Sustainable development of the agrosocial system on the basis of innovative competitiveness in the context of post-war reconstruction of Ukraine

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Abstract. The importance of sustainable development of the agrosocial system of Ukraine after the war period is considered. Focusing on innovative competitiveness, the forecasting methods necessary to achieve sustainable development in the agrosocial system are identified. It is established that the main goal of the strategy for the development of the agricultural sector of Ukraine is to develop agriculture, which will ensure food security of the country, production of high-quality agricultural products in sufficient volumes to meet the needs of the population and processing industries, and will become a reliable economic base for the socio-economic development of Ukrainian rural areas. It is determined that the post-war recovery of Ukraine directly depends on the restoration and sustainable development of the agrosocial sector, which ensures food security and economic stability through innovative competitiveness. Thus, the sustainable development of the agro-social sector involves a balance between economic growth, social justice and environmental sustainability. It is proved that in the context of Ukraine, this approach requires: economic efficiency (increased productivity and profitability of production); environmental sustainability (conservation of natural resources, reduction of negative impact on the environment); social responsibility (improvement of working and living conditions of the rural population).

1 Introduction

Ukraine, like many other countries, suffered significant losses during the war, which led to the destruction and significant weakening of the country's agro-social system. However, after the end of the war, an important task will be to restore and develop the agrosocial system. Modern conditions require not only the restoration but also the transformation of agriculture and rural areas, taking into account current trends in sustainable development and innovative competitiveness [1-3].

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The research paper is devoted to finding ways to achieve sustainable development of the agrosocial system in Ukraine based on innovative approaches. The main goal of the strategy for the development of the agricultural sector of Ukraine is to develop agriculture as an efficient and competitive sector of the economy that will ensure food security of the country, production of high-quality agricultural products in sufficient volumes to meet the needs of the population and processing industries, and will become a reliable economic base for the socio-economic development of the Ukrainian countryside [2; 4]. Thus, an important task is to choose an appropriate direction for the development of the agro-social sector, taking into account its multifunctionality, including economic, social and environmental aspects.

2 Materials and methods

In researching the sustainable development of the agrosocial system on the basis of innovative competitiveness in the context of post-war reconstruction of Ukraine, various methods are used, including the following: analysis and synthesis - in the study of the current state of the agrosocial system by analyzing statistical data, legislative acts, as well as scientific publications and expert opinions. Synthesis of the data allows to identify trends and problems of development management; expert assessments - involvement of experts in the field of agriculture, social sciences, economics and ecology to obtain qualified assessments and recommendations for forecasting and management strategies; modeling - use of computer models to analyze and forecast the development of the agrosocial system, which may include economic and mathematical modeling, social simulations, and modeling of environmental processes; SWOT analysis - identification of strengths, weaknesses, opportunities and threats to the development of the agrosocial system in order to formulate strategic recommendations for achieving innovative competitiveness; statistical analysis - use of statistical methods to assess trends in agricultural development, social indicators and environmental parameters; system analysis - study of the agrosocial system as a complex system consisting of interacting elements, taking into account their interrelationships and the impact of external factors; Delphi analysis - a systematic analysis of the agrosocial system.

The comprehensive use of this methodological framework will allow conducting a thorough study and proposing effective ways for the sustainable development of the agrosocial system on the basis of innovative competitiveness in the context of post-war recovery of Ukraine.

3 Results

Ukraine, as a country with a rich history and significant potential in the agricultural sector, is facing the challenges of post-war recovery, where sustainable development of the agrosocial system is an important aspect. In the context of a dynamic economic and environmental paradigm, innovative competitiveness is becoming a key factor for achieving sustainable development goals in the agrosocial system [5].

The agrosocial system is a complex of interconnected elements that includes agricultural enterprises, farms, rural areas, as well as social capital, cultural and other aspects. The sustainability of this system implies ensuring balanced social, economic and environmental development, where innovation and competitiveness are the driving factors in Ukraine’s post-war recovery [6].

In the context of post-war reconstruction, innovations in the agrosocial system define new approaches to production, resource management, marketing, and social aspects.

Innovation contributes to the efficiency and competitiveness of agricultural enterprises and promotes rural development [7].

The following approaches can be used to achieve sustainable development of the agrosocial system (Fig. 1).

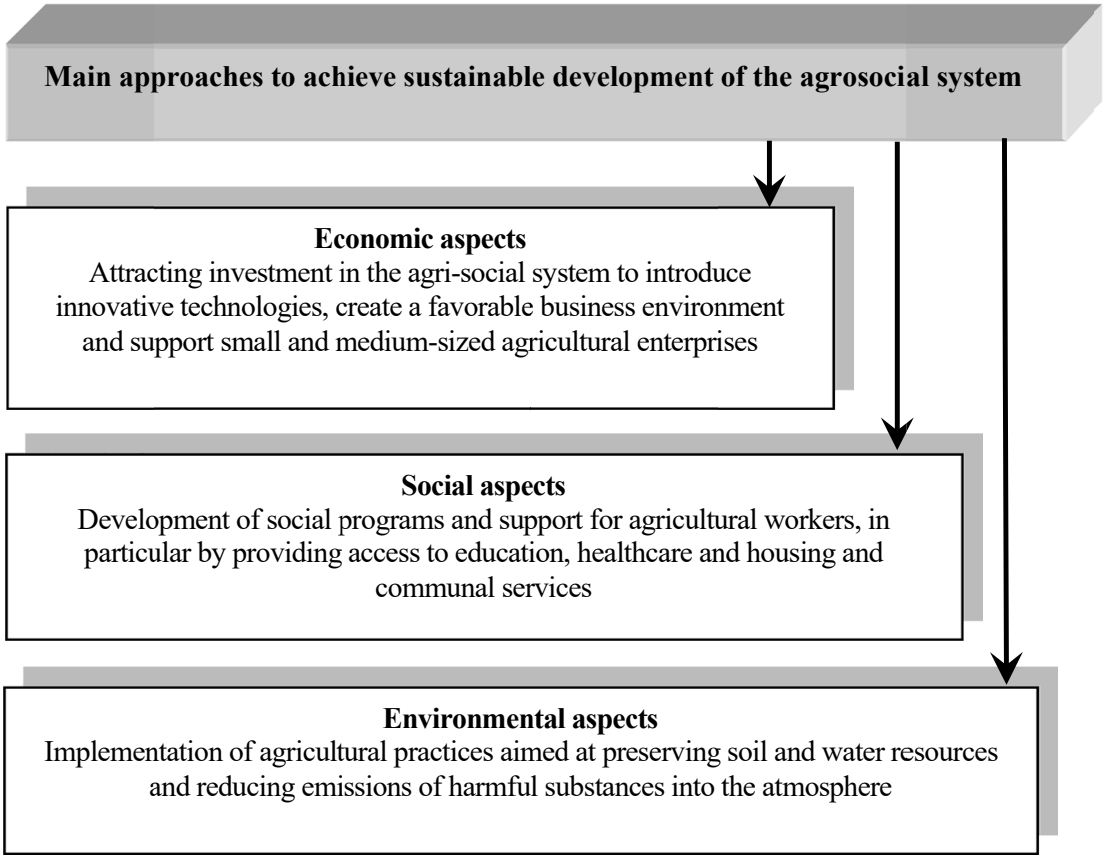

Fig. 1. Effective approaches to achieve sustainable development of the agrosocial system [8; 10].

It should be noted that in modern economic conditions it is especially important to improve the methodology for assessing the development of the agrosocial system, in particular, to create forecasts for the future, for which it is necessary to:

- ✓ to develop a multifactorial model for forecasting the development of the agrosocial system, including economic, social and environmental systems;
- ✓ to use the best options for forecasting (genetic and targeted);
- ✓ to obtain comprehensive information about the future state of the agrosocial system of Ukraine and identify possible ways to improve its efficiency;
- ✓ to identify priority measures to optimize the sustainable development of the agrosocial system on the basis of innovative competitiveness in the context of post-war recovery of Ukraine [6; 8].

Sustainable development management includes: determining the vector of effective development by setting a goal and ways to achieve this goal; ensuring the preservation of sustainable development on this vector. Here, it is necessary to use a diagnostic analysis of the state of the economic system, which defines an indicator that allows to conclude whether the agro-social system is under control and signals emergency events that require immediate action [9].

The methodology for assessing the development of the agrosocial system includes the relevant levels:

✓ conceptual and methodological (indicators are formed to assess the economic, social and environmental components of the agrosocial system, where weighting coefficients are determined for indicators of the 1st and 2nd levels of the hierarchy using the expert-analytical method);

✓ model-mathematical (the problem is structured in the form of a three-level hierarchy, where annual estimates of statistical indices are determined using fixed and variable indices, as well as fixed indices without taking into account the growth rate of the factor).

✓ analytical (it is supposed to determine the differential level of the integral indicator of ISDAS and to develop a forecast for the development of the agro-social system of Ukraine for the future) [6; 11].

Fixed indices are determined by formula (1):

$$I_m = \frac{\sum_{i=1}^{n} a_{im} \cdot A_{im}}{\sum_{i=1}^{n} A_{im}}, \quad (1)$$

I_m - fixed index m - of the year; a_{im} - is the indicator of the *m*-th year, which is the base year for the analyzed statistical index in absolute terms; A_{im} - the statistical index m - year corresponding to the factor of influence on the subsystem in absolute or relative terms; n - the number of indicators.

Variable indices or variable development indices are determined by the formula (2):

$$J_l = \frac{I_m}{I_{m+1}}, \quad (2)$$

J_l - variable indices of *l* year; I_{m+1} - fixed index $(m+1)$ year.

Fixed indices without taking into account the growth rate of the factor are determined by formula (3):

$$K_m = \frac{\sum_{i=1}^{n} a_{im+1} \cdot A_{im+1}}{\sum_{i=1}^{n} a_{im} \cdot A_{im+1}}, \quad (3)$$

K_m - fixed indices without taking into account the growth rate of the factor of m - year; a_{im+1} - indicator$_{(m+1)}$ - year; A_{im+1} - $(m+1)$ - year in absolute terms statistical index of the year corresponding to the factor of influence on the subsystem in absolute or relative terms.

The development index of the 1st level of the hierarchy shows the change in the statistical index due to the change in the indicator that is the base for the analyzed statistical index in absolute terms, calculated by formula (4):

$$IR^{(1)}_{economic,i} = \frac{\sum_{i=1}^{n}(a_{im} \cdot A_{im+1}) \cdot \sum_{i=1}^{n} A_{im}}{\sum_{i=1}^{n}(a_{im} \cdot A_{im}) \cdot \sum_{i=1}^{n} A_{im+1}}; \quad IR^{(1)}_{social,j} = \frac{\sum_{j=1}^{n}(a_{jm} \cdot A_{jm+1}) \cdot \sum_{j=1}^{n} A_{jm}}{\sum_{j=1}^{n}(a_{jm} \cdot A_{jm}) \cdot \sum_{j=1}^{n} A_{jm+1}}; \quad IR^{(1)}_{ecology,k} = \frac{\sum_{k=1}^{n}(a_{km} \cdot A_{km+1}) \cdot \sum_{k=1}^{n} A_{km}}{\sum_{k=1}^{n}(a_{km} \cdot A_{km}) \cdot \sum_{k=1}^{n} A_{km+1}}, \quad (4)$$

$IR^{(1)}_{(economic),i}, i=\overline{1;15}$, $IR^{(1)}_{(social),j}, j=\overline{1;14}$, $IR^{(1)}_{(ecology),k}, k=\overline{1;8}$ - development indices of the 1st level of the hierarchy of economic, social and environmental subsystems.

At the second level of the hierarchy, the development indices of the 2nd level of the hierarchy of economic, social and environmental subsystems are determined, which are calculated by the following formulas:

$$IR^{(2)}_{(econjmic)}=\sum_{i=1}^{15}\omega_i\cdot IR^{(1)}_{(economic),i}\ ;\ IR^{(2)}_{(social)}=\sum_{j=1}^{14}\omega_j\cdot IR^{(1)}_{(social),j}\ ;\ IR^{(2)}_{(ecology)}=\sum_{k=1}^{8}\omega_k\cdot IR^{(1)}_{(ecology),k}\ , \quad (5)$$

$IR^{(1)}_{(economic),i}, i=\overline{1;15}$, $IR^{(1)}_{(social),j}, j=\overline{1;14}$, $IR^{(1)}_{(ecology),k}, k=\overline{1;8}$ - are development indices of the 1st level of the hierarchy of economic, social and environmental subsystems; $\omega_i, i=\overline{1;15}$, $\omega_j, j=\overline{1;14}$, $\omega_k, k=\overline{1;8}$ - are weighting coefficients for the development indices of the economic, social and environmental subsystems of the 1st level of the hierarchy.

The values of the weighting coefficients $\omega_i, i=\overline{1;15}$, $\omega_j, j=\overline{1;14}$, $\omega_k, k=\overline{1;8}$ are determined by expert analysis.

The Index of Sustainable Development of the Agricultural and Social System of Ukraine (ISDAS) - - is the development index of the 3rd level of the hierarchy, which is calculated by formula (6):

$$IPAC=\omega_{economic}\cdot IR^{(2)}_{(economic)}+\omega_{social}\cdot IR^{(2)}_{(social)}+\omega_{ecology}\cdot IR^{(2)}_{(ecology)}, \quad (6)$$

$IR^{(2)}_{(economic)}$; $IR^{(2)}_{(social)}$; $IR^{(2)}_{(ecology)}$ - development indices of the 2nd level of the hierarchy of economic, social and environmental subsystems;

$\omega_{economic}, \omega_{social}, \omega_{ecology}$ - weighting coefficients for the 2nd level development indices of the hierarchy of economic, social and environmental subsystems.

The article proposes to determine the predicted value of the index of sustainable development of agrosocial system (ISDAS) using a multifactor forecasting model. The model for forecasting the development of an agrosocial system is a multifactorial model that includes the influence of three development factors: economic, social and environmental subsystems:

$$IPAC_t=IPAC_{t-1}+\Delta IR^2_{economic,t}+\Delta IR^2_{social,t}+\Delta IR^2_{ecology,t}, \quad (7)$$

$ICPAC_t$ – forecast ISDAS; $\Delta IR^{(2)}_{economic,t}$ – increase in the index of agrosocial system development due to the economic subsystem; $\Delta IR^{(2)}_{social,t}$ – increase in the index of agrosocial system development due to the social subsystem; $\Delta IR^{(2)}_{ecology,t}$ – increase in the index of sustainable development of the agrosocial system due to the environmental subsystem.

Forecast values: ISDAS (ISDAS_(t-1)), indices of: ISDAS ($ICPAC_{t-1}$), economic ($IR^{(2)}_{economic,t}$), social ($IR^{(2)}_{social,t}$) and environmental ($IR^{(2)}_{ecology,t}$) subsystem development will be determined using adaptive forecasting models, in particular, the exponential smoothing method.

Adaptive forecasting models are promising areas of research and forecasting the development of economic systems, which allow creating economic and mathematical

models that are automatically adjusted in the process. Adaptive models are able to respond quickly to changes, taking into account previous forecasts and different levels of significance of known factors.

The recurrent formula (8) is used for exponential smoothing of the series:

$$S_t = S_{t-1} + \alpha(y_{t-1} - S_{t-1}), \tag{8}$$

S_t – is the forecast value at time t; y_{t-1} – is the value of the dynamic series at $t-1$; α – is the smoothing parameter, $\alpha = const$, $0 < \alpha < 1$.

Thus, a new forecast S_t is obtained as a result of adjusting the previous forecast to account for its error. The increase in the indices of development of the agrosocial system due to the economic $\Delta IR^{(2)}_{economic,t}$, social $\Delta IR^{(2)}_{social,t}$ and environmental $\Delta IR^{(2)}_{ecology,t}$ subsystems will be assessed as an upward (downward) trend:

$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1}, \tag{9}$$

T_t – is the trend estimate; L_t – is the forecast value; β – is the smoothing constant for the trend estimate, $0 \le \beta \le 1$.

To evaluate the forecast, we determine the value of the root mean square error using formula (10):

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(y_t - S_t)^2, \tag{10}$$

y_t – the value of the series at the moment; S_t – the forecast value of the series;

The proposed factor model opens up the possibility of developing two types of forecasts: genetic (descriptive, inertial), which is based on the use of established cause-and-effect relationships between phenomena that have significant inertia in their development; targeted, which is a forecast that defines the target results to be achieved in the future. The target forecast is based on determining the conditions and prerequisites that will ensure the transition of the object from the initial state to the desired, standardized state within a specific period of time. This approach considers the relationship and sequence of phenomena from the future to the present. It includes an analysis of the chain of events and the necessary measures to achieve the target result in the future. This forecast provides a justification for the realistically achievable conditions and prerequisites for the transition of the agrosocial system to the next level of development [10; 11].

Thus, to determine the future sustainable development of the agrosocial system of Ukraine, we analyzed the increase in the values of the relevant development indices through the interaction between the economic, social and environmental subsystems.

This is due to the fact that in 2023, the index of development of the agro-social system of Ukraine (IRAS) was 1.031437063, which indicates that the agro-social system of Ukraine is at the second level of economic development - low. This indicates instability in the ratio of land, labor and material and technical resources, dominance of large agricultural holdings in the agricultural sector, which leads to inefficient structural organization of agricultural production, prevalence of single-industry, low-labor-intensive production, low employment of the rural population, deterioration of the quality of life of the rural population compared to the urban population, increased soil depletion and environmental degradation, as well as growing shortages of mineral resources and energy [9; 12].

The forecast and growth of the indices of agrosocial system development for the genetic forecast will be calculated using formulas 7-9 (Table 1).

Table 1. Growth of agrosocial system development indices for the genetic forecast.

Year	$IR^{(2)}_{economic,t}$	**Forecast** $IR^{(2)}_{economic,t}$	$\Delta IR^{(2)}_{economic,t}$	$IR^{(2)}_{social,t}$	**Forecast** $IR^{(2)}_{social,t}$	$\Delta IR^{(2)}_{social,t}$	$IR^{(2)}_{ecology,t}$	**Forecast** $IR^{(2)}_{ecology,t}$	$\Delta IR^{(2)}_{ecology,t}$
2020	1,019536	1,018532	0,00135	1,061141	1,034883	-0,00326	1,000285	1,001551	0,000353
2021	1,015996	1,019134	0,000904	1,053818	1,050638	0,008151	1,000099	1,000791	-0,00032
2022	1,017264	1,017251	-0,00077	1,041712	1,052546	0,004405	1,001721	1,000376	-0,00038
2023	1,018997	1,017259	-0,00030	1,033442	1,046045	-0,00214	1,001564	1,001183	0,000334
2024	-	1,018302	0,000504	-	1,038483	-0,00539	-	1,001412	0,000271
2025	-	1,018136	0,000102	-	1,044296	0,001331	-	1,001087	-0,00009
2026	-	1,018033	-0,00002	-	1,046313	0,001742	-	1,000979	-0,0001
2027	-	1,017803	-0,00015	-	1,045501	0,00021	-	1,001011	-0,00002

Table 2. Growth of agrosocial system development indices for the target forecast.

Year	**IPAC,** y_t	$\Delta IR^{(2)}_{economic,t}$	$\Delta IR^{(2)}_{social,t}$	$\Delta IR^{(2)}_{ecology,t}$	$\left\|\Delta IR^{(2)}_{economic,t}\right\|$	$\left\|\Delta IR^{(2)}_{social,t}\right\|$	$\left\|\Delta IR^{(2)}_{social,t}\right\|$
2020	1,03096968	0,00135	-0,00326	0,000353	0,00135	0,00326	0,000353
2021	1,030248016	0,000904	0,008151	-0,00032	0,000904	0,008151	0,00032
2022	1,029984219	-0,00077	0,004405	-0,00038	0,00077	0,004405	0,00038
2023	1,031437063	-0,00030	-0,00214	0,000334	0,0003	0,00214	0,000334
2024	-	0,000504	-0,00539	0,000271	0,000504	0,00539	0,000271
2025	-	0,000102	0,001331	-0,00009	0,000102	0,001331	0,00009
2026	-	-0,00002	0,001742	-0,0001	0,00002	0,001742	0,0001
2027	-	-0,00015	0,00021	-0,00002	0,00015	0,00021	0,00002
Max	-	-	-	-	0,01696	0,04383	0,010898

To build a target forecast, we use the following recurrent formula:

$$IPAC_0 = y_б;$$
$$IPAC_1 = IPAC_0 + \max(\left|\Delta IR^{(2)}_{economic,t}\right|) + \max(\left|\Delta IR^{(2)}_{social,t}\right|) + \max(\left|\Delta IR^{(2)}_{social,t}\right|); \quad (11)$$
$$IPAC_t = 2 * IPAC_{t-1} - IPAC_{t-2},$$

$y_б$ - is the value of the index of agro-social system development of Ukraine (ISDAS) in the base year. For further calculations, the value of the ISDAS in 2023 is taken as the base value (Table 3).

Table 3. Genetic and target forecast of the index of agrosocial system development of Ukraine.

Year	**ISDAS,** y_t	**Genetic forecast** ICPAC_t	**Target forecast** ICPAC_t
2020	1,03096968	1,02942331	-
2021	1,030248016	1,03898751	-
2022	1,029984219	1,03324589	-
2023	1,031437063	1,02933038	1,031437
2024	-	1,03196478	1,103125
2025	-	1,03924786	1,174813
2026	-	1,04090937	1,246501
2027	-	1,04113826	1,318189

The proposed factor model demonstrates the general state of the predicted sustainable development of the agrosocial system through the genetic forecast (Table 3). This forecast indicates the reasons that impede positive trends in improving the state of the agrosocial system under martial law. The main reasons include military operations, the occupation of certain territories of Ukraine, the lack of a systematic approach to management, shortcomings in the economic, social and environmental spheres, as well as the ineffectiveness of the regulatory framework for the agrosocial system and the lack of an effective mechanism of state regulation. The targeted forecast (Table 3) can be used to identify possible ways to improve the efficiency of the agrosocial system in Ukraine in the period of post-war recovery [12; 13].

Successful sustainable development of Ukraine's agrosocial system is only possible if it is viewed as an integrated structure that includes economic, social and environmental components. These components interact and influence each other, determining the success of the system. A balance between the elements of the system is a key condition for achieving integrity and efficiency, which means providing jobs that match the supply and demand for labor of different qualifications, as well as balanced development of wages and employment, social and infrastructural living conditions, and labor productivity. It is also important to ensure the growth of production and profitability, which will lead to higher living standards and improved social and demographic processes. The study found that Ukraine's current agro-social system suffers from a major imbalance. There is a significant inequality in agricultural production between crop and livestock production, as well as between cereals and vegetables. There is also a disproportion between production volumes and wages compared to other sectors of the economy, as well as between export-oriented production and rural employment [14-16].

The main task of sustainable development of the agro-social system of Ukraine is to ensure innovative competitiveness by establishing a balance between economic activity and social development of rural areas. At the level of rural settlements, it is particularly important to ensure the balanced use of land shares and adequate revenue to the budgets of village councils, which will help solve social problems in rural areas and promote the development of agrarian entities and the social complex of villages.

It is also important to ensure a balance between the number of large, medium, and small agricultural enterprises, which is key to the development of the rural labor market. Here, it is advisable to ensure demand for agricultural specialists and their training in accordance with the needs of the industry. It is also important to balance the timing of technical modernization of production with the training of specialists provided by the state. The functioning of the agrosocial system is controlled by a system of legislative and regulatory acts, which includes organizational and economic mechanisms. The organizational structure ensures coordination and regulation of agricultural activities at the sectoral level, while economic mechanisms define the rules of economic behavior of business entities [13; 14; 17-20].

Balancing the activities of agro-industrial producers with social and environmental processes is possible only through the adoption of appropriate regulations that should ensure harmony between the corporate and public interests of producers and the population. To achieve this, mechanisms such as setting price ceilings for products, production quotas, quality control, and demand stimulation can be used. Since innovation competitiveness is the driving force behind the development of Ukraine's agrosocial system, it is necessary to propose the following areas of innovation that will contribute to sustainable development (Fig. 2).

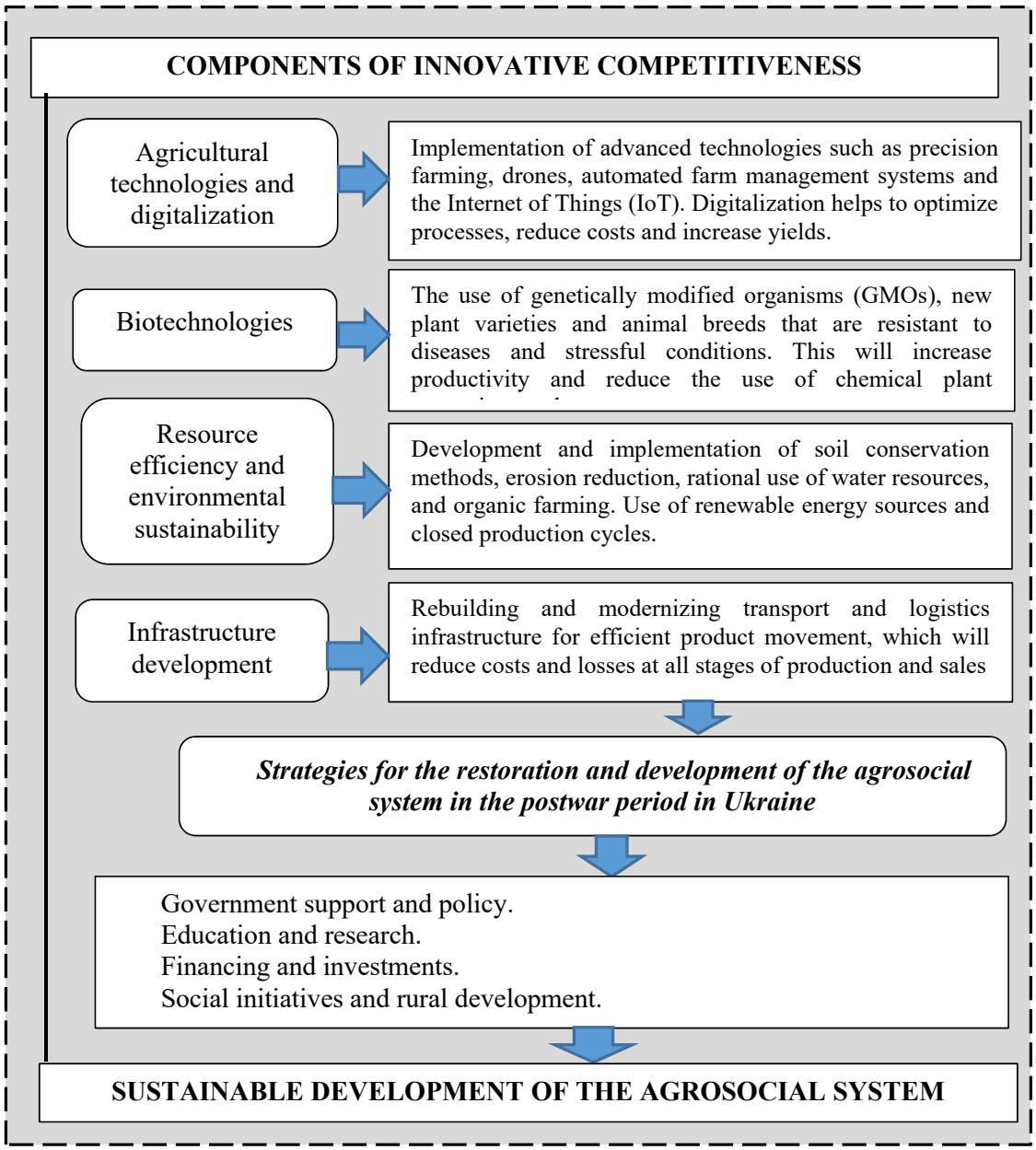

Fig. 2. Ensuring sustainable development of the agrosocial system through the components of innovative competitiveness [3; 4].

Thus, we have determined that sustainable development of the agrosocial system on the basis of innovative competitiveness is a key task for Ukraine in the context of post-war recovery, where the introduction of the latest technologies, development of the research base, support for public and private initiatives will help to increase productivity, environmental sustainability and social well-being [1; 3; 15].

To achieve the economic and social goals set out in the programs, it is important to develop specific projects for the development of various types of activities and the specifics of the functioning of organizational forms of management. It is also important to detail the issues of social development of rural areas, taking into account the population, its dynamics and structure, tax relations with local governments, the structure of rural settlements and their dynamics of change, which will contribute to a better alignment of the reform of agricultural entities with the achievement of social priorities of territorial communities in the financial sector, rural improvement, social services, etc.

4 Discussion and conclusions

Ukraine's post-war recovery poses numerous challenges to the country, among which the restoration and development of the agri-social sector is one of the most important. Given the critical role of the agri-social sector in ensuring food security and economic stability, it is necessary to focus on its sustainable development based on innovative competitiveness. Thus, sustainable development of the agrosocial sector implies a balance between economic growth, social justice, and environmental sustainability. In the context of Ukraine, this approach requires: economic efficiency (increased productivity and profitability of production); environmental sustainability (conservation of natural resources, reduction of negative environmental impact); social responsibility (improvement of working and living conditions of the rural population).

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