

Landscape structure of the Gaginsky Municipal District (Nizhny Novgorod Region, Russia)

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Abstract. The paper presents a scheme of landscape differentiation of Gaginskij municipal district of Nizhny Novgorod region (Russia) at the level of landscape types. The researched territory is located in a forest-steppe zone, has fertile soils and, therefore, is actively involved in agricultural production. The territory is characterized by a high degree of ploughing and low degree of forest cover, which, however, are strongly dependent on the landscape structure, which determines both the nature of land use and the degree of transformation of natural and territorial complexes. In the course of the research a comparative assessment of the selected landscapes was carried out according to the main indicators, characterizing their disturbance (plowing) and preservation (degree of afforestation). During the research the position of 10 points of growth of 6 plant species, listed in the Red Data Book of the Nizhny Novgorod region was established, the habitats of which also have a pronounced landscape determinism – all of them tend to tracts, the conditions of which are close to the steppe. The work is based on the analysis of scientific literature, thematic maps, Earth remote sensing data, and our own field and desk research, conducted in 2024. Geoinformation processing of materials was performed using the QGIS geoinformation system. During the research 8 landscapes were identified.

1 Introduction

The growing population of the planet, the increasing needs of people, the desire to increase the level of comfort of life entails an increase in problems, related to the depletion of resources, necessary for life, disruption, and in some places – the destruction of the living environment of people. The current situation requires a change in the approach to the organization of production and consumption of products, necessary for humanity. First, it reduces the amount of resources, consumed to what is reasonably necessary. Secondly – the most efficient organization of economic. The first task is ideological and economic in nature, the second is technological and environmental. The implementation of the second

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task lies in the field of view of geographers and is based on the integration of the principles of a systematic approach in territorial design.

Scientists' understanding of the systemic organization of a territory came several centuries ago, and an intuitive sense of these principles, based on the experience of organizing life, was gained back in the era of gathering, hunting, and fishing. Currently the details of the implementation of the landscape approach in the organization of environmental management are being actively discussed in scientific community [1], and their implementation is taking place among practitioners.

The theoretical foundations of landscape-based nature management are being developed in various sectors of the economy – agriculture [2-3], forestry [4], tourism and recreation [5], environmental protection [6], etc.

Solving the tasks of implementing the principles of the landscape approach, geographers develop methods for assessing and monitoring the current situation [7-9]. However, the most acute problem is the lack of territorial boundaries of natural and territorial complexes at the regional and local levels.

The implementation of the principles of adaptive environmental management in practice is hindered by a number of factors, one of which is the lack of detailed landscape maps. First of all, the development of landscape maps at the local level is carried out for the most significant specially protected natural territories [10], cities and, less often, agricultural lands [11].

The article presents a scheme of landscape zoning of one of the districts of the Nizhny Novgorod region – Gaginskij municipal district – whose lands are extremely actively involved in agricultural production, which, on the one hand, negatively affected the condition of geosystems and requires a speedy correction of the situation, on the other hand, agricultural products, produced here, are in demand by the market and there is an obvious interest in to increase its volume.

2 Materials and methods

The purpose of the research: to develop a scheme of landscape zoning of the territory of the Gaginskij municipal district of the Nizhny Novgorod region.

Object of research: the territory of Gaginskij municipal district of Nizhny Novgorod region.

Subject of the research: landscape structure of the territory of Gaginskij municipal district of Nizhny Novgorod region.

Research methods: descriptive, cartographic, GIS analysis, analysis of literature and stock materials, statistical, expeditionary, remote research, integrated physico-geographical (landscape) analysis, comparative geographical, geographical zoning.

The initial materials of the research. In carrying out the research the authors relied on data from scientific literature, thematic maps, Earth remote sensing materials and the results of their own field research, conducted in 2024.

3 Results

The territory of Gaginskij district is located in the south-eastern part of Nizhny Novgorod region, has an area of 1064 km². The population of the municipal district as of 01.01.2024 is 9749 people [12].

Pre-quaternary formations are represented by clays, clayey sandstones, and sands of the Cretaceous system on the southern periphery and in the north-west of the researched territory. These are rock strata, confined to watersheds, that were not eroded by erosion

processes in later geological epochs. The slopes of the valleys of the P'yana and Ezhat' rivers, where erosion processes destroyed the sediments of the Cretaceous system, are associated with older deposits of the Jurassic system, represented by clays, marls and sandstones. Even more ancient deposits of the Permian system (mudstones, clays, marls, sandstones, sands, dolomites, limestones, gypsum) are confined to the lower parts of the slopes and bottoms of the valleys of the P'yana and Ezhat' rivers [13-16]. The close proximity to the surface of the strata of the lower Permian system, containing karst rocks (gypsum, limestone and dolomite) on the bottoms of the valleys of the P'yana and Ezhat' rivers, created the prerequisites for the development of karst.

The composition of Quaternary sediments is dominated by sediment complexes of periglacial zones of glaciation and eluvial-deluvial sediments on watersheds and slopes (loams, loess-like loams, sands). Fluvioglacial deposits from the onset of the Dnieper glacier (sands with layers of loam) are common in the lower parts of the slopes of river valleys, and moraines from the Dnieper glaciation (loams with pebbles and boulders) are less common. Deposits of the first over-floodplain terrace (loams, sands) are found in areas along the P'yana River. The floodplains of the rivers are composed of floodplain alluvium (loams, sands) [17-20].

The territory of the Gaginskij municipal district is located on the northern edge of the Privolzhskaya Upland, which predetermined the active development of linear erosion and led to the formation of deeply embedded river valleys and a dense ravine-gully network. The north-eastern part of the district lies on the Mezhp'yan'e upland, while the southern part lies within the Sechenovskaya Upland. From east to west, the Gaginskij municipal district is bisected by the valley of the P'yana River, separating the Sechenovskaya upland from the Mezhp'yan'e. The amplitude of heights within the researched area is 123.5 m, from the 226 m mark on the plakor in the south-west to 102.5 m at the water's edge in the P'yana River on the north-western border of the district.

The relief is an alternation of watersheds, slopes and floodplains of rivers, complicated by a ravine-gully network. Gravity processes are locally developed, such as landslides and scree on the steep slopes of river valleys. Karst relief forms, expressed by karst craters, are confined to the bottoms of the valleys of the P'yana and Ezhat' rivers. The deepest and largest of them are filled with water and represent lakes.

The climate of Gaginskij municipal district is temperate continental with cold winters and moderately hot summers. The moisture coefficient is 0.8, which created the prerequisites for the formation of forest-steppe vegetation.

The largest element of the hydrographic network of the Gaginskij municipal district is the middle P'yana River, which crosses the territory of the district from south-east to north-west in its north-eastern part. The P'yana River receives three tributaries – the small rivers Pan'shenka, Ezhat' and Novazhenka. The territory of the entire district lies in the drainage basin of the P'yana River, which, in turn, flows into the Sura River, which is a right tributary of the Volga River. The total length of the riverbed network in the district is 232 km, the density of the riverbed network is 0.21 km/km². Temporary watercourses are widespread. This, apparently, is a consequence of a violation of the hydrological regime of small rivers, primarily a sharp increase in the unevenness of annual runoff, which was established by the authors' research in 2024. The primary reason for the imbalance of the hydrological regime of rivers in this territory should be considered a decrease in forest cover and intensive plowing of the territory. Despite the small area of the district, the values of the annual river flow modulus vary significantly within its limits: in the south-western margin less than 3 liters/s/km², in most of the district 3-4 liters/s/km², in the north-eastern margin 4-5 liters/s/km² [21]. On the floodplains of the P'yana and Ezhat' rivers, there are numerous small lakes of karst, fluvial and mixed karst-fluvial origin. Numerous ponds have been created in ravines, gullies and valleys of temporary watercourses. There are almost no

swamps, only on the floodplains of the P'yana River and they are found in the form of small-scale formations on the site of degraded lakes. The only relatively large swamp is the swamp on the floodplain of the Aratka River (a left tributary of the Ezhat' River) in the southern part of the district. Springs are confined to the lower parts of the slopes in the northern and southern parts of the district – there are seven of them within the researched territory.

The soil cover in the southern part of the district is represented by gray forest and dark gray forest soils, in the central part there are podzolized chernozems, in the northern part there are leached chernozems. There are soddy-alluvial soils on the floodplains of the rivers. The numerous ravines and gullies on the slopes are associated with the shallow-contoured soil areas of the ravine-gully complex [22].

According to the research of V.V. Alyohin and his colleagues [23], in the pre-agricultural period, communities of *Alnus glutinosa* were common in the floodplain of the P'yana River, steppes on the slopes of the P'yana River valley, and oak forests in the watershed areas. According to D.S. Averkiev, in the pre-agricultural period, the territory of the Gaginskij district was occupied by steppized oak forests [24, p. 132], and only in the northeast the forest-steppe was locally represented.

As of 1928, meadows were widespread in the floodplain of the P'yana River, oak forests were locally present in the watershed areas, and all other territories were occupied by arable land and heathlands [25].

According to K.K. Poluyahotov's scheme of forest zoning of the Gorky region [26], most of the Gaginskij municipal district lies in the zone of broad-leaved forests, and only the north-east is located in the forest-steppe, that is, K.K. Poluyahotov's position regarding the modern boundaries of vegetation coincides with D.S. Averkiev's point of view about the vegetation structure of the Gaginskij district in pre-agricultural times.

At the present stage, the forest cover of Gaginskij municipal district is 21.7%. The forests are mainly represented by hazel oak and hazel lime-tree forests on the flat interfluves, located in almost the same places as in 1928 and have almost the same area and configuration [23]. Secondary small-leaved forests – birch forests, are less common on abandoned arable land, as well as pine crops. On the floodplains of the rivers communities of *Alnus glutinosa* and willow stands are common.

Throughout the centuries of the agricultural period, indigenous vegetation experienced a powerful anthropogenic impact – farmers were attracted to fertile gray forest and chernozem soils. Arable land covers 558 km², plowed land in Gaginskij municipal district is 52.5%. The remaining areas fall on fallows and meadows, as well as lands of settlements. Vast areas are used as hay fields and pastures. Forests cover an area of 230 km², the forest cover is 21.7%.

During field research in 2024, 10 growing sites of 6 plant species, listed in the Red Data Book of the Nizhny Novgorod Region [27] and the Red Data Book of the Russian Federation [28] were identified. All discovered growing sites of rare and protected plant species have a pronounced attraction to tracts, characterized by steppe conditions, as a rule, these are the slopes of the southern exposure and the southern edges of forests.

Summarizing the points of view of scientists, who have performed paleobotanical reconstructions, vegetation map data and the results of the own field observations, it can be argued that the territory of the Gaginskij municipal district lies in the ecotonal zone of oak forests and steppes, which led to the alternation of broad-leaved and steppe communities. D.S. Averkiev [29] had a similar point of view (with some differences regarding borders), who attributed the western half of the district to the Alatyrsko-P'yanskij oak subdistrict, and the eastern half to the P'yansko-Surskij steppe subdistrict of the forest-steppe region.

According to the landscape zoning scheme developed by A.G. Isachenko, the researched territory lies in the broad-leaved subzone of the forest-steppe zone within the

Privolzhskaya landscape region [30]. F.N. Milkov classifies the territory of the Gaginskij municipal district as a forest-steppe zone, the province of forest-steppe of the Privolzhskaya Upland with significant development of broad-leaved and pine forests [31]. According to the scheme of landscape zoning of the Russian Plain, proposed by E. Rakovskaya and M. Davydova, the researched territory is located in the forest-steppe zone of the Privolzhskaya province [32]. According to the scheme of landscape districts of the Nizhny Novgorod region, developed by F.M. Bakanina, the territory of the Gaginskij municipal district lies in the forest-steppe zone (Figure 1.) within the Privolzhskaya landscape province almost completely within the Central Steppized landscape region, only the north-east of the researched territory slightly enters the boundaries of the Prisurskaya forest-steppe landscape region [33] (Figure 2).

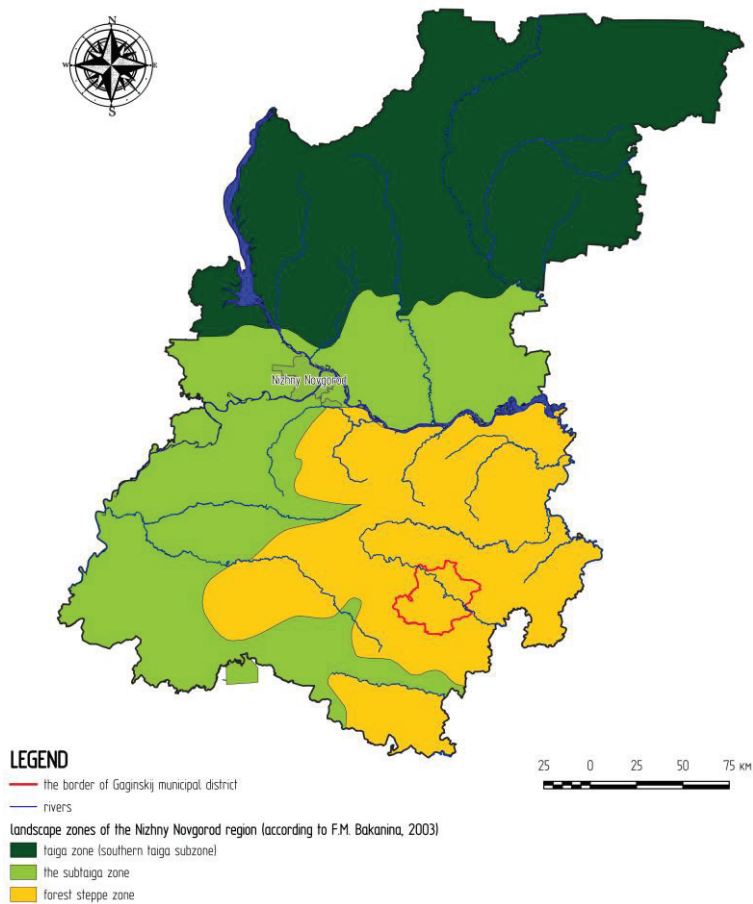


Fig. 1. The position of the territory of the Gaginskij municipal district on the scheme of landscape zones of the Nizhny Novgorod region.

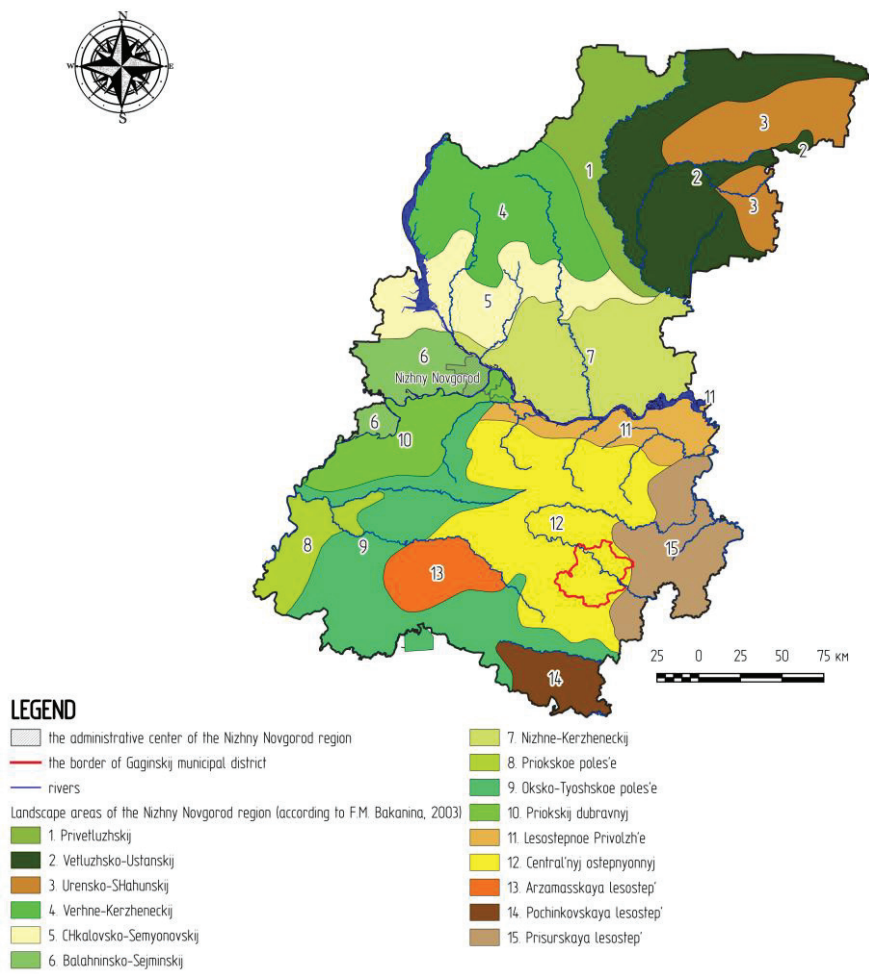


Fig. 2. The position of the territory of the Gaginskij municipal district on the scheme of landscape regions of the Nizhny Novgorod region.

In 2024 the authors conducted field and desk researches, which resulted in a landscape zoning scheme for the Gaginskij municipal district, developed at the level of landscape types, reflecting the characteristic combinations of lithogenic basis, relief, hydrographic network, soil cover, vegetation and the nature and degree of intensity of economic activity within each landscape (Figure 3). When identifying landscapes, the authors relied on a structural-genetic approach in landscape zoning and used a typological classification. Since the degree of intensity of anthropogenic impact on the landscape is an important aspect of its structure and functioning, this indicator was reflected in the name of each landscape through the value of forest cover. According to F.N. Milkov's proposals, landscapes with a forested area of less than 25% are classified as agrolandscapes, with a forested area of 25% to 50%, the landscape belongs to agroforest landscapes, with a forested area of more than 50% – to forest landscapes [34].

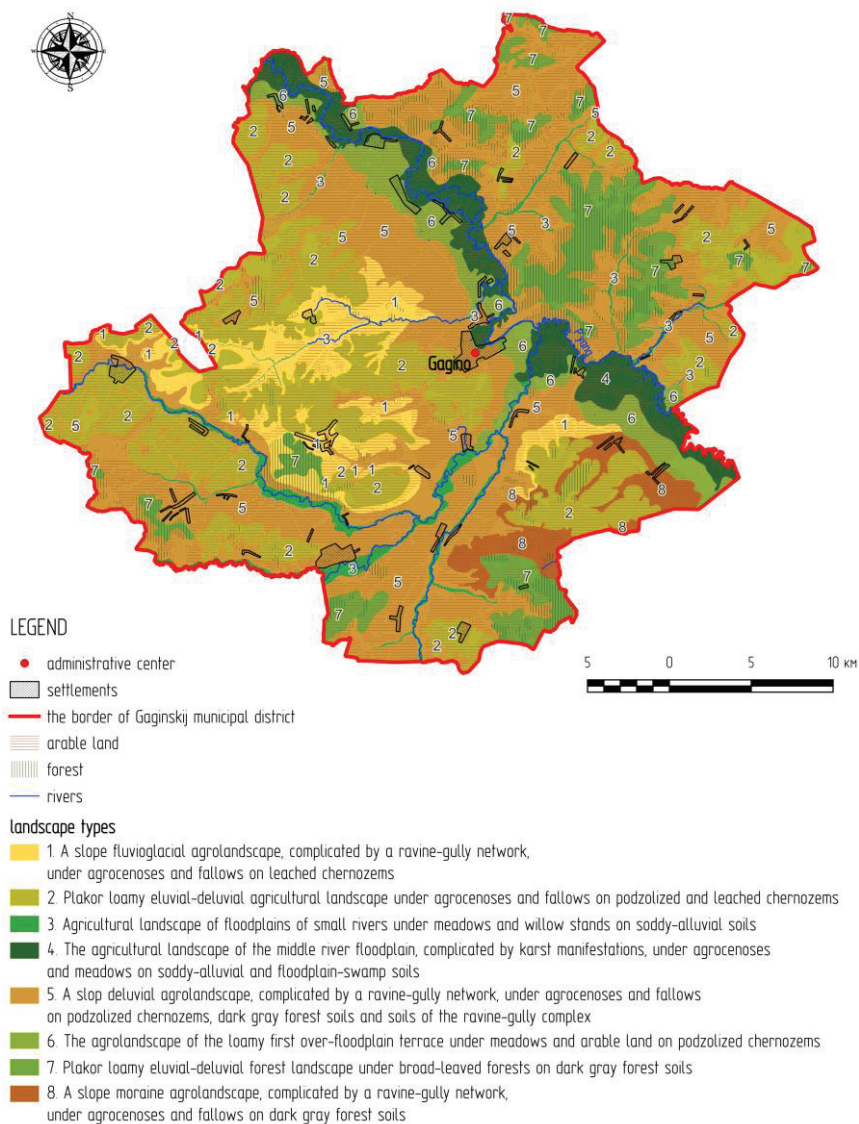


Fig. 3. The landscape structure of the territory of the Gaginskij municipal district.

Due to the significant contrast of landscape conditions in the Gaginskij municipal district, the forest cover indicators have sharp quantitative differences, which is why the landscapes identified, by the authors, are classified either as agrolandscapes or as forest landscapes.

Below is a list of the landscapes, identified by the authors, and their main characteristics are given.

1. A slope fluvioglacial agrolandscape, complicated by a ravine-gully network, under agrocnoses and fallows on leached chernozems.
The landscape is represented by several areas in the southern part of the Gaginskij municipal district, mainly in the interfluve of P'yana and Aratka rivers. The area of the landscape is 80.9 km². Quaternary sediments are represented by fluvioglacial deposits from the time of the retreat of the Dnieper glacier (sands, loams).

Due to the location of the landscape on the slopes of river valleys, the relief is complicated by numerous ravines, gullies and valleys of temporary watercourses. The hydrological network of this landscape is based on numerous small ponds, created in ravines and gullies. There are no permanent watercourses, swamps, or springs. The soil cover is mosaic-like, represented by an alternation of washed-out dark gray forest soils and podzolized chernozems with the soils of the ravine-gully complex. Vegetation is represented by agrocenoses of fields, fallow lands, meadows, and less often by broad-leaved forests, mainly lime-tree forests. Willow stands are found on the bottoms of the ravines. The forest cover is 16.5%.

The territory of this landscape is involved in economic use – gently sloping areas are being plowed, steep slopes are occupied by meadows and fallow land. The ploughing is 46.6%.

It is noteworthy that the nature and spatial organization of land use in this landscape has not changed over the century. According to the vegetation map, which reflects the state of vegetation as of the 1920s [25], most of the landscape then consisted of plowed spaces and heathlands, however, in the southern part of the landscape there was a forest area (oak forests), which has been preserved to the present day. Thus, it can be concluded that the spatial organization of land use within the given landscape has been stable for at least the last century.

2. Plakor loamy eluvial-deluvial agricultural landscape under agrocenoses and fallows on podzolized and leached chernozems.

The areas of this landscape are present on the territory of the entire municipal district, tending to the plakors. The landscape area is 252.1 km². Quaternary sediments are represented by eluvial-deluvial loams. The relief consists of flat watersheds and near-watershed slopes, within which the main relief-forming process is planar erosion; linear erosion is not pronounced. There are no water objects. The soil cover is represented by podzolized and leached chernozems.

The vegetation of this landscape has been radically transformed, the original communities of oak forests have been almost universally replaced by agrocenoses of fields and fallow lands, small-scale arrays of small-leaved forests are dispersed, lime-tree and oak forests are found locally, the forest cover is very low, amounting to 6.4%. Ploughing, due to the high soil fertility and the subhorizontal nature of the relief, convenient for the operation of agricultural machinery, is the highest in the entire district - 76.1%.

3. Agricultural landscape of floodplains of small rivers under meadows and willow stands on soddy-alluvial soils.

The areas of this landscape are stretched out in long narrow strips along small rivers, occupying their floodplains. The landscape area is 33.5 km². The lithogenic base is modern floodplain alluvium. The relief is complicated by deeps and tussocks. Due to the proximity of groundwater, the territory of this landscape is often waterlogged. The soil cover is represented by soddy-alluvial gley soils. Vegetation is represented by meadows and communities of *Alnus glutinosa* and willow stands. Economic activity is hampered by the difficult terrain and heterogeneous moisture regime and is mainly expressed by grazing, which is why the landscape, although it has a low forest cover of 16.1%, is almost untouched by arable land, the least plowed in the entire district – 6.0%.

4. The agricultural landscape of the middle river floodplain, complicated by karst manifestations, under agrocenoses and meadows on soddy-alluvial and floodplain-swamp soils.

This landscape is represented by a single area, stretching in a wide strip along the P'yana River from the eastern border of the researched territory to the north-western one. The landscape area is 69.5 km². The lithogenic basis of this landscape is alluvial loams and sandy loams, locally peat. Due to the shallow occurrence of the pre-quaternary formations,

represented by karst rocks (gypsum, limestone and dolomite) of the lower Permian system [13-16], karst is developed within this landscape. Small and shallow lakes often form in karst sinkholes. In addition to karst landforms, the surface of this landscape is complicated by manes and inter-mane depressions and riverine ramparts. The largest object of the hydrographic network is the P'yana River, in addition, there are numerous lakes of karst and channel origin. Small lowland marshes have formed on the site of degraded lakes. The soil cover is represented by soddy-alluvial and floodplain-marsh soils, often due to waterlogging, gley. Vegetation is mainly represented by meadows and fallow lands, less often by agrocenoses of fields. Woody vegetation is spread out in mosaic-like small groves or forms gallery forests along the riverbed of the P'yana River. *Alnus glutinosa* and *Salix alba* are common in the stand, and lime-tree and oak forests are less common. The forest cover is 23.1%. Communities of sedges and *Phragmites australis* of the south gravitate towards waterlogged and swampy areas. The territory of the landscape is poorly involved in economic activity, however, grazing and haymaking are carried out here, locally plowing. At the same time, two oak forests existed in the western part of the landscape a century ago [25], which have not survived to the present day, which indicates an increase in anthropogenic pressure on this landscape. The plowing area is 24.2%.

5. A slop deluvial agrolandscape, complicated by a ravine-gully network, under agrocenoses and fallows on podzolized chernozems, dark gray forest soils and soils of the ravine-gully complex.

On the territory of the Gaginskij municipal district the largest areas are occupied by slope surfaces, this landscape has the largest area: 440.6 km². The areas of the landscape are presented in all parts of the district. The lithogenic base is represented by deluvial loams. The relief is complicated by a dense ravine-gully network, sometimes there are cliffs and small landslide terraces. The hydrographic network is represented by numerous temporary watercourses and small ponds, created in the beds of these watercourses. Due to the slope nature of the landscape and the active development of linear erosion, aquifers are often exposed within the landscape, making the landscape rich in springs – 6 of the 7 springs of the Gaginskij municipal district are located here. The soil cover of the landscape is characterized by mosaicism, which is a consequence of its position on slopes of different exposures, which led to the manifestation of solar asymmetry of the slopes. The soil cover is represented by areas of podzolized chernozems and dark gray forest soils, and the areas of soils of the ravine-gully complex are confined to ravines and gullies. Due to the high soil fertility, the territory of this landscape has traditionally been intensively used in agriculture, and a century ago and now arable land and fallows were the most widespread, meadows and forests were found and are found in a mosaic. The plowing is 51.0%. It should be noted, however, that the relatively large oak grove, that existed in the northern part of the district in 1928, has survived to the present day. Along with fragments of broad-leaved forests, there are small groves of small-leaved trees within this landscape, and in some places they are being restored on abandoned arable land. Pine crops are represented locally. The forest cover is 22.6%.

6. The agrolandscape of the loamy first over-floodplain terrace under meadows and arable land on podzolized chernozems.

This landscape stretches along the agricultural landscape of the middle river floodplain, complicated by karst manifestations, under agrocenoses and meadows on soddy-alluvial and floodplain-swamp soils from the east of Gaginskij municipal district to the north-west, mainly in the left-bank part of the P'yana River valley. The landscape area is 55.1 km². The lithogenic base is represented by loams, the relief is subhorizontal, erosion processes are poorly developed, the ravine-gully network is sparse and has shallow incisions. Due to the relatively shallow occurrence of karst rocks, there are manifestations of karst, however, less numerous than in the floodplain of the P'yana River. The hydrographic network is

represented by small karst lakes and lowland marshes, formed on the site of degraded lakes. The soil cover is represented by fertile podzolized chernozems, due to which the territory is heavily plowed, the indigenous vegetation is almost everywhere replaced by agrocenoses of fields and fallows, the ploughing is very high: 63.6%. Due to the high demand for the territory of the landscape with fertile soils and a relief, convenient for plowing in agriculture, the natural vegetation is severely disturbed, the forest cover of this landscape is the smallest in the entire district: 5.2%.

7. Plakor loamy eluvial-deluvial forest landscape under broad-leaved forests on dark gray forest soils.

The areas of this landscape are dispersed in different parts of the Gaginskij municipal district and are confined to the forests. The landscape area is 97.4 km². The lithogenic basis of the landscape is loam. The relief does not have large slopes, as a result of which linear and planar erosion are poorly developed. Due to the location on the watersheds, there are no water bodies within the landscape. The soils are dark gray forest. The vegetation in this landscape has the best preservation in the entire district – mainly watershed lime-trees and oak forests are common here, the forest cover is the highest in the entire district: 74.8%, which made it possible to classify this landscape as a forest landscape. Due to the spread of fertile soils and a flat terrain that is convenient for plowing, almost all areas of the landscape, that are not occupied by forests, are plowed and occupied by agrocenoses of fields. The plowing area is 32.4%.

8. A slope moraine agrolandscape, complicated by a ravine-gully network, under agrocenoses and fallows on dark gray forest soils.

The landscape is located in the south-eastern part of Gaginskij municipal district, with an area of 33.2 km². The lithogenic base is represented by moraine loams. Due to its position on the slope, the terrain is complicated by numerous ravines, gullies and beds of temporary watercourses, in which ponds have been created, including quite large ones. In addition to temporary watercourses, there are several streams and one spring in the landscape. Fertile dark gray forest soils are in demand in agriculture, and the landscape is 53.9% plowed. The indigenous plant communities in most of the landscape have been replaced by agrocenoses of fields and fallow lands, forests have been preserved in the form of small groves on slopes and in ravines, inaccessible to plowing, the stand is represented by lime-trees. Forest cover 10.8%.

4 Discussion

The researched territory is located on the border of broad-leaved forests and forest-steppe in the conditions of the complex relief of the northern part of the Privolzhskaya Upland, has a heterogeneous lithogenic basis and is affected by a variety of geomorphological processes - fluvial, gravitational, karst. All these factors have caused the diversity of soil and vegetation cover, and prolonged and intense anthropogenic impact has left its mark on the structural and functional characteristics of landscapes, forming a complex landscape structure.

The analysis of the genesis and evolution of landscapes and their components allows for a more precise and deeper understanding of their structural and functional features, which makes it possible to effectively plan and implement economic solutions, adapting them to the specifics of the landscape base. The application of the landscape approach on the territory of the Gaginskij municipal district is all the more relevant because this territory has a high economic demand and is experiencing a strong anthropogenic impact, which has already led to a major transformation of the hydrological regime of rivers and the restructuring of plant complexes. Ignoring the principles of adaptive land use, based on knowledge of the landscape structure of the territory, will sooner or later lead to the

destruction of the landscape or a decrease in the efficiency of the economy. At the same time, the influence of the specifics of the landscape base within the researched territory itself strongly influenced the nature and intensity of the existing farming system. This is indicated, for example, by such characteristics of landscapes as ploughing and forest cover. During the research, strong differences in the quantitative values of these indicators were established, which indicates, that they are significantly determined by landscape conditions. Since both of these indicators reflect the nature and degree of intensity of anthropogenic impact, it becomes obvious that the existing process of economic use of territories depends on their landscape features.

5 Conclusion

When choosing the forms of economic development, the land user proceeds from the criterion of the possibility of performing an economic action, for example, plowing. But it is almost never guided by the criterion of the landscape's ability to withstand the type of economic activity in the volume and intensity realized, which leads to changes in the structural and functional characteristics of the landscape, and when critical pressure values are reached, to its destruction.

The scheme of landscape zoning of the Gaginskij municipal district, presented in the article, and a brief description of each type of landscape provides a scientific basis for the development and adoption of management decisions, aimed at the development of rational land use.

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