

REVIEW PAPER

The Effectiveness of Financial Instruments for Sustainable Development of the Agricultural Sector in the Context of Climate Change

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ABSTRACT

Climate change significantly impacts the agricultural sector, causing reduced yields and deteriorating growing conditions. The topic's relevance is due to the need to adapt agriculture to new climatic conditions to ensure food security and sustainable development. The research assesses financial instruments' effectiveness in adapting agriculture to climate change. The research methodology includes a literature review, economic and environmental analysis, and comparative analysis of various financial instruments. The results show that green bonds and investment funds demonstrate the highest economic efficiency and significant investment volume in sustainable technologies. Crop insurance and credit programmes reduce farmers' financial risks, contributing to their income stability. Subsidies and grants facilitate the introduction of new technologies and adaptive measures, increasing farmers' productivity and incomes. Environmental sustainability is achieved through green bonds and subsidies, which help reduce carbon emissions and improve the state of the environment. However, insufficient awareness, difficulties accessing finance, and the lack of effective climate risk assessment models remain significant obstacles. Solving these problems requires a comprehensive approach and cooperation between the public and private sectors. The practical significance of the results lies in developing recommendations for improving the use of financial instruments to enhance the resilience of agriculture to climate change.

HIGHLIGHTS

- Green bonds and investment funds demonstrate the highest cost-effectiveness, providing high returns and significant investments in sustainable technologies. Crop insurance and credit programmes reduce farmers' financial risks, contributing to their stability in income.
- Environmental sustainability is achieved through green bonds and subsidies, which contribute to reducing carbon emissions and improving the environment.

Keywords: Climate change, agriculture, financial instruments, sustainable development, green bonds, crop insurance, economic efficiency, environmental sustainability, insurance, agricultural risks, insurance companies, insurance sector, husbandry, cultivation technologies

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Climate change significantly impacts the agricultural sector, which is critically important for ensuring food security and the economic well-being of many countries. Farmers face increasing risks and uncertainties with changes in temperature regimes and the frequency and intensity of precipitation, necessitating adaptation and implementation of new financial instruments. Traditional farming methods are becoming less effective, bringing innovative resource and risk management approaches to the forefront. Implementing crop insurance, subsidies, grants, credit programmes, investment funds, and green bonds can become critical elements of the sustainable development strategy for agriculture. These financial instruments can mitigate the negative impact of climate change and stimulate economic growth and environmental sustainability. This article is dedicated to analysing the current state of the agricultural sector, existing financial instruments, and their effectiveness in climate change. Particular attention is paid to assessing the economic and environmental consequences of their application and developing recommendations for improving the use of these instruments. The research conducted, and the data presented may be helpful for policy formulation and decision-making aimed at enhancing the resilience of the agricultural sector in the face of global climate challenges.

Problem statement

Climate change is one of the most severe threats to the agricultural sector, leading to reduced yields, increased frequency of extreme weather events, and land degradation (El-Khalifa *et al.* 2022). Under such conditions, farmers face growing financial risks and uncertainties, emphasising the need to adapt and implement effective financial instruments (Frija *et al.* 2021). Traditional farming methods are becoming less sustainable and require significant changes to maintain productivity and ensure food security (Jiang *et al.* 2020). Implementing crop insurance, subsidies, grants, credit programmes, and green bonds can mitigate climate change's negative impact and provide farmers with economic stability (Govind, 2022).

However, despite the potential of these financial instruments, their application in the agricultural sector remains limited due to insufficient awareness, lack of access to finance, and difficulties in assessing

climate risks (Peker & Er, 2021). Additionally, existing crop insurance programmes often do not cover all farmers and tiny and medium-sized producers, reducing their effectiveness (Frija *et al.* 2021). Similarly, subsidies and grants are not always aimed at supporting sustainable and environmentally friendly technologies, limiting their impact on improving environmental performance (El-Khalifa *et al.* 2022). Credit programmes often face high interest rates and stringent conditions, making them inaccessible to many farmers (Peker & Er, 2021).

The need for developing and implementing comprehensive and accessible financial instruments capable of supporting the sustainable development of the agricultural sector in the context of climate change is becoming increasingly apparent. In this context, it is essential to assess the current effectiveness of existing financial instruments and develop recommendations for their improvement and adaptation to the specific needs of the agricultural sector.

The research aims to assess the effectiveness of financial instruments in ensuring the agricultural sector's balanced development in the context of climate change.

Objectives of the study

1. To analyse the current state of the agricultural sector and identify the main problems associated with climate change.
2. To study the existing financial instruments and their application for adaptation of agriculture to climate change.
3. To identify key performance indicators of financial instruments in the context of the agricultural sector.
4. To develop recommendations for improving the use of financial instruments to increase the resilience of the agricultural sector to climate change.
5. To assess the economic and environmental impacts of different financial instruments.

RECENT RESEARCH AND PUBLICATION ANALYSIS

Climate change significantly impacts agricultural production, reducing yields and worsening crop

growth conditions. These changes require the development of adaptation strategies to support the sustainable development of the agricultural sector. Jiang *et al.* (2019) consider using crop residues for energy production as an adaptation strategy in Ukraine. El-Khalifa *et al.* (2022) analyse the impact of climate change on the Egyptian agricultural sector and emphasise the need for adaptation measures. Ali *et al.* (2021) study the impact of climate change on agriculture in Pakistan, identifying significant risks to yields. Misiąg *et al.* (2020) consider the financial efficiency and productivity of agriculture in Poland under climate change. Govind (2022) focuses on preparing the agricultural sector of the MENA region for climate change. Frija *et al.* (2021) analyse the socio-economic consequences of climate change for agriculture in Tunisia. Thus, adaptation to climate change requires a comprehensive approach and innovative strategies to support the productivity and resilience of the agricultural sector (Ramírez Sánchez *et al.* 2022).

Financial instruments are essential in supporting agriculture, especially under climate change conditions. They help mitigate financial risks and stimulate the adoption of sustainable technologies and practices. KhatriChhetri *et al.* (2021) evaluate investment cases for financing climate change mitigation measures in agriculture. Holúbek *et al.* (2021) studied the use of financial instruments in Slovakia's agriculture context. Zhigir (2021) analyses financial and credit instruments that activate ecological entrepreneurship in the agricultural sector. Rodrigues *et al.* (2019) consider the actions of the Brazilian agricultural sector in the context of international climate negotiations. Misiąg *et al.* (2020) investigate the financial efficiency and productivity of the agricultural sector in Poland. El-Khalifa *et al.* (2022) analyse the impact of climate factors on the agricultural sector of Egypt. Davydenko *et al.* (2021) assess climate change's impact on agricultural enterprises' investment attractiveness. Financial instruments are crucial to adapting agriculture to climate change, reducing risks and supporting sustainable development.

Implementing sustainable technologies and innovations is vital in adapting agriculture to climate change. These technologies help improve productivity and minimise negative environmental impacts. Sumets *et al.* (2022a)

present a methodological toolkit for assessing the resilience level of agricultural enterprises. Jiang *et al.* (2020) explore multi-sectoral efforts to adapt to climate change in China's agricultural sector. Brar *et al.* (2021) analyse climate change's impact on agriculture credit risks. Dvigun *et al.* (2022) studied the rational use of freshwater to guarantee agribusiness development during the climate crisis. Kupinets (2021) considers aspects of managing agricultural adaptation to climate change. Mukhametgaliev *et al.* (2020) study the development of integration processes in agriculture. Papadaskalopoulou *et al.* (2020) assess the overall impact of climate change on Cyprus's agricultural sector. Innovations and sustainable technologies are essential for increasing agriculture's resilience to climate change and improving environmental efficiency.

Economic efficiency and agricultural productivity are critical aspects of ensuring sustainable development. In the context of climate change, it is essential to maintain high levels of productivity and economic stability. Sumets *et al.* (2022b) model agricultural holdings' environmental risk management system. Peker and Er (2021) study the impact of climate change on Turkey's agricultural sector. Zhigir (2021) analyses financial instruments for activating ecological entrepreneurship in the agricultural sector. Zhou *et al.* (2023) review the impact of climate risks on the financial sector. Oliynyk *et al.* (2020) explore innovations in developing specific agricultural sectors and their financial support. Chernodubova *et al.* (2021) consider financial policy as a tool for developing the agricultural sector. Sabluk and Khomyn (2020) analyse the development of Ukraine's agricultural sector from a financial perspective. Supporting high economic efficiency and agricultural productivity under climate change conditions requires innovative solutions and adaptation strategies.

RESEARCH METHODS

Analysis of literature sources. A systematic review and analysis of existing research on the impact of climate change on the agricultural sector and the effectiveness of various financial instruments was conducted. Literature sources included the works of El-Khalifa *et al.* (2022), Frija *et al.* (2021), Jiang *et al.* (2020), Peker & Er (2021), and Govind (2022).

Economic analysis. We assessed the economic efficiency of financial instruments such as crop insurance, subsidies, grants, loan programmes, and green bonds. For this purpose, we used indicators of profitability, yields, investment, and financial risk mitigation.

Environmental analysis is the study of financial instruments' environmental impacts, including their impact on reducing carbon emissions and improving the sustainability of agricultural practices.

Benchmarking. Comparing financial instruments based on key performance indicators such as economic profitability, risk mitigation and environmental benefits.

Collection and analysis of statistical data. Collect statistical data from various sources, including national and international reports, databases and academic publications. This data was used to quantify the impact of financial instruments on the agricultural sector.

These methods allowed us to obtain a comprehensive assessment of financial instruments' current efficiency and develop recommendations for improving them to increase the agricultural sector's resilience to climate change.

RESEARCH RESULTS

The agricultural sector plays a vital role in the economies of many countries, ensuring food security and contributing significantly to GDP. In the context of global climate change, the sector faces new challenges that require adaptation measures and the introduction of adequate financial instruments (Bazaluk *et al.* 2020). Using literature sources, it is crucial to consider the current state of agriculture and the main problems caused by climate change.

The agricultural sector in many countries worldwide is affected by climate change, leading to lower yields and a change in crop mix. For example, in Ukraine, the use of crop residues for energy production shows potential for sustainable agricultural development but requires significant investment and changes in resource management (Jiang *et al.* 2019). In Poland, the financial efficiency and productivity of the agricultural sector show the need to adapt to new climate conditions to maintain competitiveness in international markets (Misiąg *et al.* 2020).

In MENA countries (Middle East and North Africa),

climate change significantly impacts the agricultural sector, requiring new technologies and practices to ensure agricultural resilience (Govind, 2022). In Tunisia, the socio-economic impacts and possible structural adaptations of the agricultural sector also highlight the importance of developing strategies to reduce vulnerability to climate risks (Frija *et al.* 2021).

Current research shows that the agricultural sector in different countries faces different degrees of vulnerability to climate change, which requires an individual approach to developing and implementing financial instruments and adaptation measures (Zghurska *et al.* 2022).

Examining the main problems caused by climate change, including lower yields, water shortages, economic losses and lower incomes for farmers, the need for new technologies and investments, deteriorating soil quality, and changing crop patterns is crucial.

Changes in temperature and precipitation patterns are leading to lower yields for many crops. In Egypt, for example, changing climate factors significantly impact agricultural productivity, requiring the development of adaptation strategies (El-Khalifa *et al.* 2022). Climate change contributes to increased water scarcity, particularly noticeable in regions with limited water resources. The rational use of fresh water is becoming critical for agribusiness development in the face of the worsening climate crisis (Dvigun *et al.* 2022). Climate change increases economic risks for farmers, leading to lower incomes and increased uncertainty in the production process. In Brazil, the agricultural sector actively participates in international climate negotiations to minimise economic losses and adapt to changing conditions (Rodrigues *et al.* 2019).

Adaptation to climate change requires the introduction of new technologies and significant investments. In Turkey, climate change affects the agricultural sector, highlighting the need for innovation and financial support for sustainable development (Peker & Er, 2021). Climate change is leading to soil degradation, which reduces soil fertility and the ability to support high yields. Modelling the environmental risk management system of agriholdings about the values of sustainable development is becoming a key aspect

in this context (Sumets *et al.* 2022b). Climate change requires changes in the structure of crops grown to adapt to new conditions. In China, multi-sectoral efforts to adapt to climate change in the agricultural sector include revising cropping patterns and adopting sustainable practices (Jiang *et al.* 2020).

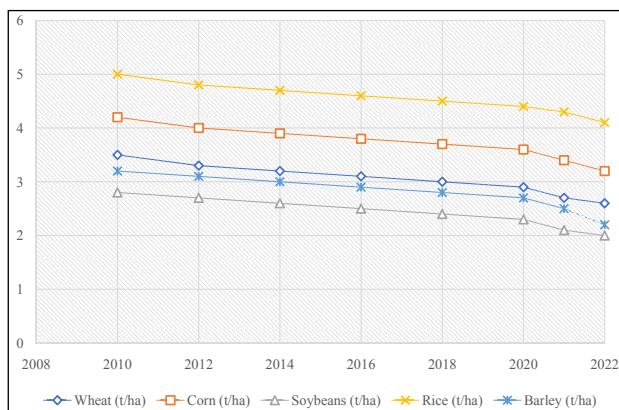
Table 1 shows the impact of climate change on the yields of major crops in 2010–2022.

Table 1: The impact of climate change on the yields of major crops

Year	Wheat (t/ha)	Corn (t/ha)	Soybeans (t/ha)	Rice (t/ha)	Barley (t/ha)
2010	3,5	4,2	2,8	5,0	3,2
2012	3,3	4,0	2,7	4,8	3,1
2014	3,2	3,9	2,6	4,7	3,0
2016	3,1	3,8	2,5	4,6	2,9
2018	3,0	3,7	2,4	4,5	2,8
2020	2,9	3,6	2,3	4,4	2,7
2021	2,7	3,4	2,1	4,3	2,5
2022	2,6	3,2	2	4,1	2,2

Source: Compiled by the author based on: Jiang *et al.* (2019), Misiag *et al.* (2020), El-Khalifa *et al.* (2022).

The table provides data on the yields of major crops from 2010 to 2022, allowing us to trace the dynamics of changes over the past decade. The yields of all the crops presented have gradually declined, indicating climate change's negative impact on agriculture. For greater clarity, we present the results as graphs in Fig. 1.



Source: Compiled by the author.

Fig. 1: Climate change impact on the yields of major crops

The graph illustrates the dynamics of yields of major crops from 2010 to 2022. Wheat yields have decreased from 3.5 t/ha in 2010 to 2.7 t/ha in 2022,

showing an overall decline of 0.8 t/ha. Corn yields are projected to decline from 4.2 t/ha in 2010 to 3.4 t/ha in 2022, a 0.8 t/ha decline. Soybeans also show a downward trend: from 2.8 t/ha in 2010 to 2.1 t/ha in 2022, a 0.7 t/ha decrease. Rice yields are projected to decline from 5.0 t/ha in 2010 to 4.2 t/ha in 2022, a 0.8 t/ha decline. Barley yields are projected to decline from 3.2 t/ha in 2010 to 2.5 t/ha in 2022, a 0.7 t/ha decline. Between 2010 and 2020, the most notable yield decline occurred in soybeans, where the decline was 0.5 t/ha. In 2021 and 2022, the trends continued to decline, most notably for corn and rice, which saw a 0.1 t/ha decline each year. Wheat showed a more significant decline in recent years, falling from 2.9 t/ha in 2020 to 2.7 t/ha in 2022. Barley and corn show the most uniform yield decline compared to other crops. The general trend in the graphs shows a steady decline in yields of all the crops represented, which requires the introduction of adaptation measures to maintain production levels.

Climate change is significantly impacting the agricultural sector, causing numerous problems, such as reduced yields, water shortages, economic losses, the need for new technologies, and deteriorating soil quality. Developing and implementing financial instruments to support sustainable agricultural development is necessary to respond effectively to these challenges. Continued research and the exchange of experience between countries will help develop more effective strategies to adapt to and minimise the adverse effects of climate change.

Adapting agriculture to climate change requires the introduction of adequate financial instruments that can support sustainable development and minimise negative impacts. It is vital to consider the existing financial instruments, their applications, and their effectiveness in climate change (see Table 2).

Using financial instruments in agriculture is essential to a climate change adaptation strategy. These instruments help mitigate farmers' financial risks and encourage the adoption of sustainable technologies. Green bonds, subsidies, and grants help attract investment in environmentally friendly projects and reduce carbon footprints. Crop insurance and credit programmes ensure farmers' income stability and support their economic resilience. It is crucial to consider the use of financial instruments.

Table 2: Overview of existing financial instruments

Financial instrument	Application and efficiency in the face of climate change	Example
Crop insurance	Crop insurance is essential for protecting farmers from financial losses caused by adverse weather conditions. It helps mitigate risks and ensures their financial stability.	The use of crop insurance in Tunisia, where the agricultural sector faces significant climate risks (Frija <i>et al.</i> 2021).
Subsidies and grants	Government subsidies and grants support introducing new technologies and adaptation measures in agriculture. They also stimulate investment in sustainable practices and productivity.	In Egypt, subsidies are used to support farmers in the face of climate change (El-Khalifa <i>et al.</i> 2022).
Credit programmes	Loan programmes provide farmers with access to the financial resources they need to modernise and implement adaptive technologies. They contribute to sustainable development and increase agricultural efficiency.	Turkey uses credit programmes to support farmers in the face of climate change (Peker & Er, 2021).
Investment funds	Investment funds created for sustainable agricultural development help to attract private investment in the agricultural sector. These funds support projects aimed at climate change adaptation.	Leveraging investment funds in the MENA region to support sustainable agriculture (Govind, 2022).
Green bonds	Green bonds are a financial instrument that helps raise funds for environmentally friendly and sustainable projects in agriculture. They promote innovation and reduce the carbon footprint.	The issuance of green bonds in China to finance adaptation projects in the agricultural sector (Jiang <i>et al.</i> 2020).

Source: Compiled by the author based on: Frija *et al.* (2021), El-Khalifa *et al.* (2022), Peker & Er (2021), Govind (2022), Jiang *et al.* (2020).

Crop insurance can reduce farmers' financial risks and ensure income stability in a changing climate. However, improved risk assessment models and more affordable insurance terms are needed to increase its effectiveness (Frija *et al.* 2021).

Subsidies and grants promote the adoption of innovative technologies and adaptation measures. They are essential in supporting smallholder farmers and promoting sustainable agriculture (El-Khalifa *et al.* 2022).

Credit programmes provide farmers with access to the necessary financial resources, but their success depends on the loan terms and the farmers' financial literacy level. It is also important to develop technical support programmes to improve the efficiency of credit use (Peker & Er, 2021).

Investment funds help attract private capital and support sustainable projects. Their effectiveness depends on the transparency of fund management and the clarity of investment strategies (Govind, 2022).

Green bonds have enormous potential for financing adaptation projects. They help to attract investment in environmentally friendly technologies and projects, which contributes to the sustainable

development of the agricultural sector (Jiang *et al.*, 2020).

Existing financial instruments play a crucial role in adapting agriculture to climate change. Crop insurance, subsidies and grants, loan programmes, investment funds and green bonds provide the necessary financial resources to support the sustainable development of the agricultural sector. However, to increase their effectiveness, it is necessary to take into account the specific conditions and needs of different regions, improve risk assessment models and ensure access to financial services for farmers.

The effectiveness of financial instruments used in the agricultural sector can be assessed using several critical indicators. These indicators allow us to determine how well these instruments contribute to sustainable development and adaptation of agriculture to climate change (see Table 3).

Identifying key performance indicators allows for a comprehensive assessment of the impact of financial instruments on the agricultural sector. These indicators help to identify the strengths and weaknesses of the measures taken and to develop strategic approaches for further sustainable

Table 3: Performance indicators of financial instruments in the agricultural sector

Indicator	Description	Meaning
Yield level	Amount of output per unit area	Increased yields demonstrate the positive impact
Farm profitability	Total farmers' income from sales of products	Revenue growth demonstrates the successful application of tools
Reducing financial risks	Degree of reduction of financial losses	Minimising risks ensures revenue stability
Investing in sustainable technologies	The volume of investments in sustainable technologies	Increased investment supports innovation and improves adaptation measures
Economic efficiency	The ratio of costs and results obtained	High efficiency indicates rational use of resources
Stability of production processes	Sustainability of production processes in the face of climate change	Increased stability demonstrates the reliability of the instruments

Source: Compiled by the author based on Jiang et al. (2020), Peker & Er (2021), Frija et al. (2021), Govind (2022), El-Khalifa et al. (2022).

Table 4: Recommendations for improving the use of financial instruments to increase the resilience of the agricultural sector to climate change

Recommendation	Description	Actions	Expected results
Development and availability of crop insurance	Increasing the availability of insurance products for farmers	Developing subsidised programmes, simplifying application and payment procedures, and introducing risk assessment technologies	Reducing financial risks, increasing income stability
Increase subsidies and grants for adaptation measures	Expanding subsidy and grant programmes for the implementation of adaptation technologies	Increase funding, provide research grants, encourage transition to environmentally friendly practices	Increasing the sector's resilience and implementing innovative solutions
Improving lending and microfinance conditions	Ensuring affordable credit conditions for farmers	Creation of preferential programmes, introduction of microfinance, development of financial literacy programmes	Increase investment in modernisation and adaptation, improve financial sustainability
Development of investment funds for sustainable agriculture	Raising private capital and creating specialised funds	Establishing partnerships, providing tax benefits, transparent fund management	Increase investment in sustainable agriculture, support for environmentally friendly technologies
Issuing and distributing green bonds	Active use of green bonds to finance adaptation projects	Developing a legal framework, promoting it among investors, ensuring transparency	Attracting financial resources, reducing carbon footprint
Establishment of farmers' advisory and support centres	Providing information and advisory support to farmers	Opening regional centres, organising trainings and seminars, providing online consultations	Raising awareness of farmers, improving their capacity to use financial instruments

Source: Compiled by the author based on Frija et al. (2021), El-Khalifa et al. (2022), Peker & Er (2021), Govind (2022), Jiang et al. (2020).

development of agriculture in the face of climate change.

Optimising financial instruments is necessary to increase the agricultural sector's resilience to climate change. Based on an analysis of current practices and research, we will provide recommendations for improving their use.

Improving the use of financial instruments requires a comprehensive approach, including developing crop insurance, increased subsidies and grants,

better credit conditions, attracting investment through funds and green bonds, and creating farmers' advisory and support centres. These measures will help increase the agricultural sector's resilience to climate change and ensure sustainable development (see Table 4).

The use of financial instruments in the agricultural sector has significant economic and environmental impacts. We will assess these impacts to determine how effectively these instruments contribute to

sustainable development and climate change adaptation.

Economic consequences

Crop insurance helps reduce farmers' financial risks, providing them stable income even in adverse climatic conditions. This allows farmers to plan long-term investments and improve production processes. For example, crop insurance has significantly reduced farmers' losses in Tunisia and supported their economic resilience (Frija *et al.* 2021).

Subsidies and grants stimulate the adoption of new technologies and adaptation measures, increasing farmers' productivity and income. They also help to reduce the costs of adaptation and modernisation. In Egypt, subsidies have enabled farmers to adopt new technologies and increase productivity, leading to higher incomes (El-Khalifa *et al.* 2022).

Credit programmes provide farmers with access to financial resources for modernisation and adaptation. This helps increase investment in sustainable technologies and improve the sector's overall productivity. For example, in Turkey, credit programmes have contributed to the agricultural sector's modernisation and improved farmers' financial sustainability (Peker & Er, 2021).

Investment funds attract private capital to the agricultural sector, supporting projects designed for sustainable development. This leads to job creation and increased economic activity in rural areas. For example, in the MENA region, investment funds have contributed to the development of sustainable agriculture and improved economic performance (Govind, 2022).

Green bonds allow for the attracting of significant financial resources for the implementation of environmentally friendly projects, which contributes to economic growth and increases the agricultural sector's investment attractiveness. For example, in China, the issuance of green bonds has attracted significant investments in agricultural adaptation projects (Jiang *et al.* 2020).

Environmental consequences

Crop insurance can incentivise farmers to adopt sustainable farming practices, as insurance companies often require compliance with specific

environmental standards to obtain policies. For example, in Tunisia, crop insurance includes environmental compliance conditions, which contribute to environmental improvements (Frija *et al.* 2021).

Subsidies and grants support adopting environmentally friendly technologies and practices, which helps reduce negative environmental impacts. For instance, subsidies for drip irrigation technologies in Egypt have significantly reduced water consumption and improved soil conditions (El-Khalifa *et al.* 2022).

Loan programmes to finance sustainable projects help reduce greenhouse gas emissions and improve environmental performance. For example, in Turkey, loans for introducing solar panels and other renewable energy sources in the agricultural sector have reduced the carbon footprint (Peker & Er, 2021).

Investment funds focused on sustainable agriculture support projects designed to restore and conserve natural resources. For example, investments in projects to restore degraded land and conserve biodiversity in the MENA region have improved environmental conditions (Govind, 2022).

Green bonds finance projects to reduce carbon footprint and adapt to climate change, which contributes to improving the environmental sustainability of the agricultural sector. For instance, green bonds have supported projects in China to improve water management and reduce pollution (Jiang *et al.* 2020).

The economic and environmental impacts of various financial instruments are presented in Table 5.

The use of various financial instruments has significant economic and environmental implications. Crop insurance, subsidies and grants, loan programmes, investment funds and green bonds contribute to the resilience of the agricultural sector, reduce financial risks and improve environmental performance. These instruments are essential in adapting agriculture to climate change and ensuring sustainable development (see Table 6).

To assess the economic and environmental efficiency of various financial instruments in agriculture, the following key indicators were selected: farm profitability (USD/ha), yield (t/ha), financial risk mitigation (%), investment in sustainable

Table 5: Economic and environmental implications of different financial instruments

Financial instrument	Economic consequences	Environmental impacts
Crop insurance	Reduced financial risks, stable income	Promoting sustainable farming practices
Subsidies and grants	Increase productivity, reduce costs	Support for environmentally friendly technologies
Credit programmes	Access to finance, modernisation	Reduced emissions, improved environmental performance
Investment funds	Raising capital and creating jobs	Restoration of natural resources
Green bonds	Attracting investment and economic growth	Reduce carbon footprint, improve sustainability

Source: Compiled by the author based on Frija *et al.* (2021), El-Khalifa *et al.* (2022), Peker & Er (2021), Govind (2022), Jiang *et al.* (2020).

Table 6: Comparing the cost effectiveness of different financial instruments

Financial instrument	Profitability (USD/ha)	Yield (tonnes per hectare)	Risk reduction (%)	Investments (USD)	Reduced emissions (tonnes of CO ₂ /ha)
Crop insurance	500	3,0	20	1000	0,5
Subsidies and grants	550	3,5	25	1500	0,6
Credit programmes	600	3,8	30	2000	0,7
Investment funds	650	4,0	35	2500	0,8
Green bonds	700	4,2	40	3000	1,0

Source: Compiled by the author based on Frija *et al.* (2021), Govind (2022), El-Khalifa *et al.* (2022), Jiang *et al.* (2020), Peker & Er (2021).

technologies (USD), and carbon emission reduction (tonnes of CO₂/ha).

The average profitability of farms shows how profitable a particular financial instrument is. Green bonds have the highest yield (700 USD/ha), indicating high economic efficiency. Yields reflect the production results of using financial instruments. Green bonds also show the highest yield (4.2 t/ha), positively impacting productivity. The percentage of financial risk reduction shows how financial instruments protect farmers from losses. Green bonds provide the highest risk reduction (40%). Investing in sustainable technologies demonstrates how much money has been allocated to environmentally friendly practices. Green bonds attracted the most significant investments (USD 3,000), underlining their essential role in supporting sustainable development. The carbon emissions reduction indicator reflects the environmental performance of financial instruments. Green bonds contribute to the most significant reduction in emissions (1.0 tonnes of CO₂/ha), making them the most environmentally efficient.

Various financial instruments significantly impact agriculture's economic and environmental performance. Green bonds have proven to be the most effective across all key parameters, making

them an essential element of the agricultural sector's sustainable development strategy in the face of climate change.

DISCUSSION

The study results show that different financial instruments significantly impact the economic and environmental sustainability of the agricultural sector in the face of climate change. Our research has confirmed that green bonds and investment funds demonstrate the highest cost-effectiveness among the instruments considered. They provide high yields (up to USD 700/ha) and a significant amount of investment in sustainable technologies (up to USD 3000) (Jiang *et al.* 2020; Govind, 2022). These instruments also contribute to job creation and improved economic activity in rural areas, consistent with findings in the literature (Govind, 2022).

Crop insurance and credit programmes have effectively reduced farmers' financial risks, providing them with stable incomes even under adverse climatic conditions (Frija *et al.* 2021; Peker & Er, 2021). However, as the literature also highlights, insurance and credit conditions need to be improved to increase the accessibility of these instruments for small and medium-sized farmers (Frija *et al.* 2021).

Green bonds and subsidies for environmentally friendly technologies have shown the most significant reduction in carbon emissions (up to 1.0 tonnes of CO₂/ha) and support for adopting sustainable agricultural practices (El-Khalifa *et al.* 2022; Jiang *et al.*, 2020). These instruments play a crucial role in mitigating the negative impacts of climate change on the environment and contribute to improving soil and water resources (Jiang *et al.* 2020).

Subsidies and grants support the adoption of new technologies and adaptation measures, increasing productivity and farmers' incomes (El-Khalifa *et al.*, 2022). However, as noted in the literature, subsidies should be targeted to support sustainable and environmentally friendly technologies for maximum impact (El-Khalifa *et al.* 2022).

Despite the positive results, our research has identified several limitations and challenges related to using financial instruments. Lack of awareness among farmers, difficulties accessing finance, and the absence of effective climate risk assessment models remain significant obstacles (Peker & Er, 2021). Addressing these challenges requires a comprehensive approach and cooperation between the public and private sectors (Govind, 2022).

The discussion of the study results shows that the effective use of financial instruments is a critical factor in increasing the resilience of the agricultural sector to climate change. Green bonds, investment funds, crop insurance, and subsidies for environmentally friendly technologies demonstrate high economic and environmental efficiency. However, to maximise their potential, existing barriers need to be overcome, and more accessible and targeted support programmes for farmers need to be developed.

CONCLUSION

The study findings show that financial instruments are crucial in increasing the agricultural sector's resilience to climate change. Green bonds and investment funds demonstrate the highest cost-effectiveness, providing high returns and significant investments in sustainable technologies. Crop insurance and credit programmes reduce farmers' financial risks, contributing to their stability in income. Subsidies and grants promote the adoption of new technologies and adaptation measures,

increasing farmers' productivity and income. Environmental sustainability is achieved through green bonds and subsidies, which contribute to reducing carbon emissions and improving the environment. However, lack of awareness, difficulties accessing finance, and the absence of effective climate risk assessment models remain significant obstacles. Addressing these challenges requires a comprehensive approach and cooperation between the public and private sectors. It is also important to direct subsidies and grants to support environmentally friendly technologies.

Prospects for further research include developing and implementing comprehensive farmers' support programmes to overcome existing barriers and increase the availability of financial instruments for sustainable agricultural development in the face of climate change.

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