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Interactive effects of soil restoration strategies on nutrient dynamics in the tropical savannah

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Abstract

Grassland soil degradation poses major environmental challenges, with nutrient depletion and disruption of microbial communities limiting ecosystem recovery. However, restoration often relies on natural regeneration (i.e, passive restoration), which is often insufficient, and thus active intervention is necessary. We established a full-factorial field experiment to test whether soil inoculum, organic amendments (manure), and physical disturbance (tillage) interact to affect soil nitrogen dynamics and microbial properties in a degraded grassland of Kenya.

The three-way treatment interaction increased NH_4^+ ($p < 0.05$), though the soil inoculum alone increased NH_4^+ even more ($p < 0.01$). Combining soil inoculum with manure reduced NH_4^+ ($p < 0.05$) while increasing microbial biomass nitrogen (MBN) ($p < 0.05$). Tillage eliminated both effects, resulting in intermediate NH_4^+ levels, an increase in NO_3 ($p < 0.05$), and a reduction in microbial biomass carbon (MBC) ($p < 0.01$). Manure alone increased MBN, while tillage consistently increased NO_3 and decreased MBC.

These results suggest three nitrogen dynamics pathways: i) mineralisation (inoculum-enhanced organic matter breakdown), ii) immobilisation (manure + inoculum-driven microbial sequestration), and iii) physical override (tillage-induced disruption of biological processes). Since the inoculation effect depended on whether manure was applied, restoration outcomes are context-dependent, so strategies should target specific goals: tillage for immediate nutrient availability, inoculation for enhanced mineralisation, or inoculum + manure for long-term biological soil development.

Keywords: Grassland restoration, nitrogen dynamics, organic amendments, soil microbes

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