NORTH DAKOTA - Nitrogen & Soil Acidification: Observations from the Northern Great Plains Research Laboratory (NGPRL) Historical Pastures

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Increasing reliance on synthetic fertilizer nitrogen (N) has prompted questions about its long-term effects on soil health. While N fertilizer is often required to enhance soil fertility, there are some notable agronomic and environmental outcomes associated with its use. One outcome, increased soil acidity, has become a concern throughout the northern Great Plains.

Soil acidity is generated through the loss of available N from the soil profile (see green box). Direct effects of increased acidity on soil properties are many, and include decreased macro- and micro-nutrient availability, accelerated weathering of clay minerals, and changes in the amount and type of microorganisms in soil. Such changes can compromise the soil's capacity to function efficiently.

How does N fertilizer increase soil acidity?

Urea and anhydrous ammonia are commonly used N fertilizers. Acidification (H^+) from these sources of synthetic N is generated via nitrification through the following simplified reactions:

$$\textit{Urea: } (NH_2)_2CO + 4O_2 \rightarrow 2NO_3^- + 2H^+ + CO_2 + H_2O$$

$$\textit{Anhydrous Ammonia: } NH_3 + 2O_2 \rightarrow NO_3^- + H^+ + H_2O$$

Based on these reactions, each mole of N oxidized to NO_3^- produces one mole of H^+. Plant uptake of NO_3^- results in the release of an equivalent amount of OH^- into the soil solution, effectively neutralizing the acidity (creating H_2O). However, loss of NO_3^- by leaching and/or its conversion to N-containing gases (N_2O, N_2) results in permanent acidification. This permanent acidification can be intensified with the export of basic cations (Ca^{+2}, Mg^{+2}) from the soil in harvested material.

Organic matter can buffer N-induced acidity due to its high surface area and prevalence of exchange sites for positively charged ions. However, effectiveness of organic matter to provide this buffering influence can decrease following decades of applied N. Changes in soil properties under two historical pastures exhibited this very outcome (see Table 1). Though soil organic carbon was not different between native vegetation and crested wheatgrass pastures, applied N to the latter resulted in much lower pH, which contributed to decreased cation exchange capacity and soil microbial biomass. Said differently, crested wheatgrass pasture with applied N exhibited greater chemical weathering (lower cation exchange capacity) and a limited capacity to efficiently cycle nutrients (lower soil microbial biomass), despite having roughly the same amount of soil organic carbon as a native vegetation pasture. Such findings underscore the important role of soil acidity to potentially affect soil function.

Table 1. Changes in soil properties under two historical pastures at the NGPRL.

Grazing Treatment	Soil Organic Carbon *(ton c/ac)*	Soil pH	Cation Exchange Capacity *($cmol_c$/ kg)*	Microbial Biomass Carbon *(lbs C/ac)*
Native vegetation; High stocking rate	12.7†	6.6	18.2	571
Crested wheatgrass; High stocking rate, N applied annually	12.8	4.8	10.4	151

†Values refer to 0-2" depth.

While many soils throughout the northern Great Plains possess calcareous (alkaline) parent material, long-term application of synthetic N to surface soil depths may negatively affect plant productivity due to increased acidity (e.g., poor germination, reduced seedling vigor, reduced herbicide efficacy). Consequently, once near-neutral soils may need to be limed to sustain production. Additionally, management practices that more efficiently use N will contribute to slowing rates of soil acidification.