The experience in the implementation of adaptive-landscape systems of agriculture in Rostov Oblast

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Abstract. The goal of the adaptive-landscape organization of the territory is to ensure effective protection of soils from degradation under the anthropogenic impact. The experiment was performed in the permanent study area located on the slope of the Bolshoy Log clough, Aksay District of Rostov Oblast from 2016 to 2019. The use of adaptive-landscape territory organization of the slope prone to erosion allowed reducing soil erosion by 35-43%. The use of soil protection treatments as the main tillage reduced soil erosion by more than 13-24%. For this, it is provided on arable lands prone to erosion and poorly eroded areas with a degree of the slope from 2 to 3°, an extended complex of agrotechnical measures is applied. Crop rotation with 40% of perennial grasses, 20% of row crops, and 40% of winter and spring grain crops is recommended. Productivity is up to 3.9 t/ha of grain units when applying manure in a dose of 5 tons and mineral fertilizers, N₄₆P₂₄K₃₀, ensuring the preservation of soil fertility at the initial level. With a 1.5-fold increase in organic fertilizers (manure at a dose of 8 tons and mineral fertilizers, N₈₄P₃₀K₄₈), productivity increases to 4.3 t/ha of grain units, and humus content increases to 4.1% (or 7.8%).

1. Introduction

The natural resources of Rostov Oblast make it possible to fully meet the food needs of the population as well as to solve the issues of supplying agricultural products to other regions [1]. Preservation and increase in fertility of degraded soils involve measures to optimize nature management based on scientifically approved forms of economic activity [2-4].

Analysis of the current situation in agriculture revealed a decrease in soil fertility, which leads to a loss of agricultural crops. According to survey data in recent decades, the humus content has decreased by 0.3-1.0% [5]. Stabilization of soil fertility parameters is impossible, due to the significant removal of nutrients with the harvest of agricultural crops. Insufficient application of organic and mineral fertilizers leads to soil degradation processes [6-9].

In some districts of the region, a decrease in the level of soil fertility is aggravated by water and wind erosion, which, additionally, significantly worsen the water regime of arable land. 2700 thousand hectares or 26.7% of the region's soils are affected by water erosion, 1120 thousand hectares or 11.1% – by wind erosion. Thus, approximately 42% of the region's territory is subject to erosion processes, and in a significant part, it is arable land [10-12]. Studies have shown that the runoff of melt-water from loose arable land is observed once every three years (probability 30%, years), and from
compacted arable land (sowing of winter wheat and perennial grasses) - twice every three years (probability 65%, years) [13]. To prevent the consequences of degradation processes, it is necessary to use soil-protective crop rotations. Improving the parameters of soil fertility contributes to an increase in the productivity of crop rotation by 14-19% [14].

In the region, there is a real need for the current and subsequent development of a new generation of farming systems: adaptive landscape, which will allow the most complete and rational use of natural resources [15]. The main efforts should be aimed at stabilizing and increasing the level of soil fertility as well as preventing the consequences of soil erosion [16, 17].

The goal of the adaptive-landscape organization of the territory is to ensure effective protection of soils from degradation under the anthropogenic impact. For this, sustainable artificial agricultural landscapes (crop rotation) are formed and rationally used. The task of such a crop rotation system is the preservation and restoration of soil fertility. One of the recommended elements of the territory organization in adaptive-landscape agriculture is the contour-strip placement of crops.

2. Models and methods

We studied the productivity of crop rotation parameters in different proportions of pure steam and perennial grasses to determine the most effective system for a particular agricultural landscape. The experiment was performed in the permanent study area located on the slope of the Bolshoi Log clough, Aksay District of Rostov Oblast from 2016 to 2019. The experiment was initiated in 1986 within the system of contour-landscape territory organization of a slope with a degree of up to 3.5-4° using a complex of simple anti-erosion structures. The soil of the experimental plot is ordinary heavy loamy chernozem on loess-like loam, moderately eroded. The initial humus content was 3.8-3.83%.

The experiment studied crop rotations with different percentages of clean fallow and perennial grasses (table 1).

| Crop rotation «A» | Crop rotation «B» | Crop rotation «C» |
|------------------|------------------|------------------|
| 20% – clean fallow, does not contain perennial grasses | 10% – clean fallow, 20% – perennial grasses. | does not contain clean fallow, 40% – perennial grasses. |
| 1. Clean fallow | 1. ½ soybean + ½ clean fallow | 1. Corn for grain |
| 2. Winter wheat | 2. Winter wheat | 2. Winter wheat |
| 3. Winter wheat | 3. Sunflower | 3. Spring barley |
| 4. Sunflower | 4. Spring barley | 4. Perennial grasses |
| 5. Spring barley | 5. Perennial grasses | 5. Perennial grasses |

Two soil cultivation systems and their after-action were studied. Chisel tillage was carried out with a chisel plow to a depth of 25-30 cm under clean fallow, sunflower and corn for grain; for soybeans and spring barley – by 23-25 cm, moldboard tillage – with a moldboard plow to a depth of 25-30 cm for clean fallow, sunflower and corn for grain; under soybeans and spring barley – by 23-25cm. We studied three options for fertilization: "0" – zero (without fertilizers), natural fertility; "1" – the first level – N_{46} P_{24} K_{30} (100 kg of a.i. per 1 ha of crop rotation area) and "2" - the second level - N_{84} P_{30} K_{48} (162 kg of a.i. per 1 ha of crop rotation area). Mathematical processing of the obtained results was carried out by the method of analysis of variance using the Excel program [18].

3. Results and discussion

3.1. Soil washout and erosion control efficiency

The use of the adaptive-landscape organization of the territory of the erosion-dangerous slope two or more times reduced soil washout due to the introduction of soil protection measures: the use of soil
protection treatments and specialized crop rotations with different percentages of clean fallow and perennial grasses. In the system of soil protection measures, one of the important elements is the anti-erosion organization of the territory based on the contour-strip placement of crops and clean steam. The essence of this technique lies in the fact that the field is occupied not by one crop but two, and they are not placed in continuous arrays but alternate with each other in separate strips from 50 to 100 m wide, depending on the steepness of the slope. The alternation of crops is carried out in a way that loose and compacted arable land replaces each other in the strips. In the summer, some strips should be occupied with erosion-resistant crops of continuous sowing (winter crops, spring crops, perennial grasses, etc.), and others - with erosion-unstable crops (clean fallow or row crops). The main feature of this event, which compares favourably with other soil protection measures, is that it does not require special machines and any significant changes in tillage techniques and crop cultivation technology (table 2).

Table 2. Soil washout in crop rotations of various designs depending on tillage, t/ha.

| Crop rotation | Soil washout, t/ha | Anti-erosion efficiency coefficient |
|---------------|-------------------|-----------------------------------|
|               | Chisel | Moldboard | Chisel | Moldboard |
| A             | 7.1    | 8.2       | 2.4    | 2.7       |
| B             | 5.1    | 6.8       | 1.7    | 2.3       |
| C             | 4.0    | 5.3       | 1.3    | 1.8       |

The placement of soil-protective crop rotations on slopes can significantly reduce erosion processes. The introduction of solid crops, such as winter wheat and perennial grasses, into the crop rotation prevents the development of water erosion. Crop rotations with clean fallow on slope lands are possible under the condition of their contour-strip placement, under the protection of erosion-resistant crops in combination with a set of anti-erosion measures. Strengthening of the complex was carried out due to ridge plowing, crevice of the soil and the formation of 18-20 cm high ridges along the border. The application of soil protective tillage reduced soil washout in crop rotation from 20% clean fallow to 13%, and in crop rotations with perennial grasses to 24% with moldboard plowing. Chisel tillage is carried out without soil overturning. Stubble and crop residues remain on the surface of the field, which can trap the soil as a result of melting snow and rainfall. Additionally, the cross-slope placement of anti-erosion forest strips slows down and reduces water flow.

The introduction of 20% of perennial grasses into the crop rotation reduced soil washout by 17-28%, in comparison with the crop rotation with clean fallow. An increase in the percentage of perennial grasses in the crop rotation halved soil washout to 43%. The presence of clean steam in the crop rotation has its positive and negative sides. The fallow field plays an important role in the agriculture of the arid region. Steam ensures the formation of not only a high yield of winter crops, for which it is the best predecessor, but also affects the entire crop rotation. In the fallow field more than in other crop rotation fields, moisture accumulates, as well as the main elements of plant nutrition. Here, the main work is carried out to protect the crop from weeds. The fallow field ensures high-quality sowing of winter wheat at the optimal time, obtaining timely germination, and normal development of plants in autumn, which is the key to obtaining a full-fledged harvest even in unfavorable years in terms of moisture supply. However, a large amount of precipitation in the autumn-winter period contributes to the development of erosion processes. To ensure the maximum retention of precipitation at the place of their fallout, special agrotechnical techniques are needed to create an anti-erosion microrelief on the surface of arable land (creating furrows and ridges). Another group of techniques is techniques that give the surface of arable land a stable surface (mulching, preservation of crop residues on the soil surface). In winter, techniques are used to ensure the retention of snow in the fields (sowing the wings, making snow rolls, strip compaction). All these measures help to protect the steam field from the development of erosion processes.

The coefficient of erosion control efficiency was calculated as the ratio of the actual soil washout to the "permissible" one. The permissible soil washout for the region is 3.0-3.5 t/ha. These calculations
were carried out based on the amount of organic matter that is formed in natural agrocenoses. Analysis of the indicator of the anti-erosion efficiency coefficient revealed the following pattern: with an increase in the proportion of perennial grasses in the crop rotation, its values decrease, which is an indicator of the stability of the agrocenosis. The optimum value of the anti-erosion efficiency coefficient is 1.0, at which the amount of washed-out soil is equal to the amount of newly formed soil. The minimum values of the anti-erosion efficiency coefficient confirm the stability of crop rotations with an increased proportion of perennial grasses (1.3-1.8). In a crop rotation containing a 20% field of perennial grasses, the anti-erosion efficiency coefficient is 2.4-2.7. In this crop rotation, the amount of washed-out soil exceeds two or more times the maximum permissible values. Moreover, the values of the anti-erosion efficiency coefficient are less in the case of chisel tillage, which performs soil protection functions (1.3).

3.2. Erosion hazard coefficients
Erosion resistance of crops can be estimated using the erosion hazard coefficient [19]. The erosion hazard coefficient in clean steam, as the most prone to erosion processes, was taken as 1.0. The rest of the crops, depending on the degree of a projective cover of the arable land, had different coefficients. The smallest coefficient was in the crops of perennial grasses and was equal to 0.08. It can be seen from the table that the highest total coefficient was calculated in the crop rotation with 20% clean fallow and equaled 0.6 in the crop rotation with 20% of perennial grasses and 10% of clean fallow: the value of the erosion hazard coefficient of crop rotation decreased to 0.4. The introduction of 40% of perennial grasses into the crop rotation reduced the erosion hazard coefficient by half in comparison with the crop rotation that contained a 20% field of clean fallow in the crop structure (table 3).

| Agricultural crop   | Crop rotation | A   | B   | C   |
|---------------------|---------------|-----|-----|-----|
| Dead fallow         |               | 1.0 | 0.5 |     |
| Winter wheat        |               | 0.3 | 0.3 | 0.3 |
| Winter wheat        |               | 0.3 |     |     |
| Grain legumes       |               |     | 0.12|     |
| Spring barley       |               | 0.4 | 0.4 | 0.4 |
| Maize for silage    |               |     |     | 0.6 |
| Sunflower           |               | 0.8 | 0.8 |     |
| Perennial grasses   |               | 0.08| 0.08| 0.08|
| Perennial grasses   |               |     | 0.08|     |
| Total crop rotation |               | 0.6 | 0.4 | 0.3 |

3.3. Productivity of crop rotations
As a result of the use of the adaptive landscape territory of the slope organization and the reduction of soil washout, fertility was stabilized and this was reflected in the productivity of crop rotations. The yield of different crops was different. To bring the results to comparable values of the yield of grain and by-products, all values were translated using coefficients in grain units (table 4).

As a result of the conducted studies, it was found that the productivity of crop rotation with a 20% field of clean fallow (2.57-3.82 t/ha, grain units) is inferior in productivity to other crop rotations by 5-28%. As noted above, this rotation is most susceptible to erosion, but in dry years, clean fallow is able to accumulate a significant amount of moisture. To obtain high-quality grain, one must have a sufficient supply of moisture and nutrients. Clean steam meets these conditions. In the zone of insufficient moisture, to which Rostov Oblast belongs, it is always possible to get a good harvest in the fields of clean steam even under adverse weather conditions. Fields sown with row crops, as well as clean fallow, are prone to erosion processes, but these products are in demand on the market. With the
reliable protection of these fields on an erosion-dangerous slope, it is possible to obtain a harvest without affecting soil fertility.

| Crop rotation | Tillage | Fertilizer application rate |
|---------------|---------|-----------------------------|
|               | «0»     | «1»                         | «2»                        |
| A             | Chisel  | 2.68                        | 3.09                       | 3.82                      |
|               | Dump    | 2.57                        | 2.94                       | 3.71                      |
| B             | Chisel  | 2.96                        | 3.72                       | 4.05                      |
|               | Dump    | 2.85                        | 3.64                       | 3.91                      |
| C             | Chisel  | 3.15                        | 3.89                       | 4.33                      |
|               | Dump    | 3.05                        | 3.78                       | 4.22                      |

Higher productivity was noted in the "C" crop rotation (3.05-4.33 t/ha, grain units) with an increased share of perennials. Crop rotation "B" with an optimal ratio of perennial grasses (20%) and clean fallow (10%) (2.96-4.05 t/ha grain units) occupied an intermediate position in productivity. In crop rotation "B", the presence of 10% of clean steam is capable of accumulating moisture, and perennial grasses are the main fodder crop for animal breeding. They are also of great importance for preventing the development of erosion processes. However, no less important is the significance of perennial grasses in increasing soil fertility and ensuring a deficit-free balance of organic matter in the soil.

The improvement of the nutrient regime of the soil due to the introduction of organic and mineral fertilizers allows you to get additional products. The introduction of organic fertilizers with a rate of 100 kg of active ingredient per 1 hectare of crop rotation area increases productivity in crop rotation from 20% of clean fallow to 14-15% compared to the option of natural fertility. In a crop rotation with 20% of perennial grasses with the same rate, productivity increases by 25-27%, and in a crop rotation with 40% of perennial grasses – by 23-24%. A 1.5-fold increase in the rate of fertilization increases productivity in crop rotation "A" by 42-44%, in crop rotation "B" by 36-37% and in crop rotation "C" by 37-38%. In a crop rotation with a 20% field of clean fallow, in the presence of soil washout of 7.1-8.2 t/ha, the fertile soil layer is washed away with the nutrients. The introduction of increased doses of fertilizers allows you to get additional products in the form of an increase in yield. Since the soil fertility is low in the crop rotation with 20% of clean steam, the productivity in the natural fertility option is lower by 10-11% than in the B crop rotation and lower by 17-18% than in the C crop rotation. The optimal structure in combination with the rational design of crop rotations, a system of tillage and fertilization provides a high yield of agricultural products per unit area, creates conditions for the restoration of soil fertility, preventing the possibility of environmental complications.

4. Conclusion
The use of adaptive-landscape territory organization of the slope prone to erosion allowed reducing soil erosion by 35-43%. The use of soil protection treatments as the main tillage reduced soil erosion by more than 13-24%. Soil-protective crop rotations of various parameters, depending on the degree of the slope in the adaptive-landscape system of the agriculture, allow soil fertility to be preserved, and, in some areas, restored. For this, it is provided:

- on lands not affected by water and wind erosion, located on a watershed and very gentle slopes up to 1°, crop rotation with 20% pure steam, 20% row crops, and 60% of winter and spring grain crops is recommended. Crop rotation productivity is up to 3.8 t/ha of grain units when applying manure in a dose of 8 tons and mineral fertilizers, N84P30K48.
• on lands prone to erosion with degree of the slopes from 1 to 2°, crop rotation with 10% of pure steam, 10% of leguminous crops, 20% of row crops, and 40% of winter and spring grain crops, and 20% of perennial grasses is recommended. Productivity is up to 4.0 t/ha of grain units when applying manure in a dose of 8 tons and mineral fertilizers, N₆₆P₃₀K₃₈.

• on arable lands prone to erosion and poorly eroded soils on slopes with a degree of the slope from 2 to 3°, an extended complex of agrotechnical measures is applied. Crop rotation with 40% of perennial grasses, 20% of row crops and 40% of winter and spring grain crops is recommended. Productivity is up to 3.9 t/ha of grain units when applying manure in a dose of 5 tons and mineral fertilizers, N₆₆P₃₀K₃₀, ensuring the preservation of soil fertility at the initial level. With a 1.5-fold increase in organic fertilizers (manure at a dose of 8 tons and mineral fertilizers, N₆₆P₃₀K₃₈), productivity increases to 4.3 t/ha of grain units, and humus content increases to 4.1% (or 7.8%).

• on lands prone to erosion, poorly or moderately eroded soils on slopes with degree from 3 to 5°, it is possible to use crop rotation with a predominance of close-growing crops or perennial grasses as a forage base for animal husbandry.

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