НОВІТНІ ТЕХНОЛОГІЇ В АПК: ДОСЛІДЖЕННЯ ТА УПРАВЛІННЯ

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METHODOLOGY AND MODEL OF AGRICULTURAL TECHNOLOGIES ENVIRONMENTAL AND ECONOMIC MANAGEMENT

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Summary

The work is devoted to the problems of solving the double problem of agricultural engineering (according to the international definition): «Feed the world and save the planet» using the ability to manage the environmental, energy and economic components of agricultural technologies.

It was confirmed that the management process sets the conditions: to plan (program), execute, evaluate and continuously act on the creation and improvement of creative agricultural technologies based on the laws of the historical development of the planet's nature (biosphere laws). Based on these principles, an abstract-logical model of the interconnection of the «environment-agricultural technologies» system, as well as the methodology for a systematic approach to climate-smart agricultural production practices, which will conserve natural resources, while increasing agricultural production, is proposed.

Goal of Research. *To Improve the model of the relationship between the environment, agricultural technologies and engineering solutions, as well as the methodology of environmental and economic management of agricultural technologies based on climate-smart agricultural practices, with the display of accurate regulation of all its constituent parts, processes and procedures.*

Research methods. *Methods of planning (programming) agricultural technologies or products in accordance with ISO recommendations; agrometeorological parameters, including vegetation indices, achieved by mathematical processing of remote sensing data (RSD) and modeling these parameters, according to the European Union project MARS (MCYFS - MARS Crop Grow Forecasting System); crop growth modeling system CGMS were used.*

Research results. *The developed model of the relationship «environment- agricultural technologies» and the methodology of ecological and economic management the agricultural technologies provides for the implementation of a hierarchical multi-circuit process of modern nature management on a geo-community basis, displaying the precise regulation of all components: forecasting systems; systems of environmental management and defragmentation of technical and technological solutions to the conditions of environmental and economic optimization.*

Conclusions. *The ecological and economic problems at the present stage of development of society* *in the production of agricultural products are considered. Possible ways of their solution have been determined on the example of an abstract-logical model of the relationship between the environment, agricultural technologies and engineering solutions, as well as the methodology of ecological and economic management of agricultural technologies.*

Key words: *biosphere, agricultural technology, agro-engineering, environmental and economic management systems.*

Introduction. «Feed the world and save the planet» - such a predictive motto of international experts in the field of agricultural engineering - members of the Club of Bologna [www.clubofbologna.org]. This dual task requires deep research in terms of the relationship between the environment and agricultural technologies, as well as the environmental management system.

Farming, taking into account the requirements of the environmental management system, puts forward new conditions: the ability to plan (program), execute, evaluate and continuously act on the creation and improvement of creative agricultural technologies based on the laws of the historical development of the planet's nature (biosphere laws).

In line with the challenge, agricultural production will have to be adapted to mitigate the imbalances in the environment-agrotechnology system through widespread adoption of climate-smart agricultural practices that include:

- all forms of production, from traditional family farms to industrialized agriculture, must adhere to an appropriate strategy, taking into account social, cultural, economic and environmental aspects;
- improving agricultural processes to increase yields and use less inputs (energy, chemicals and water) is the only effective strategy to boost food production without compromising the planet's green resources;
- the development of agricultural technology should be focused on increasing operational efficiency, reducing fuel consumption and developing guaranteed-adaptive procedures for the distribution of chemicals required for high productivity and environmental friendliness:
- the development of electronic and automatic control technologies together with satellite positioning systems, remote sensing and data collection in order to provide specific "local" farming methods (precision farming) that are able to adapt the operational parameters of the real needs of plants;
- research in agricultural technology and mechanization, and more generally in agrifood technologies, is considered a strategic priority, a key factor in meeting the future food needs of the planet;
- adequate measures should be taken by national and international authorities to assess the environmental aspects of existing machines and to promote the proliferation of modern machines designed in accordance with the new environmental and control criteria.

Tasks Setting. What and how to use in agricultural technologies, without violating the laws of development of the ecosphere, but also to increase the efficiency of production – this is one of the main tasks of science and society as a whole.

One of the ways to make assumptions about the sustainability of the eco-efficiency system is operationalization, that is, the scientific model and methodology of modern environmental management on a geobiocommunity basis with the display of the exact regulation of all its constituent parts and processes. It is looking for manufacturing solutions, processes, procedures that will lead to a greater reduction in the use of natural resources, while maintaining or even increasing the level of production.

The mentioned method provides for:

· development of an abstract-logical model of the relationship between the environment and agricultural technologies;

· development of a methodology for environmental and economic management with the ability to balance and combine the economic and environmental interests of agricultural production, timely coordinate environmental goals and targets with specific financial results of activities, guarantee to direct resources to where their use gives the greatest benefit in both financial and environmental aspects ;

• determination of the influence of mechanized agricultural technologies, and specifically complexes of machines and equipment, on the property of agrocenosis to self-recovery (homeostasis), taking into account favorable and unfavorable tendencies in the behavior of the system under the influence of external anthropogenic factors.

Methods and materials. The national standard [DSTU ISO 14001: 2015] regarding the introduction of environmental requirements to product standards defines the most important indicators that affect the environment and human health: destruction of the ozone ball; biota change; depletion of resources; pollution of air, water, soil; climate and relief change; other.

DSTU ISO 14001: 2015 «Environmental Management Systems» provides a model for the following system: «Plan - Perform – Check - Act ”or“ Plan - Do - Check - Act ”(PDCA), which allows an organization to develop, implement and maintain environmental policy in a continuous interactive process.

It is necessary to start developing an environmental management system, in accordance with ISO recommendations, in those areas where it is possible to obtain clear benefits, in particular, cost savings and compliance with environmental regulatory requirements. Subject to the successful implementation of the environmental management system, programs for further improvement of environmental and economic characteristics are being implemented.

The programming of agricultural technologies (products) based on biospheric thinking should take into account at least two components: the potential of agrobiogeocenosis and the ergatic system as an element of the ecological and economic impact on the environment and production efficiency.

Agrocenosis potential is a natural potential that determines the volume of agricultural products in a specific place under the influence of real factors of the biocenoses system. Essentially, these are forecasts of natural yields predicted using agrometeorological parameters, incl. vegetation indices achieved by mathematical processing of Earth remote sensing (ERS) data and modeling these parameters, such as, for example, according to the MARS project of the European Union (MCYFS - MARS Crop Grow Forecasting System), which includes [Kushnaryov A., 2010; Kravchuk V.I., 2000]:

• work with a meteorological base;

• work with a database of satellite imagery of medium and low visibility; • statistical processing of databases;

• forecast for the growth of crop yields.

The MCYFS array is controlled through the CGMS Crop Growth Simulation System.

Research results. Research conducted at the State Scientific Institution «Ukrainian Research Institute for Forecasting and Testing of Equipment and Technologies for Agricultural Production named after Leonid Pogorelyi» made it possible to create an abstract-logical model of the relationship between the environment and agricultural technologies, as well as the environmental management system (Fig. 1) and continue research on each component of the model [Fabio Micale; Kravchuk V. I., 2009].

It has been established that the forecasting system CGMS adapted to the conditions of Ukraine is 15-20% higher in accuracy than the forecasts made by other methods, and the resulting agro- and meteorological indicators can be used to make optimal ecological and economic decisions in specific dynamic conditions of crop vegetation.

The ergatic component is implemented through defragmentation of existing technology elements (variety, hybrid, crop rotation, fertilization and plant protection system, selection and use of machines, etc.) in order to obtain a rational use of the agro-climatic potential of territories, the biological potential of plants and the capabilities of machine technologies.

It also became possible to substantiate the soil cultivation system depending on the distribution of the humus content in depth in the arable and subsoil horizons, which gives preconditions for the development of not only energy-saving tillage methods, but also for maintaining climate stability on the globe, since fossil humus as a result of losses during cultivation crops replenish the atmosphere with carbon dioxide, increasing the greenhouse effect.

Over the past three years, the institute has been conducting experiments on the selection of a rational composition of the machine and tractor fleet (MTP) for growing cereals with different systems of soil cultivation and sowing - the AgroOlimp project [Kushnaryov A., 2010]. Each soil cultivation system contains a specific technological operation for it: the traditional system - plowing; preserving - deep loosening (chiseling); mulching - small tillage and system with Mini-Till elements - chemical weed control.

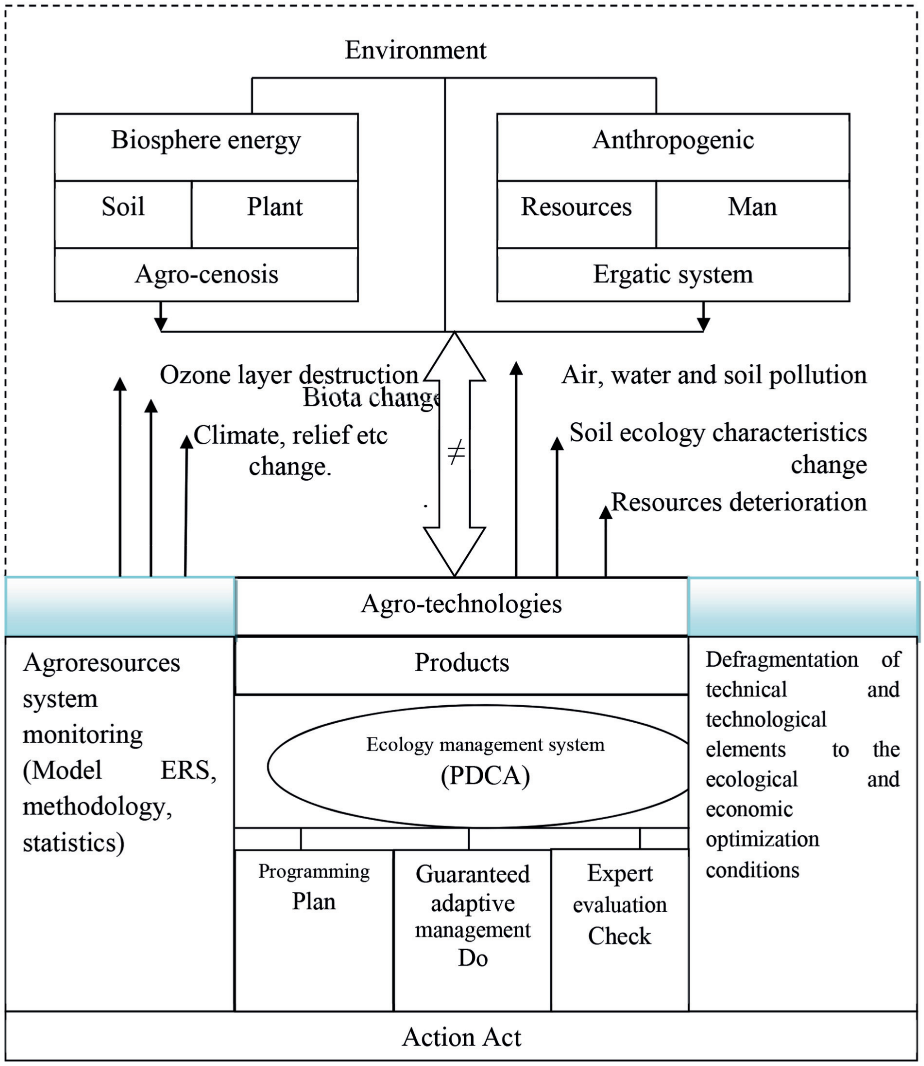

Fig. 1 – – Abstract-logical model of the relationship between the environment of agricultural technologies and the system of environmental management

Studies have shown that in the case of using preservative, mulching technologies or with Mini-Till elements, compared to traditional, fuel consumption is reduced from 47.6 to 45.3; 37.1; 29.2 l / ha or 5, 22, 39 percent, respectively [Kravchuk V.I., 2000].

The execution (implementation) of such soil cultivation systems and other programmed operations (yield mapping, monitoring of nutrient reserves, locally determined changeable rates of application of technological materials, etc.) is achieved by maintaining guaranteed-adaptive control of the working processes of agricultural machines (CXM) of the latest generation, working on electronic maps agricultural technologies using information management systems.

The work of mechanisms and working bodies of agricultural machines is associated with the transfer of an agricultural environment or an agricultural object by performing a number of technological operations from a state that does not correspond to agricultural requirements to a new state that satisfies the agricultural requirements of the formalization of this process, which will associate with the space-time transformation of the initial state S* (ti- 1) to the final state S* (T) (predicted and calculated) [Kravchuk V., 2005]. A step-by-step Δt = ti - ti-1 = ti + 1-ti change and obtaining intermediate rational environmental and economic results optimizes the achievement of the ultimate goal - obtaining a crop.

The efficiency of the SCM is determined by the function of the optimal transformation S* (ti-1) → S* (ti) →... → S* (T) and characterizes the dynamic system, which has the form

$$S\,(x,y,z,t_i,u,v) = F\,(x,y,z,t_{i-1},\Delta t,u,v), \quad (1)$$

where x, y, z, respectively, are the coordinates of the locally defined part of the field with many specific features of the physicochemical parameters of soils, biosphere and environment; (ti-1), Δt, ti - discretization of processes by the hour relative to causal phenomena; v - relevant environmental and pollution factors applied to the CXM; u - control in the form of values of states of regulated parameters of mechanisms.

Research carried out at our institute has shown [Kravchuk V., 2009; Pogoriliy L., 2003] that the proposed system implements a hierarchical multi-circuit technology, including: agricultural machines with on-board multifunctional complexes (BMC), working bodies with information and control dispensers for the introduction of rational norms of costly materials (fertilizers, pesticides, plant development regulators). Regional management of the functioning of subdivisions of the agro-industrial complex makes it possible to: increase the actual yield by 10-15% due to the precise and metered application of pesticides and mineral fertilizers; to increase the efficiency of technological operations execution up to 15%; to reduce up to 15% man-caused load on the environment.

The scientific foundations for the examination of agricultural technologies, which determine the clearly expressed advantages and no alternative to agroecophilic technologies, were formulated by academician L.V. Pogorely [Pogoriliy L., 2003], in particular, the direction of development of bioconverted complexes as a system for conducting biologized agricultural production in a particular diversified agricultural enterprise or a whole agricultural landscape [Targonya V., 2011.]. The system is based on the use of specialized technocenosis integrated into production processes for the maximum possible (from an ecological and economic point of view) biotechnological processing of all organic waste (non-commercial biomass) for the subsequent full or partial return of the converted biomass to production processes in order to reduce the energy costs of production, complete or partial elimination of the negative impact of production on the environment, rehabilitation and restoration of soil fertility, the possibility of obtaining environmentally friendly products.

In parallel with these studies, we have developed algorithms for the ecological and economic examination of agricultural technologies, taking into account their ecological, biotechnological and bioenergy characteristics. For the indicators of the homeostasis coefficient (G).

In our case, when it is necessary to determine the influence of mechanized agricultural technologies, and specifically, complexes of machines and equipment, on the self-healing property of an agrocenosis (homeostasis), it is advisable to take into account favorable and unfavorable tendencies in the behavior of the system under the influence of external anthropogenic factors. Then the degree of homeostasis (G) can be determined by the formula [Targonya V., 2011]:

$$G = \frac{V+\Delta V}{V} \Big/ \frac{Y+\Delta Y}{Y}. \quad (2)$$

As a criterion for assessing the state of agrobiocenosis (V), it is advisable to choose a change in the content of humus in the soil, and the criterion that characterizes the influence of external factors (Y) is the consumption of non-renewable energy (fuel energy; energy substantiated in means of mechanization, mineral fertilizers, pesticides, etc.).

The quantities ΔY and ΔVV can have both positive and negative values. The value of the homeostasis coefficient for biological farming technologies should not be less than one. (G≥1). Fulfillment of this requirement will testify [Targonya V., 2011] that the technocenosis provides conditions for the restoration of soil fertility, a more complete use of their biological potential, as well as ensuring the environmental safety of agricultural technologies and products.

Discussions. The problems raised in the work concern all mankind, scientists from all over the world were engaged in their solution.

Polish scientists have tackled the problems of external factors, which are an important aspect of the direction of agricultural development and agricultural policy, using a synthetic indicator that measures agro-environmental externalities at the regional level, taking into account both positive and negative aspects [Borawski, Piotr; Guth, Marta; Beldycka-Borawska, Aneta., 2020].

Also, scientists have proposed the concept of environmental efficiency, which analyzes agricultural products in relation to not only traditional resources, but also the impact on the environment [Golas, Marlena; Sulewski, Piotr; Was, Adam., 2020].

Chinese scientists examined the indicators of the energy-ecological development of agriculture using the global DEA method, while using the TOBIT panel model based on censored data to empirically analyze the impact of the popularization of mechanization on the indicators of the energy environment in the agricultural sector [Jiang, Minjie; Hu, Xinjie; Chunga, Joseph., 2020].

Croatian scientists have examined the relationship between CO2 equivalent emissions and agricultural production, taking into account additional economic and social variables that adjust the relationship of the six countries of Central and Eastern Europe [Kulyk, Piotr; Augustowski, Lukasz, 2020].

Global warming and climate change, weather disasters and disruptions are just some of the challenges that can threaten the sustainability of an ecosystem. Agriculture, as an activity at the center of the value chain, faces the challenges of climate change, while at the same time feeding a growing global population and is responsible for conserving resources and ensuring sustainability. Therefore, researchers [Hrustek, Larisa., 2020; Pajewski, Tomasz; Malak-Rawlikowska, Agata; Golebiewska, Barbara., 2020; Pham, Hannah; Sutton, Bruce G .; Brown, Paul J., 2020] more deeply studied process automation, data analysis and processing, control and management of agricultural operations that contributed to stability, survival and development.

The proposed methodology of environmental and economic management of agricultural technologies not only corresponds to the concept of minimizing the intensification of production processes, which is dominant in different countries, but also predicts a multifactorial development (action) to increase productivity and further improve the environmental characteristics of products.

Conclusions. The developed abstract-logical models of the interconnection of the «environment-agro-technologies» system, as well as the methodology of a systematic approach to agrocenosis management, is expected to be further developed on the basis of a cenological approach to the integrated use of the following components [Pogoriliy L., 2003; Targonya V., 2011; Kravchuk V. I., 2008]:

- information and forecasting systems for remote aerospace sensing;
- advanced informational ergatic-resolving systems of precision (controlled) farming;
- the integrated use of biotechnological alternatives (biologically active fertilizers, entomological and microbiological preparations for plant protection and increasing soil fertility);
- methodology for choosing scientifically grounded rational agricultural technologies and corresponding sets of machines based on the development of acceptable forecasts of indicators of the polyvariant production system «soil and climatic conditions - variety - agricultural technology - technological operations - complex of machines - quantitative and qualitative indicators of products»;
- rules for the creation of mechanized agroecotechnologies, which establish the following requirements:
    - adhere to the ecological laws of the existence of agricultural landscapes as a category of ecosystems;
    - the higher the structuring of the pro-

duction system, bioconversion complex, the more stable it is;

- to consider the whole agricultural landscape as a production system, which includes a complex of industries, and not a separate farm;
- the production part of the agrolandscape includes mechanized biotechnological systems with a high concentration of biomaterial (enzymatic plants for processing biomass into biohumus, vermicomposting plants, equipment for the production of entomological and microbiological preparations);
- agrobiocenosis should include the appropriate autotrophic and heterotrophic links for the localization of metabolite substances, toxins and external pollutants.

The system of environmental and economic management will make it possible to balance and combine the economic and environmental interests of agricultural production, to timely coordinate environmental goals and targets with specific financial results of activities, to guarantee resources to be directed where their use gives the greatest benefit, both in financial and environmental aspects.

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МЕТОДОЛОГІЯ І МОДЕЛЬ ЕКОЛОГО-ЕКОНОМІЧНОГО УПРАВЛІННЯ АГРОТЕХНОЛОГІЯМИ

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Анотація

Робота присвячена проблемам рішення двоєдиного завдання агроінженерії (за міжнародним визначенням): «Нагодувати світ і зберегти планету», використовуючи вміння управляти екологічними, енергетичними та економічними складовими агротехнологій.

Підтверджено, що процес управління висуває умови: планувати (програмувати), виконувати, оцінювати і безперервно діяти над створенням і удосконаленням творчих агротехнологій на основі законів історичного розвитку природи планети (біосферних законів). За цими принципами запропонована абстрактно-логічна модель взаємозв'язку системи «довкілля-агротехнології», а також методологія системного підходу до управління клімат-розумною сільськогосподарською практикою виробництва, яка збереже природні ресурси, одночасно збільшуючи сільськогосподарське виробництво.

Мета досліджень. *Удосконалення моделі взаємозв'язку навколишнього середовища, агротехнологій та інженерних рішень, а також методології еколого-економічного управління агротехнологіями на основі клімат-розумної сільськогосподарської практики з відображенням точного регулювання всіх складових її частин, процесів і процедур.*

Методи досліджень. *Використовували: методи планування (програмування) агротехнологій або продукції відповідно до рекомендацій ISO; агрометеорологічні параметри, зокрема вегетаційних індексів, досягнутих математичною обробкою даних дистанційного зондування землі (ДЗЗ) та моделювання цих параметрів, за проектом Європейського Союзу Mars (MCYFS - MARS Crop Grow Forecasting System); систему моделювання росту сільськогосподарських культур CGMS.*

Результати досліджень. *Розроблена модель взаємозв'язку «навколишнє середовище-агротехнології» і методологія еколого-економічного управління агротехнологіями передбачає реалізацію ієрархічного багатоконтурного процесу сучасного природокористування на геоценозной основі з відображенням точного регулювання всіх складових: системи прогнозування; системи екологічного управління і дефрагментації техніко-технологічних рішень до умов еколого-економічної оптимізації.*

Висновки. *Розглянуто еколого-економічні проблеми на сучасному етапі розвитку суспільства при виробництві продукції землеробства. Визначено можливі шляхи їх вирішення на прикладі абстрактно-логічної моделі взаємозв'язку навколишнього середовища, агротехнологій та інженерних рішень, а також - методології еколого-економічного управління агротехнологіями.*

Ключові слова: *біосфера, агротехнологія, агроінженерія, системи екологічного та економічного управління.*

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МЕТОДОЛОГИЯ И МОДЕЛЬ ЭКОЛОГО-ЭКОНОМИЧЕСКОГО УПРАВЛЕНИЯ АГРОТЕХНОЛОГИЯМИ

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Аннотация

Работа посвящена проблемам решения двуединой задачи агроинженерии (за международным определением): «Накормить мир и сохранить планету», используя умение управлять экологическими, энергетическими и экономическими составляющими агротехнологий.

Подтверждено, что процесс управления выдвигает условия: планировать (программиро-

вать), исполнять, оценивать и непрерывно действовать над созданием и совершенствованием созидательных агротехнологий на основе законов исторического развития природы планеты (биосферных законов). За этими принципами предложена абстрактно-логическая модель взаимосвязи системы «окружающая среда-агротехнологии», а также методология системного подхода к управлению климат-разумной сельскохозяйственной практикой производства, которая сохранит природные ресурсы, одновременно увеличивая сельскохозяйственное производство.

Цель исследований. *Совершенствование модели взаимосвязи окружающей среды, агротехнологий и инженерных решений, а также методологии эколого-экономического управления агротехнологиями на основе климат-разумной сельскохозяйственной практики с отображением точной регуляции всех составляющих её частей, процессов и процедур.*

Методы исследований. *Использовали: методы планирования (программирования) агротехнологий или продукции в соответствии с рекомендациями ISO; агрометеорологические параметры, в т.ч. вегетационных индексов, достигнутых путём математической обработки данных дистанционного зондирования земли (ДЗЗ) и моделирования этих параметров, по проекту Европейского Союза MARS (MCYFS – MARS Crop Grow Forecasting System); систему моделирования роста сельскохозяйственных культур CGMS.*

Результаты исследований. *Разработанная модель взаимосвязи «окружающая среда - агротехнологии» и методология эколого-экономического управления агротехнологиями предусматривает реализацию иерархического многоконтурного процесса современного природопользования на геоценозной основе с отображением точной регуляции всех составляющих: системы прогнозирования; системы экологического управления и дефрагментации технико-технологических решений к условиям эколого-экономической оптимизации.*

Выводы. *Рассмотрены эколого-экономические проблемы на современном этапе развития общества при производстве продукции земледелия. Определены возможные пути их решения на примере абстрактно-логической модели взаимосвязи окружающей среды, агротехнологий и инженерных решений, а также – методологии эколого-экономического управления агротехнологиями.*

Ключевые слова: *биосфера, агротехнология, агроинженерия, системы экологического и экономического управления.*