



## Wyoming sagebrush rangeland soils are a weak methane sink

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**Key words:** Dormant season; Soil carbon fluxes; Soil moisture; Cattle urine; Greenhouse gas

### Abstract

Dryland ecosystems cover 41% of Earth's terrestrial surface while providing 60% of the world's food production, and 50% of the world's livestock. Drylands also account for 30% of global carbon while operating as a carbon sink, carbon neutral, or a carbon source depending on the season and availability of soil moisture. Within dryland soils, methanotrophs, methane (CH<sub>4</sub>) consuming bacteria, are present and could aid in reducing methane from the atmosphere. However, the influence that methanotrophs have in the overall soil carbon flux of dryland soils is less known. To understand their influence, we established a soil flux experiment in a semi-arid Wyoming sagebrush (*Artemisia tridentata wyomingensis* Nuttall, Beetle & Young) plant community in western North America. We measured *in situ* CO<sub>2</sub> and CH<sub>4</sub> soil fluxes at 30-minute intervals for 16 days during the dormant season. For four days we established a soil flux baseline before adding 200-mL of cattle urine to a subset of plots to observe how cattle might influence soil carbon fluxes. We also added 200-mL of distilled water to the remaining plots as a control. We then measured all plots for an additional 12 days. We found that during the dormant season the sagebrush soils were consistently a weak CH<sub>4</sub> sink, while CO<sub>2</sub> was a weak source, and the addition of cattle urine only augmented those dynamics. We also found a diurnal pattern which coincided with increased surface air temperatures. During the nighttime, both soil CH<sub>4</sub> and CO<sub>2</sub> were carbon sinks, but between 0800 and 1600 hr soil CO<sub>2</sub> fluxes became a carbon source while CH<sub>4</sub> fluxes remained a carbon sink. These results suggest that our semi-arid Wyoming sagebrush rangelands can act as a methane sink even during the dormant season and the strength of the methane sink during the dormant season is based on soil moisture.

### Introduction

Even though dryland ecosystems are considered neutral carbon sinks to atmospheric CO<sub>2</sub>, dryland soil microbial communities include methanotrophs capable of consuming atmospheric CH<sub>4</sub>, making drylands potentially very important in the global carbon cycle. The importance and magnitude of CH<sub>4</sub> consumption in drylands are still uncertain, as our understanding of the underlying mechanisms driving the microbial community activity are unclear (Song et al. 2024). Generally, warm and dry or warm and moist soils provide ideal conditions for methane-oxidizing bacteria to consume the greatest amounts of CH<sub>4</sub>, while cold and wet soils reduce CH<sub>4</sub> consumption rates (Wen et al. 2024). Therefore, desert steppe drylands such as North American sagebrush steppe where soils

experience prolonged drying regimes (ca. 5 months) coincident with warming temperatures provides potentially a consistent CH<sub>4</sub> sink for atmospheric CH<sub>4</sub>.

Atmospheric CH<sub>4</sub> is the second most abundant greenhouse gas in the atmosphere and has more than tripled since preindustrial levels because of anthropogenic activities (Canadell et al. 2021). Globally, livestock account for ~30% of anthropogenic CH<sub>4</sub> emissions (Jackson et al. 2020). Methane emissions from livestock in the United States accounts for 4% of the overall CH<sub>4</sub> emissions in agriculture (Dillion et al. 2021), however it is estimated most of the emissions come from cow-calf production and stockers grazing on lower quality forage in drylands (Vargas et al. 2024). Drylands provide forage for 50% of livestock globally, suggesting soil processes in these drylands are likely impacted by livestock excreta such as urine. Livestock urine provides a high nitrogen deposit in liquid form which is readily available to soil microbes and has the potential to increase microbial activity which would result in higher soil respiration rates as well as higher CH<sub>4</sub> consumption in dryland soils. The objective of this study was to characterize how cattle urine influences soil respiration and methane consumption in the warm late-season plant dormant period of drylands soils. Specifically, we wanted to quantify if cattle urine deposition increased soil methane consumption and soil respiration because of the available nitrogen present in the urine. To address this, we added cattle urine to Wyoming sagebrush steppe soils and repeatedly monitored soil respiration and CH<sub>4</sub> consumption over a 14-day post-urine application period.

## Methods

The study was conducted at the USDA-Agricultural Research Service Northern Great Basin Experimental Range (NGBER, 43.471507, -119.691100), located about 70 km west of Burns, OR, USA. The study site is situated in a Wyoming sagebrush (*Artemisia tridentata* subsp. *wyomingensis* Bettle & Young), Sandberg's bluegrass (*Poa secunda* J. Presl.), bluebunch wheatgrass (*Pseudorogonaria spicata* [Pursh] Á. Löve) and Idaho fescue (*Festuca idahoensis* Elmer) plant community at 1397 m asl. The soils at the study site were classed as a Vil-Decantel, Variant-Ratto complex which are well drained and have a duripan at 30-50 cm. Soil texture in the top 10 cm was determined to be a sandy clay loam using the hydrometer method.

We deployed two opaque soil respiration chambers connected to an LI-8250 multiplexer and LI-7810 CH<sub>4</sub> and CO<sub>2</sub> trace gas analyzer (LI-COR Environmental, Lincoln, NE USA). The chambers sat on PVC soil collars that were placed in the interspace between Wyoming sagebrush and native bunchgrasses over bare soil. Soil fluxes were sampled every 2 hrs from 07 September 2022 to 26 September 2022. On 12 September 2022 we applied 200 ml of Angus-Hereford cattle urine to one soil respiration chamber plot, and 200 ml of DI H<sub>2</sub>O to the other soil respiration chamber plot. The amount of beef cattle urine applied to each soil respiration chamber plot equates to the average amount released during a urination event by a mature beef cow corrected for the volume of the soil respiration chamber plot (Yamulki et al. 1998, Misselbrook et al. 2016). Cattle urine was collected following FASS approved methodology (Canton et al. 2020).

## Results

Even though both chambers were less than 2 m apart we observed the variability in soils in the separation between the two treatments, which was most pronounced in the CH<sub>4</sub> flux. Regardless of this difference we observed that soil CO<sub>2</sub> flux increased the most on September 12 when urine was added to the plot compared to water; incidentally there was also a small precipitation event that occurred the night prior to the urine and water additions (Fig. 1). The influx in available nitrogen from the urine did not alter the flux direction of CH<sub>4</sub>, but subsequent precipitation events did increase the CH<sub>4</sub> flux closer to zero, indicating weaker CH<sub>4</sub> sink activity. There was a small diurnal pattern observed for the soil CO<sub>2</sub> flux between 0800 hr to 1600 hr, while there was no diurnal pattern captured for the soil CH<sub>4</sub> flux with urine added to the soil, but a potential decrease in CH<sub>4</sub> flux strength where water was added to the soil between 1000 hr and 1600 hr (Fig. 2).

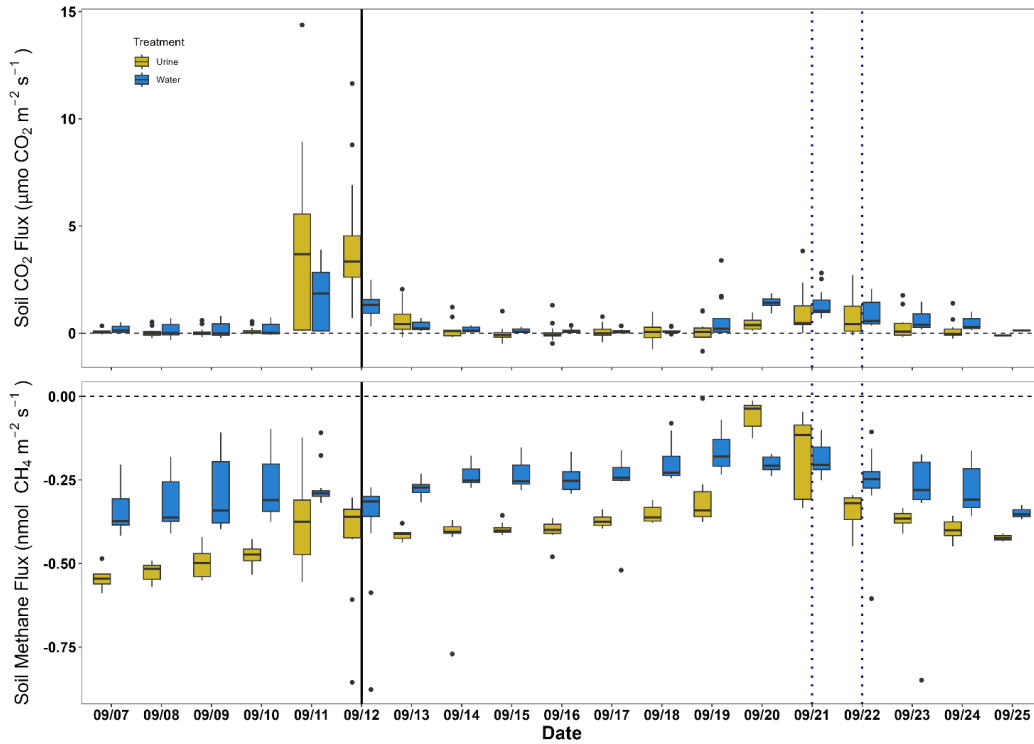


Figure 1. Daily average soil CO<sub>2</sub> (top panel) and CH<sub>4</sub> (bottom panel) fluxes from 07 September – 25 September 2022. Blue boxes are for water addition while yellow boxes are for urine addition. The black vertical bar represents the day water or urine was applied to the plots, and the dotted blue vertical line represents a day when it rained.

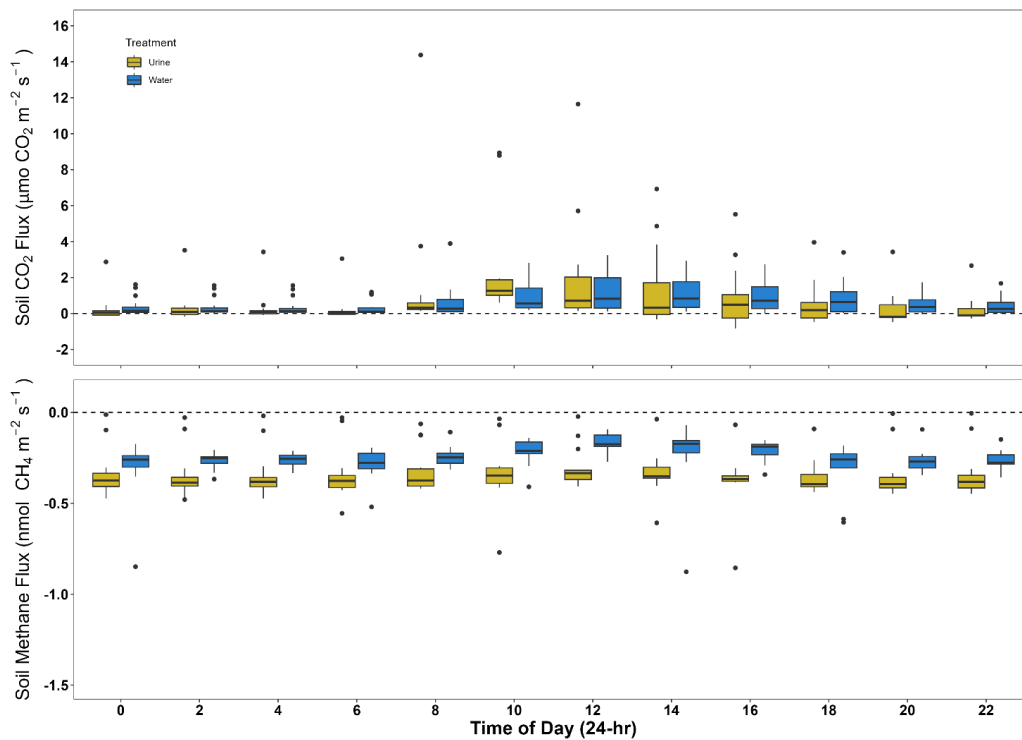


Figure 2. Diurnal soil CO<sub>2</sub> (top panel) and CH<sub>4</sub> (bottom panel) fluxes averaged across September 12 - September 25, 2022 observations. Blue boxes are for water addition while yellow boxes are for urine addition plots. Data were aggregated during their respective sampling times across the monitoring time.

## Discussion

Our data suggests that Wyoming sagebrush steppe rangeland soils act as a weak CH<sub>4</sub> sink in the dormant season regardless of the addition of beef cattle urine or water. However, this soil sink strength is reduced when under moister soil conditions. Additionally, our diurnal data showed that from 10:00 to 16:00 CO<sub>2</sub> efflux increased, regardless of urine or water additions making these soils a weak source of carbon. Over these same periods, CH<sub>4</sub> flux was consistently negative, indicating they acted as a weak methane sink regardless of diurnal variation in soil conditions. Urine deposition possibly increased CH<sub>4</sub> uptake across the study period (Fig. 1), at least in part due to decreased diurnal variation in sink strength (Fig. 2), which likely reflects greater methanotrophic microbial activity. However, this pattern needs to have additional replication to parse out the heterogeneity of soil and the actual effect of cattle urine on the sink strength of CH<sub>4</sub>. This project only demonstrates that more research is needed to study CH<sub>4</sub> dynamics in semi-arid Wyoming sagebrush steppe rangeland soil, and that it is critical to determine and how precipitation and livestock activity interact to influence seasonal CH<sub>4</sub> sink strength dynamics, and how these change across seasons and with plant community structure. Our findings and experience will be used to expand this research effort of understanding CO<sub>2</sub> and CH<sub>4</sub> dynamics to a larger spatio-temporal extent with beef cattle grazing in a native Wyoming sagebrush steppe plant community.

## Acknowledgements

We want to thank Peter Olsoy for an earlier review of this manuscript. We also want to thank Matheus Ferreira for acquiring the cattle urine following FASS approved methodology.

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