Carbon storage assessment: Note II – usual practices in the Central Region of Romania

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Abstract. The Central Region of Romania, with its agricultural diversity, is of great importance for carbon storage through soil management. As climate change pressures increase, enhancing carbon sequestration in farming becomes essential. Practices like crop rotation, cover cropping, reduced tillage, and organic fertilization enable soils to act as carbon sinks, reducing greenhouse gas emissions. A survey in Covasna, Alba and Sibiu counties, involving 74 farmers, examined current carbon storage practices, revealing varying levels of adoption. While many farmers already employ beneficial methods, there is potential for improvement with techniques such as no-till farming and agroforestry. Addressing economic, knowledge, and climatic barriers requires collaboration among governments, researchers, and farmers. This initial assessment sets the stage for advancing carbon-positive practices and sustainable agriculture in Romania.
Key Words: climate change, cover crops, soil management, survey, tillage.

Introduction. The Central Region of Romania, characterized by its rich agricultural heritage and diverse landscapes, plays a significant role in carbon storage, particularly through its soil management practices. As climate change continues to challenge traditional agricultural systems, the potential for carbon sequestration within farming landscapes has become increasingly important (Aertsens et al 2013; Davidson & Janssens 2006). The concept of carbon storage in agriculture is rooted in the ability of soils to absorb and retain carbon dioxide (CO_2) from the atmosphere, effectively mitigating greenhouse gas emissions (Guo et al 2006; Mirzaei et al 2022; Yang et al 2022). Through techniques such as crop rotation, cover cropping, reduced tillage, and organic fertilization, agricultural soils can act as carbon sinks, helping to offset the carbon footprint of farming activities (Li et al 2001; Liu et al 2023). The soil organic carbon is critical for nutrient cycling, water retention, and soil structure. High soil organic carbon levels improve the capacity of soil to support plant growth, sustain crop yields, and promote overall soil health. Soil stores more carbon than the atmosphere and terrestrial vegetation combined, making them a key carbon sink (Blanco-Moure et al 2016; Freibauer et al 2004). Increasing soil organic carbon through improved management practices is a major strategy for mitigating climate change by capturing atmospheric carbon dioxide and stabilizing it in the soil (Tilman et al 2001).

Traditional agricultural systems, often reliant on practices such as intensive tillage and monocropping, have been associated with soil organic carbon loss. However, innovative strategies like regenerative agriculture, precision farming, and biochar application are being researched for their potential to enhance soil organic carbon storage while maintaining or increasing productivity (Adamchuk et al 2004; Bah et al 2012; Balkcom et al 2013). These modern techniques focus on improving resource use efficiency and minimizing disturbances that lead to carbon loss.

The soil organic carbon dynamics are complex and vary across different ecosystems, soil types, and climatic conditions. This makes it challenging to predict the outcomes of different land use and management strategies. Advances in soil organic carbon monitoring, modeling, and remote sensing technologies are helping to address this (Balafoutis et al 2017). Strategies to increase soil organic carbon must consider potential trade-offs with other ecosystem services (e.g., water use, biodiversity conservation) and the needs of local communities (Maillard et al 2016; Yang et al 2018). Managing soil organic carbon effectively requires a combination of traditional knowledge and innovative practices aimed at balancing agricultural productivity with environmental sustainability (Nazir et al 2024). By improving soil organic carbon levels, we can not only sustain soil fertility but also play a significant role in combating global warming through enhanced carbon sequestration (Poeplau & Don 2013; Zotarelli et al 2007).

The aim of the study was to explore the current practices employed by farmers in the Central Region of Romania to enhance carbon storage, providing an in-depth analysis of how various soil management techniques contribute to carbon sequestration in the area.

Material and Method. For analyzing the usual practices performed in the Central developmental region of Romania concerning the carbon storage assessment, a survey was conducted in Covasna County, Harghita County, Alba County and Sibiu County. 26 farmers in Covansa County, 13 farmers in Harghita County, 27 farmers in Alba County and 21 farmers in Sibiu County answered to all 15 questions of the survey. 29% of the respondents were aged between 50-65 years, while the rest of 71% between 30–50 years. The areas of the farms frame within 12-190 ha. The carbon storage practices adopted by farmers, which participated to the survey are graphically presented as proportion from participants farming management. The results are also analyzed considering the respondents' attitude towards traditional practices and soil management, modern techniques and innovations, challenges in implementing carbon-positive practices, and the role of policy and support systems.

Results and Discussion. Figure 1 illustrates the level of knowledge regarding carbon sequestration terminology among survey respondents. The chart shows that 87.50% of the respondents are familiar with the term "carbon sequestration," as represented by the higher bar labeled "Yes" In contrast, 12.50% of respondents indicated that they do not have knowledge of this terminology, as reflected by the shorter bar labeled "No". This suggests a relatively high level of awareness about carbon sequestration among the respondents, though a notable minority (almost one-quarter) still lack familiarity with the concept. This discrepancy highlights the need for further education and outreach efforts to ensure broader understanding of carbon storage practices, which are crucial for enhancing soil health and mitigating climate change.

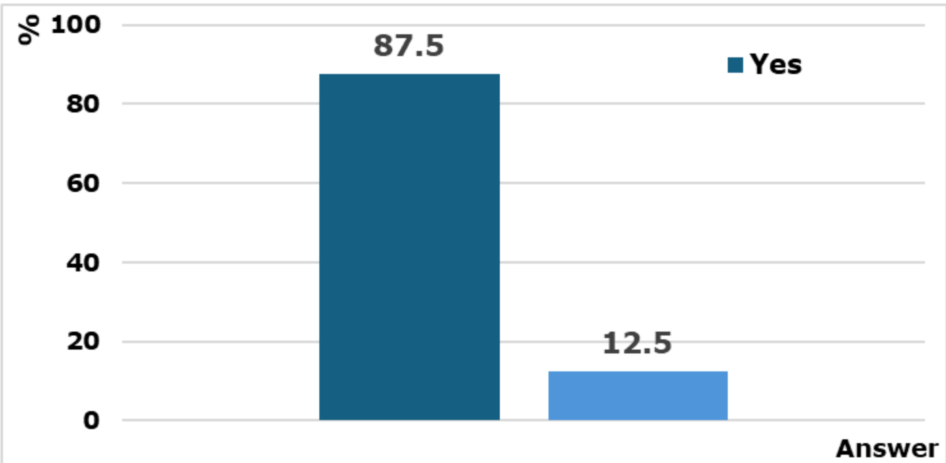

Figure 1. The knowledge of carbon sequestration terminology.

Figure 2 presents a breakdown of respondents' knowledge about various methods used to promote carbon sequestration in agriculture. The chart highlights that: 12.50% of respondents are aware of crop rotation to enhance carbon storage, making it the most recognized practice, 12.50% are knowledgeable about the use of cover crops, indicating significant awareness of this technique. 12.50% of respondents recognize the role of organic fertilizers in carbon sequestration, 25% practice the improvement of pasture maintenance technologies, while fall into the "Other" category, suggesting that some respondents are familiar with additional or alternative methods not listed in the survey. Practices such as improvement of pasture maintenance technologies and the use of deep-rooted crops are not acknowledged by any of the respondents, as their corresponding bars are absent. This distribution indicates that while there is substantial awareness of common practices like crop rotation and cover crops, there is less recognition of other important carbon storage techniques, suggesting the need for further education and promotion of a wider range of sustainable agricultural practices.

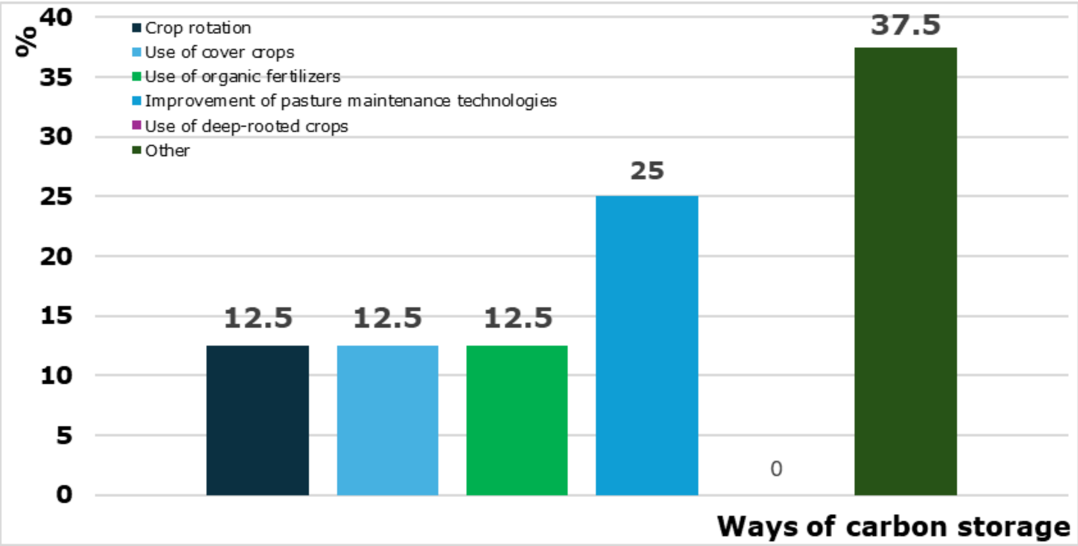

Figure 2. The knowledge of means destined to promote carbon sequestartion in agriculture.

Figure 3 illustrates the proportion of farmers using soil tillage technologies aimed at maintaining soil structure and integrity. The results show that 87.50% of respondents indicated that they do use such technologies on their farms, as represented by the "Yes" bar, and 12.50% of respondents reported that they do not use these technologies, as represented by the "No" bar. These results suggest that a significant majority of farmers are aware of and implement tillage practices that help preserve soil structure and integrity. However, there is still a sizable minority that does not use these methods, indicating the need for further efforts to promote and adopt soil conservation practices more widely. The adoption of such technologies is important for enhancing soil health, which can lead to better carbon sequestration and overall agricultural sustainability.

Figure 4 illustrates the distribution of different agricultural practices used for soil management among the surveyed farms. The data suggests that while farmers are actively engaging in some practices, especially soil analysis and crop rotation, other beneficial soil management techniques remain underutilized. This indicates potential areas for improvement and further education to promote the adoption of more diverse sustainable practices for enhancing soil health and carbon sequestration.

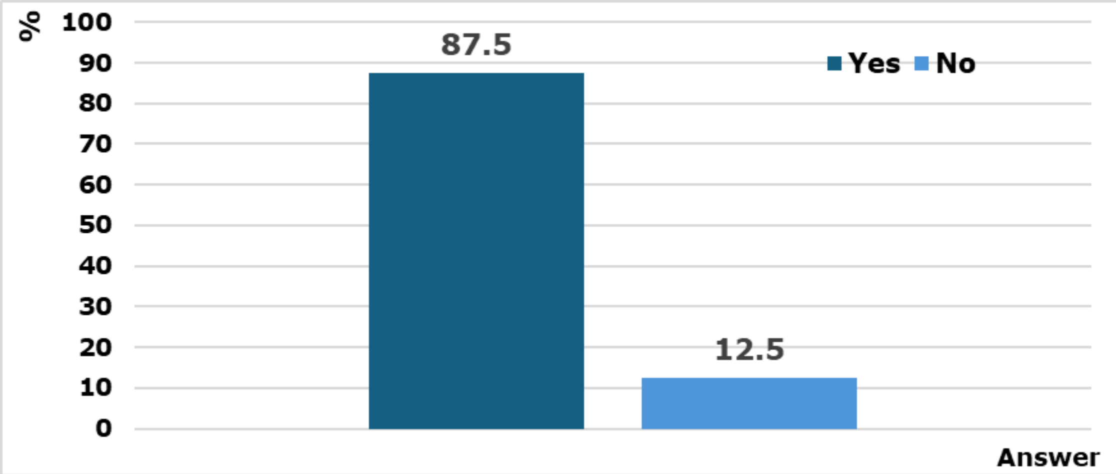

Figure 3. The level of using in farm the soil tillage technologies destined to maintain soil structure and integrity.

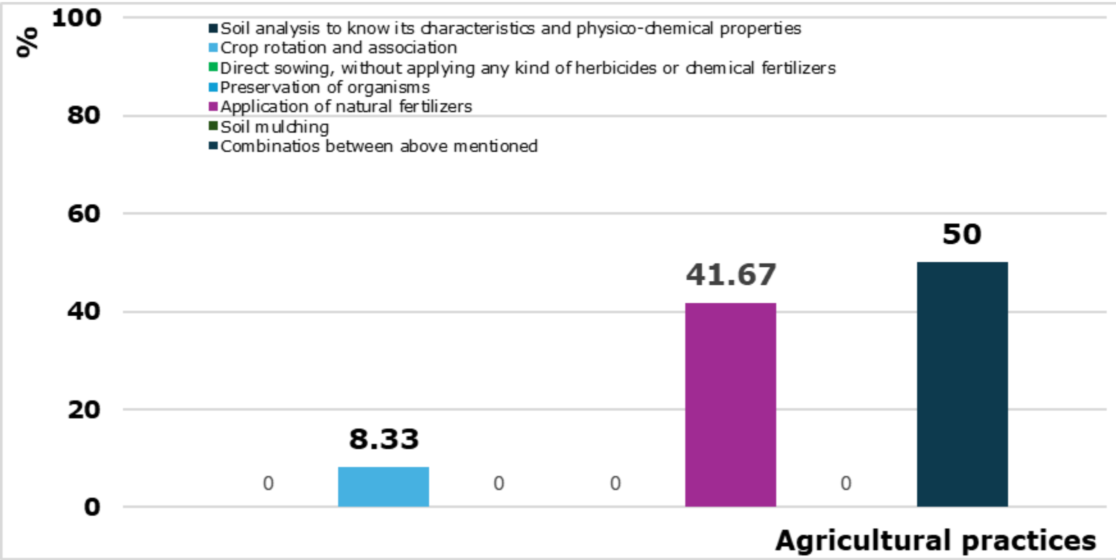

Figure 4. Types of agricultural practices for soil management used in farm.

Figure 5 shows an equal distribution between "Yes" and "No" responses, concerning the use of cover crops for maintaining soil covering and increase the organic matter supply.

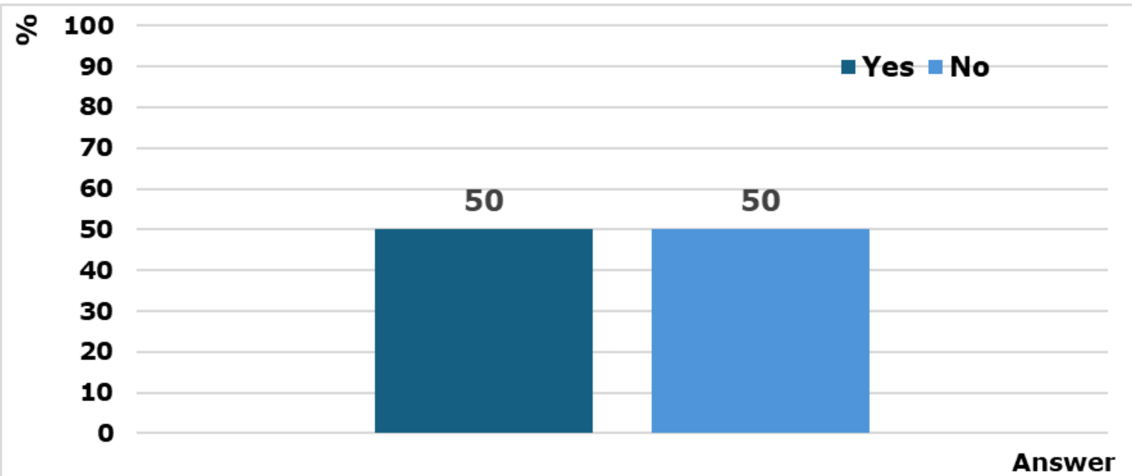

Figure 5. The level of using cover crops for maintaining soil covering and increase the organic matter supply.

The plants belonging to the categories "Herbaceous plants", "Mustard", "Raddish", "Phacellia", "Alfalfa", and unidentified "Beans", and "Cereals" are used as cover crops. "Herbaceous plants", "Mustard", "Raddish", and "Cereals" each have a share of 8.33%, "Phacellia" accounts for 16.67%, "Alfalfa" and "Beans" each represent 25%. This chart suggests a greater preference for "Alfalfa" and the unidentified category, while the other plant types are used less frequently as cover crops (Figure 6).

Figure 7 shows the preferences for different plant types used to continuously improve soil carbon content. The distribution is as follows: "Cereals" account for 62.5%, indicating the most significant preference for improving soil carbon, "Peas, beans, soy" represent 29.17%, while "Radishes, mustard, turnips, rapeseed, buckwheat" make up 8.33%. The chart suggests a strong preference for using cereals to enhance soil carbon content, followed by legumes, while other crops are less commonly used. Additionally, the y-axis title should be replaced with a more descriptive label to clarify the percentage or metric represented.

The management practices for vegetal and culture waste are represented by the following ones: leaving part of the vegetable remains: 41.67%, the most common practice; weeding immediately after harvesting: 29.17%; administration of nitrogen: 20.83%; turning the furrow at 45°: 8.33%. No respondents avoid the maintenance of plant residues. This suggests that the most preferred management practice is incorporating vegetable remains into the soil, while practices like leaving residue untouched are not favored (Figure 8).

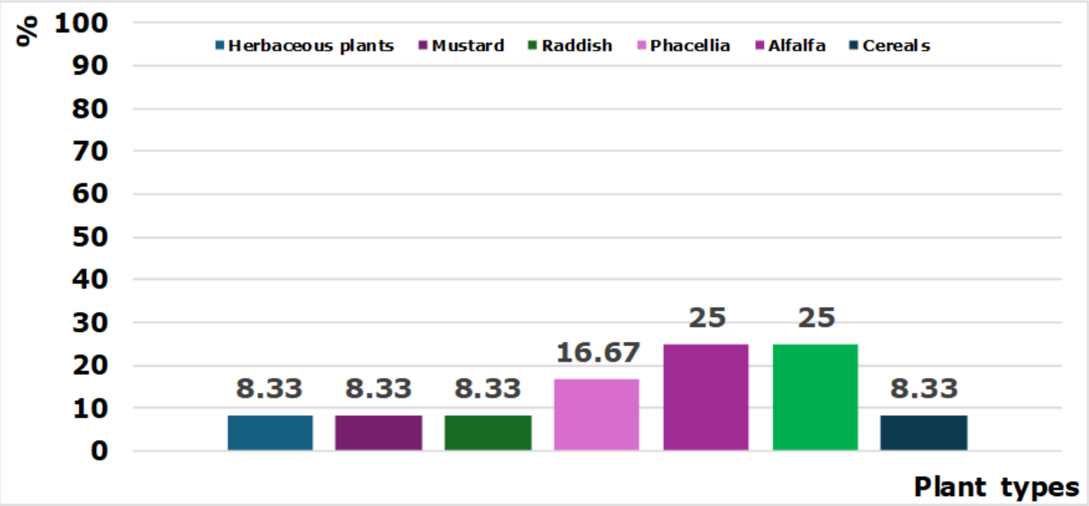

Figure 6. Types of plants used as cover crops.

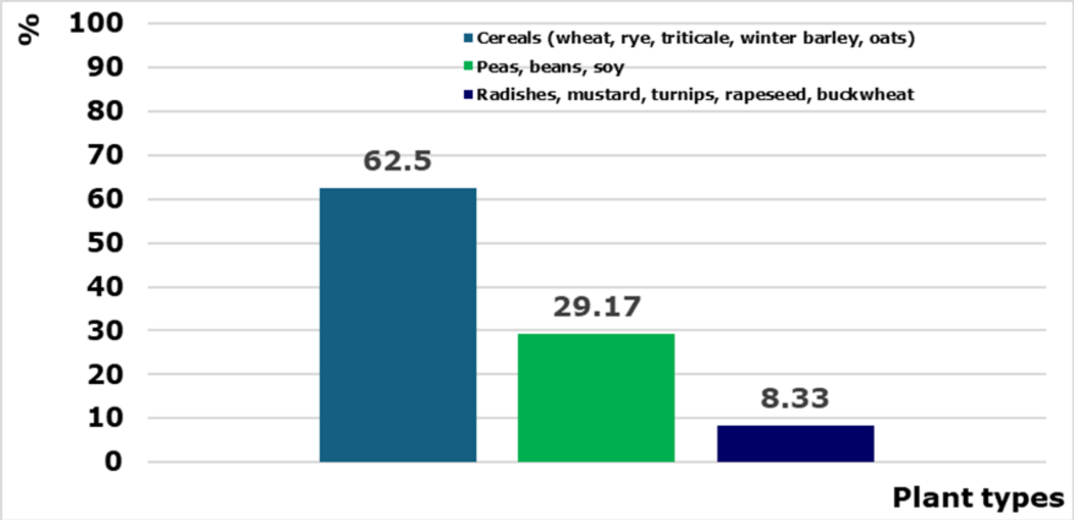

Figure 7. Types of cultures preferred for continuous improvement the soil carbon content.

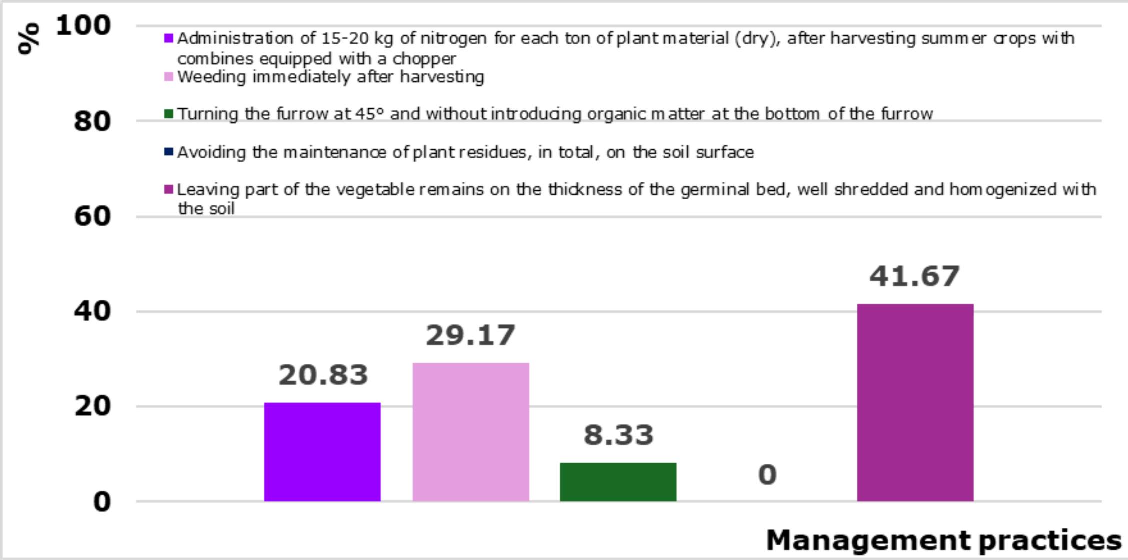

Figure 8. Management practices for vegetal and culture waste.

The respondents have a preference for using manure exclusively among those who apply organic or natural fertilizers, with no usage of compost or liquid manure. The data also suggests that a significant proportion of respondents do not use such fertilizers at all (Figure 9).

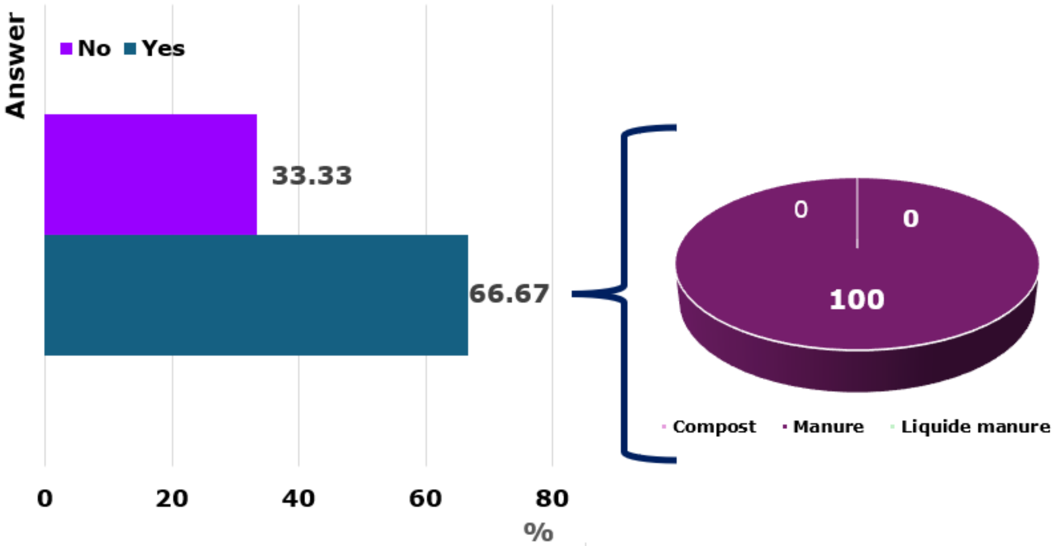

Figure 9. The level of using organic or natural fertilizers for improving soil quality and increase carbon sequestration.

Figure 10 illustrates the frequency of conducting soil analysis to assess organic carbon content and other important soil traits. No respondents conduct annual soil analyses, 16.67% conduct soil analyses at 2 years, 33.33% conduct soil analyses at 5 years, showing this is a relatively common interval, 4.17% conduct soil analyses at 10 years, and 45.83% never conduct soil analyses, indicating that nearly half of the respondents do not perform soil analysis at all. These results suggest that soil analysis is not a routine practice for many, with the most common practice being analysis every five years, followed by those who never conduct it. There is no reported annual analysis, highlighting a potential gap in frequent soil monitoring practices.

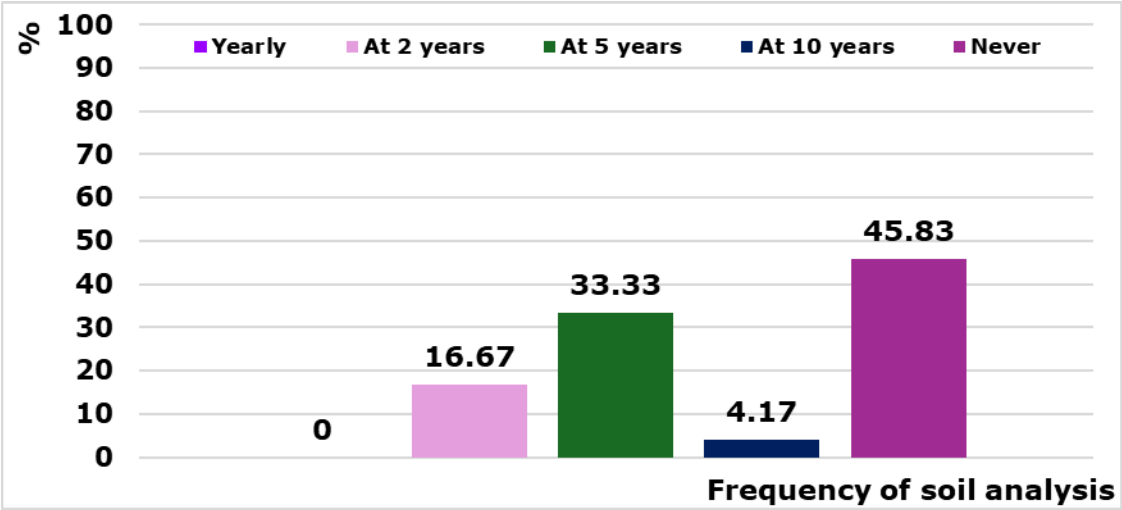

Figure 10. The frequency of using soil analysis to assess the organic carbon content and other important soil traits.

Concerning the use of water preservations technologies for maintaining soil moisture, the survey conducted in Central Developmental Area of Romania (Covasna, Harghita, Alba and Sibiu counties) shows that while some individuals do practice water conservation techniques, the majority do not, with "No tillage" being the primary method among those who do engage in these practices. "No" is reported by 70.83% of respondents, meaning that the majority do not use water preservation techniques, and "Yes" by 29.17%, indicating a smaller group that does implement these methods (Figure 11).

The data presented in Figure 12 suggests that most respondents acknowledge a moderate influence of agricultural practices on soil carbon dynamics, while strong impacts are not perceived. It indicates a consensus that agricultural practices do affect soil carbon, but not to an extreme degree.

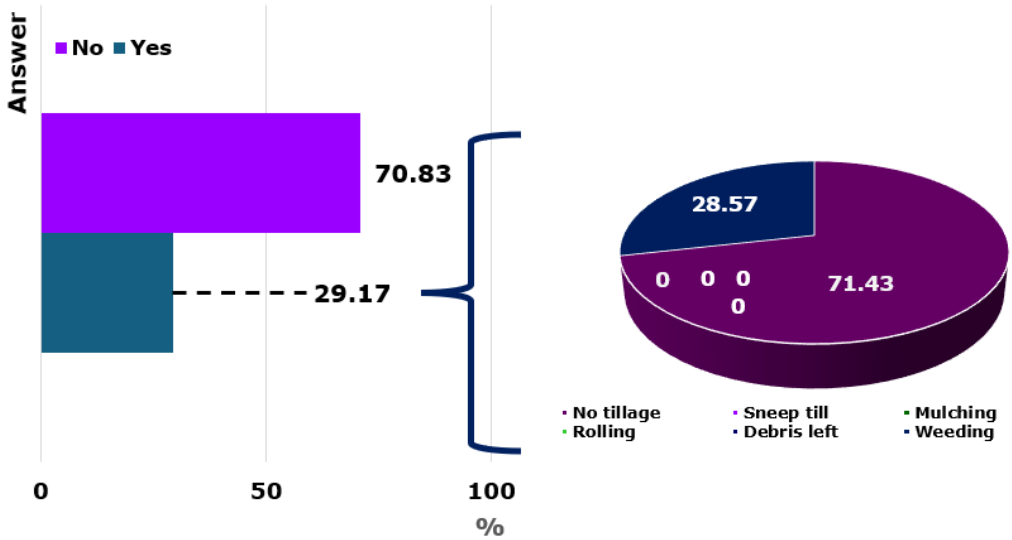

Figure 11. The level of using water preservations technologies for maintaining soil moisture.

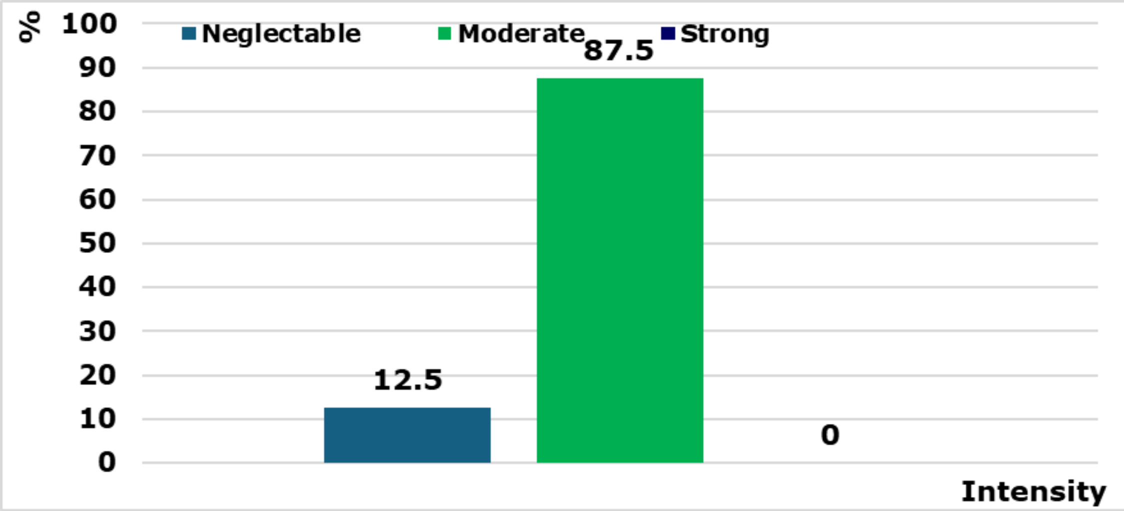

Figure 12. Assessment of the impact of the agricultural practices on organic carbon dynamics in soil.

Figure 13 illustrates various technologies and agricultural practices considered most effective for promoting carbon sequestration in soil. The data suggests a significant preference for diversifying rotational crops, followed by the use of organic materials like manure or compost. Practices like "minimum-tillage" and specific crop usage are less commonly adopted for carbon sequestration. The chart emphasizes the importance of crop diversity and organic matter in enhancing soil carbon levels.

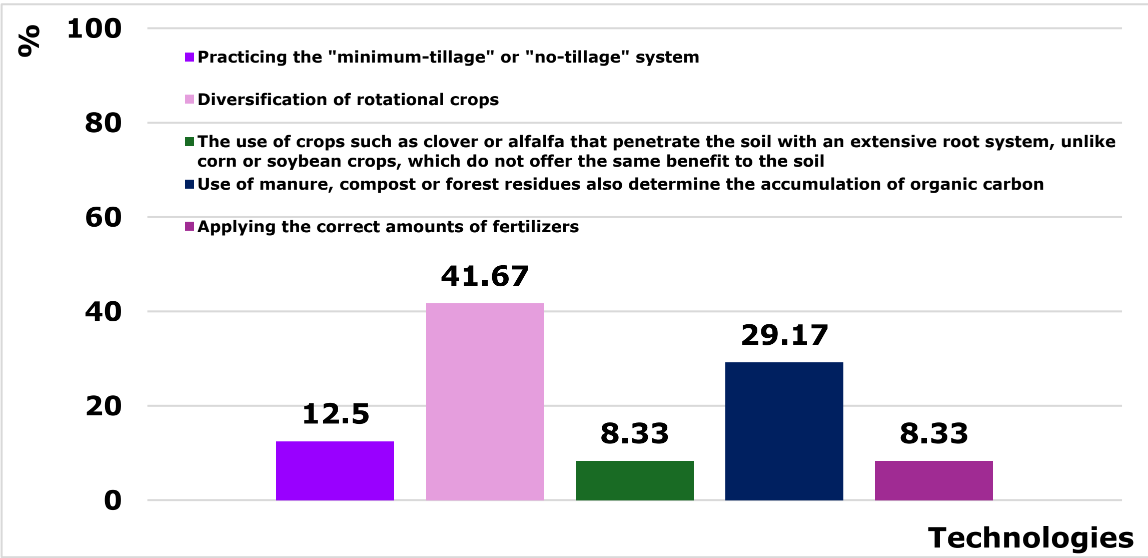

Figure 13. Technologies and agricultural practices observed as most efficient in promotion the carbon sequestration in soil.

According to our study, there is some adoption of preservation agriculture techniques, but a significant portion of respondents have yet to implement these practices to reduce soil disruption and improve carbon sequestration.

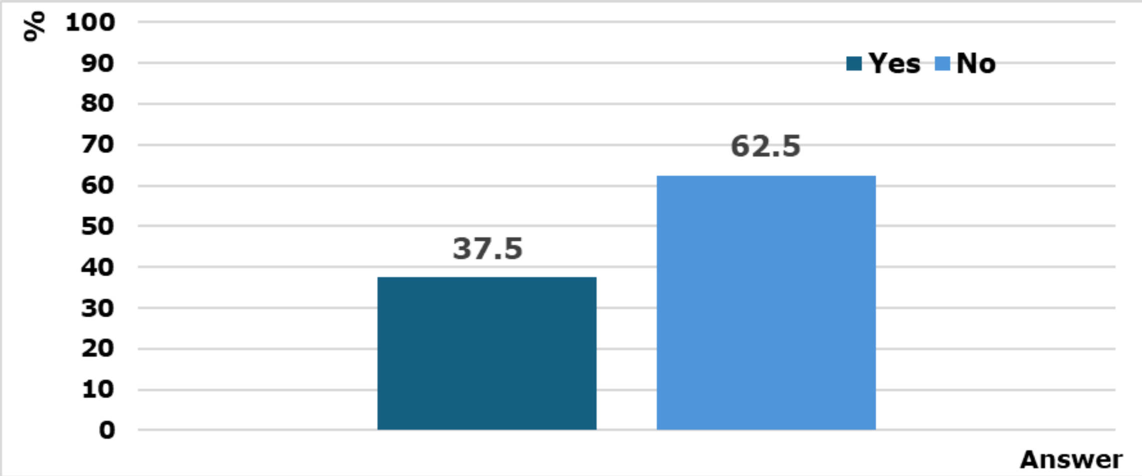

Figure 14. Implementation of preservation agriculture for minimizing the soil disruption and enhance carbon sequestration.

In Figure 15 is assessed the level of knowledge regarding the connections between agricultural practices, soil carbon sequestration, and climate change. The data suggests that while there is a general awareness of the connections between agricultural practices, soil carbon sequestration, and climate change, most individuals possess only a limited understanding. Thus, we consider there is room for further education and awareness-raising in this area.

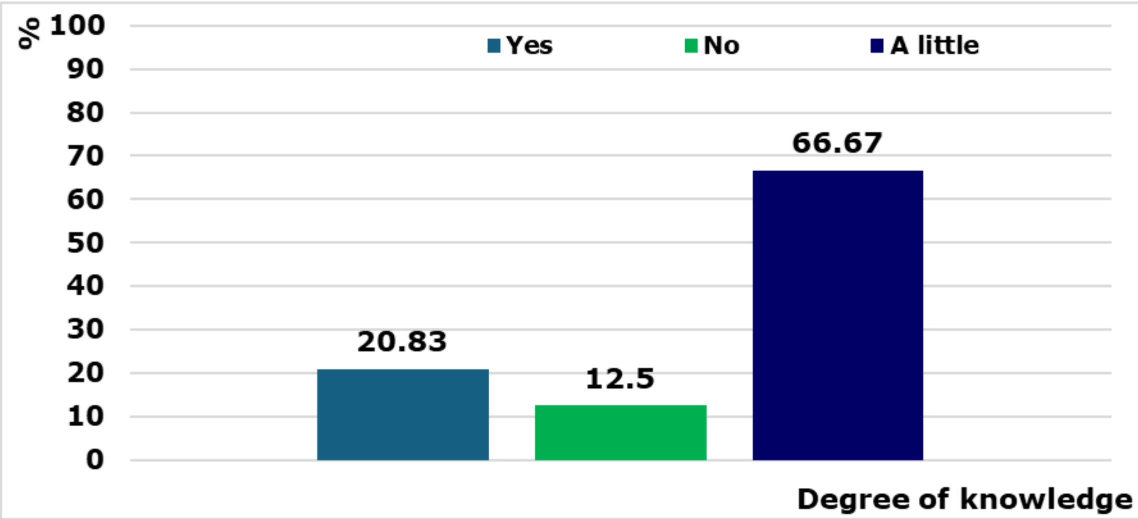

Figure 15. The knowledge of the connections between agricultural practices, soil carbon sequestration and climatic changes.

Challenges in implementing carbon-positive practices. While many farmers in the Central Region are aware of the benefits of carbon sequestration and sustainable soil management, the transition to fully carbon-positive practices faces several challenges. Economic constraints are one of the primary barriers, particularly for smallholder farmers who may lack the financial resources to invest in new technologies or labor-intensive practices like cover cropping and composting. The cost of adopting no-till machinery or organic fertilizers, for example, can be prohibitive without external support. Additionally, lack of knowledge and technical support hinders wider adoption of innovative carbon storage practices. Many farmers still rely on traditional methods passed down through generations, and while these methods are beneficial, they may not be sufficient in the context of modern climate challenges. Training programs and extension services that provide farmers with up-to-date information on soil health and carbon sequestration techniques are essential for overcoming this knowledge gap. Another significant challenge is climate variability itself. Increasingly erratic weather patterns, including prolonged droughts and intense rainfall, complicate the implementation of sustainable practices. For instance, no-till farming relies heavily on maintaining adequate soil moisture, but in regions prone to drought, these systems may not function optimally. Farmers must adapt to shifting climatic conditions while attempting to maintain or improve soil health, making carbon sequestration a complex and context-specific challenge.

The role of policy and support systems. To encourage wider adoption of carbon storage practices, policy interventions and support systems are crucial. The Romanian government, in alignment with EU agricultural and environmental goals, has the opportunity to incentivize sustainable farming practices through subsidies, grants, and education programs. Agri-environment schemes that reward farmers for implementing soil-friendly practices could accelerate the transition to carbon-positive agriculture. Additionally, carbon credit markets present an emerging opportunity for farmers to benefit financially from their carbon sequestration efforts. By quantifying and verifying the amount of carbon stored in agricultural soils, farmers could potentially sell carbon credits, creating an economic incentive to adopt and maintain sustainable practices. However, the development of such markets will require robust measurement and verification systems, as well as support from both national and international bodies.

Conclusions. The Central Region of Romania, with its diverse agricultural landscape and mix of traditional and modern farming practices, offers valuable insights into the potential for carbon sequestration in agriculture. While many farmers already employ beneficial practices such as crop rotation, cover cropping, and the use of organic fertilizers, there is still significant room for improvement in terms of adopting modern techniques like no-till farming and agroforestry. Addressing the economic, knowledge-based, and climatic challenges that farmers face will require coordinated efforts from governments, research institutions, and the farming community itself. By enhancing the capacity of farmers to implement carbon-positive practices, Romania can contribute meaningfully to global efforts to mitigate climate change while ensuring the long-term sustainability of its agricultural sector. This article, as the first note in a broader assessment of carbon storage practices, sets the stage for future investigations into more advanced technologies, policy interventions, and scalable solutions that can further enhance Romania's role in global carbon sequestration efforts.

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Conflict of interest. The authors declare no conflict of interest.

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