



UNIVERSITY OF LIFE SCIENCES "KING MIHAI I" FROM
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GREEN INNOVATIONS IN AGRICULTURE: REDUCING THE CARBON FOOTPRINT THROUGH ECO-FRIENDLY TECHNOLOGIES

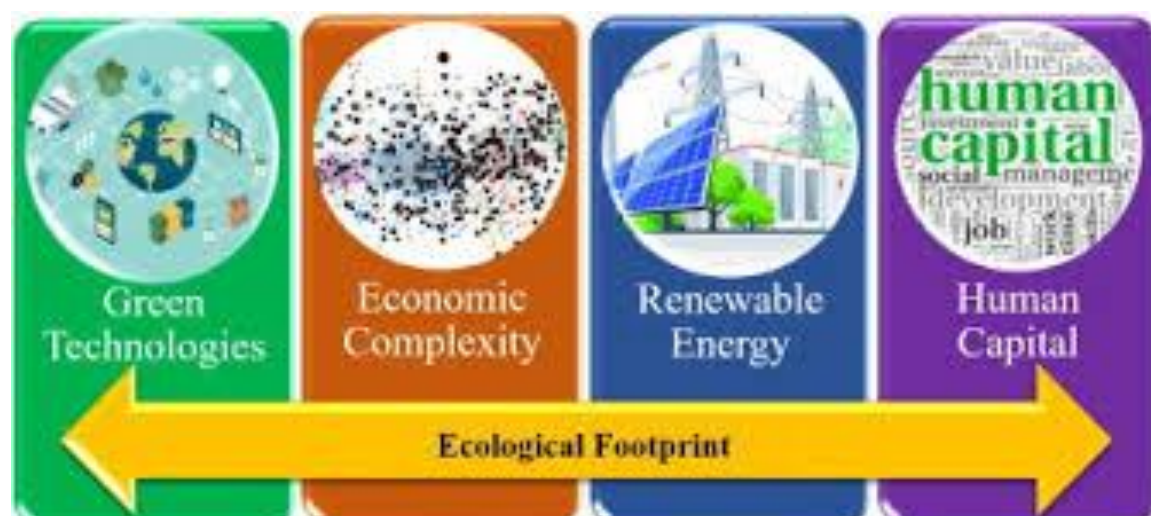
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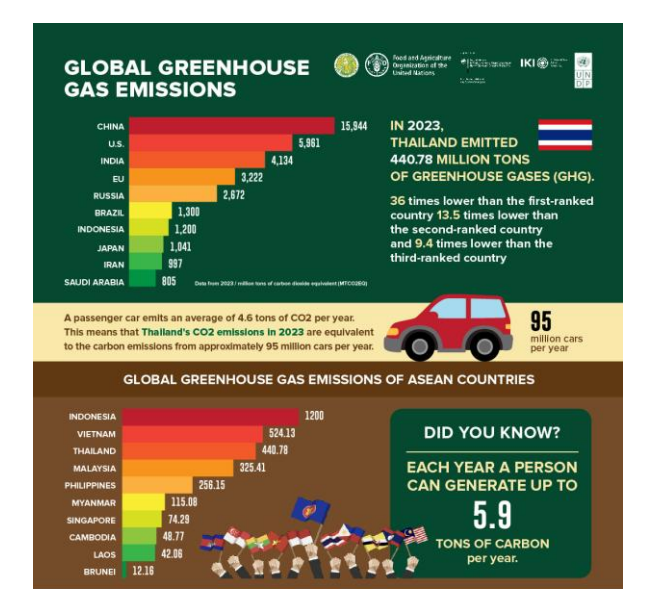
Abstract:

Agriculture remains a major contributor to global greenhouse gas emissions, primarily due to intensive soil management, synthetic fertilizer use, livestock production, and fossil fuel dependence. As the demand for food continues to rise, reducing the environmental footprint of agricultural systems has become a key global priority. This research investigates the potential of green innovations and eco-friendly technologies to lower carbon emissions and enhance sustainability in modern agriculture. The research focuses on several innovative approaches, including precision farming technologies, renewable energy integration (such as solar-powered irrigation systems), organic and bio-based fertilizers, conservation tillage, and improved waste management through circular economy practices. Field data and case studies were analyzed from farms located in Western Romania, complemented by literature findings from other European regions. Results demonstrate that adopting these eco-innovations can reduce the carbon footprint of agricultural operations by 25–35%, while simultaneously improving soil fertility, water-use efficiency, and biodiversity. However, challenges such as high initial investment costs, lack of technical knowledge, and insufficient policy incentives remain significant barriers to large-scale implementation. The study highlights the importance of strengthening farmer education, financial support mechanisms, and research–industry collaborations to accelerate the transition toward sustainable and climate-smart farming systems. In conclusion, green innovations not only contribute to emission reduction but also enhance the long-term resilience and productivity of agriculture. Encouraging the adoption of such eco-friendly technologies can play a pivotal role in aligning agricultural development with the objectives of the European Green Deal and global climate neutrality targets.



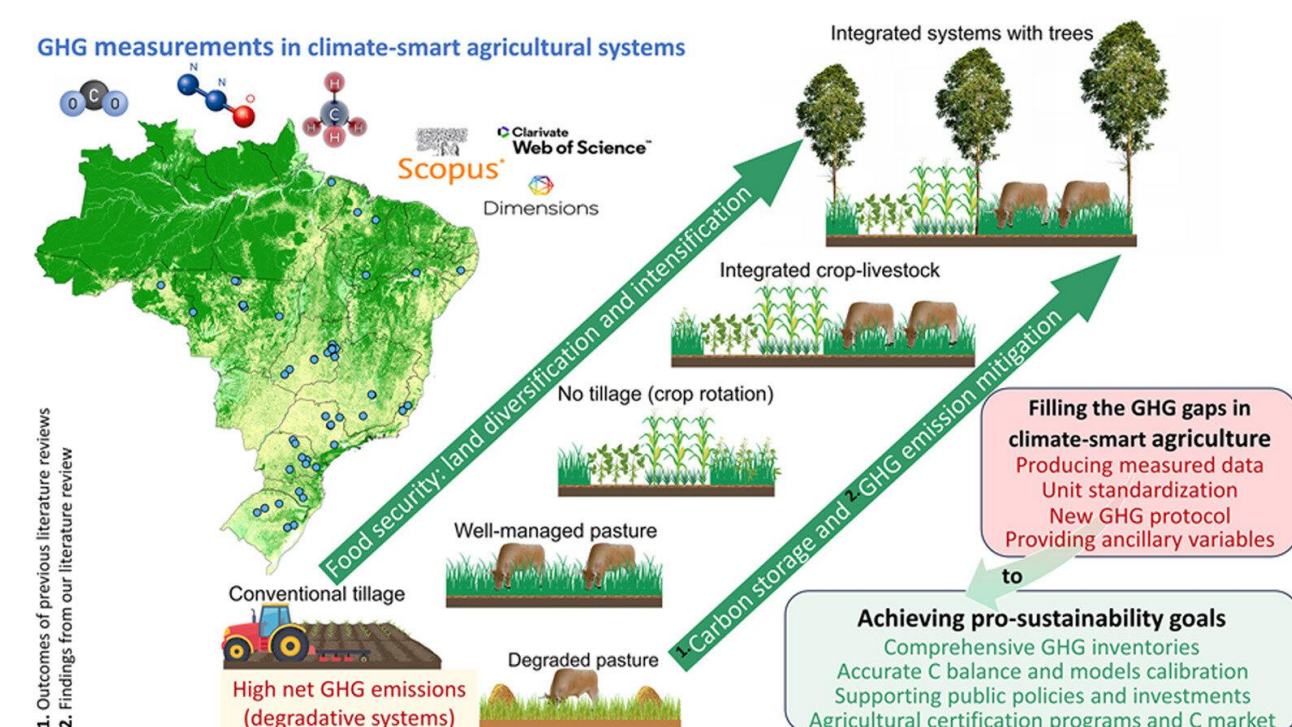
• Results and discussions

The implementation of green innovations demonstrated a clear reduction in the overall carbon footprint of agricultural activities compared to conventional practices. Farms applying precision fertilization and organic amendments recorded an average decrease of 28–35% in CO₂ equivalent emissions per hectare, mainly due to optimized nutrient use and reduced dependence on synthetic fertilizers. Similarly, solar-powered irrigation systems lowered energy-related emissions by approximately 22%, while biogas utilization from livestock waste further minimized methane emissions and improved energy efficiency. Soil analyses revealed positive changes in fertility and structure under eco-friendly management. Organic matter content increased by 0.3–0.6%, while soil pH and nutrient balance remained stable. Conservation tillage practices helped retain moisture and prevent erosion, contributing to improved long-term soil health. These findings align with studies conducted across Europe, confirming that sustainable technologies can enhance both productivity and environmental performance. Farmer interviews indicated a growing awareness of sustainability benefits but also highlighted key barriers such as high initial investment costs, limited technical knowledge, and insufficient financial incentives. Many respondents expressed interest in renewable energy and precision farming but emphasized the need for better training and support programs. Overall, the study demonstrates that integrating green innovations into agricultural systems can significantly reduce greenhouse gas emissions while maintaining or improving crop yields. The results support the transition toward climate-smart agriculture, aligning with the objectives of the European Green Deal and UN Sustainable Development Goals. Widespread adoption of such practices will require stronger policy frameworks, financial support, and continued collaboration between researchers, farmers, and technology providers. One may take a look at the situation in Asian countries and observe



Introduction

Agriculture is one of the most essential sectors supporting human life, providing food, raw materials, and employment for billions of people. However, it is also among the major contributors to environmental degradation and climate change. According to the Food and Agriculture Organization (FAO), global agricultural activities are responsible for nearly one-quarter of total greenhouse gas emissions, primarily through methane (CH₄) from livestock, nitrous oxide (N₂O) from fertilizers, and carbon dioxide (CO₂) from fossil fuel use and land-use change. The growing demand for food and bio-based resources further intensifies pressure on natural ecosystems, leading to soil depletion, water pollution, and biodiversity loss. In this context, the transformation of conventional farming systems into sustainable and low-carbon production systems has become a global priority. Green innovations represent a promising pathway for reducing agriculture's environmental footprint while maintaining or even improving productivity. These innovations integrate advanced technologies, renewable energy sources, and nature-based solutions to minimize resource consumption and emissions throughout the agricultural value chain. Examples include precision farming, which uses digital tools and sensors to optimize the use of inputs such as fertilizers and irrigation water; the adoption of organic and biofertilizers that reduce chemical dependency; renewable energy applications such as solar-powered irrigation and biogas systems; and conservation practices like reduced tillage and agroforestry. Together, these technologies can significantly enhance the sustainability and efficiency of agricultural production. Despite their potential, the implementation of green innovations in agriculture faces several barriers. These include high initial investment costs, limited access to technology, lack of awareness among farmers, and inadequate policy frameworks to support adoption. Furthermore, the effectiveness of such innovations can vary depending on local environmental conditions, soil types, and farm management practices. Therefore, it is crucial to assess not only the technological and environmental benefits but also the socioeconomic feasibility of eco-friendly agricultural transitions. The purpose of this study is to explore the contribution of green innovations to reducing the carbon footprint in agriculture and to identify practical strategies for their wider adoption. By analyzing case studies and recent experimental results from farms in Western Romania, this research aims to provide insights into the environmental and economic performance of selected eco-technologies. The findings contribute to the broader understanding of how agriculture can align with the objectives of the European Green Deal and global sustainability goals, promoting a resilient, climate-smart agricultural sector for future generations.



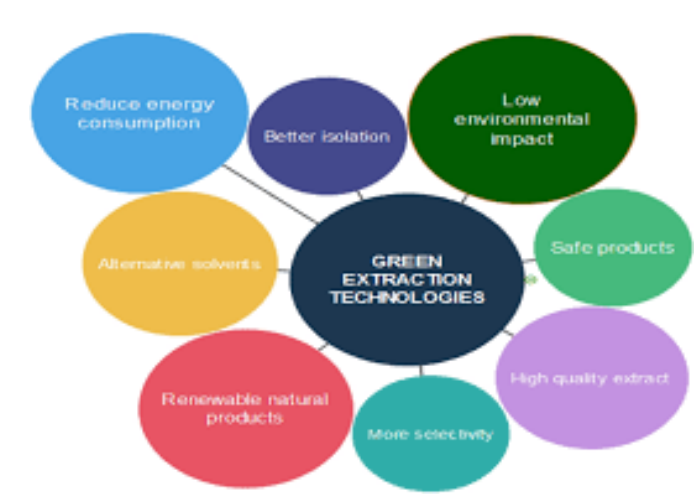
Conclusions

The findings of this research clearly demonstrate that the application of green innovations and eco-friendly technologies can make a substantial contribution to reducing the carbon footprint of agricultural systems. By integrating precision fertilization, organic amendments, renewable energy sources, and conservation tillage, farms in the western region of Romania achieved notable decreases in greenhouse gas emissions, particularly in CO₂ and N₂O outputs. The combination of renewable energy and precision technologies proved especially effective, providing measurable benefits in both energy efficiency and resource optimization. Beyond emission reduction, these sustainable practices also contributed to improving soil quality, enhancing biological activity, and increasing resilience to climate variability. The moderate rise in organic matter and improved soil structure observed on farms using eco-friendly techniques indicates that these systems



Material and method

The research was carried out in the western region of Romania, mainly in Timiș and Arad counties, where both conventional and eco-friendly farms were analyzed. The research combined field observations, data collection, and literature review to assess the impact of green innovations on the agricultural carbon footprint. Four key eco-technologies were evaluated: precision fertilization, organic fertilizer use, renewable energy integration (solar irrigation and biogas), and conservation tillage. Data were collected between March and September 2024 through on-site measurements and farmer interviews. Information on fuel and fertilizer consumption, crop yields, and soil quality indicators was recorded for each system. Carbon emissions (CO₂, CH₄, N₂O) were estimated using the IPCC 2019 Tier 1 methodology and verified with the Cool Farm Tool model. Soil samples (0–30 cm depth) were analyzed in the Environmental Protection Laboratory of Banat University, following standard procedures for organic matter, pH, and nutrient content. Statistical analyses were performed using SPSS v.27 and Excel to compare the environmental performance of traditional and green practices. Correlation and variance analyses were used to identify significant differences in emission levels, soil parameters, and resource efficiency, while qualitative data from farmer interviews supported the interpretation of practical challenges and adoption potential.



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