Soil evaluation for land use optimizing

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Abstract. The article presents the method of soil classification proposed in the course of the study in which the list of indicators proposed by the existing recommendations is optimized. On the example of one of the river basins within the boundaries of the Belgorod region zoning of the territory was carried out. With this approach, the boundaries of the territorial zones are projected along the natural boundaries of natural objects and the productivity of soils is determined as the main criterion for zoning. To assess the territory by soil properties, the features of the soil cover of the river basin were studied and vectorization of the soil variety boundaries was carried out. In the land evaluation essential and useful for the growth of crops macro- and minor-nutrient elements necessary for the growth of crops were included. To compare the soils each of the indicators was translated into relative units. The final score of soil quality is calculated as the mean geometric value of scores from 0 to 100 points for the selected diagnostic features. Through the imposition of results of soil classification and proposed by the concept of basin nature management – land management activities, five zones were identified according to the degree of suitability for use in agriculture.

1. Introduction
For introduction of basin and ecoregional approaches [1] involving optimization of land resources use, the large-scale projecting of the territories of specific agricultural enterprises is necessary. For the purpose of more effective determination of crop rotations that is based on results of land evaluation, the possibility of using land for different types of agricultural land is revealed. Three components of the geo-planning are implemented when carrying out the planning of the territory by the main components: the formation of a natural framework for the environmental safety of the territory [2], the eco engineering and economic planning which allows the final justification for planning decisions through a combined analysis.

For the implementation of land management activities that are envisaged by the concept of basin nature management [3], the large-scale design of the territories of specific agricultural enterprises is necessary. For the purposes of more effective determination of crop rotations, it is proposed to use the results of soil surveys. The possibility of using land for different types of agricultural land (plowland, perennial plantations, hayfields, pastures, etc.) is revealed based on the results of the evaluation.

2. Material and methods
At the first stage, we have studied the features of the soil cover of the Toplinka river basin and vectorized the boundaries of soil varieties. It should be noted that it is expedient to determine the composition of soil varieties on the basis of data obtained as a result of land management, materials of large-scale soil survey of land use.

According to the Order of the Ministry of Agriculture of Russia "On approval of the State registration of indicators of the state of fertility of agricultural lands" in order to generate complete and reliable information on the status and dynamics of fertility of agricultural land by various organizations and institutions, subordinated to the Ministry of Agriculture of Russia, with a frequency of once every 5-15 years there is a collecting and generalization of data containing a full complex of soil, agrochemical, phytosanitary and ecologo-toxicological agricultural land use, the results of which are not used in the
course of land evaluation works, but which can significantly increase the reliability of soil classification, which predetermines the determination of the normative crop yield of crops.

So, based on the data of a planned agrochemical survey of agricultural soils that was carried out by the Belgorod center of the agrochemical service, and using the data of the Red Book of Soils of the Belgorod Region (2007), the soils of the Toplinka river basin in the land evaluation were included not only humus, the thickness of the humus horizon, the content of physical clay and the coefficients for negative properties of soils but also essential and useful for the growth of crops macro- and minor-nutrient elements [4]: the necessary macroelements: N, P, K, Mg, Ca, S, essential necessary trace elements: Mo, Mn, Fe, Ni, Cu, Zn, B, useful elements: Co, Al, Si. In order to compare the soils, each of the indicators was translated into relative units (points), the bonitet score on the basis of fertility factor was calculated by the formula [5]:

\[ Y = A \left[ 1 - \left( 1 - \frac{x-b}{a-b} \right)^3 \right] \tag{1} \]

where \( Y \) is the (given) fertility score of the soil; \( X \) - parameter of a specific attribute of soil fertility; \( A \) - parameter of the fertility attribute of the soil-standard, \( b \) - the worst value of the same attribute of fertility; \( A \) - the volume of the scoring scale in points. The ratio \( x/a \) characterizes the saturation of the soil with a specific attribute, for example, the content of mobile phosphorus relative to its content at the potential fertility of the reference soil. The expression \( (1 - \frac{x-b}{a-b}) \) in the formula shows that the relative score (score) of one or another attribute of fertility is inversely proportional to the intensity of this attribute. The less the intensity of the attribute in the soil, the higher its score. At \( x=a \), the actual parameter of the evaluation attribute of fertility is equal to the parameter of potential fertility, and the intensity of this attribute in the soil is zero and the score of the attribute (its parameter) is equal to the highest score, for example, over a closed scoring scale of 100. The exponent in the third degree indicates that the dependence of soil fertility on the parameters of its attributes is nonlinear, and the nature of the function has the form of a parabola, i.e. soil fertility is inversely proportional to the cube of tension of the limiting attribute.

Zoning of the territory was carried out on the example of one of the river basins within the boundaries of the Belgorod region. With this approach, the boundaries of the territorial zones are laid out along the natural boundaries of natural objects, and the productivity of soils is determined as the main criterion for zoning. To carry out the evaluation of soil properties and yields, we studied the features of the soil cover of the river basin on the first stage and made vectorization of the boundaries of soil varieties. The soil classification includes essential macro-and minor elements necessary for the growth of crops the content of which was determined during the planned agrochemical survey of soils by the center of the agrochemical service. To compare the soils each of the attributes was translated into relative units (points). Total score of the soil bonitet was calculated as the geometric mean value of the scores (0 to 100 points) by selected diagnostic attributes.

Five zones were identified according to the degree of suitability for use in agriculture through the imposition of results of soil classification and land management activities that are proposed by the project of basin nature management.

The environmental and economic results of the proposed zoning of the territory were assessed based on the results of the design. Taking into account existing developments for determination of the coefficients of land ecological properties [6, 7, 8] the coefficients of ecological stability and natural protection were calculated using formulas:

Coefficient of ecological stability:

\[ K_{es} = \frac{\sum P_i B_i}{P} \tag{2} \]

where \( B_i \) is a score corresponding to an area with a certain natural security [6] \( P \) is a total area of the study, \( P_i \) is an area of the site of the i-th species.

In case when the obtained value of \( K_{es} \) is <0.33, then the territory is environmentally unstable, with \( K_{es} = 0.34-0.50 \) is unstable stable, with \( K_{es} = 0.51-0.66 \) goes into a gradation of average stability, and at \( K_{es} > 0.67 \) is environmentally stable.
Coefficient of natural protection $K_{np}$ was calculated by the formula [8]:

$$K_{np} = \frac{P_{sl}}{P_{dsl}}$$

where $P_{sl}$ is an area of stabilizing lands; $P_{dsl}$ is an area of destabilizing lands.

The higher the assessment of the natural protection of the territory ($K_{np}$) the greater is the stability of the landscape.

The scale of the coefficient of natural security [9]:

- $\leq 0.45$ – Critical (instability is well pronounced);
- $0.46-0.55$ – Stressed (unstable state);
- $0.56-0.59$ – Satisfactory (condition is relatively stable);
- $0.60-0.70$ – Relatively favorable (stability is sufficiently pronounced);
- $0.71 \geq$ – Favorable (stability is sufficiently pronounced);

The coefficient of relative intensity of the organization of the territory is calculated by formula:

$$K_{ri} = \frac{P_{sl}}{P_{dsl}}$$

The following scale corresponds to the rating:

- $> 2.41$ – Below optimal for more than 10%;
- $1.3-2.4$ – Below optimal no more than 10%;
- $0.7-1.3$ – Optimal;
- $0.39-0.7$ – Upper optimal no more than 10%;
- $< 0.39$ – Upper optimal for more than 10%.

3. Results and discussion

The territory of the selected river basin belongs to the forest-steppe zone with a significant spread of gray forest soils, dark gray forest soils, also available solonetzic and residual-carbonate black soils having individual, complexly directed types of vertical distribution of bonito characters, and in this connection the content and distribution of elements along the profile was calculated as the weighted average value for the proposed [10] horizons: 0-20, 21-40, 41-65, 66-100 cm.

According to the technical recommendations used in the determination of soil fertility in the cadastral evaluation of agricultural lands, the following attributes are used as the main ones: humus content in the plow layer, thickness of the humus horizon, content of physical clay in the plow layer and correction factors for the negative properties of soils. For the most reliable determination of the fertility of soils in agricultural lands, we consider it expedient to supplement the calculations with attributes characterizing the prosperity of soil by the most important for the growth of crops nutrition elements as well as by indicators characterizing certain agrophysical [11] and morphological properties of soils. Besides these indicators, in order to take into account the effect of agrogenic soil changes [12], the following indicators were included in the bonitet calculation: structural coefficient, mobile P and exchange K, ratio of humic acid carbon to the total carbon.

The final score of soil bonitet is calculated as the mean geometric value of the partial estimates (from 0 to 100 points) for the selected diagnostic attributes. The weighted average bonitet score according to the proposed method for the area of the Toplinka river basin is 69 points, while according to the methodology used for cadastral valuation of agricultural land in the context of soil varieties it is 57 points. In this way the proposed methodology can facilitate more efficient and reliable performance of the fiscal function by the cadastre.

Thus, due to a more detailed set of diagnostic attributes that reflect more objectively the agrogenically conditioned physico-chemical transformations of soils, the technique suggested by the author can contribute to a more effective implementation of the fiscal function by the cadastre.

It should be noted that the specific indicator of cadastral value for the proposed methodology in some cases may be lower than the estimation obtained, basing on the use of three normatively recommended diagnostic attributes of soils. However, the integration of relatively conservative soil characteristics (thickness of the humus horizon, the content of physical clay) in the proposed methodology and the results of regularly updated (every 5 years) agricultural agrochemical survey data will contribute to a
more objective and effective determination of the land tax, thereby reducing the cases of judicial contestation of its results.

Known in the world practice state mechanisms for monitoring of the use of soil fertility resources by land users should be more actively applied in Russian legislation both at the federal, regional and local levels. Russian law defines the rights and obligations of owners, users, including tenants, of land plots in the field of ensuring the fertility of agricultural land. In our opinion, introduction of regulatory and incentive measures controlling the reproduction of soils should be effective that is, besides all kinds of sanctions imposed on land users by wasteful use of land leading to land degradation, there should be established preferences and incentives (subsidies, concessional lending, reduction of the tax rate) for responsible land users, investing additional funds in ensuring soil fertility. Here, it is possible to apply the method of calculating the index of soil fertility used to determine the value of subsidies for rendering unrelated support to agricultural producers in the field of crop production in connection with the state of soil fertility.

Using the proposed method of soil evaluation, zoning of the territory was carried out on the example of the Toplinka river basin in the Belgorod Region. With this approach, the boundaries of the territorial zones are laid out along the natural boundaries of natural objects (the river basin) within the municipality. Scientific and legal support for land management activities in the organization of nature management on the basin principles is proved by the scientific studies of well-known Russian scientists in this field of knowledge and adapted to the concept of basin based nature management in the Belgorod region [3].

Through the imposition of the results of soil evaluation and land management measures that were developed in the basin nature management project, five zones were identified according to the degree of suitability for use in agriculture, in analogy with earlier proposals but taking into account the natural boundaries of the design and management object - the river basin (figure 1). The lands of the 1-3 zones can be considered as the main cultivatable fund, here for the transition to the biological path of agricultural development the following measures for rationalization of land can be offered:

- in areas with predominant slopes of 0-3° and soil bonitet of 86-100 and 61-85 points (1 zone), it is proposed to introduce field crop rotations where all types of land and any regional crop and land can be located;
- in areas with an inclination mainly of 3-5° and soil quality of at least 60 points (zone 2) it is advisable to place grain-crop rotations where the proportion of perennial grasses will be of the 50% order;
- plots on inclines of 5-7° with soil strength of 36-60 points (3 zones) - the most erosionally hazardous, here it is necessary to use grass and soil protection rotations, minimum tillage and cultivation of row crops should be limited.

Lands of the 4 zones on slopes 7-12° must be classified as transitional (low-profit) which can be used, for example, to accommodate natural forage lands or bee keeps.

The lands of the 5 zones that located on slopes above 15° with soil bonitet of 11-35 points and the lowest-yield (less than 10 points) are low-producing (unprofitable) territories which are expedient to withdraw into recurrent (irretrievable) conservation. They are possible to be restored with honey grass in case of proximity to bee keepers or transformation into forest plantations.

Thus in the course of the study, a methodology for soil classification was developed which expanded the list of indicators that are proposed by technical recommendations used in determination of soil fertility in the cadastral assessment of agricultural land. So, it is advisable to supplement the calculations with indicators characterizing soil availability with the most essential elements for the growth of crops as well as indicators characterizing individual agrophysical and morphological properties of soils in addition to the humus content in the plow layer, the thickness of the humus horizon, the content of physical clay and the correction factors for the negative properties of soils.
Figure 1. Scheme of territorial land zoning of the Toplinka river basin in the Belgorod Region (territorial zones 1-5 are explained in the text)
According to the requirements of the Ministry of Agriculture of Russia, with the frequency of once in every 5-15 years, there should be collected and generalized data, containing a full range of soil, agrochemical and environmental-toxicological surveys of agricultural land, the results of which are not used in land assessment but which can significantly increase reliability of land evaluation preceding the definition of normative yields of crops.

The results of the proposed method of land evaluation can serve as one of the main criteria for the allocation of territorial zones and zones with special conditions for the use of agricultural areas that are objects of land management.

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