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Spatial Principles of Territories Selection for Priority Development of Agroforestry Complexes

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Abstract: The creation of protective forest plantations on agricultural land is a long-term and capital-intensive investment aimed at creating sustainable agroforest landscapes. The purpose of the ongoing scientific research was to identify areas and create protective plantings, which will bring maximum effects. The methodology for achieving this goal is based on cartographic methods. Modern means of geoinformation modeling of territories and remote data make it possible to identify and follow the components of landscapes to obtain their quantitative characteristics. The result of the work carried out is a cartographic model of the study area, which allows for the analysis of the sufficiency of the number of existing forest plantations to ensure a sustainable development of the territories. The theoretical basis for determining the sufficiency of the number of forest plantations is the idea of the optimal forest cover of the territories. A review and analysis of existing points of view on the issue of optimal forest cover made it possible to identify the minimum parameters of protective forest cover. For the region of research, it is equal to 3%. The actual average value of the indicator of protective forest cover, calculated on the basis of the area of the entire study area, is 0.8%. The search for factors that determine the high efficiency of agroforestry measures made it possible to perform a differentiated assessment of the need for agroforestry measures. The ability to identify priority sites for the creation of protective forest plantations in these areas will bring maximum effects. The main principles of the search for areas of priority development are taking into account the geomorphological features of the study area, as well as the differences in the forest-growing properties of soils. The range of protective forest cover values for six geomorphologically different parts of the study area is from 0.6% to 2.7%. An analysis of the mutual arrangement of protective forest plantations and soil contours made it possible to identify the localization of spatial areas. When planning the creation of new protective forest plantations, priority is given to the most fertile lands, the indicators of protective forest cover of which are minimal.

Keywords: protective forest cover; planning for the placement of protective forest plantations; geomorphologic features of the territory; height elevation; erosion dissection; underlying rocks; forest–vegetation properties of soils

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Citation: Tubalov, A.A. Spatial Principles of Territories Selection for Priority Development of Agroforestry Complexes. *Forests* **2023**, *14*, 1225. https://doi.org/10.3390/f14061225

Academic Editors: Bo Hong, Zhe Li, Yike Hu, Liang Li and Kai Wang

Received: 11 May 2023
Revised: 8 June 2023
Accepted: 11 June 2023
Published: 13 June 2023

1. Introduction

Agroforestry is an important part of agricultural land development, which is aimed at creating sustainable landscapes [1–5]. Protective forest plantations prevent the development of water and wind degradation of the soil cover [6–13], promote the accumulation of moisture in arid regions in winter, improve the microclimate during summer months [14–16], and increase biodiversity, as well as the aesthetics of agricultural landscapes [6,7,17,18]. The economic efficiency of the completed systems of forest belts is expressed in a 10–15% increase in the yield of grain crops and a 20–25% increase in industrial crops [19–23]. The effect of protective forest plantations in dry years is more pronounced.

The extensive time horizon is one of the important distinguishing features of agroforestry [24]. Unlike chemical and water reclamation, the effects of protective forest belts do not appear immediately, but over the years, as it takes some time for trees to grow. At the same time, as a rule, the impact of protective forest belts on the surrounding landscape can be observed for decades. In many ways, the effectiveness of protective afforestation is ensured by thorough spatial planning and designing of the created systems of forest belts.

When implementing a complex, long-term, purposeful activity, the issue of ensuring its effectiveness comes to the fore [25]. In many ways, the effectiveness of protective afforestation is ensured by the thoroughness of spatial planning and design of the created systems of forest belts. The problem of finding territories for priority development is a strategic one [26]. Its solution serves to achieve the goals of sustainable development [1].

The purpose of the research is to identify territories for priority agroforestry development. The objectives of the research include the analysis of scientific sources related to the prioritization of forest reclamation works, and the approbation of the selected methodological approaches to identify the areas of priority agroforestry development in relation to the study object.

As a result of the work carried out with literary sources, three main areas of research were identified, the results of which are significant for achieving the goal set for the study. These areas are: quantitative assessment of the sufficiency of protective forest cover [27–36], taking into account the features of the territory and the allocation of the boundaries of territorial complexes [37–48], as well as the qualitative assessment of the soil cover [49–51].

The identified methodological approaches were used in relation to the research object based on the application of the QGIS and remote and cartographic data.

2. Materials and Methods

Modern cartographic methods, based on the use of remote materials and applied software packages that allow for the processing of spatial information, form the methodology for identifying the areas of higher-priority agroforestry development [52–56].

The methods used are also based on the works of the Laboratory of Geoinformation Modeling and Mapping of Agroforestry Landscapes of the Federal Scientific Center of Agroecology of the Russian Academy of Sciences [57–65]. The QGIS is the main program, which was used to create spatial models of the study area [66].

Important semantic supporting parts of the research methodology are: topographic reference of cartographic and remote materials, creation of new cartographic layers, use of measurement tools and creation of arrays of primary data characterizing the components of agricultural landscapes, calculation and analysis of specific indicators within the boundaries of the studied territorial complexes.

Binding of the materials used to geographic coordinates is the basis for conducting research using geographic information systems. These operations make it possible to use measurement tools and obtain the spatial characteristics of the studied components of agricultural landscapes.

The creation of new thematic layers makes it possible to visualize the studied components of agricultural landscape (protective forest belts, ravines, soil contours). Thanks to the tools for creating new contours, an image of the boundaries of the geomorphologic parts of the study area was obtained, as well as an image of the grouping of soils, depending on their forest growth properties.

The parameters of the area of protective forest plantations (km^2), the length of ravines (km), the number of peaks of ravines (pcs), and the area of soil contours (km^2) obtained with the help of measurement tools were correlated with the values of the areas. Specific indicators were calculated: protective forest cover (%), ravine subdivision (km/km^2), ravine subdivision (km/km^2), density of ravine tops (pcs/km^2), shares of soils of forest suitability groups (%).

The analysis of the values of specific indicators makes it possible to identify the spatial features of the studied territories.

A spatial model of protective forest plantations was created on the basis of deciphering forest belts using multi-temporal mosaics of high-resolution satellite images, which makes it possible to delineate boundaries at a 1:20,000–1:40,000 scale map. The survey was conducted from 2016–2017.

Various terms are used in the studies related to the investigation of forest cover. In this study, the parameters of the protective forest cover of the territory were determined [67]. The protective forest cover of the territory is the ratio of the area of all types of created protective forest plantations to the area of the territory under study, expressed in percentages.

The diagram of landscape–typological zoning of the Volgograd region served as the basis for developing a spatial model of landscapes of the study area [68,69]. To control the accuracy of marking of the landscape boundaries, a digital model of the relief obtained on the basis of SRTM elevation data was used. Mapping of the layer of ravines in the study area was based both on satellite images and a 1:100,000 scale topographic map.

A cartographic model of the forest conditions of the study area was built by comparing the data of a 1: 400,000 scale soil map [70], with the criteria for assessing soils according to forest conditions [50,51].

The research object is represented by agrolandscapes of the Ilovlinsky district of the Volgograd region (Figure 1). The area of the research object is 4156 km^2.

Figure 1. Location of the research object.

The natural conditions of the research object are typical for the entire dry steppe zone of the South of the Russian Federation. In accordance with the agroclimatic zoning [71], it belongs to the central steppe and southwestern steppe agroclimatic regions. Significant indicators of heat and moisture supply here are as follows: the hydrothermal coefficient is equal to 0.6–0.7; the sum of active temperatures makes 2900–3200 °C; the average temperature in July is 22.0–23.7 °C, in January—−8–−11.6 °C; the amount of precipitation during the warm period is 200–276 mm; the frost-free period is 170–175 days; and the average snow depth is 9–16 cm [72].

The soil cover is represented by soil complexes consisting mainly of Kastanozem and Phaeozem soil types. The soils are thin and formed mainly on medium and light loams. Solonetz plays a visible role in the formation of soil complexes [73].

The natural herbaceous cover consists of forb–fescue–feather grass associations. Natural tree vegetation is mainly represented by floodplain forests. Ravine forests (broad-leaved forests growing along the bottom and slopes of ravines) are few in number and mainly grow on the right bank of the Don River.

In the dry steppe zone, the lack of moisture is the main factor of productivity of cultivated agricultural plants. The territory of the Ilovlinsky district is characterized by the maximum variety of relief conditions, which is the leading factor of precipitation redistribution. Conducting research with the aim of creating sustainable agroforestry systems in changing climate conditions is in demand in this area. The results obtained can be extended to vast areas of similar landscapes.

The analysis of the protective forest cover sufficiency was carried out by comparing the protective forest cover of the studied territories with the protective forest cover of the reference area. The protective forest cover of the Kachalino experimental farm of the Federal Scientific Center of Agroecology of the Russian Academy of Sciences served as the reference area. The system of protective forest belts was created in this farm in the period from 1985–1992. The protective forest belts were laid on the basis of recommendations and standards developed at the Federal Scientific Center for Agroecology of the Russian Academy of Sciences [74,75]. The reference area is 44.6 km^2.

The analysis of numerous sources of information was an important part of our research. The methodological techniques usually applied in the processing of scientific and technical information became the basis of the 4-stage methodology used in our research. The stages include preliminary research, bibliographic analysis, analytical analysis, and synthetic analysis [76–80].

3. Results

3.1. Mapping and Assessment of the Protective Forest Cover Sufficiency of the Territory

The cartographic studies carried out resulted in the creation of a model of protective forest plantations of the study area (Figure 2), which became the starting point for further research.

The analysis of the location of the systems of protective forest belts on the territory of the Ilovlinsky district indicates the heterogeneity and unevenness of their distribution. Solid forest belts are concentrated in the central and eastern parts of the administrative district under study. In the southern and western parts of the study area, protective forest plantations are represented by single belts that do not form complete systems.

The index of protective forest cover of the Ilovlinsky district, calculated for the area of the administrative district of 4156 km^2 and the area of all protective forest plantations equal to 33.41 km^2, is 0.8%.

Table 1 summarizes the analyzed approaches to determining the necessary and sufficient forest cover of a territory.

An analysis of existing opinions on the question of optimal forest cover became the basis for establishing minimum values for protective forest cover. This value is 3%. Territories that are characterized by a smaller number should be recommended for afforestation.

3.2. The Terrain as a Factor in Determining the Priority of Agroforestry Activities

Prevention of soil erosion is one of the main goals of creating protective forest belt systems. The more developed the degradation processes, the more urgent the need for protective forest belts. Erosion distribution schemes can serve as a basis for selecting the areas of priority agroforestry development.

The development of erosion processes is largely determined by the terrain. Features of the earth's surface formation are studied in a number of interrelated sciences—physical geography, geomorphology, landscape science. The landscape is a territorial unit combining the effects of zonal (the amount of solar radiation and incoming moisture) and azonal factors (characteristics of the relief and underlying rocks) of terrain specifics. The concept of landscape differentiation is the basis for research on the distribution and mapping of modern erosion processes.

The conducted cartographic research allowed us to design a spatial landscape model of the Ilovlinsky district of the Volgograd region (Figure 3).

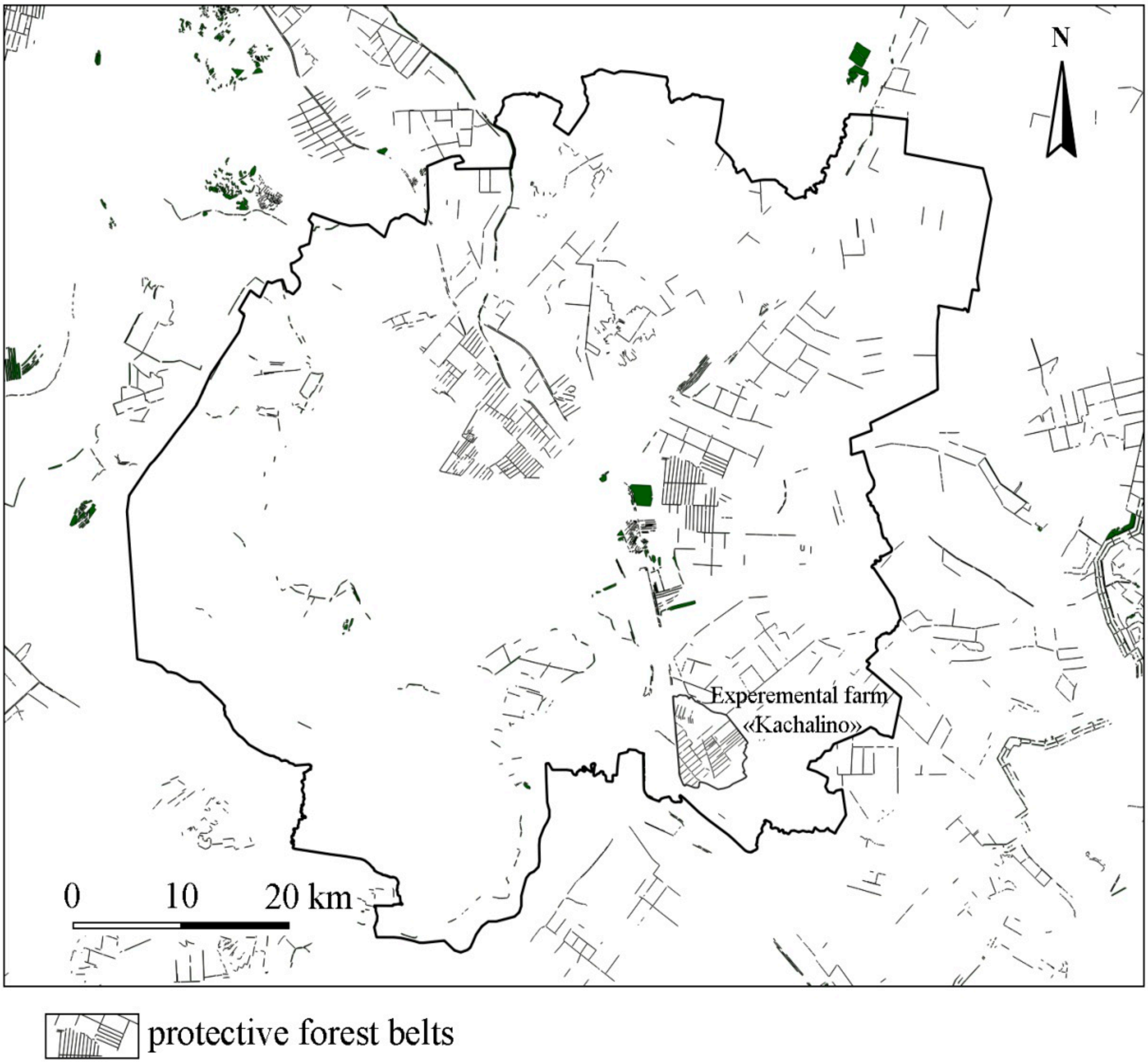

Figure 2. Protective forest plantations of the Ilovlinsky district of the Volgograd region.

The spatial model shown in Figure 3 outlines the boundaries of landscapes in the study area and contains a layer characterizing the distribution of ravines.

Taking into account the features of the terrain and related soil-forming rocks, which predetermines the redistribution of moisture and heat resources in the study area, allows us to trace the specifics of agroforestry measures in these areas.

Thus, the terrain of the Pridonsky landscape of the right bank of the Don River (an area of 1124 km^2—27% of the area of the Ilovlinsky district) is characterized by the largest difference between the maximum (240 m) and minimum elevations (37 m). The surface is heavily dissected by a ravine and gulley network. Soil-forming rocks are represented by sediments of the Triassic, Jurassic, Cretaceous, and Paleogene systems. Protective plantings (anti-erosion plantings, bank protection plantings, and clogging plantings) should be, first of all, aimed at preventing the erosion, as well as reducing the harm and consequences of its manifestation. The species composition of planted trees and shrubs should ensure the formation of durable plantations on washed-out infertile soils.

The Archedino–Don landscape occupies 1247 km^2 (30% of the study area). The terrain of this part of the Ilovlinsky district is characterized by smooth outlines. The maximum height is 130 m, the minimum is 60 m. The history of this territory is associated with the accumulation of solid runoff of ancient rivers. Soil-forming rocks are represented by alluvial–fluvioglacial sandy deposits. Manifestations of current erosion processes are minimal. The main focus should be made on the creation of complete field-protective systems of forest belts, which would prevent soil deflation. The species composition of planted trees and shrubs should include tall and fast-growing species that are able to provide maximum protection parameters.

The area of the Ilovlinsko–Medveditsky landscape amounts to 352 km^2 (8% of the territory). This natural territorial complex occupies the northern part of the study area. The elevation is 100 m (the maximum height is 150 m, and the minimum height is 50 m). The processes of water degradation are more moderate as compared to the Don landscape. The specificity of local agroforestry works should involve the creation of systems of field-protective forest belts, which allows for the regulation of runoff, as well as for providing anti-deflation protection of the soil cover.

The Ilovlinsko–Volzhsky landscape occupies 69 km^2, or 17% of the research area. The elevation is about 50 m (the maximum height is 120 m, and the minimum height is 70 m). The terrain is flattened. Erosion manifestations are insignificant. The agroforestry works should be aimed at creating complete systems of forest belts, but with a pronounced emphasis on shelter belts.

Table 1. Approaches to determining the optimal forest coverage of a territory.

No	Academic Institution, Authors, Year	Indicators of Optimal Forest Cover
1	Academy of Sciences, Laboratory of Forestry, Molchanov, 1966 [27].	Slightly hilly area 5%–10%; medium and high hilly areas 12%–20%; 25%–30% water protection forests.
2	All-Russian Research Institurte of Agroforestry, Pavlovskiy, 1988 [28].	Forest cover of arable land: 2.5%–4% in the plain conditions; 10%–12% in areas with rugged terrain.
3	Ukrainian Research Institute of Forestry and Agroforestry, Ananyev, Podkur, Kuprina, 1988 [29].	Water protection forests: steppe 16%–19%; forest-steppe 19%–23%
4	Academy of Sciences of the Lithuanian SSR, Paulukevičius,1989 [30].	Forest cover necessary for the ecological stability of landscapes: hilly plains 25%–40%; plains 10%–30%; areas with eolian deposits over 40%.
5	Altai University, Paramonov, Ishutin, Simonenko, 2003 [31].	Share of PFP in the area of arable land: minimum 4%–5%; optimum 7%–10%. Share of forest area: minimum 10%–15%; optimum 15%–20%.
6	All-Russian Research Institute of Forestry and Mechanization, All-Russian Research Institute of Agroforestry, Kalinichenko, Zykov, 1986 [32].	Anti-erosion afforestation of catchments from 3.69% to 16.8%, averaged 10.34% (flow regulating—1.5%, near-ravine and near-gulley 1.46%; on the ravine-gulley network 6.98; on valley and channel banks of small rivers 0.4%)
7	Voronezh State Agrarian University, Lopyrev, 1999 [33].	6%
8	All-Russian Research Institute of Agroforestry, Saratov State University, Baranov, Ivanov, 2005 [34].	Afforestation of arable land: forest-steppe 2.0%–2.5%; steppe 3.0%–4.0%; light soils and slopes 5%–7%.
9	Voronezh State Forest Engineering Academy, Lozovoy, 2003 [35].	Types of forest cover: arable—3%; protective—5%; agricultural—8%; water protective—24%; landscape—10%; resource and raw materials—22%; ecological—18%.
10	Steppe Institute of the Ural Branch of the Russian Academy of Sciences, Levykin, Kazachkov, Yakovlev, Grudinin, 2017 [36].	Optimum forest cover depending on the type of terrain: valley-upland—2%; watershed upland and hilly on sands and gravel—22%;watershed upland and hilly on clays and marls—4%;watershed upland and steeply-sloping—6%; floodplain terraced—4%; floodplain with a short period of flooding—15%; floodplain with a long period of flooding—50%; hilly-sandy—50%; valley-gulley—60%.

Figure 3. Landscape areas of the Ilovlinsky district of the Volgograd region: a—Pridonsky; b—Archedino-Don; c—Ilovlinsko-Medveditsky; d—Ilovlinsko-Volzhsky; e—Ilovlinsky floodplain; f—Middle Don floodplain.

The Ilovlinsky and Middle Don floodplain landscapes occupy 226 km^2 and 515 km^2, respectively (5% and 13% of the area of the Ilovlinsky district). The surface of these landscapes is strongly flattened. The elevation is 30 m (the maximum height is 70 m, and the minimum height is 40 m). Erosion manifestations are not observed. The natural forest cover of these territories is high, while the need for the creation of protective forest plantations is minimal.

The allocation of territorial complexes based on the features of terrain development ensures a more differentiated approach to investigation and evaluation of the territory under study. Table 2 presents the values of specific indicators characterizing the development of current erosion processes and the actual protective forest cover of landscape areas.

The analysis of protective forest cover allows us to note the value of 2.7% corresponding to the Archedino–Don landscape. This value is close to the value of the reference protective forest cover equal to 3%. The largest share of the Archedino–Don landscape in the area of the Ilovlinsky district determines its main contribution to ensuring the protective forest cover of the study area. The rest of the territorial complexes are characterized by values that differ significantly from the reference one, which indicates the need for agroforestry works in the future.

Table 2. Specific indicators of erosion development and protective forest cover of the landscapes of the Ilovlinsky district of the Volgograd region.

Landscape Areas	Ravine Dissection, km/km^2	Density of Ravine Tops, pcs/km^2	Protective Forest Cover, %
Pridonsky	0.84	0.96	0.6
Archedino–Don	0.06	0.09	2.7
Ilovlinsko–Medveditsky	0.42	0.6	1.1
Ilovlinsko–Volzhsky	0.05	0.1	1.6
Ilovlinsky floodplain	-	-	0.9
Middle Don floodplain	-	-	0.9
In general	0.28	0.36	0.8

The study of indicators characterizing the development of erosion allows us to note two landscape areas—Pridonsky and Ilovlinsko–Medveditsky. The values corresponding to these territories are higher than the values of the specific indicators of ravine dissection (km/km^2) and the density of ravine tops (pieces/km^2) calculated for the entire study region.

When comparing the data on water degradation and protective forest cover, we should note the territory of the Pridonsky landscape where the values of ravine erosion are maximum, and the values of protective forest cover are minimal. The considered landscape area occupies a significant share—27%. The main works related to improvement of protective forest cover in this area should be aimed at creating protective forest plantations. In other words, the right bank of the Don River in the study area can be considered as a priority territory for agroforestry activities.

3.3. Soil Cover as a Factor in Determining the Priority of Agroforestry Activities

Figure 4 shows the created cartographic model of the forest suitability of soils in the Ilovlinsky district of the Volgograd region (Figure 4).

Figure 4 reflects the boundaries of soil contours corresponding to the four groups of forest suitability obtained on the basis of summing up the soil map data. In addition, the image shows the distribution of protective forest plantations, the landscape boundaries, as well as the territories that, as a result of the analysis, were selected as priority areas for the creation of agroforestry complexes.

The first group of soil suitability for forests (quite satisfactory) is represented by dark chestnut soils, alluvial meadow saturated soils, soil complexes consisting of meadow chestnut soils, and sands slightly moussified up to 25%. This group of soils combines the most fertile types of soils.

The second group of soil suitability for forests (satisfactory) is represented by moderately washed away dark chestnut soils degraded as a result of erosion processes, as well as complexes of dark chestnut soils with chestnut solonetzes up to 25%, chestnut soils.

The third group of soil suitability for forests (conditionally satisfactory) is formed by medium eroded dark chestnut soils and chestnut solonetzes up to 25%, chestnut soils in combination with chestnut solonetzes up to 50%, slightly eroded chestnut soils, chestnut soils formed on flasks (weakly and medium stony soils), and low-humus sands (fixed).

The fourth group of soil suitability for forests (not satisfactory), includes solonetzes, chestnut soils formed on sandstones (strongly stony), low-humus sands (not fixed), complexes of solonetzes, and chestnut soils with a share of the latter up to 25%. This group includes the least fertile soil. The areas of various soil groups were calculated on the basis of the applied QGIS software package. Table 3 shows the shares of the studies soil groups in the territory of the Ilovlinsky district.

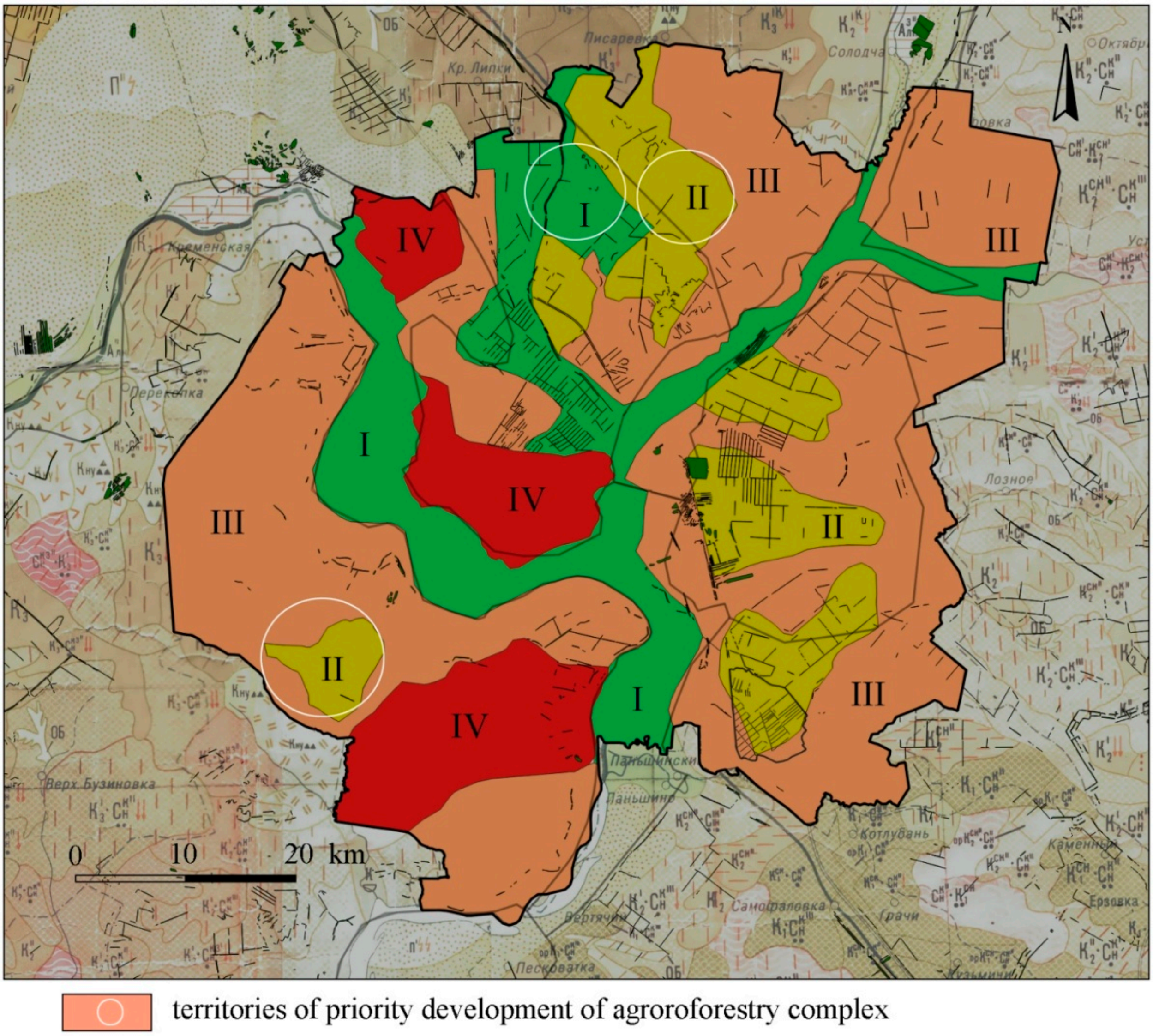

Figure 4. Forest growth conditions of the Ilovlinsky district of the Volgograd region. Forest suitability groups of soils: I—quite satisfactory, II—satisfactory, III—conditionally satisfactory, IV—not satisfactory.

The conditionally satisfactory soils belonging to the third forest suitability group are the most common in the Ilovlinsky district. They occupy 55.8% (2318 km^2) of the territory. The second and third most common groups of soils are quite satisfactory and satisfactory—17.7% (736 km^2) and 14.5% (602 km^2) of the territory, respectively. The smallest share in the territory of the Ilovlinsky district is occupied by areas where soil and plant conditions are characterized as unsatisfactory—12% (500 km^2).

An analysis of soil forest suitability data for landscape areas allows us to draw attention to some points. The most fertile lands are concentrated in the floodplain areas—Ilovlinsky floodplain and Middle Don floodplain, which are distinguished by the growth of natural forests and the minimum need for the creation of protective forest plantations.

It should also be noted that the soil cover of the Archedino–Don landscape is characterized by a significant share (46.2%) of soils belonging to Groups I and II. The rest of the territories are characterized by the predominance of soils belonging to Group III (conditionally satisfactory).

Table 4 presents the data characterizing the protective forest cover of the study area, calculated on the basis of the areas of contours of the forest suitability groups of soil.

Table 3. Shares of four forest suitability groups of soils in the Ilovlinsky district of the Volgograd region.

Landscape Areas	Share I, %	Share II, %	Share III, %	Share IV, %
Pridonsky	-	4.4	72	23.6
Archedino–Don	19.3	26.9	41.8	12
Ilovlinsko–Medveditsky	-	31.8	68.2	-
Ilovlinsko–Volzhsky	4.8	13.4	81.8	-
Ilovlinsky floodplain	46.5	5.3	42.4	5.8
Middle Don floodplain	69.3	-	16.5	14.2
In general	17.7	14.5	55.8	12

Table 4. Protective forest cover of the groups of forest suitability of soils in the landscapes of the Ilovlinsky district of the Volgograd region.

Landscape Areas	I, %	II, %	III, %	IV, %
Pridonsky	-	0.12	0.5	0.26
Archedino–Don	2.2	3	1.3	0.01
Ilovlinsko–Medveditsky	-	0.2	0.1	-
Ilovlinsko–Volzhsky	-	2.4	0.04	-
Ilovlinsky floodplain	0.3	-	0.8	-
Middle Don floodplain	0.1	-	1.2	0.4
In general	0.8	2.04	0.7	0.18

A joint analysis of Table 4 and Figure 4 makes it possible to identify at least three sites for the priority development of agroforestry complexes on the territory of the research object. These territories are in white circles in Figure 4.

Forest growth conditions of the Pridonsky landscape area as a whole are characterized by only three groups of soil suitability for forests (II, III, IV). The contour identified from the point of view of the priority of carrying out agroforestry measures is characterized by the best forest conditions in this landscape. This soil contour is characterized by the lowest indicators of protective forest cover of the territories—0.12%. Interpretation of the obtained images allowed us to reveal that this territory was in active agricultural use. Despite the development of erosion processes, the cultivation of agricultural products is profitable here. A complex of protective forest plantations consisting of anti-erosion and field-protective forest belts should be created in this territory. The area of this territory is about 50 km^2.

The territory of the Ilovlinsko–Medveditsky landscape is characterized by only two groups of soil suitability for forests: satisfactory and conditionally satisfactory. The indicators of protective forest cover of these contours are low: 0.2% and 0.1%, respectively. This territory, as well as the territory of the Pridonsky landscape, is characterized by high levels of water degradation. The creation of protective forest plantations here on the most fertile soils will increase the anti-erosion protection of this territory. The area allocated for the priority development of agroforestry complexes is about 80 km^2.

The variety of forest conditions in the Archedino–Don landscape is characterized by all four groups. A review of the indicator of protective forest cover of this area allows us to draw attention to the peculiarity: the most fertile soils corresponding to Group I have a value of indicator protective forest cover lower than less fertile soils of Group II. The spatial analysis of the protective forest belts makes it possible to single out sites for priority agroforest reclamation. The area of these sites is about 100 km^2. The creation of forest shelterbelt systems will protect the most fertile soils and increase the sustainability of agricultural production in a changing climate.

4. Discussion

Quantitative assessment of the proper parameters of protective forest cover or the question of the optimal forest cover of territories. An analysis of the identified points of view on the question of the optimal forest cover of territories [27–36], and their correlation with the natural conditions of the object of research, has become one of the arguments for substantiating the choice of the value of the reference indicator of optimal forest cover.

An analysis of Table 1 indicates that the question of the optimal forest cover of the territories is debatable. It is important to note the following circumstances, the authors, when determining the norms of optimal forest cover recommended by them, use different methodological approaches to the allocation of territorial complexes within the framework of which specific indicators are calculated. In some cases, forest cover indicators are calculated as a percentage of the total area of the territory; in others, they are tied to the area of arable land, or determined based on the area of structural elements of the relief (the area of gully lands, the primary banks of small rivers, etc.). Along with the differences between the approaches under consideration, their similarities should also be noted. In most of the sources presented, there is a relationship between the values of the indicators of optimal forest cover and the geographical area of the research, as well as the characteristics of the relief and underlying rocks.

The assessment of the protective forest cover of the territories was carried out on the basis of a comparison of the forest cover of the studied territories with the protective forest cover of the standard. Figure 2, in the southeastern part of the image, shows the location of the experimental farm "Kachalino." Cartographic works carried out confirmed the high rates of protective forest cover in this area. Despite the death of a number of forest belts as a result of fires, the protective forest cover of the farm's territory is about 3%.

The indicator of the protective forest cover of the Kachalino experimental farm corresponds to the value of the optimal forest cover given in a number of literary sources [28,34]. This indicator is the minimum among all the presented points of view corresponding to the characteristics of the territory of the object of this study. Here, when considering the issues of the validity of quantitative indicators of the sufficiency of protective forest cover, it is necessary to remember the systemic effects inherent in the systems of forest belts and absent in scattered protective forest plantations. These nuances are covered in detail [28,81].

Identification of the boundaries of territorial complexes based on the landscape approach makes it possible to identify the spatial features of the territory under study. These features are a manifestation of the genesis of the territory [37–48] and indicate a different need for agroforestry works.

In the course of this study, on the basis of remote data, the boundaries of the landscapes of the research object were specified, and the development of erosion processes was assessed. The calculation of the values of the indicator of protective forest cover within the geomorphologic parts of the study area made it possible to see the diversity of the study area. Territories were identified, the protective forest cover of which both differs from the optimal one and corresponds to it.

The assessment of the soil cover from the point of view of forest vegetation properties makes it possible to assess the adequacy of the protective forest cover of soil contours within the boundaries of landscapes and, when planning the creation of forest reclamation complexes, to develop the most fertile soils.

The influence of the properties of the soil cover on the determination of the priority of carrying out agroforestry works can be traced in research works related to the cadastral valuation of land [49] and the assessment of forest conditions of territories [50,51].

The materials presented in the work of Rakutin M.N. [49] clearly demonstrate the differences in the amount of income per 1 ha of arable land, depending on the soil and climatic conditions. Within the allocated eight soil-climatic zones for the Volgograd region, the amount of net income differs by more than three times. The results of these studies are significant from the point of view of the issue of determining the areas of priority development of forest reclamation complexes. Protective forest belts help to increase the yield of cultivated crops. The same number of forest belts, with comparable costs for their creation, in different soil and climatic conditions will lead to different increases in productivity. In other words, the greater the increase in productivity, or the more fertile the reclaimed lands, the greater the economic effect of creating protective forest belts.

In this study, the issue of assessing the need for forest reclamation measures based on the assessment of the forest suitability of soils [50,51] of the Ilovlinsky district of the Volgograd region, and the actual forest cover of identified soil contours is considered in more detail. Forest belts created in more favorable soil and climatic conditions, as a rule, are distinguished by higher ameliorative parameters, which predetermine the effects of their creation. First of all, we are talking about the maximum height of trees and the associated size of the zone of reclamation influence of the forest belt, as well as the life expectancy of trees, which predetermines the service life of forest belts as reclamation facilities.

Important remarks to the ongoing research include a number of limitations. Thus, the scale of primary materials used in this study serves the purpose of finding areas of priority development. The development of plans for agroforestry improvement will require the use of more detailed materials. They will deepen the ongoing research. When developing detailed schemes for the agroforestry improvement of the identified priority sites, it will be possible to use such a direction of spatial analysis as an assessment of the degree of danger of the consequences of the development of degradation processes. The factor of social significance of objects of degradation or the degree of danger of consequences, plays a significant role. So, for example, for roads that are affected by erosion processes (removal of fine earth on the roadway) or the threat of landslides on the hydrographic network within the boundaries of settlements, forest plantations must be created regardless of the assessment of the soil and vegetation conditions of the territory, and based on the assessment of potential harm from degradation phenomena.

5. Conclusions

The process of identifying areas of priority development of agroforestry complexes is based on the development of ideas for assessing the quantitative sufficiency of protective forest plantations, identifying geomorphologic features of the territory, and classifying territories depending on the forest cover properties of the soil cover.

Combining ideas in one study was made possible by the use of modern research methods. Geoinformation methods significantly expand the possibilities of spatial analysis of territories and reduce the complexity of research.

The result of the consistent application of the principles of spatial analysis discussed in this article is a cartographic model of the study area. This model makes it possible to obtain the values of the specific indicator of the protective forest cover of territories both for soil contours with different forest growth properties and for geomorphologically isolated parts of the object under study. Analysis of these values allows you to compare them with the standard. Promising sites for carrying out agroforestry measures are characterized by good soil and plant conditions, insufficient number of existing protective forest plantations, and location in landscapes subject to the development of degradation processes.

Promising directions for further research in law can be the development of detailed plans for the agroforestry development of the identified sites and the combination of the considered principles of spatial analysis with the study of larger areas.

Funding: This study was funded within the framework of State Assignment No 122020100312-0 "Theory and principles of formation of adaptive agroforestry-meliorative complexes of the dry steppe zone in the south of Russia in the context of climate change" to Federal Scientific Center of Agroecology, Complex Melioration, and Protective Afforestation, Russian Academy of Sciences.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data available on request.

Acknowledgments: The author thanks the Federal State Budgetary Scientific Institution "Federal Scientific Centre for Agroecology, Complex Melioration and Protective Afforestation, Russian Academy of Sciences" for providing the technical equipment for the field research.

Conflicts of Interest: The author declares no conflict of interest.

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