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Letter to the Editor

Seasonal Variability of Soil Organic Carbon Fractions Under Arable Land

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ABSTRACT

Carbon fractions in soils apparently vary not only in space, but also over time. A lack of knowledge on the seasonal variability of labile carbon fractions under arable land hampers the reliability and comparability of soil organic carbon (SOC) surveys from different studies. Therefore, we studied the seasonal variability of two SOC fractions, particulate organic matter (POM) and dissolved organic carbon (DOC), under maize cropping: POM was determined as the SOC content in particle-size fractions, and DOC was measured as the water-extractable SOC (WESOC) of air-dried soil. Ammonium, nitrate, and water-extractable nitrogen were measured as potential regulating factors of WESOC formation because carbon and nitrogen cycles in soils are strongly connected. There was a significant annual variation of WESOC (coefficient of variation (CV) = 30%). Temporal variations of SOC in particle-size fractions were smaller than those of WESOC. The stocks of SOC in particle-size fractions decreased with decreasing particle sizes, exhibiting a CV of 20% for the coarse sand-size fraction (250–2 000 μm), of 9% for the fine sand-size fraction (50–250 μm), and of 5% for the silt-size fraction (20–50 μm). The WESOC and SOC in particle-size fractions both peaked in March and reached the minimum in May/June and August, respectively. These results indicate the importance of the time of soil sampling during the course of a year, especially when investigating WESOC.

Key Words: carbon turnover, carbon pools, dissolved organic carbon, particle-size fractions, particulate organic matter, time of soil sampling, water-extractable soil organic carbon

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Soil organic matter (SOM) can be differentiated into pools with different decomposability, which have been defined, *e.g.*, by Strosser (2010), as labile, stable, and inert fractions. Labile fractions such as coarse particulate organic matter (POM) comprise only a small proportion of total SOM, but it is widely accepted that these fractions are key to soil functioning (McGill *et al.*, 1986; Qualls and Haines, 1991; Kaiser, 2001). Thus, POM is used as a quality indicator of soils (Rocha Junior *et al.*, 2013) and plays an important role in nutrient cycling (Haynes, 2005). Coleman and Jenkinson (1996), Skjemstad *et al.* (2004) and Herbst *et al.* (2012) confirmed that the implementation of POM content into SOC turnover models improves the prediction of heterotrophic soil respiration rates.

Dissolved organic carbon (DOC) belongs to the most labile soil organic carbon (SOC) pools (Strosser, 2010) and appears to be an important part of the global carbon (C) cycle (Siemens, 2003). Although there are multiple methods for extracting DOC from soils (Buckingham *et al.*, 2008; Guigue *et al.*, 2014), there is consensus that it is highly bioavailable and biodegradable (Marschner and Kalbitz, 2003; Ghani *et al.*, 2013; Shi and Marschner, 2014) and an important C source for microbes (Smolander and Kitunen, 2002; Wang *et al.*, 2003). Numerous biotic and abiotic factors, *e.g.*, plant growth, microbial community structure and its activity (Li *et al.*, 2013; Fanin *et al.*, 2015), and nitrogen (N) speciation and bioavailability (Heumann *et al.*, 2012), influence the formation of DOC (*e.g.*, Chantigny, 2003). Nitrogen availability in soils, in turn, influences the decomposition of plant litter (Mary *et al.*, 1996; Hadas *et al.*, 2004; Manzoni *et al.*, 2010). Given that decomposition itself is an important source of DOC formation (Kalbitz *et al.*, 2000; Don and Kalbitz, 2005), it is self-evident to likewise gather information on seasonal N dynamics.

Soil DOC can be obtained by water extraction, yi-

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elding water-extractable SOC (WESOC) as an additional indicator for labile SOC pool dynamics. There is some knowledge on spatio-temporal patterns of DOC at forest sites (Hishi *et al.*, 2004), or on its distribution within the soil profile (Hamkalo and Bedernichek, 2014), from which temporal patterns of DOC might also be inferred. However, no systematic assessment of temporal variations of labile C fractions at arable sites appears to have been performed. Thus, the variability of POM fractions and DOC in the course of the year on arable land is largely unexplored. As a result, there is no way of knowing to what extent sampling results portray an accurate picture of the true values throughout the year and basic recommendations on optimum sampling time are still not available. Here, we elucidate seasonal patterns of POM and DOC under arable land to evaluate whether the time of soil sampling during the course of a year is of importance. In addition, we analysed soil N and its speciation, soil temperature, and precipitation as potential controlling factors.

We selected an arable land (50°52′5.26″ N, 6°27′ 11.04″E, 108 m above the sea level), located in Selhausen, North Rhine-Westphalia, in the Lower Rhine Embayment, Germany, as the test site. Covering a size of approximately one ha, the test site is dominated by Quaternary fluvial sediments, covered with eolian silt deposits (Walter and Dorn, 2007). Mean annual temperature and precipitation are 9.8 °C and 693 mm, respectively. The annual precipitation minimum is 441 mm (1976) and the maximum 1 042 mm (1966). Data was obtained from the weather station of the Jülich Research Center, Germany. In the study period, the annual precipitation was 600 mm; the minimum was 18 mm (April) and the maximum was 92 mm (May). The soil of the test site is a Stagnic Cambisol (Skeletic) (IUSS Working Group WRB, 2015). Prior to 2012, the test site was cultivated with C3 plants only. Since then, the test site has been continuously cultivated with maize (*Zea mays* L.) (variety Atletas, KWS SAAT AG, Einbeck, Germany). Under-feet fertilization with diammonium phosphate, equal to 70 kg N ha^{-1} and 80 kg P ha^{-1}, in May was followed by fertilization with calcium ammonium nitrate, equal to 100 kg N ha^{-1}, in June. The soil was plowed and harrowed in April, prior to seeding in May. Maize was harvested, chopped, and grubbed at the end of October.

Soil samples were taken from two parallel transects that covered a high portion of the in-field heterogeneity, which was revealed by mapping the apparent electrical conductivity (EC$_{\rm a}$) (EM38-MK2, Geonics Limited, Ontario, Canada) from 0 to 75 cm depth (Corwin and Lesch, 2005) (Fig. 1). Within these transects, the content of rock fragments (> 2 mm) ranged from 160 to 400 g kg^{-1}, with a mean of 260 and a standard deviation (SD) of 70 g kg^{-1}. Soil texture (< 2 mm) varied marginally: 20%, 62%, and 15% with an SD of 2%, 2%, and 1% for sand, silt, and clay, respectively. Ten soil samples were taken monthly from March 2013 to April 2014 on 14 dates for determination of DOC. For determination of POM, 10 soil samples were taken bimonthly from April 2013 to April 2014 on 7 dates. The soil samples were taken with a soil auger, up to a depth of 30 cm (plow horizon), subsequently sieved to < 2 mm, and dried at 40 °C for 48 h. For measurement of bulk density of the fine earth (< 2 mm), soil cores were taken bimonthly from April to November on 4 dates, with a metallic cylinder with a length of 28 cm and a diameter of 16 cm (a volume of approximately 2 300 cm^3), and dried at 105 °C for 48 h.

All measurements were performed in duplicate. The DOC (determined as WESOC) and water-extractable total N (WETN) were determined as described by Tirol-Padre and Ladha (2004): 10 g of dry soil were mixed with 50 mL of Millipore® water (20 °C) and shaken in an end-over-end shaker for 1 h. Subsequently, the samples were centrifuged for 20 min at 3 000 × *g*, vacuum-filtrated with 0.45 μm nylon membrane filters (ALBET LabScience, Dassel, Germany), and kept

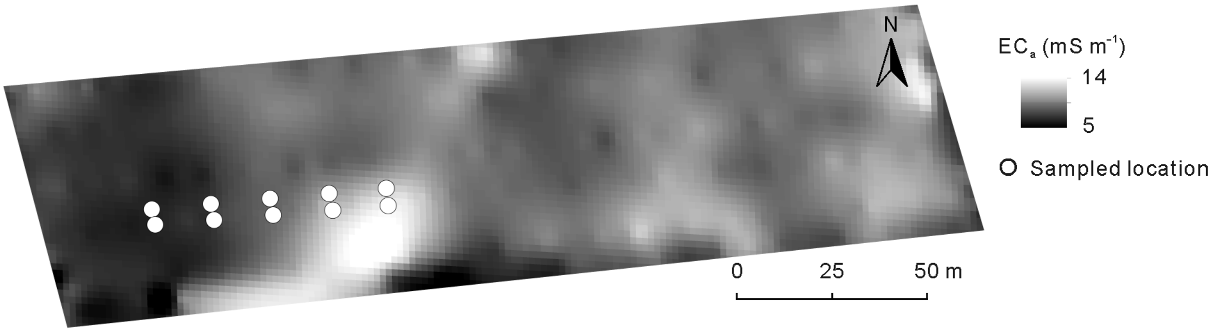

Fig. 1 Sampled locations in each of two parallel transects under arable land (maize) in the Lower Rhine Embayment, Germany, and in-field heterogeneity of the test site revealed by mapping the apparent electrical conductivity (EC$_{\rm a}$).