Assessment and spatial analysis of agricultural land erosion processes in the Samara region

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Abstract. Water and wind erosion of land causes annual damage since it leads to soil degradation and loss of fertility, reducing the economic indicators of agricultural production. Detailed systematization of land resources with an assessment of the scale and level of land degradation provides a basis for ranking areas by relevance and effectiveness of erosion protection. The article assesses the level of degradation of agricultural land in the Samara region by the scale of economic losses under the influence of water and wind erosion of soil with differentiation by administrative districts. The map of eroded lands has been developed. The results of integrated erosion zoning of the territory provide an information basis for identifying priority areas requiring anti-erosion measures, as well as for optimizing the structure of agricultural land use. The main directions of anti-erosion organization of the territory and on-farm land management, depending on the features of the landscape and the nature of damage, have been described.

1. Introduction
Erosion is the most widespread and harmful type of soil degradation. According to the Department of Land reclamation of the Ministry of Agriculture of the Russian Federation, losses due to soil erosion damage amount to 3.2-3.9 million tons of agricultural products in grain equivalent. This makes 18-25 billion rubles per year [1]. All this makes the protection of land from erosion the most important link in the process of protection and rational use of land resources.

It is known that both geological water erosion and wind erosion are natural processes and occur everywhere, practically without causing damage to ecosystems, since soil losses are compensated in the process of soil formation. At the same time, agricultural activity and its consequences such as ploughing of land, elimination of natural landscapes and the loss of soil vegetation protection, enlarged crop rotation fields, cultivation of row crops contribute to the development of degradation processes [2]. Water and wind erosion of land causes annual damage since it leads to soil degradation and loss of fertility, reducing the economic indicators of agricultural production.

It is necessary to develop and implement a set of anti-erosion measures and land management projects. Land protection from erosion and organization of rational land use should primarily be based on the analysis of factors and geographic patterns of erosion processes development, the analysis of compliance of economic activities with natural characteristics and environmental peculiarities of a territory, resistance to anthropogenic impacts [3].

According to data [4], 26.6% of agricultural land in the Samara region is subject to water erosion and the area continues to increase [5]. Today, it amounts to almost 765 thousand hectares, or 29.7%.
The total area of agricultural land with identified signs of deflation under the influence of wind erosion makes 0.7%, and about 50% are deflationary dangerous. Maps of damage to the soil cover for a number of features are provided.

The article assesses the level of degradation of agricultural land in the Samara region by the scale of economic losses under the influence of water and wind erosion of soil. The cartographic map of eroded lands distribution in the districts of the region has been made up with the aim of ranking them by priority needs and effectiveness of anti-erosion protection.

2. Methods

Levels of land degradation have been assessed in accordance with the methodology [6] based on the lack of winter wheat yield as the main food crop in the region. A shortfall of 50% (a coefficient of productivity reduction of 0.5) or more has been considered as a catastrophic consequence of degradation, and the area of damage, at which it can be achieved, has been estimated. The remaining degradation levels have been set proportionally.

The estimation of economic losses under the influence of erosion processes has been carried out on the basis of the data on scale and level of soil damage [4], taking into account the coefficients of reduced productivity of grain crops [7]. The analysis has been carried out in the context of administrative districts of the Samara region, and the recommended values of coefficients have been taken for the prevailing soils.

The Samara region is home to lands with different levels of damage (low, medium, high). According to the data [7], the effect of water erosion on cereals leads to a decrease in their productivity with coefficients of 0.95, 0.90 and 0.80, respectively. On average, the coefficient for damaged land in the Samara region (26.6% of the area of agricultural land) is equal to 0.93. Calculations show that the scale of damage for a degradation level with a coefficient of 0.5 must be at least 60% of the area. The coefficient of reduction in productivity for damaged land under the influence of deflation (0.7% of the area of agricultural land) makes 0.95. The scale of damage for a catastrophic crop shortage is estimated to be over 45% of the area. The resulting Table 1 presents levels and points (from 0 to 5) of agricultural land degradation under the influence of erosion processes.

| Point | Level of degradation | Damaged area, % | erosion | deflation |
|-------|---------------------|----------------|---------|-----------|
| 0     | conditionally absent| less than 12    | less than 9 |
| 1     | low                 | 12-24          | 9-18    |
| 2     | medium              | 24-36          | 18-27   |
| 3     | high                | 34-48          | 27-36   |
| 4     | very high           | 48-60          | 36-45   |
| 5     | catastrophic        | 60 and more    | 45 and more |

3. Results and discussion

According to the data [4], all administrative districts of the Samara region have lands that are subject to water erosion. Their area varies widely – from 1.5% (in the Volga region) to almost 50% of the area of agricultural lands (Table 2).

As shown in [4], the greatest damage to the soil cover by water erosion is characteristic of the elevated dissected plains of the forest-steppe part of the region. The development of these processes there is facilitated by a significant amount of rain and moisture reserves in the snow, the spring melting of which forms intense and destructive flows of melt water. First of all, these are lands on the slopes of the Bugulmino-Belebeevskaya upland in the North-Eastern part of the region, as well as on the high plains with a strongly dissected relief on the right bank of the Volga. Within the relatively
less divided plains of the steppe districts, water soil erosion is less pronounced in general [8].

Table 2. Damage to agricultural land in the Samara region due to erosion processes

| No | Administrative district     | Water erosion | Deflation |
|----|-----------------------------|---------------|-----------|
|    | Area of agricultural land, % | Level of degradation, point | Productivity reduction coefficient, relative units | Area of agricultural land, % | Level of degradation, point | Productivity reduction coefficient, relative units |
| 1  | Chelnovershinsky             | 26.1           | 2         | 0.98                  | 0 | 0 | 1.0 |
| 2  | Shentalinsky                | 30.0           | 2         | 0.97                  | 0 | 0 | 1.0 |
| 3  | Klyavlinsky                 | 29.5           | 2         | 0.97                  | 0 | 0 | 1.0 |
| 4  | Koshkinsky                  | 27.8           | 2         | 0.98                  | 0 | 0 | 1.0 |
| 5  | Sergievsky                  | 38.7           | 3         | 0.97                  | 0 | 0 | 1.0 |
| 6  | Isaklinsky                  | 35.0           | 2         | 0.97                  | 0 | 0 | 1.0 |
| 7  | Kamyslinskny                | 49.5           | 4         | 0.96                  | 0 | 0 | 1.0 |
| 8  | Elkhovsky                   | 28.2           | 2         | 0.98                  | 0 | 0 | 1.0 |
| 9  | Pokhvistnevsky              | 48.3           | 4         | 0.96                  | 0 | 0 | 1.0 |
| 10 | Syzransky                   | 28.8           | 2         | 0.98                  | 5.39 | 0 | 0.9972 |
| 11 | Shigonsky                   | 32.8           | 2         | 0.98                  | 7.09 | 0 | 0.9964 |
| 12 | Stavropol'sky               | 16.7           | 1         | 0.99                  | 0.47 | 0 | 0.9998 |
| 13 | Krasnoyarsky                | 22.6           | 1         | 0.98                  | 1.04 | 0 | 0.9995 |
| 14 | Kinel-Cherkassky            | 37.7           | 3         | 0.97                  | 0.03 | 0 | 1.0000 |
| 15 | Privolzhsky                 | 1.5            | 0         | 1.00                  | 6.05 | 0 | 0.9964 |
| 16 | Bezenchuksky                | 8.5            | 0         | 0.99                  | 0.07 | 0 | 1.0000 |
| 17 | Volzhsky                    | 23.9           | 1         | 0.98                  | 0 | 0 | 1.0 |
| 18 | Kinel'sky                   | 14.3           | 1         | 0.99                  | 2.80 | 0 | 0.9986 |
| 19 | Bogatovsky                  | 8.9            | 0         | 0.99                  | 0 | 0 | 1.0 |
| 20 | Borsky                      | 19.8           | 1         | 0.99                  | 0.38 | 0 | 0.9997 |
| 21 | Khvorostyansky              | 9.2            | 0         | 0.99                  | 0.69 | 0 | 0.9996 |
| 22 | Krasnoarmeysky             | 34.1           | 2         | 0.98                  | 0 | 0 | 1.0 |
| 23 | Neftegorsky                 | 17.7           | 1         | 0.99                  | 0 | 0 | 1.0 |
| 24 | Alekseyevsky                | 28.8           | 2         | 0.98                  | 0 | 0 | 1.0 |
| 25 | Pestravsky                  | 26.0           | 2         | 0.98                  | 0 | 0 | 1.0 |
| 26 | Bolsheglushitsky            | 19.7           | 1         | 0.99                  | 0 | 0 | 1.0 |
| 27 | Bolshechernigovsky          | 40.4           | 3         | 0.97                  | 0 | 0 | 1.0 |
| The region as a whole | 26.6 | 2 | 0.98 | 0.72 | 0 | 0.9995 |

The level of land degradation in the Samara region in accordance with the described methodology is estimated in the range from 0 to 4 points. The map of their distribution by districts is shown in Figure 1A.

In this connection, the largest areas of land affected by a complex of water erosion processes are in the Pokhvistnevsky and Kamyslinskny districts. The level of damage is estimated at 4 points, slightly less (3 points) – in the Kinel-Cherkassky district. Damage with a rating of 3 points is also noted in the southernmost Bolshechernigovsky district, which is associated with developed gully erosion and the influence of spurs of the Common Syrt. In total, the region has 9% of land with a very high level of degradation (4 points) and 25% – with a high level (3 points). Agricultural lands with an average level
of degradation (2 points) are the most common (40%). 7 districts out of 27 (22% of the area of degradation) have a low level of degradation (1 point) and other 4 districts (3% of the area of degradation) have no degradation signs (0 points). They are mainly located in the low-lying floodplain terraces of the Volga and Samara rivers. A catastrophic level of damage (5 points) was not recorded in any of the districts.

Figure 1. Level of land degradation in the Samara region under the influence of water (a) and wind (b) erosion

Administrative districts: 1 – Chelnovershinsky, 2 – Shentalinsky, 3 – Klyavlinsky, 4 – Koshkinsky, 5 – Sergievsky, 6 – Isakinsky, 7 – Kamyshlinsky, 8 – Elkhovsky, 9 – Pokhvistnevsky, 10 – Syzransky, 11 – Shigonsky, 12 – Stavropolsky, 13 – Krasnoyarsky, 14 – Kinelcherkassky, 15 – Privolzhsky, 16 – Bezenchuksky, 17 – Volzhsky, 18 – Kinelsky, 19 – Bogatovsky, 20 – Borsky, 21 – Khvorostyansky, 22 – Krasnoarmeysky, 23 – Neftegorsky, 24 – Alekseevsky, 25 – Pestavsky, 26 – Bolsheglushitsky, 27 – Bolshechernigovskiy

Taking into account that the coefficient of erosion on damaged areas is 0.88-0.93, the decrease in the average regional yield makes 0.96-1.00 (Table 2). It is noteworthy that the greatest degree of productivity decline does not always correspond to the areas with the greatest scale of damage. For example, in the Volga region there is the most pronounced erosion, characterized by a decrease in productivity with a coefficient of 0.88. However, the area of damage is insignificant, and the coefficient for the area as a whole remains close to 1.00.

Similarly, the development of soil deflation processes under the influence of wind erosion on the territory of the Samara region has been analyzed. In total, the region shows signs of soil deflation on 0.72% of the area of agricultural land. In most areas, there is no soil damage, and in the rest (in 10 out of 27 districts) – absence of damage is conditional. It should be noted that in most cases these are areas on the border of forest-steppe and steppe zones, with moderate moisture, woodlands on watersheds and protective forest belts. The development of wind erosion there, apparently, contributes to the relatively high proportion of sandy and loam soils in the structure of the soil cover, which are more susceptible to the influence of winds. The largest scale of damage is observed in the Syzransky, Shigonsky and Privolzhsky districts – 5-7% of the area of agricultural land (Fig. 1b).

Taking into account the small scale of deflation, the coefficient of reduced productivity for damaged land is 0.88-0.95, and in general for the relevant areas, it is close to 1.00. The most severe
damage, although in very limited areas, is noted in the Kinel-Cherkassky district. The coefficient on damaged areas is 0.88, and for the district as a whole – almost 1.00. Detailed systematization of land resources with an assessment of the scale and level of land degradation is necessary for implementing land management, working out a complex of reclamation works and protecting lands. If geospatial analysis of degraded land provides a basis for ranking areas by priority need and effectiveness of erosion protection, then its implementation and selection of protective measures are determined taking into account local conditions, involving more detailed information about the territory's landscape.

It is known that the potential danger of erosion is largely determined by the distribution of land on the slopes of the surface. Without special anti-erosion measures, erosion becomes evident on slopes with a steepness of 1°, and sometimes even 0.5°. Therefore, account of the terrain in land management in areas of land erosion is of great importance. Dissection of the territory, steepness of slopes and their exposure, and the depth of local bases of erosion are taken into account [9]. For this purpose, a map of slope steepness, a map of categories of erosion-hazardous land and other detailed data are developed and used.

It is important to correctly establish economic and intra-economic specialization in the process of anti-erosion organization of the territory. In the conditions of widespread soil erosion, solution of these issues makes it possible to ensure the most rational combination of industries and create conditions for preventing erosion processes. In particular, specialization in crop production determines the structure of acreage, taking into account the coefficient of erosion hazard of crops. The issue of types and number of crop rotations is resolved.

The map of categories of erosion-hazardous lands is used to design crop rotations. On lands where the intensity of flushing can reach 1520 t/ha (IV and V categories of erosion hazard), soil-protective crop rotations with a high specific weight of perennial grasses are designed. Cultivation of row crops and spring crops on these lands is impractical, since the yield is sharply reduced and erosion processes increase. If such lands occupy a small area or are located on the territory of small plots, they are included in field crop rotations. At the same time, eroded land is allocated to separate working areas, where perennial grasses and winter crops are placed according to the scheme of alternating crops. The main areas of arable land having the best characteristics of soil and terrain, located in large and compact arrays, are used for row and other intensive crop rotations.

Some agricultural lands characterized by soil erosion are allocated for protective forest belts, hydrotechnical anti-erosion constructions, road network. Depending on the degree of erosion and the length of slopes, about 2.5-3.0% of arable lands are allocated for forest strips on the borders of working sites and fields. The types and structure of protective forest strips are determined depending on the coefficient of division of the territory.

4. Conclusion
At the background of continuing development of erosion processes and the increase in land degradation, it is necessary to point to the insufficient effectiveness of current anti-erosion measures. Great efforts are required for the correct justification, development and implementation of measures on preventing soil erosion, as well as spatial differentiation and evaluation of their effectiveness in accordance with the conditions of territorial landscape. Anti-erosion organization of the territory in this case should be carried out in conjunction with the development of projects of on-farm land management. Therefore, geospatial analysis and consideration of all economic and environmental factors of soil degradation, assessment and ranking of areas on the effectiveness of erosion protection, integrated erosion zoning of the territory are of particular importance as an information basis for the development of such projects.

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