FINANCIAL AND ENVIRONMENTAL ASPECTS OF CARBON FARMING: PROSPECTS FOR FARMERS IN UKRAINE

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Abstract
In the context of global climate change and soil degradation, carbon farming is viewed as a promising tool for ensuring the sustainable development of the agricultural sector. This study focuses on assessing the financial and environmental dimensions of implementing such practices in Ukraine - a subject still underexplored in the national academic discourse, particularly in terms of economic feasibility for farmers. The objective is to identify potential benefits, challenges, and the level of readiness among agricultural producers to adopt this approach. The analysis also considers financial incentives, including mechanisms for generating income through the sale of carbon credits on international markets. To evaluate farmers' acceptance of these technologies, the study employs comparative analysis, a sociological survey conducted among farmers in the Mykolaiv region, and the CARVER Plus SHOCK method, which enables quantitative assessment of economic and environmental risks associated with implementation. The findings reveal major barriers to the advancement of carbon farming in Ukraine, including high initial investment costs, an underdeveloped regulatory framework, and limited access to carbon credit markets. The results suggest that, with sufficient government support, appropriate financial incentives, and developed infrastructure, this practice can become an effective instrument for enhancing the economic resilience of farming enterprises while simultaneously promoting environmental sustainability.
Keywords: financial support, carbon credits, climate change, greenhouse gases, environmentally friendly products.

Introduction

Ukraine's agricultural sector, a vital part of the national economy, is facing major challenges, including climate change, declining soil fertility, rising production costs, and the need to adapt to global environmental shifts. In this context, exploring innovative approaches that boost both economic efficiency and environmental sustainability is essential. One such approach is carbon farming, which provides both financial and ecological benefits.

Carbon farming uses agronomic practices to sequester carbon from the atmosphere and store it in the soil, lowering greenhouse gas levels. It also improves soil structure, reduces the use of chemical fertilizers, and enhances fertility. A key financial aspect is the potential to earn income by selling carbon credits on international markets, offering farmers new revenue streams.

Research confirms that financial instruments are vital for encouraging sustainable agricultural practices. Financial support can reduce carbon emissions, especially in countries with strong environmental policies (Gao et al., 2023). Likewise, tools such as green bonds, subsidies, and insurance systems are seen as essential for supporting agriculture in a changing climate (Opalchuk et al., 2024).

Carbon farming is highly relevant for Ukraine. As one of Europe's largest agricultural producers, the country has strong potential for wide-scale adoption. Moreover, climate change forces farmers to adapt, and carbon farming can help reduce agriculture's environmental footprint, improve resilience, and support sustainable growth.

However, its implementation faces obstacles, including high initial costs and the need for continuous monitoring. Small and medium-sized farms often lack the resources to adopt such practices. Government support - through subsidies, tax incentives, and carbon credit market infrastructure - is crucial for advancing this field.

International experience from the U.S., France, and Germany shows carbon farming can lower fertilizer costs, increase yields, and open new markets for eco-friendly products. For Ukraine, these practices offer valuable opportunities. With proper state support, carbon farming could become a key strategy for environmental protection and economic stability in the sector.

This study aims to assess the prospects of carbon farming in Ukraine from financial and environmental perspectives and to highlight key directions for its nationwide implementation.

To achieve this, the study sets the following tasks: analyze international experience with carbon farming; evaluate Ukraine's regulatory and financial frameworks for such practices; assess Ukrainian farmers' readiness to adopt carbon technologies; identify major barriers and risks to the development of carbon farming.

Materials and Methods

A range of methods was used to achieve the research objective. These included the analysis of scientific literature and regulatory acts to assess the legal framework governing carbon markets and environmental policy in Ukraine. Comparative analysis was applied to examine carbon farming practices in Ukraine and in developed countries such as the United States, France, and Germany, identifying both opportunities and barriers to adopting this technology domestically. Economic analysis was used to model potential benefits for farmers, including income from carbon credits and reduced agrochemical costs. Risk and barrier analysis focused on estimating potential farmer income assuming relevant infrastructure development.

Sociological methods helped gather data on the perception of carbon farming among farmers in the Mykolaiv region and identify key obstacles to its implementation. The case study method examined successful examples of carbon farming in Ukraine and abroad to adapt best practices to local conditions. In the final research stage, the CARVER Plus SHOCK method assessed the influence of economic, environmental, and political factors on carbon farming under global changes and domestic economic conditions.

The study was conducted in Mykolaiv region, Ukraine. The object of the study is the organization and implementation of carbon farming in local agricultural enterprises, as well as its economic and environmental outcomes. The subject includes theoretical, methodological, and practical aspects of carbon farming in Ukraine, with a focus on financial support for farmers and ecological effects.

The survey involved farmers, agronomists, and other experts engaged in carbon farming practices in the Mykolaiv region. It covered 47 farms across various districts and included both personal interviews and questionnaires. Conducted over three months (August to October 2024), the survey provided a comprehensive view of the characteristics and challenges of carbon farming in the region.

Results and Discussion

One of the key challenges of modern agriculture is the need to adapt to climate change and reduce greenhouse gas emissions. Carbon farming, as a strategy aimed at increasing the organic carbon content of the soil, can play an important role in ensuring sustainable production. Research (Droste et al., 2020) confirms that carbon storage in soils not only improves their fertility but also provides crop insurance against adverse weather conditions that are becoming more frequent due to climate change.

The importance of restoring soil functions and increasing their resilience to degradation is emphasized in a review of European research (Hamidov et al., 2018). The authors analyze climate change adaptation measures, including minimizing tillage, using cover crops and organic fertilizers, which helps preserve soil structure and increase carbon sequestration. The implementation of these methods on farms in Mykolaiv region allows us to assess their effectiveness in local agroclimatic conditions.

According to the latest IPCC report (2023), climate change is already affecting agricultural production, in particular through rising average annual temperatures and an increase in the number of extreme weather events. This reinforces the need to introduce carbon farming as one of the key tools for adapting to change and mitigating its negative effects.

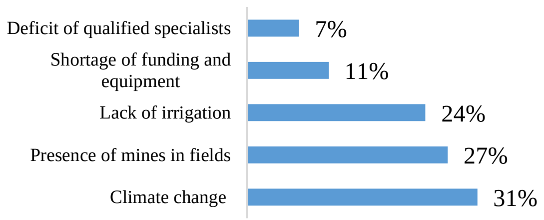
The study (Paustian et al., 2016) focuses on the concept of ‘climate-smart soils’ that provide carbon storage, improve water balance, and increase biodiversity. The implementation of such approaches can contribute to both reducing CO_2 emissions and increasing the economic efficiency of agricultural production.

According to research, carbon farming holds great potential for climate change mitigation; however, large-scale implementation depends on strong governmental backing and financial incentives (Smith et al., 2008).

From an economic perspective, a study (Tang et al., 2016) shows that the economics of carbon farming remains challenging due to high upfront investments and uncertainty in carbon credit markets. In Mykolaiv oblast, farmers show interest in new financial instruments, but lack effective mechanisms for their implementation.

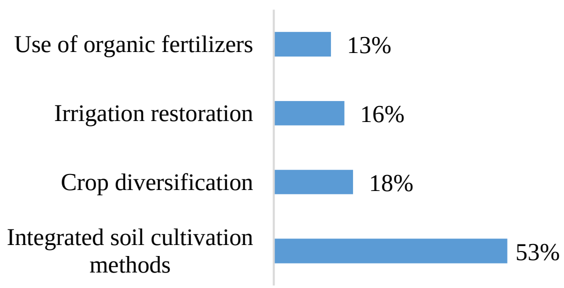
In order to analyze the real challenges and opportunities for implementing carbon farming in Mykolaiv region, a survey of 47 local farmers and agronomists was conducted. The results of the survey allowed us to identify the main risks that affect the activities of farms in the region ‘Figure 1’. According to the data, the main critical risk factors are climate change (31%), presence of mines in fields (27%), lack of irrigation (24%), shortage of funding and equipment (11%), and deficit of qualified specialists (7%).

Figure 1
Critical risk factors for farms in Mykolaiv region



According to the survey results, farmers implement various agroecological practices to adapt to new farming conditions ‘Figure 2’.

Figure 2
Agro-ecological practices of farmers’ adaptation to the current economic conditions



The most common approach is integrated soil cultivation methods (53%), which includes combined minimum and no-till technologies. A significant number of farmers use crop diversification (18%) as a strategy to reduce the risk of crop loss. Irrigation restoration (16%) remains an important priority for farms, especially in arid areas. The use of organic fertilizers (13%) is also a common practice aimed at improving soil fertility and maintaining its environmental sustainability.

The results show that although farmers in Mykolaiv region are actively implementing adaptive agroecological practices, their effectiveness remains limited due to structural and financial barriers. In particular, the high level of threats, such as field mines and water shortages, requires not only individual adaptive solutions, but also a systemic approach at the level of public policy. Compared to developed countries, where carbon farming is supported at the legislative level through subsidies and tax breaks (Paustian et al., 2016), such mechanisms are only beginning to develop in Ukraine.

Table 1

Comparative Analysis of Approaches to Carbon Farming: International Experience and Prospects for Implementation in Ukraine (based on Paustian et al., 2016; Smith et al., 2008; Tang et al., 2016)

Criteria	***Countries***			
	Ukraine	***USA***	***France***	***Germany***
State support	The initial stage of development of carbon farming, some initiatives to integrate farmers into international carbon markets.	Public and private financial support programs, incentives to reduce emissions and store carbon in the soil.	Active government support through programs to reduce emissions and improve soil quality.	Significant government subsidies for sustainable agricultural practices, emphasis on environmental sustainability and resource conservation.
Carbon credit market	Farmers get access to the international carbon credit market through special programs.	Mandatory and voluntary markets are in place, allowing farmers to sell credits to companies seeking to offset their emissions.	A developed carbon credit market provides farmers with additional income from sustainable practices.	An active market that promotes the monetization of sustainable agricultural technologies through the sale of carbon credits.
Agricultural technologies	Practices to increase the carbon content of the soil are being implemented, including cover crops, minimal tillage and organic fertilizers.	No-till technologies covering crops and crop rotation to conserve carbon and improve soil fertility are used.	Agroforestry, cover crops and organic farming are used to maintain the carbon balance.	Popular organic farming practices, crop rotations, and cover crops to maintain the carbon balance in the soil.
Barriers	Insufficient awareness of farmers about the possibilities of carbon farming, lack of government support and financial incentives.	High initial costs and volatility of the carbon credit market.	Complexity of certification procedures and lack of awareness of farmers about the benefits of carbon farming.	Bureaucratic obstacles and difficulty in accessing the carbon credit market.

The economic analysis shows that despite the potential benefits of carbon farming, its implementation requires significant initial investments, access to information on international carbon credit markets, and a stable regulatory environment. As international practices show, effective integration of farmers into this sector is possible if clear certification mechanisms and financial incentives are created (Smith et al., 2008). Therefore, the development of carbon farming in Ukraine requires a comprehensive approach that includes the adaptation of successful international practices, the creation of appropriate infrastructure, and raising awareness of farmers about the economic benefits of this management model.

Based on international experience, in countries with developed carbon credit markets (e.g., the US, France, and Germany), farmers can earn additional income by selling certified emission reduction units (Smith et al., 2008). In Ukraine, this mechanism remains at the development stage, as the legal framework does not yet ensure transparent and massive access of farmers to carbon markets. An analysis of legislative initiatives and prospective regulations shows that it is necessary to create incentives, such as tax breaks or government subsidies, to actively engage farmers in this system (Table 1).

Our analysis of the barriers to financial adoption of carbon farming in this study points to several key economic and institutional constraints that hinder the adoption of this technology in Ukraine. In particular, one of the biggest barriers is the lack of adequate financial support from the state, which prevents farmers from making initial investments in adapting to carbon practices. The absence of well-established mechanisms for monitoring, certification, and trading of carbon credits creates uncertainty in the market and reduces interest in these instruments among agricultural producers. As a result, farmers do not have a clear idea of the economic feasibility of such investments and the possibility of benefiting from the sale of carbon credits.

Additionally, legal issues and insufficient infrastructure for carbon farming significantly complicate the process of its implementation. In the absence of a stable and transparent legal framework that would regulate the carbon credit market, farmers face legal uncertainty, which creates risks when participating in carbon trading mechanisms. Given these factors, adapting to carbon practices becomes unattractive without adequate legal and economic support from the state.

It is worth noting that with the development of appropriate infrastructure and improvement of the legislative framework, carbon farming can become a powerful tool not only for mitigating climate change, but also for economic development of the agricultural sector. Given the potential for increased revenues from carbon credits and reduced costs of agrochemicals through the implementation of sustainable agroecological practices, farmers can reap significant economic benefits. However, to achieve this, it is necessary to overcome existing barriers through the introduction of appropriate financial and legal mechanisms that will ensure the transparency and stability of carbon markets in Ukraine (Dubinina & Tyvonchuk, 2024).

For a more detailed analysis of the implementation of carbon farming in Mykolaiv region, as well as to illustrate real examples of agroecological practices, Table 2 presents farms that use methods aimed at increasing the organic carbon content of the soil. The assessment of these practices allows us to highlight both positive and negative experiences in their implementation, which is important for understanding the potential benefits and challenges.

Table 2

Examples of farms in Mykolaiv region implementing carbon farming practices and their impact on soil fertility and yields

The name of the farm farms	***Implemented agroecological practices***	***Impact on soil fertility***	***Impact on yields***	***Results***
ʻOsnova – 2006’, Yelanets district	Cover crops, minimal tillage	Improving soil structure, preserving moisture	Increasing crop yields	Positive experience, improved fertility
ʻAgroLeader-D’, Voznesensky district	Use of organic fertilizers, restoration of irrigation	Improving soil fertility, increasing biodiversity	Increased yields, reduced fertilizer costs	Important experience in the use of organic technologies
ʻMarykovsky’, Pervomaisky district	Integrated soil cultivation methods, organic fertilizers	Improving the structural properties of the soil	Stable level of yields	Use of minimal tillage for conservation

Note: Source: authors’ own data, based on a 2024 survey of farms in the Mykolaiv region.

The analysis of Table 2 illustrates that the introduction of carbon farming in Mykolaiv region has the potential to improve soil fertility and increase crop yields, in particular through the use of cover crops, organic fertilizers, and minimal tillage.

At the same time, the introduction of such innovations requires a thorough assessment of possible risks related to environmental and financial aspects, as well as other factors that may affect the stability of farms. One of the most effective tools for such an assessment is the CARVER Plus SHOCK methodology, which allows to determine the vulnerability of farms to various threats. This methodology takes into account various aspects, from environmental to economic risks, and allows to assess the likelihood of their impact on farms in the context of carbon farming (Table 3). According to the assessment in the table, key factors such as criticality, availability, renewability, vulnerability, effect, recognizability, and shock help to determine the level of potential vulnerability at different stages of carbon farming implementation. Given the specifics of agricultural production in Ukraine, where carbon farming is a relatively new trend, a high score on the criticality criterion indicates the importance of this process for the long-term development of the agricultural sector and the stability of food security in the country.

Table 3

Assessment of farms using the CARVER Plus SHOCK methodology in the context of carbon farming in Ukraine

Criterion	*Description*	*Points (1-10)*
C (Criticality)	The importance of carbon farming for farm economics and food security.	9
A (Accessibility)	Ease of access to resources and infrastructure for the implementation of carbon technologies (agricultural machinery, farmer training).	7
R (Recuperability)	The time it takes for a farm to recover from environmental or financial losses (e.g., from reduced yields due to incorrectly implemented technology).	6
V (Vulnerability)	Vulnerability of farms to environmental changes or climate change (impact on soil fertility, fluctuations in weather conditions).	8
E (Effect)	The potential impact of environmental or financial issues (e.g., reduced productivity, increased costs due to improper use of technology).	9
R (Recognizability)	Ease of identification of the farm as responsible for environmental practices that may affect its reputation (green image).	8
Plus (Shock)	The psychological impact of failures to implement carbon farming technologies (e.g., impact on confidence in investment or climate change).	7

However, the importance of applying this approach lies in the analysis of accessibility and recoverability, indicators that are directly related to infrastructure and financial support. For an effective transition to carbon farming, farms must have access to the necessary resources and be able to recover from possible environmental or financial shocks. Assessment of these parameters allows us to identify at what stages the greatest difficulties arise in ensuring stability and development in the context of the introduction of environmentally sustainable technologies.

The methodology also helps to analyze vulnerability to various environmental risks, from climate change to environmental pollution, which is especially relevant for agricultural enterprises seeking to integrate the principles of carbon farming. Assessment of the effect on farm productivity, in particular, on reduced yields or deterioration of crop quality due to unstable environmental conditions, emphasizes the need to adapt to climate change and develop risk minimization strategies.

Table 4

Assessment of potential risks using the CARVER Plus SHOCK methodology for each stage of carbon farming

Stage	*Criticality (C)*	*Accessibility (A)*	*Renewability (R)*	*Vulnerability (V)*	*Effect (E)*	*Recognizability (R)*	*Shock effect (S)*	*Over all risk*
Land plot selection and soil preparation	9	7	6	8	9	7	8	54
Implementation of carbon storage technologies	8	6	6	7	8	6	7	48
Use of agricultural machinery	7	8	7	6	7	7	7	48
Monitoring and evaluation of results	9	6	5	7	9	6	7	49
Adaptation to climate change	9	7	6	8	9	8	8	55
Environmental and economic losses	8	6	7	9	9	7	8	54
Attracting investments and partners	8	7	6	6	8	7	6	48

In general, the use of CARVER Plus SHOCK allows not only to collect comprehensive information on farm vulnerabilities, but also to develop recommendations for reducing these risks. Given the importance of such a comprehensive approach to assessing potential threats, the table above illustrates the CARVER Plus SHOCK assessment of farm vulnerability at each stage of carbon farming implementation. Table 4 provides a detailed risk analysis for each stage of this process, which allows to identify the most vulnerable stages and develop strategies to minimize them.

The assessment of potential risks using the CARVER Plus SHOCK methodology for each stage of carbon farming in Ukraine, presented in Table 4, allows for a deeper understanding of the specifics of farmers' vulnerability at different stages of implementation of this innovative technology. This approach makes it possible to comprehensively assess the risks associated not only with environmental and financial factors, but also with organizational and technical aspects that may affect the efficiency of carbon farming in Ukraine.

According to the assessment, the greatest vulnerabilities were identified in the stages of organic fertilizer application and cover crop management. These stages, in particular, are characterized by high scores in terms of vulnerability (V) and effect (E), indicating a high probability of risks associated with potential technological disruptions or non-compliance with environmental standards. For example, at the stage of applying organic fertilizers, there is a high risk of negative environmental impacts and reduced efficiency of carbon farming due to possible soil or water contamination.

The cover crops and minimum tillage stages show moderate vulnerability to technical and economic threats, which may be due to imperfect infrastructure, lack of financial support, and the need to adapt to new tillage practices. These stages are marked by average values for the criteria of renewability (R) and accessibility (A), indicating the need to improve infrastructure and financing systems to ensure sustainability in the transition to sustainable agriculture.

Particular attention should be paid to the stage of monitoring and evaluation of the results of carbon farming implementation. Here, it is critical to ensure an adequate level of availability (A) of information and effective data management for timely detection of problems and correction of technological processes. The CARVER Plus SHOCK assessment of this stage indicates the need to integrate modern information systems to monitor soil conditions, carbon emissions, and other environmental parameters.

The risks associated with the financial costs of implementing carbon farming are also not insignificant. The high investment requirements for technologies that ensure minimal tillage and the use of cover crops can be a significant barrier for many farms, especially in the context of unstable financing and lack of government support.

In general, the results of the CARVER Plus SHOCK assessment for each stage of carbon farming emphasize the importance of a systematic approach to risk assessment at all stages of the implementation of this technology. They point to the need to develop comprehensive risk management strategies that cover both environmental and economic aspects. Given the specifics of agricultural production in Ukraine, it is necessary to increase the effectiveness of state policy to support farmers, in particular through financing sustainable agricultural practices, improving infrastructure and investing in innovative technologies that ensure the stability and efficiency of carbon farming.

Conclusions

1. Carbon farming is an important tool for adapting agriculture to climate change and reducing greenhouse gas emissions. The use of strategies aimed at increasing the organic carbon content in the soil improves fertility, increases resilience to adverse weather conditions, and contributes to biodiversity conservation. Effective implementation of such practices requires support at the state level and the development of financial mechanisms, particularly in the context of local agro-climatic conditions, as the experience of Mykolaiv region shows.
2. Based on the results of the analytical study and the survey, the main problems affecting farmers' activities were identified, among which the most significant are climate change, field mining, and lack of irrigation. Farmers are actively adopting agroecological practices, such as integrated tillage and crop diversification, to adapt to the new conditions. However, despite these efforts, the effectiveness of their practices remains limited due to financial and structural constraints.
3. Although Ukraine is only beginning to develop its carbon credit system, with major obstacles including limited financial support, regulatory gaps, and certification issues, the introduction of incentives like subsidies, tax relief, and transparent market rules is essential to make carbon farming economically viable and attractive for farmers.
4. An analysis of the adoption of carbon farming by farmers in Mykolaiv region shows that the use of agroecological practices, such as cover crops, organic fertilizers, and minimum tillage, has a positive impact on soil fertility and yields. These practices help to improve soil structure, retain moisture, and increase yields.
5. The CARVER Plus SHOCK risk analysis of carbon farming in Ukraine allowed for a comprehensive assessment of environmental, financial, and technical risks that are critical for a successful transition to sustainable agriculture. Risks related to insufficient infrastructure support, financing, and potential environmental losses require the development of detailed management strategies, including improving the effectiveness of government support and investments in technology.

References

Droste, N., May, W., Clough, Y., Borjesson, G., Brady, M. V., & Hedlund, K. (2020). Soil carbon insures arable crop production against increasing adverse weather due to climate change. *Environmental Research Letters*, *15*(12), Article 124034. https://doi.org/10.1088/1748-9326/abc5e3

Dubinina, M. & Tyvonchuk, Ya. A. (2024). Financial benefits of carbon farming: Analysis for farms. *Modern Economics,* 48, 23-30. https://doi.org/10.31521/modecon.V48(2024)-03

Gao, Y., Cai, M., & He, X. (2023). Influence of financial support to agriculture on carbon emission intensity of the industry. *Sustainability, 15*(3), Article 2228. https://doi.org/10.3390/su15032228

Hamidov, A., Helming, K., Bellocchi, G., Bojar, W., Dalgaard, T., Ghaley, B. B., …, & Schönhart, M. (2018). Impacts of climate change adaptation options on soil functions: A review of European case studies. *Land Degradation & Development, 29*(8), 2378–2389. https://doi.org/10.1002/ldr.3006

Opalchuk, R., Shepel, A., Dimov, I., Andrushko, R., & Andrushko, M. (2024). Ensuring sustainable development of the agricultural sector through financial instruments in the context of climate change. *Grassroots Journal of Natural Resources, 7*(3), s349–s377. https://doi.org/10.33002/nr2581.6853.0703ukr18

Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G. P., & Smith, P. (2016). Climate-smart soils. *Nature, 532*(7597), 49-57. https://doi.org/10.1038/nature17174

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., …, & Smith, J. (2008). Greenhouse gas mitigation in agriculture. *Philosophical Transactions of the Royal Society B: Biological Sciences, 363*(1492), 789-813. https://doi.org/10.1098/rstb.2007.2184

Tang, K., Kragt, M. E., Hailu, A., & Ma, C. (2016). Carbon farming economics: What have we learned? *Journal of Environmental Management,* 172, 49–57. https://doi.org/10.1016/j.jenvman.2016.02.008

Zomer, R. J., Bossio, D. A., Sommer, R., & Verchot, L. V. (2017). Global sequestration potential of increased organic carbon in cropland soils. *Scientific Reports,* 7, Article 15554. https://doi.org/10.1038/s41598-017-15794-8