LONG-TERM SOIL pH CHANGE IN RAINFED CROPPING SYSTEMS: IS ACIDIFICATION SYSTEMIC?

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CONTEXT

Soil acidification can occur through both natural and management-induced mechanisms. Acid precipitation, decomposition of organic material, and leaching of soluble salts serve as gradual, background influences contributing to slow rates of soil acidification. In contrast, management influences, such as prolonged use of ammonium-based fertilizers, application of acid-inducing chemicals, and biomass export can accelerate soil acidification. If left unchecked, acidification can irreversibly alter soil properties affecting herbicide persistence, nutrient availability, and metal toxicity.

Previous evaluations throughout the Great Plains suggest elevated N rates and/or use of no-tillage contributes to soil acidification in rainfed cropping systems. Soil pH responses to other management variables, such as cropping system diversity, have received less attention. Additionally, no multi-site evaluation of soil pH change under rainfed cropping has been conducted in the region.

OBJECTIVE

The objective of this study was to quantify soil pH change under rainfed cropping systems in the Great Plains. Datasets from Northern Plains Long-Term Agroecosystem Research (LTAR) Regional Partnership sites were used for this evaluation.

MATERIALS AND METHODS

Soil pH data were compiled from seven long-term studies near Sidney, MT, Mandan, ND, Brookings, SD, and Lincoln, NE. All studies followed traditional experimental design features with replicated treatments. Studies included wheat (*Triticum aestivum* L.)- and corn (*Zea mays* L.)-based rotations, and ranged in duration from 11 to 30 years.

Treatment attributes for long-term studies included in evaluation:

Location	Study years	Crop rotation	Tillage	N Rate (kg ha^{-1})
Sidney, MT	1984-2013	Continuous spring wheat	No	56
		Continuous spring wheat	Minimum	56
		Continuous spring wheat	Conventional	56
		Spring wheat-Barley (1984-1999); Spring wheat-Pea (2000-2013)	Conventional	44; 38
		Spring wheat-Fallow	Conventional	27
Mandan, ND	1983-1999	Spring wheat-Winter wheat-Sunflower	No	101
	1993-2012	Continuous spring wheat	No	67
		Spring wheat-Safflower-Rye		
Brookings, SD	1999-2010	Continuous corn	No	170 in 1999; As needed thereafter
		Corn-Soybean		
		Corn-Soybean-Oat pea hay-Alfalfa-Alfalfa		
	2000-2012	Corn-Soybean	No	112 in 2000; As needed thereafter
		Corn-Soybean-Spring wheat-Sunflower		
Lincoln, NE	1984-2002	Continuous corn	Conventional	108 corn/sorghum; 68 soy/oat+clov.
		Corn-Oat+Clover-Sorghum-Soybean		
		Corn-Soybean		
	1982-1998	Continuous corn	No	168
		Corn-Soybean		

Soil pH was measured from multiple depths in each study immediately prior to treatment deployment (initial) and again at a designated time reflecting either the end of the study or a scheduled sampling node (final). For purposes of this evaluation, only results from the uppermost depth increment were considered for analysis.

To evaluate potential effects of cropping system diversity on soil pH change, responsive study locations were analyzed by crop rotation type: monoculture cereal cropping, rotations without legumes, and rotations with legumes.

Soil pH analyses were conducted on dried soil ground to pass a 2.0 mm sieve. Soil pH was estimated from a 1:1 soil-water mixture with an ion-selective glass electrode. Soil pH change (ΔpH; final minus initial pH) was evaluated within individual treatments for each study using ANOVA and Tukey HSD in JMP 7.0.1.

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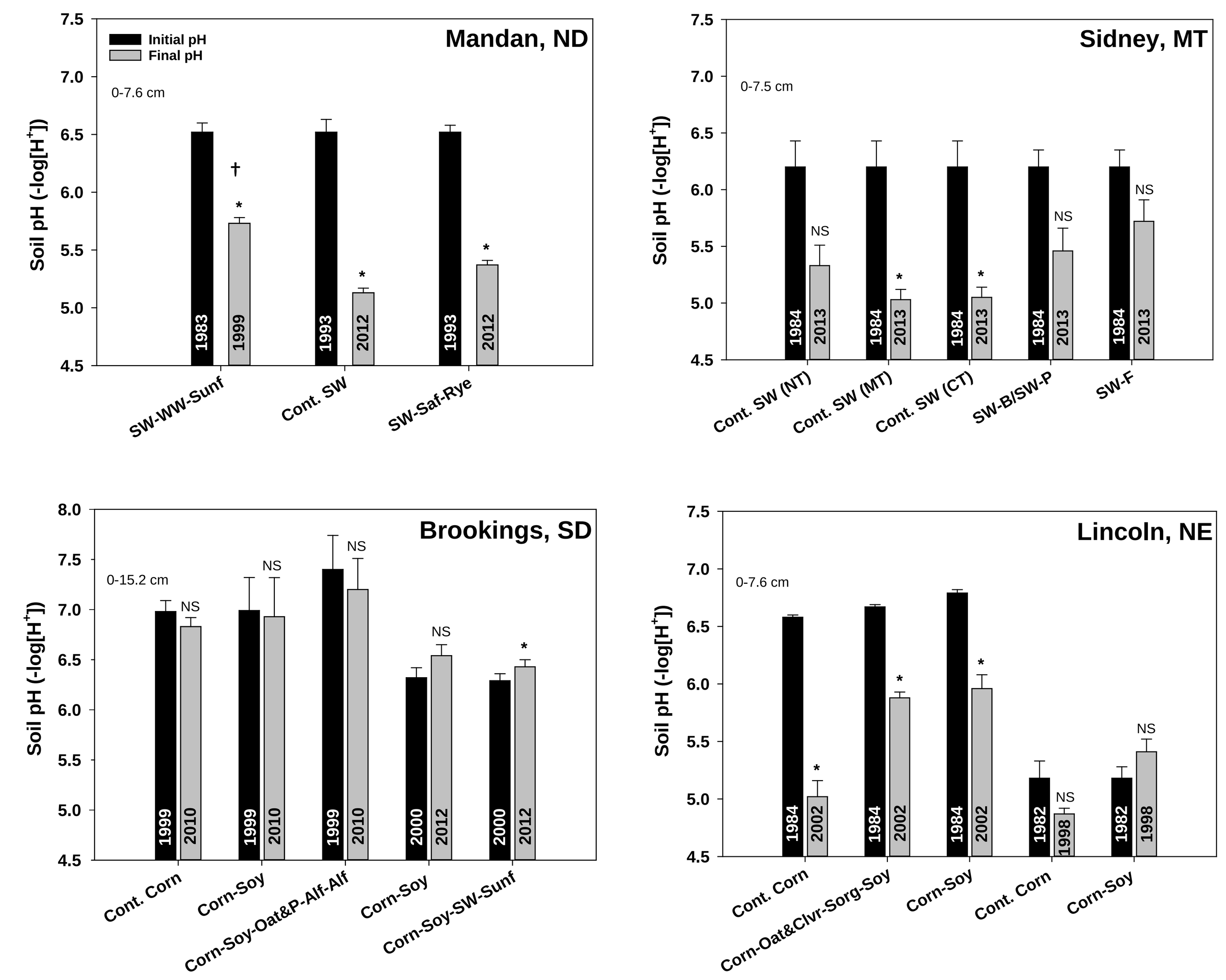
SOIL pH CHANGE BY LOCATION

Initial pH values across most locations were slightly acid to neutral, with the exception of a study initiated in 1982 near Lincoln where initial values fell within a strongly acid category. Significant soil pH changes were observed in nine of 18 comparisons across all locations and studies, with pH decreasing in eight treatments and increasing in one. Among treatments with decreasing pH, final pH values fell within moderately to strongly acid categories.



† Difference at P≤0.05 designated by *; NS = not significant.

- *At Sidney*, soil pH decreased in continuous spring wheat, but only under minimum and conventional tillage.
- *At Mandan*, soil pH decreased under all cropping treatments.
- *At Brookings*, soil pH was generally unresponsive to cropping, increasing only under a corn-soybean-spring wheat-sunflower rotation (Δ pH = 0.14±0.06).
- *At Lincoln*, soil pH decreased under all cropping treatments of one study, but did not change in another.

SOIL pH CHANGE BY CROP ROTATION TYPE

Crop rotation type	Δ pH†	Δ pH yr^{-1}
Monoculture cereal cropping	-1.31±0.12 a	-0.059±0.007 a
Rotations without legumes	-0.97±0.07 b	-0.054±0.003 a
Rotations with legumes	-0.53±0.07 c	-0.029±0.004 b

† Negative values for ΔpH (final minus initial pH) indicates acidification. Means in a column with unlike letters differ (P≤0.05).

Treatments under monoculture cereal cropping exhibited the greatest pH change, followed by rotations without legumes, and rotations with legumes (Table 2). Annual rate of pH change followed a similar numerical trend among rotation types, though annual change did not differ between monoculture cereal cropping and rotations without legumes. Nitrogen fertilization rates across rotation types did not appear to be a confounding factor affecting pH change (Mean across crop phases = 72, 84 and 89 kg N ha^{-1} yr^{-1} applied for monoculture cereal cropping, rotations without legumes, and rotations with legumes, respectively).

DISCUSSION

Though limited to seven studies across four locations, soil pH change was observed in half of the treatments evaluated. Non-responsive treatments, however, were subject to notable caveats. First, all treatments at Brookings used a deeper surface depth increment for assessment of soil pH change than other locations (0-15.2 cm vs. 0-7.5 or 0-7.6 cm). Use of a deeper depth increment at Brookings may have diluted presence of near-surface acidification. Second, initial pH values of a 16 year study near Lincoln were quite low (<5.2), thereby limiting further soil pH change from accumulated acidity.

Compartmentalization of pH outcomes by crop rotation type suggested rotations including legumes mitigated near-surface soil acidification relative to monoculture cereals and rotations without legumes. Although legumes can exacerbate soil acidification through the production and loss of symbiotically fixed N, application of fertilizer N is typically much lower to legumes than non-legumes. Accordingly, for soil types and production systems included in this study, soil acidification differences among crop rotation types were likely driven by total N load from applied fertilizer, and not legumes *per se*.

Outcomes suggest the need for more inclusive meta-analyses of soil pH change under cropping systems of the northern Great Plains and western/northern Corn Belt. Evaluation of additional sites with broad portfolios of management practices, coupled with pH outcomes with equivalent near-surface depth increments, would serve to provide a robust analysis of soil pH trends and associated drivers.