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Using biodiversity to connect rangeland forage nutritive values and methane production potential

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Abstract

In the western United States, extensive rangeland livestock grazing systems rely on the diversity of rangeland plant communities to provide vegetation structure and forage nutritive value. With an increased interest in enteric methane production from rangeland livestock across production systems, managers and policy makers need accurate and actionable information about how forage nutritive value influences enteric methane production from native rangelands. Currently, efforts to quantify and mitigate enteric methane from grazing livestock have not accounted for the spatially and temporally dynamic nature of rangeland forage resources used in extensive rangeland production systems. We clipped rangeland forage biomass at the US Sheep Experiment Station in Dubois, Idaho, USA at monthly intervals from sample points along a biodiversity gradient to quantify the nutrient value (crude protein, fiber, and organic matter). We will then estimate methane produced from each rangeland forage sample using an *in vitro* incubation system to simulate ruminant digestion. Using a combination of mixed-effect models and ordinations, we will determine the relationship between nutritive value and enteric methane potential. Understanding this relationship can help livestock managers make grazing decisions to mitigate enteric methane production when possible.

Introduction

The biodiversity of rangeland plant communities is a primary indicator for determining ecosystem integrity and the ecosystem's ability to provide goods and services that support food security, rural livelihoods, wildlife conservation, and carbon management (Ahlering et al., 2020; Pellant et al., 2020). Heterogeneity in rangeland vegetation is essential for ecosystem provisioning. As biodiversity diminishes, susceptibility to climatic variability increases, threatening short- and long-term output of important services. In the western U.S., extensive livestock production systems graze a variety of lands ranging from intact, heterogenous native plant communities to those that have been converted to more homogeneous communities. Such conversion may be intentional, e.g., introducing new plant species to enhance forage production, or unintentional, e.g., invasion of invasive species. Regardless, loss of heterogeneity reduces adaptive capacity by coupling rangeland management outcomes to just few or even a single plant species.

The nutritive value of available rangeland forage is spatially and temporally dynamic with the composition, phenology, and management driving intra-year variability (Ganskopp and Bohnert, 2009; NASEMR, 2016;

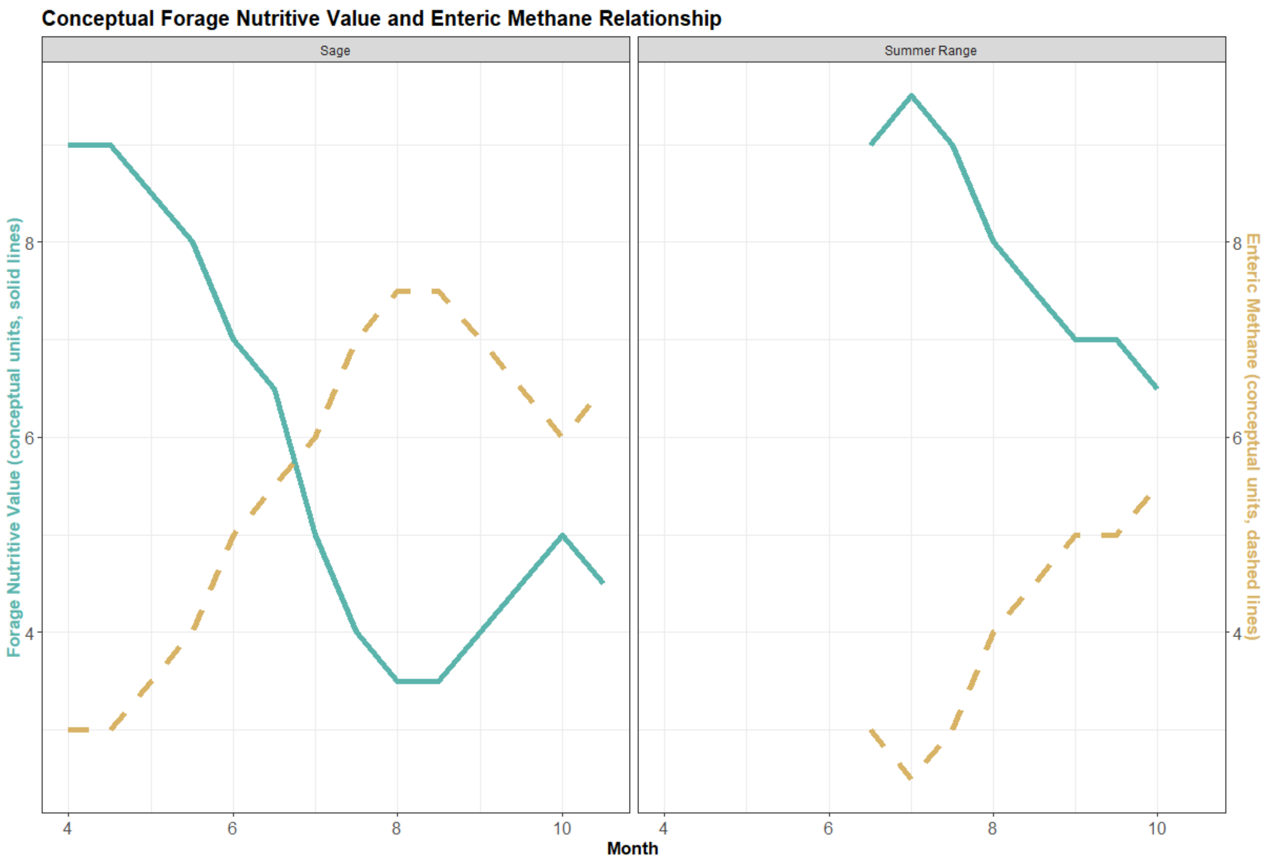
National Research Council, 2007; Spiess et al., 2024). As plant communities shift, or are altered over time, we would expect the nutritional profile of the plant community to also change. For rangeland managers, conservationists, and livestock producers, understanding how the nutritive value of a plant community shifts over the growing season within a year can inform management decisions to meet outcome expectations.

Forage nutritive value is also an indicator for enteric methane potential once digested by ruminants (Bezabih et al., 2014; Khan et al., 2021; Thompson and Rowntree, 2020), which include both domestic and native (wild) species. Of the commonly measured nutritive profile parameters, neutral detergent fiber has previously been found to have a significant, positive relationship with enteric methane production (Bezabih et al., 2014; Khan et al., 2021). With increased focus on greenhouse gas fluxes in rangelands (Recktenwald and Ehrhardt, 2024; Sanderson et al., 2020; Thompson and Rowntree, 2020; Wang et al., 2021), an understanding of intra- and inter-year variability in enteric methane potential for rangeland plant communities will facilitate long-term rangeland management towards vegetation diversity goals to minimize enteric methane potential. This research will also help expand the discussion of enteric methane production from rangelands given that the intra-season variability of rangeland forage nutritive value is currently missing from the broader discussion of enteric methane production of rangelands. As this project progresses into plant communities along the elevation gradient in the region, we will be able to compare nutritive trade-offs in grazing at different points in the growing season or losing grazing access to higher elevation communities (Wilmer et al., 2024).

For this paper, we outline our initial rangeland forage pilot project that we are currently analysing and then transition into describing the broader rangeland forage project. We are working towards documenting and quantifying the community composition, structure, and nutrition profiles of vegetation across temporal, elevation, and biodiversity gradients bedded within an extensive rangeland livestock system. We will address broader interests and issues in greenhouse gas emissions, rangeland management, animal production, and adaptive management capacity to begin filling a critical knowledge gap relevant to a variety of stakeholders that include livestock producers, land management agencies, wildlife conservationists, and policy makers. Our approach will include direct comparisons of the forage nutritive value and enteric methane potential profiles among native sagebrush steppe rangeland plant communities along biodiversity gradients. Results will provide a foundation for evaluating how losing, maintaining, or improving biodiversity affects the provisioning potential of extensive rangeland systems.

Methods

For the pilot project, we collected rangeland forage samples from two adjacent sagebrush steppe management units to compare differences in forage nutritive value and enteric methane potential between a burned and unburned area in July 2024 and then between summer (July 2024) and early fall (September 2024) for the unburned management unit. We clipped available forage in 0.25 m^2 frames at sample points distributed across each management unit after determining the species composition by cover for each frame. We then ground all samples through a 2-mm sieve using a Wiley Mill to prepare for nutrient and methane analyses. At this point in time for the project, we are transitioning to sample analysis. A subsample of each sample will be sent off for crude protein and fiber analyses and a subsample will be used to determine *in vitro* digestibility and enteric methane potential. In addition to traditional wet chemistry methods, we are also using near-infrared spectroscopy to prepare spectral calibration curves for future nutritive value analysis. We are using a Gas Endeavour *in vitro* rumen incubation system (Liu et al., 2018) to determine enteric methane potential.



Conceptual figure for the expected forage nutritive value and enteric methane potential relationship over the potential grazing seasons in eastern Idaho, USA sagebrush steppe and higher elevation rangeland plant communities. Based on existing research, we are expecting to find that forage nutritive value is inversely related to enteric methane potential. The shorter grazing season for the summer range panel is related to the shorter growing season and access logistics due to snow at higher elevations than in the sagebrush steppe panel.

Using a combination of mixed-effect models and ordinations, we will determine the overall relationships between nutritive value parameters (crude protein, acid detergent fiber, neutral detergent fiber, and acid detergent lignin), digestibility, and enteric methane potential (Spiess et al., 2024). We expect enteric methane potential to be inversely correlated with nutritive value (Khan et al., 2021; Thompson and Rowntree, 2020). For the pilot project data, we expect the available forage in the burned management unit to have a higher nutritive value (higher protein, higher digestibility, lower fiber) than the adjacent unburned management unit. We also expect the samples from the unburned management unit in July to have a higher nutritive value than samples collected from the same unit in September.

Next Steps & Discussion

Following the pilot project, we will be expanding to a manipulative experiment in summer 2025 to target the biodiversity component of this relationship between forage nutritive value and enteric methane potential in addition to temporal variability of the forage base. At the experimental study sites, we will manipulate the community within subplots through a combination of herbicide treatments to target different functional groups and investigate how removing species from the community will affect the nutritive profile. The full subplot treatment factorial at each experimental site will include: no herbicide – control, forb-targeted herbicide, shrub-targeted herbicide, forb & shrub-targeted herbicide. To capture the temporal progression of the forage, we will clip frames from each factorial subplot at monthly intervals from May through October.

We expect that the reduction in biodiversity will correspond to an overall reduction in forage nutritive value due to fewer species and functional groups contributing to the overall growth curve of the respective subplots. Similarly, we expect that samples from later in the growing season will have lower forage nutritive value and higher enteric methane potential than samples from earlier in the growing season. This will help illustrate how grazing similar plant communities at different times of the year can meet, exceed, or fail to meet an animal's nutritional needs (Wilmer et al., 2024).

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