Carbon Dynamic after Conversion of Permanent Grassland into Arable Soil

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Summary

Carbon input and balance in soils is regarded as the main criterion of agricultural sustainability. Generally, carbon dynamic depends not only on the carbon input and its decomposition rate, but it is also influenced by various agronomic practices. Therefore, changes in organic carbon stock and humic substances quality were evaluated in two different agricultural management systems (permanent grassland and intensive crop sequences). Haplic Cambisol (Czech-Moravian Highland, locality Vatín, Czech Republic) was sampled twice a year (spring and autumn) in the depth 0-20 cm during the period 2010-2016. Soil was sandy-loam textured, with middle organic carbon content and very low humic substances quality. Results showed that crop management practices directly influenced soil cumulative potential, quality of humic substances, soil reaction and amount of nutrients. Statistically significant differences were found.

Key words

carbon forms, arable soil, permanent grassland

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Introduction

Soil carbon, specifically in the form of soil organic matter, plays a key role in the functioning of soils to produce a wide range of vital environmental functions. Loss of soil carbon degrades these services, resulting in decreased of crop yields, environmental and market value of soil. Land management can also enhance soil carbon by optimal crop rotation and fallow cover crops, organic matter addition, and optimal fertilization systems tillage systems (Banwart et al., 2015). Soil organic carbon forms could be divided into stable and labile. Stable carbon forms are represented by humic acids (HA), fulvic acids (FA) and humins. Because of relatively long period of time that stable carbon spends with the soil and is thereby withheld from the atmosphere, it is often referred to as being sequestered. Carbon sequestration depends on soil capacity to store resistant plant residues and protects and accumulates the stable humic substances (HS). The degree of resistance of HA and FA is attributed to their chemical composition, especially the absence of labile (hydrolysable) linkages, and to the lack of regularly repeating units. Humin is generally considered to be a component of HS although some of its units may not have undergone the biological transformation (Swift, 1999 and 2001). Labile carbon forms are mainly introduced by dissolved organic carbon (DOC) and by carbon of microbial biomass (C_{mic}) as quoted Leinweber et al. (1995) and Degens and Sparling (1996). DOC is supposed to be very active in carbon pool and its chemical composition and mobility (the smaller and more polar an organic molecule) directly affect biological soil properties. Relationship between DOC and soil was studied by Zsolnay (2003) and Pospíšilová et al. (2011). They concluded that DOC content is controlled by its content in soil. Instead of complicated determination of DOC determination of water extractable organic carbon (WEOC) is frequently used as quoted Šestauberová and Novák (2011). Stability or lability of any organic carbon fraction could be due to either chemical composition or protection within the soil aggregates. It is supposed that chemical properties of HS are integrally linked to the soil´s behavior in nutrient cycling and supply, water retention, soil structure and soil biological parameters (Filep and Rekasi, 2011).

Many different mathematical models were proposed to characterized soil organic carbon stock (Coleman and Jenkinson, 2005; Smith et al., 2005; 2007; De Li Liu et al., 2016). They showed that the amount of soil organic carbon that is attained under agriculture largely depends upon the carbon input and its decomposition rate under various agronomic practices. Whether soils are a sink or source of carbon depends on the actual organic carbon stock, agricultural practices over time, soil properties (e.g. clay content, soil depth, content and quality of plant input, organic fertilizer input etc.), and climatic conditions.

The aim of our research was to evaluate dynamic of stabile and labile carbon forms and humic substances quality in two different agricultural management systems (permanent grassland and intensive crop sequences) during the period 2010-2016.

Material and methods

Haplic Cambisol (locality Vatín, Czech-Moravian Upland, 530 m a.s.l.) belongs to the potatoes growing area. Average annual temperature is 6.9 °C. Average annual precipitation 621 mm. Soil was sampled twice a year (spring and autumn) in 0-20 cm depth. Native grassland (*Sanguisorba-Festucetum comutatae*) was ploughed and intensive crop sequences involved 50 % of cereals, 16.6 % of root crops, and 33.4 % of technical crops. Nutrients were applied at ratios (N-P-K, kg/ha/year): 130–40–80 (winter wheat) and 60–35–80 (spring barley). Soil reaction was determined by potentiometric method in distilled water and in 1M KCl solution (1:2.5). Particle size analysis was determined by pipette method (Zbíral et al., 2010). Total organic carbon content (TOC) was determined by oxidimetric titration method (Nelson and Sommers, 1982). Fractional composition of HS was determined according to Kononova and Beltchikova method (1963) as follows: 5g of air dried soil sample, sieved at mesh size of 1mm and extracted by a mixture (1:1; 0.1M NaOH + 0.1M $Na_4P_2O_7$) for 24h. The sediment was separated by centrifugation at 2800g for 10min, washed with mixture and centrifuge again. Two individual washings were unified with original supernatant. Sum of HS and HA was determined by oxidimetric titration method in aliquot volumes. FA content was calculated as a difference between HS and HA. WEOC was determined as follows: 1 g of soil sample was suspended into 100 ml demineralized distilled water and shaking for 30 min. Then the samples were centrifuged (15 min at 3000 rpm) and filtrated through membranes filter S-PAK ™ Millipore (0.45 μm). Content of WEOC was determined according to ČSN EN 1484 and ČSN EN 12260 using high temperature (720 °C) catalytic combustion with chemo- luminescent detection of flue gases (carbon and oxygen) and spectrometric detection of CO_2 in infrared spectral region using analyser Shimadzu TOC-VCSH with auto sampler ASI-5000 (Shimadzu, Kyoto, Japan). Cmic carbon was determined by fumigation-extraction method in fresh soil samples, sieved through 5 mm according to Vance et al. (1987). Statistical analysis, including graphical outputs, was carried out using STATISTICA 12.0 (Stat-Soft Inc., Tulsa USA, StatSoft ČR s.r.o., 2014). Statistical data processing Exploratory Data Analysis /EDA/, ANOVA - Tukey test /HSD-test/ a Fisher test /LSD test/, Principal Component Analysis (PCA) for data evaluation was applied (Meloun and Militký, 2011). PCA was used for interpreting the parameters of soil organic matter (TOC, HS, HA, FA etc.) and physico-chemical properties of soil (pH, content of phosphorus and potassium, etc.). Selected measured characteristics were used as predictors (factors); they were chosen on the basis of an eigenvalue graph. Variables with impaired assumption of normality were converted using logarithmic transformation. As part of step 1, PCA was carried out with all the variables to compute the most important variables. Step 2 involved selecting active and supplementary variables for better interpretation. This stepwise analysis significantly improves the outcome of the PCA analysis in case of a smaller number of samples. PCA was used for calculating a component weight for the investigated variables (Meloun and Militký, 2011). Based on correlations and contributions in convincing factors each of the characteristics was subsequently judged for relevance to explain the multidimensional dependencies (correlations) in the factorial plane. Statistical significance was assessed at a significance level of $P = 0.05$.

Results and discussion

Studied soil was sandy-loam textured, with acid soil reaction, and low cation exchange capacity. Humus content was middle but its quality was very low. Prevalence of FA was determined and HA/FA ratio was less than 1. Humification degree was middle (30-40

Table 1. Statistical evaluation of studied soil parameters in Arable land and Permanent grassland

Characteristic	Site	HSD Test*		LSD Test**	
		Arable land	Permanent grassland	Arable land	Permanent grassland
TOC	Arable land	x	0.000177	x	0.000010
	Permanent grassland	0.000177	x	0.000010	x
HS	Arable land	x	0.000172	x	0.000000
	Permanent grassland	0.000172	x	0.000000	x
HA	Arable land	x	0.004722	x	0.004559
	Permanent grassland	0.004722	x	0.004559	x
FA	Arable land	x	0.000218	x	0.000060
	Permanent grassland	0.000218	x	0.000060	x
HA/FA ratio	Arable land	x	0.323781	x	0.323656
	Permanent grassland	0.323781	x	0.323656	x
DH I	Arable land	x	0.602599	x	0.602452
	Permanent grassland	0.602599	x	0.602452	x
DH II	Arable land	x	0.261271	x	0.261137
	Permanent grassland	0.261271	x	0.261137	x
pH	Arable land	x	0.000262	x	0.000108
	Permanent grassland	0.000262	x	0.000108	x
C_{we}	Arable land	x	0.003794	x	0.003638
	Permanent grassland	0.003794	x	0.003638	x
C_{mic}	Arable land	x	0.002175	x	0.002034
	Permanent grassland	0.002175	x	0.002034	x
K	Arable land	x	0.000172	x	0.000000
	Permanent grassland	0.000172	x	0.000000	x
P	Arable land	x	0.000172	x	0.000001
	Permanent grassland	0.000172	x	0.000001	x
Ca	Arable land	x	0.051929	x	0.051790
	Permanent grassland	0.051929	x	0.051790	x
Mg	Arable land	x	0.002702	x	0.002546
	Permanent grassland	0.002702	x	0.002546	x

Note: n = 7; * Tukey test ; ** Fisher test; P = 0,05

%). Statistical evaluation of studied soil parameters is showed in Table 1. Comparison of different carbon forms in arable soil and permanent grassland showed higher content of stable carbon form (TOC, HS, HA, FA) in grassland (Figure 1). Also labile carbon forms (WEOC, Cmic) content was higher in grassland to compare with arable soil (Figure 1). On the other hand, amount of nutrients and more favourable soil reaction was reached in arable soil. Permanent grassland was more acid and had lower nutrients content. Our observation also showed that in spite of lower content of HS, HA, and FA in arable soil we reached more favourable HA/FA ratio here soil to compare with grassland. We can say that in spite of lower content of HS their quality is higher than quality of HS in permanent grassland. Similar results were published by Tesařová et al. (2006) and Petrášová et al. (2009). They stressed that decreasing of total carbon content is evident mainly the first two-three years after ploughing and then the new, and lower equilibrium of total carbon content in arable soil took place. This effect is generally called priming effect. Further the ordination diagram (Figure 2) is showing the results of PCA analysis. Two different categories (permanent grassland and arable soil) are evident. Statistically significant separation into two categories according to balanced TOC, potassium and phosphorus content and the soil pH is evident. Total variability (PC1, PC2 and PC3) of studied parameters is higher than 94 %. On axis PC1 potassium content is in strong positive relationship with phosphorus content (r=0.90). Medium positive relationship (r=0.80–0.85) between soil reaction and potassium and phosphorus content was determined. We can also conclude that on the axis PC1, TOC is in positive relationship with FA (r=0.74) and HA (r=0.68) – see Figure 2. No significant correlation on PC2 axis was found. The PC2 axis lacks considerable correlation; rather, directions are characterised, depending on HA/FA ratio (Figure 2). In conclude it should be stress that differences in quantity and quality of soil organic matter are directly influence by crop sequence and plant species, fertilizing system (mineral and organic), tillage system and by intensity of agricultural exploitation as well. Because of depending of labile carbon forms onto total organic carbon amount regulation of carbon balance in sustainable agronomical practices is possible due to appropriate agricultural management system.

Conclusion

Land use and management practices are directly influence stabile and labile carbon forms in soil. Very high carbon accumulation potential was confirmed under permanent grassland. Accumulation potential of arable soil is depending on intensity of agriculture and management system with respect to soil type and climatic conditions.

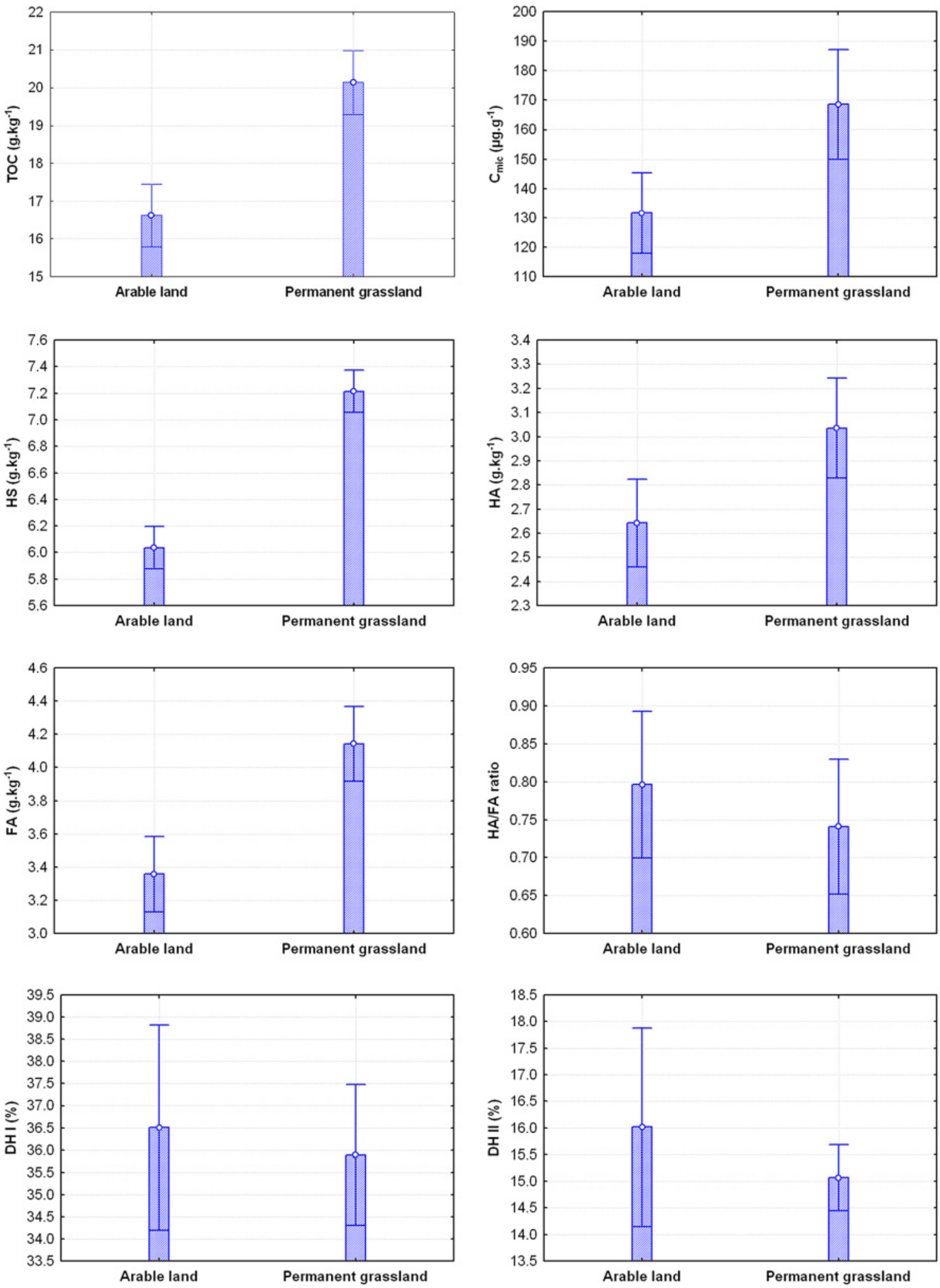

Figure 1. Content of different carbon forms and degree of humification in Arable land and Permanent grassland

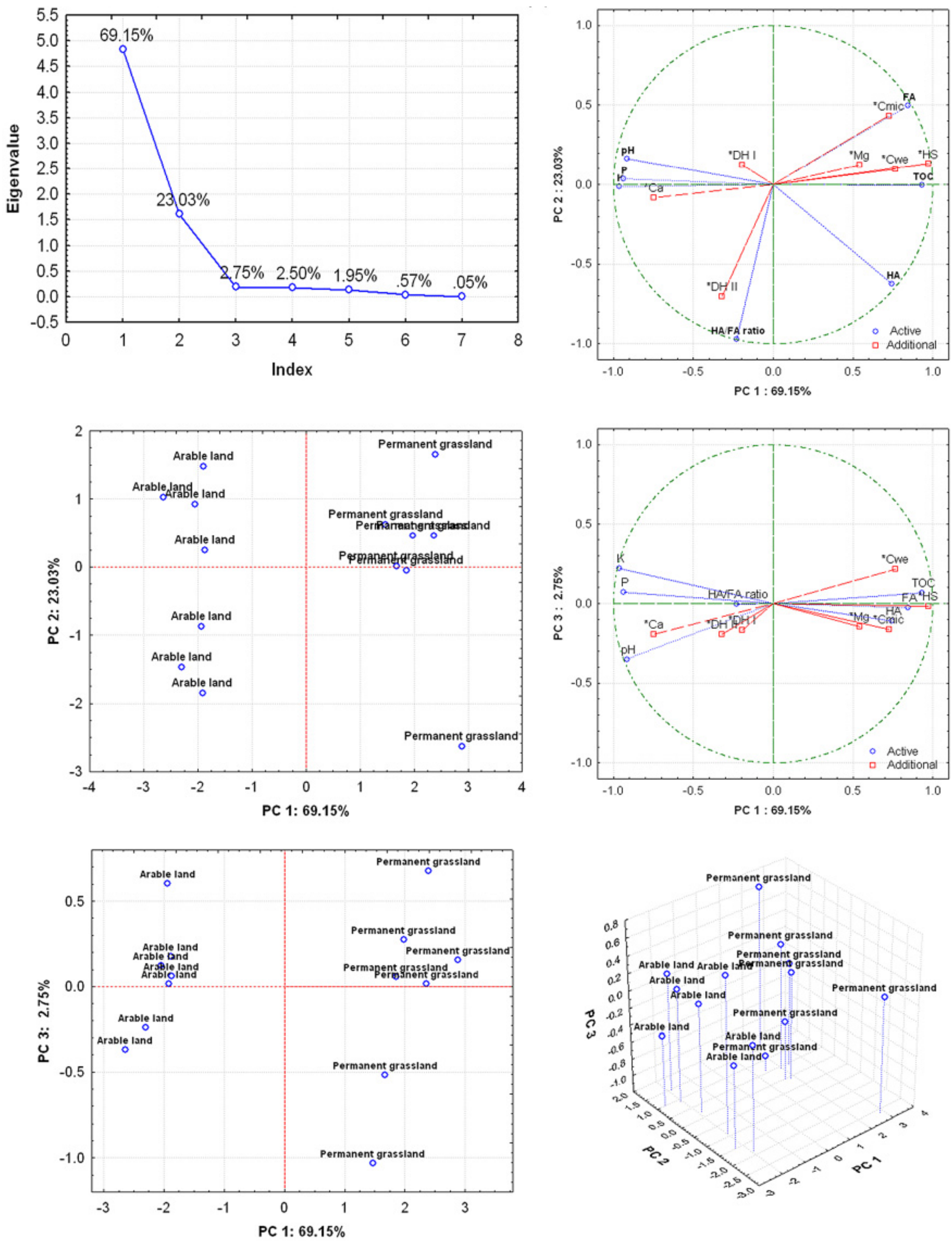

Figure 2. Multivariate statistical PCA of studied soil parameters in Arable land and Permanent grassland

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