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Biological reclamation of disturbed agricultural lands in the Volgograd Trans-Volga region

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ABSTRACT

Earthworks, such as mining, construction, laying pipes for various purposes and other activities, result in the loss of ecological systems, particularly soil cover integrity. Land reclamation allows for the establishment of a fertile soil layer, soil structure, and the accumulation of humus and other nutrients up to the level of fertility that existed before the violation. The article presents a comparative analysis of the main indicators of soil fertility of agricultural lands (pasture, hayfield, arable land) in its natural state and in the disturbed one caused by the overhaul of the main gas pipeline. The purpose of the research conducted in 2020 was in the dry-steppe zone of chestnut soils of the Volgograd region to analyze the indicators of fertility of agricultural lands that are in their natural state and subject to reclamation with an estimation of restoration costs. To characterize the level of soil fertility, the main indicators of fertility have been considered: particle size distribution, content of organic matter (humus), nitrogen (N), phosphorus (P), potassium (K), sulfur (S) and pH, which reliably characterized soil fertility in the given soil-climatic conditions of the dry steppe zone of the Volgograd region. As a result of the estimation, it was found that the cost of restoring 1 ha of arable land made 2607.13 euro, and the cost of restoring 1 ha of pasture (haymaking) reached 2096.62 euro.

Key words: Arable land, biological reclamation, land reclamation, pasture, soil fertility

INTRODUCTION

Dehumification is one of the most dangerous processes that have affected almost all arable lands in Russia (Sychev, 2003; Aidarov, 2012; Babayan *et al.,* 2012; Thi and Kazuto, 2022). Over the period from 1986 to the present, humus reserves in arable soil layers decreased by 12% in Russia as a whole, whereas over 100 years (from 1883 to 1983), its reserves had decreased by about 18-20% (Chekmarev, 2015; Ivanov and Durmanov, 2021). The consequences of humus processing and decrease in the content of macronutrients are manifested in deterioration of the ecological functions of soil (decrease in biodiversity and the volume of soil flora and fauna, violation of the interaction of biological and geological cycles), as well as in the deterioration of socio-economic functions of soils (decrease in productivity and stability of agricultural production) (Kiryushin and Ivanov, 2005; Kirmer *et al.,* 2012; Solovichenko *et al.,* 2018).

Restoration of the properties and fertility of soils disturbed as a result of human economic activity is possible through the formation of a deficit-free balance of fertility elements by means of the widespread use of grass-rotation and green-manure farming systems and the introduction of organic and mineral fertilizers (Groninger *et al.,* 2007; Sheudzhen and Bondareva, 2015; Praveen Saini *et al.*, 2021).

The technical stage of reclamation provides for the planning, formation of slopes, the removal and application of a fertile soil layer, the installation of hydraulic engineering and reclamation facilities, the burial of toxic over-burden, as well as other works that create the necessary conditions for the further use of reclaimed land for its intended purpose or for the measures aimed at restoration of soil fertility (the biological stage). The biological stage of reclamation includes a complex of agrotechnical and phytomeliorative measures aimed at improving the agrophysical, agrochemical, bio-chemical and other properties of the soil (Webber, 2008; Motorina *et al.,* 2009; Pansiu and Goteru, 2014; Laarmann *et al.,* 2015; Ashraf *et al,* 2019; Uke and Haliru, 2021).

The costs of reclamation at the biological stage include the costs of restoring the fertility of recultivated lands transferred for agricultural, forestry and other use (the cost of seeds, fertilizers and meliorants, fertilization, melioration, etc.) (Bessonova, 2011).

To calculate the costs of reclamation, it is necessary to consider the suitability indicators of the disturbed fertile soil layer and the criteria for reducing soil fertility.

According to Decree of the Government of the Russian Federation No. 612 of 22 July 2011 "On approval of criteria for a significant decrease in the fertility of agricultural land" (hereinafter – Decree No. 612), the most important criteria for a significant decrease in the fertility of agricultural land include the content of organic matter in the arable horizon (humus), alkalinity (pH), the content of mobile phosphorus (P), the content of exchangeable potassium (K).

Thus, the biological reclamation requires the formation of a fertile soil layer, soil structuring, accumulation of humus and other nutrients in order to bring the fertility level of the disturbed land plot to the initial level of fertility that existed before its violation (Buyankin *et al.,* 2019).

MATERIALS AND METHODS

Studies were carried out in the conditions of the dry steppe zone of the Volgograd region at 2020 at the Federal Scientific Center for Agroecology of the Russian Academy of Sciences (FSC of Agroecology RAS).

The research was carried out in the agricultural land of the Pallasovsky district of the Volgograd region (Fig. 1). The coordinates of the selection site: N 49°59'20,3"; E 46°58'47,1", the height at the selection point is 36 m, the accuracy of the coordinates is 3 m. The research object is represented with a field plot where the soil horizon was disturbed

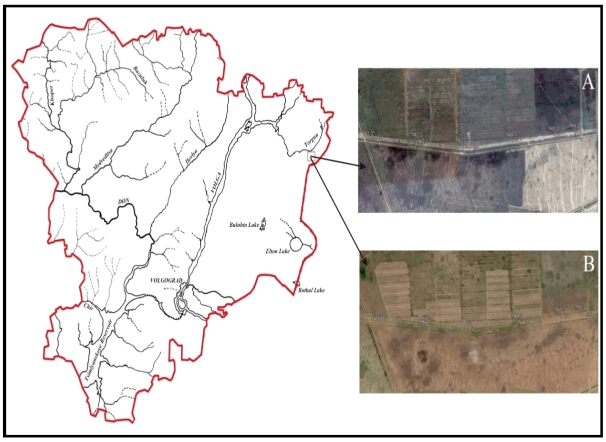

Fig. 1. Location scheme of the sampling points along the route of the disturbed land plot (a fragment of the satellite image to the state of the terrain: A - On 11 August 2016, B - On 23 June 2020).

as a result of the overhaul of the main gas pipeline.

According to natural and agricultural zoning, the object under study is in the dry-steppe zone of chestnut soils of the Volgograd region. In terms of the agro-climatic zoning of the Volgograd region, the territory of the land plot belongs to a sharply arid agro-climatic region, to a sharply arid warm area. The hydrothermal coefficient is equal to 0.65-0.55. The sum of positive air temperatures is 3000°; precipitation is 175-200 mm; average January temperatures range from -11°C to -12°C; average July temperatures range from + 22°C to +23°C. The frost-free period lasts from 148 to 160 days (Brylev *et al.,* 2011; Sazhin *et al.,* 2017).

Chestnut heavy loamy soils developed on syrt deposits predominate in the soil cover on the land plot under study.

The humus content of chestnut soils in the arable horizon with a thickness of 0-25 cm varied from 2.4 to 2.0%. The mobile forms of phosphorus and exchangeable potassium varied significantly. The average value of easily digestible phosphorus was 1.4-1.2 mg/ 100 g of soil, which indicated a weak degree of saturation. The average content of exchangeable potassium was 19.5-28.9 mg/ 100 g of soil i. e. the degree of saturation was from medium to high.

To characterize the level of soil fertility on a land plot with an area of 21,8681 hectares, we considered the main soil fertility indicators: particle size distribution, organic matter content (humus), nitrogen (N), phosphorus (P), potassium (K), sulfur (S) and pH, which reliably characterized soil fertility in the given soil-climatic conditions of the dry-steppe zone of the Volgograd region.

To assess the level of soil fertility on a disturbed land plot, a field selection of soil samples was carried out from the plot itself and from its undisturbed part. The comparative analysis of soil indicators was conducted in laboratory conditions. Soil samples were selected according to the requirements of GOST R 58595-2019 (Soils sampling) and methodological guidelines for the comprehensive monitoring of soil fertility of agricultural lands (2003), approved by the Ministry of Agriculture of the Russian Federation.

Field sampling of soil samples was carried out on 22 July 2020 in clear weather at a temperature of 24.7^0 C. Six soil samples were taken from the disturbed land plot and from the undisturbed land plot located at 50-65 m from the route of the disturbed plot. The latter samples served as a control variant during the comparative analysis of soil indicators. A description of their current state as of the date of the survey was carried out.

Soil samples were taken at the depth of the arable layer – 0-30 cm. The length of the route of the disturbed plot made 4110 m, and the distance between the sampling points in the longitudinal direction was 900 m. Fig. 1 shows the space diagram of the route of soil sampling on the disturbed land plot and on its undisturbed part.

RESULTS AND DISCUSSION

Assessment of Soil Fertility

To establish the current level of soil fertility according to the above indicators, we carried out analysis by comparing soil samples from the disturbed and undisturbed parts of the land plot. Table 1 shows the results of tests of soil indicators of the investigated land plot.

Thus, the comparative analysis of soil samples showed that along the gas pipeline route, where the soil profile was violated due to the overhaul, soil fertility indicators had values lower than in the adjacent territory with an undisturbed soil profile. The content of organic matter in almost all sites of soil sampling was reduced by 14-58.7%, alkaline hydrolysable nitrogen – by 7.4-73.8%, mobile phosphorus – by 5.7-82.2%, exchangeable potassium – by 10.9-59.2%. The hydrogen indices in soil samples from the disturbed land

Table 1. Indicators of soil fertility of the studied territory.

S. No.	No. of soil sampling points	Type of use	Indicators of soil fertility						
			Particle size distribution (phys. clay) (%)	Humus (%)	N (mg/kg)	P (mg/kg)	K (mg/kg)	S (mg/kg)	pH
1.	1.1	Pasture	47.49	2.62	43.4	43.3	760	4.3	8.53
2.	1.2	Pasture	48.0	3.05	65.8	45.9	1020	3.05	7.65
3.	2.1	Hayfield	48.52	1.42	15.4	17.4	441	835	8.18
4.	2.2	Hayfield	48.0	3.44	58.8	97.7	1080	7.0	8.4
5.	3.1	Hayfield	49.04	2.36	40.6	32.4	670	5.6	8.5
6.	3.2	Hayfield	48.52	3.4	61.6	54.4	848	4.3	7.85
7.	4.1	Hayfield	48.52	2.7	43.4	66.0	722	5.6	8.46
8.	4.2	Hayfield	50.07	3.64	71.4	140.0	100.4	3.7	7.96
9.	5.1	Uncultivated arable Covered with grass vegetation	51.36	2.4	35.0	49.5	720	62.0	8.44
10.	5.2	Fallow arable	50.59	2.34	37.8	88.0	808	6.2	8.22
11.	6.1	Uncultivated arable covered with grass vegetation	52.39	1.97	26.6	35.1	600	148	8.33
12.	6.2	Fallow arable	52.65	2.89	54.6	71.7	904	4.4	7.65

plot, on the contrary, increased by 2.6-11.5% relative to the samples from the undisturbed part. The sulfur content in all samples from the disturbed land plot had high values ranging from 6.3% to 119 times. The highest percentage of reduction in soil indicators was recorded on a soil sample from disturbed land plot No. 2.1.

A significant decrease in soil fertility as a result of changes in the numerical values of three criteria was observed only in two soil samples – No. 2.1 and No. 6.1. In the remaining four samples, a change in the numerical values of three criteria was not established.

Based on the above, restoration of the violated soil fertility to the initial level required carrying out biological reclamation.

Cost Estimation

The costs of reclamation included the costs of restoring the fertility of reclaimed lands transferred to agricultural use (the cost of seeds, fertilizers and meliorants, fertilization and melioration, etc.).

Based on the agricultural use of the land plot under study, it consisted of the pasture (hayfield) and the arable land. The total area of the land plot was 21.8681 ha. The area of the pasture (17.8010 ha) and the area of the arable land (4.0671 ha) were calculated based on a satellite image downloaded from the Google Earth electronic globe according to the state of the terrain on 14 August 2019 (Table 2).

Such a division was necessary, since the biological reclamation of arable land and pastures (hayfields) required the use of different technologies (Table 3). Restoration of disturbed plots of arable land was carried out according to the green fallow system. Green fallow was a cropped fallow, where legumes were sown for green fertilization. Fallows were sown in the first year of the reclamation period, and in the second year they were embedded in the soil. In the areas being restored for pastures, grassing with perennial grasses was carried out.

According to the requirements of biological reclamation, the term of the biological stage of reclamation (reclamation period) for arable land was two years, and for pastures – 3 years.

Based on the analysis of soil indicators and recommendations for the application of organic fertilizers in the dry-steppe zone of chestnut soils of the Volgograd Trans-Volga region, the doses of mineral fertilizers were calculated depending on the active ingredients. The results were the following: N

Table 2. Reclamation technology for arable land

S. No.	Technological procedure	Unit of measurement	Amount
	First year of reclamation period		
1.	Application of organic fertilizers (manure) with mechanized loading, with spreading	t/ha	80
2.	Plowing the soil to a depth of 30 cm	ha	4.0671
3.	Snow retention and mechanized snow rolling	ha	4.0671
4.	Harrowing in two directions to close the moisture	ha	4.0671
5.	Application of mineral fertilizers: - ammonium nitrate - double superphosphate - potassium	kg/ha	205 68 36
6.	Single-cut harrowing for soil fertilizing, loosening and mixing	ha	4.0671
7.	Pre-sowing cultivation	ha	4.0671
8.	Rolling up the plot before sowing	ha	4.0671
9.	Sowing grasses (alfalfa)	kg/ha	27
10.	Rolling up the plot after sowing	ha	4.0671
	Second year of reclamation period		
11.	Snow retention and mechanized snow rolling	ha	4.0671
12.	Disk plowing (cutting of soil formation)	ha	4.0671
13.	Tillage of green manure	ha	4.0671

Table 3. Reclamation technology for pastures (hayfields)

S. No.	Technological procedure	Unit of measurement	Amount
	First year of reclamation period		
1.	Application of organic fertilizers (manure) with mechanized loading, with spreading	t/ha	60
2.	Plowing the soil to a depth of 30 cm	ha	17.8010
3.	Snow retention and mechanized snow rolling	ha	17.8010
4.	Harrowing in two directions to close the moisture	ha	17.8010
5.	Application of mineral fertilizers:	kg/ha	205
	- Ammonium nitrate		68
	- Double superphosphate		36
	- potassium		
6.	Single-cut harrowing for soil fertilizing, loosening and mixing	ha	17.8010
7.	Pre-sowing cultivation	ha	17.8010
8.	Rolling up the plot before sowing	ha	17.8010
9.	Sowing grasses:	kg/ha	8
	- Alfalfa		10
	- Wheatgrass		10
	- Awnless brome		
10.	Rolling up the plot after sowing	ha	17.8010
	Second year of reclamation period		
11.	Snow retention and mechanized snow rolling	ha	17.8010
12.	Complementary sowing:	kg/ha	4
	- Alfalfa		5
	- Wheatgrass		5
	- Awnless brome		
	Third year of reclamation period		
13.	Snow retention and mechanized snow rolling	ha	17.8010

– 70 kg AD/ha, P – 31.2 kg AD/ha and K – 18 kg AD/ha (Samsonova, 2014).

Based on soil and climatic conditions, recommendations for the application of organic fertilizers in arid conditions, and the actual content of organic matter, and considering the requirements of biological reclamation, the norms for the application of organic fertilizers made 80 t/ha of cattle manure for arable land, and 60 t/ha of cattle manure for pasture.

Since the effectiveness of organic fertilizers decreased in the arid zone due to low soil moisture, the application of organic fertilizers was carried out in the autumn period for plowing during the first year of the reclamation period. Spreading that provided uniform distribution of organic fertilizer on the soil surface was the best method of fertilization.

The choice of grass mixture for grassing and fallow species was based on the soil conditions and the species composition of the natural pastures in the adjacent territory. Alfalfa with a seeding rate of 27 kg/ha was selected as a fallow species. The grass mixture included alfalfa and cereals – wheat grass and rump with a ratio of grasses: alfalfa – 8 kg/ha, wheatgrass – 10 kg/ha and awnless brome – 10 kg/ha. In the second year of biological reclamation, it was necessary to resow the half-norm grass mixture.

When estimating the costs of biological reclamation, the following conditions were considered:

1. The transportation of organic fertilizers was carried out from nearby livestock farms or private farmsteads, which were located at 30 km;
2. The doses of mineral fertilizers were calculated based on the planned yield of winter wheat of 4 t/ha;
3. The following mineral fertilizers were used: ammonium nitrate (34% AD) as nitrogen fertilizer; double superphosphate (46% AD) as phosphorus fertilizer; potassium sulfate (50% AD) as potassium fertilizer.

Tables 2 and 3 present the technologies for reclamation of the disturbed areas of arable land and pasture (hayfield).

The calculation of the costs of biological reclamation was made for the first quarter of 2022 at the euro exchange rate based on prices according to the Territorial Costing Standards of the Volgograd region – TES 2001. Volgograd region. Part 47 "Landscaping. Protective plantings". The cost of organic and mineral fertilizers, as well as seeds, was determined as of the first quarter of 2022, taking into account the inflation coefficient.

The cost of restoring an arable land plot with an area of 4.0671 ha was equal to 2607.13 × 4.0671 = 10603.46 euro. The cost of restoring a pasture (hayfield) plot with an area of 17.8010 ha was equal to 2096.62 × 17,8010 = 37321.93 euro.

Thus, the total cost of biological reclamation of the land plot based on its total area of 21.8681 ha amounted to 47925.39 euro.

CONCLUSION

As a result of the study of a land plot with an area of 21.8681 ha, it was found that the indicators of soil fertility along the gas pipeline route had values lower than in the adjacent territory with an undisturbed soil profile. Based on the soil and climatic conditions, the analysis of the actual values of soil indicators, the science-based recommendations for the application of organic and mineral fertilizers for the dry-steppe zone of chestnut soils of the Volgograd Trans-Volga region, which included the territory of the land plot under study, we had calculated the costs of biological reclamation of this land plot. The total cost of biological reclamation of this land plot based on its total area of 21.8681 ha in prices for the first quarter of 2022 amounted to 47925.39 euro. The results of the research will be used in the formation of systems of zonal standards for basic soil fertility in the reclamation of disturbed lands.

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