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Investment and Innovation Development of Agriculture in Ukraine

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▸ **Abstract.** The tasks facing agro-industrial production in Ukraine are to stimulate the processes of accumulation and effective use of investment resources according to the priorities of economic growth, and prospects for the development of innovation activities. The prerequisite for this is macroeconomic stability, which contributes to the accumulation of internal and external factors and resources by increasing investor confidence in economic regulatory policy and reducing the level of risk of investment activity. The issues covered in the study will primarily concern such important factors in ensuring the development of agro-industrial enterprises as innovation and investment. These concepts are widely reflected in the research of many economists, but the management of innovation projects and investment activities to ensure the economic security of agribusiness entities is not sufficiently developed. This determines the relevance of the article. The purpose of the study is to determine the nature and features of agricultural innovations, to examine the conditions and factors of innovative development of agriculture, to assess the challenges and prospects of using the latest advanced technologies in agriculture and their financial support. The following methods were used in the investigation: dialectical, systematic approach, monographic, economic-statistical, tabular, graphical, comparative analysis, abstract-logical and analytical forecasting. The features of the introduction of innovative technologies in the agrarian sector of the economy are analysed and it is revealed that agro-innovations are closely related to agrotechnical conditions of production, are linked to living organisms, are seasonal and, accordingly, have a high level of risk. The analysis of material costs for the production of cereals and the dynamics of their prices was carried out. Using the example of one of the farms of the Vinnytsia Oblast, it is calculated how precision farming technologies and energy-saving technologies can reduce the cost of grain production. The main trends in investment support for agriculture, the relationship between capital investment and GDP are identified, and their role in the implementation of agricultural innovations is clarified. The prospects of investment support of innovative activity of Ukrainian agriculture in the war period are determined. The measures to address the issues related to the introduction of innovations in agriculture are proposed. They will help to improve the production process, increase the efficiency of using internal ones and maximise the attraction of external investment in the implementation of innovative ideas

▸ **Keywords:** the agricultural sector, agricultural innovations, capital investments, precision farming, tillage technologies, food security

▸ Introduction

A prerequisite for sustainable development of the state is investment and innovation support of its economy. According to the modernist theory of economic growth of Harvard economist Robert Solow, "Economic growth has three components: Capital, labour, and general productivity (the level of technology, innovation, and quality of management)" [1].

Sustainable economic growth of agriculture requires a high level of scientific support for agricultural production (science, technology, production experience, scientific and technological personnel) and intellectualisation of the production process. Perception and implementation of innovative solutions should be a prerequisite for their implementation

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in the economic activities of agricultural production entities in a competitive market environment. However, the aggravation of a number of existing systemic problems in agriculture due to the deterioration of the material and technical base, and unequal exchange of agricultural products for industrial resources narrows the investment and financial component of economic entities and weakens their innovation activity. New determinants of innovation and investment development of agricultural production, GDP growth, can significantly intensify investments in innovation and other resources [2]. Accordingly, the implementation of innovative processes in agriculture should increase the food security of the country, provide the population with food in the required quantity and quality, and industry with raw materials [3].

In a market economy, the vast majority of agricultural enterprises need to invest in a simple and expanded renewal of fixed capital, the introduction of innovative solutions, acquisition of new varieties of plants and animal breeds, and other capital-intensive innovative and investment projects. This raises the question of finding new forms and methods of activating the organisational and economic mechanism for the development of innovation and investment activities.

One of the methods of such activation is the creation of a highly productive export-oriented agricultural sector with further innovation and investment development, focused on the introduction of advanced achievements in science and technology to update the technical, technological, organisational base of agricultural production and obtain competitive high-tech products. The increase in the share of investment indicates a significant change in the structure of expenditures in the economy: an increase in the level of savings of the population, and increased investment activity in modernization and technological innovation.

For economies with low levels of fixed capital formation, which is typical for Ukraine, investments are crucial. Since the beginning of the 2000s, the annual volume of capital investments in the Ukrainian economy is 11-20% of GDP. In times of major economic expansion in China, the level of capital investment was up to 50% of the GDP. For a sharp economic recovery, Ukraine must invest at the level of 35% of GDP for at least 5 consecutive years. This is 70-80 billion US dollars annually [1]. And in the agro-industrial complex in general, over the past five years, the index of physical volume of investments in fixed assets amounted to only 3.3%, which is insufficient for the country's economic growth.

In the current conditions of agricultural production, many problems related to the prospects for investment support for innovative activities of the agricultural sector of the Ukrainian economy have become more acute. The main ones are: an increase in prices for goods and services consumed in agriculture, limited imports of agricultural products due to military operations on the territory of Ukraine and partial occupation, and a decrease in investment resources for the expanded reproduction of the main production assets of agricultural producers.

That is why the purpose of the study was to investigate the state of investment support for innovative development of agricultural production and determine its prospects in the war and post-war period.

The relevance of the study of investment and innovation activities of agricultural enterprises is due to increased competition in the food market and the integration of Ukraine into the international economic space, which is determined by the need to form an innovative investment model for the development of the agricultural sector of the Ukrainian economy. And these issues will be especially relevant during the post-war economic recovery. They will constitute the basis of our further research and elaborations.

The issues concerning innovative and investment development of agricultural production are the subject of research of many Ukrainian and foreign scientists. Rui Hou, Shanshan Li, Hongyan Chen, Guowen Ren, Wei Gao, Lijun Liu investigated the communication mechanism and prospects for the development of an innovative ecosystem in smart agriculture based on blockchain [4]. They firstly analyse the linkage mechanism between blockchain smart agriculture and the innovation ecosystem; secondly, they distinguish the innovation ecosystem evaluation index system and measure the development efficiency of innovation ecosystems through the SBM model, which calculates the coordination of innovation ecosystem connectivity in different regions, and analyses spatio-temporal, regional differences and spatial agglomeration; thirdly, they propose to increase the efficiency of the innovation ecosystem by combining and coordinating its individual components.

The researchers argue that building an innovation ecosystem is consistent with the trend of expanding the scope of innovation, the growth of the innovation platform and the emergence of innovative behaviour helps to overcome the uncertainty, complexity and ambiguity of the innovation environment in the context of the new norm, the emergence of new ways of mass innovation, crowdsourcing and crowdfunding, as well as the cultivation of new economic formats such as e-commerce, internet finance and intelligent logistics to form a new point of economic growth.

The impact of promoting farmers' awareness of new agricultural technologies through systematic linkages in the research and development continuum on their adoption was investigated by a group of scientists Yigezu Atnafe Yigezu, Amin Mugera, Tamer El-Shater, Aden Aw-Hassan, Colin Piggin, Atef Haddad, Yaseen Khalil, Stephen Loss [5]. They believe that the low and slow adoption of innovative technologies in agriculture among small agricultural producers often hinders the development and promotion of technologies. This is especially true for those technologies that require a large initial investment.

Researchers' findings show that providing exposure and awareness of no-till technology through organised field days and demonstration trials, complemented by providing free access to expensive no-till equipment for first-time users, increases the propensity, speed and intensity of its adoption. The intensity of implementation is also positively affected by the access of agricultural producers to loans. They emphasise the importance of initial outreach to agricultural producers and the ease of testing new agricultural technologies, especially those that require large upfront investments, at low or no cost to ensure their rapid and widespread adoption.

New agricultural technologies introduced in developing countries are mostly characterised by low and slow implementation, which is disappointing for researchers, practitioners, policy makers, and investors. Any innovation carries both risks and opportunities, and agricultural producers are likely to try a new technology that is less risky and has greater expected benefits than the prevailing technology. Deciding whether to apply the technology is even more difficult when the new technology involves a large initial investment.

The ease with which innovation can be tested to confirm its benefits increases the tendency and speed of adoption by farmers, and this may depend on the extent to which it can be tested at low or no cost. The compatibility of innovation with an existing set of resources, practices, and technologies can also affect the intensity of implementation.

The decision to adopt an innovation in agriculture at the individual farm level is defined as the possibility of using a new technology in the long term, when the farmer has full information about the technology and its potential.

Lina Bjerke and Sara Johansson in their study "Innovation in Agriculture: An Analysis of Swedish Agricultural and Non-Agricultural Companies" [6] presented a quantitative analysis of how the innovation capabilities of agricultural enterprises and enterprises in other sectors differ. With unique data from a survey of Swedish firms, they showed that one-third of companies in the agricultural sector are authors of innovations. Moreover, technological innovation at the enterprise level is no more common in agriculture than in other sectors. These results indicate that agriculture is not a special case in terms of innovative products, however, it is dominated by technological innovation. The uniqueness of the study lies in the fact that it investigates the acquisition of relevant innovations by agricultural enterprises and their doubts about the state policy of innovation support. Therefore, they more often point to the need to strengthen their own knowledge in agricultural enterprises. This will improve their ability to collaborate with partners working at higher levels in the knowledge system and benefit from collaboration.

They insist on the need for an in-depth study of the features of innovation potential in agricultural firms. Many aspects of agricultural production distinguish agricultural firms from companies in other sectors, but the development of the agricultural sector suggests that there are also many similarities. In recent decades, agricultural enterprises have grown, introduced more advanced technologies, become more diversified and more market-oriented. There is a growing understanding that agricultural enterprises today initiate and implement innovation processes and should be recognized as creators of innovations, not only as consumers.

Most enterprise-level innovation studies distinguish between small and large enterprises, where the latter are expected to have more internal resources spent on innovation. The hypothesis that follows from this assumption is that large firms are more innovative than small ones. Nevertheless, research shows that a significant proportion of small enterprises engage in innovation, and the benefits of innovation are similar to those observed in large enterprises. Small firms are often more flexible and adapt faster to changing market conditions, allowing small firms to take advantage of being small through innovation. Primary sector research, however, generally proves that the impact of firm size (measured as the number of employees) on innovation is positive.

They also insist that human capital is a mandatory factor influencing the innovation potential of enterprises. It allows absorbing and assimilating knowledge in processes where ideas are transformed into commercial products and processes.

Using forecasting to understand the relationship between research findings and the future of agriculture and the food system is the research focus of Steven D. Prager, Keith Wiebe [7]. In the context of agriculture, long-term forecasting allows to investigate how investments can help agricultural development, given the expected future related to various factors ranging from climate change or policy environment to increasing production efficiency.

The researchers argue that foresight approaches, whether quantitative models, qualitative participatory processes, or a combination of both, allow to explore a large number of scenarios and evaluate the results in terms of specificity, desirability, plausibility, return on investment, equity, etc.

An important asset of forecasting approaches, in particular quantitative models, is their capacity to assist in developing an insight into how agricultural systems may respond differently in space and time to interventions. Factors that affect agriculture and the food system have temporal and spatial differences. This allows for a better appreciation of how the productivity of the food system can be improved through investment in agriculture.

A model for studying technical changes in EU agricultural enterprises is considered in their research by Amr Khafagy and Mauro Vigani [8]. The parameters of a methodology that describes the productivity of factors of production, the elasticity of substitution between two factors, and technical changes that increase productivity can be determined both exogenously and endogenously. To verify reliability, they examine the availability of Hick-neutral

technical changes and Cobb-Douglas production technology.

In their research, scientists concluded that innovations in physical capital are not enough to increase productivity, but they must be complemented by higher quality of labour. For example, innovative digital technologies and precision machines must be accompanied by qualified workers who can operate them.

Polish scientists Arkadiusz Sadowski, Monika Malgorzata, Wojcieszak-Zbierska, Patricia Beba in their study "Territorial differences in agricultural investments co-financed by the European Union in Poland" [9] investigate the relationship between the active use of EU investment support programmes by Polish farmers on the one hand, and local conditions of socio-economic development and natural and structural characteristics of agriculture on the other.

The synthetic Hellwig development indicator was used to represent complex phenomena. The study revealed a strong link between the implementation of co-financed investments and the agricultural structure at the local level. Other factors were insignificant. This suggests that the path of agricultural development does not fully depend on socio-economic and environmental conditions.

Based on the findings of their research, they concluded that there is a strong link only between the territorial heterogeneity of farmers' investment activity and the agrarian structure. There is also a high correlation between the amount of investment per farm, and between the share of investing farms and the share of farms with an area of more than 10 hectares.

They found that the processes of agricultural development at the local level are somewhat autonomous. The intensity of investment activities carried out by producers from different regions was generally independent of their wealth and availability of infrastructure.

Ukrainian scientists have also studied the essence and features of innovation activity in the agricultural sector, the development of precision farming technologies and energy-saving technologies. Among them are Mykola Rudenko [10], Taras Dudar [11], Nelya Chorna [12], Vadym Petrov [13].

Innovation and investment development of Ukrainian agriculture is at the stage of stagnation. Therefore, the results presented in the article are relevant, timely and necessary.

▸ Materials and Methods

The methodological basis of the study is a dialectical method of cognition and a systematic approach to the examination of economic features of investment and innovation development of agricultural production. At the same time, the following methods were used in the research process: monographic (in covering the standpoints scientists on the issues and problems under study, in the investigation of innovative technologies and equipment for agriculture); economic and statistical (in the analysis of the current state of investment and innovation support for agricultural production) tabular and graphic (when visually displaying the results of the study in the form of figures and tables), empirical (when studying the economic efficiency of introducing innovative technologies in an agricultural enterprise); comparative analysis (to compare the cost of growing grain using traditional and innovative technologies); analytical forecasting method (to predict the volume of investments in military and the post-war period); abstract-logical (generalisation and formulation of conclusions).

The main stages of the study are: identifying the features of agricultural production and the introduction of innovative technologies in it, their importance for the development of agriculture; calculation of the economic efficiency of grain cultivation with traditional and innovative production technologies; analysis of precision farming technologies and energy-saving technologies, their cost and economic efficiency; analysis of sources and volumes of investment support for innovative activities in agriculture; forecasting investments in agriculture; forecasting of investments in agriculture in the war and post-war periods.

The analysis and calculations were carried out based on the materials of the State Statistics Service of Ukraine (volumes of capital investments in agriculture, the ratio of GDP and capital investments), financial statements of agricultural enterprises (to calculate the effectiveness of the introduction of innovative technologies in grain production), prices of dealers of innovative agricultural machinery and other material and technical resources and services for agriculture and the author's calculations.

▸ Results and Discussion

Agriculture makes a significant contribution to the development of the national economy. It produces UAH 612 billion of products, forming 10.8% of gross added value and about 45% of exports. Ukrainian agriculture uses fixed assets worth UAH 540 billion and 41.3 million hectares of agricultural land [14]. At the same time, the innovative activity of enterprises in terms of introducing technological innovations is only 0.1-0.2% of their total number [15].

The consequence of technological modernisation determines the current state of the agricultural sector. In an effort to adhere to the basic principles of agro-innovative development, it is necessary to consider the specifics of agricultural production [16]. They are primarily related to the main factor of agricultural production – land, in particular: close connection with the reproduction of living organisms, seasonal nature of production, high level of risks, etc. Besides, the features of the innovation process are the diversity of agricultural products and products of their processing, differences in production technologies, agrotechnical and climatic conditions depending on the region, territorial dispersion.

The special features of the introduction of innovative technologies in agriculture are the diversity

of enterprises by ownership forms – collective, private, open and closed joint-stock companies, cooperatives, LLC, state enterprises; farms, private farms, and, most innovatively active, holding companies. All of them operate on their own and leased lands, ranging from 2 to 10 thousand hectares.

The permanent rise in the price of fuel, mineral fertilisers, plant protection products, seeds (Table 1), and other material and technical resources forces farmers to use them more efficiently and encourages them to introduce innovative technologies. The use of innovative technologies in agriculture allows to increase the profitability per 1 hectare due to the combination of optimal costs of material resources included in the cost price and maximum yield.

Table 1. Average price of material and technical resources and services, used in agriculture

	Year					
	2018	**2019**	**2020**	**2021**	**2022 (6 months.)**	**2022 to 2018, %**
Petroleum products	**UAH per t**					
motor gasoline	27123.8	25185.0	19980.7	28326.6	37983	140.0
gas oil (diesel fuel)	23863.2	21488.2	16466.1	28110.8	41602.9	174.3
Mineral fertilisers	**UAH/q**					
nitrogen	733.7	747.9	585.3	1337.4	29990	> 40 times
phosphorous	939.2	1001.0	909.3	1950	17750	> 18 times
potash	890.2	942.1	857.4	1457.6	21220	> 24 times
complex (concentrated NPK fertiliser)	1019.1	1169.2	1025.5	1800	25090	> 24 times
Plant protection products	**UAH/kg**					
Insecticides	388.9	460.5	374.1	762	1000	> 2.5 times
Fungicides	407.4	504.1	372.4	440	1436	> 3.5 times
Herbicides	728.6	268.4	905.8	1428	1181	162.1
plant growth regulators	107.5	180.8	79.5	175	470	> 4.3 times
Services	**UAH/ha**					
Crop protection	247.4	269.5	259.2	300	300	121.3
Plowing	697.1	717.0	721.9	600	850	121.9
Cultivation	379.0	433.3	426.8	400	600	158.3
Harvesting of agricultural crops	651.8	924.1	959.2	1,100	1500	> 2.3 times
Fertilisation	381.5	384.4	356.1	350.0	350	91.7

Source: compiled according to the State Statistics Service of Ukraine [14] and Agroantal [17]

The analysis of the table data shows that while the price of petroleum products, and, accordingly, services in agriculture for 2018-2022 increased by more than one and a half times, plant protection products – up to 4.3 times, and mineral fertilisers went up tenfold due to rising gas prices. This is due to the fact that the share of gas in the cost of fertiliser production is up to 80%, which is both raw material and energy carrier. Plant protection products, according to the results of the study, also increased in price. According to Ukrainian Agribusiness Club analyst Svitlana Lytvyn, the rise in price is caused by disruptions in the production of active substances for plant protection products by Chinese pesticide manufacturers, which are the largest in the world as a result of the energy crisis [18].

According to the World Bank, energy and food prices are expected to rise significantly in 2022. Its reason being Russia's war against Ukraine. According to forecasts, the rise in world energy prices will be at the level of 50.5% compared to 2021, with a further decrease by 12.4% in 2023. At the same time, food prices are expected to increase by 22.9%, with a decrease of 10.4% in 2023. These data are presented in the quarterly report of the World Bank Commodity Markets Outlook Report [19].

Referring to the same resource, Markiyan Klymkovetskyi notes that, since the 1970s, the rise in energy prices in the last two years has been the most significant, and for food and fertilisers, of which Ukraine and the Russian Federation were the main producers, – the highest since 2008 [19].

The Russian military invasion of Ukraine in February 2022 resulted in material losses in agriculture of almost USD 4.3 billion. only in the first three months of the war. And this is almost two-year investment income in Ukrainian agriculture. Agricultural land was damaged, equipment was destroyed (approximately USD 1 billion), and livestock was killed [20].

Process charts are the main source of technological documentation. They include technologies of production, costs of material and labour resources, volumes of operations and means of production. For each culture, such maps are drawn up separately,

considering rational and advanced production technologies of enterprises.

The study analysed the standard costs of growing winter wheat at an agricultural enterprise in Vinnytsia Oblast. Their volume at a yield of 64 c/ha amounted to UAH 25,000 per 1 ha. Accordingly, the cost price of 1 ton of wheat was UAH 3,906. Material costs accounted for 60% of the total production cost. Therefore, their optimisation with innovative solutions can be substantial savings for the company.

In 2021, the average cost of growing cereals, legumes and oilseeds in the surveyed farm was UAH 30,500 per 1 ha. Although a significant share of material resources was acquired by the company in the previous season, in 2022 production costs are expected to increase by 30.2 % (from UAH 30,500 to 39,700 per ha).

Calculations have shown that it is possible to reduce material costs by up to 35% with the help of competent and timely application of agricultural innovations. Carrying out such measures by increasing yields and gross harvest will also help to increase income by USD 150-300 per ha. An example is the above-mentioned farm (Table 2).

Table 2. Efficiency of implementation of innovative technologies for growing winter wheat on the example of farms of Vinnytsia Oblast in 2022

	Costs under conventional technology		Costs with regard to innovative solutions		Reduce costs	
	UAH	%	UAH	%	UAH	%
Total cost price of crop production	25,000	100	19,700	100	5,300	100
Material costs	15,000	100	9,700	100	5,300	35.3
incl.						
Seeds and planting material	3,000	20	2,850	29.4	150	5.0
Mineral fertilisers	6,000	40	3,000	30.9	3,000	50.0
Fuel and lubricants	4,500	30	3,400	35.1	1,100	24.4
Plant protection products	1500	10	450	4.6	1,050	70.0
Depreciation	2,000	8	2,000	10.2	X	X
Labour Remuneration	2,000	8	2,000	10.2	X	X
Other expenses	6,000	24	6,000	30.5	X	X

Source: author's calculations

In 2022, there was an increase in regulatory costs for growing winter wheat to UAH 38,000 per 1 ha. The reason for this was the increase in the value of the main cost components – fuel, mineral fertilisers, plant protection products and other material and technical resources. The calculations showed a possible reduction of costs by 7,000-8,000 UAH due to the introduction of innovative solutions-precision farming technologies, energy-saving technologies, combined tillage units. Technical innovations will help to achieve positive results in agribusiness in 2022 despite the decline in yields and rising prices for material and technical resources.

Today it is impossible to solve the problems in crop production by conventional mechanical means. Precision farming technologies can do this. The current level of scientific and technological progress makes it possible to involve electronic automated systems and GPS in their solution. Along with the information function, they control compliance with the agrotechnical requirements of production to obtain the programmed yield with the specified quality characteristics. The basic principles of precision agriculture are determined by the use and management of mobile agricultural machines regardless of their location, selective application of fertilisers and plant protection products depending on plant parameters and soil fertility in different parts of the field.

Statistics show that in the United States and Germany, 70-80% of agricultural producers use various elements of precision farming [21]. In Europe, precision farming technologies are used on an area of 0.5 hectares or more. Despite the high cost of such technologies, investments in their acquisition pay off within a year. About 90% of agricultural producers who have tried some elements of precision farming technologies, introduce their other elements.

According to the estimates of the analytical company Research and Markets, the volume of the global market for technical solutions for precision farming technologies will grow from EUR 2.7 billion in 2020 to EUR 3.7 billion in 2025 [22]. However, in Ukraine, precision farming currently covers only 15% of agricultural land.

The main users of precision farming technologies are large agricultural enterprises, farms and agricultural holdings that have an area of more than 1000 hectares and use powerful tractors of over 100 kW. They will benefit more from the installation of precision farming systems compared to low-power ones.

Systems of "precision farming", assuming a complete system, are quite expensive for both small

and most medium-sized farmers. For example, the average price of autopilot for a tractor or sprayer (automatic driving system) is UAH 200,000, agrocopter – UAH 600,000, precision seeder – UAH 600,000, self-propelled sprayer – UAH 5 million. Furthermore, additional costs should be taken into account, because the seeder or autopilot will not operate on itself, it requires a tractor. The agrocopter also needs a mixing unit, a barrel and lighting (if the drone is used for spraying). Also, a vehicle for its transportation is a necessity. All these devices require trained specialists who could operate them. Therefore, the volume of expenses is actually much larger.

The Ukrainian market of technical means for precision farming, including sets of equipment, additional canopies and aggregates for machinery, software products, services and agricultural drones today is USD 60-70 million [23].

Due to the high costs of implementing precision farming technologies, its application is limited to large enterprises and agricultural holdings. The most innovatively active were: Kernel – USD 2.7 million per 540 ha; AR Group – USD 2,0 million per 400 ha; MHP – USD 2.5 million per 360 ha; Astarta – USD 1.0 million per per 250 ha; IMC – USD 1.0 million per 124 ha; Harveast – USD 1.0 million per 123 ha; Epicentr – USD 420,000 per 112 ha [24].

The successful examples of the implementation of agro-innovations in Ukraine are the Astarta agricultural holding and Kernel. Using the GPS fuel consumption monitoring system, Astarta managed to reduce and save USD 15 million in 4 years, which is more than the annual investment volume of the seven largest agricultural holdings in Ukraine. Through differentiated fertilization, Kernel managed to save USD 120-300 per hectare, depending on the crop.

Despite the large initial investment in innovation, the invested funds are quickly recovered due to the reduction of time, material, and labour resources. Increased investment risks will be offset by rising global prices for food resources and will contribute to additional incomes of agricultural producers and an acceptable level of return on their investments.

Analysis of the effectiveness of implementing new technologies shows that the easiest way to switch to precision farming technologies with minimal costs is to analyse and map the soil. This makes it possible to increase the efficiency of technologies and reduce resource consumption by more than 20% [25].

Autopilot technology can save 10-15% of working time, 40 liters of fuel per 100 ha, 3% of seeds, 5% of plant protection products and, at the same time, improve the quality of technological operations [26].

It is possible to save 3-8% of seeds by accurately calculating the density of plant growth, considering soil fertility, humidity, and relief, by applying the technology of variable seeding rate. Seed drills with a differentiated seeding rate adjust the seeding rate depending on the specified conditions [27].

Parallel driving increases the efficiency of agricultural production by an average of 10%. In particular, it saves 10% of working time and, accordingly, 10% of wages, reduces depreciation of equipment and fuel by 10%. A widely used innovative product is the spot spray system. Modern optics, along with computing capabilities, apply the herbicide only to the detected weed. It allows reducing its costs by up to 90% [28]. Simultaneous tillage, sowing with differentiated application of various types of mineral fertilisers reduces their consumption by up to 50%. Due to the complexity of the operation, 40% of fuel is saved [28].

The issue of trampling crops (3-5% when spraying with ground equipment) and damage to the tops of plants during spraying can be avoided by using agricultural drones. Another advantage of the agrocopter, as opposed to ground equipment, is the ability to work immediately after the rain and with the possibility of local processing of field areas [29].

Today in Ukraine, precision farming systems are used for 5% of arable land, and its individual elements for 20 %. In the current conditions, the use of resource-saving technologies of soil cultivation is also relevant in Ukraine. These are no-till, mini-till, strip-till, verti-till technologies. Working with these technologies, agricultural producers can increase the economic efficiency of production by saving fuel, reduce technological impact on the soil, increase the environmental friendliness of the process of growing crops by reducing weather and climate impact. The main disadvantages are significant initial costs for the purchase of equipment, the growth of weeds and pests in the fields, pesticide load on the soil.

Each tillage system has its own advantages and disadvantages. When deciding upon the adoption of one of them, it is necessary to consider the features of the relief of the field, the natural density of the soil, its chemical composition, the amount of precipitation and the temperature regime throughout the year. In addition, the choice is affected by the level of intensity of technology and biological characteristics of the crops grown.

By applying moldboardless tillage technology, it is possible to save 27% of fuel consumption on pre-sowing works, mini-til – 43%, no-till – 86%. Improvement of the structure of the machine-tractor fleet and rational aggregation of tractors contributes to saving up to 20% of fuel and lubricants, combined units of soil cultivation simultaneously with sowing, application of mineral fertilisers and pesticides – 10-15% [30].

Generally, the use of resource-saving technologies and combined soil cultivation units reduces general production costs by 15%, and minimum tillage and precision farming technologies – by 20%. The key condition for sustainable economic development and growth of the national economy is investment in innovations, which is why they are under the focus of the state's economic policy. New highly productive and technological activities will not be possible without investment resources and no diversification of the development of the Ukrainian agricultural sector will take place. Usually, the growth of capital investment as a basis for innovation precedes the growth of gross domestic product (Table 3).

Table 3. Dynamics of gross domestic product growth and capital investment in agriculture in 2010-2021

Year	Capital investments, mln UAH	Investment growth	GDP agricultural, mln UAH	GDP growth
2010	11311	1.16	195390	1.23
2011	16703	1.48	261331	1.34
2012	19086	1.14	269983	1.03
2013	18640	0.98	315546	1.17
2014	18388	0.99	381227	1.21
2015	29310	1.59	558788	1.47
2016	49660	1.69	655569	1.17
2017	63401	1.28	727352	1.11
2018	65059	1.03	871971	1.2
2019	58555	0.9	866138	0.99
2020	50189	0.86	766532	0.89
2021	62700*	1.25	876913	1.14
Average for 2010-2021	**X**	**1,2**	**X**	**1.07**

* – estimated

Source: calculated according to the State Statistics of Ukraine [14]

The role of investment support in the operation of the agro-industrial complex of the country is that investment resources allow the introduction of advanced technologies, the latest equipment, new highly productive varieties of plants and animal breeds, innovative forms of labour organisation and production management. Innovations, new technologies and organisational solutions allow enterprises to overcome crisis situations, ensure high competitiveness of products and enterprises.

After a small investment crisis in 2019-2020 (the decline in investment was up to 20%), in 2021 the investment and innovation activities of agricultural producers intensified and again reached a figure of over USD 2.3 billion which is one of the best results since Ukraine's independence (Fig. 1) [31].

There were expectations that this process would continue in 2022, but the war will negatively affect subsequent investment processes. During 2016-2021, the total amount of capital investments per 1 ha of agricultural land ranged from USD 70 to 100. However, the innovative modernization of the agrarian sector can only be considered if the investment is no less than USD 150 per ha [23].

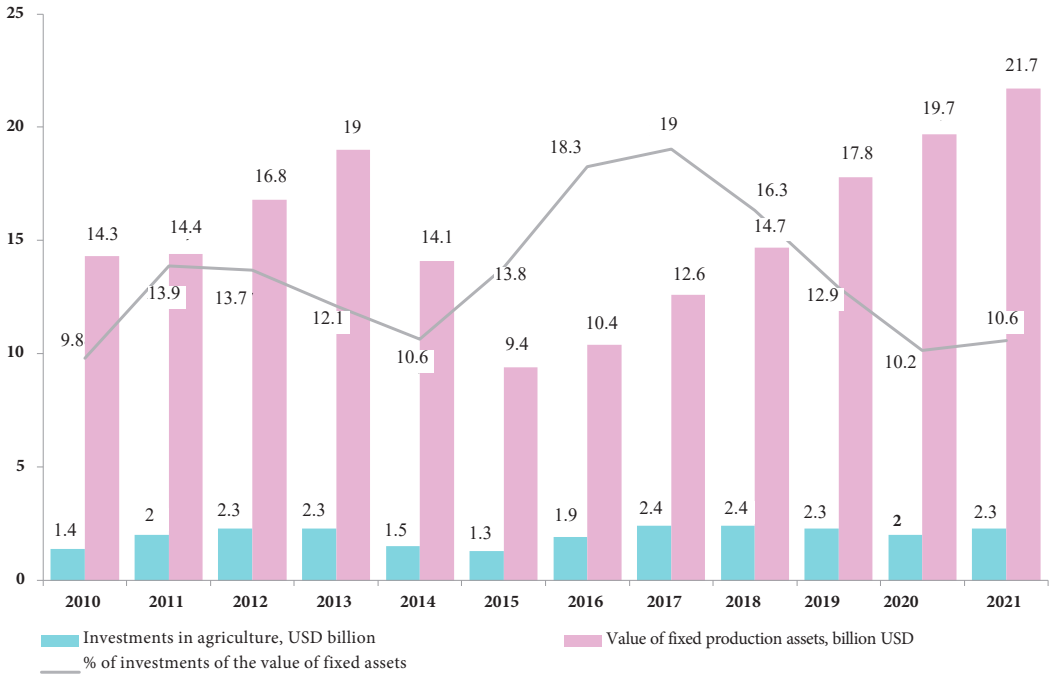

Figure 1. Dynamics of the cost of fixed assets and investments in agriculture in Ukraine
Source: calculated according to the State Statistics of Ukraine [14]

Mykola Kisil claims that the negative feature of the investment process in agriculture is the reduction of participation of small agribusiness in it. If its share in the total volume of capital investments in 2017 was 42.9%, then in 2018 – 37.6, in 2019 – 32.5, and in 2020 – 31.5%, in 2021 – less than 30.0% [32]. As for their share in the fixed production assets of agriculture, as can be seen from the figure, starting from 2017, it has been rapidly decreasing and in 2021 amounted to only 10.6% of the value of fixed assets.

Small businesses sell their products mainly to market intermediaries at lower prices. In addition, they have relatively higher risks of losing products and property as a result of raider attacks, fewer opportunities for lending and receiving state support, etc. More than 90.8% of all investments are funds of enterprises and organisations, 8.5% – bank loans and borrowings. The state's share is 0.43% [14]. Supporting and stimulating investment activities of small agribusiness entities should be one of the most important tasks of the state's agricultural policy.

The influence of large agribusiness on decision-making on the use of budget funds and the lack of transparency in the distribution of finances strengthen monopolism in the industry and restrain the investment processes for the development of small and medium-sized agricultural enterprises. The increase in agricultural raw material exports, which provides a fairly high level of profitability, negatively affects the development of both individual companies that lose incentives to invest additional investments, including in innovations, and the entire industry, as well as hinders the development of the processing industry.

The war in Ukraine will lead to a decrease in 2022 not only in the volume of exports of agricultural products and food but also in investment and innovation in the development of agri-food sectors of the economy. As a result of military operations and the occupation of part of the territory, more than 20 million tons of grain were blocked in Ukrainian seaports, most of which were intended for the UN World Food Programme [33].

Instead, the growth of world food prices will compensate only part of the loss of income of producers and increase the level of investment attractiveness of agriculture and food industry of Ukraine. Taking this into consideration, it is advisable for the national agribusiness, even in the conditions of war, to make the most of the opportunities to intensify investment and innovation activities. To this end, national, regional and local measures are needed to improve investment support for agribusiness development.

Scientists of the Institute of Agrarian Economics predicted an increase in investment activity in agriculture before the Russian military invasion of Ukraine. The volume of investments in the industry in 2022 should have amounted to UAH 72 billion. However, the impact of the war negates this forecast. It is likely that capital investments will decrease to USD 1.1-1.2 billion. [34], and investment resources will mainly be used for simple reproduction of fixed capital, maintaining existing production capacities and replenishing working capital.

No significant changes should be expected in the structure of sources of financing for capital investments for agricultural development in 2022. It is assumed that the main source of investment financing will continue to be the own funds of enterprises and organisations (more than 90% of the total), which depend on the profits received. The projected volume of capital investments in 2022 will not fully ensure the creation of appropriate conditions for the expanded reproduction of Agricultural Capital, which in the future may negatively affect the production potential of the industry and the development of innovations.

During the war, it is possible to slow down the introduction of innovative technologies due to the reduction of capital investments, problems with the logistics of agricultural machinery, seeds, plant protection products, etc. Despite the difficulties, innovatively active enterprises will continue to implement innovative solutions.

The formation of an effective agricultural policy and giving it an investment-oriented character should be considered one of the most important tasks of the state policy of socio-economic development. Although innovative investments in agriculture play an important role, investors are still investing in the production of a limited range of the most profitable low-capital and export-oriented types of agricultural products, the creation of elevator capacities, and increasing logistics and export potential. At the same time, mainly machinery and technologies, seed material and plant protection products of foreign production are used. These features of innovations in the investment process led to the fact that most of the added value created in the National Agriculture flows out of the state, and the material and technical base of the national innovation infrastructure, especially agricultural science institutions, does not develop properly.

For the successful development of the agro-food sectors of the economy in Ukraine, it is necessary to form an appropriate agricultural policy following the example of OECD member countries, where through various mechanisms of state regulation the prices for sold agricultural products exceed the input prices for production resources, which is considered as support for producers. At the same time, production output and consumed resources are estimated in world market prices. In the vast majority of countries, the ratio between the output and input prices of agricultural producers for products and resources, as well as the share of their support, is now more than one, which allows producers to form their own sources of financing investments for expanded capital reproduction, and only in Ukraine this ratio is minimal or even negative [35].

Increasing the investment attractiveness of the agricultural sector can be achieved by carrying out national measures to reform the economy and state

institutions with the functions of protecting investors, ensuring conditions for the development of entrepreneurship, state investment support for small and medium-sized agricultural businesses, ensuring the interaction of scientific institutions with agricultural enterprises in order to quickly implement innovative ideas, international investment, innovation, scientific and industrial cooperation. These measures will be especially relevant in the post-war period.

Conclusions

Thus, the widespread use of innovations and their investment support are essential elements of modern agricultural production. They will contribute to solving socio-economic issues in the agricultural sector related to the search for solutions to improve the economic efficiency of enterprises in the industry and food supply of the population. Investment and innovation development of agriculture will ensure its qualitative modernisation based on the growth of both production indicators and the improvement of the socio-economic mechanism of the agricultural sector and related industries.

This process should be accompanied by continuous use of the latest technologies for the production and processing of agricultural products, new agricultural machinery, plant varieties and animal breeds, and modern information technologies.

The main issues that currently prevail in the agricultural sector are the lack of investment resources, limited state support, inactive or partially effective legislation, and other problems caused by the war, which hinder the effective and high-quality investment and innovation development of agriculture in Ukraine.

However, it is worth noting that the use of the proposed measures to solve the problem of introducing investments and innovations in agriculture will improve the production process, increase the efficiency of using internal and maximise the attraction of external investment in the introduction of investment technologies. Thus, creating favourable conditions for investment and innovative development is a priority task for Ukraine. Otherwise, it is impossible to achieve economic growth, in particular, in enhancing the country's competitiveness in the world market.

References

[1] Svyridenko, Yu. (2022). What kind of economy are we building? *Ukrainska Pravda*. Retrieved from https://www.pravda.com.ua/ukr/columns/2022/07/8/7357131/index.amp.

[2] Makavoz, O.S., Mashchenko, M.A., Lesnaya, I.F., Ponomarenko, O.O., & Savytska, L.V. (2021). Project management of innovation and investment activities to ensure agricultural entities economic security in Ukraine. *Espacios,* 42(08), 27-40. Retrieved from https://revistaespacios.com/a21v42n08/a21v42n08p03.pdf.

[3] Trusova, N.V., Hryvkivska, O.V., Kotvytska, N.M., Nesterenko, S.A., Yavorska, T.I., & Kotyk, O.V. (2021). Determinants of the innovative and investment development of agriculture. *International Journal of Agricultural Extension,* 9(4), 81-100. Retrieved from https://www.researchgate.net/publication/353992908_Determinants_of_the_Innovative_and_Investment_Development_of_Agriculture.

[4] Hou, R., Li, S., Chen, H., Ren, G., Gao, W., & Liu, L. (2021). Coupling mechanism and development prospect of innovative ecosystem of clean energy in smart agriculture based on blockchain. *Journal of Cleaner Production,* 319, article number 128466. doi: 10.1016/j.jclepro.2021.128466.

[5] Yigezu, Y.A., Mugera, A., El-Shater, T., Aw-Hassan, A., Piggin, C., Haddad, A., Khalil, Y., & Loss, S. (2018). Enhancing adoption of agricultural technologies requiring high initial investment among smallholders. *Technological Forecasting and Social Change,* 134, 199-206 doi: 10.1016/j.techfore.2018.06.006.

[6] Bjerke, L., & Johansson, S. (2022). Innovation in agriculture: An analysis of Swedish agricultural and non-agricultural firms. *Food Policy*, 109, article number 102269. doi: 10.1016/j.foodpol.2022.102269.

[7] Prager, S.D., & Wiebe, K. (2021). Strategic foresight for agriculture: Past ghosts, present challenges, and future opportunities. *Global Food Security*, 28, article number 100489. doi: 10.1016/j.gfs.2020.100489.

[8] Khafagy, A., & Vigani, M. (2022). Technical change and the common agricultural policy. *Food Policy*, 109, article number 102267. doi: 10.1016/j.foodpol.2022.102267.

[9] Sadowski, A., Wojcieszak-Zbierska, M.M., & Beba, P. (2021). Territorial differences in agricultural investments co-financed by the European Union in Poland. *Land Use Policy*, 100, article number 104934. doi: 10.1016/j.landusepol.2020.104934.

[10] Rudenko, M.V. (2019). The impact of digital technologies on agricultural production: Methodological aspect. *Scientific Notes of Taurida National V. I. Vernadsky University. Series "Economy and Management",* 30(69)(6)), 30-37.

[11] Dudar, T. (2019). Development of innovative activity in the agrarian sector of the economy of Ukraine. *Bulletin of the Ternopil National Economic University,* 1, 60-69.

[12] Chorna, N.P. (2015). Strategic vectors of innovative development of agriculture in Ukraine. *Ekonomika i Derzhava*, 7, 22-25.

[13] Petrov, V.M. (2012). Technical support of innovative technologies in crop production. *Ekonomika APK*, 2, 100-105.

[14] Official website of the State Statistics Service of Ukraine. (n.d.) Retrieved from https://ukrstat.gov.ua/.

[15] Bolila, S. (2017). Innovative development of the agricultural sector: Problems and levers of state influence to solve them. In *Problems of regulatory and legal support of innovative activity and ways to solve them* (pp. 16-21). Kyiv: Taras Shevchenko KNU.

[16] Skakun, L.M., Kravchenko, H.V. (2018). Current state of innovative development of agriculture: Problems of innovation implementation and ways to solve them. *Young Scientist*, 11(63), 1190-1192.

[17] Mineral Fertilizers. (n.d.). Retrieved from https://agroantal.com.ua/mineralnye-udobrenija.

[18] Farmers' costs have increased significantly: Reasons. (2022). Retrieved from https://agronews.ua/news/zatraty-agrariyiv-suttyevo-zbilshylys-prychyny/.
[19] Klymkovetskyi, M. (2022). *The prices of energy resources in 2022 will increase by 50%, food products will become more expensive by 23% – the forecast of the World Bank*. (2022). Retrieved from https://hromadske.ua/posts/cini-na-energoresursi-u-2022-roci-zrostut-na-50-harchovi-produkti-podorozhchayut-na-23-prognoz-svitovogo-banku.
[20] Damages from the war in agriculture reached $4.3 billion. (2022). Retrieved from https://finclub.net/ua/news/zbytky-vid-viiny-v-silskomu-hospodarstvi-siahnuly-usd4-3-mlrd.html.
[21] Kislyuk, L.V. (2012). Modern innovative and communication technologies in the field of crop production of Ukraine. *Economy and Society*, 15, 327-332.
[22] The world market of precision agriculture will reach 3.7 billion euros in 2025. (n.d.). Retrieved from https://www.agrortk.com.ua/svitovij-rinok-tochnogo-zemlerobstva-syagne-37-mlrd-yevro-v-2025-roci/.
[23] Zakharchuk, O. (2022). *The precision farming market of Ukraine reaches $60-70 million*. Retrieved from https://agroportal.ua/news/tekhnika/rinok-tochnogo-zemlerobstva-ukrajini-syagaye-60-70-mln.
[24] TOP-7 agricultural companies that spend the most on innovation. (2019). Retrieved from https://landlord.ua/news/top-7-ahrokompanii-iaki-naibilshe-vytrachaiut-na-innovatsii/.
[25] What you need to know about variable rates. (2019). Retrieved from https://agravery.com/uk/posts/show/skola-agronomiv-so-treba-znati-pro-zminni-normi.
[26] Gavrilyuk, A. (2019). *Save resources: The Okolitsia company shared the results of using the autopilot*. Retrieved from https://agrotimes.ua/tehnika/zaoshhadyty-resursy-u-kompaniyi-okolyczya-podilylys-rezultatamy-vykorystannya-avtopilota/.
[27] Variable seed sowing rates. (n.d.). Retrieved from https://www.agrilab.ua/services/zminni-normi-visivu-nasinnya/.
[28] Zakharchuk, O.V. (2022). Point spraying allows to reduce the costs of PPE by up to 90%. *Agrotimes*. Retrieved from https://agrotimes.ua/tehnika/tochkove-obpryskuvannya-dozvolyaye-skorotyty-vytraty-zzr-do-90-naukovecz/.
[29] Shyian, D., Moskalenko, A., & Kyrychenko, Yu. (2020). The economic mechanism for the formation of land rent at agricultural enterprises. *Economics of Development*, 19(1), 35-44. doi: 10.21511/ed.19(1).2020.04.
[30] Vyshnevetska, O.V. (2015). Economic assessment of the efficiency of the use of fuel and energy resources in agricultural enterprises. *Efektyvna Ekonomika*, 6. Retrieved from http://www.economy.nayka.com.ua/?op=1&z=4151.
[31] Kisil, M. (2022). The investment potential of Ukraine's agriculture accumulated in 2021 is under threat. *National Scientific Centre "Institute of Agrarian Economics"*. Retrieved from http://www.iae.org.ua/presscentre/archnews/3346-nakopychenyy-u-2021-rotsi-investytsiynyy-potentsial-silskoho-hospodarstva-ukrayiny-pid-zahrozoyu-mykola-kisil.html.
[32] Zakharchuk, O., Kisil, M., Nechytailo, V., Pawlik, A., & Shaposhnykov, K. (Eds.). (2022). Status and prospects of investment agricultural development in Ukraine. In *Transformation of economy, finance and management in modern conditions* (pp. 58-74). Riga: Baltija Publishing.
[33] The council calls on the world to guarantee "green corridors" for the export of food from Ukraine. (2022). Retrieved from https://www.ukrinform.ua/rubric-economy/3512032-u-radi-zaklikaut-svit-garantuvati-zeleni-koridori-dla-eksportu-prodovolstva-z-ukraini.html.
[34] Experts focus on pessimistic options for forecasting capital investments in the agricultural sector. (2022). Retrieved from https://agravery.com/uk/posts/show/eksperti-orientuutsa-na-pesimisticni-varianti-prognozu-kapitalnih-investicij-v-agrosektor.
[35] Didkivska, H., Masliukova, Z., & Novytska, Ye. (2021). Influence of carbonised biomass on soil improvement, increase in yield of agricultural crops and mitigation of climate change implications. *Scientific Horizons*, 24(1), 93-100. doi: 10.48077/scihor.24(1).2021.93-100.

Інвестиційно-інноваційний розвиток сільського господарства України

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► **Анотація.** Необхідною передумовою сталого розвитку держави є інвестиційно-інноваційне забезпечення рівня її економіки. Згідно модерністської теорії економічного зростання гарвардського економіста Роберта Солоу, «економічне зростання має три складові: обсяг капіталу, обсяг праці та загальний фактор продуктивності (рівень технологій, інновації та якість врядування)». Завдання, які стоять перед агропромисловим виробництвом України, є стимулювання процесів накопичення та ефективне використання інвестиційних ресурсів за пріоритетами економічного зростання, перспективи розвитку інноваційної діяльності. Передумовою цього є макроекономічна стабільність, яка сприяє накопиченню внутрішніх та зовнішніх чинників і ресурсів шляхом підвищення довіри інвесторів до економічної регуляторної політики та зниження рівня ризику інвестиційної діяльності. Питання, висвітлені в статті, стосуватимуться, насамперед, таких важливих факторів у забезпеченні розвитку підприємств агропромислового комплексу як інновації та інвестиції. Вони знайшли своє місце в дослідженнях багатьох економістів, але управління інноваційними проектами та інвестиційною діяльністю для забезпечення економічної безпеки суб'єктів АПК недостатньо розроблені. Це визначає актуальність цієї статті. У процесі дослідження використано такі методи: діалектичний, системний підхід, монографічний, економіко-статистичний, табличний, графічний, порівняльний аналіз, абстрактно-логічний та аналітичне прогнозування. Метою даної статті є визначення сутності та особливостей аграрних інновацій, дослідження умов та факторів інноваційного розвитку АПК, оцінювання проблем і перспектив використання новітніх прогресивних технологій у сільському господарстві та їх фінансового забезпечення. Досліджено особливості впровадження інноваційних технологій в аграрному секторі економіки і виявлено, що агроінновації мають тісний зв'язок з агротехнічними умовами виробництва, мають зв'язок з живими організмами, мають сезонний характер і залежно від цього мають високий рівень ризику. Проведено аналіз матеріальних витрат на виробництво зернових та динаміку цін на них. На прикладі одного з господарств Вінницької області розраховано, як за допомогою технологій точного землеробства та енергоощадних технологій можна зменшити собівартість виробництва зернових культур. Виявлено основні тенденції інвестиційного забезпечення сільського господарства, зв'язок капітальних інвестицій і ВВП та з'ясовано їх роль в впровадженні агроінновацій. Запропоновано заходи з вирішення проблем впровадження інновацій в сільському господарстві

► **Ключові слова:** аграрний сектор, агроінновації, капітальні інвестиції, точне землеробство, технології обробітку ґрунту, продовольча безпека