https://doi.org/10.17221/138/2024-SWR

New version of PUGIS – Soil information system of the Czech Republic

Adéla Marie Marhoul[1], *Tomáš Herza*[2], *Josef Kozák*[1]*, *Jaroslava Janků*[1], *Jan Jehlička*[3], *Luboš Borůvka*[1], *Karel Němeček*[1], *Miroslav Jetmar*[3], *Petr Polák*[1,4]

[1]*Department of Soil Science and Soil Protection, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, Prague, Czech Republic*

[2]*Hydrosoft Veleslavín s.r.o., Prague, Czech Republic*

[3]*Department of Environmental Geosciences, Faculty of the Environmental Sciences, Czech University of Life Sciences Prague, Prague, Czech Republic*

[4]*Ministry of Finance of the Czech Republic, Prague, Czech Republic*

**Corresponding author: kozak@af.czu.cz*

Citation: Marhoul A.M., Herza T., Kozák J., Janků J., Jehlička J., Borůvka L., Němeček K., Jetmar M., Polák P. (2025): New version of PUGIS – Soil information system of the Czech Republic. Soil & Water Res., 20: 1–15.

Abstract: The creation of the database system represents a complex task which is difficult to coordinate. In this work, a method of the logic framework was used for the coordination of each particular step to one integral part. In the Czech Republic, most of the information about soil was gathered within a systematic soil survey (KPP) in the period 1961–1970. Information about genetic and agronomic characteristics of agricultural soils was gathered for the whole Czech Republic. The other part of the data is coming from the databases of forest soils. This contribution is a continuation of the previous research. We are aware of the fact that in the Czech Republic exist also other soil information systems. In this work we also tried to show the practical exploitation of the large soil database. We applied many approaches to assess bulk density of the soil. It was calculated for the main soil groups and it could be applied on every soil profile in PUGIS system. We also showed different possibilities of mapping soil organic concentration or amount in soils.

Keywords: application of soil data; soil databases; soil information system

The database system is usually presented as a form of data processing system that includes data in a database and a database management system. Typically, this term is used to encapsulate a data model (Bureš 2014). Singh (2011) reports that the Database Management System is a generalized software tool for data manipulation. Basically, it presents a computer system for data.

Soil information systems. Soil is an essential part of the biosphere, which requires a global approach (Panagos et al. 2012). Soil information is needed to handle a number of global environmental problems. These problems can be: food self-sufficiency issues, soil degradation, lack of water resources and, last but not least, climate changes (Batjes 2016). Public awareness has increased interest in soil protection in recent years and has also been focused on the economic and ecological values of this natural resource (Wesselink et al. 2006). In the field of soil protection, the emphasis is placed on the creation of database systems (Panagos et al. 2012).

Supported by the European Joint Program for SOIL "Towards climate-smart sustainable management of agricultural soils" (EJP SOIL) funded by the European Union Horizon 2020 research and innovation programme (Grant Agreement No. 862695). The program is realized with financial support of the Ministry of Education, Youth and Sports of the Czech Republic (MŠMT).

https://doi.org/10.17221/138/2024-SWR

Geodatabase. Geographic information systems (GIS) are often used to store spatial data and organise them into geodatabases with usage layer approaches (Machalová 2007). A geodatabase can be understood as a spatial data store in a database system. This complex can contain a large array of vector and raster data, tables, and other objects (Shah 2004). The geodatabases themselves use an object-related vector data model (Ježek 2005).

National geodatabase. Within the European Union are organized initiatives/programs aimed at obtaining data such as data on soil (Eurosoil 2012). An example of this is the EU ENVASSO project (ENVASSO 2016), part of which is the SoDa soil database. SoDa was created on the basis of international cooperation (SoDa 2016). SoDa is a useful tool for integrated data management (soil profile, analytical and map data) (Baritz et al. 2008).

Most of currently proposed soil databases are designed to be used for international monitoring and integrate data quality control mechanisms (Lacarce et al. 2009). For example, the Harmonized World Soil Database (HWSD) combines information from regional and national levels with information which is already part of the FAO-UNESCO-based Digital Soil Map of the World (FAO-SOILS PORTAL 2016).

As an example, may be mentioned the European soils database v2.0 (ESDB) which includes 73 basic or derived spatial attributes (Tóth et al. 2013).

The e-Soter project is another initiative in the field of soil data processing. The e-Soter project uses global soil and terrain databases to manage data. The project itself includes data collection in connection with previous projects such as ENVASSO and the use of data from remote sensing, data transformation, data management and data delivery via web services. The authors present the functions and development stages of soil information systems.

Pillar Four represents also the worldwide key initiative for soil data management. Pillar Four includes among other things feasibility and usability of global soil information systems (Yemefack et al. 2016).

An example of a global database is also the ISRIC-WISE - Global Soil Profile Data (Ver. 3.1) which collects data from selected locations, approximately 10 250 profiles from 149 countries (ISRIC-WISE 2016). Another initiative of the European Commission is the creation and support of the Geographical Information System of the Commission (GISCO), which is a permanent service of Eurostat. One of the main aims of GISCO is cooperation in the field of initiatives for the creation of geographic information infrastructure at European level – INSPIRE support (GISCO 2016). At the European level has been created LUCAS system that carries out survey data to provide coherent and harmonized statistics on land use and land cover within the European Union. This system represents a key part of European in-situ data collection (LUCAS 2016).

National application. Number of countries have developed national information systems according to the requirements of the European Union (EU). This approach can be demonstrated in examples of national soil information systems such as Austrian BORIS (BORIS 2016), French DONESOL (DONESOL 2016), German FISBo (FISBo 2016), ISIS (ISIS 2016), Czech SOWAC (VÚMOP 2016) and Land Information System of England and the Wels LandIS (Hallett et al. 2017), INFOSOLO (Ramos et al. 2017). There can be found examples of land-based information systems outside of the EU such as the Canadian CanSIS (CanSIS 2016) and ASRIS (ASRIS 2016) at the same time.

Among the geoportals dealing with soil, water and landscape protection in the Czech Republic can be mentioned SOWAC-GIS. This geoportal provides information such as digital maps, specialized map applications. Erosion monitoring web portal of arable land represents joint project of The State Land Office (Státní pozemkový úřad, SPÚ) and Research Institute of Soil Monitoring and Soil Protection (VÚMOP, v.v.i.). This portal is used for report on soils, record and evaluate individual erosion events. Another information system focused on soil information in the Czech Republic is PUGIS (Czech University of Life Sciences, CULS). It represents a soil information system that includes digitized soil maps (in 1 : 1 000 000, 1 : 500 000, 1 : 200 000 and 1 : 250 000), soil profile attributes, information on geomorphology, climate, vegetation, geology, maps of some soil properties such as humus content, soil texture, soil chemical properties (FAO 1999; Němeček 2000).

Requirements on soil information system. Type and quality of soil information depend on the purpose for which the data are obtained as shown for example by Hengl et al. (2007). Currently exist a wide range of monitoring techniques including non-destructive sampling methods: remote sensing and automatic sampling. These techniques generate a high density of digital soil information. Their new appropriate geographic processing and assessment techniques are important in soil management (Lagacherie & McBratney 2006).

https://doi.org/10.17221/138/2024-SWR

Yemefack et al. (2016) in their work emphasize that national information systems are an important mediator of providing digital information about the land from national to global soil information systems. According to this work data from different information providers need carefully planning, ensuring harmonization and synergy between systems and information.

The Global Soil Partnership (GSP) organized by FAO project has designed a framework for data collection and soil mapping in a global scale. The main points are the efforts to standardize, harmonize data collection and soil mapping methodology which will be include raster and polygon digital map data into one integral framework (Zucca et al. 2013).

Structure and architecture of soil information system. Baritz et al. (2008) point out that the structure of their own database (or data model) is the second most important thing in the development of a soil database after data communication rules and procedures. For the pilot area authors have programmed the database in MS Access environment. The web-based database system and service have been made available on an XML basis. Database tables for the properties of all elements in the database were easily queryable using SQL statements can be change according to individual criteria. Dupree and Crowfoot (2012) used for database environment GIS from Environmental Science Research Institute (ESRI). For example, Skalský (2008), in his work, highlights the purpose of digitization. That means transferring outputs KPP – a systematic survey of soil (data in paper forms) into machine-readable form. It is helpful to keep the original information value for re-usage of KPP data (Skalský 2008). There are problems associated with the transition from conventional soil survey to digital soil mapping, such as coarse resolution and small scale of variability (Lagacherie & McBratney 2006). Kozák and Borůvka (2013) also mentioned that the digitization of classical soil maps and the use of so-called "legacy" data brings some problems. Borůvka et al. (2002) presented new approaches for the use of data from surveys already done.

Usage of the soil information system. According to the European Commission the construction of harmonized soil information systems will provide benefits as: monitoring soil threats, public awareness and last but not least the benefits to future generations (European Commission 2006). The model for prediction of soil properties which was created by de Carvalho et al. (2014) involves a multi-linear regression (MLR) and common kriging and co-kriging.

In recent years, the amount of available and relevant soil data has increased, especially in connection with the development of pedotransfer functions. These functions help to complete the missing information (Zucca et al. 2013). Among the methods that can be used for "fitting" quantitative relations between soil characteristics and their "environment" are generalized linear models, classification and regression trees, neural networks, fuzzy systems and other geostatistical methods. Pedometric methods can be used not only to predict the missing data with the determination of accuracy of estimation. There is a rapid increase in the use of these methods because they allow predict data without costly techniques. They are highlighted primarily for their time and financial no difficulty (McBratney et al. 2003). For example, Balkovič et al. (2013) tested the usage of a formal approach to digital soil mapping, including fuzzy k-means and regression kriging. Odgers et al. (2014) utilized the classification tree method for spatial disaggregation and the classification of information into individual soil classes. Kollias and Voliotis (1991) say that the fuzzy relational database model has all the benefits of more conventional relational implementations. Yigini and Panagos (2016) used data from the LUCAS soil database when estimated the organic carbon stock in the soil. In the first phase of the study, they estimated the current stock of organic carbon through multiple regression and common kriging. In the second phase of the study, they predicted the organic carbon stock for 2050 using a set of environmental predictors.

Kodešová et al. (2011) used data from the Czech soil information system PUGIS and pedotransfer rules for assessing the mobility of pesticides in soils. Penížek and Borůvka (2004) successfully used the data from the soil survey in a database for data processing of the classical soil survey by geostatistical methods. Zádorová et al. (2011) used in their study a combination of data from a field survey, morphometric analysis, statistical methods for the delineation of koluvizem (coluvisol).

MATERIAL AND METHODS

Study area. The data in this work covers the territory of the whole Czech Republic. The climate in the Czech Republic is moderate and can be characterized by mutual penetration and mixing of oceanic and continental influences. The climate is characterized by the prevalence of western winds, intense cyclone

https://doi.org/10.17221/138/2024-SWR

activity and relatively high precipitation. Great influence on the climate of the Czech Republic has altitude and relief. Of the total area of the state territory, 52.817 km^2 (66.97%) are located at an altitude of 500 m, 25.222 km^2 (31.98%) at an altitude from 500 to 1 000 m, and only 827 km^2 (1.05%) height above 1 000 m. The average altitude of the Czech Republic is 430 m. The average annual air temperature in the Czech Republic ranges from 5.5 to 9 °C, with the warmest areas lowlands and the coldest mountain areas. Air temperature generally decreases with increasing altitude – on average about 0.6 °C per 100 m.

Project management. The creation of the database system represents a complex task which is difficult to co-ordinate. In this work was used method of logic framework for coordination each particular step to one integral part. This method can be used to determine the project parameters themselves (Doležal et al. 2016). The logical framework is a planning and communication tool and represents culture of planning management (Hrazdilová Bočková 2016).

Origin of soil data. In the Czech Republic, most of the information about soil was gathered within a systematic soil survey (KPP) in the period 1961–1970. A large part of the data in PUGIS comes from KPP. Information about genetic and agronomic characteristics of agricultural soils was gathered for the whole Czech Republic. About 800 000 soil probes were excavated during this period and more than 2 000 000 soil samples were taken at the same time. For the needs of the survey have been created original reports, basic soil maps, cartograms of texture, stonenies and wetlands, as well as cartograms for the purpose of increasing soil fertility. All materials were processed for agricultural enterprises at a scale of 1 : 5 000 or 1 : 10 000 and were supplemented with original report. Agricultural land represented 56.7% and forest represented 33.1% of the total area of the Czech Republic when the KPP was done (Smolíková et al. 2014).

Data has been recorded in MS Excel sheets and partially processed in MS Access. The classification selection of soil profiles in several soil taxonomic systems was performed (Němeček et al. 2011). The database is currently used for internal data management. This data is being used as a link with the requirements of practice and to represent the Czech Republic on an international level. For examples: Atlas of Europe, Flissod, eSoter, etc. The first attempt to create a geographic soil database in the Czech Republic was Atlas Soil of the Czech Republic (Kozák et al. 2009).

RESULTS AND DISCUSSION

Editing and adding data to the soil database. Data in PUGIS Information® were completed in cooperation with the various competent organizations. Information about forest soils was added in cooperation with the Institute for Forest Management (ÚHUL), and information about the organic carbon content was added with the contribution of the Central Institute for Supervising and Testing in Agriculture (ÚKZÚZ). Furthermore, the database was supplemented by data from the Czech-German project (INTERREG 2008) and, as a result, a soil survey of forest soils Neudertova Helebrantova et al. (2024).

PUGIS Information® was completed with climatic data (precipitation and temperature) – data were calculated as monthly simple averages from daily measurements since 1960 by Czech Hydrometeorological Institute.

Land use was supplemented by information from CORINE 2012 and 2018 (the most detailed available code). In the case of the presence of two land uses or more for one soil pit, a five-meter diameter area was considered most frequently used in the surroundings of the soil pit. This data was recorded into PUGIS Information®.

The texture of soil, texture classes, were recalculated from existing data (mainly from KPP) from classes 0.01 mm to classes 0.02 mm using the texture curve for recalculation. Graphical representation of each fraction was also added using the triangle diagram of fractions.

Information about hydromorphism and parent material was taken from the Soil Atlas of the Czech Republic (Kozák et al. 2009). Relief information (altitude, constraint) was added from State Administration of Land Surveying and Cadastre – map sheet SM 5 (2.5 × 2 km) (Digital Relief Model of 5th Generation (DMR 5G).

Within PUGIS Information System was also recalculated pH_{H_2O} to pH_{CaCl_2}. The following relationship was used according to methodology (VÚMOP): $pH_{CaCl_2} = 1.053 \times (pH_{H_2O}) - 0.683$. Cox values and humus content are in PUGIS Information® within selected district pits from the KPP. Missing Cox (oxidizable carbon) values were calculated by Welte coefficient: % humus content = Cox × 1.724.

Statistical evaluation of data. Selected data within the PUGIS were statistically evaluated using program Statistica (Ver. 12, 2016) and were processed in own interface of PUGIS programmed within HV-Map (Hydrosoft Praha).

Use of soil database data for practical implementation. Data from PUGIS Information® can be used

https://doi.org/10.17221/138/2024-SWR

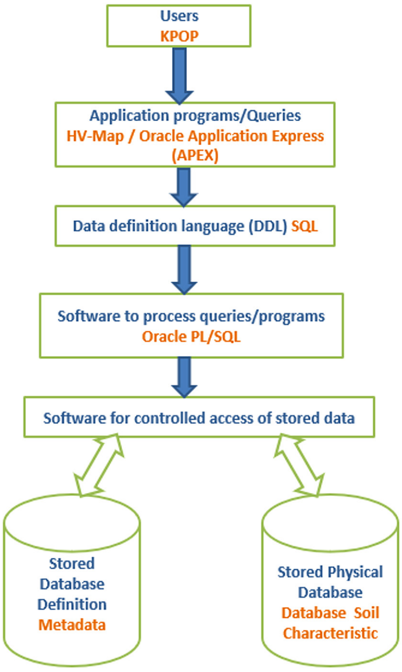

Figure 1. The scheme of PUGIS (modified scheme of Singh 2011)

primarily for (Kozák et al. 1996): prediction of organic carbon content (Yigini & Panagos 2016), the derivation of parameters for the Revised Universal Soil Loss Equation (RUSLE) (Panagos et al. 2015), soil protection against soil sealing, estimation of soil depth and estimation of potential compaction.

We applied the statistical evaluation of the database of PUGIS, for example, on the assessment of bulk density values for the soil. There is generally a lack of data on bulk density. Therefore, we applied the approach suggested in FAO cookbook (FAO 2018).

The PUGIS (Figure 1) has been proposed as part of this work according publication Singh (2011).

In the PUGIS database are currently incorporated the following numbers of soil pits: S_pits (fully analysed for all the soil characteristics from the point of view of soil chemistry and soil physics and mineralogy) 932, altogether 3 901 pits on agricultural soils and 8 665 soil pits on the forest soils.

Intuitive PUGIS users' interface is shown in Figures 2 and 3. The main agenda of PUGIS is shown in Table 1.

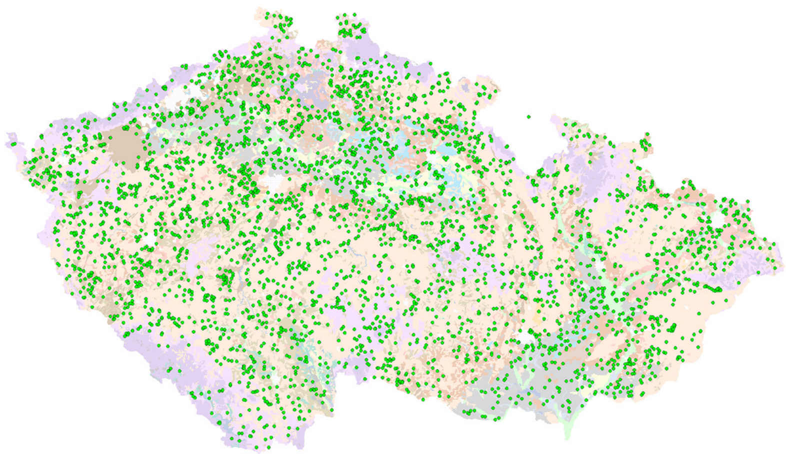

Figure 2. Soil pits on agricultural soils

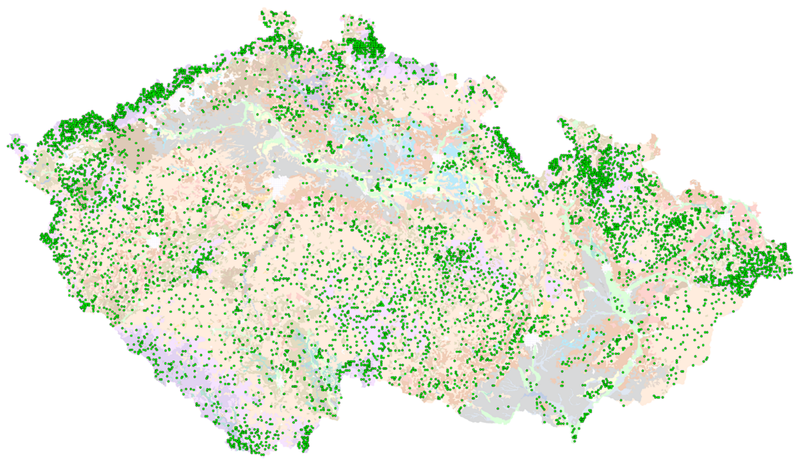

Figure 3. Soil pits on forest soils

https://doi.org/10.17221/138/2024-SWR

Table 1. The main agenda of PUGIS

Agenda	PUGIS function	Mandatory function parameters
DP	derivation of soil pit belonging to part of the soil block	soil pit coordinates
CORINE	derivation of the soil pit's affiliation to the land use polygon; determining the proportion of selected surface types in the circular distance from the soil pit	soil pit coordinates
Soil Map 1 : 250 000	derivation of soil pit affiliation to map polygon	soil pit coordinates
RVK (water retention capacity)	derivation of RVK value for soil pits	soil pit coordinates
Climatic regions	derivation of soil pit affiliation to a polygon	soil pit coordinates
Regional division of the relief	derivation of soil pit affiliation to a polygon	soil pit coordinates
Agroclimatic regions	derivation of soil pit affiliation to a polygon	soil pit coordinates
BPEJ (evaluated soil-ecological units)	derivation of soil pit affiliation to a polygon	soil pit coordinates
Geomorphology	derivation of soil pit affiliation to a polygon	soil pit coordinates
Soil classification tools	classification based on the percentage of sand, silt and clay; USDA and FAO triangle diagrams; fine soil – Novák	texture
Agenda	PUGIS function	
Pedotransfer functions	Mutual conversions	
Pedotransfer functions	calculation of bulk density based on the procedure proposed by FAO cookbook (FAO 2018)	
DPB	parts of soil blocks from the LPIS database; aggregated database of soil blocks for individual years; basic parameters are available for each part of the land block: area, average elevation, slope, orientation, predominant BPEJ (if established), current culture, organic farming regime, erosion risk and geometry	
CORINE	GIS layers of land cover (land use) with regular updates once every 6 years (EPA 2018)	
Soil Map 1:250 000	soil map 1 : 250,000, classification according to TKSP, WRB and soil-forming substrates	
RVK	map of water retention capacity	
Climatic regions	map of climatic regions	
Regional division of the relief	provinces, systems, regions	
Agroclimatic regions	macro areas, areas, districts	
BPEJ (evaluated soil-ecological unit)	map of classified soil units	
Geomorphology	geomorphological map from the soil atlas	
Soil classification tools	soil classification according to USDA, FAO; classification of soils according to Novák	
Pedotransfer functions	conversion of pH H_2O, $CaCl_2$ and KCl	
Pedotransfer functions	for determining bulk density based on the content of organic material in the soil (FAO 2018)	

DP – parts of soil cover in Czech; DPB – parts of soil blocs in Czech; Novák (Valla et al. 2000)

For a better understanding of the PUGIS functions (Table 2), the interactive screenprints of some PUGIS features are shown in Figures 4–8.

Each soil horizon is accompanied by data on chemical and physical characteristics.

The data in Table 3 represent the results of standard deviation for calculation of soil bulk density according to the suggested procedures by seven authors published in the FAO cookbook (FAO 2018). In the last column there are abbreviations of the names of the authors whose procedure was found to be the most suitable – giving the lowest value of standard deviation. The results are also shown in Figure 9.

For the use of the presented result, it could be recommended to use the method of calculation with the lowest standard deviation. We consider his approach as very useful. We exploited for that calculation all the data on bulk density available in the PUGIS database.

Another example of practical use are the data on soil organic matter. It could be expressed both as its concentration (percentage) and as a Cox or humus content in the whole soil profile per some territory (usually

https://doi.org/10.17221/138/2024-SWR

Table 2. PUGIS features

Tools	Soil texture classification USDA
	Soil texture classification FAO
	Soil texture classification Novák
	Recalculation
Soil classification	Classification TKSP
	Classification MKSP
	Classification WRB
	Humus forms
	Diagnostical horizons
	Soil substrate
	Soil units
Horizons	Colour
	Texture
	Consistency
	Grain distribution curve
	Analytics and chemistry
Classification	Taxonomic system
	Morphogenetic system
	WRB

TKSP – taxonomic soil classification system in Czech; MKSP– morphogenetic classification system of soils in Czech; WRB – World Reference Base (FAO IUSS); Novák (Valla et al. 2000)

in tones per hectare). FAO constructed a world map of humus content in soils. We contributed by the data of the Czech Republic compiling the data of humus content for the depth 0–30 cm and 30–60 cm. It was evaluated in the GIS system, and appropriate maps were derived. In the Figure 10 is shown the map of humus content in the Czech soils (depth 0–30 cm) expressed in tons per hectare of soil organic carbon.

There were also prepared the other maps of soil organic matter concentration. In Figures 11 and 12, there are shown the concentration of the soil organic matter, in this case, in the form of Cox. In this case, it is shown only a part of our territory (maps are available also for the whole territory of the Czech Republic).

The soil information system PUGIS contains, as it is apparent from Table 1, also many maps. We are giving some examples. In Figure 13 is shown a part of the map of classification of the land cover taken from the CORINE system in version 2018. The data from this system were widely used for interpretation of research results, mainly in the case of soil quality evaluation.

In Figure 14 is presented a part of the soil map of the Czech Republic 1 : 1 000 000. This map was prepared in digitized form as a contribution to soil map of Europe.

Very useful is the digitized soil map of the Czech Republic at a scale of 1 : 250 000, which is shown in Figure 15.

This map is widely used in research as well as for practical purposes. It may be combined with other maps like map of soil forming substrates, pedoclimatic regions, land use and geomorphology. For better orientation and location of map polygons it is also combined with road map.

We found also as a very useful the maps of soil evaluation (soil bonity) and maps of soil hydromorphic development and other practical soil characteristics which may be derived from the database of system PUGIS.

This contribution is a continuation of the previous research published by Němeček (1986) and Kozák et al. (1996). We know that in the Czech Republic there exist also other soil information systems. The situation was in detail described by Borůvka et al. (2018). We hope

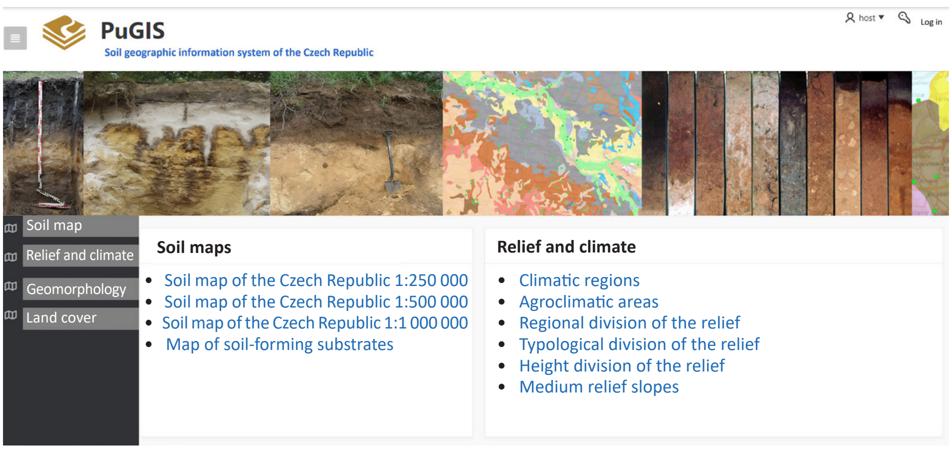

Figure 4. PUGIS interface: soil maps, relief and climate

https://doi.org/10.17221/138/2024-SWR

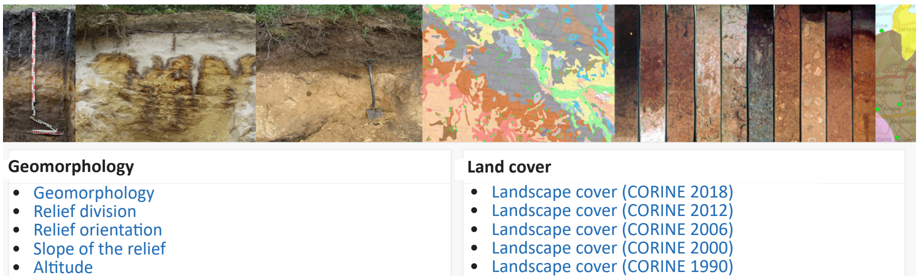

Figure 5. PUGIS interface: geomorphology and land cover

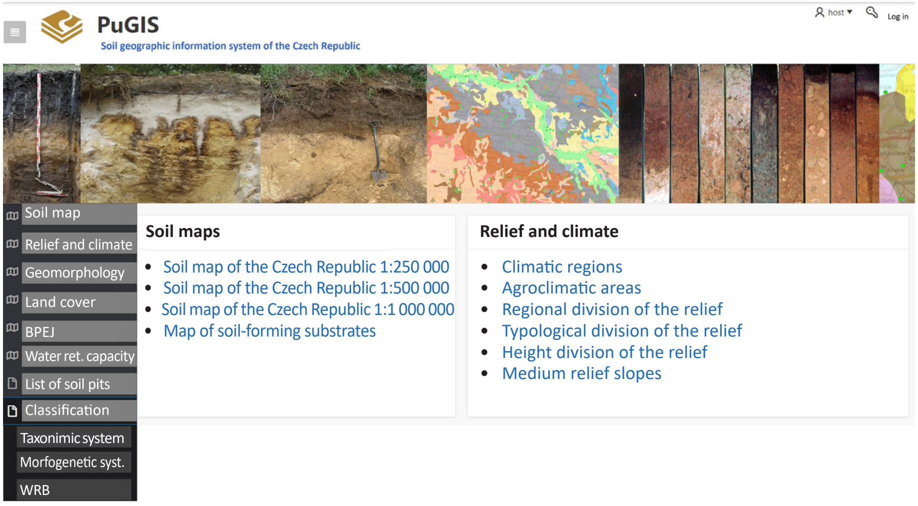

Figure 6. PUGIS interface: classification

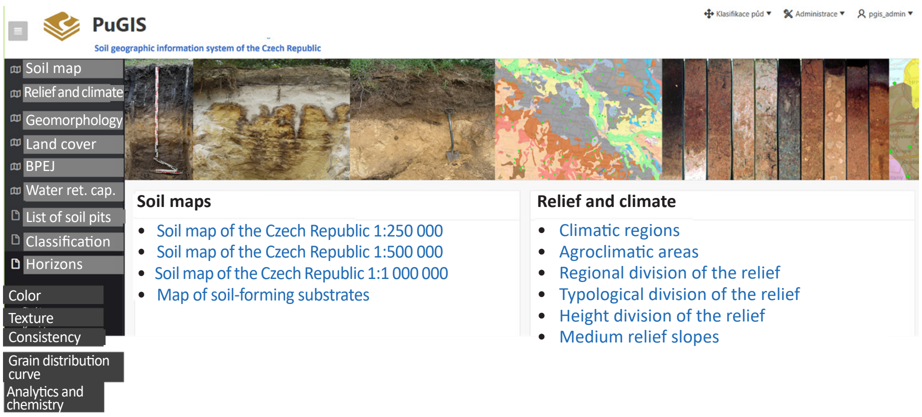

Figure 7. PUGIS interface: horizons

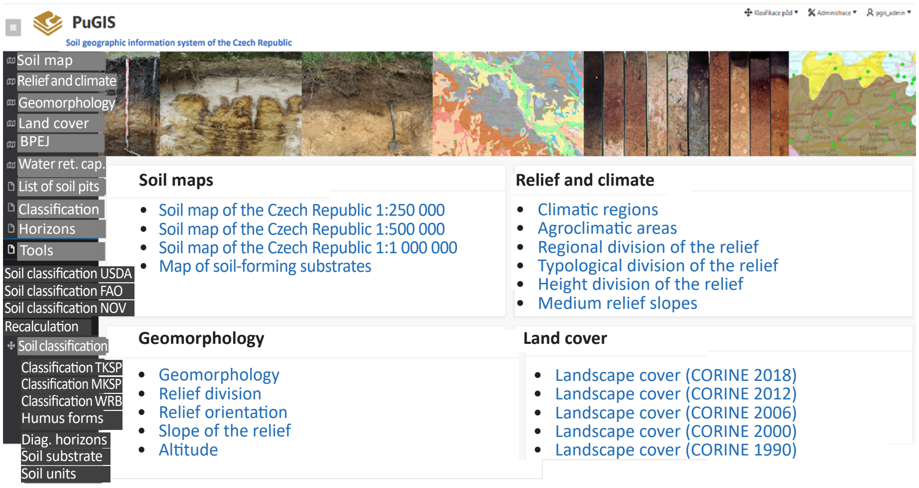

Figure 8. PUGIS interface: soil classification

https://doi.org/10.17221/138/2024-SWR

Table 3. Statistical evaluation (standard deviations) of bulk density calculation for the data on the main soil groups as classified in the Czech Taxonomic Classification System (Němeček et al. 2011)

	TYPE_ID	STDDEV_HR	STDDEV_A	STDDEV_S	STDDEV_D	STDDEV_J	STDDEV_G	LSTDDEV	BDTYP
Chernosols	glCH	0.1152	0.2223	0.1284	0.1096	0.1511	0.1340	0.1096	D
Chernosols	CH	0.0739	0.1487	0.0903	0.0653	0.1095	0.0944	0.0653	D
Fluvisols	FL	0.1558	0.2146	0.1640	0.1415	0.1186	0.1708	0.1186	J
Glejsols	GL	0.1572	0.2102	0.2045	0.1763	0.0992	0.2134	0.0992	J
Cambisols	CM	0.1000	0.1801	0.0992	0.0858	0.1167	0.1021	0.0858	D
Cambisols	CMce	0.1165	0.1828	0.1168	0.0984	0.1096	0.1269	0.0984	D
Leptosols	caLP	0.0793	0.3112	0.1105	0.1156	0.1942	0.1158	0.0793	HR
Leptosols	skLP	0.1153	0.1472	0.1279	0.1124	0.0626	0.1310	0.0626	J
Leptosols	rzLP	0.1225	0.2609	0.0631	0.1172	0.1930	0.0470	0.0470	G
Luvisols	LV	0.1123	0.1779	0.1083	0.0901	0.1139	0.1086	0.0901	D
Luvisols	AB	0.0890	0.1519	0.0728	0.0657	0.1053	0.0719	0.0657	D
Luvisols	gzPH	0.1011	0.1023	0.1067	0.0899	0.0569	0.1078	0.0569	J
Podzosols	etPZ	0.0889	0.2227	0.1206	0.1021	0.1000	0.1264	0.0889	HR
Podzosols	PZ	0.1187	0.2701	0.1009	0.0720	0.1469	0.1111	0.0720	D
Regosols	AR	0.1583	0.2262	0.1073	0.0843	0.1973	0.1063	0.0843	D
Stagnosols	ST	0.1129	0.1500	0.1457	0.1245	0.0989	0.1734	0.0989	J
Vertisols	peVR	0.0213	0.2244	0.0761	0.0332	0.1483	0.0782	0.0213	HR

STDDEV – standard deviations (the block of letters reffers to the abreviation of the name of the author whose equation was considered to give the best results (FAO 2018))
TYPE_ID – soil type abbreviation; STDDEV_HR – Honeysett and Ratkowsky (1989): BD = 1/(0.564 + 0.0556 OM); STDDEV_A – Adams (1973): BD = 100/(OM/0.244 + (100 – OM))/MBD; STDDEV_S – Saini (1966): BD = 1.62 – 0.06 OM; STDDEV_D – Drew (1973): BD = 1/(0.6268 + 0.0361 OM); STDDEV_J – Jeffrey (1970): BD = 1.482 – 0.6786 (logOM); STDDEV_G – Grigal et al. (1989): BD = 0.669 + 0.941 e(–0.06 OM) (equations from the FAO Cookbook, FAO 2018)
BD – bulk density; OM – organic matter

https://doi.org/10.17221/138/2024-SWR

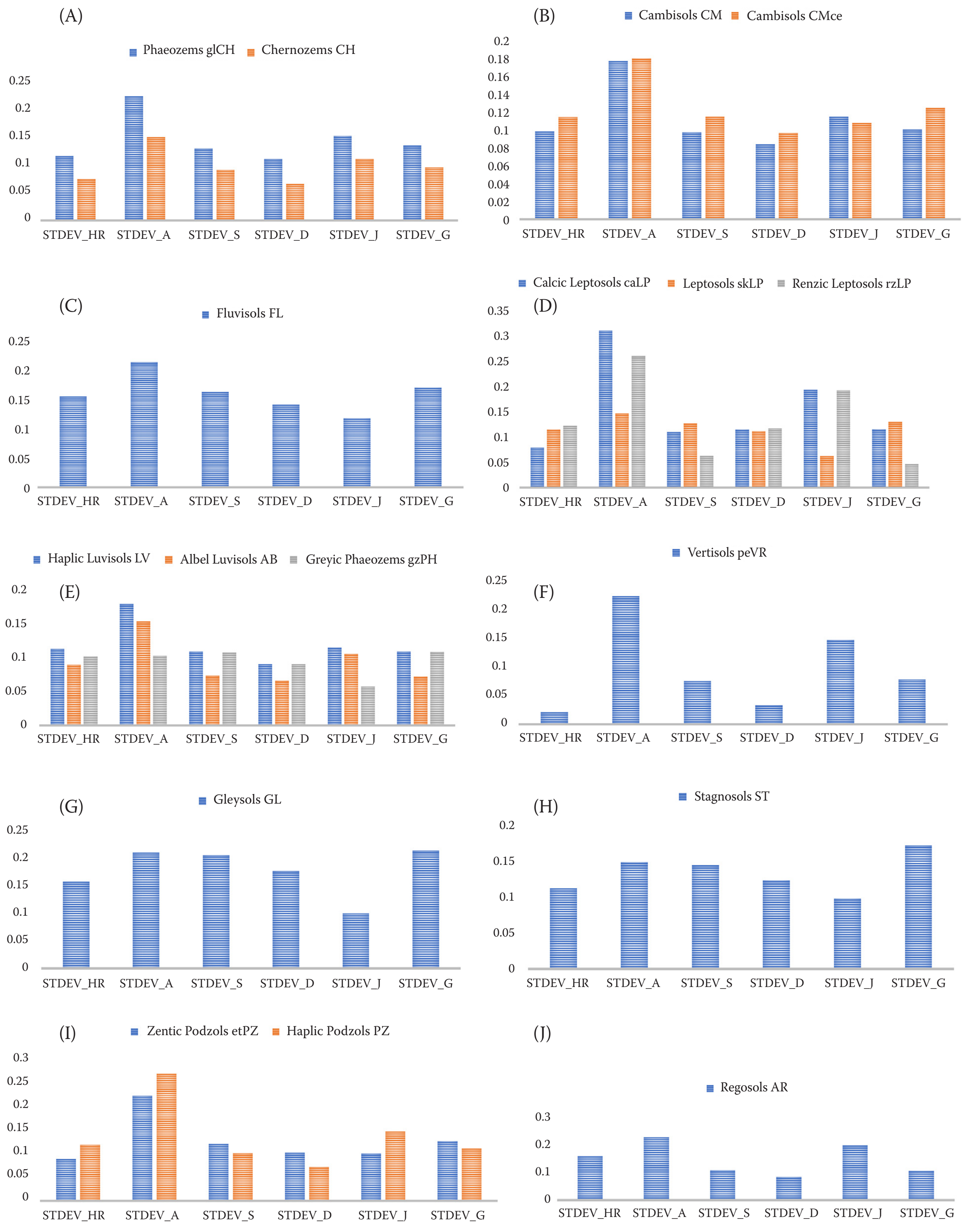

Figure 9. Statistical evaluation of bulk densities assessment for Chernosols (A), Cambisols (B), Fluvisols (C), Leptosols (D), Luvisols (E), Vertisols (F), Glejsols (G), Stagnosols (H), Podzols (I) and Regosols (J)
STDEV – standard deviations (the block of letters reffers to the abreviation of the name of the author which equation was considered give the best resuls (FAO 2018)); for details see Table 3

https://doi.org/10.17221/138/2024-SWR

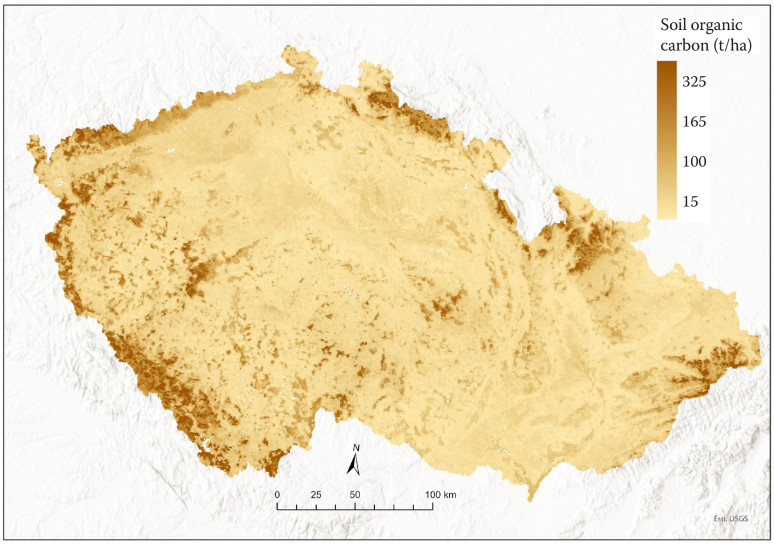

Figure 10. The map of humus content in Czech soils in the depth 0–30 cm

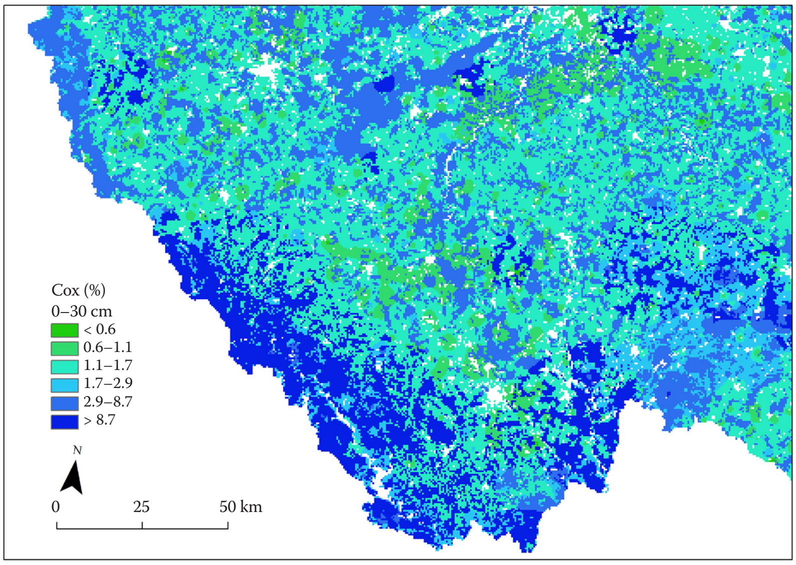

Figure 11. The concentration of oxidizable carbon (Cox) in the Czech soils in the depth 0–30 cm

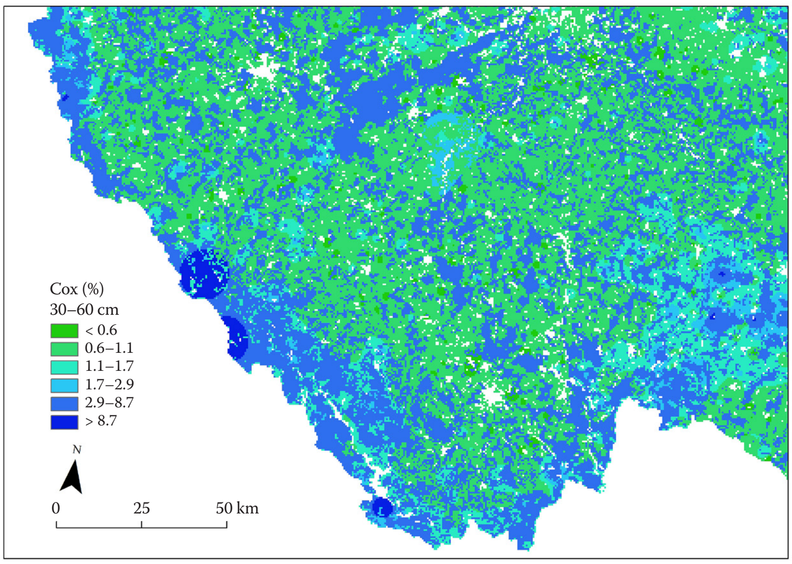

Figure 12. The concentration of oxidizable carbon (Cox) in the Czech soils in the depth 30–60 cm

https://doi.org/10.17221/138/2024-SWR

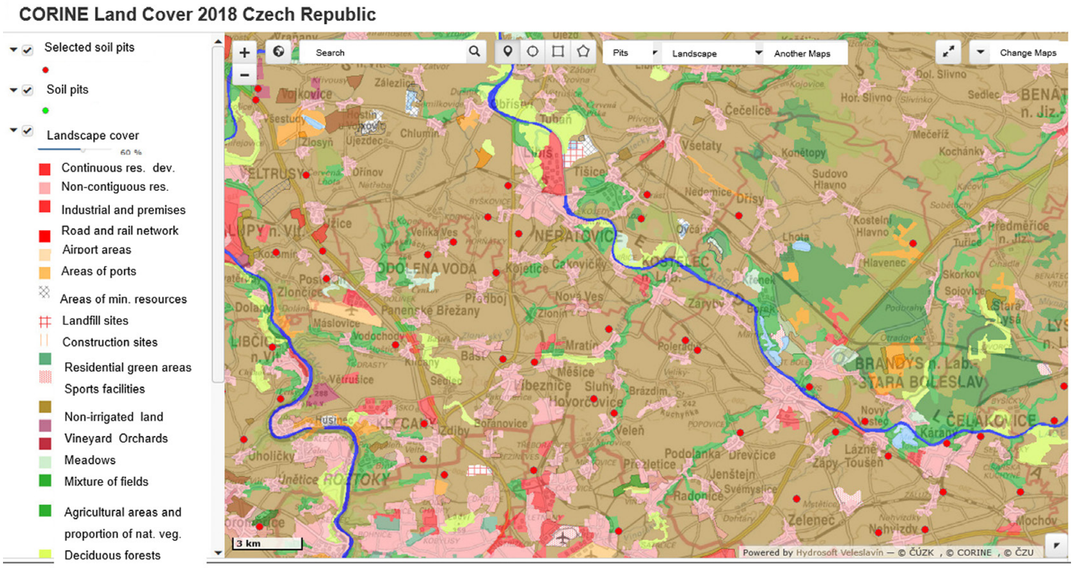

Figure 13. The map of CORINE system for the Czech Republic

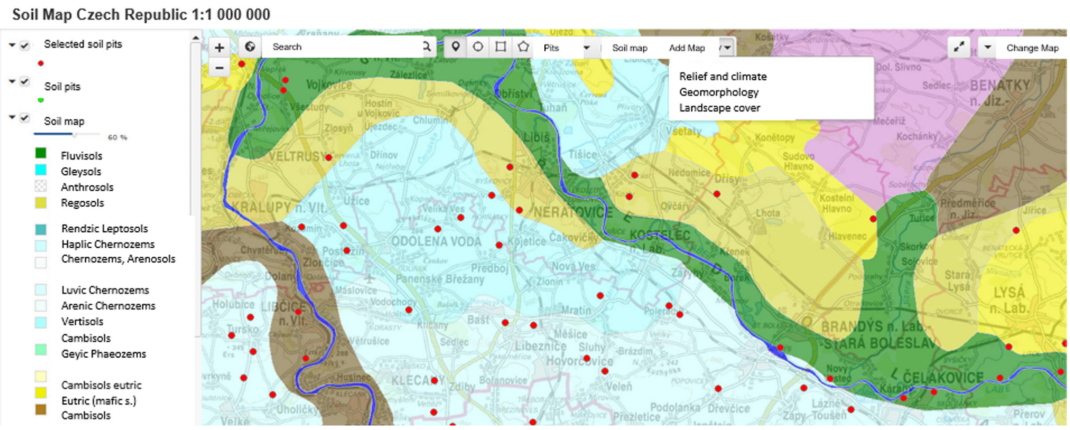

Figure 14. A part of the soil map of the Czech Republic 1 : 1 000 000

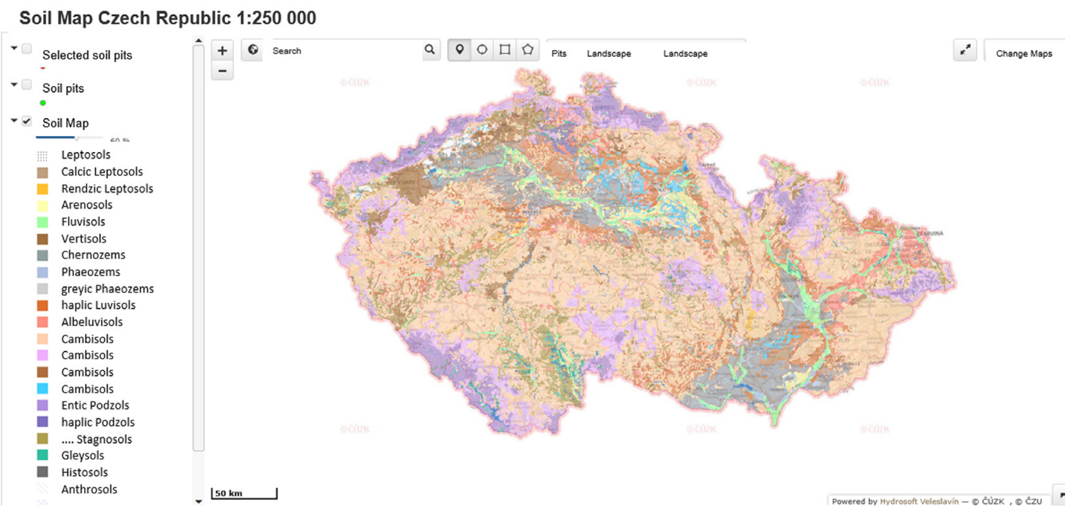

Figure 15. The soil map of the Czech Republic at scale 1 : 250 000

https://doi.org/10.17221/138/2024-SWR

for future cooperation of all the system and merge of it in one powerful system.

CONCLUSION

The new version of the soil information system of the Czech Republic PUGIS was introduced. In relatively large introduction we tried to describe the current situation in this branch of soil science. It was proved that this soil database could be successfully exploited for application pedotransfer functions to calculate missing data, in this case bulk densities of soils.

We also presented some soil map both placed into PUGIS or derived from the data in it. The system is based mainly on legacy data, but it is open for enlargement by new data gained in soil survey and soil research.

REFERENCES

ASRIS (2016): Australian Soil Resource Information System Website. Canberra, CSIRO. Available on http://www.asris.csiro.au

Balkovič J., Rampašeková Z., Hutár V., Sobocká J., Skalský R. (2013): Digital soil mapping from conventional field soil observations. Soil and Water Research, 8: 13–25.

Baritz R., Eberhardt E., van Liedekerke M.H., Panagos P. (2008): Environmental Assessment of Soil for Monitoring. Volume III: Database Design and Selection. European Commission, Joint Research Centre, Institute for Environment and Sustainability. JRC Scientific and Technical Reports. EUR 23490 EN/3–2008.

Batjes N.H. (2016): Harmonized soil property values for broad-scale modelling (WISE30sec) with estimates of global soil carbon stocks. Geoderma, 269: 61–68.

BORIS (2016): Bodeninformationssystem. Wien, Umweltbundesamt Gesellschaft. Available on http://www.umweltbundesamt.at/boris

Borůvka L., Kozák J., Němeček J., Penížek V. (2002): New approaches to the exploitation of former soil survey data. In: 17th Congress of Soil Science, Bangkok, Aug 14–21, 2002: Paper No. 1692.

Borůvka L., Penížek V., Kozák J., Marhoul A.M., Vacek O., Šrámek V., Žížala D., Poláková Š., Smatanová M., Fiala P. (2018): Combining and harmonizing soil data from different sources. Problems and approaches. In.: Arrouays D., Savin I., Leenaars J., McBratney A.B. (eds.): GlobalSoilMap. DigitalSoil Mapping from Country to Globe. Balkema, Leiden, CRC Press: 29–34.

Bureš Z. (2014): Database systems 1. 1st Ed. Jihlava, College of Polytechnics Jihlava. Available on https://kdep.vse.cz/wp-content/uploads/page/186/DEP509_Databazove-systemy_Zdenek-Bures.pdf (in Czech)

CanSIS (2016): The Canadian Soil Information Service. Ottawa, CanSIS. Available on http://sis.agr.gc.ca/cansis

Carvalho Jr W., Chagas C.D.S., Lagacherie P., Calderano Filho B., Bhering S.B. (2014): Evaluation of statistical and geostatistical models of digital soil properties mapping in tropical mountain regions. Revista Brasileira de Ciência do Solo, 38: 706–717.

Doležal J., Lacko B., Hájek M., Cingl O., Krátký J., Hrazdilová Bočková K. (2016): Project Management: Comprehensive, Practically and According to Global Standards. Prague, Grada Expert. (in Czech)

DONESOL (2016): Available on http://acklins.orleans.inra.fr/outil/donesol/donesol.php

Dupree J.A., Crowfoot R.M. (2012): Digital database architecture and delineation methodology for deriving drainage basin, and a comparison of digitally and non-digitally derived numeric drainage areas. Chapter 6, Section C, Book 11. In: Collection and Delineation of Spatial Data. Reston, U.S. Department of the Interior, U.S. Geological Survey.

ENVASSO (2016): Environmental Assessment of Soil for Monitoring. Available on: http://esdac.jrc.ec.europa.eu/projects/envasso

European Commission (2006): Proposal for a Directive of the European Parliament and of the Council Establishing a Framework for the Protection of Soil and Amending Directive. 2004/782 35/EC. COM (2006) 232. Brussels, European Union.

Eurosoil (2012): Eurosoil International Conference (1995–2012). European Communities. Available on http://eusoils.jrc.ec.europa.eu/esbn/EUSIS.html

FAO (1999): The European Soil Information System: Proc. Technical Consultation, Rome, Sept 2–3, 1999.

FAO (2018): Soil Organic Carbon Mapping Cookbook. Chapter 4. Roma, FAO: 19–34.

FAO SOILS PORTAL (2016): Available on http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/

FISBo (2016): Soil Information System FISBo BGR. Hannover, Bundesanstalt für Geowissenschaften und Rohstoffe. Available on http://www.bgr.bund.de/EN/Themen/Boden/Informationsgrundlagen/informationsgrundlagen_node_en.html

GISCO (2016): Geographical information system of the Commission. Available on http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Geographical_information_system_of_the_Commission_%28GISCO%29

Hallett S.H., Sakrabani R., Keay C.A., Hannam J.A. (2017): Developments in land information systems: Examples

https://doi.org/10.17221/138/2024-SWR

demonstrating land resource management capabilities and options. Soil Use and Management, 33: 514–529.

Hengl T., Panagos P., Jones A., Tóth G. (2007): Status and Prospect of Soil Information in South-Eastern Europe: Soil Databases, Projects and Applications. EUR 22646 EN–DG Joint Research Centre, Institute of Environment and Sustainability. Luxembourg, Office for Official Publications of the European Communities.

Hrazdilová Bočková K. (2016): Project Management: Textbook. Prague, Martin Koláček – E-knihy jedou. (in Czech)

ISIS (2016): Irish Soil Information System. Cranfield, Cranfield University. Available on http://gis.teagasc.ie/soils/index.php

ISRIC-WISE (2016): International Soil Reference and Information Centre, Soil Property Databases. Available on http://www.isric.org/data/isric-wise-global-soil-profile-data-ver-31

INTERREG (2008): Documentation for the International Project "Hazardous Substances in Soil in Relation to the Environment – Cross-border Basis for Soil Protection (Bavaria – Czech Republic)". No.: CZ.04.4.82/3.1.00.1/0060. (in Czech)

Ježek T. (2005): Assessment of the possibility of using ArcIMS for presentation of large raster data. [Master Thesis.], Ostrava, VŠB-TU. (in Czech)

Kodešová R., Kočárek M., Kodeš V., Drábek O., Kozák J., Hejtmánková K. (2011): Pesticide adsorption in relation to soil properties and soil type distribution in regional scale. Journal of Hazardous Materials, 186: 540–550.

Kollias J.V., Voliotis A. (1991): Fuzzy reasoning in the development of geographical information systems FRSIS: A prototype soil information system with fuzzy retrieval capabilities. International Journal of Geographical Information Systems, 5: 209–223.

Kozák J., Borůvka L. (2013): The experiences of building CZESOTER – Czech form of SOTER in the scale 1 : 250 000. In: GlobalSoilMaps Conference 2013, Orleans, Oct 7–9, 2013.

Kozák J., Němeček J., Jetmar M. (1996): The database of soil information system – PUGIS. Plant Production, 42: 529–534.

Kozák J., Borůvka L., Kodešová R., Janků J., Jacko K., Hladík J. (2009): Soil Atlas of the Czech Republic. 2nd Ed. Prague, CULS. (in Czech)

Lacarce E., Le Bas C., Cousin J.-L., Pesty B., Toutain B., Houston Durrant T., Montanarella L. (2009): Data management for monitoring forest soils in Europe for the Biosoil project. Soil Use and Management, 25: 57–65.

Lagacherie P., McBratney A.B. (2006): Chapter 1 Spatial soil information systems and spatial soil inference systems: Perspectives for digital soil mapping. Developments in Soil Science, 31: 3–22.

LUCAS (2016): Available on http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Land_use_-_cover_area_frame_survey_%28LUCAS%29

Machalová J. (2007): Spatially Oriented Systems for Management Decision Support. Prague, C.H. Beck. Praha. (in Czech)

McBratney A.B., Mandonca Santos M.L., Minasny B. (2003): On digital soil mapping. Geoderma, 117: 3–52.

Němeček J. (1986): Soil characteristics determining its productional and non-productional functions. Report of Research Sub-task VII-1-7-0. Prague, VÚZZP. (in Czech)

Němeček J. (2000): The status of soil mapping in the Czech Republic. In: Proceedings of a Technical Consultation: The European Soil Information System. Rome, Sept 2–3, 1999. World Soil Resources Reports, 91: 61–65.

Němeček J., Muhlhanselová M., Macků J.,Vokoun J., Vavříček D., Novák P. (2011): Czech Taxonomic Soil Classification System. 2nd Ed. Prague, CULS. (in Czech)

Neudertová Helebrantová K., Fadrhonsová V., Šrámek V. (2024): Aggregated database of forest soil chemical properties in the Czech Republic based on surveys from 2000 to 2020. Annals of Forest Science, 81: 17.

Odgers N.P., Sun W., McBratney A.B., Minasny B., Clifford D. (2014): Disaggregating and harmonising soil map units through resampled classification trees. Geoderma, 214–215: 91–100.

Panagos P., Van Liedekerke M., Jones A., Montanarella L. (2012): European Soil Data Centre: Response to European policy support and public data requirements. Land Use Policy, 29: 329–338.

Panagos P., Borelli P., Poesen J., Ballabio C., Lugato E., Meusburger K., Montanarella L., Alewell Ch. (2015): The new assessment of soil loss by water erosion in Europe. Environmental Science and Policy, 54: 438–447.

Penížek V., Borůvka L. (2004): Processing of conventional soil survey data using geostatistical methods. Plant Soil Environment, 50: 352–357.

Ramos T.B., Horta A., Gonçalves M.C., Pires F.P., Duffy D., Martins J.C. (2017): The INFOSOLO database as a first step towards the development of a soil information system in Portugal. Catena, 158: 390–412.

Shah S.D. (2004): Development of a Geodatabase and Conceptual Model of the Hydrogeologic Units Beneath Air Force Plant 4 and Naval Air Station-Join Reserve Base Carswell Field, Fort Worth, Texas. Scientific Investigations Report 2004-5062. Austin, U.S. Geological Survey.

Singh S.K. (2011): Database Systems. Concepts, Designs and Application. 2nd Ed. Delhi, Pearson.

Skalský R. (2008): Selected theoretical and methodological problems of using existing soil data in the development of geographic information. [Ph.D. Thesis.], Bratislava,

https://doi.org/10.17221/138/2024-SWR

Univerzita Komenského v Bratislave Prírodovedecká fakulta Katedra pedológie. (in Slovak)

Smolíková J., Kristenová H., Váňová V., Holub J., Žížala D., Kapička J., Papaj V., Novotný I., Vlček V., Chlubna L. (2014): Applications on SOWACGIS geoportal and their practical use. In: Proc. Contributions GIS, Ostrava, Jan 27–29, 2014. (in Czech)

SoDa (2016): ENVASSO Soil Database (SoDa). Available on http://www.bgr.bund.de/EN/Themen/Boden/Projektbeitraege_NIL/ENVASSO/ENVASSO_SoDa_en.html

Tóth G., Weynants M., van Liedekerke M., Panagos P., Montanarella L. (2013): Soil databases in support of pan-European soil water model development and application. Procedia Environmental Sciences, 19: 411-415. https://doi.org/10.1016/j.proenv.2013.06.047

Valla M.,Kozák J., Němeček J., Matula S., Borůvka L., Drábek O. (2000): Soil Science Laboratory Textbook. Prague, CULS. (in Czech)

VÚMOP (2016): Geoportál SOWAC-GIS – Geographic Information System for Soil and Water Conservation. Prague, VÚMOP. Available on https://geoportal.vumop.cz

Wesselink L.G., Notenboom J., Tiktak A. (2006): The Consequences of the European Soil Framework Directive for Dutch Policy. Netherlands Environmental Assessment Agency (MNP), MNP Report 500094003.

Yemefack M., Zhang G., Baritz R., Vargas R., Castro A., Moussadek R., Hempel J., McKenzie N. (2016): Plan of Action for Pillar Four of the Global Soil Partnership: Enhance the quantity and quality of soil data and information: data collection (generation), analysis, validation, reporting, monitoring and integration with other disciplines. Rome, FAO. Available on http://www.fao.org/3/az921e

Yigini Y., Panagos P. (2016): Assessment of soil organic carbon stocks under future climate and land cover changes in Europe. Science of the Total Environment, 557–558: 838–850.

Zádorová T., Penížek V., Šefrna L., Rohošková M., Borůvka L. (2011): Spatial delineation of organic carbon-rich Colluvial soils in Chernozem regions by Terrain analysis and fuzzy classification. Catena, 85: 22–33.

Zucca C., Biancalani R., Kapur S., Akça E., Zdruli P., Montanarella L., Nachtergaele F. (2013): The role of soil information in land degradation and desertification mapping: A review. In: Kapur S., Erşahin S. (eds.): Soil Security for Ecosystem Management. SpringerBriefs in Environment, Security, Development and Peace. Vol. 8, Cham, Springer: 31–59.

Received: November 10, 2024
Accepted: November 19, 2024
Published online: January 3, 2025