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SUSTAINABLE LAND MANAGEMENT AS AN INSTRUMENT TO IMPROVE ECOLOGICAL AND ECONOMIC EFFICIENCY OF AGRICULTURAL LAND USE

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Abstract

The goal of the research is to substantiate scientific and institutional fundamentals of sustainable land management as an instrument to improve economic efficiency of agricultural land use. The research methodology is presented as a model of the system of measures, which should be performed while adapting to the sustainable development of agricultural land management being the instrument to improve ecological and economic efficiency of land resources use. The research progress included implementation of several stages: 1) analysis of the goals of sustainable development, adapted for Ukraine for the period of 2015-2030; 2) determination of the specificity of use of the region's land and resource potential; 3) assessment of the impact of agro-technical and natural-climatic factors on the value of yield by the dispersion analysis method;4) modeling of the current and expected levels of yield of grain and soil-exhausting crops in conditions of the studied territory. To supply automation of the dispersion analysis calculations, the researchers used the computer program "Regre". The described methodology was tested on the territory of Mykolaiv region. The research defined the impact of agro-technical and natural-climatic factors on the value of yield capacity of the main agricultural crops of the region and their distinction by applying the dispersion analysis method. The research results are used to make forecasts of the level of yield of grain crops and sunflower in the future (2025). The increased yields of the main crops will provide the possibility to reduce the area of agricultural plowing, as well as expand the area of lands used for nature protection. The economic balance for the security of sustainable land management of the examined region needs crucial improvements. First, it concerns revival of land-owners' careful attitude to land. Therefore, labour and financial efforts should be focused on active application of the tools of the mechanism of land resources reproduction.

Key words*: land resources, agricultural land, sustainable development, dispersion analysis.*

INTRODUCTION

At the beginning of the 21st century, the world economy experiences principally new concepts on the ways of agrarian sphere development. The situation is forced by the growth of the world population and limited resources for satisfaction of the humanity's needs for food. According to the forecasts, made by numerous scientists, the global population will intensively increase.

Natural resources can potentially be used in a sustainable way if appropriate land management technology, regional planning and the policy framework complement one another in a purposeful way, in accordance with the principles and concepts of sustainable land management (SLM) [3].

Current conditions and use of land resources in the sector of agrarian nature management of Ukraine are characterized by the low economic and ecological efficiency. The strategy of maximum turnover of agricultural lands, out-of-date technologies of soil treatment, unsatisfactory use of fertilizers and other violations of the system of scientific arable farming cause negative effects. They are revealed in the misbalanced land use, degradation of soil, loss of fertility potential [7]. In several years, ecologically non-argued, irrational technical and technological as well as organizational land management in the agrarian sphere is capable to destroy the fertile arable layer of soil, having been created by the nature for thousands of years. In Ukraine, only one of 10 hectares of agricultural lands is in satisfactory ecological

conditions, one third of lands is eroded and degraded. The annual humus loss reaches 600-700 kg per 1 ha of agricultural lands [6].
Sustainable management of agricultural lands is one of the necessary conditions to support balanced correlation of ecological, economic and social factors of society development considering the properties of land resources and their values. The FAO considers that spatial organization of land resources, approval of the strategies of sustainable land management and land organization are important aspects to achieve sustainability and economic prosperity of each region and country in total [2]. On the contrary, attempts of agricultural producers to get maximum profit have resulted in harmful ecological consequences. The ecological crisis in land management has become a real threat. Therefore, land organization should become a principal means to secure sustainable development of land management in Ukraine, because it is characterized by many-sided activities and expects land policy, organization of rational use and protection of land, reclamation, crop-technical and anti-erosion measures [4]. The instruments and methods of land use planning in the appropriate scales should motivate and assist different and often competing users of land resources to choose the variants of land use and management, which will improve their efficiency, support stability of agricultural and food systems, contribute to management of land and water resources [1].
The science and practice face the urgent need to reconsider the paradigm, theoretical and methodological fundamentals of land management and improve the mechanism of management of the rational use of land resources. Establishment of a new philosophy and methodology of sustainable land management in Ukraine provides opportunities for application of its results both for effective land relations regulation and for organization of protection and rational use of lands, determination and organization of the system of economic and organizational measures on their fertility recovery.

MATERIALS AND METHODS

The research progress included implementation of several stages: 1) analysis of the goals of sustainable development, adapted for Ukraine for the period of 2015-2030; 2) determination of the specificity of use of the region's land and resource potential; 3) assessment of the impact of agro-technical and natural-climatic factors on the value of yield by the dispersion analysis method; 4) modeling of the current and expected levels of yield of grain and soil-exhausting crops in conditions of the studied territory.
To obtain the immediate and relevant initial information on the specificity of land resources use, the researchers used data of statistical reports as an informational base to detect possible deterioration of land quality.
To straighten the dynamic line of the yield of main agricultural crops, the straight-line equation was used [7]:

$$\bar{y}_t = a + bt, \quad (1)$$

where:
$\bar{y}_t$ – yield of crops for the period t;
a – an absolute term (equal to the theoretical value of the index in the period t = 0);
b – annual average growth (fall) of the crop yield;
t – ordinal number of the year.
Application of the method of dispersion analysis expects the following stages, i.e. logistic analysis; analysis and choice of factors to the model; composition of a multiple model and check of its significance; economic interpretation of the obtained results. To supply automation of the dispersion analysis calculations, the researchers used the computer program "Regre".
The work presents forecasts of the levels of yield of the region's agricultural crops for the period until 2025, which is composed by applying the method of analytical alignment of the yield dynamics.

RESULTS AND DISCUSSIONS

According to the internationally approved definition, sustainable development should

satisfy the needs of today's world by making no threat for the quality of future generations' life. It means that sustainable social and economic development is particular for the situation of balance between solution of social and economic problems and environmental protection, satisfaction of the necessities of life of the present generation and supply for the demands of future generations [5, 10].

Sustainable development of the sphere of agrarian land management should be considered as such conditions of the branch, which secure the best possible correlation between its economic growth, character of agricultural lands reclamation, increase of material and spiritual needs of population. Sustainable agrarian land management involves the methods of land resources use, which support the best possible ecological, social-economic parameters of agrarian landscapes functioning.

In September 2015, the Summit on sustainable development and approval of the Post 2015 Development Agenda was held within the framework of the 70th session of the UN General Assembly in New York. The Summit approved new goals of development. The Resolution of the Summit "Transforming our world: the 2030 Agenda for Sustainable Development" adopted 17 goals and 169 targets. Ukraine, along with other member-countries of the UNO, joined the global process on sustainable development security. One of the primary goals of sustainable development, adapted for Ukraine for the period of 2015-2030, is to end hunger and develop sustainable agriculture [9].

The main measures, which are necessary while adapting to the sustainable development of agricultural land management as an instrument to improve ecological and economic efficiency of land resources use, can be presented in the form of a model (Fig. 1).

The proposed model of the system of adaptive measures will help combining ecological requirements and economic interests. Therefore, it will contribute to a growth of the volume of agricultural products along with protection and improvement of the environment.

Achievement of the effect of sustainable land management, protection of the land fund integrity, and keeping to the principles of rational use of land resources are considered on the example of Mykolaiv region occupying the area of 2,458.5 thousand ha (4.1 % of the territory of Ukraine), which is the agrarian region of the country.

In the structure of agricultural lands of the studied territory, the largest share (above 69%) is occupied by arable land (Table 1). The area of agricultural lands in Mykolaiv region has recently demonstrated the tendency to reduction (in 2019, the area reduced by 118.12 thousand ha (4.8%) comparing to 2016). Such transformation of agricultural lands was partially implemented by reducing the area of arable land. In the agrarian sphere, the processes of implementation of environmental land management happen extremely slowly. Thus, a considerable share, i.e. 49.28 thousand ha (1.93%), needs conservation. Within the area of the research, 1.52% agricultural lands suffer from a combined water and wind erosion in 2019.

In terms of the main land users, the largest share of agricultural lands is used by agricultural enterprises. In the period of 2000-2019, the territory of Mykolaiv region was characterized by unstable conditions and a high level of anthropogenic burden. Ecological conditions of land resources are positively influenced by the structure of cropping area under agricultural crops, where the share of perennial herbs is relatively high (not less than one third of the total cropping area). In the studied region, the largest share in the structure of crops has been recently occupied by grain crops. Moreover, Mykolaiv region is among the top five leaders by the cropping area of soil-exhausting technical crops. Nevertheless, agricultural enterprises demonstrate the tendency to increase the level of land plowing.

A sustainable agrarian landscape is created by means of ecologically adapted organization of agricultural lands. Its main components include development and introduction of a system of crop rotations on arable lands and ways of formation of plant groups – on forage lands [1].

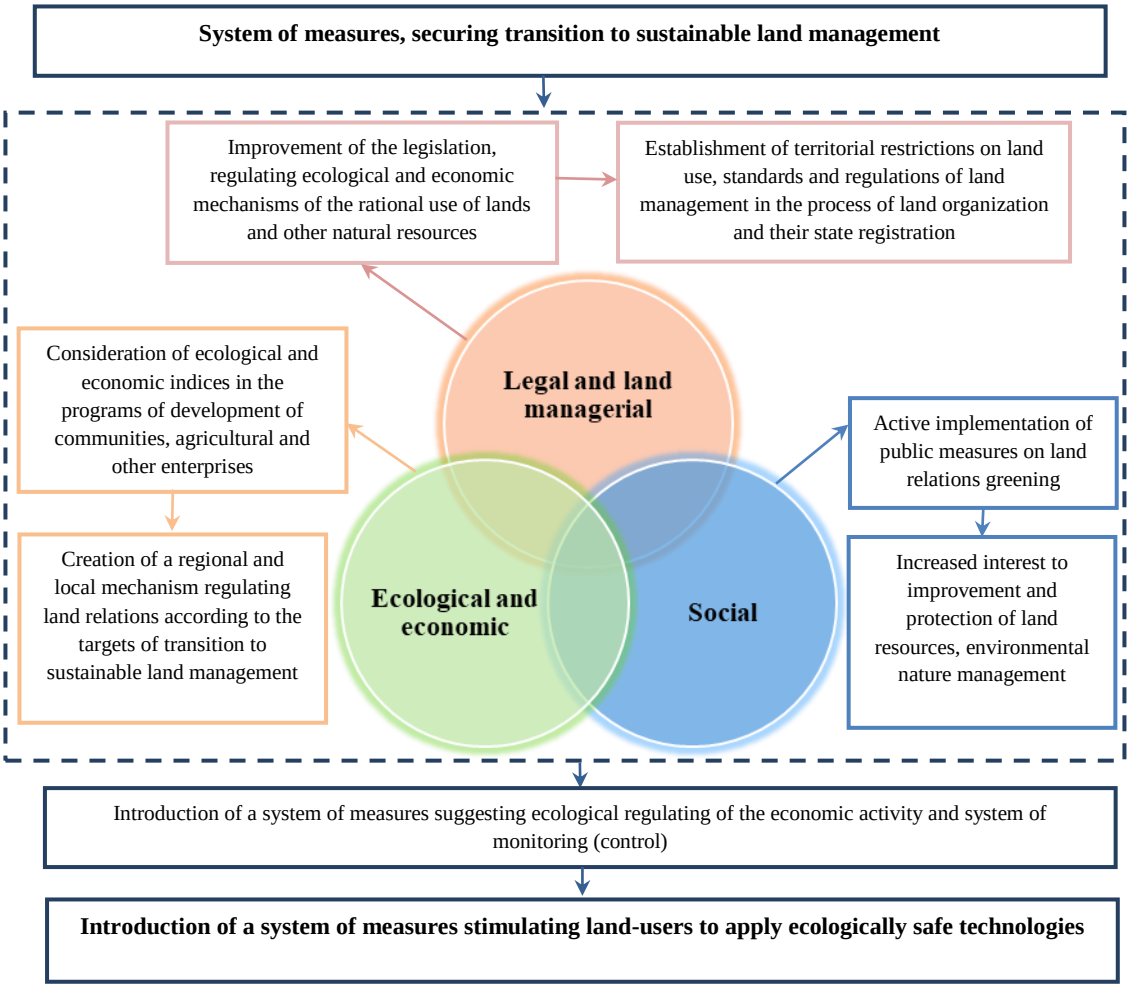

Fig. 1. Model of the system of adaptive measures on transition to sustainable land management*
*Source: Completed by the authors according to the data [9, 11].

Table 1. Structure of the land fund of the examined region (as of January 1)*

Main kinds of lands	2016		2017		2018		2019		Deviation, +,-	
	thous.ha	%	thous.ha	%	thous.ha	%	thous.ha	%	thous.ha	%
Total area	2,458.50	100.00	2,458.50	100.00	2,458.50	100.00	2,458.50	100.00	0.00	0.00
Including:										
1. Agricultural lands	2,006.20	81.60	2,006.20	81.60	2,006.20	81.60	1,888.08	76.80	-118.12	-4.80
including:										
arable land	1,699.20	69.12	1,699.20	69.12	1699.20	69.12	1,703.40	69.30	4.20	0.18
grasslands	3.10	0.12	3.10	0.12	3.10	0.12	3.57	0.10	0.47	-0.02
perennial plants	35.70	1.45	35.70	1.45	35.70	1.45	33.36	1.40	-2.34	-0.05
hayfields and pastures	268.20	10.91	268.20	10.91	267.90	10.90	255.70	10.40	-12.50	-0.51
2. Forests and other forested area, total	124.60	5.07	124.60	5.07	124.50	5.06	134.37	5.50	9.77	0.43
including the area covered by forest vegetation	101.20	4.12	101.20	4.12	101.30	4.12	121.49	4.90	20.29	0.78
3. Build-up lands	98.90	4.03	98.90	4.03	99.00	4.03	296.15	12.00	197.25	7.97
4. Open swamp lands	21.00	0.85	21.00	0.85	21.10	0.86	19.40	0.80	-1.60	-0.05
5. Open lands without or with poor vegetation	30.80	1.25	30.80	1.25	31.00	1.26	25.90	1.10	-4.90	-0.15
6. Other lands	177.00	7.20	177.00	7.20	48.10	1.96	94.65	3.80	-82.35	-3.40
Total area of lands (ground)	2,329.70	94.76	2,329.70	94.76	2,329.70	94.76	2,332.74	94.90	3.04	0.14
7. Territory, covered by surface waters	128.80	5.24	128.80	5.24	128.80	5.20	125.81	5.10	-2.99	-0.14

*Source: Completed by the authors according to the data [8].

The principal index of ecological and economic efficiency of agricultural land use is determined by the level of yield and productivity of agricultural crops and crop

rotation in total. Yield is an index of crop productivity. It is a derivative value of the factors and conditions of its formation. Therefore, variation of each factors definitely effects the ultimate value of the crop yield [7].

To identify the impact of agro-technical and natural-climatic factors on the value of yield of the principal agricultural crops in Mykolaiv region and their distinction, the dispersion analysis was used by the researchers (Table 2). The research results are used to make forecasts of the level of yields of grain crops and sunflower in the future (2025). It is expected that an increase of the yields of main crops will provide the possibility to reduce the area of agricultural plowing, as well as expand the area of lands used for nature protection.

To make calculations, the straight-line equation (1) is used. However, $\sum y = \sum \overline{y^2}$. To determine parameters a and b, the system of normal equations is composed:

$$\begin{cases} na + b\sum t = \sum y, \\ a\sum t + b\sum t^2 = \sum ty; \end{cases}$$

$$\begin{cases} 9a + 45b = 260.8, \ (\times 5) \\ 45a + 285b = 1{,}373.0; \end{cases}$$

$$\begin{cases} 45a + 225b = 1{,}304.0, \\ 45a + 285b = 1{,}373.0; \end{cases}$$

$60b = 69;$

$b = 1.15.$

The obtained value is inserted in:

$9a + 45 \times 1.15 = 260.8$. Then, $a = 23.23$.

$$\overline{y_t} = 23.23 + 1.15t.$$

For the period until 2015, yield of grain crops at the agricultural enterprises of Mykolaiv region will be determined as:

$y_{2025} = 23.23 + 1.15 \times 16 = 41.63$ centner/ha.

The dispersion characterizes the degree of absolute variation and serves for assessment of the factors' impact on the feature variation. Here is the calculation of the total dispersion, which manifests variation of yield due to the impact of agro-technical and natural-climatic factors:

$$\sigma^2_{general} = \overline{y^2} - \sum \overline{y^2} = 866.48 - 839.71 = 26.77.$$

The dispersion of the theoretical values of yield is calculated in the work. It characterizes the yield variation (change) under the impact of only agro-technical factors:

$$\sigma^2_{theoretical} = \frac{(\overline{y_t} - \sum y)^2}{n} = 79.4 \div 9 = 8.82.$$

Thus, it is obtained:

$$\frac{\sigma^2_{theoretical}}{\sigma^2_{general}} \times 100\% = \frac{8.82}{26.77} \times 100\% = 32.95\%.$$

Therefore, the impact of agro-technical measures on the change of grain crops yield at agricultural enterprises equals to 32.95%. The impact of natural-climatic factors on the yield of grain crops is 100% – 32.95% = 67.05%.

The same calculation is done for sunflower, which is a soil-exhausting technical crop (Table 3).

Table 2. Yields of grain crops at agricultural enterprises in Mykolaiv region*

Year, n	Year number, t	Yield, centner/ha, y	Calculated values		$\overline{y_t}$	Average square value of the feature, $\overline{y^2}$	$\overline{y^2}$	$(\overline{y_t} - \sum \overline{y})^2$
			t^2	t × y				
2010	1	24.5	1	24.5	24.4	600.3	-	21.1
2011	2	28.5	4	57.0	25.5	812.3	-	11.9
2012	3	16.4	9	49.2	26.7	269.0	-	5.3
2013	4	31.0	16	124	27.8	961.0	-	1.3
2014	5	32.3	25	161.5	29.0	1043.3	-	0.0
2015	6	32.1	36	192.6	30.1	1030.4	-	1.3
2016	7	34.6	49	242.2	31.3	1197.2	-	5.3
2017	8	30.6	64	244.8	32.4	936.4	-	11.9
2018	9	30.8	81	277.2	33.6	948.6	-	21.2
n = 9	$\sum t = 45$	$\sum y = 260.8$	$\sum t^2 = 285$	$\sum (t \times y) = 1{,}373.0$	$\sum \overline{y_t} = 260.8$	$\sum \overline{y^2} = 866.48$	839.71	79.4

*Source: Completed by the authors.

The calculations have provided the following results: a = 15.88, b = 0.52. Then,

$$\overline{y_t} = 15.88 + 0.52t.$$

Until 2025, the prospect of sunflower yield at agricultural enterprises in Mykolaiv region is determined as:

$y_{2025} = 15{,}88 + 0{,}52 \times 16 = 24{,}42$ centner/ha.

Thus, the impact of agro-technical measures on the change of sunflower yield at agricultural enterprises equals to 21.43%. The impact of natural-climatic factors on the yield of grain crops is 100% – 21.43% = 78.57%.

The performed calculations confirm that in Mykolaiv region, the 2025 prospects expect an increase of the yield of both grain and soil-exhausting crops. It will be equal to 41.63 centner/ha and 24.42 centner/ha respectively.

Table 3. Yield of soil-exhausting technical crops (sunflower) at agricultural enterprises in Mykolaiv region*

Year, n	Year number, t	Yield, centner/ha, y	Calculated values		$\bar{y}_t$	Average square value of the feature, $\overline{y^2}$	$\overline{y^2}$	$(\bar{y}_t - \sum \bar{y})^2$
			t^2	t × y				
2010	1	14.9	1	14.9	16.4	222.0	-	4.4
2011	2	16.6	4	33.2	16.9	275.6	-	2.5
2012	3	15.1	9	45.3	17.4	228.0	-	1.1
2013	4	22.5	16	90.0	18.0	506.3	-	0.3
2014	5	17.6	25	88.0	18.5	309.8	-	0.0
2015	6	21.3	36	127.8	19.0	453.7	-	0.3
2016	7	22.7	49	158.9	19.5	515.3	-	1.0
2017	8	16.4	64	131.2	20.0	269.0	-	2.4
2018	9	19.4	81	174.6	20.6	376.4	-	4.2
n = 9	$\sum t = 45$	$\sum y = 166.5$	$\sum t^2 = 285$	$\sum(t \times y) = 863.9$	$\sum \bar{y}_t = 166.5$	$\sum \overline{y^2} = 350.7$	342.3	16.2

*Source: Completed by the authors.

CONCLUSIONS

Results of the conducted research confirm the following suggestions:

1. The current deterioration of ecological conditions of lands, reduction of soil fertility and large-scale expansion of soil degradation processes require significant transformations in the human economic activity on agricultural lands. Protection and the most rational use of land resources, increase of land fertility can be achieved only under conditions of transition to agrarian land use referring to the model of sustainable development.
2. The impact of agro-technical and natural-climatic factors on the value of yields of main agricultural crops in Mykolaiv region and their distinction is studied by applying the dispersion analysis method. It is confirmed that the impact of agro-technical measures on the change of yield of the most common crops at agricultural enterprises variates by one third. Under such conditions, among agricultural practices, the optimal ones include non-exhausting practices of arable farming, reclamation of organic soils, economic activity on the base of climate focused methods of agricultural production.
3. The research results are used to make forecasts of the level of yields of grain crops and sunflower in the future (2025). An increase of the yields of main crops will provide the possibility to reduce the area of agricultural plowing, as well as expand the area of lands used for nature protection.

The economic balance for the security of sustainable land management of the examined region needs crucial improvements. First, it concerns revival of land-owners' careful attitude to land. Therefore, labour and financial efforts should be focused on active application of the tools of the mechanism of land resources reproduction.

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