The erosion control role of linear boundaries on a slope

Anastasia Prushchik[1*], *Vladimir* Vytovtov[1], *Yulija* Rubanik[1], and *Sergey* Boev[2]

[1]FSBSI "Federal Agricultural Kursk Research Center", 70b, Karl Marx St., Kursk, 305021, Russia
[2]Southwest State University, 94, 50 Let Oktyabrya street, Kursk, 305040, Russia

Abstract. The paper presents an assessment of soil protection from erosion by forest strips on the experimental fields of the scientific unit of the Federal State Budgetary Institution "Kursk FARC" (Medvensky district, Kursk region). The soil is leached chernozem (Chernozems leached), medium-thick, heavy loam on loess-like loams, slightly eroded. Poplar forest strips located in the lower part of the slopes of northern exposure, at the transition of slopes 3–4^0, were chosen as anti-erosion linear boundaries. To determine the soil absorption capacity, the method of sprinkling drainage areas was used. When carrying out sprinkling, forest litter was removed from the soil surface. The steady-state rate of soil absorption under field conditions was obtained to be the same within the error and amounted to, on average, 0.34±0.02 mm/min. The steady-state rate of absorption in a forest belt of twenty years of age is higher by 75.0% than in the field and by 15.1% than in a poplar forest belt with a tree stand of 40 years of age. The anti-erosion complex fulfills the task of strengthening the soil-protective role of the farming system.

1 Introduction

Erosion is the cause of irreversible loss of 23 billion tons of soil annually [1, 2]. Soil formation processes cannot restore the lost layer of soil during the time during which it was washed away. Therefore, erosion losses are considered non-renewable [3, 4].

To solve the problem of protecting soils from degradation, an adaptive landscape approach to the farming system is necessary. The main element of which is the soil-protective organization of agriculture and the creation of an agroforestry ecological framework. Planting water-regulating forest strips allows you to adjust snow distribution, reduce the runoff of melt and rainwater, and significantly reduce or completely eliminate soil loss [5]. These results are achieved by dividing the slope into short sections, reducing the speed of flowing water. The use of simple hydraulic structures, for example, the arrangement of trenches between the rows of a forest belt and a bank along the lower edge, increases the volume of absorption [6].

According to the authors [2, 7], in the European part of the Russian Federation there is more liquid precipitation, and soil loss from snowmelt in recent decades has been observed to be lower than from rain erosion.

* Corresponding author: model-erosion@mail.ru

The anti-erosion role of linear boundaries depends on the condition of the soil: the content of total humus, density, soil moisture, as well as its absorption capacity. To assess the effectiveness of forest belts, it is necessary to conduct long-term field observations at permanent stationary sites, use mathematical models that allow simulating erosion processes in a specific watershed [8] or apply physical modelling that simulates rainfall.

The purpose of the research is to assess the protection of soil from erosion by forest strips on a slope by sprinkling runoff areas.

2 Materials and methods

The research was carried out on the experimental fields of the scientific unit of the Federal State Budgetary Institution "Kursk FARC" (Medvensky district, Kursk region). The soil is leached chernozem (Chernozems leached), medium-thick, heavy loam on loess-like loams, slightly eroded.

Poplar forest strips located in the lower part of the slopes of northern exposure, at the transition of slopes $3–4^0$, were chosen as anti-erosion linear boundaries [9].

The first anti-erosion line consisted of a two-row poplar forest belts of an openwork design with a simple hydraulic structure (HTS) (Fig. 1). Coordinates: Coordinates of sampling points: 51.51392, 36.03023. The tree stand is represented by black poplar (*Populus nigra* L.) and the Robusta hybrid (*Populus euramericana Robusta*). The age of the trees is 40 years. Average height is 31.7 m. Diameter is 0.39 m. Row spacing is 3 m. Forest belt width is 4.5 m. The hydraulic structure is represented by a ditch formed in the poplar row spacing and a rampart located along the lower part of the forest belt.

Fig. 1. The first anti-erosion line.

The second anti-erosion line is represented by a two-row single-species poplar forest belts - black poplar with a pyramidal crown shape (*Populus nigra* L.) of an openwork design (Fig. 2). Coordinates: 51.50479, 36.06113. The age of the trees is 20 years. Average height is 21.3 m. Diameter is 0.18 m. Row spacing is 3 m. Forest belt width is 6 m.

Fig. 2. The second anti-erosion line.

To carry out the inventory of poplar forest belts, temporary test plots were laid out (100x4.5 m and 100x6 m). The height and age of the forest stand were determined from model trees. Diameters were measured with a measuring fork at a height of 1.3 m.

To determine the soil absorption capacity, we used the method of sprinkling runoff plots, which includes similarity criteria for artificial and natural rains [10]. For this purpose, soil monoliths with a width of 0.25 m and a depth of 0.20 m were selected in the inter-row of the studied forest belts and in the adjacent field at a distance of the same tree height (30 m and 20 m). In parallel with this, soil samples were taken to determine soil moisture and density to a depth of 0.20 m.

Physical modeling of rain was carried out using a portable laboratory-field sprinkler system (RF utility model No. 184625, 11/01/2018). Rain is monodisperse with a drop diameter of 3.99 mm. The rain fall height is 1 m for all samples. Repeat three times.

During sprinkling, the intensity of rain was measured at the beginning and end of the experiment. Runoff start time. The steady-state absorption rate was determined. The temperature of air, water and soil during the experiment was 17.5 ºC.

The moisture capacity of the forest litter was determined using the Sozykin method: the undisturbed litter was carefully transferred to a 0.2 m sieve and sprinkled for 10 minutes, and then soaked for 10, 20 and 40 hours.

3 Results and discussion

In the poplar forest belt, the soil is hidden by forest litter, which has a high water-holding capacity and prevents precipitation from penetrating into the soil. When comparing the forest litter between the studied forest belts, it was found that its thickness was 0.8 times higher in the young forest belt. This is due to the fact that the trees in the young belt are more closed and the decomposition of leaf litter occurs more slowly. However, no significant difference was established between the moisture capacity of forest litter in different forest belts. To exclude the influence of litter on the experiment, it was removed from the surface of the soil of the monoliths before sprinkling.

The condition of the soil affects the speed and intensity of water absorption. The soil density in the field is significantly higher by 17.74% than in forest belts, for which it is characterized as soil rich in organic matter, freshly plowed (according to N.A. Kachinsky) (Table 1).

Table 1. Characteristics of the soil of monoliths (0–0.2 м).

Indicators	**Variants**			
	Forest belts 20 years	**Field**	**Forest belts 40 years**	**Field**
Humidity, %	24.53±0.55	18.00±0.38	18.81±3.42	19.70±0.97
Density, г/см^3	1.02±0.03	1.24±0.03	1.04±0.04	1.19±0.03
Humus content, %	6.76±0.02	5.54±0.02	6.46±0.02	5.24±0.02

The moisture content of the soil sampled under the forest belt (20 years) is higher than in the field and in the other forest belt. There was no significant difference in soil moisture between the field and the forest belt (40 years). It can be accepted that the humidity conditions, with the exception of the young forest belt, were the same within the error.

The humus content in the soil under forest belts is higher than in the soil in adjacent fields by 18.04% and 18.88%. This is explained by the annual supply of leaf litter to the soil under the forest belt.

Surface runoff during sprinkling occurred in all variants of the experiment, but, as one would expect, it reached its greatest value in the field (Table 2). The start time of runoff is the same for the three sprinkling options and differs only for monoliths selected under a forest belt with a stand of 40 years old.

Table 2. Sprinkling parameters.

Indicators	**Variants**			
	Forest belts 20 years	**Field**	**Forest belts 20 years**	**Field**
Rain intensity, mm/min	1.71±0.01	1.74±0.02	1.81±0.01	1.79±0.02
Start time of drainage, min	1	1	2.5	1
Steady absorption rate, mm/min	1.32±0.01	0.34±0.02	1.12±0.05	0.30±0.01

Despite the different intensity of sprinkling between the pairs: forest belt and adjacent field, the same trend was obtained when the value of steady-state absorption was reached.

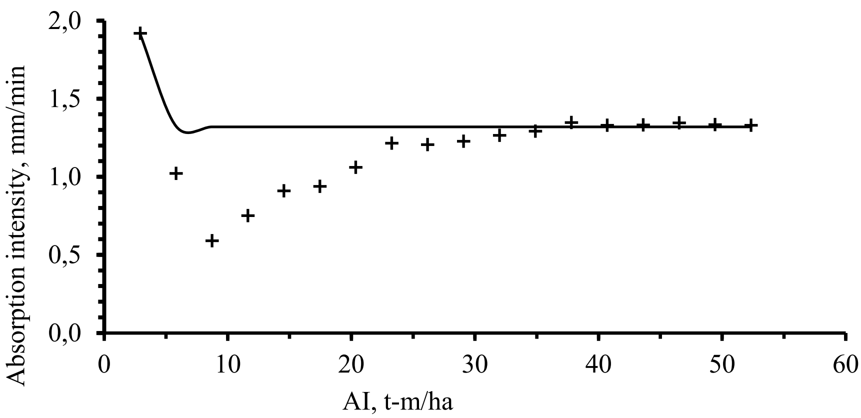

Fig. 3. Dependence of absorption intensity on the erosion index of rain in a forest belt with poplars aged 20 years (+ – measurement, solid line – calculation).

The steady-state rate of absorption under field conditions was obtained to be the same within the error and averaged 0.34±0.02 mm/min. The steady-state rate of absorption in a forest belt of twenty years of age is higher by 75.0% than in the field and by 15.1% than in a poplar forest belt with a tree stand of 40 years of age.

For monoliths selected under a forest belt (20 years), a different absorption curve was obtained, therefore, in addition to the experimental data obtained, calculations of soil absorption capacity were carried out (Fig. 3).

The characteristics of rain parameters for calculations were taken the same as during the experiment (Table 2). The curve obtained from the calculation does not have a sharp decrease in intensity in the first five minutes of sprinkling to 0.55 mm/min. The minimum calculated absorption value did not fall below 1.3 mm/min. It is important to note that according to the calculated data, the steady-state absorption intensity reliably coincided with the experimental data obtained.

4 Conclusion

As a result of the experiments, a positive effect of anti-erosion linear boundaries in the form of forest strips on the absorption capacity of the soil was established. The thickness of the litter in the young forest belt is 0.8 times greater. There was no significant difference between the moisture capacity of forest litter in different forest belts, so during the experiment it was removed from the soil surface. The density of the soil located under forest belts is 17.74% lower than in adjacent fields. The moisture content of the soil sampled under the forest belt (20 years) is 26% higher than in the field. There was no significant difference in soil moisture between the field and the forest belt (40 years). The humus content in the soil under forest belts is higher than in the soil in adjacent fields by 18.04% and 18.88%. The onset of runoff was noted after the first minute. For a 40-year-old forest belt - from 2.5 minutes. The steady-state rate of absorption under field conditions was obtained on average 0.34±0.02 mm/min. The steady-state rate of absorption in a forest belt of twenty years of age is higher by 75.0% than in the field and by 15.1% than in a poplar forest belt with a tree stand of 40 years of age.

The work was carried out within the framework of the State tasks of FSBSI «Federal Agricultural Kursk Research Center» on topic No. FGZU-2022-0002.

References

1. H.O. Shen, W.T. Zhao, Y. Zhang, D.L. Wang & L.L. Wen, Eur. Soil Sc. **53** (10), 1509 (2020)
2. V. Golosov, N. Ivanova & S. Kurbanova, Intern. J. of Sediment Research **32** (1), 60 (2017)
3. V.N. Golosov, A.L. Collins, N.G. Dobrovolskaya, O.I. Bazhenova, Yu.V Ryzhov., A.Yu Sidorchuk, Geoderma **381**, 114678 (2021)
4. P. Tsymbarovich, G. Kust, M. Kumani, V. Golosov, O. Andreeva, ISWCR **8**, 418 (2020)
5. Y.G. Chendev, V.G. Belevantsev, A.N. Gennadiev, M.A. Smirnova, S.V. Lukin, E.A. Zazdravnykh, T.J. Sauer, Eur. Soil Sci. **53**, 1033 (2020)
6. K.N. Kulik, A.R. Zubov, I.G. Zykov, A.A. Zubov, *Methodology of study of erosive processes in the agroforestry and technogenic* landscapes (EDP, Volgograd, 2018)
7. K. Maltsev, O. Yermolaev, Catena **195** (2020)
8. N. Kriuchkov, O. Makarov, Agronomy **13**, 2527 (2023)
9. A.V. Prushchik, T.Ya. Zarudnaya, V.A. Vytovtov, Zemled. **2**, 3 (2023)
10. Yu.P. Sukhanovskii, Eur. Soil Sci. **40**, 195 (2007)