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Structure of a database of national digital map of stores of organic carbon in soils of Ukraine

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The purpose. To develop structure of database for assessment of stores of organic carbon in soils of Ukraine according to specifications of Global soil partnership of Food and agricultural organization of United Nations (FAO-GSP). **Methods.** Scientific analysis, generalization and mathematical statistics. **Results.** Attributive database which contains necessary indexes for creation of national digital map of stores of organic carbon in soils of Ukraine by means of digital mapping and simulation of soils is developed. Attributive part of the database consists of 6 messages and contains the list of indexes describing places of soil profile, methods of determination of soils' properties and calculation of stores of organic carbon in soils of different type of land-use in conformity with specifications of Intergovernmental commission of experts on climate fluctuation. The designed database structure ensures the opportunity to derive representative data file for generalization and integrations with national database «Properties of soils of Ukraine» of NSC «A.N. Sokolovsky Institute of soil science and agrochemistry». The framed database includes the period of field investigations of soil covering beginning from 1959 up to 2016. Content of database is integrated into Global digital map of stores of soil organic carbon of FAO. **Conclusions.** The offered structure of database may be used for development of similar specialized relational databases with the purpose of their application in digital mapping and simulation of soils. Creation of the specialized processing center with the uniform harmonized system of storage of information on the state of soil covering will ensure an opportunity of its use for scientific researches and formation of soil-protecting policy of the state.

Key words: *soils, database, organic carbon, stores of carbon, digital map of organic carbon.*

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Introduction. Soil organic carbon is the main component that affects most processes and determines fertility of soil. The ability of the soil to accumulate organic carbon contributes to reducing greenhouse gas emissions into the atmosphere, mitigating the effects of climate change, and achieving the Sustainable Development Goals (SDGs) [1-2]. The soil organic carbon stock is used as an important indicator for monitoring land and soil degradation in the programs of the Food and Agriculture Organization of the United Nations (FAO) to achieve a neutral level of degradation [3].

Most of the existing global and national estimates of soil organic carbon stocks are made by using digital soil mapping and modeling techniques (DSMM) [4]. DSMM is the creation of forecast maps by computer analysis of field soil surveys information and spatial characteristics of soil factors [5]. According to A.B. McBratney [6], for the construction of a digital prediction map using digital soil mapping and modeling techniques 3 main components are needed: 1 - soil parameters, 2 - environmental covariates, and 3 - components of the analysis of spatial information. With the help of these technologies, it is possible to create maps for assessing of soil degradation, changes in soil properties due to climate, economic activity, etc.

The United Nations Convention to Combat Desertification (UNCCD) and its Science Policy Interface (SPI), in conjunction with the Global Soil Partnership (FAO-GSP), was initiated by the creation of the Global Soil Organic Carbon Map (GSOCmap) based on national spatial assessments of soil carbon stocks carried out using the digital soil mapping techniques.

This article presents one of the stages of the work that was carried out during the preparation of the first edition of the national digital map of soil organic carbon stocks in the framework of the agreement between the National Scientific Center «Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky» and FAO as a voluntary contribution from Ukraine to the Global Soil Organic Carbon Map (GSOCmap) [7-8].

According to the principles of digital soil mapping and modelling, one of the stages of creating the map is the development of the attributive part of the database (DB) and filling the database.

The purpose of research is to develop a soil database (DB) for the assessment of soil organic carbon stocks in Ukraine, according to the specifications of the Global Soil Partnership of the Food and Agriculture Organization of the United Nations (FAO-GSP).

Materials and methods of research. As a prototype for the creation of the digital map database, a national database "Soil Properties of Ukraine" NSC "ISSAR named after O.N. Sokolovsky" was used [9]. The contents of the attributive part of this database are adapted to the national requirements for the description of the soil profile and land use type [10], and has a high correlation with the international databases [11]. In order to determine the list of attribute indicators of the developed DB, the FAO-GSP guidelines for sharing national data/information to compile a Global Soil Organic Carbon map (GSOC17) has been processed [12].

Results. One of the key tasks in developing a database structure of soil properties is to define a set of attributes, which provides a comprehensive description of information for processing and compatibility with existing soil databases and the possibility of integration into national or global databases.

The FAO-GSP manual [12] sets out the basic requirements for attribute data for building a national digital map of soil organic carbon stocks. In particular, the calculation of soil organic carbon stocks should be made in accordance with the recommendations of the Intergovernmental Panel on Climate Change [13]. Based on these recommendations, a list of attributes of the database was formed (Table 1).

Table 1 List of attributes of the database

01 Description of the soil sampling site
ID soil profile or soil sample Administrative region Administrative district Settlement Latitude Longitude
02 Characteristics of the soil and land
Soil name Land use /land cover type Type of forest vegetation *
03 Description of the soil profile
Index of soil horizon Upper horizon boundary, cm Lower horizon boundary, cm Upper boundary of layer for sampling, cm Lower boundary of layer for sampling, cm Peat depth, cm **
04 Indicators for calculating organic carbon stocks
Soil organic carbon (C),% Soil organic carbon in the forest floor,% * Dry weight of the forest floor material sampled, kg/m^2 * Content of granulometric fractions > 1 mm, % Content of granulometric fractions <0.01 mm,% Content of granulometric fractions <0.001 mm,% Bulk density, g/cm^3 Stones, %

05 Date of soil observation and methods of determination of soil properties
Date of observation Method of determination the content of soil organic carbon Method of determination the bulk density Method of estimation of stoniness
06 References and contact information
Source of information The author of the data Contacts (email address, mobile phone)
* - additional attributes for forest soils ** - additional attributes for peat bogs

The main component of the database is the spreadsheet records in Excel. Each entry contains information about a single object under investigation (for example, soil profile) for a selected set of attributes, which are the fields of the spreadsheet.

The attributive part of the database was divided into 6 main thematic blocks; the list of attributes of each of them is consistent with the parts of the database "Soil Properties of Ukraine" and the existing model data organization, which provides a simple import of the contents of the developed database to the national database. In addition, the proposed method of structuring attribute data in one spreadsheet is more accessible to users, which allows the rapid collection of large data arrays and, if necessary, easy to transform into a relational database.

Since the calculation of organic carbon stocks is carried out according to different formulas for soil with different land use types, three separate forms of spreadsheets with the appropriate set of attributes were prepared. The basic set of attributes for agricultural lands (mineral soils) was supplemented with attributive parameters of forest conditions, the content of organic carbon in the forest litter, the dry weight of the selected layer of forest litter in the spreadsheet for surveyed forest soils, and the peat depth for the peatlands.

The forms of spreadsheets were sent to data providers and organized collection of information on field surveys of organic carbon in regions of Ukraine. After receiving the filled-in files, the conversion of the submitted data into the FAO-GSP formats were carried out and a composite attribute table was created, the content of which was used to create a national soil carbon stock map and integrated into the FAO Global Soil Organic Carbon map [8].

The database contains information on the content of organic carbon in more than 3,000 surveyed soil types throughout the territory of Ukraine and the Autonomous Republic of Crimea. Of the total volume of the database, about 45.7% of soil profiles are represented chernozems, and 13.4% - podzolized soils (Fig. 1). The least in the formed DB is represented solonetzs and solonchaks. The content of the main data array in the database corresponds to the structure of the soil cover and is representative for the territory of Ukraine.

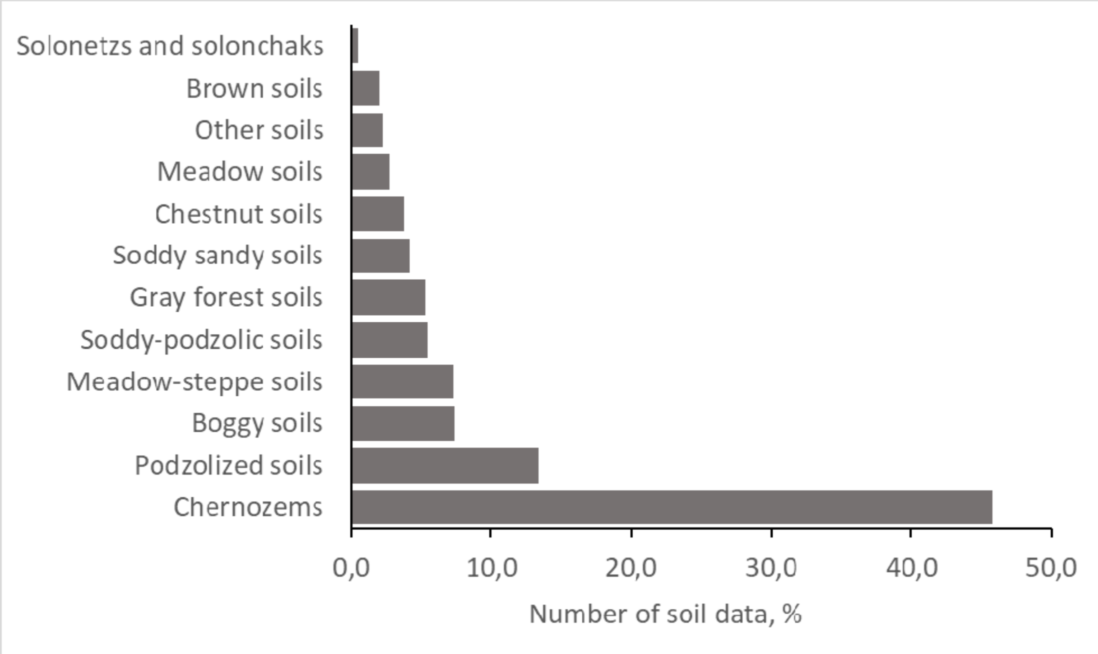

Fig. 1 Distribution of surveyed soil types

The data set covers of field surveys conducted in the period 1959 - 2016 (Figure 2). Moreover, about 16.8% of the available data in the current basic sample from the database is the results of the country's soil cover surveys conducted before 1990, about 28.1% - between 1990 and 2010 and 55.1% after 2010.

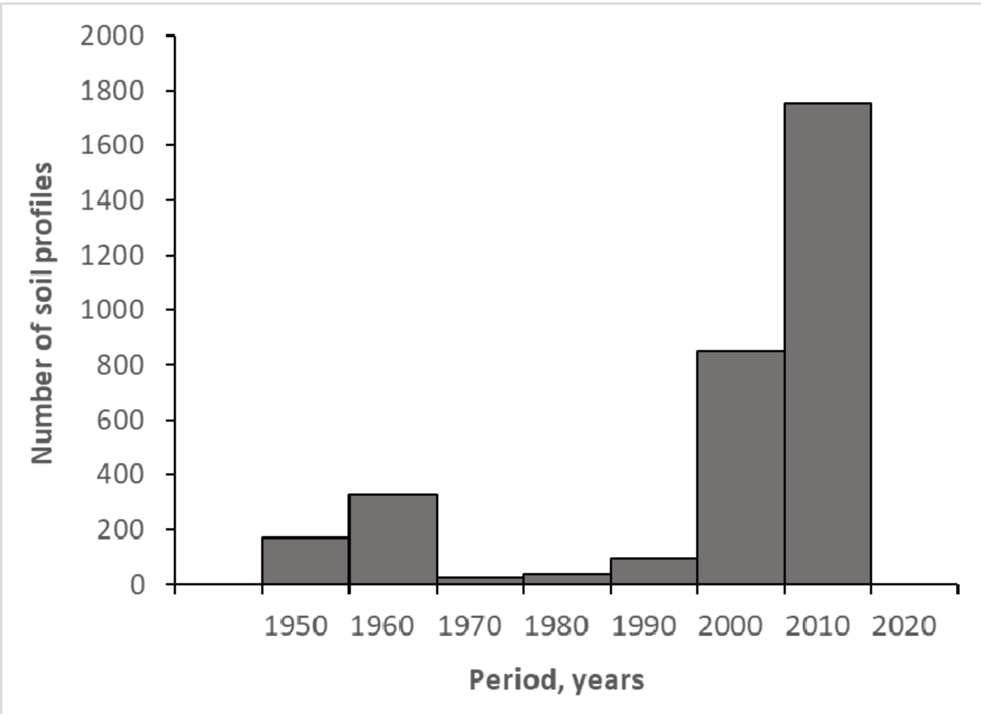

Fig. 2 Distribution of surveyed soil types over the periods

The creation of the national digital soil organic carbon stocks map became possible thanks to the close collaboration of scientists from the National Academy of Agrarian Sciences of Ukraine, the National Academy of Sciences of Ukraine and higher education institutions that are not indifferent to the problems of soil degradation.

Today, information about the current state of the soil resources in Ukraine is distributed among various agencies involved in soil and land monitoring. In addition, its scope, periods and objects of surveys, methodology and set of indicators are different. For the compilation and analysis of diverse data, the compilation of periodic national reports on carbon inventories, information to the public on the state of the soil resources and possible environmental risks, a unified, harmonized information system with open access to all soil related information is needed. The availability the open access soil information system will allow to use soil data as for scientific research as for the providing of soil protection policies, as implemented in the European Union (EU) due to the harmonized LUCAS (Land Use and Coverage Area Frame Survey), the development and administration of which is commissioned by the European Soil Data Center [14]. The results of the LUCAS database processing were taken into account when implementing the Common Agricultural Policy of the EU through the introduction of targeted support for special agro-ecological measures - afforestation, conservation of agricultural land, and others.

Conclusions

The developed DB is an ordered data set (attributes) for mapping and monitoring of soil organic carbon content and stocks in accordance with FAO-GSP guidance. The proposed structure of the database can be used to develop relational databases for the purpose of their use in digital soil mapping. The systematic addition of database content to new data arrays will allow developing of digital soil mapping in Ukraine, and creating high-resolution maps. Database content needs to be integrated with other soil data to assess of soil and land degradation.

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