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Geoinformation Analysis of the Territorial Features of the Agrolandscape Complex of the Dry-Steppe Natural-Climatic Zone Applying GIS Technologies

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Abstract Mapping of the agrolandscape survey site within the boundaries of Frolovsky district of the Volgograd region is aimed at determining its geomorphometric characteristics, specifying the area and boundaries, as well as assessing environmental stability and integrity. The agrolandscape studied is agricultural with an area of plowing more than 70%, and the share of forest strips is minimal, accounting for 1,8%. A quarter of the agrolandscape is covered by the slopes and the beams which amount to 25%. Based on the digital relief model, the geographic coordinates of the analyzed polygon were obtained, and the maximum and minimal elevations and exposure of slopes were determined. The boundaries of 20 arable land plots with a total area of 2070,88 hectares were specified. The main types of the slopes are highlighted: flat surfaces (steepness up to 1°) – 30,0%; very gentle (steepness 1-2°) – 55,0%; gentle (steepness 2-3°) – 15.0%. The stability of the agrolandscape was assessed by a number of indicators. Low degree of protection by forest plantations ($K_{field\text{-}protective\ forestation}$ = 2,5), high degree of area ploughing ($K_{index\ of\ ploughing}$ = 72,8), lack of species diversity of agroecosystem (J_p = 3,9), increased roughness and articulation by beams and ravines ($K_{articulation}$ = 0,38) indicate that this agrolandscape is ecologically unstable ($K_{ecological\ stability}$ = 0,14). All these factors result in decreasing the ability of the agrolandscape to reproduce, to self-preserve and to restore the potential of soil productivity. The novelty of the research lies in the creation of a local geoinformation system of regional agro-landscape complexes and the identification of priority areas for agricultural production.

Keywords Agrolandscape, Mapping, Polygon, Environmental Sustainability

1. Introduction

The problems of preserving the quality of land resources, increasing the stability of the agrolandscape and the effective use of land in the agricultural industry require the development and implementation of scientific farming systems based on the regional characteristics and the condition of agrolandscape complexes. Interaction of natural, ecological and socio-economic conditions in a particular territory allows to determine the most possible options for optimizing the agrolandscape, assessing the condition of its individual components and outlining measures for their implementation [1].

The landscapes are components and elements of an open geosystem with their own characteristic of time formation and relative stability [2]. Many domestic scientists show particular interest in landscape and ecological approaches [3,4]. A.N. Kashtanov defines the agrolandscape as "a complex, interconnected and mutually agreed territorial-ecological and bioenergetic system, which is the necessary basis for agricultural production" [5]. G.I. Shvebs and A.P. Shcherbakov use the concept of "cultural agrolandscape," which means "a combination of various elements of agrolandscape including arable land, meadows, forests, forest strips, water bodies, natural landscapes, recreation areas, roads and other social, economic and engineering infrastructure" [6,7]. Leading specialists in land reclamation A. V. Albensky, V. N. Vinogradov, K. N. Kulik, E. S. Pavlovsky, A. S. Rulev, A. S. Yuferev, V. G. and others [8-13] dwell upon with the sustainability of the landscape, increasing its biological diversity, stabilizing the ecological situation and preventing desertification. The scientific papers of O.V. Ruleva and A.S. Ruleva [14] include information about the implementation of landscape planning methods that make it possible to use the natural and ecological potential of land and to ensure sustainable environmental management.

Landscape studies are the most important component in a comprehensive study of the functioning of the natural systems. Through landscape and landscape-ecological studies, a set of various research methods is used both expeditionary (reconnaissance surveys and visits of the investigated areas, route observations, making landscape profiles, research on "test" areas, etc.) and office control (comparative cartographic, landscape decoding of air and space images, compilation of zoning maps, landscape and landscape-ecological maps, etc.).

Intensive exploitation of lands suitable for agricultural production can provoke negative phenomena, namely salinization, reduced soil fertility, destruction of the humus layer, withdrawal of agricultural land from circulation and others that directly impact on the productivity and integrity of the entire agrolandscape complex. The academic papers of G. I. Shvebs [6], A. N. Kashtanov [15], M. I. Lopyrev [16], Trofimov, I. A. [17], Tregubov, P S. [18], V. D. Ivanova [19] and others were devoted to problems of disturbed lands. The foreign scientists have made substantial contributions to learning and struggling with the destructive processes of soils and ways of prevention [20-23]. A German geographer K. Troll is the founder of landscape-ecological interpretation of images from space [24]. Application of decoding methods at the objects of mapping makes it possible to assess the objectivity and depth of analysis of the morphological structure of landscape components.

2. Materials and Methods

The methodology of geoinformation analysis based on the landscape approach includes the compilation of a complex of thematic maps that provide the analysis of the territory by means of the differentiation of the landscape components. When mapping in the geo-information environment, the spatial levels of agrolandscape are specified, a spatial base is created to assess the landscape conditions and available resources and the existing natural-ecological framework of the territory. At the same time, the impact of various factors on the landscapes, forecasting the directivity and speed of processes in agrolandscapes are studied. When studying the dynamics of agrolandscapes, a spatial change in their boundaries is distinguished. It is necessary to take into account the level of dynamics of geosystems. There are weak responders to changes in external factors - low-dynamic (lithology, macrorelief) and strong responders - dynamic (vegetation cover).

The primary task of the study is to carry out the theoretical explanation of the methodology of geoinformation assessment of the arrangement of landscapes on the example of the Frolovsky district of the Volgograd region. The next stage is the selection of test sites and sites for detailed surveys. Further, landscape analysis of the territory is carried out, and office studies of the state of the landscapes of the studied territory are carried out.

After collecting and summarizing the information, an overview space map of the study region is created. The test polygons are planned. After that, the space maps of selected test areas are compiled. In order to establish the state of the studied agrolandscapes and characterize the arrangement of the territory, it is necessary to interpret and carry out geoinformation analysis of the space samples of the test polygons. For this purpose, the cartographic layers of the local geoinformation system are prepared by components of the studied agrolandscape, based on the data of remote sensing of Earth of high or ultra-high spatial resolution. The main geoinformation system for performing mapping is QGIS version 3. This is a user-friendly geographic information system, the advantage of which is the free distribution nature, the ability to connect multiple modules, as well as compatibility with the popular Qgis2web and NextGIS data publishing tools [25].

When mapping all components of the agrolandscape, the dates of the images were specified using the Google Earth program. The space images from the Landsat-8 satellite were used, located on GIS services for free use and allowing for the entire range of studies related to acquire information on the condition of agricultural land. Such studies have proven themselves well in such works [21], [26,27]. The processing methods are based on the application of QGIS 3.22 program tools and they include loading, processing and combining spectral bands into a color-synthesized image. To obtain data on heights, a global digital elevation model SRTM 3 was used, which made it possible to obtain the following data – minimum and maximum heights, elevation changes, slope steepness data, including the average slope values over the entire studied area, the distribution of the area, the coordinates of the areas and others to study the spatial distribution of all the studied contours [22,23].

To determine the spatial location of soil contours in the studied areas, a vector geoinformation cartographic layer (soil map) was used. The basis was the soil map of the Volgograd region M 1: 400,000 dated on 1989. Decoding of the main layer – the arable land is carried out based on the information of ultra-high spatial resolution and correction, according to data of high spatial resolution. When decoding, the most important point is to distinguish the boundaries of not only fields, but also field roads, forest strips and other elements.

The process of interpreting and creating a database at different levels of roads has certain features, among which it should be mentioned the process of selecting the current ultra-high-resolution image, the correct identification of dirt roads in areas of livestock points, as well as the identification of the current dirt roads in places of creating parallel paths. The use of several ultra-high spatial resolution sources of remote sensing of the Earth, such as Google, Yandex, Bing (World View 2, 3 satellites), which are connected with WMS layers, is an important aspect in interpretation of the necessary spatial objects. The use of two or more sources is necessary for a more accurate definition [25].

To identify the condition of the studied agricultural landscape, the geoinformation and local data sources were used, including pixel images on the satellite images with a resolution of 0,4 to 10,0 m. An electronic survey space map reflects the general state of the agricultural landscape and also determines the position of monitoring objects.

The satellite images are transformed by using geographic coordinates reference files in a way that the coordinates of control objects on the image and the topographic base match. After that, a control comparison of the coincidence of objects in the image and topographic map is carried out and their coordinates are checked with the coordinates on the topographic basis [28].

The method of agrolandscape mapping is carried out at the following stages: 1) interpretation of aerospace images; 2) field calibration; 3) extrapolation of deciphering features; 4) field control; 5) re-interpretation and implementation of the obtained data in the cartographic material [29, 30]. Field calibration is carried out in the representative places (test areas) of agrolandscapes, where the correspondences are established between the landscape components on the space images and in nature; the deciphering features of vegetation and soil varieties are formed and the visual comparison of the shape and structure of the object is also established [30]. The stage of analysis of landscape-ecological factors and degradation processes makes it possible to substantiate the methodology of using geoinformation technologies to assess the degradation, preservation of all components of the agrolandscape, to type zones according to the degree of environmental and economic stress and to carry out zoning of the same type of territories.

3. Result and Discussion

3.1. Study Area

The Volgograd region in terms of the availability and use of land resources occupies a leading position, having 11 287,0 thousand hectares, of which 9451,2 thousand hectares are assigned to land users who are part of the agro-industrial complex. A significant share of agricultural land is 82%. The availability of a great number of landowners and land users is supposed to have a high degree of anthropogenic impact on that category of land, which leads to degradation and destruction of soil fertility [30]. Land resources are not only a socio-economic platform for meeting the needs of the population, but also the ecological potential for the development of the territory, an agrolandscape, which inseparably connects a number of components: the natural layer of the atmosphere, soil, water and plant resources.

In the historically formed natural and agricultural zoning of the territory of the Volgograd region, three zones are distinguished: steppe, dry-steppe and semi-desert. The provinces are classified in the zones. There is the South Russian province with black-earth soils in the steppe zone; in the dry-steppe zone there are the Manychsko-Donskaya and Zavolzhskaya provinces with dark chestnut and chestnut soils and in the semi-desert zone there is the Pre-Caspian province with light chestnut soils. The most significant provinces in the area are the dry-steppe and semi-desert zones which occupy 71,0% and the steppe zone occupies 29,0% [31]. The dry-steppe zone is more subject to natural and anthropological impact due to its vast territory. This is a zone of intensive agriculture and preservation of the natural-ecological balance that is considered to be the most important component in implementing agricultural activities.

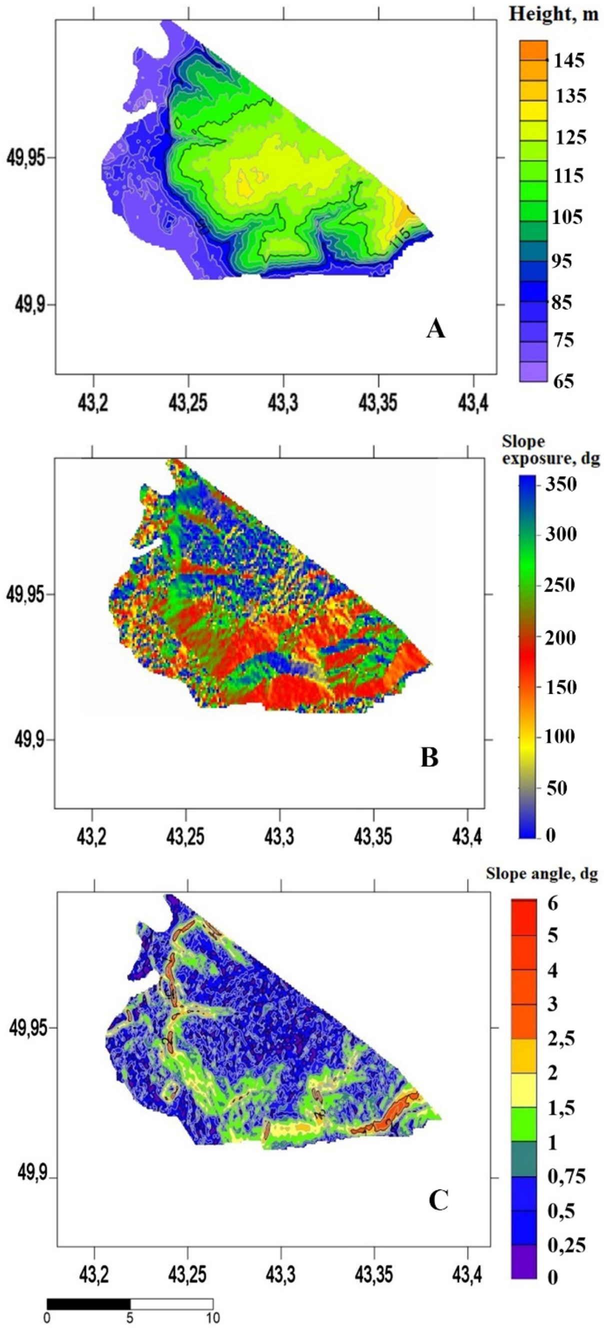
Mapping and analysis of the landscape territorial characteristics were carried out within the boundaries of the Frolovsky district of the Volgograd region, which belongs to the dry-steppe natural-climatic zone. The landscape of this territory is characterized by its location in the southern part of the Volga Upland. The terrain of the study area is quite diverse, mainly flat, complicated by small gullies and depressions. The grain size distribution of all soil subtypes is argillaceous and heavy loamy. Soil varieties are represented by zonal chestnut and dark chestnut soils, in combination with solonets, the content of which varies from 10 to 74%. The absolute surface elevations vary from 86,05 to 126,91 m according to the Baltic elevation system. The slopes are gentle in most cases but steep in some places.

3.2. Polygon Characteristics

The analyzed region is characterized by a zone of dark chestnut soils and chestnut soils in combination with solonets with a thickness of 40-45 cm with natural fertility, humus 3-4,5%, with a pH level of 7. The groundwater are located at depths from 1,1 to 11,5 m. The level of groundwaters is not constant, but it is subject to seasonal fluctuations. The amplitude of seasonal variation reaches 1,2-1,5 m depending on the season and the degree of abundance of water. According to the results of the analysis of previous surveys, the long-term fluctuations in the groundwater level are insignificant because of the good drainage of the area and high water-transmitting capability of the soils.

The agrolandscape polygon is characterized by an area of 2845 hectares, of which arable land occupies 2070,88 hectares, forest strips amount to 52,2 hectares. The rest area of 720,0 hectares is occupied by slopes and gullies and 1,9 hectares are under the roads.

To determine the distinctive geomorphometric characteristics of the polygon, the analysis of the digital relief model is carried out to demonstrate a visual image of the earth's surface, the smallest and largest elevation marks, etc. (Figure 1).



A – isolinear elevation map; B – slope exposure map; C – slope angles map

Figure 1. Morphometric characteristics of the study area

The following results were obtained: the coordinates of the northern point: 49°58′28″ N; 43°17′17″ E; the southern point: 49°54′36″ N; 43°17′29″ E; the western point of the polygon: 49°57′19″ N; 43°15′46″ E; the eastern point: 49°55′45″ N; 43°22′05″ E. The height difference is 40,86 m. The average steepness throughout the polygon is 1,2°; the maximum steepness of the surface slope is 3,81°.

The agrolandscape is a land massif consisting of a complex of interconnected natural-man-made components, as well as elements of the farming system that are necessary for the construction of an area possessing a relatively autonomous set of food, water, heat, air and other modes with characteristics of a common (unified) ecological system [32].

The agrolandscape studied is typical of a predominance of agricultural land that is arable land and arable land plots. Therefore, on the space image the various contours of arable land were identified taking into account its purpose. The boundaries of 20 plots of arable land with a total area of 2070,88 hectares were clarified. The minimum surveyed area is 6,443 hectares; the maximum arable land area is 335,15 hectares. The average size of the arable contour is 103,54 hectares (Table 1).

The slopes of the studied water collection are characterized by:

- flat surfaces (steepness up to 10) – 30,0%;
- very gentle (steepness 1-20) – 55,0%;
- gentle (steepness 2-30) – 15,0%;

The system of protective forest plantations at the test polygon is represented by the insignificant plantations and it includes 15 forest strips with an area of 52,2 hectares.

3.3. Data Collection and Data Analysis

When considering this agrolandscape as part of the natural landscape distinguished by its agro-ecological functions and designed for the production of crops and meeting human needs, it is necessary to assess its stability and ability to self-restore. M.I. Lopyrev [33] considers the agrolandscape to be environmentally sustainable if it ensures high productivity and preservation of natural soil fertility with intensive use in the farming system. According to V.I. Kiryushin, the stability of the agrolandscape is the ability to keep the given productive and social characteristics, preserving the biosphere ones. Stable agrolandscape is characterized by a lack or low level of degradation processes.

The study of the landscape structure of the territory under consideration is aimed at clarifying the actual situation in its current use, making forecasts to stabilize the individual components of the agrolandscape and the effective functioning of the entire system as a whole. This study included several stages of work: landscape and environmental analysis, diagnosis and prognosis.

The first stage includes the study of all components, the establishment of spatial links, anthropogenic impacts and the definition of environmental functions. The following components are subject to evaluation: arable land, forest strips, field roads, ravine-beam network. The degree of positive or negative environmental impact depends on the nature and level of anthropogenic impact. The agrolandscape studied was evaluated by a number of characteristics (Table 2):

- coefficient of area ploughing ($K_{index\ of\ ploughing}$)
- coefficient of filed-protective forestation ($K_{field-protective\ forestation}$);
- coefficient of ecological stability of the landscape territory ($K_{ecological\ stability}$);
- coefficient of roughness and articulation by beams and ravines ($K_{articulation}$);
- index of ecological diversity (J_p = 3,9).

Table 1. Geomorphometric characteristics of the test polygon within the boundaries of the Frolovsky district of the Volgograd region

№	№ site	Square of land, ha	Perimeter, km	Maximum slope steepness	Average slope steepness	Slope location
1	Arable land 46	146,13	8,315	4,04	1,2	west
2	Arable land 47	56,32	3,304	4,04	1,2	west
3	Arable land 48	108,33	7,007	3,24	1,3	west
4	Arable land 49	131,1	14,42	4,04	1,2	west
5	Arable land 50	181,74	6,119	4,09	2,17	south-east
6	Arable land 51	38,3	3,54	5,25	2,02	south
7	Arable land 52	74,38	4,121	1,86	0,86	north-west
8	Arable land 53	180,31	7,038	1,74	0,69	south-east
9	Arable land 54	39,54	2,807	2,94	1,24	south-east
10	Arable land 55	35,631	2,907	3,72	1,45	south
11	Arable land 56	43,53	4,264	5,05	1,17	south
12	Arable land 57	39,40	3,469	4,2	1,05	south-east
13	Arable land 58	33,60	2,733	3,2	1,23	south
14	Arable land 59	9,21	1,48	2,36	1,07	south-east
15	Arable land 60	232,47	6,335	1,67	0,6	north-east
16	Arable land 61	335,15	8,13	1,58	0,65	north
17	Arable land 62	236,77	8,236	2,5	0,78	south-east
18	Arable land 63	117,59	6,279	1,91	0,71	north
19	Arable land 64	24,94	1,974	3,09	1,55	south
20	Arable land 82	6,443	1,081	2,82	2,23	south
Total		2070,88				

Table 2. Parameters of agrolandscape stability

Components of agrolandscape	Occupied area, ha	% to total area	Estimated parameters				
			Kfield-protective forestation	Kecological stability	Kindex of ploughing	Jp	Karticulation
Arable land	2070,88	72,8	2,5	0,14	72,8	3,9	0,38
Forest strips	52,2	1,8					
Field roads	1,9	0,07					
Ravines, gullies	720,0	25,3					
Total area of agrolandscape	2845,0	100					

The estimated landscape is exposed to high intensification of agriculture due to the significant area of the arable land (72,8%) and an insignificant share of medium-stabilizing land (forest strips) – 1,8%. There is a lack of species diversity of the agroecosystem (index of ecological diversity – 3.9), which reduces the ability of the agrolandscape to reproduce, self-preserve and restores the potential of soil productivity. The coefficient of roughness and articulation by beams and ravines (coefficient of articulation) is 0,38 which confirms the presence of a small number of gentle slopes (15,0%). According to the scientists' research [32], the flat lands are subject to flushing by 15-20%. The effectiveness of the protective effect of forest plantations is only 2,5%, and this does not provide the protective effect of the entire agrolandscape. Using these data, the evaluated agrolandscape can be characterized as environmentally unstable ($K_{ecological\ stability}$ – 0,14).

The second stage is to assess the agrolandscape and its suitability for agricultural production. Assessment of the level of plowing of the territory makes it possible to determine the current state, to clarify the presence of erosion processes, while the lack of the required number of protective forest plantations only aggravates this situation. The combination of a high degree of ploughing of the territory of the polygon (more than 72%) and a low degree of protection by forest plantations (2,5%) leads to the fact that a significant part of nutrients being influenced by the erosion processes is irretrievably lost. In the circumstances when there is insufficient protection from erosion processes, the plowed fields occupying the significant area of agrolandscape are potentially predisposed to the development of these processes, which lead to a decrease in productivity [34].

Having carried out the research based on modeling and mapping of the erosional landscapes, within the boundaries of the test polygon, the following was established: the influence of slope angle (X), drain line length (L), as well as correction coefficients (flush, exposure and slope shape) on the value of potential soil washing (M).

$$M = (59{,}6*EXP(0{,}107*X))-60{,}4*Ksoil*Kslshape*Kslex \quad (1)$$

Table 3. Calculation of soil flushing

№	**№ of arable land**	**Soil**	**Medium steepness,°**	**Slope length, km**	**Estimated slope wash t/ha**	**Wash of total plot area, t**
1	Arable land 46	Chestnut with salt chestnut 25-50%	1,2	1,063	8,67	1266,95
2	Arable land 47	Chestnut with salt chestnut 25-50%	1,2	0,69	9,86	555,32
3	Arable land 48	Chestnut with salt chestnut 25-50%	1,3	0,448	5,75	622,90
4	Arable land 49	Chestnut with salt chestnut 25-50%	1,2	0,715	7,08	928,19
5	Arable land 50	Chestnut with salt chestnut 25-50%	2,17	1,533	13,62	2475,30
6	Arable land 51	Chestnut with salt chestnut 25-50%	2,02	1,391	15,89	608,59
7	Arable land 52	Chestnut with salt chestnut 25-50%	0,86	0,606	-	58,02
8	Arable land 53	Dark chestnut 0,5	0,69	0,56	-	277,67
9	Arable land 54	Chestnut with salt chestnut 25-50%	1,24	0,67	4,59	181,49
10	Arable land 55	Chestnut with salt chestnut 25-50%	1,45	0,64	8,54	304,29
11	Arable land 56	Chestnut with salt chestnut 25-50%	1,17	0,54	8,18	356,08
12	Arable land 57	Chestnut with salt chestnut 25-50%	1,05	0,585	4,69	184,79
13	Arable land 58	Chestnut with salt chestnut 25-50%	1,23	0,54	6,27	210,67
14	Arable land 59	Dark chestnut	1,07	0,155	1,84	16,95
15	Arable land 60	Dark chestnut	0,6	1,104	-	295,2
16	Arable land 61	Dark chestnut	0,65	1,8	-	496,0
17	Arable land 62	Dark chestnut 0,5	0,78	1,81	-	364,62
18	Arable land 63	Dark chestnut	0,71	0,793	-	174,03
19	Arable land 64	Chestnut with salt chestnut 25-50%	1,55	0,328	10,79	269,10
20	Arable land 82	Chestnut with salt chestnut 25-50%	2,23	0,275	15,61	100,58

The calculated range of soil washing is 2070,88 hectares of the areas of arable land with an average slope steepness. 30% of the study area has minimum soil washing within the permissible values, which do not cause intensive erosion processes. These are slopes with steepness up to 1^0. The calculated value of soil washing for a specific area of each arable land plot of the test polygon with an average slope from $1\text{-}2^0$ ranges from 16,95 tons to 1266,95 tons. These lands belong to the second group of erosion hazards. And the estimated total soil washing of the test areas of arable land with a slope steepness of more than 2^0 amounts to 3184,48 tons. Thus, the studied polygon is 70% subject to soil washing and its value is 8081,2 tons. The average value of soil washing from 1 hectare of arable land throughout the polygon is 3,9 tons.

4. Conclusions

The direct influence of production and non-production activities on the natural properties of the landscape leads to the fact that they lose their stability, as well as the ability to self-repair and transform into natural-anthropogenic. A special place among anthropogenic landscapes is occupied by agrolandscapes. Due to its natural features (abundance of positive temperatures, aridity of the climate with characteristic sharp temperature differences in the seasons of the year and with a lack of precipitation), the landscapes of the dry-steppe zone of the Volgograd region have a significant natural impact, as well as anthropogenic, on the form of intensive use of agricultural land, plowing of natural lands (hayfields, pastures), which leads to the development of degradation processes that worsen their condition.

The principle of landscape-ecological research based on geoinformation assessment and mapping of agrolandscapes of the dry-steppe zone of the Volgograd region made it possible to:

- analyze the current state of all components of the agrolandscape in the territory of the Frolovsky district of the Volgograd region using current aerospace information;
- establish spatial connections between components, as well as their influence on each other;
- carry out agro ecological assessment of agrolandscape stability for a number of indicators;
- assess the suitability of the agrolandscape for agricultural production.

Data obtained on geomorphometric characteristics, boundaries and areas of land, which can be used to identify potentially predisposed to degradation areas of arable land (P46, P49), to calculate the potential soil washing throughout the study site, thereby to determine the categories of land subject to erosion hazard. At this stage the significance of the obtained results is reflected in the optimization of the structure of the agrolandscape which is a decrease in the percentage of plowing of the landfill area due to potentially predisposed areas and an increase in the degree of protection by forest plantations to the optimal level.

Based on the fact that the optimal amount of forest plantations should be at least 4% of the arable land area, the area of the protective forest plantations should be 82,8 hectares instead of the existing 52,2 hectares. The main provisions of the organization of agrolandscapes were formulated by V.V. Dokuchaev [35] in the scientific work "Our steppes before and now." The existing system of agricultural production is plowing. The absence of medium-stabilizing lands (natural hayfields and pastures) can lead to complete degradation of the agrolandscape, which is already environmentally unstable [36].

The main element of the complex for optimizing the agrolandscape within the boundaries of the Frolovsky district of the Volgograd region is the creation of protective forest plantations on an area of 30 hectares, to conduct further surveys and select areas with favorable forest-growing properties, to design pasture-moving and hay-turning areas.

The planned changes in the structure of land, crop production areas will become a powerful means in the management and functioning of the agrolandscape, increasing its natural resource potential, and sustainability. Thus, at this stage the problem of optimizing the agrolandscape will be solved, as well as the problem of the preservation of the ecological framework of natural complexes in which, on the one hand, the maximum accounting and conservation of natural resources are taken into accoun; on the other hand, the limitation of anthropogenic impact should also be considered.

Reliable geographically coordinated data can be obtained quickly using space survey information, which significantly increase the speed of work, the relevance of the obtained data, and minimize the cost of work with field research.

Geographic information systems (GIS) are today the most modern and promising systems, and are designed to identify, map, fix, both certain objects and the processes that take place in them. The possibility of using satellite systems with certain technical characteristics remains an essential and obligatory condition. However, insufficient accuracy for a detailed study of objects of small areas (irrigated land, etc.), as well as possible errors in interpretation can not be ruled out.

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