Carbon storage assessment: Note I – usual practices in the North-Western Region of Romania

[1]F. Camelia Oroian, [2]Antonia Odagiu, [3]Olga Vizitiu, [1]Iulia C. Mureșan, [2]Petru Burduhos, [2]I. Valentin Petrescu-Mag

[1] Faculty of Horticulture and Business in Rural Development, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania; [2] Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania; [3] National Research and Development Institute for Soil Science, Agrochemistry and Environment Bucharest, Bucharest, Romania. Corresponding author: A. Odagiu, aodagiu@gmail.com

Abstract. Land use and management practices greatly impact soil organic carbon levels as they influence the balance of organic carbon in soils through both inputs and outputs. The interaction between aboveground and belowground ecosystems is key to understanding carbon sequestration and its optimization. This article analyzes farming practices related to carbon storage, drawing on a survey conducted among farmers in the North-Western Region of Romania. The survey, aimed at highlighting typical practices for carbon storage assessment, involved 106 farms from Bistrița Năsăud, Maramureș, Sălaj and Bihor counties. 17% of the respondents were aged 50-65, while the remaining farmers were between 30-50 years old. For clarity, the results are visually represented in graphs showing the distribution of farming practices concerning carbon sequestration. The survey revealed a growing awareness of carbon storage in the North-Western Region, though the degree of practice adoption varies. Farmers are adopting beneficial techniques such as crop rotation, cover crops, and organic fertilization, but improvements are needed in areas like no-till farming and regular soil analysis. Promoting these techniques could significantly enhance soil carbon storage, supporting both sustainable agriculture and climate change mitigation.
Key Words: agriculture, cover crops, soil, survey, tillage technologies.

Introduction. Understanding the dynamics of soil organic carbon and its interaction with land use and management practices is crucial for several reasons, particularly for enhancing soil fertility and addressing climate change (Lal et al 2011; Meyers 2001; Tilman et al 2001). The soil organic carbon refers to the carbon component of organic compounds in the soil, which originates from plant residues, microbial biomass, and organic amendments. The amount of soil organic carbon stored in soil plays a key role in regulating soil health, agricultural productivity, and the global carbon cycle (Aires et al 2008; Chen et al 2009). Land use and management practices significantly influence soil organic carbon levels, as they directly affect the inputs and outputs of organic carbon in soils. The interaction between aboveground (plant biomass and residue) and belowground ecosystems (roots, soil microorganisms) is essential to understanding carbon sequestration and how it can be optimized (Hunt et al 2004; Schoeneberger 2009; Shi et al 2021). Effective management practices can lead to greater carbon inputs from plants and reduced carbon losses through soil respiration and erosion. The conservation agriculture includes practices such as minimal tillage, crop rotation, and maintaining soil cover, and these approaches help protect the soil structure, reduce erosion, and increase organic carbon input through plant residues (Guo et al 2006; Zotarelli et al 2007).

The integration of trees and shrubs into agricultural landscapes enhances carbon sequestration by promoting deeper root systems and continuous organic material inputs, while also improving soil structure. The addition of organic materials like compost or manure improves soil organic carbon by directly increasing the organic matter content (Lin et al 2019; Triberti et al 2016). These amendments also stimulate microbial activity, contributing to the breakdown and stabilization of organic matter in the soil (Li et al 2001).

The conversion of natural ecosystems (forests, grasslands) into agricultural systems often leads to a significant reduction in soil organic carbon due to the loss of organic matter and increased soil disturbance (Liu et al 2023; Xu et al 2016). However, reforestation, afforestation, or the conversion to more sustainable land use practices can reverse this trend by enhancing carbon storage (Poeplau & Don 2013). Sustainable grazing practices, such as rotational grazing, prevent overgrazing, enhance plant growth, and promote carbon sequestration in pasturelands. Unmanaged grazing, on the other hand, can lead to soil degradation and soil organic carbon depletion (Zhang et al 2015).

In the North-Western Region of Romania, carbon storage practices in agriculture have gained increasing attention, especially as global awareness of climate change and soil health continues to grow. Farmers play a pivotal role in the carbon cycle, as their management of land and crops directly influences the carbon sequestration potential of the soil. This article provides an analysis of farming practices related to carbon storage, based on a survey conducted among farmers in North-Western Region of Romania.

Material and Method. In order to emphasize the usual practices performed in the North-Western developmental region of Romania (47.0722° N latitude and 23.5735° E longitude) for carbon storage assessment, a survey was conducted in Bistrița Năsăud, Maramureș, Sălaj, Satu Mare and Bihor counties. 35 farmers in Bistrița Năsăud County, 13 in Maramureș County, 21 Sălaj County, 11 Satu Mare County and 37 in Bihor County answered to 15 questions included in the survey. 17% of the respondents were aged between 50–65 years, while the rest of them between 30–50 years. The 55 farms area frame within 5–300 ha. The issues addressed concern five areas of carbon storage practices in agriculture, namely key, notable and carbon friendly practices, and also adoption of carbon-enhancing techniques, soil testing for carbon content, traditional practices and soil management, modern techniques and innovations and challenges in promoting carbon storage. For a better understanding, the answers are represented as graphic representations of the proportions of respondents' practices concerning carbon sequestration.

Results and Discussion

Understanding carbon storage. According to the data, most farmers are familiar with the term "carbon storage", though there is some variation in practices aimed at enhancing carbon sequestration. A significant proportion of farmers implement techniques such as crop rotation and cover crops, which help maintain soil structure and organic matter, thus promoting carbon storage (Figure 1). The key practices identified concern: crop rotation and association, use of cover crops, soil management and tillage practices, and organic and natural fertilizers (Figures 2–9).

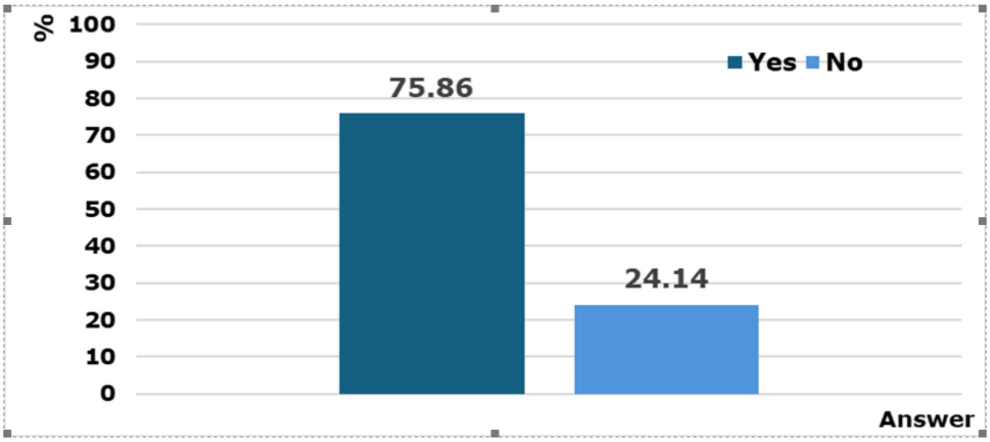

Figure 1. The knowledge of carbon sequestration terminology.

Crop rotation and association. A majority of respondents implement crop rotation, citing its benefits for improving soil health. Some farmers also practice intercropping (association of crops), which enhances biodiversity and prevents soil depletion.

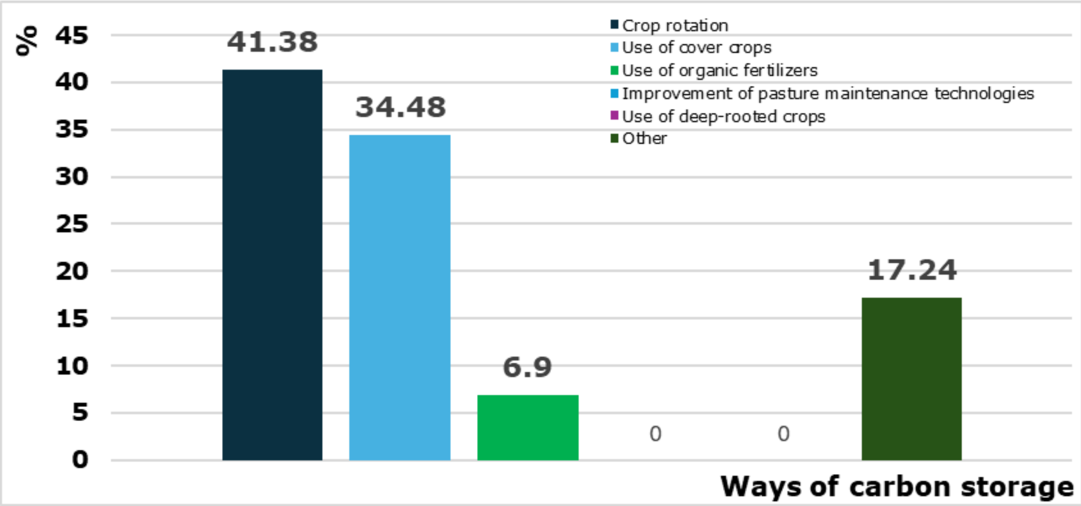

Figure 2. The knowledge of means destined to promote carbon sequestration in agriculture.

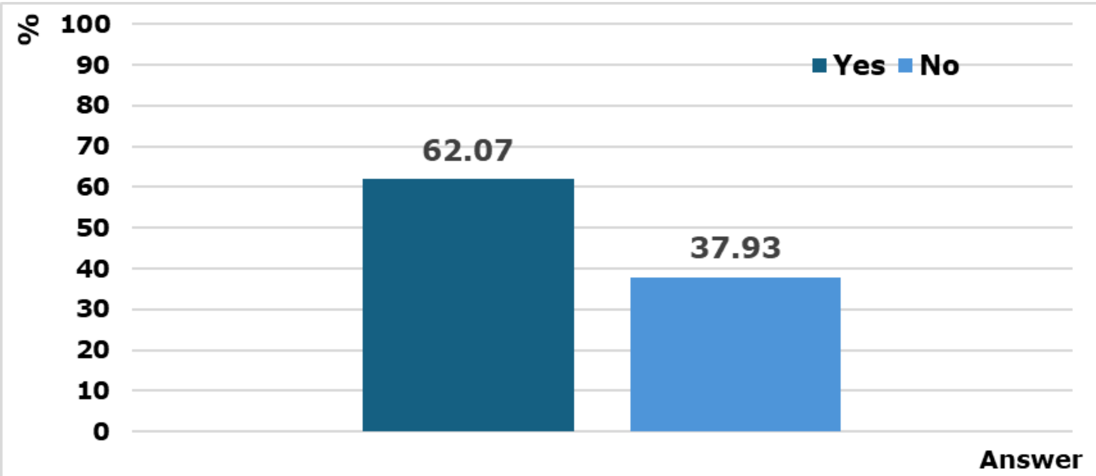

Figure 3. The level of using in farm the soil tillage technologies destined to maintain soil structure and integrity.

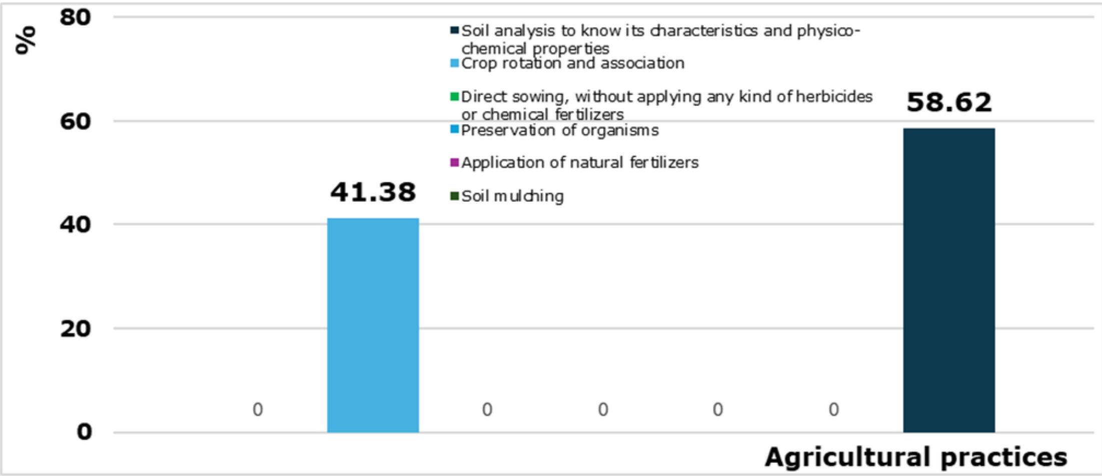

Figure 4. Types of agricultural practices for soil management used in farm.

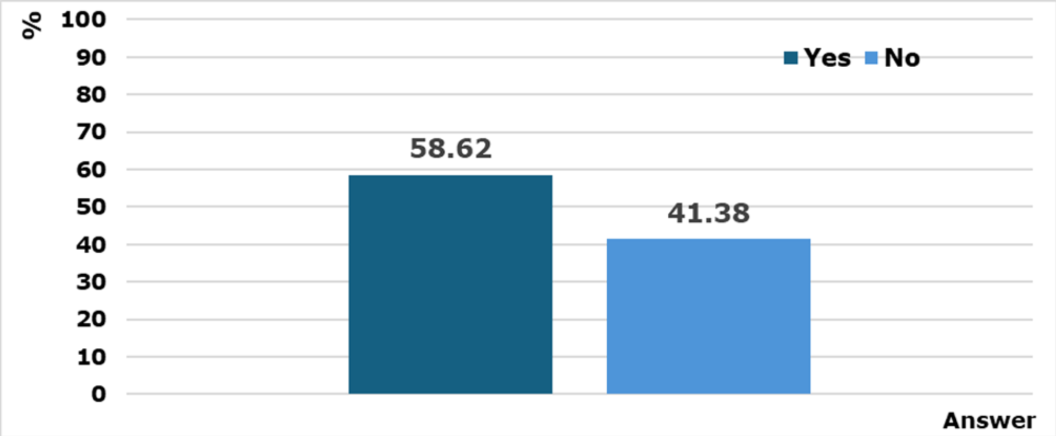

Figure 5. The level of using cover crops for maintaining soil covering and increase the organic matter supply.

Use of cover crops. Cover crops, such as lucerne (alfalfa), mustard, and radishes, are commonly used to protect soil during off-season periods. They not only prevent erosion, but also contribute to organic matter and enhance the soil's ability to store carbon.

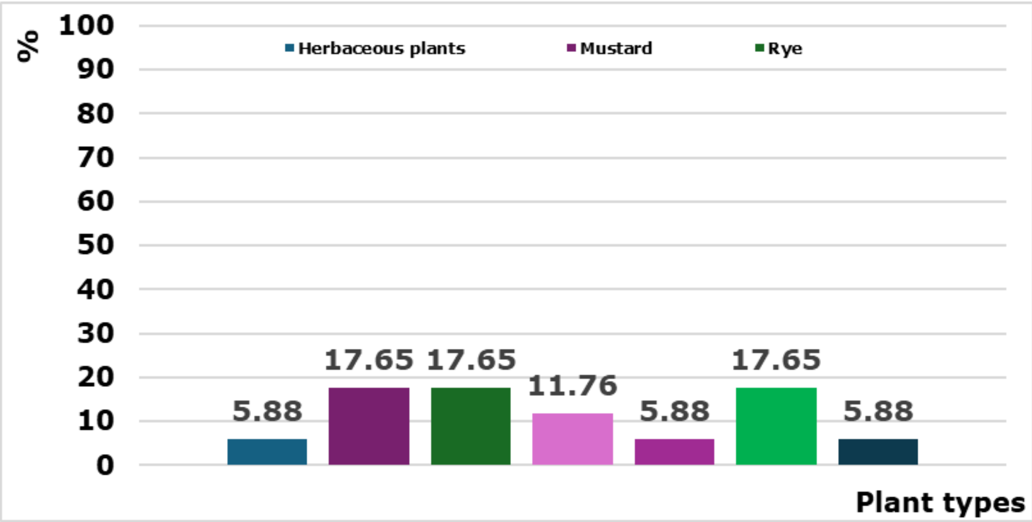

Figure 6. Types of plants used as cover crops.

Soil management and tillage practices. Various tillage techniques are used, including minimum tillage and no-tillage systems, which reduce soil disturbance and thus improve the potential for carbon storage. However, some farmers continue with conventional tillage practices, which may negatively affect soil organic carbon levels.

Organic and natural fertilizers. Many farmers use organic inputs like compost, manure, and natural fertilizers. These inputs play a vital role in enriching the soil with organic carbon. Regular application of manure was noted by some farmers as a method to accumulate organic matter over time. The carbon-friendly practices in promoting carbon storage in the region are mulching and organic residue management, cover crop choice, and minimal soil disturbance. The survey indicated that farmers who use advanced soil management techniques (such as leaving crop residues on the soil or applying compost) see moderate to significant improvements in soil carbon storage (Figures 4–9).

Mulching and organic residue management. Farmers reported the practice of leaving organic residues from previous crops (such as cereals and legumes) on the soil, allowing them to decompose naturally and enrich the soil with organic matter.

Cover crop choice. Mustard and lucerne were among the popular cover crops for their deep-rooting characteristics, which help sequester carbon in deeper soil layers.

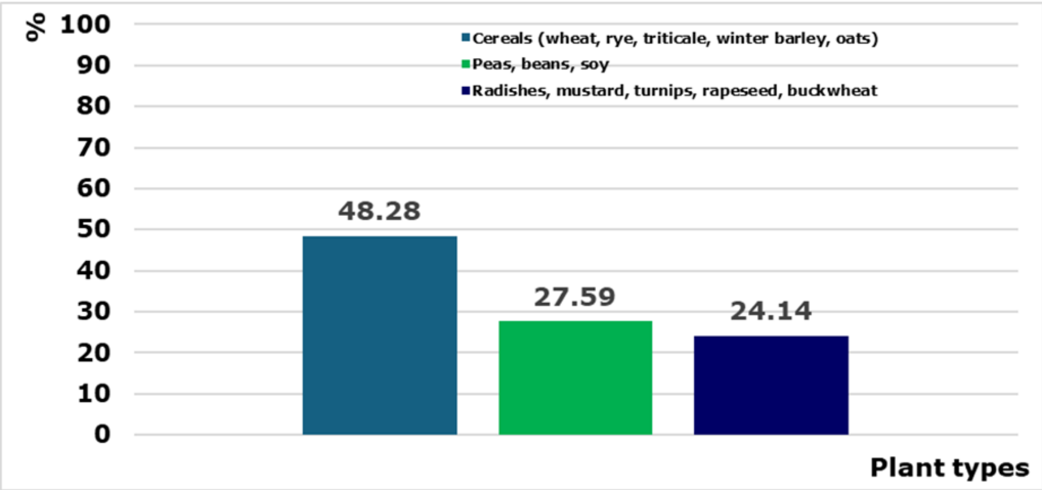

Figure 7. Types of cultures preferred for continuous improvement the soil carbon content.

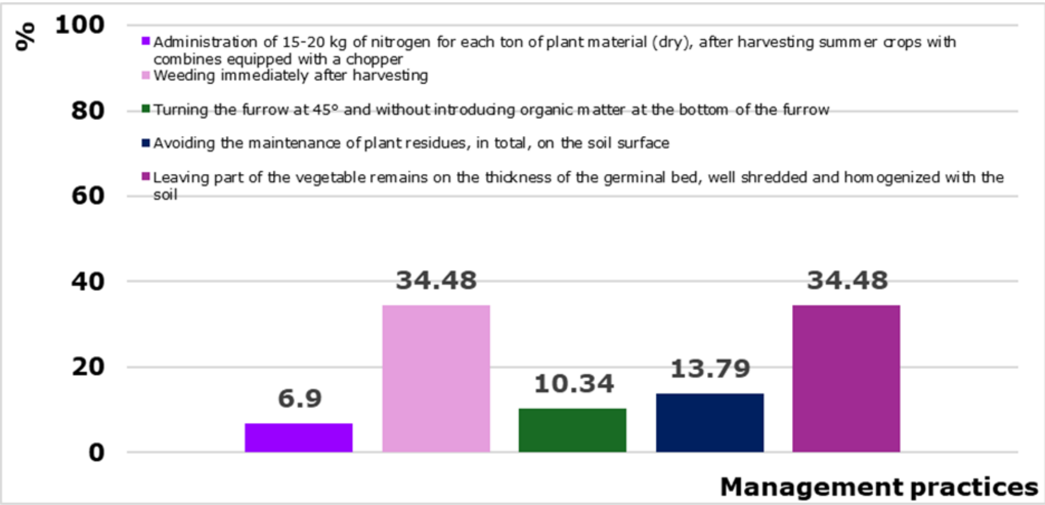

Figure 8. Management practices for vegetal and culture waste.

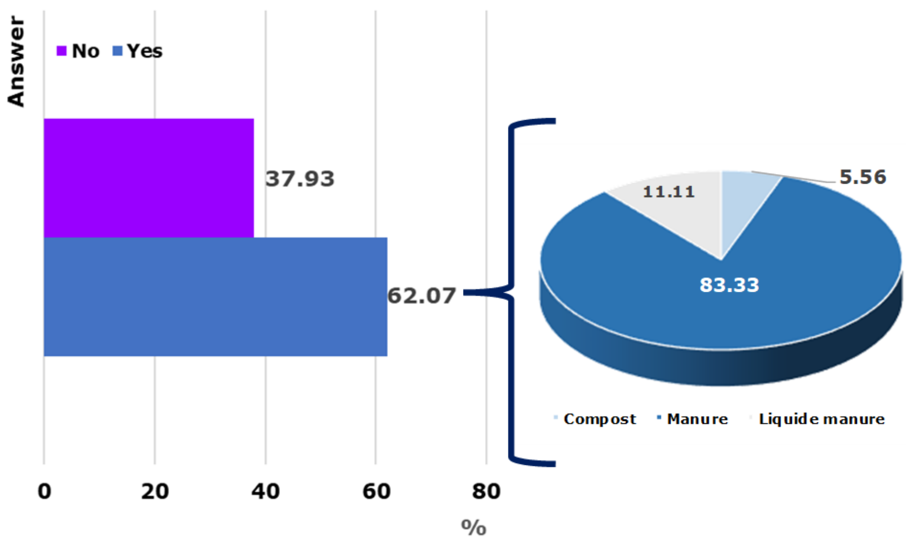

Figure 9. The level of using organic or natural fertilizers for improving soil quality and increase carbon sequestration.

Soil testing for carbon content. Regular soil testing is not widely practiced, with many farmers conducting soil analysis only once every few years. Nevertheless, those who do conduct tests have a better understanding of their soil's carbon dynamics and can make more informed decisions regarding carbon management (Figure 10).

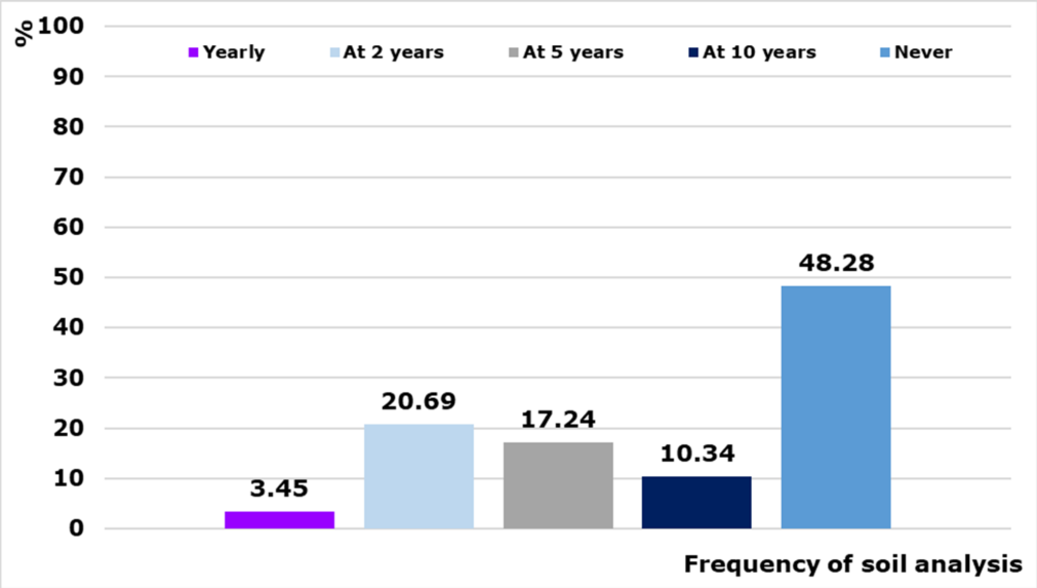

Figure 10. The frequency of using soil analysis to assess the organic carbon content and other important soil traits.

Minimal soil disturbance. No-tillage and minimum-tillage systems were mentioned as effective in preserving the soil's structure and reducing CO_2 emissions from soil disturbance (Figure 11).

Adoption of carbon-enhancing techniques. Farmers in the North-Western Region tend to adopt practices based on their farm size and geographic location. Larger farms often have more resources to implement advanced techniques such as soil analysis and conservation agriculture, while smaller farms focus on traditional methods like crop rotation and fertilizer application.

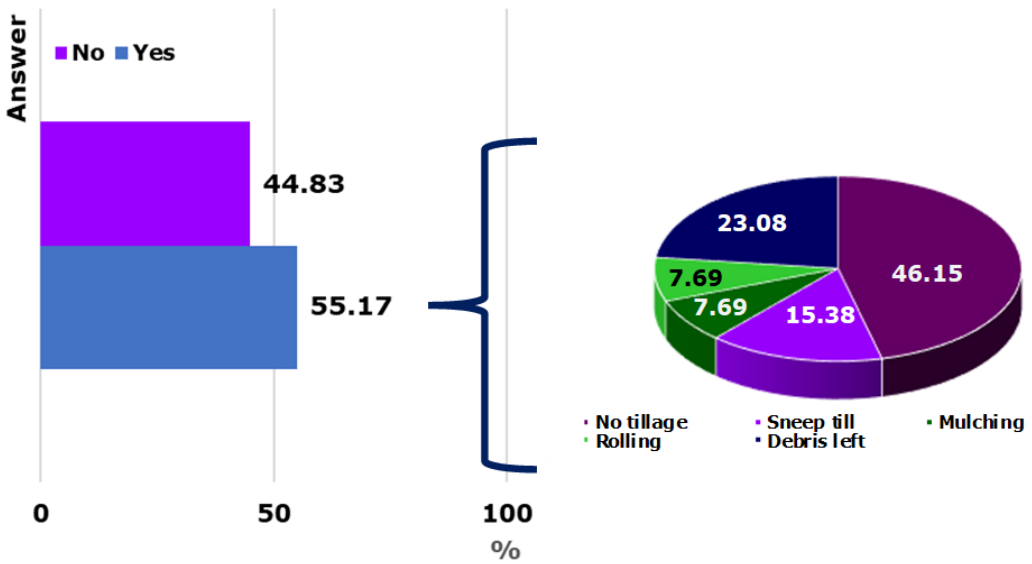

Figure 11. The level of using water preservations technologies for maintaining soil moisture.

Traditional practices and soil management. The agricultural landscape of the North-Western Region of Romania is shaped by both small-scale subsistence farming and larger commercial enterprises, each employing a variety of soil management practices. Traditional practices, such as crop rotation and mixed farming systems, have long been integral to the region’s farming culture. Crop rotation, where farmers alternate different types of crops on the same plot of land over time, helps prevent soil degradation and encourages the retention of organic matter. This, in turn, enhances the soil's ability to store carbon (Figures 12-15).

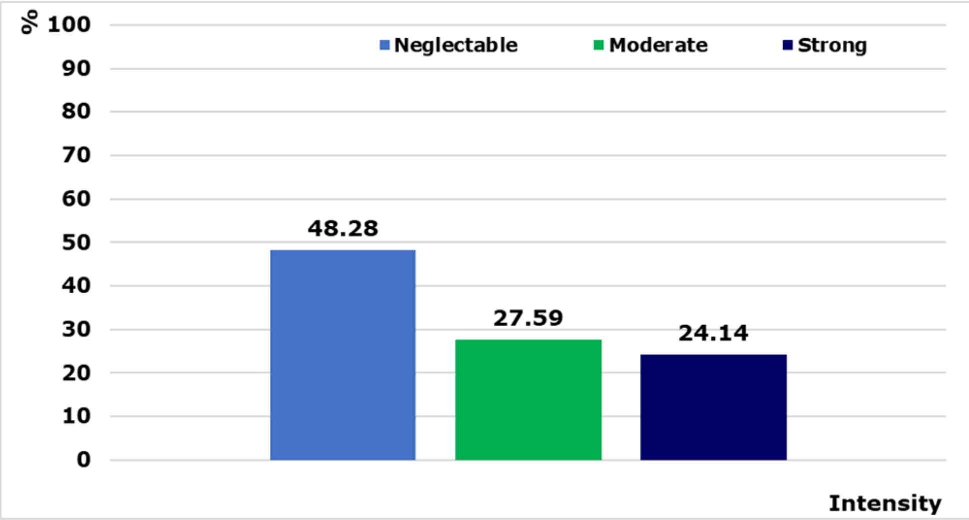

Figure 12. Assessment of the impact of the agricultural practices on organic carbon dynamics in soil.

Another key traditional practice is the use of cover crops, particularly legumes like lucerne (alfalfa) and clover, which are grown during off-seasons to protect and enrich the soil. These cover crops not only prevent erosion but also improve soil structure and promote carbon sequestration through increased organic matter. In the Central Region, farmers widely recognize the benefits of cover crops, especially in improving soil fertility and reducing the need for chemical fertilizers.

However, while these practices are beneficial, they are often labor-intensive and time-consuming, leading to uneven adoption rates among farmers. Smallholder farmers, in particular, may struggle with the resources and knowledge needed to fully implement these techniques, especially when balancing productivity with sustainability.

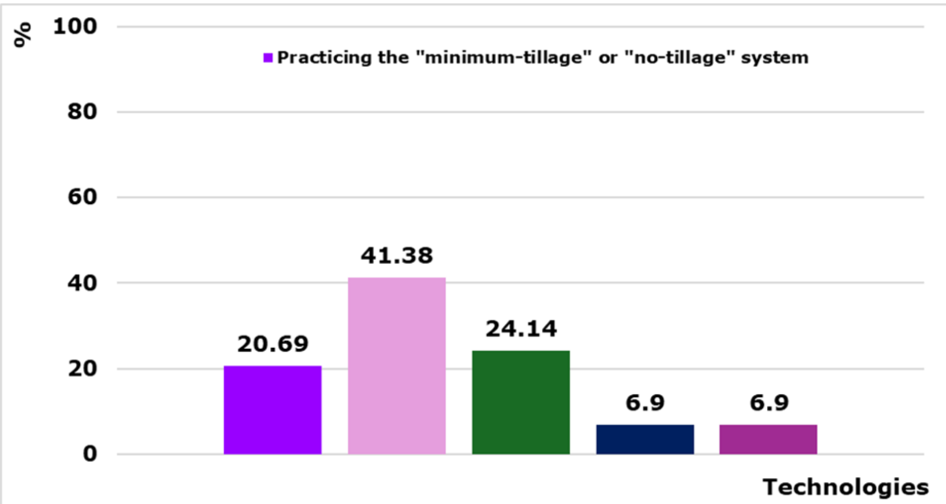

Figure 13. Technologies and agricultural practices observed as most efficient in promotion the carbon sequestration in soil.

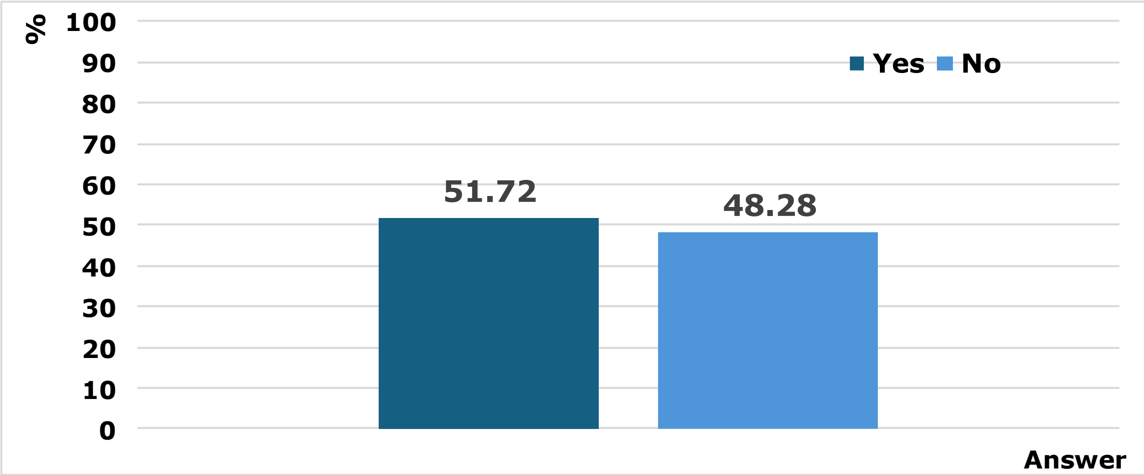

Figure 14. Implementation of preservation agriculture for minimizing the soil disruption and enhance carbon sequestration.

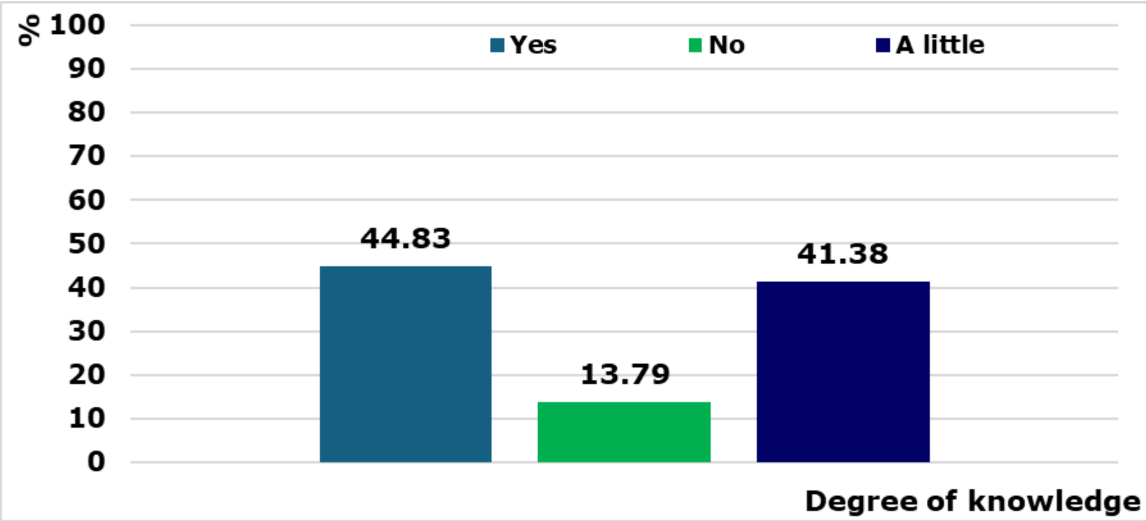

Figure 15. The knowledge of the connections between agricultural practices, soil carbon sequestration and climatic changes.

Modern techniques and innovations. In recent years, modern farming techniques have begun to gain traction in the North-Western Region, driven by a growing awareness of the need for climate-resilient agriculture. Conservation tillage methods, such as no-till and minimum tillage, are increasingly adopted to reduce soil disturbance and maintain carbon-rich organic layers. By minimizing the physical disruption of the soil, these practices help preserve soil structure and reduce the release of carbon back into the atmosphere. Another innovation in the region is the growing use of organic fertilizers and compost as opposed to synthetic chemical inputs. Organic matter such as manure, crop residues, and compost not only provides essential nutrients for crops but also plays a crucial role in enhancing the soil's carbon storage capacity. The integration of organic materials into the soil promotes microbial activity, which is essential for the long-term sequestration of carbon.

Additionally, some farmers are experimenting with agroforestry systems, where trees and shrubs are integrated into crop and livestock systems.

Agroforestry offers multiple benefits, including improved biodiversity, enhanced soil moisture retention, and significant carbon storage both in the soil and in the biomass of the trees themselves. Though still in the early stages of adoption in the Central Region, agroforestry holds significant potential as a sustainable farming practice.

Challenges in promoting carbon storage. Despite the positive trends in some areas, challenges remain economic constraints and lack of education. Many farmers highlighted the high cost of adopting advanced practices such as minimum tillage or purchasing organic fertilizers. Some farmers, particularly older ones, have limited knowledge of carbon storage benefits and its connection to climate change. As climate change continues to be a pressing concern, it is crucial for regional agricultural policies to support farmers in adopting sustainable soil management practices. Providing education, technical assistance, and financial incentives can help bridge the gap between traditional practices and more carbon-efficient methods.

Conclusions. The survey of agricultural practices in the North-Western Region of Romania reveals a growing awareness of carbon storage, though the degree of practice adoption varies. Farmers are incorporating beneficial techniques such as crop rotation, cover crops, and organic fertilization, but there is still room for improvement in practices like no-till farming and regular soil analysis. Promoting these techniques could play a significant role in enhancing soil carbon storage, contributing to both agricultural sustainability and climate change mitigation.

Acknowledgements. This research work was carried out with the support of the Ministry of Agriculture and Rural Development, and also was financed from Project ADER Partnership No. 19.1.1/2023.

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

References

Aires L. M., Pio C. A., Pereire J. S., 2008 Carbon dioxide exchange above a Mediterranean C3/C4 grassland during two climatologically contrasting years. Global Change Biology 14:539–555.

Chen S. P., Lin G. H., Huang J. H., Jenerette G. D., 2009 Dependence of carbon sequestration on the differential responses of ecosystem photosynthesis and respiration to rain pulses in a semiarid steppe. Global Change Biology 15:2450–2461.

Guo Y., Amundson R., Gong P., Yu Q., 2006 Quantity and spatial variability of soil carbon in the conterminous United States. Soil Science Society of America Journal 70:590–600.

Hunt J. E., Kelliher F. M., McSeveny T. M., Ross D. J., Whitehead D., 2004 Long-term carbon exchange in a sparse, seasonally dry tussock grassland. Global Change Biology 10:1785–1800.

Lal R., Delgado J. A., Groffman P. M., Millar N., Dell C., Rotz A., 2011 Management to mitigate and adapt to climate change. Journal of Soil and Water Conservation 66:276–285.

Li Z., Jiang X., Pan X., Zhao Q. G., 2001 Organic carbon storage in soils of tropical and subtropical China. Water, Air, & Soil Pollution 129:45–60.

Lin Y., Slessarev E. W., Yehl S. T., D’Antonio C. M., King J. Y., 2019 Long-term nutrient fertilization increased soil carbon storage in California grasslands. Ecosystems 22:754–766.

Liu Y., Li C., Cai G., Sauheitl L., Xiao M., Shibistova O., Ge T., Guggenberger G., 2023 Meta-analysis on the effects of types and levels of N, P, and K fertilization on organic carbon in cropland soils. Geoderma 437:116580.

Meyers T. P., 2001 A comparison of summertime water and CO_2 fluxes over rangeland for well watered and drought conditions. Agricultural and Forest Meteorology 106:205–214.

Poeplau C., Don A., 2013 Sensitivity of soil organic carbon stocks and fractions to different land-use changes across Europe. Geoderma 192:189-201.

Schoeneberger M. M., 2009 Agroforestry: working trees for sequestering carbon on agricultural lands. Agroforestry Systems 75:27-37.

Shi L.-H., Li C., Tang H.-M., Cheng K.-K., Li W.-Y., Wen L., Xiao X.-P., 2021 Effects of Long-term fertilizer management on soil labile organic carbon fractions and hydrolytic enzyme activity under a double-cropping rice system of Southern China. Ying Yong Sheng Tai Xue Bao 32:921–930.
Tilman D., Fargione J., Wolff B., D'Antonio C., Dobson A., Howarth R., Schindler D., Schlesinger W. H., Simberloff D., Swackhamer D., 2001 Forecasting agriculturally driven global environmental change. Science 292:281–284.
Triberti L., Nastri A., Baldoni G., 2016 Long-term effects of crop rotation, manure and mineral fertilisation on carbon sequestration and soil fertility. European Journal of Agronomy 74:47–55.
Xu X., Zhang W., Xu M., Li S., An T., Pei J., Xiao J., Xie H., Wang J., 2016 Characteristics of differently stabilised soil organic carbon fractions in relation to long-term fertilisation in brown earth of Northeast China. Science of the Total Environment 572:1101–1110.
Zhang Q., Zhou W., Liang G., Sun J., Wang X., He P., 2015 Distribution of soil nutrients, extracellular enzyme activities and microbial communities across Particle-Size Fractions in a Long-Term Fertilizer Experiment. Applied Soil Ecology 94:59–71.
Zotarelli L., Alves B. J. R., Urquiaga S., Boddey R. M., Six J., 2007 Impact of tillage and crop rotation on light fraction and intra- aggregate soil organic matter in two oxisols. Soil and Tillage Research 95:196–206.

Received: 16 September 2024. Accepted: 03 October 2024. Published online: 28 October 2024.
Authors:
Firuţa Camelia Oroian, Faculty of Horticulture and Business in Rural Development, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Manastur, 400372 Cluj-Napoca, Romania, e-mail: camelia.oroian@usamvcluj.ro
Antonia Odagiu, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Manastur, 400372 Cluj-Napoca, Romania, e-mail: aodagiu@gmail.com
Olga Vizitiu, National Research and Development Institute for Soil Science, Agrochemistry and Environment Bucharest, Bd. Marasti, no 61, Bucharest, Romania, e-mail: olga.vizitiu@icpa.ro
Iulia Cristina Mureșan, Faculty of Horticulture and Business in Rural Development, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Manastur, 400372 Cluj-Napoca, Romania, e-mail: iulia.muresan@usamvcluj.ro
Petru Burduhos, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Manastur, 400372 Cluj-Napoca, Romania, e-mail: petru.burduhos@usamvcluj.ro
Ioan Valentin Petrescu-Mag, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Manastur, 400372 Cluj-Napoca, Romania, e-mail: ioan.mag@usamvcluj.ro

How to cite this article:
Oroian F. C., Odagiu A., Vizitiu O., Mureșan I. C., Burduhos P., Petrescu-Mag I. V., 2024 Carbon storage assessment: Note I – usual practices in the North-Western region of Romania. AES Bioflux 16(1):50-59.