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Carbon Farming: A Systematic Literature Review on Sustainable Practices

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***Abstract* – Carbon farming, a sustainable agricultural method, aims to sequester carbon dioxide from the atmosphere, mitigating climate change through regenerative practices that improve soil health and biodiversity while reducing GHG emissions. This research conducts a systematic literature review to identify various carbon farming practices and their potential contributions to climate goals and mitigation efforts. The systematic literature review investigated the relationship between prominent topics related to carbon farming and its practices. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses were used for the review. SCOPUS database was utilised for its extensive coverage of scientific journals and high-quality data. Keywords such as "carbon farming", "agriculture", and "carbon sequestration" were selected based on their relevance to carbon farming and its promotion through the European Union's Common Agricultural Policy 2023–2027. Specific criteria were applied to refine the selection process of articles, ensuring the selection of the most relevant ones. The analysis of articles reveals that each carbon farming method offers unique advantages and considerations for soil health and carbon sequestration. Tillage practices show promise in enhancing soil carbon levels despite potential drawbacks like soil compaction. Cover crops, perennial plants, agroforestry, and crop rotation each offer significant carbon sequestration potential.**

***Keywords* – Agriculture; carbon sequestration; climate change mitigation; regenerative practices.**

1. Introduction

The European Union (EU) has set a target to decrease greenhouse gas (GHG) emissions by at least 55 % by 2030. On February 6, 2024, the European Commission recommended an even more ambitious GHG reduction goal, aiming for a reduction of 90 % by 2040. This proposed target for a 90 % reduction in GHG emissions by 2040 represents a notably ambitious objective [1]. As the need to confront climate change and its repercussions on the environment has become more apparent and pressing, stakeholders and policymakers across various sectors increasingly recognise the imperative for collaborative action and innovative solutions to mitigate its impacts and foster a sustainable future. Given its status as one of the primary sources of GHG emissions, the agricultural sector is pivotal in combating climate change. It is imperative for the agricultural industry to actively engage in mitigation efforts and embrace sustainable practices to address this global challenge effectively [2], [3].

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Existing agricultural practices have led to a decline in soil organic matter [4], [5]. Carbon-based agriculture aims to counteract this trend by harnessing plants' ability to absorb carbon dioxide through photosynthesis and other practices that help sequester soil carbon. By doing so, not only can carbon emissions be mitigated, but numerous additional benefits can also be realised. These include improved food quality, environmental conditions, water quality, increased biodiversity, and ecological resilience. Recognising the value of this service, it is crucial to apply carbon-based agricultural methods, as they contribute to reducing GHG emissions [6]. Sustainable agricultural practices should prioritise environmental effects, economic profitability, social responsibility, and environmental stewardship, considering these aspects when developing policies due to agriculture's mechanisation and potential environmental impacts [7].

The EU's Common Agricultural Policy (CAP) for 2023–2027 is a prominent framework guiding agricultural practices, emphasising integrating carbon farming methods within the EU's agricultural sector. This is achieved through various mechanisms such as eco-schemes, agri-environmental initiatives, climate-focused measures, conditional requirements, and investments at the farm level [8]. Despite these efforts, whether the EU's CAP effectively enhances the agricultural sector's capacity to mitigate climate change and improve overall sustainability remains uncertain [9].

Carbon farming practices have emerged as a pivotal strategy in pursuing European climate neutrality [10]. These practices encompass a variety of agricultural techniques aimed at enhancing carbon sequestration in soils and vegetation, thereby mitigating GHG emissions [11]. Central to carbon farming practices is recognising that sustainable agricultural practices, including carbon farming, are essential for achieving these targets [12]. The EU defines carbon farming as a "green business model" encouraging landowners and managers to improve land management practices, leading to increased carbon sequestration in living biomass and soil [13].

Previous research indicates that carbon farming can significantly contribute to climate change mitigation [10], [14], [15]. The economic implications of carbon farming are noteworthy, as farmers can benefit from carbon credits and other financial incentives associated with adopting these practices [16]. For a successful implementation of carbon farming, supportive policies and frameworks that facilitate knowledge sharing and provide economic incentives for farmers are required [17]. Integrating carbon farming into existing agricultural systems can improve resilience to climate change while promoting biodiversity and soil health [18], [19]. There is a growing recognition of the need for innovative and sustainable agricultural approaches that can effectively reduce atmospheric carbon levels while promoting agricultural sustainability [10], [20]. However, despite the potential benefits, adopting these practices still needs consistency across different regions and farming systems, highlighting the need for comprehensive evaluations of their effectiveness and implementation challenges [21], [22]. A systematic review can provide valuable insights into the methodologies, benefits, and limitations of carbon farming [23]. Furthermore, understanding the socio-economic implications of carbon farming is crucial for fostering adoption and ensuring that these practices contribute to environmental sustainability and farmer livelihoods [24], [25]. Thus, a systematic literature review is essential to synthesise existing knowledge, identify gaps, and guide future research and policy initiatives in carbon farming.

Article outlines the findings of a thorough literature review to identify and examine the most sustainable agricultural practices to ensure climate change mitigation in the EU and determine related topics to carbon farming. The review concentrates on determining carbon farming practices and their benefits, limitations and overall implementation.

2. METHODOLOGY

2.1. Systematic Literature Review under the PRISMA 2020 Statement

This systematic literature review aims to evaluate open-access articles available in Scopus regarding carbon farming practices and their role in achieving climate neutrality in Europe. The review will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure transparency, rigour, and reproducibility in the research process [26].

The systematic literature review investigates the relationship between the most prominent topics related to carbon farming and its practices. This methodology outlines the systematic approach to identify, select, and analyse relevant literature on carbon farming. SCOPUS database was utilised to curate relevant publications due to its extensive coverage of scientific journals and provision of high-quality data [7]. The SCOPUS database was used to select the articles, particularly the advanced search within the article title, abstract, and keywords. The keywords chosen for this study were selected based on their relevance to carbon farming, namely "carbon farming", "agriculture" and "carbon sequestration". The EU's CAP is connected with carbon farming and its practices, as it is promoted through the EU's CAP 2023–2027 [8]. Specified keywords were used for this research. This approach ensures that the selected articles directly address the intersection of agriculture, climate change mitigation, and carbon management. This step provides a focused search of literature pertinent to carbon farming practices and current topics that are related to it.

The inclusion criteria for this review consist of Articles published in English, Open-access articles, Studies focusing on carbon farming practices and their impact on climate neutrality, Empirical studies, reviews, and theoretical papers published within the last ten years. Exclusion criteria will include Articles not available in full text, Studies not related to carbon farming or climate neutrality, and non-peer-reviewed articles, such as editorials and opinion pieces. The search strategy is developed using Boolean operators (AND, OR) to combine keywords effectively: "Carbon farming" AND "Agriculture" AND "carbon sequestration". The selection process involves two independent reviewers who screen titles and abstracts for relevance. A narrative synthesis is conducted to summarise the findings of the included studies [27], [28]. This systematic literature review provides valuable insights into the role of carbon farming practices in achieving climate neutrality in Europe, highlighting the importance of sustainable agricultural practices in mitigating climate change. A process flow for identifying and analysing relevant articles was developed (Fig. 1).

This systematic approach guaranteed the inclusion of only the most relevant articles for this research, bolstering the credibility and validity of the research findings. Between 2018 and 2020, the European Commission undertook a two-year study on establishing and executing carbon farming within the EU. This initiative was pivotal in introducing carbon farming practices into the EU agricultural sector. [29]. Recognising carbon farming as a critical solution for reducing CO_2 emissions and advancing climate neutrality, the European Commission introduced the Farm to Fork strategy in 2021. Within the EU's CAP, incentives are provided to land managers to adopt sustainable practices, which notably encompass carbon farming. This integration underscores the influence of the Farm to Fork strategy on shaping the objectives and implementation of the EU's CAP to prioritise sustainability, including carbon sequestration efforts [30].

Following an examination of the literature within SCOPUS, a significant surge in articles related to the specified keywords within this research was observed between 2009 and 2024. It was determined that keywords would be enclosed within curly brackets instead of quotation marks to enhance precision in the search results. This modification ensures that the search exclusively targets the exact keyword, including the specific wording, thereby refining the results for greater accuracy.

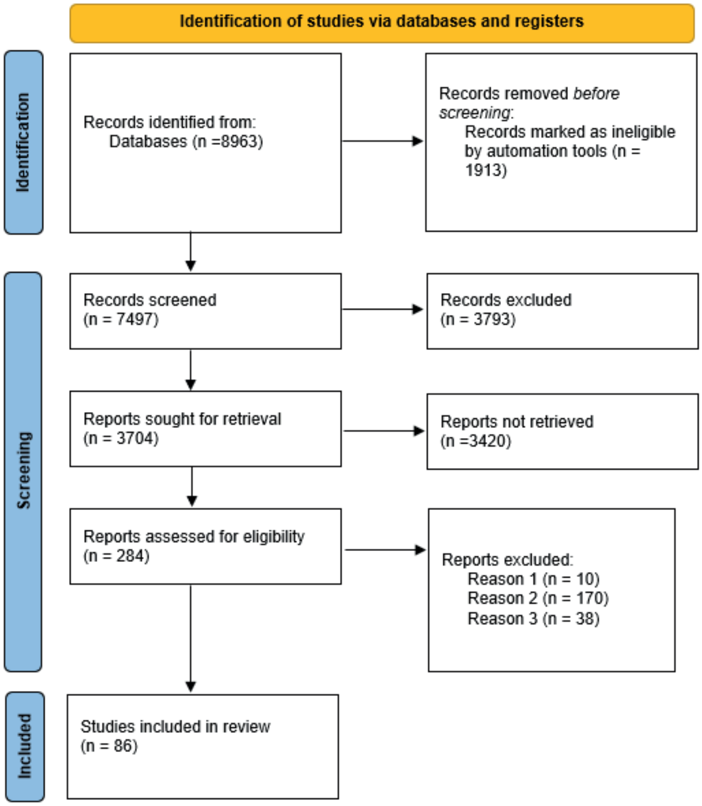

Fig. 1. Flow diagram of systematic literature analysis.

Following the established criteria, a meticulous selection identified 86 pertinent articles for further analysis. Subsequently, a comprehensive article screening procedure was implemented to evaluate the relevance of the articles based on the research topic. Only articles meeting predetermined criteria were retained through careful screening for subsequent in-depth analysis. Further articles were excluded if they focused solely on specific sites outside the EU region or specific practice applications irrelevant to the EU.

3. RESULTS

VOSviewer was employed to ascertain the most prominent countries in this research, considering their document count and link strength. Through analysis with *VOSviewer*, relevant keywords for "carbon farming" were identified based on selected articles (Fig. 2).

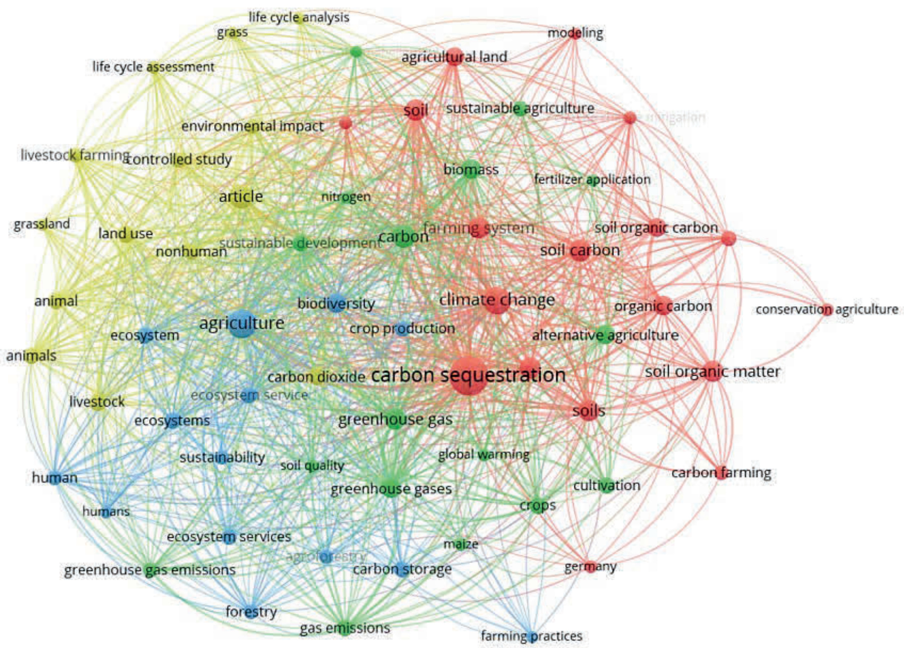

Fig. 2. Relevant keywords to carbon farming.

A minimum occurrence threshold of 5 was set to assess link strengths between "carbon farming" and associated practices, providing insight into the indication of carbon farming practices. The keyword "carbon farming" demonstrated 35 links with other relevant keywords, with notable link strengths observed with "carbon sequestration", "soil carbon", and "climate change", each exhibiting a link strength of 5. The keywords "carbon sequestration" yielded 62 links, while "soil carbon" generated 54 and other pertinent keywords. This observation underscores the significant relevance of these keywords to the broader topic under consideration.

However, keywords such as "crop rotation", "tillage", "fertiliser application", and "soil conservation" also emerged, indicating potential carbon farming practices. Interestingly, all relevant keywords connected to "carbon farming" did not exhibit as prominent indications of carbon farming practices as initially expected.

By conducting a thorough analysis of the articles, valuable insights were gained, enabling the identification of carbon farming practices described in scientific literature.

3.1. Carbon Farming Practices

Carbon farming encompasses a variety of practices aimed at enhancing soil carbon sequestration, thereby contributing to climate change mitigation. The methods employed in carbon farming can significantly influence soil health, nutrient availability, and overall agricultural productivity. This synthesis will explore the main findings regarding carbon farming methods and practices, drawing on multiple references to provide a comprehensive overview.

3.1.1. Tillage Practices

Tillage practices are one of the promising techniques of carbon farming. Various tillage methods, particularly conservation tillage, have been mentioned in scientific literature due to the potential to improve soil health and increase carbon storage in agricultural systems. Conservation tillage and no-tillage minimise soil disturbance and help preserve soil organic carbon (SOC) levels [15], [31]. Traditional tillage practices can lead to significant losses of soil organic matter, exacerbating soil erosion and degrading soil structure [32]. Furthermore, studies have demonstrated that reduced tillage and cropping intensification can offset anthropogenic CO_2 emissions while improving soil fertility [33]. The retention of crop residues is another critical aspect of minimum tillage systems that promotes soil carbon accumulation [34]. The use of conservation tillage with the integration of cover crops can improve the carbon sequestration potential of agricultural lands [35], [36]. However, the effectiveness of these management practices can vary significantly depending on soil type and climate [37]. Conservation tillage promotes higher SOC levels, but the actual impact can depend on various factors, like employed management and the environmental context, highlighting the need for tailored approaches in carbon farming [38]–[42]. These practices mitigate climate change by increasing SOC and improving soil health and agricultural sustainability [43]–[45]. As farmers increasingly recognise the benefits of reduced tillage and residue retention, the potential for carbon farming to climate change mitigation and sustainable carbon cycles becomes more pronounced [46]–[48].

3.1.2. Cover Crops

Cover crops are increasingly recognised as a leading component of carbon farming practices, contributing to soil carbon sequestration and improving ecosystem services. According to Begum *et al.* [49], implementing cover crops has improved SOC sequestration across various European climatic regions, suggesting that integrating cover crops into farming practices can maintain soil health and fertility. Furthermore, the role of cover crops in nutrient cycling is well documented. Alcala-Herrera *et al.* [50] emphasise that cover crops, enhance the abundance and activity of genes involved in nitrogen cycling. The study indicates that increased labile carbon and nitrogen inputs from cover crops, can improve soil health and increase carbon storage. Cover crops can mitigate GHG emissions associated with conventional agricultural practices. Aguilera *et al.* [51] revealed that organic systems that utilise cover crops have a lower carbon footprint. The findings of Ghiglieno *et al.* [52] support the notion that organic viticulture, which incorporates cover crops, has a lower carbon footprint compared to conventional methods. Their research indicates that cover crops contribute to reduced GHG emissions due to better soil management and increased organic carbon levels in the soil, reducing the environmental impact of agricultural practices. Drexler's [53] research indicates that hedgerows can enhance carbon storage in agricultural landscapes, reinforcing cover crops' role in reducing agricultural practices' environmental impact. Attia *et al.* [54] conducted a modelling study demonstrating how cover crops and crop rotations increase yield and soil organic carbon. Another research [55] focuses on the role of cover crops in increasing soil carbon stock. Vicente-Vicente *et al.* [56] demonstrate that soil carbon sequestration rates are significantly enhanced under cover crop management practices, especially during the initial years of implementation.

3.1.3. Intercrops

The existing literature analysis shows the relationship between the enhancement of SOC levels and the use of intercropping systems compared to monoculture systems. Kim *et al.* [57] reported that intercropping systems can improve soil structure and stability. Intercropping has been associated with improved nutrient cycling and enhanced soil health. Doyeni *et al.* [58] noted that intercropping systems can facilitate better nutrient flow and availability, improving soil fertility. Herrera *et al.* [59] found that intercropping enhances the abundance and activity of soil microbial communities promoting soil health. Additionally, studies by Koppelmäki *et al.* [60] have shown that intercropping can improve soil aggregate stability, essential for maintaining soil structure and preventing erosion. Studies by Paul *et al.* [61] emphasise that intercropping can enhance carbon sequestration while reducing nitrous oxide emissions, underscoring the potential of intercropping as a viable strategy for climate change mitigation. The findings from various studies underscore the importance of intercropping as an important carbon farming practice. By enhancing soil carbon stocks, improving nutrient cycling, and potentially reducing GHG emissions, intercropping can contribute to sustainable agricultural systems. The review by Block [62] emphasises that practices such as intercropping, along with no-till and organic amendments, are essential for increasing humus content and promoting carbon sequestration.

3.1.4. Biogas and Biomethane

Biogas and biomethane play an essential role in carbon sequestration. Koppelmäki *et al.* [60] highlighted that integrating biogas production improves soil carbon stocks. Bumbiere *et al.* [15] emphasised the potential of biogas production as a carbon farming solution and identified various carbon farming practices, including biogas and biomethane production, as essential for achieving carbon neutrality in agriculture. Doyeni *et al.* [58] demonstrated that using nutrient-rich digestate from biogas production can improve soil fertility and increase crop yields, thereby contributing to higher soil organic carbon levels. Ruf and Emmerling [63] described biomass partitioning and nutrient fluxes in cropping systems utilising biogas feedstocks, indicating that perennial crops used for biogas production can enhance soil carbon sequestration. Carter *et al.* [64] discussed the environmental sustainability of biogas systems, noting that they can significantly reduce the overall GHG emissions. The research by Kim *et al.* [57] supports the notion that biogas production can lead to lower carbon emissions, suggesting that transitioning to biogas can reduce the carbon footprint of agricultural systems. Integrating biogas production into agricultural systems offers numerous practical benefits for carbon farming. Wu [65] emphasised that land-free bioenergy production from agricultural waste can help avoid food-feed-land conflicts while contributing to carbon sequestration.

3.1.5. Carbon Sequestration by Soils

Soil management practices are one of the critical strategies for carbon sequestration, mitigating climate change and enhancing soil health. Rosinger *et al.* [66] emphasise that the potential for carbon sequestration is predominantly determined by site effects rather than management. This finding is echoed by Volungevičius *et al.*, who highlight the critical role of land use changes in affecting SOC dynamics.[67]. Effective carbon farming strategies must consider local soil characteristics alongside management practices. The type of agricultural system employed also plays a crucial role in SOC sequestration. Chen *et al.* [68] demonstrate that paddy soils exhibit a significantly higher efficiency in SOC sequestration than upland soils, with paddy systems being 39–127 % more effective in capturing organic carbon. The efficiency of capture or organic carbon by soils is particularly pronounced in warmer climates. Therefore, the climatic conditions must be factored into carbon farming strategies. Sae-Tun *et al.* present an approach to assess soil health advances in conservation farming systems, linking soil aggregation to improved SOC retention [69]. Ghaley *et al.* [43] support this notion by assessing the benefits of conservation agriculture on soil functions, demonstrating that such practices can lead to significant improvements in SOC levels and soil quality. Begum *et al.* [49] evaluated the impact of crop diversification on SOC dynamics across different climatic regions in Europe, reinforcing the importance of sustainable agricultural practices in enhancing SOC sequestration [70]–[75].

3.1.6. Perennial Plants

The carbon sequestration potential of perennial crops is significant due to deeper root systems. Research has demonstrated that perennial crops can sequester substantial amounts of carbon in above-ground biomass and soil [76], [77]. Ledo *et al.* [78] highlighted that perennial crops contribute to increased SOC levels. The ability of perennial plants to maintain soil cover year-round reduces soil erosion, enhancing their role in carbon farming [78], [15]. Cultivation of perennial crops has been linked to improved nitrogen dynamics in the soil. Perennial systems support nitrogen-fixing plants, contributing to healthier soil ecosystems and increased carbon sequestration [79]. Integrating legumes in perennial cropping systems has improved nitrogen availability, thereby supporting higher biomass production and carbon capture [10], [80]. The potential for perennial crops to provide sustainable income through diverse products makes them attractive as a viable agricultural practice [76], [81]. Nevertheless, the shift towards perennial agriculture requires supportive policies and investment in research and development [81]–[83].

3.1.7. Agroforestry

According to Herder *et al.* [84], agroforestry occupies approximately 15.4 million hectares in the European Union, covering about 3.6 % of the total territorial area of the European Union. These systems can sequester carbon in biomass and soil. Tefera [85] highlights that agroforestry practices can effectively capture atmospheric CO_2. Moreover, Torralba *et al.* [86] showed that agroforestry systems enhance carbon storage and improve soil quality and biodiversity. Enabling trees into farming systems creates a multi-layered environment that supports greater biomass accumulation than monoculture systems, leading to increased carbon sequestration. Agroforestry practices contribute to enhanced biodiversity, improved soil health, and increased resilience to climate change [14]. Ahmad [87] noted that agroforestry enhances soil fertility and water efficiency. Furthermore, Visscher [88] indicates that agroforestry systems can improve nutrient cycling and reduce soil erosion, enhancing ecosystem services. Despite the recognised benefits, adopting agroforestry practices in Europe faces several challenges. Jalón *et al.* [89] reported declining traditional agroforestry practices across Europe, primarily due to economic pressures and changing agricultural policies. Moreover, den Herder *et al.* [90] highlighted that policy frameworks often do not adequately support agroforestry initiatives, limiting financial incentives for farmers to transition to these systems.

3.1.8. Organic Fertilisation and Biochar

Biochar and organic fertilisation are increasingly recognised as effective carbon farming practices in Europe. Biochar has gained attention for its ability to sequester carbon in soils. Studies indicate that biochar can significantly enhance SOC levels [91], [92]. For instance, Li *et al.* [93] demonstrated that biochar application can lead to substantial carbon sequestration, making it a viable strategy for long-term carbon storage. Research by Wang *et al.* [94] highlights the potential of biochar to mitigate GHG emissions due to biochar's ability to decrease N_2O emissions from agricultural soils, particularly in finely textured soils prone to denitrification [95]. Furthermore, biochar enhances soil aggregation and stability [96].

Biederman and Harpole [97] demonstrated that biochar positively affects plant productivity and nutrient cycling. Biochar's porous structure provides a habitat for soil microorganisms, further contributing to enhanced soil biological activity [98]. Combining biochar with organic fertilisers can lead to synergistic effects, improving nutrient availability and soil structure [99]. For instance, Keskinen *et al.* [99] found that broiler manure biochar significantly increased soil nutrient content and improved crop yields. Moreover, integrating organic fertilisers with biochar can enhance the stability of organic matter in soils [96]. The co-application of biochar and organic fertilisers has improved soil moisture retention and reduced nutrient leaching, which is critical for sustainable agricultural practices [100]. Despite the benefits of biochar and organic fertilisation, there are barriers that hinder their widespread adoption in Europe, like farmers' awareness, biochar quality variability, and the need for more policy support [101]. Future research should focus on optimising biochar production methods and assessing the long-term impacts of biochar and organic fertilisation on soil health and carbon sequestration [96], [102].

3.1.9. Crop Diversity and Rotation

Crop diversity and rotation have significantly influenced soil organic carbon levels. Poeplau and Don [103] indicated that covering crops in rotation systems can enhance SOC stocks by replacing fallow periods with active carbon assimilation periods. This practice increases carbon storage and improves cropland soils' net ecosystem carbon balance. Mccauley [104] highlighted that diverse cropping systems, including perennials and polycultures, lead to higher soil carbon storage. Lugato *et al.* [105] emphasised that adopting best management practices, such as optimised rotation schemes and residue management, can sequester significant amounts of carbon in European arable soils. Their findings suggest that diverse crop rotations can enhance soil structure and fertility, promoting long-term carbon sequestration. Beillouin *et al.* [106] found that crop diversification positively affects biodiversity and ecosystem services. Gaudin *et al.* [107] showed that increased crop diversity mitigates weather variations and improves yield stability. The study highlights that greater temporal and spatial diversity in cropping systems enhances soil properties associated with moisture retention. The economic viability of crop diversity and rotation practices is also critical. Weigel *et al.* [108] analysed data from Bavaria, demonstrating that crop diversity can stabilise farm revenue, particularly in market fluctuations. Their findings suggest agricultural policies should promote crop diversity to enhance economic resilience and environmental sustainability. Ryschawy *et al.* [109] noted that financial pressures and policy frameworks often favour monoculture systems, which can limit the implementation of diverse cropping strategies. Future studies should explore the long-term impacts of diverse cropping systems on soil health and productivity across different European agroecosystems.

3.1.10. Grazing Management

Grazing management practices significantly influence soil organic carbon levels in grasslands. Conant *et al.* [110] synthesised various grazing management interventions, highlighting that improved grazing practices can increase SOC stocks. Similarly, McSherry and Ritchie [111] found that moderate grazing can enhance SOC in temperate grasslands, while overgrazing leads to degradation and carbon loss. Tessema *et al.* [112] indicated that well-managed grasslands can substantially affect carbon sequestration, while prolonged overgrazing results in high SOC losses. Kleppel and Frank [113] noted that the interdependence of various components in grazing ecosystems, including production, nutrient cycling, and carbon storage, underscores the need for holistic grazing management approaches. Well-structured grazing systems can improve habitat quality for various species, thus enhancing overall biodiversity. Machmuller *et al.* [19] demonstrated that rotational grazing practices can significantly increase soil organic matter and improve forage quality, enhancing ecosystem services. Liebig *et al.* [114] highlighted the long-term benefits of grazing management on soil health and carbon sequestration, emphasising that sustainable grazing practices contribute to improved soil structure and increased microbial activity, further enhancing ecosystem resilience. Future research should focus on optimising grazing management strategies tailored to European regional contexts.

4. DISCUSSIONS AND CONCLUSIONS

Based on the comprehensive analysis of various carbon farming practices, it is evident that each method offers unique advantages and considerations for prompting soil health and carbon sequestration. Tillage practices demonstrate promise in enhancing soil carbon levels, albeit with potential drawbacks such as soil compaction. Cover crops are vital in improving soil health and increasing SOC, with the choice of crop species and management practices influencing their effectiveness. Perennial plants offer substantial carbon sequestration potential, although their implementation may lead to methane emissions and yield trade-offs. Agroforestry, while sustainable, may present challenges in terms of budget, area suitability, and farmer preference, suggesting a need for careful consideration before widespread adoption. Finally, crop rotation emerges as a versatile strategy for reducing soil erosion, enhancing soil organic matter, and increasing yields. However, its impact on SOC may vary depending on factors such as plant species and rotation practices. Overall, the findings underscore the importance of adopting a holistic approach to carbon farming, integrating multiple practices tailored to local conditions and objectives to maximise carbon sequestration potential while ensuring environmental sustainability and agricultural resilience. Further research and on-the-ground implementation efforts are warranted to refine and validate the efficacy of these practices in diverse agrarian landscapes.

It is essential to acknowledge that the selected articles address carbon farming practices and explore methods for assessing their sustainability and feasibility in implementation and maintenance. Utilising appropriate methods and systems to evaluate the sustainability of carbon farming practices for specific locations, budgets, and the overall feasibility of maintenance is crucial. Using carbon farming practices ensures that farmers can make informed decisions regarding adopting and continuing practices that align with their resources and objectives, thereby maximising carbon farming initiatives' effectiveness and long-term viability.

In conclusion, this research provides a solid foundation for ongoing exploration and refinement of effective carbon farming practices. Future studies will focus on evaluating the feasibility and sustainability of these practices, thereby advancing the understanding and implementation of strategies that promote carbon sequestration and environmental stewardship in agriculture.

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REFERENCES

[1] Commission presents recommendation for 2040 emissions reduction target to set the path to climate neutrality in 2050. [Online]. [Accessed 01.04.2024] Available: https://ec.europa.eu/commission/presscorner/detail/en/ip_24_588
[2] Bartzas G., Doula M., Hliaoutakis A., Papadopoulos N. S., Tsotsolas N. Low carbon certification of agricultural production using field GHG measurements. Development of an integrated framework with emphasis on mediterranean products. *Case Studies in Chemical and Environmental Engineering* 2024:9:100666. https://doi.org/10.1016/j.cscee.2024.100666
[3] Kreft C., Angst M., Huber R., Finger R. Farmers' social networks and regional spillover effects in agricultural climate change mitigation. *Climatic Change* 2023:176:8. https://doi.org/10.1007/s10584-023-03484-6
[4] Voltr V., Menšík L., Hlísníkovský L., Hruška M., Pokorný E., Pospíšilová L. The soil organic matter in connection with soil properties and soil inputs. *Agronomy* 2021:11(4):779. https://doi.org/10.3390/agronomy11040779.
[5] Abdeldaym E. A., Traversa A., Cocozza C., Brunetti G. Effects of a 2-year application of different residual biomasses on soil properties and potato yield. *CLEAN – Soil, Air, Water* 2018:46(12):1800261. https://doi.org/10.1002/clen.201800261
[6] Israel M. A., Amikuzuno J., Danso-Abbeam G. Assessing farmers' contribution to greenhouse gas emission and the impact of adopting climate-smart agriculture on mitigation. *Ecological Process* 2020:9:51. https://doi.org/10.1186/s13717-020-00249-2
[7] Strapchuk S. I., Mykolenko O. P. Factors of Sustainable Intensification in Agriculture of Ukraine: Evidence from the Enterprises of the Kharkivska Oblast. *Scientific Bulletin of Mukachevo State University Series Economics* 2021:8:3:9–17. https://doi.org/10.52566/msu-econ.8(3).2021.9-17
[8] Armstrong J. H., Kamieniecki S. Sustainability Policy Research: A Review and Synthesis. *Policy Studies Journal* 2019:47(S1):S45–S65. https://doi.org/10.1111/psj.12320
[9] Promoting carbon farming through the CAP. EEB – The European Environmental Bureau [Online]. [Accessed 01.04.2024]. Available: https://eeb.org/library/promoting-carbon-farming-through-the-cap/
[10] Cuadros-Casanova I., Cristiano A., Biancolini D., Cimatti M., Sessa A. A., Mendez Angarita V. Y., Dragonetti C., Pacifici M., Rondinini C., Marco M. D. Opportunities and challenges for Common Agricultural Policy reform to support the European Green Deal. *Conservation Biology* 2023:37(3):e14052. https://doi.org/10.1111/cobi.14052
[11] Saikanth D. R. K., Kishore A. J., Sadineni T., Singh V., Upadhyay L., Kumar S., Panigrahi C. K. A review on exploring carbon farming as a strategy to mitigate greenhouse gas emissions. *International Journal of Plant & Soil Science* 2023:35(23):380–388. https://doi.org/10.9734/ijpss/2023/v35i234253.
[12] Tang K., He C., Ma C., Dong W. Does carbon farming provide a cost-effective option to mitigate GHG emissions? Evidence from China. *Australian Journal of Agricultural and Resource Economics* 2019:63(3):575–592. https://doi.org/10.1111/1467-8489.12306.
[13] Doukas Y. E., Salvati L., Vardopoulos I. Unraveling the European agricultural policy sustainable development trajectory. *Land* 2023:12(9):1749. https://doi.org/10.3390/land12091749
[14] Gadzhiev N., Khasbulatova Z. S., Baysangurova A. A. Study of carbon sequestration processes in forestry on carbon farms. *BIO Web of Conferences* 2023:63:07006. https://doi.org/10.1051/bioconf/20236307006.
[15] Rijal S. Agroforestry system: approaches for climate change mitigation and adaptation. *Big Data in Agriculture* 2019:1(2):23–25. https://doi.org/10.26480/bda.02.2019.23.25.
[16] Bumbiere K., Sanchez F. A. D., Pubule J., Blumberga D. Development and assessment of carbon farming solutions. *Environmental and Climate Technologies* 2022:26(1):898–916. https://doi.org/10.2478/rtuect-2022-0068.
[17] Van Hoof S. Climate change mitigation in agriculture: barriers to the adoption of carbon farming policies in the EU. *Sustainability* 2023:15(13):10452. https://doi.org/10.3390/su151310452
[18] Dumbrell N. P., Kragt M., Gibson F. What carbon farming activities are farmers likely to adopt? A best – worst scaling survey. *Land Use Policy* 2016:54:29–37. https://doi.org/10.1016/j.landusepol.2016.02.002.
[19] Reidsma P., Wolf J., Kanellopoulos A., Schaap B., Mandryk M., Verhagen A., Ittersum M. Climate change impact and adaptation research requires integrated assessment and farming systems analysis: a case study in the Netherlands. *Environmental Research Letters* 2015:10(4):045004. https://doi.org/10.1088/1748-9326/10/4/045004
[20] Machmuller M. B., Kramer M. G., Cyle K. T., Hill N., Hancock D. W., Thompson A. Emerging land use practices rapidly increase soil organic matter. *Nature Communications* 2015:6(1):6995. https://doi.org/10.1038/ncomms7995
[21] Nevalainen O., Niemitalo O., Fer I., Juntunen A., Mattila T., Koskela O., Liski J. Towards agricultural soil carbon monitoring, reporting, and verification through the field observatory network (FiON). *Geoscientific Instrumentation, Methods and Data Systems* 2022:11(1):93–109. https://doi.org/10.5194/gi-11-93-2022
[22] Avasiloaiei D. I., Calara M., Brezeanu P. M., Gruda N. S., Brezeanu C. The evaluation of carbon farming strategies in organic vegetable cultivation. *Agronomy* 2023:13(9):2406. https://doi.org/10.3390/agronomy13092406
[23] Scotton M. Seed production of semi-natural grasslands: amount and variability in an unfertilized upright brome and a fertilized tall oat-grass meadow. *Grass and Forage Science* 2020:75(4):409–423. https://doi.org/10.1111/gfs.12502
[24] Kasirao G., Himavarsha P., Tomar S., Sharma A. Carbon farming – the healing lungs of future agriculture: a review. *Pollution Research* 2023:42(3):331–334. https://doi.org/10.53550/pr.2023.v42i03.004

[25] Evans M. C., Carwardine J., Fensham R. J., Butler D., Wilson K. A., Possingham H. P., Martin T. G. Carbon farming via assisted natural regeneration as a cost-effective mechanism for restoring biodiversity in agricultural landscapes. *Environmental Science & Policy* 2015:50:114–129. https://doi.org/10.1016/j.envsci.2015.02.003.

[26] Gan Y., Liang C., Chai Q., Lemke R., Campbell C. A., Zentner R. P. Improving farming practices reduces the carbon footprint of spring wheat production. *Nature Communications* 2014:5(1):5012. https://doi.org/10.1038/ncomms6012

[27] Page M. J., Moher D., Bossuyt P. M., Boutron I., Hoffmann T., Mulrow C. D., McKenzie J. E. Prisma 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ* 2021:372:n160. https://doi.org/10.1136/bmj.n160

[28] Ardern C. L., Büttner F., Andrade R., Weir A., Ashe M. C., Holden S., Winters M. Implementing the 27 Prisma 2020 statement items for systematic reviews in the sport and exercise medicine, musculoskeletal rehabilitation and sports science fields: the persist (implementing prisma in exercise, rehabilitation, sports medicine and sports science) guidance. *British Journal of Sports Medicine* 2021:56(4):175–195. https://doi.org/10.1136/bjsports-2021-103987

[29] Aguinis H., Ramani R. S., Alabduljader N. Best-practice recommendations for producers, evaluators, and users of methodological literature reviews. *Organizational Research Methods* 2020:26(1):46–76. https://doi.org/10.1177/1094428120943281

[30] Commission sets the carbon farming initiative in motion - European Commission [Online]. [Accessed 01.04.2024]. Available: https://climate.ec.europa.eu/news-your-voice/news/commission-sets-carbon-farming-initiative-motion-2021-04-27_en

[31] Carbon Farming [Online]. [Accessed 01.04.2024]. Available: https://climate.ec.europa.eu/eu-action/sustainable-carbon-cycles/carbon-farming_en

[32] Cavalaris C. Rotational tillage practices to deal with soil compaction in carbon farming. *Soil Systems* 2023:7(4):90. https://doi.org/10.3390/soilsystems7040090

[33] Melero S., López-Garrido R., Murillo J., Moreno F. Conservation tillage: short- and long-term effects on soil carbon fractions and enzymatic activities under Mediterranean conditions. *Soil and Tillage Research* 2009:104(2):292–298. https://doi.org/10.1016/j.still.2009.04.001

[34] Álvaro-Fuentes J., López M., Arrúe J., Moret D. Tillage and cropping effects on soil organic carbon in Mediterranean semiarid agroecosystems: Testing the Century model. *Agriculture Ecosystems & Environment* 2009:134(3–4):211–217. https://doi.org/10.1016/j.agee.2009.07.001

[35] Li Y., Zhou L., Chang S., Cui S., Jagadamma S., Ghiglieno Q., Cai Y. Residue retention promotes soil carbon accumulation in minimum tillage systems: implications for conservation agriculture. *The Science of the Total Environment* 2020:740:140147. https://doi.org/10.1016/j.scitotenv.2020.140147

[36] Kyriakarakos G. Carbon farming: bridging technology development with policy goals. *Sustainability* 2024:16(5):1903. https://doi.org/10.3390/su16051903

[37] Block J. Farmers' willingness to participate in a carbon sequestration program – a discrete choice experiment. *Environmental Management* 2024:74(2):332–349. https://doi.org/10.1007/s00267-024-01963-9

[38] Rosinger C., Keiblinger K., Bieber M., Bernardini L., Huber S., Mentler A., Bodner G. On-farm soil organic carbon sequestration potentials are dominated by site effects, not by management practices. *Geoderma* 2023:433:116466. https://doi.org/10.1016/j.geoderma.2023.116466

[39] Haddaway N., Hedlund K., Jackson L., Kätterer T., Lugato E., Thomsen I., Isberg, P. How does tillage intensity affect soil organic carbon? A systematic review protocol. *Environmental Evidence* 2016:5:1. https://doi.org/10.1186/s13750-016-0052-0

[40] Mihelič R. Effects of transitioning from conventional to organic farming on soil organic carbon and microbial community: a comparison of long-term non-inversion minimum tillage and conventional tillage. *Biology and Fertility of Soils* 2024:60(3):341–355. https://doi.org/10.1007/s00374-024-01796-y

[41] Sae-Tun O., Keiblinger K., Rosinger C., Mentler A., Bodner G. Characterization of aggregate-stabilized dissolved organic matter release – a novel approach to determine soil health advances of conservation farming systems. *Plant and Soil* 2022:488(1–2):101–119. https://doi.org/10.1007/s11104-022-05713-w

[42] Pesce S. A modified version of RothC to model the direct and indirect effects of rice straw mulching on soil carbon dynamics, calibrated in two Valencian citrus orchards. *Soil Systems* 2024:8(1):12. https://doi.org/10.3390/soilsystems8010012

[43] Taghikhah F., Costanza R., Voinov A. DAESim: a dynamic agro-ecosystem simulation model for natural capital assessment. *Ecological Modelling* 2022:468:109930. https://doi.org/10.1016/j.ecolmodel.2022.109930

[44] Ghaley B., Rusu T., Sandén T., Spiegel H., Menta C., Visioli G., Henriksen C. Assessment of benefits of conservation agriculture on soil functions in arable production systems in Europe. *Sustainability* 2018:10(3):794. https://doi.org/10.3390/su10030794

[45] Paul C., Bartkowski B., Dönmez C., Don A., Mayer S., Steffens M., Helming K. Carbon farming: are soil carbon certificates a suitable tool for climate change mitigation? *Journal of Environmental Management* 2023:330:117142. https://doi.org/10.1016/j.jenvman.2022.117142

[46] Longo M., Ferro N., Izaurralde R., Furlan L., Chiarini F., Morari F. Deep soc stock dynamics under contrasting management systems: is the epic model ready for carbon farming implementation? *European Journal of Agronomy* 2023:145:126771. https://doi.org/10.1016/j.eja.2023.126771

[47] Smith P. Olesen J. Synergies between the mitigation of, and adaptation to, climate change in agriculture. *The Journal of Agricultural Science* 2010:148(5):543–552. https://doi.org/10.1017/s0021859610000341
[48] Mattila T. Do carbon farming practices build bioavailable nitrogen pools? *Soil Use and Management* 2023:39(4):1532–1544. https://doi.org/10.1111/sum.12930
[49] Olsson L. Jerneck A. Farmers fighting climate change – from victims to agents in subsistence livelihoods. *Wiley Interdisciplinary Reviews Climate Change* 2010:1(3):363–373. https://doi.org/10.1002/wcc.44
[50] Begum K., Zornoza R., Farina R., Lemola R., Álvaro-Fuentes J., Cerasuolo M. Modeling soil carbon under diverse cropping systems and farming management in contrasting climatic regions in Europe. *Frontiers in Environmental Science* 2022:10. https://doi.org/10.3389/fenvs.2022.819162
[51] Alcalá-Herrera R., Moreno B., Aguirrebengoa M., Winter S., Robles-Cruz A.B., Ramos-Font M.E., Benítez E. Role of Agricultural Management in the Provision of Ecosystem Services in Warm Climate Vineyards: Functional Prediction of Genes Involved in Nutrient Cycling and Carbon Sequestration. *Plants* 2023:12(13):527. https://doi.org/10.3390/plants12030527
[52] Aguilera E., Guzmán G. I., Alonso A. M. Greenhouse gas emissions from conventional and organic cropping systems in Spain. I. Herbaceous crops. *Agronomy for Sustainable Development* 2014:35(2):713–724. https://doi.org/10.1007/s13593-014-0267-9
[53] Ghiglieno I., Simonetto A., Facciano L., Tonni M., Donna P., Valenti L., Gilioli G. Comparing the carbon footprint of conventional and organic vineyards in northern Italy. *Sustainability* 2023:15(6):5252. https://doi.org/10.3390/su15065252
[54] Drexler S., Don A. Carbon sequestration potential in hedgerow soils: results from 23 sites in Germany. *Geoderma* 2024:445:116878. https://doi.org/10.1016/j.geoderma.2024.116878
[55] Attia A., Marohn C., Shawon A. R., de Kock A., Strassemeyer J., Feike T. Do rotations with cover crops increase yield and soil organic carbon? – A modeling study in southwest Germany. *Agriculture, Ecosystems & Environment* 2024:375:109167. https://doi.org/10.1016/j.agee.2024.109167
[56] Mattila T. J., Hagelberg E., Söderlund S., and Joona J. How farmers approach soil carbon sequestration? Lessons learned from 105 carbon-farming plans. *Soil and Tillage Research* 2022:215:105204. https://doi.org/10.1016/j.still.2021.105204
[57] Vicente-Vicente J. L., García-Ruiz R., Francaviglia R., Aguilera E., Smith P. Soil carbon sequestration rates under Mediterranean woody crops using recommended management practices: A meta-analysis. *Agriculture, Ecosystems & Environment* 2016:235:204–214. https://doi.org/10.1016/j.agee.2016.10.024
[58] Kim J. H., Jobbágy E. G., Richter D., Trumbore S. E., Jackson R. B. Agricultural acceleration of soil carbonate weathering. *Global Change Biology* 2020:26(10):5988–6002. https://doi.org/10.1111/gcb.15207
[59] Doyeni M. O., Barčauskaitė K., Buneviciene K., Venslauskas K., Navickas K., Rubežius M., Tilvikienė V. Nitrogen flow in livestock waste system towards an efficient circular economy in agriculture. *Waste Management Research: The Journal for a Sustainable Circular Economy* 2022:41(3):701–712. https://doi.org/10.1177/0734242x221123484
[60] Herrera R., Moreno B., Aguirrebengoa M., Winter S., Robles-Cruz A. B., Ramos-Font M. E., Benítez E. Role of agricultural management in the provision of ecosystem services in warm climate vineyards: functional prediction of genes involved in nutrient cycling and carbon sequestration. *Plants* 2023:12(3):527. https://doi.org/10.3390/plants12030527
[61] Koppelmäki K., Lamminen M., Helenius J., Schulte R. P. Smart integration of food and bioenergy production delivers on multiple ecosystem services. *Food and Energy Security* 2021:10(2):351–367. https://doi.org/10.1002/fes3.279
[62] Paul C., Bartkowski B., Dönmez C., Don A., Mayer S., Steffens M., Helming, K. Carbon farming: are soil carbon certificates a suitable tool for climate change mitigation? *Journal of Environmental Management* 2023:330:117142. https://doi.org/10.1016/j.jenvman.2022.117142
[63] Block J. B., Danne M., Mußhoff O. Farmers' willingness to participate in a carbon sequestration program – a discrete choice experiment*.* *Environmental Management* 2024:74(2):332–349. https://doi.org/10.1007/s00267-024-01963-9
[64] Ruf T. Emmerling C. Biomass partitioning and nutrient fluxes in silphium perfoliatum and silage maize cropping systems. *Nutrient Cycling in Agroecosystems* 2022:124(3):389–405. https://doi.org/10.1007/s10705-022-10242-0
[65] Carter M. S., Hauggaard-Nielsen H., Heiske S., Jensen M. B., Thomsen S. T., Schmidt J. E., Ambus, P. Consequences of field N_2O emissions for the environmental sustainability of plant-based biofuels produced within an organic farming system. *GCB Bioenergy* 2011:4(4):435–452. https://doi.org/10.1111/j.1757-1707.2011.01132.x
[66] Wu F., Pfenninger S., Muller A. Land-free bioenergy from circular agroecology—a diverse option space and trade-offs. *Environmental Research Letters* 2024:19(4):044044. https://doi.org/10.1088/1748-9326/ad33d5
[67] Rosinger C., Bodner G., Bernardini L. G., Huber S., Mentler A., Sae-Tun O., Keiblinger, K. M. Benchmarking carbon sequestration potentials in arable soils by on-farm research on innovative pioneer farms. *Plant and Soil* 2022:488(1–2):137–156. https://doi.org/10.1007/s11104-022-05626-8
[68] Volungevičius J., Feiza V., Amalevičiūtė-Volungė K., Liaudanskienė I., Šlepetienė A., Kuncevičius A., Poškienė J. Transformations of different soils under natural and anthropogenized land management. *Zemdirbyste-Agriculture* 2019:106(1):3–14. https://doi.org/10.13080/z-a.2019.106.001
[69] Chen X., Hu Y., Xia Y., Zheng S., Ma C., Rui Y., Su Y. Contrasting pathways of carbon sequestration in paddy and upland soils. *Global Change Biology* 2021:27(11):2478–2490. https://doi.org/10.1111/gcb.15595

[70] Sae-Tun O., Keiblinger K. M., Rosinger C., Mentler A., Mayer H., Bodner G. Characterization of aggregate-stabilized dissolved organic matter release - a novel approach to determine soil health advances of conservation farming systems. *Plant and Soil* 2022:488(1–2):101–119. https://doi.org/10.1007/s11104-022-05713-w

[71] Hirte J., Walder F., Heß J., Büchi L., Colombi T., Heijden M. G. v. d., Mayer J. Enhanced root carbon allocation through organic farming is restricted to topsoils. *Science of the Total Environment* 2021:755:143551. https://doi.org/10.1016/j.scitotenv.2020.143551

[72] Valujeva K., O'Sullivan L., Gutzler C., Fealy R., Schulte R. P. The challenge of managing soil functions at multiple scales: an optimisation study of the synergistic and antagonistic trade-offs between soil functions in Ireland. *Land Use Policy* 2016:58:335–347. https://doi.org/10.1016/j.landusepol.2016.07.028

[73] Zanella A., Bolzonella C., Lowenfels J., Ponge J., Bouché M. B., Saha D., Fukuoka M. Humusica 2, article 19: Techno humus systems and global change–conservation agriculture and 4/1000 proposal. *Applied Soil Ecology* 2018:122:271–296. https://doi.org/10.1016/j.apsoil.2017.10.036

[74] Schulte R. P., O'Sullivan L., Vrebos D., Bampa F., Jones A., Staes J. Demands on land: mapping competing societal expectations for the functionality of agricultural soils in Europe. *Environmental Science & Policy* 2019:100:113–125. https://doi.org/10.1016/j.envsci.2019.06.011

[75] Soinne H., Hyyrynen M., Jokubė M., Keskinen R., Hyväluoma J., Pihlainen S., Heikkinen J. High organic carbon content constricts the potential for stable organic carbon accrual in mineral agricultural soils in Finland. *Journal of Environmental Management* 2024:352:119945. https://doi.org/10.1016/j.jenvman.2023.119945

[76] Gantlett R., Bishop J., Jones H. E., Lukac M. Modern arable and diverse ley farming systems can increase soil organic matter faster than global targets. *Ren Agriculture and Food Systems* 2024:39. https://doi.org/10.1017/s1742170524000103

[77] Bessou C., Basset-Mens C., Tran T., Benoist A. LCA applied to perennial cropping systems: a review focused on the farm stage. *The Int. Journal of Life Cycle Assessment* 2012:18(2):340–361. https://doi.org/10.1007/s11367-012-0502-z

[78] Zucaro A., Forte A., Fagnano M., Bastianoni S., Basosi R., Fierro A. Comparative attributional life cycle assessment of annual and perennial lignocellulosic feedstocks production under Mediterranean climate for biorefinery framework. *Integrated Environmental Assessment and Management* 2015:11(3):397–403. https://doi.org/10.1002/ieam.1604

[79] Ledo A., Smith P., Zerihun A., Whitaker J., Vicente-Vicente J. L., Qin Z., Hillier J. Changes in soil organic carbon under perennial crops. *Global Change Biology* 2020:26(7):4158–4168. https://doi.org/10.1111/gcb.15120

[80] Means M., Crews T. E., Souza L. Annual and perennial crop composition impacts on soil carbon and nitrogen dynamics at two different depths. *Renewable Agriculture and Food Systems* 2022:37(5):437–444. https://doi.org/10.1017/s1742170522000084

[81] Adebiyi J. A., Olabisi L. S., Snapp S. S. Understanding perennial wheat adoption as a transformative technology: evidence from the literature and farmers. *Renewable Agriculture and Food Systems* 2015:31(2):101–110. https://doi.org/10.1017/s1742170515000150

[82] Scott E. I., Toensmeier E., Iutzi F., Rosenberg N., Lovell S. T., Jordan N. R., Leib E. B. Policy pathways for perennial agriculture. *Frontiers in Sustainable Food Systems* 2022:6. https://doi.org/10.3389/fsufs.2022.983398

[83] Danso-Abbeam G., Amin K. M., Ogundeji A. A. Enhancing household welfare through perennial crop production in northern Ghana. *Sustainability* 2022:15(1):451. https://doi.org/10.3390/su15010451

[84] Kantar M. B., Tyl C., Dorn K. M., Zhang X., Jungers J. M., Kaser J. M., Wyse D. L. Perennial grain and oilseed crops. *Annual Review of Plant Biology* 2016:67(1):703–729. https://doi.org/10.1146/annurev-arplant-043015-112311

[85] Herder M. d., Moreno G., Mosquera-Losada M. R., Palma J., Sidiropoulou A., Santiago-Freijanes J. J., Burgess P. J. Current extent and stratification of agroforestry in the European Union. *Agriculture, Ecosystems & Environment* 2017:241:121–132. https://doi.org/10.1016/j.agee.2017.03.005

[86] Tefera Y. Potential of agroforestry for climate change mitigation through carbon sequestration: review paper. *Agricultural Research & Technology* 2019:22(3):556198. https://doi.org/10.19080/artoaj.2019.22.556196

[87] Torralba M., Fagerholm N., Burgess P. J., Moreno G., Plieninger T. Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. *Agriculture, Ecosystems & Environment* 2016:230:150–161. https://doi.org/10.1016/j.agee.2016.06.002

[88] Ahmad F., Talukdar N. R., Biradar C., Dhyani S. K., Rizvi J. Harnessing the potentiality of farm landscape for trees based on satellite evaluation: a GIS modeling perspective. *Anthropocene Science* 2022:1(2):278–294. https://doi.org/10.1007/s44177-022-00025-1

[89] Visscher A. M., Meli P., Fonte S. J., Bonari G., Zerbe S., Wellstein C. Agroforestry enhances biological activity, diversity and soil-based ecosystem functions in mountain agroecosystems of Latin America: a meta-analysis. *Global Change Biology* 2023:30(1). https://doi.org/10.1111/gcb.17036

[90] Jalón S. G. d., Burgess P. J., Graves A., Moreno G., McAdam J., Pottier É., Vityi A. How is agroforestry perceived in Europe? An assessment of positive and negative aspects by stakeholders. *Agroforestry Systems* 2017:92(4):829–848. https://doi.org/10.1007/s10457-017-0116-3

[91] Herder M. d., Moreno G., Mosquera-Losada M. R., Palma J., Sidiropoulou A., Santiago-Freijanes J. J., Burgess P. J. Current extent and stratification of agroforestry in the European Union. *Agriculture, Ecosystems & Environment* 2017:241:121–132. https://doi.org/10.1016/j.agee.2017.03.005

[92] Sarkhot D. V., Berhe A. A., Ghezzehei T. A. Impact of biochar enriched with dairy manure effluent on carbon and nitrogen dynamics. *Journal of Environmental Quality* 2012:41(4):1107–1114. https://doi.org/10.2134/jeq2011.0123

[93] Wang J., Xiong Z., Kuzyakov Y. Biochar stability in soil: meta-analysis of decomposition and priming effects. *GCB Bioenergy* 2015:8(3):512–523. https://doi.org/10.1111/gcbb.12266

[94] Li H., Lu Z., Ma H., Jin S. Effect of biochar on carbon dioxide release, organic carbon accumulation, and aggregation of soil. *Environmental Progress & Sustainable Energy* 2013:33(3):941–946. https://doi.org/10.1002/ep.11867

[95] Wang L., Deng J., Yang X., Hou D. Role of biochar toward carbon neutrality. *Carbon Research* 2023:2(2). https://doi.org/10.1007/s44246-023-00035-7

[96] Liu Q., Liu B., Zhang Y., Hu T., Lin Z., Liu G., Xie Z. Biochar application as a tool to decrease soil nitrogen losses (NH_3 volatilization, N_2O emissions, and N leaching) from croplands: options and mitigation strength in a global perspective. *Global Change Biology* 2019:25(6):2077–2093. https://doi.org/10.1111/gcb.14613

[97] Ghorbani M., Neugschwandtner R. W., Soja G., Konvalina P., Kopecký M. Carbon fixation and soil aggregation affected by biochar oxidized with hydrogen peroxide: considering the efficiency of pyrolysis temperature. *Sustainability* 2023:15(9):7158. https://doi.org/10.3390/su15097158

[98] Biederman L. A., Harpole W. S. Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis. *GCB Bioenergy* 2012:5(2):202–214. https://doi.org/10.1111/gcbb.12037

[99] Wigan M. B. Impact of biochar application on chemical and microbial properties of soil. *International Journal of Multidisciplinary: Applied Business and Education Research* 2023:4(7):2503–2510. https://doi.org/10.11594/ijmaber.04.07.27

[100]Keskinen R., Hyväluoma J., Sohlo L., Help H., Rasa K. Fertilizer and soil conditioner value of broiler manure biochars. *Biochar* 2019:1(3):259–270. https://doi.org/10.1007/s42773-019-00020-7

[101]Hamad A. A. A., Ni L., Shaghaleh H., Elsadek E., Hamoud Y. A. Effect of carbon content in wheat straw biochar on N_2O and CO_2 emissions and pakchoi productivity under different soil moisture conditions. *Sustainability* 2023:15(6):5100. https://doi.org/10.3390/su15065100

[102]Tisserant A., Cherubini F. Potentials, limitations, co-benefits, and trade-offs of biochar applications to soils for climate change mitigation. *Land* 2019:8(12):179. https://doi.org/10.3390/land8120179

[103]Zhou H., Zhang D., Wang P., Liu X., Cheng K., Li L., Pan G. Changes in microbial biomass and the metabolic quotient with biochar addition to agricultural soils: A Meta-analysis. *Agriculture, Ecosystems & Environment* 2017:239:80–89. https://doi.org/10.1016/j.agee.2017.01.006

[104]Poeplau C., Don A. Carbon sequestration in agricultural soils via cultivation of cover crops – a meta-analysis. *Agriculture, Ecosystems & Environment* 2015:200:33–41. https://doi.org/10.1016/j.agee.2014.10.024

[105]McCauley K., Barlow K. Regenerative agriculture: increasing plant diversity and soil carbon sequestration on agricultural landscapes. *SURG Journal* 2023:15(1). https://doi.org/10.21083/surg.v15i1.7196

[106]Lugato E., Bampa F., Panagos P., Montanarella L., Jones A. Potential carbon sequestration of European arable soils estimated by modelling a comprehensive set of management practices. *Global Change Biology* 2014:20(11):3557–3567. https://doi.org/10.1111/gcb.12551

[107]Beillouin D., Ben-Ari T., Malézieux É., Seufert V., Makowski D. Positive but variable effects of crop diversification on biodiversity and ecosystem services. *Global Change Biology* 2021:27(19):4697–4710. https://doi.org/10.1111/gcb.15747

[108]Gaudin A. C. M., Tolhurst T. N., Ker A. P., Janovicek K., Tortora C., Martin R. C., Deen W. M. Increasing crop diversity mitigates weather variations and improves yield stability. *Plos One* 2015:10(2):0113261. https://doi.org/10.1371/journal.pone.0113261

[109]Weigel R., Koellner T., Poppenborg P., Bogner C. Crop diversity and stability of revenue on farms in central Europe: an analysis of big data from a comprehensive agricultural census in Bavaria. *Plos One* 2018:13(11):0207454. https://doi.org/10.1371/journal.pone.0207454

[110]Ryschawy J., Choisis N., Choisis J., Gibon A. Paths to last in mixed crop–livestock farming: lessons from an assessment of farm trajectories of change. *Animal* 2013:7(4):673–681. https://doi.org/10.1017/s1751731112002091

[111]Conant R. T., Cerri C. E. P., Osborne B. B., Paustian K. Grassland management impacts on soil carbon stocks: a new synthesis. *Ecological Applications* 2017:27(2):662–668. https://doi.org/10.1002/eap.1473

[112]McSherry M. E., Ritchie M. E. Effects of grazing on grassland soil carbon: a global review. *Global Change Biology* 2013:19(5):1347–1357. https://doi.org/10.1111/gcb.12144

[113]Tessema B., Sommer R., Piikki K., Namirembe S., Notenbaert A. M. O., Tamene L., Paul B. K. Potential for soil organic carbon sequestration in grasslands in East African countries: a review. *Grassland Science* 2020:66(3):135–144. https://doi.org/10.1111/grs.12267

[114]Kleppel G. S., Frank D. A. Structure and functioning of wild and agricultural grazing ecosystems: a comparative review. *Frontiers in Sustainable Food Systems* 2022:6. https://doi.org/10.3389/fsufs.2022.945514

[115]Liebig M. A., Gross J., Kronberg S. L., Phillips R. Grazing management contributions to net global warming potential: a long-term evaluation in the northern great plains. *Journal of Environmental Quality* 2010:39(3):799–809. https://doi.org/10.2134/jeq2009.0272