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THE FEATURES OF ANALYSIS OF EFFICIENCY OF IMPLEMENTATION TECHNOLOGICAL INNOVATIONS IN AGRICULTURE

Introduction. *The innovation activity in the agrarian sector has its specific features, insofar as implementation of some innovations may cause the negative consequences in the economic, social, and environment spheres, therefore, they shall be assessed by a degree of danger.*

Problem Statement. *It is difficult to predict and to measure the possible consequences of innovation, since there is no standard (procedure) for assessing innovation risks in agriculture. Therefore, the improvement of methodology for assessing the effectiveness of implementing innovations in the agrarian sectors remains important. In addition, methods for analysis of efficiency of innovation implementation, which summarize the positive and negative consequences in different aspects of agricultural activity, need to be further improved.*

Purpose. *To develop a concept of the comprehensive assessment of the effectiveness of implementation of technological innovation in the agricultural sector.*

Materials and Methods. *Abstract, logical, comparative analysis, monographic method, expert assessments. To analyze the effectiveness of innovations, the system of indicators has been proposed. It has been formed using the methods of decomposition, analysis and synthesis. While selecting indicators, a content-analysis of scholarly research literature has been applied.*

Results. *A concept for the comprehensive assessment of expediency of implementation of technological innovations based on integral indicator of efficiency of innovations has been proposed. It takes into account possible influence of innovation on the technologic, economic, and environment characteristics of different agricultural sectors. Its application enables making decision on expediency of implementation of a certain kind of innovation.*

Conclusions. *This approach provides comprehensive assessment, simplicity of calculations, saving of time, and minimization of subjectivity of expert evaluation.*

Keywords: innovation, implementation efficiency, and agriculture.

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Modern society is reasonably called a society of innovation, the level of implementation of which in agriculture of Ukraine as one of the strategic sectors of the economy, unfortunately, has been insufficient. Modern technologies for crop and livestock production are widely used only by large agricultural holdings, while the innovation activity of medium and small agricultural farms is quite low.

In addition to a scarce funding as the main reason for the technological lag behind the leading economies, the innovation development of agriculture is also hampered by many fears and prejudices. Producers are restrained by prejudices of adverse effect of innovation on the economic and social indicators, the possibility of producer's dependence on innovative products, job cuts, and so on. For consumers, agricultural innovation is often associated with technologies that may be harmful to human health and the environment. A large part of the population prefers crop and livestock products made by conventional technologies, which have a natural look, taste, and smell. "Conventional technologies" in contrast to "advanced innovative technologies" for many consumers mean "natural", "useful", "without GMOs and chemicals".

These fears are not all considered reasonable. However, some of them really need to be carefully checked, and the possible negative consequences of the introduction of certain innovations shall be assessed in terms of danger. In our opinion, a synergetic combination of traditions and innovations is possible in the agricultural sector, provided that all the consequences of their implementation have been analyzed.

However, it should be recognized that both theoretical and practical aspects of the impact of innovations on the economic activity of agricultural enterprises in Ukraine have not been comprehensively analyzed. Thus, it is important to study the features of innovation activity of domestic agriculture. In addition, methods for analyzing the effectiveness of innovation, which summarize the favorable and unfavorable consequences in various aspects of agricultural activity, need further improvement.

It is generally accepted that the term "innovation" was introduced into scientific terminology in 1911, by Joseph Alois Schumpeter who defined it as the manufacture of a new useful product, previously unknown to consumers or the creation of a new quality of product [1]. Thus, a new direction having not only theoretical significance, but also practical application in economics was initiated.

Traditional views on innovation are given in the researches of the classics of economics, H.W. Chesbrough [2] and G. Mensh [3]. Later, theoretical and practical aspects of innovation have been studied by foreign researchers, in particular, H. Hocde, B. Triomphe, M. Dulcire [4], G. Faure [4, 5], P.-Y. Le Gal, P. Dugue, S.M. Novak [5], M. Schut, J.-J. Kadilhon, M. Misiko, I. Dror [6] and by Ukrainian economists G.E. Maznev [7], P.T. Sabluk [8], Yu. O. Lutsenko, M. Y. Malik [9], V.V. Gotra [10] and others [8, 9, 11–15] who deal with innovations in the agricultural sphere.

Currently, the theoretical aspects of innovation continue to be studied by researchers and practitioners in various fields. However, despite the need for a comprehensive approach to analyzing the innovation efficiency in agriculture, in the academic literature, the scholars sometimes narrow it to the technological and economic factors, while paying much less attention towards the assessment of environment and social impacts. Therefore, given the insufficient coverage of this aspect of the analysis of innovation, there is a need to deepen research in terms of assessing the innovation efficiency in the context of sectoral specificity.

Based on the analysis of publications related to innovations in agriculture, using elements of content analysis (identification of the most frequently studied subjects), the spread of subjects discussed in the context of possible risks of technological innovation in agriculture has been assessed and a system of indicators to assess the innovation efficiency in this area has been formed.

This research aims at developing a concept for comprehensive assessment of technological innovation efficiency in the agricultural sector, taking into account the analysis of their comprehensive impact on agricultural performance.

The main objectives of the study are as follows:

- to characterize the features of development and implementation of technological innovations in the agricultural sector and to determine their specifics for the current status of economic and technological development of Ukraine;
- to develop proposals on the methodology for evaluating the results of innovation activities of agricultural enterprises.

To achieve this goal, the following research methods have been used:

- the abstract-logical and comparative analysis, for disclosing the essence and features of innovation in the agricultural sector of Ukraine;
- the monographic method, for comprehensive study of certain types of innovations in agriculture;
- the expert assessments, for developing a methodology for assessing the impact of innovations on the results of agricultural activitiesi;
- the dialectical method, for theoretical generalizations on the definition of problems and ways to overcome them, the formation of conclusions;
- the methods of decomposition, analysis, and synthesis, to form a system of indicators to analyze the effectiveness of innovation;
- the content analysis of literature sources in the relevant field, for the selection of indicators of innovation efficiency in the agricultural sector;
- the graphic and tabular methods of formalization, for presenting the results of the research.

We believe that all new methods, ideas, products, which have a fundamentally new qualitative nature and used for the first time by a particular business entity and bring specific economic or social benefits, are referred to innovation. New or improved types of products, services, production processes, and technologies are able to ensure competitiveness and to significantly raise the efficiency of agricultural enterprises. Innovation is a single option for agricultural development, but the current state of innovation in the agricultural sector of Ukraine is, at least, unsatisfactory. Low level of innovation implementation is one of the factors that lead to the domestic agricultural sector lagging behind the world leading economies in terns of key technical, economic, and organizational indicators.

Modern science distinguishes many types of innovations. In our opinion, depending on the field of application of innovation, it is advisable to classify innovations into the five groups: manufacturing (including product, technology, object, intellectual products); non-production operating (market, marketing; organizational and managerial, etc.); ecological; personnel and social; and financial ones. This research aims primarily at studying the efficiency of technological innovations that improve the technical and technological process of agricultural production.

Technological innovations in the agricultural sector result in growing productivity of animal husbandry and crop yields. Summarizing the opinion of the researchers who have studied this issue [7—15], today, the most effective in agricultural business are the following types of technological innovations: agrobiotechnology (engineering technologies of genetically modified organisms, cell biology, DNA technology, marker selection, biopesticides, enzymes, etc.), introduction of cartography, precision farming, GPS-monitoring-based management and development of organically oriented management systems.

The technological innovations in agriculture have the following peculiarities:

- they are associated with living organisms, so it is necessary to carefully check the possible negative consequences of certain innovations;
- innovations are mainly modifications, i.e. focused mainly on improving the properties or productivity of the object, rather than inventing a fundamentally new product or technology;
- have a long-term process of development of biotechnological innovations related to biological processes;

- are characterized by a high economic risk of investing in innovative activities because of a high probability of failure to obtain the expected results and a long payback period. That is why the leading role in the development of innovations belongs to research institutions and powerful producers of agricultural machinery and raw materials, while medium and small producers only use them;
- the introduction of innovations has both favorable, neutral and unfavorable consequences to be discussed below.

The efficiency of innovation activity of the agricultural enterprises in Ukraine should be analyzed taking into account certain conditions, the main of which are as follows:

- the medium and small producers are not able to finance not only to carry out R&D independently, but also to implement them at their own expense. The main source of funding for innovation in domestic agricultural enterprises is their own funds. Because of the lack of a favorable investment climate, stable economic and political situation in the country, investors rather cautiously put money in this industry. Therefore, it is important for Ukraine to increase the share of government in financing the innovative activities of agricultural enterprises;
- a long payback period under the condition of inflation and high interest rates on bank loans in Ukraine significantly reduces return on investment in innovation;
- the possibility to receive partial reimbursement of innovation costs. In particular, in 2017, the government reimbursed 20% and, in 2018, 25% of the cost of purchased agricultural machinery and equipment manufactured in Ukraine;
- the development of innovation is constrained by the imperfection of the legal framework of R&D activities and the inconsistency of national policy on mechanisms for government support and tax incentives for innovation in the agricultural sector. The R&D component of the economic development is a priority of government policy only on paper, whereas in fact, science, innovation, and education are excluded from the list of the main productive forces of the industry.

Despite the instability of innovation activity, such leading domestic holdings as *Kernel Group*, *Astarta-Kyiv*, *Mriya* and others have been implementing advanced R&D developments.

To identify the types of indicators that most fully characterize the impact of technological innovations on the results of economic activity in agriculture, experts (researchers and farmers) have been involved, and materials of scholarly research publications and electronic resources of agricultural producers for 2017—2018 have been used.

The main quantitative indicators that characterize the results of innovation activities of agricultural enterprises often include:

- the number of introduced new technological processes;
- the number of implemented low-waste, resource-saving technologies;
- the number of innovative products, the production of which has been mastered;
- innovative product sales;
- the number of new types of equipment, the production of which has been mastered;
- the percentage of introduction of certain innovations among enterprises in the industry.

The results of the introduction of innovations in agricultural production, in our opinion, shall be evaluated by the areas in which they are implemented (Fig. 1).

It should be noted that some of these effects may appear immediately, while others manifest themselves over time, even decades later. For instance, in the first years after the introduction of organic farming, there is reported a decrease in yield by 10—15%, but in the future the yield increases significantly.

Despite the list of favorable effects of innovation in the agricultural sector, it is also important to keep in mind that the introduction of innovations can have neutral or even adverse consequences.

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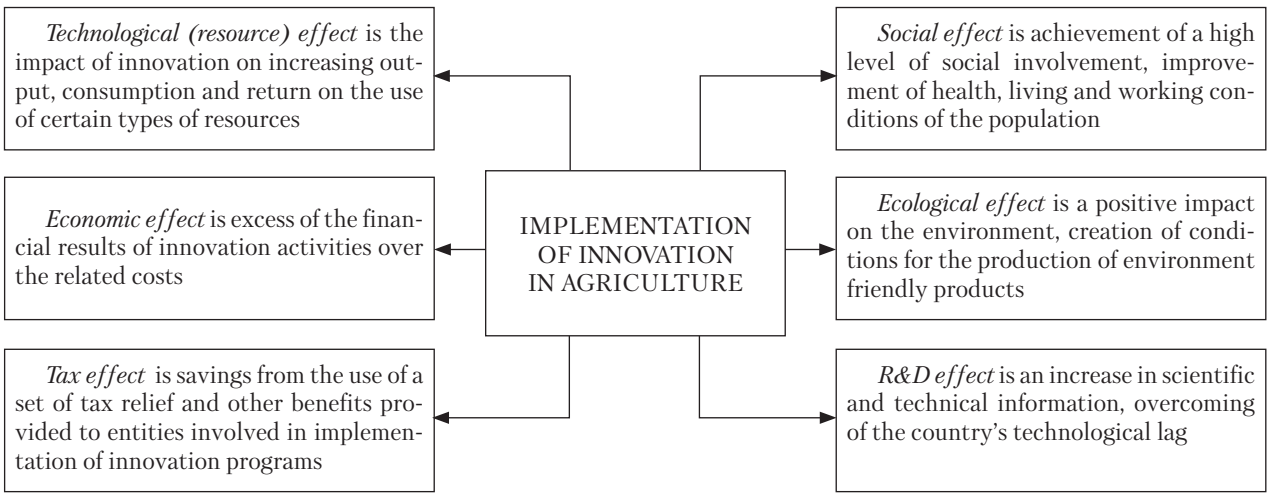

Fig. 1. Innovation performance at agricultural enterprises

The unfavorable effects manifest themselves:

- economically: if the cost of an innovation exceeds the value of its results;
- socially: if an innovation results in escalating threats to human health, cutting jobs, deteriorating working conditions, etc.;
- ecologically: harmful impact of a new type of activity on the environment (reduction of soil fertility, pollution of groundwater and rivers with pesticides, increased gas emissions, etc.).

However, there are cases where the social and environment effect of some innovations has not been scientifically proven. For example, there have been no convincing research results that confirm possible or negative consequences of the use of genetically modified organisms (GMOs), as neither a threat to the health of people who consume such products, nor the possibility of crossing GMOs with other plants or animals, which may lead to mutations, nor dependence of farmers on GMO producers, assuming that GMO-containing agricultural products do not give good progeny, has been confirmed so far.

Because of improper use of some technological innovations in agriculture in the past, the possibility to produce organic products in the future may be lost. If pesticides and mineral fertilizers were added to soil for a long time, before growing organic products on it, it is necessary to clean it by phytoremediation or bacterial degradation of contaminated areas.

Thus, only those innovations that ensure cheap and environment friendly production of high-quality crop and livestock products and have a positive social effect shall be implemented.

The innovation way of development requires from agricultural enterprises to invest significant financial resources. Significant costs of modeling, testing, and implementing innovations determine the importance of the innovation efficiency analysis for agricultural producers.

Since every agricultural enterprise that intends to introduce a particular innovation is interested in a comprehensive assessment of its results, to make a final decision, the authors propose to use the Integrated Innovation Performance Index (IIPI) based on generalized experience, with results of authors' research taken into consideration (Fig. 2).

This approach is divided into the following stages:

1. Selection of data for calculating indicators of technological, economic, social, and environment assessment of the results of innovation;
2. Calculation of specified indicators;
3. Evaluation of indicators, in points; and

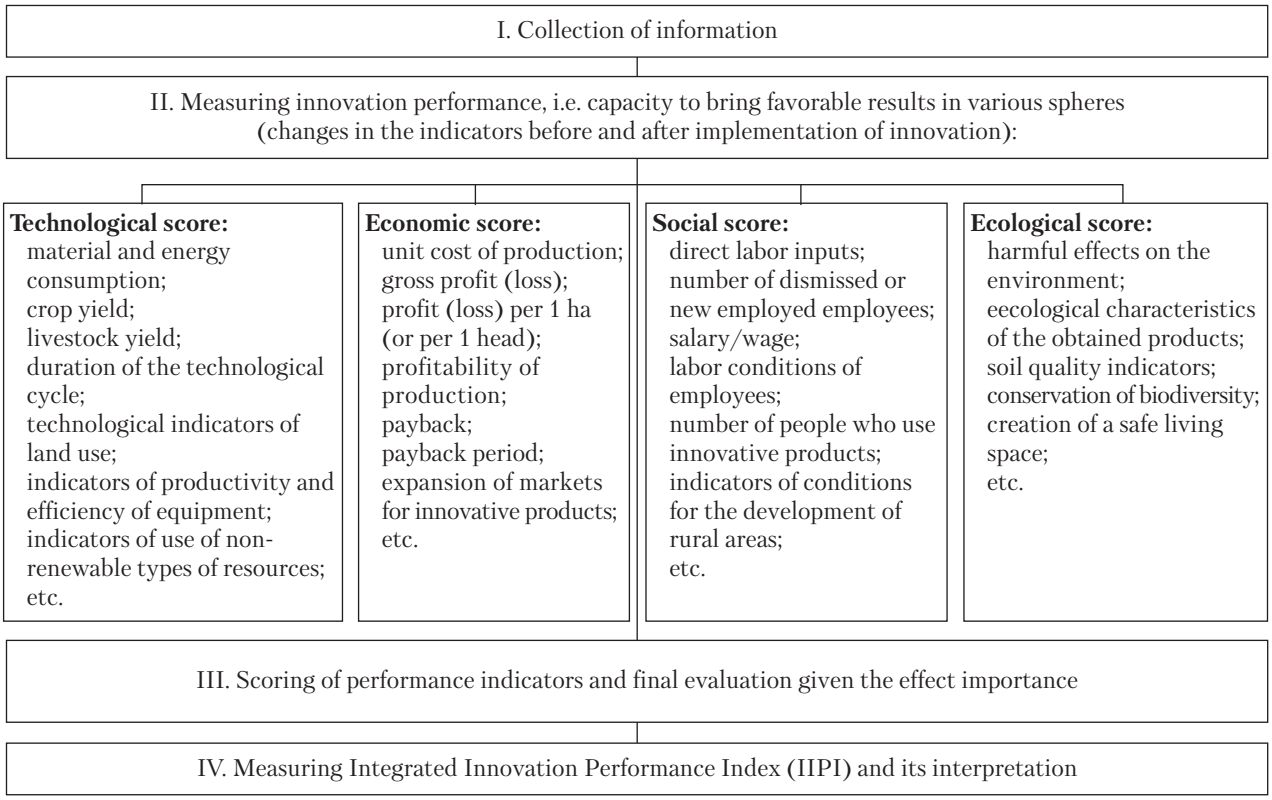

Fig. 2. Stages of evaluation of technological innovation performance in agriculture

4. Calculation of IIPT and conclusions on the feasibility of introduction of specific innovation in economic practice.

At the first stage, initial information is collected and comprehensively processed. The data sources for innovation efficiency analysis are as follows:

- specifications for equipment, technology, etc.;
- norms and standards of material, labor, and financial inputs, productivity rates;
- cost estimates, business plans;
- commercials, catalogs, price lists of innovation developers;
- collections of statistical data, reference books;
- information base of the Internet, publications on specific research or business experience, research reports;
- information on the actual and possible pollution of the environment, compliance with safety standards, the amount of damage caused, etc.

At the second stage, the indicators of technological, economic, social, and environment efficiency are calculated. The list of indicators that form the basis of a comprehensive assessment (Fig. 2) is indicative, it can be amended with other indicators, some of them may be replaced for indicators of interest for a particular manufacturer. In our opinion, a set of 20 indicators is optimal for calculations.

The first group of performance indicators consists of the data characterizing the technological and resource effect. This segment of the evaluation is the most unstable, as it depends on the peculiarities of the technology of production of certain types of crop or livestock products. For example, material consumption in dairy farming is assessed based on the cost of feed, electricity, heat, water, means of animal protection, etc.

The second group of indicators is formed by economic factors, because, from the economic point

of view, the introduction of innovations gives competitive advantages that enable growing sales, generating additional income, reducing costs per unit of output, i.e. increasing profit. In market conditions, the main driving force and economic result that characterizes success or failure of the innovation is net profit. So, it is necessary to focus efforts on possible ways to improve it.

The analysis of social efficiency is about changes of working conditions and living standards of people. In particular, it covers the assessment of the class of hygienic classification of labor conditions at a particular production, in accordance with the Government Sanitary Standards and Rules *Labor Hygienic Classification Based on the Harmfulness and Danger of the Labor Environment, Severity and Intensity of the Labor Process* No. 248 dated 08.04.2014. Also, it is necessary to assess the dynamics of indicators of rural development (condition of roads, communications, compliance with sanitary requirements, employment rate, technical condition of socio-cultural facilities, etc.).

To assess the environment efficiency, it is proposed to compare indicators of the harmful effects of production processes on the environment, soils, agricultural plants and animals, and quality of products (before and after the introduction of innovation), based on government standards of Ukraine.

At the third stage, each indicator is scored (Table).

Evaluation of Innovation Efficiency Indicators in Various Spheres of Agriculture

Indicator	Result of innovation introduction		
	Adverse effect (–1 point)	Barely visible or hardly detectable effect (0)	Favorable effect (+1 point)
1. Technological score			
1.1 — Yield, cwt per 1 ha (for crop farming)	Decline	Subtle (± 5%) or hardly assessable changes	Increase
Or 1.1 – Livestock (cattle and poultry) yield, cwt, thousand heads (for cattle breeding)	»	Subtle (± 5%) or hardly assessable changes	»
1.2 — fuel consumption per unit of product, cwt	Increase	Unchanged	Decrease
1.3 — Energy consumption per unit of product, kW·h per cwt	»	»	»
1.4 — Labor inputs per unit of product, man-h per cwt	»	»	»
1.5 — Duration of technological cycle, days	»	Subtle or hardly detectable	Reduction
2. Economic score			
2.1 — Unit cost of product, UAH	Increase	Subtle (± 5%) or hardly assessable changes	Decrease
2.2 — Materials consumption, UAH	»	Unchanged	»
2.3 — Capital intensity, UAH	»	»	»
2.4 — Gross profit (loss), UAH	Decrease in profit (increase in loss)	»	Increase in profit (decrease in loss)
2.5 — Profit (loss) per 1 ha (or head), UAH	»	Unchanged or subtle changes	»
2.6 — Profitability, %	Decrease	Subtle (± 3%) or hardly assessable changes	Increase
2.7 — Cost recovery	»	Unchanged or subtle changes	»
2.8 — Efficiency rate	»	Unchanged	»
2.9 — Payback period, years	Over 5 years	3—5 years	Less than 3 years
2.10 — Reduction in the cost of product per 1 UAH investment	≤5%	Subtle (± 5%) or hardly assessable changes in the cost	≥5%

End of table

Indicator	Result of innovation introduction		
	Adverse effect (–1 point)	Barely visible or hardly detectable effect (0)	Favorable effect (+1 point)
3. Social score			
3.1 — Dismissed or new employed employees/ workers, people	Reduction	Unchanged	New employed people
3.2 — Average wage, UAH	Decrease	»	Increase
3.3 — Employees/workers and consumers who use innovation product, people	»	Subtle (± 5%) or hardly assessable changes	»
3.4 — Class of labor hygienic classification, labor conditions	3 class, harmful; 4 class, dangerous labor conditions	2 class, admissible labor conditions	1 class, optimal labor conditions
3.5 — Dynamics of rural development	Decline	Unchanged or subtle changes	Growth
4. Ecological score			
4.1 — Harmful effects on the environment (air pollution, discharges to groundwater, rivers, etc.)	Aggravation	Subtle (± 5%) or hardly assessable changes	Reduction
4.2 — Effect on the health of plants and livestock	»	»	»
4.3 — Ecological characteristics of the product quality	Worsening	Unchanged or subtle changes	Improvement
4.4 — Soil quality (humus content, depth of arable layer, nutrient supply, acidity, degree of susceptibility to erosion, salinity, waterlogging, etc.)	»	»	»
4.5 — Biodiversity of the region (flora and fauna)	Decrease	Kept at the same level	Recovery of losses

At the fourth stage, the Integrated Innovation Performance Index (IIPI) is calculated. In the authors' opinion, not all the mentioned effects have the same weight when deciding to innovate. In particular, the key indicators for assessing innovation in agriculture are as follows:

- crop yield, cwt per 1 ha (for crop production);
- livestock yield, cwt, thousand heads (for cattle breeding);
- unit cost of production, UAH;
- profitability, %;
- ecological characteristics of the product quality;
- indicators of soil quality (humus content, depth of arable layer, nutrient supply, acidity, degree of susceptibility to erosion, salinity, waterlogging, etc.).

If one or several key indicators show a negative effect, each is assigned with -3 points instead of –1 point, and if there is a positive effect, the indicator is scored +2 points instead of +1 point.

The sum of scores is the integrated innovation performance index:

$$\text{IIPI} = \sum_{n}^{1} Б \times К_{В}, \quad (1)$$

where Б is score of each indicator, points; $К_{В}$ is weight of specific indicators (paragraphs 1.1, 2.1, 2.6, 4.3, 4.4 in Table 1): –3 for adverse effect, +2 for favorable effect.

Thus, having evaluated the individual components of the integrated index, one can find its value by summing the results.

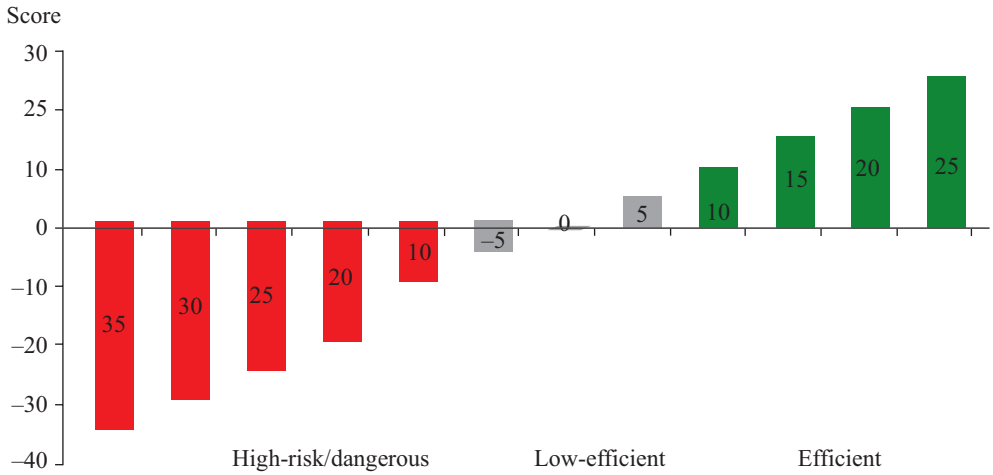

Fig. 3. Measuring innovation performance based on integrated index

The calculation method is developed in such a way that IIPI ranges from –35 to 30. The higher the indicator, the higher the investment attractiveness of innovation.

Based on IIPI, conclusions on the innovation efficiency and proposals are formulated (Fig. 3).

If IIPI is 10 or higher, the innovation is efficient and feasible for implementation. In the case of neutral result (inefficient innovation), the innovation may be implemented provided there are free funds or prospects for favorable effects in the future; it can be used in related industries or after improvements by the developer, and so on. Innovations that are dangerous from the standpoint of various types of effects shall be rejected as unfeasible.

Some types of effects shall be evaluated by, at least, three experts. In order to increase the objectivity of the assessment, the expert group shall include employees of stakeholders, representatives of innovation developer corporation, as well as independent experts (researchers, highly qualified employees of other agricultural enterprises). The experts for the risk assessment and for the entire evaluation procedure shall be selected in accordance with generally accepted rules and principles that are widely described in the literature.

Proceeding from the results of individual assessments of various indicators the average indicator is calculated. To assess the consistency of experts' opinions, it is mandatory to check their answers using the concordance factor, Pearson's test or Kendall's or Spearman's criteria [16].

The proposed method for evaluating the results of innovation implementation has been tested on the *Clearfield* innovation system. This system, developed by *BASF*, according to the manufacturer, enables producing almost clean crops, even in very weedy fields. The effect is achieved through the most effective combination of a certain herbicide and high-yielding hybrids resistant to it, obtained by conventional methods of selection (without the use of genetic engineering). The developers believe, the introduction of this innovation enables obtaining cost-effective and more environment friendly products by reducing the negative effects of herbicides. This has been confirmed by the results of our expert assessments based on which this innovation is concluded efficient for agricultural enterprises.

CONCLUSIONS

1. The research has shown that agricultural enterprises shall take into account the economic, technological, environmental, and social components of efficiency when making a decision whether to implement a certain technological innovation. Particular attention shall be paid to possible unfavorable consequences in the economic, environment, and social spheres.

2. To make the optimal decision, when selecting an innovation, it is proposed to use an Integrated Innovation Performance Index (IIPI) that allows making conclusions and proposals on the feasibility of introducing a particular innovation in economic practice. The authors' method for evaluating the results of technological innovations in agriculture includes the following stages: information selection, calculation of indicators, scoring of indicators, calculation of Integrated Innovation Performance Index (IIPI) and conclusions on the feasibility of this innovation.

The developed approach to the evaluation of innovation can be used as an element of the methodology for assessing the investment attractiveness of individual innovation projects in agricultural sector.

We recognize that the proposed approach to assessing the innovation efficiency is still only a conceptual approach and that the quantitative criteria can be clarified after repeated testing of the methodology. The problem is complicated by the fact that some adverse effects of innovations cannot be pre-identified and minimized.

The proposed methodology is planned to be improved. In particular, further research will focus on developing an assessment scale that takes into account the different degrees of risk of not achieving the planned results of innovation because of influence of various factors. In the future, the analysis process can be supplemented with modules of problem-oriented software packages, which are usually based on the developed mathematical apparatus.

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ОСОБЛИВОСТІ АНАЛІЗУ ЕФЕКТИВНОСТІ ВПРОВАДЖЕННЯ ТЕХНОЛОГІЧНИХ ІННОВАЦІЙ В СІЛЬСЬКОМУ ГОСПОДАРСТВІ

Вступ. Інноваційна діяльність в аграрній сфері має галузеві особливості, оскільки можливими є негативні наслідки впровадження окремих інновацій, які повинні оцінюватися за ступенем небезпеки в економічній, соціальній та екологічній сферах.

Проблематика. Передбачити та розрахувати ймовірні наслідки впровадження інновацій у сільському господарстві складно через відсутність стандарту (протоколу) оцінки інноваційних ризиків. Отже, вдосконалення методичних підходів оцінки ефективності впровадження інновацій у галузях аграрного виробництва залишається актуальним. Крім того, потребують подальшого удосконалення методи аналізу ефективності впровадження інновацій, які узагальнюють позитивні та негативні наслідки у різних аспектах сільськогосподарської діяльності.

Мета. Розробка концепції комплексної оцінки ефективності впровадження технологічних інновацій в аграрному секторі.

Матеріали й методи. Абстрактно-логічний, порівняльного аналізу, монографічний, експертних оцінок. Для аналізу ефективності інновацій запропоновано систему індикаторів, які формувалися з урахуванням прийомів декомпозиції, аналізу та синтезу. Під час відбору показників до системи індикаторів було застосовано контент-аналіз наукової літератури.

Результати. Запропоновано концепцію комплексної оцінки доцільності впровадження окремих технологічних інновацій за інтегральним показником ефективності інновацій, яка враховує можливий вплив інновацій на технологічні, економічні, соціальні та екологічні характеристики різних галузей сільського господарства. Застосування розробленої методики забезпечує можливість прийняття рішення щодо доцільності запровадження певної інновації.

Висновки. Розроблений підхід забезпечує комплексність оцінки, простоту розрахунків, економію часу, мінімізацію суб'єктивності оцінок експертів порівняно з аналогічними методиками аналізу ефективності інновацій.

Ключові слова: інновації, ефективність впровадження, сільське господарство.