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Article

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INNOVATIVE MANAGEMENT OF BIOMASS COST VALUES BASED ON ACCOUNTING AND ANALYSIS OF PRODUCTION COSTS OF AGRICULTURAL ACTIVITIES

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Abstract: *The newest directions for evaluating the ecological and economic behaviour of agricultural enterprises involve the full use of by products, such as biomass. The main items of biomass costing (for the example of baled corn) are identified: the cost of corn waste in the field, the cost of twine for forming bales, the cost of fuel and lubricants, wages and social contributions, the cost of operation and depreciation of agricultural machinery, and other production and logistics costs. Based on the study of the structure of production costs that form the cost of biomass, it was found that the main share is made up of labour costs. With the purpose of complex optimization of the operating costs of agricultural activities, the necessity of introducing an innovative biomass cost management system based on automated accounting and analysis with the use of global positioning technologies, aerial monitoring with the help of drones, and the Internet of Things has been proven. The use of technologies for collecting and processing accounting information on agricultural activities for the formation of information arrays on the planned volume of harvested crops, salaries of operating personnel, fuel and lubricants, equipment depreciation and the need for routine maintenance of agricultural machinery, as well as additional operating and transportation costs, has been proposed. An innovative analytical model has been developed to study the impact of agricultural conditions (harvest volume, average wage of a production worker, distance from fields to storage or processing facilities, level of logistics organization, quality of agricultural products, level of use of the latest agricultural technologies and agricultural machinery) on production costs, which is the basis for operational and predictive innovative management of biomass costs. The innovation of the model lies in the use of linguistic variables,* i.e., *factors that are not quantifiable but can be economically evaluated. For the practical implementation of an innovative biomass cost management system, the use of the information scheme, which includes all the information components, on the basis of which managers develop and offer the best management solutions to minimize the cost of biomass, has been proposed. The need to reflect accounting and analytical information on the cost of biomass in integrated reporting (sustainability reporting) to inform internal and external stakeholders about the formation and use of alternative energy sources determines the prospects for further research in this area.*
Keywords: innovative management; biomass cost; agricultural activities; accounting; analysis; operating costs.

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1. Introduction. The cost of production is one of the key indicators of a business entity's performance since its size directly affects the company's profit. Cost management requires the search for innovative approaches and the organization of activities in such a way as to maximize the efficient use of financial, material, labor and other available resources. The cost price directly affects the pricing policy of the enterprise, i.e., the price paid by the end consumer. If a product is of global importance, i.e., if it is necessary and useful for all members of society, if it has a positive impact on the environment and helps to solve primary needs, then cost management at the micro level will have a global effect. Guided by this principle, the object of the present research is to account for and analyse biomass production as an alternative renewable energy source. Innovative approaches to managing its value will reduce the price of electricity generated from biomass and enable the widespread use of biofuels. Activation of the popularity of renewable energy sources (RES) in the world is driven by the situation caused by the difficult economic consequences of the pandemic and the results of one of the worst energy crises in decades, which was caused by the military events in Ukraine. In addition, the global climate scenario reflects a negative situation: abnormal heatwaves in Europe, drought in Africa, and large-scale flooding in Pakistan and Libya (Brych et al., 2023). In March 2023, the Intergovernmental Panel on Climate Change (IPCC) published a report emphasizing the urgent need to develop current steps and long-term strategies for the transition to renewable energy sources in all sectors (IPCC, 2023). The International Renewable Energy Agency responded to the call in its report "World Energy Outlook 2023: the path to 1.5°C" published in June 2023 (IRENA, 2023b), where it substantiates the key role of bioenergy in the implementation of a positive climate scenario. In particular, the report highlights the high potential for replacing traditional fossil fuels in all priority energy sectors (industry, construction, and transportation) worldwide. Corn is one of the most popular sources of biomass, as all parts of the plant are used to produce bioenergy products:

- grain – as a raw material for the production of first-generation bioethanol;
- stem, stalk (vore), leaves, wrapper – as a raw material for the production of biogas, second-generation bioethanol and solid biofuels (pellets and briquettes) (UABIO, 2022).

Compared with other types of agricultural biomass, large volumes of corn produced worldwide and with high fuel characteristics (UABIO, 2022) create an opportunity to introduce innovative technologies for harvesting by products of this energy crop. The production of solid biofuels from corn by products is economically and technically feasible. In particular, one of the leading technologies is harvesting corn residues into bales. The formation of its cost depends on a number of factors, the regulation of which will minimize the costs associated with the harvesting of this type of biomass and, as a result, affect the price of electricity for the end consumer.

The purpose of this study was to improve the accounting and analysis of the cost of rectangular bales made of corn by products as solid biofuels for the creation of innovative approaches to managing the cost of biomass. The main objectives of the article are to substantiate the structure of costs by cost items for harvesting and logistics of baled corn; identify priority factors influencing cost (quantitative and qualitative); build an innovative model of biomass cost management depending on factors that can be adjusted at the enterprise level; and develop an information scheme of innovative management for providing recommendations concerning the minimization of the cost of obtaining rectangular bales of corn by products. The results of this study may be useful for managers of agricultural enterprises making decisions on regulating the cost of biomass as an alternative energy source, accounting scientists as a basis for developing a biomass accounting methodology, and people interested in the concept of smart consumption for understanding the impact of microeconomics on the environment and climate in a global sense.

2. Literature Review. The pace of renewable energy use in the world has accelerated significantly in recent years (Figure 1). Austria, Sweden, and Denmark have the largest shares of renewable energy in the overall consumption structure. Bioenergy is a common priority for these countries. Sweden and Austria actively use hydropower, while Denmark prefers wind power (Eurostat, 2022). There are many planned or already implemented projects around the world with partial or complete transitions to renewable energy. The most well-known projects planned at both the country and city levels are the following:

- Denmark plans to achieve 100% heat and electricity production from renewable sources by 2035 and 100% energy from renewable sources in all sectors by 2050.
- In addition, 100% of the electricity and 85% of the heat generated from renewable energy sources (RES) has already been generated in Iceland.
- Costa Rica has been covering 100% of its electricity needs from RES since 2015. The plan is to achieve full decarbonization by 2030.

– Saudi Arabia has a strategy to completely abandon fossil fuels by 2040 and replace them with renewable energy sources.

– The Uruguayan government has made an official statement that 94.5% of the country's electricity needs are covered by renewable sources. The goal is to reduce carbon emissions by 88% compared to the average in previous years and achieve full decarbonization by 2030.

– Some U.S. cities (Burlington, Aspen, and Vermont) fully use renewable energy. The cities of San Francisco, Ithaca, Palo Alto, San Jose, San Diego, Georgetown, and Greensburg also follow a strategy of transition to renewable energy.

– Vancouver (Canada): In 2015, commitments were made to switch to 100% with RES.

– Frankfurt (Germany): Full decarbonization of the city is planned by 2050 through alternative automotive fuels and RES.

– Copenhagen (Denmark): The goal is to achieve 100% heat and electricity production from renewable sources by 2035 and 100% energy from RESs in all sectors by 2050. Currently, 98% of the population uses heat from biomass.

– Munich (Germany): the goal is 100% of electricity from RESs for all consumers by 2025.

– Sydney (Australia): The goal is to produce 100% of the electricity, heat and cooling from RESs by 2030 (IRENA, 2023a).

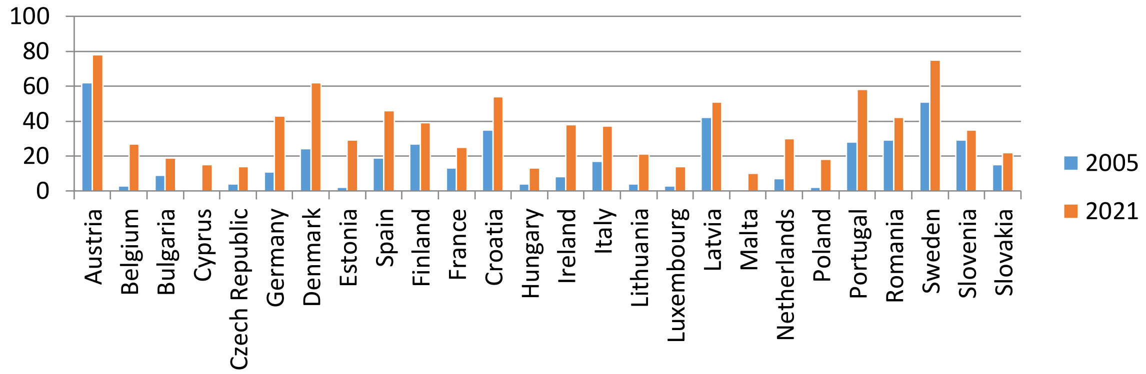

Figure 1. Share of renewable sources in total electricity consumption in EU countries (%)
Sources: developed by the authors based on (Eurostat, 2022).

In addition to countries and cities, the following world-famous brands have also joined the strategy of transition to renewable energy: Google, Microsoft, IKEA, Virgin Group, Johnson & Johnson, Nike, Voya Financial and Walmart, Apple, Facebook, RWE, Procter & Gamble, Starbucks, E. ON, and others. They plan to meet their energy needs in all areas of their business only through the use of renewable sources. An increase in investment in innovative technologies for the collection and use of such a source of renewable energy as biomass is observed. In particular, in 2022, 36 billion gallons of biomass fuel were produced compared to 2008, when this figure was only 9 billion gallons (Eurostat, 2022). Concerning the biomass types, there has been a slight decrease in liquid biofuels, biogas, and municipal waste over the past two years, mainly due to the economic impact of the COVID-19 pandemic (Borysiak et al., 2022). However, there was an exception for solid biomass. After a slight decrease in capacity between 2019 and 2020 (-130 MW or -0.8%), capacity started to increase again between 2020 and 2021 and reached the highest level ever recorded (+209 MW or +1.3%) (IRENA, 2023a). The actuality of implementing innovative technologies for the production and use of biomass as one of the most widely used sources of renewable energy is confirmed by the availability of a significant number of scientific papers on this topic. In particular, the scientific space includes research on the economic aspects of managing the bioenergy sector. For example, Kousar et al. (2023) identified and proposed ways to minimize transportation costs in the organization of biomass supply chains. In this respect, Nunes and Silva (2023) explained the impact of changing the sequence of biomass supply on the final cost of processing into a bioproduct. Instead, Fang et al. (2023) proposed analysing costs in the context of the life cycles of biomass production and use in bioenergy. Domingues et al. (2022) compared the cost of biomass in different countries, which made it possible to identify national characteristics and various factors that affect the operating costs of enterprises. Similar studies, but in the context of different types of biomass, were conducted by Dangprok et al. (2022), who explained the impact of biomass variation on the operating costs of bioenergy enterprises. Giakoumatos and Kopsidas (2023) investigated the cost-effectiveness of using biomass as an adsorbent for environmental clean up. Villasenor-Derbez et al. (2023) also worked in this direction, comparing the potential economic benefits of biomass processing with the operating costs of its production. Dangprok et al. (2023) developed a macroeconomic model for optimizing the costs of producing clean biomass bioenergy, taking into account its cost. However, reducing the cost of biomass production and processing, as shown by Walter Pinto-Neto et al. (2023), can lead to a loss of quality parameters. Therefore, it is important to develop optimization models that consider the cost and quality characteristics of biomass. The emergence of external environmental costs in biomass production was explained by Olba-Zięty et al. (2023) as an opposite reaction against the legal and political features of agricultural production.

The economic aspects of biomass production and processing, justifying its cost, are the subject of active scientific research by scientists only during the current time period (2022-2023). However, the issue of managing the cost of biomass at the micro level and identifying the factors influencing it that are controlled by the enterprise to minimize operating costs for a product that is actively used in bioenergy remains unresolved. Insufficient attention has also been given to the accounting and analytical aspects of managing the cost of agricultural products, which determines the relevance of the topic of the article and allows us to formulate its purpose.

3. Methodology and research methods. The purpose of this study is to position the accounting and analysis system as an informational basis for the innovative management of biomass costs, which will lead to operational and predictive planning of management actions under the conditions of the use of the latest information and communication technologies. To achieve the formed tasks, the analytical methods of studying economic processes were used in the article. In particular, to determine the components (cost elements) of biomass cost formation, structural analysis was performed based on an empirical study of the activity of global agricultural holdings; to identify temporal tendencies in the cultivation of crops valuable for biomass production, a dynamic analysis of statistical information from open sources was used. Mathematical calculations and graphical visualization were performed using MS Excel spreadsheets. The article also develops an optimization function for determining the cost of biomass (baled corn), taking into account the influence of variable factors. To establish the dependence of the cost of biomass (baled corn) on the deparate factor, the following formula was used:

$$y(x_1, x_2, x_3, x_4, x_5, x_6, x_7) = \vec{\phi}^T(\vec{x}) * \vec{\beta}, \quad (1)$$

where $y(x_1, x_2, x_3, x_4, x_5, x_6, x_7)$ are the factors of influence; $\vec{\phi}^T(\vec{x})$ is a set of functions that indicate the structure of the model and the aggregate impact of factors on the cost; and $\vec{\beta}$ is a vector of unknown coefficients.

Thus, the formula has the following form:

$$\hat{y}(\vec{x}_k) = \vec{\phi}^T(\vec{x}_k) * \vec{b}, \quad (2)$$

where $\hat{y}(\vec{x}_k)$ is the modelled value of the cost price at the k-agricultural holding; $\vec{b}$ is the vector of measurement of the coefficients of the calculation model, which is calculated in such a way as to maximize the coordination of the given data with the predicted data using the factor of minimizing the standard deviation between them:

$$\sum_{K=1}^{N}(y_k - \vec{\phi}^T(\vec{x}_k) * \vec{b}) \xrightarrow{\vec{b}} \min, \quad (3)$$

The specified data are displayed in the following form:

$$\vec{x}_k \to y_k, K = 1, \ldots, n \quad (4)$$

The result of formula (3) is the unknown values of the coefficients in the form of finding the least squares method:

$$\vec{b} = (F^T * F)^{-1} * F^T * \vec{Y}, \quad (5)$$

$$\text{where } F^T = \begin{pmatrix} \phi_1(\vec{x}_1), \ldots, \phi_1(\vec{x}_k) \ldots \phi_1(\vec{x}_n) \\ \vdots \\ \vdots \\ \phi_m(\vec{x}_1), \ldots, \phi_m(\vec{x}_k) \ldots \phi_m(x_n) \end{pmatrix} \quad (6)$$

where F is a matrix of quantitative expressions of the basic functions for the given factors that affect the cost of production at the n- agricultural holding and Y is the vector of the cost received by the n- agricultural holding.

The significance of the coefficients was calculated with the help of Student's criterion:

$$t(b_j) = \frac{|b_j|}{S(b_j)}, \quad (7)$$

where $S^2(b_j)$ is the diagonal element of the covariance matrix.

The values of the calculated Student's criterion $t(b_j)$ were compared with the table coefficients for the determined probability α and the degree of freedom N-m. If the value $t(b_j)$ is less than the table value, then given the probability 1-α, we assume that the regression coefficient is close to zero and is not significant. To check the adequacy of the cost forecasting model, we used the coefficient of determination (R^2). A closeness of the coefficient to 1 means that the dependence is adequate. The coefficient of determination was calculated by the following formula:

$$R^2 = 1 - \frac{S^2}{S_y^2}, \quad (8)$$

where $S_y^2 = \frac{\sum_{k=1}^{N}(y_k - \frac{1}{N} * \sum_{k=1}^{N} y_i)}{n-1}$ is the dispersion of random cost values for each of the n- agricultural holdings.

The factors were averaged to reduce rounding errors in the calculation of regression coefficients via the following formula:

$$\tilde{X}_i = \frac{x_i - x_{imin}}{ximin_{imax}}, \quad (9)$$

where $\tilde{X}_i$ is the value of the i-factor and $ximin_{imax}$– is the smallest and largest numerical value in the range.

Some of the factors do not have a quantitative value, which complicates the process of calculating the impact on production costs. However, given the importance of these sets in the process of product formation, the theory of illegible sets was used to express them. Factors of influence that do not have quantitative value are described by linguistic variables. The expression of these words is not a number but rather a linguistic word, which was transformed into a quantitative term with the help of the correspondence function. The value of such a function ranges from "0" to "1". To visualize the interdependence between the factors of influence and the effective features (Figure 3), graphical methods and MATLAB software were used. The empirical data for the study were obtained from the internal reporting of Ukrainian and Polish agricultural holdings for 2022. Since the cost information is confidential (contains commercial secrets), the names of the agricultural holdings are not given. To ensure comparability, the cost data are presented in euros, taking into account the exchange rates of the national banks of Ukraine and the Republic of Poland. To develop a model of complex management of biomass cost, innovative and systematic methodological approaches were used. The method of innovative research lies in taking into account the latest trends in obtaining and processing information using information and communication technologies, such as the global positioning system, the Internet of Things, and aerial monitoring using drones. This systematic method allows us to take into account all the information components (planning, accounting, control and analysis) that ensure the collection, processing, transmission and interpretation of data for the purpose of biomass cost management. At the final stage of the study, induction and scientific generalization methods were used to construct conclusions summarizing the results of the article and the author's proposals.

4. Results.

4.1. *Identification of costs and formation of biomass cost*

To identify the factors influencing the cost of baled corn, it is necessary to study the process of its formation, determine the structure of costs and determine their impact on the final result. The main stages of harvesting and logistics of baled corn include the following: baling of waste corn; collecting bales in the field and loading them onto appropriate vehicles; transportation of bales to storage warehouses; unloading, sorting and stacking in warehouses (UABIO, 2022). The calculation of cost was conducted on the basis of the following conditional data: the cost of corn remaining in the field as a by-product was 5.1 Euros, and the annual volume of baled corn harvested was 2,000 tons. The corn yield from the field is 4 tons per hectare. The distance from the fields to the storage facility is 25 km. The harvesting process lasts 12 hours a day. The cost of twine for forming bales is 3.8 euros. Other production and logistics costs - 1.1 Euros. The cost of diesel fuel is 1.5 Euros (internal reporting, 2022a). According to the identified data, the company needs to have the following equipment as a minimum: a tractor (1 unit), a baler for the tractor (1 unit), a telescopic loader in the field (1 unit), a telescopic loader in the warehouse (1 unit), and a truck for transportation (2 units). The fuel consumption per ton of baled corn was calculated and is shown in Table 1.

Table 1. Calculation of fuel consumption for machinery operation

Number	Name of equipment	Fuel consumption *l/hour*	Fuel consumption *1/100 km*	Hours of operation	Distance to boiler house	Fuel quantity	Total fuel cost	Fuel cost, Euro/t
1	Tractor	30		98		2940	4410	2,20
2	Telescopic loader in the field	13		231		3003	4504,5	2,25
3	telescopic loader at the warehouse	7		231		1617	2425,5	1,21
4	Truck		35		4800	1680	2520	1,26
					Total	9240	13860	**6,93**

Sources: Developed by the authors based on (Internal reporting, 2022a).

According to the amount of equipment, the following employees need to be hired: a tractor driver (1 person), a telescopic loader operator (2 people), and a truck driver (2 people). The calculation of labor costs is shown in Table 2.

Table 2. Calculation of labour costs

Number	Position	Number of people	Wage per hour (km), Euro	Number of working (km)	Amount of wage	Taxes on wage	Amount of wage with taxes	Wage, Euro/t
1	Tractor driver	1	30,3	98	2969,4	593,88	3563,28	1,78
2	Telescopic loader operator	2	27,8	231	6421,8	1284,36	7706,16	3,85
3	Truck driver	2	2,1	4800	10080	2016	12096	6,05
					Total	3894,24	23365,44	**11,68**

Sources: Developed by the authors based on (Internal reporting, 2022a).

The calculation of the costs of the above equipment is presented in Table 3 (costs are attributed in proportion to the number of hours worked, as indicated in Table 1).

Table 3. Calculation of equipment maintenance costs

Number	Name of equipment	Amount of depreciation by the production method, Euro	Maintenance, repair and current repair costs, Euro	Total cost of machinery per season, Euro	Equipment costs, Euro/t
1	Tractor	1571	804	2375	1,1875
2	Baler	582	411	990	0,495
3	Telescopic loader in the field	1765	986	2751	1,3755
4	Telescopic loader at the warehouse	1746	953	2699	1,3495
5	Truck	1459	843	2302	1,151
			Total		**5,56**

Sources: Developed by the authors based on (Internal reporting, 2022a).

After all the cost items for the selected stages are summed, the cost of baled corn for a given volume of 2,000 tons will be 34.27 Euros. Figure 2 clearly illustrates the structure of the costs for harvesting and logistics of baled corn. The largest share (34%) is spent on wages and related accruals. It can be concluded that harvesting biomass for further processing into electricity to meet public needs and obtaining the lowest price are more profitable in countries where the average wage in the relevant industry is the lowest.

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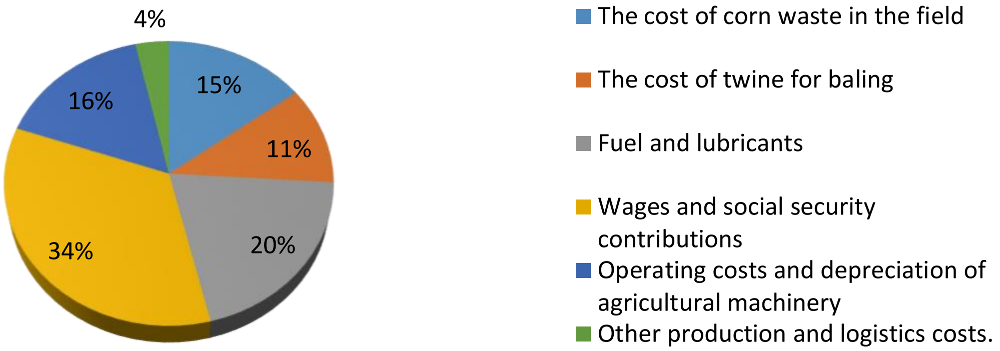

Figure 2. Structure of costs for harvesting baled corn
Sources: developed by the authors.

The largest corn producers in the world are shown in Table 4. The United States is the world leader in terms of gross corn production for grain. According to preliminary data, in 2022/2023, US corn production totaled 348.8 mln tons (30.3 percent of the world production), with an average yield of 11.1 t/ha. In other countries, corn production in 2022/2023 was as follows: China, 277.2 million tons; Brazil, 133.0 million tons; the EU, 52.9 million tons; Argentina, 34 million tons; and Ukraine, 27.0 million tons (USDA, 2023).

Table 4. Major corn producers in the world

Number	Country/region	Gross harvest, t/ha					
		2017/2018	2018/2019	2019/2020	2020/2021	2021 2022	2022/2023
1	USA	371,1	364,3	347,8	352,1	382.9	348.8
2	China	259,1	257,3	260,8	265,8	272.6	277.2
3	Brazil	82,0	101,0	101,0	108,4	116.0	133.0
4	EU	62,0	64,2	65,0	67,2	71.4	52.9
5	Argentina	32,0	51,0	50,0	49,8	49.5	34.0
6	Ukraine	24,1	35,8	35,5	36,4	42.1	27.0
7	India	28,8	27,2	29,0	30,1	33.7	36.0
8	Mexico	27,6	27,6	25,0	26,1	26.8	26.50
	The world	1080,3	1122,2	1111,5	1145,4	1218.7	1150.7

Sources: Developed by the authors based on USDA (2023).

Considering the statistics on average wages in different countries (Worlddata, 2023), it is more profitable to harvest biomass in the following countries: India, Ukraine, Mexico, and China. The cost of baled corn will decrease due to lower labour costs.

4.2. An analytical model for studying the impact of agricultural production factors on biomass cost.

Based on the analysis of the data obtained in the process of calculating the cost, the factors that influence the cost of the final biomass product – rectangular bales of corn by products – have been identified. Among the factors studied, the most significant ones were identified: the volume of harvesting, the average wage of a production worker per hour, the distance from the fields to the place of storage or processing, the level of logistics organization, the quality of agricultural products, and the level of use of the latest agricultural technologies and agricultural machinery. Table 5 shows the factors and their corresponding designations that will be used in the calculations.

Table 5. Factors influencing the cost of rectangular bales of corn by-products

Name of the factor	Designation in the formula
Volume of harvesting, tons	X1
Average wage of a production worker per hour, euros	X2
Distance from the fields to the place of storage or processing, km	X3
Quality of agricultural products	X4
Level of logistics organization	X5
Level of use of the latest agricultural technologies and machinery	X6

Sources: developed by the authors.

The first three factors are quantitative and thus are clear for the formation of the dependence function. Some of the factors are not quantitative (level of logistics organization, quality of agricultural products, level of use of the latest agricultural technologies and agricultural machinery). It can be assumed that the influence of these factors is significant, although management may ignore them. The numerical values of the factors affecting the cost of production and the results of the quantitative interpretation of illegible factors obtained using MS Excel are presented in Table 6. To reduce errors from rounding and ensure high certainty in the calculation of regression coefficients, the factors were averaged using formula 9.

Table 6. Quantitative display of factors influencing the cost of baled corn

Number of global agricultural holdings	Cost price per 1 t of baled corn, Euro (Y)	X1	X2	X3	X4	X5	X6
1	24,83	120 920	28,4	40,3	0,9	0,9	1
2	25,75	121 355	26,5	47,1	0,8	0,7	0,7
3	26,68	75 218	27,8	35,6	0,8	0,9	0,8
4	27,62	77 171	27,1	42,8	1	0,9	0,8
5	27,93	69 172	26,8	58,4	0,9	1	1
6	28,39	67 132	26,5	45,3	0,9	0,8	0,5
7	29,62	56 167	25,4	64,3	0,8	0,8	0,2
8	30,14	57 215	26,1	65,3	1	1	0,7
9	30,34	44 712	25,1	70,1	0,4	0,8	0,8
10	31,48	47 120	25,7	50,3	0,8	0,9	0,9

Sources: developed by the authors based on (Internal reporting, 2022b).

Regression analysis of the data for the given model structure was performed using the MS Excel spreadsheet, and the results are shown in Table 7.

Table 7. Results of the regression analysis of the relationship between the cost and the factors that influence it

Sequence number	Basic functions	Regression coefficients	Quantile of the Student indicator	Significance
j	$\gamma_j(x)$	b_j	$t(b_j)$	
1	X1	-31,44	0,02	yes
2	X2	34,54	0,04	yes
3	X3	28,54	0,01	yes
4	X4	27,67	0,01	yes
5	X5	-41,11	0,02	yes
6	X6	21,98	0,02	yes

Sources: developed by the authors.

The significance of the coefficients was checked by calculating Student's coefficient (confidence level $\alpha = 0.05$) and the coefficient of determination $R^2 = 0.99$. The results confirm the correctness of the regression analysis. As a result of the conducted calculations, a regression model of the dependence of cost on the selected factors was obtained:

$$Y = -31{,}44X_1 + 34{,}54X_2 + 28{,}54X_3 + 27{,}67X_4 - 41{,}11X_5 + 21{,}98X_6 \quad (10)$$

The given model is an innovative tool for managing the cost of biomass within the factors controlled by managers of agricultural enterprises. The Gini coefficient can be used to predict the cost of baled corn through interactions with the factors identified in the study, each of which was confirmed to be significant by Student's coefficient.

The interdependence between the factors of influence and the resultant trait can be visually represented using a graph (Figure 3). Each of the factors under consideration is significant and therefore important for making management decisions. For the first factor (X_1), where the regression coefficient is negative, there is an inverse relationship between the cost of production and the quantity of output. This is explained by the fact that variable costs increase in parallel with volume, while unallocated overhead costs (salaries of the manager responsible for the harvesting process, etc.) decrease per 1 ton of baled corn. An increase in the salaries of employees directly involved in the process (X_2) directly affects the growth of production costs, as evidenced by the positive value of the regression coefficient and the cost structure in Figure 2. For the third factor, analysing the stages of corn baling, it is obvious that the distance to the storage warehouse (X_3) significantly increases the cost, as it affects variable costs (the amount of fuel used, drivers' wages, depreciation of equipment calculated using the production method, frequency of its repair, etc.).

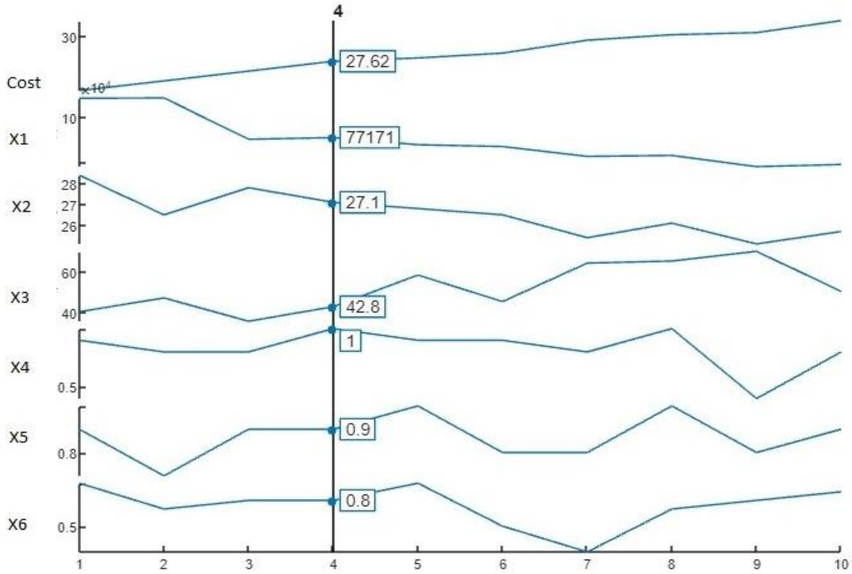

Figure 3. Dependence of the cost of baled corn on the studied factors
Sources: developed by the authors.

A related factor is the level of logistics organization (X_5), which is a significant factor according to the regression analysis. With an increase in the level of logistics organization, the cost of biomass decreases. The study of the impact of logistics on the performance of enterprises confirms the need for management to maintain a focus on this factor. Regarding the quality of agricultural products (X_4), the coefficient demonstrates an increase in the cost of biomass, while the quality characteristics of agricultural products increase. This situation occurs because the company will incur additional costs to meet quality standards, and the cost of corn waste in the field will increase, which directly affects the increase in production costs. The regression coefficient indicates that an increase in the use of modern agricultural technologies and agricultural machinery (X_6) affects the increase in the cost of baled corn. This situation is a consequence of the fact that new machinery is more expensive and, accordingly, leads to higher depreciation costs. On the other hand, modern machinery breaks down less often, which reduces the cost of spare parts and repairs. However, the results of the study show that the share of depreciation is greater for overall equipment costs than for repair and maintenance costs. Therefore, the use of new machinery increases the cost of baled corn.

4.3. Information scheme of innovative biomass cost management

The developed analytical model of cost planning for biomass production (10) should be used as the basis for innovative cost management. Primary data on the production processes of growing and producing biomass should be collected using innovative information and communication technologies (Zadorozhnyi et al., 2018). The use of information processing technologies is the technological basis for the implementation of the management concept of "precision agriculture". Modern unmanned aerial vehicles are capable of conducting aerial monitoring of agricultural activities. Based on crop area measurements and yield information, it is possible to predict the optimal volume of biomass harvested. Immediately after the start of harvesting, drones can be used to generate information on the planned volume of main products and by-products (including biomass) of agricultural products (Desyatnyuk et al., 2021).

The volume of biomass harvesting can be linked to the amount of wages of production personnel. At most agricultural enterprises, wages are set in proportion to the time spent performing direct functional duties or the volume of harvested crops. While it is difficult to directly associate hourly wages with biomass production, quantitative parameters of production personnel can be the basis for identifying wages at the cost of agricultural products. For example, the share of by-products, such as biomass, traditionally accounts for 10% of the revenue from crop sales. Accordingly, the same percentage of the wages of personnel involved in agricultural activities should be included in the cost of biomass. In other words, 10% of the salaries of production personnel with monthly wages and seasonal workers whose activities can be correlated with the amount of agricultural products received should be included in the cost of biomass.

This situation is similar to the transportation costs for the movement and storage of biomass. With the use of Global Positioning Technology, it is possible not only to track the location of agricultural machinery but also to carry out automated accounting of costs associated with the operation of all vehicles. By monitoring the distance travelled by specialized or freight vehicles, it is possible to calculate the consumption of fuel and lubricants. Traditional calculations of the costs associated with the operation of specialized agricultural machinery after its return to the parking lot or at the end of the reporting period do not provide operational data for innovative and timely management. It is advisable to write off the cost of fuel and lubricants automatically after each trip or production task is completed by the agricultural machinery.

It is advisable to depreciate agricultural machinery at the same frequency, which also constitutes a significant component of biomass costs. When using the production method of depreciation, it is possible to determine the dependence of the depreciation of certain parts or units of technical means on the volume of the harvested crop. In this case, depreciation is calculated without the need to wait for the end of the current month but rather for much shorter time periods, which is extremely important for innovative biomass cost management. The use of agricultural machinery with a significant level of wear and tear can be inefficient due to the high consumption of fuel and lubricants and losses of agricultural products during harvesting. Therefore, worn-out machinery needs to be replaced with newer and more innovative machinery, which will lead to an increase in agricultural productivity. Like in payroll accounting, one tenth of the cost of fuel and lubricants and the depreciation of fixed assets should be included in the cost of biomass.

An important criterion for increasing the cost of biomass is its quality. The quality of agricultural products determines their usefulness and future value in the market. Modern Internet of Things technologies integrated into harvesting equipment can detect the quality parameters of agricultural products (Muravskyi et al., 2022). At the time of harvesting, biomass can be automatically analysed in a laboratory to determine its chemical, physical, or organoleptic properties. If the quality of the biomass does not meet the established standards, a decision may be made on the need for measures to restore the reference consumer characteristics. Such measures may include mechanical processing for reducing the fraction or structure, drying to reduce the moisture content, and storing in appropriate conditions for additional biological transformations, which are associated with additional operating costs. When identified by the Internet of Things technologies, noncompliance with the quality requirements for the harvest should be promptly considered in the cost price as a need to improve the quality properties of biomass. To take into account the above production costs, information about which is collected using innovative information and communication technologies, it is advisable to use this information scheme in the innovative management of biomass costs (Figure 4).

The information based on the results of correlation and regression analysis is the basis for biomass cost management. It is advisable to use analytical data for automated predictive calculations of biomass costs even before the completion of operational processes during production. Agricultural and processing enterprises have an effective mechanism for influencing the cost of biomass. To adjust the costs of biomass production, a company's management can make management decisions regarding each production factor. Before the end of the operational cycle of obtaining biomass ready for further use, management can initiate certain actions based on the recommendations of the automated management system. Management decisions are aimed at reducing the number of employees in favour of automated harvesting; using more modern agricultural machinery that minimizes the consumption of fuel and lubricants and losses of agricultural products during the harvesting process; involving third-party logistics companies in the transportation of biomass to storage or processing sites; optimizing storage space for more efficient storage; etc. Changes in each of the operating factors of biomass production can affect other factors. A decrease in some operating costs leads to an increase in others. However, the use of the proposed innovative model of biomass cost management (10) enables the formation of an optimal mechanism for balancing all operating costs under current operating conditions. When deciding to change any of the production factors in an automated cost management system, it is advisable to calculate the proposed correlation and regression model. In the case of a negative assessment of the results, when savings in total operating costs are not achieved, the management decision by the automated cost management system is not recommended for implementation. As a result, an innovative management system is an effective method for preventing ineffective management decisions.

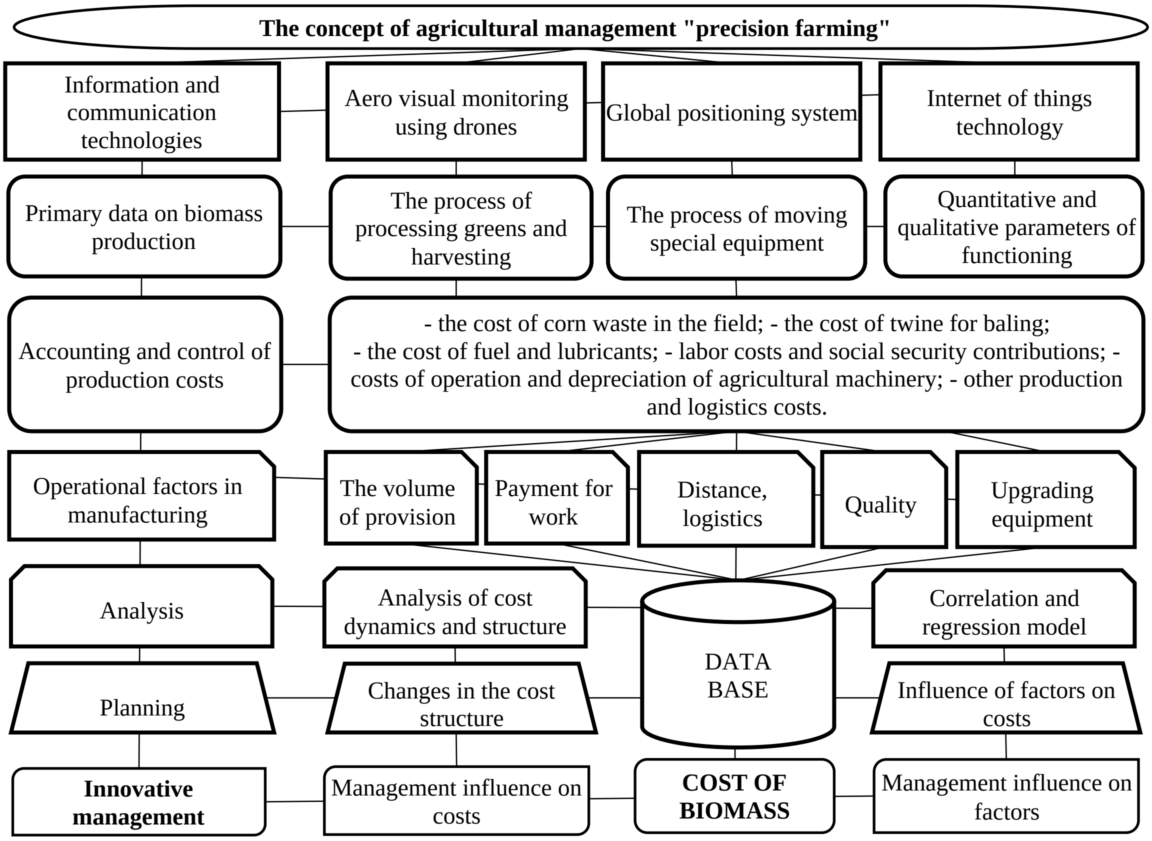

Figure 4. Information scheme of innovative biomass cost management
Sources: developed by the authors.

5. Conclusions. Global climate change and the need for the efficient use of natural resources have stimulated the search for new ways to support the environmental and economic behaviour of business entities. A promising area for optimizing agricultural activities in the context of increasing environmental friendliness and reducing the economic value of agricultural products is the full use of by products, such as biomass. An important element of managing biomass production and processing is the identification of costs in the process of determining the cost. The main items of biomass costing (for the example of baled corn) are the cost of corn waste in the field; the cost of twine for baling; fuel and lubricants; wages and social security contributions; operating costs and depreciation of agricultural machinery; and other production and logistics costs. Studies of the structure of production costs that make up the cost of biomass have shown that the majority of production costs are composed of labour costs. Accordingly, the regions (countries) with the lowest labour costs are the best for the territorial location of biomass production and processing enterprises.

However, enterprises have a mechanism for minimizing other operating costs of biomass production, which involves innovative cost management. The basis of biomass cost management information is an automated accounting system based on Global Positioning Technologies, aero visual monitoring using drones, the Internet of Things, etc. The use of technologies for collecting and processing accounting information on agricultural activities enables the formation of information arrays about the planned volume of harvested crops, wages of production personnel, fuel and lubricant costs, equipment depreciation and the need for current repair of agricultural machinery, as well as additional operating and transportation costs associated with logistics and biomass quality assurance. Accounting data can be obtained even before the end of the operating cycle or reporting period, which is the basis for the operational management of agricultural activities. However, accounting data require analytical processing to ensure effective management of biomass costs. By combining a set of basic analytical functions that explain the impact of variable factors on operating costs and regression analysis, an innovative model for managing biomass costs (based on baled corn) was developed. Its use makes it possible to determine the dependence of biomass cost on the following factors: harvesting volume, average wage of an operational employee, distance from fields to storage or processing facilities, level of logistics organization, quality of agricultural products, and level of use of innovative technologies and agricultural machinery. The innovation of the model lies in the use of linguistic variables, i.e., factors that do not have a quantitative expression but can be economically assessed.

The applied use of the developed model ensures the selection of the best combination of operational factors, which leads to a reduction in the cost of biomass. For the practical implementation of an innovative biomass cost management system, it is advisable to use the proposed information scheme. The information relationship scheme justifies the possibility of automatically calculating the costs of obtaining agricultural products on the basis of which managers are offered the best management decisions that minimize the cost of biomass. The limitation of the use of the obtained model is that it can be applied only to agricultural products such as baled corn since it was developed on the basis of empirical data from global agricultural holdings of only this type of biomass. Further research should be conducted in the direction of reflecting biomass in integrated reporting (sustainability reporting) to form a holistic information mechanism for the internal and external management of an important alternative energy source.

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Інноваційне управління собівартістю біомаси на основі обліку та аналізу виробничих витрат агродіяльності

Новітні напрями екологічної та економічної поведінки підприємств агросфери передбачають повне використання побічної продукції, якою є біомаса. Ідентифіковано основні статті калькулювання собівартості біомаси (на прикладі тюкованої кукурудзи), якими є: вартість відходів кукурудзи в полі, вартість шпагату для формування тюків, витрати на паливо-мастильні матеріали, витрати на заробітну плату та відрахування на соціальні заходи, витрати на функціонування та амортизацію агротехніки та інші виробничі і логістичні витрати. На основі дослідження структури виробничих витрат, з яких формується собівартість біомаси, виявлено, що основну частку становлять витрати на оплату праці. З метою комплексної оптимізації операційних витрат агродіяльності доведено необхідність запровадження інноваційної системи управління собівартістю біомаси на основі автоматизованого обліку й аналізу з використанням технологій глобального позиціонування, аеровізуального моніторингу з допомогою дронів, Інтернету речей. Запропоновано використовувати технології збору та обробки облікової інформації про агродіяльність для формування інформаційних масивів щодо: планового обсягу зібраного урожаю, заробітної плати операційного персоналу, витрат паливо-мастильних матеріалів, амортизації обладнання та необхідності поточного ремонту агротехніки, а також додаткових експлуатаційних і транспортних витрат. Розроблено інноваційну аналітичну модель дослідження впливу умов агродіяльності (обсяг заготівлі, середня зарплата виробничого працівника, відстань від полів до місця складування чи переробки, рівень організації логістики, якість агропродукції, рівень використання новітніх агротехнологій та агротехніки) на виробничі витрати, що є підґрунтям для оперативного та предективного інноваційного управління собівартістю біомаси. Інноваційність моделі полягає у використанні лінгвістичних змінних, тобто чинників, що не мають кількісного вираження, але можуть бути економічно оцінені. Для практичної імплементації інноваційної системи управління собівартістю біомаси запропоновано використовувати сформовану інформаційну схему, яка включає усі інформаційні компоненти, на основі яких менеджерам розробляються і пропонуються найбільш оптимальні управлінські рішення для мінімізації собівартості біомаси. Необхідність відображення обліково-аналітичної інформації про вартість біомаси в інтегрованій звітності (звітності сталого розвитку) з метою інформування внутрішніх та зовнішніх стейкхолдерів щодо формування і використання альтернативних джерел енергії визначає перспективність подальших наукових досліджень у цій сфері.

Ключові слова: інноваційне управління; собівартість біомаси; агродіяльність; облік; аналіз; операційні витрати.