Cadastral appraisal of lands: agricultural aspect

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Abstract. A methodology for information preparation for cadastral valuation of agricultural lands is proposed. The methodology was tested during agricultural lands appraisal in Samara Region. The current results were compared to previous ones. Average variation in the region between maximum and minimum yields in districts is 1.95, given that the maximum variation is 2.58 (Yelkhovsky District) and the minimum is 1.44 (Bogatovsky District). In 6 districts the ranking created based on 'cadastral appraisal' indicator does not coincide with rankings based on other indicators. Though in 21 districts both rankings are in line with each other.

1. Introduction
In modern conditions of agriculture development, it is important to remember that the land fund is a basis for the agricultural production, therefore, it is necessary to use the land fund fully and in an appropriate and cost-effective way, in order to successfully meet the challenges of the agro-industrial complex, related to providing population with food, and industrial manufacturing with raw materials [1, 2].

In recent years’ economic valuation of lands has become a necessity as a result of new land relations in the Russian Federation. Land valuation is the process of determination of their relative productive value as means of agricultural production, or in other words, rate of return from lands of different quality [3, 4].

The purpose of the research is to improve the quality of cadastral land appraisal, taking into account its soil and climate characteristics. In this regard, a target was set to develop a methodology for creating a data array needed for a more accurate calculation of cadastral value.

2. Methods and materials
Types of soil or soil groups, similar in genesis and use (evaluation groups), are usually subject to assessment, as well as agricultural lands of farms and district of the region [5, 6]. The land valuation methodology states that the main criteria for appraisal of land suitability for agricultural crops farming is their long-term yield, which depends on soil fertility, its properties, climatic conditions, and agricultural productivity level.
Knowledge of soil types, their occurrence and composition is needed for the quantitative and qualitative accounting of land funds, and an accurate determination of their value as means of production. To valuate land resources, it is important to address natural, soil-climatic, and economic conditions, and take into account the data on scientifically based crop rotations.

3. Results and discussion
Soil identity and moistening adequacy have predetermined the subdivision of Samara Region into three land appraisal areas: northern, central, and southern. Based on these appraisal groups and their morphological, physical, and chemical characteristics, rating scales were created with such basic indicators as soil properties and features.

The soil zoning is well represented in the region, due to the gradual change of bioclimatic factors from north to south: from gray forest soils, leached and typical chernozems in the north of the region to southern chernozems, chestnut soils, solonetz and solonchak soils in the south.

Chernozem soils prevail in Samara Region. They cover 72.2% (3921.4 kha) of total arable land area [7, 8] (table 1).

| Table 1. Structure of soil cover in Samara Region. |
|-----------------------------------------------|
| Soils                          | Total land area, kha | Agricultural lands | Including, % Including | Other lands |
|---------------------------------|----------------------|-------------------|------------------------|------------|
| Rendzina                        | 9.6                  | -                 | -                      | 0.2        |
| Gray forest                    | 392.4                | 9.8               | 7.3                    | 2.0        | 90.2      |
| Chernozem                      | 3921.4               | 85.4              | 72.2                   | 12.7       | 14.6      |
| Dark chestnut                  | 152.1                | 98.1              | 75.1                   | 22.6       | 1.9        |
| Others                         | 652.3                | -                 | -                      | -          |

Rendzina soils only occur under forest areas of Samarskaya Luka and Zhiguli Mountains.

Gray forest soils cover 392.4 kha, mostly under forest lands (90.2%). They are common on the right bank and in northeast of the left bank of Volga river. They also occur in the interfluve of Malyi Kinel river and Samara.

Gray forest soils are similar in their structure and properties to chernozem soils, they cover 313.2 kha of total land area. Gray forest soils are humus rich (5-6%) and differ in texture. They have a high natural fertility.

Chernozems account for the largest part of soil cover and are the main natural resource of agriculture in the region. They are represented in a number of genetic subtypes, genera and species.

Typical chernozems is the most common group of soils in the region. They occupy 1178.5 kha and contain a high percentage of humus.

Dark chestnut soils only occur in southeast of steppe zone of the region. They cover the area of 152.1 kha and are very satisfactory as arable lands, especially in terms of bogara and irrigation [9, 10].

There are two natural economic zones in the region, characterized by the following data (table 2).

| Table 2. Samara Region Land Fund. |
|-----------------------------------|
| Category                 | Units | Natural-climatic zones | Region |
| Total land area          | Kha   | North   | Central | South | 5253 |
| Agricultural lands       | Kha   | 1395    | 2397    | 1461  | 4003 |
| %                      | %     | 76.4    | 65.7    | 93.3  | 76.2 |
| Including:              | Kha   | 802     | 1251    | 1075  | 3092 |
| Arable land             | %     | 57.5    | 50.7    | 73.6  | 58.9 |
| Hay fields              | %     | 36      | 69      | 8     | 113  |
|                      | %     | 2.5     | 2.9     | 0.6   | 2.2  |
Agricultural lands represented by arable lands, hay fields and pastures, occupy more than three quarters of the total land area. The land in the north is plowed by about 59%, in the south - by more than 73%, in the central area - by about 51%.

The northern area is a typical forest steppe with podzolic, leached, and chernozem soils alternating with each other, which occupies about 1.4 mha (26.6%), including 1.1 mha of agricultural lands (20.4%), 0.8 mha (15.4%) of them are arable lands.

The central area is a southern forest steppe, passing in a steppe with typical and ordinary chernozems. The total land area is about 2.4 mha (45.3%), including 1.6 mha (29.9%) of agricultural lands, and 1.1 mha (23.3%) of them are arable lands.

The southern area is steppe with southern calcareous chernozems prevailing, with the inclusion of dark chestnut soils with varying degree of alkalinity. It occupies 1.5 mha (28.1%) of land in the region, including 1.4 mha (26.8%) of agricultural lands, 1 mha (19.2%) of which are arable lands [11, 12].

Agricultural value of soils is not the same. Typical, leached, and podzolic chernozems are characterized by an intensive soil-forming process. These soils are mostly medium humic, with percentage of humus in the topsoil of heavy-textured soils from 6 to 8%. Concentration of humus in typical heavy-textured chernozems is 5.6-6%, in southern chernozems - 4.5-5.3%. Dark chestnut soils are poorer, with percentage of humus from 3 to 3.6%. Gray forest soils contain a high percentage of humus - 5-6% [13, 14].

Analysis of soil samples from each sampling unit has shown that, for the most part, land areas are represented by soils with similar characteristics. Besides that, in some fields soil complexes and catenary sequences can be found. Soil complexes include both main soil types (chernozem, chestnut, gray forest soil) and soils that are inarable because of their low productivity (alluvial, wet meadow, eroded, and warp soils, etc.), or because of their negative factors (salinity, alkalinity, calcareousness, cobbles, etc.). In applied agriculture these soil complexes prove to be inefficient, and they are usually used not as arable lands, but as pastures. Specific crop rotations are usually generated for particular fields and zones.

Crop rotation means that every year different crops are cultivated on the same piece of land (crop rotation field) in accordance with the accepted rotation scheme.

Choice of crop rotation needs to be based on particular farm conditions and, more importantly, moisture conditions, soils, relief, amount of forests, supply of labor, capital goods, composition of crops and their cost [15, 16].

In order to conduct cadastral appraisal, it is proposed to use typical crop rotations for every type of soil (table 3).

Table 3. Standard crop rotations for different natural-climatic zones of Samara Region.

| №/n  | Chernozems       | Gray forest soils          | Chestnut soils        |
|------|------------------|---------------------------|-----------------------|
| 1    | Fallow           | Fallow                    | Fallow                |
| 2    | Winter wheat     | Winter rye                | Winter wheat          |
| 3    | Millet           | Buckwheat                 | Summer wheat          |
| 4    | Summer wheat     | Summer wheat              | Summer wheat          |
| 5    | Annual grasses   | Annual grasses for hay    | Annual grasses for hay|
| 6    | Summer wheat     | Summer wheat              | Sunflower             |
| 7    | Sunflower        | Sunflower                 | Perennial grasses for hay (emergency field) |
Annual change of crops, belonging to different biological groups (except perennial grasses), is the basic principle of crop rotation generation. Typical crop rotation is aimed at soil fertility maintenance through cultivation of crops that improve soil properties naturally. Calculation of land value using income approach, based on typical crop rotations, is consistent with the purpose of cadastral appraisal of land, that is without consideration of impact of such land improvements as fertilization.

To validate this statement, the balance of humus, as key element for soil fertility, was calculated. All three options are characterized by positive humus balances (chernozem - 962 kg/ha; gray forest soils - 1089.5 kg/ha; chestnut soils - 615.1 kg/ha).

For all considered types of soil such crop rotations are proposed that not only maintain the humus balance, but also increase its percentage in soil. Thus, there is no need for additional costs for fertility, so these costs are zero given effective crop rotations.

Agricultural crops yield is one of the basic efficiency factors for commercial use of agricultural lands. The main sources of data on yield are reports, prepared by territorial body of the State Statistics Service in Samara Region. Average yield is defined as the arithmetic mean over the past five years, in order to decline influence on calculation of data obtained during the best or the worst years.

For further calculation of predictive yield on individual farms, a 'yield score' indicator is applied. Its value is calculated as the ratio of average yield in the area to average soil bonitet of the area [5, 17].

Knowing soil bonitet of a particular farm and the yield score, predicted yield of the farm can be defined. Yield scores for specific crops and areas are presented in table 4.

### Table 4. Average bonitet score and yield score.

| Category      | Average score for the area | Score |
|---------------|---------------------------|-------|
|               |                           | For winter wheat | For summer wheat | For sunflower | For perennial grasses | For buckwheat |
| South area    | 56                        | 0.219           | 0.150           | 0.148         | 0.169                 | 0.134         |
| Central area  | 66                        | 0.276           | 0.182           | 0.131         | 0.189                 | 0.117         |
| North area    | 67                        | 0.272           | 0.165           | 0.135         | 0.187                 | 0.111         |

According to official data provided by the Ministry of Agriculture of the Russian Federation and State Statistics Committee of the Russian Federation, selling price of crop products over the period from 2006 to 2010, was (table 5) [18, 19]:

### Table 5. Major crop products pricing in Russia at 1st of January 2019, rubles/t.

| №  | Crop      | 2006 | 2007 | 2008 | 2009 | 2010 | 5-year average |
|----|-----------|------|------|------|------|------|----------------|
| 1  | Wheat     | 3060 | 4653 | 5103 | 4260 | 3867 | 4189           |
| 2  | Rye       | 2474 | 3586 | 4382 | 3810 | 3411 | 3533           |
| 3  | Buckwheat | 5352 | 5927 | 6197 | 5771 | 8153 | 6280           |
| 4  | Millet    | 2559 | 3622 | 4088 | 3956 | 3832 | 3611           |
| 5  | Sunflower | 4957 | 9342 | 9699 | 8321 | 10605| 8585           |
| 6  | Hay       | 1500 | 1500 | 1500 | 1500 | 1500 | 1500           |

Taking into account the average agricultural crops yield during the same period, revenues from sales of agricultural products per ha in areas will be (table 6):
Table 6. Average revenue from agricultural products per hectare sales in Samara Region districts.

| Category          | Winter wheat | Summer wheat | Sunflower | Perennial grasses | Buckwheat | Average per ha |
|-------------------|--------------|--------------|-----------|-------------------|-----------|----------------|
| South area        | 5 176        | 3 532        | 7 109     | 1 428             | 4 705     | 3 920          |
| Central area      | 7 558        | 5 000        | 7 393     | 1 858             | 4 774     | 4 622          |
| North area        | 7 617        | 4 622        | 7 777     | 1 870             | 4 634     | 4 638          |

Table 7. Total costs and labor input per ha of standard crop rotation (by chernozem example).

| Category          | Sunflower | Perennial grasses | Annual grasses | Buckwheat | Millet | Summer wheat | Winter wheat | Winter rye |
|-------------------|-----------|-------------------|----------------|-----------|--------|--------------|--------------|-----------|
| Yield, centner/ha | 8         | 10                | 10             | 8         | 7      | 15           | 15           | 15        |
| Total costs per ha, rubles | 6999.4 | 1417.8           | 3416.2         | 5065.8    | 4844.0 | 5262.9       | 5947.7       | 6347.7    |
| Salary, rubles/ha | 999.1 | 435.3             | 686.5          | 1238.3    | 1301.9 | 943.4        | 1155.2       | 1155.2    |
| Labor input, man-hour | 3.2 | 1.6               | 2.4            | 4.0       | 4.2    | 3.4          | 4.0          | 4.0       |
| Variable costs per ha, rubles | 4838.8 | 850.5             | 2147.5         | 3064.5    | 2748.7 | 3451.1       | 3697.4       | 4097.4    |

To calculate costs for agricultural crops farming (table 7), flowcharts were drafted. Software for calculation of flowcharts in the field of agriculture, developed by staff of the FSBEI of Higher Education 'Samara State Agrarian University', was used as the basis of calculation.

Table 8. Calculation of standard crop rotation costs made with use of soil technological property index (TPI).

| TPI | Chernozem | Chestnut | Gray forest |
|-----|-----------|----------|-------------|
| 1.0 | 2648.19   | 2633.83  | 2737.67     |
| 1.1 | 2913.01   | 2897.21  | 3011.44     |
| 1.2 | 3177.83   | 3160.59  | 3285.20     |

Calculation of costs is complemented with soil technological property index values. Costs totals are represented in table 8.

Initial data:
- Crop rotations typical for specific types of soil;
- Average yield in areas;
- Bonitet scores of farms;
- Soil technological properties.

Calculation algorithm:
- Find the average yield in areas for specific crops over five years;
- Determine the average bonitet score in areas;
- The average bonitet score is consistent with average yield in areas;
- Changes in scores by farms define yield fluctuations (without consideration of fertilization impact);
- Determine yields of particular crops for certain farms;
- Create flowcharts for particular crops with consideration of yield fluctuations;
- Adjust obtained data, taking into account soil technological properties;
- Average costs per ha considering chosen crops rotations;
- Determine average selling prices for particular crops over the period of 3-5 years;
- Compare prices obtained and costs per ha. Determine the difference.

The proposed methodology was used in cadastral valuation of agricultural lands, carried out in Samara Region in 2012.

4. Conclusion
To assess the results of the methodology application, areas were ranked according to cadastral values of 2006, minimum, maximum, and average yields [17, 20]. Based on the analysis, following conclusions can be made:

- minimum yields were in 2006 and 2010, maximum - 2008 and 2011. However, if one analyzes these indicators, it can be seen that most areas show different pictures, even within the same climatic zones. It seems very difficult to describe such variation, if possible at all;
- on average across the region the variation between maximum and minimum yields in areas is 1.95. The maximum variation is 2.58 (Yelkhovsky District), the minimum is 1.44 (Bogatovsky District);
- in six areas the ranking created based on 'cadastral appraisal' indicators, does not coincide with rankings based on other indicators. Though in 21 districts both rankings are in line with each other.

Results of the analysis show that the methodology for cadastral appraisal of agricultural lands is correct. It is used to carry out the main task: agricultural land plot with the worst fertility and minimum agroclimatic potential value costs less than the land plot with a higher fertility level. Besides that, the proposed methodology is based on data provided by the Federal State Statistics Service, which ensures data reliability. These factors determine the merits of the proposed methodology for the state cadastral appraisal of agricultural lands.

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