Agroecological assessment of the effectiveness of different systems of soil protection measures in the reproduction of fertility of slope gray forest soils

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Abstract. The increasing anthropogenic impact on the slopes, the involvement of new slope lands in the production sphere require reliable substantiation of their erosion resistance. The study of the effectiveness of the influence of the contour-band organization of the territory and various doses of fertilizers on the intensity of rain and snowmelt runoff, the composition and properties of flat gray forest soils was the main goal of our study. The object of the study was a plot of gray forest middle loamy soils located on the slopes of the western exposure, in 12 soil sections. The article presents a study of the influence of the contour-band structure of plots using cattle droppings and top dressing on the fertile properties of gray forest soils. We used standard research methods to determine the amount of humus and determine the aggregate properties of the soil, as well as to determine the properties of the solid phase of the soil density. We established the level of impact of the forest belt organized in the study area, while taking into account that we applied top dressing on the study area, which affects the nominal influence of factors that led to an increase in the environmental stability of the studied soils. It is proved that runoff-regulating contour forest belts provide optimization of density and increase in soil porosity, improve water-air regime, activate living organisms of agrobiocenosis, increase the thickness of the humus layer, content and reserves of humus in the soil up to 3,6% and 130,7 t/ha depending on its location on the slope. It is established that the use of fertilizers as top dressing on the studied destroyed soils significantly increases the yield of plant crops, as well as increases their environmental sustainability. The study of slopes from
the standpoint of assessing, analyzing, and predicting their erosion resistance is an important direction of soil protection agriculture and in solving the food insecurity in Russia. Due to the intensive reduction of the area of agricultural land, the decrease in soil fertility, the problem of anti-erosion protection of land requires an immediate solution.

1. Introduction
The degree of manifestation of the destruction of the soil cover and the damage caused as a result of economic activity of the population is very high. To restore the destroyed soils, significant changes in the rules of nature management and environmental protection measures are required [1-13]. Scientists have established a significant degree of dynamics of the level of fertility of slope soils and morphogenetic characteristics of agricultural soils, which makes it necessary to develop and justify effective soil protection measures in these territories, which should be aimed at restoring the ecological properties of eroded soils [13-14]. It is known that under the conditions of increasing anthropogenic pollution of soils and landscapes, the function of soil resistance to pollution and its ability to self-purification [12; 15] acquires great importance. Globally, there is a problem in that current land-use practices have adverse effects on soil cover [12; 15].

The aim of our research was to study the influence of an organized forest strip on the study area at different doses of top dressing on the ecological properties of gray forest soils [1; 9;11]. Russia has been experiencing significant changes in land use in recent decades due to the increased demand for agricultural products [13]. This causes multiple changes, which can manifest themselves in a decrease in the ecological properties of the soil, leading to a deterioration in soil quality and a continued decrease in productivity [14]. Soil quality plays an important role for the air-water balance and the formation of the composition of natural waters, as precipitation, in contact with the soil surface, penetrates deep into the soil, then enters into chemical reactions with the mineral and organic components of the soil, soil animals, microorganisms and plant root systems [3; 6]. As a result of these reactions, the atmospheric moisture entering the soil forms the soil solution and groundwater, enriching with mineral and organic substances [7-11]. Indirectly, this reduces the negative impact on the external environment of enterprises that produce components for energy [4]. The method of application in the activated sludge process is the most frequently used biological technology for wastewater treatment [2; 4-7]. There is also the problem of removing non-ferrous and heavy metals from wastewater as a result of anthropogenic impact on the soil cover [2; 8; 10].

The transformation of soil organic matter in cultivated soils leads to soil degradation and, ultimately, to the impossibility of ensuring sustainable agricultural production if restoration measures are not carried out [15].

It is known that ecosystems of river basins located in different climatic zones respond ambiguously to climate change [13]. The data obtained by the scientists make it possible to predict the dynamics of the soil-productive potential under conditions of changing climatic characteristics, such as temperature and precipitation [14]. Data on the density of soil particles are of great importance in conducting soil research, since it is necessary to assess the harmful effects on the soil cover, the rate of deposition of particles, relative saturation, thermal conductivity, heat capacity, and volumetric ratios of water and air [15].

Our research includes the study of both water and chemical processes in soil samples [13-14]. Soils are also formed in floodplains and river deltas when flood waters flood and create new layers of alluvium of different granulometric and chemical composition [3; 12]. The soil cover of floodplains varies in composition and properties, depending not only on their geographical location, but also on the location of different areas relative to the location of reservoirs [1-2; 5-6].

2. Materials and methods
Our research was conducted from 2014 to 2018 on the territory located in Russia in the Orel region in the Novosilsky district, which have the following geographical coordinates 53.057237, 37.184836. In order to study the influence of forest belts on the fertile properties of gray forest soils located on the
slopes of land plots, and on the yield of plant crops, we selected for observation two land plots located in the protected areas of stands of oak petiolate, created in 1926. The studied soils are characterized by gray forest, ordinary, medium-heavy, medium-loamy on podzolized loess-like loams (Albic LUVISOLS), have the following morphological structure of the soil section: O - forest litter 0-4 cm thick; humus-accumulative horizon A, gray, lumpy-powdery, 36 cm thick; humus-eluvial horizon AEL, whitish-gray, 15-18 cm thick, nutty-lumpy structure, with the presence of a whitish powder; transitional horizon ELBT brown, dark brown, 10-15 cm thick, nut structure, with a light whitish powder; brown illuvial textural horizon Bt, walnut-prismatic structure, compacted, presence of humus-clayey films with a gradual transition to the parent rock, differing in different degrees of erosion in different parts of the slope of the soil. The study was carried out by the method of water balance using wastewater. The operations were organized in territories that are over 1000 years old. In our scientific experiments, we carried out: surveys, meteorological observations, as well as the determination of the depth of freezing, when taking into account the distribution of water in the soil, also took into account the flow of meltwater, soil washing and yield. We determined the snow density at each runoff site using the VS-43 weight snow meter. The water reserves in the snow were determined by the formula $Q = H \cdot d$, where $H$ - means the height of the snow cover, cm; $d$ - snow density, $g / cm^3$.

On the selected areas of slope lands, 6 soil sections were laid, characterizing the composition and properties of gray forest soils. On the soil slopes with the placement of protective plantings along the contour, we laid three soil plots:

- Land plot №1 on the watershed - $A_{p16}$ 0 $A_{16}$ 16 36 - AEL 36 50 - ELBT 50 63 - Bt 63 82 - BtC 82 112 - C 112 14;
- Land plot №2 in the middle part of the soil slope - $A_{p17}$ 0 $A_{17}$ 29 - AEL 29 46 - ELBT 46 75 - Bt 75 88 - BtC 88 108 - C 108 14;
- Land plot №3 in the lower part of the soil slope - $A_{p14}$ 0 $A_{14}$ 32 - AEL 32 60 - ELBT 60 75 - Bt 75 99 - BtC 99 133 - C 133 14.

It was necessary to determine the intensity of soil erosion on the soil slopes, unprotected by forest protection strips, on three soil plots, where everything is laid at all levels of the slopes:

- On the watershed soil section № 4 $A_{p22}$ 0 $A_{1}$ 22 - AEL 22 32 - ELBT 32 62 - Bt 62 87 - BtC 87 14;
- Land plot №5 in the middle part of the soil slope $A_{p15}$ 0 $A_{1}$ 15 - AEL 15 30 - ELBT 30 45 - Bt 45 58 - BtC 58 70 - BtC 70 14;
- Land plot № 6 in the lower part of the soil slope $A_{p12}$ 0 $A_{1}$ 12 - AEL 12 24 - ELBT 24 45 - Bt 45 62 - BtC 62 83 - BtC 83 100 - C 100 14.

We took soil samples from each soil layer of the profile. We studied the effect of top dressing (NPK) on the productivity of plant crops. We conducted research in the field of crop rotation, where the following crops were alternated, such as barley - oats - barley-vetch-oats, in order to further scientifically substantiate the system of top dressing to preserve and increase the fertility of eroded soils. The selected soil samples were analyzed according to the method of I.V. Tyurin edited by V. Simakov; Cumulative soil analysis was performed according to N.I. Savvinov during dry sifting of soils; The density of the solid phase of soils was determined by the pycnometric method. The following fertilizers were used: mixed compost on straw bedding, semi-dry, with a dry organic matter content of 21%, humidity - 75%, nitrogen content - 0.5%, phosphorus content - 0.25%, potassium content - 0.6%; mineral fertilizers were introduced: the amount of ammonium nitrate (34%), the proportion of potassium chloride (60%), the proportion of double superphosphate (39%).

3. Results and Discussion

The influence of distribution along the contour of forest plantations on slope soils in the study area shows that the absence of a protective forest will lead to a decrease in water reserves in the soil, which leads to a decrease in the quality of plant crops [5; 7].
Thus, the soil of the slopes where there is a forest is protective, there is an increase in the thickness of the upper soil layer, since there is more water in the upper soil layer of the slopes, which is located in the upper and middle parts of the observed soil slopes.

The largest supply of productive moisture in the soil layer located in the lower part of the control sample of the slope is due to the accumulation of additional water from the upper part of the soil horizon on the slope. The volume of effective water in the soil layer (1 meter) on the soil slope in the conditions of the arrangement of plantings along the contour is the largest in the range from 188.7 mm to 211.6 mm, while water is distributed more evenly over the entire soil slope (table 1).

It also plays an important role in soil fertility and density. It is not only the density of the upper arable layer of the soil and the subsurface soil layer, as this determines the permeability soils and the depth of germination of plant roots [4; 9].

| Table 1. Indicators of soil density and porosity in the solid phase. |
|---------------------------------------------------------------|
| Density of the soil phase of the soil, g/cm³ | Soil density, g/cm³ | Total soil porosity, % | Number of soil particles <0.001 mm, % | Density of the solid phase of the soil, g/cm³ | The density of the soil, g/cm³ | Soil porosity, % | Amount of soil particles <0.001 mm, % |
| Top of soil slope | 2.5 | 1.2 | 53 | 21 | 2.6 | 1.2 | 52 | 17 |
| Middle part of the soil slope | 2.6 | 1.2 | 49 | 23 | 2.5 | 1.3 | 53 | 13 |
| Lower part of the soil slope | 2.5 | 1.2 | 49 | 25 | 2.5 | 1.3 | 51 | 22 |

The increased density of the soil leads to a decrease in its porosity, for example, if in the gray forest soil on soil slope with a protective forest soil porosity was established in the range of 53% -51%, in the soil slope without shelterbelts soil porosity is reduced to 52-49%. This depends on the location of the observed sites on the soil slopes, as well as on the middle and lower levels of the soil slope. Thus, we estimated the amount of soil porosity as unsatisfactory for the upper arable horizon of the soil. At the same time, it should be noted that the greatest value of soil porosity is usually promoted by the penetration of water into the soil layer, a decrease in surface drainage and an increase in the water-air regime of soils, which ultimately has a positive effect on the overall growth and development of cultivated plants.

The structural state of soils and water-resistant structural aggregates is significantly influenced by the granulometric composition of soils and the content of silt particles in them. Studies have established a change in the content of silt particles in the humus horizons of soils, depending on the intensity of erosion processes. Thus, the processes on soil slopes not protected by a contour forest belt cause an increase in the removal of small particles of silt from the soil in all parts of the slope and their regular accumulation occurs in the lower soil layer of the slopes. The presence of such protective forest belts on soil slopes with gray forest soils leads to a decrease in soil migration processes in all layers of arable soil horizons on the slopes.

Our research has proved the positive impact of the location of the forest contour strip on the study area on the factors that increase the fertility of gray forest soils, namely: forest belts are designed to optimize the density and increase soil porosity, which facilitates the penetration of natural waters into the soil, as well as improves the water-air regime in soils.

Protective stands along the contour are designed to regulate rainwater runoff, preserve the natural structure of gray forest soil, prevent erosion of soil processes, as well as create improved conditions for the vegetation process of plants and the accumulation of organic substances in the soil cover. It is
due to the impact of protective stands along the contour of the site that organic and mineral nutrients are less lost from the soil, thereby initiating the process of soil formation.

The most important characteristic of soil fertility is the formation of humus, since organic substances strongly affect the redox and toxicological regime of the soil, as well as positively affect the composition of the soil and both the water and thermal regimes of the soil.

The influence of forest belts on the formation of humus in the upper layer of the soil and in the soil section of gray forest soil indicates a positive effect of the protective forest located along the contour on the humus regime of the soil. It should be added that due to the influence of protective forests on the state of the soil layer, organic substances are better preserved in the upper layer of the soil. For example, the amount of humus formed in the upper layer of gray forest soils on the slopes on which the forest belt is distributed is set from 3% to 4%, and in the upper and middle parts of the slopes, the humus content in the soil is 3.5% -4.0%, as evidenced by the stability of the amount of humus in the soils of the slopes in the most devastated parts of the slope.

4. Conclusion
Thus, our research has established a high influence of factors that increase the fertile properties and environmental stability of soils in the territory with the placement of forest stands, which are regulators of water flow and mineral fertilizers, gray forest soils:

Water-regulating forest belts contribute to the optimization of soil density, thereby increasing the porosity of the soil, also contributes to the penetration of water flows and the accumulation of water in soils, has a positive effect on the agrobiocenosis.

On the soil slope when placing forest strips in the soil upper layer, we found an increased amount of formed humus, which was evenly distributed over the entire soil slope and ranged from 3.5% humus to 4% humus.

In the lower parts of the soil slopes, special differences were observed in the amount of humus in the upper soil layer both in the area with the location of protective forest belts and in the area without the location of protective forest belts; the amount of humus in the layer decreased slightly and ranged from 3.2% to 3.4%.

The high efficiency of the action of increasing doses of organic fertilizers on the productive capacity of eroded gray forest soils and the responsiveness of crop rotation crops has been proved.

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