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Long-term diversified crop rotations have little effect on soil organic carbon concentration and biochemistry

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Introduction

- Soil organic carbon (SOC) enhances nutrient supply to plants and water-holding capacity, having significant impact on crop yield.
- Deeper rooting crops have been proposed as a strategy to mitigate atmospheric carbon dioxide by increasing subsoil carbon stocks (1).
- Forage-based rotations are known to have greater belowground carbon inputs than more common grain-based rotations.
- Previous studies have demonstrated greater SOC in diverse forage-based rotations compared to grain-only rotations, despite similar C inputs (2).
- The biochemical composition of soil organic matter can aid in understanding of:
  - Origin of SOC, whether plant- or microbial-derived
  - The stability of soil C

Hypothesis

- Rotations including a deep-rooted perennial forage crop can enhance SOC by delivering more root C deeper into the soil profile, where SOC concentrations are lower and there is greater capacity for C accumulation.

Objective

- To determine the effect of diversified forage-based crop rotations on SOC and biochemical composition in surface and subsoils as compared to grain-only crop rotations.

Table 1. Crop rotations at three Iowa State University research sites

		Grain-Only (2-yr)				Forage-based Rotations (4-yr)			
			Mean C Inputs, Mg C ha^{-1} yr^{-1}				Mean C Inputs, Mg C ha^{-1} yr^{-1}		
Site	Study Duration	Rotation[1]	Aboveground C inputs	Belowground C inputs	Total C Input	Rotation[1]	Aboveground C inputs	Belowground C inputs	Total C Input
Kanawha	60 yrs	C-S	3.19(0.10)	1.81(0.07)	5.00 (0.17)	C-C-O/A-A	2.73(0.10)	2.44(0.07)	5.17(0.17)
Nashua	35 yrs	C-S	3.48(0.14)	1.97(0.10)	5.45(0.23)	C-C-O/A-A	2.85(0.14)	2.62(0.10)	5.46(0.23)
Marsden	12 yrs	C-S	3.24(0.08)	1.84(0.06)	5.08(0.13)	C-S-O/A-A	2.10(0.08)	2.18(0.06)	4.70(0.13)

[1] C = corn (*Zea mays*), S = soybean (*Glycine max*), O = oats (*Avena sativa*), A = alfalfa (*Medicago sativa*). Oats were undersown with alfalfa
[2] Average annual C inputs were estimated based on crop yields (2003-2014) and allometric equations described by Bolinder et al. (2007)

Methods

- We sampled two crop rotations at three Iowa State University Research Farm locations (Table 1) during fall of 2014.
- Samples were collected during the corn phase of both rotations (first corn phase of 4-yr at Nashua and Kanawha).
- Soil samples were taken at four depths (0-15, 15-30, 30-60, 60-90 cm).
- Soil samples were dried, ground, and analyzed for soil organic C by dry-combustion analysis.
- Samples were analyzed for concentration of phenolic lignin residues released by cupric oxide oxidation and analyzed using GC-FID. We assessed concentrations of cinnamic acids, as well as aldehyde, ketone and acid forms of syringyl and vanillyl. The sum of these compounds (λ8 phenolic compounds) divided by the whole SOC concentration was used to represent the contribution of lignin residue-C to SOC.
- Samples were analyzed for carbohydrates. Extraction was done using sulfuric acid and autoclaving, and extractions were analyzed using AEC-PAD. Relative contributions of microbial- and plant-derived carbohydrates were represented by a ratio of carbohydrate monomers:

$$\frac{Microbial}{Plant} = \frac{Galactose + Mannose}{Xylose + Arabinose}$$

Results & Discussion

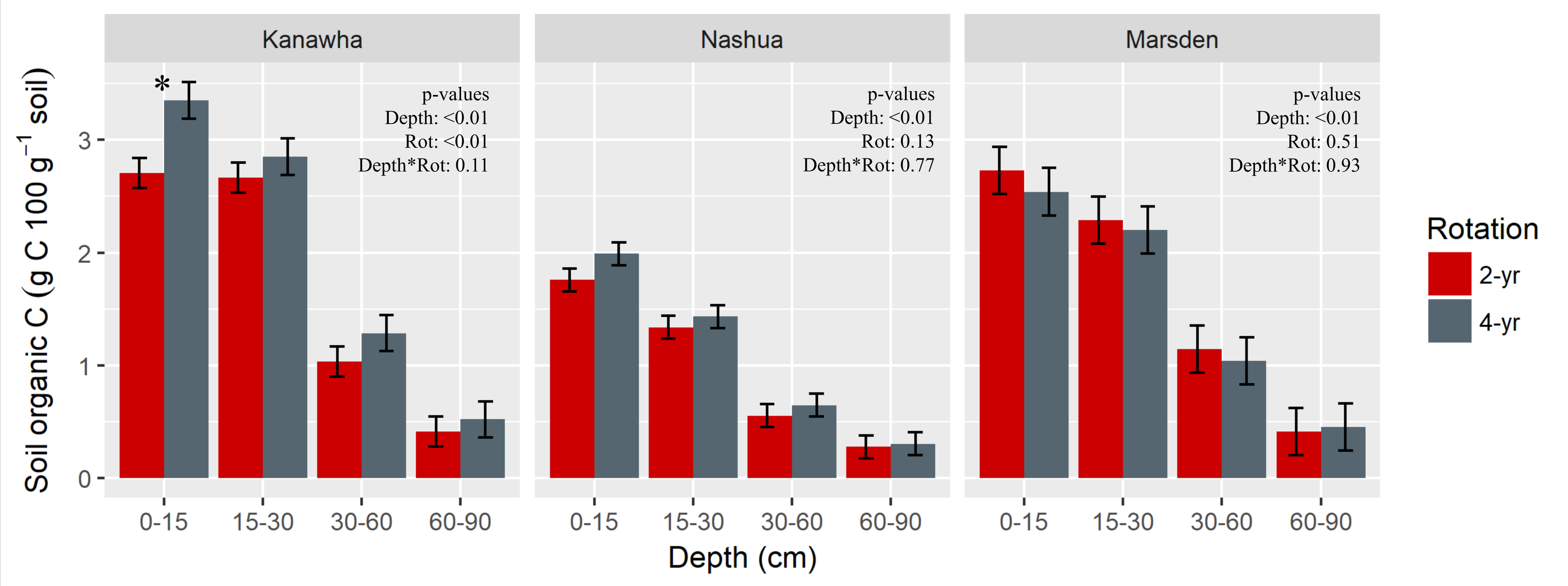

Figure 1. Percent of soil organic carbon by depth in a grain-only (2-year) and diversified (4-year) rotation. Error bars are ±1 standard error. The asterisk indicates means are significantly different between crop rotations for a given depth (P<0.05).

- Soil organic C concentrations decreased with depth at all three sites (Figure 1).
- Soil organic C concentrations tended to be greater in 4-year rotations than 2-year rotations at two of the three sites, but this effect was only significant for the surface soil at Kanawha (*P*<0.05).

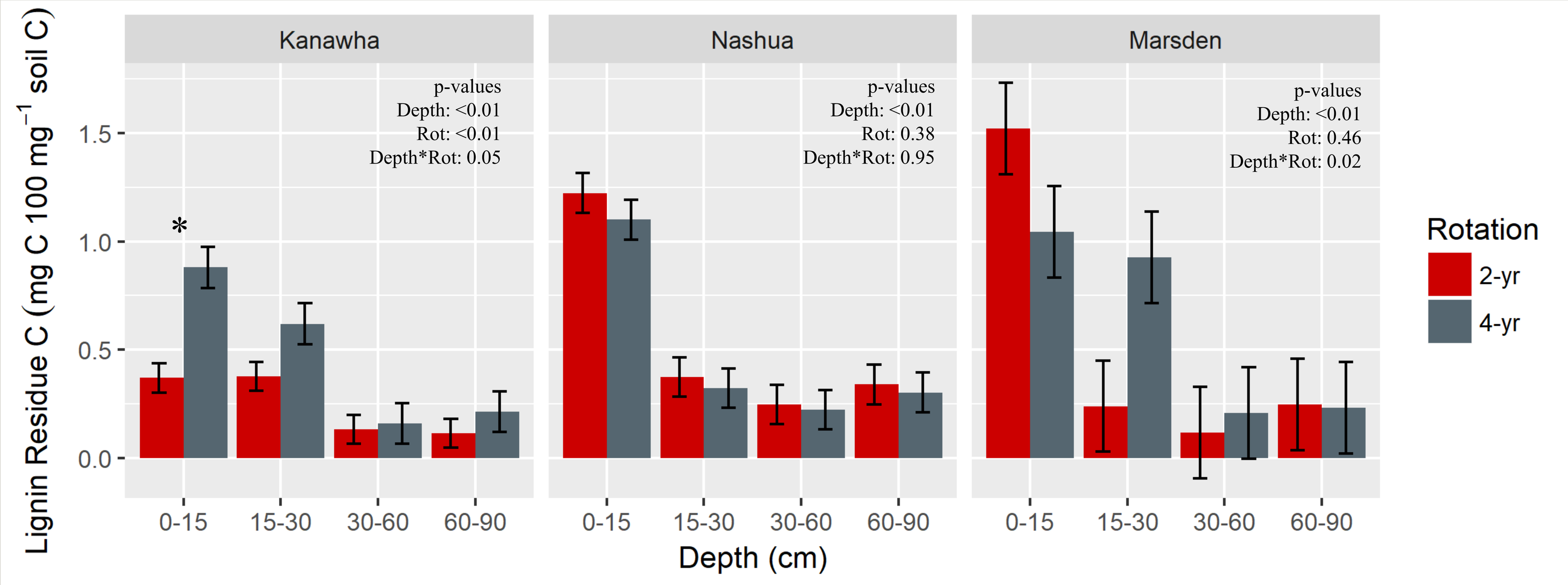

Figure 2. Percent of soil organic carbon as lignin residue carbon by depth in a grain-only (2-year) and diversified (4-year) rotation. Error bars are ±1 standard error. The asterisk indicates means are significantly different between crop rotations for a given depth (P<0.05).

- The proportion of total SOC as lignin residue-C decreased with depth at all three sites, but the rotation effect was inconsistent among sites (Figure 2).
- A decrease in the proportion of SOC as lignin residue-C suggests decreased plant-C input and/or greater extent of decomposition deeper into the soil profile.

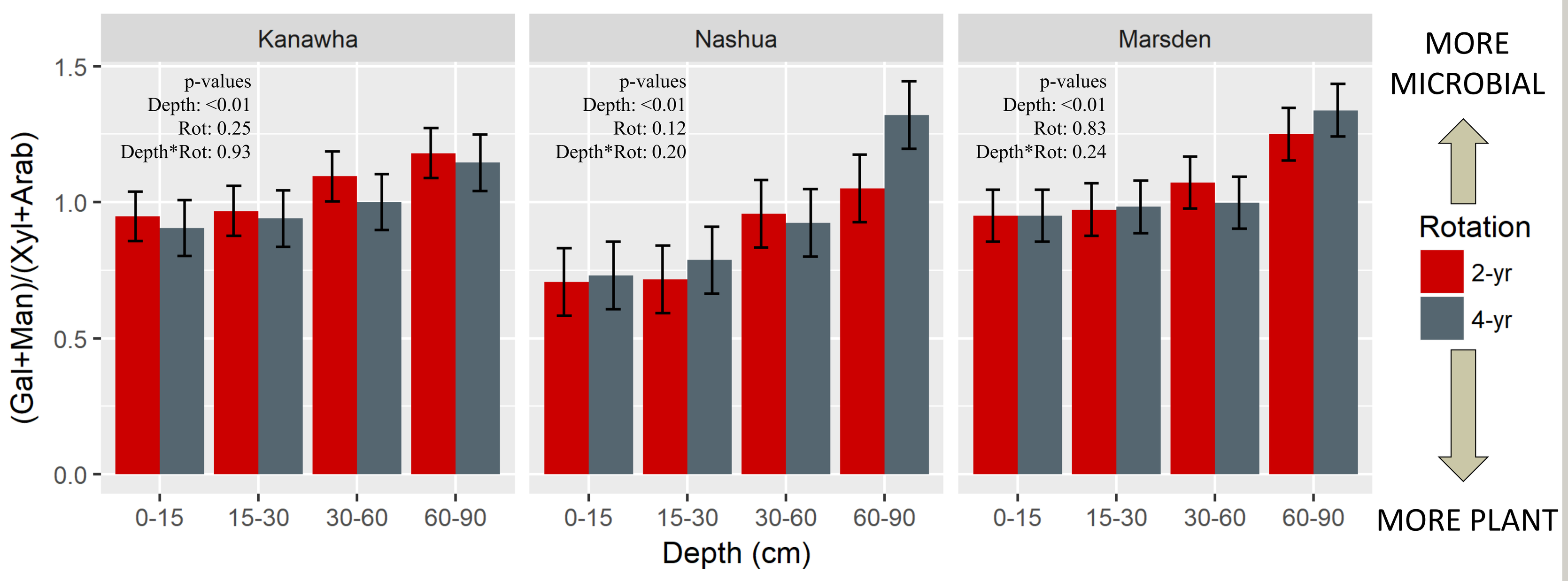

Figure 3. Relative abundance ratio of microbial-derived carbohydrates (Galactose + Mannose) to plant-derived carbohydrates (Xylose + Arabinose) by depth in a grain-only (2-year) and diversified (4-year) rotation. Error bars are ±1 standard error.

- The relative abundance ratio of microbial-to plant-derived carbohydrates increased with depth at all sites, but no rotation effect was found at any site (Figure 3).
- This finding aligns with the lignin residue trends (Figure 2) and previous studies which have shown SOC in subsoils is enriched in microbial-derived C compounds and depleted in plant-derived C compounds when compared to topsoil SOC (3).

Conclusions

- Despite greater belowground inputs, the forage-based rotations had little impact on SOC concentration, vertical distribution, or biochemical composition.
- The biochemical composition of SOC reflected increasing extent of microbial processing at depth.

References

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(3) Rumpel and Kogel-Knabner 2011. Deep Soil Organic Matter- A Key but Poorly Understood Component of Terrestrial C Cycle. Plant and Soil Journal.