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SYSTEMIC VISION OF ECOLOGICAL AND ECONOMIC INTERACTION OF LAND-USE FACTORS IN MODERN AGROSPHERE

The conceptual framework of systemic interaction of ecological and economic factors in the optimization of modern system of land use is specified. The processes of agricultural land use under current conditions, the principles and regularities of environmentally sound use and protection of lands are investigated; economic and environmental assessment of ecologically safe farming system is made.

Keywords: *ecologization; biologization; farming system; land use; environmentally friendly products; soil fertility; crop allocation modelling; optimization of soil nutrition.*

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СИСТЕМНЕ БАЧЕННЯ ЕКОЛОГО-ЕКОНОМІЧНОЇ ВЗАЄМОДІЇ ЧИННИКІВ СУЧАСНОГО ЗЕМЛЕКОРИСТУВАННЯ В АГРОСФЕРІ

У статті визначено концептуальні засади системної взаємодії еколого-економічних чинників оптимізації сучасної системи землекористування. Досліджено процеси використання земель сільськогосподарського призначення в сучасних умовах, принципи і закономірності екобезпечного використання й охорони земель, здійснено економічне та екологічне оцінювання екобезпечної системи землеробства.

Ключові слова: *екологізація; біологізація; система землеробства; землекористування; екологічно чиста продукція; родючість ґрунту; моделювання розміщення посівів; оптимізація ґрунтового живлення.*

Форм. 6. Рис. 5. Літ. 14.

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СИСТЕМНОЕ ВИДЕНИЕ ЭКОЛОГО-ЭКОНОМИЧЕСКОГО ВЗАИМОДЕЙСТВИЯ ФАКТОРОВ СОВРЕМЕННОГО ЗЕМЛЕПОЛЬЗОВАНИЯ В АГРОСФЕРЕ

В статье изложены концептуальные основы системного взаимодействия эколого-экономических факторов оптимизации современной системы землепользования. Исследованы процессы использования сельскохозяйственных угодий в современных условиях, принципы и закономерности экологически безопасного использования и охраны земли, выполнена экономическая и экологическая оценка экобезопасной системы земледелия.

Ключевые слова: *экологизация; биологизация; система земледелия; землепользование; экологически чистая продукция; плодородие почвы; моделирование размещения посевов; оптимизация почвенного питания.*

Introduction. Current land use in agriculture should be considered from the perspective of the system support of ecological and economic requirements. Land resources play a key role in the economy of Ukraine as they are the basis for the production of food and raw materials for industries. Transition to market economy, the introduction of private land ownership, creation of various business patterns led to the increased interest in rational land use and methods of farming.

The problem of environmentally sound use of lands in recent years is of particular relevance, as the irrational deployment of agricultural lands in Ukraine caused a

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reduction in soil fertility, spread of erosion processes, increasing the area of contaminated and degraded lands. This requires the development, justification and implementation of measures to ensure their effective and environmentally sound use.

One of the essential and objective properties of the soil, enhancing its extraordinary usefulness and indispensability for human life and activities, is its fertility. The problem of soil conservation, yields gain, agriculture intensification or ecologization, search and implementation of economic and mathematical methods to study land-use factors were always of scientific interest, since their solution allows for ecological and economic interactions in field husbandry and, as a result to improve living standards and welfare (Korchinska and Khadakivska, 2011). Therefore, this problem remains relevant to this day: the economic crisis is reflected primarily on the quantity and quality of products manufactured in agriculture, reduction of product range and quality deterioration.

Latest research and publications analysis. The subject attracts attention of researchers of different branches of human knowledge: soil scientists who study the nature of soil and plant properties as well as the experts in applied mathematics, cybernetics, trying to offer directions for optimal use of soil resources by application of mathematical methods and modern IT to solve such problems. One of the economic reforms in Ukraine is the land reform, its strategic goal is to provide the most rational and highly effective land use, comprehensive protection and extended reproduction of soil fertility, ecologically balanced farming and prompt solution on this basis of food problem, creation of national agroindustrial complex, competitive at European and world agrofood markets (Kvasha, 2012; Mesel-Veselyak, 2011; Fedorov, 2011).

Theoretical and practical aspects of the conservation and restoration of land resources, the increase of soil fertility, their protection and rational use were studied by national and foreign scholars. To the problems of effective and ecologically safe land use significant attention was paid by well-known scientists and agricultural economists: P. Borshchevskyi (1999), S. Kvasha (2012), S. Korchinska and O. Khadakivska (2011), V. Mesel-Veselyak (2011), M. Fedorov (2011) and others.

Unresolved issues. Importance of improving the efficacy of land use in agriculture, including environmental factors, as well as the lack of studies of this problem determines the relevance of this work. In addition, there is a set of debating points of ecological and economic efficacy of organic farming that requires additional research. The problem relevance, insufficient degree of its study regarding the current needs of the economy stipulate the objective of the present study.

The objective of this paper is the systemic review of the problems of ecological and economic monitoring and development of recommendations on land use on the basis of ecological and economic models applied in modern agribusiness. Thus, let us analyse the possibility to optimize the crop allocation on the fields of different fertility to increase the output of environmentally friendly products of crop production sectors, taking into account soil fertility.

Key research findings. Analysing the abovementioned we conclude that improvement of the environmental consciousness of modern society is a necessary condition for its sustainable development (Tihonov, 1990; Ierokhin, 2002).

According to most scientists, agricultural ecologization should include the following key factors: the creation of farming systems that protect soils, partial transi-

tion to biological agriculture, agro-ecological monitoring, determination of damage from erosion and other types of land degradation, the development of measures on responsibility and material incentive of land users for soil conservation and soil fertility recovery (Mesel-Veselyak, 2011: 43–50).

The achievements of science and best practice testify that the increase of soil fertility, which in turn is closely associated with the reproduction of humus, its accumulation in soils, is the basis of sustained growth in agriculture productivity. Annual humus losses due to mineralization and soil erosion are 11–12 mln tons, which is equal to the loss of around 3–4 bln UAH (Medvedev, 2001). The eighth round of the agrochemical survey low and very low humus content was fixed at 16% of Ukraine's lands (Figure 1).

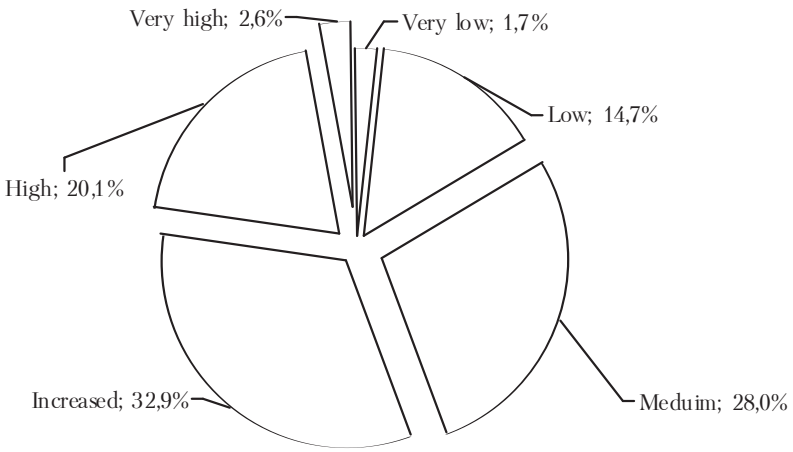

Figure 1. **Distribution of agricultural lands of Ukraine by humus content,** *based on the data from the State Agency of Land Resources of Ukraine*

It is necessary to realize the potential productivity of crops not by high doses of fertilizers, but through optimization of all properties and life processes in the soil that will ensure its fertility recovery, creation of nutrient, water and air regimes in the soil, meeting the biological requirements of plants and optimization of biotic soil activity level. Although the effect of environmental conditions on the production is not thoroughly investigated, these conditions are starting to play an increased role in planning of agricultural production (Tihonov, 1990). The objective of ecological and economic planning is to ensure the balance between production and environment, where the prime importance should be given to lands. Based on the study and the analysis of the general concepts of ecoentrepreneurship (Borshchevskyi, 1999; Pylypenko, 2003) a model of ecological and economic planning in agriculture is proposed (Figure 2).

Mathematical modelling of land management is a complex economic and environmental target.

The purpose of soil fertility models development is the regulation of knowledge about fertility, the impact assessment on the state of land use and the possibility of optimal crops allocation at farms on soils of different fertility. Ecological direction in contemporary agricultural production requires high yields along with land friendliness, maintenance and restoration of soil fertility. Fertility models are an approximate

reflection of soil properties to meet the needs of crops under certain environmental and socioeconomic conditions. Developed as a part of the study, the scheme of system of soil fertility models on the basis of the model of optimization of crop allocation makes it possible to optimize the basic processes of soil fertility (Figure 3).

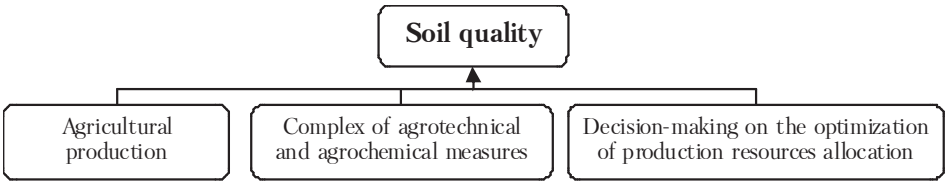

Figure 2. **Model of ecological and economic planning of agricultural production,** *developed by the authors*

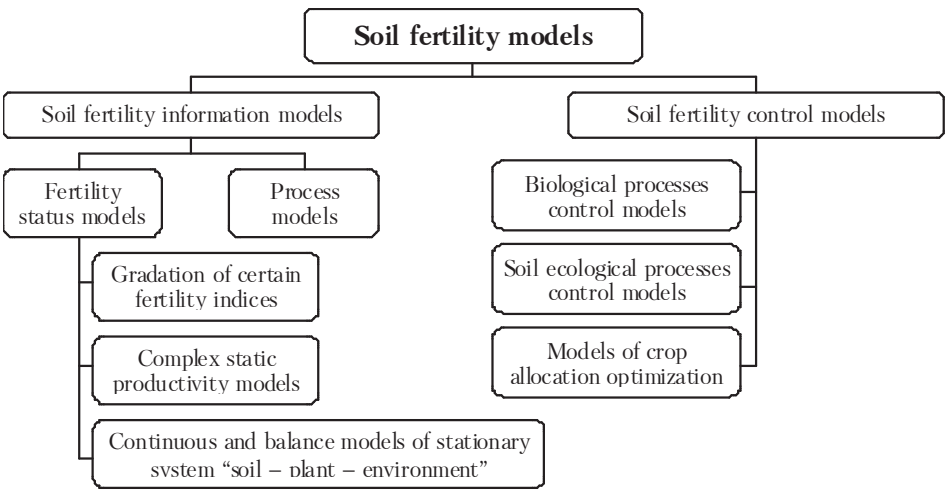

Figure 3. **The system of mathematical models of soil fertility,** *developed by the authors*

The proposed system of models as compared to other environmental models is compact, takes into account all agronomic conditions and the requirements of soils and crops sufficiently.

The calculation procedure is that first they determine the part of the crop for which there will be enough nutrients from the soil by specially designed production functions. A number of methods are developed to solve this problem, but the real value of fertilizers in agricultural production can be properly understood only in conjunction with other factors forming the level of crop yields within the same period.

Forecasting of yield indices of certain cultures is taking into account non-linear character of the cause-effect relationship in the system "soil fertility – fertilizer – yield".

The application of environmentally sound land-use technologies provides not only increased soil fertility, rational land use and positive impact on the environment, but also allows receiving ecologically clean products, the demand for which is growing annually. Yield cultivated using environmentally sound practice will probably be smaller and will require more time and strength than the yield cultivated using mod-

ern intensive technologies. But the demand for environmentally friendly products is constantly growing. And that is why there is an urgent need to expand environmentally friendly food production. Therefore, every country that cares about its future needs to develop a network of such technologies and enterprises.

In Europe there are countries where more than 10% of all agricultural lands are under organic farming: Liechtenstein (about 30%), Austria (over 16%), Sweden and Switzerland (11%). The largest areas of organic lands are in Spain (1.1 mln ha) and Italy (1 mln ha). Among Ukrainian neighbours Poland and the Czech Republic should be noted (Willer et al., 2008). According to the fficial statistics of IFOAM, in Ukraine, the total area of certified organic farmlands in 2010 was over 300 ths ha (Figure 4), the number of certified organic enterprises over the past 10 years has increased fourfold.

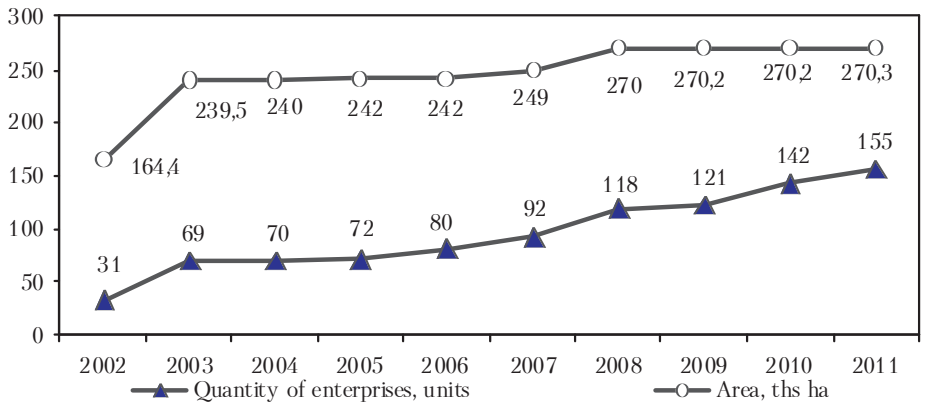

Figure 4. **The dynamics of the total area of organic farmlands and the quantity of organic enterprises in Ukraine,** *based on the data from the Organic Federation of Ukraine*

The prerequisites for the establishment of market of environmentally friendly products are: the development of legal framework for the regulation of environmentally safe agricultural production; the creation of appropriate infrastructure, which should be understood as introducing a system of accreditation for the farms that carry on ecologically safe agriculture, standardization, certification and labelling of environmentally friendly products, information provision; state support for the development of such farm units via grants, subsidies, benefits and incentives for the production of environmentally friendly products (Gaydutskyi, 2012).

In order to improve the efficacy of environmentally sound land use we offer to group separately the measures to maintain environmentally friendly land state, as those that require financial investments and those that can be performed by land users themselves without additional investments, using a scientific approach to economy management (Figure 5). It is determined that even the implementation of measures of the second group, i.e. by land users themselves, will help to improve the ecological condition of farmlands and the economic indicators of farms activities.

According to the results of the studies it was found that the abrupt transition from traditional agriculture to its alternative types in domestic conditions is not justified.

The introduction of alternative farming allows obtaining good yields of crops only at high quality soils with optimum nutrients contents. On the rest of agricultural lands it is necessary to perform the gradual transformation of traditional (intensive) farming into integrated with environmental orientation, which must be economically and ecologically balanced, i.e. include the main components of alternative systems with simultaneous application of small doses of chemicals. The discovery of herbicides and pesticides is one of the most important achievements of modern science and the economic effect of pesticides is extremely high.

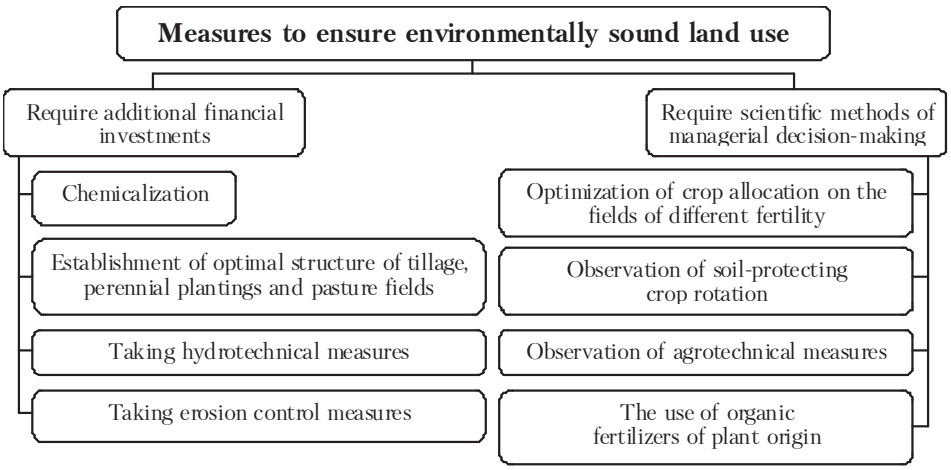

Figure 5. **Measures to maintain environmentally friendly land state,** *developed by the authors*

The economic efficiency of the pesticides use is confirmed by the following facts: in the USA one person employed in agriculture could, except himself, provide 4 city residents with farm products in 1850, 11 residents – in 1940, 55 residents – in 1974, 104 residents – in 1990, 160 residents – in 2010. Calculations, carried out by experts in the USA (IFOAM, 2002), demonstrate that without large-scale use of pesticides the crop yield would decrease by 50% and the quantity of animal products (meat, milk, wool) – by 25%. All this suggests that humanity at the present stage of its development is not able to refuse from chemicals in agriculture. This is especially noticeable during the period of population "explosion", when the problem of food resources is extremely acute.

Taking into consideration all the features of the current land use, simulation of this process and the specific formulation of our problem, ecological and economic model of optimization of soil nutrition of crops will be as follows:

Let us maximize the total yield per unit:

$$Z = \sum\sum t_{ij} X_{ij} \to \max, \quad (1)$$

where $i \in M_1$; $j \in M_2$; M_1 – the set of land plots ($i = n$); M_2 – the set of crops ($j = m$); t_{ij} – economic efficiency of production cultivation of the j-th crop on the i-th field; X_{ij} – the desired planting acreage of the j-th crop on the i-th field; S_i – the area of each of n land plots; S_j – the area of each of m crops in the cropping pattern; ξ_{ij} –log-

ical factor, which provides for possible allocation of the *j*-th crop on the soil of the *i*-th plot.

The optimal allocation of crops must meet the following conditions:

1. According to the use of arable land:

$$\sum \xi_{ij} X_{ij} = S_i \, (i \in M_1), \tag{2}$$

$j \in M_2$.

2. According to the cropping pattern:

$$\sum \xi_{ij} X_{ij} = S_j \, (j \in M_2), \tag{3}$$

$i \in M_1$

3. According to the acceptable region of the variables:

$$S_{ij}^{\min} \geq X_{ij} \geq S_{ij}^{\max}, \tag{4}$$

where S_{ij}^{min}, S_{ij}^{max} – the minimum and the maximum acceptable values of the variables accordingly.

4. Natural conditions of non-negativity of variables: $X_{ij} \geq 0 \, (i \in M_1, j \in M_2)$.

The developed methods allow during the determination of yield Y_{ij} of *j*-th crop on the *i*-th soil take into account the complexity of soil mineral composition. Thereby, the yield is calculated by the formula:

$$Y_{kij} = \frac{a_{ki} \times E_i \times f_{kij}}{B_{kj}}, \, k \in M, \; i \in M_1, j \in M_2, \tag{5}$$

where M – the set of nutritional components; k – the number of nutritional component, $k \in M$; M_1 – the set of land plots; M_2 – the set of crops; i – the number of land plot, $i \in M_1$; j – the number of crop, $j \in M_2$; a_{ki} – the content of *k*-th nutritional component in the soil of *i*-th land plot (mg/1 kg of soil); E_i – the conversion factor of aki in kg of active substance; f_{ki} – the utilization coefficient of the *k*-th nutritional component on the *i*-th soil by the *j*-th crop; b_{kij} – the removal of *k*-th nutritional component by crop yield unit.

Due to the fact that the biomass growth rate of one or another species of plant is limited by nutritional component, which is in the ecological minimum, and depending on consumption, the balance between different components may change and different chemical substances will be present in the ecological minimum, Y_{ij} – the yield of *j*-th crop on the *i*-th soil is determined as:

$$Y_{ij} = \min; \; Y_{kij} = \min \frac{d_{ki} E_i f_{ij}}{B_{kij}}. \tag{6}$$

Y_{ij} is the coefficient of effective soil fertility and shows which part of yields may be formed by means of nutrient-supplying capacity of soil available for plants. This transformation model provides an opportunity to present it as a transportation problem, because crops fulfil the role of a consumer, and plots of varying fertility – the one of a supplier. In this case simulation is fulfilled and task results can be interpreted as performance indicators of the use of soils potential by each crop. So, as an outcome, we have a plan of crop allocation on fields with different fertility, developed on condition of optimization of soil nutrition with environmental and economic assessment of the efficiency of land use in accordance with the given scheme of crops distribution.

Conclusions. The analysis performed and the test results confirm the efficiency of crop allocation optimization. The practical importance of the results obtained is that the proposed and adapted to the conditions of farm model can be used to plan the structure of crop rotation and spatial crop allocation on the fields with different fertility to fulfil ecological and economic requirements in agricultural production.

Under market conditions an effective use of land resources for organic or ecologically balanced farming is of high priority. One of the ways to solve the assigned tasks on harmonization of ecological and economic requirements of modern land use is the proposed system of mathematical models that includes the rational organization of cropping patterns, optimizing mineral and organic fertilizers usage, programming of crop yields, based on the use of mathematical optimization methods, application software programs and information systems.

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Стаття надійшла до редакції 14.03.2013.