ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Optimization of Land Use in The Agricultural Landscapes of Northern Kazakhstan On the Basis of the Landscape Approach.

Nataliya Ozeranskaya*, Tulegen Karbozov, Akerke Bekturganova, Bakhytgul Zhuparkhan, and Valentina Kononova[1]

Department of Land Development, S.Seifullin Kazakh AgroTechnical University, 010011, Astana, Kazakhstan

ABSTRACT

This paper proposes to identify the basis for the organization of rational land use in order to increase the efficiency of agricultural production on the environmental basis for the steppe landscapes of Northern Kazakhstan. The article considers the problems and peculiarities of intra-farm land management on the landscape basis. The regionalized sample helped to identify the objects of study - typical agroformations of Akmola region in Kazakhstan. The creation of a model of optimal agricultural landscape included the following stages: the investigation and generalization of the main characteristics of landscape components, the construction of a cartographic model of agrolandscapes, the realization of agrolandscape microzonation of the territory, the development of the optimal land use model based on the landscape approach. In landscape microzonation, it is suggested to distinguish the following microzones: conservation, restricted use, agricultural potential restoring, and the intensive use of field, meadow and pasture landscapes. It is recommended to ensure the ecological diversity of landscapes by reducing the arable land, increasing the area of more ecologically sustainable forage lands, expanding the strip sowing of perennial crops on the arable land.

Keywords: adaptive land use, agricultural landscape, land management, territory planning, the landscape-ecological approach.

Corresponding author

ISSN: 0975-8585

INTRODUCTION

The current state of agricultural landscapes shows the development of negative processes that lead to the violation of their balance. This is often due to the fact that the system of land management activities, defining the landscape structure, was developed without proper environmental assessment of landscape components and their relationships. The problem of rational land use is particularly relevant in specialized in agricultural production northern regions of Kazakhstan which maintain the main production of food grain of the spring wheat [12], [13].

Currently, most of the lands of Northern Kazakhstan, intensively used in agriculture, need an optimal restoration. Many studies [1], [2], [3], [4], [5] (Armand, 1975; Chupakhin and Andriishin, 1989; Gendelman, 1999; Geras'kin, 2008; Golovanov, Kozhanov and Sukharev, 2005) have found that over the period from the beginning of the development of virgin lands, humus content in the southern chernozem and dark chestnut soils of the North-Kazakhstan region has decreased by 20-30%, i.e. lost about one-quarter of the stock of humus [8]. Openness and instability, inherent to the steppe landscape even in its natural state, was exacerbated by an anthropogenic influence. Modern organization of the former virgin lands is a square and rectilinear outline of monoculture agrolandscape arrays. This system of territory planning does not take into account the features of the structure and functioning of the landscape. Degradation of soil cover has a negative impact on the productive function of the landscape. Soil erosion and ravines continue to expand. All this affects the economy of agricultural organizations and the efficiency of agricultural production in general [1].

Given the above, we can conclude that the modern character of land use should be reconsidered. There is a need for a radical restructuring of the existing land use, which should be linked to the natural-resource potential of agricultural lands.

The main mechanism of rational land use is land management. The landscape approach to land management should take into account the peculiarities of territory differentiation, since the area of each agricultural enterprise is characterized by its own diversity and a combination of landscape complexes. Only on this basis, it is possible to develop the environmentally sound projects of land management, which should provide an organization of rationally transformed landscapes. The present paper proposes to identify the basis for the organization of rational land use in order to increase the efficiency of agricultural production on the environmental basis for the steppe landscapes of Kazakhstan.

The purpose of this study is to search for opportunities of the realization of the landscape approach in intra-farm land management in the conditions prevailing in Northern Kazakhstan. The objectives of the study include:

- Determination of homogeneous structural territorial landscape units;
- Functional microzonation of land use;
- Establishment of an optimal structure of the agricultural landscape;
- Environmentally sound spatial arrangement of agricultural landscape elements along with the definition of a rational configuration of all elements of the agricultural landscape.

As far as there are no techniques of intra-farm land management of agroformations on the landscape basis in science and industrial practice of Kazakhstan, the scientific novelty of this research consists in (1) the development of landscape microzonation methods on the territory of the agricultural enterprise of the steppe landscape zone of Northern Kazakhstan, and (2) the determination of features of the intra-farm organization of the territory on the landscape basis for the conditions of Northern Kazakhstan by the example of agroformations in Akmola region [5].

MATERIALS AND METHODS

To achieve the objectives, the methods of monographic and cartographic analysis, design methods and experimental design are suggested to be used.

During the development of intra-farm land management projects on the landscape basis the following procedure has been determined:

- Analysis of the landscape structure.
- Study of the intensity of erosion processes.
- Agrolandscape microzonation.
- Land organization on the landscape basis.
- Arable land arrangement on the landscape basis.

The content of the research question determined the choice of the following methods. The monographic research method was used in the review of the published scientific papers on rational land use organization and the current state of intra-farm land management problems. At the same time, there were highlighted such basic concepts (approaches) as agro-ecological and ecological landscape and identified the unsolved problems in the organization of agricultural lands and planning of their territory on the landscape basis.

The study was based on the principles of a systematic approach, which suggests the consideration of landscape as a system consisting of interrelated and interacting components and able to maintain its balance, and is the basis of the landscape approach to land management. At the same time, land use of a certain enterprise should be presented as a set of landscape systems of various ranks [16].

In accordance with the objective of the study, land management projects have been developed on the landscape basis in the area of typical objects with the help of logical and physical modeling. The creation of the model of optimal agricultural landscape included the following stages:

- Investigation and generalization of the main characteristics of landscape components;
- Preparation of the cartographic model of agricultural landscapes;
- Realization of agrolandscape microzonation of the territory;
- Elaboration of the model of optimal land use based on the landscape approach.

The investigation and generalization of the original data was performed during the analysis of landscape conditions of the land use of typical objects; at the same time, there were identified the key natural and anthropogenic components of the landscape that are part of the field anthropogenic systems. The next stage was the examination of land use plans and component-based maps (soil, geobotanical, relief maps) with the help of the graphical analysis.

With the use of the graphic modeling of the territory of the selected land use, the maps of erosion processes and large-scale landscape maps-hypotheses were compiled.

In the course of preparatory work during the drafting of the land use project by the method of data grouping, there was realized the landscape microzonation of the territory of agricultural enterprises with the combination of landscape units in microzones with similar landscape conditions and usage.

Following the agrolandscape microzonation, the authors developed a model of optimal land use in the form of intra-farm land management projects on the basis of the landscape approach.

Since the territory of Akmola region is dominated by steppe landscapes, the analysis of landscape conditions was carried out using the example of typical objects of the steppe zone – a production cooperative “Madeniet”, limited liability partnerships (LLP hereinafter) “Krasnaya Polyana”, “Veselovsky” and “Sharafutdinov” of Akmola region. The typicality of these objects is supported by the fact that the characteristics of both natural and anthropogenic components (types, correlation and land arrangement) on their territory correspond to the structure of agricultural landscapes of Akmola region [4]. The relief of the territory of “Sharafutdinov” LLP is generally a slightly rolling plain, dotted with numerous flow hollows with the depth up to 2 meters and slightly gentle slopes 1-1.5 km long. Dark chestnut soils are heavy-textured. The solar method of snowmelt, peculiar to these climatic conditions, causes the development of water erosion of soil on long gentle slopes.

ISSN: 0975-8585

RESULTS AND DISCUSSION

Consider the features of the organization of the territory based on the landscape approach using the example of "Madeniet" Printing and Publishing the land use of which is located in the steppe zone of Kazakhstan arid province in conditions of a harsh continental climate. The average annual rainfall is 300 mm. A great part of the territory "Sharafutdinov" includes lands potentially suitable for arable, most of the territory is represented by southern low-humus calcareous chernozems. In addition, different types of solonetz and soil, exposed to water erosion, became widespread. The farm specializes in the production of spring wheat. The total land area is 9,071 ha, 99% of which – agricultural grounds. The agricultural landscape is monocultural, as it consists predominately of arable lands – 8,776 ha or 97%, and pastures occupy only 280 ha or 3% (Figure 1). In the analysis of landscape conditions, the morphological structure of the landscape has been studied. Preliminary large-scale maps-hypotheses have been compiled on the basis of maps that take into account natural and anthropogenic landscape factors. The basis for this development was the existing planning and cartographic materials on a scale of 1:25,000 (land use plan and component-based maps).

In constructing landscape maps, there are distinguished relatively small natural and territorial complexes, the formation and development of which is conditioned by the local characteristics of each specific area – facies, sub-landmarks. Facies is the most simple, indivisible territorial unit and basis of landscape structures of all types. Facies were only determined when one relief element (slope, watershed) contained soils of the same type. Sub-landmarks were determined when one relief element formed several facies, similar in origin and composition of natural components [17]. The boundaries of sub-landmarks were carried out by morfoizograf lines or lines of slope break.

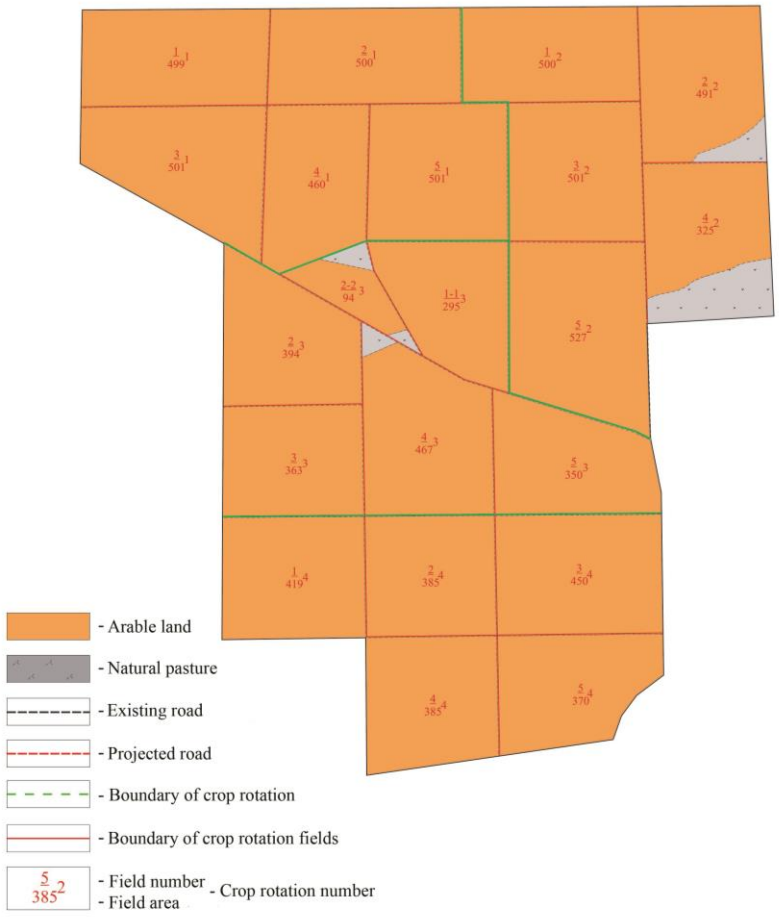

Figure 1: Arable land arrangement on the basis of the existing territory organization of "Sharafutdinov" LLP

The landscape map of "Sharafutdinov" LLP shows 22 landscape units located on the microrelief elements (watershed surfaces, water-dividing and ravine slopes), on the territory of microrelief forms (ravine, flow hollows, potholes) (Figure 2).

ISSN: 0975-8585

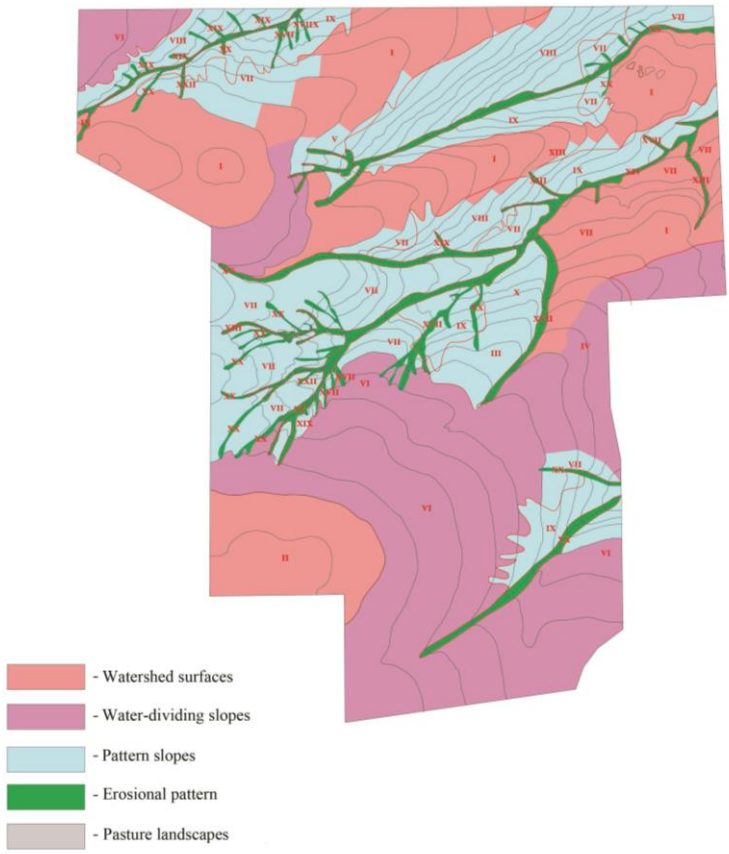

Figure 2: The landscape map of "Sharafutdinov" LLP

The landscape map, compiled for the territory of the agricultural enterprise, usually has a large number of landscape units, which impedes using it for land management purposes. The basis convenient for the territory organization should be a map that generalizes small landscape units into larger on the basis of the similarity of their use – a map of agrolandscape microzonation.

For agrolandscape territory microzonation, a landscape map-hypothesis, a map of modern territory organization, an agro-map, a map of the slope wash intensity and a scheme of ecological zonation have been studied and combined. As a result, there has been compiled a map, marking microzones with different functional purposes - morphological landscape units (facies, sub-landmarks), united in groups on environmental state and feasibility of use with the establishment of appropriate measures - agrolandscape microzones. Agrolandscape microzones were determined by the homogeneity of relief, soil and erosion processes (washout); within their boundaries, the same measures are being designed for their use [3].

During the development of the agrolandscape map, there were allocated five agrolandscape microzones on the territory of "Sharafutdinov" LLP, united in ecological and landscape microzones based on the landscape strips of one high-altitude range.

The microzone of conservation included territories with limited economic activity. In "Sharafutdinov" LLP, these are potholes and flow hollow bottoms. Small potholes are saucer-shaped depressions, which are the natural accumulators of the flow. Their territories contain natural biocenoses in the slightly changed forms and they perform the role of micro conservation areas – reserves. In addition, the economic use should exclude the bottoms of flow hollows on arable land provided they are laid down in perennial grasses. They simultaneously perform two functions - erosion control (hollow protection against further linear erosion) and environmental (becoming landscape ecological niches).

The second agrolandscape microzone is the restoration of agricultural capacity. Water erosion processes (evidenced by washed-off soils and flow hollows) were observed on the territory of arable land in

"Sharafutdinov" LLP. Therefore, it is necessary to take measures to prevent and stop soil erosion. The main anti-erosion measure in this micro-zone is the introduction of soil-protecting crop rotations. Depending on the degree of soil erosion danger, the measures are differentiated by sub-zones:

- Lands on the pattern cultivated slopes with the intensity of erosion from 10 to 16 t/ha, requiring the introduction of soil-protecting crop rotations with strip sowing of perennial grasses;
- Lands on the pattern cultivated slopes with the intensity of erosion over 16 t/ha, requiring the introduction of soil-protecting crop rotations with strip sowing of perennial grasses in combination with water-absorbing agro-technical measures.

The third agrolandscape microzone is the zone of the intensive use of field landscapes. In this microzone, lands are suitable for cultivation and, on the basis of specialization, are used to produce grain harvest. The factor limiting agricultural crop capacity in the steppe zone is moisture, so the main task here is to translate the flow from the surface to subsurface by introducing soil and water protection technologies. The territory of this microzone is differentiated by moisture-retention measures:

- Facies and sub-landmarks of the watershed plateau with calcareous soils;
- Facies and sub-landmarks of water-dividing slopes with the intensity of erosion from 2.5 to 8 t/ha;
- Facies and sub-landmarks of water-dividing slopes with the intensity of erosion from 8 to 10 t/ha.

The agrolandscapes of the watershed plateau, where calcareous soils are widespread, are potentially dangerous with respect to soil erosion. The main anti-erosion and water saving measure here, as throughout the whole territory, is subsoil tillage leaving stubble remains on the soil surface. To prevent the deflationary danger, the field fallow-grain zonal crop rotations with the strip fallow arrangement and spring wheat crops are introduced [2].

In agricultural landscapes of water-dividing slopes with the intensity of erosion from 2.5 to 8 t/ha it is recommended to arrange the zonal crop rotations with tillage in the direction of horizontal lines (contour). When the intensity of erosion is from 8 to 10 t/ha, the zonal crop rotations are implemented in combination with water-absorbing agronomic measures (deep processing) [9].

The fourth agrolandscape microzone is the use of meadow landscapes. In "Sharafutdinov" LLP, it includes facies and sub-landmarks of the erosional pattern located in the cultivated areas. On the territory of the microzone, haying should be alternated in accordance with the terms of grass ripening in the cutting rotation system.

The fifth agrolandscape microzone is the use of pasture landscapes. It includes lands of the pasture value, which provide for a normalized cattle grazing in compliance with anti-erosion requirements. Pasture landscapes are located on the slopes of riverside terrace. In addition, this micro-zone includes two parcels with pastures located inside the arable block. On the territory of this microzone, it is necessary to alternate cattle grazing in combination with the measures to restore the grass stand in the pasture rotation system.

Then, on the basis of agrolandscape microzonation the project of intra-farm land management was designed (Figure 3). The main objectives of the project were the organization of grounds and the arrangement of arable land. They were implemented in the experimental design as follows.

During the organization of grounds, there was the transformation of land parcels with regard to landscape conditions. Lands of the first microzone were removed from the arable area and transferred into hayfields of the radical improvement. The area of arable land of "Sharafutdinov" LLP transformed into hayfields of the radical improvement amounted to 1,010 ha. They are mainly located on arable land parcels divided by the ravine system. Flow hollows, ravine bottoms are laid down in perennial grasses to prevent erosion [12].

The project of arable land management consisted in the organization of crop rotations and the arrangement of their territory. During the organization of crop rotations based on the map of agrolandscape microzonation, there were defined different types, locations and boundaries of crop rotations. In "Sharafutdinov and K°" LLP, there were designed two soil-protecting and two field crop rotations. In accordance with the agrolandscape map, the soil-protecting crop rotations are located in the territory of the

second microzone (Figure 3). They are designed to reduce soil erosion, since 50% of them are in perennial grasses, placed in the stripes of a width of 200 m alternating with the stripes of wheat. The remaining area of arable land is located in the microzone of the intensive use of the field landscapes, and there are two projected field crop rotations on its territory, rich in grain crops and having the fallow field in its composition. In the fallow field, the fallow stripes alternate with crops of wheat. The areas of soil-protecting crop rotations are 1,744 ha and 1,608 ha, the area of field crop rotations – 1,958 ha and 2,406 ha. The average field area in the project is 390 ha [7], [10], [11].

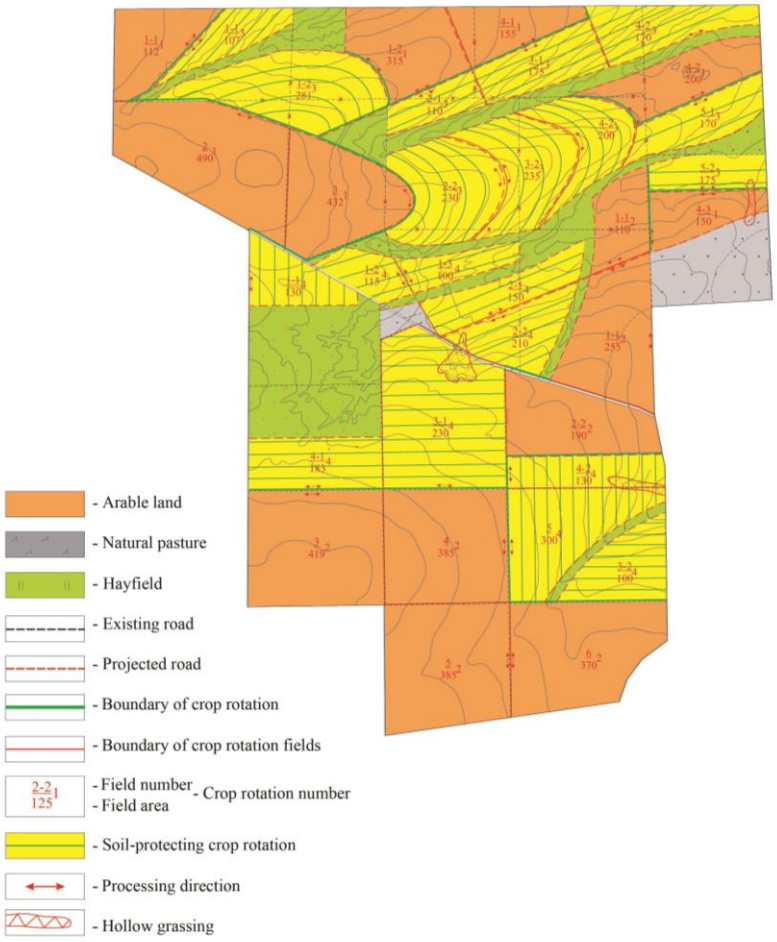

Figure 3: Project of land management of "Sharafutdinov" LLP on the landscape basis

During the arrangement of the crop rotation territory, fields were designed as homogeneous units taking into account the boundaries of landscape groups. As a result, the boundaries of the majority of the existing fields were changed, and their shape was transformed from rectangular to irregular. This is due to the fact that the boundaries of fields and work areas were combined with the boundaries of landscape contours for the creation of homogeneous areas [8]. New roads, which serve as the boundaries of fields and work areas, are on the structural lines that divide the landscape units. Most of the fields of crop rotation consist of work areas, which was contributed by the presence of transformed areas and compliance with the settings of uniformity for landscape conditions (Figure 3). These changes are associated with the transformation of the rectangular-rectilinear organization of the territory into contour, which is the basis for the organization of the territory of arable land on the landscape basis [14].

During the arrangement of the territory of sloping landscapes, the following types of the territory organization were used: rectilinear contour, with the processing direction across the slope, and curved-circuit, with the processing along the contours based on a given radius of curvature. Accordingly, the field boundaries and work areas in the territory of the second microzone and sloping landscapes of the third microzone were oriented in the direction of the contours.

This study has obtained scientifically grounded results on land management based on the landscape approach, which takes into account the requirements of the adaptive-landscape systems of agriculture and specific land management requirements. The project of agroformation land management has determined the homogeneous territories in terms of landscape and ecological aspects, highlighted the provisions and conditions of their use and established their boundaries [18]. Since the land use of selected farms is typical of the steppe zone of Kazakhstan, it can be argued that the landscape features of the given region were taken into account in the development of the projects. During the organization of the territory, there has been defined the procedure for distinguishing landscape microzones and describing the peculiarities of the organization and arrangement of agricultural and arable lands on the basis of the landscape approach. Thus, it can be said that the purpose of the research has been achieved and the objectives have been fulfilled.

The organization of the territory on the landscape basis involves land use optimization. The criterion for the correctness of the problem solution is the sustainability of the generated agricultural landscape, which is manifested in a sharp reduction in the development of negative processes that affect the productive function of the agricultural landscape and ensure the reproduction of natural resources. Evaluating the designed solutions developed in this work, one can say that the organizational and economic measures stabilize the landscape and ecological balance of landscape systems on the territory of the North-Kazakhstan region. This is reflected in the implementation of the principles of the landscape approach in the organization of the land use territory as follows:

1. Since the spatial and species diversity ensures the ecological balance of the landscape, the main focus of the organization of the land use territory was a rejection of monocultural landscapes. The ecological diversity of landscapes was achieved through the reduction of arable land, the expansion of the area of more ecologically sustainable forage lands and strip sowing of perennial crops in the territory of arable land.
2. The optimization of land use involves a combination of exploitation, amelioration and conservation. This principle is implemented through the allocation of microzones on the land use territories that provide both a resource-reproducing function of the agricultural landscape and an environment-stabilizing function.
3. The ecological sustainability of the landscape is manifested by a decrease in erosion and drought, the reproduction of soil fertility and consistent productivity [15]. Since the proper functioning of the landscape as a sustainable ecological system is possible only with its rational arrangement, the organization of the arable land territory, situated on the slopes, in the developed projects is based on the contour-ameliorative organization of the territory [6].
4. The ecological expediency of the proposed designed solutions should be combined with their economic efficiency. Evaluation of the results was produced by the computational and constructive method. The economic indicators of the existing organization of the territory were compared with the designed numbers, developed on the landscape basis. Those of “Sharafutdinov” LLP turned out to be cost effective, as compared to the current numbers, because the calculated additional net income is higher by about 104 million tenge. It is mainly provided by the introduction of a set of measures preventing soil erosion and increasing the moisture content of arable land (Table 1).

Table 1: Cost effectiveness of the project of land management on the landscape basis of “Sharafutdinov” LLP

Indicators	Unit of measure	At the moment of land management	According to the project
Economic indicators	thous. tenge		
1. Nonrecurring costs:			
- for the construction of field roads		-	290.4
2. Annual losses and costs:			
- losses by sterile spills during field processing;		966.2	1,014.9
- costs of empty running on crop rotation;		417.7	501.3
- costs of anti-erosion measures.		-	4,021.0
Total annual losses:		1,383.9	5,727.6
3. Reduced costs:	thous. tenge	1,383.9	5,762.4
4. The cost of additional grain production at the expense of moisture-accumulating measures	thous. tenge		

Total: including: - strip cropping - cross-slope tillage - contour cultivation - stubble-mulch tillage (with the use of subsurface cultivator)		- - - - -	297,600.0 164,248.0 108,010.0 1,878.0 23,464.0
5. The cost of gross output: - grain - perennial grasses		 2,850,270.0 -	 2,603,558.0 151,544.0
6. Losses of gross output of grain at the expense of introducing soil-protecting crop rotations		-	195,168.0
7. Additional net income		2,848,886.1	2,952,696.0

Similar results were obtained when analyzing the projects of land management and other typical objects. Consequently, the designed suggestions for the organization of the land use territory, based on landscape microzonation, are not only ecologically expedient, but also cost effective.

CONCLUSIONS

- In the context of the steppe zone of Kazakhstan, an optimal organization of agroformation land use should take into account the landscape conditions. The need to use the landscape approach in the design of the optimal landscape is objective because it ensures ecological expediency and economic efficiency of designed solutions. It is dictated by the fact that the traditional division of the lands of Kazakhstan according to the categories of suitability cannot provide proper land management decisions on specific land parcels.
- For the construction of the projects of intra-farm land management of the steppe zone, a scheme of agrolandscape microzonation acts as the basis defining the functions of each individual parcel of agricultural land with regard to its resistance to anthropogenic load and preservation of the landscape and ecological balance.
- In order to optimize land use and to improve the environmental soundness of the territory organization in the agricultural enterprises of Northern Kazakhstan, it is necessary:
    - to establish an optimal, environmentally sound land structure by transforming arable lands into forage; it is also possible to change the specialization of farms with a focus on the development of the livestock industry;
    - to establish an optimal direction of land use (intensive use, conservative or requiring agricultural capacity restoration) based on agrolandscape microzonation with the mandatory allocation of contours intended for nature protection purposes by creating a network of micro-reserves and landscape-ecological niches;
    - to transform a rectangular-rectilinear organization of the territory on the slope arable land into contour-ameliorative, with the introduction of soil and water protection technologies;
    - to set an optimal configuration for each work area and crop rotation field in order to create natural and economic complexes that fit into the structure of the natural landscape.
- The practical significance of the obtained results consists in the given recommendations and suggestions that can be used to change land management practices during the development of intra-farm land management projects.

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