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Assessment of Forest Suitability of Soils in the Dry Steppe Zone of the Volgograd Region

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ABSTRACT

Background: Assessing the forest suitability of soils is one of the key areas of agroforestry science. Research in this direction makes it possible to characterize areas where tree and shrub vegetation does not grow under natural conditions. The research carried out makes it possible to assess the possibilities of afforestation in the area of interest; they contribute to the perception of landscape diversity in the context of the reclamation efficiency of the created systems of protective forest plantings, their productivity and durability. Identification of soil suitability for forests is closely related to the assessment of soil quality and fertility. The study of forest suitability of soils has a pronounced regional aspect. This article presents materials from cartographic studies of the dry steppe zone of the Volgograd region of the Russian Federation. The study region is characterized by a wide variety of soil cover. Dark chestnut, chestnut soils and light chestnut soils are common in this zone. The processes of erosion, salinizationand deflation make a great contribution to the diversity of soil complexes.

Methods: In this work, the cartographic research method is the main one. Achieving the research goal, creating a cartographic model of the forest vegetation properties of the study area, was carried out in three stages. At the first stage, the contours of the soil map at a scale of 1:400000 were classified into forest suitability groups. During the second stage, based on the functionality of the QGIS software package, new soil contours were created. At the third stage, area characteristics were taken, share parameters were calculated and an analysis of changes in soil cover was carried out in natural and economic areas. The research materials presented in this article were obtained during the implementation of the state task of the research work of the FSC of Agroecology RAS. The research period is from 2021-08 to 2023-11.

Result: The result of the research is the creation of a cartographic model of the forest suitability of soils in the dry steppe zone of the Volgograd region. Based on measuring the areas of soil contours for each of the 17 administrative districts, the ratio of groups of forest suitability of soils was established. The revealed value of the share indicator for the study area as a whole is as follows: soils I, forest suitability groups occupy 10.4% of the territory; II -9.3%; III - 68.3%; IV - 12%. The data obtained are necessary for planning agroforestry work in the study area.

Key words: Durability of protective forest plantations, Effectiveness of agroforestry measures, Forest suitability of soils, Planning of agroforestry measures, Soils of the dry steppe zone, Zone of influence of the protective forest belt.

INTRODUCTION

The assessment of forest suitability of soils in territories is an important component of agroforestry research (Mattis *et al.*, 1984; Manaenkov, 2014). This assessment makes it possible to identify the most promising territories for agroforestry development. Planting protective forest plantings on soils, characterized by better forest growing conditions, makes it possible to ensure their durability, high parameters of ameliorative influence and resistance to adverse climatic factors. The creation of complete systems of forest strips increases the protection of cultivated agricultural plants and contributes to obtaining stable yields (Abakumova *et al.*, 2004; Abakumova *et al.*, 2006; Dinh *et al.,* 2024).

The history of the development of research into forest vegetation properties of soils is quite long and multifaceted. Such scientists as G.F. Morozov (Morozov, 1970), V.N. Sukachev (Sukachev, 1972), P.S. Pogrebnyak (Pogrebnyak, 1955), A.L. Bellegarde (1960) and others dealt with the issues of studying forest suitability. In the arid zone, the issue under consideration was given attention by L.T. Zemlyanitsky (Zemlyanitsky, 1950), A.M. Byaly (Byaly, 1971), A.P. Biryukova (Biryukova, 1957), G.N. Vysotsky (1960), V.M. Kretinin (Kretinin, 1993; Kretinin, 2004), B.A. Isupov (Isupov, 1967) and others. The issue of studying the forest-growing properties of sands was paid attention to by such scientists as A.G. Gael (Gael, 1952), N.F. Kulik (Kulik, 1970), Vinogradov V.N. (Vinogradov, 1980), A.S. Monaenkov (Manaenkov, 2014) and others. Works on the classification

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of types of forest growing conditions are also common in foreign literature. Thus, according to O.G. Chertov (Chertov *et al.,* 2018), studies related to the assessment of edaphic characteristics of habitats include: the German doctrine of habitats Standortslehre (Stahr *et al.*, 2008); North American forest habitat classifications (Barnes *et al.,* 1982; Pojar *et al.*, 1987).

Despite the deep degree of knowledge and developed methodology for assessing the forest suitability of soils, there is a need for further research. The reasons for this situation lie in the close connection of the issue under study with soil mapping. When creating more detailed soil maps, new opportunities arise for assessing the forest vegetation properties of soils in the study area, improving the quality and accuracy of the assessment (Kretinin 1993; Koshelev *et al.* 2024; Ramamoorthy *et al*. 2024).

The purpose of the study was to create a cartographic model of the forest suitability of soils in the dry steppe zone of the Volgograd region, based on a generalization of soil map data at a scale of 1: 400000.

MATERIALS AND METHODS

The research methodology consists of three stages. The first stage is the classification of soil map contours into soil forestability groups. The second stage is the creation of a cartographic model of soil forest suitability based on the use of the QGIS software package (Burtsev, 2021; Lurie *et al.*, 2016). The third stage is the creation of an array of areal characteristics and the calculation of the parameters of the share that is occupied by forest suitability groups of soils in the study area.

The task of the first stage of the research is to identify the correspondence of the diagnostic criteria of soil forest suitability groups to the soil contours of the used soil map at a scale of 1: 400000. The criteria for soil forest suitability groups in this study are those developed by V.M. Kritinin. and Isupov B.A. (Kretinin, 1993; Kretinin, 2004) the following indicators of forest suitability: particle size distribution; humus content in the arable horizon, %; thickness of humus horizons, cm; degree of erosion, content of water-soluble salts in the layer 0-100 cm, %; fresh water level; rockiness and rubble, %; participation of non-forestable soils in the complex, %. The result of the research at the first stage is the distribution of symbols for the contours of the soil map according to groups of forest suitability of soils.

The task of the second stage is to create a cartographic model of the forest suitability of soils in the study area. The tasks that are solved during this stage are the following: topographic binding of the original raster image of the soil map; creation, based on generalizations obtained at the first stage of research, a layer of boundaries of forest suitability group contours; development and assignment of attributes to the created polygons of the cartographic model (color, characteristics of polygon boundaries, *etc.*). The result of the research at this stage is a spatial model of the forest vegetation properties of the soils of the study area, made in digital form and allowing for measurements of the areal characteristics of the created polygons.

The task of the third stage was to analyze the resulting cartographic model and identify the characteristics of the forest vegetation properties of the soils of the study area. During this stage of the research, the following tasks were solved: taking parameters of the area occupied by groups of forest suitability of soils-completely satisfactory, satisfactory, conditionally satisfactory and not satisfactory-within the framework of the administrative-territorial division of the study area, calculating share indicators, constructing diagrams. The result of the research is the identification of spatial characteristics of the forest vegetation properties of the soils of the study area.

The basis for creating a cartographic model of forest growth conditions of the dry steppe zone was the soil map of the Volgograd region Scale 1:400000 (Soil map of the Volgograd region, 1985). This map summarizes the materials of large-scale soil surveys by A.N. Zhulidova, N.I. Ivashkova, B.P. Chursina. It characterizes the distribution of the main types of soils (Degtyareva *et al.,* 1970) and allows one to assess the state of the soil cover based on indicators characterizing the granulometric composition of soils, the development of water and wind erosion, the participation of saline soils in the structure of the soil cover and characterizes the depth of salts in them. The map used allows us to characterize the distribution of sandy massifs and underdeveloped soils formed on crushed stone and flasks. In previous studies (Kretinin, 1993) related to the assessment of forest conditions, a more generalized.

The object of research is the dry steppe zone of the Volgograd region. Its area within the Volgograd region is 59,667 km^2. The boundaries of the zone were determined in accordance with the natural-agricultural zoning scheme M 1: 2000000 shown on the soil map M 1: 400000 (Soil map of the Volgograd region, 1985). In accordance with this scheme, the Volgograd region is represented by three zones: steppe, dry steppe and semi-desert. The largest areas belong to the dry steppe zone, which occupies 54% of the territory. The steppe zone occupies 30% of the territory, the semi-desert zone occupies 16% of the territory, Fig 1.

The dry-steppe zone of the Volgograd region, represented by three natural and economic regions: central, dry-steppe chestnut-alkaline; southern dry steppe chestnut-alkaline; eastern dry steppe chestnut-salt and chestnut. These areas differ in the geomorphological features of the territory, affecting the redistribution of precipitation. The largest area is occupied by the central dry-steppe chestnut-alkaline region - 31% of the area of the Volgograd region. 13% is occupied by the southern dry steppe chestnut-alkaline and 10% by the eastern dry steppe chestnut-alkaline and chestnut.

The climate of the dry steppe zone is characterized by a high degree of continentality and aridity (Atlas of the Volgograd region, 1993; Volgograd Region: Natural Conditions, Resources, Economy, Population, Geoecological State, 2011). The duration of the growing season with an average daily air temperature above + 10°C is 160 - 190 days and the sum of temperatures during this time is 2200 - 3500°C. The frost-free period is 150 -190 days. Annual precipitation is 250 - 350 mm. A significant part of the dry steppe zone is characterized by a large number of days with droughts and low moisture coefficients of 0.33 - 0.55. The main soils here are Dark chestnut, Chestnut, Light chestnut (Classification and diagnostics of soils of the USSR, 1977), which corresponds to Haplic Kastanozems Chromic (World reference base for soil resources, 2006; Unified State Register of Soil Resources of Russia, 2024). When moving from the northwest to the southeast, the amount of saline soils increases, Solonetzes (Classification and diagnostics of soils of the USSR, 1977) or Haplic Solonetz Albic Chromic (World reference base for soil resources, 2006; Unified State Register of Soil Resources of Russia, 2024). Natural feeding grounds are represented by dry-steppe tussock-grass vegetation with a predominance of fescue-feather grass and wormwood-fescue grass stands (Atlas of the Volgograd Region, 1993; Degtyareva *et al.*, 1970).

The dry steppe zone of the Volgograd region, as an object of research, is characterized not only by the maximum share of area in the Volgograd region, but also by the diversity of soils. This zone is characterized by the presence of soils widespread both in the semi-desert Solonetzes zone (Classification and Diagnostics of Soils of the USSR, 1977) and Dark chestnut soils similar in their properties to soils widespread in the Southern chernozems steppe zone (Classification and Diagnostics of Soils of the USSR, 1977) or Calcic Chernozem (World reference base for soil resources, 2006) and Chernozems ordinary (Classification and Diagnostics of Soils of the USSR, 1977) which corresponds to Voronic Chernozem (World Reference Base for Soil Resources, 2006). Reclamation solutions developed in a given area can be extrapolated to large areas.

The object of research is an important source of production of valuable food grain crops such as wheat, barley, rye. The aridity of the climate makes it possible to obtain harvests of the most valuable durum varieties. Wheat flour grown in the dry steppe zone of the Volgograd region has a high gluten content; it is used to produce bread and pasta of the highest quality. Scientific research related to the development of reclamation solutions aimed at preserving and reproducing soil resources in a given territory is extremely relevant and in demand.

The work was carried out at the Federal Scientific Center for Agroecology of the Russian Academy of Sciences. The work period is from 2021-08 to 2023-11.

RESULTS AND DISCUSSION

The result of the research carried out at the first stage is to establish, using the soil map, the nomenclature of the occurring soil differences and identify their compliance with the classification criteria of soil forest suitability groups. The obtained generalized research results are presented in Table 1.

An analysis of Table 1 shows that the first group of forest suitability of soils is represented by the most fertile types of soils unaffected by the processes of water and wind erosion: southern chernozem and ordinary chernozem, meadow-chernozem, alluvial meadow soils, dark chestnut soils. The second group of forest suitability of soils is represented by less fertile chestnut soils, as well as soils included in the first group, but characterized by the development of water degradation processes or an increased content of water-soluble salts. The third group of soil suitability for forestry is represented by light chestnut soils, as well as soil complexes in which non-forestable saline soils (solonetzes) occupy a share of up to 10-25%. The third group of forest suitability

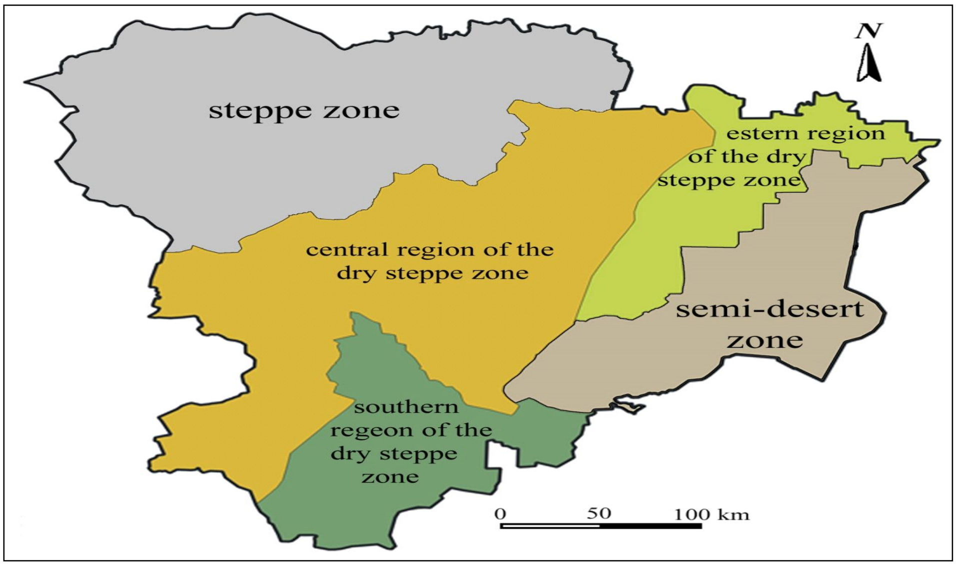


Fig 1: Object of research, boundaries of natural economic areas of the dry steppe zone of the Volgograd region.

of soils also includes weakly and moderately humified sands, underdeveloped chernozems and dark chestnut eroded soils. The fourth group of soil suitability for forests is represented by soils and substrates: solonetzes, developed sands, chestnut underdeveloped soils, as well as soil complexes in which non-forestable soils predominate.

The result of the work was the creation of a spatial model of forest vegetation properties of soils in the dry steppe zone of the Volgograd region. This cartographic model is presented in Fig 2.

Analysis of the image of the cartographic model of forest vegetation properties of soils allows us to identify two visually perceived features of the location of the contours. The first feature is associated with the distribution of soils of the first and fourth forest suitability groups. There is a tendency for the first group of soils to gravitate towards the northwestern border of the study area and the fourth to the southeastern border of the dry steppe zone. The second feature is related to the size of soil contours. On the right bank of the Don River the size of the contours is smaller. This difference is due to the topography of the study area. The right bank of the Don River is characterized by a greater dismemberment of the territory by a hydrographic network.

The implementation of a cartographic model of soil suitability for forests made it possible, based on the use of the capabilities of the QGIS software package, to measure the areas of the created soil contours. To provide a detailed description of the study area, the measurements of area parameters took place taking into account the boundaries of the administrative-territorial division of the Volgograd region Fig 3. The data obtained are presented in Table 2 and summarized in the diagram of Fig 4.

Analysis of the table data indicates that, in general, soils of the third group predominate in the dry steppe zone. They occupy 40,728 km^2, which is 68.3% of the territory. Further in order and by decreasing area occupied are soils of groups IV, I, II. They occupy 7185, 6184, 5570 km^2, which is 12; 10.4; 9.3% of the study area.

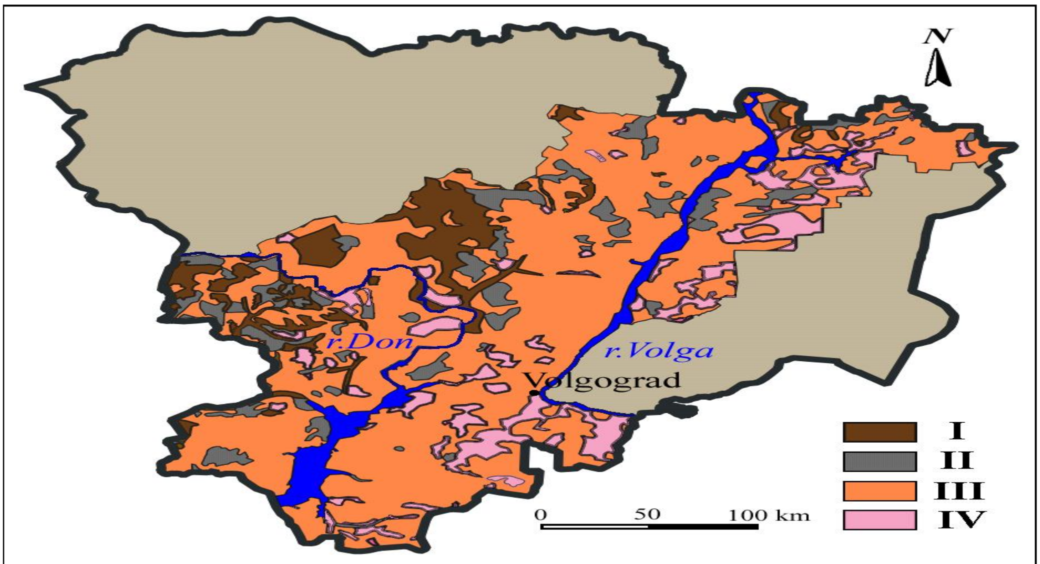
Table 1: Classification of soil map contours at a scale of 1:400000 according to groups of forest suitability of soils*.

I-completely suitable for forest	II -satisfactorily suitable for forest	III - conditionally suitable for forest	IV - not suitable for forestry
К_3^{II}; dark chestnut, thickness of the humus layer medium-thick	$\text{К}_3^{I}\downarrow$; dark chestnut, humus horizon thickness low-power, slightly washed out	К_1; $\text{К}_{1*\text{Сн}*}$; light chestnut; the same in combination with solonetzes 10-25%	Сн; solonetzes
Чл^{II}; meadow-chernozem, thickness of the humus layer medium-thick	$\text{К}_3^{\text{Сн}}$; dark chestnut, saline	$\text{К}_2\ II\downarrow\downarrow$; $\text{К}_2^{\text{Сн}}$; $\text{К}_2^{II}*\text{Сн}^{\text{К}I*}$; $\text{К}_2^{\ II*}\text{Сн}^{\text{К}III**}$; chestnut, thickness of the humus layer medium-thick, medium washed; the same saline; the same in combination with solonetzes 10-25%; the same in combination with solonetzes 25-50%	$\text{Сн}^{\text{К}I*}\ \text{К}_3^{I*}$; solonetzes in combination with dark chestnut 10-25 %, humus horizon thickness low-power
Алн^{II}; alluvial meadow, thickness of the humus layer medium-thick	К_2^{II}; chestnut, thickness of the humus layer medium-thick	$\text{К}^{3I}\downarrow\downarrow$; dark chestnut, humus horizon thickness low-power, medium washed	$\text{Сн}^{\text{К}I}\ \text{К}_2^{I*}$; solonetzes in combination with chestnut 10-25 %, humus horizon thickness low-power
		$\text{К}_3^{II}*\text{Сн}^{\text{К}I**}$; dark chestnut, thickness of the humus layer medium-thick, in combination with solonetzes 25-50%	$\text{Сн}^{\text{К}I}\ \text{К}_2^{I**}\downarrow\downarrow$; solonetzes in combination with chestnut 25-50 %, humus horizon thickness low-power, medium washed
		$\text{К}_3^{I}*\text{Сн}^{\text{К}I*}$; dark chestnut, humus horizon thickness low-power, in combination with solonetzes 10-25 %	$\text{Сн}^{\text{К}I}\text{К}_1^{*}$; solonetzes in combination with light chestnut 10-25 %
		П^{II}; sands, humus horizon thickness medium-thick	$\text{П}^{I}\uparrow\uparrow$; sands, humus horizon thickness low-power, medium wind erosion
		$\text{А}_{\text{лн}}^{3II}$; $\text{А}_{\text{лн}}^{3II*}\text{Сн}^{\text{К}I**}$; alluvial meadow, saline, thickness of the humus layer medium-thick; the same in combination with solonetzes 10-25%	$\text{К}_{\text{ну}}$;chestnut underdeveloped, very rocky, formed on opoka, sand, sandstone and light loam

* The names of the soil contours correspond to Classification and Diagnostics of Soils of the USSR, 1977.

Calculating the areas of forest suitability groups of soils within the boundaries of natural economic zoning made it possible to confirm the natural features of the territory. Their identification is important for solving issues of specialization of agricultural production. Analysis of the diagram of the figure confirms the general pattern of changes in soil cover in the direction from northwest to southeast. In this direction, the share of groups I and II decreases and the share of groups III and IV increases.

The reasons for the existing soil changes lie in climate change and geomorphology. The interaction of these factors determines the characteristics of the manifestations of



I – completely suitable for forest; II – satisfactorily suitable for forest; III – conditionally suitable for forest; IV - not suitable for forestry.

Fig 2: The boundaries of forest suitability groups for soils in the dry steppe zone of the Volgograd region:

Table 2: Area of forest suitability groups of soils in the dry steppe zone of the Volgograd region, km^2.

Natural-agricultural region	Administrative region	I*	II*	III*	IV*
	Serafimovichsky	1372	686	2210	55
	Frolovsky	2110	190	959	0
	Olkhovsky	186	606	2373	60
	Kotovsky	103	209	2043	87
Central dry steppe	Kletsky	911	703	1582	359
	Ilovlinsky	736	602	2318	500
	Dubovsky	0	0	3000	52
	Kamyshinsky	15	360	3164	24
	Surovinsky	336	455	2354	254
	Chernyshkovsky	178	377	2524	0
	Kalachevsky	0	190	3475	560
Southern dry steppe	Oktyabrsky	0	44	3410	357
	Kotelnikovsky	0	67	2964	440
	Svetloyarsky	0	0	1507	1678
	Bykovsky	0	217	2228	965
Eastern dry steppe	Nikolaevsky	0	433	1805	1198
	Staropoltavsky	237	431	2812	596
Central dry steppe	10 districts	5947	4188	22527	1391
Southern dry steppe	4 districts	0	301	11356	3035
Eastern dry steppe	3 districts	237	1081	6845	2759
Total for the dry steppe zone	17 districts	6184	5570	40728	7185

I - completely suitable for forest; II - satisfactorily suitable for forest; III* - conditionally suitable for forest; IV*- not suitable for forestry.

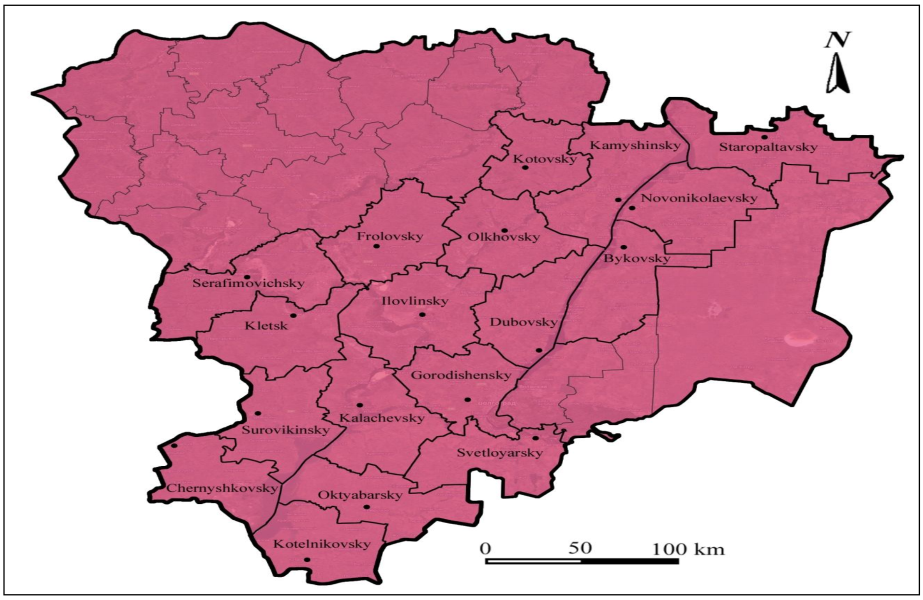


Fig 3: Borders and names of administrative districts of the Volgograd region located in the dry steppe zone.

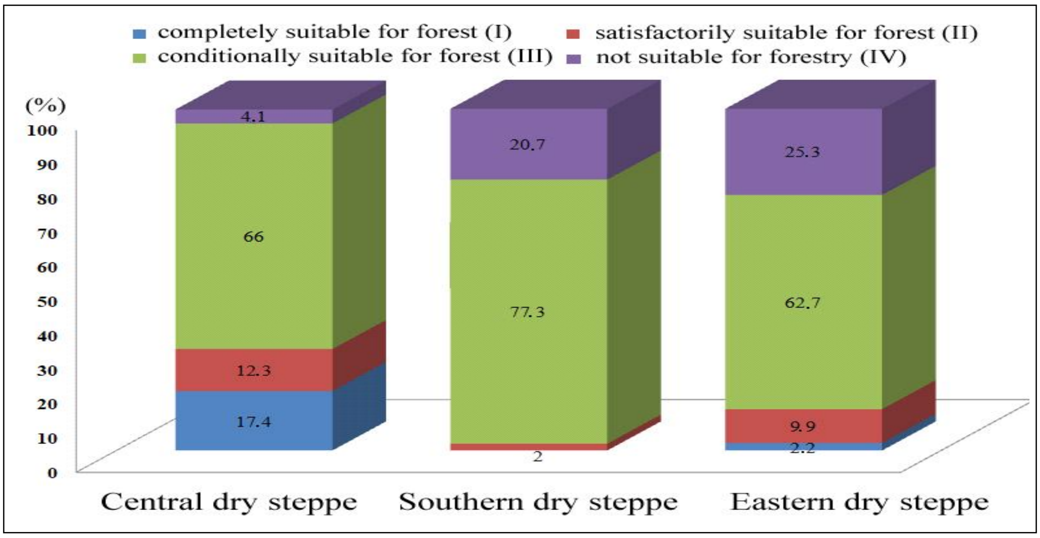


Fig 4: Diagram of changes in the proportion of forest suitability groups of soils in three natural and economic regions of the dry steppe zone of the Volgograd region, %.

degradation processes. Thus, in the central and southern dry-steppe region, the predominant type of degradation is erosionand in the eastern dry-steppe region, deflation. Saline soils are most widespread in the eastern and southern dry-steppe natural and economic regions.

In agricultural production, this feature is manifested in changes in the structure of land. As soil fertility decreases, the amount of arable land decreases and the amount of pastures increases. This is clearly visible from the map and diagram (Atlas of Thematic Maps for Agroleomelioration and Protective Aforestation, 2007).

All these features are important for planning agroforestry activities. Thus, in areas with widespread erosion, it is necessary to create anti-erosion forest belts. In areas where deflation occurs, shelterbelt forests are provided. Protective forest plantations and plantings for animals are created on pastures. These forest belts differ in their design, creation technology and tree species used (Abakumova *et al.*, 2004; Abakumova *et al.*, 2006).

It is important to take into account the identified features of the forest vegetation properties of the soil cover when selecting tree species used in the creation of protective forest plantations. In the central dry steppe region, dark chestnut soils predominate; in this natural and economic region it is possible to create protective forest belts of common oak (*Quercus communis*) and green ash (*Cinis viridi*). In the southern and eastern natural-economic regions, chestnut and light chestnut soils predominate; in this area it is possible to create protective forest belts from more drought-resistant species such as white acacia (*Acacia alba*), as well as salinity-resistant small-leaved elm (*Ulmus parva-foliati*), (Mattis *et al.*, 1984; Semenyutina, 2002).

An important and interesting question is the question of comparing the newly obtained data from the study with previously conducted studies.

The closest to the topic of the current research is the study by V.M. Kretinin (Kretinin, 1993). In this study, the assessment of the soil-vegetative properties of soils was carried out within the framework of agroforestry areas and natural zones of Russia, based on soil map data 1: 2500000 (Soil map of the Russian Federation, 1988). Summarizing the data obtained by the researcher, the arithmetic average values of the share (%) occupied by soils of four forest suitability groups within the dry-steppe were calculated zones of Russia as a whole. They are as follows: first - 29%, second - 24%, third -26%, fourth - 21%. In this study, the revealed values of the proportion of soil groups for the dry steppe zone of the Volgograd region are as follows: first - 10.4%, second 9.3%, third 68.3% and fourth 12%. The findings vary markedly. It should be noted the predominance of soils of the third group and smaller shares of the first and second and fourth groups of soils.

The difference in the data obtained can be explained by regional specifics. The dry steppe zone, in addition to the Volgograd region, extends to the territory of the eastern and central parts of the Stavropol Territory, the Republic of Dagestan, the north of the Chechen Republic, the Ingush Republic, the central and eastern part of the Rostov region, the western part of the Republic of Kalmykia, the central and southeastern part of the Saratov region, the Orenbur region, Altai Territory (Kretinin, 2009). The dry steppe zone of Russia covers an area of about 218,210 km^2 (Zonn *et al.*, 2004). The area of the dry steppe zone in the Volgograd region is 59,667 km^2 or 27.3% of the area of the dry steppe zone in Russia. Changes in the ratio between groups of forest suitability of soils are a manifestation of regional specificity and a feature of the study area.

The revealed fact of a smaller proportion of soils in the first and second groups of soil suitability for forests and an increase in the proportion of soils in the third group for the dry steppe zone of the Volgograd region is important for agroforestry research. This feature of the study area makes relevant the issues of identifying priority territories for agroforestry development and determining their location (Tubalov, 2023). The development of principles and priority directions for the implementation of protective afforestation is one of the strategic directions for the development of agroforestry (Kulik *et al.*, 2018).

CONCLUSION

The result of the research is the creation of a cartographic model of the distribution of soils of four groups of forest suitability in the dry steppe zone of the Volgograd region. The created map is based on the application of soil map data at a scale of 1:400000. The study area, with a total area of 59,667 km^2, is characterized by the following ratio of forest vegetation groups: first 10.4%; second 9.3%; third 68.3%; fourth 12%.

Assessing forest conditions is a key condition for increasing the effectiveness of agroforestry measures. The resulting cartographic model can be used to plan agroforestry work - identifying areas for priority development of agroforestry systems and developing medium-scale plans for agroforestry development of these territories.

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Conflict of interest

All authors declared that there is no conflict of interest.

REFERENCES

Abakumova, L.I. *et al.* (2004). Encyclopedia of agroforestry. VNIALMI, Volgograd. 675 pp.

Abakumova, L.I. *et al*. (2006). Agroforestry. 5th edition, revised and expanded.VNIALMI, Volgograd. 473. Volgograd. 198 pp.

Atlas of thematic maps for agroleomelioration and protective afforestation. (2007). VNIALMI, Volgograd. 150 pp.

Barnes, B.V.; Pregitzer, K.S.; Spies, T.A.; Spooner, V.H. (1982). Ecological forest site classification. Journal of Forestry. V. 80: 493-498 pp.

Bellegarde, A.L. (1960). Introduction to the typology of artificial forests in the steppe zone of Ukraine. Collection of articles: Artificial forests of the steppe zone of Ukraine. Kharkov University Publishing House, Kharkov. 423 pp.

Biryukova, A.P. (1957). The influence of irrigation on the water and salt regime of soils in the Southern Trans-Volga region. Abstract of the dissertation for the degree of Doctor of Agricultural Sciences. Soil Institute named after V.V. Dokuchaev, Moscow. 16 pp.

Burtsev, A.G. (2021). Basics of QGIS for urban planners: workshop. Ural University Publishing House, Yekaterinburg. 185 pp.

Byaly, A.M. (1971). Water regime in crop rotation on chernozem soils of the Southeast. Gidrometeoizdat, Leningrad. 232.

Chertov, O.G.; Nadporozhskaya, M.A.; Palenova, M.M.; Priputina, I.V. (2018). Edaphology in the structure of soil science and ecosystem ecology. Russian journal of ecosystem ecology. 2018.V. 3(3). doi: 10.21685/2500-0578-2018-3-2.

Classification and diagnostics of soils of the USSR. (1977). Kolos Press, Moscow. 223 pp.

Degtyareva, E.T.; Zhulidova, A.N. (1970). Soils of the Volgograd region. Nizhne-Volzhsky book publishing house, Volgograd. 321.

Dinh, K.H.T. Shima, K. (2024) Soil Properties Variation Valued in Relation to Land Use and Management Practices in Vietnam. Indian Journal of Agricultural Research. Doi: 10.18805/IJARe.AF-818.

Gael, A.G. (1952). Afforestation of hummocky sands in arid regions. Geographgiz, Moscow. 218 pp.

Isupov, B.A. (1967). Forest vegetation properties of soils of the Volga-Akhtuba flood plain and the Volga delta and their changes under the influence of woody vegetation. Abstract of the dissertation for the scientific degree of Candidate of Agricultural Sciences. Novocherkassk Engineering Reclamation Institute, Novocherkassk. 19.

Koshelev, A.V. Shatrovskaya, M.O. Kretinin, V.M. (2024) Influence of Forest Strips on Changes in Soil Properties in the Agrolandscape. Indian Journal of Agricultural Research. 58: 2. 323-330. doi**:** 10.18805/IJARe.AF-799.

Kretinin, V.M. (1993). Forest suitability of soils in agroforestry areas. Forest reclamation and landscape. Collection of scientific papers 1 :(105). VNIALMI, Volgograd. 50-59 pp.

Kretinin, V.M. (2004). The influence of agroforestry on the accumulation of humus and biophilic elements in the soils of various natural zones of Russia. Eurasian Soil Science 6. 745-751.

Kretinin, V.M. (2009). Forest reclamation of soils. VNIALMI, Volgograd. 198 pp.

Kulik, K. N. *et al.* (2018). The strategy of protective forestation development in russian federation for a period till 2025 year, remade and supplemented. FSC of Agro-ecology RAS, Volgograd. 36 pp.

Kulik, N.F. (1970). Water regime of sands in the south-east of the European part of the USSR. Abstract of the dissertation of the Doctor of Biological Sciences. Moscow State University named after M.V. Lomonosov, Moscow. 28 pp.

Lurie, I.K.; Samsonov, T. E. (2016). Computer science with basics of geoinformatics. Part 2. Basics of geoinformatics. Tutorial. Moscow State University Publishing House, Moscow. 200 pp.

Manaenkov, A.S. (2014). Forest reclamation of arid zone arenas. VNIALMI, Volgograd. 420 p.

Mattis, G.Y.; Pavlovsky E.S.; Kalashnikov A.F. (1984). Agroforestry Director's Handbook. Timber industry, Moscow. 246 pp.

Morozov, G.F. (1970). Teaching about the forest. Selected works, volume 1. Timber industry, Moscow. 458 pp.

Pogrebnyak, P.S. (1955). Fundamentals of forest typology. Publishing house of the Academy of Sciences of the Ukrainian SSR, Kyiv. 456 pp.

Pojar, J., Klinka, K., Meidinger D.V. (1987). Biogeoclimatic ecosystem classification in british columbia. Forest Ecology and Management. 22(1-2): 119-154.

Ramamoorthy, P., Christy, Nirmala, Mary, P., Saravanapandian, P. Gurusamy, A., Kumutha, K. (2024). Geo statistical tool for soil fertility assessment in pulses growing area of melur block, madurai district, tamil Nadu. Indian Journal of Agricultural Research. 58(2): 331-335. doi: 10.18805/IJARe.A-5929.

Semenyutina, A.V. (2002). An assortment of trees and shrubs for the reclamation of agricultural and urban landscapes in the arid zone. Russian Agricultural Academy, Moscow. 59 pp.

Soil Map of the Russian Federation, Scale 1: 2500000. (1988). The map was developed at the academy of agricultural sciences. Soil Institute and other Research Institutes. Moscow.

Soil map of the Volgograd Region, Scale 1:400000. (1985). Volgograd branch of the southern state design institute for land management, Volgograd.

Stahr, K., Kandeler E., L. von Herrmann; Streck T. (2008). Bodenkunde und Standortlehre. Soil Science and Location Theory. Ulmer. UTB. 318 pp.

Sukachev, V.N. (1972). Fundamentals of the theory of biogeocenology. Selected works, volume 1. Science, Leningrad. 418 pp.

Tubalov, A.A. (2023). Spatial principles of territories selection for priority development of agroforestry complexes. Forests 14: 1225. https://doi.org/10.3390/f14061225.

Unified State Register of Soil Resources of Russia. Date of access: 02/06/2024. https://egrpr.esoil.ru/content/1sem.html Vinogradov, V.N. (1980). Development of sands. Kolos, Moscow. 272 pp.

Volgograd Region: Natural Conditions, Resources, Economy, Population, Geoecological State. (2011). Peremena Press, Volgograd. 528. pp.

Vysotsky, G.N. (1960). Steppe afforestation. Selected works. Selkhozgiz, Moscow. 435 pp.

World reference base for soil resources. (2006). International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports. FAO Press, Rome. 106: 203.

Zemlyanitsky, L.T. (1950). The relationship between forest and soil in the steppe and forest-steppe zones. Goslesbumizdat, Moscow. 56 pp.

Zonn, I.S.; Trofimov, I.A.; Shamsutdinov, Z.Sh.; Shamsutdinov, N.Z. (2004) Land resources of arid territories of Russia. Arid Ecosystems. 10 (22-23): 87-101.