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METHODOLOGY OF SPATIAL PLANNING OF AGRICULTURAL LAND USE

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Abstract

The article describes the methodology of spatial planning and organization of agricultural land use in land management projects that provide ecological and economic justification of crop rotation, based on ecological-landscape and ecological-economic basis. It's advantage in comparison with the methodology of the Soviet planning system is that it harmonizes the issues of economic development, organization and production technology, the structure of the territory in accordance with local natural conditions with productive and spatial properties of soils, their natural potential. The methodology was tested on the example of agricultural land use of the NSP "Nyva" in the Stavyshchenskyi rayon of Kyivska oblast. This methodology is based on social, economic and environmental aspects. It is substantiated that the economic efficiency of arable land use depends on the creation of appropriate organizational-territorial conditions. Field and forage crop rotation were introduced in the studied territory, considering the physical, geographical and economic conditions within the agro-landscape type of land use. It has been proved that social efficiency is ensured through the additional jobs creation and improvement of the life quality of local people. The determining factor for calculating the ecological efficiency of arable land use is the maintenance of a non-deficit humus balance. In particular, the humus balance in field and forage crop rotations was calculated for 2018 and 2019. A humus deficiency balance between 0.22 and 0.48 t/ha was obtained in three of the nine crop rotation fields, which prompted us to adjust the fertilizer system.

Key words: *spatial planning, ecological-landscape approach, ecological-economic approach, land management project, humus balance*

INTRODUCTION

In recent decades, an imbalanced deficient farming system has been dominating in Ukraine, which is associated with the disregard of environmental laws and regulations of land and nature management, and imperfect legal support in the field of land protection. As a consequence, we have a high economically and ecologically unjustified level of agriculturally used lands (80%) [9], which has led to the intensification of the agrarian sector, the dispersion of material resources, the attraction of unsuitable land as arable land. Neglect on environmental requirements for land use has a negative impact on economic performance.

There are also environmental losses associated with soil destruction, erosion and other degradation processes. Currently, annual humus losses are between 600 and 700 kg per 1 ha of agricultural land [4, p.180].

Obviously, the implementation of rational use and protection of land measures should be based on scientifically substantiated methodological foundations of their spatial development in such a sequence: "territory – landscape – land plot – soil" [5, p.20]. Therefore, the territorial planning of the organization of agricultural land use should be based on the principles of ecological-landscape and ecological-economic approaches to the arrangement of the territory in the course of land management process.

Due to the rapid change of the economic system in Ukraine there is a systematic redistribution of land resources, new land ownings and land use organizations are being formed. Currently, various organizational and legal forms of management (joint-stock companies, private and private-lease enterprises, agricultural cooperatives, farms, etc.) are functioning in the structure of agricultural land use. Huge agrarian enterprises, one of these agro-formations, contribute to improving the overall efficiency of agricultural production through the use of modern high-tech equipment and the latest technologies. At the same time, they displace part of small agricultural enterprises, including farmers, from the land lease market, which negatively affects the socio-economic situation in the countryside.

Usually, newly created entities do not adhere to the classical principles of organization of agricultural land use of territory (ignoring crop rotation factor, measures for protection of land (soils), projects of internal land management, etc.), which led to a sharp deterioration of the quality of land [8, p.4].

Scientific studies of the National Academy of Sciences of Ukraine show that crop rotation, if is scientifically substantiated, can be the basis of agriculture, because it regulates biological, nutrient and water balances of soil and the rate of detoxification of harmful substances entering the soil in the process of agricultural production. The same introduction of crop rotation helps to protect the environment, preserve and enhance the natural fertility of soils. And the placement of basic crops on suitable land for them increases yields and reduces the cost of production.

The purpose of the case study is to develop a crop rotation on the basis of ecological-landscape and ecological-economic principles on the territory of study site and to achieve a non-deficit humus balance in this crop rotation.

Literature review. The substantiation of theoretical and methodological foundations of the directions of use of arable lands of Ukraine on the basis of their classification according to the suitability for cultivation of agricultural crops, taking into account specific features of natural and environmental conditions of the environment, is studied in the works of D.I. Babmindra, D.S. Dobriak, O.P. Kanash, I.A. Rozumnyi [2]. Formation of ecological and economic approaches to rationalization of agricultural land use and protection, formation of sustainable land use – A.V. Barvinskyi, H.D. Hutsuliak, O.S. Dorosh [7]. The basic principles of introduction of contour-melioration organization of territory are revealed in the works of O.H. Tararico and M.H. Lobas [11]. V.M. Tertiak grounded the basics of landscape typing of land use, improved the method of ecological and landscape land use of agricultural enterprises, which is based on the data assessment of land and resource potential of the territory [6]. Scientific bases of formation of soil protection systems of agriculture on agro-landscape basis for different agro-ecological groups of lands of agricultural land uses of the forest-steppe zone are grounded in the works of V.F. Kaminskyi [8], V.M. Kryvov [10] and others. But issues related to ecological-economic and ecological-landscape approaches in the development of land management projects for ecological and economic justification of crop rotations and land management are not sufficiently researched.

MATERIALS AND METHODS

Given the current conditions of the development of a market-oriented system of land use, priority must undoubtedly be given to the environmental-landscape and ecological-economic component in the development of land management projects. The underestimation of the heterogeneity and variability of landscape conditions over time and space during crop rotation planning on the territory of agricultural land use leads to the emergence of negative processes that affect the productivity and quality of land. In this regard, the ecological-landscape organization of the territory should become the basis for designing fields in land management projects.

There is an opinion in the scientific community that a methodological approach to the organization of ecological and economic justification of crop rotation and land management of agricultural enterprises on an ecological-landscape basis should combine the ecological-landscape approach (as a general construction of agro-landscape) with agro-ecological landscape approach [6, p. 29].

The methodology of territorial and spatial planning of the organization of agricultural land use based on ecological-landscape and ecological-economic approaches in land management projects was implemented in the preparation of the land management project that provides ecological and economic justification of crop rotation and land use management of the NSP "Nyva" in the Stavyshchenskyi rayon of Kyivska oblast. The project identifies measures aimed at protecting land (soils) and increasing their productivity, improving agricultural landscapes, optimizing land structure with the most favorable ratio, preserving degraded land, and outlining approaches to their use. The importance of developing such projects is seen in the scientific substantiation of proposals related to:

(1)creation of appropriate territorial and spatial conditions for agricultural production, considering the suitability of soils for growing basic crops;

(2)determination of the crop rotations types, considering the specialization of agricultural production with the subsequent design of fields in these crop rotations and drawing up a scheme of crop rotation;

(3)identification of protection, sanitary protection zones for regime-forming objects with a corresponding restricted land use regime.

In the process of crop rotation planning on the territory of the research object, based on the existing agricultural production groups of soils and their condition, as well as the relief, we have identified the types of agricultural landscapes. In determining the types of landscapes, the steepness of the slope plays a significant role. Depending on the type of landscape, we choose what proportion of the area is appropriate to cultivate at the same time, as well as the choice of crops and technologies for their cultivation in order to protect the soil from erosion processes, humus loss and depletion.

Then it is necessary to identify the types of crop rotations needed and design them based on the types of agro-landscapes located in the design area, the production specialization of the enterprise or farm, employment in animal husbandry (the need for production of feed) and the demand for certain types of crop production on the market.

There are the following types of crop rotations:

(I)Field (the most widespread, designed mainly in large areas for the production of basic crops);

(II)Cereal;

(III)Forage (designed mainly on the territories of farms that include livestock production);

(IV)Non-rotation areas (are not assigned to any crop rotation without intensive agricultural production).

Further, a set of measures for reproduction of land fertility on the territory of the study object is developed, if necessary. The next step is to evaluate the effectiveness of rotation. The environmental component of rotation efficiency can be achieved by a non-deficit humus balance.

Humus balance can be calculated as the difference in humus loss and revenue for each crop rotation. In our study, the technique of H.Y. Chesniak has been applied. The level of humus inflow into the soil is accounted for by the humification of nutrient-root residues (R_1) and the formation of humus from organic fertilizers (R_2), which in sum represent the total humus revenue (Rg): [3]

$$R_g = R_1 + R_2$$

Humus level growth from the humification of nutrient-root residues depends on what crop was grown this year on a particular field, since different amount of residues remain after different plants. This is determined by the coefficient of accumulation (Ka). The degree of humification, which is determined by the coefficient of humification (Kg) depends on crop grown at that particular year as well. Accordingly, to determine the revenue from the humification of nutrient-root residues, the yield (Y) of the respective crop must be multiplied by both of the above coefficients: [1]

$$R_1 = Y \times K_a \times K_g$$

The formation of humus from organic fertilizers depends entirely on the amount of organic fertilizers introduced and is added to the amount of humus formed from the nutrient-root residues.

Instead, determining the humus expense component (Lg) in the fertile soil layer is a more complicated process. Humus is lost primarily due to the following processes: humus mineralization (Mg) and humus loss due to water erosion (Le): [3].

$$L_g = M_g + L_e$$

The mineralization of humus is determined by the following formula:

$$M_g = G \times h \times \rho \times K_m \times K_b,$$

where G is the humus share in the soil's arable layer (%), this is one of the soil's main genetic indicators, influenced by climate, particle size distribution and erosion.

h – depth of the arable layer (cm), depending on the culture.

ρ – the soil folding density (g/cm^3), depends on the particle size distribution and humus content and ranges from 1.00 to 1.60 g/cm^3.

K_m – humus mineralization rate, the annual proportion of humus that is mineralized (determined over an average of several years). Mineralization depends on the frequency of cultivation and soil-climatic zone.

K_b – relative index of biological productivity, which characterizes the ratio of local climatic conditions of humus mineralization to the average in Ukraine taken as 1 [1].

The loss of humus under the influence of water erosion can be calculated using the next formula:

$$L_e = L_s \times G,$$

where Ls is the soil losses under water erosion influence, which depend on the soil-climate zone and slope and are shown in table 1.

G – the humus share in the soil (%) [12].

Table 1. Annual soil losses under the influence of water erosion on the slope lands of Ukraine

Soil and climate zone	Slope, %	Earth particles washed away, t/ha
Polissia (Woodlands)	0.5-2	7-8
	2-5	17-20
	5-10	50-65
Forest-steppe	0.5-2	6-10
	2-5	17-37
	5-10	60-95
Steppe	0.5-2	1.5-4.5
	2-5	6-45
	5-10	23-45

Source: Humus loss due to erosion, Studopediia (stand 02.02.2020)

RESULTS AND DISCUSSIONS

In the study site, the most common are dark gray soils with varying degrees of erosion, and black soils with varying degrees of erosion. For the planning of land conservation measures related to the increase of fertility of lands close in genesis, production indices and conditions of occurrence, by relief and soil cover and their implementation within the land use area, eight high-yielding soils were selected.

In the course of the researches within the land use area 5 types of agro-landscapes were identified, the characteristics of which are given in Table 2.

Table 2. Types of agricultural landscapes, their characteristics within the territory of the study object

Type of agro-landscape	Slope, degrees	Acceptable area of arable land, %
plain field	plateaus with a slope of less than 1°	75-80
slope-hollow	slopes of 1–3° with hollows without ravines	not more than 70
slope-ravine	catchment areas on slopes of 3–5° steepness	55-60
beam-ravine	beams and ravines with slopes of 5–7°	not more than 30
steep slope	steep slopes of over 7° with dense network of ravines	not more than 30

Source: developed by authors.

In the studied territory, considering the physical, geographical and economic conditions within the landscaping type of land use, field and forage crop rotations were introduced, the characteristics of which are given in the Table 3.

Table 3. Characteristics of crop rotations and non-rotation areas within the territory of the study object

Name of crop rotation	Number of fields	Total area, ha	Field code	Average field area, ha
Field	9	1,618.2	I	179.8
Forage	4	197.9	IV	49.5
Non-rotation areas	2	40.7	1	-
Sum		1,856.8	X	X

Source: developed by authors.

Field crop rotation is foreseen on flat lands with predominance of black soils. This crop rotation is planned on 9 fields with a total area of 1,618.2 ha (average field size is 179.8 ha), within which the following rotation of crops is envisaged: 1. perennial grasses; 2. winter wheat; 3. soybeans; 4. barley; 5. sunflower; 6. corn on silage; 7. winter wheat; 8. sugar beet; 9. corn for grain; 10. barley with sowing of perennial grasses.

Forage grassland crop rotation is projected on flat lands and partly on slopes up to 3-5º with predominance of typical black soils. This crop rotation is planned on 4 fields with a total area of 197.9 hectares (average field size – 49.5 hectares), within which the following rotation of crops is envisaged: 1. perennial grasses; 2. perennial herbs; 3. winter wheat for green fodder (corn for green fodder); 4. annual grasses with sowing of perennial grasses.

The importance of developing a land management project lies in defining a set of measures related to the cultivation of soils and the reproduction of their fertility within the agricultural production groups of soils (Table 4).

Table 4. Complex of measures for reproduction of soil fertility on the territory of the study object

<table>
<tr><th>№</th><th>Measures</th><th>The content of the measure and its quantitative characteristics</th><th>Note</th></tr>
<tr><td colspan="4">Black earth poorly degraded, medium loam (code of agricultural production group 41d, 49d, 51d)
Black earths typica with low humus and highly degraded, medium-loam and washed away (agricultural group 53d, 55d, 56d)
The total area is 1826.2 ha</td></tr>
<tr><td>1</td><td>Cultures used in rotation</td><td>Soils are suitable for all grain, fodder, industrial and vegetable crops.</td><td></td></tr>
<tr><td>2</td><td>Methods of tillage</td><td>The combined tillage should be used: a combination of flat-cut and surface plowing.
For improvement of agrophysical properties – timely cultivation of soil, saturation of rotation of legumes on sloping lands (agricultural production group of soils 49d, 55d), application of only shelf-free cultivation.
All technological operations of cultivation, sowing, care of crops should be carried out only across the slopes.</td><td>It is better to avoid deep plowing.</td></tr>
<tr><td>3</td><td>Supporting liming</td><td>Due to the decalcification of soils, it is advisable to deacidify them with liming (especially for agricultural groups of soils 4Id, 49d, 51d).</td><td>Dose 3 t/ha once every 10 years.</td></tr>
<tr><td>4</td><td>Application of organic and mineral fertilizers</td><td>Fertilizer application in the rate of 12-14 t/ha to ensure a non-deficit humus balance.
Application of phosphate and nitrogen fertilizers for industrial and vegetable crops.
Potash fertilizers application only if needed</td><td>Application by tape method during sowing.</td></tr>
</table>

Source: developed by authors.

The project activities have been evaluated in economic, social and environmental aspects. In fact, the systematic principle of land use, which tries to find a way to combine three mechanism's components, which contribute to realization of the land use system goals. This principle as well provides the optimal correlation between soil quality improvement, economic growth and improvement of life quality of local residents. Economic efficiency can be achieved in the way of creation of territorial and organizational conditions suitable for agricultural production processes efficiency improvement. Territorial properties of the land are reflected in the cost of production, which is affected by yield, technological properties of soils, contours of land, etc. Social efficiency is determined by the level of life quality (creation of new jobs, improvement of working conditions and life of the local people, etc.).

A decisive indicator of the ecological efficiency of arable land is the maintenance of a non-deficit humus balance in the fertile soil layer. We have calculated the humus balance in field and forage crop rotations on the territory of the studied object as of 2018 and 2019. The calculation of the humus balance for 2019, performed on the planned yield, using the principle of obtaining the desired positive humus balance in rotation.

Table 5. Calculation of humus balance in field rotation soils on the territory of the study object for 2019

№ of field	The volume of humus in the fertile soil layer, t/ha, (%)	Culture grown on the field	Yield (Y), t/ha	Humus revenue (R_g)							Humus loss (L_g)			Humus balance, t/ha
				humification of nutrient-root residues (R_1)			formation of humus from organic fertilizers (R_2)			total revenue t/ha	humus mineralization (Mg), t/ha	humus loss due to water erosion (Le), t/ha	total humus loss	
				coefficient of accumulation (Ka)	coefficient of humification (Kg)	total humification, t/ha	manure	other organic fertilizers	sum, t/ha					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	101.08 (3.11)	Sugar beet	35.0	0.11	0.10	0.39	2.70	-	2.70	3.09	1.35	0.25	1.60	1.49
		Corn for the grain	8.0	1.30	0.23	2.39	–	"	*	2.39	0.65	0.25	0.90	1.49
2	95.88 (2.95)	Barley	4.0	1.60	0.22	1.41				1.41	0.61	0.24	0.85	1.09
3	126.38 (3.57)	Winter wheat	5.5	1.30	0.25	1.79			’	1.79	0.70	0.29	0.99	0.80
		Barley	4.0	1.60	0.22	1.41	-	-	-	1.41	0.70	0.29	0.99	0.42
4	124.96 (3.53)	Winter wheat	5.5	1.30	0.25	1.79		-		1.79	0.69	0.28	0.97	0.8**2**
		Perennial herbs	18.0	1.70	0.25	7.65				7.65	0.43	0.28	0.71	6.94
5	130.63 (3.69)	Sunflower	2.5	1.70	0.15	0.64	1.08		1.08	1.72	0.72	0.30	1.02	0.70
6	127.40 (3.92)	Perennial herbs	18.0	1.70	0.25	7.65				7.65	0.50	0.31	0.81	6.84
7	117.33 (3.61)	Winter wheat	5.5	1.30	0.25	1.79				1.79	0.75	0.29	1.04	0.75
8	121.23 (3.73)	Corn for silage	45.0	0.16	0.15	1.08	2.70		2.70	3.78	0.77	0.30	1.07	2.71
9	129.35 (3.98)	Soy	2.1	1.3	0.23	0.63	1.08		1.08	1.71	0.83	0.32	1.15	0.56

Source: calculated by authors.

The calculation of the humus balance in the soil in terms of crop rotation fields is given in Table 5.

According to the actual 2018 yield, a positive humus balance was obtained on 1, 2, 4, 5, 7 and 9 fields. In other fields (3, 6 and 8), where soybean, barley with perennial grass and sunflower were grown respectively, deficient humus balance (from 0.22 to 0.48 t/ha) was recorded.

This indicates that in order to stabilize the humus state of the soil within these fields of crop rotation it is necessary to adjust the fertilizer system of both its precursor and the pole-catching crop.

In addition, there is a need to attract alternative sources of organic fertilizer replenishment by maximizing the use of livestock waste and by-products, including straw as an organic fertilizer and expanding the use of bacterial fertilizers.

In this respect, it is necessary to follow the developed zonal standards of the structure of acreage of major groups of crops, which allows to master biological principles in the development, introduction of field, forage and other crop rotations with a high degree of use of bioclimatic potential and to realize the idea of ecological rationalization of agriculture.

Humus balance in accordance with our proposals is calculated in Table 5.

CONCLUSIONS

On the basis of the conducted researches the advantages of the combination of ecological-landscape and ecological-economic approaches in the development of land management projects on ecological-economic justification of crop rotations and the ordering of lands providing the combination of economic, ecological and social components of the mechanism of realization of the goals of the land-use system are substantiated. The proposed approach ensures the systematicity, dynamic and integrity of the process of spatial planning of the organization of agricultural land use.

An indispensable condition for conducting highly productive, competitive agricultural production is the resource conservation and increase of soil fertility, the prevention of degradation processes, which is largely determined by the nature of land use. The developed project managed to achieve a non-deficit humus balance.

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