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Abstract

A multispecies riparian buffer strip (MRB) was established along Bear Creek in central Iowa by the Agroecology Issues Team at Iowa State University (ISU) in order to assess the ability of the MRB to positively impact soil erosion and process non-point source pollutants to improve water quality. Soil organic matter (SOM), and especially biologically-active soil organic matter, is considered to be an important soil quality indicator variable because of it has relationship to critical soil functions like erodibility and the capacity of the soil to act as an environmental buffer. The objectives of this study were to examine trends in SOM C accrual and to quantify intra-seasonal changes in SOM C and particulate organic matter (POM) C for each vegetation zone of a MRBS seven years after establishment on previously cultivated or heavily grazed soil. Total SOM C and POM C in soil under perennial vegetation (poplar, switchgrass and cool season grass) were significantly higher than under cropped soil. Total POM C changed within vegetation type over the four month study period, whereas total SOM C did not. After six growing seasons, SOM C increased 8.5% under poplar grown in association with cool season grass, and 8.6% under switchgrass. The results are very promising and suggest that changes in SOM C can occur in a relatively short time after the establishment of perennial vegetation in a MRB. These changes should increase the ability of MRB soil to process non-point source pollutants.

Keywords

Glicine max, Panicum virgatum, Populus X euramerican, particular organic matter

Disciplines

Forest Sciences | Hydrology | Natural Resources Management and Policy | Soil Science

Comments

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Assessing soil quality in a riparian buffer by testing organic matter fractions in central Iowa, USA

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Abstract. A multispecies riparian buffer strip (MRB) was established along Bear Creek in central Iowa by the Agroecology Issues Team at Iowa State University (ISU) in order to assess the ability of the MRB to positively impact soil erosion and process non-point source pollutants to improve water quality. Soil organic matter (SOM), and especially biologically-active soil organic matter, is considered to be an important soil quality indicator variable because of it has relationship to critical soil functions like erodibility and the capacity of the soil to act as an environmental buffer. The objectives of this study were to examine trends in SOM C accrual and to quantify intra-seasonal changes in SOM C and particulate organic matter (POM) C for each vegetation zone of a MRBS seven years after establishment on previously cultivated or heavily grazed soil. Total SOM C and POM C in soil under perennial vegetation (poplar, switch-grass and cool season grass) were significantly higher than under cropped soil. Total POM C changed within vegetation type over the four month study period, whereas total SOM C did not. After six growing seasons, SOM C increased 8.5% under poplar grown in association with cool season grass, and 8.6% under switchgrass. The results are very promising and suggest that changes in SOM C can occur in a relatively short time after the establishment of perennial vegetation in a MRB. These changes should increase the ability of MRB soil to process non-point source pollutants.

Introduction

Riparian zones have important geomorphic and hydrologic roles that can support high levels of biological productivity (Van and Jackson, 1990). Although riparian areas may occupy only a small area of a watershed, they represent an extremely important component of the overall landscape (Elmore and Beschta, 1987). Healthy riparian zones may help control transport of sediments and chemicals to stream channels (Lowrance et al., 1984). Most riparian zones have long been negatively influenced by human activities. Numerous approaches have been adopted for mitigating the adverse impacts of agriculture practices within the context of a bioassimilative strategy. These include the restoration of riparian vegetative buffer strips (Osborne and Kovacic, 1993).

In 1990, a multispecies riparian buffer (MRB) was established along Bear Creek in central Iowa by the Agroecology Issues Team at Iowa State

University (ISU). The team is supported through the Leopold Center for Sustainable Agriculture, which is located on the university's main campus in Ames. Bear Creek is typical of many streams in central Iowa where the primary land use of the watershed, including the riparian zone, is row crop production agriculture (corn and soybean) or intensive grazing (Schultz et al., 1995). Five years after establishment of the MRB along Bear Creek, Schultz et al. (1995) report dramatic alterations in the appearance and function of the riparian buffer strip. After four growing seasons, root biomass increased significantly below the MRB compared with agricultural crops.

Soil organic matter (SOM) is an important ecosystem component in both natural ecosystems and in intensively-managed agricultural systems (Paul, 1984). SOM is also considered to be an important soil quality indicator variable because it has a good relationship to critical soil functions like productivity, erodibility and the capacity of the soil to act as an environmental buffer by absorbing or transforming potential pollutants (Sikora and Stott, 1996). Recent research suggests that some of these soil functions may be more directly related to the most biologically-active forms of SOM, and not with the total SOM content (Cambardella and Elliot, 1993).

During the past 20 years, ample evidence has accumulated to demonstrate that physical fractionation of soil provides a significant tool in the study of SOM distribution and dynamics (Christensen, 1992). Physical fractionation techniques are considered chemically less destructive, and the results acquired from analyses of the soil fractions are expected to relate more directly to SOM *in situ* (Chirstensen, 1996).

Particulate organic matter (POM) is one example of a biologically-active form of SOM that is isolated using physical fractionation (Cambardella and Elliot, 1992a). Particulate organic matter is considered to be a good indicator of soil quality because it responds rapidly and selectively to changes in land use and soil management (Janzen et al., 1992; Cambardella and Elliott, 1992a; Sikora et al., 1996; Cambardella, 1997).

The objectives of this study were to examine trends in SOM C accrual and to quantify intra-seasonal changes in SOM C and POM C for each vegetation zone of a MRBS seven years after establishment on previously cultivated or heavily grazed soil.

Materials and methods

Field sampling

Soils were collected from an experimental MRB that was planted in 1990 along Bear Creek which is located in north central Iowa, within the geological landscape feature called the Des Moines Lobe, a depositional remnant of the Late Wisconsinan glaciation. The basic design of the MRB consists of three zones of vegetation planted parallel to the stream. The first zone is five rows of trees, grown in association with a cool season grass understory, planted closest to and parallel to the stream at a 1.2 × 1.8 spacing. The trees in this MRB are *Populus X euramericana* 'Eugenei', a poplar hybrid. The second vegetative zone consists of a row of redosier dogwood (*Cornus stolonifera* Michx.) and a row of ninebark (*Physocarpus opulifolius* L.). The shrubs were planted at a 0.9 × 1.8 m spacing. The third zone is a 7.3 wide strip of switchgrass (*Panicumm virgatum* L.) planted upslope from the shrubs at the interface of the cropped field. Controls consist of a cool season grass filter strip that was grazed prior to the study. Dominant grass species in this filter strip are brome grass (*Bromus inermis* Leysser.), timothy (*Phelum pratense* L.) and fescue (*Festuca* sp.).

Both the poplar and the cool season grass filter strips are located on an alluvial floodplain where the dominant soil type is Coland (fine-loamy, mixed, mesic Cumullic Haplaquoll). The switchgrass plots are located on soils that have been cultivated for more than 75 years and the soils are mapped as Coland, with some inclusions of Clarion (fine-loamy, mixed, mesic Typic Hapludoll). Soils under soybean (*Glicine max* (L.) *Merr*) are mapped as Clairon.

Soil sampling for the study was conducted along three transects that extended from the stream edge, through the riparian area, toward the riparian zone-agricultural field interface (Figure 1). Samples were collected monthly between August and November. Five cores were collected at random from each vegetation per plot per transect with a 2.5-cm-diameter steel coring bit to a depth of 35 cm and composited. The composite, moist soil sample was gently broken by hand, passed through a 2-mm sieve and air-dried. The large pieces of stubble and root that passed through the sieve were removed by hand.

Laboratory methods

A method combining chemical dispersion with particle-size separation was used to isolate POM from air-dried, 2-mm sieved soil taken from each vegetation plot (Cambardella and Elliott, 1992b). A 5-g subsample was removed to determine total organic C and a 30-g subsample was dispersed in 100 mL of 5 g L^{-1} sodium metaphosphate and shaken on a reciprocating shaker for 15 h. The dispersed soil sample was passed through a 53-μm sieve and rinsed several times with water. The mineral-associated (silt+clay) fraction that passed through the sieve was dried at 70 °C. The mineral-associated fraction and the whole soil samples were ground on a roller mill to pass through a 250 μm.

Total organic C in the whole soil and in the mineral-associated fraction were determined by dry combustion on a Carlo Erba CHN analyzer (Carlo Erba Instruments, Milano, Italy). The amount of C in the POM fraction was calculated as the difference between total soil organic carbon and mineral-associated C.

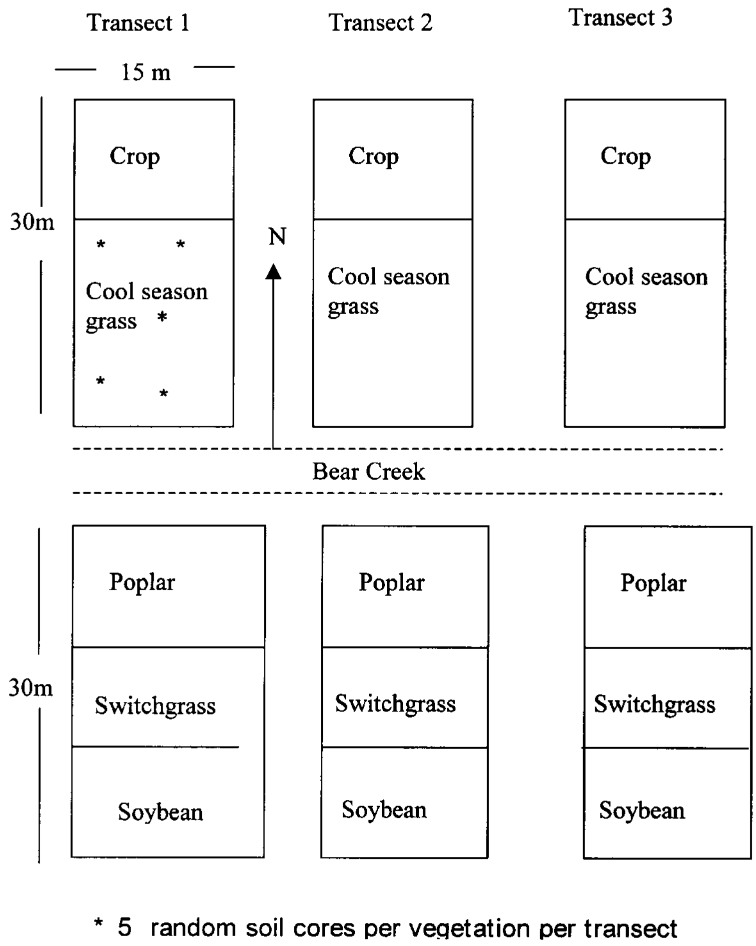

Figure 1. Plot layout showing the experimental design and vegetation in central Iowa, USA.

Differences among treatments were tested by a one-way analysis of variance and linear contrasts with a 0.05 significance level (SAS Institute, 1990).

Results and discussion

Total SOM C in perennial vegetation plots (poplar, switchgrass and cool season grass) was significantly higher (≥ 107 Mg ha^{-1}) than in the cropped (≤ 88 Mg ha^{-1}) treatments (Figure 2). Poplar plots had consistently, but not significantly, higher SOM C over the four samples months than cool season grass plots ($P \leq 0.05$). No significant differences in SOM C were observed between soils under switchgrass and cool season grass ($P \leq 0.05$). Soil organic

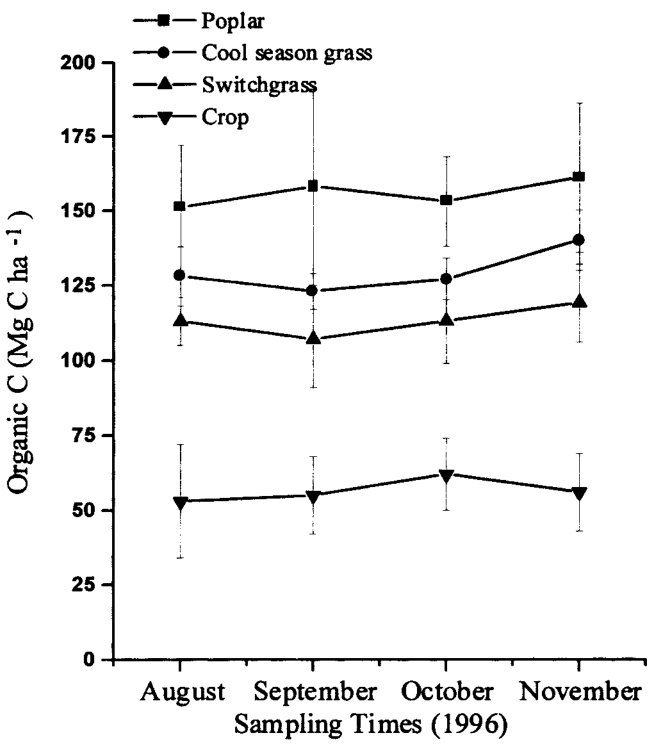

Figure 2. Temporal changes in total organic carbon of 35 cm for the four vegetation classes in central Iowa, USA. (Each point is the mean of three sampling sites, with five samples per site per sampling.)

matter C under switchgrass was significantly lower (107–119 Mg ha^{-1}) than under poplar (151–161 Mg ha^{-1}) (Figure 2).

The amount of total SOM C in the perennial vegetation plots in October 1991, one year after establishment of the MRB, was 123, 141, 104, and 60 Mg ha^{-1} for soil under cool season grass, poplar, switchgrass, and soybean, respectively (Table 1) (Schultz et al., 1993). After five growing seasons, SOM C in the top of 35 cm of soil increased 8.5% under poplar, 3.2% under cool season grass, 8.6% under switchgrass, and 3.3% under soybean (Table 1). The rate of SOM C sequestration under cool season grass was 1.80 Mg ha^{-1} yr^{-1}, and under soybeans, 0.40 Mg ha^{-1} yr^{-1}. The cool season grass and soybean zones have been in place for many years and these systems are likely in equilibrium with respect to SOM C. Soil organic matter C was sequestered at a rate of 2.4 Mg ha^{-1} yr^{-1} for the poplar zone and 1.8 Mg ha^{-1} yr^{-1} for switchgrass zone. Lal et al. (1997) observed that the rate of SOM C sequestration in the top 20 cm of an Alfisol soil in western Nigeria was 7 to 12 Mg ha^{-1} yr^{-1} for *Glycine* and *Melinis* grasses, and 1.4 Mg ha^{-1} yr^{-1} for *Panicum*. Fisher et al. (1994 and 1995) observed that grass pastures of *Brachiria humidi-*

Table 1. Changes in carbon content of 0–35 cm depth in response to a multi-species riparian buffer planted in 1990 in central Iowa, USA.

Vegetation type	Soil C (Mg ha^{-1})		Soil C gains	
	1991[a]	1996	Mg ha^{-1}	%
Poplar[b]	141	153	12	8.5
Cool season grass	123	127	4	3.2
Switchgrass	104	113	9	8.6
Crop[c]	60	62	2	3.3

[a] From Schultz et al. (1993).
[b] Poplar is grown in association with cool season grass.
[c] Soybean had been in rotation with corn.

cola alone and grown in association with the legume *Arachis pintoi*, sequestred 4.1 Mg ha^{-1} yr^{-1} and 11.7 Mg ha^{-1} yr^{-1}, respectively, over a 6-year period.

Total POM C in soil under perennial vegetation comprised 16–23% of the total soil C, and was generally higher under poplar than under grass. Perennial vegetation had significantly more POM C than the cultivated systems, where POM C comprised only 9–13% of the total soil C, except during October, when it peaked at 15–18% (Figure 3).

Total POM C changed within vegetation type over the four month study period, whereas total SOM C did not (Figure 3). Poplar and switchgrass showed a slight, but consistent increase in POM C from August to November. The pattern for cool season grass was less consistent, but POM C was greatest in November compared to the previous three months. Particulate organic matter C for the cropped treatment showed little change except for the October sample date. The peak in October is likely related to increased root inputs as a result of harvest.

Particulate organic matter C is biologically available and a source of C and energy for soil microorganisms. Denitrification has been identified as the predominant soil process for removal of nitrate-N in stream riparian zones (Hill, 1996). The importance of a continuous supply of C to be used as an energy source for sustained NO_3^-–N removal by denitrifying bacteria suggests that linkages between POM and denitrification are important in riparian zones.

Conclusions

We have demonstrated that riparian buffer zones have the potential to improve the quality of agricultural soils that have been intensively cultivated. These early results are very promising and suggest that changes in SOM C can occur in a relatively short time after the reestablishment of perennial vegetation. We may be able to synchronize temporal changes in POM C with temporal changes in denitrification rate, thereby insuring a tight linkage between den-

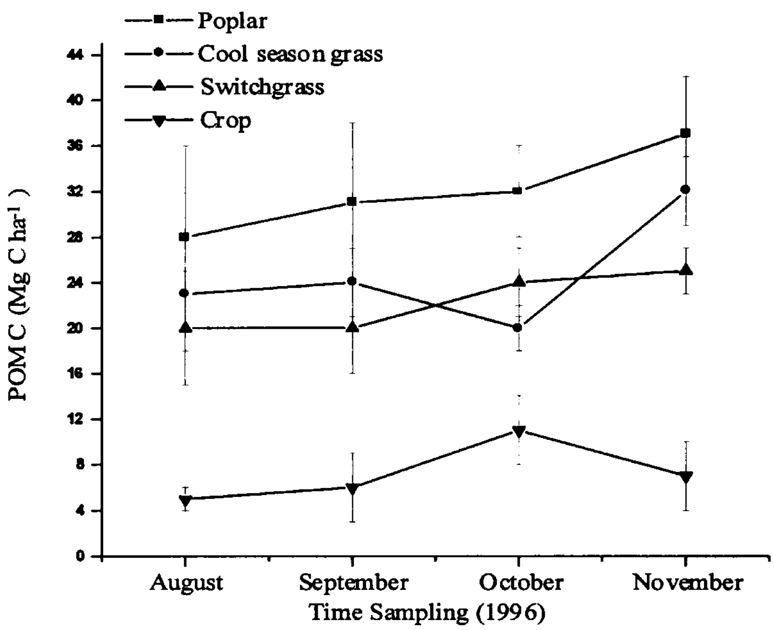

Figure 3. Temporal changes in POM-C of 35 cm for the four vegetation classes in central Iowa, USA. (Each point is the mean of three sampling sites, with five samples per site per sampling.)

itrifying bacteria and the energy source needed to drive denitrification. These changes should increase the ability of MRB soil to process non-point source pollutants.

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