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THEORETICAL ASSESSMENT OF SUSTAINABLE SOIL MANAGEMENT PRACTICES AND THEIR CONTRIBUTION TO ACHIEVING FARM AND CLIMATE GOALS

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Abstract. The new European strategy envisages addressing the problems of climate change, which significantly affects the agricultural sector, as, for example, in Latvia it accounts for 22% of all greenhouse gas emissions. However, the data show that since joining the European Union, the main objective has been to increase the productivity of the sector. Therefore, in order to achieve the set climate goals, it is necessary to evaluate the implementation of practices corresponding to the goals set, where, as part of this study, we examine the theoretical benefits of sustainable soil management, as well as evaluate the information available in literature sources about the current situation.

The data show that currently, the implementation of such practices is in the process, as it has been observed that it is affected by both technical and financial problems, where it is expected that the implementation of these practices will increase. As well as it is concluded that sustainable soil management practices ensure the achievement of goals of different categories - financial, environmental, and social. Therefore, to objectively evaluate the benefits, a complex approach is needed.

Key words: cover cropping, no-till, minimal tillage, carbon cycle, northern Europe.

JEL code: Q10, Q56

Introduction

Agriculture is a vital sector of Latvia's economy, contributing approximately 4.6% of the country's GDP and employing over 3% of the population. However, the sector also contributes to greenhouse gas emissions (GHG), with approximately 22% of Latvia's emissions coming from the agricultural activities, where the trend of the sector GHG is only increasing (European Parliament, 2021). At the same time European Union (EU) has set a goal of reducing its GHG emissions by 55% by 2030, compared to 1990 levels. This target was set in 2020 as part of the European Green Deal, which aims to make Europe carbon-neutral by 2050. To achieve this goal, the EU is investing in different climate-efficient measures to reduce emissions, where one of them is carbon farming. European Commission implies that even at the low end of estimated potential, carbon farming could offset 26% of the EU's annual agricultural emissions, which in 2019 were 389 Mt CO_2 yr^{-1} (McDonald et al., 2021).

Carbon farming practices are increasingly recognized as a way to mitigate the environmental impact of agriculture and offer economic benefits for farmers. For instance, cover cropping can reduce soil erosion and nutrient loss up to 40%, while intercropping can diversify crops and generate additional income streams. These practices can also sequester carbon in the soil or plant biomass, reducing GHG emissions and supporting climate change mitigation efforts. Despite these potential advantages, Latvian farmers has implemented only limited amount of carbon farming practices, that increase soil organic carbon content. Such practices could reduce CO_2 emissions by 0.5 to 7 t CO_2 per ha^{-1} annually. (McDonald et al., 2021). This may be due in part to a lack of knowledge and awareness of the benefits of these practices, as well as financial and technical barriers (Vanino et al., 2023). Therefore, a theoretical analysis of all kind of benefits of carbon farming practices in Latvia is important to encourage the adoption of these practices by farmers. In this paper we **aim** to highlight the potential benefits of sustainable soil management practices for individual farmers and the broader economy, while also contributing to climate change mitigation efforts. Accordingly, the **tasks** are as follows: 1. analyse the theoretical framework for sustainable soil management and its contribution from the agronomical perspective; 2. evaluate how such practices fit into

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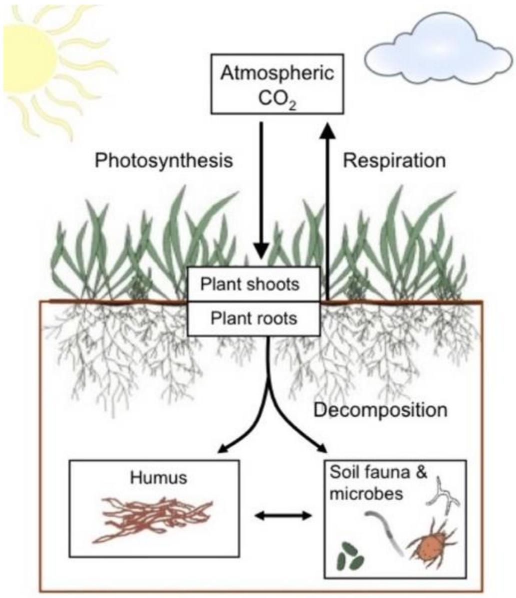
the agricultural sector of Latvia; 3. define the outcome of the implemented practices and their belonging to a specific beneficial category.

Research results and discussion

1. Theoretical framework of mineral soils, soil organic carbon and soil fertility

Mineral soils make up about 90% of the Earth's land surface and are formed through the weathering of rock and other materials over time. They consist of mineral particles, like sand, silt, and clay, which accumulate with organic matter and microorganisms to create a complex soil ecosystem. Mineral soils vary depending on climate, geology, and topography, with arid regions having more sand and humid regions having more clay and organic matter. They support plant growth, provide habitat for soil organisms, and cycle important nutrients. At the same time an important component of mineral soils is soil organic carbon (SOC), which consists of carbon-containing organic matter such as plant and animal residues, decayed organic matter, and living microorganisms. It is an important soil component that is essential for maintaining soil health and productivity. SOC is formed through the process of photosynthesis, in which plants absorb carbon dioxide from the atmosphere and convert it into organic compounds, which are then deposited in the soil (Fig. 1.) (Ontl, Schulte, 2012; Daryanto et al., 2020).



Source: Ontl, Schulte, 2012

Fig. 1. **Soil organic carbon (SOC) cycle in soil**

When organic matter enters the soil, it can be broken down by soil microorganisms, releasing nutrients that can be taken up by plants, as well as contributing to the formation of stable soil aggregates and soil structure. SOC is an important part of the global carbon cycle because it can act as a carbon sink, helping to mitigate the effects of climate change by sequestering carbon from the atmosphere, where carbon dioxide is one of the greenhouse gas emissions responsible for global warming. However, human activities such as land-use change and intensive agricultural practices can lead to SOC loss, which can negatively affect soil health and exacerbate the effects of climate change. The amount and quality of SOC in mineral soils depend on a range of factors, including climate, vegetation type, land use, and soil management practices and it can influence soil properties such as water-holding capacity, nutrient availability, soil structure and biodiversity and also carbon sequestration (Aertsens et al., 2013; McDonald et al., 2021).

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FAO has identified key practices that increase organic matter, and hence carbon, in soil. Mainly emphasizing the increase of biomass - more efficient plant cultivation, ensuring the water regime and the need for nutrients, as well as emphasizing the incorporation of plant residues into the soil, which can be achieved by cover cropping, leaving plant residues or straw on the field, and the use of organic fertilizers (manure, digestate). In addition, an essential practice is the preservation of organic matter in the soil, or "conservation", which is basically done by reducing mechanical tillage, choosing minimal tillage or even no tillage (FAO, 2017). The same is stated also by various authors, where in addition to FAO practices, there are included also organic farming and legume crop incorporation in crop rotations (Söderström et al., 2014; Hajduk et al., 2015).

Analysing soil management practices that can increase SOC sequestration in croplands, available information shows a great variability, often ranging from 0.1 to over 1.0 t C ha^{-1} yr^{-1}, where 1 t C is equivalent to 3.67 t CO_2 (Paustian et al., 2019). For example, change in tillage practice may sequester from 0.37 to even 1.06 and 1.39 t CO_2 ha^{-1} yr^{-1} (Aertsens et al., 2013). Research conducted in temperate climate conditions shows, that no-till benefits most of the time are associated with plant residues left on field as well as cover crop and crop rotational changes, where it is also found out, that cereal straws may sequester from 0.2 to 0.7 t CO_2 ha^{-1} yr^{-1} (Kertesz, Madarasz, 2014), while the use of cover crops, combined with reduced tillage, can increase the organic carbon stock more rapidly. Practising them yearly, the amount of stored carbon can reach 0.58 t CO_2 ha^{-1} yr^{-1} (Gay et al., 2009). Also Niggli et al. (2009) estimates that reduced tillage combined with organic fertilizers and high plant biomass can sequestrate up to 1.8 t CO_2 ha^{-1} yr^{-1}.

Evaluating SOC sequestration by using sustainable soil management practices, it is concluded, that overall EU potential range from 9 Mt CO_2 yr^{-1} to 56-70 Mt CO_2 yr^{-1} (Roe et al., 2021). It is also important to note that a large part of Europe's soils are mineral soils, which means that changes in soil management are essential not only for the potential capture of emissions, but also for the preservation of their fertility, as they require sustainable management, which also includes the return of biomass to it (Wiesmeier et al., 2019). However, at the same time, it must be taken into account that even within the borders of Europe, climatic conditions vary significantly, for example, Northern Europe - from Poland up to Norway and Finland together covers 74% of all peatlands and is characterized by particularly high air humidity. Also, in this region, soil management is essential to reduce carbon emissions. On the other hand, for example, in southern Europe, as in Spain, agroforestry is mentioned as one of the most effective ways to limit soil degradation (Roe et al., 2021). Therefore, it is essential to identify the climatic conditions of the specific territory, as well as the practices used by farmers and how they can be reconciled with the solutions proposed in the theoretical literature.

2. Implications for Latvian agriculture

Agricultural sector is the third largest emitter of GHG emissions in Latvia, which in 2020 emitted a total of 21.5% of the total emissions in the country (2250.88 kt CO_2 eq.). The largest part - 51.6% - is made up of emissions from agricultural soils, 38% animal intestinal fermentation processes, while the remaining 7.2% is manure management and 3.1% liming and urea use (LVGMC, 2022).

As 51.6% of the emissions comes from agricultural soils, country's latest summary shows, that in Latvia there are 2.3 Mha, where 1.97 Mha or 89.7% are classified as cultivated land. The largest sector is grain cultivation, the sown area of which in 2021 was 777.4 thousand hectares or 59.6% of the entire sown area. Data analysis in a 20-year long period shows that the approximate distribution between crops is 55% winter and 45% spring crops, and evaluating the sowing structure of cereal areas, it is concluded that the largest areas are sown with winter wheat - 54.9% of the entire cereal area. Beside grains, also rapeseed has an important role in the agricultural sector of Latvia, where in 2021 its sowing area occupied 147 Kha – 132 Kha of winter and 14 Kha of spring rapeseed (Zemkopibas ministrija, 2022).

There is currently very little information on soil cultivation practices, but after evaluating the data available from the EU and FAOSTAT as well as practical experience, it can be concluded that at least 65% of the entire arable land area is plowed, less than 10% is cultivated with the minimum type of soil cultivation, while approximately 3% with direct sowing, whereas information is not available for 22% of the area (Agri-environmental indicator…, 2020). And it is stated that reduced tillage systems have the same or even higher yield than conventional-till, at least in short term (Auzins et. al., 2021).

Therefore, it can be concluded that, although no-till tillage is gradually entering the agricultural sector of Latvia, traditional tillage still dominates.

Evaluating data of cover cropping and undersows in Latvia, it can be concluded that these specific practices in arable land areas are increasing – in 2019 they were 175 Kha, while in 2021 already 214 Kha. Similar situation can also be observed in the cultivation of nitrogen-fixing crops – in 2019, they were 307 Kha, and in 2021 already 316 Kha (Zemkopibas ministrija, 2022).

Although the existing information on the types of tillage, as well as cover crop sowing areas is relatively little, it is expected that it will be more widely available in the coming years, as the new CAP 2023-2027 envisages Ecoschemes support for both the documentation of the tillage types and cover crop sowing (The commission approves…, 2022).

Nevertheless, theoretical literature shows that the mentioned soil management practices contribute to the good properties of soil as a resource, it has been concluded that their integration in farms is a relatively big challenge. For this reason, in the following, we will look at the main factors influencing the transition to more sustainable practices. In addition, it is important to note that there is a significant lack of qualitative method studies in Latvia that would analyse the farmers' position and general attitude towards the use of sustainable practices. The base of the existing researches mainly emphasizes the increase of productivity and its analysis - the correlation of soil cultivation methods and yield, and the economic justification is studied, but there is a significant lack of research that would explain the psychological factors. Therefore, studies from all over Europe will be used to analyse the main challenges, with an emphasis on the northern part of Europe.

Soil conditions and yield variability: The possibility for production fluctuation or losses is one of the main worries that farmers may have when thinking about no-till operations. However, findings show that no-till methods resulted in either no yield loss or a gain in yields (Daryanto et al., 2020). No-till boosted crop output by an average of 6.6%, according to a meta-analysis of 28 research comparing it to conventional tillage techniques (Pittelkow et al., 2015). In the long term, using no-till farming techniques can boost crop yields, despite some short-term production variability. However, it's important to note that not all soil types are suitable for no-till. For instance, soils with high clay content may become compacted and resist water penetration, making conservation tillage a more suitable option in certain cases, and, as an example, no-till also can result in lower soil temperatures and slower seedling emergence in soils with large levels of surface residue. However, studies have shown that incorporating no-till with techniques like cover cropping can lessen these issues and enhance soil health (Kravchenko et al., 2017).

Pest, weed and fertilizer management: While it is true that tillage plays a crucial role in managing weeds, pests, and nutrients, the perception that no-till farming requires more inputs is not entirely unfounded. Eliminating or reducing tillage without implementing alternative management techniques may result in increased use of herbicides, pesticides, and fertilizer (Kertesz, Madarasz, 2014). Nevertheless, such negative consequences can be prevented by utilizing alternative strategies. For optimal results with no-till farming, it is crucial to consider three key factors. Firstly, it should be a permanent practice to enable soil life to thrive and prevent harm to soil structuring processes. Secondly, a permanent cover of organic material is necessary to protect the soil from environmental factors and provide nourishment for soil organisms, resulting in benefits such as carbon sequestration, erosion control, and water infiltration. Finally, sowing a variety of crops, either by rotating them or sowing them together, is crucial to imitate the stability and resilience of natural systems (Daryanto et al., 2020).

For instance, research has shown that adopting cover crops and diverse crop rotations can assist to reduce weed pressure over time - the right species choice is important, where different mixtures is able to provide nutrient retention and to reduce the use of herbicide due to their phytosanity properties. At the same time, however, it should be borne in mind that their sowing properties, such as sowing rate and time, are also important factors (Fraiser et al., 2017; Travlos et al., 2017).

Equipment and material costs: When conducting a study on the position of Scandinavian farmers regarding cover cropping, it was concluded that, mainly as a result of lack of knowledge and also high costs, farmers are not motivated to sow cover crops. The respondents mainly point out that cash crops are mostly winter species, which means that the time of harvest and the sowing of the following winter crops is quite a busy time, which accordingly makes it difficult to sow cover crops, because the priority is cash crops, which bring immediate monetary result. Likewise, the interviewed farmers stated that they are not sure that cover crops provide the expected result and some even admitted that when making the basic crop fertilization plan, they do not take into account the generated nutrients by cover cropping. And they also mentioned the high implementation costs, for example seed costs, but at the same time only 20% of farmers have ever tried to use their own seed material. Looking at the profile of a farmer who has integrated cover crops into his crop rotation, it can be concluded that they are mostly with the higher education, younger than 50 years, farmers with experience in the cultivation of special crops, and often they are organic farmers (Peltonen-Sainio et al., 2023).

No-till is mainly associated with high equipment costs – sowing machinery, cultivator and others, but at the same time, reduced tillage can significantly save operational costs, as well as depending on the climatic conditions, improve the yield of crops due to the improvement of the qualitative properties of the soil (Deines et al., 2019). It is also defined that reduced tillage also affects the yield, but the main cause of this is mostly high soil compaction, nutrient deficiencies, and/or high weed pressure (Pittelkow et al., 2015), which can be corrected by higher vegetation index or, for example, establishing cover crops. It is expected that reduced tillage will continue to grow, where the main driver is reduced operating, labour, and input costs, and on enhancing environmental benefits, which will affect soil erosion. This will also be facilitated by the new CAP, where eco-schemes provide financial support for minimal or no-tillage (The commission approves…, 2022).

Lack of knowledge. Vanino and others (Vanino et al., 2023) conducted a study where they researched sustainable soil management position of various European regions, including Latvia, and it was concluded that one of the most important challenges is the exchange of knowledge. Although the challenges in soil conservation differ in European regions, all industry stakeholders jointly concluded that the main problems are: 1. creation of new and appropriate solutions; 2. effective exchange of knowledge; and 3. transfer of the information obtained through research to the end-consumer, or in this case, how the scientific institutions deliver the information to the farmers. These problems have also been highlighted by Demenois et al. (2020), where it was concluded that most of the limitations are not entirely technical, but

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rather refer to the low level of knowledge, lack of experience and skills, proper management of processes, which also results in the ability to fully evaluate social, environmental and financial benefits.

Summarizing the above, it can be concluded that mainly two problems arise: 1. lack of knowledge and thus faith in the practices to be implemented and 2. the ability to fully assess the financial as well as additional benefits. Although these problems complement each other, they are fundamentally affected by different factors, so in the following we will consider a theoretical framework for the evaluation of sustainable practices.

3. Definition of benefits in implementing sustainable soil management practices

Adopting sustainable soil practices can provide a range of benefits that extend beyond just enhancing soil health. They can improve crop yields, reduce production and operational costs, and increase farms profitability (Ontl, Schulte, 2012). In addition, these practices can also have a significant impact on mitigating climate change by decreasing GHG emissions from fertilizer use and tillage and increasing carbon sequestration in the soil, helping to improve water quality by reducing runoff and erosion, retaining water in the soil, and enhancing biodiversity, wildlife habitat, and ecosystem services like pollination and pest control (Aertsens et al., 2013). Overall, the adoption of sustainable soil practices can result in numerous positive outcomes for farmers, the environment, and society as a whole.

Table 1

Benefits of sustainable soil management (SSM) practice implementation and distribution by category (F – financial, E – environmental, S – social).

Beneficial outcome	Category			Description	References
	F	E	S		
Soil fertility increase	x	x		SSM promotes beneficial soil organisms like microbes, fungi, and earthworms, which enhance soil health, nutrient cycling, and plant growth. This leads to more resilient and productive soil that can better withstand pests, diseases, and climate change impact like droughts, floods etc and produce higher yields.	(5) (7) (8)
Higher crop yields	x		x	SSM improves soil organic matter increase, improve nutrient cycling, which leads to more productive crop growing and resilient soil. Various authors indicate, that crop yield may increase from 5 to 15%. This leads to higher farm profitability and overall economic development.	(1) (3) (6) (7)
Input and operational cost reduction	x	x	x	Minimal and no-tillage can reduce the need for fuel, machinery and labour, while saving time resources. Cover cropping can reduce the need for synthetic fertilizers and pesticides.	(1) (3) (5)
Improved water and air quality		x	x	SSM can have a profound impact on improving water and air quality. Through the reduction of soil erosion and runoff, and the promotion of healthier soils that retain water and nutrients more effectively, these practices can effectively mitigate the negative impact of nutrient and sediment runoff on downstream ecosystems and aquatic habitats. Particularly, these practices help to address the pressing issue of nitrate and phosphorous contamination, which leads to eutrophication. As well as reduce ammonia emissions.	(3) (5) (7) (8)
Reduced GHG emissions		x	x	Tillage change from conventional to reduced and no-till can decrease CO_2 emissions by 33 to 46%. As well as reduced fertilizer input reduces ammonia and nitrate emissions.	(1) (5) (7) (8)
Reduced soil erosion	x	x		Cover cropping and reduced tillage can help to improve soil structure and reduce erosion, which can help to protect water quality and prevent soil loss. This leads to healthier soil material as well as environmental benefits.	(5) (7) (8)
Biodiversity enhancement		x	x	SSM practices like cover cropping, intercropping and reduced tillage promote plant diversity, which exposes the soil to a wider range of organic compounds. This supports a greater variety of soil organisms and creates a more complex and resilient soil ecosystem, which attracts also other species e.g. pollinators, birds and others.	(7) (8)
Exchange of knowledge and cooperation	x	x	x	SSM can encourage collaboration and knowledge sharing among farmers, researchers, and other stakeholders in agriculture. This can promote more sustainable and fair food systems and encourage involved parties towards new innovations and best practices.	(2) (4) (9)
Additional income streams	x	x	x	SSM also contributing to carbon farming practices provides an opportunity to participate in different carbon sequestration schemes from private and governmental sector. Farms can receive additional subsidies for implementing such practices, as well as certifies sequestered carbon on their soils and receives payments for each ton of CO_2.	(8)
Improved food security	x		x	Food security improvement by boosting crop yields, enhancing food quality, and increasing nutritional value. This leads to more resilient and productive agricultural systems, which can provide better access to healthy food for local communities.	(1) (2) (3) (6) (7)
Enhanced rural livelihoods	x		x	Improving soil management can boost farm productivity and profitability, create job opportunities, and support local economic development, ultimately enhancing rural livelihoods.	(2) (4)

(1) Auzins et al., 2021; (2) Peltonen-Sainio et al., 2023; (3) Kertesz, Madarasz, 2014; (4) Rust et al., 2020; (5) Daryanto et al., 2020; (6) Pittelkow et al., 2015; (7) Ontl, Schulte, 2012; (8) Aertsens et al., 2013; (9) Aznar-Sánchez, 2020

Source: author's construction

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By summarizing the most frequently mentioned benefits in the theoretical literature and grouping them accordingly to their usefulness in a specific category, it can be concluded that all of the mentioned benefits fall into more than one category. As well as at least 3 of them creates financial, environmental and social benefits.

Evaluating the proposed practices and benefits at the national level, it can be concluded that no-till is still relatively underdeveloped, while minimal tillage is becoming more and more relevant (Eurostat, 2020). This can be associated both with the high costs required for the renewal of the machinery, as well as with the additional amount of knowledge to be acquired, which is necessary to change the usual way of farming (Peltonen-Sainio et al., 2023). However, when evaluating the changes in the subsidy paid out over the years, it can be seen that both the area of legumes and the establishment of cover crop areas are constantly increasing (Zemkopibas ministrija, 2022).

Looking at the GHG emissions and the current situation in Latvia, it can be concluded that emissions from soil management consists of direct dinitrogen emissions from the following factors - organic soil management, the use of nitrogen mineral fertilizer, organic manure and other types of organic fertilizers, post-harvest residues and pastures. Indirect emissions of nitrous oxide from managed soils are determined by evaporation and leaching processes. They are an important source of emissions, accounting for 51.6% of the total emissions of the agricultural sector in 2020, in which nitrogen mineral fertilizers accounted for the majority of total agricultural emissions, where the share is as follows: soil management (34%), managed organic soils (24%), post-harvest residues (15%). Emissions from pastures and nitrogen mineral fertilizers have been growing the fastest in recent years. This can be explained by the increase in the number of beef cattle in the pastures and the increase in the sowing area (LVGMC, 2022). This factor could also be improved to some extent by including more sustainable use of soil treatments. It can also be concluded that this will be facilitated by the new CAP, where the involvement of farmers in the implementation of sustainable practices is encouraged by applying for support of eco-schemes, where, for example, Eco-scheme No. 1 provides EUR 43 support per hectare, if the crop rotation is diversified and the number of several species is introduced depending from managed hectares; Eco-scheme No. 2 contributes to improving the quality of water and soil, limiting erosion, reducing the use of PPP, preserving biological diversity, incl. preservation of pollinators, where the amount of support varies, but, for example, by integrating cover crops, it is possible to receive 80 EUR per hectare, as well as Eco-scheme No. 4 envisages promoting reduced soil cultivation methods, ensuring the improvement of the natural fertility and health of the soil, air and moisture circulation, increasing organic content and the amount of phosphorus in the soil - by introducing reduced tillage practices, it is possible to receive financial support of 15 EUR per hectare (*Kopejas Lauksaimniecibas*…, 2023).

It is also important to note that there are various types of additional income streams that are increasingly developing in the agricultural market, for example, voluntary carbon market (VCM) mechanisms, which provide that by integrating sustainable soil management practices, it is possible to certify the tons of CO_2 sequestrated to the soil, which can then be sold. Currently, in 2023, there are two companies in Latvia that already offer their programs - the Danish company Agreena and the Estonian company eAgronom, which provide that farmers can sequester up to 0.5 to 2 t of CO_2 ha^{-1} yr^{-1} in specific climatic conditions (Dienas bizness, 2022; Lauku bizness, 2023). It is expected that this market will continue to develop, where a significant contributing factor will be the carbon removal framework developed by the European Commission, the purpose of which is to develop a binding VCM framework and guidelines for all the member states (Hunt, 2022).

The obtained information shows that the benefits are not unambiguous, as often assessed by farmers and other representatives of the industry (Peltonen-Sainio et al., 2023), so when considering the implementation of any sustainable soil management practice, the additional contribution that it brings must be taken into account, which obviously makes it difficult to evaluate it from monetary perspective.

Conclusions

1) Sustainable soil management refers to the inclusion of environmentally friendly practices in the daily production process - minimal tillage or no-till technology, cover crop and intercrop cultivation, use of organic fertilizers, crop rotation diversification. The aim of these practices is to increase soil organic matter, reduce nutrient leaching and soil erosion, and reduce emissions from agricultural sector.
2) Currently, the implementation of such practices is in the process, as it has been observed that it is affected by both technical and financial problems, where it is expected that with the actualization of climate change and the implementation of relevant political strategies, popularity of these practices will increase.
3) By summarizing the benefits of implementation of sustainable soil practices, it can be concluded that each of them ensures the achievement of goals of different categories - financial, environmental and social. Therefore, in order to objectively evaluate the benefits, a complex approach must be used, which is often a challenge at the farm level.

Bibliography

1. Aertsens, J., De Nocker, L., Gobin, A. (2013). Valuing the carbon sequestration potential for European agriculture. *Land Use Policy*, Volume 31, p. 584-594. Retrieved: https://doi.org/10.1016/j.landusepol.2012.09.003 .
2. Eurostat. (2020). *Agri-environmental indicator - tillage practices*. Retrieved: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_tillage_practices&oldid=581849#Analysis_at_country_level
3. Auzins, A., Kazotnieks, J., Leimane, I., Miglavs, A. (2021). Assessment of carbon dioxide emissions from different tillage systems. *Engineering For Rural Development*: Jelgava. Retrieved: https://www.tf.llu.lv/conference/proceedings2021/Papers/TF332.pdf
4. Aznar-Sánchez, J.A., Velasco-Muñoz, J.F., López-Felices, B., del Moral-Torres, F. (2020). Barriers and Facilitators for Adopting Sustainable Soil Management Practices in Mediterranean Olive Groves. *Agronomy 2020*, 10, 506. https://doi.org/10.3390/agronomy10040506
5. European Parliament (2021). *Climate action in Latvia*. Retrieved: https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/696194/EPRS_BRI(2021)696194_EN.pdf
6. Daryanto, S., Wang, L., Jacinthe, P.A. (2020). No-till is challenged: Complementary management is crucial to improve its environmental benefits under a changing climate. *Geography And Sustainability*, Vol. 1, Issue 3, pp 229-232. https://doi.org/10.1016/j.geosus.2020.09.003.
7. Deines, J.M., Wang, S., Lobell, D.B. (2019) Satellites reveal a small positive yield effect from conservation tillage across the US Corn Belt. *Environmental Research Letters*, Vol. 14, Issue 124038. DOI 10.1088/1748-9326/ab503b
8. Dienas bizness. (2022). *Pirmie lauksaimnieki Latvijā saņem samaksu par aprēķinātajiem oglekļa kredītiem*. Retrieved: https://www.db.lv/zinas/ietekme-uz-vidi-neatkarigas-parbaudes-kas-janem-vera-lai-iesaistitos-oglekla-tirgu-510538
9. FAO. (2017). *Voluntary Guidelines for Sustainable Soil Management*. Retrieved: https://www.fao.org/3/bl813e/bl813e.pdf
10. Frasier, I., Noellemeyer, E., Amiotti, N., Quiroga, A. (2017). Vetch-rye biculture is a sustainable alternative for enhanced nitrogen availability and low leaching losses in a no-till cover crop system. *Field Crops Research*, Vol. 214, pp.104-112. https://doi.org/10.1016/j.fcr.2017.08.016.
11. Gay, S., Louwagie, G., Sammeth, F., Ratinger, T., Cristoiu, A., Marechal, B., Prosperi, P., Rusco, E., Terres, J., Adhikari, K., Bodis, K., Cenci, R., Gardi, C., Houskova, B., Reuter, H., Rodriguez-Lado, L., Stolbovoy, V., Toth, G., Schuler, J., Kutter, T., Funk, R., Helming, K., Doublet, S., Houtin, M., Pointereau, P., (2009). Addressing Soil Degradation in EU Agriculture: Relevant Processes, Practices and Policies - Report on the project Sustainable Agriculture and Soil Conservation (SoCo). Luxembourg: European Commission. DOI: https://data.europa.eu/doi/10.2791/69723
12. Hajduk, E., Właśniewski, S., Szpunar-Krok, E. (2015). Influence of legume crops on content of organic carbon in sandy soil. *Soil Science Annual*, Vol. 66, pp. 52-56. DOI: 10.1515/ssa-2015-0019.
13. Hunt, C. (2022). *EU proposes certification framework for carbon removals*. Retrieved: https://www.abatable.com/blog/eu-carbon-removal-certification-framework

14. Kertész, B., Madarász, A. (2014). Conservation Agriculture in Europe. *International Soil and Water Conservation Research*, Vol. 2, No. 1, pp. 91-96.
15. *Kopējās Lauksaimniecības Politikas stratēģiskais plans*. (2023). Retrieved: https://www.zm.gov.lv/lv/media/5409/download?attachment
16. Kravchenko, A. N., Toosi, E. R., Guber, A.K., Ostrom, N. E., Yu, J., Azeem, K., Rivers, M. L., Robertson, G.P. (2017). Hotspots of soil N2O emission enhanced through water absorption by plant residue. *Nature Geoscience*, Vol. 10, pp. 496-500.
17. Zemkopības ministrija. (2022). Latvijas Lauksaimnieciba 2021. Retrieved: https://www.zm.gov.lv/lv/media/4617/download?attachment
18. Lauku bizness. (2023). *Sāk oglekļa noglabāšanas sertifikāciju*. Retrieved: https://laukubizness.lv/zinas/sak-oglekla-noglabasanas-sertifikaciju/
19. LVGMC (Latvian Environment, Geology and Meteorology Centre). (2022). *Greenhouse gas inventories summary 2022*. Retrieved: https://videscentrs.lvgmc.lv/files/Klimats/SEG_emisiju_un_ETS_monitorings/Zinojums_par_klimatu/SEG_kopsavilkums/Majas_lapai_LVGMC_2022_seginvkopsavilkums.pdf
20. McDonald, H., Frelih-Larsen, A., Lóránt, A., Duin, L., Pyndt Andersen, S., Costa, G., Bradley, H. (2021). Carbon farming – Making agriculture fit for 2030. Study for the committee on Environment, Public Health and Food Safety (ENVI), Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg.
21. Niggli, U., Fließbach, A., Hepperly, P., Scialabba, N. (2009). Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems. FAO.
22. Ontl, T.A., Schulte, L.A. (2012) Soil Carbon Storage. *Nature Education Knowledge*, Vol. 3, Issue 10, p.35
23. Paustian, K., Larson, E., Kent, J., Marx, E., Swan, A. (2019). Soil C Sequestration as a Biological Negative Emission Strategy. *Frontiers in Climate*, Vol. 1. https://doi.org/10.3389/fclim.2019.00008
24. Peltonen-Sainio, P.; Jauhiainen, L.; Joona, J.; Mattila, T.; Hydén, T.; Känkänen, H. (2023). Sowing and Harvesting Measures to Cope with Challenges of Cover Crops Experienced by Finnish Farmers. *Agronomy*, Vol. 13, 499. https://doi.org/10.3390/agronomy13020499
25. Pittelkow, C.M., Linquist, B.A., Lundy, M.E., Liang, X., van Groenigen, K.J., Lee, J., van Gestel, N., Six, J., Venterea, R.T., van Kessel, C. (2015). When does no-till yield more? A global meta-analysis. *Field Crops Research*, Vol. 183, Pages 156-168. https://doi.org/10.1016/j.fcr.2015.07.020.
26. Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., Deppermann, A., Doelman, J., Emmet-Booth, J., Engelmann, J., Fricko, O., Frischmann, C., Funk, J., Grassi, G., Griscom, B., Havlik, P., Hanssen, S., Humpenöder, F., Landholm, D., Lawrence, D., et al. (2021). Land-based measures to mitigate climate change: Potential and feasibility by country. *Global Change Biology*, 27, 6025– 6058.
27. Rust, N., Ptak, E., Graversgaard, M., Iversen, S., Reed, M., de Vreis, J., Ingram, J., Mills, J., Neumann, R., Kjeldsen, C., Muro, M., Dalgaard, T. (2020). Social capital factors affecting uptake of sustainable soil management practices: a literature review. *Emerald Open Research*, Vol.2 DOI:10.35241/emeraldopenres.13412.1.
28. Söderström, B., Hedlund, K., Jackson, L.E. et al. (2014). What are the effects of agricultural management on soil organic carbon (SOC) stocks?. *Environmental Evidence*, Vol. 3, Issue 2. https://doi.org/10.1186/2047-2382-3-2
29. *The Commission approves the CAP Strategic Plans of Estonia and Latvia*. (2022). Retrieved: https://agriculture.ec.europa.eu/news/commission-approves-cap-strategic-plans-estonia-and-latvia-2022-11-11_en
30. Travlos, I., Kontopoulou, C., Kanatas, P., Panagopoulou, M., Bilalis, D. (2017). Cover crops against herbicide-resistant invasive weeds. *Agronomy*, Vol. 60, pp. 425-429
31. Vanino, S., Pirelli, T., Di Bene, C., Bøe, F., Castanheira, N., Chenu, C., Cornu, S., Feiza, V., Fornara, D., Heller, O., Kasparinskis,R., Keesstra, S., Lasorella, M.V., Madenoğlu, S., Meurer, K.H.E., O'Sullivan, L., Peter, N., Piccini, C., Siebielec, G., Smreczak, B., Thorsøe, M.H., Farina, R. (2023) Barriers and opportunities of soil knowledge to address soil challenges: Stakeholders' perspectives across Europe. *Journal of Environmental Management*, Vol. 325, Part B, 116581, https://doi.org/10.1016/j.jenvman.2022.116581.
32. Wiesmeier, M., Urbanski, L., Hobley, E., Lang, B., Lützow, M., Marin-Spiotta, E., Wesemael, B., Rabot, E., Ließ, M., Garcia-Franco, N., Wollschläger, U., Vogel, H.J., Kögel-Knabner, I. (2019). Soil organic carbon storage as a key function of soils - A review of drivers and indicators at various scales. *Geoderma*. Vol. 333, pp. 149-162. DOI: 10.1016/j.geoderma.2018.07.026.