

# Assessment of the Ecological Condition of Landscapes of the Volgograd Trans-Volga Region

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**Abstract**— the article analyses the main reasons for decrease in productivity and ecological stability of agricultural landscapes in the Volgograd Trans-Volga region: plowing of virgin lands, haphazard mode of pasture lands use, unsustainable agricultural land use, lack of forest reclamation measures. Authors define adaptive landscape approach to nature management. They showed the role of protective afforestation in stabilization and improvement of ecological situation in the territory. The paper presents the method of complex assessment of combined impact of natural and anthropogenic factors on landscapes condition of the Volgograd Trans-Volga region. The main criteria were as follows: soil suitability for forest growth (dominance of the group of soil suitability for forest growth in the landscape), protective forest cover of arable land, plough-disturbance, indices of agricultural land degradation (erosion, deflation and salinization). The method of zoning of ecological conditions by B. V. Vinogradov was considered as the basis for characteristics of landscapes environmental distress according to the following categories: norm, risk, crisis and disaster. The article revealed that the most part of landscapes of the Trans-Volga region (that makes 66.7%) is at a crisis stage, disaster – 28%. Category of norm accounts for 1.2%, at risk – 4.1% of the area of agricultural land in landscapes. On the basis of GIS technologies and previously developed original thematic maps (landscape, soil, forest reclamation, etc.) for the study region, the final map of ecological condition of landscapes of the Trans-Volga region was constructed. When optimizing the structure of farmland, first of all, it is necessary to focus on forest reclamation measures that will ensure the agro-ecological stability of landscapes, reducing the damage from anthropogenic impact on the territory. Authors suggest recommendations for planting protective forest plantations depending on the forest conditions of the territory and the ecological condition of the landscapes.

**Keywords:** *landscape assessment, ecological condition of landscapes, anthropogenic load, land degradation, soil suitability for forest growth, protective afforestation, mapping*

## I. INTRODUCTION

The Volgograd Trans-Volga region is characterized by a sufficiently high degree of economic development. Since long ago, the lands of the Trans-Volga region have been used for cattle grazing. In the late nineteenth century, there appeared a new form of land tenure – local shifting cultivation in narrow shallow gullies [1]. Soils of large narrow shallow gullies were used continuously, there were durum wheat, mustard and fodder grasses grown. Due to plowing of virgin lands in the 50-60s of the last century, increase in population, development of livestock industry, agriculture in the region was reoriented. Up to this time, there was cattle-breeding economy with little farming in narrow shallow gullies, and with land plowing it acquired a cattle-farming character. Separate crop rotation fields were located in close proximity to one another, large arable areas were formed. There was an outbreak of land deflationary desertification because of plowing of virgin lands, overgrazing and irrational use of agricultural land in the 70-80ies.

Currently, in the territory of the Trans-Volga region, the farmers, other individuals as well as farms continue to deplete land resources by aiming at obtaining maximum profit for themselves without maintaining potential of these lands. Intensive agriculture undertaken without regard to the laws of nature and society development, led to natural landscape destruction, enhancing land degradation and desertification, water regime degradation, loss of productivity and ecological stability of cultivated land. Arable and pasture lands were the most unprotected.

In order to make agricultural lands of the Trans-Volga region highly productive, an adaptive landscape approach to nature management is necessary, it is aimed at stabilizing structural and functional properties of the landscape by adapting economic activity to these properties [2-8]. In the complex of measures to stabilize and improve the environmental situation, protective afforestation is the most long-term action [9, 10]. Protective forest plantations are the main structural element of soil protection systems of

agriculture, which have an impact on natural factors and erosion-hydrological processes, thereby preventing or sharply reducing land degradation rate [11-13].

The assessment of ecological situation in the territory of the Volgograd Trans-Volga region unites landscapes into homogeneous groups distinguished by the need for forest reclamation actions.

## II. MATERIALS AND METHODS (MODEL)

To unite landscapes into groups, it is necessary to identify indicators characterizing landscapes according to their ecological condition [14-22].

TABLE I. NORMALIZATION OF INDICATORS OF LANDSCAPES ECOLOGICAL CONDITION

Indicators, %	Points			
	1	2	3	4
soil suitability for forest growth	100-75.1	75-50.1	50-25.1	25-0
Protective forest cover	3.0-2.26	2.25-1.6	1.5-0.76	0.75-0
Plough-disturbance	0-20	21-40	41-60	61-80
Index of erosion	0-6.25	6.26-12.5	12.51-18.75	18.75-25
Index of deflation	0-10	11-20	21-30	31-40
Index of salinization	0-15	16-30	31-45	46-60

In our case, the main criteria were soil suitability for forest growth (dominance of the group of soil suitability for forest growth in the landscape), protective forest cover of arable land, plough-disturbance, indices of degradation of agricultural lands (erosion, deflation and salinization) [23].

They are included in the soil and soil-erosion groups of indicators, which are the most important in characterizing zones of environmental distress [24].

The method of zoning of ecological conditions by B. V. Vinogradov was considered as the basis for characteristics of landscapes environmental distress by following categories: norm, risk, crisis and disaster. For each of the estimated indicators, we identified 4 equal ranges (table 1). Landscapes with an indicator of category "disaster" correspond to a score of 4, and landscapes of category "norm" – a score of 1.

## III. RESULTS AND DISCUSSION

Data on plough-disturbance and forest cover of the territory for each landscape area are presented in table 2.

Area of environmental norm is characterized by a weak level of degradation that corresponds to the background state of the land, area of ecological risk involves areas with a moderate level of degradation, ecological crisis zone involves areas with a severe level of degradation, and ecological disaster zone involve areas with a very strong level of degradation.

The universality of this scale lies in the fact that it regulates the modes of landscapes use, reduces anthropogenic load on a particular territory and environmental stress, optimizing production of agricultural products in accordance with the level of desertification [25].

Table 3 reflects calculation of integral index, carried out by finding the average value for 6 indicators. The value of final score is in the range from 2.3 to 3.3.

TABLE II. INDICATORS OF PLOUGH-DISTURBANCE AND AFFORESTATION OF ARABLE LAND IN LANDSCAPES

Landscape areas	Area, thousand hectares	Area of arable land, thousand hectares	Share of arable land, %	Area of PF, thousand hectares	Share of PF, %	Forest cover of arable land, %
I Privolzhsky	153.3	101.9	66.5	1.3	0.82	1.2
II Ilovatsky	119.5	54.3	45.4	0.9	0.72	1.6
Syrtovy	106.0	54.7	51.6	0.3	0.24	0.5
IV Yeruslano- Torgunsky	316.8	91.7	28.9	1.3	0.42	1.5
V Gorkovsko- Torgunsky	84.5	24.1	28.5	0.2	0.22	0.8
VI Dzhanibeksky	788.8	163.2	20.7	0.5	0.06	0.3
VII Zavolzhsky	450.0	224.7	49.9	2.9	0.64	1.3
VIII Eltonsky	205.4	57.5	28.0	0.1	0.05	0.2
IX Botkolski	108.4	3.1	2.8	0.0	0.000	0.0
X Priakhtubinsky	314.9	55.4	17.6	0.3	0.10	0.6
TOTAL	2647.6	830.5		7.7		

TABLE III. INDICATORS OF ECOLOGICAL CONDITION OF LANDSCAPES IN THE VOLGOGRAD TRANS-VOLGA REGION

Landscape areas	Area, thousand hectares	Share of groups of Soil suitability for forest growth		Forest cover		Plough-disturbance		Index of erosion		Index of deflation		Index of salinization		Average score
		%	Point	%	Point	%	Point	%	Point	%	Point	%	Point	
I Privolzhsky	153.3	13.3	4	1.2	3	66.5	4	8.89	2	24.17	2	33.47	3	3.0
II Ilovatsky	119.5	57.4	2	1.6	2	45.4	3	16.27	3	30.84	3	31.3	3	2.7
Syrtovy	106.0	12.7	4	0.5	4	51.6	3	16.27	3	30.84	3	31.3	3	3.3
IV Yeruslano-Torgunsky	316.8	7.2	4	1.5	3	28.9	2	13.39	3	18.64	2	43.75	3	2.8
V Gorkovsko-Torgunsky	84.5	0.0	4	0.8	3	28.5	2	2.65	1	6.43	1	56.19	4	2.5
VI Dzhanybeksky	788.8	0.8	4	0.3	4	20.7	1	3.14	1	4.97	1	46.9	4	2.5
VII Zavolzhsky	450.0	7.3	4	1.3	3	49.9	3	12.65	3	33.34	4	30.04	2	3.2
VIII Eltonsky	205.4	1.2	4	0.2	4	28.0	2	2.65	1	6.43	1	56.19	4	2.7
IX Botkulski	108.4	0.0	4	0.0	4	2.8	1	2.65	1	6.43	1	56.19	4	2.5
X Priakhtubinsky	314.9	2.0	4	0.6	4	17.6	1	2.56	1	5.26	1	44.71	3	2.3

As a result, ranges for mapping of landscapes ecological distress zones involve: 0-1 – "norm", 1-2 – "risk", 2-3 – "crisis", 3-4 – "disaster".

Based on values of the final score, according to the assessment of environmental distress, a map (figure 1) was drawn up, which clearly shows the distribution of zones in the landscape areas corresponding to the condition of "crisis" and "disaster".

The analysis of the developed map (figure 1) showed that the main part of the Trans-Volga region involves landscapes located in the zone of ecological crisis (I, II, IV, V, VI, VIII, IX, X), the area of which is 79% of the area of the studied territory.

Zone of ecological disaster accounts for 21%, it includes the Syrtovy and the Zavolzhsky landscape areas. Zones of ecological norm and risk are not reflected on the map within the boundaries of the considered landscape areas because of small contours not provided by the scale of the final maps, but they can be distinguished by the forest reclamation map, which combines the contours of granulometric composition of soils and groundwater levels.

To construct the final map of zones of landscapes ecological condition with distinguished zones of ecological norm and risk in the Global Mapper software, we overlapped previously developed original thematic maps

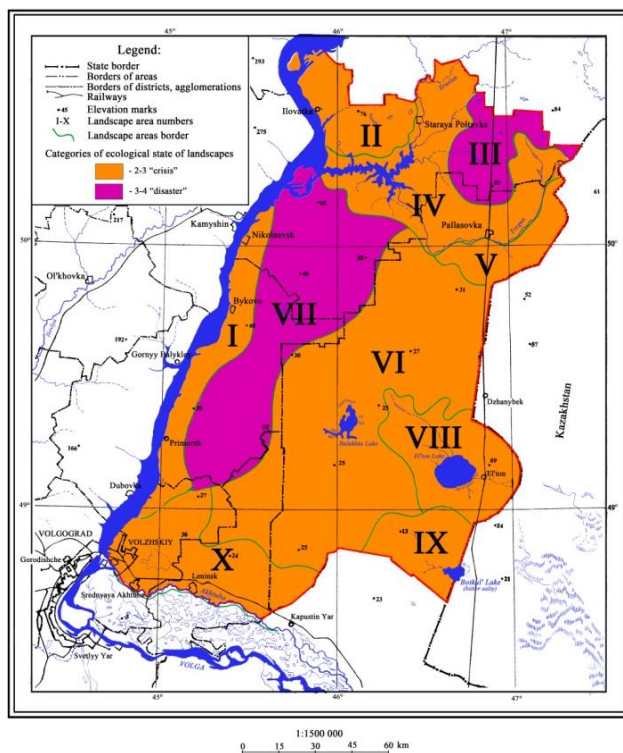


Fig. 1. Map of zones of environmental distress

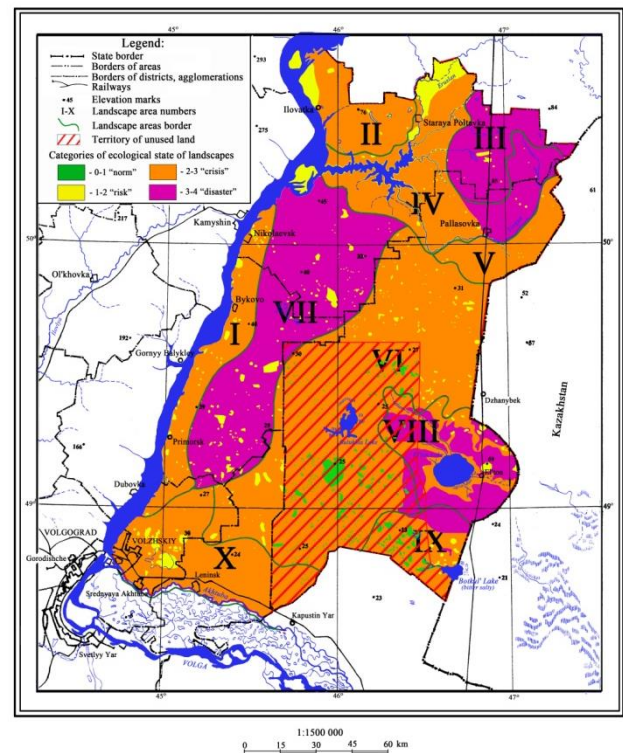


Fig. 2. Map of zones of ecological condition in the territory of the Trans-Volga region

landscape [26], forest reclamation [27], which consider the presence of small contours (according to granulometric composition of soils and groundwater level) and zones of environmental distress. As a result, we constructed a map of zones of ecological condition in the territory of the Trans-Volga region (figure 2) and defined their areas (table 4).

Analysis of data presented in table 4 showed that most of the landscapes are in crisis, averaging 66.7%, and ranging from 42.8% to 98.7%. In disaster – 28%, but within the boundaries of landscapes, this figure is quite high, for example, in the Syrtovy district, it reaches 98.7%. Category of norm accounts for 1.2%, at risk – 4.1% of the area of agricultural land in landscapes.

The zone of ecological norm includes local relief depressions in the form of numerous swallow holes, narrow shallow gullies and limans (long narrow lagoons) present on the territory of non-agricultural lands, which occupy an area of 31.7 thousand hectares of the area of landscape areas contour. They are characterized by greatest moisture supply due to redistribution of snow and meltwater on the microrelief, which contributes to the development of meadow vegetation on them and formation of fertile meadow-chestnut soils favorable for growth of tree and shrub species [28]. Since these lands are removed from agricultural use, numerous saucer-shaped depressions are not plowed and are in a relatively stable condition.

The environmental risk zone includes sandy land that is unstable and easily exposed to wind erosion. Such territories are located in the Volga landscape area on the sandy ridge along the Volgograd reservoir, in Ilovatskiy region in the Cherebaevskaya floodplain and the Kustarevskiy Peski area as well as in Yeruslan Torgunskiy region – the

Peschanoye area, and plowed up lands of swallow holes, narrow shallow gullies and limans (long narrow lagoons) and make up 107.8 thousand ha.

The zone of ecological crisis (1765.1 thousand hectares) is characterized by a high share of group 3 (soil suitability for forest growth) from 50 to 90% of the contour area. The main soils are chestnut saline medium-rich in complex with saline medium-deflated and medium-washed 10-25%. Afforestation of arable land in these landscapes varies from 0.2 to 1.6%, and due to high rates of plough-disturbance is unable to provide its full protection [21]. The salinization index of agricultural lands (30-56%) is characterized by high indicators, which has high values in all landscapes of the Trans-Volga region without exception.

The zone of ecological disaster (743 thousand hectares) corresponds to landscapes with a high share of participation of group 3 (soil suitability for forest growth) 55.9-63.4% of the area of the contour, and in total with group 4 is more than 90%. The main soils are chestnut saline medium-rich with saline and light chestnut small-and- medium-rich with saline of two- and three-membered complexes 25-50. Syrt landscape district with 52% of the plough-disturbance area has a low forest cover of arable land (0.5%), Zavolzhsy district also has a high plough-disturbance (50%) and low afforestation of arable land (1.3%). High indices of salinization are associated with processes of secondary salinization under irrigation.

When optimizing the structure of farmland, first, it is necessary to focus on forest reclamation measures that will ensure agro-ecological stability of landscapes, reducing the damage from anthropogenic impact on the territory.

TABLE IV. DISTRIBUTION OF ZONES OF ECOLOGICAL CONDITION IN LANDSCAPES OF THE TRANS-VOLGA REGION

Landscape areas	Area of landscape areas, thousand hectares %	Area of zones of ecological condition, thousand hectares %			
		<i>Norm</i>	<i>Risk</i>	<i>Crisis</i>	<i>Disaster</i>
I Privolzhsky	<u>153.3</u> 100%	<u>0</u> 0%	<u>8.0</u> 5.2%	<u>145.3</u> 94.8%	<u>0</u> 0%
II Ilovatsky	<u>119.5</u> 100%	<u>0</u> 0%	<u>13.0</u> 10.9%	<u>106.5</u> 89.1%	<u>0</u> 0%
Syrtovy	<u>106.0</u> 100%	<u>0</u> 0%	<u>1.3</u> 1.3%	<u>0</u> 0%	<u>104.7</u> 98.7%
IV Yeruslano- Torgunsky	<u>316.8</u> 100%	<u>0</u> 0%	<u>30.3</u> 9.5%	<u>211.0</u> 66.7%	<u>75.5</u> 23.8%
V Gorkovsko- Torgunsky	<u>84.5</u> 100%	<u>0</u> 0%	<u>1.1</u> 1.3%	<u>83.4</u> 98.7%	<u>0</u> 0%
VI Dzhanybeksky	<u>788.8</u> 100%	<u>24.9</u> 3.2%	<u>7.3</u> 0.9%	<u>754.2</u> 95.6%	<u>2.4</u> 0.3%
VII Zavolzhsy	<u>450.0</u> 100%	<u>0</u> 0%	<u>19.3</u> 4.3%	<u>0</u> 0%	<u>430.7</u> 95.7%
VIII Eltonsky	<u>205.4</u> 100%	<u>0.6</u> 0.3%	<u>11.9</u> 5.8%	<u>88.1</u> 42.8%	<u>104.9</u> 51.1%
IX Botkulski	<u>108.4</u> 100%	<u>6.0</u> 5.5%	<u>6.3</u> 5.9%	<u>71.2</u> 65.7%	<u>24.9</u> 22.9%
X Priakhtubinsky	<u>314.9</u> 100%	<u>0.2</u> 0.1%	<u>9.3</u> 3%	<u>305.4</u> 96.9%	<u>0</u> 0%
Total:	<u>2647.6</u> 100%	<u>31.7</u> 1.2%	<u>107.8</u> 4.1%	<u>1765.1</u> 66.7%	<u>743</u> 28.0%

On the part of lands belonging to the categories "norm" and "risk", forest plantations protection enables oasis (rain-fed and irrigated) agriculture, horticulture, afforestation. Areas with the most fertile unsalted soils are used as arable land. Land with shallow fresh or slightly mineralized

groundwater are used for gardens. Some of part of sands should be used for forests of protective and economic (recreational and economic) purpose.

On sabulous and sandy lands, in the category of norm and risk, in order to fix them and protect them from wind



erosion, it is advisable to grow pine (*Pinus sylvestris* L.), in inter-mud depressions with groundwater (GW) at a depth of 0.5–0.7 m – black alder (*Alnus glutinosa* L.).

Durability and estimate indicators of plantings in the territories in the category of crisis, decrease with increasing mineralization of GW, as their growth is accompanied by salt accumulation in the soil and GW, causing their drying. It is recommended to create plantations of drought- and salt-resistant tree and shrub species: low elm (*Ulmus pumila* L.), ash-leaved maple (*Acer negundo* L.), Tatar maple (*Acer tataricum* L.), common pear (*Pyrus communis* L.), oleaster (*Elaeagnus angustifolia* L.), Siberian pea shrub (*caragana arborescens* Lam.), Tatar honeysuckle (*Lonicera tatarica* L.), Golden currant (*Ribes aureum* Pursh), juneberry (*Amelanchier ovalis* Medikus), etc.

The most unfavorable forest growing conditions in terms of water and salt characteristics are typical of lands with inaccessible groundwater, which lack additional sources of moisture to atmospheric precipitation, they are in the category of disaster. In such conditions, it is impossible to grow full-fledged and durable protective forest plantations (except for irrigated areas). Here tree and shrub plantations quickly thin out and die if there is no additional moisture in the form of surface runoff or snow accumulation. However, in depressions with soil suitable for forest growth (in narrow shallow gullies, swallow holes and limans) it is possible to create forest outliers. In forest outliers such breeds as silver-chain (*Robinia pseudoacacia* L.), green ash (*Fraxinus lanceolata* Borkh.), low elm (*Ulmus pumila* L.), Tatar honeysuckle (*Lonicera tatarica* L.) and Tatar maple (*Acer tataricum* L.) grow well.

#### IV. CONCLUSION

In general, landscapes of the Trans-Volga region are in a state of crisis (66.7 %) and disaster (28%). This is due to unsatisfactory forest conditions, high agricultural development of the region in the northern and central parts and insufficient degree of forest-reclamation protection of farmland.

Thus, maintaining ecological balance of landscapes is an urgent task for the Volgograd Trans-Volga region, since plowing virgin lands, haphazard mode of use of pasture lands, depleting agricultural land use, lack of forest reclamation activities have led to increased land degradation processes. Measures to create protective forest plantations will improve ecological situation in the region as soon as possible.

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