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ECOLOGICAL AND ECONOMIC ASPECTS OF THE EFFICIENCY OF POLISSIA ORGANIC PLANT MODELS

Purpose. *The objective of the article is to investigate theoretically the possibility of harmonization of ecological and economic aspects of functioning of organic agricultural products production models under natural and climatic conditions of crop enterprises of Polissia zone in the Region of Chernihiv.*

Methodology / approach. *The study was conducted at the Institute of Agricultural Microbiology and Agro-Industrial Manufacture of the National Academy of Agrarian Sciences of Ukraine during 2011–2020. The analysis of ecological and economic efficiency of organic crop rotations was made based on the results of the proprietary research on the example of generalization of predicted results of the developed standard models of organic crop rotations at crop enterprises of Polissia zone. Main methods: modelling (development, in particular, of standard models of crop rotations, modelling of the size of fertilizer potential over time by years); predicting (prediction of receipt and expenditure of nutrients, organic matter), balance (calculation of balances of humus and key nutrients), calculation and design (calculation of the basic parameters of economic efficiency); abstract and logical (formulation of the provisions of the article based on the analysis of studies of other authors, drawing conclusions based on the results of studies conducted).*

Results. *Developed typical crop rotation models are characterized by positive predictive humus balances and acceptable key nutrient balances (NPK). With the implementation of 'organic' prices for agricultural products, most crops achieve an acceptable level of profitability. However, in order to achieve a competitive level of profitability of organic production, it must be provided with an appropriate economic mechanism of its functioning, in particular higher prices compared to traditional agricultural products, etc. Harmonization of economic and ecological aspects in simulated crop rotations is achieved primarily by selecting crops with high yields, which are mainly characterized by insufficient or low level of ecological efficiency, and crops with high or medium ecological efficiency, which having insufficient or low economic efficiency, compensate mostly negative ecological consequences of growing crops with high economic efficiency. This is accompanied by achievement of the ecological balance of agrocenoses and an acceptable level of economic efficiency of organic models. The practical aspect of the activities of specific farms in relation to the choice of the appropriate model of organic management should take into account not only considerations of ecological and economic efficiency, but also the level of resource provision within these limits.*

Originality / scientific novelty. *The possibility of harmonization of economic and ecological aspects and achievement of their acceptable level in crop rotations of organic agriculture for crop enterprises has been theoretically substantiated. For the first time, the methodological approach developed by the authors on the distribution of costs for the production and application of organic fertilizers between crops during crop rotation in proportion to the duration and amount of fertilization was implemented.*

Practical value / implications. *Typical models of crop rotations of organic farming for crop enterprises in Polissia were developed. Methods of choosing a certain model were proposed both according to the criteria of ecological and economic efficiency, and taking into account the organizational and economic capabilities and resource provision of a particular business entity.*

Key words: *ecological and economic efficiency, organic production, plant models, crop rotations.*

Introduction and review of literature. In traditional systems of agricultural production, the main criterion of production efficiency is economic, which is due to the very philosophy of goods-money relations and the market form of their implementation. The level of dominance of the anthropogenic factor, in particular production chemicalization means, depends mainly on the ratio between their value and return. At the same time, the ecological aspects of production efficiency and the consequences of increasing anthropogenic pressure on the environment are often underestimated, and the degree of their consideration depends mainly on the level of environmental awareness of a particular business entity. In organic production, it is the ecological criterion that is decisive as the basic principle and essence of its functioning. At the same time, in market conditions, organic (ecological) production systems should have an appropriate level of economic efficiency, as a motivating factor for businesses, which is also emphasized in [1]. This determines the relevance of the study of ecological and economic aspects of the efficiency of organic systems and finding ways to harmonize the relationship between them. In addition, with the lack of distribution of organic production in Ukraine, the importance of modelling the situation is growing, including to ensure the variability of studies and predicting the results in order to choose the best option.

Scientists of institutions of the system of the National Academy of Agrarian Sciences of Ukraine (NAAS) and other scientific and educational institutions are involved in the development of scientific bases of development of organic production of agricultural products in Ukraine (NAAS Program of scientific research (PSR) 07 'Scientific bases for developing organic production of agricultural products and mechanisms of its functioning in Ukraine' 2011–2015, NAAS PSR 03 'To develop scientific bases of functioning of organic agricultural product production systems with the maximum involvement of renewable resources' 2016–2020).

In our previous research on this topic, we have developed, in particular, methodological approaches to the formation and evaluation of ecological and economic efficiency of organic models [2], prediction of the fertilizing potential of crop rotations of organic production [3].

Various aspects of assessing the efficiency of agricultural production in the currently dominant agricultural systems have been widely studied and covered by a number of national researchers. At the same time, much less attention is paid to the ecological problems, especially their combination with economic criteria [4]. For instance, it was found that agricultural enterprises introduce mainly product and technical innovations, less common they apply soil protection innovations, which is largely influenced by the socio-cultural psychological type of agribusiness owners and managers, and does not contribute to the reproduction of soil fertility [5]. At the same time, it is known that, according to the established view in national and foreign science, the expanded reproduction of soil fertility is one of the main factors of ecological and economic sustainability of land use. Thus, it has been established, in particular, that those agricultural enterprises of Ukraine that provide a positive balance of humus in the process of their land use, reach a significant level of sustainable competitiveness, which is a convincing example of competitiveness based on rational land use [6]. It was also proved that increasing financial support, in particular, for agricultural enterprises with low soil fertility, can act as a compensation for low fertility and, thus, increase productivity of agricultural production [7], which is especially relevant for low-fertile soils in Polissia.

In terms of the efficiency of organic production, there are some attempts to theoretically maximize the productivity of organic crop rotations regarding cost. For example, by optimizing the structure of sown areas using an economic-mathematical model for organically oriented land use systems, their profitability can reach 39.7 % vs. 17.3 % for conventional systems [8]. A number of foreign authors and some national researchers conducted ecological and economic assessment of agrarian ecotechnologies by a set of parameters [9; 10; 11]. Although the need to comply with ecological criteria is not in doubt, but the quantitative resulting parameters are currently covered to a lesser extent [12]. As for the possibility of profitable organic production at a competitive level, today there is no single opinion. A number of researchers are inclined to believe that as a result of lower productivity of organic production in the absence of synthetic agrochemicals, its economic efficiency will be lower compared to conventional farming systems [13; 14; 15; 16]. Other authors believe that organic production will be cost-effective [17; 18; 19], which is confirmed by the practical results of some organic farms in Ukraine [20]. Some researchers highlight different trends in this regard, both in terms of individual economic parameters and in relation to different types of products, in particular, crop production [10; 21].

However, mentioned studies, especially national ones, do not sufficiently cover, in particular, the possibility of harmonization of ecological and economic vectors of efficiency of organic agricultural production, which is especially relevant for crop enterprises (when it is not possible to use manure). Also, special attention needs to be paid to the observance of state principles for the development of organic models (providing, first of all, own population with available organic food, etc.).

The purpose of the article is to investigate theoretically the possibility of harmonization of ecological and economic aspects of functioning of organic agricultural products production models under natural and climatic conditions of crop enterprises of Polissia zone in the Region of Chernihiv.

Methodology. When developing models, the main criterion for their product orientation is the need to ensure effective demand of own population in organic food. Since currently organic producers under the pressure of market and economic factors (low prices for organic products, insufficient effective demand of Ukrainians, etc.)

mostly prefer narrow specialization in export-oriented and niche products, as evidenced by other researchers [22]. This took into account both conventional for this natural and climatic zone (Polissia) factors of formation of the branch structure of farms (for example, the suitability of soil and climatic conditions for potato production, etc.) and modern trends in agricultural production (in particular, growing corn for grain, soybeans, etc. is becoming increasingly popular). In addition, under the conditions of a limited number of soils suitable for organic production, when choosing production areas, preference should be given to crops intended for food purposes (potatoes, cereals, etc.) with an appropriate set of best predecessors and crops according to ecological criteria (fertilization, soil fertility, phytosanitary aspects, etc.). The need for even distribution of the total amount of agricultural work during the year with the smoothing of peak periods (growing winter crops, etc.) has been taken into account. Models of crop orientation were selected for the analysis in order to determine the theoretical possibility of achieving ecological balance and profitable operation in the absence of the possibility of using manure.

Parameters of crop yields were determined using the balance method based on the predicted size of the fertilizing potential of crop rotations by the provision of key nutrients, calculated according to the methods [2; 3].

The assessment of ecological efficiency was carried out according to the predicted balances of humus and compounds of the key plant nutrients. These calculations were performed on a methodological basis [23] taking into account the specifics of this study and clarifying some average standards according to the results of relevant publications [3] and the level of the studied models (crop rotation, enterprise) in contrast to the regional level [23].

The assessment of economic efficiency was carried out by the parameters of profit per 1 ha of crop rotation (sowing) area and profitability of production. The cost of operational activities was modelled according to [24] taking into account the technological operations of organic farming [25]. The method [26] was used to calculate the cost of production. It should be emphasized that in the practice of economic calculations, according to current methodological approaches, the allocation of costs for the production and use of organic fertilizers is carried out directly and in full on the crop under which they were introduced [27]. At the same time, in our opinion, the application of such a methodological approach to some extent distorts the final economic results (which may adversely affect, in particular, the investment attractiveness of individual crops), since the fertilizing effect of organic fertilizers extends over several years and subsequent crop rotations. Considering the above, we propose to distribute the costs of production and application of organic fertilizers between crops during crop rotation in proportion to the duration and amount of fertilization effect. As a methodological basis for the allocation of costs for the production and use of organic fertilizers for crops in crop rotation during its rotation, the average nutritive efficiency (NE) for the key nutrients by years of fertilization were established as standards.

Cost parameters were calculated by the average prices for resources and agricultural products in 2017–2019, according to statistics. At the same time, the parameters of the revenue part were calculated both by the actual prices prevailing in the Region of Chernihiv for agricultural products and by the prices with an 'organic mark-up', which, according to various data, may exceed the 'usual' ones by an average of 30 % to 40 %.

Results and discussion. Schemes of the developed typical crop rotations are given in Table 1. They provide options for the number of fields in crop rotation from five to seven, to provide more choice regarding the conditions of a particular enterprise.

Table 1

Schemes of the developed organic crop rotations for Polissia crop enterprises

Field No.	Model No. 1		Model No. 2		Model No. 3		Model No. 4	
	basic crop	green manner after basic crop	basic crop	green manner after basic crop	basic crop	green manner after basic crop	basic crop	green manner after basic crop
1	Clover for seeds	x	Clover for seeds	x	Clover for seeds	x	Clover for seeds	x
2	Winter rye	Lupine	Winter wheat	Radish	Winter rye	Radish	Winter rye	Lupine
3	Millet	Radish	Soybean	Winter rye	Corn for grains	Winter rye	Millet	Radish
4	Potato	Winter rye	Buckwheat	Radish	Pea	x	Pea	x
5	Spring wheat with clover undersowing	x	Barley with clover undersowing	x	Winter wheat	Radish	Winter wheat	Radish
6	x	x	x	x	Oat with clover undersowing	x	Potato	Winter rye
7	x	x	x	x	x	x	Spring wheat with clover undersowing	x

Source: developed by the authors under the results of own researches.

The developed fertilizer system for these crop rotations is based primarily on in-house resources without their involvement from the outside – it is basic, i. e. available to all producers, in particular Polissia zone, and can be supplemented by revenues from external sources depending on local conditions. It provides for the complete return to the soil of crop by-products; growing green manure after all basic crops (except clover and winter predecessors), saturation of crop rotations with legumes and grain legumes, pre-sowing bacterization of seeds of all basic and intermediate crops with microbial fertilizers and foliar treatment with biological products.

According to our prediction calculations, the developed fertilizer system theoretically allows to form over time such size of fertilizing potential which is sufficient for achievement of acceptable levels of crops productivity under conditions of organic production. This conclusion confirms the graphical representation of the dynamics of yield levels on the example of the basic commodity crops of one of our crop rotations – No. 1 (Fig. 1). As can be seen from the graphs of the dynamics of predicted yields, they stabilize at a certain level over time. At the same time, the results of mathematical alignment of actual parameters testify to the constancy of the mentioned tendency. It should be noted that we have aligned the dynamics of the predicted yields using various functions (linear, logarithmic, polynomial with x^2, x^3) and as a result Fig. 1 shows the results that demonstrated the highest closeness of relation (R^2), which, as it can be seen, reaches almost 1. The established patterns also apply to crops of all other developed models.

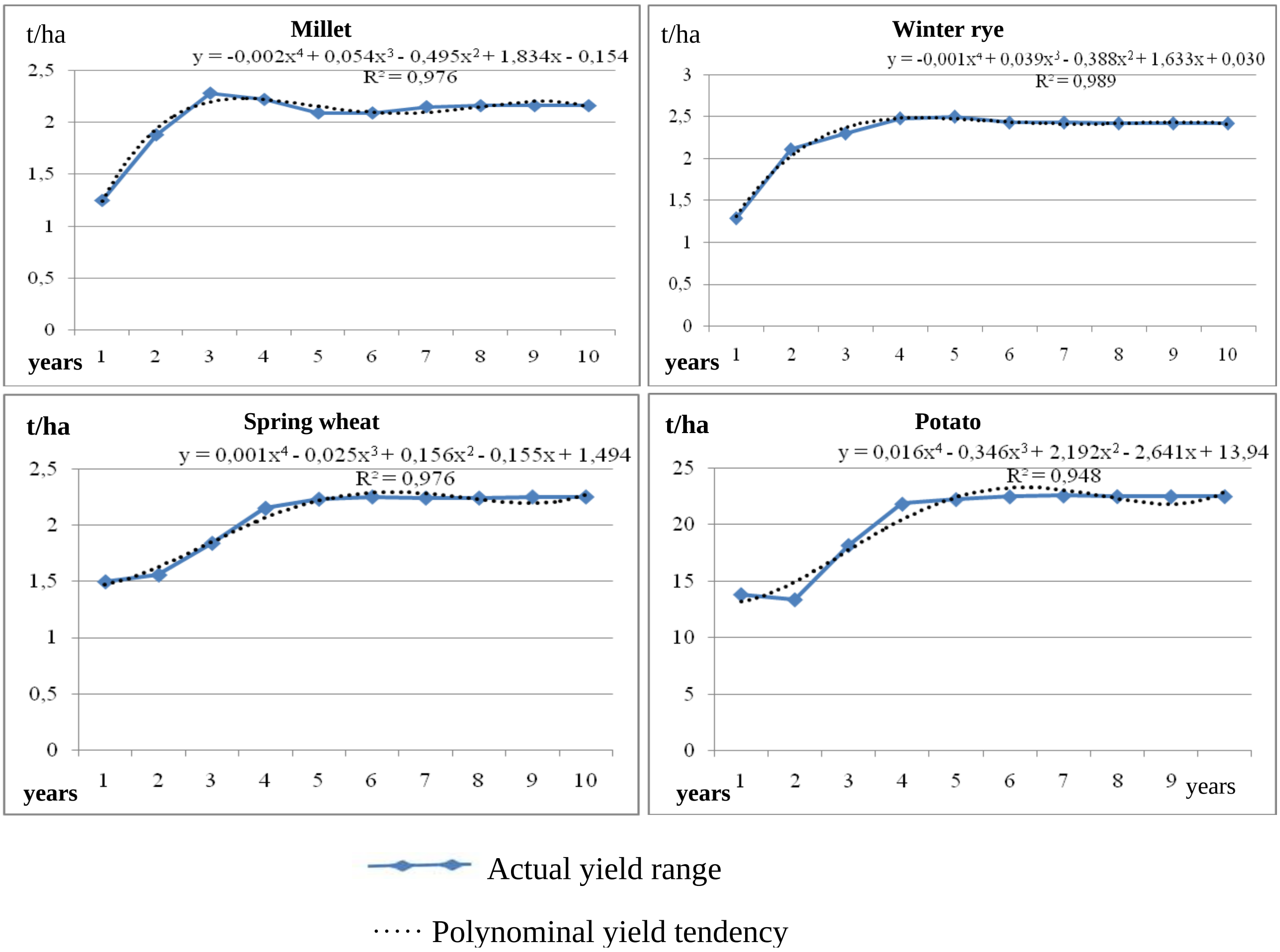

Fig. 1. Dynamics of yield of the basic commodity crops of crop rotation No. 1 (according to prediction calculations), t/ha by years of development of crop rotation and 1st rotation

Source: developed by the authors under the results of own calculations.

Prediction calculations of humus balances for the considered crop rotations are provided in Table 2.

Table 2

Prediction calculations of humus balances by crop rotations (on average during a year after crop rotation development), t assuming calculated as 1 ha of crop rotation area

Parameters	Crop rotation models			
	No. 1	No. 2	No. 3	No. 4
Losses of humus from mineralization and leaching under the basic crops	1.82	1.76	1.91	1.90
Humification of by-products and residues	2.00	1.76	2.03	1.89
including from straw and clover residues	0.66	0.66	0.55	0.47
Humus balance by the basic crops	+0.18	0	+0.12	-0.01
Humification of green manure biomass	0.10	0.09	0.10	0.13
Humus balance by crop rotation	+0.28	+0.09	+0.22	+0.12
Balance intensity, %	115.4	105.1	111.5	106.1

Source: calculated by the authors under the results of own researches.

As can be seen from all models, a positive predictive balance of humus is provided with an intensity not less than the recommended limits [28] (this ecological criterion was applied to form crop rotations). At the same time, due to the return to the soil of the whole mass of by-products and surface-root residues in general, crop rotation is practically achieved without deficit-humus land use. The leading role in this regard belongs to the clover, humus formation from the aboveground mass and root residues which can provide 0.47 to 0.66 t per year per 1 ha of crop rotation area. By this ecological criterion, this crop is included in our composition of all studied crop rotations, despite the possible problems with the sale of seeds. As can be calculated from the Table 1, the share of clover in the structure of sown areas should be at least 14.3 %.

A significant contribution to achieving a positive balance of humus belongs to the formation of humus (preservation of humus) due to the biomass of green manure (0.09 to 0.13 t/ha per year). Moreover, most of the basic crops of the studied models are characterized by a negative balance of humus (Table 5) and only due to green manure in a number of relevant crop rotation fields, deficit-free balances are achieved.

Thus, due to the scheduled measures of organic matter entry into the soil in crop rotations of organic farms, it is theoretically possible to achieve positive humus balances, which is especially relevant given the current trends of livestock reduction and corresponding reduction of manure introduction.

On another aspect of ecological efficiency – the balances of key nutrients – prediction calculations are provided in Table 3.

The above data show that in different cases there are both positive and negative balances of individual elements. At the same time, in contrast to the established views on the problems of nitrogen supply in traditional agriculture, all these organic models show positive nitrogen balances and their significant intensity, primarily due to the saturation of crop rotations with legumes.

Table 3

Prediction calculations of balances of the key nutrients by crop rotations (on average during a year after crop rotation development), kg/ha

Parameters	Model No. 1			Model No. 2			Model No. 3			Model No. 4		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Added part (according to the general content of NPK)	133	20	86	129	20	77	123	27	79	120	20	91
Expenditure part (loss and yield removal rates)	112	27	89	105	28	60	106	30	76	106	28	82
Balance (+/-)	+21	-7	-3	+24	-8	+17	+17	-2	+3	+14	-8	+9
Balance intensity, %	118.2	75.0	96.9	123.2	71.9	128.6	115.8	92.0	104.2	112.7	72.2	110.7
The ratio of deficit to soil reserves, %	x	1.6	1.3	x	2.1	x	x	0.8	x	x	2.1	x

Source: calculated by the authors under the results of own researches.

In one case, a negative potassium balance is predicted (in model No. 1, primarily due to the maximum allowable saturation of crop rotation with potatoes). As for phosphorus, in all studied models it is in deficit with a rather low balance intensity, primarily due to its relatively low content in the provided elements of fertilizer systems. On the one hand, this may confirm the fears of some researchers about the problem of phosphorus nutrition in organic farming. On the other hand, according to our calculations, the critical factors in the formation of yields of specific crops in terms of productive fertilizing potential in these crop rotation models are mainly nitrogen and sometimes potassium, and phosphorus in all cases remains in excess. Therefore, additional application of phosphorus fertilizers, for example in the form of phosphorus-containing minerals of natural origin, will not be economically justified. The phosphorus deficiency is compensated by relatively easily renewable natural reserves, and the low level of deficit compared to these reserves (0.8 to 2.1 %) can be considered acceptable for maintaining the ecological balance of the agrocenosis according to [25]. In addition, we did not take into account the additional supply of nutrients due to the achieved positive balance of humus, given the insufficient study of these processes for mathematical formalization.

Thus, due to the widespread use and activation of biological factors of the fertilization process and the appropriate selection of crops in organic crop rotations, opportunities are created to achieve an acceptable level of ecological efficiency by the balance of key nutrients.

The main parameters of economic efficiency of the studied models are shown in Table 4.

The obtained data show that ‘normal’ prices do not ensure the achievement of the required level of profitability of organic production. And although all models are cost-effective, they are not able to compete with intensive technologies in terms of cost-effectiveness. In addition, positive average profitability values by models are achieved mainly due to one or two high-yield crops: in models No. 1 and No. 4 – potatoes, in model No. 2 – soybeans and buckwheat, in model No. 3 – corn. At the same time, most other crops of the studied models at these price levels are unprofitable or low-yield.

Table 4

Prediction calculations of the main parameters of economic efficiency by crop rotations (*on average during a year after crop rotation development*)

Crop rotation models	Expenses, UAH/ha	For average actual prices in 2017–2019			For prices in 2017–2019 with 'organic mark-up'		
		profit, UAH/ha	income, UAH/ha	profitability, %	profit, UAH/ha	income, UAH/ha	profitability, %
Model No. 1	18,281	24,606	6,326	34.6	31,988	13,708	75.0
Model No. 2	9,682	12,502	2,820	29.1	16,253	6,571	67.9
Model No. 3	9,880	10,491	611	6.2	13,639	3,759	38.0
Model No. 4	16,381	19,906	3,525	21.5	25,878	9,497	58.0

Source: calculated by the authors under the results of own researches.

With the introduction of 'organic' product prices, most crops reach an acceptable level of profitability, with the exception of spring wheat, rye, barley and pea (pea – in the model No. 4), which are characterized by insufficient profitability (Table 5). At the same time, the profitability of simulated crop rotations in general increases significantly. Therefore, in order to achieve a sustainable level of competitiveness of organic production, it should be provided with an appropriate price mechanism for its functioning, as is practiced in other countries. In particular, the association of farmers in Kerala (India) into a kind of trade organization (Fair Trade Alliance Kerala (FTAK)) allowed to sell their organic products for export without intermediaries, thus raising prices by 20 % to 50 % [30], and research on the example of organic technologies in New Zealand showed that, to increase profitability to the level of traditional technologies, prices for organic products should be higher by 27 % to 45 % [18].

If we combine the analysis of parameters of economic and ecological efficiency of the considered models (Table 5), we can see that in terms of specific crops, these two phenomena are mainly multifaceted. As can be seen from the above data, crops with high profitability are characterized mainly by a lack of ecological efficiency. Positive or close to them balances of compounds of individual nutrition elements by these crops are caused by specificity of processes of receipt and assimilation of various nutrients and level of fertilization. In turn, crops with high or medium ecological efficiency, usually with low economic efficiency, compensate mainly for the negative ecological consequences of growing high-yielding crops (this does not eliminate the need to find ways to increase the profitability of low-yield crops, primarily through government regulation of pricing). This is accompanied by the achievement of ecological balance and an acceptable level of economic efficiency of organic models in general. These patterns are traced in the results of other studies in this area. For example, E. Blasi et al. found that crops with negative ecological parameters support farm income, while crops with a positive ecological balance make a very limited contribution to economic profitability and emphasize the need to find a compromise between economic and ecological consequences of agricultural activities [31]. At the same time, J. Rosa-Schleich et al. [32] concluded that organic practices, along with other diversified farming systems, allow to achieve the highest ecological and economic benefits. However, according to these researchers, additional financial instruments are needed for their wider implementation.

Table 5

Main parameters of economic (at prices with 'organic mark-up') and ecological efficiency of crops of modelled crop rotations

Agricultural crop (or appropriate crop rotation field)	Model	Income, UAH/ha	Profitability, %	Balance intensity, %			
				humus	N	P_2O_5	K_2O
Crops with high economic efficiency level (over 80 % profitability)							
Soybean	2	**13,384**	**118.0**	*28.2*	**105.3**	*53.5*	**112.7**
Corn grains	3	**10,060**	**111.4**	**100.0**	92.2	87.1	*57.4*
Potato	1	**58,054**	**108.8**	*75.6*	*71.6*	*61.0*	*54.7*
Buckwheat	2	**8,344**	**83.5**	93.0	**100.9**	95.4	**132.7**
Potato	4	**42,671**	**81.6**	61.8	94.3	88.2	86.9
Crops with moderate economic efficiency level (30 % to 80 % profitability)							
Millet	1	*4,863*	*45.0*	83.6	94.2	91.1	**142.6**
Winter wheat	2	6,575	65.8	**100.0**	**102.1**	**97.2**	**198.7**
Winter wheat	3	4,553	42.7	93.8	*60.8*	*34.6*	**111.2**
Clover seeds	2	*2,720*	*38.7*	**326.7**	**224.6**	80.5	**103.0**
Clover seeds	3	*2,963*	*43.7*	**326.7**	**224.6**	80.5	**103.0**
Clover seeds	1	2,622	*36.8*	**326.7**	**224.6**	80.5	**103.0**
Oat*	3	3,324	35.2	81.1	90.4	**145.7**	*73.3*
Clover seeds	4	2,631	37.0	**326.7**	**224.6**	80.5	**103.0**
Millet	4	5,076	47.0	84.6	**144.4**	**142.5**	**138.8**
Pea	4	7,862	56.2	76.3	**106.6**	67.7	**100.7**
Winter wheat	4	4,747	44.2	95.2	**107.6**	59.2	**144.4**
Crops with insufficient or low economic efficiency level (below 30 % profitability)							
Spring wheat*	4	2,236	21.8	41.2	**112.7**	81.7	**140.4**
Barley*	2	*1,830*	*18.2*	*69.8*	*68.4*	*30.7*	88.2
Winter rye	1	*1,433*	*15.2*	**98.1**	**135.5**	**114.3**	**153.9**
Spring wheat*	1	*1,567*	*14.7*	*74.6*	*66.9*	*31.9*	88.0
Winter rye	3	*1,273*	*13.3*	**97.6**	**117.5**	**101.3**	**174.1**
Winter rye	4	*1,256*	*13.3*	**96.3**	**130.2**	44.3	**122.2**
Pea	3	*380*	*2.8*	*54.2*	**105.3**	**99.7**	**136.2**

Notes: semi-bold font – high, positive value of the event;
normal font – moderate, acceptable value of the event;
italics – insufficient or low (negative) value of the event;
* – taking into account the place of the selected crops in the developed crop rotations (cover for clover) their straw is placed into the soil together with clover straw, i. e. for the second year after their harvest, which enhances the fertilizing potential of the clover field, impoverishing, in turn, the corresponding parameters of the fields of these crops. In fact, these crops can be attributed to crops with high ecological efficiency.

Source: calculated by the authors under the results of own researches.

In addition, it should be noted that, in the practical aspect of using the results of this study in the activities of specific farms, we should take into account, in our opinion, also the following points. If we compare the parameters of ecological and economic efficiency of models 1 and 4, we can see that model No. 1 has a more attractive appearance compared to model No. 4 by the majority of parameters. In the ecological aspect, this is due primarily to the higher share of clover and rye (model No. 1 – 20 %, model No. 4 – 14.3 %) in the structure of crops areas, which has the highest yield of by-products in relation to the basic one (hence the high fertilizing potential). In economic terms, the highest share of potatoes (model No. 1 – 20 %, model No. 2 – 14.3 %), as the most profitable, at a given price situation, of the crops of the two models. At the same time, the choice of a particular model will also depend on the organizational and economic capabilities of the farm. In a practical sense, for a 5-field crop rotation (model No. 1) of 974 ha (the actual average size of crops enterprise in the Polissia zone of the Region of Chernihiv at the time of research as potential producers of organic products in this production area) one potato field (20 % in structure of sown areas) fully complies with current regulations, but actually it means almost 200 ha, which requires a high level of technical security, etc., especially in terms of organic production. Therefore, for farms with a lower level of resource provision, the choice of model No. 4 (with a lower share and, accordingly, the area of potato) may be more realistic despite the lower level of ecological and economic efficiency compared to model No. 1.

Conclusion. In crop rotations of organic agriculture, built on ecological criteria, a state of sustainable ecological equilibrium of agrocenoses is achieved over time. In the models of crop orientation in the absence of manure, a positive balance of humus is formed primarily due to the complete return to the soil of by-products and maximum saturation of crop rotations with intermediate green manure crops. An important element of the ecological component of production is the use of microbial preparations, in particular with fertilizing action, which, by activating and optimizing the nutrients of the production process, increase biomass. A significant contribution to the formation of ecological balance belongs to the selection of crops in the direction of harmonization of conditions for the formation of potential (with high humus-forming potential) and effective (including nitrogen accumulated in the process of symbiotic nitrogen fixation of legumes and grain legumes) soil fertility. A special place and a leading role belongs to the clover, which is a universal crop, forming the main part of the fertilizing potential of crop rotations, which is then spent on ensuring the productivity of subsequent crops. To achieve this, the share of clover in the structure of sown areas of such crop rotations must be at least 14.3 %. The set of the listed factors allows to reach positive balances of humus and acceptable balances of the key nutrients with compensation of insignificant deficiencies, first of all phosphorus, at the expense of renewable soil stocks without disturbance of ecological balance of the modelled agroecosystems.

In order to achieve a competitive level of profitability of organic production, it should be provided with an appropriate economic mechanism for its operation, in particular higher prices compared to conventional agricultural products, etc.

Harmonization of economic and ecological aspects in simulated crop rotations is achieved primarily by selecting crops with high yields, which are mainly characterized by insufficient or low level of ecological efficiency, and crops with high or medium ecological efficiency, which, having insufficient or low economic efficiency, compensate mostly negative environmental consequences of growing crops with high economic efficiency. This is accompanied by the achievement of the ecological balance of agrocenoses and an acceptable level of economic efficiency of organic models.

Not only considerations of ecological and economic efficiency, but also, within these limits, the level of resource provision should take into account in the practical aspect of the activities of specific farms in relation to the choice of the appropriate model of organic management.

Prospects for further research are the development of an economic mechanism for state support of organic agricultural production in Ukraine in order to ensure its competitive functioning. Particular attention needs to be paid to the development of state support measures during the period of achieving the above acceptable parameters of ecological sustainability and productivity of modelled agrocenoses, which, as noted above, are achieved after crop rotation (first rotation), and in full, according to previous calculations – closer to the end of the second rotation. At the same time, the achievement of ecological sustainability parameters can be ensured earlier, but will be accompanied by deterioration of economic parameters in the short or medium term (depending on the duration of rotation) and potential producers of organic products need additional state support measures to choose this development scenario.

References

1. Naspetti, S., Eine Bteich, M., Pugliese, P. and Salame, N. (2016), Motivation and values of farmers in Lebanon: a comparison between organic and conventional agricultural producers. New Medit, vol. 15, no. 2, pp. 70–80.

2. Khalep, Yu. M., Moskalenko, A. M., Volkohon, V. V., Yemets, Yu. H. and Khalep, A. Yu. (2015), *Otsinka ekoloho-ekonomichnoi efektyvnosti modelei orhanichnoho vyrobnytstva silskohospodarskoi produktsii* [Evaluation of ecological and economic efficiency of the models of organic production of agricultural products], Chernihiv, Ukraine.

3. Khalep, Yu. M., Volkohon, V. V. and Moskalenko, A M. (2015), Predicting fertilizing ability in the organic production models. *Bulletin of Agricultural Science*, no. 8, pp. 45–49. https://doi.org/10.31073/agrovisnyk201508-09.

4. Moskalenko, A. M. (2015), *Teoretychni ta metodolohichni zasady efektyvnoho vykorystannia silskohospodarskykh zemel Polissia Ukrainy* [Theoretic and methodological basis of the efficient use of agricultural lands of Ukrainian Polissia], Publisher Lysenko M. M, Nizhyn, Ukraine.

5. Kucher, A. and Kucher, L. (2017), State and problems of transfer of innovations in land use of agricultural enterprises. *Marketing and Management of*

Innovations, no. 3, pp. 43–52. https://doi.org/10.21272/mmi.2017.3-04.

6. Kucher, A. (2019), Influence of organic carbon balance in the soil on the formation of sustainable competitiveness of the agrarian enterprises. *Agricultural and Resource Economics*, vol. 5, no. 4, pp. 11–136. https://doi.org/10.22004/ag.econ.300035.

7. Kucher, A. (2020), Soil fertility, financial support, and sustainable competitiveness: evidence from Ukraine. *Agricultural and Resource Economics*, vol. 6, no. 2, pp. 5–23. https://doi.org/10.22004/ag.econ.303854.

8. Voronkova, O., Zadimidcenko, A., Goloshchapova, L., Polyakova, A., Kamolov, S. and Akhmetshin, E. (2018), Economic and mathematical modeling of regional industrial processes. European Research Studies Journal, vol. XXI, is. 4, pp. 268–279. https://doi.org/10.35808/ersj/1119.

9. Beltrán-Esteve, M., Reig-Martínez, E. and Estruch-Guitart, V. (2017), Assessing eco-efficiency: a metafrontier directional distance function approach using life cycle analysis. *Environmental Impact Assessment Review*, vol. 63, pp. 116–127. https://doi.org/10.1016/J.EIAR.2017.01.001.

10. Galnaitytė, A., Kriščiukaitienė, I., Baležentis, T. and Namiotko, V. (2017), Evaluation of technological, economic and social indicators of different farming practices in Lithuania. *Economics & Sociology*, vol. 10, no. 4, pp. 189–202. https://doi.org/10.14254/2071-789X.2017/10-4/15.

11. Ivanyshyn, V. V. and Tarhoian, V. S. (2008), Ecological and economic aspects of the use of production agrarian ecotechnologies for competitive ecologically safe products. *Ekonomika APK*, no. 3, pp. 46–49.

12. Moskalenko, A. M. (2015), Ecological and economic justification of crop rotations for Ukrainian Polissia. *Actual problems of economics*, no. 10, pp. 235–243.

13. Bazylevych, V., Kupalova, G., Goncharenko, N., Murovana, T. and Grynchuk, Y. (2017), Improvement of the effectiveness of organic farming in Ukraine. *Problems and perspectives in management*, vol. 15, is. 3, pp. 64–75. https://doi.org/10.21511/ppm.15(3).2017.06.

14. Karimi, F., Sultana, S., Shirzadi Babakan, A. and Royall, D. (2018), Land suitability evaluation for organic agriculture of wheat using GIS and multicriteria analysis. *Papers in Applied Geography*, vol. 4, is. 3, pp. 326–342. https://doi.org/10.1080/23754931.2018.1448715.

15. Ostapenko, R., Herasymenko, Y., Nitsenko, V., Koliadenko, S., Balezentis, T. and Streimikiene, D. (2020), Analysis of production and sales of organic products in Ukrainian agricultural enterprises. *Sustainability*, vol. 12(8), 3416. https://doi.org/10.3390/su12083416.

16. Tanchyk, S. P., Tsiuk, O. A. and Vialyi, S. O. (2009), Development of organic farming in Ukraine. *Bulletin of Agricultural Science*, no. 1, pp. 11–15.

17. Adamtey, N., Musyoka, M. W., Zundel, C., Cobo, J. G., Karanja, E., Fiaboe, K. K., Messmer, M. M. and other (2016), Productivity, profitability and partial nutrient balance in maize-based conventional and organic farming systems in Kenya. *Agriculture, Ecosystems & Environment*, vol. 235, pp. 61–79.

https://doi.org/10.1016/j.agee.2016.10.001.

18. De Leijster, V., Verburg, R. W., Santos, M. J., Wassen, M. J., Martínez-Mena, M., de Vente, J. and Verweij, P. A. (2020), Almond farm profitability under agroecological management in south-eastern Spain: accounting for externalities and opportunity costs. *Agricultural Systems*, vol. 183, 102878. https://doi.org/10.1016/j.agsy.2020.102878.

19. Patyka,V. P., Harmashov, V. V., Buriachkivskyi, V. H. and Pylypenko, V. M. (2003), Comparative efficiency of the conventional and biological technology of winter wheat cultivation in the settings of the south of Ukraine. *Ekonomika APK*, no. 7, pp. 51–55.

20. Antonets, L. S., Pysarenko, V. V., Lukianenko, T. V. and Pysarenko, Yu. H. (2010), Formation of the market of ecologically safe products upon organic farming. *Ekonomika APK*, no. 12, pp. 75–79.

21. Krause, J. and Machek, O. (2018), A comparative analysis of organic and conventional farmers in the Czech Republic. *Agricultural Economics – Czech*, vol. 64, is. 1, pp. 1–8. https://doi.org/10.17221/161/2016-AGRICECON.

22. Bondar, V. (2016), Organic grain production market of Ukraine: prospects and trends. *Baltic Journal of Economic Studies*, vol. 2, no. 3, pp. 17–22. https://doi.org/10.30525/2256-0742/2016-2-3-17-22.

23. Baliuk, S. A., Hrekov, V. O., Lisovyi, M. V. and Komarysta, A. V. (2011), *Rozrakhunok balansu humusu i pozhyvnykh rechovyn u zemlerobstvi Ukrainy na riznykh rivniakh upravlinnia* [Calculation of humus and nutrients balance in the farming of Ukraine at different management levels], Municipal Enterprise “Miska Drukarnia”, Kharkiv, Ukraine.

24. Sabluk, P. T., Melnyk, Yu. F., Zubets, M. V. and Mesel–Veseliak, V. Ya. eds (2008), *Tsinoutvorennia ta normatyvni vytraty v silskomu hospodarstvi teoriia, metodolohiia, praktyka. T.1 Teoriia tsinoutvorennia ta tekhnolohichni karty vyroshchuvannia silskohospodarskykh kultur* [Pricing and standard costs in the agriculture: theory, methodology, practice. Vol. 1 Theory of pricing and technological charts for growing crops], NSC «IAE», Kyiv, Ukraine.

25. Manko, Yu. P., Tsiuk, O. A., Krotinov, O. P., Vdovychenko, V. K. and Tarasenko, O. O. (2008), *Model systemy ekolohichnoho zemlerobstva v Lisostepu Ukrainy: metodychni rekomendatsii dlia vprovadzhennia u vyrobnytstvo* [Ecological farming system model in Ukrainian Forest Steppe: guidelines for implementation in the production], Ahrarna osvita, Kyiv, Ukraine.

26. Sabluk, P. T., Melnyk, Yu. F., Zubets, M. V. and Mesel–Veseliak, V. Ya. eds (2008), *Tsinoutvorennia ta normatyvni vytraty v silskomu hospodarstvi teoriia, metodolohiia, praktyka. T.2 Normatyvna sobivartist i tsiny na silskohospodarsku produktsiiu* [Pricing and standard costs in the agriculture: theory, methodology, practice. Vol. 2 Standard cost and prices for agricultural products], NSC «IAE», Kyiv, Ukraine.

27. Ministry of Agrarian Policy of Ukraine (2001), Guidelines for planning, accounting and calculating product (works, services) cost at the agricultural

enterprises, available at: http://www.uazakon.com/big/text1528/pg1.htm.

28. Tarariko, Yu. O. ed (2005), *Bioenerhetychna otsinka silskohospodarskoho vyrobnytstva: naukovo-metodychne zabezpechennia* [Bioenergetic assessment of agricultural production: scientific and methodological], Ahrarna nauka, Kyiv, Ukraine.

29. Prianishnikov, D. N. (1963), *Izbrannye sochinenija. T. 1: Agrohimija* [Selected works. Vol. 1: Agrochemistry], Publishing house for agricultural literature, Moscow, Russia.

30. Karunakaran, N. and Sadiq, M. S. (2019), Socio economic aspect of organic farming practices for improving farmer's income in some locations of Kerala, India. *Bangladesh Journal of Agricultural Research*, vol. 44, no. 3, pp. 401–408. https://doi.org/10.3329/bjar.v44i3.43474.

31. Blasi, E., Passeri, N., Franco, S. and Galli, A. (2016), An ecological footprint approach to environmental–economic evaluation of farm results. *Agricultural Systems*, vol. 145, pp. 76–82. https://doi.org/10.1016/j.agsy.2016.02.013.

32. Rosa-Schleich, J., Loos, J., Mußhoff, O. and Tscharntke, T. (2019), Ecological-economic trade-offs of diversified farming systems–a review. *Ecological Economics*, vol. 160, pp. 251–263. https://doi.org/10.1016/j.ecolecon.2019.03.002.

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