Agricultural Landscape Quality as a Key Factor Fostering Environmentally Safe Use of Agricultural Lands in the Arid Steppe of the Altai Region

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Abstract. The current economic affairs and land and property matters in Russia, its regions, and settlements require adequate approaches, methods, and mechanisms for managing, planning, and organizing safe and sustainable agricultural land use. Many landowners and land users have significantly diverse and, in some cases, inconsistent interests regarding land resources. Therefore, the new organization of the agricultural land use system should consider the commercial interests of landowners and state priorities related to the sustainable use of land resources, their conservation, and the protection of the entire natural environment based on the qualitative features of contemporary agricultural landscapes. The object of this study, the arid steppe of the Altai Krai, has long been a farming territory of great significance. Within the borders of the dry steppe, nine municipal districts of the region are located. The subject of the study is the quality of agricultural land. The zoning was carried out, considering that the studied area is included in the joint distribution of water and wind erosion. The location of agrarian land considered as the study object, exceeds 1.7 million hectares. More than 1.4 million hectares of them are designated as potentially blown lands, and about 160 thousand hectares are erosion threatening ones. The best part of the arable land surface is subject to soil degradation. Forage lands suffer from the joint occurrence of corrosion. The total number of points calculated based on agricultural land quality indicators significantly differs in municipal districts. Thus, there are different land-use sustainability of economic entities and their environmental safety.

Keywords: Altai Krai · Agricultural land · Quality of agricultural landscape · Land use · Agricultural land-use security

1. Introduction
Specialists from the Altai Krai surveying expedition's soil party in 1957–1960 [15] and soil scientists from Moscow State University named after M. V. Lomonosov [2] launched the study of the agricultural land quality in the Altai Krai. In 1971, the project team's specialists drawing up the master plan of erosion control measures, carried out several land surveys. The erosion-preventing plan for the Altai Krai, approved by the Ministry of Agriculture of the RSFSR on August 27, 1971, became the basis for developing a package of erosion-preventing measures.

A. N. Kashtanov, in his monograph [8], described soil-erosion zoning of the Altai Krai. According to the conducted zoning, the studied area of the arid steppe is included in the zone of joint occurrence of water and wind erosion. A. N. Kashtanov, the Russian Academy of Sciences academician, identified three soil-erosion districts within the arid steppe. The East Kulundinsky soil blowing and soil erosion
district includes the Burlinsky district, the Khabarsky, German National, Suetsky, Blagoveshchensky, Rodinsky districts, and the western part of the Baevsky district. Vostochno-Kulundinsky region of soil blowing and erosion includes Volchikhinsky and Yegoryevsky districts, and western parts of the Romanovsky and Novichikhinsky districts. Prialeytsky district of soil blowing and corrosion comprises most of the Rubtsovsy district, the west part of the Pospelikhinsky district, and a small Kuryinsky district.

Contemporary studies [3, 9, 17] aim to organize agricultural land use, considering the current condition of the territory and farming landscapes' problems. The indicators characterizing the terrain, the amount of heat and precipitation, the type of agricultural land, the ratio of environment-forming land, and the degree of soil erosion and soil blowing are used as a study basis. Therefore, this study is topical. The work aims to study the quality features of a large agricultural territory of the Altai Krai related to the arid steppe. To achieve this goal, it is necessary to characterize the degree of degradation in the investigated area and determine its stability.

2. Materials and Methods

The natural zone's binding to the municipal districts' boundaries included in the investigated area allowed the authors to use official data and statistical materials characterizing the resources and ecological potential of the territory, its current conditions, and land use. The research is based on statistical and cartographic information contained in the official reports of the Federal Agency for State Registration, Cadastre, and Cartography "On the condition and use of the land fund in the Altai Krai," the Department of Environmental Protection "On the condition and environmental protection in the Altai Krai" dated back over the years, statistical reference books on agriculture, and literature data [10, 13]. The authors also used a variety of cartographic materials available in scientific publications and official authorities.

The primary information was arranged using the cartographic method, analysis, synthesis, and the monographic method, which are generally accepted in the study of stochastic systems. The study of causal relationships between the elements forming the studied object (land use in the Altai Krai) was carried out through system analysis [16, 18].

3. Results

The arid steppe subzone is confined mainly to the East Kulunda subprovince of the Kulundinskaya lowland plain (figure 1). The subzone's length in the meridional direction amounts to more than 300 km, in the sub-latitudinal – from 40 to 100 km, at an average of 70 km. The subzone includes nine administrative districts: Burlinsky, Khabarsky, German National, Suetsky, Blagoveshchensky, Rodinsky, Volchikhinsky, Egorievsky, Rubtsovsy. In this research, we will use the numbering of municipal districts in the figures and tables in the same sequence in which they are listed above. The total area of the arid steppe amounts to about 23.9 thousand km².
The rivers Bourla, Suetka, Kulunda, and Alei, cross the subzone in a southwestern direction. The Khabarsky and German National districts belong to the Burla river basin. The Suetka river drains the Suetsky district’s territory, Blagoveshchensky district – by the Kulunda river, Rodinsky district – by the Kuchuk river, Rubtsovsky district – by the Alei river. Temporary streams of the Volchikhinsky district end in the Kasmalinsky hollow of the ancient runoff, and those of the Yegoryevsky district – in the Barnaul hollow of the old runoff [1].

The diversity of soils is determined mainly by the Altai Krai [6, 7], which territory is located within two regions that are sharply different in natural terms (mountain and plain). Among the soils of the Altai Krai, almost all soil types of the Russian Federation’s latitudinal soil zones (sod-podzolic, gray forest soils, chernozems, and chestnut soils) are present, except for tundra soils and wet subtropics soils. In combination with them, intrazonal semi-hydromorphic soils (meadow-chernozem, meadow-chestnut soils) and bog soils are found. The variegation of the soil cover within the Priobsk plateau and the Kulundinskaya lowland plain is intensified by the halogen family (saline lands, sodic soils, stable soils), which form soil-cover complexes with zonal and intrazonal grounds surrounding them.

The leading branches of the economic activity are agriculture and the processing of agricultural (crop and livestock) products. Additionally, the chemical industry is developed in the Blagoveshchensky district, the woodworking industry, forestry – in the Volchikhinsky and Egorievsky districts, and machine building Rubtsovsky district.

The arid steppe's land fund within these administrative districts' boundaries, as of January 1, 2015, amounts to 2,426,085 ha and is presented in table 1.

| Land category                                | Area   | %    |
|----------------------------------------------|--------|------|
| Total area                                   | 2,426,085 | 100  |
| Agricultural land                            | 1,887,528 | 77.8 |
| Residential area                             | 37,554  | 1.5  |
| Industrial land                              | 55,188  | 2.3  |
| Lands of specially protected areas           | 154     | –    |

Figure 1. The location of the object of study in the Altai Krai. Source: [15].
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According to the data displayed in table 1, more than three-quarters of the arid Kulunda region (East Kulunda dry steppe subprovince) is occupied by agricultural landscapes consisting of farming lands. Another 14% of the territory is occupied by the forest fund's grounds, including extraordinary natural formations – ribbon pine forests, which perform an environmental function. The landscapes with pine forests are located in the ancient runoff's hollows – Burlinskaya, Kulundinskaya, Kasmalinskaya, and Barnaulskaya hollows. The most extensive pine forests are found in Volchkhisnky, Yegoryevsky, and Rubtsovsky districts. The districts are arranged in proportion to the decrease in the share of forest land.

The remaining five land categories account for slightly more than 8% of the territory. Moreover, almost 4% of the subzone is occupied by the lands of the water fund. Additionally, 3.8% remained on urbanized territories – industrial and residential lands. In the land structure of settlements that occupy 1.5% of the territory, the largest share (50%) is occupied by agricultural lands (gardens, individual plots). Up to a quarter of the lands of settlements are occupied by buildings and constructions. Industrial lands are represented by land plots occupied by energy facilities, automobile and railway transport, defense, communication, computer, and television facilities.

Based on the share of agricultural land, table 2 presents the grouping of administrative districts of the Altai Krai arid steppes according to the degree of agricultural land development. Five groups of lands were allocated within the investigated area according to the degree of agricultural land development.

| Groups | Degree of agricultural land development | Share of agricultural lands, % |
|--------|----------------------------------------|--------------------------------|
| I      | Very poorly developed                   | <40                            |
| II     | Poorly developed                        | 40–55                          |
| III    | Moderately developed                    | 55–70                          |
| IV     | Highly developed                        | 70–85                          |
| V      | Very highly developed                   | >85                            |

Source: Compiled by the authors.

We found no administrative districts with a shallow degree of agricultural development in the subzone. The Yegoryevsky district belongs to the poorly developed of farm terms. The Blagoveshchensky and Volchkhisnky districts are considered as moderately developed. Only the Rubtsovsky district may be classified as highly developed. Five districts (the Burlinsky, German National, Rodinsky, Suetsky, and Khabarsky districts) belong to highly developed ones. The degree of agricultural development in the administrative regions is determined by the arid steppe's natural complexes' structural features.

The current quality condition of the agricultural land of the arid steppe is presented in table 3. The assessment is based on the Federal Agency for State Registration, Cadastre, and Cartography materials.
Table 3. The quality of agricultural lands in the arid steppe of the Altai Krai (as of January 01, 2015).

| No | Quality of lands | Area |
|----|------------------|------|
|    |                  | Thous. | %   |
| 1  | Agricultural lands, total | 1,741.7 | 100 |
| 2  | Including erosion-threatening of these | 158.3 | 9   |
|    | Eroded           | 128.5  | 7    |
|    | Slightly-eroded  | 112.3  | 6    |
|    | Medium-eroded    | 15.8   | 1    |
|    | Severely-eroded  | 0.4    | –    |
| 3  | Including potentially blown land, of these | 1,427.7 | 82  |
|    | Blown land       | 1,080.0 | 62  |
|    | Slightly blown   | 964    | 55   |
|    | Moderately blown | 110.6  | 6    |
|    | Severely blown   | 5.4    | 0.3  |
| 4  | Including wetland, of these | 11.4 | 0.7 |
|    | Inundated        | 11.0   | 0.6  |
|    | Noninundated     | 0.4    | 0.1  |
| 5  | Including saline land | 98.8 | 6   |
| 6  | Including sour land | 7.4 | –   |

Source: Compiled by the authors.

The data above concluded that erosion processes do not have a wide geographical distribution in the arid steppe. Eroded agricultural land makes up only 9% of its territory. At the same time, three-quarters of erosion-threatening lands were transformed into eroded ones. Slightly washed soils prevailed (86%). The remaining area of eroded land went into the category of medium-washed. They account for 15.8 thousand ha or less than one percent of the total agricultural land area. The limited development of erosion in the arid steppe is explained by a small vertical and horizontal dissection and small angles of the surface slope (not more than 1.5°).

Based on the above data, large areas of the arid steppe are subject to destruction by the wind. The development of soil blowing processes is facilitated by a high degree of plowing, flat-wavy terrain, light granulometric composition of soils, arid climate, and low soil moisture reserves in the arable layer of the ground [4, 11, 12, 18]. Potentially blown land territories include more than 80% of the agricultural land. More than three-quarters of potentially blown agricultural lands became blown, of which about 90% of the lands were slightly blown, and 10% were moderately blown. The calculation of potentially blown agricultural land shows that the farming land of the investigated areas is marked with a "very high" (89%–94%) and "high" (68%–79%) share of potentially blown agricultural land. The first group of districts includes the German, Rodinsky, Volchikhinsky, and Yegoryevsky districts, and the second group contains the remaining five districts (figure 2).
The share of potentially blown land

Figure 2. The share of blown agricultural land in the administrative districts of the arid steppe. Source: Compiled by the authors.

Despite the high share of blown agricultural land, the Rubtsovsky district is marked with a “very low” (10%) share of blown land. The Suetsky district, which is in the same group as the Rubtsovsky district, belongs to districts with an “average” (41%) share of blown land. The Khabarsky district belongs to districts with a “high” (75%) share of blown agricultural land. The remaining six districts are included in the group with a “very high” (83%–95%) share of blown land. However, four districts (German, Rodinsky, Volchikhinsky, and Yegoryevsky districts) have a very high share of blown agricultural land. Two more districts (Blagoveshchensky and Burlinsky districts) belong to the group with a high proportion of potentially blown lands (figure 3).

Figure 3. The share of blown land in administrative districts of the arid steppe. Source: Compiled by the authors.
The absence of a direct correlation between the share of blown lands and the share of potentially blown agricultural lands is explained by the different resistance of soils to blowing, which depends on the particle size of soil, moisture reserves in the ground, the number of days without precipitation (or with rainfall less than 5 mm), the number of days with dry winds, dust storms during the blowing period (April-May), the number of days with snowstorms affecting the blowing of the soil in the winter period, the share of field-protecting forest stands, etc.

4. Discussion
On the ground of the agricultural land quality assessment, reliable information was obtained on the ratio of the areas with eroded and blown lands with various degrees of degradation (weak, medium, strong), and on areas that remained uneroded unblown. Using data on the ratio of the agricultural land area (arable land, hayfields, pastures) that have changed in quality and remained unchanged, that is, not subject to the influence of erosion and blowing, the authors conducted a critical assessment of the land quality, which, although indirectly, allows us to form an opinion on the stability of a large territory under agricultural land and its environmental safety.

To determine the stability of the investigated districts' agricultural landscapes in the arid steppe, we used data on the non-eroded (non-blown) share, the share of weakly, moderately, and highly eroded, and weakly, moderately, and positively blown agricultural lands. According to the area's share or specific gravity with one or another indicator of land quality from the total area of agricultural land, five classes or groups of land were identified: very low, low, medium, high, and very high. Each land group is assigned a score from 1 to 5. For example, the smaller the proportion of non-eroded arable land or the higher the balance of weakly (moderately or strongly) eroded arable land, the more the agricultural landscape deviates from the equilibrium state (i.e., from the initial one) and the more its stability changes. Therefore, the higher the total number of points for all quality indicators, the less sustainable the geosystem (territory).

The total number of points calculated based on agricultural land quality indicators is presented in table 4.

| Table 4. The total number of points calculated based on agricultural land quality indicators. |
|---------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Agricultural land              | Administrative districts | 1* | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Erosion-threatening lands       | Arable land            | 3  | 3 | 3 | 4 | 3 | 3 | 3 | 5 |   |
|                                 | Hayfields              | 4  | 4 | 4 | 4 | 8 | 4 | 5 | 4 | 4 |
|                                 | Pastures               | 4  | 4 | 5 | 4 | 6 | 10| 5 | 4 |   |
|                                 | Sum                    | 11 | 11| 11| 17| 11| 14| 17| 12| 13|
| Potential blown lands           | Arable land            | 13 | 9 | 12| 10| 12| 13| 12| 4 |   |
|                                 | Hayfields              | 9  | 5 | 7 | 6 | 9 | 13| 6 | 16| 4 |
|                                 | Pastures               | 8  | 5 | 12| 8 | 7 | 11| 10| 15| 12|
|                                 | Sum                    | 30 | 19| 31| 24| 28| 36| 29| 43| 20|
|                                 | Total score            | 41 | 30| 42| 41| 39| 50| 46| 55| 33|

Source: Compiled by the authors.

Based on the above data, it is possible to assume that the erosion resistance is significantly higher than blowing arid steppe (the total score is 3). Based on the sum of the points, the stability of arable land in the Suetsky and Rubtsovsky districts is less than in other areas. The area under hayfields is less stable than the site under arable land. The pastures’ territory is even less stable than the size of arable land and hayfields, as it appears from a slight increase in the total number of points. A more noticeable decrease in pasture territory sustainability is noted in the Suetsky and Volchikhinsky districts compared to other
districts.

The anti-blowing resistance of arable land is slightly lower than that of hayfields and pastures. Although the degree of arable land stability in administrative districts significantly varies, the total number of points for arable land ranges from 4 to 13. The highest degree of arable land resistance to the blowing effects is observed in the Rubtsovsky district. The more massive granulometric composition of soils, higher moisture reserves, and other soil and climate features. The least resistible are the arable lands in the Burlinsky and Volchikhinsky districts where sandy soils are widespread with less moisture and a large number of days with dry winds and strong winds. The minimal stability of the territory of hayfields and pastures is characteristic of the Yegoryevsky district. The Khabarsky, Suetsky, and Volchikhinsky districts have a higher degree of hayfield stability, and the Khabarsky and Blagoveshchensky districts are sustainable pasture territories.

The highest blowing resistance is in evidence on the Khabarsky and Rubtsovsky districts’ agricultural lands, and the lowest – on those of the Rodinsky, Volchikhinsky, and Yegoryevsky districts.

A very high degree of agricultural land resistance to the combined effects of erosion and blowing is characteristic of the Khabarsky and Rubtsovsky districts. The total points are 30 and 33. A shallow degree of agricultural land resistance to the development of erosion and blowing is observed in the Rodinsky and Yegoryevsky districts (the sum of points is equal to 50 and 55).

The ranges of the territorial stability degree under agricultural lands toward erosion, blowing processes, and joint occurrence are presented in table 5.

| Degree of stability | Stability groups, points |
|---------------------|--------------------------|
|                     | erosion | blowing | both erosion and blowing |
| Very low            | >15     | >36     | >49                      |
| Low                 | 14–15   | 36–30   | 49–43                    |
| Medium              | 13–14   | 30–24   | 43–27                    |
| High                | 12–13   | 24–18   | 37–31                    |
| Very high           | <12     | <18     | <31                      |

Source: Compiled by the authors.

Statistically, the features of stability indicators of arid steppe agricultural lands (table 6) confirm that all the studied areas’ rural lands are more resistant to erosion. This is indicated by the narrow range of variation and the minimum values of variance and standard deviation, which measure the studied attribute's dispersion. Judging by the variation coefficient's amount, the attribute variability is considered (V = 15%).

| Statistical characteristics | Stability, points |
|-----------------------------|------------------|
|                             | erosion | blowing | both erosion and blowing |
| Range of variability, R     | 11–17   | 12–43   | 25–55                    |
| Mean, x                     | 13      | 28      | 41                       |
| Dispersion, S²              | 6       | 82      | 86                       |
| Standard deviation          | 2       | 9       | 9                        |
| Sampling means an error, Sx | 1       | 3       | 3                        |
| Relative sampling mean error, Sx,% | 5 | 11 | 7 |
| Coefficient of variation, V%| 15      | 32      | 22                       |

Source: Compiled by the authors.
Concerning blowing and the combined effect of erosion and blowing, the indicators of agricultural land stability change over a broader range of variation. The degree of attribute variation is considered significant (V = 22% and 32%).

The assessment of the significance of differences between the arithmetic means values for each rank (gradation) of agricultural land stability to the combined effects of erosion and blowing was determined by the ratio of the mean difference (d) to its error Sd, i.e., by the criterion t. The assessment was conducted according to B. A. Dospekhov [5]. The evaluation compares the actual value of the criterion t with theoretical significance levels at 5% and 1%.

The actual value of the t-criterion is determined for all five ranks of agricultural land stability. A comparison of actual and theoretical values of t suggested that the criterion for all gradations of agricultural land stability is more than theoretical values at 5% and 1% significance levels; that is, the difference is significant.

5. Conclusion
Summarizing the above, the environmental safety of agricultural land use depends on many factors. The main ones include the terrain, agricultural land type, erosion, and blowing development. Moreover, the granulometric composition of soils, soil moisture reserves, wind speed, degree of climate aridity, and other factors should be considered. Being aware of the current condition of the developed agricultural territory and monitoring the quality indicators of land use, it is possible to manage the above characteristics. The analysis of the farm landscape quality in the arid steppes of the Altai Kria exhibited its heterogeneity within the selected soil and climatic zone. The investigated area is more resistant to water erosion and has much less resistance to blowing and joint occurrence. These malicious processes should be regulated through the organization of sustainable and safe agricultural land use on an ecological-landscape basis.

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