RESOURCE POTENTIAL OF AGRICULTURE IN UKRAINE: ENERGY CONSERVATION AND FOOD SUPPLY

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Abstract: The article presents a scientific approach to the assessment of the effective development of the resource potential of agriculture, which is based on the methodological basis of two mutually complementary models – energy saving of resources in the industry and functional indicators of food supply. The methodological basis of energy saving of resources in the industry is presented, which integrates with a large number of models and is combined into two processes – limiting energy consumption and increasing the energy efficiency of resources. A new model for calculating the index of ensuring the ecological and energy value of food products is proposed. The level of energy security in the intensive activity of subjects of agricultural production, their energy efficiency, industry costs for fuel energy consumption during production of products was determined. The volumes of own production of agricultural products and import of food products in Ukraine from European partners are given. The reference module for the development of the resource potential of agriculture in the regions according to the net profit is determined, as the interdependence of financial profiles in the length of the vector of the integral index.

Keywords: food products, labour resources, energy resources, financial resources, international partnership

1 INTRODUCTION

Agriculture of Ukraine is one of the most important generating resource sectors of the economy, as it is related to the reproduction of the country's resource poten-

tial, which includes the availability and consumption of safe, nutritious and balanced food products for all citizens, is the basis of the socio-economic stability of society and health of nation. The resource potential of agriculture in Ukraine is increasingly becoming a platform for efficient production adapted to changes in the European environment, increasing productivity and product quality, as well as developing innovative approaches to reproducing the food complex on the basis of integration into the global economic space.

This is happening on the platform of socio-economic reforms in this direction to achieve promising economic parameters in the mechanism of forming the energy independence of the agricultural sector as a lever for increasing the food supply of rural areas. At the same time, the need for economic positioning of energy alternatives of the resource potential of Ukraine's agriculture and its possibilities for effective production and rational consumption of new types of energy created from agricultural raw materials allows for the formation of a self-sufficient system of energy production and energy consumption of agricultural production subjects in the absence of state guarantees for cost reduction energy resources that have a direct impact on food security in the country (Podsokha et al., 2023).

Note that the development of agriculture in Ukraine depends on energy conservation, despite the fact that the energy component of the resource potential of agricultural regions is formed by factors of functionality and efficiency of management. The branches of agriculture for the national economy guarantee stable conditions for the food supply of the population and socio-economic standards of living, and are the employed capital in which the most effective redistribution of values for society takes place. Along with this, in the existing business environment, there is a lack of cost-acceptable energy resources that would stimulate investments in the production and technological component of the resource potential of agriculture with greater added value and a reduction in the labour intensity of production (Dibrova et al., 2023).

However, the energy instability in the conditions of martial law in Ukraine disorients the producers of agricultural products, and even more so, in the peak periods of seasonal production, requires the search for alternative directions of their recovery in order to regulate the food supply in the country, on the basis of the “green” economy and to minimize the impact of the cost of energy resources for the production and technological process (Geletukha, 2020). Agrarians of Ukraine during the period of unsettled military conflict in the country insist that the state agrarian policy be transformed into the implementation of nationally adaptive mechanisms for the formation of energy independence and guarantees of food security in agriculture in order to stabilize the economic process, through the implementation of models for reducing energy costs and timely energy supply (Vatsa and Miljkovic, 2022).

Outlining the complexity of the development of the resource potential of agriculture in the conditions of the conflict period, which affects the food and energy component of the production and technological process of the subjects, it should be noted that these processes form a whole complex of organizational interactions that take place at different levels of management and are characterized by diversity (Urba and Kopytko, 2022).

In view of this, the organization of energy conservation in agriculture in order to minimize resource costs and reduce the price of food products in peak periods of food shortages requires the development of a new conceptual approach aimed at a clear sequence of stages of effective management of the energy efficiency of farmers, united within a single mechanism for the development of resource potential. In the conditions of European integration transformations in Ukraine, which are taking place under the pressure and reluctance of the aggressor country to accept inevitable defeat and reluctance to end the military conflict peacefully, the government requires decisive actions to change the course of the agricultural sector towards energy independence and the introduction of alternative types of energy.

Displacing the allegorical influence of the terrorist country from the agriculture of Ukraine is inevitable, since a clear awareness of the consequences of the military aggression of a neighboring country affected the consciousness of the rural population and their reluctance to cooperate in a single energy-saving resource supply system to improve the capacity of agriculture between countries, which in the pre-war period had a sufficient arsenal of food supply tools and took place on the basis of the rational use of natural, labour, material and technical, energy, investment and financial resources in each region, provided a sufficient amount of food products through export potential (Serhiienko et al., 2023).

Taking into account the general need to improve the production of agricultural products, the growth of the influence of the resource potential of agriculture is obvious, since changes in the food supply of Ukraine are currently taking place during the transformation of zonal, regional and economic specialization of production and concentration of resources. They are important factors in increasing the effective activity of new business entities adapted to the regional bioclimatic, demographic, socio-economic conditions and market environment (Trusova et al., 2022).

Therefore, the priority of our research is the development of a scientific approach to the assessment of the effective development of the resource potential of agriculture, which is based on the methodological basis of two mutually complementary models – energy conservation of resources in the industry and functional indicators of food supply, which allows restoring the market infrastructure in the direction of energy-efficient processes production, promote the development of a new energy supply system, balance the financial support of regions from international partners and guarantee food security for the country's population.

2 LITERATURE REVIEW

The resource potential of agriculture represents a complex and integrated system that equips production entities with a balanced combination of technological and economic resources. These resources are pivotal for ensuring energy-efficient, environmentally sustainable, and economically viable agricultural production, including the processing, storage, and sale of agricultural products.

M. Swaminathan (1991) underscored the importance of cost-effective technological solutions for enhancing productivity, emphasizing that sustainable intensification can reduce input costs while increasing yields. Similarly, D. Pimentel et al. (1997) highlighted the economic benefits of transitioning to renewable energy sources and energy-efficient technologies in agriculture, which can significantly lower energy expenses and production costs.

Energy prices significantly influence agricultural economics, particularly in commodity-dependent systems. M. Manera, M. Nicolini, and I. Vignati (2013) highlighted the role of financial speculation in energy and agricultural futures markets, indicating that price volatility can destabilize food supply chains. Mitigating such risks through diversified energy sources and market stabilization policies could enhance economic resilience in agriculture.

D. Tilman et al. (2002) provided an analysis of agricultural sustainability, emphasizing the need for innovative farming practices to meet global food demand while mitigating environmental degradation. J. Bruinsma (2003) predicted that future agricultural challenges would demand higher resource efficiency driven by technological advancements. Nowadays, P. Czyzak and T. Mindekova (2024) explore the innovative concept of agrivoltaics (agri-PV) in Central European agriculture. Agri-PV involves the dual use of land for crop production and solar energy generation, offering farmers an innovative solution to enhance their income while contributing to energy sustainability. This dual-purpose not only lowers energy costs but also generates additional revenue, increasing the economic stability of agricultural enterprises.

A. Mergoni, A. R. Dipierro and C. Colamartino (2024) examines the complex interplay between efficiency, sustainability, and environmental risks within the European agricultural sector. The authors explore how intensification efforts aimed at maximizing productivity often conflict with long-term sustainability goals and escalate environmental risks such as biodiversity loss, soil erosion, and water contamination. The study emphasizes the need for balanced approaches that integrate technological advancements, sustainable farming practices, and risk management strategies to achieve holistic progress.

The sustainability in agriculture also hinges on market access and competitiveness. F. Blanco and L. Qorlazja (2024) stressed the importance of financial accessibility for smallholder farmers and the modernization of agricultural practices to enhance market integration. Additionally, the study highlights the challenges posed by outdated systems and limited access to international markets. By addressing challenges, such as limited market integration and outdated technologies, it can be implement tailored financial policies and investment strategies to enhance agricultural productivity and global competitiveness.

Policies and incentives play a crucial role in fostering the economic sustainability of agriculture. B. Bourget (2024) criticized uneven policy implementation in the EU, suggesting that tailored approaches are necessary to address the unique economic challenges of different regions. The development of targeted subsidy pro-

grams, tax benefits for adopting sustainable practices, and investment in rural development can stimulate economic growth in agriculture.

So, the main condition for the development of a highly efficient resource potential of agriculture is the compliance of the interregional structure of production with requirements and its adaptability to the natural and economic features of the production and technological process, which is constantly changing under the influence of changes in the amount of energy resources. At the same time, even the most radical changes in the economic plan do not reduce the role of agricultural entities in the food supply of the country with the rational use of the totality of resources and the expanded reproduction of the economic, social and ecological components of the agrarian system, both in the present and in the future.

3 MATERIALS AND METHODS

Within the agrarian system of production, technological generation is used within the limits of the needs for artificial energy and natural resources of agrarian origin with a defined composition and methods of their use in the field of agriculture. For each stage of the development of technological generations in the agricultural production system, separate elements of the resource potential are inherent, which ensure the level of energy conservation in the activities of agricultural entities: optimization of technologies, reduction of energy losses and overspending, reduction of the cost of energy consumption and a comprehensive solution to the issue of energy conservation.

Measures that allow solving these tasks include: precision farming; use of no-till technologies; use of wide-grip and combined machine-tractor units; use of energy-saving technical means; optimization of production logistics; monitoring and control of energy consumption; as well as activities aimed at reducing dependence on fuel price fluctuations. This makes it possible to reduce fuel consumption by 20-70% in the general system of energy consumption of agricultural production entities, as well as rationally use resource potential to increase the level of labour productivity, reduce the cost of production, which is consistent with the concept of energy saving in food supply business models (Vatsa and Miljkovic, 2022).

The development of the resource potential of agriculture is a rather complex process, which is related to the technological features of a specific industry, and, in addition, it covers a whole complex of components of food supply and criteria for energy conservation of resources in a pure and embodied form (Figure 1).

Within the framework of the economic mechanism of effective development of the resource potential of agriculture (Figure 2), subjects of agricultural production take measures to implement its elemental and structural components, which include reimbursement of the cost of resources when they are purchased or when ownership is obtained; payment of fines as a result of violation of the requirements and norms of exploitation of agricultural lands. These elements actively interact with elements of the market situation – pricing.

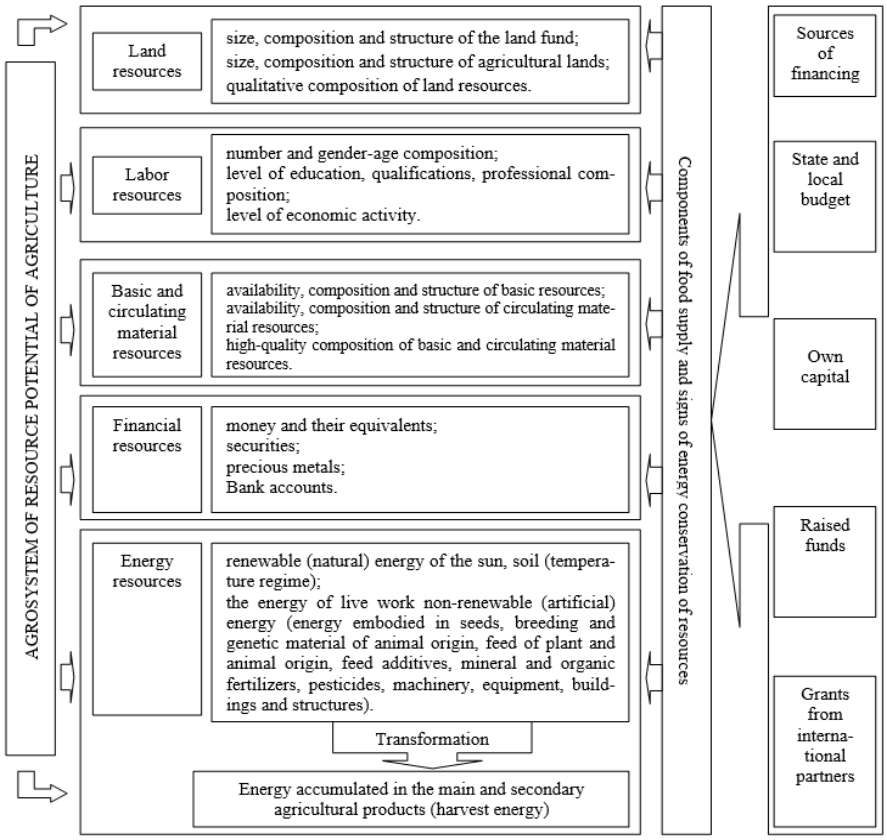

Figure 1 Agrosystem of the resource potential of agriculture and its sources of financing. Source: built by the authors based on data of Ilyashenko and Kalinichenko (2020); Polishchuk (2017); Zalisco (2018)

Their implementation makes it possible to improve the production and technological cycle with a given structure of land plots for agricultural crops and to introduce directions for energy saving taking into account environmental factors, provided the transition from an extensive method of production to a qualitatively new level of land use.

The accumulation of quality production criteria is combined with the structural component of the resource potential of agriculture, aimed at protecting land resources, increasing soil fertility, increasing the level of intensive energy-saving technologies in the cultivation of agricultural crops, increasing the efficiency of agricultural production. The energy-saving no-till technology is aimed at greening production, is especially relevant for the development of functional economic incentives for food supply in rural areas with the modern development of the resource potential of agriculture. This no-till technology allows you to minimize costs when the market

value of energy carriers, seeds, mineral fertilizers, fuel and lubricants increases; ensure a high level of yield of agricultural crops; reduce the negative impact of disincentives on the efficiency of using the resource potential of agriculture (Voronovsky, 2020; Vyshnevetska, 2020).

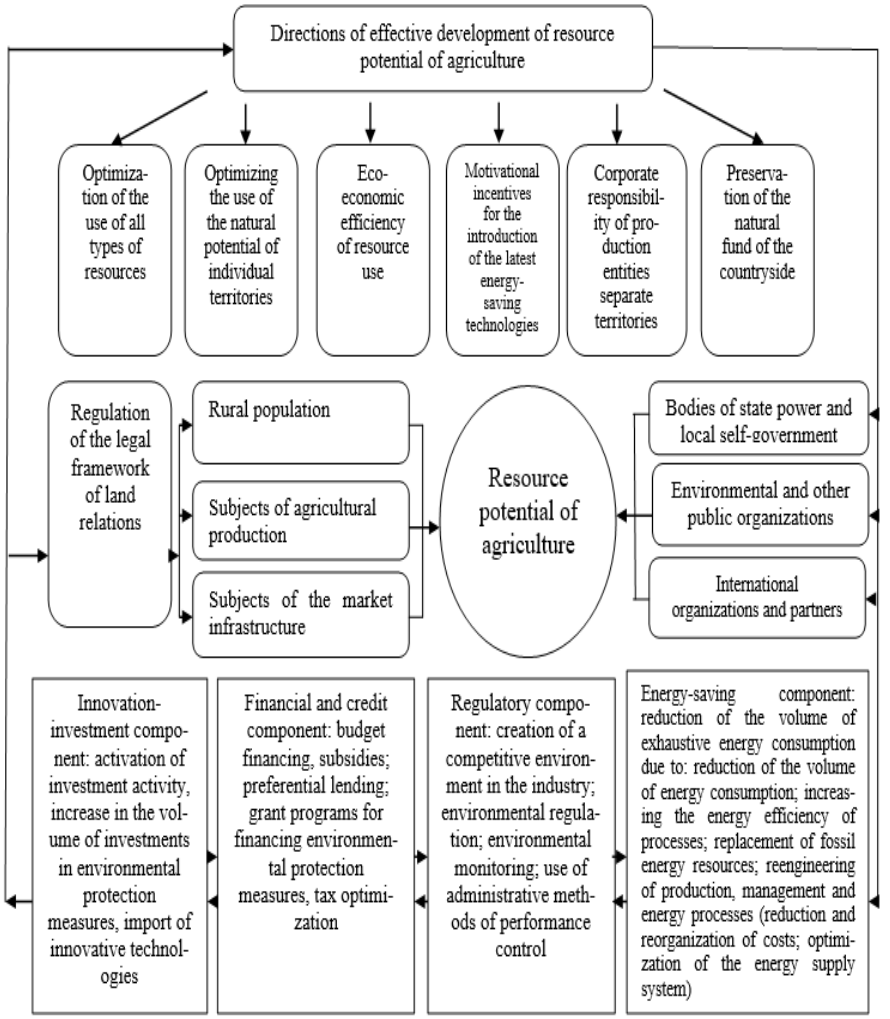

Figure 2 Economic mechanism of development of resource potential of agriculture.
Source: built by the authors

No-till technology is used in the cultivation of legumes and oilseed crops with the increase of their export potential with the limitation of zero tillage, grinding of nutrient waste (residues) and their uniform distribution over the field (Gavrylko, 2020). As a result, a soil protective coating is formed, which resists erosion, ensures moisture conservation, prevents clogging with vegetation, activates soil microflora, contributes to the restoration of the fertile soil layer and increases the yield of agricultural crops.

In order to assess the increase in the efficiency of the use of land resources, as the main component of the resource potential of agriculture, taking into account the main aspects of safe use of soils, we built two economic and mathematical models for maximizing the profit of agricultural production entities: one – with the existing technology and crop rotation system, the other – with taking into account the maximum permissible saturation limits of crop rotations with separate crops and pure pairs when using no-till technology.

The formulated objective functions have the form (Dorosh, 2007; Gradovy, 2020):

$$f(x)^T = \sum_{i=1}^{n} c_i x_i \rightarrow max \quad , \tag{1}$$

$$f(x)^V = \sum_{i=1}^{n\Sigma} v_i x_i \rightarrow min \quad , \tag{2}$$

where $f(x)^T$ – target function of sales revenue; $f(x)^V$ – target function of costs for commodity products; i – the number of the corresponding variable; j – restriction block number; c_i – the price per unit of the i-th product; v_i – cost price of the i-th product unit; x_i – volume of production of i-th products.

Conditionally variable elements of the economic-mathematical model of the use of no-till technology in the industry are the following (Dorosh, 2007; Gradovy, 2020):

$$x_i \geq 0 \quad , \tag{3}$$

area of agricultural land:

$$\sum_{i=1}^{n} s_{ij} x_i \leq S \quad , \tag{4}$$

where S_{ij} – coefficient of the area of the i-th variable at the j-th restriction; S – arable land area;

use of labour resources:

$$\sum_{i=1}^{n} t_i x_i \leq T \quad , \tag{5}$$

where, t_i – labour costs for the i-th product; T – total possible labour costs;

production of products:

$$\sum_{i=1}^{n} a_i x_i = Q_i \quad , \tag{6}$$

where a_i – is the yield level of the i-th crop; Q_i – volume of production of the i-th product;

product implementation:

$$\sum_{i=1}^{n} b_i x_i = R_i \quad , \tag{7}$$

where b_i − the yield of the i-th crop is multiplied by the planned marketability coefficient of the corresponding type of product; R_i − volume of sales of the i-th product.

To solve the economic-mathematical problem, it is necessary to find the most acceptable structure of cultivated areas in principle, which would be able to ensure the most complete use of the most important basic and circulating material resources while complying with the ecological requirements of agriculture.

The structural objects of the resource potential of agriculture take into account the no-till technology, which is part of the energy saving system of the industry and is a multifunctional organizational-technological and ecological-economic process of an open type with a production-innovation and investment-financial cycle of the movement of resources in the food supply of the country under the condition close interaction between the subjects of the agricultural system (in terms of internal and external resource elements that characterize the stimulating and destimulating factors of the resource potential of agriculture) (Trusova et al., 2022).

The methodological basis of energy saving of resources in the industry is integrated with a large number of models that combine two processes – limiting energy consumption and energy efficiency of resources (Korol, 2011; Makarenka et al., 2019):

$$LEC + EE \Rightarrow ES \quad , \tag{8}$$

where LEC – is the energy consumption limitation factor; EE – energy efficiency factor; ES – is the final energy saving factor.

Any surplus in energy consumption leads to an increase in the cost of agricultural products and a decrease in the profit of the subjects of the agricultural system. At the same time, too much energy restriction is also economically unprofitable, as it leads to a deterioration in the quality of agricultural products or a decrease in the volume of its production" (Ivanenko and Ivanenko, 2021).

It is worth noting that the factors of energy saving () and energy efficiency () have different nature and, accordingly, methodological basis. Processes of the saving energy stem from the global trend of exhaustion of fuel energy resources and the desire to reduce their consumption. Processes of the energy efficiency involve an increase in production volumes per unit of energy consumption.

To determine the amount of energy contained in the produced agricultural products in relation to the amount of non-renewable energy spent on its production, the coefficient of energy efficiency is used. The value of this indicator characterizes the energy efficiency of production. If it is less than 1, then the production is inefficient from an energy point of view, in the interval 1-1.5 there is a low level of efficiency, in the interval 1.5-2.5 – average, more than 2.5 – a high level of energy efficiency (Moroz and Shtanko, 2021).

The energy efficiency indicator can be expressed using three different models, which characterize (Perevozova et al., 2022):

– intensive energy consumption:

$$K_{ee} = \frac{P_d \times n, n \geq 1}{E_c \times k, k \geq 1} \quad , \tag{9}$$

– efficient energy consumption:

$$K_{ee}=\frac{P_d \times n, n \geq 1, n \geq k}{E_c \times k} \quad , \tag{10}$$

– energy saving model:

$$K_{ee}=\frac{P_d \times n, n \geq 1}{E_c \times k, k \leq 1} \quad , \tag{11}$$

where n – is the conditional coefficient of increase in energy output obtained as a result of the production of agricultural products; k – the conditional coefficient of the volume of energy used for the production of agricultural products.

The presented options for changing energy consumption are characterized by a fundamental difference. Thus, the intensive option of energy consumption involves an increase in the volume of energy output due to an increase in energy consumption. Effective energy consumption involves the predominance of the increase in energy output over the increase in energy consumption. At the same time, the increase in output energy must necessarily be positive and higher than the increase in energy consumption, and the increase in energy consumption is not necessarily positive. The basis of the energy-saving model is the reduction of energy consumption with zero or positive increase in energy output as a result of agricultural production.

The energy capacity of the industry is formed by power machines (energy resources), which are calculated in kilowatts (kW) or joules (J). The total energy capacity is determined by formula (12) (Perevozova et al., 2022):

$$EC_c = E_d + E_{ed} + E_{dt} + E_{md} \quad , \tag{12}$$

where EC_c – total energy capacity of the industry, kW(J); E_d – power of internal combustion engines, kW(J); E_{ed} – power of electric motors, kW(J); E_{dt} – capacity of machines and equipment for mechanization and automation of technological processes, kW(J); E_{md} – power of mechanical engines, kW(J).

The presented methodical algorithm for energy conservation of agricultural resources is the main lever of energy management, which has a target vector of greening and security of the country's food supply level through an integral indicator based on the determination of the sum of variable coefficients of food independence (Khayetska, 2022).

It is proposed to link the index of food supply with the index of energy saving of resources in the field of agriculture and to modify them into a model for calculating the index of ensuring the ecological and energy value of food products (formula 13):

$$I_{ecfp}=\frac{(I_{EAi}+V_{ea_i})+(I_{AGRi}+V_{agr_i})+(I_{QSERi}+V_{qser_i})+(I_{VAP_i}^{sfs}+V_{VAP_i}^{sfs})}{100} \pm \Delta P \pm \Delta RE \pm \Delta RC \quad , \tag{13}$$

where I_{ecfp} – the index of ensuring the ecological and energy value of food products; I_{EA_i} – an indicator of the economic feasibility of energy saving resources in the field of agriculture; V_{ea_i} – the weight of the indicator of the economic feasibility of energy saving resources in the field of agriculture; I_{AGR_i} – in-

dicator of availability of greening of resources in the agrosystem of agricultural production entities; V_{agr_i} – the weight of the indicator of the availability of environmentalization of resources in the agrosystem of agricultural production entities; I_{QSER_i} – an indicator of the quality and safety of energy resources in the agrosystem of agricultural production entities; V_{qser_i} – the weight of the indicator of the quality and safety of energy resources in the agrosystem of agricultural production entities; $I_{VAP_i}^{sfs}$ – indicator of the value of products in the system of food supply standards; $V_{VAP_i}^{sfs}$ – the weight of the product value indicator in the food supply standards system; $\pm \Delta P$ – growth (inhibition) of changes in labour productivity; $\pm \Delta RE$ – growth (inhibition) of change in resource return; $\pm \Delta RC$ – growth (inhibition) of changes in the profitability of capital.

With the help of the index method, the impact of changes in these factors is evaluated, which in the process of comparing the researched trends allow to identify favorable and unfavorable trends in the effective development of the resource potential of the country's agriculture. That is, the value of the indicator (factor), which is a stimulator, is defined as the ratio of its actual value to the optimal value. At the same time, if the actual value of the indicator is higher or equal to the optimal value, it is equal to 1. Accordingly, the indicators (disincentive factors) are defined as the ratio of the optimal value to the actual value, and if the value is lower than or equal to the optimal value, it acquires the value "1" (Kozlovskyi et al., 2019; Levkina et al., 2019).

Determination of the optimal (limit) value of the indicators is carried out depending on their properties on the basis of the normative method. In some cases, an expert assessment is carried out. For relative indicators, which characterize the dynamic trend of the increase of the indicator from the base period, the optimal value is equal to 100% (Trusova et al., 2022). The optimal (marginal) values of indicators for evaluating the integral index of the effective development of the use of the resource potential of agriculture, taking into account the level of energy saving of resources in the industry and the index of ensuring the ecological and energy value of food products are shown in the Table 1.

The proposed scientific approach to assessing the effectiveness of the use of the resource potential of agriculture is based on the methodology of the system-structural approach in the process of interaction of its natural, production, financial, energy elements and other sources of its financing and creates a new form of agrosystem of agricultural production entities for meeting the needs of consumers with food products, stopping the degradation of agricultural land, stimulating the productive activity of labour resources, increasing the level of resource return and capital profitability.

Table 1 Optimal (limit) values of the indicators of the integral index of the effective development of the resource potential of agriculture in the country

Indicator	Optimal values	Criterion of optimality
Coefficient of ensuring ecological stability	1	Stimulator
Index of changes in the level of ecological stability of the functioning of agricultural lands in the agrosystem of economic entities, %	100	Stimulator
Index of changes in humus content in agricultural land, %	*	Stimulator
Ecological and agrochemical assessment of agricultural land, point	100	Stimulator
The level of erosion of agricultural land, %	8	Destimulator
Intensity of erosion of land plots for agricultural crops for industrial purposes, %	100	Destimulator
Index of productive activity of labour resources	10	Stimulator
The level of economic activity of labour resources, %	100	Stimulator
Increase in yield of grain, leguminous and fodder crops, %	100	Stimulator
Gross volume of agricultural products in actual prices per 1 ha of agricultural land, USD/ha	*	Stimulator
Index of changes in the volume of agricultural products, %	100	Stimulator
Coefficient of land yield	*	Stimulator
Energy saving index of resources in the industry, %	*	Stimulator
Return on capital index, %	*	Stimulator
Index of ensuring the ecological and energy value of food products, %	*	Stimulator

Source: developed by the authors

Note. * – is the highest value among the studied objects

4 RESULTS

The occupation of the regions of Ukraine by the aggressor country has caused a reverse process of the functioning of the resource potential of agriculture, which faces real ecological and economic factors that affect the level of its effective use. More than 38% of agro-food production was concentrated in regions where hostilities have taken place or are ongoing. Each of the affected regions was a leader in the production of certain food products. For these reasons, 25% of economic entities engaged in agricultural activities in Ukraine have stopped or reduced production volumes (FAO, 2022).

Despite certain socio-economic difficulties, agriculture in Ukraine occupies an important place in the country's economy. In 2023, 4.9% of the value of fixed assets and 11.7% of capital investments of the country's economy were accumulated in the agricultural sector. The specific weight of agriculture reaches 9.3% of gross product and 10.8% of gross added value. In the structure of exports, the share of agricultural products is 9.3%, the preponderance of exports over imports is 1.7 times. Note that

wages in agriculture are 15.8% lower than the average for the national economy, and final energy consumption is only 3.5% (Figure 3).

Based on the volume of gross production, the main parameters of energy consumption and energy efficiency of agricultural entities of Ukraine demonstrate the downward dynamics of the linear indices, which are shown in Figure 4.

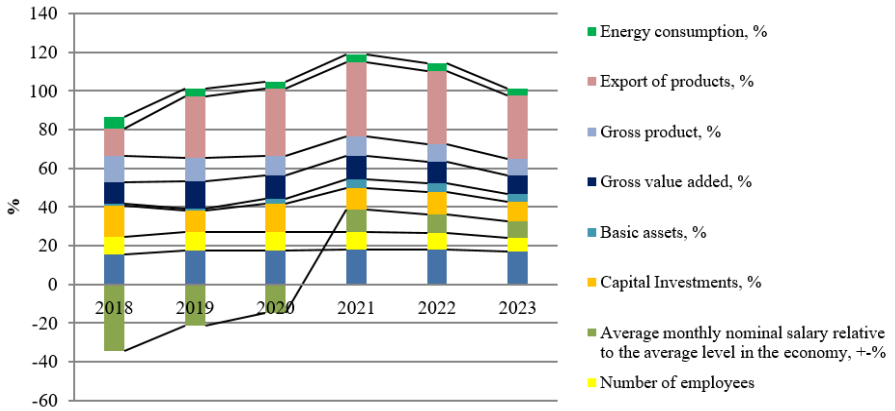

Figure 3 Indicators of the development of agriculture in the economy of Ukraine for 2018-2023. Source: built by the authors from the data of State Statistics Service of Ukraine (2024)

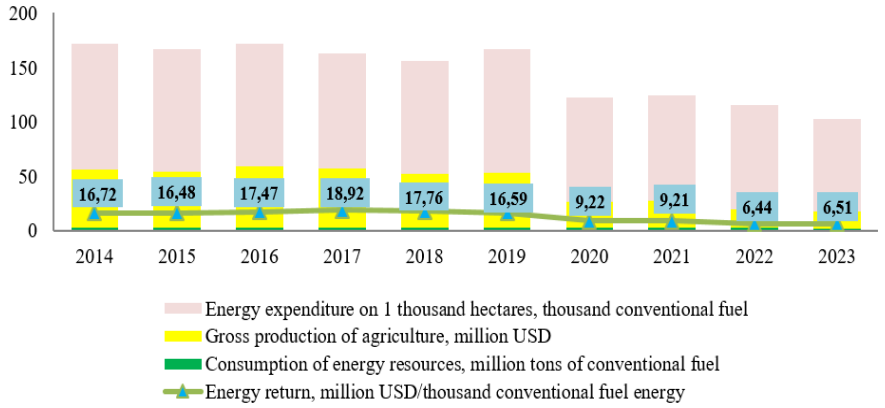

Figure 4 Energy efficiency of agricultural production entities of Ukraine for 2014-2023. Source: built by the authors from the data of State Statistics Service of Ukraine (2024)

During 2018-2023, agricultural commodity producers provided at a sufficient level the internal needs of the population of Ukraine in terms of food supply with the main types of crop and livestock products (Figure 5).

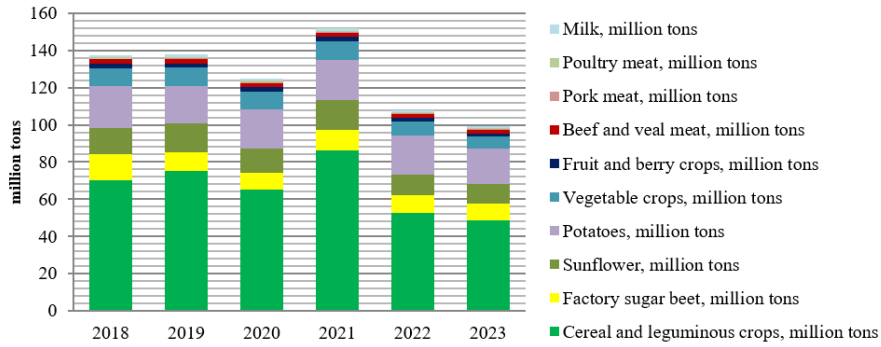

Figure 5 Volume of gross production of agricultural crops in Ukraine for 2018-2023. Source: built by the authors from the data of State Statistics Service of Ukraine (2024)

The largest energy costs in the form of consumption of petroleum products were recorded in the production of cattle meat (0.290 thousand conventional fuel/ton) and pig meat (0.133 thousand conventional fuel/ton). In crop production, the most energy-consuming is the production of soybeans (0.043 thousand conventional fuel/ton) and rapeseed (0.038 thousand conventional fuel/ton). The remaining types of crop production (wheat, corn for grain, sugar beet) are characterized by an almost equal value of energy consumption (0.012-0.014 thousand conventional fuel/ton), (Figure 6).

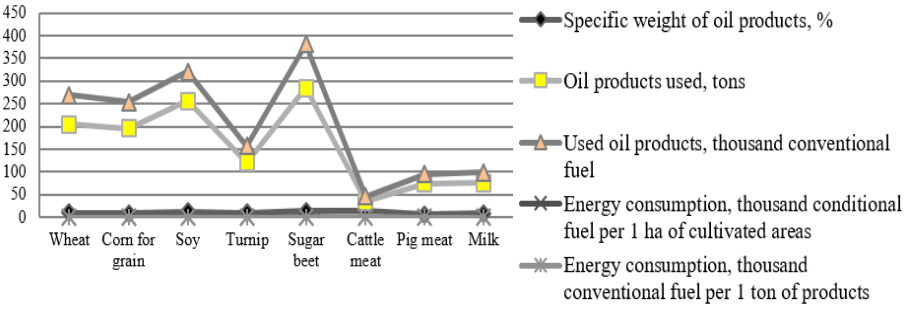

Figure 6 Average energy consumption of petroleum products during the production of products by subjects of agricultural production of Ukraine on average for 2018-2023. Source: built by the authors from the data of State Statistics Service of Ukraine (2024)

For the studied period of 2018-2023, a characteristic feature is that, with the exception of sugar beet, all other types of products either maintained the level of energy consumption (wheat) or significantly decreased it. The largest decrease in this indicator was observed in the production of corn for grain (-33.3%).

The key negative trends in the energy efficiency of agricultural entities of Ukraine for 2014-2023 are a reduction in the level of energy yield – by 2.6 times; from the level of 2021, the decrease of this indicator during the period of martial law in the country gained rapid momentum – 1.4 times. This is accompanied by a sharp decrease in the gross output of agriculture – by 3.4 times; compared to 2021, the value of this indicator was additionally reduced by 1.6 times.

In general, the situation reflects the negative aspects of energy conservation, according to which the size of the resource potential of agriculture is accompanied by a reduction in energy consumption, which is caused by a reduction in the area of agricultural lands due to their partial occupation by the aggressor country, which in aggregate weakens the economic effects of energy consumption processes occurring in the industry.

In contrast to the resource-based method of energy efficiency research, cost-based methods allow you to calculate the actually achieved level of energy consumption in relation to the financial indicators of the activities of agricultural entities (Figure 7).

Despite the crisis in Ukraine's agriculture, with the help of European partners, the food supply in the country demonstrates high resilience and adaptability to the manifestations of risks caused by military aggression. A significant factor affecting food security is the import of food products (Figure 8).

Thus, during 2021-2022, there is a significant reduction of all main groups of food products imported into Ukraine. In 2022, only 12.2 billion USD of agro-food products were imported into Ukraine, which is 21.3% less than the level of 2021 (in 2021, the volume of imports was 15.5 billion USD).

Since the beginning of the war, domestic prices for the main grain products within the country have significantly decreased (about 30% loss of the domestic price) against the background of rising costs, due to the increase in the cost of input material resources and the creation of “price scissors”, which led to a decrease in the level of profit. A significant decrease in the price of goods, along with relative stability or growth in the prices of material resources, accelerated the reduction of margins and the laundering of funds from the assets of agricultural entities (Krylov, 2023).

In 2022, rural households almost completely satisfied the country's food supply needs in eggs, vegetables and potatoes, and a third – in meat products, milk and fruits (Figure 9).

After the second year of the war in Ukraine, a significant number of private peasant farms were forced to reduce or stop agricultural activities, especially in the occupied territories. Territorial communities in Ukraine are forced to independently provide the owners of rural households and internally displaced persons with food

products on the basis of the program “Gardens of Victory” (NISS, 2022; Resnikova, 2022).

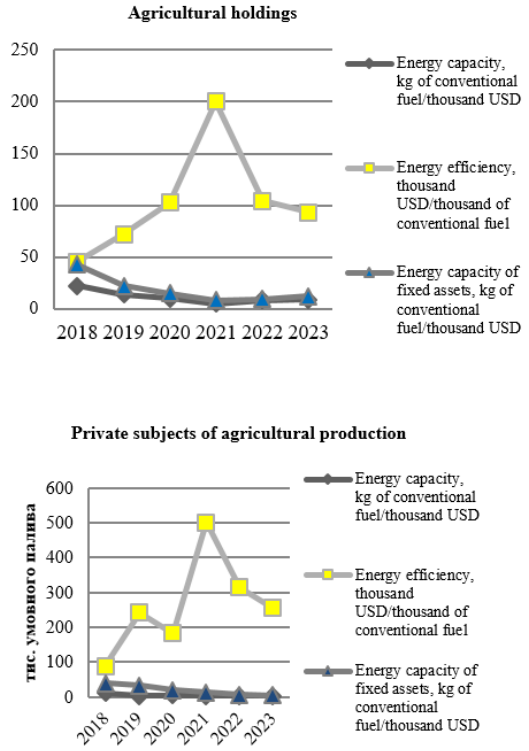

Figure 7 The level of energy consumption of resources by subjects of agricultural production of Ukraine for 2018-2023. Source: built by the authors from the data of State Statistics Service of Ukraine (2024)

In 2023, USD 47.72 million of expenditures of the special fund of Ukraine to support the development of agricultural entities were financed under the program “Granting loans to farms” – 20.25 million USD (Ministry of Agrarian Policy and Food of Ukraine, 2024a). Given the limited financial resources in the state and local budgets of the country, grant support from international financial donors is an important source of funding for the functioning of agricultural entities. Thus, for 2022-2023, the Ministry of Agrarian Policy of Ukraine together with international institutions provided the following types of financial support: non-refundable aid for 1 hectare and for one head of cattle – 61 thousand applications for 66.96 million USD; soft loans under the 5-7-9% program were issued (57.02 thousand applications from farmers for a total amount of 7.92 billion USD were satisfied); 180 applications for the development of horticulture in the amount of 96.73 million USD (AgroPolit, 2023; Ministry of Agrarian Policy and Food of Ukraine, 2024b).

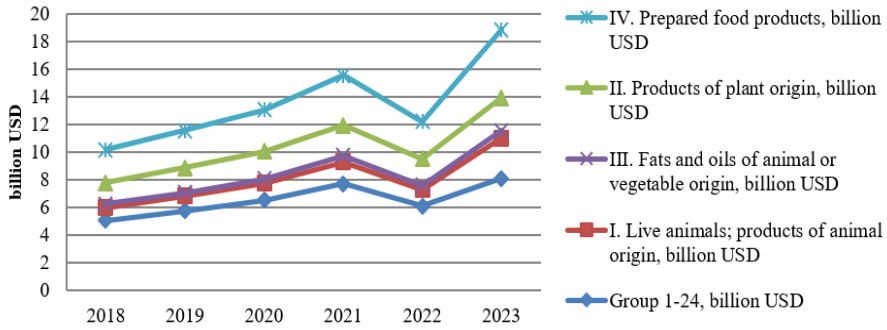

Figure 8 The volume of imports of food products to Ukraine from European partners for 2018-2023, billion USD. Source: built by the authors from the data of State Statistics Service of Ukraine (2024)

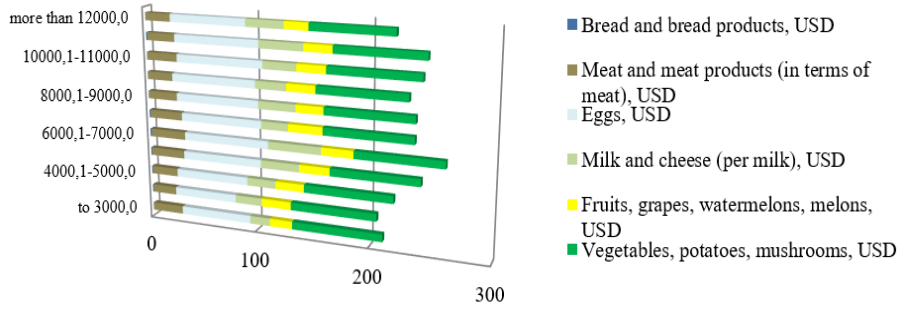

Figure 9 The share of consumed food products produced by rural households of Ukraine, depending on the amount of average per capita equivalent total income in 2022, USD. Source: built by the authors from the data of State Statistics Service of Ukraine (2024)

Therefore, a set of appropriate measures on the part of the state makes it possible to balance the export opportunities of agricultural entities and restore contractual agreements regarding the supply of agricultural products to EU and African countries. In the future, programs will be implemented to reorient farmers to the large-scale shipment of finished products to processing and food complexes for the one hundred percent restoration of the food supply of the domestic market with their own products and meeting the needs of consumers.

Ukrainian farmers, in the conditions of war-induced difficulties, are looking for ways to reduce production costs, in particular, to optimize cultivation technologies. Despite the limited financial resources, the subjects of agriculture remained the main suppliers of food products and ensuring the food crisis in Ukraine. In the course of

2018-2023, a significant dynamic fluctuation of the gross volume of grain and leguminous crops was observed. This indicates significant differences in the use of natural and energy resources between different regions of the country and the insufficient level of implementation of innovative energy technologies by them in the cultivation of agricultural crops, especially by small agricultural entities (Geletukha, 2021).

The assessment of the sectoral structure of agricultural production entities of Polissia and Western agrozones of Ukraine confirms the correctness of the selected options for optimizing natural and energy resources according to the criterion of maximum profit. The calculations take into account agroclimatic features and the energy value of the soil under agricultural land, which confirm the direct relationship between the yield of winter wheat at an unchanged sowing area and energy costs for fuel and lubricants (correlation coefficient is 0.662). At the same time, the energy costs of fertilizers in the cost structure of 1 cent of production amount to 603.0 USD. In 2023, the average purchase price in Ukraine for class II wheat was 210 USD/ton, class III – 205 USD/ton, class IV – 188 USD/ton. Compared to 2022, prices have increased by more than 50%.

According to the results of the calculations, under the condition of using no-till technology when growing winter wheat, the total costs for 1 ha in 2023 amounted to 46.3 thousand USD (according to the traditional technology, the total costs for 1 ha amounted to almost 53.0 thousand USD). That is, with a winter wheat yield of 46.5 t/ha, the cost of 1 t of produced products equaled 798 USD (according to traditional technology – 1139 USD). At the selling price of wheat at USD 210/ton, the profit of 1 ha was almost 30.0 thousands USD which ensured a product profitability of more than 56%.

According to the results of the economic-mathematical model, a comparative assessment of the use of traditional technology and no-till technology was carried out, taking into account the energy value of the soils exploited by agricultural production entities in the regions of the Polissia and Western agrozones of Ukraine (Figure 10 and 11).

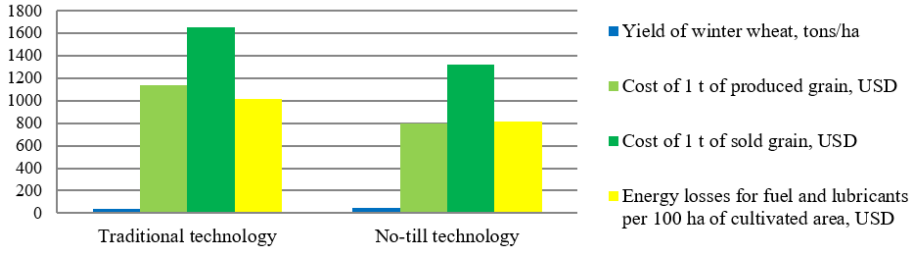

Figure 10 Evaluation of technologies for growing winter wheat in the regions of the Polissia and Western agrozones of Ukraine in 2023. Source: built by the authors from the data of State Statistics Service of Ukraine (2024)

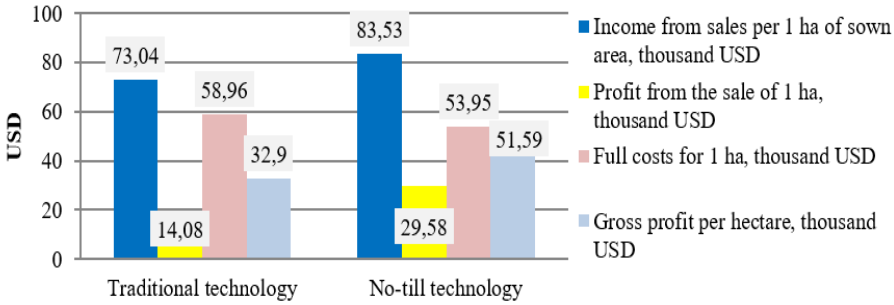

Figure 11 Indicators of the efficiency of agricultural production in the regions of the of Polissia and Western agrozones of Ukraine when using energy-saving technologies. Source: built by the authors from the data of State Statistics Service of Ukraine (2024)

Thus, the natural-energy and economic elements of the resource potential of agriculture on the example of the regions of Polissia and Western agrozones of Ukraine demonstrate the main dominant factor – the energy value of agricultural lands. In addition, it makes it possible to implement financial assistance from international partners in those regions of the of Polissia and Western agrozones of Ukraine, where significant grants are directed to finance efficient land use when changing traditional technologies to innovative ones.

For comparison, the performed calculations make it possible to justify that the profitability of winter and spring wheat production can increase to 40%, which positively characterizes the economic component of the industry, and technological operations using the no-till technology allow improving the ecological component of the resource potential of agriculture in the regions of Polissia and Western agrozones of Ukraine (Figure 12).

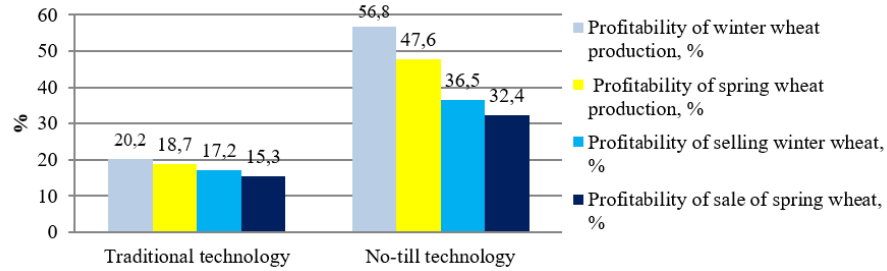

Figure 12 The level of profitability of winter and spring wheat production with energy-saving technology in the regions of Polissia and Western agrozones of Ukraine for 2023. Source: built by the authors from the data of State Statistics Service of Ukraine (2024)

In order to maintain a balanced amount of food supply, it is necessary to rely on a sufficient level of accumulation of food products in the regions in order to meet the needs of consumers. This circumstance must be taken into account due to the fact that the majority (50%) of agricultural products are produced by economic entities that are the main consumers of energy resources and that interconnect them with the energy of other resources, in the form of the energy value of food products, based on consumer standards basket per person and differentiation of the received incomes, which are returned to the subjects of agricultural production in the form of added value, which is distributed between land, production, financial and other resources, to increase labour productivity, resource return and capital profitability. According to the results of the research, the target criteria of the integral index of ensuring the ecological and energy value of food products in the regions of the Polissia and Western agrozones of Ukraine, which is a key parameter for the effective development of the resource potential of agriculture, were determined (Figure 13).

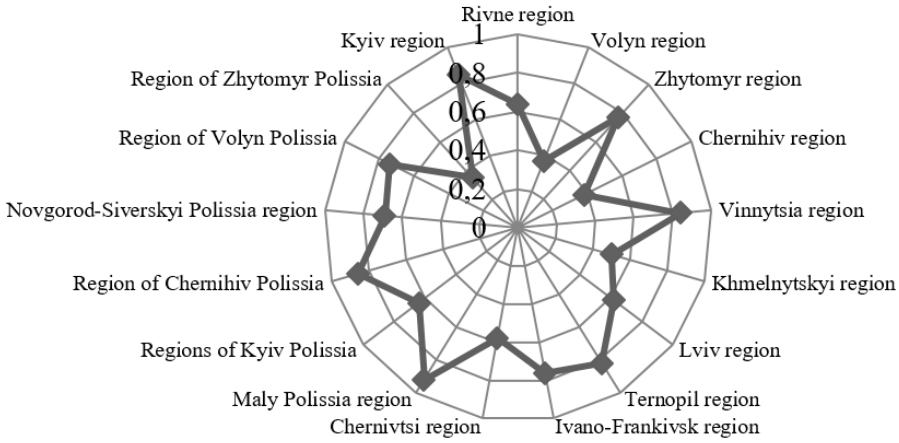

Figure 13 Integral index of ensuring environmental and energy value of food products in the regions of Polissia and the Western agrozones of Ukraine in 2023. Source: calculated by the authors

Thus, among the regions of Polissia and Western agrozones of Ukraine, the highest level of ensuring the ecological and energy value of food products has the subjects of agriculture located in Vinnytsia region (0.84), Ternopil region (0.82), in the region of Maly Polissia (0.92), in in the region of Chernihiv Polissia (0.86) and in the region of Kyiv Polissia (0.85). At the same time, the vast majority of subjects of agricultural production have a low level of the index – in the range from 0.50 to 0.76. Subjects of agricultural production in Khmelnytskyi region (0.50) and Chernivtsi region (0.58) have a critical condition and irrational use of resource potential

and its use to ensure the ecological and energy value of food products. The Zhytomyr Polissia region (0.35), Chernihiv region (0.38) and Volyn region (0.37) have a crisis level of resource potential.

Thus, the evaluation of the interaction of indicators in the integral index of ensuring the ecological and energy value of food products (formula (13)) shows that the intensive anthropogenic load of environmental factors on the land resources of agricultural production entities, under the condition of inactive use of innovative energy technologies in the technological process can lead to a critical level of food supply in some regions of Polissia and Western agrozones of Ukraine. This is especially relevant in the period of martial law, when there is an unsystematic redistribution and exploitation of resources, which worsens the quality indicators of productivity.

Using a differentiated approach to determining the optimal (marginal) value of the integral index of the development of the resource potential of agriculture in order to stop negative trends in the studied regions, we carried out simulation modeling of the change in indicators according to the criteria for financing the economic activity of agricultural production entities for 2024-2026, by strengthening the influence of modules of financial assistance from international partners on the overall result (Figure 14).

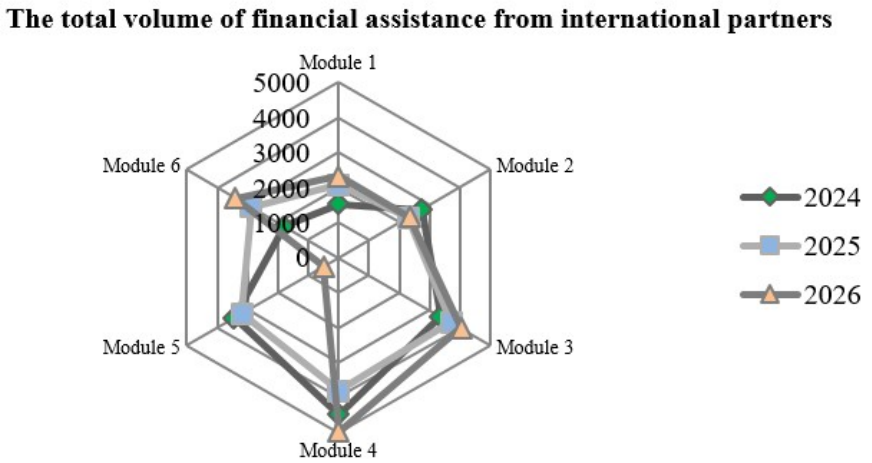

Figure 14 Estimated amount of financial assistance from international partners for the restoration of the development of the resource potential of agriculture in the regions of the Polissia and Western agrozones of Ukraine for 2024-2026, million USD. Source: calculated by the authors

Simulation modeling of the regions of the Polissia and Western agrozones of Ukraine on the platform of system analysis of indicators of financial activity of agricultural production entities makes it possible to determine the reference module of resource potential development as the interdependence of financial profiles along the

length of the vector of the integral indicator, which is calculated as follows (Trusova et al., 2021):

$$I_{RP}=\sqrt{\sum_{i=1}^{n}Q_i^2} \quad , \tag{13}$$

where Q_i – factors (financial indicators) of the length of the integral index of development of the resource potential of agriculture in the regions, i = 1, … n – modular financial profiles of the resource potential of agriculture in the regions (in our case n = 6).

In some cases, the length of the integral index in the homogeneity of observation vectors can have a meaningful interpretation. In particular, with a set of (n) elements of the module, the matrix ($\{W_{ij}\}_{n\times n}$) is used, where, W_{ij} – is the annual volume of financing from the i-th source to the j-th region. Therefore, the length of the distribution of the financial component ()in the integral index of resource potential development will take the form (Trusova et al. 2021):

$$f_{ij}=\left(\frac{W_{ij}}{\left(\sum_{(1\le j\le n)}W_{ij}\right)}+\frac{W_{ji}}{\left(\sum_{(1\le i\le n)}W_{ji}\right)}\right)\div 2 \quad . \tag{14}$$

Based on the systematic analysis of factors (financial indicators) influencing the level of development of the resource potential of agriculture in the studied regions, from the standpoint of the financial activity of agricultural production entities, module 3 was chosen as a benchmark, where all indicators are the highest compared to module 6. The correctness of the choice is confirmed data on the profitability of the main activity, which also reproduces the efficiency of the use of financial resources in the structure of the resource potential in modules 3 and 4 (Figure 15 and 16).

Thus, taking into account geoeconomic trends, the greening of agricultural lands in the regions of the Polissia and Western agrozones of Ukraine will make it possible to eliminate the negative disincentive factors of the resource potential of agriculture, which are associated with the increase in the level of material and energy intensity of production. It is also necessary to take into account the trends of steady growth in demand for agricultural land, which, even in war conditions, do not limit the possibility of intensification of production.

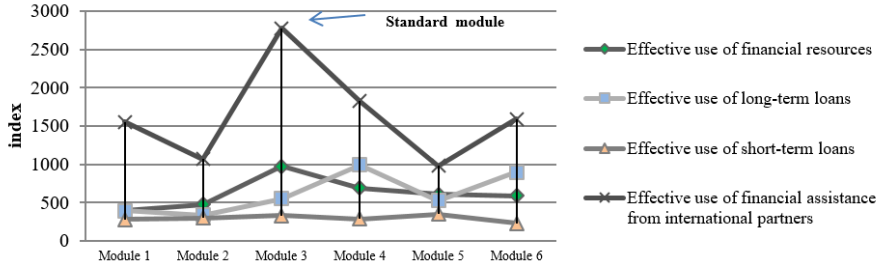

Figure 15 Reference module of resource potential of agriculture according to indicators of financial activity of subjects of agricultural production in the regions of Polissia and Western agrozones of Ukraine for 2024-2025. Source: calculated by the authors

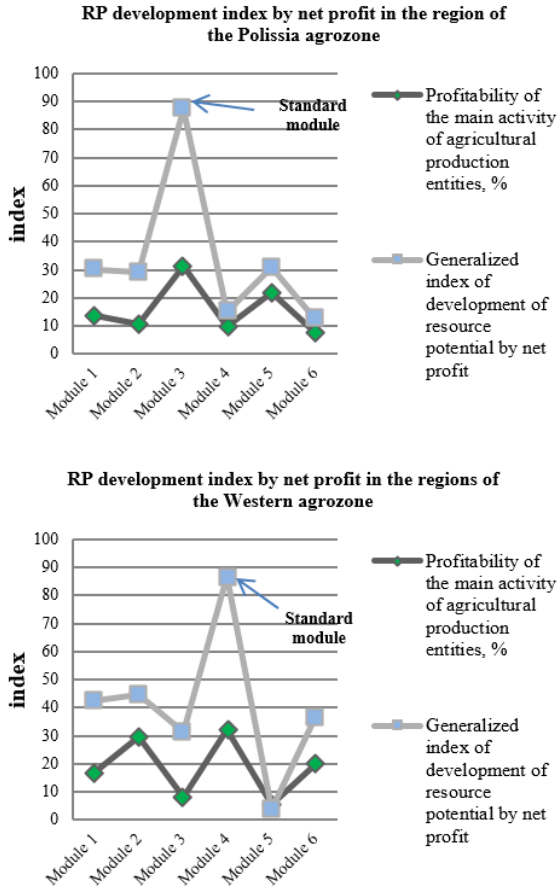

Figure 16 The reference module for the development of the resource potential of agriculture by net profit in the regions of Polissia and Western agrozones of Ukraine for 2024-2025. Source: calculated by the authors

System analysis and simulation modeling showed that under the existing probability of the chosen one "standard", the integrated index of the resource potential of agriculture in the regions of the Polissia and Western agrozones of Ukraine is subject to the adaptation of modules 3 and 4. Due to the impossibility of implementing rapid global changes in the food supply and energy supply system, due to military operations in the country, it is necessary to direct efforts to the transition to the "neighboring" module, providing positive dynamics of management of financial resources of agricultural production entities within the given parameters.

5 CONCLUSION

The modern agrarian system of agriculture in Ukraine is capable of ensuring the effective use of resource potential, which is the main generator of the reproduction and protection of agricultural lands, and, therefore, of effective energy conservation of resources, competitive development of agricultural production entities that are capable of ensuring food, financial and energy security in conditions of the ecological crisis of the war period. In order to reduce and overcome the anthropogenic load of factors on the resource potential of agriculture, at the state level, strategic directions of safe intensification of land use should be implemented in the development model of rural areas with the accelerated introduction of innovative energy technologies, taking into account the need to restore sustainable economic growth of the industry in the long term.

The active actions of international financial institutions regarding the development of the resource potential of agriculture in the post-war period of recovery of the Ukrainian economy will allow stabilizing food, financial, environmental and energy security for the harmonization of processes in the agrarian system at the regional and local levels. At the same time, the attributes of Ukraine's strategic national priorities when interacting with international partners should be aimed at ensuring ecological-economic and socio-economic relations, which, taking into account geo-economic changes in the country, should implement energy-saving programs for rural united territorial communities and activate their actions on the basis eco-innovative tools that transform the agrosystem of the resource potential of agriculture and are aimed at the formation of: economic prerequisites for ensuring the profitability of agricultural production entities not below the average level of the state economy; socialization of land use and protection of the rights of the rural population to own and dispose of land; state food security programs; guarantees of public-private partnership in terms of budget financing, credit investment for the restoration of natural, production, and energy components of the resource potential in rural areas; mechanisms and methods of land market development through the formation of favorable price, financial and credit, insurance, tax and budget policies with the aim of implementing eco-innovations that increase the energy efficiency of agricultural land.

The process of modernization of the natural-ecological and socio-economic elements of the resource potential of agriculture can be ensured by: forming the economic and legal foundations of state influence on the development of agricultural production of corporate structures, which must bear social responsibility for obtaining a large-scale economic effect from the energy of land use; direct these results to the reproduction and protection of agricultural lands; increasing the fertility of land to fill the agricultural market with raw agricultural products; promoting the spread of integrated vertical cooperation with the aim of introducing new eco-innovative technologies in the production business model, reducing the labour intensity of agricultural products, their further processing and sale.

The basis of food supply in the country depends on the development of the resource potential of agriculture, which generates the energy of the produced products necessary for the population. Since the process of food supply is vitally important, the food complex of agriculture must meet the necessary needs of the population for food products. This is especially relevant for industrial regions and territories with insufficiently developed agriculture, which have peculiarities of conducting agricultural production and providing the population with food products. This requirement puts forward conditions that do not wait for the gradual development and formation of economically sustainable agriculture under the influence of favorable factors, market relations, business conditions, and business climate. The state and conditions of agricultural development in terms of providing the population with food are determined not only by market factors, they are regulated by authorities and local self-government bodies, which become coordinators of actions between agricultural producers and consumers.

The guaranteeing for Ukraine's safe food supply: cessation of hostilities and demining of agricultural lands; recognition of agriculture as one of the priority branches of the national economy; attraction of investments in the food sector and its credit support; the development of public-private partnership in agro-industrial integration and cooperation, which will allow the use of large-scale production of agricultural products; approximation to global standards and certification of agricultural and food products due to innovative energy technologies, which will allow national producers to increase export opportunities on world markets and increase the level of consumption of their own goods.

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Zdrojový potenciál poľnohospodárstva na Ukrajine: šetrenie energiou a zásobovanie potravinami

Súhrn

Moderný agrárny systém poľnohospodárstva na Ukrajine je schopný zabezpečiť efektívne využitie potenciálu zdrojov, ktoré sú hlavným generátorom reprodukcie a ochrany poľnohospodárskej pôdy, a tým efektívneho šetrenia zdrojov energie a konkurencieschopného rozvoja subjektov poľnohospodárskej výroby. Tie sú schopné zabezpečiť potravinovú, finančnú a energetickú bezpečnosť v podmienkach ekologickej krízy vojnového obdobia. V záujme zníženia a prekonania antropogénnej záťaže faktorov na zdrojový potenciál poľnohospodárstva by sa na úrovni štátu mali do modelu rozvoja vidieka implementovať strategické smery bezpečnej intenzifikácie využívania pôdy s urýchleným zavádzaním inovatívnych energetických technológií, berúc do úvahy potrebu obnoviť udržateľný ekonomický rast odvetvia v dlhodobom horizonte.

Aktívne pôsobenie medzinárodných finančných inštitúcií v oblasti rozvoja zdrojového potenciálu poľnohospodárstva v povojnovom období oživenia ukrajinskej ekonomiky umožní stabilizáciu potravinovej, finančnej, environmentálnej a energetickej bezpečnosti pre harmonizáciu procesov v agrárnom systéme na regionálnej a miestnej úrovni. Atribúty strategických národných priorít Ukrajiny pri interakcii s medzinárodnými partnermi by zároveň mali smerovať k zabezpečeniu ekologicko-ekonomických a sociálno-ekonomických vzťahov, ktoré by s prihliadnutím na geoekonomické zmeny v krajine mali realizovať programy šetrenia energiou pre vidiecke územné spoločenstvá a aktivizovať ich činnosť na základe ekoinovačných nástrojov, ktoré transformujú agrosystém zdrojový potenciál poľnohospodárstva. Tieto nástroje sú zamerané na vytváranie ekonomických predpokladov pre zabezpečenie rentability subjektov poľnohospodárskej výroby nie pod priemernú úroveň štátneho hospodárstva, na socializáciu využívania pôdy a ochranu práv vidieckeho obyvateľstva vlastniť pôdu a disponovať s ňou, či na štátne programy potravinovej bezpečnosti. Okrem toho stelesňujú záruku verejno-súkromného partnerstva z hľadiska rozpočtového financovania, úverových investícií na obnovu prírodných, výrobných a energetických zložiek potenciálu zdrojov vo vidieckych oblastiach, podporujú mechanizmy a metódy rozvoja trhu s pôdou prostredníctvom tvorby výhodnej cenovej, finančnej a úverovej, poistnej, daňovej a rozpočtovej politiky s cieľom zavádzania ekoinovácií, ktoré zvyšujú energetickú efektívnosť poľnohospodárskej pôdy.

Proces modernizácie prírodno-ekologických a sociálno-ekonomických prvkov zdrojového potenciálu poľnohospodárstva možno zabezpečiť formovaním ekonomických a právnych základov vplyvu štátu na rozvoj poľnohospodárskej výroby podnikových štruktúr, ktoré musia niesť spoločenskú zodpovednosť za získanie rozsiahleho ekonomického efektu z energie využívania pôdy. Potrebné je taktiež nasmerovať tieto výsledky na reprodukciu a ochranu poľnohospodárskej pôdy a zvýšenie úrodnosti pôdy s cieľom naplniť poľnohospodársky trh surovými poľnohospodárskymi produktmi. Nemenej dôležitá je taktiež podpora šírenia integrovanej vertikálnej spolupráce s cieľom zavádzania nových ekoinovačných technológií do výrobného obchodného modelu, znižovania náročnosti práce pri tvorbe poľnohospodárskych produktov, ako aj podpora ich ďalšieho spracovania a predaja.

Základ zásobovania potravinami v krajine závisí od rozvoja zdrojového potenciálu poľnohospodárstva, ktoré generuje energiu z vyrobených produktov potrebnú pre obyvateľstvo. Keďže proces zásobovania potravinami je životne dôležitý, potravinový komplex poľnohospodárstva musí spĺňať nevyhnutné potreby obyvateľstva v oblasti potravinových produktov. To platí najmä pre priemyselné regióny

a územia s nedostatočne rozvinutým poľnohospodárstvom, ktoré majú špecifiká v oblasti poľnohospodárskej výroby a zásobovania obyvateľov potravinami. Táto požiadavka je urgentná a nečaká na postupný rozvoj a formovanie ekonomicky udržateľného poľnohospodárstva pod vplyvom priaznivých faktorov, trhových vzťahov, či vhodnej podnikateľskej klímy. Stav a podmienky rozvoja poľnohospodárstva z hľadiska zásobovania obyvateľstva potravinami nie sú určované len trhovými faktormi, ale regulujú ich orgány štátnej správy a miestnej samosprávy, ktoré sa stávajú koordinátormi akcií medzi poľnohospodárskymi výrobcami a spotrebiteľmi.

Zaručenie bezpečných dodávok potravín pre Ukrajinu je podmienené zastavením nepriateľských akcií a odmínovaním poľnohospodárskej pôdy a uznaním poľnohospodárstva ako jedného z prioritných odvetví národného hospodárstva. Kľúčová je tiež príťažlivosť investícií do potravinárskeho sektora a jeho úverová podpora, rozvoj verejno-súkromného partnerstva v agro-priemyselnej integrácii a spolupráci, čo umožní využitie kapacít veľkovýroby poľnohospodárskych produktov. Cieľom je taktiež približovanie sa ku globálnym štandardom a certifikácia poľnohospodárskych a potravinárskych produktov vďaka inovatívnym energetickým technológiám, čo národným výrobcom umožní zvýšiť exportné možnosti na svetové trhy a zvýšiť úroveň spotreby vlastnej produkcie.