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ECOLOGICAL SUSTAINABILITY OF AGRICULTURAL LANDSCAPES IN THE NORTH KAZAKHSTAN REGION

Abstract. The article describes the agricultural landscapes in North Kazakhstan region. The work shows the results of study and assessment of ecological landscape sustainability in the research area. Based on the analysis and scientific literature we specified the ecological state of soil as a sustainability factor of agrolandscapes. Assessment of landscape sustainability in main natural and agricultural areas of the region was studied on the basis of complex soil-ecological properties. Here we identified natural and agricultural areas with relative and low agrolandscape sustainability. Within the agrolandscape studies we should draw attention to the necessity of developing and improving uniform methodological approaches to the assessment of ecological state and sustainability of agrogenic landscapes.

Keywords: agrolandscape, natural-agricultural area, sustainability, assessment, soil, agricultural production.

Introduction

High agricultural development of North-Kazakhstan Region (NKR) and as a consequence long-term anthropogenic agricultural load on natural geosystems have led to a vast range of environmental problems and threats in the region. Dehumification and reduction of soil fertility, expansion of wind and water erodible areas, degradation and environmental disturbance of agricultural lands and reducing of their sustainability can be clearly observed in the region. Adverse environmental consequences of agricultural activities determine the necessity of development and implementation of measures aimed at optimization of ecological state of agrogenic landscapes and maintaining their sustainability. Such studies should be aimed at solving important tasks – improving of agricultural efficiency and ensuring of food security of the region and the country as a whole [1, 2, 3]. The above problems determine urgency of the undertaken research.

The purpose of the study is to assess ecological state and sustainability of present agricultural landscapes of NKR.

The object of the research includes agricultural landscapes of NKR – natural-economic systems which are complex systems with component structure and multiple internal relationships.

Materials and approaches of the research

Theoretical and methodological basis of the research is formed by the researches of national and foreign scientists in the field of geoecology and landscape, agrolandscape and soil science. The study of agrogeosystems from the point of view of landscape approach is described in the studies of several scientists (A.G. Isachenko, 1980, 2004; M.A. Glazovskaya, 1988; F.I. Milkov, 1977, 1984, 1988). The study was based on the concept of agricultural landscape (V.N. Nikolayev, 1987, 1992, 1999). Approaches and evaluation criteria were chosen from the works of K.V. Zvorykin (1984), V.I. Kiryushin (1996, 2005, 2011), B.I. Kochurov (1993, 1999), M.I. Lopyrev (1995, 2012, 2015), F.N. Ryanskiy (1990, 1993), I.V. Orlova (2013, 2014), M.A. Altieri (1989), M. Arshad (1992), A. Wesel (2009), E. Malezieux (2012) and others.

As initial information for the research we used maps, archive materials and scientific publications of organizations and institutions of the industry (such as Department of Land Register and Engineering Survey of Real Estate of Government for Citizens State Corporation NJSC of North Kazakhstan Region, Department of Statistics of NKR, Republican Scientific and Methodical Center of Agrochemical Service RSE of the Kazakhstan Ministry of Agriculture, KSU Department of Agriculture of NKR, etc.) for the period of 2010-2018 and space images from Landsat 8. In addition, we used our own data obtained during field studies in 2017-2018.

The study was conducted using the following approaches: a set of landscape-geographical approaches, comparative-geographical, cartographic, mathematical, systematic and statistical methods, extrapolation and cross analysis.

According to V.I. Kiryushin [4] sustainability of agricultural landscapes is an ability to maintain the given productive and social functions and to preserve the biosphere ones. In the view of the scientist, sustainable agricultural landscape is characterized by lack or low (acceptable) level of degradation processes.

M.I. Lopyrev [5] notes in his work that an agricultural landscape is environmentally sustainable if it ensures high productivity and preservation of natural soil fertility under intensive agricultural use.

From our perspective, sustainable ecological state of agricultural landscapes involves the ability to withstand agricultural activities and their consequences while maintaining basic properties and specified production and environmental functions that ensure favorable conditions for agricultural plants and animals, as well as the ability of their self-regeneration.

Assessment of ecological sustainability of agricultural landscapes is an important issue in agrolandscape research. Despite some knowledge of this issue, currently the agrolandscape science has not yet developed a unified system of assessing sustainability of agroecosystems. There is an unresolved problem of determining quantitative and qualitative criteria (factors) of assessment and methods for their determination. It requires development and validation of scales of ecological agroecosystems sustainability and determination of ecological sustainability levels. The question of justification of methodical approaches to ecological assessment of agroecosystems is still under discussion [6-9].

Analysis of the literature [10-17] showed that assessment of ecological sustainability of agroecogenic landscapes use a wide range of different factors and parameters which depend on goals, scope and approaches applied. Factors of agrolandscape sustainability can be represented by functions, modes and properties of soils, structure, organization and productivity of agroecocenoses, degree of actual erosion of the territory, intensity and balance of biogeochemical cycles, bioenergy indices, environmental capacity, environmental balance of land structure, economic factors of agricultural production, and others.

The approach based on consideration of agricultural landscape as a complex system of interrelated components claims certain attention. In this case, assessment of agricultural landscape implies the use of two groups of factors (criteria) – general and special. General factors assess overall ecological sustainability of agroecosystems, while special factors assess its components. Thus, sustainability of an agricultural landscape is characterized by its overall sustainability and sustainability of its components and functioning [18].

According to their functional and structural properties agrolandscapes are little apart from natural complexes. In this regard, most of the studies related to determining agricultural landscape sustainability use the same factors, approaches and methods as those being used in assessment of state and sustainability of natural landscapes and ecosystems.

According to M.A. Glazovskaya [19], sustainability of a landscape is difficult to directly measure and rank. The reason for this is that when assessing landscapes according to a sustainability property it is impossible to use any direct figures specific to the property. Such factors can be defined as basic properties of a landscape and its components. The approach can be also applicable in determining sustainability or unsustainability of agroecogenic landscapes to external influences.

In this study we used ecological state of soil and main soil-ecological qualities and parameters as an indicator of agrolandscape sustainability. Soil is the basic structural component of an agricultural landscape and the main means of agricultural production. It performs the functions of accumulation and transfer of moisture and nutrients to the plants, and provision of living space. It also serves as the link of cycles and mass-energy transfer and performs other important ecological functions. Its ecological state and properties largely influence over productivity and sustainability of agroecosystems. In this regard, soil is one of the objective indicators of landscape sustainability and plays an important role in assessment of the properties of agroecosystems.

We identified the following soil and ecological characteristics for the assessment: grain size distribution; humus layer thickness (cm) and amount of organic compounds (%); acidity-alkalinity of soil solution; providing soils with major nutrients (N, P, K, mg/kg); content of chemical elements and their compounds (chlorides, sulfates, nitrates, mM per 100 g of soil; copper, zinc, manganese, cobalt, sulphur, mg/g); content of residual quantities of pesticides (DDT, mg/g); trace amount of petrochemicals (mg/g).

The study of soil ecological state of agrolandscapes was conducted at index plots that were allocated based on agroclimatic, natural and agricultural zoning, soil nature, landscape and morphological properties and specific nature of agricultural production. Map of natural-agricultural areas of the region and positions of index plots are shown in Figure 1.

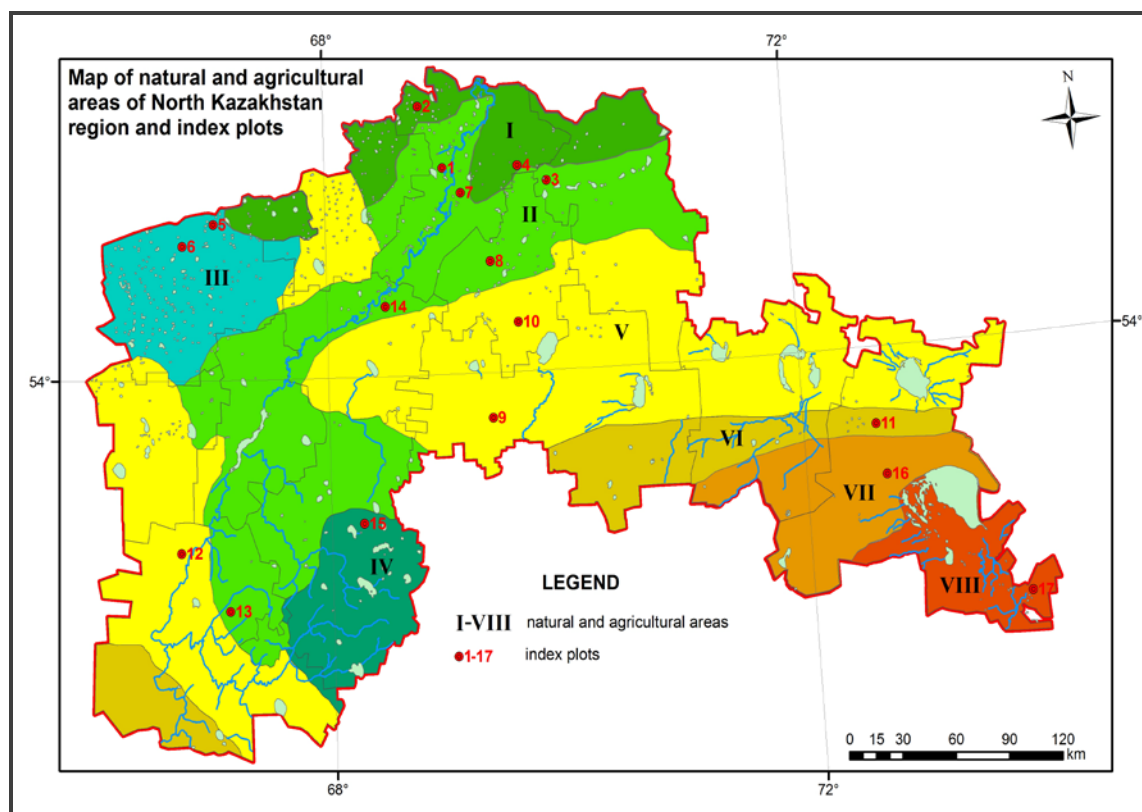


Fig. 1. Map of natural and agricultural areas of North Kazakhstan region and index plots

During the field studies of arable agricultural landscapes in major natural-agricultural areas of North Kazakhstan Region we made soil sections, studied physical properties and morphological features of the soils, and take soil samples from upper layer (A_{arable}).

Laboratory analytical testing of collected soil samples was made in accordance with approved methods in the Branch of National Center of Expert Review of the Committee of Public Health of the Kazakhstan Health Ministry in North Kazakhstan Region.

Assessment of landscape sustainability was conducted through the method of appraisal by point that is widely used in geoenvironmental studies.

Indicators of all the analyzed soil and environmental properties driven from the analysis of materials [20, 21] and the results of field work were converted into relative values (points) based on the developed scale. In accordance with the requirements of agronomic and agrochemical properties of soils in arable lands and regional natural and geographical features of the research area the highest score (5) was given to the optimal conditions of the soil-ecological environment conducive to the growth of crops and their productivity, and the lowest (1) – to the least favorable.

Scores for each of the analyzed factors were summed up. The total score was converted into percentage (%) relative to the maximum possible score (100 points) that is the most favorable environmental condition of soil and, therefore, the greatest degree of sustainability of an agricultural landscape. Calculation of the summary scores was carried out according to the formula [22]:

$$C = \frac{100 \sum_{g=1}^n C_g}{Q},$$

where C means assessment of ecological state of the soil and sustainability of the agricultural landscape, in %; C_g is score for each indicator; Q is maximally possible amount of points; g is the index number of the indicator; and n – number of indicators (characteristics).

Statistical calculations and data processing were performed using software package of Microsoft Office, Statistica 6.0, ArcGIS 10.1.

When developing a scale of agroecosystems sustainability we used the approach proposed in the works of F.N. Ryanskiy [22] and I.V. Orlova [9] and modified it in relation to the studied region. Depending on the score expressed in percent (%) we propose five levels of ecological sustainability of agroecosystems: stable (81-100%), relatively stable (61-80%), less stable (41-60%), unstable (21-40%), highly unstable (less than 20%).

Results and discussion

In accordance with the scale we qualified the agrolandscapes of the region to the second and third group of sustainability that are characterized by relative and low sustainability to external influences.

Dimensional analysis of the data showed that the maximum value of scores and evaluation is defined in agricultural landscapes of steppe plain-and-depression natural-agricultural area with ordinary and calcareous chernozems and equals to 62 (Sustainability Assessment 73%) points, as well as in forest-steppe lake-ridge area with shallow chernozems, gray forest and solonets complexes with total 65 points (Sustainability Assessment 77%). The natural agricultural areas are located within forest-steppe and northern steppe moderately dry natural subzone.

Agricultural landscapes of dry-steppe wavy-ridges area with dark chestnut and southern chernozem soils and bedrock outcrops and arid-steppe sloping plains of natural-agricultural areas with southern calcareous chernozem soils have shown the minimum amount of points – 50 (Sustainability Assessment 59%). They belong to southern arid steppe and dry steppe natural subzones.

Sustainability of agrolandscape ecological condition of the two above mentioned natural-agricultural areas is assessed to be as less stable. Agroecosystems located within these areas require deliberate restoration and maintenance of ecological sustainability. Agricultural production is possible here only with preservation of agricultural and natural capacity of the landscape, limitation of agricultural use and agrogenic load.

Sustainability of agrolandscape ecological state of 4 natural-agricultural areas: forest-steppe plain-and-depression area with meadow-chernozem soils, patches of chernozem and large solids of solonets soil; outlier forest-steppe undulating plain area with ordinary chernozem and patches of meadow-chernozem soils; forest-steppe sugar-loaf mountain area with ordinary chernozem soils and bedrock outcrops; arid-steppe flat-plain area with ordinary solonchaks and southern chernozem soils is estimated as relatively stable; and part outlier forest-steppe lake-ridge area with shallow chernozems, gray forest and solonets complexes; steppe plain-and-depression area with ordinary and calcareous chernozem soils.

Despite long and intensive use the agricultural landscapes in these natural-agricultural areas have relatively high initial natural agricultural capacity. The areas are promising for further agricultural use upon the condition of implementing measures to maintain natural ecological capacity.

The ratio of maximum (77%) and minimum (59%) indicators of sustainability is defined as 1,3:1. It generally means that there are relatively small differences in ecological state and level of landscape sustainability of the agricultural landscapes of the region.

At an average agricultural landscapes of the northern semi-dry steppe subzone has 69% of sustainability. To the North and South of the subzone the landscapes sustainability indicator reduces. The differences in total point score and, respectively, in assessment of sustainability amounts to 3-6% (points) while advancing northwards to forest-steppe outliers (66%) and typical forest steppe (63%) subzones and up to 6-10% (points) while advancing southwards to arid (63%) and dry-steppe (59%) subzones.

In order to increase sustainability of agricultural landscapes characterized by insufficiently stable ecological conditions it is necessary to develop a set of measures for optimization and restoration of their ecological balance and enhancement of natural-ecological capacity. The solution of this problem is possible with maintenance of high level of agriculture, carrying out soil-conservation agronomic techniques and measures of conservation and reproduction of soil fertility (science-based crop rotations, tillage and fertilizing systems, diversification of crops, etc.).

With a view to ensuring ecological sustainability of agrogenic landscapes it is essential to strike a balance between ecological capacity, natural agrocapsity and safe agrogenic load on them. Development of an optimal spatial structure of agricultural landscapes and crop acreage with regard to natural-zonal features and landscape structure of the region is very important. Agroecosystems with unstable ecological condition need maintaining and increasing of area of environment-stabilizing lands (forests and natural pasture areas) and reducing the number of destabilizing (arable) lands.

Conclusions

Assessment of agricultural landscape sustainability is an important issue of agrolandscape research. At the present time due to the aggravation of environmental problems in the agricultural sector study and assessment of ecological state and sustainability of agricultural landscapes are of particular importance.

The crucial problems of agricultural nature management in the region were identified in this study. Most issues come from decrease of ecological sustainability of agrolandscapes and necessity of certain measures for its optimization. An important tool to achieve ecological stability and sustainability of agrogenic landscape can be landscape-agroecological planning.

Table 1. Assessment Table of Agrogenic Landscapes Sustainability of North-Kazakhstan Region

No.	Natural Subzone	Natural-agricultural area	Background Landscape	Agricultural Landscape	Index Plot No.	Total points	Sustainability Assessment, %
1	Typical Forest-Steppe	I Forest-steppe plain-and-depression area with meadow-chnozem soils, patches of chernozem and large solids of solonets soil	Flat sloping near-valley plain composed of Middle Quaternary alluvial loams and sandy loams with loessial surface, forb-grass associations, and aspen-birch forests, sedge-willow thickets on ordinary chernozem and meadow-chnozem with fragments of gray forest soils	Arable, used for crop planting	1	52	61
			Flat undulating plain with lake basins and small ridge elevations composed of Lower Quaternary loessial loams with feather grass-fescue-bluegrass vegetation and aspen-birch forests and groves on leached chernozem soils with patches of gray forest and fragments of meadow-chnozem soils	Arable, used for crop planting	2	54	64
			Slanting flat plain composed of Lower Quaternary loessial loams with feather grass-fescue-forb vegetation, aspen-birch forests and groves on soil complexes of ordinary chernozem and solonets soils with patches of gray forest weakly solodic soils	Arable, used for crop planting	4	54	64
2	Outlier Forest Steppe	II Outlier forest-steppe undulating plain area with ordinary chernozem and patches of meadow-chnozem soils	Undulating with lake depression plain composed of Lower Quaternary loess-like loams with feather grass-fescue-bluejoint vegetation and aspen-birch groves on ordinary chernozemsoils with patches of meadow-chnozem and solod soils	Arable, used for crop planting	3	58	68
			Near-valley plain composed of Upper Quaternary alluvial sediment complex with forb-feather grass vegetation, goldilocks-fescue-wormwood spots and aspen-birch groves on ordinary graveled chernozem and meadow-chnozem soils	Arable, used for crop planting	7	55	65
			Undulating plain with depressions composed of Middle Quaternary	Arable, used for crop	8	56	66

			loess-like loams with multiforb-silaus-red feather grass vegetation and patches of steppe aspen-birch groves on ordinary chernozem soils with patches of solonets and solod soils	planting			
			Slanting undulating plain composed of Middle Quaternary loess-like loams with silaus-red feather grass-fescue vegetation and aspen-birch groves on ordinary chernozem soils together with solod soils.	Arable, used for crop planting	14	56	66
		III Outlier forest-steppe lake-ridge area with shallow chernozems and gray forest soils and solonets complexes	Sloping plain with small-ridges terrain and lake depressions composed of Low Quaternary loess-like loams with feather grass-fescue vegetation and wormwood associations in combination with aspen-birch groves and sedge-willow thickets on ordinary solonetsous chernozem and meadow-chernozem soils with patches of gray forest soils	Arable, used for crop planting	5	55	65
			Wavy-depressioned ridged plain with some boggy depressions composed of Low Quaternary complex of lake-alluvial sediments with feather-grass-bluejoint vegetation and aspen-birch groves with brier undergrowth on soil complexes of solonetsous steppe chernozem soils with spots of solod and meadow-boggy soils.	Arable, used for crop planting	6	65	77
		IV Forest-steppe sugar-loaf mountain area with ordinary chernozem soils and bedrock outcrops	Steeply undulating plain composed of undifferentiated deluvial-proluvial loess-like loams with goldilocks-fescue-wormwood groups and patches of pine-birch steppe forests on ordinary solonetsous chernozem soils with complex of solonets and solod soils.	Arable, used for crop planting	15	52	61
	3 North Steppe Semi-Dry	V Steppe plain-and-depression area with ordinary and calcareous chernozem soils	Flat undulating plain with mild benches composed of Low Quaternary loess-like loams with feather-grass-silaus associations on ordinary chernozem soils and sparsely ordinary calcareous chernozem soils.	Arable, used for crop planting	9	57	67
			Flat undulating plain composed of Low Quaternary loess-like loam with multiforb-silaus-red feather grass vegetation on ordinary calcareous chernozem soils.	Arable, used for crop planting	10	59	69
			Flat slightly sloping plain with benches composed of Middle Quaternary loess-like loams with red feather grass-forb vegetation and fescue goldilocks-woodworm associations on calcareous chernozem soils.	Arable, used for crop planting	12	58	68

			Hilly-steep plain with small benches composed of undifferentiated deluvial-proluvial loess loams with forb-red feather grass vegetation and patches of aspen-birch forests on ordinary chernozem soils with spots of solod and meadow-chernozem soils.	Arable, used for crop planting	13	62	73
4	South Steppe Arid	VI Arid-steppe flat-plain area with ordinary solonchaks and southern chernozem soils	Flat sloping plain composed of Low Quaternary loams, clays and sands with grass-forb vegetation and fescue-woodworm associations on the complexes of southern solonchaks chernozem and meadow-chernozem soils.	Arable, used for crop planting	11	56	66
		VII Arid-steppe sloping plains area of natural-agricultural areas with southern calcareous chernozem soils	Slightly sloping plain composed of Low Quaternary loams, clay and sand with grass-forb vegetation and some fescue-wormwood associations on the complexes of southern calcareous chernozem soils with patches of solonchaks soils.	Arable, used for crop planting	16	50	59
5	Dry Steppe	VIII Dry-steppe wavy-ridges area with dark chestnut and southern chernozem soils and bedrock outcrops	Low slightly sloping plain with erosion-deluvial slopes composed of Middle Quaternary loams and sandy loams with loessial surface and with feather-fescue-goldilocks and fescue-wormwood groups on dark-chestnut solonchaks and steppe solonchaks soils.	Arable, used for crop planting	17	50	59

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Мажитова Г.З., Джаналеева К.М., Доскенова Б.Б.

Экологическая устойчивость агроландшафтов Северо-Казахстанской области

Резюме. В работе представлены результаты изучения и оценки экологической устойчивости агроландшафтов Северо-Казахстанской области. В качестве параметра устойчивости агрогенных ландшафтов определено экологическое состояние почв. Выполнена оценка устойчивости агроландшафтов по основным природно-земледельческим районам области на основе комплекса почвенно-экологических характеристик. Выявлены природно-земледельческие районы с относительной и малой устойчивостью агроландшафтов.

Ключевые слова: агроландшафт, природно-земледельческий район, устойчивость, оценка, почва, сельскохозяйственное производство.

Мажитова Г.З., Джаналеева К.М., Доскенова Б.Б.

Солтүстік Қазақстан облысының агроландшафттарының экологиялық тұрақтылығы

Түйіндеме. Мақалада Солтүстік Қазақстан облысының агрогендік ландшафттарының экологиялық тұрақтылығын зерттеу мен бағалаудың нәтижелері ұсынылған. Агроландшафттардың тұрақтылық параметрі негізінде топырақтың экологиялық жағдайы анықталды. Топырақ-экологиялық сипаттамалар кешенінің негізінде облыстың негізгі табиғи-ауылшаруашылық аудандарында агроландшафттар тұрақтылығына бағалау жүргізілді. Агроландшафттарының салыстырмалы және төмен тұрақтылығы бар табиғи-ауылшаруашылық аудандары анықталды.

Түйін сөздер: агроландшафт, табиғи-ауылшаруашылық ауданы, тұрақтылық, бағалау, топырақ, ауыл шаруашылық өндірісі.

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RESEARCH AND DEVELOPMENT OF THE IMITATION MODEL OF POLLUTION SUBSTANCES DISSEMINATION AND THEIR SUCTION ON THE EARTH SURFACE

Abstract. Conducted research on the development of a simulation model for predicting the process of dispersion of pollutants and their subsidence on the surface of the earth. Based on Gaussian models, an ARMI (Atmospheric Scattering from Many Sources) model is proposed, which allows to simulate dispersion of pollutants and their deposition on the surface of the earth, as well as integrated accounting of emissions from coming one and many sources. The developed model of ARMI provides an estimate with a large supply of the most critical environmental conditions (the maximum concentration of pollutants on earth for a limited time is - 1 hour). In order to obtain an assessment with a large stock of the most critical environmental conditions, a "short-term" version of ASMS was adopted, which is able to recognize difficult and exacerbated pollution situations.

Keywords: model, simulation model, Gauss model, dispersion of pollutants, Atmospheric Scattering from Many Sources (ASMS), thermal oxidizer.