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State and prospects of fuel supply for agriculture in Ukraine

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Abstract. In the context of martial law in Ukraine, when the oil refining industry has stopped and most of the logistics chains have been destroyed, the issue of ensuring the availability of fuel and energy resources for agricultural production – the guarantor of food supply in Ukraine and the world – is of particular relevance. The purpose of the article was to study the consumption of petroleum products in the agricultural sector

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of Ukraine under martial law, to investigate the state and state regulation of the market and fuel from petroleum products, and to forecast their price in the future. The following methods were used in the article: dialectical, abstract and logical, statistical, correlation and regression, tabular and graphical, analysis of series of dynamics and structural changes, comparison, strategic planning and forecasting. Based on the results of the research carried out using statistical methods, the article analyses the consumption of petrol and diesel fuel by agricultural enterprises and calculates their cost per hectare of harvested area. It was found that the decrease in fuel consumption in 2022 was due to the fact that $\frac{1}{4}$ of the sown areas were not sown due to the war. The share of fuel used for the needs of the agricultural sector was also investigated. The correlation and regression analysis revealed a close relationship between the exchange rate and the price of diesel fuel in Ukraine, and a negative relationship between the world oil price and the price of diesel fuel. Due to the established dependence, a model for calculating the price of diesel fuel based on world oil prices and the exchange rate is developed, and the price is calculated. It is substantiated that the main economic method of state regulation of the fuel market is the establishment of an excise tax. It is concluded that the reduction in the consumption of fuel and energy resources in the agricultural sector of Ukraine has led to a decrease in the energy intensity of agricultural products. The results of the research are of practical importance, which will allow identifying destabilizing factors in the oil and oil products market, as well as formulating the State's policy that will promote the use of energy resources, in particular liquid fuel, in agriculture under martial law

Keywords: agricultural enterprises; energy intensity; energy security; martial law; oil products; import; logistics

INTRODUCTION

Since February 2022, the role of the Ukrainian agricultural sector in the food supply has been particularly significant in the world. The main factors behind its limitations were the reduction in crop areas due to the occupation and in the war zone, disruption of the logistics of both agricultural products and logistics of the industry, including energy supply. Given that agriculture mainly uses liquid fuels made from petroleum products and Ukraine's high dependence on imports of this type of energy, this issue requires special attention and control to ensure its immediate resolution. The presence of numerous participants in the Ukrainian fuel market and the integration of Ukraine's economy into the global economy have a decisive impact on changes in oil fuel prices. Fluctuations in oil prices, the exchange rate and Russia's military aggression against Ukraine contributed to the imbalance in the Ukrainian petroleum products market.

The price situation on the Ukrainian fuel market is complicated by the cooperative actions of traders. This is reflected in the asymmetry of prices, when a large jump in the value of an external factor causes a rapid rise in the price of petroleum products and a slow decline in the period of its weakening. All of this has a significant impact on the development of the national economy, given that oil prices are the main determinants of the overall price level, making the study relevant and timely.

The problem of using fuel and energy resources in the agricultural sector of Ukraine was studied by O. Zakharchuk *et al.* (2021). The vector of his research was aimed at providing agriculture with light oil products, their use in various technological processes, and

the possibility of saving energy resources in the process of applying innovative agricultural technologies. Consumption in agricultural enterprises was also studied by O. Zakharchuk and O. Vyshnevetska (2020). In addition to fuel consumption by the agricultural sector, they paid special attention to energy efficiency and energy security, price parity for agricultural products and oil products. They paid much attention to the study of the oil products market, the production infrastructure of the oil refining industry, and government regulation of these issues. S. Strapchuk studied the production and consumption of bioenergy resources. Strapchuk (2021). The author found that biodiesel production requires large land areas, so it is worth considering whether it is advisable to reduce the area under food crops in favour of energy crops. It has been found that biofuel production is not widespread enough, so most of the harvested rapeseed and soybeans are exported.

The efficiency of energy use in agriculture was substantiated by N.V. Pryshlyak (2021). External and internal economic and non-economic factors influencing the pricing of petroleum products in Ukraine were studied by V. Melnychuk & A. Melnychuk (2019). Aspects of legal regulation of trade in petroleum products in Ukraine were studied by V.S. Levchenko (2020). The state and prospects of development of the fuel market of Ukraine were studied by V. Kapustyan & I. Siretska (2018). They concluded that one of the main destabilizing factors in its development was significant import dependence with an unstable exchange rate. In their research, they argue that the Ukrainian oil refining industry is not able to fully respond to the changing socio-economic situation in Ukraine, and the

effectiveness of market reforms in the industry is low. In addition, they believe that the privatization of oil refineries has not given an impetus to the development of these enterprises, privatization agreements have not been fulfilled and, as a result, even minimal investment commitments for technical re-equipment of the industry, which is highly monopolized, have not been fulfilled.

The fuel and energy problems of agriculture under martial law have not been thoroughly studied. Firstly, this concerns the mechanisms for overcoming the fuel crisis that arose in the first year of the war, the loss of a significant percentage of imported fuel, the destruction of oil refineries and oil depots, and the enormous increase in fuel prices, all of which had a significant impact on Ukraine's food security and the development of the entire economy. That is why the purpose of the study was to assess the trends in quantitative and qualitative changes in fuel and energy resources used in agriculture, energy intensity and energy supply of agricultural production, the state, and state regulation of the oil fuel market, and the calculation of its price for 2023-2024.

MATERIALS AND METHODS

The research methodology is based on the dialectical method of scientific cognition (in the study of processes and phenomena that occur with the provision of energy resources to agriculture in Ukraine under martial law); abstract and logical (in substantiating theoretical provisions for reducing energy intensity in agriculture); statistical (to quantify the situation on the fuel market in absolute and relative terms); correlation and regression (to build a model for calculating the price of diesel fuel in Ukraine, taking into account the

The main economic method of state regulation of the fuel market is to set the excise tax rate. It was the method of structural shifts that was used to analyse the excise tax rates on fuel in Ukraine for the period 2011-2023. This period was not chosen by chance, as it was the time when Ukraine's energy import dependence was beginning to increase and the production of fuels and lubricants of Ukrainian origin was significantly reduced. At the same time, the Tax Code of Ukraine (n.d.), which is the main state price regulator of fuel in Ukraine, was introduced. To build a model for calculating the price of diesel fuel depending on the world oil price and the exchange rate, the correlation and regression analysis and forecasting methods were used. The initial information was an array of monthly data from the Ministry of Finance of Ukraine on world oil prices, diesel prices and the exchange rate from January 2014 to December 2022 (Prices and markets, n.d.).

The information base of the study included reference and information publications, the regulatory

framework of state economic regulation of the development of the agricultural sector of the economy (Official web portal of the Parliament of Ukraine), statistical and analytical data of the Ministry of Agrarian Policy and Food of Ukraine, the Ministry of Energy of Ukraine, the Ministry of Finance of Ukraine, the State Statistics Service of Ukraine, the State Customs Service of Ukraine, and scientific electronic sources.

RESULTS AND DISCUSSION

The importance of Ukraine's fuel and energy complex is determined by its role in the functioning of social and economic infrastructure. Its dependence on natural reserves of energy resources, imports, capital intensity and significant share in the cost of production of all sectors of the economy require special attention. By the early 2000s, there were oil refineries in seven regions of Ukraine. Their total capacity was 52 million tonnes per year. This was enough to cover the national economy's demand for domestically produced petrol and diesel fuel. The scale of the oil refining infrastructure is also evidenced by the 4,625 km long oil pipeline system with a capacity of 30-35 million tonnes per year. The design capacity of the Ukrainian oil transportation system is 100 million tonnes per year, and the capacity of the tank farm is 4 million m³ (Zakharchuk et al., 2021).

Ukraine's loss of subjectivity in the field of oil products supply is indicated by a 75% reduction in energy infrastructure by 23 February 2022. In 2022, new transport routes were developed and the fuel supply system was changed. Ukraine's fuel market has been completely rebuilt. An extensive fuel supply system has been created. Logistics has changed radically, which has led to an increase in costs. During the war period, the volume of fuel transported by petrol tankers increased from 0.5 to 50%. Fuel importers also changed. 95% of petrol and 75% of diesel are imported from Romania, Lithuania, Slovakia, Greece, Bulgaria, and Poland (State Customs Service of Ukraine, 2023).

In 2011-2023, the total consumption of petrol and diesel fuel by sectors of the national economy was 1.7-4.6 million tonnes and 4.7-6.3 million tonnes, respectively. The largest share of consumed fuel resources is accounted for by agriculture, the military sector, transport, and industry. The share of agricultural enterprises in the total consumption of diesel fuel is over 29%, and petrol – 7%. The corresponding figures for industry are 15-20% and 6%, and for transport, 2.5-4% and 19-20%. The relative stability in the consumption of fuel and energy resources by sectors of the national economy was disrupted after the full-scale invasion on 24 February 2022. The share of the military sector in total diesel fuel consumption in 2022 increased to 37.6%, which was more than half as much in pre-war 2021 (15.8%) (Fig. 1) (State Statistics Service of Ukraine, n.d.).

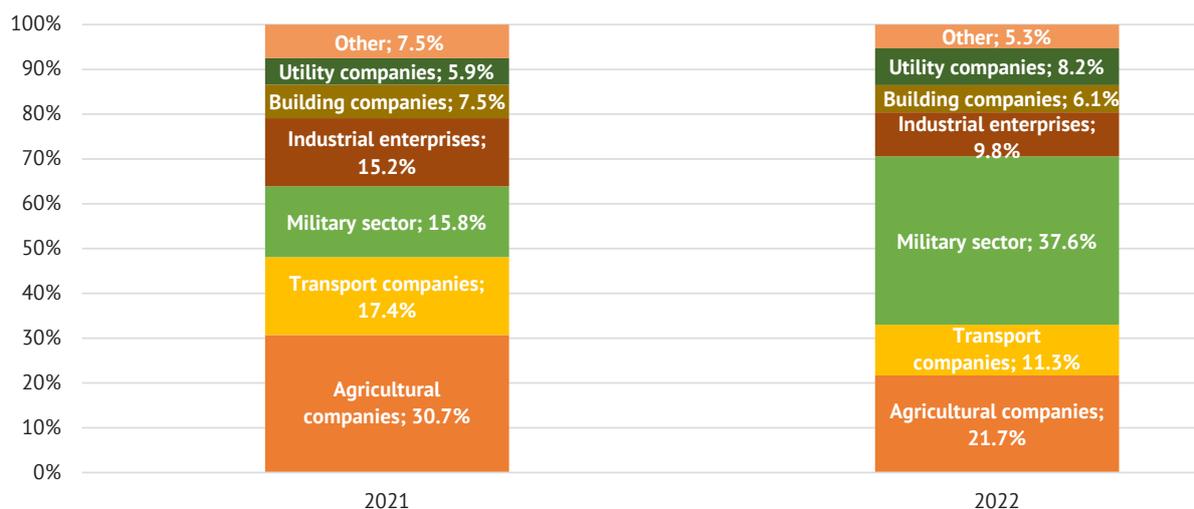


Figure 1. Share of major fuel consumers in 2021 and 2022

Source: (Market of oil products in Ukraine ..., 2023)

While agriculture and transport were the largest consumers of petroleum products before the beginning of 2022, the structure changed in favour of the military sector with the outbreak of war. In 2022, the share of fuel consumption by the military sector was 2.4 times higher than that of the agricultural sector. However, the agricultural sector

remains the main consumer of fuel in the national economy. The total consumption of diesel fuel in agriculture in 2023 was 972 thousand tonnes (calculated value), which is 33% less than in pre-war 2021. The situation is the same with petrol (Table 1).

Table 1. Fuel consumption by agricultural enterprises, thousand tons

Type of fuel	Year									
	2014	2015	2016	2017	2018	2019	2020	2021 (provisional)	2022 (calculation)	2023 (estimated)
Motor petrol	149.3	132.8	130.3	125	106	111.3	84.4	96.0	93.1 (60.0)	64.8
Diesel	1412.6	1255.6	1319.3	1345	1445	1604.3	1314.2	1459.4	1477.9 (900.0)	972.0
Petrol for 1 ha of sowing, kg	7.9	7.1	6.9	6.5	5.5	5.7	4.3	4.8	6.6 (4.2)	4.3
Diesel fuels for 1 ha of sowing, kg	75.0	67.1	70.2	69.8	74.6	81.8	66.6	72.3	100 (63.7)	68.0

Note: *2022 in the numerator until February 24, 2022, in the denominator after February 24, 2022

Source: 2014-2020 – State Statistics Service of Ukraine. (n.d.). 2021-2023 authors' calculations. 2021-2022 – authors' calculations

The decrease in consumption of petroleum products in Ukrainian agriculture since independence was due to a 13% reduction in sown areas, a change in the structure of sown areas in favour of less energy-intensive crops, a fourfold reduction in the agricultural machinery fleet, the introduction of energy-saving technologies and a reduction in livestock. In 2022-2023, fuel consumption was affected by the war. Due to the large, occupied territories or those in the combat zone and the mining of the already liberated territories, not all agricultural land was cultivated. Since about a quarter of the sown areas were not sown in 2022, diesel consumption decreased to 900 thousand tonnes and petrol consumption to 60 thousand tonnes. In addition, in 2022, out of 764.3 thousand units, 109.6 thousand units of agricultural machinery (14.3%) were destroyed and 50.7 thousand units (6.6%) were damaged, with total losses of USD 4.7 bil-

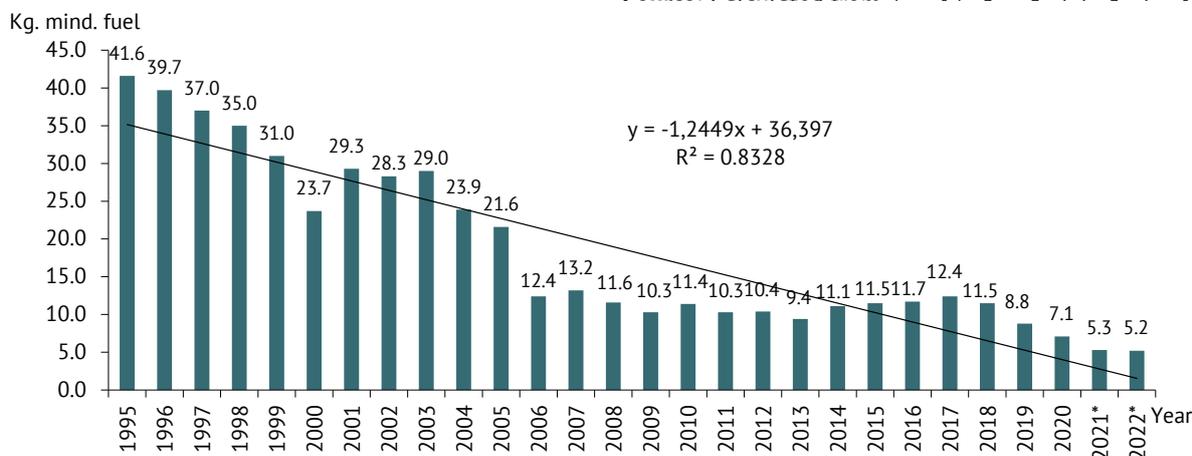
lion – USD 4.3 billion and USD 0.4 billion, respectively (Report on direct damage..., 2023). The liberation of territories and their partial demining in 2023 had consequences for agriculture. Crop areas were expanded, but they did not have a significant impact on the level of fuel and energy consumption. In 2023, compared to 2022, it increased (according to estimates) by only 8%.

At the same time, the company used combined tillage units that simultaneously perform several technological operations, alternative fuels, increased the share of low-energy crops in the structure of sown areas, and introduced advanced energy and resource-saving technologies. Agricultural and transport operations con-

sumed 85% and 15% of diesel fuel, respectively. Petrol was used mainly for transport (56%) and 44% for agricultural operations. Reduced energy consumption in agriculture has led to an 8-fold reduction in the energy intensity of agricultural products – 5.2 kg of standard fuel

in 2022 compared to 41.6 kg in 1995 (Fig. 2).

Figure 2. Energy intensity of gross agricultural products, i.e. of fuel per 1,000 hryvnias of gross production
Note: 2021*, 2022* is an estimated value
Source: Calculated from data of the State Statistics Service of Ukraine (n.d.)



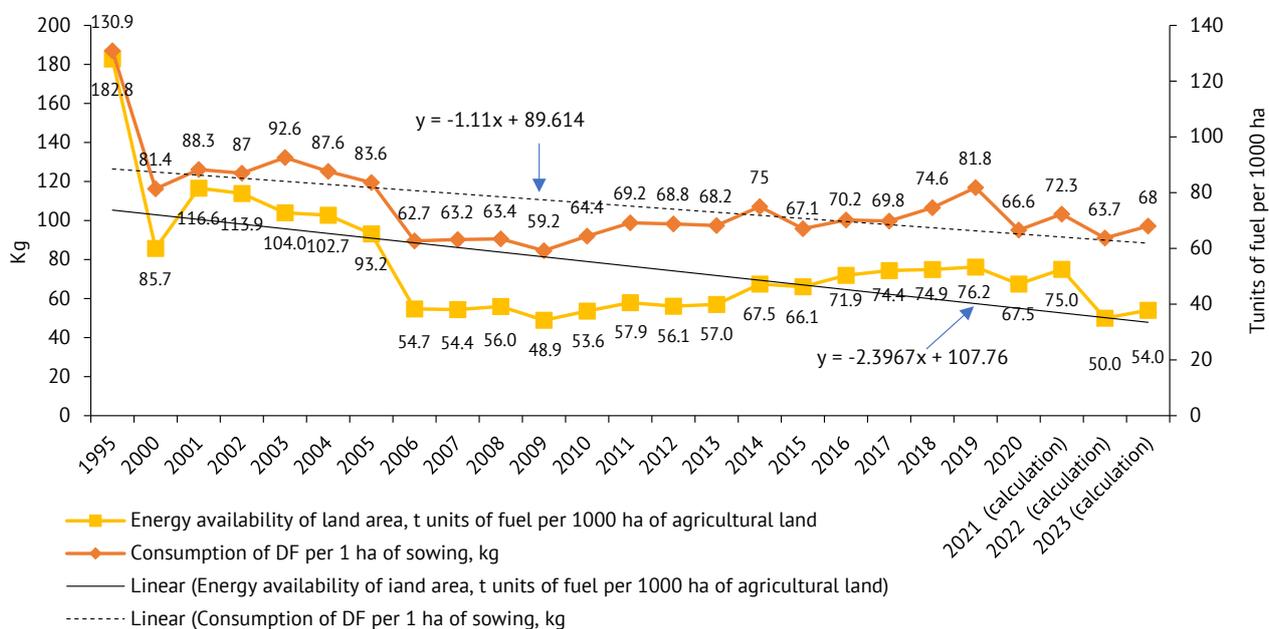
Ukraine. (n.d.)

Between 1995 and 2023, fuel consumption per 1,000 hectares of agricultural land decreased by 3.4 times and in 2022 amounted to 50 tonnes of equivalent fuel. At the same time, the cost of oil fuel per hectare of harvested

area increased. This was driven by rising fuel prices, the introduction of intensive technologies, which involve increasing the density of mechanized operations and increasing crop yields.

Figure 3. Energy security of the land area, i.e. of fuel per 1,000 hectares of agricultural land

Source: calculated from data of the State Statistics Service of Ukraine (n.d.)



The national economy is characterized by inter-sectoral price imbalances. Prices for oil products are growing faster than for agricultural products (State Statistics Service of Ukraine, n.d.). To purchase them, agricultur-

al enterprises need to sell more agricultural products annually (Table 2). In 1995, 1 tonne of diesel fuel cost 2.7 tonnes of grain, and in 2022 it cost 9.8 tonnes (>3.7 times). Compared to 2021, this figure has doubled. A similar trend is observed for all types of agricultural

products.

Table 2. Equivalence of the exchange of agricultural products and oil fuel, i.e.

	Year												
	1995	2000	2005	2010	2016	2017	2018	2019	2020	2021	2022	2022 to 1995, times	2022 to 2021, times
for 1 ton of petrol													
Grain	2.7	3.1	6.3	5.9	5.4	6.6	5.8	7.7	4.8	4.5	9.8	3.7	2.2
Sunflower	0.9	2.6	2.7	2.2	2.2	2.7	2.7	3.72	2.1	1.7	3	3.3	1.8
Sugar beets	5.5	11.2	14.8	13.9	21.9	30.3	33.5	39.6	26.35	24.4	32.8	6.0	1.34
Beef	0.4	0.7	0.4	0.7	0.9	0.8	0.8	1	0.7	0.8	1.1	2.8	1.4
Milk	1.7	2.5	2.3	2.3	3.4	3.5	3.4	3.6	2.6	2.8	4	2.4	1.4
for 1 ton of diesel fuel													
Grain	2.3	3	6.7	5.9	4.4	7.7	7.4	7.4	4.9	4.5	9.8	4.3	2.4
Sunflower	0.8	2.6	2.8	2.2	1.8	3.2	3.4	3.6	2.1	1.7	3.3	4.1	1.9
Sugar beets	4.8	11	15.7	13.9	17.7	35.1	42.6	37.9	26.9	24.3	36.2	7.5	1.5
Beef	0.4	0.6	0.5	0.7	0.7	0.9	1	1	0.7	0.8	1.2	3	1.5
Milk	1.5	2.5	2.5	2.3	2.8	4	4.4	3.5	2.6	2.7	4.4	2.9	1.6

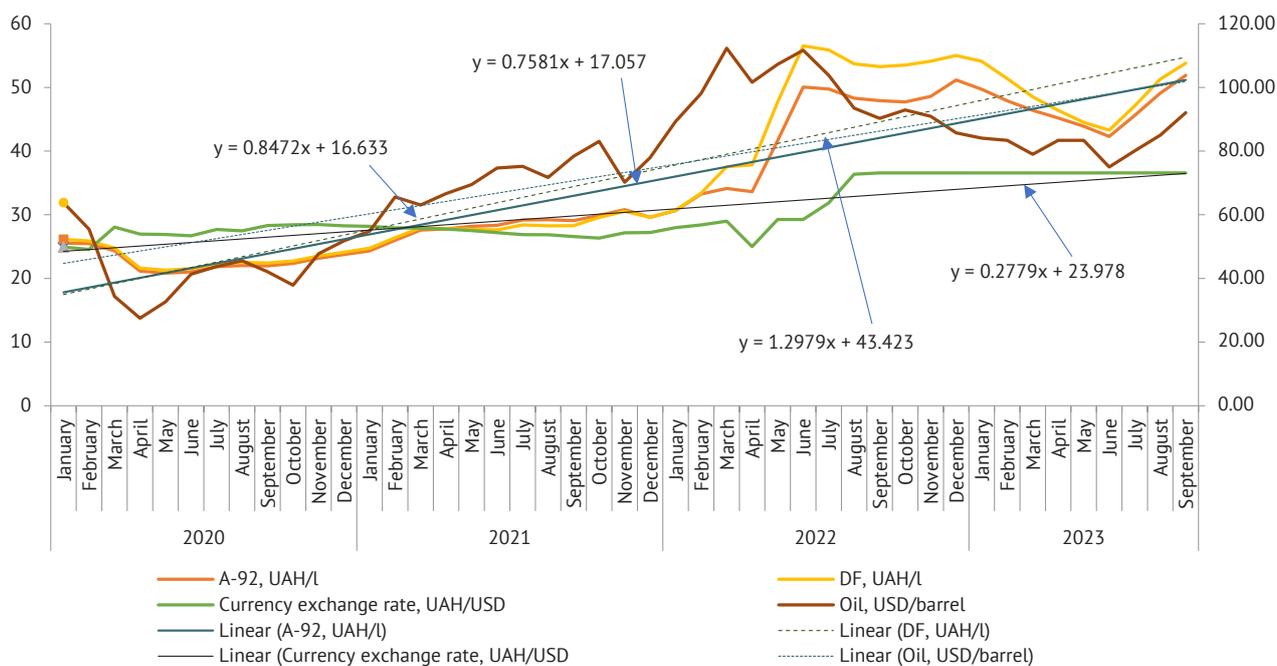
Source: calculated based on the data (State Statistics Service of Ukraine, n. d.)

According to the State Customs Service of Ukraine (n.d.), in 2022, imports of petroleum products to Ukraine

in monetary terms amounted to USD 8.8 billion. This is 56% higher than in 2021. In physical terms, imports amounted to 7.3 million tonnes, which is 17% less than in the previous year. According to the research, the retail price of diesel fuel depends on the global oil price and the exchange rate by 79.3%, while other factors account for 20.7%. However, in 2022, other factors also determined the dynamics of prices in the fuel market, especially the rise in the cost of transportation logistics. Starting in February 2022, the rise in fuel prices was driven by higher logistics costs and, consequently, higher dealer costs, in addition to the increase in oil

prices and changes in the national currency exchange rate. To slow down price growth and stabilize prices, the tax burden was reduced by cutting the value added tax from 20% to 7% and cancelling the excise duty. This has yielded results, and the dynamics of price growth has slowed down (Fig. 4). Improved logistics and sufficient imports in the second half of 2022 and early 2023 stabilized prices. And the refund of excise tax and VAT from 1 July 2023 led to an increase in prices.

Figure 4. Dynamics of world prices for oil, petrol, diesel fuel, and the exchange rate of the US dollar to UAH
Source: compiled according to information from the



Ministry of Finance of Ukraine, n. d.

Every year, in mid-February, before the start of spring field work, fuel prices begin to rise seasonally. During

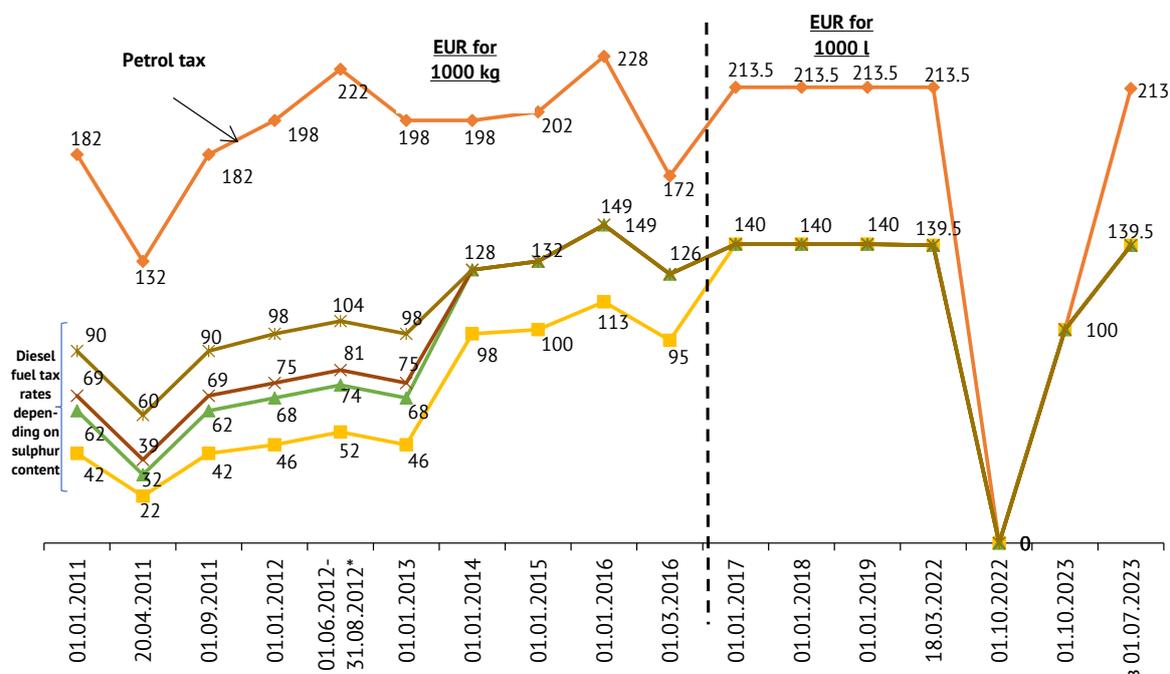
this period, retail prices for fuels and lubricants used in agriculture (low-octane petrol and diesel) will increase. Since February 2022, fuel prices have risen sharply, from 29.4 UAH/l in January to 49.5 UAH/l in June for petrol and 29.4 and 56.4 UAH/l for diesel, following the start of the Russian invasion and preparations for spring field work. On average, petrol prices increased by 70% and diesel prices by 92%. The rise in prices for petroleum products was also driven by the lack of diversity in supply routes, with only European supply remaining. For the first time since October 2014, the price of Brent Crude Oil on the global market reached USD 115 per barrel. USD per barrel (Ministry of Finance of Ukraine, n.d.).

Despite forecasts of further growth in the price of oil products, from mid-July 2022, the price began to decline and by the end of August it had fallen by 5% (Prices and markets, n.d.). For example, in the same period in Poland, the price of petrol was 5.8-6.4 zlotys

(45-49 UAH) per litre compared to 6.6-6.8 zlotys (48-50 UAH) per litre in May of the same year (Ceny Paliw w calej Polsce..., 2022). In other words, the price dynamics on the Ukrainian petroleum products market were changing in sync with the European one.

The main economic method of regulating the fuel market is the excise tax. Until 2014, excise rates on diesel fuel were determined by the sulphur content. Starting from 2014, the number of excise rates was reduced to two, and a single rate was introduced from 2017 to 2023. In 2016, the excise tax rates on petroleum fuel were transferred from EUR per 1000 kg to EUR per 1000 litres without increasing taxation, i.e. the excise tax rate was adjusted by the conversion factor of kilograms to litres (Tax Code of Ukraine, n.d.). In 2017-2022, the excise tax rates on petroleum products remained unchanged (Fig. 5).

Figure 5. Size excise tax on petroleum products in Ukraine, 2011-2023



* From 01.06.2012 to 31.08.2012, the average rate with a ten-day adjustment, depending on the average price of 1

Source: formed according to changes in the legislation of Ukraine in 2011-2023 (Tax Code of Ukraine, n. d.)

On 15 March 2022, the Law on Additional Tax Incentives to Support Businesses in Time of War (Draft Law

on Amendments to Section ..., 2022) was adopted and came into force on 17 March, aimed at, among other things, curbing prices for petroleum products. The law abolished the excise tax on fuel and reduced the VAT rate from 20 per cent to 7 per cent. In August 2022, the Cabinet of Ministers approved draft amendments to the Tax Code of Ukraine (Draft Law on Amendments to Section..., 2022) to partially refund the excise tax on petroleum products that was in effect before the war. The excise tax on fuel was set at EUR 100/1,000 litres, which is almost double the pre-war excise tax rate for

petrol and one and a half times higher for diesel fuel. This is significantly lower than the minimum level in the European Union – 359 euros/1000 litres, as stipulated by Directive 2003/96/EC (Tax Code of Ukraine, n.d.).

For example, tax rates in EU countries are as follows: for diesel fuel, the UK – 647 euros/1000 litres, Italy – 617, Belgium – 600, Ireland – 515, the Netherlands – 512, Malta – 472, Germany – 470, Slovenia – 430, the Czech Republic – 418, Slovakia – 398; for Euro-Super 95 petrol: the Netherlands – 808 euros/1000 litres, Italy – 728, France – 691, Finland – 684, Germany – 655,

the United Kingdom – 647, Sweden – 639, Estonia – 563, Latvia – 520, Spain – 473 (Fuel taxes in the EU, 2023). Since May 2021, average retail prices for petroleum products have been regulated by the Ministry of Economy of Ukraine and reviewed every ten days. These measures somewhat restrained fuel price increases. The Resolution of the Cabinet of Ministers of Ukraine No. 594 (2022) suspended the quarantine regulation that set the maximum trade markups to the average price of petroleum products sold at petrol stations. The decision to suspend was made with the expectation that prices would not exceed UAH 52 per litre of petrol and UAH 58 per litre of diesel fuel. With the outbreak of hostilities on the territory of Ukraine on 24 February 2022, the country's supply of petroleum products became a matter of national importance. The situation was most challenging for agriculture, which is in constant need of diesel fuel to run agricultural machinery. Therefore, traders' competition for the right to supply fuel to agricultural producers became another factor in strengthening competitiveness. This restrained the increase in retail prices (Draft Law on Amendments to Section..., 2022; Resolution of the Cabinet of Ministers of Ukraine No. 594, 2022, Tax Code of Ukraine, n.d.).

From 1 July 2023, VAT was refunded in Ukraine (from 7 to 20%), while the excise tax was increased from EUR 100 per 1000 litres to EUR 213 for petrol and EUR 139.4 for diesel fuel (Law of Ukraine No. 9174, 2023). This decision was made due to: the volume of petroleum products consumption, which will bring additional monthly revenues to the state budget of about UAH 8 billion; a decline in oil prices: from \$140/barrel in March 2022 to \$75/barrel in early 2023 (Ministry of Finance of Ukraine, n.d.); and the foreign exchange costs of petroleum products during martial law are the highest after weapons. This will reduce the outflow of foreign currency, while an increase in the tax burden and, consequently, higher prices will cause a decline in oil fuel consumption.

The need to increase the efficiency of agricultural production in the face of a permanent rise in the price

of oil products makes the issue of the energy intensity of agricultural products a pressing one. The low solvency of farmers, insufficient technical and technological support, and uneven fuel price increases are the reasons for negative processes in agriculture. Therefore, the problem of sufficient energy supply to meet their needs remains acute. During 2014-2023, the dynamics of prices for petroleum products and global oil prices changed synchronously in certain periods. While the global trend of declining oil prices was the opposite, the dynamics of prices for petroleum products in Ukraine had the opposite trend. This is primarily due to the upward trend in the exchange rate. Given the results of the analysis, it can be argued that the macroeconomic stability of the country is an objective condition for the effective functioning and development of the national fuel market.

The article uses multiple correlation and regression analysis to identify the impact of individual factors and their combination on the price of petroleum products and to establish price trends for the future. Based on the results of the regression analysis, a model for calculating the price of diesel fuel depending on world oil prices (X1) and the exchange rate (X2) is built:

$$Y = -9.9018 + 0.1192X_1 + 1.0989X_2 \quad (1)$$

The calculated regression coefficients show the level of influence of individual factors independent of each other on the resultant indicator. In particular, the value of $b_1 = 0.1192$ shows that an increase in the world oil price by USD 1 per 1 barrel. USD per 1 barrel leads to a 12 kopecks increase in the price of 1 litre of diesel fuel at a constant dollar exchange rate (the second factor). The value of $b_2 = 1.10989$ shows that an increase in the exchange rate of 1 USD by 1 UAH will lead to an increase in the price of diesel fuel by 1.1 UAH per 1 litre, with the world oil price unchanged (the first factor). Substituting the projected values of oil prices and the exchange rate into the equation, the projected prices for diesel fuel in Ukraine in 2023-2024 were obtained (Table 3).

Table 3. Forecasted prices for diesel fuel in Ukraine in 2023-2024

Price of 1 barrel of Brent oil, USD	The price is 1 USD, hryvnias		
	36.56	38.50	40.00
78.0	49.57	51.70	53.35
90.0	51.00	53.13	54.78
105.0	52.79	54.92	56.57

Source: own calculations

According to the model, in 2023-2024 the price of diesel fuel in Ukraine will increase due to the main factors.

The built regression model for calculating the price of diesel fuel in Ukraine depending on the price of oil and the currency is the basis for identifying the directions of development of the oil products market and forecasting their prices in the short term.

Overall, the fuel and energy market is quite dynamic. The situation on it changes under the influence of internal and external factors. The growth in fuel prices is influenced by the war in Ukraine, which resulted in the suspension of fuel production by oil refineries, the in-

stability of the national currency and price fluctuations in the global crude oil market. The increase in the cost of petroleum products, in turn, affected the agricultural sector. Limited fuel supplies in the first half of 2022 due to constant shelling and, against the backdrop of this situation, a rapid rise in fuel prices, led to a reduction in the number of technological operations carried out in the production of agricultural products. Improved logistics and sufficient imports in the second half of 2022 and early 2023 stabilized prices and brought agricultural production back to normal.

The issue of the agricultural sector's supply of petroleum products, given the industry's great social significance, is of interest to both Ukrainian and foreign scholars. For example, W. Zhang *et al.* (2023) investigate the dependence of prices in retail petroleum product markets on world oil prices. In their study, they used a nonlinear time series analysis approach that takes into account the unique features of petroleum product markets and found asymmetric price adjustments depending on price shocks in the global oil market. This approach confirms the understanding of long-term price relations, short-term dynamic adjustments and mechanisms of price reaction to sharp changes in crude oil prices in the context of fuel markets.

The same conclusion was reached in their research by another group of scientists who studied the impact of market regulation on price fluctuations in the oil products market in the long term (He & Lin, 2023). They also studied the dependence of petrol and diesel prices on the price of oil. Their findings show that the asymmetric response of petrol and diesel prices to crude oil prices is basically the same. Only the long-run asymmetry was confirmed, while the short-run asymmetry was not tested. The long-run equilibrium price is slowly rising against the backdrop of oil price fluctuations, most likely due to the increasing market power of oil companies. This means that market power is approaching monopoly.

The relationship between fuel consumption and agricultural productivity has been studied by J. Hu *et al.* (2023). The researchers also study the impact of other factors such as the state of industries, population structure, and energy structure. The relationship between agricultural economics and energy management has also been studied from the perspective of impact-based policy. X. Wen *et al.* (2018) used univariate modelling to determine the impact of the petroleum product pricing reform on industry development. Their research indicates that upward price adjustments have a greater impact on market volatility than downward adjustments.

The dependence of taxation on fuel consumption in the national economy and by the population was studied by A.L. Proque *et al.* (2022). The results of their research indicate that tax policy directly affects production costs in industries that use vehicles more intensively or consume fuel directly in the production process, making changes in household income and con-

sumption more significant. This leads to a change in the budgetary constraints of the poorer segments of the population through the income and substitution effect – a reduction in other consumption items. Meeting the growing demand for fuel and energy resources in the context of their shortage was studied by B. Lin & M. Raza (2021). Using a translogarithmic production function, they determined the elasticity of substitution of energy inputs (petroleum products, electricity) with non-energy inputs (labour and capital). They determined the limit to which energy inputs can be interchangeable without losing economic efficiency.

The fuel consumption of technical means used in agriculture and its savings at different stages of the production process were also studied by P. He *et al.* (2019). They proposed a mathematical model that can describe a model for scheduling agricultural machinery with a minimum fuel consumption to optimize fuel consumption in non-working activities (travelling between fields and within fields). And they proved the possibility of saving up to 19.5% of fuel on internal logistics. Their research provides a general framework for reducing fuel consumption of heterogeneous agricultural machinery by taking into account non-working distances in intra- and inter-field logistics and making these agricultural vehicles more economical and environmentally friendly.

The long- and short-run relationships between fossil fuel prices, including oil and petroleum products, and agricultural commodity prices were investigated by S-M. Yoon (2022). The results of his research show a significant short-term bidirectional causality between oil, bioethanol, and grain prices. There is an asymmetric and non-linear relationship between these variables. There are also policy implications in this regard, such as energy price stability, reducing energy dependence on fossil fuels, promoting agricultural development, environmental sustainability, energy conversion and reducing greenhouse gas emissions.

Energy consumption is a matter of global concern, namely due to the limited availability of energy sources and the consequences in the form of gas emissions. In the agricultural sector, this issue is of additional concern, given that it is an economic activity that is sensitive to the cost of inputs. The aim of the study by V.J.P.D. Martinho (2016) is to analyse the energy use efficiency of European Union countries at the farm level in terms of agricultural output and agricultural area used. The researcher argues that increasing labour productivity in agriculture can reduce the need for energy and other inputs.

Given the high price of crude oil, the biofuel market is growing. In such circumstances, it is also important to introduce energy-saving technologies when using agricultural machinery. M. Mattetti *et al.* (2022) studied the issues of saving fuel resources in the operation of agricultural machinery, in particular tractors. They investigated technical innovations that can save fuel and,

as a result, reduce emissions of pollutant gases such as carbon monoxide (CO), nitrogen oxide (NOX), particulate matter (PM) and hydrocarbons (HC), gases emitted with the greenhouse effect, such as CO₂.

Studying the prospects for increasing the energy autonomy of the agro-industrial complex of Ukraine, G. Kaletnik (2019), using the experience of highly developed countries in alternative energy sources, proved that diversification of energy sources helps to reduce the level of energy dependence of the agro-industrial complex and is one of the factors of increasing the competitiveness of agricultural products in the market by reducing production costs.

Studying the scientific works of scientists from different countries who have studied fuel consumption and its market, it is impossible not to agree with their main ideas and conclusions: prices for petroleum products directly depend on the world oil price and government regulation of the petroleum products market, and the number of technological operations performed in the production of agricultural products affects the efficiency of agricultural production and is a key factor in increasing its competitiveness. Therefore, given the limited availability of petroleum-based fuels, it is important for Ukraine to develop biofuel production and diversify its supply of foreign oil fuels.

CONCLUSIONS

The study showed that over the past decade, the consumption of fuel and energy resources by the agricultural sector of Ukraine has significantly decreased. The consumption of diesel fuel decreased by 40% and petrol by 2.5 times. Since petrol is mainly used in agricultural production for transporting products, the significant reduction in consumption is explained by the involvement of third-party organizations in transportation. The decrease in diesel consumption had a number of positive and negative reasons. The negative factors include the rise in the price of fuel and energy resources, which entails a reduction in the number of technological operations performed and, accordingly, a decrease in the efficiency of agricultural production. On the positive side, the introduction of innovative technologies that allow saving fuel by using combined tillage machines, energy-saving tillage technologies

and precision farming. This, in turn, helped to reduce the energy intensity of agricultural land and increase the energy efficiency of agricultural production.

The structure of fuel consumption by industry has also changed. Prior to Russia's full-scale invasion of Ukraine in February 2022, the agricultural sector had been the main consumer of petroleum products for a long time. Its share in total consumption was about 30%. The war changed the structure in favour of the military sector. Its share increased to 37% of total consumption in the country, more than double the pre-war period.

The war and the resulting crisis in Ukraine's economy led to an increase in fuel and energy prices in the first half of 2022 by 70% for petrol and over 90% for diesel. At the same time, disruptions in the logistics of agricultural products due to constant shelling led to a decline in their value and further exacerbated the problem of price disparity. Even the government's policy of restraining fuel prices by reducing taxation and cancelling the excise duty in 2022 had only a temporary effect. Over the past year, the increase was 1.5-2 times, depending on the type of agricultural product.

Calculations showed a very close relationship between the price of fuel, the global oil price, and the exchange rate of the national currency against the US dollar. The established dependence made it possible to forecast changes in fuel prices in the short term for 2023-2024, depending on changes in these indicators. An increase in each of them will inevitably lead to an increase in the cost of petroleum products on the Ukrainian market. Therefore, in the current environment, it is important to restore and develop Ukraine's own production of both oil products and biofuels to reduce the overdependence of the national economy and the agricultural sector in particular on external factors that affect the fuel market, which will require further research on this topic.

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CONFLICT OF INTEREST

There is none.

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Стан та перспективи забезпеченості сільського господарства паливом в Україні

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Анотація. В умовах воєнного стану в Україні, коли нафтопереробна промисловість зупинилася, а більшість логістичних ланцюгів зруйновано, питання забезпеченості сільськогосподарського виробництва – гарант продовольчого забезпечення України і світу, паливно-енергетичними ресурсами набуває особливої актуальності. Мета статті – дослідити споживання нафтопродуктів в аграрному секторі України в умовах воєнного стану, дослідити стан та державне регулювання ринку та пального з нафтопродуктів зпрогнозувати їх ціну на перспективу. У статті було використано наступні методи: діалектичний, абстрактно-логічний, статистичний, кореляційно-регресійний, табличний і графічний, аналізу рядів динаміки та структурних зрушень, порівняння, стратегічного планування та прогнозування. За результатами досліджень, здійснених з використанням статистичних методів, проаналізовано споживання сільськогосподарськими підприємствами бензину та дизельного палива, а також розраховано їх вартість на гектар зібраної площі. Встановлено, що зменшення обсягів використання пального у 2022 р. пов'язане з тим, що ¼ посівних площ не було засіяно у зв'язку з війною. Було також досліджено, яка частка пального використовується для потреб аграрного сектору економіки. За результатами кореляційно-регресійного аналізу виявлено тісний зв'язок між валютним курсом і ціною на дизпалива в Україні та негативний – між світовою на нафту і ціною на дизельне пальне. Завдяки встановленій залежності розроблено модель розрахунку ціни на дизпаливо, виходячи з світових нафтових цін на валютного курсу та проведено розрахунок ціни. Обґрунтовано, що основним економічним методом державного регулювання ринку пального є встановлення акцизного податку. Зроблено висновок, що скорочення споживання паливно-енергетичних ресурсів у аграрному секторі України призвело до зменшення енергомісткості аграрної продукції. Результати досліджень мають практичне значення, яке дозволить виявити дестабілізуючі чинники на ринку нафти і нафтопродуктів, а також сформулювати політику держави, яка сприятиме використанню енергетичних ресурсів, зокрема рідкого палива, у сільському господарстві в умовах воєнного стану

Ключові слова: сільськогосподарські підприємства; енергомісткість; енергозабезпеченість; воєнний стан; нафтопродукти; імпорт; логістика