Geographic analysis of environmental assessment results of agricultural land in Samara region

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Abstract. The study presents spatial analysis of agricultural land degradation in the Samara Region with an assessment of economic losses under the influence of negative factors. The characteristics of ecological state of lands are made in the context of administrative districts on the basis of indicators of the degree of degradation and the decrease coefficient in the productivity of grain crops. The data of soil surveys and the results of modeling the potential production rate of grain crops were used. Assessment of yield losses of grain, ranking of areas according to the potential effectiveness of actions to restore soil fertility and soil protection were carried out. The results obtained create an information basis for the ecological and economic substantiation of soil protection actions and the determination of geographical priorities of their application.

1. Introduction
Soils are the property of any country in the world and along with the climate they determine the possibility of agricultural production and agricultural potential. Under the influence of wind, surface water runoff, changes in the hydrological regime, influence on the soil-forming process of the underlying rocks and other reasons the ecological state of lands, and in particular of the upper soil layer, undergoes continuous changes.

The agro-industrial impact on arable soils provokes larger-scale changes in the soil cover and in a short time can cause soil depletion. Irrational land exploitation (excessive irrigation, use of water with a high salt content), regulation of river beds and the organization of reservoirs also provoke changes in the soil cover, in some places up to salinization and alkalinization of soils acquiring hydromorphic properties and waterlogging. Significant efforts and material investments are required to restore soils, prevent their degradation [1], or informed decisions on the withdrawal of the corresponding lands from reproduction. The information basis for the development of such projects is the data of soil surveys, environmental monitoring of lands, comprehensive analysis of natural properties and the development of degradation processes.

Large-scale soil and geobotanical special surveys of lands were carried out in Russia in 1992-2000 and the state registration of indicators of the state of soil fertility was performed in 2002-2004. [2]. Maps of changes in soil cover characteristics (filtration coefficient, soil mass, damage area, dissection by ravines, groundwater level, etc.) were obtained [3]. This makes it possible to identify the geographical patterns of the development of negative ecological processes, to determine the degree of soil damage by the severity of changes in its properties and to take them into account for the purpose of greening land use and agricultural production [4].
In order to manage land resources and protect lands, it is most expedient to express the assessment of degradation in economic indicators, for example, in proportion to the amount of crop shortfall caused by the violation of the ecological state of land and a decrease in fertility [5]. This will clearly show the scale of losses and will justify the feasibility and effectiveness of application of a set of actions to restore soil fertility and soil conservation land management projects.

The purpose of this work is a spatial analysis of the degradation of agricultural land in the Samara Region with an assessment of economic losses under the influence of negative factors. The tasks include classification and zoning of damaged lands with differentiation by administrative districts, ranking districts according to the potential effectiveness of measures to restore soil fertility and soil protection.

2. Materials and Methods
The Samara Region is located in the southeastern part of the East European (Russian) Plain, in the middle reaches of the Volga River. The territory is characterized by a predominantly wavy relief (the highest elevations of 350 m are noted in the northeast of the Region and in the right-bank part) and a low degree of surface water supply. The predominant soils in the Samara Region (97.5% of the arable land) are chernozems (ordinary, typical, leached, southern) the distribution of which is subject to the laws of zoning with a gradual decrease in the level of fertility from northern to southern regions [6].

The main limiting factor is the aridity of conditions in most of the territory (the amount of annual precipitation is 270-450 mm; droughts and dry winds are typical) [7]. Besides, the overwintering conditions often reduce the productivity of wintering crops as a result of crops freezing (in the southern regions with a weak snow cover) and damping off (mainly in the northern regions with a thick snow cover and a longer period of its occurrence).

Various combinations of the landscape of the territory and soil and climatic resources create a variety of conditions for production activities and prerequisites for disturbing the ecological state of soils. According to [8], it was established that the main processes that determine the ecological state of the soil cover in the Samara Region is the development of water erosion (on average, 26.6% of the area of agricultural land in the Region). To a much lesser extent and locally, the processes of soil deflation under the influence of wind erosion, degradation due to the violation of the water-salt balance (overwetting, waterlogging of soils, salinization, formation of salt marshes and solonetzes), and clogging by stones are expressed.

Summarizing the data on the scale of disturbed lands and the severity of processes, the degree of land degradation under the influence of negative factors was assessed [9]. In accordance with the methodology [10], each administrative district of the region was assigned a level of degradation and a score (from 0 to 5), based on the lack of yield of winter wheat, as the main food crop in the region.

The assessment of economic losses was carried out taking into account the coefficients of reducing the productivity of grain crops [11], as well as the area and degree of damage [8]. The integrated coefficient of productivity decline was calculated as the product of corresponding coefficients taking into account the degradation types.

3. Results and discussion
As a result of the conducted research, it was found that the total area of land degradation in the Samara Region amounted to 35.6% of agricultural land, the degree of degradation corresponds to 2 points and is characterized as average. At the same time, there are significant differences in the scale of degradation by districts of the Region (Table 1). Only in Khvorostyansky District, the degradation score corresponds to 0 points (“conditional absence of damage”). Four more districts (Privolzhsky, Bezenchuksky, Bogatovsky and Neftegorsky) have a score of 1 point (low level). Kamyshlinsky and Pokhvistnevsky fell into the category with a catastrophic level (5 points). The majority of areas (84% of damaged areas) have medium, high and very high degradation level (Figure 1).
Table 1. Characteristics of agricultural land degradation in Samara Region under the influence of complex of negative processes

| Administrative region        | Degree of degradation, score | Productivity reduction factor, relative units | Standard yield, c/ha | Production rate loss, t | District loss rank, number |
|------------------------------|------------------------------|---------------------------------------------|----------------------|------------------------|----------------------------|
| Chelnovershinsky             | 2                            | 0.97                                        | 28.6                 | 2547                   | 20                         |
| Shentalinsky                 | 3                            | 0.97                                        | 25.8                 | 3019                   | 16                         |
| Klyavlinsky                  | 3                            | 0.97                                        | 25.4                 | 2706                   | 17                         |
| Koshkinsky                   | 2                            | 0.97                                        | 30.9                 | 4370                   | 9                          |
| Sergievsky                   | 4                            | 0.96                                        | 32.6                 | 16938                  | 2                          |
| Isaklinsky                   | 4                            | 0.96                                        | 31.7                 | 8146                   | 4                          |
| Kamyshlinsky                 | 5                            | 0.96                                        | 26.7                 | 4724                   | 8                          |
| Elkhovky                     | 2                            | 0.98                                        | 30.7                 | 2570                   | 19                         |
| Pohvistnevsky                | 5                            | 0.96                                        | 29.0                 | 11258                  | 3                          |
| Syzransky                    | 3                            | 0.97                                        | 26.8                 | 3753                   | 14                         |
| Shigonsky                    | 3                            | 0.97                                        | 25.5                 | 3775                   | 13                         |
| Stavropol                    | 2                            | 0.98                                        | 27.7                 | 2706                   | 18                         |
| Krasnoyarsk                  | 2                            | 0.97                                        | 28.2                 | 4147                   | 10                         |
| Kinel-Cherkassky             | 3                            | 0.97                                        | 29.9                 | 7666                   | 5                          |
| Privolzhsky                  | 1                            | 0.99                                        | 27.7                 | 496                    | 25                         |
| Bezenchuksky                 | 1                            | 0.98                                        | 26.6                 | 1806                   | 23                         |
| Volzhsky                     | 2                            | 0.97                                        | 30.7                 | 4823                   | 7                          |
| Kinelsky                     | 2                            | 0.98                                        | 26.8                 | 2463                   | 21                         |
| Bogatovsky                   | 1                            | 0.99                                        | 27.8                 | 392                    | 27                         |
| Borsky                       | 2                            | 0.98                                        | 29.6                 | 2203                   | 22                         |
| Khvorostyansky               | 0                            | 0.99                                        | 24.5                 | 431                    | 26                         |
| Krasnoarmeyskiy             | 3                            | 0.97                                        | 28.5                 | 5980                   | 6                          |
| Neftegorsk                   | 1                            | 0.98                                        | 27.3                 | 1274                   | 24                         |
| Alekseevsky                  | 2                            | 0.97                                        | 27.1                 | 4055                   | 11                         |
| Pestravsky                   | 2                            | 0.97                                        | 27.1                 | 3940                   | 12                         |
| Bolsheglushitsky             | 2                            | 0.98                                        | 28.2                 | 3466                   | 15                         |
| Bolshechernigovsky           | 4                            | 0.94                                        | 24.6                 | 20392                  | 1                          |
| **Region as a whole**        | **2**                        | **0.97**                                    | **28.0**             | **130046**             | **–**                      |

Note: Target yields and productivity losses are determined for an estimated set of crops in grain equivalent.

The Bolshechernigovsky District (the productivity decrease factor is 0.94) was noted with the highest value of the integrated coefficient of productivity decline as a result of soil degradation. Pokhvistnevsky, Kamyshlinsky, Sergievsky, Isaklinsky is the group of districts with a coefficient of 0.96. In most areas, the productivity decline rate is 0.97-0.99 (Figure 1).
Figure 1. Assessment of land degradation in the Samara Region as a result of the action of a complex of negative processes: degradation score (a) and coefficient of productivity decline (b) (administrative districts: 1 - Chelnovershinsky, 2 - Shentalinsky, 3 - Klyavlinsky, 4 - Koshkinsky, 5 - Sergievsky, 6 - Isaklinsky, 7 - Kamyshlinsky, 8 - Elkhovsky, 9 - Pokhvistnevsky, 10 - Syzransky, 11 - Shigonsky, 12 - Stavropolsky, 13 - Krasnoyarsky, 14 - Kinelcherkassky, 15 - Privilzhsky, 16 - Bezenchucksy, 17 - Volzhsky, 18 - Kinelsky, 19 - Bogatovsky, 20 - Borsky, 21 - Khvorostyansky, 22 - Krasnoarmeysky, 23 - Neftegorsky, 24 - Pestravsky, 25 - Bolsheglushitsky, 26 - Alekseevsky, 27 - Bolschechernigovsky)

To assess economic losses under the influence of negative factors, we used the results of bioclimatic potential modeling (BCP) of the territory, expressed by the value of the potential (really possible) yield of a set of crops recommended for cultivation [12]. Taking into account the differentiation by the districts of the size of the BCP and the coefficient of productivity decline, there was obtained the distribution of economic losses as a result of land degradation. Since the magnitude of today’s losses will correspond to an increase in yield in the event of full restoration of fertility, it can be considered as an indicator of the potential effectiveness of soil protection measures.

According to the given data, productivity losses for the Region amounted to over 130 thousand tons in grain equivalent. The districts of the forest-steppe zone of the Region (districts 1-13 - Figure and Table) are characterized by both the highest values of the bioclimatic potential and the most pronounced land degradation (2-5 points). With the values of the productivity decrease coefficient being 0.96-0.97, the losses amount to more than 70 thousand tons in grain equivalent. With full restoration of land, these areas can provide about 54% of total increase in productivity in the Region. A particularly significant contribution (16.9 and 11.3 thousand tons) is made by Sergievsky and Pokhvistnevsky Districts with high productivity potential (32.6 and 29.0 c/ha) and degradation scores of 4 and 5 points. A significant increase in yield (1.39 and 1.15 c/ha) can also be expected in Isaklinsky and Kamyshlinsky districts (productivity potential 31.7 and 26.7 c/ha, degradation 4 and 5 points, respectively), but their contribution to the gross yield is less significant due to lower land area.

Besides, the attention is drawn to the significant scale of damaged land in the Bolshechernigovsky District of the dry-steppe zone of the Region (assessment of the degree of degradation is 4 points). Taking into account relatively low potential of productivity (24.6 c/ha) and significant areas of agricultural land, the increase in yield will provide an increase in agricultural production by 20.4 thousand tons in grain equivalent.
A lesser effect is suggested by soil protection measures in other areas of dry steppe zone, as well as in the steppe (areas 15-26) - the degree of damage there is not so significant in comparison with those discussed above. The only exception is the Kinel-Cherkassk District with a damage assessment of 3 points. The estimate of a yield increase amounted to 0.88 c/ha, which can provide 7.7 thousand tons of gross harvest.

A detailed arrangement of land resources and spatial analysis of degraded lands provide basis for ranking areas according to the potential effectiveness of actions and measures aimed to restore fertility and protect soil. As a result, rank 1 and the economic priority of carrying out soil protection measures were established for the Bolshechernigovsk District, the top five also included the northeastern districts of the Region, i.e. Sergievsky, Pokhvistnevsky, Isaikinsky and Kinel-Cherkassky. The last on the list were Bogatovsky, Khvorostyansky and Privolzhsky districts, where productivity losses are the smallest and do not exceed 1,000 tons in grain equivalent.

4. Conclusion

Thus, the data from monitoring the ecological state of lands and assessing degradation using the results of modeling the potential productivity of lands were used to assess economic losses. The results can be used for ecological and economic substantiation of on-farm land management projects on an adaptive-landscape basis in order to optimize the ecological structure of the land fund and the structure of agricultural land, preserve and restore the land-resource potential of the territory.

Geographic analysis of the results of ecological state of land and the ranking of areas according to the potential effectiveness of measures to restore soil fertility and protect soils makes it possible to determine the priorities of their introduction by area. Establishing an expedient priority for resolving issues of greening land use and soil protection are necessary stages in a comprehensive solution to land conservation problems create an information basis for planning soil protection works and land management.

5. Acknowledgments

The work was carried out in the framework of the Project Meteorological Substantiation of Agricultural Technologies and Design (registered under No. 116041210128 in the Unified state information system for accounting of scientific research, experimental design and technological works for civil purposes).

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