Database of agricultural soils of the Western Sayan

I G Eremina* and N V Kutkina
Scientific Research Institute of Agricultural Problems of Khakassia, 5, Sadovaya st.,
Zelyonoe village, Ust-Abakan district, the Republic of Khakassia, Russian Federation

*E-mail: e.i.g.231720@yandex.ru

Abstract. Based on the long-term soil research, the database “Agricultural Soils of the foothills of the Western Sayan of Khakassia” with a wide range of soil characteristics for various purposes and uses was formed and registered. The database contains attribute information about the current state of arable and postagrogenic soils in the foothills of the Western Sayan of the Republic of Khakassia. The set of independent materials is presented in the form of tables, queries, forms, reports and catalogues of text files (docx), photos (JPEG), which contain information about soil forming factors, soil classification and distribution by natural and climatic zones on the research territory. Currently, the database includes a description of 17 representative soil profiles with an optimal set of indicators, a detailed description of each pedologic horizon, an accurate geographical reference and a digital photography of each reference soil profile. It contains the taxonomic attribute of the dominant and codominant soils in various classification systems (SC RF; WRB, 2006; FAO, 1988). The main information object is the type (subtype) of soil, which includes systematized factors of soil criteria (a list of 18 sets): morphological description of the soil profile, indicators of pedological property, chemical, physical and chemical, agrophysical, hydrophysical and other indicators.

1. Introduction
Currently, a number of soil information systems of various levels and directions have been created: databases of soil resources of world level (HWSD, ISRIC-World Soil Information) and European level (European Soil Bureau Network), which contain information about world soil resources and are designed to solve global problems [1–4]. A number of countries have created national (state) network of soil information systems. A review of existing specialized databases on Russian soils has shown that the territory has been studied irregularly; they differ in some specificity, and often contain the most up-to-date information for a particular region [5–13].

Despite a large number of studies in this direction, the studies on the creation and application of soil databases are represented insufficiently in the Republic of Khakassia today. The Unified state register of soil resources of Russia (USRSRR) does not contain up-to-date data describing the structure of the soil cover of Khakassia; the main part of the scientific information presented there is compiled with a description of particular types and subtypes of soils with reference to the sources dated back to 1990 [14]. Over the past period, the composition of the soil cover structure, area and land-use regime have changed significantly [15–18].

The soil cover of the Republic of Khakassia also has its own characteristics and peculiar features, the soil site significantly changes not only within the boundaries of the soil type and subtype, but also in local landscape conditions [15, 16]. Modern agroecosystems are characterized by instability and...
reduced ability to resist degradation processes. The diversity of the soil cover is determined by differences in natural and climatic conditions and surface topography, and also appears as a result of widespread negative process (deflation initially) and progressing soil degradation [19].

This determined the choice of the study objects of this work – agricultural soils of the foothills of the Western Sayan. The research was conducted in Beya foothill-steppe landscape-geographical area, bordering the mountain taiga of the Western Sayan with a narrow strip. The territory of the Western Sayan foothills is situated in the southern part of the Republic of Khakassia. In the system of soil-geographical regionalization, the research territory comes under the Minusinsk zone of ordinary and southern chernozems, leached chernozems and grey forest soils [20]. According to agroclimatological zoning [21], the territory is considered to be insufficiently warm (the sum of temperatures above 10°–1,800 °C), insufficiently humid (the humidity factor 0.8–1.2). The creation of a specific soil database which contains an objective index determining the qualitative and quantitative description of the current state of the soil cover is of particular relevance for the South of Central Siberia, since its territory is characterized by the diversity and complexity of environmental conditions of soil formation. Based on advanced materials of condition of arable and postagrogenic soils of the foothills, a Database of soil characteristic (DB) «Agrosoils of the foothills of the Western Sayan in Khakassia» was created, the certificate of state registration № 2020620804 was received, the authors are Kutkina N. V., Eremina I. G., the right holder is FSFRI "Scientific Research Institute of Agricultural Problems of Khakassia".

2. Study materials and research methods

In the foothill part of the forest-steppe, true and dry steppe, temporary variations in the fertility of postagrogenic soils were studied by the method of geminate sections linked to previously studied areas. With the help of modern GIS technologies and at-ground soil and geobotanical studies, the soil map was corrected. The informational basis for GIS was a soil map digitized from the hard copy at a scale of 1 : 25,000. The linking of scanned fragments of the soil map, the soil contours digitization, the adjustment of soil contours vector layer, gridding to the area were carried out. The satellite imagery of the Landsat 8 type was used for the work. The results of satellite observations are freely available on the websites [22].

The genotype of soils was determined by diagnostic signs [23–24]. Physical and agrophysical properties of soils were determined by the methods described in the manual [25]. In the regulated laboratory of FSBI of the Agrochemical service station “Khakasskaya”, the following chemical soil tests were carried out by common methods: granulometric composition, the pipette method with the soil preparation by sodium pyrophosphate; the humus content according to Tyurin in modification of CSRIAS; total nitrogen according to Kjeldal; adsorbed cations of Ca and Mg, Na by a flame photometry detector; the content of P2O5 and K2O according to Chirikov in Chernozems podzolized and Chernozems leached, according to Machigin in Chernozems ordinary, Chernozems southern and Chestnut soils; pH by the colorimetric method (by the salt velocity method in the forest-steppe soils and by the aqueous method in the steppe soils).

For the Database creation the Microsoft Access software package was used, which systematized and unified a large amount of experimental data from soil examination conducted from 2010 to 2018. A large and diverse amount of data was integrated: analytical and textual information stored on paper. According to the digital model of soil description [14], the obtained material was systematized (a unified form of data presentation, a set of attributes necessary for soil description). The classification of the material determined the database structure formation and the logical scheme for creating files based on a particular characteristic – territorial, natural and climatic, thematic. The obtain data input was made in the required form, using an electronic spreadsheet at different levels of generalization. Mathematical processing of the research results was carried out by methods of variation statistics and analysis of variance using the SNEDEKORV4 software [26]. The collection, calculation and filling of the Database on soil properties were carried out.
3. Result and discussion
The typical composition of arable and postagrogenic soils on the research territory is dominated by chernozems of different subtypes, minor ordinary chernozems are mainly developed on the ridges and hills of the area, southern chernozems lie lower in the south, medium ordinary chernozems and sometimes leached chernozems are situated on the northern banks. In the lowland there are saline and deep saline southern and ordinary chernozems. Chestnuts soils are referred mainly to flat terrain features that fit to ancient river terraces. Meadow–chernozemics, meadow, solonchaks and lithic soils occupy a small area, they do not form extensive outlines, and their ploughness is small. The typical composition of arable and postagrogenic soils of the Western Sayan foothills of Khakassia is presented in the table1.

**Table 1.** The typical composition of arable and postagrogenic soils of the Western Sayan foothills.

| Names of soils [23] | Area, ha | %   |
|---------------------|----------|-----|
| **Forest-steppe**   |          |     |
| Type Chernozems     | 15,185.9 | 16.3|
| Including:          |          |     |
| subtype chernozems podzolized | 285.6  | 0.3 |
| subtype chernozems leached  | 14,900.3 | 16.0 |
| Type Meadow–chernozemics | 292.7  | 0.3 |
| Type Meadow         | 424.2    | 0.5 |
| **True steppe**     |          |     |
| Type Chernozems     | 61,304.2 | 66.0|
| Including:          |          |     |
| subtype chernozems ordinary | 45,703.1 | 49.2|
| subtype chernozems southern | 15,601.1 | 16.8|
| Type Meadow–chernozemics | 195.1  | 0.2 |
| **Dry steppe**      |          |     |
| Type Chestnuts      | 13,633.6 | 14.7|
| Including:          |          |     |
| subtype dark chestnuts | 4,837.1 | 5.2 |
| subtype chestnuts  | 8,796.5  | 9.5 |
| Type Meadow-chestnuts | 367.2  | 0.4 |
| Type Alluvials      | 359.0    | 0.4 |
| Type Solonchaks    | 240.9    | 0.2 |
| Type Solonetzes     | 726.4    | 0.8 |
| Shallow soil        | 214.4    | 0.2 |
| **Total area**      | 92,943.6 | 100|

The structure of the soil database defines several blocks similar in their distribution and representation of data types. Storing of results in the form of databases allows to structure the data obtained, as well as to make analysis using a variety of forms and queries. In general, the structure is reflected in the form of basic two-dimensional tables consisting of separate fields with a text data type; the key fields are linked to auxiliary tables and documents of all blocks. The initial data are formed into 23 main tables, 5 reference tables, a system of queries and report forms. After defining the database structure based on the conceptual model, the additional information part is implemented by various applications.
The data scheme at the first stage includes the allocation of natural and climatic zones on the research territory (forest-steppe, true steppe, dry steppe) with different types of soils characteristic of the selected territories and occupying a significant area in the component composition of arable land. The created soil database «Agricultural Soils of the foothills of the Western Sayan of Khakassia» is represented by several levels of generalization: 1 – Province, 2 – Area, 3 – Forest-steppe soil (Chernozems podzolized, Chernozems leached, Meadow–chernozemics, Meadow), 4 – True steppe soil (Chernozems ordinary, Chernozems southern, Meadow–chernozemics solonchakous), 5 – Dry steppe soil (Dark chestnuts, Chestnuts, Meadow-chestnuts solonchakous, Alluvials, middle steppe Solonets). To fill in the information field of the database in this block, separate documents-files are created that contain the required reference data.

This is followed by structuring soil descriptions by dividing them into taxonomic units (type, subtype, genus, and species). The initial data contain the taxonomic affiliation of the dominant soil within the current national and international classification systems, the world reference database of soil resources (WRB), as well as the author's name of the soil. There is a description of the prevailing types, and the file contains information about the occupied area of the studied soils.

In order to systematize the data on the structure of a typical soil profile, a single form of indicators was used. The next block is presented by the indicators that characterize the environmental conditions of the cross section location and the usage type of the territory. Information about the regional features of macro–, meso–, and microrelief, the nature of the vegetation cover, the parent rock material and underlying bedrock, the ground water occurrence, climatic variables, etc. was used.

This is followed by a block that contains quantitative (numerical) indicators of analytical data and characterizes the pedological properties. The structure of the soil database defines objects that include descriptions of soil types (subtypes) and pedologic criteria, as well as descriptions of soil indicators. The main object of the database is a specific soil crossover with its most complete set of pedologic horizons, characterized by a specific set of attributive data. The crossovers with the most typical soil profile are selected from the variety of the studied soils; the soils presented by them occupy the dominant area in the component composition of the territory as a whole. Separate soil subtypes are divided according to the genesis of the parent rock material and the granulometric composition. At the present time, the database includes information on 17 soil profiles with a digital photograph of each reference soil crossover.

As a result of the research, tables of pedologic criteria were created:

1. configuration and morphological characteristic of the soil profile (type, number and indices of pedologic horizons, morphological indicators and elements);
2. chemical composition of humus;
3. determination of mobile phosphorus and exchangeable potassium;
4. exchangeable base;
5. material composition and highly soluble salt;
6. granulometric composition;
7. physical characteristics;
8. aggregate composition;
9. pedologic hydrolytic constants;
10. acidity and alkalinity.

This section provides a record of the numeric value of the measured characteristic, the method of its definition or measurement, as well as the units of measurement (taking into account both widely used units and previously accepted in SI) according to the uniform standards.

The specialization of the positional application of crossovers is their geographical address, which is determined by geographical coordinates; currently, the geographical address is a mandatory attribute for the database. The database includes information about the exact geographical location of soil profiles using GPS satellite navigation technology. The specified coordination reference will help to mark this soil crossover on the map of Russia in the future. The separate document-files (Word Document)
containing qualitative (descriptive) characteristics of the studied soils and copyrighted photographs of soil profiles (JPEG) were created.

All systematized data are carried in the soil description card, which is the main data item in the created soil database. The soil description card contains complete information about a specific soil: the classification position (the name of the soil according to the SC of the Russian Federation), the date of profile laying, coordinates and altitude above sea-level, morphological configuration, detailed characteristic of each pedologic horizon, a large set of analytical information, economic use, display and degree of erosion processes. The file card index is formed from a set of separate soil description cards.

4. Conclusion

Based on the long-term soil research, the database «Agricultural Soils of the foothills of the Western Sayan of Khakassia» was formed and registered, which provides information on the current state of arable and postagrogenic soils of the foothills, with a wide range of soil characteristics for various purposes and uses. Information on the current economic use and degradation of soil cover will help to make an objective conclusion about the direction and the acceptable level of anthropogenic impact on the environment and optimize the use and protection of soil resources. The contemporary database (DB) «Agricultural Soils of the foothills of the Western Sayan of Khakassia» with a variety of pedologic properties will serve as a basis for the rational use and protection of soils, monitoring, as well as the practical implementation of information technology in all spheres of land relations. Geographical coordinates of soil profiles in the Database will allow to display them on the maps of Russia and to put them in the Unified state register of soil resources of Russia. The collected and systematized information about the soil cover of Khakassia will be available to all specialists.

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