Estimated acreage structure for units of mesoscale zoning of the Samara region

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Abstract. Economically and environmentally sound concept of agriculture in any soil and climatic zone should be based on rational structure of acreage and cultivation of most biologically relevant crops, which are demanded in the market, produce environment-forming influence on soil fertility and state of agrocnoses. At the same time, crops shares in structure of acreage should best suit the properties of the territory, taking into account their spatial diversity. Based on this, an estimated structure of acreage for units of mesoscale complex agroclimatic zoning of the Samara region has been developed. It is based on the analysis of sowing structure in farming systems, normative and real crop yields in recent years, taking into account the recommendations of scientific institutions of the Samara region on saturation of crop rotation with grain crops, sunflower, corn and other cultures.

1. Introduction
Land assessing is a complex multi-dimensional task, which can be solved depending on their designated purpose and type of use. For agricultural land suitable for tillage, it is decided from profitability of land use in production, and is based on assessment of natural agropotential of the territory (NAP).

Natural agropotential is determined by a combination of conditions and resources of the territory, mainly soil-climatic, and varies significantly over the territory. Within the framework of natural and agricultural territory zoning main factors of natural environment are consistently taken into account and spatially differentiated, which together give an idea of conditions diversity. There are also various indicators which quantitatively characterize the complex of NAP factors. On this basis, the design of the structure of cultivated areas and crop rotation, the solution of other issues on rational land use organization is carried out.

The modern concept of agriculture in any soil-climatic zone should be based on the cultivation of crops which are most suitable for biological properties demanded on the market, taking into account their impact on soil fertility and state of agrocnoses [1, 2]. In this case, acreage structure optimization will ensure high economic efficiency and sustainability of crop production, with the most productive use of arable land and introduction of proper crop rotation [3–5]. The same principles of forming the crops structure provide objectivity and reliability of land productivity assessing, determining their type of use and economic indicators [6].

The work was performed in order to determine estimated set of crops and estimated structure of sown areas in mesozones of the Samara oblast in relation to productivity and land valuation.
2. Conditions and methods

In works [6, 7] the territory agroecological potential (AP) is considered as a complex indicator of natural resources of agricultural production, calculated for agroclimatic subzones of corresponding land assessment districts (LAD). Formed agroclimatic subzones are based on land suitability for growing crops analysis. Administrative districts which are suitable for growing a certain set of crops are grouped into a single subzone. The question of land suitability is solved by comparing of its heat and moisture supply conditions (by sum of active temperatures and moisture ratio) to the corresponding values of economic indicators.

For the formed agro-climatic subzones the moisture coefficient (MC), climate continentality coefficient (CC) and agroecological potential value (AP) are calculated:

\[
MC = \frac{Ac \cdot Rf}{\sum_{t>10} + 500},
\]

\[
CC = \frac{360 \cdot (T_{max} - T_{min})}{\phi + 10},
\]

\[
AP = \frac{\sum_{t>10} \cdot (MC - P)}{CC + 100},
\]

where \( Rf \) is the annual sum of rainfall, \( Ac \) is an additional coefficient, accounted for foothill and mountain areas, \( T_{max} \) and \( T_{min} \) are average temperatures of the warmest and coldest months of the year, \( \phi \) is the geographical latitude of an area, \( \sum_{t>10} \) is a sum of temperatures above 10ºC, \( P \) is correction.

The standard grain yield \( Y_s \), c/ha calculated depending on the agroecological potential value

\[
Y_s = 33.2 \cdot 1.4 \cdot \frac{AP}{10.0} \cdot C_1 \cdot C_2 \cdot C_3 \cdot C_4,
\]

also characterises the natural agropotential of the territory and is a complex indicator of soil-climatic resources (\( C_1-C_4 \) – correction coefficients for humus and physical clay contents in arable layer, humus horizon thickness, negative soil properties). Regarding it, the standard productivity of a set of estimated crops is then determined in grain equivalent in accordance with the crop structure recommended for this subzone.

In this approach, the diversity of climatic resources of the territory comes down to a few options (according to the number of mesozones). However, in the territory of the Samara region, this method does not clarify the differences in conditions enough. So, AP in all subzones of the 1st LAD (Fig. 1) is the same (6.1), in the 2nd LAD AP of subzones 4 and 5 are almost identical (5.6 and 5.7). The reason for this is use of only main summative indicators of climate resources for calculating AP, without taking into account factors dynamics during vegetation and variability over years.

We carried out an analysis of the territory NAP of the Samara region based on the results of the production process of grain crops simulation [8]. The standard yield of winter and spring wheat and spring barley is calculated taking into account characteristics of soil fertility [16], as well as time structure and spatial distribution of climate factors. Based on the natural-agricultural zoning of the territory and spatial distribution of calculated standard grain yield, the complex mesozoning of the territory is done. [9]. For each mesozone, an estimated crops structure is determined in accordance with principles of ensuring high gross yield, profitability and production stability. It is based on the acreage structure analysis in farming systems, normative and real crop yields in recent years, taking into account the recommendations of scientific institutions of the Samara region on saturation of crop rotation with grain crops, sunflower, corn and other cultures.
3. Results and discussion

The results of complex mesoscale zoning of the Samara region are shown in figure 2, and characteristics of the zones are given in table 1.

Figure 2. Comprehensive soil and climatic assessive mesozoning of the Samara region.

Taking into account the existing market relations, economic efficiency of grain and feed crops production, reduction of on-farm needs in pabular grain and feed, there was a significant transformation in acreage structure in agricultural enterprises of the region. Area of pure fallow and
winter wheat increased, while area under oat, millet, buckwheat, legumes, annual and perennial grasses, and silage crops decreased. Sowing area of sunflower has increased sharply. A high-cost crop, sugar beet, has disappeared from the structure of acreage.

As a result of significant reduction of environment-enhancing crops area, primarily perennial and annual grasses, legumes, and silage, grain precursors quality has decreased. Grain crops began to be placed after grain precursors. Profitability of sunflower cultivation leads to uncontrolled increase of its area to 30-50%, as a result, the crop returns to its former place after 2-3 years, which leads to fields clogged with broomrape, accumulation of pests, diseases, and reducing crop yield and soil fertility [10].

Table 1. A generalized description of estimate mesozones of the Samara region

| Natural zone | Mesozone | Standard grain yield, c/ha | Soil humus content, % | Soil productive moisture stock (August), mm | Sum of temperatures, °C | Precipitation (April-October), mm |
|-------------|---------|-----------------------------|-----------------------|------------------------------------------|------------------------|-----------------------------------|
|             |         |                             |                       |                                          | above +10°C            | below –10°C                      |                                  |
| Forest-steppe | 1a     | 23.1                         | 5.6                   | 125                                      | 2133                   | 1183                              | 350                              |
|             | 1b     | 26.2                         | 5.5                   | 100                                      | 2300                   | 1130                              | 312                              |
|             | 2      | 24.7                         | 6.0                   | 108                                      | 2167                   | 1200                              | 317                              |
|             | 3      | 21.6                         | 4.7                   | 100                                      | 2350                   | 1010                              | 325                              |
|             | 4      | 19.3                         | 3.7                   | 75                                       | 2400                   | 1001                              | 300                              |
| Steppe      | 5a     | 17.0                         | 4.0                   | 75                                       | 2500                   | 1059                              | 300                              |
|             | 5b     | 20.9                         | 5.0                   | 88                                       | 2450                   | 1126                              | 325                              |
|             | 5c     | 19.6                         | 3.7                   | 100                                      | 2400                   | 1148                              | 317                              |
|             | 5d     | 17.7                         | 3.8                   | 75                                       | 2500                   | 1193                              | 350                              |
| Dry steppe  | 6      | 16.0                         | 3.6                   | 50                                       | 2500                   | 1137                              | 275                              |
|             | 7      | 11.3                         | 2.8                   | 50                                       | 2600                   | 1125                              | 250                              |

Such kind of acreage structure does not ensure reproduction of soil fertility, and in the future will not meet the interests of the producers, as the soil properties will deteriorate, weeds, diseases and pests will accumulate. As a result, costs for maintaining soil fertility, certain crop yield level and quality will increase.

In this regard, a new approach to acreage structure justification and formation is overdue. When changing the structure of acreage, you need to keep in mind different effects of cultivated crops on soil fertility and general state of farming system in addition to market considerations (to cultivate sunflower, buckwheat, winter wheat, spring durum wheat, barley, peas, soy, chickpeas, lentils, millet, etc.).

All this leads to the conclusion that it is necessary to adjust crops structure within the framework of the ensure rational land use strategy, taking into account current economic realities of agricultural production and preserve soil fertility need.

Currently, it is desirable that the area of winter crops in the structure of sown areas was at a 15% level, placing them after pure fallow, in years with good water availability in forest-steppe areas, it is possible to place winter crops after occupied and green-manured fallow. To increase the area of leguminous crops, perennial grasses, as valuable high-protein crops and nitrogen accumulators, soil fertility improvers to 3-9% percent are advisable. The area of grain crops should be maintained at a 15-20% level. If possible, expasion of corn crops area for grain, millet, buckwheat to 5-8% is needed. The sowing area of sunflower should not exceed 15%, i.e. it should return to its value of 6-7 years ago [10].

The proposed crop structure is shown in table 2. It is formed on a base of integrated analysis of shortcomings in existing structure of crops, shifting accents of agricultural production in modern
conditions, and has the differentiation by mesozones of the Samara region taking into account the spatial-temporal structure of climate.

The problem of conditions heterogeneity and some differences in sets of suitable crops in mesozones 5a, 5b and 5d remains. In particular, conditions of Alekseevskiy, Khvorostyanskiy and Krasnoarmeyskiy districts are transitional from the steppe to dry steppe zone and the percentage of soybean and corn may be higher than in the corresponding mesozones. However, these crops are not the main ones, and the difference in the share of their area would be only 1-2%, so the estimated crop structure can be formed for the mesozone as a whole. For more details, an economic justification and analysis of gross fees stability is required.

Table 2. Estimated structure of acreage

| Mesozone      | Pure fallow | Winter wheat | Spring wheat | Spring barley | Oat | Legumes | Millet and buckwheat | Grain maize | Sunflower | Herbs or other crops |
|---------------|-------------|--------------|--------------|---------------|-----|---------|-----------------------|-------------|-----------|---------------------|
| Mesozone 1a   | 15          | 15           | 15           | 10            | 7   | 9       | 1                     | 3           | 15        | 10                  |
| Mesozone 1b   | 15          | 15           | 15           | 10            | 7   | 8       | 2                     | 3           | 15        | 10                  |
| Mesozone 2    | 15          | 15           | 15           | 11            | 6   | 8       | 2                     | 3           | 15        | 10                  |
| Mesozone 3    | 15          | 15           | 15           | 11            | 5   | 8       | 4                     | 4           | 15        | 8                   |
| Mesozone 4    | 15          | 15           | 15           | 11            | 5   | 8       | 4                     | 4           | 15        | 8                   |
| Mesozone 5a   | 15          | 15           | 15           | 15            | 5   | 5       | 4                     | 4           | 15        | 7                   |
| Mesozone 5b   | 15          | 15           | 15           | 15            | 4   | 5       | 5                     | 5           | 15        | 6                   |
| Mesozone 5c   | 15          | 15           | 15           | 15            | 3   | 5       | 5                     | 5           | 15        | 7                   |
| Mesozone 5d   | 15          | 15           | 15           | 17            | 3   | 4       | 5                     | 5           | 15        | 6                   |
| Mesozone 6    | 15          | 15           | 15           | 19            | 2   | 3       | 6                     | 5           | 15        | 5                   |
| Mesozone 7    | 15          | 15           | 15           | 19            | 2   | 3       | 8                     | 5           | 15        | 3                   |

4. Conclusion

Rational use of soil and land resources in agricultural landscapes with high and stable crop yields and soil fertility preservation is impossible without landscape-ecological systems of agriculture and development and implementation of adaptive agricultural technologies. Differentiation of crops by districts and mesozones of the region, creation of rational acreage structure and economically justified crop rotations is crucial in improving efficiency and sustainability of agriculture. This will not only increase the yield and sustainability of grain and other crop production, but also increase profits, production profitability, reduce the needs of agro-industrial complex in labor resources and equipment, improve soil fertility.

Correct solution of the issues on formation of a set of cultures, differentiation of sown areas structure for mesoscale zoning units also contribute to increasing land valuation reliability and strengthening their natural condition.

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References

[1] Kislov A V, Glinushkin A P, Kashcheyev A V and Sudarenkov G V 2018 Agriculture 6 6-10
[2] Sans G H C, Aguiar S, Vallejos M and Paruelo J M 2018 Land Use Policy 70 313-321
[3] Kiryushin V I 2018 *Agriculture* 3 3-7
[4] Akimenko A S 2018 *Agriculture* 6 11-14
[5] Kaim A, Cord A and Volk M 2018 *Environmental Modelling and Software* 105 79-93
[6] 2010 *Handbook of Agroclimatic Assessment Zoning of the Russian Federation Entities* (Moscow: Maroseyka)
[7] Ogleznev A K, Bulgakov D S, Suhanov V A et al 2007 *Assessment of the quality and classification of land according to their suitability for use in agriculture* (Moscow: Goszemkadastrsyemka – VISHAGI)
[8] Samokhvalova E V 2017 *Meteorology and Hydrology* 4 102-112
[9] Samokhvalova E V, Kutilkin V G and Zadilin S N 2019 *IOP Conf. Ser.: Earth Environ. Sci.* 341 012031
[10] Garkusha A A, Nazarenko P N, Purgin D V and Kravchenko V I 2018 *Agriculture* 2 41-43