# Spatial Redistribution of Nitrogen by Cattle in Semiarid Rangeland

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# Spatial Redistribution of Nitrogen by Cattle in Semiarid Rangeland

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## Abstract

Nitrogen (N) availability can strongly influence forage quality and the capacity for semiarid rangelands to respond to increasing atmospheric $CO_2$. Although many pathways of nitrogen input and loss from rangelands have been carefully quantified, cattle-mediated N losses are often poorly understood. We used measurements of cattle N consumption rate, weight gains, and spatial distribution in shortgrass rangeland of northeastern Colorado to evaluate the influence of cattle on rangeland N balance. Specifically, we estimated annual rates of N loss via cattle weight gains and spatial redistribution of N into pasture corners and areas near water tanks, and used previous studies to calculate ammonia volatilization from urine patches. Using measurements of plant biomass and N content inside and outside grazing cages over 13 yr, we estimate that cattle stocked at 0.65 animal unit months (AUM) $\cdot$ $ha^{-1}$ consumed 3.34 kg N $\cdot$ $ha^{-1}$ $\cdot$ $yr^{-1}$. Using an independent animal-based method, we estimate that cattle consumed 3.58 kg N $\cdot$ $ha^{-1}$ $\cdot$ $yr^{-1}$ for the same stocking rate and years. A global positioning system tracking study revealed that cattle spent an average of 27% of their time in pasture corners or adjacent to water tanks, even though these areas represented only 2.5% of pasture area. Based on these measurements, we estimate that cattle stocked at 0.65 AUM $\cdot$ $ha^{-1}$ during the summer can remove 0.60 kg N $\cdot$ $ha^{-1}$ in cattle biomass gain and spatially redistribute 0.73 kg N $\cdot$ $ha^{-1}$ to areas near corners and water tanks. An additional 0.17 kg N $\cdot$ $ha^{-1}$ can be lost as $NH_3$ volatilization from urine patches. Cumulatively, these cattle-mediated pathways (1.50 kg N $\cdot$ $ha^{-1}$) may explain the imbalance between current estimates of atmospheric inputs and trace gas losses. While $NO_x$ emission remains the largest pathway of N loss, spatial N redistribution by cattle and N removed in cattle biomass are the second and third largest losses, respectively. Management of cattle-mediated N fluxes should be recognized as one means to influence long-term sustainability of semiarid rangelands.

**Key Words:** grazing management, Great Plains, large herbivores, nitrogen cycling, semiarid grassland, shortgrass steppe

## INTRODUCTION

Although water is the primary resource limiting plant growth in semiarid, temperate rangelands, soil nitrogen (N) availability can strongly influence forage production and protein content (Burke et al. 1998; LeBauer and Treseder 2008), and the distribution and growth rate of large herbivores (Hyder et al. 1975; Ganskopp and Bohnert 2009). The response of semiarid rangelands to increasing atmospheric $CO_2$ concentrations in terms of forage quantity and quality is also likely to be regulated by soil N availability (King et al. 2004; Milchunas et al. 2005; Reich et al. 2006; Dijkstra et al. 2010). In rangelands with low rates of atmospheric N deposition, understanding pathways of N loss or redistribution is therefore important both for contemporary management and for understanding future responses to climate change (Pineiro et al. 2010). Over the past half-century, long-term studies and syntheses have substantially advanced our understanding of soil N transformations and pathways of gaseous N loss in semiarid, temperate rangelands (Burke et al. 2008; Mosier et al. 2008). Because these ecosystems are characterized by low precipitation, leaching of N rarely occurs. Rather, N loss primarily occurs through gaseous emissions, with the highest loss as $NO_x$ (Table 1; Mosier et al. 2008). Lower loss rates can occur via denitrification in late winter, ammonia volatilization from aboveground vegetation, and $N_2O$ emissions (Table 1; Mosier et al. 2008).

The amount of N cycled through domestic livestock in these ecosystems can be significant relative to other components of the N cycle. Most N consumed by livestock is retained in the ecosystem either as dung, urine, or standing livestock biomass, but livestock can influence N losses via three pathways. First, N is removed in the form of biomass gained by livestock whenever these animals are removed from the system. Second, a portion of N deposited as urine is volatilized to the atmosphere. Third, livestock could spatially redistribute N if certain areas within pastures consistently receive greater inputs of dung and urine relative to the amount of N consumed there. Because large herbivores move and consume forage nonrandomly at spatial scales from individual plants to landscapes (Coughenour 1991; Bailey et al. 1996), N intake and excretion are often spatially uncoupled. Depending upon its magnitude, spatial redistribution of N could significantly influence forage production and quality in those areas of the landscape where N consumption consistently exceeds dung and urine deposition.

Estimates of the magnitude of these three pathways, particularly spatial redistribution, have generally been lacking in semiarid rangelands or are based on studies with limited

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