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Forecasting and modelling the rye market, as a niche grain crop, under conditions of increasing mineral fertiliser costs

Anatolii Dibrova*
Doctor of Economic Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-2503-2431
Viktoriia Baidala
Doctor of Economic Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-1532-2913
Tetiana Mirzoieva
Doctor of Economic Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-0034-6138
Ludmila Stepasyuk
PhD in Economic Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-7258-9243
Alla Chmil
Doctor of Philosophy, Assistant
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-2690-5903
Larysa Dibrova
PhD in Economic Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-4877-0496

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*Corresponding author

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Abstract. The cultivation of rye as a niche crop is gaining increasing importance in Ukraine. However, the rising cost of mineral fertilisers necessitates forecasting and market modelling to mitigate risks and enhance the economic efficiency of production. This study aimed to assess the current state of supply and demand in the rye market, which is considered a niche grain crop, and to forecast the effects of changes in mineral fertiliser costs on key market parameters under probable scenarios. The research employed comparative analysis, tabular representation, statistical economic approaches, abstract-logical reasoning, and econometric modelling. In particular, the econometric partial equilibrium model AGMEMOD has been utilised. The potential of rye as a niche crop has been revealed, the current state of its production has been analysed, and the key factors influencing the formation of supply and demand in the Ukrainian rye market have been identified; the dynamics of the supply and demand balance in the rye market, taking into account various economic and other factors, have been analysed; a forecast has been made of the consequences of changes in the cost of mineral fertilisers on the main parameters of the development of the rye market in Ukraine under several probable scenarios. The forecast extended to 2026 and evaluated the effects of different changes on yields, sown areas, gross production, and the economic efficiency of rye cultivation. The research provided a foundation for improving the efficiency of decision-making and implementation of management strategies, contributing to the achievement of national agricultural policy objectives, including ensuring food security. The proposed methodological approaches and research findings may be valuable for public and sectoral authorities in developing priority measures aimed at enhancing the performance of the domestic grain sector

Keywords: agricultural policy; rye; niche crops; grain market; diversification; food security; mineral fertilisers; AGMEMOD

INTRODUCTION

In the context of escalating global food security challenges, new demands are emerging for the formulation of agricultural policy, alongside a growing emphasis on the diversification of agricultural production. Diversification is facilitated through the expansion of niche crop cultivation, both within traditional farming systems and under the principles of organic production. The potential of niche crops lies in their ability to enhance global food security and deliver a range of additional benefits across economic, agrotechnological, environmental, and social dimensions. Economically, niche crops help mitigate market risks, serve as raw materials for high-value-added products, and provide additional income streams for farmers, particularly for small and medium-sized enterprises. Agrotechnologically and environmentally, niche crops offer advantages such as diversifying crop rotations, increasing agricultural biodiversity, improving soil health, and contributing to climate change mitigation. From a social perspective, cultivating niche crops supports the development of small-scale agricultural enterprises, generates additional employment opportunities in rural areas, and fosters rural community development. Given these considerations, focused research on the development of agricultural markets – particularly using the example of a specific niche crop under conditions of rising mineral fertiliser costs – is increasingly relevant and warrants detailed investigation.

Research indicates that diversified farming systems provide greater employment opportunities for rural populations without reducing profitability for agricultural producers. For instance, A. Sánchez *et al.* (2022) emphasised that promoting diversification, particularly through the expansion of niche crops, is a promising strategy for ensuring sustainable livelihoods for farmers and adequate nutrition for households and society. A. Mavroeidis *et al.* (2022) highlighted that niche crops hold significant potential for the future of agriculture and align with the UN's Sustainable Development Goals. Similarly, A. Pradhan *et al.* (2021) noted that many niche crops – also referred to as alternative, speciality, indigenous, or underutilised crops – are resilient to abiotic stresses, well-suited to marginal environments, and represent a rich pool of genetic resources for enhancing future yields. Integrating such crops into existing farming systems can help establish sustainable, nutritious, healthy, and diverse food systems, particularly in marginalised agroecological contexts. Furthermore, S. Padulosi *et al.* (2021) and I. Kakabouki *et al.* (2021) demonstrated that several niche crops exhibit high acclimatisation and adaptive potential to conditions such as salinity, drought, waterlogging, and lowfertility soils. Hirich *et al.* (2020) noted in their study that utilising marginal lands, which constitute a significant portion of available arable land, through the introduction of stress-resistant niche crops has the potential to enhance their agricultural productivity. This, in turn, could improve food security by increasing the availability of food resources.

L. Clinton *et al.* (2020) highlighted that niche crops are high-value agricultural products but are associated with relatively higher risks and increased production costs, necessitating a cautious approach to their integration into cropping systems. In the absence of adequate

information on production technology, management, and marketing, agricultural producers may face the risk of low economic profitability. Conversely, with a well-planned and professional approach to cultivating niche crops, producers can unlock new market opportunities. This observation is particularly relevant for Ukraine. For instance, O. Drebot and M. Vysochanska (2024) noted that the strategic production and export of niche products are viewed as effective pathways to addressing economic challenges both in the agricultural sector at large and for individual producers. Furthermore, in the current environment, the growing trend of healthy eating is increasing consumer willingness to pay for novel and unique products, providing farmers with opportunities to access regional, domestic, and global markets with innovative offerings (Cherevko & Cherevko, 2020). This statement is especially pertinent given the wide variety of niche (speciality or alternative) crops available globally and in specific regions or countries. It is important to note that a crop may simultaneously be considered a primary, secondary, or niche crop depending on the region or country. For example, rye, which is classified globally as a secondary cereal, is considered a niche crop in Ukraine due to its relatively small cultivation area compared to traditional commercial crops.

This study aimed to assess the current state of supply and demand in Ukraine's rye market and to forecast the impact of changes in mineral fertiliser costs on key development parameters under probable scenarios through to 2026, using the AGMEMOD econometric partial equilibrium model.

MATERIALS AND METHODS

This article was prepared as part of the research project titled "Forecasting the Development of the Market of Grain Niche Crops in the Conditions of Challenges and Threats to Food Security of Ukraine (Using the AGMEMOD Partial Equilibrium Econometric Model)", with the state registration number 0123U102156. The study employed the following methods: comparative analysis was utilised to evaluate the current state of rye production, identify trends, and compare indicators such as yield, gross harvest, and cultivated area across various groups of producers in Ukraine. This method was also used to determine Ukraine's position among the leading rye-producing countries globally; tabular method facilitated the organisation and visual representation of analytical data and research findings; the statistical-economic method was applied for collecting and analysing data to identify the status, trends, and patterns in the development of key parameters of Ukraine's rye market; factor analysis to identify and evaluate the impact of key factors on the efficiency of rye production; abstract-logical method supported the formulation of conclusions, generalisation of research results, and development of theoretical propositions; econometric modelling was used to assess the impact of mineral fertiliser costs on key parameters of rye market development in Ukraine, forecast future trends, and justify optimal strategies to reduce costs and enhance production efficiency in the country.

The data used for this study were collected from various sources, including the Ministry of Economy of Ukraine (2024), the Ministry of Finance of Ukraine (2024), the Ministry of Agrarian Policy and Food of Ukraine (2024), the State Statistics Service of Ukraine (2024), the World Bank (2024), the International Monetary Fund (2024), the US Department of Agriculture (2024), Statistics. FAOSTAT (2024), the International Trade Centre (2024), and the OECD (2024). Additionally, the research incorporated information from Ukrainian and international scientific publications, as well as the authors' own studies and practical observations.

To evaluate the impact of changes in mineral fertiliser costs on key parameters of the rye market in Ukraine, the econometric dynamic partial equilibrium model AGMEMOD (Agricultural Member State Modelling) was employed. This model is designed for detailed analysis and forecasting of the effects of agricultural policy decisions on agricultural production, markets, and the economies of both European Union member states and neighbouring countries. The equations describing the key parameters of the Ukrainian rye market were estimated using time series data covering the period from 1992 to 2021. The equations were assessed as linear regressions using the ordinary least squares method in the statistical software R. Prior to estimation, the data underwent rigorous processing, including the identification and correction of inconsistencies and missing values, to ensure high accuracy and reliability in the analysis. This approach accounted for all key factors influencing the rye market and allowed the development of a detailed model suitable for forecasting market trends under changing economic and political conditions.

This study involved a four-step regression selection process:

1) *Hypothesis formation*. Based on microeconomic theory and specific industry characteristics, hypotheses were formulated regarding potential relationships between dependent and explanatory variables. This stage involved identifying key factors that could potentially influence the outcomes and constructing a theoretical model to represent these relationships;

2) *Graphical analysis of relationships*. After formulating hypotheses, the potential relationships between variables were analysed graphically. This allowed for a visual assessment of the nature and strength of the relationships, as well as the identification of potential anomalies or non-linearities that could affect the results of the regression analysis;

3) *Autocorrelation testing*. Variables were tested for autocorrelation. This involved using statistical tests to detect dependencies between consecutive values of

variables, ensuring the accuracy and reliability of the regression estimates;

4) *Analysis of estimation results*. The results of the regression estimation were analysed in detail to assess the overall fit of the model, statistical significance, and consistency with the hypotheses. This stage involved checking the adequacy of the model using various criteria, such as the coefficient of determination (R^2), significance of regression coefficients, and analysis of model residuals.

This comprehensive systematic approach to regression selection ensured a high level of accuracy and reliability in the obtained results, allowing for a deep understanding of the relationships between variables and informed conclusions about the development of the Ukrainian rye market. The coefficient of determination (R^2) which indicates the proportion of the variance in the dependent variable that is predictable from the independent variable(s), 1 was 0.269. This means that the regression equation explains only 26.9% of the variation in the dependent variable due to the variation in the independent variable. However, for complex models with limited datasets, this value of the coefficient of determination can be considered acceptable and sufficient for assessing its reliability. Furthermore, the p-value of the regression equation is 0.00000000000000358, indicating the high statistical significance of all variables in the model, as the value is much smaller than the threshold value of 0.05. This confirms that the variables in the model have a significant impact on the dependent variable. All other regression estimation results obtained using R software are presented in Figure 1, allowing for a detailed analysis of the model parameters and drawing well-founded conclusions about its adequacy and reliability.

Based on the analysis conducted, equations that demonstrated higher statistical reliability and better reflected the current trends of the dependent variables were added to the AGMEMOD model. These equations were carefully selected to ensure a more accurate and reliable estimation of key market parameters. The introduction of such equations enabled the model to more effectively account for interactions between different variables and provide more precise forecasts of agricultural market development. This, in turn, increases the utility of the AGMEMOD model for analysing policy decisions and developing strategies for agricultural sector development, providing a deeper understanding of economic processes and market responses to external influences.

```
ll:
plm(formula = yld_ry_t ~ 0 + trend08 + price1_ry_real_uah_hkg,
    data = pdata_subs_no_Ukr, model = "random")

Unbalanced Panel: n = 24, T = 5-8, N = 183

Effects:
                var std.dev share
idiosyncratic 0.204   0.451  0.51
individual    0.197   0.444  0.49
theta:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   0.59    0.66    0.66    0.66    0.66    0.66

Residuals:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 -1.222  -0.262  -0.018   0.001   0.211   1.569

Coefficients:
                      Estimate Std. Error z-value             Pr(>|z|)
trend08                0.94842    0.08118   11.68 < 0.0000000000000002 ***
price1_ry_real_uah_hkg 0.02736    0.00667    4.11              0.00004 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    49.8
Residual Sum of Squares: 36.4
R-Squared:      0.269
Adj. R-Squared: 0.265
Chisq: 66.5287 on 2 DF, p-value: 0.00000000000000358
```

Figure 1. *Regression estimation using R packages*
Source: *authors' calculations based on (Nykolyuk et al., 2023)*

The primary equations for modelling and forecasting the main demand and supply parameters of the rye market in Ukraine include:

1. Area harvested with rye, thousand hectares (Equation (1)):

$$RYAHAUA = RYASHUA \times RYAHAUA. \quad (1)$$

2. Rye yield, tonnes per hectare (Equation (2)):

$$RYYHAUA = 0.94842 \times TREND08 + \\ + 0.02736 \times RYPFNUA(-1)/GDPDUA(-1). \quad (2)$$

3. Gross rye production, thousand tonnes (Equation (3)):

$$RYSPRUA = RYYHAUA \times RYAHAUA. \quad (3)$$

4. Domestic consumption, thousand tonnes (Equation (4)):

$$RYUDCUA = RYUFOUA + RYUFEUA + RYUDLUA. \quad (4)$$

5. Feed use, thousand tonnes (Equation (5)):

$$RYUFEUA = \max(50 - 520.471 - 0.4555181 \times \times \frac{RYPFNUA}{GDPDUA} + 0.0570071 \times CMSPRUA. \quad (5)$$

6. Food use, thousand tonnes (Equation (6)):

$$RYUFDUA = RYUPCUA \times POPUA. \quad (6)$$

7. Food and seed use, thousand tonnes (Equation (7)):

$$RYUFOUA = RYUFDUA + RYUFSUA. \quad (7)$$

8. Rye price on the domestic market, UAH per centner (Equation (8)):

$$RYPFNUA = \max(0.0001)$$
$$RYPFNUA = 4.5278 + 0.8383*\text{BAPFNUA}. \quad (8)$$

9. Profitability of rye production in real prices from the previous period, thousand UAH (Equation (9)):

$$RYEGUUA = \frac{RYPFNUA(-1)}{GDPDUA(-1)} - \frac{RYCGUUA}{GDPDUA}. \quad (9)$$

10. Rye imports, thousand tonnes (Equation (10)):

$$RYSMTUA = 0.02 + \max(0.RYUDCUA - RYSPRUA). \quad (10)$$

11. Rye exports, thousand tonnes (Equation (11)):

$$RYUXTUA = 0.02 + \max(0.RYSPRUA - RYUDCUA). \quad (11)$$

Notation:
RYAHAUA – area harvested with rye;
GRAHAUA – total grain area;
RYYHAUA – rye yield;
RYSPRUA – gross rye production;
RYUDCUA – domestic consumption volume;
RYCCTUA – ending stocks;
RYUFEUA – feed use;
RYUDLUA – losses;
RYUFDUA – food use;
RYUFSUA – seed use;
RYUFOUA – food and seed use;
RYPFNUA – domestic market price of rye per centner;
RYUOTUA – processing;
RYCGUUA – production costs per hectare of rye area;
RYEGUUA – rye profitability;
BAPFNUA – price of barley (as a rye substitute) from the previous period;
GDPDUA – GDP deflator;
GDPDUA (-1) – GDP deflator from the previous period;
TREND08 – logarithmic trend;
POPUA – population of Ukraine;
EXRDUA – USD to UAH exchange rate;
RYSMTUA – rye imports;
RYUXTUA – rye exports.

The database for the Ukrainian model country begins in 1992. For the current study, it has been updated to 2021, and where possible, to 2022. These data series encompass a wide range of indicators reflecting the state of the agricultural sector. These include observations on crop production in terms of yields and harvested areas, livestock numbers and productivity, slaughter weights, and production of oilseeds and oilcakes. Domestic data use covers aspects such as feed use, human consumption, processing, and product losses. Additionally, the database includes information on agricultural product prices, stock changes, imports, and exports. This comprehensive dataset enables detailed analysis and modelling of agricultural markets, ensuring accurate and comprehensive forecasts and aiding in informed decision-making for the development of Ukraine's agricultural sector.

Data on most domestic market prices and supply components were obtained from the State Statistics Service of Ukraine (2023). For information on export and import volumes, components of domestic consumption, and domestic prices for oils and oilseed meal, data from Statistics. FAOSTAT (2024) and the International Trade Centre (2024) were used. Data for 2022 was collected from publicly available commodity price databases and reports from the Ministry of Agrarian Policy and Food of Ukraine (2024). This provided a comprehensive and accurate dataset for analysis and modelling, which in turn contributed to a deeper understanding of market dynamics.

Forecasts of agricultural commodity balances in the AGMEMOD model are based on several factors, such as agricultural and trade policy, production costs, world market prices for agricultural products, and macroeconomic indicators including national GDP, GDP deflator, exchange rate, and population. These factors are exogenous variables, meaning they are not calculated or forecasted by the model itself. Their observed and forecasted values are collected from various external sources such as national and international statistical services, analytical reports, and economic forecasts. These data are then input into the model as a separate component representing the modelling assumptions. This allows for the consideration of external influences on the agricultural sector and provides more accurate and reliable forecasts, supporting effective decision-making in agricultural policy and management.

While the model allows for simulations with various global market price values, the current study was conducted within the general parameters defined by the

OECD-FAO Agricultural Outlook (OECD-FAO..., 2023). Therefore, the historical and projected values of global market prices for the analysed commodities correspond to the data presented in the EU Agricultural Outlook. This ensured consistency and comparability of the research results with international standards and forecasts, increasing the reliability and robustness of the conclusions. The use of these authoritative sources allowed for the consideration of a wide range of global economic and political factors affecting agricultural markets, providing a more comprehensive approach to analysing and forecasting the development of the agricultural sector.

However, the full-scale Russian armed aggression against Ukraine significantly hindered the process of updating and expanding the information for modelling due to limited access to statistical data. At the time of writing this article, the authors were unable to obtain complete official statistical data for 2022-2023 to construct the model. Additionally, 2022-2023, characterised by a state of war, exhibited a trend of decline in all indicators, and data from these years could have affected the reliability of the modelling. Moreover, the economic shocks caused by the war significantly impacted the trends in the rye market, which is important to consider when interpreting the results. Given these limitations, the authors of the study used the most up-to-date data available until 2021, which allowed them to build a model based on the most recent complete data, considering the need to obtain a reliable modelling result. However, changes in the market caused by economic fluctuations and an unstable situation may affect the reliability of future forecasts, therefore the results should be considered in light of these limitations.

RESULTS

A review of the global rye market in 2023 reveals that EU countries were the leading producers in terms of harvested area and production volume (Table 1), with Ukraine ranking among the top ten. Notably, the group of leading countries in terms of harvested rye area and production volume was not identical, indicating the significance of intensive production methods. This is confirmed by the top ten countries with the highest rye yields, which included only three countries from those leading in harvested area in 2023 (belarus, Canada, and Turkey) (Table 1). In terms of initial rye stocks, domestic consumption, and ending stocks in 2023, EU countries were also the leaders (Table 2). Countries consuming more rye than they produced in 2023 included the USA, Turkey, Norway, and Kazakhstan, indicating an existing demand for this grain.

***Table 1**. Rye production worldwide, 2023*

Leading countries by harvested rye area	Harvested area, thousand hectares	Leading countries by rye production volumes	Production volume, thousand tonnes	Leading countries by rye yield	Yield, tonnes/ hectare
EU	1,830	EU	7,750	Switzerland	6
rf	875	rf	1,900	Norway	6
belarus	310	belarus	780	EU	4
USA	121	Canada	375	UK	4
Canada	115	Turkey	320	Albania	3
Turkey	110	USA	266	Bosnia and Herzegovina	3
Argentina	90	Ukraine	230	Serbia	3
Ukraine	80	Argentina	165	belarus	3
Australia	45	Norway	50	Canada	3
Kazakhstan	30	Kazakhstan	40	Turkey	3

***Source:** Indexmundi (2023)*

As the research revealed, ending stocks of rye worldwide in 2023 were quite low, and in some countries, they were completely absent (Table 2). Meanwhile, Ukraine in 2023 was among the top ten in terms of initial stocks, domestic consumption, and ending stocks.

***Table 2**. Initial stocks, domestic consumption, and ending stocks of rye by leading countries worldwide, 2023*

Initial stocks, thousand tonnes	Country	Domestic consumption, thousand tonnes	Country	Ending stocks, thousand tonnes	Country
362	EU	7,700	EU	387	EU
179	rf	1,850	rf	149	rf
106	Canada	750	belarus	72	Canada
42	Ukraine	518	USA	65	belarus
37	belarus	334	Turkey	60	Ukraine
19	USA	230	Canada	16	USA

Table 2. Continued

Initial stocks, thousand tonnes	Country	Domestic consumption, thousand tonnes	Country	Ending stocks, thousand tonnes	Country
14	Turkey	202	Ukraine	5	Kazakhstan
5	Kazakhstan	165	Argentina	1	Japan
1	Japan	55	Norway	0	Republic of Korea
0	Republic of Korea	45	Kazakhstan	0	Turkey

Source: *Indexmundi (2023)*

In 2023, the global rye market was valued at USD 3.76 billion and is projected to grow by 2.23.3% over the next decade (Rye Market Share..., 2024). In terms of application, the current global rye market is classified into segments such as bakery products, alcoholic beverages, animal feed, and other uses.

The main advantages of multifunctional rye and the diverse opportunities it offers include: high nutritional content; cover crop properties; and adaptability to climatic conditions – rye can grow in harsher climates and poorer soils than other cereals, making it valuable for regions with less fertile soils and more extreme weather conditions; potential for sustainable cultivation, as it contributes to lower CO_2 emissions, consumes less nitrogen and water compared to other cereals, and exhibits erosion resistance – rye's root system effectively holds the soil, reducing the risk of erosion and thus contributing to soil fertility and ecological sustainability; the ability to produce a range of high-value products, including those with high nutritional value and aligned with the popular trend of healthy eating; niche market potential – as a niche crop, rye can have stable market demand, especially in the health food and organic product sectors. This allows farmers to obtain a higher price for their products; opportunities for agricultural diversification – growing rye contributes to crop rotation diversification, reducing risks associated with monocultures and instability in markets for other cereals; opportunities for livestock development – rye is also used as animal feed, making it an important component in livestock farms; potential for biomass production in the context of bioenergy development.

Despite rye's multifunctionality and significant economic potential, Ukraine has witnessed a steady decline in its cultivation and production for several decades. Traditionally, rye is grown in the Polissia region of Ukraine, specifically in the northern parts of Sumy, Zhytomyr, Rivne, Chernihiv, and Volyn regions. On the sandy soils of Polissia, rye outperforms wheat in terms of yield. Since 1990, the peak of gross rye harvest in Ukraine occurred in 1995 at 1,208 thousand tonnes, followed by a decline. Compared to 1995, the gross harvest in 2023 decreased by 19 times to 230 thousand tonnes (Table 3). However, over this period, the gross harvest of rye in Ukraine fluctuated significantly. Until 2021, when the Ukrainian rye market began to activate, the state was not a major rye exporter. In 2020, Ukraine exported only 17 thousand tonnes of rye, while in 2021, this figure increased to 162 thousand tonnes. This can be explained by Ukrainian companies developing new profitable markets. However, 2022-2023 was characterised by a decline in rye exports from Ukraine due to the full-scale Russian invasion.

Table 3*. Rye market in Ukraine*

Years	Gross harvest, thousand tonnes	Initial stocks, thousand tonnes	Domestic consumption, thousand tonnes	Ending stocks, thousand tonnes	Export, thousand tonnes	Import, thousand tonnes
1990	919	203	1,426	287	0	250
1995	1,208	250	1,188	250	29	9
2000	968	104	1,000	88	1	17
2005	1,054	339	1,050	274	69	0
2010	464	411	650	189	38	2
2015	394	106	420	75	21	16
2020	459	48	402	90	17	2
2021	600	90	415	114	162	1
2022	285	114	337	42	20	0
2023	230	42	202	60	10	0

Source: *Indexmundi (2023)*

In the 2021/22 marketing year, Spain, Turkey, and Poland were among the most active buyers of Ukrainian rye. Ukraine's share in global rye exports during this period increased not only due to the growth of its own production but also due to a decrease in supply from other exporters. For a long time, the Netherlands (which purchased USD 41.9 million worth of rye in 2020), Spain (USD 60.8 million in 2020), and Germany (USD

189 million) were traditional destinations for Ukrainian rye exports. In 2022, despite the war, South Korea and Japan surpassed Spain and Germany in export volumes. As a result, in recent years, the geographical scope of Ukrainian rye exports has expanded to East Asian countries. Rye was exported to these regions for the production of alcoholic beverages, animal feed, fertilisers, and rye straw. In 2023, the top three exporters of Ukrainian rye were Poland (39%), Germany (33%), and Slovakia (24%) (State Customs Service..., 2023). Overall, this segment is highly profitable for Ukrainian agricultural producers as they face virtually no competition in this niche crop market.

Despite the existing demand, Ukraine witnessed a trend of increasing sown areas under rye in 2020-2021. In 2021, the area under cultivation reached 175 thousand hectares, which is 59.5 thousand hectares (51.5%) more than in 2019 (Table 4). However, in 2022-2023, sown areas of rye decreased significantly by 11.7% and 30.7%, respectively, compared to 2019. Consequently, rye grain production also decreased. This is primarily attributed to the full-scale russian invasion. Meanwhile, the crop yield in 2019-2023 was quite stable and fluctuated within the range of 27-35 centners per hectare across different categories of farms. Lower rye yields were typical for household farms, while higher yields were characteristic of agricultural enterprises. Although, overall, rye yields in Ukraine are currently quite low compared to other leading rye-producing countries.

Table 4. *Level and dynamics of rye production in Ukraine by main producers*

	2019	2020	2021	2022	2023	2023 to 2019, %
Sown area, thousand hectares						
All types of farms	115.5	140.0	175.0	102.0	80.0	69.3
Including agricultural enterprises	57.9	82.6	116.3	57.6	38.9	67.2
Of which: farms	10.6	16.4	21.5	n/a	n/a	
households	57.6	55.9	55.7	44.4	40.4	70.1
Production, thousand centners						
All types of farms	3,346.8	4,567.8	5,931.5	3,140.3	2,311.8	69.1
Including agricultural enterprises	1,792.9	3,047.2	4,440.2	1,959.1	1,175.6	65.6
Of which: farms	329.9	636.6	779.6	n/a	n/a	
households	1,553.9	1,520.6	1,491.3	1,181.2	1136.2	73.1
Yield, centners/hectare						
All types of farms	28.9	33.2	34.5	30.9	29.4	101.7
Including agricultural enterprises	31.0	37.2	38.1	34.2	30.9	99.7
Of which: farms	31.2	39.5	36.6	n/a	n/a	
households	26.8	27.3	26.9	26.7	27.9	102.2

Note: *n/a – data not available*
Source: *Plant Growing in Ukraine (2022)*

It should be noted that modern rye varieties and hybrids have a yield potential of 10-12 tonnes per hectare, which is one of the key arguments supporting the high economic potential of rye. In recent years, there has been a growth in the share of hybrids in the Ukrainian rye market – almost half of rye areas are sown with hybrids. This is due to their higher yield, greater resistance to pests, lower seeding rate, and consequently, higher profitability compared to varieties. An argument in favour of hybrid rye is that it is a cheaper raw material with a high content of crude protein, the use of which provides a noticeable economic effect for livestock farms.

As of 2023, rye production in Ukraine was almost evenly distributed between agricultural enterprises (50.9%) and household farms (49.1%). However, as recently as 2021, the majority of rye in Ukraine was grown by agricultural enterprises. In 2021, they produced 4,440.2 thousand centners of rye, accounting for 74.6% of the gross harvest. Significantly, during 2019-2021 (before the full-scale russian invasion), households (by 136%) and agricultural enterprises (by 147.7%) significantly increased their rye production. This was facilitated by both an increase in sown areas under rye and a growth in yields. This trend can be seen as one of the indicators that niche crops are increasingly attracting the attention of farmers, particularly small agricultural businesses, which may not be able to compete with large enterprises in the production of so-called "cash crops". For these businesses, focusing on a specific niche and diversifying their crops is a viable strategy for effective development.

While exploring the advantages of rye that contribute to its economic value and potential, it is essential to focus on the primary factors hindering its production. First and foremost, rye exhibits different storage characteristics compared to wheat: even under favourable

conditions, rye's seed viability declines, whereas wheat can retain its viability for a year or more. Overcoming this obstacle, i.e., preserving the quality of rye seed, can be achieved by selecting optimal varieties. Another reason for the relatively small scale of rye cultivation, particularly in Ukraine, is its comparatively lower yield. However, as the experience of leading rye-producing countries demonstrates, yield primarily depends on cultivation technology rather than the crop itself. Niche crops like rye have significant potential. Breeders have already developed rye varieties with yields comparable to other cereal crops. Ukrainian agricultural market experts assert that in 9 out of 10 years, winter rye produces a high yield (⩾ 5 tonnes/hectare), although there is a risk of crop failure once every 26 years, primarily due to weather conditions (Opara, 2020). The concentration of Ukrainian farmers on traditional, widely cultivated commercial crops, for which well-established domestic and international markets exist, also negatively impacts the development of rye production and its market. These crops have established distribution channels, making it more challenging for rye to gain a significant market share.

Furthermore, one of the most significant factors currently hindering the development of rye production in Ukraine is the steady increase in the cost of mineral fertilisers. The sharp rise in global natural gas prices in 2021 led to a substantial increase in the cost of mineral fertilisers. This is because up to 80% of the production cost of mineral fertilisers depends on the use of natural gas as a primary raw material. As a result of this increase in gas prices, production costs for fertiliser companies have risen significantly, which, in turn, has affected the final product price. This situation has created an additional financial burden on farmers, which could have influenced their decisions regarding production volumes and the use of agrochemicals.

According to the World Bank, global mineral fertiliser prices increased by an average of 80% in 2021. In the first quarter of 2022, they rose by almost another 30% (World Bank Group, 2022). As shown in Table 5, for the period from January 2020 to January 2024, global prices for diammonium phosphate, urea, and potassium chloride increased by 2.25, 1.56, and 1.06 times, respectively (World Bank, 2024). The highest global prices for mineral fertilisers were recorded in April 2022, which was due to the imposition of economic sanctions on russia and belarus following russia's full-scale invasion of Ukraine, as well as export restrictions on fertiliser exports imposed by China (World Bank Group, 2022, The World Bank..., 2024). Similar trends are observed when analysing the Fertiliser Affordability Index (FAI), which is used to assess the economic affordability of fertilisers for farmers. This index is calculated as the ratio of fertiliser costs to agricultural product prices. A higher index indicates that fertilisers are less affordable for farmers, as their cost is relatively high compared to the income from agricultural sales.

***Table 5**. Dynamics of global mineral fertiliser prices, USD per tonne*

Period	Diammonium phosphate	Urea	Potassium chloride	Fertiliser Affordability Index (FAI)
January 2020	264.9	215.4	268.7	0.77
January 2021	421.3	265.0	255.5	0.75
January 2022	699.4	846.4	785.6	1.82
April 2022	954.0	925.0	1,202.0	1.92
January 2023	631.0	443.8	508.8	1.34
January 2024	596.3	335.4	284.0	0.98
April 2022 to January 2020, times	3.60	4.29	4.47	2.49
January 2024 to January 2020, times	2.25	1.56	1.06	1.27

***Source:** compiled by the authors based on data from the World Bank (2024)*

Conversely, a lower index indicates that fertilisers are more affordable, as their cost is relatively low compared to the income from product sales. The highest global FAI was recorded in April 2022, reaching 1.92. Overall, after high FAI values in the period from 2022 to 2023, the index decreased to 0.98 only in January 2024. This change indicates an improvement in the economic affordability of fertilisers for farmers, which may contribute to increased fertiliser use and higher crop yields.

As previously noted, one of the main drivers of rising mineral fertiliser prices, both globally and in the Ukrainian market, remains high natural gas prices, which continue to increase. For example, at the TTF (Title Transfer Facility) gas hub in the Netherlands, the price of natural gas increased from USD 263.5 to USD 412.2 per 1,000 m^2 between June 1, 2023, and June 3, 2024, or by 56.4% (Ministry of Finance of Ukraine, Gas prices..., 2024). In addition, the increased cost of electricity and logistics services in Ukraine indicates that the trend of rising mineral fertiliser prices will continue. High energy and logistics costs affect the overall cost of fertiliser production, which ultimately is reflected in their market price. Thus, farmers and agricultural producers, particularly in Ukraine, may face further increases in the

cost of purchasing mineral fertilisers, which could affect their production decisions and economic efficiency.

The high prices of mineral fertilisers, coupled with the adherence to modern agricultural technologies, significantly increase the production costs of grain crops. According to estimates, the production cost of agricultural products may increase by 10-12% due to the rising cost of fertilisers (Ministry of agrarian policy...). Small and medium-sized family farms, which cultivate small areas of land (up to 400-500 hectares) and have limited working capital for fertiliser purchases, are particularly vulnerable to these changes. As a result, many farmers will be forced to reduce their fertiliser use, as the additional benefit of their application does not compensate for the purchase costs. This can lead to a decrease in yields and overall production efficiency, negatively impacting farmers' financial situation and the stability of the agricultural sector as a whole (Gromov, 2022).

From a scientific and practical standpoint, it is crucial to assess the economic consequences of changing mineral fertiliser prices on key parameters of the rye market in Ukraine. Such assessments can only be preliminary, as there is insufficient data for a detailed analysis. For example, some agricultural producers managed to purchase mineral fertilisers in advance, while others are doing so under the current challenging conditions, and some plan to make purchases in the spring, hoping for a decrease in market prices or government compensation. Due to the different procurement strategies and uncertainty in the fertiliser market, accurate calculations of the impact of changing fertiliser prices on the rye market require a comprehensive approach and additional data. These factors complicate the analysis but make it critically important for understanding and forecasting the development of the agricultural sector in the face of fluctuating fertiliser prices.

To assess the impact of changing mineral fertiliser prices on key parameters of supply and demand in the Ukrainian rye market, an econometric dynamic partial equilibrium model – AGMEMOD – was used. According to the fundamentals of economic theory, agricultural product and factor markets are closely interconnected and influence each other. For example, an increase in gross grain harvests leads to a rise in demand for mineral fertilisers. This increased demand stimulates a growth in domestic fertiliser prices, which, in turn, affects market prices for grain crops. The interdependence between these markets means that changes in one segment can have significant consequences for others. Therefore, analysis using the AGMEMOD model allows for a more accurate prediction of the impact of changing mineral fertiliser prices on the overall situation in the rye market, including production costs, product prices, and producer incomes. This approach provides a deeper understanding of economic processes and supports the adoption of effective decisions in the field of agricultural policy and management.

To assess the impact of production factors on the development of the rye market, various production costs were included in the AGMEMOD model. These costs encompass rent for agricultural land and property, wages, fuel and lubricant costs, seeds, and mineral fertilisers. These costs were calculated per hectare of harvested area for the period from 1992 to 2021. The inclusion of these costs in the AGMEMOD model allows for a more detailed analysis of their impact on key parameters of the rye market, including yield, gross harvest, and profitability. This approach contributes to a better understanding of the economic conditions in which farmers operate and aids in the development of policies aimed at supporting and developing the agricultural sector:

$$RYCGUUA = R + RP + S + SPM + FL + MF \times K_n, \quad (12)$$

where *RYCGUUA* is the production costs of rye per hectare of the sown area; *R* is the land rent per hectare of agricultural land, UAH; *RP* is the rent for the property per hectare, UAH; *S* is the labour costs per hectare, UAH; *SPM* are the costs for seeds and planting material per hectare, UAH; *FL* is the fuel and lubricant costs per hectare, UAH; *MF* are the costs for mineral fertilisers per hectare, UAH; K_n is the coefficient for changes in mineral fertiliser costs.

In this study, the authors hypothesise that changes in the cost of mineral fertilisers influence key parameters of the rye market by altering the costs per hectare of cultivated land. To assess this impact, three different scenarios were developed and modelled. These scenarios were designed to analyse various possible situations and their consequences for the Ukrainian rye market, taking into account changes in the cost of mineral fertilisers. Each scenario reflects a certain level of change in fertiliser costs and its impact on yield, production costs, gross harvest, and other key market parameters. This approach allows for a detailed examination of potential economic consequences and provides well-founded recommendations for producers and policymakers on managing risks associated with changes in fertiliser costs. The baseline scenario assumes that the cost of mineral fertilisers per hectare remains at the 2022 price level. Other scenarios model an increase in fertiliser costs by 50%, 100%, and 150% compared to the baseline level. To introduce these scenarios into the model, the coefficient of change in mineral fertiliser costs (Kn) was used according to formula 12. Thus, for the "+50%", "+100%", and "+150%" scenarios, Kn is 1.5, 2.0, and 2.5, respectively.

As evidenced by Table 6, the results of the modelling scenarios confirm that, with an increase in the cost of mineral fertilisers compared to the baseline scenario, the average rye yield exhibits a steady downward trend. This is likely because small and medium-sized farms, which primarily grow rye as a niche crop, will be forced to reduce fertiliser application rates due to

their high cost. A decrease in fertiliser use can lead to a decline in soil fertility and, consequently, a decrease in yield. This is particularly relevant for small farmers who have limited financial resources and cannot afford additional expenses for expensive fertilisers. Such changes can have a significant impact on the overall productivity of the agricultural sector and the economic stability of farms. According to the modelling results, an increase in the cost of mineral fertilisers will also lead to a reduction in sown areas and, consequently, to a decrease in gross rye harvests compared to the baseline scenario. If the harvested area of rye remains at around 143.7 thousand hectares, the gross harvest with an increase in the cost of mineral fertilisers will decrease to 462 thousand tonnes, which is 9.2% less compared to the baseline scenario.

***Table 6**. Modelling scenarios of the impact of changes in mineral fertiliser costs on key parameters of the rye market in Ukraine using the AGMEMOD model*

	Baseline scenario, 2022	Scenarios of mineral fertiliser price changes relative to the baseline scenario, 2022		
		"+50%"	"+100%"	"+150%"
Average yield, thousand /hectares	3.24	3.21	3.21	3.21
Harvested area, thousand hectares	157.2	143.7	143.7	143.7
Share of rye in total cereal area, %	1.0%	1.0%	1.0%	1.0%
Gross harvest, thousand tonnes	508.7	462.0	462.0	462.0
Import, thousand tonnes	0.02	0.02	0.02	0.02
Change in stocks at year-end, thousand tonnes	232.8	150.6	150.6	150.6
Total Resources	**508.76**	**462.0**	**462.0**	**462.0**
Export, thousand tonnes	135.54	125.9	125.9	125.9
Feed use, thousand tonnes	50.0	50.0	50.0	50.0
Seed use, thousand tonnes	34.6	31.6	31.6	31.6
Losses, thousand tonnes	19.6	17.8	17.8	17.8
Food use, thousand tonnes	269.1	236.8	236.8	236.8
Total Resources	**508.8**	**462.0**	**462.0**	**462.0**
Consumption fund	373.2	336.2	336.2	336.2
Production/Domestic consumption	1.36	1.37	1.37	1.37
Feed costs/Production	0.10	0.11	0.11	0.11
Export/Production	0.27	0.27	0.27	0.27

***Source:** authors' calculations based on data from Plant Growing in Ukraine (2022), Balances and Consumption..., 2021)*

Furthermore, it was found that an increase in the cost of mineral fertilisers does not have a significant impact on the volumes of rye exports and imports, as this crop is primarily grown to meet domestic market needs, although, as noted above, the potential for exporting the crop from Ukraine exists. The obtained modelling results, according to which an increase in the cost of mineral fertilisers by 50%, 100%, and 150% did not affect the yield, sown areas, and gross harvest of rye, are interpreted as follows. Firstly, due to the low elasticity of costs, the volumes of gross rye harvest may be less sensitive to changes in the cost of fertilisers compared to other factors. This means that farmers can use fertilisers more efficiently or replace them with other agronomic practices, which will allow them to maintain yields at a stable level even with a significant increase in cost.

Secondly, farmers may have stockpiles of fertilisers purchased at lower prices, allowing them to temporarily avoid the impact of rising costs on yields. Such reserves can be used to maintain stability in production. Thirdly, agricultural producers may adapt their agronomic practices in response to rising fertiliser prices. This may include more precise fertiliser application, the use of organic fertilisers, or changes in crop rotation, which helps to maintain productivity. Fourthly, changes in yield and areas may only become noticeable after several years. The impact of rising fertiliser costs may be more pronounced in the long term; in the forecast year, such changes may not yet have had time to manifest. Fifthly, the AGMEMOD model may have taken into account other compensating factors that reduce the impact of rising fertiliser costs on the predicted indicators. For example, an increase in grain prices may offset the increase in production costs.

Therefore, changes may be more noticeable over time as the gradual accumulation of negative effects from high fertiliser costs can influence long-term trends in the industry. However, in the short term, farmers may find ways to maintain production stability through adaptive strategies and agronomic solutions. Using the econometric model AGMEMOD, a forecast was developed for the medium-term consequences of increasing the cost of mineral fertilisers (a scenario of a +100% increase in fertiliser costs compared to the actual data for 2021) on the development of the rye market in Ukraine for the period up to 2026 (Table 7).

***Table 7**. Forecasting the consequences of changes in the cost of mineral fertilisers on key parameters of the development of the rye market in Ukraine using the AGMEMOD model (scenario of a "+100%" increase in fertiliser costs compared to 2021)*

	Actual data for 2021	Forecast data for the period up to:		
		2024	2025	2026
Average yield, thousand /hectares	3.43	3.11	3.16	3.21
Harvested area, thousand hectares	172.90	143.12	143.60	143.71
Gross harvest, thousand tonnes	593.00	445.25	454.30	461.99
Import, thousand tonnes	0.02	0.02	0.02	0.02
Export, thousand tonnes	238.67	94.61	111.06	125.85
Feed costs, thousand tonnes	35.00	50.00	50.00	50.00
Sowing costs, thousand tonnes	33.00	31.49	31.59	31.62
Losses, thousand tonnes	8.00	17.14	17.49	17.78
Food use, thousand tonnes	278.35	252.03	244.19	236.76
Consumption fund	354.35	350.66	343.27	336.16
Production/Domestic consumption	1.67	1.27	1.32	1.37
Feed costs/Production	0.06	0.11	0.11	0.11
Export/Production	0.40	0.21	0.24	0.27

***Source:** authors' calculations based on data from Plant Growing in Ukraine (2022), Balances and Consumption… (2021)*

The results of the forecast indicate that under the scenario of a "+100%" increase in the cost of mineral fertilisers, the key parameters of supply and demand in the Ukrainian rye market, as a niche grain crop, compared to the actual data for 2021, will reach the following indicators in 2026: the average yield will decrease from 3.43 to 3.21 tonnes per hectare; the harvested area will remain at around 144 thousand hectares; the gross harvest will decrease from 593 to 462 thousand tonnes, or by 22.0%; the use of rye for animal feed will remain at a fixed level, which is primarily due to negative trends in the development of the livestock industry in Ukraine; the ratio of production to domestic consumption will decrease from 1.67 to 1.37, but this will be quite sufficient to meet domestic needs; the ratio of exports to production will have a slight upward trend from 0.21 to 0.27. These forecasts indicate a significant impact of rising mineral fertiliser costs on the productivity and economic performance of rye production. Although harvested areas will remain stable, a decrease in yield and gross harvest can create additional challenges for the Ukrainian agricultural sector, primarily for small and medium-sized farms.

DISCUSSION

The results of this research, in the context of the multifunctionality of the niche crop rye, are connected to several other studies that focus on the properties of this crop and the opportunities provided by its production and processing. For example, B. Brockmueller *et al.* (2022) investigated the impact of rye on biodiversity, while W.L. Carrasco-Chilón *et al.* (2023) highlighted the potential for growing rye in arid conditions. However, the difference of this study in the context of the significance of the niche crop rye lies in the generalisation of its characteristics that form its multifunctionality, rather than highlighting a specific one. Similarly, the issue of ensuring food security and shaping effective agricultural policy has been the focus of many researchers in various interpretations, from different perspectives, and using examples from different countries. For instance, R. Byaruhanga *et al.* (2023) substantiated the prerequisites for sustainable food security through the establishment of national food sovereignty. M.A. Djan (2023) investigated the opportunities associated with ensuring food security in cities and in the context of global megatrends that shape the future world. It should be noted that the authors of the current study support the emphasis on global megatrends and in this research also highlighted the fact that the rye market today is largely dependent on the popular trend of healthy eating. In turn, I. Petrunenko *et al.* (2021) studied the issue of ensuring food security in the EU countries in the context of sustainable development and emphasised the need for a systematic improvement of the food security policies of EU member states, which echoes the results of this specific study, in which the authors substantiate the interconnection between the development of rye production and sustainable development.

Food security, agricultural potential, and agricultural productivity are directly linked to the development of production and markets for niche crops, such as rye. In this regard, the results of this study, in the context of the advisability of agricultural production diversification, are similar to the conclusions presented in the scientific publication by T.X. Neik *et al.* (2023), in which the scientists propose diversifying food markets, agricultural production, and technologies to ensure global food supply and build resilience to potential future shocks. In turn, T.X. Neik *et al.* (2023) consider agricultural diversification in the context of producing a crop as popular worldwide as rice, while the authors of this publication, on the contrary, consider the possibilities of diversifying agricultural production through

the widespread cultivation of niche crops, particularly rye. Furthermore, the findings of C. Di Bene *et al.* (2022) support the results obtained in this study regarding the economic feasibility of incorporating rye into crop rotations. The authors also prove that combining agricultural diversification, including crop rotation, cover crops, and perennial crops, with low-cost management strategies such as agroecology, conservation agriculture, and organic farming, contributes to increasing crop productivity and the sustainability of the farming system in the long term. At the same time, the difference of this study is an attempt to generalise the advantages of rye as a niche agricultural crop and the opportunities provided by its production and processing in environmental, sociological, agronomic, and economic terms.

It is important to note that the majority of studies on rye production and its market focus on the advantages of this crop, while this study also addresses the barriers that hinder the development of rye production and its market. In particular, a distinctive feature of this study is the identification of a key factor that negatively affects the development of the rye market in Ukraine, such as the rising cost of mineral fertilisers. In this regard, the most significant scientific and practical novelty of this study is the forecasting of the rye market under various probable scenarios using the econometric partial equilibrium model AGMEMOD, within which an assessment was made of the impact of changes in the cost of mineral fertilisers on the main parameters of the formation of supply and demand in the Ukrainian rye market. Forecasting and modelling the market to reduce risks and increase the economic efficiency of production.

CONCLUSIONS

Therefore, rye, as a niche crop, is characterised by its multifunctionality and enjoys stable demand on the market, particularly in the health food and organic product sectors. This allows farmers to obtain a higher price for their produce. Additionally, growing rye contributes to crop rotation diversification, reducing risks associated with monocultures and the instability of other grain markets. Ultimately, this positively impacts food security levels. As of 2023, Ukraine was among the top 10 countries in the world in terms of rye production, consumption, and export. However, the development of rye production and its market under current challenges is hindered by several factors. The most threatening and restraining factor for the development of the rye market, according to the authors, is the rising cost of mineral fertilisers. Based on the conducted research, the impact of changes in the cost of mineral fertilisers on the main parameters of supply and demand in the rye market under probable scenarios has been quantitatively justified using the econometric partial equilibrium model AGMEMOD. Calculations have shown that under the "+100%" scenario (an increase in the cost of mineral fertilisers compared to 2021), the gross harvest of rye in Ukraine will decrease from 593 to 462 thousand tonnes, or by 22.0%, due to a decrease in yield by 6.3% and harvested area by 16.9%.

Regression results indicated that due to the low elasticity of costs, the volumes of gross rye harvests in Ukraine were less sensitive to changes in fertiliser prices compared to other factors. Specifically, modelling a 50%, 100%, and 150% increase in the cost of mineral fertilisers did not affect the average yield, harvested area, or gross harvest of this niche grain crop. This means that farmers can optimise fertiliser use or replace them with other agronomic methods, allowing them to maintain yields at a stable level even with a significant increase in fertiliser costs. In particular, they can implement precision agriculture, which involves using modern technologies to optimally determine the amount of fertiliser required for each field plot. This reduces costs and increases efficiency; they can use organic fertilisers or green manure, which contribute to improving soil structure and increasing its fertility without significant additional costs. Another approach could be the application of integrated nutrient management methods that optimise the use of both organic and mineral fertilisers. Given the above, ensuring that farmers have access to mineral fertilisers and maintaining low food prices will become new global challenges for many countries. Such steps will help strengthen the agricultural sector of Ukraine, making it more resilient to economic and market fluctuations, and will contribute to preserving the country's food security in the face of current threats and challenges. The prospects for further scientific study in this direction are closely related to the continued application of the AGMEMOD econometric model to forecast markets for niche crops in the context of the need to ensure food security in Ukraine and the world.

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CONFLICT OF INTEREST

None.

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Прогнозування і моделювання ринку жита, як нішевої зернової культури, в умовах зростання вартості мінеральних добрив

Анатолій Діброва
Доктор економічних наук, професор
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-2503-2431
Вікторія Байдала
Доктор економічних наук, професор
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-1532-2913
Тетяна Мірзоєва
Доктор економічних наук, професор
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-0034-6138
Людмила Степасюк
Кандидат економічних наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-7258-9243
Алла Чміль
Доктор філософії, асистент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-2690-5903
Лариса Діброва
Кандидат економічних наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-4877-0496

Анотація. Вирощування жита як нішевої культури в Україні набуває дедалі більшого значення, але через зростання вартості мінеральних добрив необхідне прогнозування та моделювання ринку для зниження ризиків і підвищення економічної ефективності виробництва. Метою даного дослідження була оцінка поточного стану попиту і пропозиції на ринку жита, яке розглядається як нішева зернова культура, та прогнозування наслідків зміни вартості мінеральних добрив на ключові параметри його розвитку за ймовірними сценаріями. У рамках дослідження застосовано такі методи, як: порівняльного аналізу, табличний, статистико-економічний, абстрактно-логічний, економетричне моделювання, зокрема використано економетричну модель часткової рівноваги AGMEMOD. Було розкрито потенціал жита як нішевої культури, сучасний стан його виробництва і визначено ключові чинники, що впливають на формування попиту і пропозиції на ринку жита в Україні; проаналізовано динаміку балансу попиту і пропозиції на ринку жита, враховуючи різні економічні та інші фактори; здійснено прогнозування наслідків зміни вартості мінеральних добрив на основні параметри розвитку ринку жита в Україні за кількома ймовірними сценаріями. Прогноз охоплював період до 2026 року та дозволяє оцінити вплив різних змін на врожайність, площі посівів, валові збори та економічну ефективність виробництва жита. Дослідження надає передумови для підвищення ефективності ухвалення та реалізації управлінських рішень, сприяючи досягненню цілей державної аграрної політики, в тому числі стосовно забезпечення продовольчої безпеки. Запропоновані методичні підходи і результати дослідження можуть бути корисними для органів державного та галузевого управління при розробці пріоритетних напрямів, спрямованих на підвищення результативності вітчизняної зернової галузі

Ключові слова: аграрна політика; жито; нішеві культури; ринок зерна; диверсифікація; продовольча безпека; мінеральні добрива; AGMEMOD