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GENESIS AND GEOGRAPHY OF SOILS

Technologies and Standards in the Information Systems of the Soil-Geographic Database of Russia

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Abstract—The achievements, problems, and challenges of the modern stage of the development of the *Soil-Geographic Database of Russia* (SGDBR) and the history of this project are outlined. The structure of the information system of the SGDBR as an internet-based resource to collect data on soil profiles and to integrate the geographic and attribute databases on the same platform is described. The pilot project in Rostov oblast illustrates the inclusion of regional information in the SGDBR and its application for solving practical problems. For the first time in Russia, the GeoRSS standard based on the structured hypertext representation of the geographic and attribute information has been applied in the state system for the agromonitoring of agricultural lands in Rostov oblast and information exchange through the internet.

Keywords: soil database, geoinformation systems, standards of information exchange, monitoring

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INTRODUCTION

Application of information technologies (IT) to store, retrieve, and manipulate data of soil inventories and to monitor the state of the soil cover and make management decisions is one of the major challenges facing modern soil science. The works in this field stimulate integration processes in the development of unified approaches to the classification and diagnosis of soils, the use of similar units of measurements and analytical methods, and the application of common criteria for global soil-ecological monitoring. In recent decades, considerable achievements have been gained in the creation of databases on soil resources and their practical application. However, the advancement in this field throughout the globe is very uneven. The most significant progress has been achieved in the countries of Western Europe and North America and in Australia [26, 28, 32].

The use of IT in Russian soil science dates back to the end of the 1970s [14]. The first works were aimed at standardization and coding of the characteristics of soil properties [13, 21] and the development of a unified soil terminology. As a result, several soil information systems were created [16, 31]. These works were performed using computers available at that time; magnetic tapes were sometimes used to store data [14]. Database management systems had to be created from scratch.

Subsequently, information systems and corresponding software improved fairly quickly [1, 17]. A large group of authors made an inventory of land resources of Russia, including soils, and produced a CD-ROM with this information [34]. The problems of integration of Russian soil databases and soil databases of the European Union had to be solved [20]. Special manuals and textbooks on soil informatics for students and researchers were published [18].

The work on the *Soil-Geographic Database of Russia* was initiated by the Dokuchaev Soil Science Society in 2005 [24]. In 2008, it was intensified [25]. By 2010, the structure of the attribute data was developed [9], and the program for the local data input and conversion (Soil-DV ver. 1) on a server was created. The major requirements for supporting software tools, including programs for data administration, data editing, data input from the Internet and from local sources, data retrieval and remote queries (with metadata search), and information output through the Internet, were formulated. The problems of the inventory and formalization of archived soil data and the development of information support of the research and educational programs were also raised. It was planned to link attribute data on the soil profiles with spatial data on their distribution (soil maps). The works in this field have been performed in recent years.

At present, the new stage of the full-fledged development of the SGDBR is being realized [2, 23]. The *Unified State Registry of Soil Resources of Russia* has been prepared and published. It includes soil descriptions, the inventories of soil resources for separate subjects of the Russian Federation, and the map of soil-ecological zoning of Russia. It is realized in a digital format. The first version of this registry has been published. It is also available on a CD-ROM [7].

The information system (IS) of the SGDBR is aimed at solving various practical problems [22]. It integrates a considerable volume of digital information on the soil resources of Russia [8, 12] and links the spatial (geographic) and attribute databases on a common platform on the Internet. Thus, the SGDBR is a software tool and internet resource (http://www.soil-db.ru) designed for collecting formalized data on the soil profiles in the autonomous (local) and web-based (Internet) regimes. The local database management system is realized in MS Access format. It has a hierarchical structure of classification tables synchronized with reference tables in the main database on the webserver. The work with the local database management system allows one to obtain a properly structured description of one or several soil profiles with indication of the author (information supplier) on a special card. These data can be uploaded to the Internet resource. Then, their expert evaluation is performed in order to decide on the feasibility of inclusion of these data in the general database. In the process of working on the Internet (as a client of the system), immediate correction and modification of the data are possible. The interface used in the local regime is identical in its appearance and the set of classifiers to that used in the web-based regime.

Information about the geographic coordinates of soil profiles in the IS makes it possible to display their location on the maps of Russia. At present, the cartographic block of the IS SGDBR incudes a series of maps in vector format: the soil map on a scale of 1 : 2.5 M [12], the map of soil-ecological regions on the same scale [8], and the map of administrative division of the Russian Federation on a scale of 1 : 1 M. The web interface allows the user to look for the location of the soil profiles and soil polygons on a static map and to obtain information on the presence of particular soil profiles and soil polygons within a specified rectangular area. It is also possible to display information on the soil profiles on a dynamic (online) Yandex map.

The cartographic information—location of the profiles—makes it possible to perform additional control of the uploaded data. It is also possible to obtain attribute information on the soil polygons (from the map) and to perform various calculations for point-size data (soil profiles) and for polygonal (soil polygons, natural zones, etc.) objects. Thus, it is possible to perform data averaging within the given artificially selected or natural polygons.

One of the powerful tools for the analysis of information is the query form analogous in its appearance to the forms for the input and editing of attribute information. However, in the query form, numerical data (e.g., the absolute height of the given soil profile or various parameters of physical and chemical analyses of the soil samples) are presented as intervals within which the requested data should be found. Qualitative characteristics and names are selected in the case of their strict matching. Blank fields ("not determined" for the classifiers and "0" for numerical data) are not taken into account in the queries. The selection of required data follows the logic scheme "and" for all the filled fields. The searching form allows one to select the soil profiles or soil samples (soil horizons) fitting the requested parameters for the soil profiles or soil horizons, respectively. The results of the search can be displayed on maps or downloaded in a tabular format for offline calculations.

The IS also makes it possible to upload photos of the soil profiles or soil horizons (up to three photos per a given profile) to the database. More detailed information on the IS SGDBR can be found in [22]. Overall, the database management system contains 180 reference tables of various soil classifiers and tables with direct information on the soil profiles and soil horizons. At present, the attribute part of the database includes 45 characteristics for the soil profiles and 250 characteristics for each of the soil horizons (soil samples).

The SGDBR project was initially designed as a continuously developing system with broadening functional capacity, including new opportunities offered by the geographic information systems [19]. The development of information technologies, the success of national soil information systems abroad, and the appearance of analogous regional systems in Russia call for the next stage of the SGDBR development with new challenges and new problems that have to be solved. These problems can be subdivided into three groups:

(a) The problems related to the inclusion of regional information in the SGDBR with allowance for the specificity of particular regions; special mechanisms to supply, correct, and actualize regional soil data have to be developed;

(b) The problems related to the expansion of the information structure of the SGDBR and the development of standards for information exchange both within this system and with other systems developed by different agencies dealing with soil data; and

(c) The problems related to practical use of the SGDBR for solving various applied tasks of the inventory of soil resources, soil-ecological monitoring, land evaluation, and optimal resource management at the regional and national levels.

Areas of chernozems in Rostov oblast (thousand hectares)

Data source	Total area of the type of chernozems	Subtypes of chernozems			
		ordinary chernozems	southern chernozems	calcareous ordinary chernozems	solonetzic and primitive chernozems (without division)
I	6497	827	3540.7	2013.6	115.7
II	6549	538.5	2697.8	2429.3	883.4
III	6504	158	2842	2070	1434
IV	5998	654	2688	2015	631

(I) soil map of Rostov oblast edited by Prof. S.A. Zakharov (1939); 1 : 500000 (671 soil polygons); (II) soil map of the Russian Federation (1988); 1 : 2.5 M (51 soil polygons for Rostov oblast); (III) calculations of P.A. Sadimenko (1974); cited from [4]; and (IV) soil map of Rostov oblast developed by the Southern Institute for Land Management (1975); 1 : 300000; vectorized by the Dokuchaev Soil Science Institute (1277 soil polygons).

REGIONAL INFORMATION IN THE SGDBR

One of the challenges of the SGDBR project is the unification and inclusion of archived data of regional soil surveys in the system. Rostov oblast was selected as a pilot region. To include the results of large-scale soil surveys performed in the Soviet Union in 1955–1990 in the SGDRB, the legends to the corresponding maps with some local and obsolete soil names had to be unified. This made it possible to upload attribute data on the surveyed soils to the system. The results of modern agrochemical surveys accumulated in regional databases of the Agrochemical Service of the Ministry of Agriculture of the Russian Federation (with data on representative soil profiles) can also be included in the SGDBR. Such data will provide the basis for the long-term soil monitoring programs. To include geospatial information from the large- and medium-scale maps of the soil surveys, they had to be vectorized. At present, the IS SGDBR serves as a geoinformation system of monitoring of agricultural lands in Rostov oblast. This part of the SGDBR was created within the framework of a contract with the government of Rostov oblast. In the future, data from other regions can also be included in the SGDBR.

At the moment of preparation of this paper, the SGDBR contained information on about 1000 soil profiles. This number is far from being sufficient taking into account the fact that the number of soil polygons on the soil map of Russia (1 : 2.5 M scale) also included in the SGDBR is nearly 30000. The reasons for such a slow upload of data on the individual soil profiles have to be specially analyzed. However, it seems more productive to pay attention to the potential sources of new data. In particular, these are the databases of regional agroindustrial enterprises. In Rostov oblast, the structure of the regional database and the software supporting it are compatible with the IS SGDBR. Regional databases are regularly renewed and supplied with actual soil data, so their use for the further development of the SGDBR seems to be promising. Unfortunately, these databases are far from being complete; i.e., they do not include full information on 250 characteristics of soil horizons and 45 characteristics of soil profiles that have to be introduced into the SGDBR. At the same time, the practical value of regional databases is very high, since they have been created in order to meet practical demands of the agroindustry.

However, for their adequate representation in the SGDBR, the database structure has to be supplemented with a number of “local” soil characteristics to reflect the specificity of soil-agrochemical surveys. For example, soil names applied in these surveys in Rostov oblast had to be specified in agreement with the classification system used in the SGRBR; i.e., soil types and subtypes had to be identified; some characteristics used in the separation of soil genera and species had to be added to the descriptions of the soil profiles in the regional database. Local soil names have also been preserved in the structure of the database. Special fields to display data on the bulk contents of heavy metals and on their exchangeable forms had to be introduced. The necessity of these modifications in the SGDBR structure can be illustrated by the results of calculation of the area of chernozems in Rostov oblast with the use of different information sources (table).

It can be seen that the difference in the areas calculated for the type of chernozems is no more than 1%. However, at the subtype level, the difference reaches dozens of percent. Only 80% of the main soils of Rostov oblast according to [4] can be found in the legend to the soil map of Russia (1 : 2.5 M scale) included in the SGDBR. During the small-scale soil mapping, the principle of topological rather than geographical reliability is followed, especially for small soil areas, and we can expect the overestimation of the area of subdominant soils. In general, the calculation of soil areas for a given region on the basis of a small-scale map may lead to significant errors.

The differences related to the characterization of parent materials, soil textures, and some other soil characteristics applied at the genus and species levels, as well as to the characteristics of soil water and wind erosions, humus contents, and other properties attesting to the degree of soil degradation, are even more

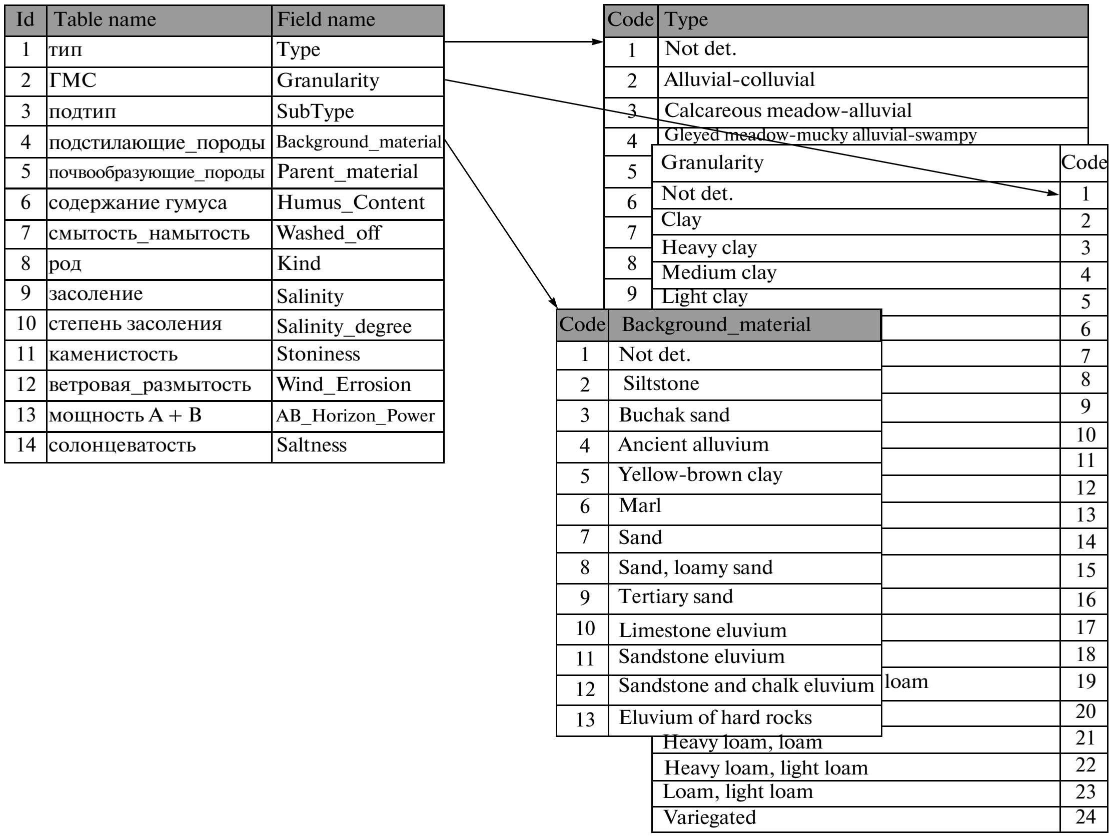

Fig. 1. Structure of classifiers for the legend to the large-scale soil map of Rostov oblast.

significant. To monitor the dynamics of these valuable soil characteristics, the names of corresponding soils shown on different maps have to be unified, and the results of calculations have to be presented in a compatible way. To achieve this, special correlation tables for taxonomic soil characteristics applied by regional soil scientists have to be developed. It is necessary to convert local and obsolete soil names and soil characteristics on the regional maps into the names and characteristics accepted in the SGDBR. In particular, this can be realized via "separation" of the regional soil names into a number of taxonomic characteristics with the use of unified classification tables for each of these characteristics (Fig. 1).

Within the framework of this approach, the SGDBR plays the strategic role of ordering and unification of the large-scale regional soil registries. The correlation tables applied in neighboring regions should be quite similar (or completely coincide). The integral national soil registry developed upwards "from the bottom" in this way [33] should be compatible with the list of soils currently shown on the small-scale soil map (about 200 major soils). However, the boundaries of soil polygons and the calculations of soil areas based on the large-scale regional soil maps should be much more accurate. This approach should provide much more detailed information on the agricultural land of Russia (12.9% of the entire territory of Russia) as the most valuable land resource (because large-scale soil surveys have mainly been performed for agricultural land). This is necessary for a more efficient monitoring of these lands and their proper assessment. As for nonagricultural lands, regional information on them is at least no less detailed than that currently available from the SGDBR.

INFORMATION STRUCTURE AND INTERSYSTEM EXCHANGE

The resolution of the Government of the Russian Federation from August 9, 2013 No. 681 "On the State Ecological Monitoring..." lists eight federal ministries and agencies responsible for compatibility of information systems used for environmental monitoring purposes. All these information systems developed by different agencies include some soil information. In order to ensure intersystem exchange of soil information, some common principles should be developed [5, 10]. The main ones are as follows:

(a) Distributed storage, modification, and updating of the primary (raw) data with proper fixation of the history and temporal series of observations;

(b) Representation of data in some common formats and in compatible units with the application of self-describing data structures, i.e., the structures in which soil data are supplied with the names of corresponding indicators adopted in the local storage systems and with indication of the methods of their determination, the applied classification system, measurement units, and other metadata; in the exchange of information, these data should also be accompanied by the spatial information in a standardized format; and

(c) Implementation of protocols and standards for exchange of spatial and attribute information aimed at creating "situational awareness" of the users via combining traditional GIS technologies and specialized servers of geographic databases.

These three aspects of information exchange are interdependent. In the IS SGDBR, they are realized in the GeoRSS standard based on the structured hypertext information used on the Internet. In essence, GeoRSS is an extension of the RSS (really simple syndication) web feed format that includes representation of spatial (location) data in the hypertext format encoded in the geography markup language (GML) or some other standards. Fragments of a soil profile description in the IS SGDBR are shown in Fig. 2. In these fragments, the values of the particular characteristics of the profile and its horizons are listed together with their names, methods of determination, and information sources. Thus, they compose a "self-describing" structure in the hypertext XML (extensible markup language) format. The geographic coordinates of the profile in the WGS84 reference system are placed in the end of the description. It important that the XML format was initially designed for the Internet rather than for data storage in local database management systems.

Broadcast stream data in XML (streams, not files) publicly provided by data servers on the Internet are often used to organize news columns on the websites. RSS is one of the standards for the organization of such information channels. In the GeoRSS standard, spatial information (points, lines, polygons, and boxes) about the object is provided; it is complemented by the attribute information.

An example of the soil profile description given above is available from the server through the following query: http://www.soil-db.ru/Get_Profile.ashx?Mode=415. This example illustrates the ability to display spatial and cartographic information from various suppliers (such as Yandex, Google, Microsoft, and ESRI ArcGIS) in the web browser; in addition, information layers created in standalone GIS applications and uploaded to the Internet can be displayed (Fig. 3). This principle is applied in many national systems of land monitoring, including the *Atlas of Agricultural Lands of the Ministry of Agriculture of the Russian Federation* (http://atlas.mcx.ru/). The thematic information (e.g., on the boundaries of the fields, farming areas, agricultural use, etc.) is prepared in the offline regime and then uploaded to the Internet.


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Fig. 2. Fragments of a soil profile description in the GeoRSS standard (in Russian).

Let us briefly describe the procedure of information exchange as illustrated by Fig. 3. A browser of the client's computer addresses a query about some spatial object (1) to the "domestic" website with a simultaneous request for shaping the base layer (such as satellite image) to the server providing geo-content. The webserver formalizes information request and sends a query (4) to find the desired object on the basis of its attribute characteristics or its spatial location to the geo-content server. Both servers form their answers (2) and (5) in the GeoRSS format (i.e., in the form of XML stream); these answers are combined and visualized in the browser on the client's computer. This process is usually cyclical, and its spectacular visualiza-

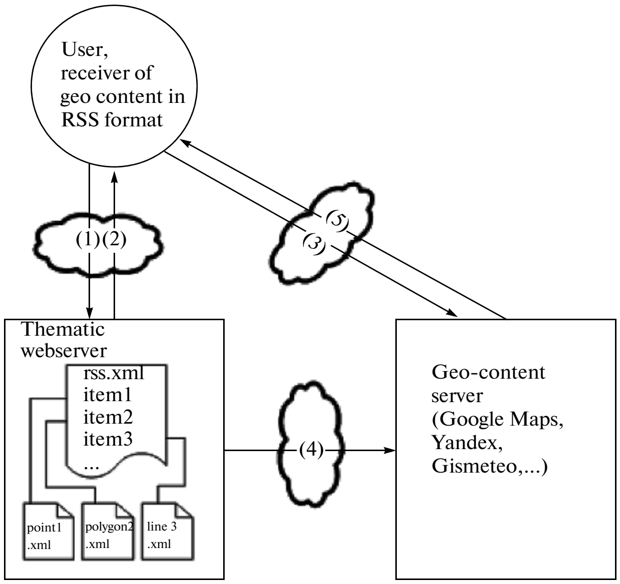

Fig. 3. Information exchange with the use of GeoRSS and a provider of geographic content (Google Maps, etc.).

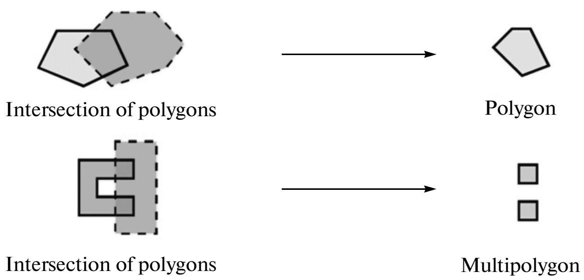

Fig. 4. Intersection of the boundaries of a field and a soil polygon on the SQL server. In the first case, a single polygon is obtained; in the second case, a multipolygon is obtained.

tion creates the illusion of a "real" monitoring. As long as information about relatively simple polygons with stable boundaries (e.g., field boundaries) is used, cartographic services can visualize multilayered *static* spatial information and attribute data on limited areas relatively quickly. However, the situation changes when information on soil polygons with complex sinuous boundaries is used. In addition, attribute data on the agrochemical soil properties are often renewed. The processing of this information is much more difficult and time consuming. In this case, several problems have to be solved. First, it takes time to prepare this information for the input offline, so that the updating of information is far from being satisfactory. Second, the visualization of soil data as a layer drastically overloads information channels. This means that the access of farmers—the main users in rural areas of Russia—to this information is limited. Even in the case of broadband internet connection, the processing of this information increases requirements for the power of personal computers. Third, even a simple spatial analysis of soil data (e.g., calculation of the degree of soil heterogeneity of the fields with consideration for the diversity of soil polygons and their areas (Fig. 4)) is virtually impossible in such systems.

To overcome these difficulties, a number of database servers (Oracle, Microsoft SQL, PostGIS SQL) have been developed. These systems can operate not only with usual types of data (integers, floating point numbers, text, logical data, etc.) but also with spatial data types. Storage of soil data in these databases makes it possible to perform spatial analysis on the database servers, to create specialized web applications for data entry, modification, and updating, and to visualize the results in a static form.

In fact, the difference between the GIS server and the SQL server can be reduced to two points:

—SQL server can create "new knowledge" as a result of spatial analysis and promptly update the information, whereas GIS server cannot do this.

—GIS server is designed for rapid visualization of multilayered spatial information, whereas SQL is not designed for this purpose.

In this context, the structure of a distributed information system aimed at solving the problems discussed above can represent a combination of GIS and SQL servers specialized with respect to the sources of spatial information and with respect to its complexity and the need for information updating (Fig. 5).

A prototype of this system is implemented in the IS SGDBR and, for the first time in Russia, introduced into the state system for agromonitoring of agricultural lands in Rostov oblast. Data on the boundaries of the particular fields, reports from farmers, and current data of agrochemical surveys are stored on the server of the Ministry of Agriculture of Rostov oblast. The topographic base map, land cadaster, meteorological information, and satellite images are supplied by the corresponding services in the GeoRSS format. Soil data (soil polygons and characteristics of soil profiles) are contained in the IS SGDBR. Upon a request from a client for some soil information about the particular field, the geometry of the field (polygon) is transferred as a parameter to the SQL server of the IS SGDBR, which performs necessary spatial analysis (e.g., the assessment of erosion hazard or the soil complexity of the field) and then returns the result (in the form of attribute and spatial information) to the client. Note that the processing of initial information by the SQL server involves complex operations of spatial intersection or integration of the polygons of irregular shapes. This is a distributed system not only because of the data storage in different places but also because of the principle of specialization of webservers (for economists, agronomists, ecologists, etc.). It is not very efficient in terms of the immediate navigation across the territory. It is designed for professionals with good understanding of generated queries. It benefits from a guaranteed response time for complex spatial queries and from the exhaustive information returned to the client.

As noted above the IS SGDBR is a pioneer system that utilizes the described principles of geoinformation exchange with soil information in Russia. The principles of GeoRSS have already been applied in Russia in other spheres. Thus, the principles of geoinformation exchange on the Internet have been suggested for geophysical research and for statistical analyses of archived data [6]. Considerable progress has been achieved in the development of database management systems for inherently imprecise data with huge arrays of "nonrectangular" data (such as soil polygons) with allowance for their historicity (which is essential for monitoring purposes) [3]. Groups for neogeography have been organized (http://neogeography.ru/rus/); they follow the principles of "situational awareness" or unity of the information field for all tiers of the information system with the key role of the end users in the updating and verification of the information and in the creation of spatially localized data of various natures. The term neogeography is not a neologism in the Russian language. It was introduced by the prominent Soviet geographer and the dean of the Geographical Department of Moscow State University (1945–1955) Academician K.K. Markov more than 50 years ago. In the modern definition, neogeography is the new generation of methods and tools to operate with the geospatial information differing from the previously used information (maps and GIS) in three major aspects:

—the use of geographic coordinate systems instead of cartographic projections,

—the use of rasterized rather than vectorized geographic information, and

—the use of open-source hypertext formats for geospatial data.

It is interesting that an analogous term—neopedology—was suggested by Morozov in 2007 [11] to denote the inclusive understanding of soil processes via integration of data from different directions in soil science.

At present, the problems of standardization of the exchange of geospatial soil information in Russia are being solved at the level of separate initiative groups. In the developed countries, similar problems are tackled at the national or international levels.

The *GlobalSoilMap.net* project aimed at the collection (prediction) of soil properties for a global grid of 3 arcsec by 3 arcsec is being developed by coordinating and supporting institutes on each of the continents. In this project, standards for the collection, storage, and exchange of data on a limited number (up to 12) of soil properties are specified and have to be followed by the participating institutes [29]. In turn, regional organizations may enlarge the list of characteristics; archived data, including vectorized soil maps, can be used. Thus, they can shape their own standards for the

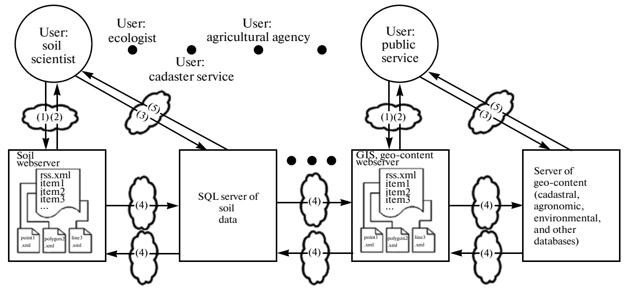

Fig. 5. Distributed system of "cloud" computing: specialized Web-SQL servers and Web-GIS servers and suppliers of visualization tools and global spatial information for soil monitoring purposes.

exchange of soil information on the Internet. Thus, in 2008, the Department of Natural Resources of Canada approved standards for the work with geospatial information on the basis of GeoRSS.

In the European Community, the INSPIRE (Infrastructure for Spatial Information in Europe) project was launched in 2007. The work of the corresponding committee is aimed at the creation (by 2019) of the information infrastructure ensuring open access to the spatial environmental information in Europe. INSPIRE is based on several common principles:

—Data should be collected only once and kept where they can be maintained most effectively.

—It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications.

—It should be possible for information collected at one level/scale to be shared with all levels/scales—detailed for thorough investigations, general for strategic purposes.

—Geographic information needed for good governance at all levels should be readily and transparently available.

—It should be easy to find available spatial data, evaluate data fitness for particular needs, and know the conditions applicable to their use.

A "roadmap" of the work on this project has been developed, and thematic working groups have been organized. The Soil Group has developed specifications for the spatial data theme *Soil* [28]. Within the framework of this project, information exchange is also based on the GeoRSS standard.

The problems of information exchange concern not only programmers and IT staff but also specialists in thematic fields (in our case, soil science) because of the challenges of matching different scales, classification decisions, terminology, etc. In essence, the structure of the information system depends on the solution of these problems. At the same time, it is a two-directional process, because modern soil geographic databases are developed by specialists with consideration for their implementation in the GeoRSS standard. In this context, the structure of the information system on soil resources of Australia (ASRIS) is of great interest (http://www.asris.csiro.au/index_ie.html#). This system is based on the *Atlas of Australian Soils* [26] developed in the 1960s and digitized in the 21st century. To supplement this system with new soil data, the SITES (Soil Information Transfer and Evaluation System) standard is used [32]. This standard deals with some proper soil problems, such as the distinction between sampling, monitoring, and reference soil profiles. The descriptions of the soil profiles may include data on up to five horizons (which is close to the approaches of Russian pedologists). Expert filtering of data in a hierarchical structure "state → agency → project → officer → site → observation" is similar to the approach in the SGDBR, as well as guidelines for the cooperative collection, storage, and collation of data.

Thus, the SGDBR can be considered the first step on the way of integration of Russia into the European and global soil information space. The IS SGDBR as a public center for the collection, storage, and presentation of extensive soil information is compatible with the analogous databases of the European Union, the United States, and FAO. The next step implies the development of standards for the exchange of spatial soil data between the corresponding systems. Such standards are to be developed by professional teams. We suppose that the organization of such teams in Russia is a challenge for the Dokuchaev Soil Science Society rather than for state agencies.

APPLICATION OF THE SGDBR FOR SOLVING PRACTICAL PROBLEMS

Currently, the IS SGDBR is in transition from the design stage to the stage of trial operation and solving meaningful problems owing to the expansion of the functional capacity of the system for theoretical and practical applications.

The objectives of soil-ecological monitoring, cadastral valuation of land resources, and optimum resource management are mainly related to regional competence [19]. Soil information is of particular interest to various environmental and resource management agencies in the regions. In this case, the IS SGDBR can play a coordinating role in supplying the users with relevant information. However, at the local level, some important indicators, such as cadastral valuation, lists of most valuable and specially protected soil areas, and soil suitability for agriculture, are often determined with use of local assessment scales that may not coincide with those available in the SGDBR. In this case, an advantage of the SGDBR is the presence of recitals to the indicators (in the nominal or ordinal scales) and the lists of standardized methods for the determination of quantitative values. To implement these functions of the SGDBR, an information system on soil classification is being developed (http://infosoil.ru/).

The value of the IS SGDBR for solving practical regional problems consists in the prompt provision of the requested information together with the descriptions of classifiers for nominal scales and the methods of determination quantitative indicators. Local information systems will have to generate "top-down" correlation tables [27] and then apply them for handling data at the local level. Information supplied to the SGBDR by some regional agency will become available for other agencies without additional approvals. The most important point is the identity of query objects in the "soil polygon → soil profile → soil horizon" hierarchy for the users ensured by the system. Information exchange protocols are to ensure availability, quality, and "transparency" of access to the geospatial soil information at all the levels.

One more direction in the use of SGDBR for solving practical regional problems is the *adaptation* of theoretical concepts and tools of soil informatics to the possibilities of modern information systems. There are certain difficulties hampering practical application of gathered information:

—The lists of parameters necessary for calculation algorithms may not match really collected data of the regional monitoring systems.

—The need to move from interactive expert systems toward automated extraction of knowledge from the accumulated and organized data (data mining).

This approach was implemented in a test mode in the IS SGDBR for the assessment of land suitability for crop growing, land reclamation measures, and the risk of erosion. For this purpose, it was necessary to adapt numerous methods, algorithms, and interactive programs [15, 30] for solving the problems in the distributed database. A special module to evaluate land suitability (LAND) was developed by the Dokuchaev Soil Science Institute in 1989 on the basis of the FAO methodology and included in the IS SGDRB. The initial data for the calculations include 16 parameters, such as the position of land plots within a catchment, slope, heat supply, depth of bedrock, soil moistening, degree of erosion, and texture. In reality, these parameters are separately stored in different databases (agronomic, soil, land management) of various organizations. Currently, the possibility of automated collection of these parameters for the automatic operation of the predictive algorithm is being tested.

The first results were obtained for a pilot project in Matveevo-Kurgan district of Rostov oblast. As noted above, the geoinformation monitoring system of the Ministry of Agriculture of Rostov oblast (GIS MA RO) exchanges information with the IS SGDBR on the Internet. Thus, a distributed computing system is formed. The IS SGDBR contains a digital elevation model of the district and the results of large-scale (1 : 25000) soil surveys (maps and attribute data on soil profiles). Information on farmers' fields is contained in the GIS MA RO. Integrating these information sources, one can obtain data on 11–12 parameters of the 16 aforementioned parameters. On this basis, it is possible to estimate the degree of soil heterogeneity of the fields and to calculate the coefficients necessary for the cadastral valuation of land plots.

At this stage, the volume of information participating in the information exchange can be roughly estimated. For the given district with the total area of nearly 200000 ha, the cropland area reaches 150000 ha. Vectorized data are available for nearly 3000 crop rotation fields and about 3000 soil polygons. Data of the agrochemical monitoring of the fields are contained in the GIS MA RO. At present, they characterize each particular field as a whole. These data are supplied to the IS SGDBR for further calculations together with data on coordinates of the centers of these fields.

CONCLUSIONS

In conclusion, it should be noted that the combination of soil information from federal and regional agencies together with the adaptation of the existing theoretical algorithms of soil science and their implementation on a distributed network of servers of geographic information databases on the Internet offers an efficient mechanism for solving a wide range of applied and theoretical problems. With the improvement of standards for information exchange and with integration of new regions into this system (which is a difficult task that requires state and public support), the efficiency of the system will undoubtedly increase. This is a good challenge for Russian soil scientists.

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