the extent of erosion for a given territorial unit or evaluating other types of its vulnerability and degradation, in a similar way as in SOVEUR (Soil Vulnerability Mapping in Central and Eastern Europe), GLASOD (Global Assessment of Soil Degradation), and ASSOD (Asian Human-Induced Soil Degradation Status) projects.

SOTER database outputs are usually presented in the scale of 1:1 000 000, but the works on a 1:250 000 version have already started.

Czech SOTER

(a) units definition
- supra-regions of main soil forms, the definition of which contains a general lithology
- grouped parent materials
- grouped soil forms (mosaics of taxonomic units and their substrate forms)

(b) outlook

The second version of SOTER soil map of the CR with the scale of 1:250 000 has been finished.

Němeček and Kozák (2003b) suggest the following procedure:
- clear-cut definition of the Czech and mixed mega-regions,
- correlation of SOTER units with soil associations,
- adaptation of the system with respect to the needs within the CR as well as the international collaboration.

Methodology of creation of SOTER thematic layers on a middle- and a detailed scale in the pilot area of Litoměřice district, based on the data from the General survey of agricultural soils

All the accessible data and technical tools have been used for processing the SOTER soil map on the middle and detailed scales. The selected procedure is concerned mainly with how the existing SOTER methodology, developed for an overview map scale, will work on more detailed scales, and whether it is rational to process SOTER maps on more detailed scales with the aim to utilise them further in other national IS. If it proves positive, a specific procedure of the construction of these maps will be a topic for discussion.

For the construction of both the middle-scale and the detailed SOTER soil maps, a geomorphological layer was used, which had been processed as a part of the first version of the Czech SOTER map with the scale of 1:250 000. In the future, it will be necessary to adapt geomorphology to appropriate scales (the procedure selected is provisionally only schematic). However, this is going to be a long-term process, as the conceptions of geomorphology for the scale of 1:250 000 have not yet been unified internationally. The use of geomorphology at appropriate scales and considering the mutual relations between soil and geomorphology will, among others, change the shape of the created geomorphic and geomorphic-lithologic units as contrasted with Figures 1–3 of the article. First, it is necessary to chase away any existing doubts concerning the suitability of the SOTER project for the construction of the soil maps more detailed than the maps on overview scale. The SOTER project could contribute to the process of the soil map creation at the soil survey and GIS maps construction.

First, a vector layer of soil polygons was created for the sample area in accordance with the International SOTER methodology. Afterwards, the polygons were reclassified from the Genetic-agronomic classification of the General survey of agricultural soils (hereafter GAK KPZP) to taxons of the Taxonomic soil classification system (hereafter TKSP CR) according to the soil forms and according to the dominant SOTER units. After being assigned to parent materials, the reclassified soils are called main soil forms and their abbreviations subsume the soil type and subtype symbol according to TKSP CR (e.g. Chernozem modal – CEm), as well as the parent material number as used in the soil forms map (e.g. 05 – loess), consequently, e.g. CEm05 – Chernozem modal on loess. In SOTER maps construction, it is not the parent materials of the valid taxonomic system (TKSP CR) that are used; instead, they are replaced by parent materials of the soil forms map, from which the conversions for CZESOTER maps already exist in the manual of the soil geographic system developed at the CULS. The work with the archive data (GAK KPZP) lacks an official methodology for the conversion from the archive-data parent materials to the soil-form-map parent materials, and from the soil forms map to SOTER parent materials. With the aim to close the gap, the conversions between GAK KPZP's and the soil forms map parent materials were dealt with in a dissertation thesis (Sládková 2007).

A geomorphological layer was applied to the reclassified soil polygons, divided into categories presently defined for a standard SOTER layer, using the Czech geomorphological modifications (PUGIS). By unification, the actual SOTER layer was created. These polygons were then supplied with the codes of dominant SOTER units to be written into an attribute table created in ArcView software for SOTER layer. For the map thus created, a coloured legend was created and for the middle-scale map, the acreages of individual dominant SOTER units in the district were calculated. The data about the selective, or primary probes from the maps with the scale of 1:5 000, may serve for the final specification of the course of the main geomorphic-lithological units.

Another perspective is added to soils and parent materials by inclusion of geomorphology – SOTER units are created (and just as the soil association units they can be divided into primary, secondary, and accessory ones). While soils in the main soil forms are identified in terms of TKSP CR, in SOTER units they are generalised and identified using only a few letters. This is the structure of the SOTER unit symbol: the abbreviation of a geomorphological region (e.g. LD – dissected lowlands) is followed by a parent material number (e.g. 05 – marls, clays, possibly with shallow covers) and a small letter indicating the soil group (e.g. c – Chernozems), i.e., for instance, LD05c.

RESULTS AND DISCUSSION

Litoměřice district is a region of mainly flat lowlands (LF), lowlands (LL), and dissected lowlands (LD). The prevailing SOTER parent materials (according to PUGIS) are: terrace gravel, sand, clayed or shallow-loess-covered terraces (01), loess, loesslike sediments, possibly with another subsoil (02), polygenetic, glacial loams, heterogeneous deep slope deposits (03), and marls, clays, possibly with shallow covers (05).

Flat lowlands abound with Chernozem and Brown soil on loess, loesslike sediments, possibly with another subsoil, Chernozems on marl, clay, possibly with shallow covers, Fluvizems from fluvial

Figure 1. Geomorphologic regions with highlighted main soil forms on the Litoměřice 4-3 map sheet SMO 5 (LD – dissected lowlands, LF – flat lowlands)

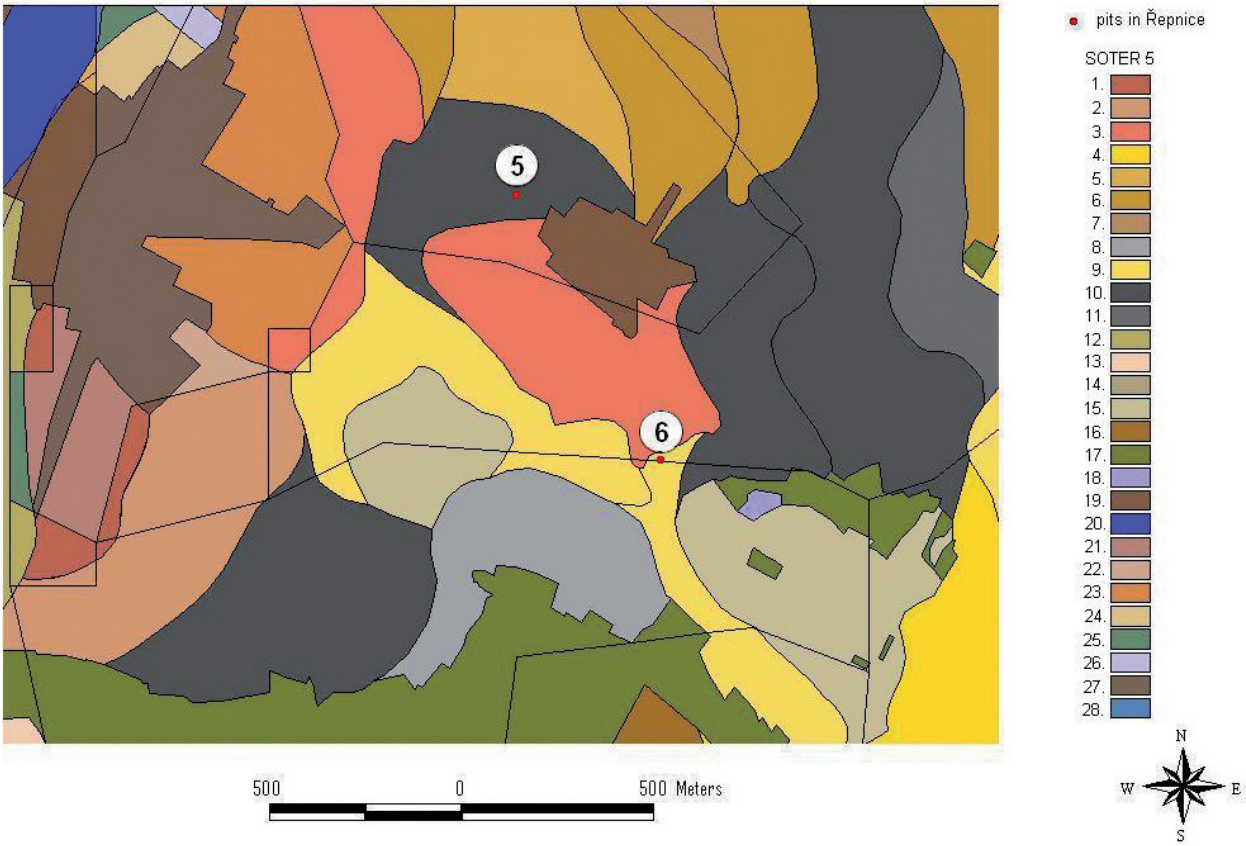

Figure 2. The SOTER soil map of the Litoměřice district with the scale of 1:5 000 – the map sheet Litoměřice 4-3 (LD – dissected lowlands, LF – flat lowlands)

1 – LD01/05r: dissected lowlands; double parent material of terraces gravelly sands, sands, earthenware or terraces covered by shallow loess, and marls, clays, possibly with shallow covers; within Arenosols, Cambisols; 2 – LD01c: dissected lowlands; terraces gravelly sands, sands, earthenware or terraces covered by shallow loess; Chernozems; 3 – LD01r: dissected lowlands; terraces gravelly sands, sands, earthenware or terraces covered by shallow loess; within Arenosols, Cambisols; 4 – LD01v: dissected lowlands; terraces gravelly sands, sands, earthenware or terraces covered by shallow loess; rendzic, calcaric Leptosols; 5 – LD02b: dissected lowlands; loess, loesslike sediments (possibly with another subsoil); haplic Luvisols; 6 – LD03k: dissected lowlands; polygenetic, glacial loams, heterogeneous deep slope deposits; Cambisols (in general); 7 – LD03m: dissected lowlands; polygenetic, glacial loams, heterogeneous deep slope deposits; eutric Cambisols; 8 – LD03p: dissected lowlands; polygenetic, glacial loams, heterogeneous deep slope deposits; fine textured Cambisols; 9 – LD03r: dissected lowlands; polygenetic, glacial loams, heterogeneous deep slope deposits; within Arenosols, Cambisols; 10 – LD05c: dissected lowlands; marls, clays, possibly with shallow covers; Chernozems; 11 – LD05p: dissected lowlands; marls, clays, possibly with shallow covers; fine textured Cambisols; 12 – LD06f: dissected lowlands; fluvial sediments; Fluvisols; 13 – LD12n: dissected lowlands; basalts, serpentines; within Leptosols; 14 – LD13b: dissected lowlands; another mafic rocks; haplic Luvisols; 15 – LD18v: dissected lowlands; sedimentary rocks, coarse textured weathering products; rendzic, calcaric Leptosols; 16 – LD19r: dissected lowlands; sedimentary rocks, fine textured weathering products; within Arenosols, Cambisols; 17 – LD FOREST: dissected lowlands; forest; 18 – LD UNPRODUCTIVE AREA: dissected lowlands; unproductive area; 19 – LD URBAN AREA: dissected lowlands; urban area; 20 – LD WATER: dissected lowlands; water; 21 – LF01/05r: flat lowlands; double parent material of terraces gravelly sands, sands, earthenware or terraces covered by shallow loess, and marls, clays, possibly with shallow covers; within Arenosols, Cambisols; 22 – LF01c: flat lowlands; terraces gravelly sands, sands, earthenware or terraces covered by shallow loess; Chernozems; 23 – LF01r: flat lowlands; terraces gravelly sands, sands, earthenware or terraces covered by shallow loess; within Arenosols, Cambisols; 24 – LF02b: flat lowlands; loess, loesslike sediments (possibly with another subsoil); haplic Luvisols; 25 – LF06f: flat lowlands; fluvial sediments; Fluvisols; 26 – LF UNPRODUCTIVE AREA: flat lowlands; unproductive area; 27 – LF URBAN AREA: flat lowlands; urban area; 28 – LF WATER: flat lowlands; water

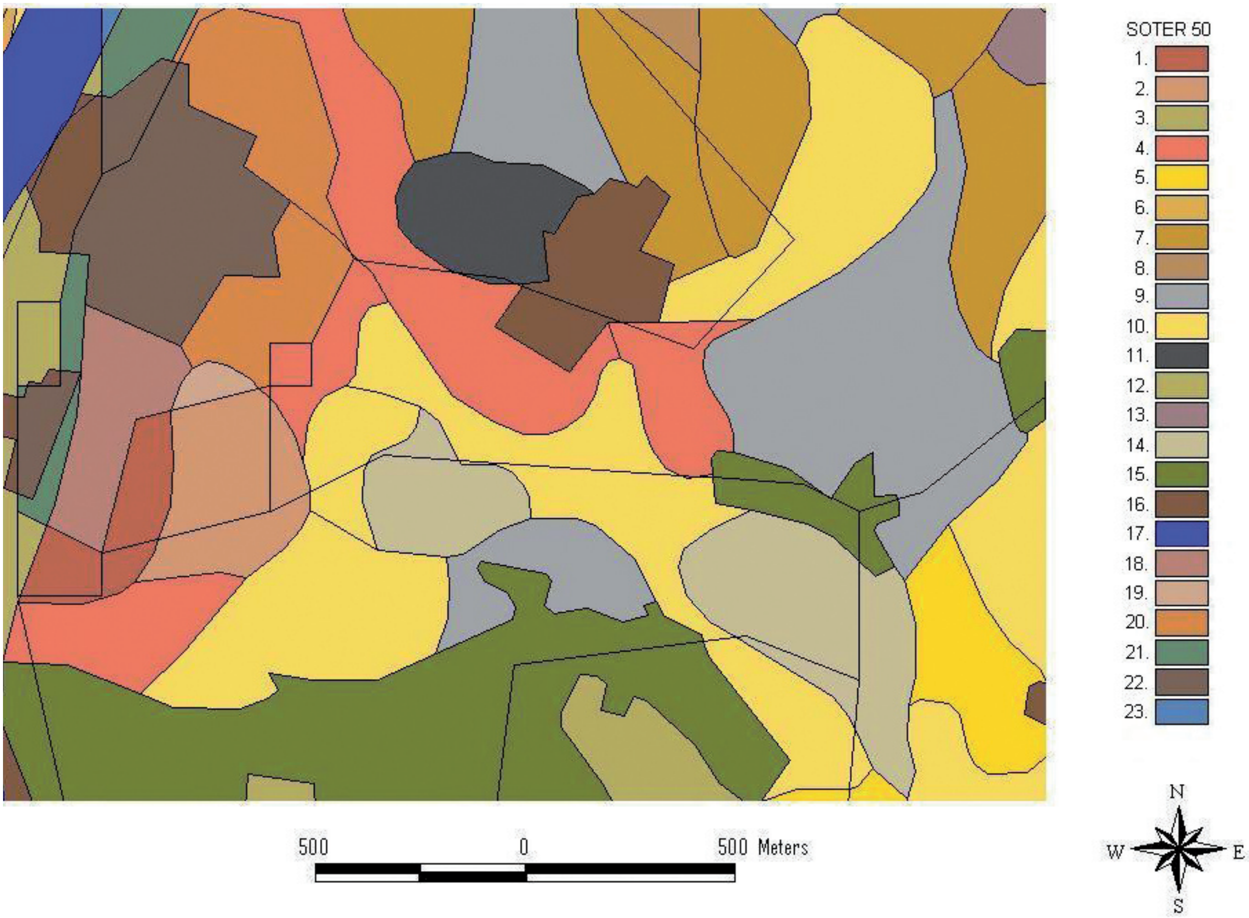

Figure 3. The SOTER soil map with the scale of 1:50 000 of the Litoměřice district – the map sheet Litoměřice 4-3 (LD – dissected lowlands, LF – flat lowlands)

1 – LD01/05r: dissected lowlands; double parent material of terraces gravelly sands, sands, earthenware or terraces covered by shallow loess, and marls, clays, possibly with shallow covers; within Arenosols, Cambisols; 2 – LD01c: dissected lowlands; terraces gravelly sands, sands, earthenware or terraces covered by shallow loess; Chernozems; 3 – LD01m: dissected lowlands; terraces gravelly sands, sands, earthenware or terraces covered by shallow loess; eutric Cambisols; 4 – LD01r: dissected lowlands; terraces gravelly sands, sands, earthenware or terraces covered by shallow loess; within Arenosols, Cambisols; 5 – LD01v: dissected lowlands; terraces gravelly sands, sands, earthenware or terraces covered by shallow loess; rendzic, calcaric Leptosols; 6 – LD02b: dissected lowlands; loess, loesslike sediments (possibly with another subsoil); haplic Luvisols; 7 – LD03k: dissected lowlands; polygenetic, glacial loams, heterogeneous deep slope deposits; Cambisols (in general); 8 – LD03m: dissected lowlands; polygenetic, glacial loams, heterogeneous deep slope deposits; eutric Cambisols; 9 – LD03p: dissected lowlands; polygenetic, glacial loams, heterogeneous deep slope deposits; fine textured Cambisols; 10 – LD03r: dissected lowlands; polygenetic, glacial loams, heterogeneous deep slope deposits; within Arenosols, Cambisols; 11 – LD05c: dissected lowlands; marls, clays, possibly with shallow covers; Chernozems; 12 – LD06f: dissected lowlands; fluvial sediments; Fluvisols; 13 – LD12m: dissected lowlands; basalts, serpentines; eutric Cambisols; 14 – LD18v: dissected lowlands; sedimentary rocks, coarse textured weathering products; rendzic, calcaric Leptosols; 15 – LD FOREST: dissected lowlands; forest; 16 – LD URBAN AREA: dissected lowlands; urban area; 17 – LD WATER: dissected lowlands; water; 18 – LF01/05r: flat lowlands; double parent material of terraces gravelly sands, sands, earthenware or terraces covered by shallow loess, and marls, clays, possibly with shallow covers; within Arenosols, Cambisols; 19 – LF01c: flat lowlands; terraces gravelly sands, sands, earthenware or terraces covered by shallow loess; Chernozems; 20 – LF01r: flat lowlands; terraces gravelly sands, sands, earthenware or terraces covered by shallow loess; within Arenosols, Cambisols; 21 – LF06f: flat lowlands; fluvial sediments; Fluvisols; 22 – LF URBAN AREA: flat lowlands; urban area; 23 – LF WATER: flat lowlands; water

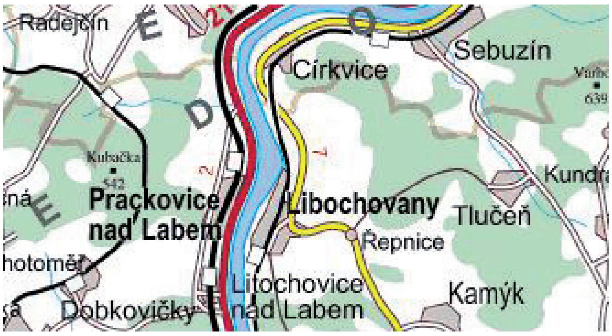

Figure 4. Details of a topographical map – Řepnice (Pit No. 5; localisation – Řepnice cadastre; coordinates: X-761.293,37; Y-986.439,60)

sediments, Pararendzinas on sedimentary rocks, middle textured weathering products, and Rankers on terrace gravel, sand, brownearth or terraces covered by shallow loess.

Soils prevailing in lowlands are: Chernozem on loess, loesslike sediments, possibly with another subsoil, and on marl, clay, possibly with shallow covers, Fluvizem from fluvial sediments, Rankers on terrace gravel, sands, brownearth or terraces covered by shallow loess, Pararendzinas on sedimentary rocks, middle textured gruss, and Brown soils on loess, loesslike sediments, possibly with another subsoil.

In the dissected lowlands, the soils that occur are especially Chernozem on marl, clay, possibly with shallow covers, Rankers on polygenetic, glacial loams, heterogeneous deep slope deposits, and Brown soils on loess, loesslike sediments, possibly with another subsoil.

The SOTER map with the scale of 1:50 000 depicting the entire Litoměřice district has a very comprehensive legend, mainly due to the above mentioned geomorphological and soil complexity of the district and due to the scale used; soils upon double parent materials are defined into separate SOTER units, which results in a rapid increase in the number.

The details of the map were further increased by processing the cutout of the SOTER Litoměřice district soil map with the scale of 1:5 000 (Fig-

Figure 5. The location of pit No. 5 (map sheet: Litoměřice 4-3; classification – GAK KPZP: ČMl 15/63a-16; TKSP CR: CEm, PSc/SC)

Soil profile: *Ap-AC-C*

Soil profile stratigraphy		GAK KPZP	TKSP CR	WRB
1	0–31 cm	OrHca	Ack	Ak
2	31–54 cm	Hca/Pca	ACk	ACk
3	54–87 cm	Pca	Ck	Ck (calcareous sand)
4	more than 1 m	Dca	Dk	Dk (carbonated slope deposit)

Reasons for the selection: Chernozem parameters specification; a composite of calcareous parent materials (calcareous sandstone, carbonated slope deposit, loess, marl with impurity of basalt); the depth of humus horizon up to 2 m (the proposal for a refinement of TKSP CR in regard to humus horizon thickness of Koluvizem soil type)

Figure 6. Visualization of the profile of pit No. 5

ure 2). First, it was necessary to vectorise the Litoměřice 4-3 map sheet. As we can see in the PUGIS geomorphology layer (Figure 1), from the geomorphological point of view, dissected lowlands (LD) prevail – they are highlighted in green-brown colour – but flat lowlands (LF) – pink colour – are present as well.

From the 1:50 000 SOTER soil map of Litoměřice district, the map sheet SMO 5 Litoměřice 4-3 (Figure 3) was chosen to illustrate the differences between different-scale maps of the same territory.

This area was chosen as a sample area due to its variety of the soil cover. As Figure 2 shows, the soils represented in this area are: Chernozem, Pararendzina, and Regozem on terrace gravel, sand, brownearth or terraces covered by shallow loess, Brown soil on loess, Cambizem, Pelozem, and Regozem on polygenetic, glacial loam, heterogeneous deep slope deposits, Chernozem and Pelozem on marl, clay, possibly with shallow covers, Fluvizem from fluvial sediments, Rankers on basalt and serpentine, Brown soil on other mafic rocks, Pararendzina on sedimentary rocks, middle textured gruss, and Kambizem on sedimentary rocks, fine textured gruss. Figure 2 also shows the territory of Řepnice village, forests, water (the Elbe river), as well as the unproductive areas. In Figure 2, two dug soil pits are highlighted; which had been selected on the basis of a survey and from which samples were taken in the soil survey of the Litoměřice district in 2006 (pits No. 5 and 6). The goal of this survey was to start the process of refinement of the valid Taxonomic soil classification system – TKSP CR's (2001). For the test pits, such particular soils and parent materials were selected that are typical for this district and which meet the purpose.

In pit No. 5 – the dominant SOTER LD01c unit, which can be found in the 1:5 000 SOTER soil map SOTER in the area of the dominant unit LD05c – it was (in TKSP CR terms) Chernozem modal or Chernozem with the characters of hydromorphic process, on calcareous sandstone, in the depth of more than 1 meter carbonated slope deposit occurred (the pit in Figures 4–6). The carbonate content greatly varies in this locality. It should be noted that in the valid soil system classification it is necessary to clarify whether it is allowed to classify the Chernozem 'carbonated' feature as a subtype, a variety, or both.

Figure 4 depicts the details of the map showing pit No. 5, Figure 5 depicts its location and Figure 6 visualises its profile.

In the same territory, within just a few meters, we can locate Chernozem modal on marl and loess (Figure 7), Chernozem modal on carbonated slope deposit (with loess and debris of basalt), under which layers of marl and calcareous sand occur (Figure 8), or a humus horizon, up to 2 meters thick, because of which it would be suitable to classify the soil as Koluvizem (the proposal for TKSP CR's refinement). The combination of Chernozem and calcareous sandstone (01c) is unique to the CR – in the Litoměřice district it takes up, including top layers of double parent materials, 1 986.58 ha (2.49% of the agricultural land of the district).

Figure 7. Double parent material of marl and loess

Figure 8. Triple parent material of carbonated slope deposit, marl, and calcareous sandstone

The difference in the classification of the real and the mapped dominant SOTER unit in the particular point is caused by different moisture contents of the individual parts of the territory as well as by the fact that in the nearest surroundings of the pit, marl is the prevailing parent material.

Pit No. 6 (Figures 9 and 10) – the dominant SOTER unit LD18v, included in the soil map SOTER with the scale of 1:5 000 in the dominant unit LD03r – is classified after TKSP CR as Pararendzina arenic on calcareous sandstone (the proposal on TKSP CR's refinement), shimmed with arenaceous marl. Moreover, calcareous deluvium occurs around the pit, and the slope opposite the pit shows visible horizontal passages ranging from arenaceous marl to calcareous sandstones. The combination of Pararendzina and calcareous sandstone (18v) spreads out on the Litoměřice district over the area of 8 634.72 ha (10.81% of the agricultural land of the district).

The difference in the dominant SOTER units for a pit and a polygon in which it is found, is caused by the inaccuracy in the (otherwise accurate) mapping of the concrete sheet of the soil map with the scale of 1:5 000 of the Litoměřice district. The surroundings of the pit happen to show transitions between four dominant SOTER units – without GPS technology the boundaries between the soil types in such complicated conditions can be miscalculated easily.

Figure 9 shows the location of the test pit No. 6, Figure 10 shows its profile.

In order to improve the SOTER system, it will be possible to apply the layer with test pits from the 1:5 000 soil map to the geomorphological SOTER layer, to unify both layers by GIS operations, to reclassify selective test pits into dominant SOTER units, and by means of the test pits thus reclassified to specify the 1:250 000 SOTER soil map.

Figure 9. The location of pit No. 6 (cadastre Řepnice; coordinates: X-760.958,64; Y-987.066,18; map sheet: Litoměřice 4-3; classification – GAK KPZP: RAh 15; TKSP CR: PRkr, PSc, with packings of arenaceous marl)

Soil profile: *Ad-Cr*

Soil profile stratigraphy:		GAK KPZP	TKSP CR	WRB
1	0–27 cm	d	Ad	A
2	from 27 cm	P	Cr	C

Reasons for the selection: change in classification of former Rendzinas; Pararendzina cambic arenic on calcareous sandstone (the proposal for the refinement of TKSP CR by permitting cambic horizon at Pararendzinas from light and heavy parent materials)

Figure 10. Visualisation of the profile of pit No. 6

For standard usage of the SOTER methodology in the soil maps construction it is necessary, besides securing a sufficient amount of digital data usable in GIS, besides the refinement of the soil and parent materials convertor, and besides TKSP CR refinement, to develop a methodology for grouping parent materials of the valid soil classification system and to resolve the issues of geomorphology.

Consequently, the soil data processing in the international SOTER system could extend similar national as well as international projects. Its pedological part is comparable to the soil atlases giving the profiles of the main soil types and subtypes. As an interdisciplinary project, it is related to the Czech BIS, which records the climate, soil, vegetable production, and economy. Through the evaluation of the land utilisation, it is linked up to an international, certified, and frequently up-dated CORINE-Land Cover. It seems especially suitable to interconnect BIS and SOTER, rather then their competitive development or potential abolition of BIS due to the intended revoking of the tax on agricultural land.

Current BIS and SOTER characteristics

BIS

– it is limited to the Central European area; it closely resembles a similar system in Germany (see e.g. SINE 2002, 2006)
– the scale of 1:5 000
– information: climate, main soil unit, slope, exposition, skeleton content, soil depth, boulders quantity
– it is related to the agricultural land evaluation, including the soil production ability estimation; it is also possible to use the data from the Central Institute for Supervising and Testing in Agriculture (CISTA)
– as the EU applies the land evaluation and relevant subsidies to the LFA, it is necessary to promote actively EU interest in BIS.

SOTER

– it is an international project
– the scales of 1:1 000 000 and 1:250 000
– information: geomorphology (facilitating maps creation and construction), land utilisation, vegetation, climate
– the evaluation of the production ability in outlook; it is realistic, because the EU considers the productive function of soil as its cardinal function (e.g. Jones 2006)
– the EU is highly interested in the project

The main point in interconnecting BIS and SOTER is the preservation of the national tradition in the soil evaluation and at the same time taking advantage of the EU interest in the development of the SOTER system, which enables not only the integration of geomorphological layers, main soil forms, and soils, but also the land utilisation, vegetation, and climate and their connection with the layers from socio-economic databases, e.g. on the production ability. The related polygons of layers on top of each other facilitate the immediate and simultaneous representation of information about these topics and their analyses. The SOTER also enables the creation of a relief model on the basis of the real terrain data; last but not least it enables the accurate identification of the test pits and plotting on the latest lines into maps (eliminates map sheets inaccuracies).

The most serious obstacles to the convergence of the above-mentioned systems are: non-existence of an international agreement on geomorphology, entrance layer of the entire database, and for BIS the lack of data in digital form, in the resemblance applicable for GIS.

It offers also linking of SOTER and LPIS MoA CR, especially in the problems of the land utilisation and LFA (EU soil subsidies).

However, in order to become such a universal international database, working without laborious conversions and on national levels, SOTER needs to go through an extensive unification of the conception of the individual SOTER layers, and to have SOTER maps created not only on an overview scale.

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