Original scientific paper
UDC 658.1:63(497.2)"2010/2019"
658.1:663/664(497.2)"2010/2019"

MODELING THE SOCIO-ECOLOGICAL-ECONOMIC EFFICIENCY OF RESOURCE-SAVING DEVELOPMENT MANAGEMENT OF AGRI-FOOD ENTERPRISES

Olena Lopushynska[1], Ievgen Buriak[2], Ihor Sabii[3], Liudmyla Pankova[4], Olena Ribeiro Ramos[5], Tetiana Ivanenko[6*]

[1]I. Markina Department of Management, Poltava State Agrarian University, Skovorody str. 1/3, 36003 Poltava, Ukraine
[2]Department of Management, Kremenchuk Mykhailo Ostrohradskyi National University, Pershotravneva str. 20, 39600 Kremenchuk, Poltava region, Ukraine
[3]National Scientific Center "Institute of Agrarian Economics", Heroiv Oborony str. 10, 03127 Kyiv, Ukraine
[4]Department of Management and Business Administration, Cherkasy State Technological University, Shevchenko av. 460, 18006 Cherkasy, Ukraine
[5]Department of Accounting, Finance and Information Technologies, Luhansk National Agrarian University, Slobozhanska str. 68, 92703 Starobilsk, Ukraine
[6]Department of Hotel and Restaurant Business and Business Organization, Mykolaiv National Agrarian University, Georgiy Gongadze str. 9, 54020 Mykolaiv, Ukraine

[*]e-mail: g494409@gmail.com

Abstract

The article emphasizes the prospects of environmental and resource-saving development of agri-food enterprises. It is noted that the priority task today is to create a basis for determining the model for assessing the socio-ecological-economic efficiency of resource-saving development of agri-food enterprises, which will ensure the transition of enterprises to a strategy of lean resource consumption in conditions of limited natural resources. Insufficient and fragmented coverage in the scientific literature of methodological support for assessing the effectiveness of management of resource-saving development of modern agricultural enterprises is noted. The purpose of the study is to improve the methodology for assessing the management of resource-saving development of enterprises in the agri-food sector.

The study selected the importance of indicators of agricultural sector development for the period 2010 - 2019 for the group of agri-food enterprises of Poltava, Zaporizhia and Luhansk regions, and the authors propose use of their method "Triad 6R". This methodology was used to assess the management of resource-saving development of modern agricultural enterprises. The developed author's methodology "Triad 6R", in contrast to the existing ones, is based on the calculation of coefficients combined into groups of economic, social and environmental efficiency, allows to identify the shortcomings of management strategies in the context of greening production and to determine the prospects for the development of an enterprise in the triad of "environmental-socio-economic" relations.

As a result of calculation of the integral indicators the management efficiency of resource-saving development, it was defined that the specified enterprises had the highest values of the integral indicators in 2019. The highest integral indicators are observed in the group of enterprises of Poltava region during the whole period under study; the integral indicator of resource efficiency management of the group of enterprises of Luhansk region was mostly less than this value for the group of enterprises of Zaporizhzhia region during 2012-2016. However, in subsequent years, the integral indicator of efficiency for enterprises in Zaporizhzhia and Luhansk regions was practically at the same level.

For the first time in the scientific world, the authors of the article developed the method "Triad 6R", which allowed to determine the socio-ecological and

economic effect of the agri-food sector of Ukraine. The theoretical and practical provisions developed by the authors have been brought to the level of methodological recommendations proposed for implementation into practice by enterprises of the agri-food sector in the formation and implementation of regional development strategies. Of practical importance are the calculated changes in economic, social and environmental performance indicators of enterprises in the agri-food sector of Ukraine, which will positively affect the sustainable development of rural areas in the context of resource conservation.

***Key words**: Ecological Safety, Management, Resource Saving, Agri-food Enterprises, Methodology "Triad 6R".*

1. Introduction

Environmental safety and effective development of territories are priorities in world and regional politics. To achieve these goals, a necessary condition is to increase the efficiency of the activities of enterprises in the agri-food sector based on the principles of sustainable development. The main factor in increasing the efficiency of the functioning of enterprises in the agri-food sector is the development and implementation of a modern innovative economic model based on the principles of resource conservation. The problem of reducing the resource intensity of products of enterprises in the agri-food sector is the lack of effective management mechanisms for economical production and imperfection of existing methods for assessing the management effectiveness of resource-saving development of agri-food enterprises. Consequently, there is a need to develop scientific and practical provisions on the process of modeling the management of resource-saving development of enterprises in the agri-food sector. The above will allow interested stakeholders to obtain sufficiently complete and objective information about the functioning of the enterprise in the direction of using resources and will have a positive effect on the sustainable development of territories. The purpose of the study is to improve the methodology for assessing the management of resource-saving development of enterprises in the agri-food sector.

In the scientific literature, the issues of resource-saving development and its evaluation are reflected in the scientific works of scientists of the world scientific community. Moles [1], explored ensuring sustainable agricultural development through the economical use of limited agricultural resources in Sri Lanka. Gómez-Sal *et al.*, [2], raised the question of the methodology for assessing the technological process in agricultural landscape systems in the context of resource conservation and waste-free production. Foerstl *et al.*, [3], Ting [4], Bilgen and Sarikaya [5], Xu *et al.*, [6], Hnatenko *et al.*, [7], analyzed the influence of the external environment on resource conservation and sustainable development. The authors identify strategies to minimize the negative impact of industry on the natural environment. Williams [8], Chofreh *et al.*, [9], Lozhachevska *et al.*, [10], and Semenov *et al.*, [11], defined methods of modeling resource conservation are presented and ways of management of policy of economical use of natural resources. Kuzmicheva and Parakhin [12], considered the issues of resource conservation and increasing the competitiveness of crop production through innovative greening. In the work by Craheix *et al.*, [13], promising technologies for conservation of resources in agriculture are proposed and attention is focused on the need for their further assessment and improvement. Lieder and Rashi [14], Dobes *et al.*, [15], and Brüggemann *et al.*, [16], grouped a system of indicators to assess the efficiency of resource use in industry in order to ensure resource conservation and greening of production. Zaman [17], and Cunha *et al.*, [18], tested a holistic approach and methods of resource conservation in the context of ensuring environmental sustainability and waste-free production. In the work by Anjulo *et al.*, [19], the issue of the need to preserve biodiversity and land use of Ethiopia was raised; an assessment of the legislation and policy of the state in the direction of land use planning was presented. Gazzola *et al.*, [20], focused on the need to monitor social processes and the natural environment in the study of resource conservation or greening. Sudarkina [21], considered the models of resource conservation in agriculture, the concept of zero waste is developed, the basis of which is the modeling of zero waste from production. Wang *et al.*, [22], investigated the bibliometric analysis of ecological behavior of business entities in the direction of conservation and management of resources. The authors paid special attention to the methods of ecology management and ecosystem resource conservation. He *et al.*, [23], Özbuğday *et al.*, [24], and Mayovets *et al.*, [25], assessed the effectiveness of investment policy and investment decisions in the direction of ensuring energy efficiency and resource efficiency. In the research by Qin *et al.*, [26], the existing measures for the conservation of land and water resources in China are considered and the effectiveness of the investment policy aimed at agricultural production is assessed. Markina *et al.*, [27], substantiated the theoretical and methodological bases of using outsourcing as one of the most important directions of resource-saving development of agri-food enterprises. Zos-Kior *et al.*, [28], pointed out the need to intensify investment policy in the context of resource conservation and proposed modeling of the process of forming an investment program for agricultural cluster management. Rossokha *et al.*, [29],

and Mazur *et al*., [30], investigated the directions of improvement of management for resource-saving activities of enterprises. Despite the significant achievements of scientists, most enterprises in the agri-food sector have significant shortcomings regarding the formation of an effective management system for resource-saving development. The above stipulates the need to improve the assessment of the efficiency of management of resource-saving development of enterprises and methodological support of this direction of management activities. It is necessary to develop and test a methodological approach to the integral assessment of the economic (for each type of resource), social and environmental efficiency of management of resource-saving development of agri-food enterprises.

That's why, the purpose of the study is to improve the methodology for assessing the management of resource-saving development of enterprises in the agri-food sector.

2. Materials and Methods

In the process of the research, it was used the following methods: the methods of analysis of hierarchies, the modified main component, the faceted one - to improve the methodology for determining the efficiency of resource use and management of resource-saving development of enterprises in the agri-food sector. In order to objectively assess the management of resource-saving development of enterprises in the agri-food sector, a comprehensive assessment methodology "Triad 6R" has been developed, including quantitative and qualitative indicators of the economic, social and environmental efficiency of material, human, financial, intangible, informational and time resources. It is proposed to assess the effectiveness of resource-saving development management through the calculation of integrated indicators of economic, social and environmental subsets, within which the integrated indicators of efficiency of all types of resources are determined.

The author's methodology "Triad 6R" was tested at a group of enterprises in Poltava, Zaporizhzhia and Luhansk regions for the period 2010 - 2019. Using comparative, cluster analysis and grouping, an effective assessment of the effectiveness of resource-saving development of agri-food enterprises was conducted. Economic-statistical, tabular and graphical methods allowed to visually reflect the state and trends of management efficiency of resource-saving development of agri-food enterprises. The use of these methods allowed assessing the effectiveness of resource-saving development management of the enterprise on the basis of the concept of sustainable development.

3. Results and Discussion

To objectively assess the effectiveness of management of resource-saving development of agri-food enterprises based on the author's methodology "Triad 6R", we denote by X the set of all primary indicators selected to assess the effectiveness of resource-saving development of agri-food enterprises. This set can be represented as a combination of three subsets (1):

$$X = X_1 \cup X_2 \cup X_3 \quad (1)$$

Where: X_1 – a set of economic efficiency indicators, X_2 – set of social efficiency indicators, X_3 – a set of environmental performance indicators. Economic efficiency indicators can be divided into groups according to the type of resources used.

According to this division, the set X_1 is a union (2):

$$X_1 = \bigcup_{i=1}^{7} X_{1i} \quad (2)$$

Where: X_{11} - a set of indicators of efficiency of use of material resources, X_{12} - a set of indicators of human resource efficiency, X_{13} - a set of indicators of efficiency of financial resources use, X_{14} - a set of indicators of the effectiveness of the intangible assets use, X_{15} - a set of indicators of the effectiveness of the information resources use, X_{16} - a set of indicators of time use efficiency, X_{17} - a set of indicators of financing resource-saving measures.

This structure of the system of indicators makes it possible to comprehensively assess the effectiveness of resource-saving development management and is the basis for an integral assessment.

Let us introduce the notation for the primary indicators included in the sets X_1, X_2 and X_3. Let $X_{1i} = \{x_{1ij}\}_{j=1}^{m_i}$, where m_i - the number of indicators in the subset X_{1i}, $X_2 = \{x_{2j}\}_{j=1}^{n}$, where n - the number of indicators in the subset X_2, $X_3 = \{x_{3j}\}_{j=1}^{r}$, and where r - the number of indicators in the subset X_3. Then there is equality $X = \left\{\{x_{1ij}\}_{j=1}^{m_i}\right\}_{i=1}^{n} \cup \{x_{2j}\}_{j=1}^{n} \cup \{x_{3j}\}_{j=1}^{r}$. Within the set of economic efficiency of the use of material resources (X_{11}), a system of primary indicators is determined, including capital productivity, capital-to-labor ratio, fixed assets availability ratio, fixed assets retirement ratio, fixed assets profitability ratio, material efficiency, inventory turnover ratio, raw material waste ratio. For the purpose of an objective assessment within the set of economic efficiency of the use of human resources (X_{12}), primary indicators are identified that reflect the productivity of personnel, the utilization rate of labor resources, and the rate of staff turnover. Within the set of economic efficiency of the use of financial resources (X_{13}), a number of primary indicators-coefficients are determined: the economic efficiency of the use of financial resources, coverage, asset turnover, turnover of receivables and payables, equity capital turnover, autonomy, the ratio

of equity and debt capital, current liquidity, absolute liquidity, quick liquidity, provision with own circulating assets, maneuverability of own circulating assets. Within the set of economic efficiency of using intangible assets (X_{14}), the rate of disposal of intangible assets, the rate of renewal of intangible assets, the rate of return on intangible assets, and the rate of return on intangible assets are determined as primary indicators. For a set of primary indicators of the economic efficiency of the use of information resources (X_{15}), the following coefficients are identified: completeness of information, accuracy of information, inconsistency of information, timeliness of information provision, reliability, proprietary software, and proprietary hardware. In order to conduct an objective and comprehensive assessment within the set of economic efficiency of the use of time resources (X_{16}), the following coefficients are identified as primary indicators: the use of the working period, the use of downtime, the use of working time. Within the set of economic efficiency of financing resource-saving measures (X_{17}), the following primary coefficients are identified: financing of resource-saving development, resource-saving services, preservation of material, financial, human, intangible, information and time resources. To determine the integral assessment of the economic efficiency of resource-saving development of enterprises in the agro-food sector of Ukraine, it is necessary to calculate the integral estimates of the efficiency of using material, human, financial, intangible, information, time resources and indicators of financing resource-saving measures. We denote these estimates by v_1, v_2, v_3, v_4, v_5, v_6, v_7, respectively. The information basis for the determination of estimates v_i is the corresponding set of primary indicators $X_{1i} = \{x_{1ij}\}_{j=1}^{m_i}$. For the research, the values of these indicators were selected for the period of 2010-2019 for a group of agri-food enterprises of Poltava, Zaporizhzhia and Luhansk regions. We denote by $x_{1ij}(t, q)$ the indicator value x_{1ij} in t-th year in q region. The parameter t takes a value from t = 1 in 2010 to t = 10 in 2019. The parameter q takes a value q = 1 for Poltava region, q = 2 for Zaporizhzhia region, q = 3 for Luhansk region.

To obtain an integrated estimate, it is advisable to reduce the indicators x_{1ij} to a comparative form. To do this, it is necessary to replace them with the corresponding normalized indicators y_{1ij}, which are dimensionless and vary in the range from 0 to 1. For indicators-stimulators, that is, indicators whose increase corresponds to increasing resource efficiency, normalization is carried out on the basis of equality (3):

$$y_{1ij}(t,q) = \frac{x_{1ij}(t,q) - x_{1ij}^{min}}{x_{1ij}^{max} - x_{1ij}^{min}} \quad (3)$$

For indicators-destimulators, that is, indicators whose increase in values corresponds to a decrease in the efficiency of resource saving - on the basis of equality (4):

$$y_{1ij}(t,q) = \frac{x_{1ij}^{max} - x_{1ij}(t,q)}{x_{1ij}^{max} - x_{1ij}^{min}} \quad (4)$$

Where: $y_{1ij}(t,q)$ - normalized value of the primary indicator x_{1ij} in the t-th year for the q-th region, $x_{1ij}^{min} = \min_{t,q} x_{1ij}(t,q)$, $x_{1ij}^{max} = \max_{t,q} x_{1ij}(t,q)$

The integral estimate v_i, which corresponds to the subset X_{1i}, is defined by equality (5):

$$v_i(t,q) = \sum_{J=1}^{m_i} a_{ij} y_{1ij}(t,q) \quad (5)$$

Where: $v_i(t,r)$ - integral assessment value v_i for q-th region in the t-th year, $y_{1ij}(t,r)$ - normalized value of the primary indicator x_{1ij} for the q-th region in the t-th year, a_{ij} - weighting factor of the indicator x_{1ij}, m_i - the number of indicators in the set X_{1i}.

Therefore, to calculate the integrated assessment, it is necessary to determine the weighting factors a_{ij}.

To determine these coefficients, it is advisable to use the modified principal component method. This method is based on the study of statistical relationships between indicators. The covariance matrix K_{1i} of the normalized indicators y_{1ij} is determined, elements of which are the coefficients of covariance between these indicators. Next, the maximum eigenvalue λ_i^{max} of this matrix and the eigenvector corresponding to this value A_i should be determined. Weighting factors a_{ij} in the integral assessment V_i are chosen proportional to the squares of the components of this eigenvector.

Table 1. Covariance matrix of normalized indicators of economic efficiency of the material resources use, determined by the method of the modified principal component

	y_{111}	y_{112}	y_{113}	y_{114}	y_{115}	y_{116}	y_{117}	y_{118}
y_{111}	0.0656	-0.0687	0.0354	-0.0225	0.0284	-0.0278	0.0449	-0.0212
y_{112}	-0.0687	0.1007	-0.0447	0.0560	-0.0505	0.0367	-0.0679	0.0494
y_{113}	0.0354	-0.0447	0.0615	-0.0357	0.0313	0.0004	0.0308	-0.0127
y_{114}	-0.0225	0.0560	-0.0357	0.0889	-0.0394	0.0284	-0.0523	0.0423
y_{115}	0.0284	-0.0505	0.0313	-0.0394	0.0552	-0.0139	0.0484	-0.0319
y_{116}	-0.0278	0.0366	0.0004	0.0284	-0.0139	0.0669	-0.0337	0.0286
y_{117}	0.0449	-0.0679	0.0308	-0.0523	0.0484	-0.0337	0.0666	-0.0463
y_{118}	-0.0212	0.0494	-0.0127	0.0423	-0.0319	0.0286	-0.0463	0.0561

Source: calculated by the authors.

To assess the indicators of the set $X_{11,}$ the covariance matrix of normalized indicators of the efficiency of the material resources use was determined (Table 1).

Weighting factors are given in Table 2.

Table 2. Weighting factors of primary indicators in the integral assessment of the economic efficiency of the material resources use

Normalized indicator	Primary indicator	Weighting factor a_{1j}
y_{111}	Return on assets	0.110956
y_{112}	Capital-labor ratio	0.255935
y_{113}	Fixed asset usability ratio	0.068854
y_{114}	Fixed asset disposal rate	0.148225
y_{115}	Profitability ratio of fixed assets	0.099162
y_{116}	Material efficiency	0.055507
y_{117}	Inventory turnover ratio	0.169744
y_{118}	Waste-free ratio of raw materials	0.091627

Source: calculated by the authors.

An integral assessment of the efficiency of the material resources use is determined by the equality: $v_1 = 0.110956\, y_{111} + 0.255935\, y_{112} + 0.068854\, y_{113} + 0.148225\, y_{114} + 0.099162\, y_{115} + 0.055507\, y_{116} + 0.169744\, y_{117} + 0.091627\, y_{118}$. A similar algorithm determines the covariance matrices of normalized indicators and weighting factors of primary indicators to assess the efficiency of human resources, financial resources, use of intangible resources, information resources, time resources, financing of resource-saving measures. Based on the results of these actions, it was established that the integral assessment of the effectiveness of the use of human resources is determined by the equality: $v_2 = 0.375034\, y_{121} + 0.374667\, y_{122} + 0.2502\, y_{123}$. From this equality, we can conclude that the greatest impact on the overall result of the integral indicator has the productivity of staff, the utilization rate of labor resources is slightly less significant, and the employee turnover rate has the least impact.

According to the calculations, the integral assessment of the efficiency of the use of financial resources is determined by the equality: $v_3 = 0.045625\, y_{131} + 0.193248\, y_{132} + 0.043472\, y_{133} + 0.025889\, y_{134} + 0.025408\, y_{135} + 0.042148\, y_{136} + 0.236099\, y_{137} + 0.113098\, y_{138} + 0.159201\, y_{139} + 0.058081\, y_{1310} + 0.014714\, y_{1311} + 0.038888\, y_{1312} + 0.004212\, y_{1313}$. Based on the calculations, it can be concluded that the autonomy coefficient has the greatest impact on the integral indicator of the efficiency of the financial resources use. An integral assessment of the efficiency of using intangible resources is determined by the equality: $v_4 = 0.244926\, y_{141} + 0.437053\, y_{142} + 0.073116\, y_{143} + 0.244926\, y_{144}$. Thus, on the basis of the calculations, it was determined that the coefficient of renewal of intangible assets has the greatest impact on the overall result of the efficiency of using intangible resources. On the basis of the calculations, it was determined that the integral assessment of the efficiency of using information resources is determined by the equality: $v_5 = 0.12243\, y_{151} + 0.280688\, y_{152} + 0.0000012\, y_{153} + 0.228293\, y_{154} + 0.125104\, y_{155} + 0.140175\, y_{156} + 0.103234\, y_{157}$. An integral assessment of the efficiency of using time resources is determined by the equality: $v_6 = 0.111111\, y_{161} + 0.5776\, y_{162} + 0.147929\, y_{163.}$ Based on the calculations of the weighting factors, it was determined that the downtime utilization rate has the greatest impact on the integral indicator of the efficiency of the use of time resources. An integral assessment of the effectiveness of financing resource-saving measures is determined by the equality: $v_7 = 0.112829\, y_{171} + 0.118749\, y_{172} + 0.076342\, y_{173} + 0.129528\, y_{174} + 0.224108\, y_{175} + 0.094495\, y_{176} + 0.075955\, y_{177} + 0.167936\, y_{178}$.

After determining the integral assessment of indicators of the effectiveness of the use of material, human, financial, intangible, information, time resources and financing of resource-saving measures, it is necessary to determine an integral assessment of the economic efficiency of the resource-saving development management of the enterprise w_1. This assessment is determined by equality (6):

$$w_1(t,q) = \sum_{i=1}^{7} \beta_i v_i(t,q) \qquad (6)$$

Where: $v_i(t,q)$ - integral assessment value v_i in the t-th year for the q-th region, β_i - weighting factor v_i in the overall integral assessment w_1 of the economic efficiency of resource-saving development management of enterprises in the agri-food sector of Ukraine.

Weighting factors β_i determined by the method of the modified principal component. Covariance matrix K_1 of integral assessments v_i is shown in Table 3.

The weighting factors β_i of assessments v_i in the integral assessment w_1 are proportional to the components of the eigenvector of this matrix corresponding to its maximum eigenvalue. The values of these factors are given in Table 4.

Integral assessment of economic efficiency of resource-saving development management of enterprises of agri-food sphere of Ukraine is determined by equality: $w_1 = 0.011664\, v_1 + 0.06833\, v_2 + 0.000502\, v_3 + 0.033416\, v_4 + 0.279524\, v_5 + 0.231746\, v_6 + 0.374789\, v_7$.

Table 3. Covariance matrix of integral assessments of the economic efficiency of resource-saving development management of enterprises in the agri-food sector of Ukraine, determined by the method of the modified principal component

	v_1	v_2	v_3	v_4	v_5	v_6	v_7
v_1	0.004994	0.00552	-0.00187	0.004543	0.006237	0.006044	0.009303
v_2	0.00552	0.036139	0.015349	0.015796	0.02361	0.01289	0.006201
v_3	-0.00187	0.015349	0.033418	0.000822	0.01382	0.009983	-0.01062
v_4	0.004543	0.015796	0.000822	0.021023	0.010691	0.006514	0.01239
v_5	0.006237	0.02361	0.01382	0.010691	0.045535	0.03821	0.033483
v_6	0.006044	0.01289	0.009983	0.006514	0.03821	0.040128	0.033694
v_7	0.009303	0.006201	-0.01062	0.01239	0.033483	0.033694	0.07274

Source: calculated by the authors.

Table 4. Weighting factors of assessments vi in the integral assessment w1 of the economic efficiency of resource-saving development management of enterprises in the agri-food sector of Ukraine

Assessment, v_i	Economic content of the assessment, v_i	Weighting factor, β_i
v_1	Integral assessment of the material resources efficiency	0.011664
v_2	Integrated assessment of the human resource efficiency	0.06833
v_3	Integral assessment of the financial resources efficiency	0.000502
v_4	Integral assessment of the efficiency of using intangible assets	0.033416
v_5	Integral assessment of the efficiency of using information resources	0.279524
v_6	Integral assessment of the time resources efficiency	0.231746
v_7	Integral assessment of financing resource-saving measures	0.374789

Source: calculated by the authors.

To assess the overall efficiency of resource-saving development management of enterprises in the agri-food sector of Ukraine, not only the economic component is important, but also the social one. In order to determine the integral indicator of the social efficiency of resource-saving development management of the enterprise within the subset (X_2), a system of primary indicators was formed, namely the coefficients: industrial injuries, satisfaction with working conditions, assessment of satisfaction with management, assessment of the psychological climate in the team, assessment of satisfaction with the content of development, development of the business qualities of employees and personal potential, the formation of the value-orientational unity of the team, the growth rate of the average wage, positive feedback from consumers.

The next step is to determine an integral assessment of the social efficiency of resource-saving development management of enterprises in the agri-food sector w_2. The information basis for determining this assessment is a set of primary indicators $X_2 = \{x_{2j}\}_{j=1}^{n}$. We denote by $x_{2j}(t, q)$ indicator value x_{2j} in the t-th year in the region q. To obtain an integral assessment, we replace the indicators x_{2j} with the normalized indicators y_{2j} in the same way as it was done for the indicators of economic efficiency.

The integral assessment w_2, which corresponds to the subset X_2, is determined by equality (7):

$$w_2(t,q) = \sum_{j=1}^{n} \gamma_j y_{2j}(t,q) \qquad (7)$$

Where: $w_2(t,r)$ - integral assessment value w_2 for the q-th region in the t-th year, $y_{2j}(t,r)$ - normalized value of the primary indicator x_{2j} for the q-th region in the t-th year, γ_j - weighting factor of the indicator x_{2j}, n - the number of indicators in the set X_2 (n = 10).

Weighting factors γ_j are determined by the modified principal component method using the covariance matrix of normalized indicators of social efficiency. Then the integral assessment of the social efficiency of resource-saving development management of enterprises in the agri-food sector is determined by the equality: $w_2 = 0.036749\, y_{21} + 0.095357\, y_{22} + 0.10765\, y_{23} + 0.130032\, y_{24} + 0.135277\, y_{25} + 0.135792\, y_{26} + 0.096038\, y_{27} + 0.120201\, y_{28} + 0.001568\, y_{29} + 0.141301\, y_{210}$. For the purpose of an objective comprehensive assessment of the environmental efficiency of resource-saving development management of enterprises in the agri-food sector of Ukraine, a system of primary indicators was formed, namely the coefficients: natural intensity, ecological content, resource intensity of the process, environmental friendliness of the facility, environmental friendliness of production.

At the next stage of the study, it is necessary to determine an integral assessment of the environmental efficiency of resource-saving development management of agricultural enterprises w_3. The information basis for determining this assessment is a set of primary indicators $X_3 = \{x_{3j}\}_{j=1}^{r}$. We denote by $x_{3j}(t, q)$ indicator value x_{2j} in the t-th year in the region q. To obtain an integral assessment, we replace the indicators x_{3j} with the normalized indicators y_{3j} in the same way as it was done for the indicators of economic and social efficiency.

The integral assessment w_3, which corresponds to the subset X_3, is determined by equality (8):

$$w_3(t,q) = \sum_{j=1}^{r} \delta_j y_{3j}(t,q) \quad (8)$$

Where: $w_3(t,r)$ - integral assessment value w_3 for the q-th region in the t-th year, $y_{3j}(t,r)$ - normalized value of the primary indicator x_{3j} for the q-th region in the t-th year, δ_j - weighting factor of the indicator x_{3j}, r - the number of indicators in the set X_3 (r = 5).

Weighting factors δ_j are determined by the modified principal component method using the covariance matrix of normalized environmental performance indicators. Then, the integral assessment of the environmental efficiency of resource-saving development management of enterprises in the agri-food sector is determined by the equality: $w_3 = 0.187402\, y_{31} + 0.008798\, y_{32} + 0.414221\, y_{33} + 0.222218\, y_{34} + 0.167363\, y_{35}$.

An integral assessment of the efficiency of resource-saving development management of enterprises in the agri-food sector, including the economic, social and environmental components, is determined by the equality (9):

$$W(t,q) = \sum_{k=1}^{3} \lambda_k w_k(t,q) \quad (9)$$

Where: the weighting factors λ_k are determined by the modified principal component method.

In this case, the covariance matrix K of integral assessments w_k has the following form (Table 5).

Table 5. Covariance matrix of integral assessments of resource-saving development management of the enterprises, determined by the method of the modified principal component

	w_1	w_2	w_3
w_1	0.036423	0.016796	0.023235
w_2	0.016796	0.051404	0.024867
w_3	0.023235	0.024867	0.059847

Source: calculated by the authors

Weighting factors λ_k of the assessments w_k in the integral assessment W are proportional to the components of the eigenvector of this matrix corresponding to its maximum eigenvalue. The values of these factors are given in Table. 6.

Table 6. Weighting factors of the assessments w_kin the integral assessment of the efficiency of resource-saving development management of enterprises in the agri-food sector of Ukraine

Assessment, w_k	Economic content of the assessment, v_i	Weighting factor, λ_k
w_1	Integral assessment of economic efficiency	0.193512
w_2	Integral assessment of social efficiency	0.322738
w_3	Integral assessment of environmental efficiency	0.48372

Source: calculated by the authors.

Thus, the integral assessment of the efficiency of resource-saving development management of enterprises in the agri-food sector of Ukraine is determined by the equality: $W = 0.193512\, w_1 + 0.322738\, w_2 + 0.48372\, w_3$.

On the basis of the obtained equalities, integral assessments of the efficiency of resource-saving development management of agri-food enterprises and private integral assessments corresponding to economic, social and environmental efficiency were calculated. For a group of enterprises in Poltava region, they are given in Table 7, Zaporizhzhia region - in Table 8, Luhansk region - in Table 9.

Table 7. Integral assessments of the efficiency of resource-saving development management of the group of enterprises of agri-food sector of Poltava region during 2010 - 2019

Indicators	Years									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Assessment of economic efficiency	0.6028	0.5837	0.6623	0.7205	0.6901	0.7112	0.7072	0.7983	0.8216	0.8447
Assessment of social efficiency	0.5433	0.6732	0.6650	0.7582	0.7924	0.8563	0.8754	0.8852	0.9391	0.9705
Assessment of environmental efficiency	0.2572	0.2430	0.2425	0.4177	0.2413	0.5529	0.4900	0.6544	0.7430	0.8864
Integral assessment	0.4164	0.4477	0.4601	0.5862	0.5060	0.6814	0.6564	0.7567	0.8215	0.9054

Source: calculated by the authors.

Table 8. Integral assessments of the efficiency of resource-saving development management of a group of enterprises in the agri-food sector of Zaporizhzhia region during 2010 - 2019

Indicators	Years									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Assessment of economic efficiency	0.1227	0.1501	0.1696	0.2049	0.2971	0.4164	0.4154	0.5149	0.5801	0.5191
Assessment of social efficiency	0.5376	0.5554	0.6297	0.6077	0.7713	0.7888	0.8319	0.8502	0.8893	0.9066
Assessment of environmental efficiency	0.1850	0.1454	0.3520	0.3678	0.3036	0.6007	0.6011	0.5508	0.7627	0.8941
Integral assessment	0.2868	0.2786	0.4063	0.4137	0.4533	0.6257	0.6397	0.6405	0.7682	0.8256

Source: calculated by the authors.

Table 9. Integral assessments of the efficiency of resource-saving development management of a group of enterprises in the agri-food sector of Luhansk region during 2010 - 2019

Indicators	Years									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Assessment of economic efficiency	0.4328	0.4124	0.4847	0.5086	0.4838	0.5187	0.5166	0.6167	0.6091	0.6508
Assessment of social efficiency	0.2229	0.3549	0.3294	0.0604	0.3082	0.4946	0.5145	0.5052	0.5667	0.5902
Assessment of environmental efficiency	0.2453	0.2340	0.2365	0.4147	0.2412	0.6563	0.5811	0.7607	0.8522	0.9956
Integral assessment	0.2743	0.3076	0.3145	0.3185	0.3097	0.5775	0.5471	0.6504	0.7130	0.7980

Source: calculated by the authors.

The dynamics of the integral assessment of the management efficiency of resource-saving development of an agri-food enterprises group in Poltava, Zaporizhzhia and Luhansk regions during 2010 - 2019 is reflected in Figure 1.

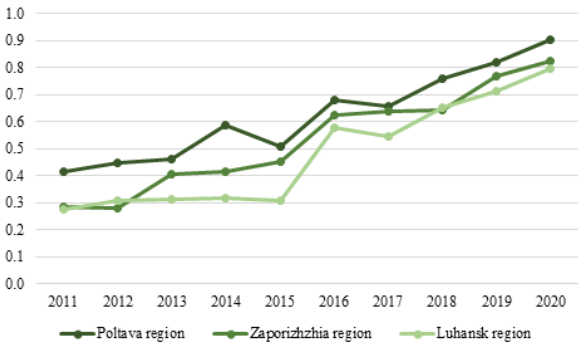

Figure 3. Dynamics of the integral indicator of the management efficiency of resource-saving development of enterprises in the agri-food sector of Ukraine during 2010 - 2019
Source: calculated by the authors

As a result of calculation of the integral indicators the management efficiency of resource-saving development, it was defined that the specified enterprises had the highest values of the integral indicators in 2019. The highest integral indicators are observed in the group of enterprises of Poltava region during the whole period under study; the integral indicator of resource efficiency management of the group of enterprises of Luhansk region was mostly less than this value for the group of enterprises of Zaporizhzhia region during 2012 - 2016. However, in subsequent years, the integral indicator of efficiency for enterprises in Zaporizhzhia and Luhansk regions was practically at the same level.

4. Conclusions

- An important result of the management of resource-saving development of the enterprise is the presence of a culture of resource-saving, which has a positive effect not only on the activities of the enterprise, but also ensures environmental safety at the macro level. In modern economic conditions, the project approach is of particular importance.
- Consequently, in order to objectively and comprehensively assess the management of resource-saving development of enterprises in the agro-food sector of Ukraine, it is advisable to use the method of calculating the integral indicator.
- As a result of approbation of the proposed assessment method, it was revealed that the group of enterprises of Poltava region has the highest indicator of the efficiency of resource-saving development management, and the lowest indicators during the study period are observed at enterprises of Luhansk

region, however, during 2017-2019, there is a tendency to a rapid increase.

- In order to make effective management decisions to ensure the effective use of all types of resources in the enterprise, it is important to have information not only about the current state, but also about the probable value of these indicators in the next period. The proposed methodology "Triad 6R" will allow timely assessing the efficiency of using the resources of an enterprise and planning promising activities in the context of greening production.

5. References

[1] Moles J. (1992). *A synthetic approach to sustainable agriculture and resource conservation*. Agriculture and Human Values, 9, pp. 64-71.

[2] Gómez-Sal A., Belmontes J. A., Nicolau J. M. (2003). *Assessing landscape values: a proposal for a multidimensional conceptual model*. Ecological modelling, 168, (3), pp. 319-341.

[3] Foerstl K., Reuter C., Hartmann E., Blom C. (2010). *Managing supplier sustainability risks in a dynamically changing environment - Sustainable supplier management in the chemical industry*. Journal of Purchasing and Supply Management, 16, (2), pp.118-130.

[4] Ting G. (2011). *Researches of developing strategies and guarantee mechanism of energy saving and emission reduction on paper-making enterprises - Case study of Shandong Haiyun high-efficiency ecological park*. Energy Procedia, 5, pp. 674-678.

[5] Bilgen S., Sarıkaya I. (2015). *Exergy for environment, ecology and sustainable development*. Renewable and Sustainable Energy Reviews, 51, pp. 1115-1131.

[6] Xu Y., Wang Z., Chiu Y. H., Ren F. (2020). *Research on energy-saving and emissions reduction efficiency in Chinese thermal power companies*. Energy and Environment, 31, (5), pp. 903-919.

[7] Hnatenko I., Shtuler I., Romashko O., Rubezhanska V., Bulkot G., Bugay N. (2021). *The innovative potential of agro-processing enterprises in the context of resource conservation and crisis management*. Journal of Hygienic Engineering and Design, 35, pp. 61-66.

[8] Williams B. K. (2011). *Adaptive management of natural resources – Framework and issues*. Journal of environmental management, 92, (5), pp. 1346-1353.

[9] Chofreh A. G., Goni F. A., Klemeš J. J. (2017). *Development of a roadmap for Sustainable Enterprise Resource Planning systems implementation (part II)*. Journal of cleaner production, 166, pp. 425-437.

[10] Lozhachevska O., Navrotska T., Melnyk O., Kapinus L., Zos-Kior M., Hnatenko I. (2021). *Management of logistics and marketing behavior of innovation clusters in territorial communities in the context of digitalization of society and the online market*. Laplage em Revista, 7, (3), pp. 315-323.

[11] Semenov A., Kuksa I., Hnatenko I., Sazonova T., Babiy L., Rubezhanska V. (2021). *Management of Energy and Resource - Saving Innovation Projects at Agri-Food Enterprises*. TEM Journal, 10, (2), pp. 751-756.

[12] Kuzmicheva Y., Parakhin N. (2014). *Use of biological factors in increasing efficiency of resource conservation and crop production stability*. Vestnik OrelGAU, 49, pp. 3-6.

[13] Craheix D., Angevin F., Doré T., Tourdonnet S. (2016). *Using a multicriteria assessment model to evaluate the sustainability of conservation agriculture at the cropping system level in France*. European Journal of Agronomy, 76, pp. 75-86.

[14] Lieder M., Rashid A. (2016). *Towards circular economy implementation: a comprehensive review in context of manufacturing industry*. Journal of cleaner production, 115, pp. 36-51.

[15] Dobes V., Fresner J., Krenn C., Růžička P., Rinaldi C., Cortesi S., Chiavetta C., Zilahy G., Kochański M., Grevenstette P., Graaf D., Dorer C. (2017). *Analysis and exploitation of resource efficiency potentials in industrial small and medium-sized enterprises - Experiences with the EDIT Value Tool in Central Europe*. Journal of Cleaner Production, 159, pp. 290-300.

[16] Brüggemann H., Stempin S., Meier J. (2020). *Consideration of digitalization for the purpose of resource efficiency in a learning factory*. Procedia Manufacturing, 45, pp. 140-145.

[17] Zaman A. U. (2016). *A comprehensive study of the environmental and economic benefits of resource recovery from global waste management systems*. Journal of cleaner production, 124, pp. 41-50.

[18] Cunha P., Neves S., Marques A., Serrasqueiro Z. (2020). *Adoption of energy efficiency measures in the buildings of micro-, small- and medium-sized Portuguese enterprises*. Energy Policy, 146. <URL: https://doi.org/10.1016/j.enpol.2020.111776. Accessed 8 March 2021.

[19] Anjulo A., Chauhan R., Hooda M. (2016). *Bio-resource Conservation and Land Use in Ethiopia*. International Journal of Economic Plants, 3, (1), pp. 38-43.

[20] Gazzola P., Campo A., Onyango V. (2019). *Going green vs going smart for sustainable development: Quo vadis?*. Journal of cleaner production, 214, pp. 881-892.

[21] Sudarkina L. (2019). *Prerequisites for developing a system of resource conservation management in agriculture*. Problems of systemic approach in the economy, 6, (74), pp. 141-148.

[22] Wang F., Peng X., Wei R., Qin Y., and Zhu X. (2019). *Environmental behavior research in resources conservation and management: A case study of Resources, Conservation and Recycling*. Resources, Conservation and Recycling, 141, pp. 431-440.

[23] He Y., Liao N., Bi J., and Guo L. (2019). *Investment decision-making optimization of energy efficiency retrofit measures in multiple buildings under financing budgetary restraint*. Journal of cleaner production, 215, pp. 1078-1094.

[24] Özbuğday F., Findik D., Özcan K., and Başçı S. (2020). *Resource efficiency investments and firm performance: Evidence from European SMEs*. Journal of Cleaner Production, 252. <URL:https://doi.org/10.1016/j.jclepro.2019.119824. Accessed 8 May 2021.

[25] Mayovets Y., Vdovenko N., Shevchuk H., Zos-Kior M., Hnatenko I. (2021). *Simulation modeling of the financial risk of bankruptcy of agricultural enterprises in the context of COVID-19*. Journal of Hygienic Engineering and Design, 36, pp. 192-198.

[26] Qin C., Tang Z., Chen J., and Chen X. (2020). *The impact of soil and water resource conservation on agricultural production - An analysis of the agricultural production performance in Zhejiang, China.* Agricultural Water Management, 240. <URL:https://doi.org/10.1016/j.agwat.2020.106268. Accessed 8 May 2021.

[27] Markina I., Lopushynska O., Lopushynskyi Y. (2020). *Outsourcing of business processes as a mechanism of resource-saving development management of agri-food enterprises.* International Humanitarian University Herald Economics and Management, 45, pp. 74-78.

[28] Zos-Kior M., Shkurupii O., Hnatenko I., Fedirets O., Shulzhenko I., Rubezhanska V. (2021). *Modeling of the Investment Program Formation Process of Ecological Management of the Agrarian Cluster*. European Journal of Sustainable Development, 10, (1), pp. 571.

[29] Rossokha V., Mykhaylov S., Bolshaia O., Diukariev D., Galtsova O., Trokhymets O., Ilin V., Zos-Kior M., Hnatenko I., Rubezhanska V. (2021). *Management of simultaneous strategizing of innovative projects of agricultural enterprises responsive to risks, outsourcing and competition.* Journal of Hygienic Engineering and Design, 36, pp. 199-205.

[30] Mazur N., Khrystenko L., Pásztorová J., Zos-Kior M., Hnatenko I., Puzyrova P., Rubezhanska V. (2021). *Improvement of Controlling in the Financial Management of Enterprises.* TEM Journal, 10, (4), pp. 1605-1609.