



Impacts of organic matter amendments on carbon and nitrogen dynamics in grassland soils



Rebecca Ryals^{a,*,1}, Michael Kaiser^{b,2}, Margaret S. Torn^c, Asmeret Asefaw Berhe^b, Whendee L. Silver^a

^a University of California, Berkeley, Department of Environmental Science, Policy, and Management, 137 Mulford Hall #3114, Berkeley, CA 94720, USA

^b University of California, Merced, School of Natural Sciences, 4225 N Hospital Rd, Atwater, CA 95301, USA

^c Lawrence Berkeley National Laboratory, Earth Sciences Division, 1 Cyclotron Rd, Berkeley, CA 94720, USA

ARTICLE INFO

Article history:

Received 7 February 2013

Received in revised form

1 August 2013

Accepted 9 September 2013

Available online 20 September 2013

Keywords:

Density fractionation

Diffuse Reflectance Infrared Fourier

Transform spectroscopy

Carbon sequestration

Soil amendment

Grassland ecosystems

ABSTRACT

Organic matter amendments have been proposed as a means to enhance soil carbon (C) stocks on degraded soils. However, only few data exist on rates of soil C sequestration or the fate of added C in grassland soils, which are generally thought to have high C storage potential. We measured changes in the amount of C and nitrogen (N) in soils and in the composition of soil organic matter (SOM) following a single application of composted organic matter in two annual grasslands from different bioclimatic zones (coastal and inland valley). There was a significant increase in bulk soil organic C content at the valley grassland, and a similar but non-significant trend at the coastal grassland. Physical fractionation of soil three years after organic matter amendment revealed increases in C and N in the free- and occluded light fractions in both the valley and coastal grasslands. Amendments resulted in a greater relative increase in the N stored in light soil fractions compared to C, leading to lower C:N ratios. Diffuse Reflectance Infrared Fourier Transform (DRIFT) spectroscopy showed an increase in the ratio of carboxyl and carbonyl functional groups to aliphatic methyl and methylene groups in the free- and occluded light fractions. These data show that the organic matter amendment was incorporated in the free light and occluded light fractions over three years. Our results indicate that a single application of compost to grassland soils can increase soil C and N storage in labile and physically protected pools over relatively short time periods and contribute to climate change mitigation.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Soil organic matter (SOM) plays an important role in ecosystems by retaining and supplying plant nutrients, improving soil aggregation, reducing soil erosion, and enhancing water holding capacity (Tisdall and Oades, 1982; Brady and Weil, 2002). Grassland soils are generally thought to be rich in organic matter, but poor management, vegetation shifts, and changes in climate have decreased SOM stocks in many of the world's grasslands (Asner et al., 2004; Bai et al., 2008). The large global extent of grasslands with

depleted organic matter stocks has focused attention on the management of these ecosystems for C sequestration to help mitigate climate change (Asner et al., 2004; Bai et al., 2008; Conant et al., 2011; Follett, 2001; Lipper et al., 2010; Morgan et al., 2010). Management-induced soil C sequestration has been studied in agricultural systems in the context of conservation tillage, cropping, organic and synthetic fertilization, and residue incorporation (Paustian et al., 1997; Lal, 2002; Kaiser et al., 2007; Kong et al., 2009; Lugato et al., 2010). In contrast, information regarding the impact of grassland management on soil C sequestration is much more limited (Conant et al., 2001; Follett, 2001; Lal, 2002; Derner and Schuman, 2007).

Organic matter amendments have been proposed as a means to increase C storage in soils (Cabrera et al., 2009; Powlson et al., 2012); this can occur directly from the C inputs in the amendment and indirectly from increased plant production (Eghball and Power, 1999; Ryals and Silver, 2013). Organic matter amendments to soils have been related to enhanced soil water holding capacity (Gagnon et al., 1998; Zebarth et al., 1999; Pandey and Shukla, 2006),

* Corresponding author. Present address: Brown University, Environmental Change Initiative, MacMillan Hall Box #1951, Providence, RI 02906, USA. Tel.: +1 401 863 2799.

E-mail addresses: rebecca_ryals@brown.edu, rebeccaryals@gmail.com (R. Ryals).

¹ Now: Brown University, Environmental Change Initiative, 167 Thayer St, Providence, RI 02912, USA.

² Now: University of Kassel, Department of Environmental Chemistry, Nordbahnhofstr. 1a, 37213 Witzenhausen, Germany.

decreased bulk density (Lynch et al., 2005), and improved soil fertility (Mader et al., 2002). Amendments may also increase organic nitrogen (N) in soils, which could act as a slow release fertilizer enhancing net primary productivity (Ryals and Silver, 2013). Furthermore, organic matter amendments could provide opportunities for greenhouse gas offsets if materials are diverted from high emissions sources, such as food waste from landfills (Powelson et al., 2012; DeLonge et al., 2013).

However, the fate of organic matter amendments in grassland soils remains unclear. Most organic matter amendments are applied to the soil surface. The proportion of this material that is incorporated and retained in soils over time is unknown, but is likely a function of the chemical composition of the material added and the specific soil and environmental conditions of the site. Several mechanisms can act to stabilize added C and N including physical protection via soil aggregation by, for example, microbial production of binding agents in the course of organic matter decomposition (Golchin et al., 1994; Six et al., 1998; Gulde et al., 2008). Detecting and interpreting changes to soil C and N pools can be difficult, particularly in ecosystems with relatively large standing stocks of bulk soil C and N. If organic matter that is applied to the surface is not sorted or separated when soils are sampled and analyzed, increases in soil C and N stocks may be greatly exaggerated.

Soil physical fractionation techniques can improve our ability to detect management-induced changes in pools of C and N, and have been used widely in agricultural and forested ecosystems (Chivenge et al., 2007; He et al., 2008; Powelson et al., 2012). Fractionation provides an indication of the physical location of C and N in the soil matrix (Sollins et al., 1996). Turnover of SOM is governed, in part, by the accessibility of organic substrates to decomposers (Dungait et al., 2012), and also by the chemical quality of the material (Jastrow et al., 2007; Conant et al., 2011). Assessments of SOM chemical characteristics are commonly used to infer its potential reactivity (Kögel-Knabner et al., 2008). By combining physical fractionation and chemical characterization, it is possible to identify fractions with different SOM stabilization potentials (Sohi et al., 2001; Poirier et al., 2005) to assess their relevance for long-term soil C and N storage.

In this study, we investigated the effects of an organic matter amendment (compost) over a three-year period on C and N storage in two grassland soils. We used a combination of field and laboratory approaches to determine the fate of the amendment over time. We hypothesized that a single application of composted organic matter would promote soil C and N sequestration primarily through an increase in the free light fraction of the SOM pool over the short-term (3 y), that N storage would be lower relative to C in soil fractions due to losses during mineralization, and that sequestered C would be dominantly composed of the amendment material. We combined measurements of bulk soil C and N pools with physical fractionation procedures and Diffuse Reflectance Infrared Fourier Transform (DRIFT) spectroscopy to track the fate of the added compost in the two grassland soils.

2. Material and methods

2.1. Study sites and experimental design

The study was conducted in valley grasslands at the Sierra Foothill Research and Extension Center (SFREC) in Browns Valley, CA (39.24 °N, 121.30 °W) and coast range grasslands (hereafter referred to as “coastal”) in Nicasio, CA (38.06 °N, 122.71 °W). Valley and coastal grasslands represent the two dominant grassland types in California (Kuchler, 1964; Brown et al., 2004): Valley grasslands occupy the hot, dry interior regions of the Central Valley and Sierra Nevada foothills. Coastal grasslands occur adjacent to the coast and

experience milder summertime temperatures and greater winter rainfall (Jackson and Bartolome, 2002). At the valley grassland site, annual precipitation averages 730 mm/y (22 y mean), and mean air temperatures range from 2 °C in January to 35 °C in July. Soils are derived from Mesozoic and Franciscan volcanic rock and classified as in the Auburn–Sobrante complex in the Xerochrepts and Haploeralfs great groups (Beaudette and O’Geen, 2009). At the coastal grassland site, annual precipitation averages 950 mm/y (37 y mean), and mean air temperatures range from 6 °C in January to 20 °C in July. Soils are derived from Franciscan mélange and classified as the Tocaloma–Saurin–Bonnydoon series in the Haploxerolls and Argixerolls great groups (Beaudette and O’Geen, 2009). Both grassland types are dominated by non-native annual grasses (e.g. *Avena barbata*, *Festuca perennis*), with native perennial grass species (e.g. *Stipa pulchra*, *Danthonia californica*) also present at the coastal grassland.

Paired plots (25 m × 60 m) were established in three watersheds at each site in October 2008. Treatments consisted of a one-time organic matter amendment and a non-amended control. An organic-rich soil amendment was added as a single application of commercially available composted dry organic green waste (Feather River Organics, Marysville, CA) with a N concentration of 1.87% and a C:N ratio of 11. A thin surface dressing approximately 1.3 cm thick (equivalent to 7 kg/m², 1.42 kg C/m², and 129 g total N/m²) was applied in December 2008.

2.2. Organic matter amendment characteristics

Subsamples of the amendment were collected from multiple locations in the compost pile, dried at 65 °C, finely ground, and analyzed for C and N concentration on a Carlo Erba Elemental Analyzer (Lakewood, NJ). Three 250 g subsamples of compost from the same feedstock were used to determine particle size class components. These subsamples were separated into the size classes <1, 1–2, 2–4.75, and >4.75 mm through sequential sieving. Each size class was weighed, finely ground, and analyzed for C and N concentration in duplicate on a Carlo Erba Elantech elemental analyzer (Lakewood, NJ) using atropine as a standard.

2.3. Soil texture, pH, and bulk density

Soil texture was determined using the hydrometer method adapted from Gee and Bauder (1986). We sampled soils along three transects in each plot (0–10 cm depth) using a 6 cm diameter corer; three samples were collected and composited per transect to yield 3 sample replicates per plot and 9 samples replicates per treatment at each site. Soils were air dried, and rocks were removed with a 2 mm sieve prior to texture analyses. Soil pH was measured in a ratio of 1:2 soil to water (McLean, 1982).

Soil bulk density was measured to 100 cm depth in 10 cm depth increments in one pit per plot. We carefully excavated 10 cm diameter cores approximately 5 cm back from the face of the pit. All bulk density measurements were corrected for rock volume and mass. Upon extraction from cores, dry rock masses and volumes were measured and subtracted from total bulk density calculations (Robertson et al., 1999).

2.4. Total soil organic carbon and nitrogen

Soils were collected prior to compost application and at end of each water year (WY; typically May or June) for three years using a 7 cm diameter corer ($n = 9$ per depth per plot). Sample depths were 0–10, 10–30, 30–50, and 50–100 cm at the coastal grassland and 0–10, 10–30, and 30–50 cm at the valley grassland where soils were shallower. Roots and identifiable compost litter were

Download English Version:

<https://daneshyari.com/en/article/8364968>

Download Persian Version:

<https://daneshyari.com/article/8364968>

[Daneshyari.com](https://daneshyari.com)