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Response of water extractable organic matter and its fluorescence fractions to organic farming and tree species in poplar and robinia-based alley cropping agroforestry systems

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ABSTRACT

Organic farming and agroforestry both have the potential to develop sustainable and environmental-friendly agroecosystems and to sequester more soil organic C (SOC). In a long-term field trial, we evaluated the effect of 21-year organic farming and 4-year agroforestry (Robinia and Poplar-based alley cropping system) on water extractable organic matter (WEOM). The technique combining excitation emission matrix (EEM) spectra with parallel factor analysis (PARAFAC) was used to reveal the components of WEOM. In addition, WEOM was characterized by UV absorbance and fluorescence spectra. Organic farming generally increased SOC and total N contents but decreased the WEOM content as well as the WEOM components indicated by the maximum fluorescence intensity (F_{max}). Specific UV absorbance (SUVA) and humification index (HIX) of WEOM in organic farming implied WEOM in the organic farming had more components with aromatic structure but less humified. Higher fluorescence (FI) and freshness indices (BIX) of WEOM in organic farming system indicated that a higher percentage of WEOM was microbial-derived in the organic than in the integrated farming system. Robinia showed positive effect on SOC and total N contents in comparison with poplar and had stronger effects on the WEOM components, although the WEOM content did not differ between the two tree species. The significant farming × trees interactions on SOC and water extractable organic carbon (WEOC) indicated that the robinia effects were more pronounced in the organic farming system. Thus, the change of SOC was the result of interactive effect of farming and hedgerow trees in an agroforestry system. The low-input organic farming and robinia tended to result in change of quality of WEOM and led to enrichment of substances of high stability in WEOM. From above, the combination of organic farming and robinia trees is an important means for developing sustainable agricultural systems and soil carbon sequestration.

1. Introduction

Soil WEOM is an active, mobile and complex fraction of soil organic matter (SOM) and is sensitive to land use and management practices (Dong et al., 2009; Mao et al., 2012; Xu et al., 2013). WEOM participates in multiple soil processes, such as SOM translocation and mineralization, denitrification and trace gas production, solubility, transportation and toxicity of organic contaminants (Chantigny, 2003; Stark et al., 2007; Xu et al., 2013). It was also reported that WEOM modulates soil microbial community as a feedback to the production of WEOM from microbial activities (Bausenwein et al., 2008). Moreover, land-use and management practices were repeatedly reported to influence the dynamics of WEOM and biodegradability by affecting soil biochemical properties and structure and WEOM composition (Chantigny, 2003; Marschner and Kalbitz, 2003; Xu et al., 2013).

Agroforestry systems combine agriculture and forestry into a production system and are recognized as integrated approaches for sustainable land use aside from their contribution to climate change adaptation and mitigation (Ramachandran Nair et al., 2009; Lorenz and Lal, 2014). Agroforestry promotes C sequestration in tropical and temperate regions (Montagnini and Nair, 2004; Nair et al., 2010), depending on tree species and management of the agroforestry system (Lorenz and Lal, 2014). Trees, especially broadleaf trees having deep and extensive root systems and high belowground to aboveground biomass ratios, enhancing the potential for soil C sequestration (Laganiere et al., 2010; Lorenz and Lal, 2014). However, positive, neutral, and negative effects of trees on SOC pool have been observed in the meta-

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analysis of Laganiere et al. (2010). They reported that positive effects of planting conifer trees other than *Pinus* spp. on SOC pools may be negligible. In contrast, the planting of trees with N-fixers symbiosis for afforestation can increase the SOC pool as indicated by the >30% increase in SOC pools (Johnson and Curtis, 2001; Lorenz and Lal, 2014). Moreover, compared with studies on SOC stocks, research on the effects of agroforestry systems on SOM quality and composition, for example on labile WEOM is scarce.

Many studies showed the positive effects of organic farming on SOC stocks (Gattinger et al., 2012) and the biomass and diversity of soil microorganisms (Mäder et al., 2002; Fließbach et al., 2007; Birkhofer et al., 2008). The application of cattle farmyard manure (Heinze et al., 2010) and a more diverse crop rotation strengthens nutrient cycling in organic farming. However, no information exists whether the combination of organic farming and agroforestry results in an additive positive impact. The current agroforestry trial offers the unique possibility to investigate the effects of tree species (poplar and robinia) and organic farming on WEOM, investigating the following hypotheses: (1) Organic farming increases SOC and WEOM contents, especially that of the components of WEOM revealed by EEM-PARAFAC technique. (2) N_2-fixing robinia has stronger positive effects on SOC and WEOM than poplar, especially close to the hedgerow.

2. Materials and methods

2.1. Field experiment

Filed experiments have been carried out conducted in Scheyern Research Farm (TERENO site) located 40 km north of Munich (Germany) (48.50°N, 11.45°E) since 1992. The altitude of the farm ranges between 445 and 500 m (a.s.l.). The mean annual precipitation is 803 mm and mean annual temperature is 7.4 °C (Schröder et al., 2002). The central part of the research station was divided into two parts (in 1992): organic and integrated farming system, each striving for ecological and economical sustainability. Moreover, detailed studies on management-induced changes were carried out in plots sub-divided in integrated and organic farming (Schröder et al., 2002). The soil types are sandy to loamy Cambisols, derived from tertiary sediments and partly covered by loess and most of the soils have loamy texture (Flessa et al., 2002; Kölbl and Kögel-Knabner, 2004). The soils of current organic and integrated alley-cropping farming (agroforestry) field are comparable and have a soil texture of silty loam (USDA) and the soil particle distribution of top soil is 27% sand, 54% silt and 19% clay for organic field and 27% sand, 50% silt and 23% clay for integrated field.

In 2009, agroforestry parcels were incorporated into fields under both integrated and organic farming systems. Three swaths of trees, each comprised of several different species were planted in an alley cropping for the purpose of bioenergy production (30 m length for each tree species) and leaving 30 m wide arable soil for crop production (Fig. 1). The poplar (*Populus maximowiczii* × *P. nigra*) and Robinia (*Robinia pseudoacacia* L.) strip systems were chosen for this study in both organic and integrated systems as they are commonly used tree species in German agroforestry systems. The experiment consisted of four treatments with three replications: organic farming + poplar (O-pop), organic farming + robinia (O-rob), integrated farming + poplar (I-pop), and integrated farming + robinia (I-rob). The plot for each treatment is 30 × 30 m in size. The treed portions of both systems do not receive fertilizer either in manure or mineral form and do not receive weed control via mechanical means or pesticide. The tree density of poplar and robinia are the same.

The organic farming system is low-input, utilizing nitrogen fixing cover crops instead of mineral nitrogen or synthetic inputs as green manures. Also no pesticide or herbicide was applied. Soils were tilled with moldboard. A seven-field crop rotation was run in the organic farming system: (1) Grass–clover–alfalfa (GCA) (*Lolium perenne* L. + *Trifolium pratense* L. + *Medicago sativa* L.), (2) potatoes (*Solanum tuberosum* L.) + mustard (*Sinapis alba* L.) as cover crop, (3) winter wheat (*Triticum aestivum* L.), (4) sunflower (*Helianthus annuus* L.) + GCA as cover crop, (5) GCA, (6) winter wheat, and (7) winter rye (*Secale cereale* L.) + GCA as cover crop. In the integrated farming system, soils were tilled by harrowing and chiseling, and the tillage intensity was reduced to a level to control weed as well as to conserve soil. Pesticides were completely forbidden in organic farming system while in necessity it is applicable in the integrated farming system. A four-field crop rotation with cover crops was run in the integrated farming system: (1) winter wheat; (2) potatoes; (3) winter wheat; and (4) maize (*Zea mays* L.).

2.2. Sampling and soil properties

Sampling plots were randomly set in the tree row (0 m), transition area (2 m from the tree row: 2 m) and middle of crop area (15 m from the tree row: 15 m) corresponding to poplar and robinia strips in organic and integrated farming system (Fig. 1). In May 2013, before vegetation developed after a special long winter time, three replicate composite samples were collected at a depth of 0–25 cm. SOC and total N

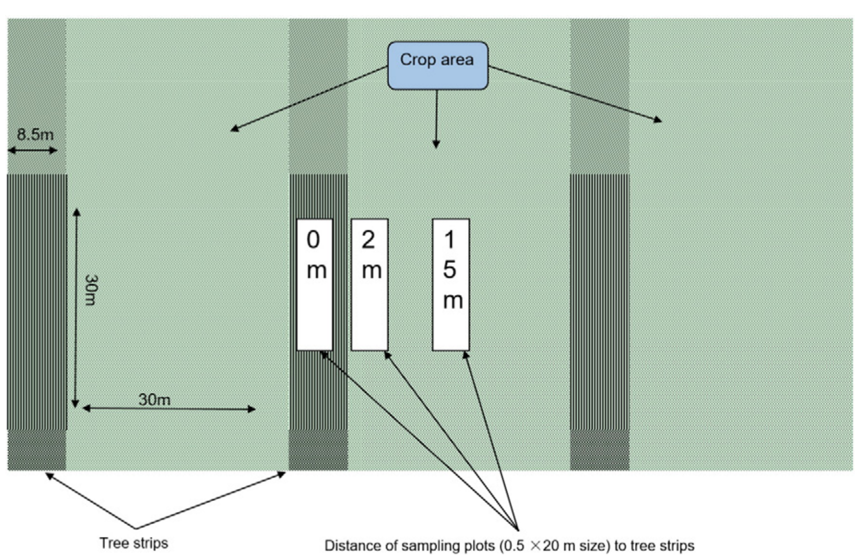

Fig. 1. Experimental layout of alley cropping agroforestry systems and sampling sites (0 m, 2 m and 15 m).