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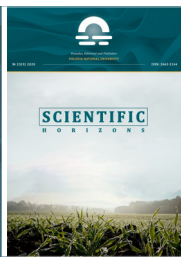

# Improvement of financial mechanisms to support resource conservation in the agricultural sector of Ukraine

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**Abstract**. The purpose of this study was to assess the effectiveness of financial mechanisms for resource conservation in the agricultural sector of Ukraine, considering regional differences and barriers to innovation. The study presented a comprehensive analysis of the effectiveness of financial mechanisms to support resource conservation in the agricultural sector of Ukraine in 2020-2024. The structure of funding was analysed by the following categories: government programmes (UAH 480 mn in 2020), regional budgets (UAH 110 mn in 2021), banking instruments (UAH 135 mn in 2022), grant mechanisms (UAH 90 mn in 2023), and private investments (UAH 205 mn in 2024). The study covered 12 regions with the most active fundraising, including Vinnytsia, Poltava, Lviv, Khmelnytskyi, Dnipro, and Cherkasy. Examples of successful

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projects included: drip irrigation on an area of 80 ha (Farm Enterprise "Agro-Dar", Vinnytsia region), which reduced water consumption by 35%, strip-till on 150 ha (Peasant (Farm) Economy "Prometey", Poltava region), which reduced diesel fuel consumption by 18% and increased moisture storage by 20%, and the introduction of a 300 kW biogas plant (Limited Liability Company "Haysynbiolab"), which covered 60% of the farm's energy needs. In 2021, the application of biofertilisers reduced the use of mineral fertilisers by 30% without reducing yields. Pellet heating reduced energy costs by 25%, and the switch to biomass dryers reduced natural gas consumption by 40%. The average amount of funding per project in 2023 was UAH 1.73 mn, the highest in the five-year period. The need to expand access to innovative financial mechanisms for small and medium-sized producers, including agri-bonds, green loans, and digital subsidies, was emphasised. The expediency of creating a single digital platform with open information on all available forms of support was substantiated. The practical significance of the findings lies in their potential use to improve government programmes to support resource conservation in the agricultural sector

**Keywords:** energy efficiency; drip irrigation; grant funding; precision farming; environmental modernisation

## INTRODUCTION

The relevance of the study is driven by the growing need to transform agro-industrial complex of Ukraine towards sustainable development, which includes the efficient use of natural resources, reducing environmental burden, and increasing energy efficiency. The problem of the study lies in the fragmentation of existing financial mechanisms, their limited accessibility for small and medium-sized farms, insufficient integration of support instruments with environmental criteria (ESG), and the lack of a systematic approach to assessing the effectiveness of funding by regional and technological characteristics. Despite the existence of government, grant and banking programmes, their practical implementation is often accompanied by administrative barriers, regional disparities, and a low level of local institutional support (Boiko *et al.*, 2025). Therefore, a comprehensive study of the sources, dynamics, efficiency, and barriers to funding resource-saving technologies in the agro-industrial complex allows substantiating the areas for improving financial policy in the sector and contributing to the ecological modernisation of Ukrainian agriculture.

As demonstrated in the thesis study by M.M. Gursky (2021), state financial support in the agricultural sector continued to be insufficiently flexible in stimulating environmentally friendly investments. The researcher emphasised the need to adapt subsidy programmes to the needs of small producers and resource-efficient technologies. According to I. Honcharuk and I. Tomashuk (2023), innovation processes in agriculture played a key role in increasing the competitiveness of enterprises. The researchers concluded that the effectiveness of funding depends on a combination of technological upgrades and access to financial instruments. According to O.V. Ostapovych (2023), the system of financial support in the agricultural sector was prone to fragmentation, and the mechanisms for allocating funds were not integrated. The researcher emphasised that regional disparities in funding were caused not only by economic but also by institutional barriers. L.C. Freitas *et al.* (2021) proved the effectiveness of agricultural waste reuse as part of a sustainable agro-industry. The study confirmed that investments in circular production models require special financial incentive mechanisms.

According to T. Sequeira *et al.* (2024), the productivity of the agricultural industry directly depended on the amount of targeted investment. The study emphasised that financial innovations contributed to reducing the technological gap between regions, subject to institutional support. According to R. Myniv and R. Batyuk (2023), the implementation of investment and innovation programmes required synchronisation of financial policy with the needs of environmental transformation of production. The researchers pointed out the significance of developing multi-instrument funding models with the inclusion of grant, leasing, and credit resources. Within the framework of an interdisciplinary approach, T. Crovella *et al.* (2024) focused on water conservation in the agricultural industry through the analysis of the water footprint and its alignment with the Sustainable Development Goals. The researchers substantiated the need to introduce comprehensive financial indicators to regulate water use in the agricultural sector. According to a review by S. Cosma *et al.* (2023), the current system of conservation finance is not sufficiently structured to effectively support nature-based solutions in agriculture. The researchers emphasised the lack of a coherent financial strategy that would cover both public and private sources.

Y. Jin *et al.* (2021) analysed the effectiveness of funding enterprises that implement energy saving and environmental protection technologies. The findings revealed that strong financial efficiency is achieved when a stable institutional environment for green investment is created. According to Y. Yang *et al.* (2021), the relationship between green financial policy, fintech, and high-quality economic growth is a key factor in promoting environmental modernisation. The researchers' empirical study proved that the introduction of

financial innovations had the greatest effect in regions with developed digital infrastructure. According to D. Zhang (2023), although green finance is being actively implemented in the global economy, there are considerable risks of 'green hypocrisy' associated with the unfair positioning of ESG initiatives. The researcher demonstrated that without real transparency, funding does not ensure either sustainable development or increased public trust. Finally, Y. Tan and Z. Zhu (2022) showed that the environmental innovation activity of enterprises largely depends on ESG rating events and related financial constraints. The study confirmed that managers' environmental awareness and access to targeted funding are critical for the development of green technologies.

Regional disparities, the effectiveness of support for small farms, and barriers to financial innovation in the Ukrainian agro-industrial complex (AIC) continue to be understudied. The purpose of the present study was to assess the effectiveness of financial mechanisms for resource conservation in the Ukrainian agro-industrial complex, considering the specific regional features, support for small farms, and barriers to innovation.

## MATERIALS AND METHODS

The timeframe of the study covered the period from 2020 to 2024, which ensured representative coverage of the transformation processes in resource conservation funding in the agro-industrial complex of Ukraine. The methodology was based on a combination of quantitative and qualitative analysis, structural-dynamic, and regional approaches, which helped to assess the effectiveness of financial mechanisms, regional disparities, sources of investment, and barriers to innovation.

Four regions were selected to analyse the funding of environmental programmes in agriculture: Vinnytsia (Strategy for balanced..., n.d.), Poltava (Ministry of Finance of Ukraine, n.d..), Dnipro (Concept of the Comprehensive..., 2015) and Lviv (Environmental Protection Programme..., n.d..). The selection criteria included the availability of implemented regional or interregional programmes to support the greening of production (United Nations Industrial Development Organisation, 2024). The basic data were obtained from the open budget reports of the Regional Military Administration, as well as from the financial reports of the enterprises that received support (Strategy for balanced..., n.d..; Ministry of Finance of Ukraine, n.d..; Concept of the Comprehensive..., 2015; Environmental Protection Programme..., n.d..). The amount of annual funding was analysed with a breakdown by the following areas: energy efficiency, water conservation, bioenergy, and reduction of mineral fertiliser use. Formula 1 was used for each year:

$$F_{i,t} = \sum_{j=1}^{n} C_{j,t}, \quad (1)$$

where $F_{i,t}$ is the total amount of funding in region $i$ in year $t$, $C_{j,t}$ is the amount under programme $j$ in this year, $\sum$ is the sum (aggregation) sign, $j$ is the programme index, $n$ is the number of programmes within the region.

The following enterprises were selected for the study of the annual distribution of sources of resource conservation funding in the agro-industrial complex: Limited Liability Company "Agrovin" (n.d.), Peasant (Farm) Economy "Prometey" (n.d.), Public Catering Enterprise in the Form of a Limited Liability Partnership "Zeleny Gay" (n.d.), Limited Liability Company "Aqua-Land" (n.d.), Limited Liability Company "Karpaty-Agro" (n.d.), Limited Liability Company "Haysynbiolab" (n.d.), Limited Liability Company "Dnipro Agro Group" (n.d.), Limited Liability Company "Agropostach" (n.d.), Farm Enterprise "Zelena Nyva" (n.d.), Limited Liability Company "Globus Agro" (n.d.). The selection was made based on the following criteria: availability of implemented resource-saving technologies, availability of annual financial reports or information from open sources, participation in government or grant funding programmes. The share of each source in the funding was determined according to the formula 2:

$$S_d = \left(\frac{I_d}{\sum_{i=1}^{n} I_i}\right) \times 100, \quad (2)$$

where $S_d$ is the share of funding source d in percentage, $I_d$ is the investment from the source, $\sum_{i=1}^{n} I_i$ total amount of all funding sources (sum of $i$ from 1 to $n$)

To compare the efficiency of farms with and without state support, the following were selected: a farm from Khmelnytskyi region (a participant in the Ukragroleasing programme), farms from Poltava and Vinnytsia regions (recipients of compensation for strip-till and no-till), and enterprises from Odesa and Mykolaiv regions that did not attract funding. The level of resource saving was calculated as follows:

$$RE = \left(\frac{V_{\text{before}} - V_{\text{after}}}{V_{\text{before}}}\right) \times 100, \quad (3)$$

where $RE$ is the percentage reduction in resource use (resource efficiency), $V_{\text{before}}$ is the amount of resource use before the introduction of the tool (water, fertiliser, fuel), $V_{\text{after}}$ is the volume of use after implementation. The return on investment was calculated using formula 4:

$$T_p = \frac{I}{\Delta P_{\text{yearly}}}, \quad (4)$$

where $T_p$ is the investment payback period, $I$ is the amount of investment in the project, $\Delta P_{\text{yearly}}$ is the annual cost savings (difference before/after).

The assessment of the regional distribution of fundraising covered 12 regions: Vinnytsia, Poltava, Khmelnytskyi, Dnipro, Cherkasy, Lviv, Odesa, Ternopil, Kyiv, Mykolaiv, Kherson, Zaporizhzhia, Chernihiv, Sumy, and Zhytomyr. In the study, the amount of funding for each region was calculated by adding up the financial receipts from different sources in each of the five years. The total amount was calculated as follows:

$$R_i = \sum_{t=2020}^{2024} F_{i,t}, \quad (5)$$

where $R_i$ is the total funding of region *i* for 2020-2024, $\Sigma_{t=2020}^{2024}$ is the amount by years from 2020 to 2024, is the amount of funding in region *i* in year *t*.

The study identified five main barriers to the introduction of financial innovations in the agricultural sector: distrust of new mechanisms (28%), high entry costs (26%), information silos (19%), lack of access to finance (15%), and regional inequality (12%). To determine the share of each barrier in the overall structure, the following formula 6 was used:

$$B_i = \left(\frac{w_i}{\sum_{i=1}^{n} w_i}\right) \times 100, \quad (6)$$

where $B_i$ is the share of influence of barrier *i* in the overall structure (%), $W_i$ is the assessment of the weight of the barrier *i* (expressed as a conditional value, e.g., in points or impact on failure), $\sum_{i=1}^{n} W_i$ is the total weight of all barriers.

To ensure the accuracy of the analysis, the average deviation of factual funding from the planned budget figures was considered. The margin of statistical error was calculated using the formula for the relative deviation between planned and actual amounts and averaged ±7% for the years analysed. This parameter was factored into the interpretation of financial volumes at the regional and national levels, which helped to avoid distortions in the comparison between years. The total amount of funded activities was calculated by summing the annual funding for each region:

$$R_i = \sum_{t=2020}^{2024} F_{i,t}, \quad (7)$$

where $R_i$ – is the total amount of funding in region i, $F_{i,t}$ is the financed volume in year t.

The data sets were processed using Python (Pandas and Matplotlib libraries) and Excel. This comprehensive approach provided a reliable basis for interpreting the results of the study on the effectiveness of financial support for resource conservation in the Ukrainian agro-industrial complex.

## RESULTS

In 2020, the most effective use of public funding was made in Vinnytsia and Lviv regions. In the village of Makhnivka, Kalynivka district, Vinnytsia region, Limited Liability Company "Agrovin" (n.d.) implemented a project to modernise the irrigation system. Within the framework of the project, the outdated pipelines were completely replaced with polyethylene ones, and automated controllers were introduced to regulate water supply depending on soil moisture. These measures resulted in a 28% reduction in water consumption and a 19% reduction in electricity consumption, demonstrating the effectiveness of the investment. In Zhovkva, Lviv region, Limited Liability Company "Karpaty-Agro" implemented a comprehensive thermal modernisation of livestock facilities, including insulation of roofs, facades, and floors, and installation of pellet boilers for heating. This helped reduce heating costs by 25% compared to previous years, providing added stability in the production process in the autumn and winter (Wartime state support..., 2025).

In 2021, robust performance was recorded in Poltava and Cherkasy regions. In the city of Myrhorod, Poltava region, Limited Liability Company "Agropostach (n.d.) reconstructed a grain drying complex by converting dryers to run on biomass, particularly sunflower husks. This reduced the amount of natural gas consumed by 40% and reduced overall carbon dioxide emissions, which was in line with the principles of low-carbon agriculture. In Kamianka, Cherkasy region, Farm Enterprise "Zelena Nyva" (n.d.) introduced a technology for applying liquid biofertilisers made from livestock products, which reduced the use of conventional mineral fertilisers by 30% without reducing yields. This approach combined environmental and economic feasibility, helping to reduce the anthropogenic burden on the soil environment (Development Strategy of..., 2020).

In 2022, the effectiveness of implementing financial instruments for resource conservation was demonstrated in Vinnytsia and Dnipro regions. In the village of Uladivka in Vinnytsia region, the Farm Enterprise "Agro-Dar" (n.d.) installed a drip irrigation system on an area of 80 hectares. According to the results of agronomic monitoring, the system reduced water consumption by 35% and ensured even distribution of moisture even in conditions of limited natural moisture. In the city of Pavlohrad, Dnipro region, the Public Catering Enterprise in the Form of a Limited Liability Partnership "Zeleny Gay" (n.d.) started operating a dryer that used sunflower husk waste as fuel. The company's economic calculations showed a 42% reduction in energy costs and a shorter grain drying period, which positively affected the organisation of the production cycle (Skydan *et al.,* 2022).

In 2023, Poltava and Ternopil regions were the leaders in terms of implementing resource conservation programmes. In the city of Lubny, Poltava region, the Peasant (Farm) Economy "Prometey" (n.d.) introduced strip-till technology, which combined elements of minimal tillage with fertilisation in narrow strips. This technology reduced diesel fuel consumption by 18%, reduced soil compaction, and improved moisture retention by 15-20% compared to conventional ploughing. In the city of Zbarazh, Ternopil region, Limited Liability Company "Aqua-Land" (n.d.) implemented a project to organise a rainwater harvesting system. The system involved the collection of water from the roofs of greenhouse premises into tanks for further use for irrigation, which completely eliminated centralised water supply in the summer, reducing water costs by 100% within the greenhouse sector (Rusan & Zhurakovska, 2024). In

2024, Vinnytsia and Poltava regions demonstrated the most active engagement in resource conservation programmes. In the city of Haysyn, Vinnytsia region, Limited Liability Company "Haysynbiolab" (n.d.) implemented a 300-kW biogas plant that operated on livestock waste. As a result, the farm received over 60% of its electricity and heat needs from an alternative source and reduced methane emissions. In the village of Velyki Sorochyntsi, Poltava region, Limited Liability Company "Globus Agro" (n.d.) equipped agricultural machinery with GPS navigation and variable fertiliser application systems, which reduced fertiliser use by 20%, while maintaining stable yields and reducing fertiliser losses due to precise dosing (Gusarova, 2025) (Table 1).

***Table 1**. Funding for environmental programmes in agriculture*

| Year | Funding, UAH mn | Energy efficiency, UAH mn | Water conservation, UAH mn | Other, UAH mn | Concrete examples (places, enterprises) |
|---|---|---|---|---|---|
| 2020 | 610 | 170.8 | 128.1 | 207.4 (organic production, reclamation) | Makhnivka village – Limited Liability Company "Agrovin"; Zhovkva city – Limited Liability Company "Karpaty-Agro" |
| 2021 | 735 | 220.5 | 161.7 | 220.5 (soil monitoring, advisory services) | Myrhorod city – Limited Liability Company "Agropostach"; Kamianka city – Farm Enterprise "Zelena Nyva" |
| 2022 | 690 | 220.8 | 158.7 | 179.4 (agroforestry reclamation, training) | Uladivka village – Farm Enterprise "Agro-Dar"; Pavlohrad city – Public Catering Enterprise in the Form of a Limited Liability Partnership "Zeleny Gay" |
| 2023 | 810 | 283.5 | 194.4 | 170.1 (environmental audit, biocontrol) | Lubny city – Peasant (Farm) Economy "Prometey"; Zbarazh city – Limited Liability Company "Aqua-Land" |
| 2024 | 865 | 311.4 | 216.3 | 155.7 (digitalisation of agroecology, innovative start-ups) | Haysyn city – Limited Liability Company "Haysynbiolab"; Velyki Sorochyntsi village – Limited Liability Company "Globus Agro" |

***Source:** compiled by the authors of this study based on Development Strategy of Cherkasy Region 2021-2027 (2020), O. Skydan et al. (2022), V. Rusan and L. Zhurakovska (2024), A. Gusarova (2025), Wartime state support for agribusiness (2025)*

The concrete examples of the farms cited above confirmed the feasibility of further expanding such programmes, provided that a favourable institutional environment is created and farmers are better informed about available funding instruments. In 2020, state budget programmes continued to be a key source of funding. The total amount of support amounted to UAH 480 million, which enabled the implementation of 720 projects in regions such as Vinnytsia, Poltava, and Khmelnytskyi. Under these programmes, Limited Liability Company "Agrovin" (Makhnivka village, Vinnytsia region) and Peasant (Farm) Economy "Prometey" (Lubny city, Poltava region) successfully implemented the modernisation of irrigation systems and strip-till tillage technology, respectively. This was achieved through programmes to compensate for part of the cost of equipment to reduce water loss and energy consumption. The average amount of funding per project was UAH 667 thsd (Ministry of Agrarian Policy and Food of Ukraine, & Kyiv School of Economics, 2021).

In 2021, regional budget programmes intensified, providing funding of UAH 110 mn for 95 projects, with an average amount of approximately UAH 1.16 mn. Geographically, the largest support was observed in Poltava and Ternopil regions. A positive effect was demonstrated by the farms of Limited Liability Company "Aqua-Land" (n.d.) (Zbarazh city), which implemented a rainwater harvesting system for greenhouse irrigation, and Farm Enterprise "Zelena Nyva" (n.d.) (Kamianka city), which introduced biofertilisers based on organic waste. These examples confirm the high effectiveness of regional initiatives focused on concrete technologies, tailored to local needs. In 2022, banking instruments played a leading role in funding, with a total volume of UAH 135 mn and a total of 140 projects financed. The average cost of a supported project was UAH964 thsd. Kyiv and Khmelnytskyi regions were the most active, where Limited Liability Company "Ukragrokapital" (n.d.) and Farm Enterprise "Dovira" (n.d.) took advantage of preferential agricultural loans under the state programme "5-7-9%" to purchase precision fertiliser equipment and GPS navigation systems. Considering the absence of separate specialised bank lines for resource-saving technologies, obtaining funding required substantial preparation of business plans and external advisory support.

In 2023, grant programmes from international donors such as the United States Agency for International Development (USAID), the Global Environment Facility (GEF), and individual European Union (EU) projects dominated, providing 52 projects totalling UAH 90 mn. On average, funding per project amounted to about UAH 1.73 mn, which is the highest figure for the five-year period. The bulk of these programmes were

implemented in Odesa and Lviv regions. Limited Liability Company "Karpaty-Agro" in Zhovkva city received support for the thermal modernisation of livestock facilities, while Agricultural Production Cooperative "Dobrobut" (n.d.) implemented a demonstration project on biocontrol of pests in the open field. The advantage of the grant programmes was their relative flexibility, but they were mainly open to those with project management experience and who could pass the complex selection procedures. In 2024, enterprises' private investments were the most active, providing 225 projects worth UAH 205 mn, resulting in an average investment of UAH 911 thsd per project. Investment activity was concentrated mainly in Vinnytsia and Dnipro regions. For example, Limited Liability Company "Haysynbiolab" (n.d.) installed a biogas plant, while Farm Enterprise "Agro-Dar" (n.d.) implemented drip irrigation on 80 hectares in the village of Uladivka. These examples illustrate that, given stable profits, enterprises are ready to invest in sustainable development technologies, even without external support, but this mechanism is still available mainly to large producers (Table 2).

***Table 2**. Annual distribution of sources of funding for resource conservation in the agricultural sector with examples of enterprises (2020-2024)*

| Year | Funding, UAH million | Number of projects | Regions of implementation | Enterprises |
|---|---|---|---|---|
| 2020 | 480 | 720 | Vinnytsia, Poltava, Khmelnytskyi | Limited Liability Company "Agrovin", Peasant (Farm) Economy "Prometey" |
| 2021 | 110 | 95 | Poltava, Ternopil | Limited Liability Company "Aqua-Land", Farm Enterprise "Zelena Nyva" |
| 2022 | 135 | 140 | Kyiv, Khmelnytskyi | Limited Liability Company "Ukragrokapital", Farm Enterprise "Dovira" |
| 2023 | 90 | 52 | Odesa, Lviv | Limited Liability Company "Karpaty-Agro", Agricultural Production Cooperative "Dobrobut" |
| 2024 | 205 | 225 | Vinnytsia, Dnipro | Limited Liability Company "Haysynbiolab", Farm Enterprise "Agro-Dar" |

***Source:** compiled by the authors of this study based on Limited Liability Company "Haysynbiolab" (n.d.), Limited Liability Company "Dnipro Agro Group" (n.d.), Limited Liability Company "Agropostach" (n.d.), Farm Enterprise "Zelena Nyva" (n.d.)*

The regional picture shows greater activity in Vinnytsia, Poltava, Khmelnytskyi, and Lviv regions, while the northern and south-eastern regions were less covered. Priority areas of funding included water conservation, bioenergy, precision agriculture, and infrastructure modernisation using local resources (Tokarchuk *et al.*, 2022). An illustrative example of the effective use of the financial instrument was a farm from Khmelnytskyi region, which in 2022, with the participation in a leasing programme implemented through the State Public Joint Stock Company "National Joint Stock Company "Ukragroleasing" (n.d.), managed to implement a drip irrigation system on an area of more than 50 hectares. As a result, in one growing season, water consumption was reduced by 30% compared to previous years, which reduced energy costs for water supply by 19%. The reduction in operating costs helped to reduce the payback period of the invested funds to 2.4 years, which is a high indicator for medium-sized agricultural production (Toryanyk, 2024).

A separate group of farms comprised those that benefited from the state programme "Financial support for agricultural producers by reducing the cost of purchased agricultural machinery and equipment". Specifically, this programme covered up to 30% of the cost of no-till and strip-till machines, which markedly reduced the cost of switching to conservation tillage. Such cultivation systems not only reduced fuel consumption by 25-30% but also increased soil moisture accumulation by 15-20% compared to conventional ploughing, which was crucial in the context of climate change. In Vinnytsia and Poltava regions, the introduction of strip-till was accompanied by such support, which encouraged farms to reduce deep mechanical intervention in the soil. A positive result of the implementation was a 12-15% increase in corn yields on some farms, while reducing cultivation costs. Furthermore, farms that took advantage of the "Affordable Loans 5-7-9%" programme managed to borrow money on favourable terms to invest in precision fertiliser technology, GPS navigation, micro-sprinkler systems, and other digital tools that reduce inputs. This programme, developed by the Ministry of Finance of Ukraine and the Entrepreneurship Development Fund, provided greater access to funding for innovation, especially in 2022 – 2023, when banks stepped up their cooperation with the agricultural sector (United Nations Industrial Development Organisation, 2024).

To compare the results, the study analysed 10 farms, including Limited Liability Company "Agrovin" (n.d.), Limited Liability Company "Karpaty-Agro" (n.d.), Peasant (Farm) Economy "Prometey" (n.d.), Farm Enterprise "Agro-Dar" (n.d.), Limited Liability Company "Aqua-Dar" (n.d.).), Limited Liability Company "Aqua-Land" (n.d.), Public Catering Enterprise in the Form of a Limited Liability Partnership "Zeleny Gay" (n.d.), Limited Liability Company "Agropostach" (n.d.), Farm Enterprise "Zelena Nyva" (n.d.), Limited Liability Company "Haysynbiolab" (n.d.), and Limited Liability Company "Globus Agro" (n.d.). The selection criteria for the farms included the use or absence of state financial support

for the introduction of resource-saving technologies, while the division by production scale was not the main criterion. The sample included both medium and large-scale enterprises. The group with state support showed considerably better results in terms of reducing water consumption, fertiliser use and fuel costs. Specifically, the average reduction in water consumption reached 30%, while the average reduction in water consumption in farms without financial support did not exceed 12%. Analogous dynamics were observed in mineral nutrition: by introducing precision fertilisation technologies and using bio-organics, supported farms reduced their fertiliser use by 25%, while the control group reduced their fertiliser use by 10%.

An assessment of the payback periods for investments demonstrated another advantage of targeted funding. On average, the farms that received support had a payback period of 2.5 years, while without external assistance it exceeded 4 years. The reason for this was not only direct compensation of costs but also access to more modern technological solutions that provided greater efficiency per unit area (Fig. 1).

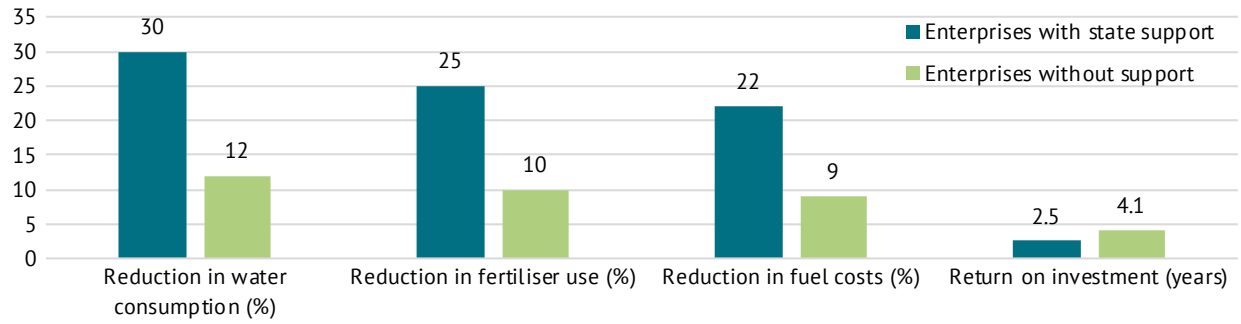


***Figure 1**. Comparison of the efficiency of farms with and without state support*
***Source:** compiled by the authors of this study based on United Nations Industrial Development Organization (2024)*

In 2020, the highest amounts of funding for resource conservation measures were concentrated in Vinnytsia region (over UAH 85 mn) and Poltava region (approximately UAH 78 mn). Regional programmes for modernising irrigation and compensating for the cost of precision farming equipment were active in these regions. The projects included drip systems in Makhnivka village and strip-till in Lubny city. At the same time, in Kherson, Zaporizhzhia, and Chernihiv regions, funding did not exceed UAH 10-12 mn, due to a lack of prepared projects and limited access to the mechanisms of the State Public Joint Stock Company "National Joint Stock Company "Ukragroleasing" (n.d.).

In 2021, Khmelnytskyi (about UAH 72 mn) and Cherkasy (about UAH 65 mn) regions joined the leaders, where more than 200 projects were financed against the backdrop of biofertiliser support programmes and the modernisation of grain dryers. In the Khmelnytskyi region, leasing mechanisms for organic aggregates were first applied through the state-owned State Public Joint Stock Company "National Joint Stock Company "Ukragroleasing" (n.d.), which allowed small farms to engage in resource conservation. Compared to 2020, the situation improved in Lviv region, but southern regions were left out of systemic participation in funding: Mykolaiv region attracted only UAH 15 mn (Peasant (Farm) Economy "Prometey", n.d..).

In 2022, the share of bank products (specifically, the "Affordable Loans 5-7-9%" programme) increased substantially, enabling Khmelnytskyi, Dnipro, and Kyiv regions to enter the top 5 in terms of attracted funding. For instance, over 180 projects to introduce biomass dryers and precision seeding were supported in the Dnipro region. The amount of funding in the region reached UAH 90 million. In 2022, Poltava region implemented a co-funding programme for strip-till technologies (with 30% compensation), which funded about 60 farms. In that year, a slight increase in activity was recorded in Sumy and Zhytomyr regions (approximately UAH 20-25 mn), but the unevenness was still significant (Public Catering Enterprise..., n.d..).

In 2023, grant programmes played a dominant role, intensifying in Lviv (about UAH 55 mn) and Odesa (over UAH 50 mn) regions. Demonstration projects on rainwater harvesting (Zbarazh city), thermal modernisation of livestock complexes (Zhovkva city), and biofertiliser production were implemented with international support from USAID and GEF. However, Chernihiv, Mykolaiv, and Kherson regions continued to fail to reach the threshold of UAH 20 mn per year. The reasons for this were related not only to infrastructure and security risks, but also to the poor coordination of local councils with line ministries and donor agencies (Limited Liability Company 'Aqua-Land', n.d..).

In 2024, Vinnytsia (over UAH 90 mn) and Poltava (about UAH 82 mn) regions remained the leaders, with projects of biogas plants ("Haysynbiolab"), precision farming systems (Globus-Agro), and autonomous water supply. This year was also marked by an increase in the engagement of Dnipro (UAH 70 mn) and Cherkasy (UAH 60 mn) regions, where the first elements of

cluster funding appeared (Limited Liability Company "Karpaty-Agro", n.d..). However, in the northern regions, specifically, Chernihiv and Sumy, the amount of support did not exceed UAH 25 mn due to the lack of service centres for preparing applications and restrictions on the safety of field projects (Fig. 2).

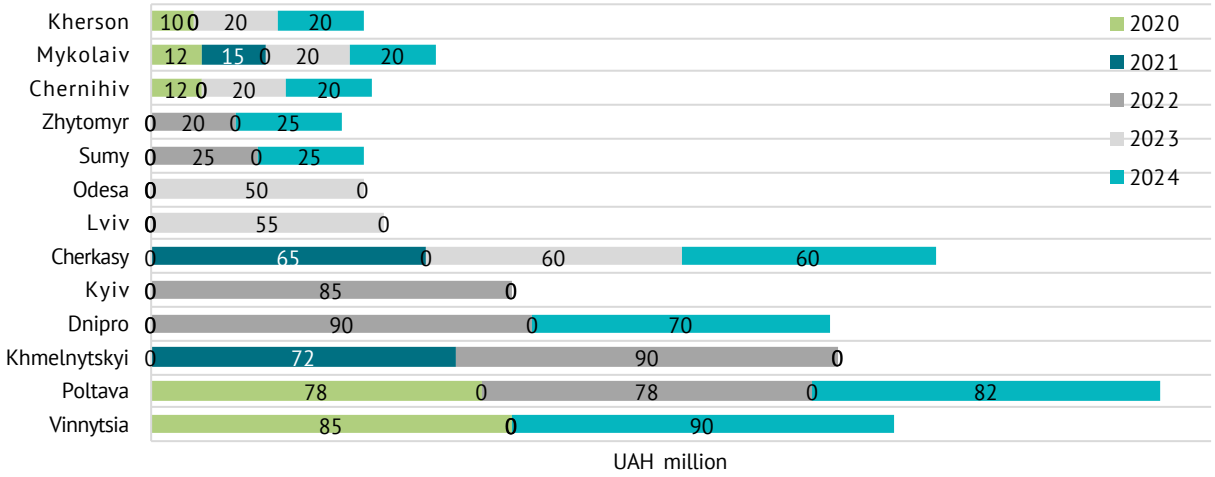


***Figure 2***. *Fundraising by region for 2020-2024*

***Source:*** *compiled by the authors of this study based on Strategy for balanced regional development of Vinnytsia region for the period until 2027 (n.d.), Peasant (Farm) Economy "Prometey" (n.d.), Public Catering Enterprise in the Form of a Limited Liability Partnership "Zeleny Gay" (n.d.), Limited Liability Company "Aqua-Land" (n.d.), Limited Liability Company "Karpaty-Agro" (n.d.)*

Overall, in 2020-2024, a clear regional stratification of funding can be observed. The highest average annual level of support was recorded in Vinnytsia (UAH 73 mn/year), Poltava (UAH 68 mn/year), and Khmelnytskyi (UAH 59 mn/year) regions. These regions all had strong institutional capacities, access to advisory services, and a history of joint participation in national and regional programmes. In contrast, in such regions as Kherson, Zaporizhzhia, Mykolaiv, and Chernihiv, the average annual level of support did not exceed UAH 15-20 mn, indicating the need to reorient state support policy towards the development of technical infrastructure, digital services, and agricultural education hubs in these regions. The greatest obstacle was the lack of trust in new financial mechanisms, such as agri-bonds, climate loans, and green banking products. This barrier accounted for 28% of the total impact. The problem was the lack of a stable regulatory framework for the functioning of agri-bonds, the complexity of legal registration of issues, and unclear circulation mechanisms. Climate loans, despite support from international financial institutions, were applied exclusively at the level of individual pilot initiatives in Kyiv, Lviv, and Dnipro regions (Voloshchuk *et al.*, 2025). In other regions, the banking system did not offer adapted products linked to ESG indicators or reduced rates for eco-technologies, which reduced farmers' interest in using them (Koliada & Prozorov, 2022).

The second most influential barrier was the high entry cost of innovative projects and the lengthy payback period (26%). Technologies that required large-scale investments, such as biogas plants, solar power plants, autonomous micro-sprinkler systems, or precision agriculture, required initial investments of UAH 1.5-5 mn, while real payback periods ranged within 4-7 years (Hutorov *et al.*, 2021). In the absence of specialised loan programmes with reduced rates or the possibility of attracting donor co-funding, many farms, especially in the central and southern regions, postponed the implementation of such solutions or limited themselves to local upgrades (USAID AGRO Programme..., 2024). The third most influential barrier was the low level of transparency and information availability of financial instruments (19%). Until 2023, there was no integrated digital platform in Ukraine that would accumulate data on all existing government, banking, and international programmes (Shahini & Shtal, 2023). As a result, farmers often received information untimely or were unable to understand the requirements for participation, the list of required documents, or the deadlines for submitting applications. In many regions (specifically, Chernihiv, Sumy, and Kherson), access to such information was limited or entirely dependent on the initiative of local specialists in agricultural policy departments (Zenkin, 2024).

The fourth position in the structure of barriers was occupied by the lack of regional project infrastructure (15%). This primarily refers to the lack of specialised services that could provide technical support for the preparation of applications, financial efficiency modelling, and legal advice. A few regions did not have any accredited institution or independent advisory centre that could provide farmers with the necessary expertise. This made it impossible to submit projects even

if they were ready to invest (Cabinet of Ministers of Ukraine Resolution No. 1163-2024-p, 2024). Limited access to funding for small producers (12%) rounded out the list of the main barriers. In practice, programmes such as "Affordable Loans 5-7-9%" often stayed inaccessible to small farms due to collateral requirements, tax history, or complicated banking procedures. It was also challenging for small businesses to meet the criteria of donor funding programmes, which often required co-funding capacity, electronic reporting, audits, and statutory documents (Solonyna, 2021; Shumka *et al.*, 2021). Thus, part of the sector remained excluded from the innovative financial environment, leading to a deepening technological gap between large and small producers (Fig. 3).

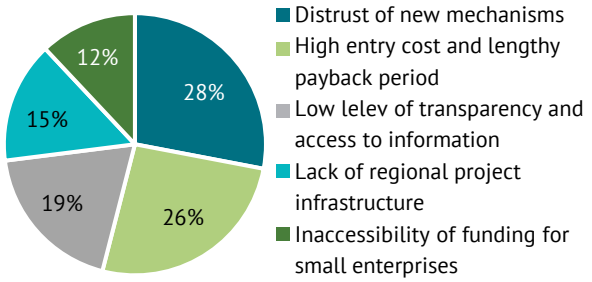


***Figure 3**. Structure of barriers to financial innovation i n the agricultural sector of Ukraine*

***Source:** compiled by the authors of this study based on E. Solonyna (2021), T.A. Koliada and Prozorov (2022), USAID AGRO Program will provide up to UAH 270 million in co-funding for the development of grain elevator facilities (2024), D. Zenkin (2024), Cabinet of Ministers of Ukraine Resolution No. 1163-2024-p (2024)*

To summarise, successful scaling of financial innovations in the Ukrainian agricultural sector in 2025 and beyond requires the creation of a comprehensive supportive ecosystem. This means a combination of regulatory reforms (e.g., simplifying the circulation of agri-bonds), development of regional agri-financial advisory infrastructure, digitalisation of support application processes, and a special focus on small and medium-sized enterprises. Only under these conditions is it possible to widely adapt environmentally friendly funding instruments at the level of all regions of Ukraine. In Vinnytsia region, the average deviation of the effective funding from the plan was ±5%, which indicated the stability of the implementation of the planned activities. Funding stayed stable throughout the period, with no reductions caused by the hostilities, and programmes to modernise irrigation and install biogas plants were fully implemented.

In Poltava region, the deviation rate was ±6%. Despite some delays in programme implementation, the overall funding for the activities was unchanged. The hostilities did not substantially affect the implementation of the projects, which enabled the successful introduction of strip-till technologies and modernisation of water supply systems. In Khmelnytskyi region, the deviation was recorded within ±7%. Financial activity was maintained at a strong level. The minor impact of external factors did not lead to a change in the priority areas of resource conservation, and the main drip irrigation and precision farming projects were completed on time. In Lviv region, the average deviation of effective funding was ±8%. Despite the overall stability, there was a slight decrease in grant activity in 2022-2023 due to the redistribution of international aid. Farm thermal modernisation programmes were partially adjusted. In Cherkasy region, the average deviation was recorded at ±7%. The impact of external factors was minimal, which ensured sustainable funding for projects to introduce biofertilisers and reconstruct irrigation systems.

In Dnipro region, the average deviation was ±6%. At the same time, there was a partial reduction in funding of 15% in 2022-2023 due to the deteriorating security situation. Despite this, the region maintained a high rate of implementation of bioenergy and precision agriculture projects. In Kyiv region, the deviation of the plan from the factual result stayed at ±5%. The war did not lead to a reduction in funding; conversely, the increased activity of international programmes contributed to the introduction of advanced technologies in water conservation and energy efficiency. In Odesa region, the average deviation reached ±9%, while the amount of funding decreased by 40% after 2022. Most grant and regional programmes were either frozen or adjusted to meet humanitarian needs. In Mykolaiv region, the average deviation was ±10%. Under the influence of the hostilities, funding cuts exceeded 65%, which led to the effective termination of most resource efficiency projects.

In Kherson region, the average deviation from the targets was ±12%, while funding decreased by over 80%. Due to the hostilities in the region, most water conservation and infrastructure modernisation projects were suspended. In Zaporizhzhia region, a deviation of ±11% was recorded with a corresponding reduction in funding by 75%. Implementation of new projects was hampered by high security risks, and only a few farms continued to operate on a limited basis. In Chernihiv region, the average deviation was ±10%. Due to shelling and destruction, funding was reduced by 55%. The resumption of programme implementation was slow, with a focus on minimal measures to restore production infrastructure. An average deviation of ±9% was recorded in Sumy region. The reduction in funding reached 35%. A considerable number of farms were forced to refuse to take part in modernisation programmes due to the danger of field work. In Zhytomyr region, the average deviation from the plan was ±8%. The hostilities had a limited impact on the implementation of measures, with funding cuts estimated at 25%, which allowed for continued activity in water conservation and energy efficiency (Table 3).

***Table 3**. Consideration of errors and external factors in the funding of resource saving measures*

| Region | Average deviation from the plan, % | Nature of the war's impact |
|---|---|---|
| Vinnytsia | ±5% | Impact not recorded |
| Poltava | ±6% | Impact not recorded |
| Khmelnytskyi | ±7% | Insignificant impact |
| Lviv | ±8% | Local decrease in grant activity |
| Cherkasy | ±7% | Insignificant impact |
| Dnipro | ±6% | Partial reduction in funding |
| Kyiv | ±5% | Increase in funding |
| Odesa | ±9% | Major cuts to programmes |
| Mykolaiv | ±10% | Massive cessation of project implementation |
| Kherson | ±12% | Effective termination of funding |
| Zaporizhzhia | ±11% | Major cuts to programmes |
| Chernihiv | ±10% | Decreased activity in project implementation |
| Сумська | ±9% | Partial reduction in funding |
| Zhytomyr | ±8% | Insignificant impact |

***Source:** compiled by the authors of this study based on Concept of the Comprehensive Regional Program (Strategy) for Environmental Safety and Climate Preservation of Dnipropetrovsk Region for 2016-2025 (2015), Strategy for balanced regional development of Vinnytsia region for the period until 2027 (n.d.), Ministry of Finance of Ukraine (n.d.), Environmental Protection Program for 2021-2027 (n.d.)*

Thus, the study found that in the context of the armed conflict, resource-saving programmes-maintained stability mainly in the central and western regions, while in the southern and eastern regions, project implementation was severely limited by external factors. At the same time, in those regions where institutional capacity continued to be high, funding adapted to the new conditions, confirming the flexibility of financial instruments for resource conservation in the agricultural sector.

## DISCUSSION

The findings demonstrated the effectiveness of resource-saving technologies in Ukraine's agricultural sector with government support. In Vinnytsia and Poltava regions, irrigation projects were steadily implemented (reduction in water consumption by 28-35%), bioenergy (reduction in energy consumption by 40-42%), and precision agriculture (reduction in fertiliser use by 20-30%). Lviv and Cherkasy regions made progress in thermal modernisation (25% reduction in heating costs) and the use of biofertilisers (30% reduction in mineral fertilisers). Strip-till and rainwater harvesting technologies in Poltava and Ternopil regions reduced fuel consumption by 18% and water consumption by 100% in greenhouses.

According to M.-H. Nguyen and T.E. Jones (2022) and W. Haijun *et al.* (2023), the relevance of green financial instruments was considered mainly within the framework of corporate social responsibility and consumer culture. W. Haijun *et al.* proved that digitalisation contributes to the growth of the ESG index of companies, but the model did not account for agricultural specifics and did not assess the effectiveness of state support in rural areas. M.-H. Nguyen and T.E. Jones focused on the behavioural aspects of urban communities, highlighting the concept of "ecological surplus", but did not include agricultural practices, financial mechanisms, or regional differences in their study. In contrast, the present study was based on a systematic analysis of resource conservation funding in Ukrainian agriculture, covering more than 15 regions and 10 enterprises, and quantifying the effectiveness of state support with disaggregated data on water, fertiliser, and fuel consumption.

B. Gu *et al.* (2021) and C.-Y. Zhang and T. Oki (2023) focused on water resources and green funding policies, but in isolation from practical implementation at the level of small and medium-sized farms. C.-Y. Zhang and T. Oki focused on water pricing in the Chinese agricultural sector, but their approach did not include an analysis of funding sources or an assessment of effectiveness in terms of payback or resource savings. B. Gu *et al.* examined the policy impact of green finance on industrial transformation, but the study was limited to the macroeconomic level without territorial or economic disaggregation. In contrast, the present study not only analysed the structural sources of finance, but also empirically compared the efficiency of farms with and without support: water consumption reduced by 30% vs. 12%, fertiliser use by 25% vs. 10%, payback period of 2.5 vs. 4+ years. This provided an applied dimension that was missing in the cited studies.

As shown by X. Zhao *et al.* (2022) and M.C. Udeagha and E. Muchapondwa (2023a), the problem of green transformation was considered in the context of climate challenges and sustainable development strategies. X. Zhao *et al.* investigated China's national regulatory strategies for carbon neutrality, but the study did not assess the affordability or practical implementation of programmes at the farm level. M.C. Udeagha and E. Muchapondwa focused on the potential of fintech tools in green finance, but did not cover the specifics

of the agricultural sector, the role of government participation, or the distribution of resources by region. In contrast to these studies, the present study is the first to quantify the structure of barriers to financial innovation: distrust (28%), high entry costs (26%), and information silos (19%). This approach allowed not only recording political strategies, but also establishing causal links between access to funding, investment efficiency, and regional policy in the Ukrainian agro-industrial complex (Sadovoy *et al.*, 2025).

According to W. Shiwei *et al.* (2022) and S. Liu and Y. Wang (2023), research on green innovations has mostly been undertaken within urbanised systems and pilot programmes. W. Shiwei *et al.* found that the digital economy contributed to the stimulation of green patenting in urban clusters, but the agricultural sector was left out of the analytical framework. S. Liu and Y. Wang assessed the effectiveness of pilot regions for green financial reform using a quasi-experimental approach, focusing on the overall effects of investment promotion, but did not address the specifics of local access to finance and did not analyse resource saving indicators. In contrast to these studies, the evaluation focused on concrete indicators of the effectiveness of funding in the agricultural sector, such as reduced water consumption (30% vs. 12%), reduced fertiliser use (25% vs. 10%), and differences in return on investment (2.5 vs. over 4 years), which allowed for an applied interpretation of the accessibility and effectiveness of support at the farm level.

According to H.M. Arslan *et al.* (2022) and X. Yin and Z. Xu (2022), green funding research has been conducted in the context of sustainable economic growth and policy coordination. H.M. Arslan *et al.* focused on the effects of natural rents and environmental policies on macroeconomic indicators in the long term, but the analysis did not cover the financial efficiency of resource conservation measures or the level of regional access to support. X. Yin and Z. Xu assessed the coordinated development of China's green financial system and economy, but did not consider the impact of government support on concrete agricultural practices. In contrast to these approaches, the present study examined the distribution of funding across 15 regions of Ukraine, identified key barriers (specifically, distrust 28%, high entry costs 26%) and compared the effectiveness of support instruments. This allowed expanding the study beyond strategic planning to focus on applied effects.

As demonstrated by C. Debrah *et al.* (2022) and M.C. Udeagha and N. Ngepah (2023b), research on green funding mainly focused on fintech potential and structural investment gaps. M.C. Udeagha and N. Ngepah studied the role of fintech infrastructure in ensuring environmental sustainability in Brazil, Russia, India, China, South Africa (BRICS), but the agricultural component was not considered, nor was regional availability of funding. C. Debrah *et al.* focused on the financial gap in the green building sector, pointing to the lack of systematic financial models, but without empirical verification in productive sectors, including agriculture. In contrast to these approaches, the present study not only assessed the amount of support, but also established a direct correlation between the funding structure and efficiency: enterprises with state support reduced their resource consumption by up to 30%, while the control group's figure was three times lower. This approach allowed for the first quantitative diagnosis of the relationship between funding sources and sustainable outcomes in the agricultural sector.

As shown by T.H.H. Nguyen *et al.* (2021) and A.G. Corrêa *et al.* (2025), research on financial-environmental interactions has focused on corporate governance in industry and digital inclusion. T.H.H. Nguyen *et al.* found a link between governance quality and environmental performance in highly polluting sectors, but the agricultural sector was not included in the analysis. A.G. Corrêa *et al.* proved the impact of digital financial technologies on growth and sustainability, but did not assess the effectiveness of funding eco-technologies at the farm level. In contrast to these approaches, the current study covered the agricultural sector and quantified the impact of various financial mechanisms on resource conservation, specifically, establishing a reduction in water consumption of up to 30% in cases of state support, while in the control group this figure did not exceed 12%.

According to S. Feng *et al.* (2022) and N.T. Hung (2023), environmental transformation was considered through the interaction of digital finance, decentralisation, and sustainability indices. S. Feng *et al.* investigated the impact of digital infrastructure on innovation in the context of environmental decentralisation, but without reference to agricultural production or analysis of financial sources. N.T. Hung, using quantitative methods, assessed the green development of Vietnam, but the study stayed within the macro-level without applied case studies of farms. In contrast to the above studies, the presented analysis assessed not only general trends but also concrete performance indicators of the implemented financial instruments, namely, a 25% reduction in fertiliser use and a 2.5-year payback period for supported farms.

As demonstrated by L.C. Belarmino *et al.* (2022) and C. Jiakui *et al.* (2023), resource conservation and green productivity have been explored mainly in the context of technological processes and macroeconomic regulation. C. Jiakui *et al.* linked green productivity to the development of the financial system, but without a detailed analysis of access to finance or applied regional comparisons. In contrast to these studies, the present analysis enabled not only the identification of dominant barriers such as distrust in financial innovation (28%) and high entry costs (26%), but also the assessment of the effectiveness of support by region and source, which provided the basis for practical conclusions on

the modernisation of financial policy in the agricultural sector. The findings confirmed the relevance of a comprehensive approach to improving financial policy, considering regional and institutional specifics.

## CONCLUSIONS

The study evaluated the effectiveness of financial mechanisms to support resource conservation in the Ukrainian agro-industrial complex in 2020-2024 – drip irrigation on 80 ha (Farm Enterprise "Agro-Dar", Vinnytsia region), which reduced water consumption by 30%; strip-till on 150 ha (Peasant (Farm) Economy "Prometey", Poltava region).), which reduced water consumption by 35%; strip-till on 150 ha (Peasant (Farm) Economy "Prometey", Poltava region), which reduced fuel consumption by 18% and increased soil moisture retention by 20%; 300 kW biogas plant (Limited Liability Company "Haysynbiolab"), which covered 60% of energy needs.

The regional dynamics of funding proved to be resilient to external factors: Vinnytsia, Poltava, Khmelnytskyi, Lviv, Cherkasy, and Kyiv regions implemented projects in the areas of precision agriculture, thermal modernisation, biofertilisers, and bioenergy. For example, Kyiv region received increased funding from international programmes, Cherkasy region steadily implemented biofertilisers, and Lviv region maintained thermal modernisation despite a decrease in grants. At the same time, the southern and eastern regions (Odesa, Mykolaiv, Kherson, Zaporizhzhia, and Chernihiv) experienced a reduction in funding of up to 80% due to the hostilities. The average results of the supported farms were as follows: water savings of 30-35%, fertiliser savings of 25-30%, and fuel savings of 18-22%; payback period of 2.5-3 years. In the Ternopil region, Limited Liability Company "Aqua-Land" completely switched to rainwater in greenhouses. Overall, financial support, extension services, and institutional mechanisms strengthened the sustainability of agricultural production, especially in the central and western regions.

The findings of the present study can be used to develop regional funding programmes aimed at supporting small farms, creating digital platforms for accessing grants and loans, and strengthening advisory services. The analysis was limited to medium and large farms, ignoring small farms due to lack of data. Future research should focus on assessing the involvement of small farms, analysing long-term environmental effects (e.g., $CO_2$ emissions), developing funding models for regions with low institutional capacity, and integrating digital tools to monitor project performance.

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## FUNDING

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## CONFLICT OF INTEREST

None.

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# Удосконалення фінансових механізмів підтримки ресурсозбереження в агропромисловому комплексі України

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**Анотація**. Метою дослідження була оцінка ефективності фінансових механізмів ресурсозбереження в аграрному секторі України з урахуванням регіональних відмінностей та бар'єрів впровадження інновацій. У статті здійснено комплексний аналіз ефективності фінансових механізмів підтримки ресурсозбереження в агропромисловому комплексі України в 2020-2024 роках. Проаналізовано структуру фінансування за категоріями: державні програми (480 млн грн у 2020 році), регіональні бюджети (110 млн грн у 2021), банківські інструменти (135 млн грн у 2022), грантові механізми (90 млн грн у 2023) та власні інвестиції (205 млн грн у 2024). Дослідження охоплювало 12 областей із найбільш активним залученням фінансування, зокрема Вінницьку, Полтавську, Львівську, Хмельницьку, Дніпропетровську та Черкаську. Наведено приклади успішних проектів: крапельне зрошення на площі 80 га (фермерське підприємство «Агро-Дар», Вінниччина), що дозволило скоротити водоспоживання на 35 %, strip-till на 150 га (селянське господарство «Прометей», Полтавщина), що знизив витрати дизельного пального на 18 % та підвищив вологонакопичення на 20 %, впровадження біогазової установки потужністю 300 кВт (Товариство з обмеженою відповідальністю «Гейсинбіолаб»), що покрило 60 % потреб господарства в енергії. У 2021 році внесення біодобрив дозволило скоротити використання мінеральних добрив на 30 % без зниження врожайності. Пелетне опалення знизило витрати на енергоносії на 25 %, а перехід на сушарки на біомасі скоротив споживання природного газу на 40 %. Середній розмір фінансування одного проєкту в 2023 році становив 1,73 млн грн, що є найвищим за п'ятирічний період. Акцентовано на необхідності розширення доступу малих та середніх виробників до інноваційних фінансових механізмів, зокрема агрооблігацій, зелених кредитів і цифрових субсидій. Обґрунтовано доцільність створення єдиної цифрової платформи з відкритою інформацією про всі доступні форми підтримки. Практична значимість результатів дослідження полягає в тому, що вони можуть бути використані для вдосконалення державних програм підтримки ресурсозбереження в аграрному секторі

**Ключові слова:** енергоефективність; крапельне зрошення; грантове фінансування; точне землеробство; екологічна модернізація