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Carbon, nitrogen and organic C fractions in topsoil affected by conversion from silvopastoral to different land use systems

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Abstract The conversion of silvopasture to different land use systems cause effective changes in soil carbon distribution, due to disturbances in soil aggregation promoted by soil management and changes in crop residues inputs and decomposability. We evaluate the C and N stocks, and organic C fractions in soils under continuous arable land (AR) and silvopasture with apple trees and grass (SP); and after 4 years of conversion from silvopasture to arable land (SP-AR) and grassland (SP-GL). Total N (TN) and organic C (TOC), as well as microbial biomass carbon (C_{MB}), light fraction (C_{LF}) and heavy fraction (C_{HF}) were evaluated at two different depths (0–10 and 10–20 cm). After 4 years of conversion, SP-AR and SP-GL presented C and N stocks similar to the observed for SP when the 0–20 cm depth was considered. However, AR presented TOC and TN stocks around 21 and 10% lower than SP, respectively. SP-AR tended to present the lowest C_{MB} stocks and was positively correlated with salt extractable organic C ($r^2 = 0.60$, $P < 0.001$). C_{LF} values declined by 62% from 0–10 to the 10–20 cm at SP and SP-GL, however there was no variation with increasing depth for AR and SP-AR. C_{HF} represented the highest C fraction in soil, corresponding to 82% of TOC. Except for AR, $\delta^{13}C$ values of the light fraction increased with increasing depth. In general, heavy fraction tended to be more enriched in $\delta^{13}C$ than light fraction. In a long-term, conventional tillage can significantly contribute to reduce TOC and TN stocks when compared to the silvopastoral system.

Keywords Soil organic matter · C pools · Free light fraction · $\delta^{13}C$ natural abundance · Silvopasture · Conventional tillage

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Introduction

In agricultural systems, soil carbon stocks are affected by changes in land use systems or management practices. When forest or silvopastoral systems are converted to arable lands is expected an effective decrease in soil carbon stocks (Apezteguía et al. 2009; Haile et al. 2008; Schroth et al. 2002). This can be attributed to reduced inputs of organic matter, increase of decomposability of crop residues, and tillage effects that break-up aggregates and exposes organo-mineral surfaces (Post and Kwon 2000). Furthermore, the establishment of silvopasture as well as the conversion of silvopasture into different land use systems modifies above- and belowground productivity, rooting depth and distribution, and the quantity and quality of organic matter inputs (Haile et al. 2008). Hence, the equilibrium between C inputs and outputs will probably be altered by the land use change until a new equilibrium be reached (Guo and Gifford 2002).

Soil organic matter (SOM) is represented by a variety of fractions. The main differences among these fractions are related to the degree of decomposition, recalcitrance and turnover rate. SOM fractions, such as microbial biomass carbon (C_{MB}) and light fraction organic carbon (C_{FL}), generally respond more rapidly to changes in land uses than total organic matter contents (Leifeld and Kögel-Knabner 2005; Leite et al. 2003; Wu et al. 2003) and heavy fraction (C_{HF}), which is associated with clay and silt. C_{FL} represents a free and noncomplexed carbon pool, which can be physically fractionated by density separation (Roscoe et al. 2001; Sohi et al. 2001; Wu et al. 2003). Light fraction has been considered as a dynamic fraction that reflects in short-term shifts in SOM storage and turnover induced by different land use systems (Leite et al. 2003; Maia et al. 2007; Murage et al. 2007). Microbial biomass is defined as the living component of SOM (Sparling 1997), which is strongly influenced by environmental factors including soil moisture and temperature (Post and Kwon 2000). C_{MB} corresponds to a small portion of TOC, which has been shown to be more sensitive to provide indications of changes and future trends in SOM caused by land use conversion (Llorente and Turrión 2009; Maia et al. 2007; Sparling 1997). For that reason, the study of different C fractions, are useful tools to assess changes caused by different land use systems.

The carbon isotopic techniques, especially ^{13}C natural abundance have been often used to trace the origins of organic matter and the dynamics of soil C transformations (Balesdent and Mariotti 1996; Bernoux et al. 1998; Diels et al. 2004; Roscoe et al. 2001). Therefore, the evaluation of $\delta^{13}C$ of more stable C fractions, such as light and heavy fractions, could provide important information about age and degree decay of the organic C associated with these fraction as well as the effects of land use system on these fractions of SOM.

There are few studies on land use effects on stocks of soil C and N (Billen et al. 2009; Chen et al. 2009) and C fractions (Leifeld and Kögel-Knabner 2005; Mueller and Koegel-Knabner 2009) in soils from Germany, especially studies involving soil conservation practices and arable land. The objective of our work was to evaluate the effects of land use conversion from silvopasture to arable land and grassland, as well as continuous arable land and silvopasture on soil organic C dynamics. In addition to the C and N stocks we separated SOM into different pools of microbial biomass carbon (C_{MB}), light fraction (C_{LF}) and heavy fraction (C_{HF}) based on the mean residence time of each fraction.

Materials and methods

Study areas and sampling

The sampling areas were located on farm fields in Gransee (53°00′N, 13°08′E; 50 m asl) in northeastern Germany, with mean annual temperature of 9.7°C and precipitation of 568 mm. The sites are on well drained loamy sand soils (Luvic Arenosols) cultivated under different land use systems comprising:

SP: Silvopasture, apple tree and grass use for >50 years;
SP-GL: Grassland for 4 years of use after >46 years of silvopasture (apple tree + grass);
SP-AR: Arable land for 4 years of use after >46 years of silvopasture (apple tree + grass);
AR: Arable land use for >50 years.

The silvopastoral system (SP) was established in an area of approximately 3 ha, which has been cultivated with apple trees and orchard grass (*Dactylis glomerata*) over the past 50 years. The apple trees were cultivated with 8.0 × 8.0 m space among plants. The area was cultivated as fruit garden for production of apple fruit from 1960 to 1989. After government subsidies for discouragement of apple fruit production due to the excess of supply, the commercial exploitation of apple fruit was abandoned. However, the apple trees were preserved and the area has been historically grazed by cattle at a low to moderate grazing intensity with the benefits of tree shadow for the animals.

The SP-GL corresponded to an area of 3 ha closed to the other sites, which presented the same characteristics of the silvopastoral system described above, but was converted to grassland in 2004. The apple trees were removed and the grass represented by orchard grass (*Dactylis glomerata*) maintained in the area. No fertilizers or manure were applied after conversion.

The SP-AR corresponded to an adjacent area of 8 ha, which presented the same characteristics of the silvopastoral system described above, but was converted to arable land in 2004. In this same year was applied 4.0 Mg ha^{-1} of lime. From 2005 to 2008, the crop rotation system was lupin-oat-rape when 100, 200, and 130 kg ha^{-1} of N were applied to each crop, respectively. The management system is conventional, in which soil is disc ploughed at 20 cm each 2 years and twice disc harrowed using a tractor.

The AR has been cultivated over the past 50 years under continuous arable land with different crop rotation systems and corresponds to an area of approximately 8 ha. Recent crop rotation system was represented by barley–sunflower–rye when 100, 50 and 100 kg ha^{-1} of N were applied to each crop, respectively. The area is cultivated under conventional tillage system, in which soil is disc ploughed at 20 cm each 2 years and twice disc harrowed using a tractor.

The soils at each sampling site were taken in April 2008 at two different depths (0–10 and 10–20 cm) with three replicates for each depth. Each replicate was a composite of 40 subsamples bulked together. Portions of the fresh subsamples were stored at 4°C for later determination of microbial biomass. The remaining portions were air dried, sieved to 2 mm and stored for chemical and physical analyses.

Analyses

The soil pH in water (1:2.5) was measured after 1 h contact using a glass electrode (MTW, Wilhelm, Germnay). Total P in soil was determined by inductively coupled plasma emission spectrometry (iCAP 6000 Series, Thermo Scientific, Bremen, Germany) after digestion of nitric acid (HNO_3). The soil bulk density was determined by the core method and soil texture by the pipette method. Amorphous Fe and Al oxides were determined by the acid ammonium oxalate method according to Schwertmann (1964).

Total organic C and total N contents were analyzed by dry combustion (Vario El III Elementar Analyzer, Elementar Analysensysteme, Hanau, Germany). As no inorganic carbon was present in the soil samples, total C content corresponded to total organic carbon (TOC) content. The C and N stocks for each depth, were determined according to Batjes (1996):

$$Y_{\text{stock}}\,(\text{Mg ha}^{-1}) = X \times BD \times th \times (1 - S) \times 10^{-1}$$

where X is the nutrient (C or N) concentration (g kg^{-1}); BD is the bulk density (Mg m^{-3}), th is the thickness of the soil layer (cm), and S is the stone content.

The C of microbial biomass (C_{MB}) was determined by the irradiation-extraction method, using microwave (Islam and Weil 1998), and 0.5 mol l^{-1} K_2SO_4 as extractant. Mass of 20 g of fresh soil samples were microwaved using a total of energy exposure of 800 J g^{-1} soil. Irradiated and non-irradiated samples were placed in centrifuge tubes, mixed with 80 ml of 0.5 mol l^{-1} K_2SO_4 and were shaken at 250 rpm for 1 h. The soil suspension was centrifuged at 1,500×g for 5 min and filtered. The C concentrations were determined using a Shimadzu TOC 5000 analyzer (Shimadzu, Kyoto, Japan). The C_{MB} was obtained by difference between irradiated and non-irradiated samples divided by a conversion factor (0.33) used to convert the flow of C for the microbial biomass C (Sparling and West 1988). Salt extractable organic carbon (SEOC) was extracted with 0.5 mol l^{-1} K_2SO_4 filtered through 0.45 µm membrane filters and C concentration determined using a Shimadzu TOC 5000 analyzer.

Light organic matter fraction was isolated by flotation in sodium iodide (NaI) solution, with a 1.8 g cm^{-3} density as proposed by Sohi et al. (2001). Mass of 5.8 g of soil was placed in a 50 ml centrifuge tube with approximately 40 ml of NaI solution with 1.8 g cm^{-3} density. The centrifuge tubes were shaken and centrifuged at 1,500×g for 15 min. The supernatant with floating particles was filtered using a GF92 glass fiber filter (Whatman, Dassel, Germany) under vacuum. The procedure was repeated again as described above and the floated particles combined to form one. All material collected on filter paper was washed three times with 500 ml of deionized water, dried for 48 h at 70°C and weighed. The C content in the light fraction (C_{LF}) was determined by dry combustion (Vario El III Elementar Analyzer). The soil residue in the centrifuge tube was washed once with 0.01 mol l^{-1} $CaCl_2$ and 5 times with distilled water. The residue was considered as heavy fraction, which was ground by hand with mortar and pestle. The C content in the heavy fraction (C_{HF}) was determined by dry combustion (Vario El III Elementar Analyzer).

Abundance of ^{13}C in the light and heavy fraction was determined using an isotope ratio mass spectrometer (Delta V Advantage, Thermo Scientific, Bremen, Germany), connected to an elemental analyzer (Vario El III). The isotope ratios were expressed as $\delta^{13}C$ relative to the Pee Dee Belemnite (PDB) standard:

$$\delta^{13}C(‰) = \left[\frac{\left(^{13}C/^{12}C\right)_{sample}}{\left(^{13}C/^{12}C\right)_{reference}} - 1\right] \times 1000$$

where $(^{13}C/^{12}C)_{sample}$ is the stable isotope ratio of the sample and $(^{13}C/^{12}C)_{reference}$ is the stable isotope ratio of the PDB standard.

Statistical analysis

The effect of different land use systems on organic C and N stocks and distribution of organic C fractions in soil, for each depth, was evaluated by the variance analysis (ANOVA) and the differences between averages by Tukey test at 5% of probability. All statistical analyses were done using SAEG 9.1 (Funarbe 2007).

Results

Soil carbon and nitrogen stocks

The values of soil bulk density varied from 1.35 to 1.52 Mg m^{-3} at 0–10 cm and from 1.51 to 1.75 Mg m^{-3} at 10–20 cm depth (Table 1). Total organic carbon (TOC) stocks ranged from 8.6 to 16.1 Mg ha^{-1} at 0–10 cm and from 7.7 to 13.4 Mg ha^{-1} at 10–20 cm depth (Fig. 1). Soils under SP and SP-GL presented highest TOC contents in the upper layer. On average, C stocks declined by 47% from the 0–10 to the 10–20 cm layer in treatments where soil was not revolved. Nevertheless, there were no variations for TOC stocks between soil layers under SP-AR and AR systems. When the 0–20 cm layer was taken into account, only AR differed from the other land use systems containing the lowest amount of TOC. Total nitrogen (TN) followed the same trend as C, with the lowest value at AR study site (0.87 Mg ha^{-1} at 0–10 cm). Except for AR, C/N ratio was similar (around 12.5 ± 0.2) for all land use systems at 0–10 cm depth.

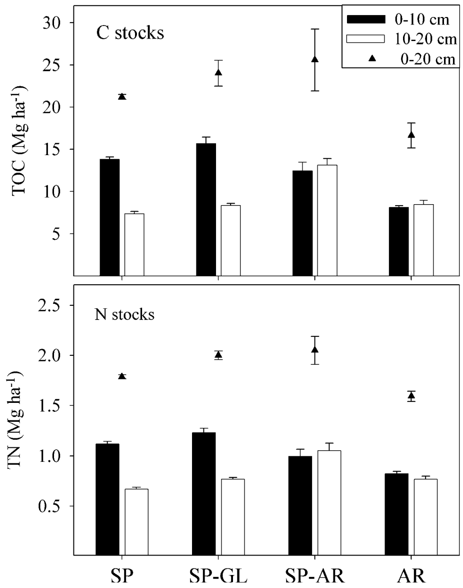

Fig. 1 Soil C and N stocks in soil under different land use systems in the 0–10, 10–20 and 0–20 cm layers. Vertical bars represent the standard error (n = 3). *SP* continuous silvopasture, *SP-GL* conversion silvopasture to grassland, *SP-AR* conversion silvopasture to arable land, *AR* continuous arable land

Soil carbon fractions

Values of microbial biomass C (C_{MB}) varied from 0.103 to 0.162 Mg ha^{-1} at 0-10 cm depth (Table 2). Comparing with SP, the C_{MB} stocks in the SP-AR was reduced by 30% at 0–10 cm depth. At 10–20 cm, C_{MB} stocks increased 17% for SP-GL compared with SP. However, there were no significant differences for C_{MB} stocks among the studied treatments and depth. The C_{MB} corresponded, on average, to 1.2% of

Table 1 Soil physical and mineralogical properties in the 0–10 and 10–20 cm layers

Sites	Layer (cm)	BD ($Mg\ m^{-3}$)	Sand (%)	Clay (%)	Silt (%)	Al_{ox} ($mg\ kg^{-1}$)	Fe_{ox} ($mg\ kg^{-1}$)	pH	SEOC ($g\ kg^{-1}$)
SP	0–10	1.35	81.5	3.9	14.6	902	1492	5.07	0.072
	10–20	1.51	81.1	3.9	15.0	1091	1534	5.00	0.064
SP-GL	0–10	1.44	80.5	3.8	15.7	793	1364	5.66	0.070
	10–20	1.75	82.3	3.8	14.0	980	1642	5.43	0.054
SP-AR	0–10	1.44	86.7	3.0	10.2	740	1850	6.30	0.048
	10–20	1.74	86.1	2.7	11.2	642	1514	6.33	0.048
AR	0–10	1.52	85.4	3.4	11.2	1053	1501	5.33	0.061
	10–20	1.62	87.2	3.0	9.8	1142	1619	5.55	0.045

BD bulk density, Al_{ox} and Fe_{ox} oxalate-extractable aluminium and iron, *SEOC* salt extractable organic carbon (0.5 mol l^{-1} K_2SO_4), *SP* continuous silvopasture, *SP-GL* conversion silvopasture to grassland, *SP-AR* conversion silvopasture to arable land, *AR* continuous arable land

Table 2 Microbial biomass (C_{MB}), light fraction (C_{LF}), and heavy fraction (C_{HF}) carbon stocks in soil under different land use systems at 0–10, 10–20 and 0–20 cm depth

Treatments	C_{MB} ($Mg\ ha^{-1}$)	C_{LF} ($Mg\ ha^{-1}$)	C_{HF} ($Mg\ ha^{-1}$)
0–10 cm			
SP	0.150	3.18	11.7
SP-GL	0.162	3.43	11.4
SP-AR	0.103	2.50	9.6
AR	0.157	1.90	7.2
$LSD_{0.05}$	0.062	1.48	4.9
$P > F$	0.054	0.041	0.061
10–20 cm			
SP	0.151	1.19	6.6
SP-GL	0.182	1.33	7.5
SP-AR	0.150	2.53	9.6
AR	0.141	2.29	7.3
$LSD_{0.05}$	0.064	0.84	2.9
$P > F$	0.224	0.003	0.019
0–20 cm			
SP	0.300	4.37	18.3
SP-GL	0.345	4.76	18.9
SP-AR	0.254	5.03	19.2
AR	0.298	4.19	14.4
$LSD_{0.05}$	0.091	1.87	6.9
$P > F$	0.069	0.452	0.127

SP continuous silvopasture, *SP-GL* conversion silvopasture to grassland, *SP-AR* conversion silvopasture to arable land, *AR* continuous arable land

TOC in the 0–10 cm layer and was positively correlated with salt extractable organic C (SEOC) concentration ($r^2 = 0.60$, $P < 0.001$) at both depths.

The AR presented the lowest values of light organic C fraction (C_{FL}) in the 0–10 cm layer and SP-GL the highest (Table 2). At 10–20 cm depth, the C_{FL} contents were reduced to more than half at SP and SP-GL. Therefore, AR and SP-AR showed the highest values of C_{LF} at a 10–20 cm and also as a result of mixing of both layers (0–20 cm). C_{LF} corresponded, on average, to 21% of TOC at 0–10 cm depth. At 10–20 cm, C_{FL} represented 15.5% of TOC for SP and SP-GL. The arable land systems showed an increase in the proportion of C_{FL}/TOC with time, corresponding to 19% after 4 years of conversion (SP-AR) and to 25% after more than 30 years under arable land use (AR).

The C of the heavy fraction (C_{HF}) varied from 7.2 and 11.7 Mg ha^{-1} and from 6.6 to 9.6 Mg ha^{-1} at 0–10 and 10–20 cm depth, respectively (Table 2). SP and SP-GL tended to present higher values of C_{HF} in the upper layer. In the 10–20 cm layer, the SP-AR area had the highest stock of C_{HF}. When the sum of both layers was considered, AR presented values of C_{HF} stock 25% lower than the observed in the other treatments. On average, the C_{HF} stock corresponded to 80 and 84% of TOC in the 0–10 and 10–20 cm layer, respectively.

Stable carbon isotope ratio ($\delta^{13}C$) of light and heavy fractions

The $\delta^{13}C$ values varied from −27.0‰ to −25.1‰ (Fig. 2). Except for AR, $\delta^{13}C$ values of the light fraction increased with increasing depth, which means that 4 years after conversion to arable land,

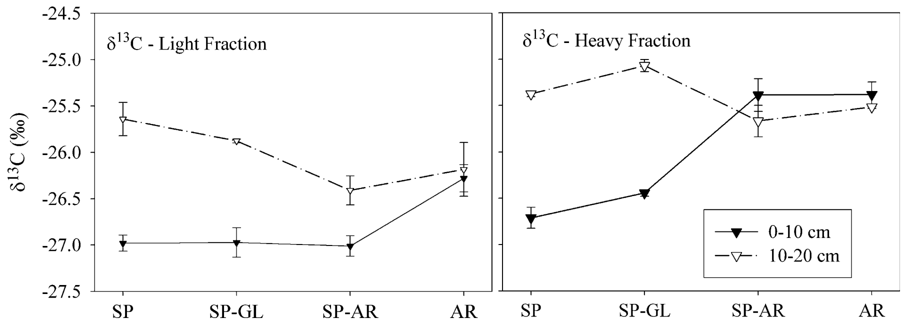

Fig. 2 Carbon isotopic composition (δ^{13}C) of light and heavy fractions at 0–10 and 10–20 cm depth. Vertical bars represent the standard error (n = 3). *SP* continuous silvopasture, *SP-GL* conversion silvopasture to grassland, *SP-AR* conversion silvopasture to arable land, *AR* continuous arable land

did not cause significant changes of δ^{13}C in the light fraction. Although, considering the heavy fraction, the increase of δ^{13}C with increasing depth was observed only for SP and SP-GL. At both depths, the heavy fraction was more enriched in ^{13}C than the light fraction. In general, the heavy fraction was enriched by 1.0–3.4%, except for SP-AR in the 0–10 cm layer, which was enriched by 6.6%.

Discussion and conclusions

After 4 years of conversion from silvopastoral system into arable land and grassland, total C and N stocks values were similar to the observed for silvopasture when the 0–20 cm depth was considered. This fact suggests that longer time period is required to identify the effects of land use conversion on the soil C stocks. Switching from tree-based system, e.g. silvopasture to conventional arable land is expected reduction in soil C stocks due to the disturbances in soil aggregation promoted by intensive soil management (Haile et al. 2008; Post and Kwon 2000; Schroth et al. 2002). We observed that after 50 years of continuous arable land, soil TOC and TN stocks were 21 and 10% lower than under SP in the 0–20 cm depth interval, respectively. This indicates that in a long-term conventional tillage can significantly contribute to reduce TOC and TN stocks when compared with silvopastoral systems. According to Freibauer et al. (2004), conversion of permanent crops, e.g. silvopastoral system to arable land might contribute to decrease soil C sequestration at a rate of 1.0–1.7 Mg ha^{-1} y^{-1}. When land use is converted to intensive management system, soil carbon is lost more rapidly than it accumulates (Freibauer et al. 2004). Tillage affects the equilibrium of soil C balance through the physical disturbance and mixing of soil and exposure of disrupted aggregates, and through the incorporation of plant residues in the soil (Paustian et al. 1997).

Total C stocks under AR and SP-GL were in accordance with Chen et al. (2009), who reported TOC stocks for grassland around 40% higher than arable land in the 0–20 cm depth interval. Grassland also showed similar values of TOC and TN compared with SP, but contrary to arable land, land use conversion to grassland is expected increasing TOC and TN. Several studies have been shown that grassland management systems can contribute to significant increases of TOC and TN stocks (Chen et al. 2009; Conant et al. 2001). In the long-term, areas under grassland have similar potential to store TOC as areas under tree-based land use systems (Franzluebbers et al. 2000). The effect of grassland on soil C stocks is related to its intensive root cycling system, which has great content of lignin (Martens 2000).

C_{MB} stocks decreased non-significantly with SP-AR system as compared to SP in the 0–10 cm layer, probably due to the availability of low contents of C forms more easily decomposable, e.g. salt extractable organic C, which was positively correlated with C_{MB} stocks ($r^2 = 0.60$, $P < 0.001$). However, the area cultivated over the past 50 years under continuous arable land presented similar C_{MB} values compared with SP and SP-GL. C_{MB} corresponds to a small portion of TOC, which has been shown to be more sensitive to provide indications of changes and future trends in SOM caused by modified management practices (Llorente and Turrión 2009; Maia et al. 2007; Sparling 1997). Contrasting these findings, Hungria et al. (2009) observed that the microbial biomass was not clearly affected by different land use systems. Wu et al. (2003) did not observe differences in the C_{MB} among different land use systems in the

0–5 cm layer, but they found higher C_{MB} for a soil conservation tillage system in the 5–10 cm depth and attributed these differences to the higher moisture content at this depth. The quality and quantity of soil C inputs as well as nutrient availability are important factors affecting the C_{MB} content (Lugato et al. 2006).

The conversion of silvopasture to arable land as well as to continuous arable land (AR) system modified the distribution of C_{LF} in both layers as a result of incorporation of crop residues and disruption of aggregates. There were no differences of C_{FL} values with increasing depth for AR and SP-AR, however C_{LF} declined by 62% from 0–10 to the 10–20 cm layer at SP and SP-GL. AR and SP-AR treatments presented similar values of C_{LF} and amounted 1.90 and 2.50 Mg ha^{-1} at the 0–10 cm depth, respectively. Similar result was found in an Orthic Brown Chernozemic soil under continuous arable land in Canada, in which value of C_{FL} at 0–10 cm depth corresponded to 1.98 Mg ha^{-1} (Wu et al. 2003). In northeastern Brazil, Maia et al. (2007) reported values of C_{FL} around 7.0 Mg ha^{-1} in soil under silvopastoral system in the 0–12 cm layer. Despite not statistically significant, the same authors observed C_{FL} values around 40% lower under conventional tillage systems. Considering the sum of C_{FL} in both layers (0–20 cm) there was no significant differences among treatments. Although, SP-AR tended to present higher value of C_{FL} probably, due to the disruption of aggregates that exposes intra-aggregate materials increasing in a short-term the contents of light fraction.

The AR study site tended to present the lowest values of C_{HF} at 0–10 cm depth (7.2 Mg ha^{-1}), however the difference was not significant when compared with the others treatments. Wu et al. (2003) found similar amounts of C_{HF} in soil cultivated under continuous arable land (7.8 Mg ha^{-1}) in the 0–10 cm layer. The same authors observed significant increases in C_{HF} in soil under forage crop for 10 years after 70 years of arable land compared with continuous arable land. In our study, the C_{HF} represented the highest C fraction in soil and corresponded to 82% of TOC when the sum of depths (0–20 cm) was taken into account.

Except for AR, δ^{13}C values of the light fraction increased with increasing depth. Although, considering the heavy fraction, this effect was observed only for SP and SP-GL. The increase in δ^{13}C of organic matter with increasing depth in soils has been reported in several studies under undisturbed soils cultivated with C_3 plants, and is attributed to isotopic discrimination associated with decomposition process (Accoe et al. 2002; Balesdent and Mariotti 1996; Bernoux et al. 1998). However, management systems with soil ploughing modify the distribution of C in the top 20 cm layer as a result of crop residues incorporation and mixture of upper and lower layers. The heavy fraction was more enriched in δ^{13}C than light fraction. In general, soil δ^{13}C tends to increase when size of physical organic matter fractions decrease (Balesdent and Mariotti 1996), probably due to preferential use of ^{13}C-depleted molecules for respiration during decomposition process, which may induce a progressive ^{13}C enrichment in the residual organic matter (Accoe et al. 2002).

In conclusion, long-term experiments are essential to identify effects of land use conversion on C and N stocks in whole soil. In a short-term, arable land system modifies the distribution of C and N between upper and lower layer. Despite the observed tendency of low C_{MB} values for recent conversion to arable land, microbial biomass was not clearly affected by changes in SOM promoted by different land use systems. Therefore, more investigations under field conditions are necessary to better understand the effects of land use systems on this soil C fraction. The distribution of light and heavy fraction are also altered by management system, however the stocks are maintained when considering the sum of different layers. The altered δ^{13}C composition of light and heavy fractions emphasizes the effect of soil disturbances promoted by conventional tillage system on the SOM dynamics.

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