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Accumulation of SOC and Carbon Fractions in Different Age Red Fescue Permanent Swards

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Abstract: One of the practices often mentioned to achieve climate change mitigation is the long-term cultivation of perennial plants. The objective of the study was to estimate changes in the accumulation of soil organic carbon (SOC) and its fractions in 0–10, 10–20, 20–30 cm, and within 0–30 cm soil layer of red fescue (*Festuca rubra* L.) swards that differ in age (5, 10 and 15 years) as well as to compare them with the arable field. Our results show that SOC accumulation at 5-year-old cultivation of red fescue is high, later this SOC increase slowed down from 71% in the 0–30 cm soil layer when land use was converted from arable field to 5-year-old sward to 1% from 10 to 15 years. The level of water extractable organic carbon (WEOC) in the 0–30 cm soil layer of swards was significantly higher compared to the arable field. The positive effect of these swards in the accumulation and stabilization of organic carbon during humification in the soil was also determined. The largest amounts of mobile humic substances (MHS) and mobile humic acids (MHA) accumulated in the 0–10 cm layer of sward soil (3.30–4.93 and 1.53–2.48 g kg^{-1}, respectively). In conclusion, the findings suggest that a conversion from arable to soil under permanent grass cover significantly improves carbon status.

Keywords: soil organic carbon; carbon fractions; mobile humic substances; mobile humic acids; water-extractable organic carbon; *Festuca rubra* L.; permanent sward

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1. Introduction

Climate change influences the environment around the world and affects all areas of human life: health, agriculture and food supply chains, economy, etc. [1–6]. Carbon dioxide is one of the greenhouse gases and has been increasing rapidly in the atmosphere since the beginning of the industrial revolution [7,8]. As this amount continues to increase [9], various strategies and techniques are being pursued to mitigate these processes. Among them are proposed different land management practices that promote carbon sequestration in the soil [10,11]. One of the practices often mentioned to achieve this objective is the long-term cultivation of perennial plants [12,13].

Swards and pastures are a dominant land use worldwide and have traditionally been used for grazing and livestock production [14]. In agriculture-developed countries, the primary strategy for modern agriculture is the inclusion of grass in fields with new agricultural technologies when the single planting mode is replaced, and a comprehensive agricultural system is inducted [15]. In these systems, perennial grasses can not only be the members of the crop rotation, but due to their superb resistance to environmental conditions, their use is wide; for example, they can be a source of biomass for bioenergy production, protective grass hedge in fields to prevent soil erosion and nutrient leaching, and so on [16,17]. It is noticeable that the ambitious Green Deal of the European Union does not pay enough attention to grasslands and the services provided by their ecosystems [18,19]. The number and intensity of these services range depending on the purpose for which the grassland is developed and cultivated. In the literature, there are various options for the systematization of ecosystem services, but the most common categories are: provisioning services-food, fiber, forage, biofuel; supporting services-biodiversity, soil structure, erosion control, nutrient cycling, carbon sequestration; regulating services-climate regulation, freshwater, flood regulation, pollination, disease, and pest control; and cultural services-recreation, esthetics, education [20,21]. Although the importance of biodiversity for the provision of many of these services is accentuated [22], monospecies lawns complete the same functions, especially when their management intensity is reduced [23].

One of the important multifunctional roles of the perennial grasses with extensive root systems, as carbon sinks, is to capture atmospheric CO2 through photosynthesis and to store large amounts of organic carbon in above and belowground biomass [24]. Therefore, they are the primary source of soil organic carbon via the shoot and root residues, the release of root exudates, symbiotic associations with microorganisms and mycorrhizae, and poorly degradable compounds produced by plants promote the formation of stable aggregates, thus contributing to carbon stabilization in soil [25]. Sustainable soil management should seek to maintain a balance between sward degradation and productivity, influencing soil carbon storage [26].

Soil management practices, such as tillage change soil structure and disrupt aggregates, increase compaction, and disturb soil ecosystems, which cause an increase in SOC mineralization and release CO_2 to the atmosphere. Soils under conservation tillage or no-till provides more significant physical protection of carbon and therefore promote carbon accumulation compared to soils with conventional tillage [27,28]. According to the results of many studies, this land-use change results in a loss of carbon dioxide from the soil, and the reverse change can increase soil carbon stocks. Regardless, it may take decades for SOC to recover to entry levels after a period of intensive land use [29,30].

SOC content represents soil quality and indicates soil erosion and degradation. In addition, SOC is involved in regulating many soil processes, such as water retention, degradation of pesticides and herbicides, and the soil's ability to absorb plant-available nutrients [31]. Water-extractable organic carbon, as the most active SOC pool, can contribute to changes in SOC concentration, stabilization, preservation, and influence on soil processes. The high biodegradability of WEOC has implications for soil CO_2 efflux, which depends on land use changes. The highest concentrations of WEOC are found in forest soils, then in grasslands, and the lowest in arable soils [32,33].

Another labile part of the SOC that was analyzed in our study is the mobile humic substances, humic and fulvic acids, which also actively participate in the chemical processes in the soil. Mobile humic acids are classified as young and active forms of humus and are characterized by faster turnover and can be used as carbon and energy or N, S, and H sources by microorganisms and plants due to short-term nutrient cycling [34,35].

Festuca rubra L. (Poaceae) is a perennial grass across-the-board in the temperate zone in Europe, northern Africa, Asia, and North America. This grass grows fast, tolerates drought, and nutrient-poor soil (it grows on clay, loam, and sandy soil), and can form sustainable lawns with minimal water, pesticides, and fertilizers inputs [36,37]. These properties are ensured by the extensive tufted rhizome root system, which reaches a depth of 45–50 cm in the soil [37,38]. Varieties of creeping red fescue have a larger root mass and a greater percentage of total root mass in the deeper soil layers than varieties of other fescues [37]. Due to these comprehensive adaptability and resistance characteristics, red fescue is widely used both as a monoculture and in mixtures with other plants for forage production, sports, and ornamental lawns in sports fields, parks, or gardens [37,39]. There are also practices and research on using red fescue as a cover crop or plant for soil phytoremediation and erosion protection on slopes and poor soils, etc. [38,40,41].

After reviewing the previous sources and considering the characteristics of red fescue, we hypothesized that a change in soil use from the arable field to sward might increase the accumulation of carbon compounds in the soil consistently for the age of turfs. In this case, the objective of the study was to estimate changes in the accumulation of soil organic carbon and its fractions in 0–10, 10–20, 20–30 cm, and within 0–30 cm soil layer of red fescue swards that differs in age (5, 10, and 15 years) as well as to compare them with the arable field.

2. Materials and Methods

2.1. Study Area and Sampling

The research was carried out in the central part of the Middle Lithuanian Lowland at the experimental base of the Lithuanian Research Centre for Agriculture and Forestry, located in Akademija, Kedainiai district (55°23′46.3″ N 23°51′53.4″ E), in perennial swards on a *Cambisol* (Figure 1) [42]. The soil was classified according to WRB (2014) [43]. Based on the environmental stratification of Europe, this site is located in the Nemoral zone with a cool temperate climate and a short growing season of 195 days [44], the annual mean precipitation is 600–650 mm, and the mean annual temperature is 6.5–7.0 °C (according to standard climate norm 1991–2020).

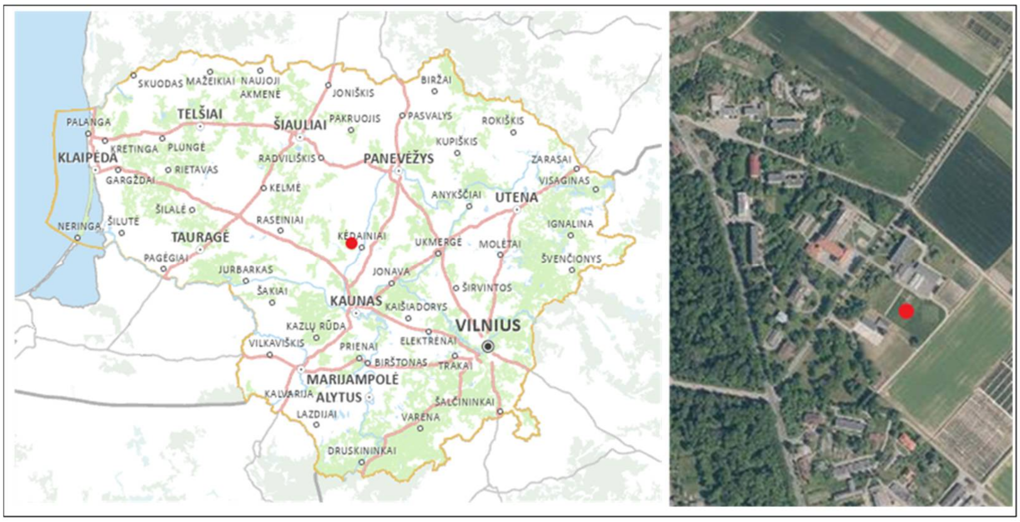

Figure 1. Experimental site in Akademija, Kedainiai district, Lithuania.

Firstly, the initial purpose of the field experiment was to monitor the resistance of various perennial grasses suitable for installing lawns to climatic conditions and their impact on the survival of these plants over the years. Secondly, it has become relevant to study the effect of investigated swards on carbon changes and to study the interaction of these swards and soil. For the field experiment, a non-intensive field management model was chosen. The seeds were sown manually (seed rate 8 kg ha^{-1}) in 2 m^2 plots in three field replicates in separate blocks every 5 years: in 2006, 2011, and 2016. During the season, the aboveground biomass was cut 2–3 times, depending on the intensity of grass growth and the amount of precipitation, by chopping the biomass and spreading it on the field. The swards were fertilized once a season after the first cutting with commercial fertilizer (ammonium nitrate) at the rate of N_{40} kg ha^{-1}. Weed control with herbicides was carried out every 2 years and did not affect all weed species that eventually became established in the swards. In this experiment, red fescue (*Festuca rubra* variety 'Gludas') stood out; the highest resistance and firm turf characterized its fields. This is creeping red fescue with good weed suppression properties developed based on the wild ecotype in Lithuania. Plants of this variety already in the first year of sowing form a relatively dense and decorative lawn that resists adverse climate conditions. In the spring, the plants turn green early and keep their green color until late autumn [45,46].

To compare the research results, soil samples were taken from the adjacent arable field, where shallow tillage (10–15 cm) was applied each year. These plots were occupied by plants for a short period of the growing season due to being used to grow different grass seedlings.

Soil samples for the chemical analyses were taken with a steel auger from three replicates of the topsoil (0–10, 10–20, and 20–30 cm depth). Plants biomass was cut manually from each replicate of a 2 m^2 field plot twice per growing season of *Festuca rubra*: first time at a heading stage and second—before the end of vegetation, on June 8 and September 14, respectively. The yield of fresh grass biomass was weighed immediately after harvesting. Aboveground biomass was separated into grass, legume, and forbs by performing the swards botanical composition analysis for these groups and weighted in every cut.

Soil properties. The soil (0–30 cm) contained 58.0% of silt, 40.6% of sand, and 1.4% of clay, and the soil is classified as silt loam [47]. The pH was close to neutral (pH_{KCl} 6.5), and the soil was high in both phosphorus (P_2O_5 297 mg kg^{-1}) and potassium (K_2O 424 mg kg^{-1}), and low in nitrogen (0.90 g kg^{-1}).

2.2. Chemical Analyses of Soil and Plants

Soil chemical analyses were conducted at the LAMMC, Institute of Agriculture, Chemical Research Laboratory. The soil samples were crushed and sieved through a 2 mm sieve and mixed. For the analysis of SOC, MHS, MHA, MFA, and WEOC the samples were further passed through a 0.25 mm sieve. The content of SOC was determined according to the Nikitin modification of the Tyurin dichromate oxidation method using wet combustion at 160 °C for 30 min. SOC measurement was performed with a spectrophotometer at a wavelength of 590 nm, using glucose as a standard [48,49]. MHS were extracted with 0.1 M NaOH. The soil suspension in NaOH solution was periodically shaken for 24 h at ambient temperature. 10 mL of a saturated Na_2SO_4 solution was added and MHS was separated by centrifugation at 3800 rpm (centrifuge Universal 32, Tuttlingen, Germany) for 10 min. For MHS determination, an aliquot of the extract was evaporated to dry mass and quantified spectrophotometrically. To determine MHA, a selected volume of the extract was acidified to pH 1.3–1.5 with 1 M H_2SO_4 and heated at +68–70 °C in a thermostat to precipitate the MHA. The MHA were determined after wet-combustion by spectrophotometric measurement analogous to SOC [50,51]. MFA in the soil were calculated by the following formula: MFA (g kg^{-1}) = MHS (g kg^{-1})—MHA (g kg^{-1}). The reagents of a recognized analytical grade and only deionized water was used during the analysis. Determination of WEOC: the soil sample was poured with distilled water at a ratio of 1:5, and the aqueous extract was prepared by shaking, centrifuging, and filtering. The following automatic measurement procedure is based on the IR detection method after UV-catalyzed persulphate oxidation in a nitrogen environment. During this process, WEOC was oxidized to carbon dioxide and measured operating the ion chromatograph (SKALAR, Netherlands), This analysis procedure is completed according to the methodology guided by SKALAR, using $C_8H_5KO_4$ as a standard [52].

The dry matter yield (DMY) of grasses was determined by weight. The grass samples of 0.5 kg were collected per plot and dried at a temperature of +105 °C in a forced-air oven to a constant weight.

2.3. Statistical Analysis

The experimental data on soil parameters are presented as mean and standard error (SE), and three field replicates were used for calculations. For statistical analysis, we used the software SAS Enterprise, version 7.1 (SAS Institute Inc., Cary, NC, USA).

One-way analysis of variance (ANOVA) was performed. Significant differences among treatment means were assessed by Fisher's test, where *p*-values were calculated, and a value of $p < 0.05$ was considered statistically significant. Pearson's correlation was used to examine relationships between SOC and carbon fractions contents as well. The results were significant at $p < 0.01$.

3. Results and Discussions

3.1. Soil Organic Carbon

The study showed the distinction of SOC accumulated in the soil under different age swards and arable fields. The most significant amounts of SOC gained were observed in the upper (0–10 cm) soil layer of red fescue swards (Figure 2).

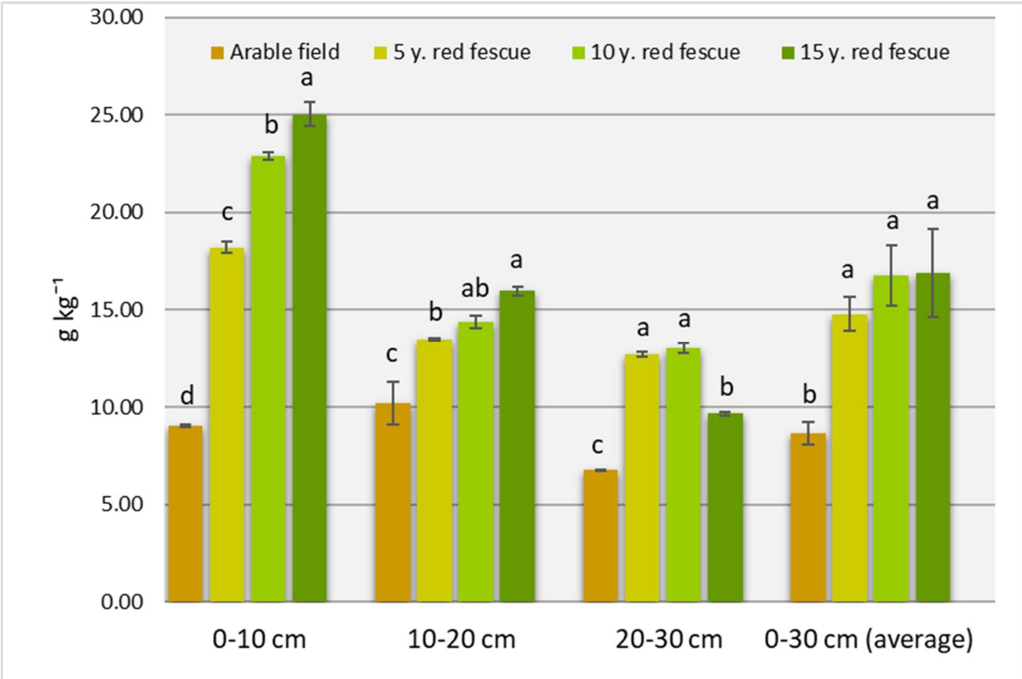

Figure 2. Soil organic carbon (SOC) content as influenced by different ages of red fescue (*Festuca rubra* L.). Different letters indicate statistically significant differences ($p \leq 0.05$) of SOC content g kg^{-1} in various age red fescue swards (5 y., 5 years; 10 y., 10 years; 15 y., 15 years) in 0–10, 10–20, 20–30 and 0–30 cm soil depth; error bars are shown as the standard error (SE) of the mean.

In the soil layer of 0–10 cm, a significant increase in the content of SOC was observed during the growing the *Festuca rubra*: from 18.2 g kg^{-1} for 5 years; 22.9 g kg^{-1} for 10 years; and 25.1 g kg^{-1} for 15 years. The soil, which did not grow grasses, and was used as an arable field, was significantly poorer in terms of SOC. When growing *Festuca rubra* for 15 years, the amount of SOC in a layer of 0–10 cm increased by 1.8 times compared to that in the arable field. In the soil layer of 10–20 cm, the same trend in SOC changes was found; only the changes were weaker compared to the 0–10 cm layer.

Based on the work of other researchers, it is reported that grasslands can accumulate SOC for 25 years or more, and over time the carbon balance in the soil is settled [53]. Our research shows that the time of sward cultivation had a positive effect on the accumulation of SOC in 0–10 cm and 10–20 cm soil layers, as well as in all 0–30 cm soil layers. In the soil layer of 20–30 cm, the 15-year-old sward only tended to increase the amount of SOC, compared to the sward of the 10 years old, but the SOC amount was higher than the arable field in this soil layer.

Our results show that initial SOC accumulation is significantly higher in the newly established sward; however, later than this increased tempo was weaker and slowed down. The increase of SOC in the 0–30 cm soil layer was (in relative values) 71% when *Festuca rubra* was converted from arable field to sward at 5 years of the installation of sward and 13% increase in the five years period from 5 to 10 years. In the 0–30 cm soil layer, only a 1% increase emerged during the next five years period when grass was grown for 15 years. The decrease in carbon sequestration may partly be explained by the invasion of weeds in the sward [53]. Consequently, although slow, soil carbon accumulation tends to increase in all 0–30 cm soil layers when the arable fields are turned into grasslands and grown for a long time [29]. The differentiation of the amount of SOC in the different soil layers also increases—more SOC accumulates in the upper layer of 0–10 cm, compared to deeper layers. According to other researchers' data, the highest mass of red fescue roots is also at this depth [37,38].

3.2. Water-Extractable Organic Carbon

Water-extractable organic carbon is an important element in improving soil properties. WEOC is not a homogenous pool [54]. As a rule, it is considered the most unstable SOC fraction, and its importance in agriculture has long been recognized for its role in the absorption of nutrients by plants, as well as in participation in the activity of soil microorganisms [34,35]. In our study, the largest amounts of WEOC accumulated in the 0–10 cm soil layer of sward soil (Figure 3). A significant increase in the amount of WEOC in the soil was found from 0.372 g kg^{-1} for the grass grown for 5 years; 0.413 g kg^{-1} for 10 years; and 0.445 g kg^{-1} for 15 years. When comparing the concentration of WEOC in the soil, where grasses grew for 15 years, and for the arable field, the concentration of WEOC in sward soil was as much as 1.9 times higher; in the soil layer of 10–20 cm this indicator was 1.6 times, and in the soil layer of 0–30 cm this indicator was 1.5 times higher than the arable field. This indicates the positive role of *Festuca rubra* in the accumulation of SOC, as well as the change in its values in different layers of soil occupying it with swards. Our results confirm the scant results summarized in the works of other researchers that a higher amount of WEOC is determined in grassland than in arable soils and increases with a longer period of soil occupation by perennial plants [33].

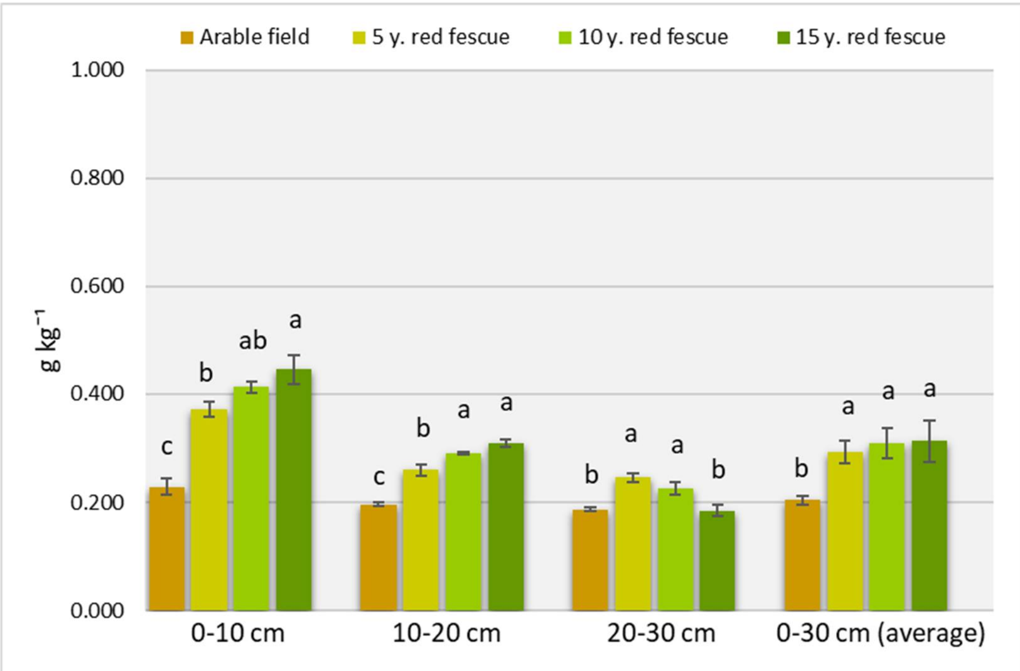

Figure 3. Water-extractable organic carbon (WEOC) content as influenced by different age red fescue (*Festuca rubra* L.). Different letters indicate statistically significant differences ($p \leq 0.05$) of WEOC content g kg^{-1} in various age red fescue swards (5 y., 5 years; 10 y., 10 years; 15 y., 15 years) in 0–10, 10–20, 20–30, and 0–30 cm soil depth; error bars are shown as the standard error (SE) of the mean.

Over time, as the use of the grass is longer, the root system is likely to weaken, and the grown-up forbs have less volume and often shorter roots [55,56], making it harder for the organic matter from the grass biomass to reach the 20–30 cm layer. This can be confirmed by the characteristics of the predominant forb hawkweed (*Pilosella officinarum* F. W. Schultz et Sch. Bip. (syn. *Hieracium pilosella* L.) (Figure 4): shallow, fibrous rooting system, depth ranges from 4 to 14 cm, and many without root hairs. The roots of these plants also secrete phytotoxic chemicals into the soil and may suppress the growth of competing plants [56]. Further, there is evidence that soils under hawkweed have higher and immediately outside hawkweed patches have the lowest organic carbon values [57]. Other researchers concluded that the content of the microorganisms that decompose organic matter decrease in this layer [58,59], and the accumulation of various kinds of organic matter and WEOC in this layer does not occur.

Figure 4. Different age red fescue (*Festuca rubra* L.) in experimental fields in October 2021. The photos show how hawkweeds spread as the grass ages; simultaneously, red fescue retains the suppression properties of other weeds. Additionally, a clear thinning of the swards is not visually noticeable.

As a result, it was established that in the lower 20–30 cm layer, the concentration of WEOC in the soil used for the grass by 15 years decreased from 0.246 g kg^{-1} to 0.184 g kg^{-1}, which is 1.3 times. Although on average, the WEOC content in the 0–30 cm layer continues to increase as the age of the grass gains, the differentiation according to soil layers also increases. Furthermore, on average, in the 0–30 cm layer, the difference in WEOC concentration between the arable field and settled sward is reduced compared to the upper soil layer.

3.3. Humified Carbon Fractions

Numerous research concludes that some of the soil carbon fractions are more sensitive to management practices than the total SOC [60]. There is not much evidence in differently used agricultural soils on the changes in MHS, MHA, and MFA, which are influenced by the management practices and can be considered as indicators of the changes occurring in the soil.

Our study showed that sward cultivation increased the accumulation of MHS compared to the arable field. The results, as shown in Table 1, indicate that the largest amounts of MHS and MHA accumulated in the 0–10 cm soil layer of sward soil. A significant increase in the amount of MHA in the soil was found from 3.30 g kg^{-1} for the grass grown for 5 years; 4.52 g kg^{-1} for 10 years; and 4.93 g kg^{-1} for 15 years. When comparing the concentration of MHS and MHA in the soil, where grasses grew for 15 years, and the arable field, the concentration in sward soil (0–10 cm) was as much higher, 2.5 and 2.2 times, respectively. A clear benefit of *Festuca rubra* in the accumulation and stabilization of organic carbon during humification in the soil with the participation of MHS in these processes could be identified in this analysis and other studies as well [34,35].

Table 1. Humified carbon fractions content g kg^{-1} in the soil as influenced by different age red fescue (*Festuca rubra* L.) swards in 0–10, 10–20, 20–30, and 0–30 cm soil depth.

	Soil Layer cm	MHS g kg^{-1}	±SE	MHA g kg^{-1}	±SE	MFA g kg^{-1}	±SE
Arable field	0–10	1.995	0.105	1.156	0.020	0.839	0.105
	10–20	1.772	0.087	0.661	0.032	1.111	0.087
	20–30	1.523	0.014	0.857	0.021	0.666	0.014
	0–30	1.783		0.891		0.872	
Red fescue 5 y.	0–10	3.303 *	0.010	1.534 *	0.008	1.769 *	0.010
	10–20	1.796	0.040	0.705	0.037	1.091	0.040
	20–30	1.729 *	0.017	0.768	0.020	0.961 *	0.017
	0–30	2.004		1.002		1.274	
Red fescue 10 y.	0–10	4.518 *	0.038	2.128 *	0.075	2.390 *	0.038
	10–20	2.136 *	0.030	0.861 *	0.022	1.275	0.030
	20–30	1.751 *	0.028	0.894	0.009	0.857 *	0.028
	0–30	2.588		1.294		1.507	
Red fescue 15 y.	0–10	4.932 *	0.024	2.482 *	0.128	2.45 1*	0.024
	10–20	2.388 *	0.055	1.057 *	0.070	1.331 *	0.055
	20–30	1.249	0.034	0.537	0.017	0.712	0.034
	0–30	2.718		1.359		1.498	

Abbreviations. MHS, mobile humic substances; MHA, mobile humic acids; MFA, mobile fulvic acids; 5 y., 5 years; 10 y., 10 years; 15 y., 15 years; SE, standard error of the mean represents error values; * significantly different contents compared to the analogous soil depth in the arable field at the $p < 0.05$ level.

3.4. Soil Organic Carbon and Water-Extractable Organic Carbon Correlation

Correlation analysis showed a strong positive relationship between MHA, MFA, WEOC, and SOC content in soil: $R^2 = 0.753$; $R^2 = 0.893$ $R^2 = 0.904$, respectively (at $p < 0.01$) (Figure 5). There are not many studies with different plants, especially grasses, that examine the changes in the amount of these fractions in the soil or their correlation with SOC; however, our data are consistent with the established trends in other land uses. For example, Hamkal Z. and Bedernichek T. reported the distribution of WEOC in forest and arable soils and the correlation with SOC ($R^2 = 0.55$ and $R^2 = 0.65$) [54]. In our study, a stronger positive correlation was found between these indicators ($R^2 = 0.904$).

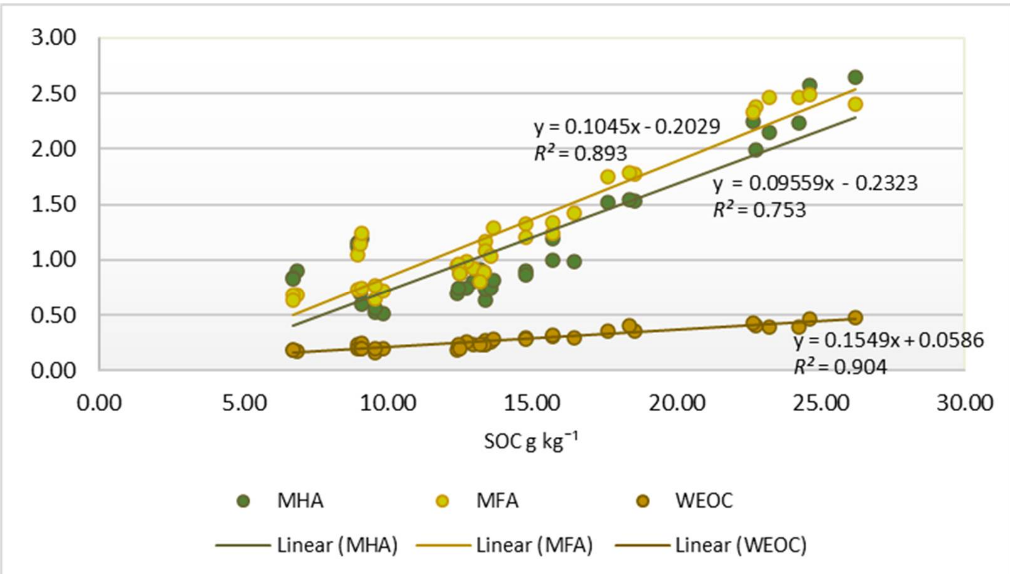

Figure 5. Relationship between soil organic carbon (SOC) content and mobile humic acids (MHA); mobile fulvic acids (MFA); water-extractable organic carbon (WEOC) content g kg^{-1}. The results are significant at $p < 0.01$.

WEOC, MHA, and MFA perform essential functions in the soil ecosystem and plant nutrition cycle [33–35,54]. The increase in their amount, which depends on SOC, is significant to ensure the stability of these processes. Our study also verified that the highest amounts of these compounds are in the upper 0–10 soil layer, where the most intensive decomposition of organic residues occurs [61].

3.5. Grass Dry Matter Yield

During the experiment, it was found that the yield and botanical composition of *Festuca rubra* swards also depended on their age (Table 2). The highest yield was obtained from the cultivation of red fescue sward for 10 years—2616 kg ha^{-1}. At the age of 15 years the yield of the permanent sward of red fescue tended to decrease due to its aging and an increase in the mass part of various plants up to 47.3%. As mentioned earlier in the section on WEOC in the soil, hawkweed was the dominant forb in the swards investigated (Figure 4), with the largest percentage of the biomass which increasing over the years (Table 2). These plants are difficult to control with herbicides [56,62,63], especially when it chooses the non-intensive field management model like in our case. Legumes plants found in the experiment fields were *Trifolium repens* L. and *Lotus corniculatus* L., but their spread was minor. A low diversity of forbs in the swards is a characteristic of red fescue due to its good overgrown of other plants and its allelopathic properties by reducing root and shoot growth of certain weeds [37].

Table 2. Dry matter (DM) yield and botanical composition of different age red fescue (*Festuca rubra* L.) swards.

	DM kg ha^{-1}	Red Fescue %	Legumes %	Forbs %
Red fescue 5 y.	1786 ± 72.58	97.4	1.2	1.4
Red fescue 10 y.	2616 ± 98.06	56.8	23.5	19.7
Red fescue 15 y.	2208 ± 52.55	52.7	16.2	31.1

Abbreviations. 5 y., 5 years; 10 y., 10 years; 15 y., 15 years; standard error (SE) of the mean is used to represent error values.

However, even with the decline of red fescue in the grassland and the spread of other plants, organic carbon continued to accumulate, especially significantly in the 0–10 cm soil layer. This indicates that many residues and dead roots were deposited here [37,38], and their decomposition processes, however slow [64], led to carbon sequestration.

Although the natural environment plants in the lawns disrupt the generally established perception of the aesthetics of this greenery [37], we should revise the broader use of grasses, especially under the changing climate conditions, and consider different composition biodiversity services in ecosystems [22]. In this instance, the red fescue is a great basis for the initial prevention of soil erosion [38] and has been cultivated for a long time as the lawns of homes, sports fields, and parks, as well as in areas with barren conditions, poorly maintained roadsides, and areas with other needs [37]. Additionally, these swards contribute to carbon accumulation in soil [53], and we investigated this issue more profoundly in our study.

4. Conclusions

The results of our investigation show that converting of arable land to sward (*Festuca rubra*) is expected to sequester atmospheric carbon by increasing SOC accumulation in *Cambisol*. Additionally, our results show that SOC accumulation at the initial stage of 5-year-old cultivation of *Festuca rubra* is significantly high. Later, this SOC increase tempo was weaker and slowed down. The increase of SOC in the 0–30 cm soil layer is as follows: when land use was converted from arable field to 5-year-old sward, 71%; moderate, 13% increase in the five years period from 5- to 10-year-old sward; and only 1% increase after next five years period when sward was grown from 10 to 15 years. The level of WEOC in 0–30 cm soil layer of red fescue grown for a long time was also significantly higher compared to the arable field. The positive effect of *Festuca Rubra* in the accumulation and stabilization of organic carbon during humification in the soil was determined. We concluded that the largest amounts of MHS and MHA also accumulated in the 0–10 cm layer of sward soil (3.30–4.93 and 1.53–2.48 g kg^{-1}, respectively).

In summary, we can say that the cultivation of red fescue had a significant positive effect on the accumulation of SOC and its fractions in the soil, which increased with time when the soil was occupied by these plants.

Much research today focuses on ways to mitigate climate change while ensuring sustainable environmental management. Therefore, we believe it is important to compare the effect of different perennial grass species on carbon sequestration potential. In addition, we define the goal of such research as studying deeper soil layers than 0–30 cm and performing these studies in different types of soils because SOC is stored in deep soil layers, where its mineralization rate is low and, due to the formation of physical protection, stabilized organic mineral complexes are completed [65]. With more data, recommendations could be made for the selection of plants that could contribute to faster carbon sequestration in different regions.

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