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Assessing the environmental footprint of grazing bison in the United States

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Abstract

The bison is a highly held species in the United States (U.S.) due to its historic and cultural significance along with its distinction as the national mammal. Despite a drastic decline in the 1800s, the U.S. bison population is rebounding with nearly 250,000 existing within private operations, federal, state and public herds, and public lands (U.S. Department of Agriculture 2024). A majority of this population is owned and raised privately as livestock. However, several herds also exist as conservation or Indigenous herds. As the bison production sector continues to grow, its impact on the climate is coming into question. Similar to other grazing ruminant livestock, bison emit greenhouse gases (GHG), which are often publicly associated with negative environmental impacts. However, bison can also positively impact the environment by contributing to healthy grasslands and carbon sequestration through grazing action. South Dakota State University (SDSU) was recently awarded a commodity development grant focused on grazing livestock producers, including bison producers. A primary goal of this project is to assess the environmental impacts of bison grazing systems and to encourage sustainable land management practices by providing producers with practice incentives and creating novel market opportunities. To accomplish this, SDSU is partnering with bison producers in the Northern Great Plains to implement sustainable grazing and land management practices and subsequently measure, monitor and verify associated GHG and carbon impacts. Measurements include soil carbon and GHG, along with estimates of bison GHG emissions measured using GreenFeed (C-Lock, Inc., Rapid City, SD, USA) technology. Data generated from this project will help establish baseline environmental impact estimates for grazing bison, which are needed to help inform producer management decisions and guide future market development opportunities.

Introduction

While tens of millions of Plains bison (*Bison bison bison*) once roamed the plains of North America, a sharp decline in bison numbers occurred in the 1800s, driven by a number of factors including commercial hunting, disease introduction, environmental conditions (e.g., drought), and division of the plains by railroad expansion (Boyd and Gates 2006). This drastic decline ultimately led to one of the first major conservation movements in North America, with numbers dwindling to a few hundred in the late 1880s. Conservation efforts were first led by private citizens, with government efforts later gaining momentum to reestablish the Plains bison population (Freese et al. 2007).

The Plains bison is unique in its multi-faceted significance as a production, conservation, and cultural species. Greater than 90% of today's bison are managed for commodity production purposes. However, bison are publicly recognized as culturally important because of their Indigenous culture status and their designation as the U.S. national mammal. As the commodity production sector continues to grow, the impact of bison production on the climate is being scrutinized. Bison are ruminants that generate and emit greenhouse gases (GHG) similarly to beef cattle (Stoy et al. 2021), and these GHG are frequently associated with negative impacts on the environment. However, these grazing ruminants also have potential to positively influence carbon sequestration and soil health in grasslands through changes in plant species composition and carbon distribution (Reeder and Schuman 2002). Additionally, intentional grazing management can result in more carbon sequestration than GHG emissions (Teague et al. 2016) and improved nitrogen cycling (Vega Anguiano et al. 2024), indicating that grazing livestock systems can support ecologically healthy grasslands and ecosystems and promote greater biodiversity (Ratajczak et al. 2022; Tielkes and Altmann 2021).

While bison reintroduction has been successful in growing the Plains bison population, the GHG impacts of such reintroductions are unknown. There have been limited attempts at understanding GHG emissions from bison, including using eddy covariance (Stoy et al. 2021) and gas chambers (Galbraith et al. 1998) to estimate GHG on enclosed bison along with employing known energy requirements to estimate historical herd emissions (Kelliher and Clark 2009). However, numerous factors can influence methanogenesis and subsequent measures of GHG, including (but not limited to) host genetics, age and diet along with seasonality and type of production system. The recent development of GreenFeed technology (C-Lock Inc., Rapid City, SD) has enabled GHG sampling on individual grazing livestock. This technology has been used to successfully collect GHG emissions data on both grazing (Husmann et al. 2024; Waghorn et al. 2016) and confined (Ryan et al. 2022) cattle. Use of GreenFeed technology to collect GHG measurements on grazing bison will help inform the environmental impact of bison production and reintroduction. Our objective is to collect GHG measurements on grazing bison along with relevant soil carbon, forage and climatic data to provide baseline knowledge for bison grazing systems in the Northern Great Plains of the U.S.

Methods

We are currently engaged in a large-scale, five-year study focused on bison and beef calves produced on operations in the Northern Great Plains that implement approved conservation practices, such as cover crop grazing, conservation cover and range plantings, and prescribed grazing. A critical component of this project is determination of GHG emissions and carbon sequestration associated with grazing bison and beef cattle. To accomplish this, we have established cooperative partnerships with three bison operations and four beef cattle operations located in South Dakota and Wyoming. GreenFeed units are deployed at each operation to collect GHG measures from grazing animals. Additionally, soil samples are actively being collected from each operation for determination of soil organic carbon and bulk density along with microbial community size and composition, which can be earlier indicators of changes in carbon sequestration potential. The goal of this initial report is to share preliminary results from the first year of GHG data collection on grazing bison.

Study Sites - Bison

South Dakota State University established cooperative partnerships with three bison operations to measure GHG emissions of grazing bison. These operations were selected because they are located in different geographic gradients across Wyoming and South Dakota and ultimately represent the greater study area of the Northern Great Plains. Historical grazing activity information is being collected for each site, but all sites have been grazed by bison in recent years. Site 1 is located near Custer, South Dakota, and consists of approximately 650 hectares at a mean elevation of 1,320 m. The dominant vegetation consists of western wheatgrass and green needlegrass, along with big bluestem and sideoats grama. The predominant soil type is silty clay loam. Ambient temperatures range annually from 2.2-13.3 °C and average precipitation is 551 mm. Site 2 is located near Gillette, Wyoming, and consists of approximately 20,900 hectares at a mean elevation of 1,524 meters. The dominant vegetation is Wyoming big sagebrush along with shrub needle and thread, western wheatgrass, crested wheatgrass and blue grama. The predominant soil type is loamy. Ambient temperatures range annually from 0.3-14.7 °C and average precipitation is 337 mm. Site 3 is located near Fort Pierre, South Dakota, and consists of >59,000 hectares at a mean elevation of 750 meters. The dominant vegetation is from the Western wheatgrass community. The predominant soil type is dense clay. Ambient temperatures range annually from 2.0-16.3 °C and average precipitation is 477 mm.

GreenFeeds

The GreenFeed pasture system from C-Lock (c-lockinc.com) collects gas flux measures of primarily methane (CH_4) and carbon dioxide (CO_2), with oxygen (O_2) and hydrogen (H_2) as additional options. The system reads the animal's electronic identification tag upon entry and dispenses a small amount of pelleted feed as an attractant. As the animal consumes the bait, a fan draws air at a continuous rate past the animal's mouth to enable the capture of eructation events. The animal must be within an approved head proximity for a minimum of 2 minutes with adequate airflow (> 29 L/s) for a measurement to be recorded. Animals can be measured multiple times each day and settings regarding the number of visits, number of bait drops per visit and timing of allowed visits can all be modified in the machine interface.

There is no standard adaptation procedure for bison on GreenFeed units. Therefore, the procedure for GreenFeed introduction and use varied by site due to differences in pasture size and herd management. At Site 1, a subset of bison heifers (n = 12) was initially adapted to the GreenFeed units during the Fall of 2023 before being combined with the main herd (n = 115) in 2024. At Site 2, the GreenFeed units were rotated alongside the yearling and 2-year-old bison (n = 618) as part of the rotational grazing plan. At Site 3, bison (n = 3,133) were placed into relatively smaller pastures of < 567 hectares to encourage initial use; however, average pasture size at Site 3 at the time of GreenFeed unit introduction was considerably larger than at Sites 1 and 2, ranging from 2,740-4,474 hectares.

Results

GreenFeed Use and GHG Emissions

GreenFeed adoption was unsuccessful at Site 3 with only two observations recorded. This was likely due, in part, to the substantially larger pasture size, machine movement restrictions and limited labour resources. The herd at Site 3 is also enrolled in a grass-fed program, restricting the type of bait used in the machine to alfalfa pellets. Site 1 also used alfalfa pellets but Site 2 used a textured sweet feed as bait. GreenFeed adoption success was much greater at Sites 1 and 2. The number of monthly GreenFeed observations at Sites 1 and 2 are shown in Table 1, along with monthly means for the two greenhouse gases of primary interest, CO_2 and CH_4. In total, 1,696 observations were recorded across Sites 1 and 2 in 2024 (to-date). No observations were recorded at Site 2 in April due to temporary bison relocation to another grazing allotment.

GHG Emissions

Averages and standard deviations for CO_2 (g/d) and CH_4 (g/d) for Sites 1 and 2 are also presented in Table 1; results from Site 3 are not shown due to the limited data collection from that herd. A simple t-test indicated no difference ($P > 0.10$) in either CO_2 or CH_4 across the two sites.

Table 1. GreenFeed observations and CO_2 and CH_4 emissions collected from grazing bison at Sites 1 and 2 in 2024.

Site	Month	GreenFeed Observations	[1] CO_2, g/d	[2] CH_4, g/d
1	January	243	6,047.37 (1,106.5)	146.34 (52.3)
1	February	159	5,791.64 (1,150.3)	127.45 (50.7)
1	March	238	5,809.51 (1,085.9)	134.91 (46.3)
1	April	306	5,410.92 (1,285.8)	120.64 (41.3)
1	May	87	6,931.43 (1,624.2)	196.69 (71.2)
1	June	52	7,687.42 (1,611.5)	194.80 (84.3)
1	July	70	8,421.40 (1,615.7)	222.98 (80.4)
1	August	59	6,654.10 (1,129.5)	190.7 (62.8)
2	March	9	6,125.75 (1,023.9)	144.89 (44.3)
2	May	9	5,754.40 (647.4)	153.96 (35.9)
2	June	140	6,623.39 (1,266.5)	157.66 (70.0)
2	July	183	6,887.39 (1,167.3)	165.98 (65.7)
2	August	122	6,469.23 (1,266.5)	157.96 (76.4)
2	September	19	6,217.32 (1658.8)	145.35 (74.3)

[1] CO_2 mean (CO_2 standard deviation), g/d

[2] CH_4 mean (CH_4 standard deviation), g/d

Discussion

Grazing lands account for 25% of the global sequestration potential of carbon storage (Follett and Reed 2010) and the role of grazing animals – including bison - is critical in the control of the carbon cycle (Schmitz et al 2023). There is limited GHG data on grazing bison, and data captured from this study over the next five years will be fundamental in documenting GHG emissions in foraging bison and furthermore understanding the role of bison grazing systems in net carbon sequestration on grasslands.

We have demonstrated that GreenFeed units can be successfully adapted for bison use. It does appear, however, that limiting pasture size may be critical for successful adoption by bison. A smaller pasture size may help to ensure closer proximity to a GreenFeed unit, which could be an important factor considering differences in grazing behaviour between bison and cattle. However, it is also worth considering that limiting pasture size may influence other effects associated with bison grazing and carbon cycling. Finally, limiting other supplement availability and/or choosing a more enticing bait may be critical in persuading bison to use the GreenFeed with only a small amount of pelleted feed bait.

While GHG estimates did not differ across the two bison sites included here, further analysis and data collection are needed to determine differences associated with season and forage type and availability. Forage samples were collected routinely at each site across the grazing seasons, and associated climate data has been archived. Additionally, soil samples were collected at each site and will be analysed for soil organic carbon and bulk density along with soil microbial communities. These data collectively will help establish the baselines for bison grazing systems in the Northern Great Plains.

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