Application of modern GIS technologies for inventory of protective forest strips, identification of waterlogged areas

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Abstract. Earlier there were conducted the studies of the climatic, soil, environmental and economic characteristics of natural landscapes and agricultural land in Krasnodar Territory, for example, Dinskoy district. It is located on the territory of the V-natural landscape. There were shown the results of study of the qualitative state of field-protective forest belts and their influence on the processes of expansion of land area waterlogged arable land using GIS technology as a tool of information-cartographical support of researches. The identification of forest strips in GIS was carried out, their area was determined, the types of forest strips were established, the condition and degree of damage were assessed, the area of beams whose growth is due to the violation of the natural watercourse was determined. There have been identified the areas and sites of necessary repair works and laying of new forest strips, areas and sites of field-protective forest strips that prevent natural water flow and which are planned for cutting down. The capital investments in the laying, restoration and uprooting of damaged and planned forest strips are calculated. The use of GIS technologies in the study makes it possible to increase the accuracy of the results of the assessment and forecast of the development of degradation processes, reduces the cost of research, and ensures an increase in efficiency of land use in agricultural production.

1. Introduction

The climatic, soil, environmental and economic parameters of natural landscapes and agricultural land of Krasnodar Territory were shown in previously completed studies. They were made in accordance with the methodological handbook "Agroecological assessment of lands, design of adaptive-landscape systems of agriculture and agricultural technologies", developed under the editorship of an academician of Russian Academy of Agricultural Sciences, A. L. Kiryushin [1]. The studies considered the following tasks: the boundaries of the natural and agricultural landscapes of Krasnodar Territory were clarified, there were determined the areas of land subject to degradation processes by the type and degree of their manifestation within the natural landscapes. The characteristic of the V-alluvial-loess-like plain landscape with plowed steppes is presented in table 1. Weak and medium wind erosion prevails, occupying 80.5 % of the total area of agricultural land.

The unique chernozems of the Kuban-Azov plain, when actively used in agricultural production, lose their soil fertility; during the period of intensive development of the Western Pre-Caucasian steppes, the humus content of the soils decreased by 25-30 % [2-3]. The reason is the activation of the processes of wind and water erosion in the absence of anti-erosion measures, the growth of...
anthropogenic load, which manifests itself in a high degree of plowing with an insufficient share of medium-stabilizing land, violation of the scientifically based structure of cultivated areas.

**Table 1.** Natural-climatic, soil and ecological features of the natural landscape of the V alluvial-loess-like plain landscape with plowed steppes.

| Rates                                      | Values  |
|--------------------------------------------|---------|
| Area of landscape – total, th. ha          | 460.2   |
| including agricultural areas               | 371.5   |
| Arable land                                | 350.4   |
| forest strips                              | 7.1     |
| Ratio of areas, % arable land: meadows: forests | 76:2:3 |
| Coefficient of plowing (K_p)               | 0.76    |
| Coefficient of anthropogenic load (Cal)    | 3.84    |
| Index of woodiness (I_f)                   | 0.03    |
| Humus content in the horizon A, %          | 3.8–4.2 |

**Prevailing soils**

Chernozems are typical low-humus and weak-humus heavy and powerful. meadow-chernozem compacted and merged soils

Negative processes on the agricultural area, %:

- weak and medium wing erosion: 80.5
- weak and medium water erosion and weak: 1.2
- strong water erosion: 0.7
- waterlogged arable land: 17.6

The tendency to increase the area of wetlands, which occupy 17.6 percent of the total area of agricultural land is manifested on the V-alluvial loess plain landscape site with plowed steppes. Waterlogged areas are traditionally appeared in meadow-chernozem, compacted and merged soils, and results the formation of traps and closed depressions. The beam-river network, as a component of the natural landscape, is capable of self-stabilization, which is expressed in the self-cleaning of watercourses by flood waters, but the backwater and blocking of the beam network with forest strips and roads increasingly hinder this process [2-5]. The reason of the increase in the area of existing beams and the appearance of new ones is the construction of roads in embankments, the creation of forest belts that block the natural watercourse, the use of heavy equipment, the presence of dams and ponds on steppe rivers. These factors change the hydrological regime of territories, violate the natural drainage of soil. The consequences of waterlogging are manifested in the wetting of crops, their diseases, the inability to carry out agricultural work in the optimal time, loss of structure, compaction, soil gluing reducing soil fertility.

The research was continued in order to study the qualitative state of the protected forest strips and to take into account the expansion of the area of flooded areas of beam depressions and arable land.

**2. Materials and methods**

The problems are formulated and solved on the example of the Dinskoy district, which is located on the territory of the V-alluvial-loess-like plain landscape with plowed steppes:

- To study the quality condition of protective forest strips, determine the areas of necessary repair work (logging, planting instead of lost ones, etc.), laying new forest strips;
- To study the influence of existing forest strips on the processes of expansion of the area of beams and areas of waterlogged arable land;
• To identify areas of protected forest strips that prevent natural water flow and areas that are planned for cutting down;
• To calculate the amount of capital investment in measures for care, cutting down and laying of protective forest strips.

The use of GIS technologies as a tool for information and cartographic determination of the state of field-protective forest strips and the amount increase of beams, increasing their area due to the area of arable land, is proposed.

The following data were the sources of information:

• Satellite images from interactive app Google Earth Pro 2020 (spatial dimension about 0.5 m);
• "Soil and Ecological Atlas of Krasnodar Territory" compiled by specialists of the Committee on Land Resources and Land Management of Krasnodar Territory, Kuban State Agrarian University and the Institute of Kuban Scientific Institute “GIPROZEM” in 1999;
• "Analytical note on the use and condition of land in Krasnodar Territory", developed by the FSUI “Goszemkadastrsemka” in 2008;
• Materials of geobotanical research of soils of Krasnodar Territory for different years made by specialists of Kuban Scientific Institute “GIPROZEM”.

The soil analysis was carried out, a field survey of part of the forest protective strips and part of the beam system of the Dinskoy district was conducted.

3. Results
According to satellite images 2020, high and superhigh dimension and cartographic materials of soil surveys in areas of the Dinskoy district of Krasnodar Territory there was made the evaluation of quality status and changes of protective forest plantations and beam system, there was conducted the vectorization of forest belts and beam depressions with a description of the areas of plots of forest strips, impeding natural watercourse, defined by the planned cutting down areas of forest belts and land area expansion of the beam depressions due to the flooding of plots of arable land. The identification of forest belts in GIS was performed, the categories of land occupied by the forest belts were defined, the assessment of the extent of damage was made, the type of forest belts was identified, the area of the beams was determined and its growth occurs due to a violation of a natural watercourse blocking the beam by the forest strip or road in the embankment. The formation of mounds elongated along the forest belts, which have an Aeolian origin as a result of the deposition of fine-grained soil, moved by the wind from the fields, sometimes more than a meter high, was revealed. The location of the mounds is intermittent, their presence and height are related to the nature of soil, which affects the wind speed in the surface layer. The mounds formed along the forest strips block the beam runoff, contributing to the development of local waterlogging in the adjacent fields [2-6].

The area of the studied protective forest plantations was 2698 ha. The results of the study showed that almost all plantings do not fully perform a protective role, 197.4 hectares of partially damaged protective forest strips are subject to restoration, 226.7 hectares of protective forest plantations are completely lost. Capital investments in the laying, restoration and uprooting of lost forest strips are shown in table 2.

4. Discussion
In the conditions of the Western Ciscaucasia, the main role of forest strips is to reduce the speed of winds in the eastern direction, to prevent wind erosion of the soil, especially in late winter and early spring, when the arable land is not protected by crops. The main protective forest strips are oriented perpendicular to the prevailing wind direction in the meridian direction, from north to south. The main direction of the beam-river flow in the territory of the Kuban-Azov plain is latitudinal, from east to west, from the spurs of the Stavropol upland to the Sea of Azov. At the same time, there is an
intersection of the beam system with forest strips, and the protective forest strip as an engineering structure violates the natural landscape, prevents the flow of the entire beam-river network. As a result, the surrounding area loses its natural drainage, there is a rise in ground water and waterlogging of soil horizons [5]. When crossing a forest-belt beam, there is a barrier to water flow, which leads to the expansion and increase in the area of the beams due to arable land (figure 1). It is established that 80 % of forest strips are in extremely unsatisfactory condition, do not perform protective and water-regulating functions. There is a violation of the windswept or delicate design, compaction by means of underwood. Maintenance of forest strips is carried out in insufficient volume, especially since forest strips are not the property of land users (landowners) [7].

Table 2. Technical and economic efficiency of agroforestry ameliorative works in the Dinskoy district.

| Rates | Dinskoy district |
|-------|-----------------|
| Capital investments in the laying/restoration of lost protective forest strips, thousand rubles/ha | 4793.3 |
| Laying of lost field-protective forest strips – total area, ha | 226.7 |
| capital investment, billion rubles | 1.1 |
| Restoration of field-protective forest strips – total area, ha capital investment, billion rubles | 197.4 |
| Uprooting of protective forest strips in places of “blocking” of beams | 0.9 |
| Capital investments in the uprooting of protective forest strips in places where beams are blocked, thousand rubles/ha | 406.9 |
| Total area of protected forest strips located in beams, ha | 20.6 |
| Capital investment, billion rubles | 8.4 |
| Area of sites of increased amount of beams in the expense of arable land, ha | 9.2 |
| Annual lost profit, thousand rubles | 225.8 |

Figure 1. The increase in the area of the beam as a result of blocking the beam network with a forest strip.
Protective forest plantations are polluted by waste, damaged by fires and unauthorized cutting, and by pest diseases (figure 2).

Figure 2. A sparse and partially thickened forest strip polluted with household waste.

According to our calculations, 100 hectares of arable land in Krasnodar Territory should have at least 7 – 8 hectares of protective forest plantations, only in this case the agroforestry ameliorative system will perform water-regulating and protective functions. Now in the region there are only 3.4 hectares of forest belts per 100 hectares of arable land, in the Dinskoy district – 3.6 hectares.

In accordance with Federal law No. 477-FL of 27.12.2019 “On Amendments to the Federal law” on “Land Reclamation” and certain Legislative Acts of the Russian Federation in terms of improving the legal regulation of agroforestry amelioration”, the rules of accounting and maintenance of forest plantations are established. Problematic issues of agroforestry amelioration are beginning to be resolved at the state level [8]. The implementation of works on the creation of forest belts and maintenance work in them requires significant capital investments, benefits, grants, state subsidies and programs directed to the implementation of a set of measures for protection, preservation, care and restoration [9-10].

5. Conclusion
The use of GIS technologies in scientific research allows you to:

- To improve the accuracy of the assessment result and forecast of the development of degradation processes;
- To reduce production costs for research, since the bulk of the work is performed in office conditions;
- To achieve an increase in the efficiency of land use in agricultural production.

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