DOI: 10.12731/2658-6649-2022-14-2-338-355
UDC 332.2

AGRICULTURAL LAND PROTECTION AS A BASIS OF SUSTAINABLE LAND MANAGEMENT IN THE DRY STEPPES OF ALTAI KRAI

V.L. Tatarintsev, Yu.S. Lisovskaya, L.M. Tatarintsev

Sustainable development of the entire biogeocoenosis area is considered a driving factor in ensuring agricultural land protection. The balance between the use of ecosystems, their anthropogenic transformation, and protection should be based on optimizing the use of the natural environment. Anthropogenic activity in agriculture is conducted within the boundaries of the formed landscapes that are subsequently transformed into agricultural landscapes. Agricultural landscapes, in turn, are not resistant to external and internal factors and, thus, need protection. More than 80% of agricultural land in Altai Krai subject to varying degrees of degradation need sustainable development. The nutrient inputs recommended by the regional agrochemical service have not been observed over the past 25 years of farming in rural areas. Moreover, there are no projects for organizing the plots of agricultural enterprises taking into account the landscape specifics. Unfortunately, there are no sufficient conditions for organizing organic land use. Adaptive landscape land management can serve as a basis for the protection of agricultural land and a viable mechanism for the sustainable development of agricultural land use. Based on the example of agricultural landscapes located in the arid steppes of Altai Krai, we revealed the trends of sustainable development of agricultural land use. At the first stage, we evaluated the agro-ecological role of the physical and geographical conditions of the territory and the state of agricultural landscapes. At the second stage, we carried out agro-ecological zoning of the research object. Finally, at the third stage, we proposed ways to optimize and protect agricultural land in the arid steppe.

Keywords: *Altai Krai; arid steppe; sustainable development of agricultural land use; agricultural landscapes; agro-ecological zoning; agricultural land protection*

For citation. *Tatarintsev V.L., Lisovskaya Yu.S., Tatarintsev L.M. Agricultural Land Protection as a Basis of Sustainable Land Management in the Dry Steppes of Altai Krai. Siberian Journal of Life Sciences and Agriculture, 2022, vol. 14, no. 2, pp. 338-355. DOI: 10.12731/2658-6649-2022-14-2-338-355*

ОХРАНА ЗЕМЕЛЬ СЕЛЬСКОХОЗЯЙСТВЕННОГО НАЗНАЧЕНИЯ КАК ОСНОВА УСТОЙЧИВОГО УПРАВЛЕНИЯ ЗЕМЛЕПОЛЬЗОВАНИЕМ В ЗАСУШЛИВЫХ СТЕПЯХ АЛТАЙСКОГО КРАЯ

В.Л. Татаринцев, Ю.С. Лисовская, Л.М. Татаринцев

Устойчивое развитие всей территории биогеоценоза считается движущим фактором в обеспечении охраны земель сельскохозяйственного назначения. Баланс между использованием экосистем, их антропогенной трансформацией и охраной должен основываться на оптимизации использования природной среды. Антропогенная деятельность в сельском хозяйстве ведется в границах сформировавшихся ландшафтов, которые впоследствии трансформируются в агроландшафты. Агроландшафты, в свою очередь, неустойчивы к внешним и внутренним факторам и поэтому нуждаются в охране. Более 80% сельскохозяйственных угодий Алтайского края, подверженных разной степени деградации, нуждаются в устойчивом развитии. Внесение питательных веществ, рекомендованное региональной агрохимслужбой, за последние 25 лет ведения сельского хозяйства в сельской местности не соблюдалось. Кроме того, отсутствуют проекты организации участков сельскохозяйственных предприятий с учетом ландшафтной специфики. К сожалению, нет достаточных условий для организации органического землепользования. Адаптивное ландшафтное управление земельными ресурсами может служить основой для охраны сельскохозяйственных угодий и действенным механизмом устойчивого развития сельскохозяйственного землепользования. На примере агроландшафтов, расположенных в засушливых степях Алтайского края, были выявлены закономерности устойчивого развития сельскохозяйственного землепользования. На первом этапе мы оценили агроэкологическую роль физико-географических условий территории и состояния агроландшафтов. На втором этапе проводили агроэкологическое районирование объекта исследования. Наконец, на третьем этапе нами были предложены пути оптимизации и защиты сельскохозяйственных угодий в засушливой степи.

Ключевые слова: *Алтайский край; засушливая степь; устойчивое развитие землепользования сельскохозяйственного назначения; агроландшафты; агроэкологическое районирование; охрана земель сельскохозяйственного назначения*

Для цитирования. *Татаринцев В.Л., Лисовская Ю.С., Татаринцев Л.М. Охрана земель сельскохозяйственного назначения как основа устойчивого управления землепользованием в засушливых степях Алтайского края // Siberian Journal of Life Sciences and Agriculture. 2022. Т. 14, № 2. С. 338-355. DOI: 10.12731/2658-6649-2022-14-2-338-355*

Introduction

The sustainability of the agroecosystem depends on the measures related to the protection of agricultural land carried out based on the agricultural landscape optimization. The principles of optimization and organization of agroecosystems are described in detail in agro-ecological literature [5; 6; 9; 10; 11; 15; 18; 19; 20; 22;]. However, the current challenges (an increase in the export of agricultural products, sustainable development of rural areas, organic and digital farming), determining the growth vector of agricultural land use both in Russia (by geographical areas) and in Altai Krai (by natural zones) require further research of modern methods and mechanisms for the development of agricultural land use. The arid steppe Kulunda deserves particular attention, the territory of which is limited by the amount of precipitation and the sum of temperatures. Furthermore, the natural complexes of this territory (landscapes) are the least resistant to anthropogenic impact [16; 17]. Therefore, the research problem is highly relevant for increasing the sustainability of agricultural land use as the basis of the anthropogenic component of geosystems.

Consequently, the research goal was the agro-ecological substantiation of measures for protecting agricultural lands of the arid steppes of Altai Krai, which are the basis for the sustainable development of agricultural land use.

To achieve this goal, we conducted a comprehensive agro-ecological assessment of agricultural land related to the research object. Additionally, we determined the agro-ecological state of the agricultural land, taking into account the degree of soil erosion and the monitoring of soil and agro-climatic parameters of adequate fertility. As a final step, we assessed the sustainability of agricultural landscapes in the arid steppe Kulunda, conducted agro-ecological zoning of the territory, and outlined the development pattern of agricultural land use considering protective measures.

Considering the studied agrarian significant territory, the following data were obtained for the first time:

- Agro-ecological assessment was carried out, and the ecological state of agricultural lands was determined, considering its deflation;

- Assessment of the sustainability of agrarian landscapes and agro-ecological zoning of the territory was made;
- Measures aimed at improving the sustainability of agricultural land were proposed.

Materials and methods

The research is based on comprehensive surveys of the territory conducted by the Altai Scientific Research Institute for Land Design (*AltaiNIIgiprozem* JSC) dating to 1969–1999. The map of quaternary deposits [8], as well as the works of Adamenko [2] and Zanin [6], allowed us to describe the geological conditions of the research area [2; 7].

Additionally, the study relies on the ecological-landscape method, which is used to study the behavior of agricultural landscapes; it can be attributed to as a type of system analysis. The system approach aims to study deterministic and probabilistic systems. The latter include biogeocoenosis modified due to anthropogenic activity: agricultural landscapes with ecological-landscape features differentiated by types of agricultural land.

Also, we used a cartographic method applying GIS technology to systematize the quantitative and qualitative characteristics of agricultural land. The obtained unique maps of natural-assessment, agro-ecological, and other zoning of the arid steppe area are based on digitized thematic maps related to different field research periods.

In addition, we applied (1) the historical method (analysis of biogeocoenosis and agricultural landscapes); (2) methods of mathematical processing of primary data; (3) analysis and synthesis methods; (4) modeling of processes and objects; and (5) the abstract-logical method in the structural analysis of the territory and the typification of lands [12; 21].

Results

The territory covered by the arid steppe landscapes of Western Kulunda was chosen as a research object. Table 1 presents the land fund of the arid-steppe Kulunda. More than 70% of the arid-steppe Kulunda (Western Kulunda arid-steppe subprovince) is represented by agricultural landscapes (agricultural lands). The rest of the area is assigned to the lands of the forest fund, which includes unique ribbon pine forests performing a nature conservation function. These landscapes are located in the southern part of the arid-steppe Kulunda [14]. Geographically, they are located in the Klyuchevsky, Mikhailovsky, and Uglovsky municipal districts, forming a specific physical and geographical area that differs from other districts of Western Kulunda.

Table 1.

Land fund of arid-steppe Kulunda

Land category	Area	
	thou. ha	%
Total area	1827.9	100
Lands of agricultural use (I)	1285.0	72.6
Settlement lands (II)	21.0	1.1
Industrial lands (III)	10.3	0.6
Lands of specially protected territories and objects (IV)	0.01	–
Forest lands (V)	409.6	22.4
Water fund lands (VI)	32.1	1.8
Reserve lands (VII)	27.9	1.5

The land fund structure in the administrative districts of the arid-steppe Kulunda (Table 2) also indicates the predominance of agricultural land in all regions, which are practically everywhere subject to degradation processes.

Table 2.

Land fund by municipal districts, thousand hectares/%

Land category	Municipal districts*						
	1	2	3	4	5	6	7
Total area	143.2/ 100	208.3/ 100	178.2/ 100	198.0/ 100	304.3/ 100	311.4/ 100	484.5/ 100
I**	137.6/ 96.2	177.2/ 85.1	171.2/ 96.1	180.3/ 91.3	230.0/ 75.5	159.9/ 51.3	228.5/ 47.5
II	1.9/1.3	1.8/0.9	1.3/0.7	2.3/1.2	2.8/0.9	5.0/1.6	5.9/1.2
III	0.3/0.2	2.1/1.0	1.1/0.6	2.2/1.1	2.2/0.7	1.8/0.6	0.6/0.1
IV	–	–	–	–	0.005/–	0.005/–	–
V	2.7/1.9	1.9/0.9	0.6/0.3	1.0/0.5	49.0/16.1	126.6/40.6	227.8/47.0
VI	–	10.7/5.1	1.4/0.8	4.5/2.3	8.4/2.8	7.1/2.3	–
VII	–	5.9/2.8	0.3/0.2	2.5/1.3	0.2/0.01	0.6/0.2	18.2/ 3.8

Note: *) 1–7 – German National District, Slavgorodsky, Tabunsky, Kulundinsky, Klyuchevsky, Mikhaylovsky, and Uglovsky districts; **) I–VII – land category; see Table 1.

We assessed the current structural and functional organization of agroecosystems to stabilize agricultural landscapes and increase their stability (productivity). The analysis is based on the quality of agricultural land within the research territory.

Agricultural lands predominate in the structure of agricultural landscapes. Therefore, arable land amounts to 71% of agricultural land, the share of pastures – 20%, fallow lands, and hayfields – 8.5%, and about 0.05% is occupied by perennial plantations.

We analyzed the structure of the agricultural lands of the research object in the municipal areas of the arid-steppe Kulunda and concluded that their area in the agricultural landscape increases as the research territory moves from north to south. In the same direction, there is a decrease in the share of agricultural land and arable land. The share of fodder land, land under trees and shrubs, protective forests, and swamps, on the contrary, is increasing.

As for agricultural land, we divided the municipal districts of the arid-steppe Kulunda into classes according to the degree of agricultural reclamation (see Table 3).

Table 3.

Classes of municipal districts according to the degree of agricultural reclamation

Class	Degree of reclamation	Agricultural land in relation to the area of the district, %
I	Very slightly reclaimed	<40
II	Slightly reclaimed	40–55
III	Moderately reclaimed	55–70
IV	Highly reclaimed	70–85
V	Very highly reclaimed	>85

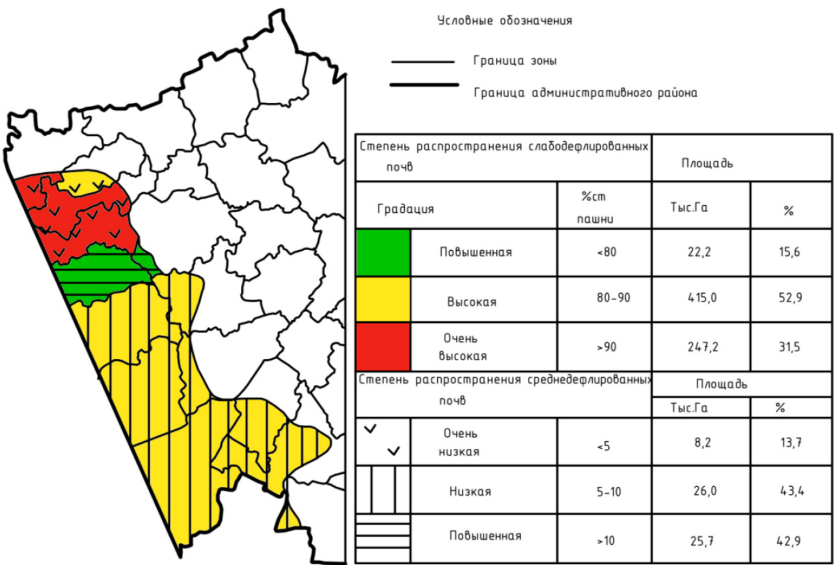

Fig. 1. Map of soil blowing of arable land

According to the classification, Mikhailovsky and Uglovsky districts are "slightly reclaimed," Klyuchevsky is considered a "highly reclaimed" area, German National District, Slavgorodsky, Tabunsky, and Kulundinsky districts are "very highly reclaimed" territories.

Arid-steppe Kulunda is a flat plain with slopes not exceeding 0.5°. There is almost no erosion there, and erosion threatening lands is only 1.2% of the agricultural land area. The same cannot be said for the other process – soil blowing (Fig. 1). The reasons for the high blowing hazard are (1) the light particle size distribution, (2) low precipitation in late spring and early summer, (3) wind speed of more than 15 m/s, and (4) predominance of arable land in the structure of the land. The blown agricultural land area covers more than 1 million hectares or almost 90% of the research territory (Table 4).

Table 4.

Quality of agricultural lands, thousands hectares

Quality	Agricultural lands			
	total	including		
		arable	hayfields	pastures
Total area	1227.3	866.5	50.3	247.3
Erosion-threatening, total of these:	1093.5	862.0	40.6	152.2
Eroded, total	1070.0	843.4	40.6	148.5
Slightly-eroded	943.5	767.4	28.6	115.8
Medium-eroded	121.4	76.5	10.1	30.1
Severely-eroded	5.1	2.0	1.4	1.7

Based on the classification of soils according to environmental stress [3], slightly-eroded soils belong to the "moderate risk" zone, medium-eroded soils – to the "high risk" zone, and severely-eroded soils – to the "moderate crisis" zone. Next, we calculated the weighted average score of the environmental stress of the territories of municipal districts, where we considered the relative contribution to the structure of arable land soils of different erosion degrees. Non-eroded soils and a score of 0 corresponded to the "norm"; scores 1, 2, and 3, respectively – slightly-eroded, medium-eroded, and severely-eroded soils. In the districts, the weighted average score of environmental stress fluctuates in the range of 1.02–1.30, which corresponds to the state of the "moderate risk" zone. In the areas with a lower anthropogenic load on land, the score varies from 1.02 to 1.09, and the agro-ecological state of the land is more stable compared to other lands, whereas in the Kulunda district, the score of environmental stress was 1.25, and in the German national district – 1.3.

Based on the agro-ecological assessment of the erosion of the soil cover of arable land, the natural resource potential of the soils of the arid steppe zone should be reduced by 23%–29% in districts [1]. This situation is due to the fact that the yield of grain crops in eroded areas is 25%–30% lower compared to the initially non-eroded soils. The productivity of natural hayfields and pastures decreased by about the same amount.

The productivity of the chestnut soils of the arid-steppe Kulunda decreased due to the loss of humus and the scattering of the upper humus horizon, which initially ranged from 0.33 m in the Mikhailovsky district to 0.48 m in Klyuchevsky district on chestnut soil. Soil-blowing reduced the thickness of the humus layer by 20%–49%; that is, the losses ranged from 7 to 24 cm of the upper fertile layer. Before anthropogenic impact on the territory, chestnut soil contained almost 3% of humus in horizon A, whereas now this value decreased to 1.6%–2.1%.

Some studies [4; 13] showed that the loss of 0.1 m of the humus layer or 1% of humus threatens with lost profit, in kind, equal to 0.3 t/ha of grain crops. In the study area, grain losses are about 0.5 t/ha, which indicates degradation of the agro-ecological state of chestnut soils.

On slightly-eroded soils, the yield of grain crops decreases by almost 25%, on medium-eroded soils – by 25%–40%, and on severely-eroded soils – by 40% or more. Therefore, it is economically inconvenient to use severely-eroded lands in agriculture since their productivity decreased by almost half, and the cultivation costs remained at the level of lands not subject to degradation. In our opinion, strongly eroded soils should be “preserved” by transferring them to fallow or sowing perennial grasses.

Sustainable functioning of the territory is associated with anthropogenic impact on the soil cover, agricultural landscape, and biosphere in general. These factors led to the aggravation of regional agro-ecological problems associated with massive land degradation, deterioration of their ecological state and functional capabilities. This fact is evidenced by the ecological assessment indicators of the territory of the arid-steppe Kulunda presented in Table 5.

The agro-ecological value of the soils of Western Kulunda is relatively low; furthermore, it will continue to deteriorate because stereotypes of using these lands remained, which caused the desertification of this territory.

The arid steppe has a remarkably high plowing degree of land resources. In the German National District, where 87% of agricultural land is arable land, the plowing degree is exceptionally high. The Mikhailovsky and Uglovsky districts are characterized by relatively low plowing capacity since their territory is naturally covered by forest; there are few arable territories.

Table 5.

Ecological assessment of land use

Municipal districts	Plowing degree, %	Arable land erosion index, score	Index of erosion hazard in crops structure	Index of anthropogenic load, score	Index of ecological stability	Index of landscape state
German National District	87	1.30	0.51	3.89	0.18	0.12
Slavgorodsky	60	1.02	0.68	3.53	0.27	0.20
Tabunsky	73	1.04	0.66	3.71	0.25	0.17
Kulundinsky	71	1.25	0.61	3.66	0.24	0.14
Klyuchevsky	52	1.09	0.71	3.50	0.28	0.07
Mikhaylovsky	31	1.05	0.71	3.35	0.32	0.24
Uglovsky	21	1.09	0.46	3.32	0.42	0.62

Land reclamation based on light soils in the past contributed to the development of wind erosion. On arable land, the erosion index is equal to one; it corresponds to the wide distribution of slightly-eroded soils. This index is even higher in the Kulunda municipal district since medium- and severely-eroded soils are widespread on arable land. The irrational structure of cultivated areas also promotes the development of wind erosion.

Therefore, almost all agricultural crops prevailing in the structure of the cultivated areas of the considered territory do not protect the soil from wind-blowing, and what is most important, do not provide the reproduction of organic matter, in particular, its labile part. Organic matter is not introduced into the soils from the outside, the balance becomes negative, and their agro-ecological value decreases, since humus, mineral nutrients, and moisture are lost.

For instance, in the Kulundinsky district, Tabunsky district, and especially in the German National District, the lands experience a significant anthropogenic load (score close to 4), confirmed by the calculated environmental indicators. In other areas of the subzone, the load is reduced to an average (score 3). In other areas of the subzone, the load decreases to an average one (point 3). Only the territory of the Uglovsky district is environmentally sustainable. The ecological stability index is below 0.33.

The index of the landscape state, which is calculated by correlating environmentally stabilizing landscape components, indicates the catastrophic situation of agricultural landscapes. These territories are devoid of natural (quasi-natural) components that improve the landscape condition and landscape functioning, thereby increasing its agro-ecological value in general and its components, in particular. The state of the landscape state is considered optimal when the index of the landscape state rate exceeds 0.80.

Based on the analysis of the agro-ecological state of the land, we can say that agricultural crops respond differently to the environmental conditions (heat and moisture supply, agrophysical characteristics of soils, etc.), providing them with different productivity. To ensure the sustainable development of agricultural land use, adapted to the impact of agro-ecological factors, one should distinguish agro-ecological types of land by territory and set limits on their use and optimization while simultaneously solving the problems of land protection.

We grouped agro-ecological classes of lands, ranking them according to the principle of complication of factors limiting the cultivation of grain crops, considering how to overcome them. The selection of land types within the research territory was carried out based on the compliance of the environmental parameters of the territory (moisture supply, erosion hazard, wind-blowing, waterlogging, alkalinity) with the life-sustaining environment of grain crops.

Limiting factors became the basis for identifying agro-ecological subgroups. Determining land classes, we considered the lithology of parent rocks (alluvial and loess), subclasses – their particle-size determination. The steepness of the slopes served as the basis for distinguishing land species and the proximity of microclimatic conditions – for distinguishing subspecies.

Therefore, in the arid-steppe Kulunda, we identified five agro-ecological groups of lands (Fig. 2). The first group includes chestnut and dark chestnut automorphic non-eroded soils on high and low-lying drained (sedentary) plains. The group consists of two classes of land: (1) chestnut and dark chestnut automorphic soils on elevated drained (sedentary) loess plateaus, composed of windblown alluvial deposits of the Krasnodubrovskaya suite; (2) chestnut and dark chestnut automorphic soils on low (drained) flat ancient alluvial sandy and sandy loam plains of the Middle Quaternary Age, referred to the Kulunda suit. The group covers almost 19 thousand hectares, 15.9 of which are located in the German National District.

The second group includes chestnut and dark-chestnut eroded soils of low-lying ancient alluvial plains and elevated loess plateaus. The group occupies 881.4 thousand hectares or 97.9% of the eroded arable land area. By the degree of erosion, the subgroups include slightly-, medium-, and severely-eroded lands. Moreover, 50.4 thousand hectares (65% of the total area of medium-eroded soils) are located in Klyuchevsky and Kulundinsky districts. The largest area of medium-eroded arable land (35.7 thousand hectares) is observed in the Kulundinsky municipal district. The area of severely-eroded soils in arable land amounts to almost 2000 hectares; about 76% of them are located in the Tabunsky district and 20% – in the Mikhailovsky district. Other agro-ecological units are distinguished according to the principles described for the first group.

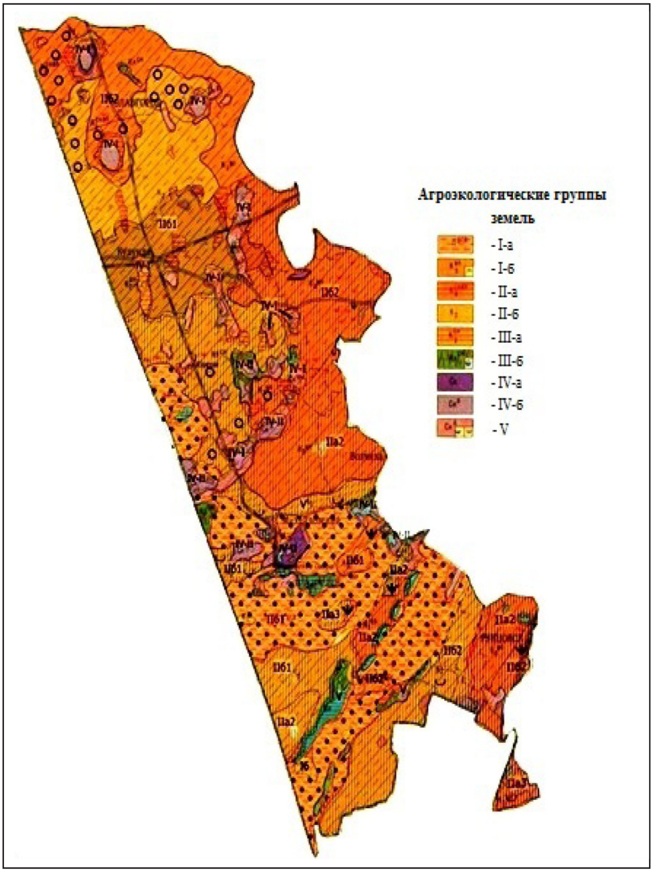

Fig. 2. Map of agro-ecological groups of lands. Note: Agro-ecological groups of lands. I – non-eroded soils, II – eroded soils, III – erosion-threatening soils, IV – saline soils, V – chestnut and dark chestnut poorly formed soils of low-lying, slightly hilly, alluvial-aeolian dune-ridge sandy terraces.

The third group comprises erosion-threatening chestnut and dark-chestnut soils of low-lying ancient alluvial plains and elevated loess plateaus of varying complexity. Three subgroups of lands are identified in this group, varying in the degree of dissection: with a dissection coefficient of less than 0.3 km/km^2; 0.3–0.6 km/km^2; 0.6–0.9 km/km^2. The territories are located along hollows and ridge, near water bodies; the occupied areas are relatively small. These areas are complex in sustainable agricultural land use, as they are developed by wind and water erosion.

Saline lands became the basis of the fourth group. This group of lands includes soil complexes with sodium soils less than 10% of the total area. Within the group, according to the conditions of complexity and hydrological regime, we identified four subgroups. Such lands are widespread throughout the research area; moreover, they have a low production potential and resistance to anthropogenic activities.

The fifth group includes chestnut and dark chestnut poorly formed soils of low-lying, slightly hilly, alluvial-aeolian dune-ridge sandy terraces. Land areas of this group are distinguished along the troughs of the ancient runoff. The land is not suitable for agriculture due to its poor quality, although it used to be plowed in the past. Currently, agricultural producers abandoned the use of these territories, and they are overgrown with woody vegetation.

The number of groups and subgroups may vary in accordance with the accumulated information on the qualitative composition of land resources. Each group of lands has particular agro-ecological factors that must be taken into account when organizing sustainable agricultural land use. Such a strategy will allow us to overcome their limiting influence on the territory.

For example, it is easy to influence the mineral elements for the nutrition of land supply. The reaction of the environment (pH), the composition of the soil biota, and exchangeable sodium content can be regulated. The bulk density, structural state of the soil, water, thermal regimes, and humus content can be limitedly regulated. It is impossible to control the particle-size and mineralogical composition of the soil, relief, and weather conditions. “Controllability” of agro-ecological factors must be considered while developing measures to eliminate their negative impact on crops, protect land resources and, as a result, organize sustainable agricultural land management.

Thus, anti-erosion agricultural land management should be the basis for their protection. Targeted protection should ensure wind speed regulation, the accumulation of organic substances, conservation, and rational use of moisture, reduction of air and soil temperatures.

Discussion

When forming agro-ecological land types from elementary areas of agricultural landscapes, we used a landscape map of Altai Krai [8] and soil maps of agricultural enterprises (scale 1: 25000) conducting economic activities in the research area. Within the five groups of lands, we identified 11 types of lands: (1) field anti-blowing, (2) meadow anti-blowing, (3) meadow anti-blowing and anti-erosion, (4) field anti-erosion-anti-blowing, (5) soil-protective anti-erosion-anti-blowing, (6) meadow, (7) forest-meadow, (8) sodium-meadow, (9) nature protective saline, (10) nature protective forest, and (11) inarable land. Using the example of the most intensively used types of land in agro-industrial production in the arid-steppe Kulunda, we will exhibit a complex of protective measures that contribute to the sustainable development of agricultural land use in the research area.

The first type of land (field anti-blowing), found in all municipal areas located in the arid-steppe Kulunda, is suitable for growing all agricultural crops without exception. The lack of nutrients in the soil is compensated by mineral and organic fertilization; soil-protective crop rotations with green manure fallow are introduced into the crop structure. Perennial grasses in forage crop rotation should occupy 50%–70% of the area, providing a positive balance of organic substance. By mulching the soil surface with plant residues, placing crops in strips, as well as sowing wings and additional planting of field-protection forest belts (width 50–100 m), we achieve a decrease in wind speed, aeolian transfer of small soil particles, and an optimal microclimate for agricultural plants.

The next type of land is field anti-erosion-anti-blowing. It is used with restrictions in field crop rotation where water and wind erosion are considered limiting factors. Their negative impact can be partially offset by implementing measures proposed for lands of the first type. Cross-sowing of agricultural crops should be applied when water erosion occurs. Anti-erosion plantations are necessary because the territories are confined to an elevated loess plateau with a wavy-hollow relief with slope angles up to 1.5.

All other land types, acting as limiting agro-ecological factors affecting the land-use area, have factors that cannot be controlled. Therefore, the conservation measures provided for such lands must be rigorous. The recommendations are related to the transfer from arable land to fodder lands: partial or complete tinning of the territory, territories associated with the environment stabilization function (forest lands), reclamation, and hydraulic structures; that is, these lands are associated with additional capital investments.

Conclusion

The agro-ecological analysis of agricultural land use carried out in this research paper on the example of the arid Kulunda territory allowed us to identify the limiting factors reducing the efficiency of agricultural land use and simulate a set of protective measures aimed at its stabilization and optimization. The proposed differentiated organization of agricultural land use, based on taking into account natural characteristics, includes agrotechnical, forest improvement, organizational and economic measures (development of special land reclamation projects; changes of the cadastral value, the amount of tax or rent, subsidies and subventions for agricultural producers) to protect soil from blowing and erosion. This step is aimed at creating conditions for increasing soil fertility; moreover, it contributes to the solution of various tasks, such as (1) the reproduction of the natural resource potential of the arid steppe area of Altai Krai, (2) the ecological sustainability of agricultural landscapes, (3) the organization of innovative organic land use and, as a consequence, will increase the efficiency of land use in agriculture, that means it will affect their sustainable development.

References

1. Chernogorov A.L., Chekmarev I.I., Vasenev I.I. Gogmachadze G.D. *Agroekologicheskaya otsenka zemel' i optimizatsiya zemlepol'zovaniya* [Agro-ecological land assessment and land-use optimization]. Moscow, Lomonosov Moscow State University, 2012, 268 p.
2. Adamenko, O.M. *Mezozoy i kaynozoy Stepnogo Altaya* [Mesozoic and Cenozoic steppe Altai]. Novosibirsk, Nauka, 1974, 165 p.
3. Burlakova, L.M. *Kontseptual'nyye polozheniya yestestvennogo ispol'zovaniya zemel'* [Conceptual provisions for the rational use of land]. *Ekologiya i bezopasnost' zhiznedeyatel'nosti cheloveka v usloviyakh Sibiri* [Ecology and safety of human life in Siberia]. Barnaul, Altai State University Publishing House, 1997, pp. 34-38.
4. Burlakova, L.M. *Plodorodiye Altayskikh chernozemov v sisteme agrotse-noza* [Fertility of Altai chernozems in the agro-cenosis system]. Novosibirsk, Nauka, 1984, 198 p.
5. Vasenev I.I. *Agroekologicheskoye modelirovaniye i proyektirovaniye (interaktivnyy kurs): uchebno-prakticheskoye posobiye* [Agroecological modeling and design (interactive course): An educational and practical guide]. Moscow: Publishing house of RGAU - MSHA named after K. A. Timiryazev, 2010, 260 p.
6. Tatarintsev V.L., Tatarintsev L.M., Makenova S.K., Shostak M.M. *Geoekologicheskaya otsenka landshaftov kak osnova organizatsii ustoychivogo agrarnogo zemlepol'zovaniya* [Geoecological assessment of landscapes as a basis for organization of sustainable agrarian land use]. *Ustoychivoye razvitiye gornykh sobytiy* [Sustainable Development of Mountain Territories], 2021, vol. 13, no. 4, pp. 485-497.
7. Zanin G.V. *Geomorfologiya Altayskogo kraya* [Geomorphology of Altai Krai. Natural zoning of Altai Krai]. *Prirodnoye rayonirovaniye Altayskogo kraya* [Natural zoning of the Altai Territory] (Edited by B.N. Luzgin). Moscow: Publishing House of the USSR Academy of Sciences, 1958, pp. 62-98.

8. Zarutskaya I.P. *Altayskiy kray. Atlas* [Atlas of Altai Krai.]. Barnaul, GUGK, 1978, 222 p.
9. Kashtanov A.N. Shcherbakova A.P. *Landshaftnoye zemledeliye. Chast' 1-2* [Landscape farming. Part I-II.]. Kursk, VNIIZIZPE, 1993, 98 p.
10. Kiryushin V.I. *Kontseptsiya adaptivno-landshaftnogo zemledeliya* [The concept of adaptive landscape farming] Moscow, Moscow State Agricultural Academy named after K. A. Timiryazev, 1993, 63 p.
11. Kiryushin V.I. *Ekologizatsiya zemledeliya i tekhnologicheskaya politika* [Greening agriculture and technology policy]. Moscow, Moscow State Agricultural Academy named after K. A. Timiryazev, 2000, 473 p.
12. Kiryushin V.I. *Ekologicheskiye osnovy zemledeliya* [Ecological foundations of agriculture]. Moscow, Kolos, 1996, 365 p.
13. Kudryavtsev A.E. *Agroekologicheskoye sostoyaniye plodorodiya pakhotnykh pochv Altayskogo Priob'ya i mezhgornykh kotlov Altaya: Dis. dok. biol. Nauk* [Agro-ecological state of fertility of arable soils of the Altai Ob region and intermontane hollows of Altai: Dis. doc. biol. Sciences]. Ufa, 2013, 50 p.
14. Latysheva O.A., Tatarintsev V.L., Tatarintsev L.M. *Okhrana zemel': agroekologicheskiy aspekt (na territorii Altayskogo kraya): monografiya* [Land protection: Agro-ecological aspect (on the example of Altai Krai): monography]. Barnaul, RIO Altai State University, 2018, 124 p.
15. Tatarintsev V.L., Tatarintsev L.M., Matsyura A.V., Bondarovich A.A. *Organizatsiya sel'skokhozyaystvennogo zemlepol'zovaniya v Altayskom kraye s primeneniyem landshaftnogo analiza* [Organization of sustainable agricultural land use in the Altai Krai based on landscape analysis]. *Ustoychivoye razvitiye gornykh territoriy* [Sustainable Development of Mountain Territories], 2020, vol. 12, no. 3, pp. 339-349. http://naukagor.ru/ru-ru/about/textsofarticles
16. Panfilov V.P. *Fizicheskiye svoystva i vodnyy rezhim pochvy Kulundinskoy stepi* [Physical properties and water regime of soils in the Kulunda steppe]. Novosibirsk, Nauka, 1973, 260 p.
17. Tatarintsev L.M. *Fizicheskoye sostoyaniye pakhotnykh pochv yuga znachitel'noy chasti Sibiri: monografiya* [The physical condition of arable soils in the south of Western Siberia: monography] Barnaul, Publishing House of ASAU, 2005, 300 p.
18. Tatarintsev L.M. *Ekologicheskiye aspekty sel'skokhozyaystvennogo zemlepol'zovaniya v Altayskom kraye* [Environmental aspects of agricultural land use in Altai Krai]. Vestnik Altayskogo gosudarstvennogo agrarnogo universiteta [Bulletin of the Altai State agrarian university]. 2010, no. 1, pp. 49-52.
19. Tatarintsev L.M., Tatarintsev V.L., Kiryakina Yu.Yu. *Organizatsiya sovremennogo zemlepol'zovaniya na ekologo-landshaftnoy osnove: monografiya* [Orga-

nization of modern land use on an ecological-landscape basis: monography] Barnaul, Publishing House of ASAU, 2011, 106 p.
20. Tatarintsev L.M., Tatarintsev V.L., Pakhomya O.G. *Faktory plodorodiya kashtanovykh pochv, sukhiye stepi, yuzhnykh masshtabov i urozhaynost' yarovoy pshenitsy: monografiya* [Fertility factors of chestnut soils of dry steppe in the south of Western Siberia and yield of spring wheat: Monography]. Barnaul, AGAU Publishing House, 2005, 105 p.
21. Schwebs G.I. Metodicheskiye ukazaniya po landshaftnym issledovaniyam dlya sel'skokhozyaystvennykh predpriyatiy [Methodological guidelines for landscape research for agricultural purposes]. Moscow, VASHNIL, 1990, 58 p.
22. Tatarintsev V., Lisovskaya Yu., Tatarintsev L. Agricultural landscape quality as a key factor fostering environmentally safe agricultural land use in the arid steppe of the Altai Region // IOP Conference Series: Earth and Environmental Science, 2021, vol, 670, e012036. https://iopscience.iop.org/issue/1755-1315/670/1

Список литературы

1. Агроэкологическая оценка земель и оптимизация землепользования / Черногоров А.Л., Чекмарев И.И., Васенев И.И. Гогмачадзе Г.Д. М.: Московский государственный университет им. М. В. Ломоносова, 2012. С. 268.
2. Адаменко О.М. Мезозой и кайнозой Степного Алтая. Н.: Наука, 1974. С. 165.
3. Бурлакова Л.М. Концептуальные положения рационального использования земель // Экология и безопасность жизнедеятельности человека в условиях Сибири. Б.: Издательство Алтайского государственного университета, 1997. С. 34-38.
4. Бурлакова Л.М. Плодородие Алтайских черноземов в системе агроце-ноза. Н.: Наука, 1984. С. 198.
5. Васенев И.И. Агроэкологическое моделирование и проектирование (интерактивный курс): учебно-практическое пособие. М.: Издательство РГАУ - МСХА им. К. А. Тимирязева, 2010. С. 260.
6. Геоэкологическая оценка ландшафтов как основа организации устойчивого аграрного землепользования / Татаринцев В.Л., Татаринцев Л.М., Макенова С.К., Шостак М.М. // Устойчивое развитие горных территорий. 2021. Т. 13. № 4. С. 485-497. http://naukagor.ru/ru-ru/about/textsofarticles
7. Занин Г.В. Геоморфология Алтайского края // Природное районирование Алтайского края. [Под ред. Б.Н. Лузгин]. М.: Изд-во АН СССР, 1958. С. 62-98.
8. Заруцкая И.П. Алтайский край. Атлас. Б.: ГУГК, 1978. С. 222.
9. Каштанов А.Н., Щербакова А.П. Ландшафтное земледелие. Часть 1-2. К.: ВНИИЗИЗПЭ, 1993. С. 98.

10. Кирюшин В.И. Концепция адаптивно-ландшафтного земледелия. М.: Московская государственная сельскохозяйственная академия имени К. А. Тимирязева, 1993. С. 63.
11. Кирюшин В.И. Экологизация земледелия и технологическая политика. М.: Московская государственная сельскохозяйственная академия имени К. А. Тимирязева, 2000. С. 473.
12. Кирюшин В.И. Экологические основы земледелия: Учеб. для с.-х. вузов. М.: Колос, 1996. С. 365.
13. Кудрявцев А.Е. Агроэкологическое состояние плодородия пахотных почв Алтайского Приобья и межгорных котловин Алтая: Дис. док. биол. наук. У.: 2013. 50 с.
14. Латышева О.А., Татаринцев В.Л., Татаринцев Л.М. Охрана земель: агроэкологический аспект (на примере Алтайского края): монография. Б.: РИО Алтайского ГАУ, 2018. С.124.
15. Организация устойчивого сельскохозяйственного землепользования в Алтайском крае с применением ландшафтного анализа / Татаринцев В.Л., Татаринцев Л.М., Мацюра А.В., Бондарович А.А. // Устойчивое развитие горных территорий. 2020. Т. 12. № 3. С. 339-349. http://naukagor.ru/ru-ru/about/textsofarticles
16. Панфилов В.П. Физические свойства и водный режим почв Кулундинской степи. Н.: Наука, 1973. С. 260.
17. Татаринцев Л.М. Физическое состояние пахотных почв юга Западной Сибири: монография. Б.: Изд-во АГАУ, 2005. С. 300.
18. Татаринцев Л.М. Экологические аспекты сельскохозяйственного землепользования в Алтайском крае // Вестник Алтайского государственного аграрного университета. 2010. №1. С. 49-52.
19. Татаринцев Л.М., Татаринцев В.Л., Кирякина Ю.Ю. Организация современного землепользования на эколого-ландшафтной основе: монография. Б.: Изд-во АГАУ, 2011. С. 106.
20. Татаринцев Л.М., Татаринцев В.Л., Пахомя О.Г. Факторы плодородия каштановых почв сухой степи юга Западной Сибири и урожайность яровой пшеницы: монография. Б.: Изд-во АГАУ, 2005. С. 105.
21. Швебс Г.И. Методические указания по ландшафтным исследованиям для сельскохозяйственных школ. М.: ВАСХНИЛ, 1990. С. 58.
22. Tatarintsev V., Lisovskaya Yu., Tatarintsev L. Agricultural landscape quality as a key factor fostering environmentally safe agricultural land use in the arid steppe of the Altai Region // IOP Conference Series: Earth and Environmental Science, 2021, vol, 670, e012036. https://iopscience.iop.org/issue/1755-1315/670/1

DATA ABOUT THE AUTHORS

Vladimir L. Tatarintsev

Altai State University
61, Lenin Ave., Barnaul, 656049, Russian Federation
kafzem@bk.ru
ORCID: https://orcid.org/0000-0002-5368-726X

Yulia S. Lisovskaya

Altai State University
61, Lenin Ave., Barnaul, 656049, Russian Federation
kafzem@bk.ru
ORCID: https://orcid.org/0000-0003-3551-627X

Leonid M. Tatarintsev

Altai State Agricultural University
98, Krasnoarmeyskiy Ave., Barnaul, 656049, Russian Federation
kafzem@bk.ru
ORCID: https://orcid.org/0000-0002-4308-6110

ДАННЫЕ ОБ АВТОРАХ

Татаринцев Владимир Л.

Алтайский Государственный Университет
просп. Ленина, 61, г. Барнаул, 656049, Российская Федерация
kafzem@bk.ru

Лисовская Юлия С.

Алтайский Государственный Университет
просп. Ленина, 61, г. Барнаул, 656049, Российская Федерация
kafzem@bk.ru

Татаринцев Леонид М.

Алтайский Государственный Аграрный Университет
просп. Красноармейский, 98, г. Барнаул, 656049, Российская Федерация
kafzem@bk.ru

Поступила 03.02.2022 Received 03.02.2022
После рецензирования 10.02.2022 Revised 10.02.2022
Принята 28.02.2022 Accepted 28.02.2022