Soil texture and root biomass influence carbon storage through impacts on microbial enzyme activities across a heterogeneous agroecosystem

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Bioenergy: potential impacts on soil C storage

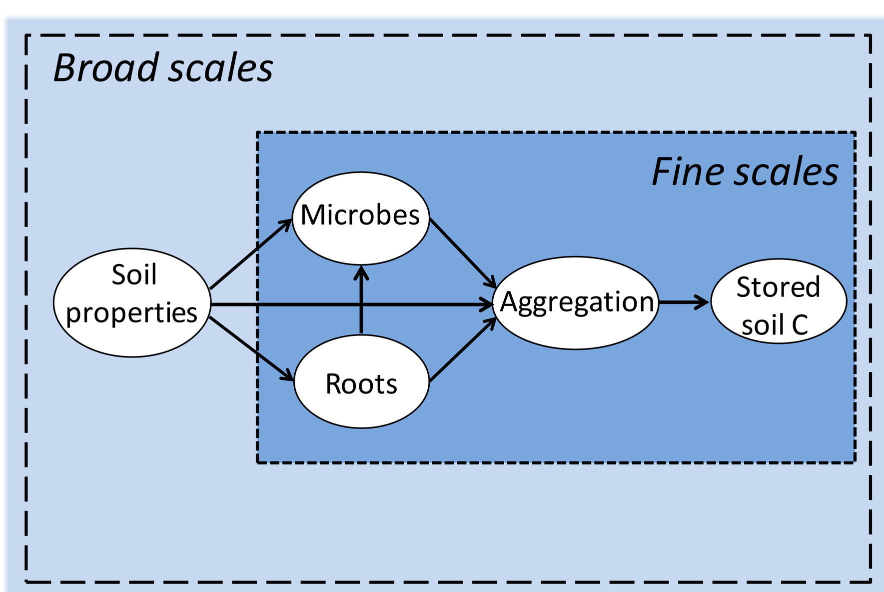
- Land use changes prompted by bioenergy may alter belowground carbon (C) dynamics leading to shifts in soil C storage.
- 'Marginal' sites not well-suited for annual row crops are targeted for bioenergy production with perennials because of the expected benefits from increased soil organic matter (SOM).
- Model predictions of soil C responses to bioenergy crops are dependent on understanding ecosystem drivers of C cycling processes operating at multiple scales.
- Short-term accumulation of soil C occurs primarily through the physical protection of organic matter resulting from increased soil aggregation.
- We investigated the importance of multiple environmental drivers of short-term (3 years) changes in physically protected C across a heterogeneous agroecosystem—containing both highly productive and 'marginal' soils—using structural equation modeling.

Fine- & broad-scale processes drive formation of iPOM-C

Soil aggregation dynamics drive C storage: aggregates trap **particulate organic matter (iPOM)**, physically protecting C within microsites & reducing decomposition.

At ***broad scales***, soil physical, chemical & biological properties vary.

Both fine- and broad-scale drivers influence iPOM, ***but the relative influence of each are not well understood.***



Fine-scale rhizosphere processes (root-microbe interactions, microbial biomass) influence aggregation & iPOM-C.

*Enzymes break down SOM, **but the role of microbial enzyme activities on iPOM-C formation processes are unknown**.*

We tested two hypotheses:

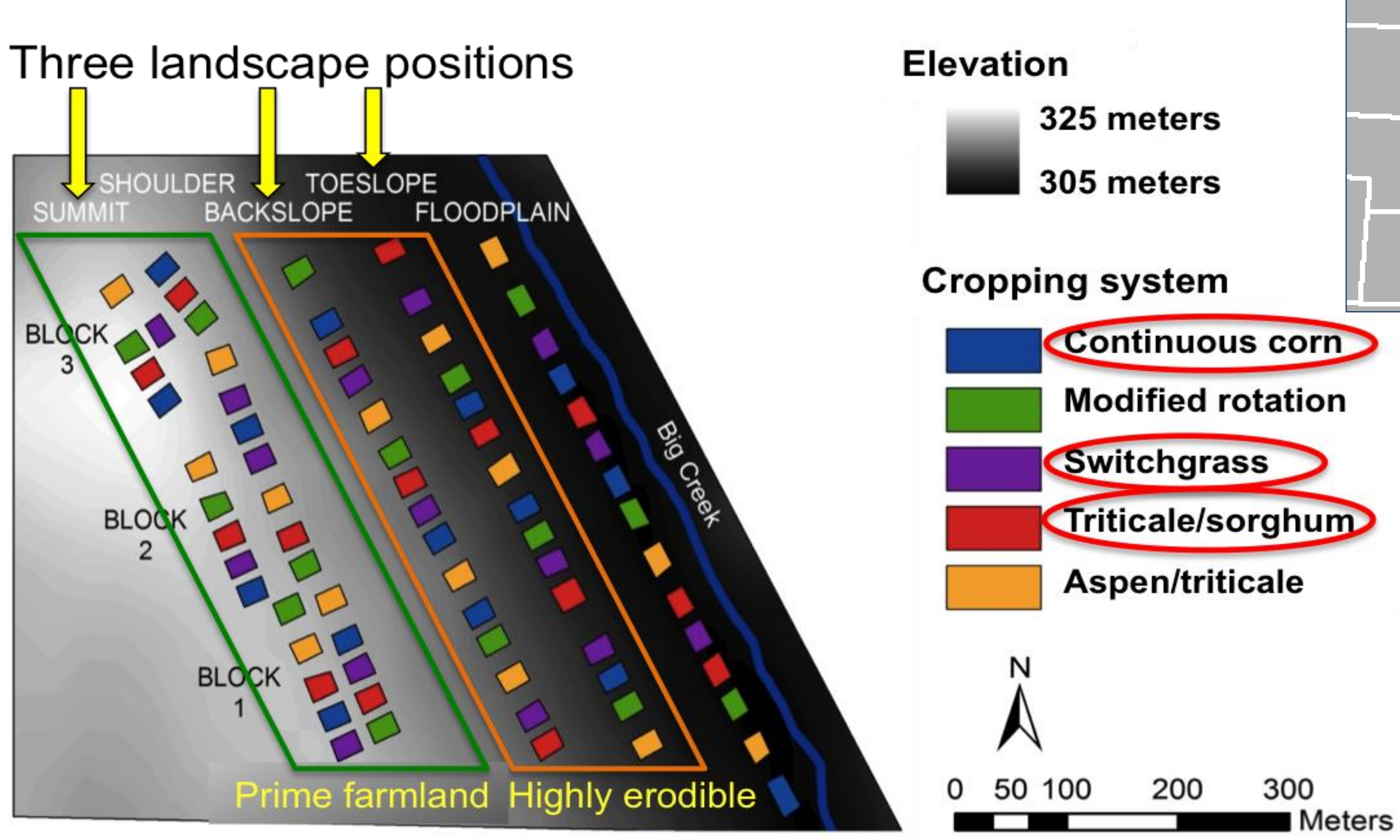
H_1: Soil variation at broad scales (e.g. nutrients, texture) have ***direct*** impacts on aggregation, and ***indirect*** impacts through fine-scale processes.

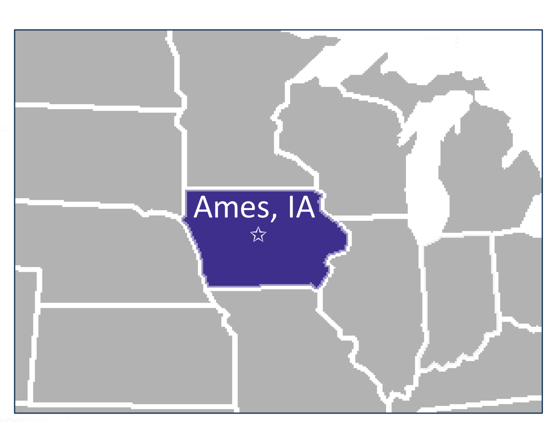
H_2: Microbial biomass and extracellular enzyme activities positively impact iPOM-C levels through effects on aggregate formation.

The Landscape Biomass Project

Data were collected from 27 plots (0.06 ha in size) from 2009-2012

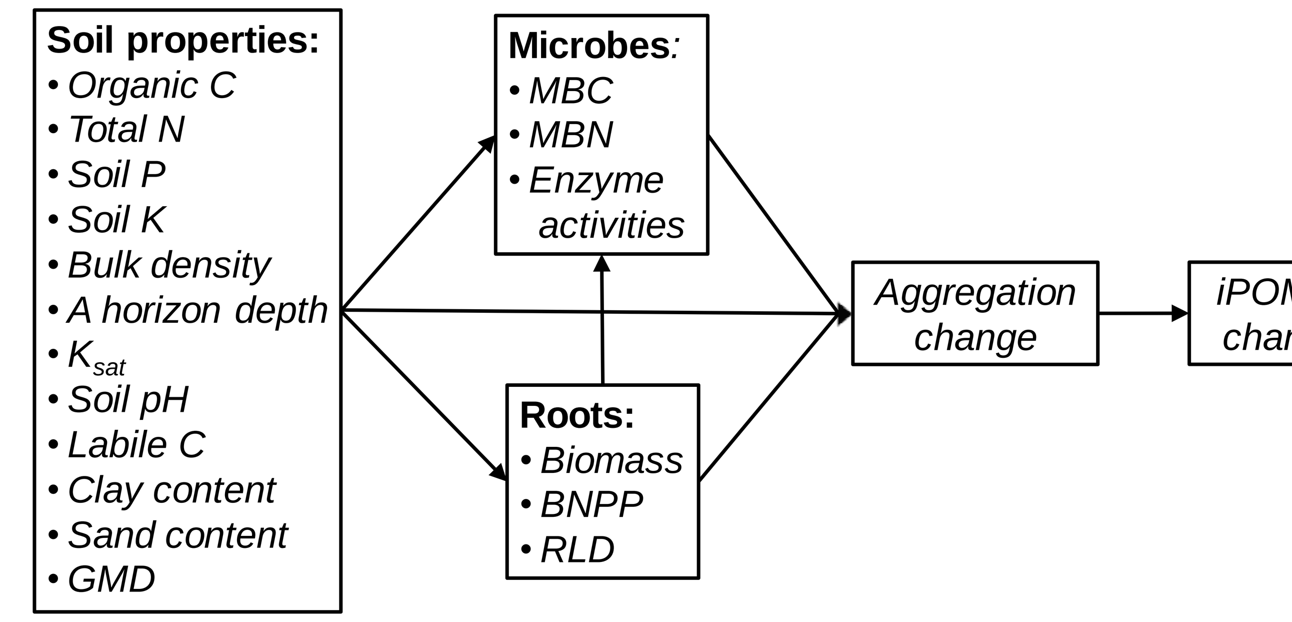
- Located on three positions sited across **a topographic gradient**
- Three bioenergy cropping systems were included





Our *a priori* model included...

- 11 soil chemical, physical & biological properties (Ontl et al. 2013).
- Three microbial community variables (Hargreaves & Hofmockel 2014).
- Three variables describing root characteristics (Ontl et al. 2013).
- Changes in soil aggregation (Ontl et al. *In review*).
- Changes in iPOM-C (Ontl et al. *In review*).



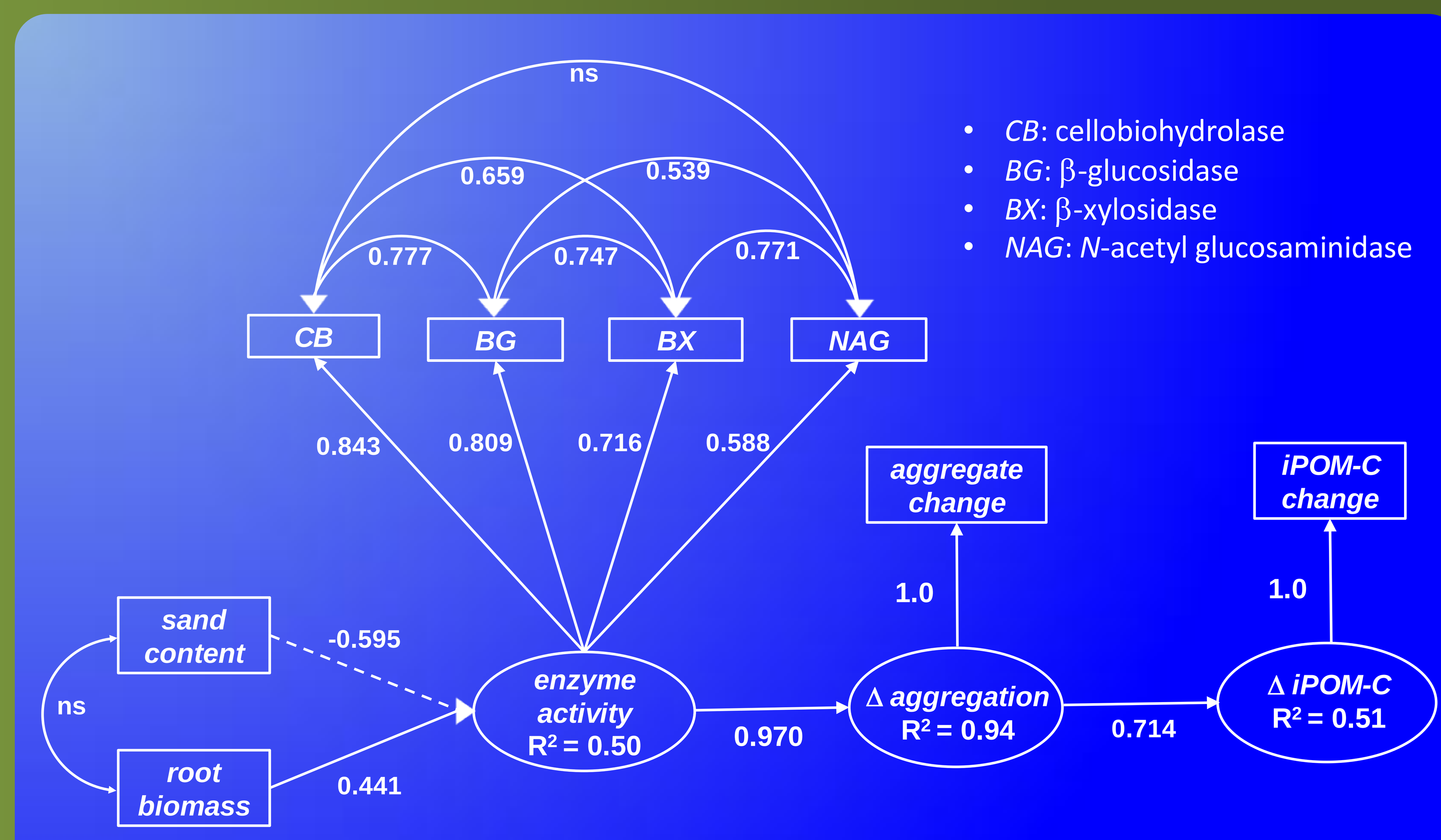
Structural Equation Modeling Results

H_1: Broad-scale drivers affected C storage, but only *indirectly* through influences on fine-scale root-rhizosphere processes:

- **Sand content negatively influenced potential enzyme activities.**
- **Land use had significant effects on root biomass (data not shown, Ontl et al. 2013a).**

H_2: Fine-scale drivers strongly affect iPOM-C changes:

- **Root biomass positively influenced enzyme activities.**
- **Enzyme activities were strongly linked to aggregation change.**
- **Aggregation changes positively influenced shifts in iPOM-C.**



Straight arrows indicate causal paths between variables, curved arrows indicate covariance. Dashed arrows signify negative relationships. Standardized parameter estimates are shown; parameter estimates are significant unless otherwise indicated (ns). Numbers inside circles represent variance explained by the model (R^2).

Model goodness-of-fit measures

χ^2	15.3	CFI[c]	0.99
Df[a]	13	RMSEA[d]	0.08
P-value[b]	0.291	SRMR[e]	0.047

	Criteria
[a] Model degrees of freedom	>0
[b] χ^2 *P*-value	>0.05
[c] Comparative Fit Index	>0.90
[d] Root Mean Square Error of Approximation	<0.08
[e] Standardized Root Mean Square Residual	<0.08

Pathway			Unstandardized Estimate	SE	Critical ratio	*P*-value	Standardized Estimate
LATENT VARIABLES							
BG	→	enz	1.000	0	1	0	0.809
CB	→	enz	1.746	0.160	10.884	<0.001	0.843
BX	→	enz	1.801	0.231	7.778	<0.001	0.716
NAG	→	enz	0.591	0.136	4.362	<0.001	0.588
REGRESSIONS							
stcrop	→	enz	0.275	0.101	2.716	0.007	-0.595
sand	→	enz	-0.625	0.185	-3.368	0.001	0.441
enz	→	agg	0.137	0.027	5.085	<0.001	0.970
agg	→	ipom	5.192	0.979	5.302	<0.001	0.714

References:

Hargreaves SK & Hofmockel KS. 2014. Physiological shifts in the microbial community drive changes in enzyme activity in a perennial agroecosystem. *Biogeochemistry* 117: 67–79.

Ontl TA, Hofmockel KS, Cambardella CA, Schulte LA, Kolka RK. 2013a. Topographic and soil influences on root productivity of three bioenergy cropping systems. *New Phytologist* 199: 727–737.

Ontl TA, Cambardella CA, Schulte LA, Kolka RK. *In review.* Soil aggregation and carbon pools respond quickly to changes in land use and tillage across a heterogeneous agroecosystem. *Soil Science Society of America Journal*.