2023

Research Report

AgNext

COLORADO STATE UNIVERSITY

SUSTAINABLE SOLUTIONS
FOR ANIMAL AGRICULTURE

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Welcome Letter from Dr. Kim Stackhouse-Lawson

As I reflect on the two years since launching AgNext, I am most proud of the incredible team that has joined Colorado State University to advance sustainability in animal agriculture. This team works tirelessly to innovate scalable solutions that advance the sustainability and resiliency of society's most complicated food system: animal agriculture. They conduct their work in partnership with the supply chain, co-developing innovative solutions to the industry's most wicked problems. As I think about all that this outstanding team of scientists has accomplished since coming together since the Fall of 2022, I am humbled by the opportunity to work alongside such world class scientists.

I welcome you to review the past year of work that this multi-disciplinary team has successfully and collaboratively completed while maintaining a key focus on maintaining balance along the three pillars of sustainability: social, economic, and environment. In this document you will find these leading animal agriculture experts' most recent study results. The pages of this document will highlight expert knowledge and findings in rangeland, intensive grazing, feedlot, and dairy systems, and economics that keeps driving the industry toward profitability and efficiency.

We hope that our research inspires sustainable innovation across the supply chain, and we look forward to continued engagement that inspires our next scientific question. We will continue to provide solutions that propel the industry toward the continued food security of our Nation, protection of our natural resources, profitability of our producers, and advancement of our communities.

-Dr. Kim Stackhouse-Lawson, Director of AgNext and Professor of Animal Science

United Nations Sustainable Development Goals

The United Nations developed 17 goals that strive towards sustainable development. At AgNext, we align to the sustainable development goals through our research.

Communications Recognition

Designed by: Julia Giesenhagen

Photography by: Erica Giesenhagen, Rebecca Crook, Sydney Gradisar-Jansen

Edited by: Dr. Kim Stackhouse-Lawson, Dr. John Ritten, Jenn Rieskamp

Research Disclosure

The contents of this Research Report are summaries of research from AgNext faculty, affiliate faculty, and graduate students. For further clarification and for access to references, please use the contact information at the bottom of each report. Much of the data in this report is preliminary in nature and may change before final publication.

About AgNext

AgNext is a leader for research in animal and ecosystem health while enhancing profitability of the supply chain and serves as the crossroads for producers, industry partners, and researchers to come together to innovate real time solutions for sustainable animal agriculture. Our research focuses on advancing the science of animal agriculture to ensure a continued safe, secure, and nutritious food supply. Our mission is to identify and scale innovation that fosters the health of animals and ecosystems to promote profitable industries that support vibrant communities.
Learn more at agnext.colostate.edu.

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Our Team

AgNext's Team consists of feedlot specialists, dairy specialists, economists, modelers, nutritionists, veterinarians, researchers, communicators, undergraduate, and graduate students. A multidisciplinary team of this kind is unique in academia and is a large part of our success in finding sustainable solutions for animal agriculture. With our broad team, we are able to explore system tradeoffs and innovate solutions that bridge the three pillars of sustainability.

Dr. Kim Stackhouse-Lawson
Director

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Head of Strategy and Communications

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Associate Professor of Feedlot Systems

Dr. Greg Thoma
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Maya Swenson
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Noah Winters
Corporate Sustainability Intern

Agricultural Economics

Angus cow and her calf at the Agricultural Research, Development and Education Center (ARDEC).

Community Security in Beef Production Sustainability

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Introduction:

Cattle producers face numerous challenges. Sustaining their operations in a secure community context has importance for animal care, resource management, and keeping the business profitable. Social challenges producers face often relate to dynamics changing in the population, including consumer preferences, land-use change, and immigration policy.

Objectives:

Collect and analyze national and regional scale socio-economic and industry data relevant to community security issues and US beef production sustainability.

Methods:

The researchers coupled primary sociological data from interviews collected during the experiment with secondary economic data compiled from multiple sources, aggregated, and analyzed as a part of this study.

A total of 63 semi-structured personal interviews were conducted with producers, industry experts, and community leaders. Interviews ranged from 30 minutes to 3.5 hours, and averaged 65 minutes. Interview questions generally focused on characterizing trends and challenges producers face in operations, and how those factors relate to connectivity for their local, regional, and industry-related communities.

Sources for secondary economic and industry related data include National Agricultural Statistics Service surveys and agricultural censuses, and Livestock Marketing Information Center. Data were collected as state-level reported values and aggregated as summed totals or weighted averages based on the number operations in a given state in each region.

Results:

Over the last several decades, the US beef industry has continued a spatial shift and consolidation, with greater concentration of the inventory moving northward and to the center of the US. While some cases can be seen at the state level, regional averages illustrate the wider pattern of a shift in beef cow inventory to the Central and Northern Great Plains (Figure 1).

At the same time, trends in both consolidation and fragmentation are observed in different beef industry sectors. While feedyards and a relatively small percentage of large operations dominate a majority of the total inventory, a majority of producers across regions operate with <100 head, and the vast majority of those have <50 head.

This dichotomy ties directly to community security issues by compounding challenges with ranch succession, large-scale effects in the environment (such as drought, disease risk, invasive plants, wildlife conservation, etc.), as well as population dynamics external to production. Experiences collected through interviews echoed trends observed in time-series economic data on a number of levels.

Based on interviews, many producers experience long-term anxiety over operation viability from year-to-year as well as challenges with legacy effects related to ranch succession. The majority of producers described greater levels and diversity of threats to their operations having worsened in recent years compounding the 'normal' economic beef production cycle.

While the industry must value attention to policy and programming that addresses both the animals and producers, the inverse dichotomy in these results indicates the need for understanding structural challenges which may grow wider over time. As such, additional strain could occur for the majority of producers tied to rural community landscapes and places they rely on not only for equipment and inputs, but also social connectivity and options for securing ranch succession scenarios.

Because of the large tracts of land managed by thousands of operators nationwide, cattle producers also contemplate resource stewardship daily and need community-based support to maintain that environmental health. As such, industry programming to sustain security for rural communities has vital implications for the long-term infrastructure and human capital needed to meet the supply/demand balance of providing quality protein to the US population and export markets. These factors relate to risk management and emphasize the value, if not need, to maintain a diversity and range of operation size within production sectors, geographies, and processing/distribution. The synthesized social- and economic-related data for this analysis indicate that gradient of diversity is fundamental to long-term community security and viability for cattle producers.

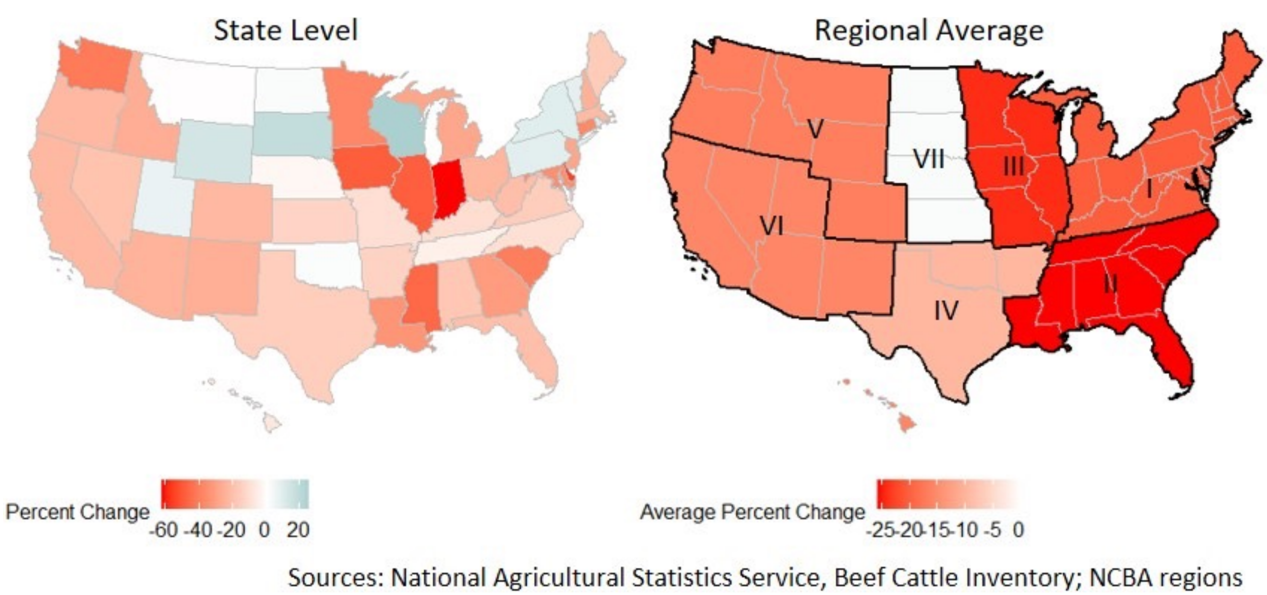

Figure 1: Change in US Beef Cow Inventory, State-level percent change and NCBA region average percent change, 1980 to 2021.

Acknowledgements: Funded in Part by the Beef Checkoff.
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8 DECENT WORK AND ECONOMIC GROWTH

11 SUSTAINABLE CITIES AND COMMUNITIES

A Ranching Economic Analysis of Ventenata (Ventenatadubia) Control in Northeast Wyoming

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Introduction:

Invasive species pose a threat to the livelihoods of many people living on rangelands of the western United States. Generally, control of invasive species is shown to be economically beneficial at the landscape scale. In contrast, economic analyses for private ranches often find that conservation practices, such as invasive species control, are not economically viable. Within mosaics of public-private land ownership; control of invasive plants presents challenges that may make economic justification difficult. In northeast Wyoming, ventenata [*Ventenata dubia* (Leers) Coss.] (*V. dubia*) is a relatively new invader in the Great Plains ecoregion that threatens forage production on ranches. Information on the economic impacts of this invasive grass in this region is important to help ranchers and land managers make informed, sound, management approaches.

Objectives:

Our objective is to explore the economic costs of managing *V. dubia* for two options available to a ranch operation: purchasing extra hay to offset losses in forage or controlling *V. dubia* with herbicide. We want to answer whether *V. dubia* damages are high enough, and control costs low enough, to justify management on private land ranches in northeast Wyoming.

Methods:

We collected perennial and annual vegetation biomass data of *V. dubia* infested areas in Sheridan County, Wyoming, from 2019 to 2022. Using this data, and information from Weed and Pest offices across Wyoming, managing *V. dubia* in Major Land resource Area 58b, we estimated the loss of forage due to this invader. We then calculated the cost of purchasing additional hay needed to offset this loss of forage and maintain a 500-head cattle herd given three invasion severity scenarios; 8%, 32%, and 50% forage loss. Using a range of forage utilization rates (25%, 35%, and 50%) and discount rates for a Net Present Value (NPV) analysis (3%, 5%, 7%, 10%), we compared these costs with the cost of controlling *V. dubia* with indaziflam in a partial budget analysis. Utilization rates were used to account for a range of management approaches, as well as serve as a proxy for site productivity. In essence, utilizing less of the available forage on a given site is similar to the site producing less forage in our calculations. These costs were estimated as the three-year Net Present Value.

Results:

We found that controlling *V. dubia* with indaziflam was a cheaper option compared to purchasing additional hay at 50% forage utilization in all of our scenarios and at all discount rates given our assumptions (Table 1). However, when utilization of available forage or site productivity was low, and where higher discount rates were used, purchasing supplemental hay was warranted over *V. dubia* in some cases. In these cases, support and coordination among neighboring landowners is needed to overcome trade-offs between realized and potential losses due to further weed spread and to achieve effective landscape-scale control. Coordination works by aligning individuals' motives with their neighbors, thereby considering the costs and benefits to neighboring properties. In northeast Wyoming, for example, the NRCS has implemented a cost-share program to relieve much of the cost of control, making control even more realistic for most landowners and facilitating coordination between them.

There are many ranch-specific differences that may make a different option more feasible, and we did not explore options of reducing herd sizes. However, previous research has shown that herd reduction options can also have negative repercussions for ranches, including being forced from the industry. This highlights the dangers that annual grass invasion has on financial feasibility of ranches in the Western US.

		Option cost (NPV over 3-yr chemical control)					
		8% forage loss		32% forage loss		50% forage loss	
Utilization rate	Discount rate	Buy hay	Apply herbicide	Buy hay	Apply herbicide	Buy hay	Apply herbicide
%				US$			
25	3	94,486	118,530	377,943	474,120	**590,536**	**529,648**
	5	91,886	118,530	367,542	474,120	**574,285**	**529,648**
	7	89,444	118,530	357,776	474,120	**559,025**	**529,648**
	10	86,052	118,530	344,206	474,120	**537,822**	**529,648**
35	3	**94,486**	**91,715**	**377,943**	**366,862**	**590,536**	**422,389**
	5	**91,886**	**91,715**	**367,542**	**366,862**	**574,285**	**422,389**
	7	89,444	91,715	357,776	366,862	**559,025**	**422,389**
	10	86,052	91,715	344,206	366,862	**537,822**	**422,389**
50	3	**94,486**	**71,604**	**377,943**	**286,418**	**590,536**	**341,945**
	5	**91,886**	**71,604**	**367,542**	**286,418**	**574,285**	**341,945**
	7	**89,444**	**71,604**	**357,776**	**286,418**	**559,025**	**341,945**
	10	**86,052**	**71,604**	**344,206**	**286,418**	**537,822**	**341,945**

Figure 1: NPV of the costs of *Ventenata dubia* strategies (buy hay to offset forage losses or apply herbicide) at the end of a 3-yr period on a 500-head, private land ranch in Major Land Resource Area 58b.

Acknowledgements: We thank the NRCS and the Sustainable Rangelands Roundtable for primary funding of this research. The Nature Conservancy provided partial support for this work through the Nebraska chapter's J.E. Weaver Competitive Grants Program. This research was supported in part by the intramural research program of the U.S. Department of Agriculture–National Institute of Food and Agriculture, Hatch accession no. 1013280 and McIntire-Stennis accession no. 7001691. We also thank the ranching families (names redacted for privacy) for allowing our research to take place on their properties. Finally, we thank Wyoming Game and Fish, Wyoming State Lands, Wyoming Agricultural Experiment Station, Beth Fowers, Jordan Skovgard, Jaycie Arndt, Jodie Crose, Tyler Jones, Shawna LaCoy, Nancy Webb, Heidi Schueler, Steve Paisley, Kelsey Crane, and Kerry White for their contributions to this research in the lab and field.

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Current and Potential Economic Impacts of 10 Invasive Weed Species in Wyoming

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Introduction:

This study focuses on the agricultural value lost and at risk from 10 weed species in Wyoming at the county and state level. Lost household income resulting from direct economic loss due to weed infestation has quantifiable ripple effects across the state economy, which are estimated. This analysis does not consider economic impacts related to recreation, ecosystem services, wildfire, wildlife habitat, or the like.

Objectives:

The overall objective of this study is to accurately estimate the current economic impacts of invasive weeds to Wyoming's economy with a specific focus on agriculture, and to estimate future potential value placed at risk if target species were allowed to expand into all suitable habitat. The study serves as a pilot study, setting out sound methods to quantify economic impacts using the best spatial extents for targeted invasive weeds. Results provide a basis to compare costs from lost agricultural value across invasive species and counties, as well as for ongoing comparisons over time.

Methods:

Estimating foregone economic value resulting from weed infestations on agricultural land requires 1) a non-impacted baseline economic value of agricultural production, 2) the proportion of area impacted by weed infestations, and 3) the proportion of reduced value due to each weed species. The cost of weed presence is estimated as the product of these in each of Wyoming's 23 counties for agricultural uses that are impacted by each of the 10 identified weed species. Summing across county estimates provides an estimate of statewide direct effects. Secondary impacts to employment, labor income, value added, and output loss stemming from statewide direct loss to agricultural values are estimated using a household income model in IMPLAN.

Results:

Statewide agricultural value reduced by weed infestation observed in 2021, and potential loss estimated on potential habitat, are reported in Table 1. As both direct and potential impacts to agriculture from reduced rents on agricultural land in Wyoming, cheatgrass has the highest loss estimates statewide with $29 million in direct loss on observed acres and $110 million in potential loss from infestation on suitable habitat. Direct impacts from land with observed or impacted cheatgrass infestations in 2021 is equivalent to 11% of non-impacted agricultural value with potential impacts of 43% the value of Wyoming's agricultural lands.

Of course, any estimate of economic impacts from weed infestation are only as good as the area and distribution measures that inform it. Improved weed presence estimates, more targeted spatial impacts, better suitable habitat models, weed impacts to specific crops, and observed trends over time are all potential additions to enhance these methods. Further, the methods used to estimate agricultural value lost to infestation from each selected weed species are a simple reduction in agricultural cash rent for relevant land types (cropland versus pasture and hay or rangeland). Valuing losses and costs related to weed infestation on non-agricultural wildlands, to recreation, ecosystem services, wildfire, wildlife habitat, or the like, provide numerous other extensions.

	Agricultural value lost from weed infestation (% of non-impacted agricultural value)	
Invasive weed	Estimated loss on present and impacted area	Potential loss on suitable habitat
Cheatgrass / downy brome (*Bromus tectorum*)	$28,697,257 (11%)	$109,841,084 (43%)
Hoary cress / whitetop (*Lepidium draba*)	$723,523 (<1%)	$82,737,008 (32%)
Leafy spurge (*Euphorbia esula*)	$572,413 (<1%)	$5,042,826 (2%)
Medusahead wildrye (*Taeniatherum caput-medusae*)	$23,003 (<1%)	$2,446,034 (1%)
Palmer amaranth (*Amaranthus palmeri*)	$68 (<1%)	$1,411,938 (<1%)
Perennial pepperweed (*Lepidium latifolium L.*)	$157,623 (<1%)	$31,690,566 (12%)
Russian knapweed (*Acroptilon repens)*	$705,205 (<1%)	$89,986,377 (35%)
Russian olive (*Elaeagnus angustifolia*)	$9,484 (<1%)	$1,701,662 (1%)
Ventenata (*Ventenata dubia*)	$1,001,475 (<1%)	$27,087,402 (11%)
Yellow starthistle (*Centaurea solstitialis*)	$0 (0%)	$21,799 (<1%)

Table 1: Statewide direct and potential agricultural loss estimates from 10 invasive weed species in Wyoming

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Price Slide Tool for Marketing Steers

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Introduction:

The question of when to market steer cattle is a decision that can determine a profitable or not profitable year for many producers in Wyoming and Colorado. For many producers, this decision is based on how markets are performing, feed availability, and their past experiences.

Objectives:

The objective of this price slide decision making tool is to assist beef producers in market timing decisions. This tool will ultimately be available for use on mobile devices to more easily help in making these important decisions.

Methods:

Feeder steer sales data for the months of July through November from 1992-2021 were compiled from USDA-NASS for 100 lb. increments for Wyoming and Colorado, and normalized to 2021 dollars. Fed steer prices and December futures corn prices were needed to formulate regressions for the price slide. Fed steer prices and December futures corn prices were used to estimate the cost of feeding these steers during different periods of the year and number of days on feed. These data were taken from USDA-NASS and matched to the feeder steer prices range from 1992-2021. All data was normalized to 2021 dollars to account for inflation.

Regressions were compiled for each of the marketing months from July to November for Colorado and Wyoming. The regressions allow the tool to describe which of the inputs contribute to output prices at differing levels. Regressions were determined in Excel to develop the tool. Variables needed to complete the tool were month marketed, year, price received, weight, weight squared, weight cubed, December corn future price, December corn future price X weight, and fed future price.

Results:

This tool estimates sales price (per cwt) for marketing months August through November in Wyoming and Colorado. The tool allows a producer to input current December corn and Fed steer prices. The tool calculates the estimated marketing values based on current or estimated animal weights, allowing producers to determine optimal marketing months based on their current situation.

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Climate Adaptation and Concentration in the U.S. Livestock Sector

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Introduction:

Climate risks represent a serious threat to cattle production. Drought causes forage loss, inhibits animal weight gain, and raises production costs, all leading to lower incomes for ranching families and their rural economies. Following the droughts of 2011 and 2012, insufficient forage led producers in Texas to liquidate 24% of their cattle herds. These trends may have disparate impacts on cattle producers based on the risk mitigation options available to them. Large well-capitalized operations who own or lease large amounts of pasture, or have access to public grazing alternatives may reduce their stocking rates less dramatically than ranchers with limited substitutes. Due to the biological nature of cattle production, even short-term drought can lead to significant long-term disruptions in beef production. Additionally, inventory reductions in drought-suffering regions may be offset by increases in other regions through spatial spillover effects. The combined effects could lead to greater concentration of beef production in certain regions or at certain scales. Unlike the dairy or pork industries, the cow-calf and stocker sectors of the beef supply chain have not experienced consolidation on a large scale. Figure 1 shows the distribution of U.S. beef cattle operations across size classes. While the number of beef cattle operations overall has fallen slightly over time, the share made up of the largest operations has not grown significantly.

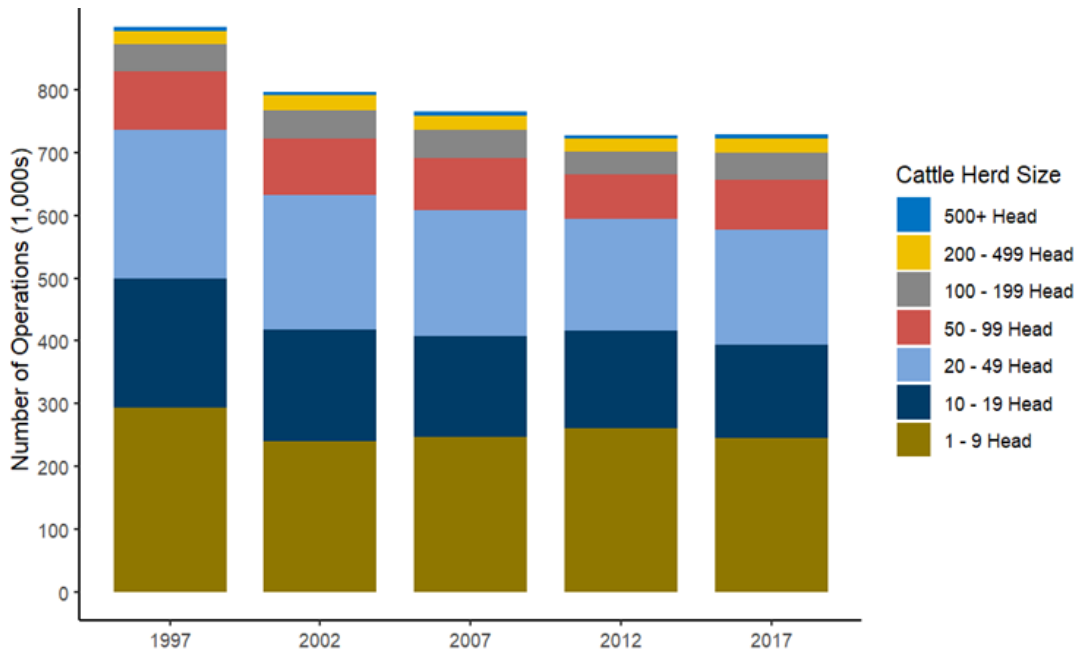

Figure 1: Beef Cattle Operations by Herd Size, 1997-2017, Source: USDA NASS Census of Agriculture

Objectives:

This project will explore spatial and temporal changes in U.S. beef production in response to drought, and the factors that may mediate these effects. Existing studies find that local beef cow inventories are sensitive to climate and that these effects persist over time. We will extend this work by looking at heterogeneous temporal and spatial effects of drought across regions.

Methods:

We collect beef cattle inventory totals and the number of beef cattle operations by U.S. county from the USDA Census of Agriculture for the last 5 census years for the Western and Great Plains states. Our primary drought measure is the annual county Palmer Drought Severity Index (PDSI), a commonly used soil moisture index. Additional covariates such as cattle prices, feed costs, and regional characteristics will be collected from various sources. We will employ a spatial panel regression technique that incorporates dynamic effects as well as spatial spillovers. This will allow for the estimation of both local climate effects on cattle inventories over time, and spatial effects of climate shocks in neighboring regions. To test for heterogenous climate response, we will interact these variables with relevant farm characteristics and risk management attributes that vary geographically and temporally.

Results:

Early results indicate that local drought conditions are predictive of the average herd size within a county. Table 1 reports initial regression results from a panel regression model where the dependent variable is the log of average herd size. The coefficients on the PDSI variables imply a polynomial, inverted U-shape, relationship between herd size and moisture. These suggest that the average number of animals per farm contracts under extreme drought and extreme wet conditions. For example, a change from normal conditions to “mild” drought reduces the average herd size by 1%, while a change from “severe” to “extreme” drought causes herd sizes to fall by more than 7%. Understanding the extent of these effects is key for predicting the long-run effects of climate change on the beef cattle industry. The sensitivity of these relationships to practices such as rotational grazing and government policy, and the potential spatial effects will be the focus of this work going forward.

VARIABLE	Coef.	Std. Error
PDSI (5-yr avg.)	0.01***	(0.004)
PDSI (5-yr avg.) squared	-0.01***	(0.001)
County fixed effects	Yes	
Year fixed effects	Yes	
Observations	3,928	
R2	0.12	
F Statistic	66.91***	

Note: *p<0.1; **p<0.05; ***p<0.01

Table 1: The Relationship Between Avg. Beef Cattle Herd Size and Climate

Contact: Nathan DeLay, nathan.delay@colostate.edu

Dairy Systems

Dairy animals eating at a dairy operation.

Use of Automated Body Condition Scoring From Dry-Off to Calving for Health and Milk Yield Assessment in Early Lactation Holstein Cows

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Introduction:

The impact of inadequate body condition during dry-off and close-up periods significantly affects dairy cows' health, reproduction, and performance of the next lactation. Negative energy balance and body condition loss have been related to fat and labile protein mobilization due to the increased nutrient demand to support the onset of lactation and to decreased dry matter intake during the first three weeks after calving. A significant proportion of lactating cows lose body conditions after calving and approximately 30 and 50% of high-producing cows are affected by reproductive, mammary gland, or metabolic diseases. Research shows a close relationship between body condition loss and increased disease incidence. Therefore, body condition scoring (BCS) is commonly included in herd health management at dry-off and calving. However, traditional BCS methods rely on visual examination of subcutaneous fat that are highly inconsistent between evaluators and impractical for preventive health assessment in large herds. Recent technology allows automatic BCS using camera systems installed in the milking parlor, which allows daily assessments of body energy reserves, evaluation of specific points of interest in lactation, and real time management decisions. As automatic BCS offers high frequency, consistent, and precise data, and opens possibilities to study the BCS dynamics in large groups of lactating cows.

Objectives:

The aim of this study was to evaluate the associations between the dynamics of automated BCS from dry-off to calving and early lactation disease in a population of high-producing Holstein cows.

Methods:

We performed an observational retrospective study on BCS, health, and milk yield records from 9,430 lactations in 6,884 Holstein cows calving between April 2019 and March 2021 in a commercial dairy operation located in Windsor, CO. Daily BCS (1 to 5 scale with 0.1 increments) and milk yield (Kg/d) were retrieved from Delpro® software and disease occurrence data was obtained from DairyComp305®. The BCS values were determined for every study cow at dry-off and at calving. Additionally, BCS change (∆BCS) was calculated between calving and dry-off. Individual BCS at dry-off, calving, and ∆BCS were categorized in four quartiles (Q1: lowest BCS – Q4: greatest BCS; Q1: greatest BCS loss – Q4: greatest BCS gain). Finally, cows affected by at least one reproductive, metabolic, and other health conditions within 60 days after calving were classified as sick, and unaffected cows were classified as healthy. BCS at dry-off, calving, ∆BCS, and milk yield were compared between sick and healthy cows. Additionally, milk yield was compared among BCS and ∆BCS categories.

Results:

We determined that sick cows had significantly greater BCS at dry-off and at calving. Conversely, sick cows had deeper ∆BCS between dry-off and calving (Figure 1). When we categorized BCS, cows in the lowest BCS at dry-off had greater probability of disease while there were no differences in the probability of disease between the BCS categories at calving. Regarding ∆BCS, greatest ∆BCS increased the chances of disease. In addition, we observed differential patterns of BCS dynamics by disease type in primiparous cows, while these patterns were not clearly observed in multiparous cows. Remarkably, we did not observe an association between BCS at calving and milk yield. Only BCS at dry-off influenced the subsequent milk yield performance.

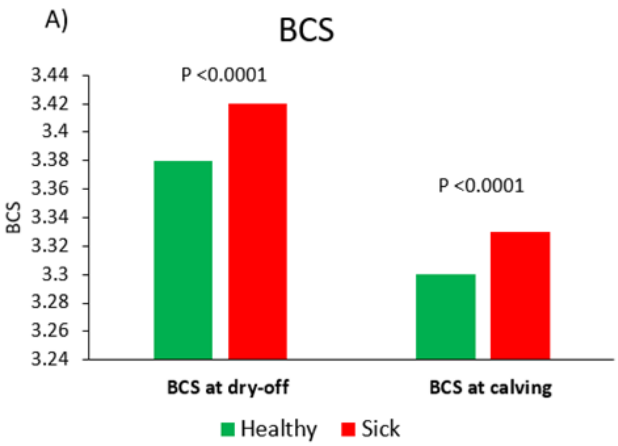

Figure A: BCS means for health and sick cows at dry-off.

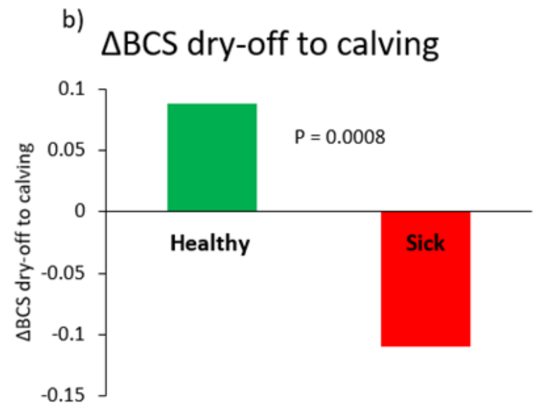

Figure B: BCS change (∆BCS) means for healthy and sick cows.

Acknowledgements: We thank Wolf Creek Dairy for allowing access to their BCS and cow data, Juaquin Azocar from DeLaval and Albert De Vries for their technical and scientific contribution on this research as well as the co-authors of the following publications: https://pubmed.ncbi.nlm.nih.gov/35973819/ - https://pubmed.ncbi.nlm.nih.gov/37085950/

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Funded by: USDA-NIFA grant no. 2019-67021-28823

Multi-Criteria Decision Analysis for Assessing Social Acceptance of Strategies to Reduce Antimicrobial Use in the Dairy Industry

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Introduction:

Antimicrobial resistance (AMR) is a serious threat for public health. In dairy systems, antimicrobials are used for treating and preventing diseases that cause animal suffering and decreased productivity. Inevitably, antimicrobial use (AMU) exerts selective pressure, favoring survival of resistant microorganisms and/or the activation of dormant resistance genes. To respond to the AMR threat, governments have implemented policies aiming to reduce AMU in livestock systems. The development of policy may be subject to the social acceptability of the regulatory environment by farmers, consumers, and public health entities. Therefore, methods allowing to include the interests and perceptions of dairy industry stakeholders are needed for defining the directions of AMU policy. In this sense, multiple-criteria decision analysis (MCDA) is a useful tool to assist in the decision-making of AMU regulations as it ranks strategies according to several criteria and preferences and prioritize the acceptability of current and novel policy.

Objectives:

Our objective was to develop a MCDA framework for assessing the social acceptability of potential strategies for reducing AMU in animal agriculture, using the French dairy industry as model.

Methods:

The social acceptability of four policy strategies (STRA01. current AMU policy, STRA02. total AMU interdiction, STRA03. AMU interdiction for prophylaxis and metaphylaxis, and STRA04. subsides for reducing AMU by 25%) to reduce AMU in the dairy sector was evaluated using MCDA. This analysis included interviews of dairy producers, consumers, and public health representatives collecting their perceptions about the impact of the proposed strategies on criteria measuring environmental, economic, social, and political dimensions of dairy industry sustainability. Each participant was asked to weigh each criterion after observing Figure 1A). Preferences were ranked using the Preference Ranking Organization Methods for Enrichment Evaluation (PROMETHEE) approach and were compared between each strategy. The preferences of each stakeholder group were visualized using aggregated decision maps, in which the extent of concordance between stakeholder groups can be assessed by their axis proximity (Figure 1B).

Results:

In the producers' group, the most accepted strategy was to maintain the current AMU regulations, whereas total AMU interdiction, AMU interdiction for prophylaxis and metaphylaxis, and subsides for reducing AMU by 25% were not accepted at all. In consumers, the most accepted strategy was total AMU interdiction followed by interdiction for prophylaxis and metaphylaxis use, while the current AMU policy and subsidies were not accepted. Finally, the public health representatives only accepted total interdiction. Figure 1B allows to compare preferences between stakeholder groups. Stakeholder axes proximity indicates higher degree of agreement, whereas policy strategies closer to the axes indicate the most preferred strategy. This study offers an MCDA approach to assess stakeholders' perceptions of potential strategies to reduce AMR. Although the strategies considered in this study might not be plausible in the current dairy industry, our MCDA framework can be applied with an ample range of strategies to be evaluated by relevant stakeholders in the food-animal supply. Full manuscript can be found at: https://pubmed.ncbi.nlm.nih.gov/36671209/

	Criteria	STRA01	STRA02	STRA03	STRA04
Environmental	ALEA[1]	0.27	0	0.17	0.2
	Attributable fraction (%)	0.04	0	0.026	0.03
Economic	Production costs (€/1000L)	494	684	667	617.5
	Farmers' revenues (€/1000L)	334	473	451	417.5
	Culled cow price (€/kg)	2.4	2.64	2.4	2.4
	Product price (€/L)	0.78	1.85	1.05	0.96
Social	Mortality rate (%)	3.8	4.8	4.1	4.04
	Culling rate (%)	21.3	50.5	31.5	28.6
Political	Regulatory framework	Moderate	Very high	High	Moderate
	Investment policies	High	High	Moderate	Very high

Figure 1A: Sustainability criteria and scaled measures used in the PROMETHEE ranking approach of policy strategies to reduce AMU. [1]ALEA: Animal Level of Exposure to antimicrobials; [2]Fraction of antimicrobial-resistant human infections attributable to animal agriculture.; STRA01: Baseline, current strategy of antimicrobial use in France; STRA02: Total antimicrobial interdiction; STRA03: Antimicrobial interdiction for prophylaxis and metaphylaxis use; STRA04: Subsidies to reduce antimicrobial use by 25%.

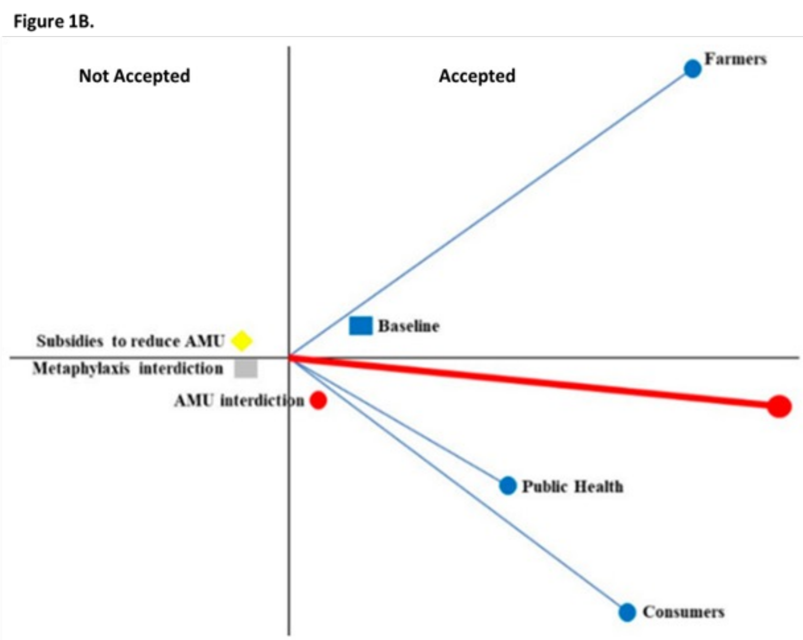

Figure 1B: Aggregated decision map of stakeholders judging policy strategies for AMU reduction.

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Assembling Dairy Cow's Behavior Data for Enhancing Herd Preventive Medicine and Dairy Systems Sustainability

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Introduction:

In dairy cattle, behavior monitoring provides a holistic reference of the health, reproductive, and productive status of dairy animals. The advancement of dairy precision technologies in recent years has allowed for the precise measure of rumination, eating, activity, and resting behavioral time budgets in dairy cows, which are currently used for individual early disease and heat detection. This research proposes moving from early disease detections to disease prevention by estimating population behavioral thresholds associated with commonly occurring diseases in early lactation cows. These behavioral thresholds may be used as risk indicators of disease for developing preventative managements and improve the health and productive performance of dairy cows.

Objectives:

The aims of this study were to compare the peripartum behavioral time budgets of rumination, eating, active, and resting behaviors between cows affected by reproductive, metabolic, infectious, or multiple disease during the first 21 days after calving and healthy cows; and to estimate thresholds of behaviors associated with health status.

Methods:

A retrospective analysis was performed from lactation records obtained from a certified organic dairy farm located in Northern Colorado, milking 1,200 Holstein cows. The dataset consisted of an open population of cows calving between October 2018 until August 2019. A total of 1,117 cows were included in a single cohort observed from 21 days before calving until 21 days after calving. A health status category classified cows diagnosed with reproductive, metabolic, infectious, or multiple disease during the first 21 days and healthy cows. Rumination, eating, active, and resting time budgets (min/day) were measured by CowManager® ear tags attached to the left ear. Disease occurrence data was retrieved from PCDART®. Daily means of behavioral budgets were estimated and compared between the health status categories. Additionally, the effect of behavioral time budget increments on the probability of disease within 21 days after calving was estimated and thresholds that maximized sensitivity and specificity for disease detection were calculated.

Results:

Lactating dairy cows affected by disease event category showed distinguishable patterns of behavior around calving. Cows affected by infectious disease showed lower active time 5 days before calving. Increments of rumination, eating, and active time were associated with greater probability of remaining healthy during the first 21 days after calving. Behavioral thresholds were significantly associated with all disease events analyzed in this study. A significant threshold provides the ability to classify dairy cows with increased risk of disease during the peripartum period. For multiple disease events, the significant thresholds at calving day were 306, 237, 517, 253 min/d of rumination, eating, time active, and time not active, respectively. Figure 1 shows the dynamics of rumination among the health status categories %.

These thresholds could be used to classify cows susceptible to multiple disease events and perform targeted preventative management before the onset of disease. Thus, the early identification of high-risk animals will allow to use preventative management more efficiently and reduce the impact of disease on production losses, animal welfare, antimicrobial use, and worker health improving the overall sustainability of dairy operations.

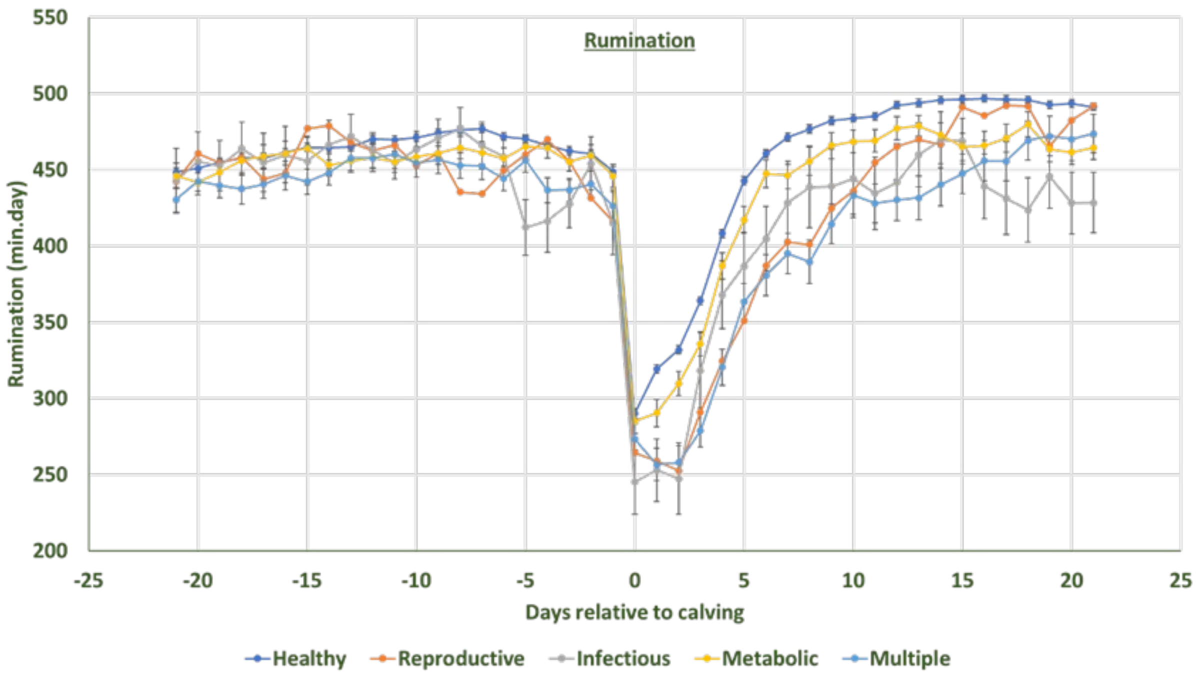

Figure 1: Behavioral budget dynamics of rumination for cows diagnosed (means and error bars) with reproductive, metabolic, infectious, or multiple disease during the first 21 days after calving.

Acknowledgements: We thank Aurora Organic Dairy for allowing access to herd health and behavioral data.

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Effects of Perinatal Exposure to Extreme THI on Serum Total Proteins, Transfer of Passive Immunity, and Health of Preweaned Holstein Heifers Raised in Dry Climate

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Introduction:

Adaptation to historic climate patterns and climate change is critical for the sustainability of the dairy industry. The US is divided into six climate zones including tropical, dry, moist subtropical, moist continental, polar, and highlands. Therefore, as milk is produced in all 50 states, understanding farms' microclimate and their effects on animal health and performance will be essential for controlling thermal stress in dairy cattle. The impact of ambient conditions associated with physiologic signs of stress and dampened productivity is commonly measured by the temperature and humidity index (THI). This index combines the effects of air temperature and relative humidity, and it is used to estimate the extent of thermal stress in dairy cattle. Nonetheless, little information is available about differences in thermoregulation under hot or cold conditions between calves and adult cattle. Moreover, THI thresholds linked to calf heat stress or cold stress are not well established for preweaned calves or adjusted by farm microclimate. It has been suggested that calf discomfort, determined by increased respiratory rate and shade-seeking behavior, can be observed at THI ≥ 72 and that temperature surpassing 77°F along with relative humidity above 50% cause heat stress signs in calves. Regarding cold stress, some studies have suggested that temperatures below 46°F increase the energy requirements for maintenance, although other studies have observed lower ADG, water intake, and respiratory and metabolic rates below 25°F. Due to the large variety of climates, determining thermal exposure zones accounting for farm's climate area is needed, especially in dry regions where the weather is characterized by large day to night fluctuations in temperature and humidity. This variation might cause transient exposure to maximum THI (MaxTHI) that could be neglected if daily THI averages are used as a thermal exposure risk factor for impaired calf health and performance.

Objectives:

The aim of this study was to assess the effects of thermal zone exposure, determined by MaxTHI, during the perinatal period on serum total proteins (STP), transfer of passive immunity (TPI), and health of preweaned Holstein heifers, raised under dry climate in the eastern plains of Colorado.

Methods:

Eight-hundred and sixty-four Holstein heifer calves were considered for a retrospective evaluation from 2 d before birth until 65 d of age. The retrospective analyses included Holstein heifers born between June 2017 and June 2018, in a certified organic dairy farm in the eastern plains of northern Colorado, USA. To calculate daily THI, two temperature/relative humidity sensors were installed at 3 meters above the ground between the hutch lines. Ambient THI was calculated using the equation: THI = (1.8 x T + 32) – ((0.55 – 0.0055 x RH) x (1.8 x T – 26)), where T = temperature (°C) and RH = relative humidity. The daily MaxTHI readings were categorized in thermal exposure levels as heat stress (THI ≥70), cold stress (THI <50), and thermoneutral (THI >50 - ≤70) from 2 days before birth to 7 days of life. Scours and pneumonia diagnosis information was retrieved from farm records until 65 days of life. Thus, STP values and TPI (poor ≤ 5.7 g/Dl; good >5.7 - <6.2 g/dL; excellent ≥ 6.2 g/dL) and disease frequencies were compared between calves exposed to heat stress, cold stress, and thermoneutral conditions.

Results:

Calves exposed to thermoneutral THI conditions during the peripartum period had greater STP. However, we found that MaxTHI exposure interacts with the blood sampling age as shown in Figure 1, where calves sampled between 4 to 7 days of life have greater SPT when exposed to thermoneutral conditions at birth. Similarly, calves exposed to thermoneutral conditions 2 days before calving and at birth had greater probability of being categorized as having good or excellent TPI. Regarding the occurrence of scours and pneumonia, we determined that calves exposed to thermoneutral conditions have a lower probability of being diagnosed with these disorders during the preweaned period. Additionally, we observed seasonality in the incidence of scours and pneumonia with higher frequencies during the hot and cold season, respectively. We suggest that the use of MaxTHI can be used to gauge calf exposure to extreme conditions in climates with highly variable conditions, even within the same season. Additionally, the assessment of THI during peripartum provides an opportunity to control MaxTHI exposure and improve health in preweaning period.

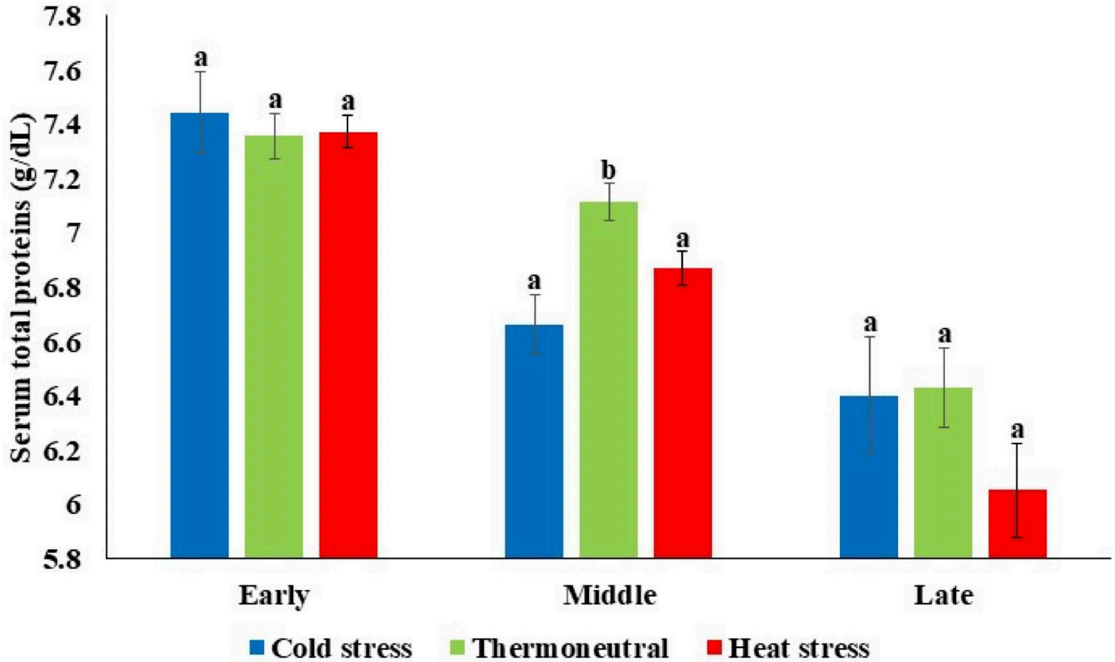

Figure 1: Serum total protein concentration (means and error bars) in calves sampled at early, middle, and late age and exposed to heat stress, cold stress, and thermoneutral maximum THI conditions during the day of birth. Sampling age levels: 1 to 3 days (early), middle: 4 to 7 days (middle), and late: 8 to 10 days (late) of life.

Acknowledgements: We thank Aurora Organic Dairy for allowing access to calf health data.
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Evaluating the Impact of Intranasal Immunotherapy on Pulmonary Immunity, the Respiratory Microbiome and Calf Health on a Local Dairy

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Introduction:

Bovine Respiratory Disease (BRD) causes morbidity and mortality in both beef and dairy systems. Antibiotics are commonly relied upon for metaphylactic and individual animal treatment protocols, which increases the risk of antibiotic resistance and may negatively impact the host microbiome. Over the last 50 years, there has been little to no improvement in the rates of productivity and death losses in cattle diagnosed with BRD. Evaluation of alternative therapeutics that may enhance host immunity are crucial for improving animal welfare and reducing the development of antibiotic resistance. Additionally, the continued improvement of animal health depends on an improved understanding of the interaction between the host microbiome and immune cell regulation.

Objectives:

Assess the efficacy of intranasal immunotherapy as a BRD prevention strategy in preweaned dairy calves and demonstrate whether immunotherapy modulates host immunity and the respiratory and fecal microbiome.

Completion of these objectives will help to determine whether nasal immunotherapy is an effective alternative treatment to antibiotics. This treatment has the potential to reduce the overall use of antimicrobials on farms and decrease the development of antibiotic resistance. These are crucial goals for producers to protect calf welfare and public health.

Methods:

A total of 50 preweaned dairy calves will be randomly enrolled at 1 week of age into a treatment group that will receive an immunomodulatory nasal spray (n=25) and a control group that will receive a saline placebo (n=25). The immunotherapy consists of a liposome complex that has broad affinity for toll-like receptors (LTC), theoretically stimulating the innate mucosal immune response. The innate immune response is a calf's first arm of defense against pathogens and affords protection against a diverse array of bacterial and viral challenges.Calves will receive 3 LTC or control treatments (0.1 ml LTC in 2 ml diluent or 2 ml diluent) prior to weaning at 56 days of age. Calves will be monitored weekly for clinical and subclinical BRD using a standardized scoring system and lung ultrasound for 10-weeks. Deep nasopharyngeal swabs and bronchoalveolar lavage fluid will be collected before and after treatments to monitor changes in the respiratory microbiome and immune response in the upper and lower airway. Briefly, total DNA and RNA will be extracted for 16S rRNA amplicon sequencing and RT-qPCR immune gene expression analysis, respectively. Correlations between changes in the relative abundance of dominant genera and differential expression of immune genes will be compared between treatment and control calves. Serum will be collected to evaluate changes in circulating cytokines. Feces will be collected to evaluate Salmonella shedding status and identify changes in the fecal microbiome between the treatment and control groups.

Results:

A preliminary dose titration study was performed to evaluate the safety of LTC treatment in preweaned dairy calves. A total of 20 calves were enrolled at 1 week of age and were randomly assigned 4 treatment groups (placebo (group 1; n=5), 0.01 ml LTC (group 2; n=5), 0.05 ml LTC (group 3; n=5), and 0.1 ml LTC (group 4; n=5)). There were no significant differences in rectal temperature or clinical respiratory score up to 7 days after treatment between groups (Figure 1). Therefore, the highest dose (0.1 ml LTC) will be utilized for the clinical trial to facilitate the strongest innate immune response.

The preliminary study ensures an adequate safety profile of this immunotherapy medication. If the larger clinical trial indicates effectiveness in reducing the risk of BRD, this therapy could be further developed into a commercial product. This product would be an innovative disease prevention strategy in protecting calf health while reducing overall farm use of antimicrobials.

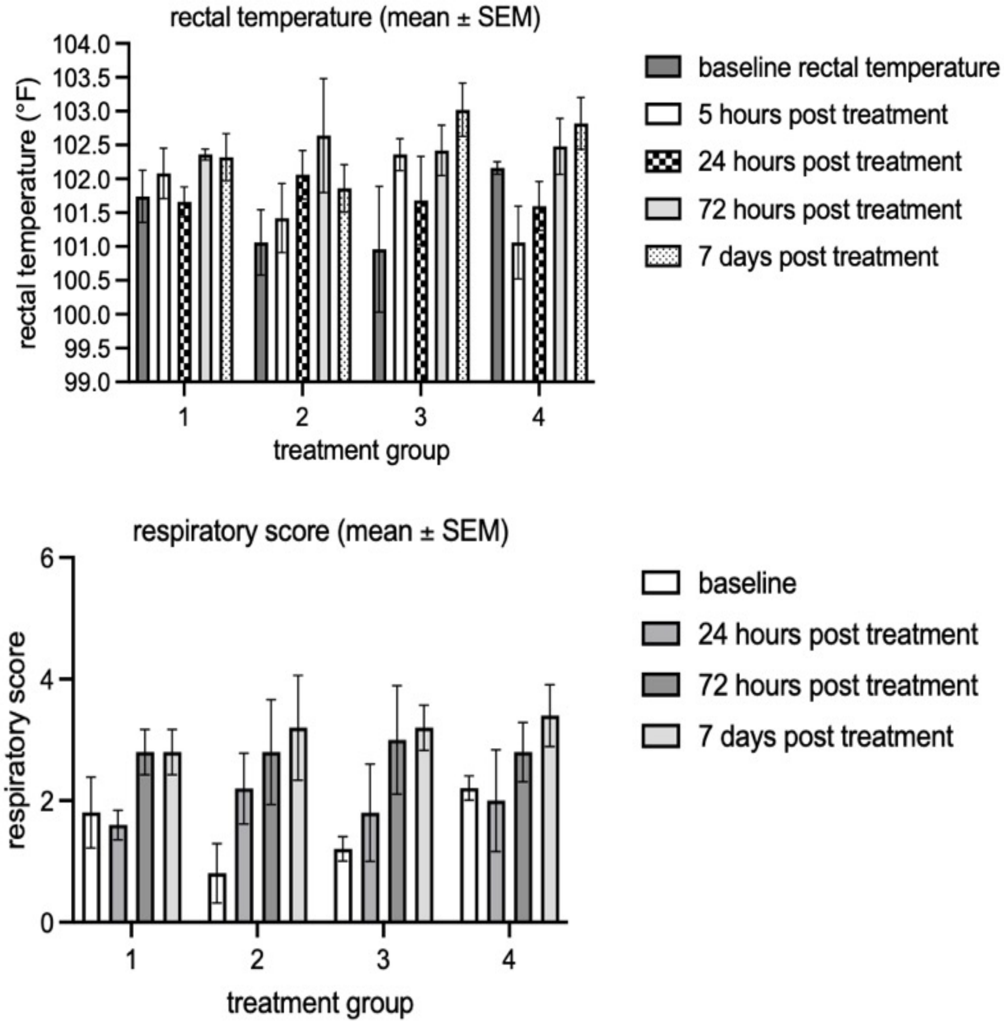

Figure 1: Preliminary effects of various LTC doses on calf health.

Acknowledgements: We are grateful to our local dairies for their collaboration and participation in this study.
Contact: Sarah Raabis, sarah.raabis@colostate.edu
Funded by: CVMBS - USDA Animal Health and Disease Funds

Feedlot Systems

Steer at the Climate-Smart Research Facility next to a GreenFeed machine designed by C-Lock Inc.

How Do Crossbred Angus-Holstein Steers Compare to Purebred Holstein Steers in the Feedlot?

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Introduction:

In recent years, there has been an increase in the use of beef semen on dairy cows and heifers, creating an increasing number of beef-on-dairy crossbred cattle. These crossbred cattle are being marketed to the feedlots instead of purebred Holstein steer calves based on increased carcass quality. The National Association of Animal Breeders indicated that domestic beef semen sales have increased 242%, from 2.5 million in 2017 to 8.7 million in 2021. While use of beef semen on dairy animals is increasing due to its potential financial benefit to both the dairy farmer and feedlot operator, there is a lack of data to quantify how those beef-on-dairy offspring will perform in the feedlot. Therefore, our objective was to determine the effects of cattle genetic group, Holstein versus Angus-Holstein crossbred, on feedlot growth performance of calf-fed steers.

Methods:

Sixty purebred Holstein and sixty Angus-Holstein crossbred steers arrived at the UC Desert Research and Extension Center in Holtville, CA at approximately 129 kg. Cattle were fed a steam-flaked corn-based diet and management was similar to local commercial feedlots. Live body weights and dry matter diet intake (DMI) were measured monthly, and carcass characteristics data were collected at the end of the feeding period (328 days).

Results:

There was no effect ($P > 0.05$) of cattle breed on final body weight or average daily gain (ADG) during the 328 days that cattle were on feed. However, Angus-Holstein crosses had a 3% decrease ($P \leq 0.05$) in DMI), which led to 5% increase ($P \leq 0.05$) in grain to feed ration compared to purebred calf-fed Holstein steers.

There was a breed effect ($P \leq 0.05$) on all the carcass characteristics presented in Table 2. Compared to the purebred Holstein steers, the crossbred Angus-Holstein steers had heavier hot carcass weights, greater dressing percentages, greater back fat thickness, larger ribeye area, greater marbling score, and greater preliminary yield grade. There was no effect ($P > 0.05$) of cattle breed on liver abscesses, pinkeye, or morbidity.

Angus-Holstein crossbred steers were more feed efficient and had improved carcass characteristics compared to purebred Holstein steers. More research is needed to build larger data sets on growth performance of crossbred calf-fed beef on dairy steers compared to purebred calf-fed Holstein steers. Moreover, regardless of cattle breed, calf-fed steers in the current study had only 3.75% of liver with abscess.

Figure 1: Finished purebred holstein steer (left), and crossbred Angus-Holstein steer (right) one day before harvest.

Item	Holstein	Holstein x Angus
Days on test	328	328
Pen replicates	20	20
Initial body weight	130.3	129.3
Final body weight	611.6	619.8
DMI, kg/d*	8.06	7.79
ADG, kg/d	1.47	1.49
ADG/DMI, kg/kg*	0.182	0.192
*Denotes statistical differences (P ≤ 0.05) between breeds		

Table 1: Influence of cattle breed on growth performance of calf-fed Holstein and Holstein x Angus steers

Item	Holstein	Holstein x Angus
HCW*, kg	375.2	386.3
Dressing percentage*, %	61.4	62.3
KPH*, %	3.22	3.43
Fat thickness*, cm	0.55	0.89
Longissimus muscle area*, cm^2	79.1	86.9
Marbling score*	4.49	5.38
Liver abscess, %	5	2.5
Pinkeye, %	12.5	23.3
Morbidity, %	6.3	7.5
*Denotes statistical differences (P ≤ 0.05) between breeds		

Table 2: Influence of cattle breed on carcass characteristics and health of calf-fed Holstein and Holstein x Angus steers.

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Funded by: This project was supported through the University of California Agricultural Experiment Station with Hatch funding from the USDA National Institute of Food and Agriculture (CA-D-ASC-6578-H).

Effects of Extended Colostrum Feeding to Calf-Fed Dairy-Beef Cross Steers on Health, Performance, Fecal Resistome, and Carcass Characteristics

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Introduction:

Antibiotics have been used effectively in veterinary and human medicine to fight bacterial diseases for more than 80 years. However, inappropriate antibiotic use in livestock production can contribute to increased prevalence of antibiotic resistance through selective pressure on bacteria with antibiotic resistance genes. Exposure to antibiotics early in life may also negatively impact the calf gut microbiome leading to dysbiosis. In pre-weaned dairy heifer calves, diarrhea is the leading cause of morbidity and mortality, representing a significant animal health and welfare concern. In addition to animal health and welfare concerns, digestive diseases, such as diarrhea, in the early life of dairy calves have been associated with negative long-term consequences such as decreased calf performance. However, the literature has not explored the long-term health effects of pre-weaned calf diseases on dairy bull calves raised to enter the beef production chain. Bovine colostrum contains a high concentration of immune and bioactive factors that improve immune function and calf development. Colostrum components such as immunoglobulins, natural antimicrobial factors, growth factors, anti-inflammatories, and nutrients may be a reasonable alternative to antimicrobials in managing diarrhea in young dairy calves. Therefore, the objectives of the current study are to quantify and determine the effect of extended colostrum feeding (up to 14 days after birth) on disease incidence, growth performance, fecal resistome (antimicrobial resistance gene profiles), microbiome, and carcass characteristics during the production cycle of calf-fed beef on dairy cross steers.

Methods:

Phase 1 – Calf-ranch - Two hundred beef on dairy (Angus × Holstein) bull calves (≈35 kg) originating from dairy farms in the Central Valley of California will be shipped in the first 24h after birth to a commercial calf raising facility. Calves will be housed individually and randomly assigned to 1 of 4 treatments. Treatments are 1) Calves with failure of transfer of passive immunity (FTPI) with no supplemental colostrum (no extended colostrum); 2) Calves with FTPI with 10% supplemental colostrum (failure TPI, with extended colostrum for 14 days); 3) Calves with successful transfer of passive immunity (TPI) with no supplemental colostrum (success TPI, no extended colostrum); 4) Calves with successful TPI with 10% supplemental colostrum (success TPI, with extended colostrum for 14 days). Dry matter intake (DMI) will be estimated daily, and calves will be weighed every 14 days during the pre-weaning phase and every 28 days post-weaning. Blood samples will be taken upon arrival on days 1, 7, 14, 21, 35, and 56 to measure serum immunoglobulin G level serum total protein. Trained staff researchers will visually evaluate calves for possible signs of bovine respiratory disease (BRD), including abnormal respiration, mentation, and head and neck carriage.

After calves are weaned on day 56. All animals will be moved from individual hutches to group pens in the commercial calf-ranch. Calves will be continuously fed the concentrated based diet that they were receiving during the weaning phase ad libitum up to 140 days when calves will be shipped to the Agricultural Research, Development and Education Center – (ARDEC) in Wellington, Colorado.

Phase 2 – Feedlot - Dairy-beef bull calves from phase one (≈150 kg) will be used to evaluate the effects of extended colostrum feeding on feedlot growth performance and carcass characteristics. All steers will be fed a corn-based diet. Cattle will be monitored daily by trained personnel for signs of BRD and digestive illness and assigned a clinical illness score ranging from 0 to 4. Steers will be sent for processing at a nearby processing plant after they reach ~300 days-on-feed. Hot carcass weights and liver scoring, including abscess scores, will be obtained from all steers at slaughter. For calculating steer performance, live weights will be reduced by 4% to account for digestive tract fill.

Fecal Resistome and Microbiome - Previous research has reported that the inclusion of colostrum in calf diets during their early life may play an important role in the development of the gut microbiome. Additionally, the improvement in calf immunity may reduce the rate of therapeutic antimicrobial use in young calves, which may reduce the selection pressure on antimicrobial resistance in animals' gut microbiome. Thus, it is important to monitor this change of microbiome and resistome in animals along with their health. Rectal fecal materials will be collected from calves on days 1, 14, 56, and 112 days old, and one week before the harvest (~450 days of life). Samples will be analyzed for Generic Escherichia coli (E. coli) confirmed by PCR and indole/oxidase reaction will be used as the indicator of pathogenic E. coli. The susceptibility of 500 selected E. coli isolates (the estimated E. coli prevalence across all the samples is about 60%, low in young neonatal calves but high in adult cattle) to antimicrobials on NARMS plates will be determined using the Minimum Inhibitory Concentration. Results of resistance, intermediate resistance, and susceptibility will be interpreted according to the criteria of the Clinical Laboratory Standard Institute. The microbial community DNA of the fecal samples will be extracted and sequenced on Illumina NovaSeq 6000 using shotgun metagenomic approach. The fecal resistome and microbiome will determine by aligning the qualified reads to a customized antimicrobial resistant gene database and microbiome database. Additionally, to study the functional composition of fecal microbial communities, qualified reads will be annotated using DIAMOND against two reference databases, the Carbohydrate-Active EnZymes database and the Clusters of Orthologous Groups of proteins database. Appropriate biostatistical analyses will be conducted to determine the effect of colostrum on the change of cattle gut microbiome and resistome throughout their lifetime.

Timeline: Phase 1 of the current project will start during the summer of 2023.
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Funded by: The California Department of Food and Agriculture

How Do We Improve preparedness for an Incursion of Foot and Mouth Disease in Beef Operations?

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Introduction:

The incursion of any highly contagious infectious disease into livestock populations can be massively disruptive to multiple facets of the food system. We are focused on preparedness of the beef industry, the single largest sector of the Colorado agricultural economy, for an incursion of Foot and Mouth Disease (FMD). An effective effort to prepare and respond to a contagious disease incursion requires cooperation, communication, and prompt coordinated implementation of control measures across scales and institutions. For FMD, biosecurity methods need to be deployed across all production sectors, closely linked with the actions of emergency responders. National survey data shows most producers understand the disease and the danger it represents, but less than 10% of producers have adopted the proposed plans. The emergency response will follow the guidelines published by USDA in the *Foot and Mouth Disease Response Plan: The Red Book*, detailing actions to be taken by Regulatory Officials to control and eradicate the infection. In addition, a multi-year collaboration of industry, state, federal, and academic representatives has developed the *Secure Beef Supply Plan* (SBS) that provides voluntary actions that can be taken to support Continuity of Business for producers, transporters, packers, processors and allied industries who choose to participate. Our preliminary data suggest that the current lack of preparedness is not just a producer response issue, but a challenge that involves interactions between all components of the system including biophysical, regulatory, socio-cultural, and economic. In the current project, we will utilize community participatory research to explore what supports the implementation of biosecurity practices and how various stakeholders can collaborate to improve preparedness.

Objectives:

1.) Establish a multi-stakeholder advisory group to participate in shaping the research questions and analysis.

2.) Conduct a systematic review of disaster preparedness over time to evaluate effective interventions to enhance SBS participation.

3.) Hold multi-stakeholder meetings, interviews, and focus groups to establish the range of systemic factors that contribute to participation in SBS actions. This systems assessment will identify leverage points that enhance SBS participation.

Methods:

This exploratory social science project will use a case comparison method to begin to understand barriers and opportunities for livestock disease preparedness. Case comparison is a common method used to understand complex problems through triangulating multiple data sources. We will begin with the following research questions: What supports and hinders the implementation of biosecurity practices?

How do various stakeholders collaborate to improve preparedness? We follow a community participatory research approach in which the research questions evolve with the involvement of community stakeholders. Finally, we anticipate developing a systems model of the emergency management system that will be employed in case of an FMD incursion and establishing leverage points that can be used to enhance response across the system to minimize negative impacts.

Contact: Frank Garry, fgarry@colostate.edu
Funded by: CVMBS - USDA Animal Health and Disease Funds

2 ZERO HUNGER

Decision Support Tools for Western Region Livestock Disease Outbreak Response: Pilot Study of Colorado Foot and Mouth Disease Vaccination Plan

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Introduction:

There is urgent need for the U.S. animal health sector to improve its preparedness to respond to an outbreak of foreign animal disease. For this pilot project we focus on Colorado and Foot and Mouth Disease (FMD), and the tools needed to inform an effective vaccine deployment strategy for use by the State Veterinarian. The tools, protocols and team that will be established during this pilot project will be easily applied to additional states and other diseases.

An inherent problem with the incursion of any highly contagious infectious disease is that many variables must be considered while a rapid response is being formulated. Data driven models developed and tested prior to an outbreak can have a dramatic impact on preparedness and the effectiveness of real-time response. Such models can be used to explore potential outbreak trajectories, the effect of response actions and identify both costs and benefits for effective response. FMD is the most contagious disease of livestock and is a high priority concern due to severe economic impacts and international trade restrictions implemented in response to detection. This project is developing a first-of-its-kind CO specific FMD vaccination plan based on scientific determinants, co-developed by multiple stakeholders. This project will provide the analysis and decision support tools for a FMD vaccination plan for CO, plus the team to support their use.

Objectives:

1.) Develop a collaborative team of CSU, Colorado Department of Agriculture, CDA, and USDA: APHIS:Veterinary Services personnel prepared to support the State Veterinarian in decision-making. 2.) Identify and implement CO-specific parameters and scenarios for use in an established livestock disease model to support the State Veterinarian with science-based decision-making. 3.) Develop visualization tools to help with interpretation of model outcomes and predictions.

Methods:

We have established a team of experts from CSU, CDA, and USDA as a unique resource for the development of regional FMD decision support tools. The group has mature disease-spread modeling capability, strong connections with the livestock industries, and includes members with regulatory oversight. The US Disease Outbreak Simulation (USDOS) is an established livestock disease model ideally suited for this project as it was developed specifically for the U.S. A significant challenge for FMD modeling in the U.S. is the lack of complete livestock demographic and shipment data. We will tailor USDOS to CO by developing CO-specific parameters and response scenarios of interest with input from subject matter experts. We anticipate having a functional model with visualization tools to assist the State Veterinarian with decision making by Fall 2023.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Contact: Frank Garry, fgarry@colostate.edu
Funded by: Anschutz Foundation: Pandemic Preparedness Fund

Assessing Climate Adaptation, Resiliency, and Impact in the U.S. Fed Cattle Industry

A.K. Schilling, S.E. Place, K.R. Stackhouse-Lawson, and P.H.V. Carvalho
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Introduction:

As the climate changes, there may be more intense weather events that challenge the resiliency and adaptive capacity of the beef supply chain. As extreme weather events become more common, feedyards may consider increasing the proportion or percentage of *Bos indicus* species of cattle in their operations, which are known for their heat tolerance. Research has not been conducted to assess the practicality nor climate impact of *Bos indicus* versus *Bos taurus* cattle in both heat and cold stress in US feedlot conditions. Therefore, we are evaluating the seasonal adaptive capacity and GHG emissions of *Bos indicus* and *Bos taurus* finishing cattle.

Objectives:

Determine seasonal adaptive capacity and resiliency of *Bos indicus* vs. *Bos taurus* species and enteric methane (CH_4) and nitrogen (N) use efficiency from finishing steers treated with common technologies.

Methods:

For this trial, 400 steers (~355 kg) in two replicated seasonal turns (n = 200/season), will be housed in 20 10-head typical feedlot pens for the first 90 d and then be moved to 4 Climate Smart Research Pens (50 steers/pen, 1 pen per treatment and breed combination) for the remainder of the finishing period. The Climate Smart Research Pens contain five SmartFeed systems, one GreenFeed emission measurement system, two SmartScales, and are equipped for nutrient (N, and P) mass balance. The experimental design is a seasonally replicated completely randomized design, with a 2 by 2 factorial arrangement of treatments with two species of cattle (*Bos indicus* and *Bos taurus*) and two treatments (Natural; never ever program and Conventional; receiving monensin, tylosin, ractopamine hydrochloride, and implanted twice during the feeding period with Synovex Choice and Synovex Plus as a reimplant strategy. Cattle within each species will be blocked by body weight and randomly assigned to a pen.

A subset of the 400 steers will be sampled using the GreenFeed system for enteric CH_4, O_2 consumption, H_2 emissions, and CO_2 emissions across the two seasons depending upon acclimation (approximate n=65 per species and treatment combination). At the completion of each feeding period, mass balance will be determined to evaluate predicted NH_3, total N and P (n=2). The SmartFeed systems will measure individual animal intake and the SmartScales will monitor partial animal body weights. Animals will also be weighed every 28 d and ADG and G:F will be evaluated. Genomic predictions and genotypes of experimental animals will be obtained from tissue samples. Animal welfare will be evaluated during the last 90 d of the feeding period in both seasons by observing animal behavior and physiological biomarkers. Once transported to a commercial packing facility, mobility will be scored. Following harvest, carcass data will be collected to determine YG, QG, PYG, HCW, quality defects, liver abscesses scores, and heart scores. Finally, we will evaluate the profitability based on economic implications, tradeoffs, and carcass quality and quantity.

Following the completion of this trial, more information on the resiliency and adaptivity of the beef supply chain will be available, along with improved baseline GHG emissions that reflects an industry typical production environment.

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2 ZERO HUNGER
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION

Grazing Systems and Rangeland Management

Animals wearing virtual fence (vence) technology at the Central Plains Expereimental Range (CPER).

Principles for Successful Livestock Grazing Management on Western Rangelands

K. E. Jablonski[1] and K. R. Stackhouse-Lawson[1]
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Working Group: Derek Bailey- New Mexico State University Kirk Davies- USDA-ARS (OR), Justin Derner- USDA-ARS (WY/CO), Karen Launchbaugh- University of Idaho Aaron Lien- University of Arizona, Paul Meiman- University of Nevada-Reno, Leslie Roche- University of California-Davis, Eric Thacker- Utah State University, Lance Vermeire- USDA-ARS (MT)

Introduction:

ivestock grazing management in the diverse rangelands of the Western U.S. is enormously complex. Across a wide range of climates and ecosystems that are characterized by a lack of predictability, human managers aim to sustainably produce livestock products while maintaining ecologically healthy rangelands. For more than a century, range scientists have aimed to provide usable information to producers to increase their likelihood of success. However, no concise statement of what we have learned exists. While this is largely due to the diversity and complexity of grazing management, it creates problems for producers, industry, extension, and range scientists themselves as compelling but evidence-challenged narratives fill the void.

Objectives:

Our objective for this project was to work with the range science community to identify a set of concise, evidence-based, and adaptable principles for successful livestock grazing management on western semi-arid and arid rangelands.

Methods:

We created the principles using an iterative survey and feedback process between an eight-member advisory committee and a group of >80 grazing management experts from across the west. After initial work by the advisory team, a widely distributed survey elicited lengthy responses totaling >25,000 words of wisdom about successful grazing management. We then distilled these into a set of draft principles, which were debated and revised among the advisory team. These draft principles were then returned to the initial survey respondents for further feedback. We also received feedback from >100 range professionals in a “campfire conversation” session at the 2023 Society for Range Management Annual Meeting. The advisory team further debated and revised to arrive at seven principles, structured as short memorable statements followed by paragraph-length descriptions that highlight key ideas and practices.

Results:

The seven identified principles are intended to evolve with conversation, debate, and more research. Already, we are adapting them for use in a guidebook for Colorado ranchers and have heard from extension and NRCS staff across the west that they intend to use them in outreach work. With the development of an associated checklist, these principles are ideal for use by industry organizations seeking to support successful livestock grazing management in their supply chains.

Figure 1: Short versions of the seven principles for successful livestock grazing management.

Acknowledgements: Thank you to participating survey participants. EJ Raynor and Anna Shadbolt provided additional edits and insights.

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Developing Biodiverse Resiliency Through the Implementation of Virtual Fence Technology

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Introduction:

Precision livestock management technology is evolving quickly, and its many applications are being discovered as often as it is being utilized. Validation and concomitant refinement of this technology can only be achieved through ecosystem-specific experimentation and producer-friendly suggestions. This study will investigate different uses of virtual fence in grazing cow-calf pairs and steers to achieve a variety of sustainability goals, including balancing the delivery of the ecosystem services: forage provisioning, emissions mitigation, and biodiversity maintenance on a working ranch. In the USDA-ARS Central Plains Experimental Range near Nunn, Colorado, we will employ Vence, a virtual fence system for livestock, in conjunction with GreenFeed systems to collect enteric emissions data from British-breed yearling steers. By coupling Vence and Greenfeed technologies we will be able to relate grazing behavior and enteric methane emissions of individual animals. Lastly, at the nearby U.S. Forest Service's "Owl" Grazing Allotment on the Pawnee National Grassland permitted to a local producer, we will be evaluating Vence's capability to manage herds of cattle in a precision management system, ultimately enabling producers to manage their land with less labor costs and more exact management. We will evaluate the possible benefits or shortcomings of using virtual fence over physical fence to graze overgrown wetland and riparian areas. Our goal is to provide knowledge of advanced technology to producers for the management of their lands, environments, and businesses.

Objectives:

The objective of these studies is to investigate the effectiveness of different approaches to utilize virtual fences with efforts focused on sustainability in working rangelands of the western Great Plains.

Methods:

For these studies we used the virtual fence product, Vence. There are 120 yearling steers collared at the USDA-ARS Central Plains Experimental Range and 112 cows collared owned by a local producer on the Owl allotment. Collared cows will be accompanied by calves that will not be collared. They will be turned out and monitored throughout the May to September grazing season. We will be collecting biodiversity indicators and water quality samples from the riparian areas before, during and after the implementation of a virtual fence barrier. There will be an adaptative grazing management plan at each research site, as the grazing behaviors and patterns evolve different virtual fences will be created to achieve a more precise grazing behavior in the cattle.

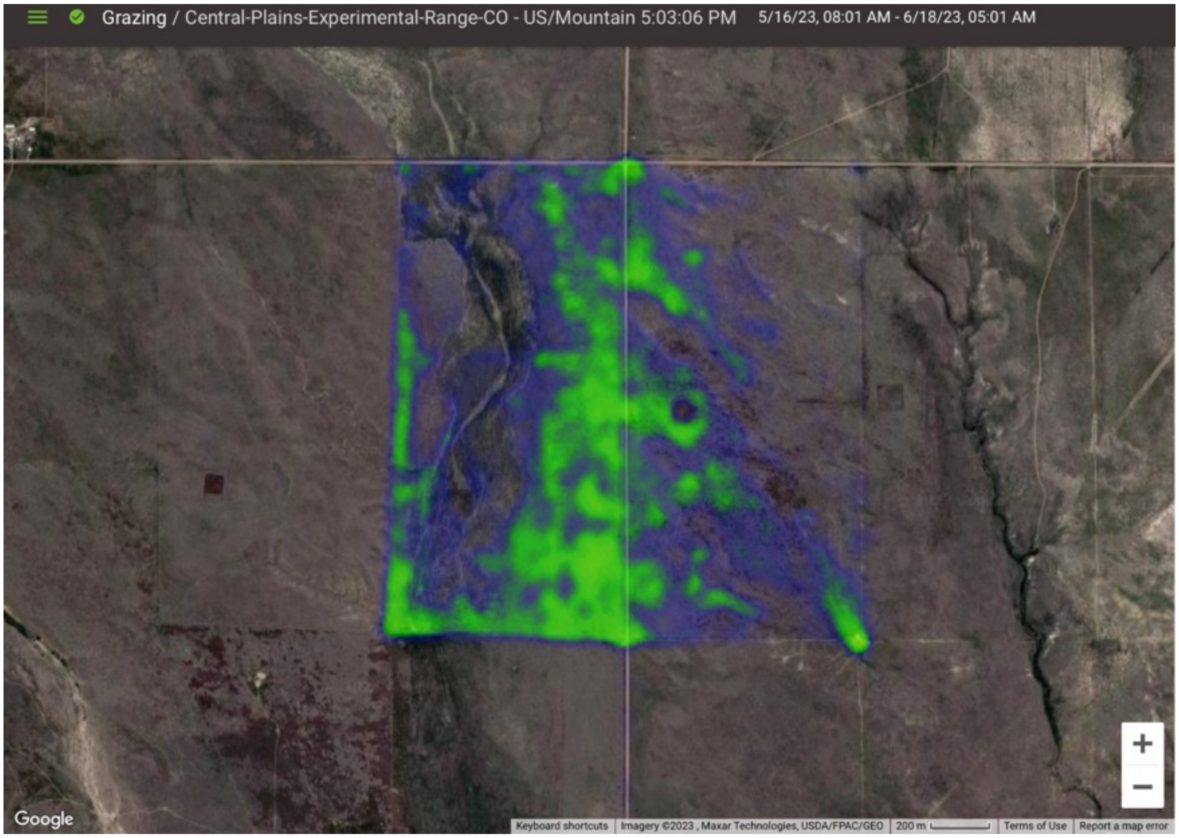

Figure 1: Grazing hot spot distribution, tracked by virtual fencing collars on grazing cattle.

Acknowledgements: Colorado Cattlemen's Association, USDA-ARS Central Plains Experimental Range, Crow Valley Livestock Cooperative

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Funded by: National Fish and Wildlife Foundation

Secondary Production of the Central Rangeland Region of the United States

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Introduction:

Rangelands are the dominant non-cultivated land use across central North America and encompass a wide gradient in mean annual precipitation (MAP) extending from <350 to >900 mm. Substantial efforts have examined spatial and temporal variation in aboveground net primary production (ANPP or forage) across this gradient. In contrast, net secondary productivity (NSP; e.g., livestock weight gain) has not been evaluated in a similar manner. However, livestock production, which is a form of NSP, supported by primary production is the dominant non-cultivated land use and economic driver in these regions. Evaluating long-term forage-to-livestock weight gain efficiency across the Central Great Plains can inform sustainable rangeland management strategies in response to precipitation variability. This contribution provides a new understanding of consumer (i.e., livestock) response to precipitation variability and adds another level of foundational knowledge of rangeland resource response to climatic variability in addition to well-known plant (or forage) production-precipitation relationships.

Objectives:

We compared both forage and British breed yearling steer weight gain from moderately stocked pasture at long-term research stations across the Central Great Plains to reconcile inconsistencies in our understanding of aboveground resources, ANPP and NSP, and relationships with variation in precipitation.

Methods:

We employ ANPP and NSP datasets (mean length = 19 years) from six rangelands with a long history of moderate stocking to determine precipitation–productivity relationships, sensitivities to dry-year precipitation, and regional trophic efficiencies (e.g., the ratio of livestock weight gain: ANPP). Sites were located in Nunn, Colorado, Cheyenne Wyoming, Cottonwood South Dakota, Mandan North Dakota, Hays Kansas, and Manhattan Kansas (Fig. 1). ANPP was represented by plant biomass clippings from grazing exclosures (caged vegetation without grazing), while NSP was the product of season-end steer weight minus steer entry weight in the same pasture as ANPP measurements for 1991 to 2019. The precipitation (PPT)–productivity relationship is derived from multi-year PPT (resource) and ANPP or NSP (product) measurements which are through a temporal or spatial lens. Temporal models are derived from individual rangeland sites in which PPT and the resource, ANPP or NSP, have varied over time. Spatial models are based on mean values from site-based forage and weight gain data that varied over a precipitation gradient, the Central Great Plains spanning eastern Colorado to eastern Kansas (Fig. 1).

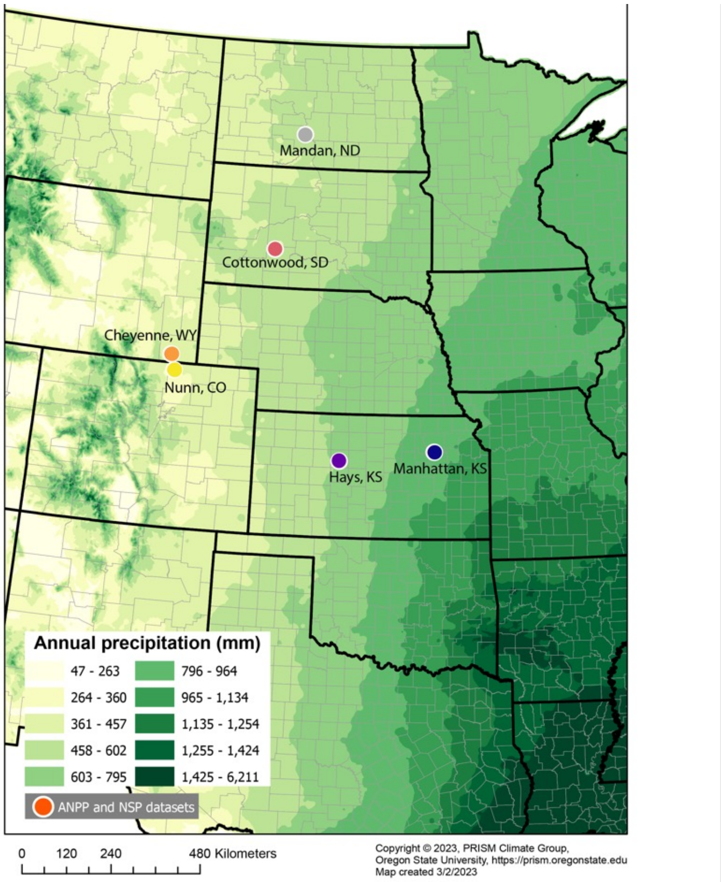

Figure 1: Mean annual precipitation for the 1991-2019 study period across the central Great Plains precipitation gradient.

Results:

PPT-ANPP relationships were linear for both temporal (site-based; Fig. 2A) and spatial (across MAP; Fig. 2D) gradients. The ANPP-NSP relationship was either linear or saturating at the site level (i.e., the temporal model; Fig. 2C) and linear for the spatial model (Fig. 2F). The site-level model for the ANPP- NSP relationship showed a weak, descending relationship for livestock weight gain when ANPP surpassed the site mean. The spatial PPT-NSP model revealed PPT mediated a saturating relationship for NSP as sites became more mesic; a finding that contrasts with many plant-based PPT-ANPP relationships. A saturating response to high growing season precipitation suggests biogeochemical rather than vegetation growth constraints may govern NSP. Specifically, lignin-rich Kentucky Bluegrass-dominated pasture (Mandan, ND) and native, perennial warm-season grasses (Kansas) reduced the efficiency of more eastern rangeland to convert forage to beef.

A more comprehensive understanding of the mechanisms leading to differences in consumer (cattle) and producer (forage) responses will require multi-site experiments to assess biotic and abiotic determinants of multi-trophic level efficiency and sensitivity. Our assessment of precipitation along a spatial gradient reveals 1) a linear increase in forage with increasing precipitation across the region, and 2) livestock production was limited by lignin-rich forage as sites moved eastward. An understanding of how precipitation variability influences forage and livestock production in the Central Great Plains is possible through the evaluation of long-term data in moderately stocked rangeland. Evident regional variation in the efficiency of converting forage to weight gain informs broad scale management of rangeland resources through the provisioning of new information on precipitation-resource relationships across space and time.

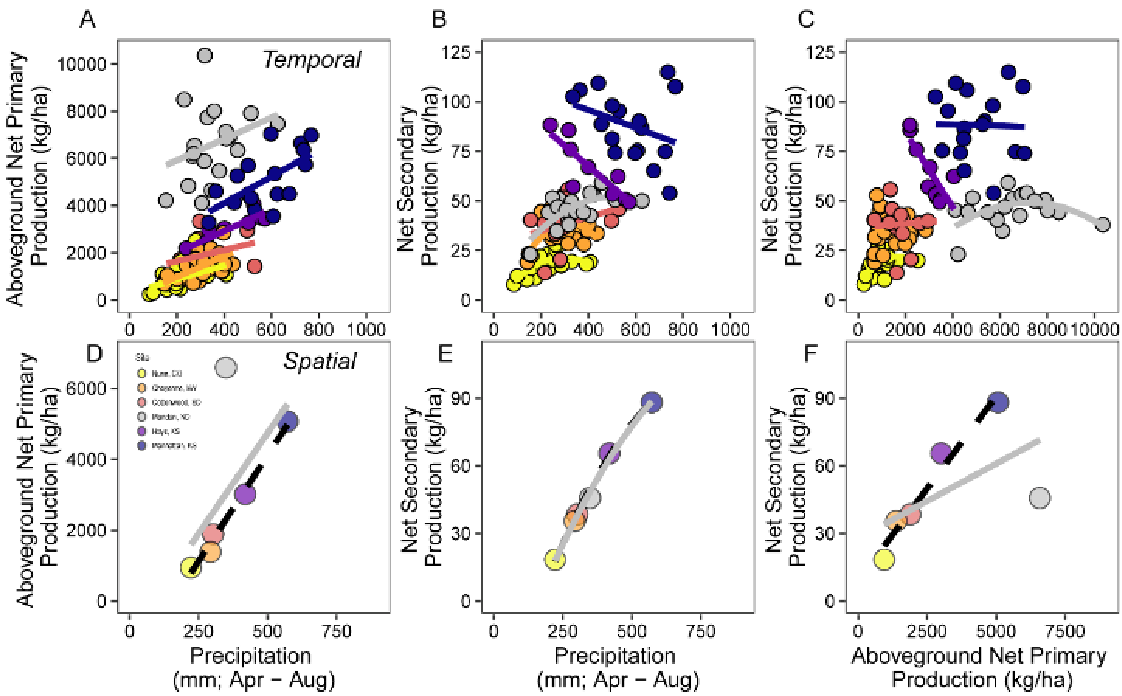

Figure 1.
A-C: Temporal models are site-based and relate interannual variability in precipitation (PPT) to interannual variability in aboveground net primary production (ANPP) and net secondary production (NSP). Relationships between A) ANPP and precipitation PPT, B) NSP and PPT, and C) NSP and ANPP derived from annual observations.
D-F: Spatial models relate PPT (and ANPP) to mean ANPP (and NSP) across multiple sites. Relationships between D) ANPP and PPT, E) NSP and PPT, and F) NSP and ANPP are derived from multi-year observations. Line of best fit is shown for data set with Mandan, ND (gray line) and without Mandan, ND (dashed black line).

Acknowledgements: This work was supported by the Long-Term Agroecosystem Research (LTAR)-Department of Agriculture (ARS), United States Department of Agriculture (USDA).
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Greenhouse Gas Mitigation

Image of the Climate-Smart Research Facility located at the Agricultural Research, Development, and Education Center (ARDEC).

Impact of Low-Level Tannin Supplementation on Enteric Methane Emissions, Estimated Nitrogen Excretion, Oxidative Stress, and Animal Performance in Organic Dairy Heifers

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Introduction:

Methane (CH_4) and nitrous oxide (N_2O), resulting from enteric fermentation and manure, respectively, are the primary components of the dairy industry's GHG footprint. While there has been considerable research conducted to identify strategies that reduce enteric CH_4 emissions, minimal progress has been made in identifying practical strategies to mitigate cattle emissions. Identifying abatement strategies that are capable of reducing GHG emission from dairy cattle production systems at scale while simultaneously benefiting animal performance and health is a significant opportunity for the dairy industry and could aid in producer adoption. Tannins have historically been explored due to their potential to reduce CH_4 and reactive-nitrogen (N) emissions, while also benefiting animal health.

Objectives:

The objective of this study was to determine the impact of low-level tannin supplementation on enteric CH_4 emissions, estimated N excretion, oxidative stress, and animal performance in organic dairy heifers.

Methods:

Heifers were supplemented with Silvafeed® ByPro, a Schinopsis lorentzii condensed tannin product, at increasing levels as recommended by the manufacturer: 0% (CON), 0.075% (LOW), 0.15% (MED), and 0.30% (HIG) of DMI. Based on a 28-day (d) acclimation, 20 certified organic Holstein heifers (BW = 219 ± 17 kg) were randomly assigned into one of the four treatment groups and stratified based on initial body weight. A 7-d pretrial gas analysis was performed prior to the study to account for individual animal emission differences. Daily, heifers were supplemented with one kg of sweet feed and tannin in accordance with the assigned treatment in individual feeding stanchions for 45 d and fed a basal total mixed ration (TMR) through four SmartFeed Pro intake measurement bunk systems (C-Lock Inc., Rapid City, SD) which allowed for measurement of individual animal feed intake. Daily, one GreenFeed automated head chamber system (AHCS, C-Lock Inc., Rapid City, SD) was used to continuously evaluate CH_4 and carbon dioxide (CO_2) production throughout the duration of the study. Fecal samples were collected on d 0, 23, and 45 prior to treatment and TMR feeding. Statistical analysis was conducted in R© (R Core Team, 2021, v. 4.1.2), where data were analyzed as a completely randomized design with the individual animal (n=20) as the experimental unit. Data was analyzed using the Type III ANOVA procedure, and a pairwise comparison was analyzed for dependent variables by treatment using the least squared means procedure with the Tukey HSD adjustment applied.

Results:

Individual animal CH_4 production in g/hd/d naturally exhibits some degree of variation. Between animal variation across all treatments from d 0 to 45 for average CH_4 production in g/hd/d had a coefficient of variation (CV) of 39% (Figure 1). No significant difference was observed between treatments for daily

CH_4 production (P=0.97), CO_2 production (g/hd/d; P=0.96), CH_4 as a percent of gross energy (GE) intake (Y_m; P=0.84), CH_4 yield (MY; g CH_4/kg dry matter intake (DMI); P=0.84), or CH_4 emissions intensity (EI; g CH4/kg of average daily gain (ADG); P=0.71). Similarly, a treatment effect was not observed for DMI (P=0.92), ADG (P=0.53), or feed efficiency (G:F; kg of body weight gain/kg of DMI; P=0.42). Daily DMI and CH_4 were correlated, with 42% of the variation in daily CH_4 production explained by DMI (R2=0.42; Figure 2). No significant difference was observed among treatments for nitrogen intake (P=0.93), fecal output (P=0.98), fecal N (FN; P=0.98), fecal neutral detergent fiber (NDF; P=0.33), or fecal acid detergent fiber (ADF; P=0.30). Estimated urine N (UN; P=0.66), FN:UN (P=0.93), and N excretion (P=0.72) did not differ among treatments. Ultimately, the results of this study would not indicate that low-level tannin supplementation alters CH_4 emissions, estimated N excretion, or animal performance in organic Holstein heifers.

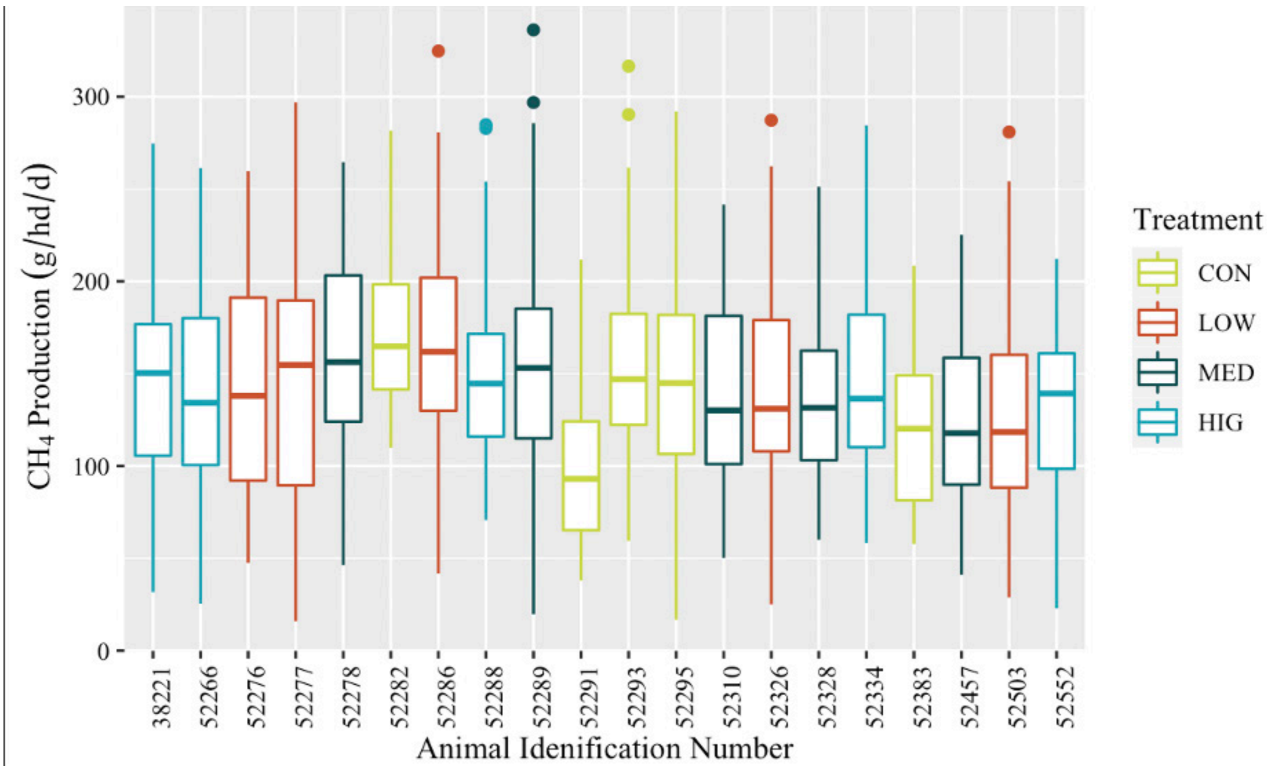

Figure 1: Variation in individual organic Holstein heifer (n=20) CH_4 production in g/hd/d by treatment with tannin supplementation at 0% (CON), 0.075% (LOW), 0.15% (MED), and 0.30% (HIG) of DMI from d 0 to 45.

Acknowledgements: Aurora Organic Dairy for their partnership in this research trial and for donating the cattle, facilities, and additional labor necessary to complete this research.

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Impact of Cattle Origin on Enteric Methane Emission, Emission Intensity, and Animal Performance in Stocker Steers Grazing Extensive Semi-Arid Rangelands

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[2]USDA, Agricultural Research Service, Rangeland Resources and Systems Research Unit, Cheyenne, WY USA 82009

Introduction:

In the United States, animal agriculture accounts for approximately 4% of greenhouse gas (GHG) emissions and enteric methane (CH_4) production accounts for approximately 30% of total CH_4 emissions. Current beef industry life-cycle assessments indicate that approximately 60-70% of the industry's GHG emissions and 70-80% of the industry's CH_4 emissions are from grazing systems, prompting a need for mitigation strategies focused in grazing environments. However, GHG emissions are largely unknown from cattle grazing extensive semi-arid rangelands.

Objectives:

1. Determine how origin, or the place in which an animal is born and weaned from, impacts enteric CH_4 emissions and animal performance in stocker steers relocated to a common grazing system in a shortgrass steppe ecosystem.

2. To assess producers' knowledge, attitudes, skills, and/or awareness changes as a result of their participation in an educational field day and improve collaboration between research institutions, government organizations, and producers.

Methods:

An observational study was conducted with 26 steers (BW=322 ± 39 kg) grazing on a high-productivity shortgrass steppe pasture (>1000 kg of forage/acre; 320-acre pasture) in Nunn, Colorado during the summer of 2022 at the USDA-ARS Central Plains Experiment Range from May to August. Steers were sourced from 2 origins 1) local shortgrass steppe steers from Crow Valley Livestock Cooperative, Inc. (CVLC); 19 steers and 2) south-central Nebraska tallgrass prairie steers from USDA Meat Animal Research Center (MARC); 7 steers. Daily CH_4 was measured with one GreenFeed (C-Lock, Inc., Rapid City, SD) from July to August. Of the 26 steers, 12 steers total steers voluntarily acclimated to the GreenFeed, 9 steers sourced from CVLC and 3 steers sourced from MARC. One GreenFeed was used to measure daily CH_4 production (g/hd/d), which was used to calculate CH_4 emissions intensity (EI; g CH_4/kg BW gain). Animal performance was determined using 28 d interval animal body weights (kg) used to calculate average daily gain (ADG). Statistical analysis was conducted in R using a Type 3 ANOVA model with origin as a fixed effect.

Results:

Daily CH_4 production ranged from 153 to 238 g/hd/d (Figure 1). Daily CH_4 production was greater for steers originating from CVLC (P=0.044; Figure 2) but CVLC steers had a lower CH_4 emissions intensity (g CH_4/kg of body weight gain; P=0.033; Figure 3). Moreover, CVLC steers had a greater ADG than MARC steers (P=0.0064; Figure 4). The results of this study indicate that cattle origin alters CH_4 emissions and animal performance in stocker steers grazing extensive semi-arid rangelands.

Figure 1.

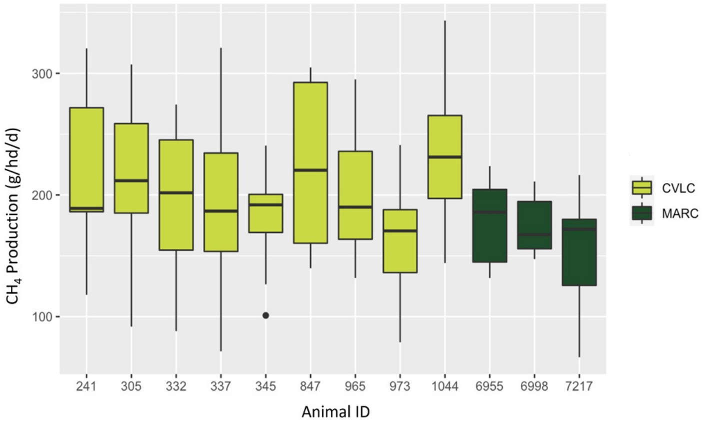

Figure 1: Average daily CH_4 production in grams per head per day from individual steers grazing shortgrass steppe rangeland near Nunn, CO during the dry 2022 grazing season.

Figure 2.

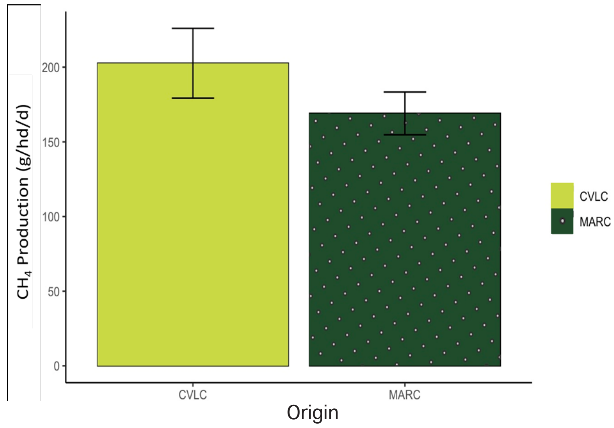

Figure 2: CH_4 production in grams per head per day by origin during the summer 2022 grazing season on shortgrass steppe rangeland. A significant difference was observed between origin (CVLC; n=12, MARC; n=3). (P=0.044)

Figure 3.

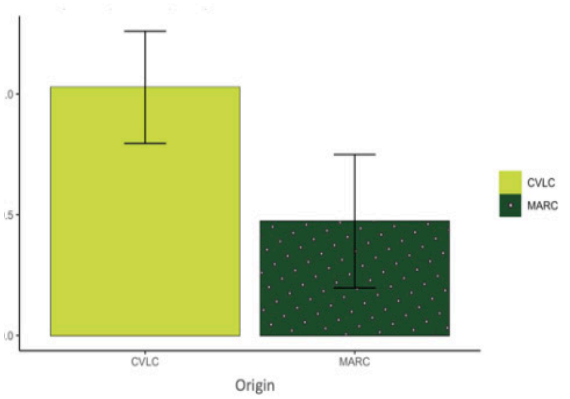

Figure 3: Average daily gain (ADG) in kilograms of body weight gain per day by origin during the summer 2022 grazing in shortgrass steppe rangeland. A significant difference was observed between origin (CVLC; n=12, MARC; n=3). (P=0.0064).

Figure 4.

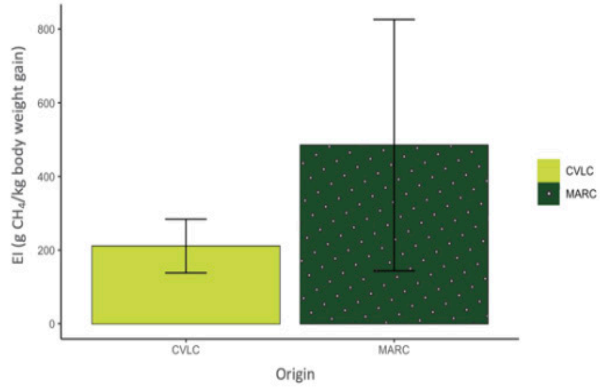

Figure 4: CH_4 emissions intensity (EI) in grams of CH_4 produced per kilogram of body weight gain by origin with during the summer 2022 grazing season on shortgrass steppe rangeland. A significant difference was observed between origin (CVLC; n=12, MARC; n=3). (P=0.033).

Acknowledgements: This study was conducted in partnership with USDA-ARS.
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Funded by: Western Sustainable Agriculture Research and Education (Project # GW22-232) grant program.

2 ZERO HUNGER

13 CLIMATE ACTION

Designing a Roadmap to Achieve NetZero in the U.S. beef and Dairy Production

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Introduction:

The reduction of greenhouse gas (GHG) emissions is one of the most urgent priorities of the beef and dairy sectors and this has been highlighted since the establishment of NetZero goals by companies, industry associations, and the government for the coming decades. However, knowing how to meet these commitments is challenging for beef and dairy producers due to the lack of accurate baseline measurements, the inability to report and predict reductions in emissions, and unavailability of scalable solutions. It is also imperative that increases in production happen in tandem with the implementation of practices that lead to NetZero beef and dairy. In this context, we designed a roadmap with collaboration from stakeholders in the beef and dairy supply chains to assist in planning and implementing NetZero actions.

Objectives:

The main goal of this project was to design a roadmap to achieve NetZero commitments for beef and dairy production in the coming decades, considering the feasibility and profitability of each strategy for the sector. We also identify gaps and opportunities for additional research and innovation to achieve NetZero.

Methods:

This research was conducted by the scientific advisory group (SAG) had the main responsibilities of selecting strategies, establishing a research agenda, and designing a roadmap to achieve NetZero in the U.S. beef and dairy sectors. The study included four phases and was organized through a facilitation methodology to help the SAG to organize ideas and prepare the roadmap. The first phase consisted of meetings with members of the SAG between June 2022 and October 2022, during which the group listed and discussed strategies to reduce GHG emissions in beef and dairy production in the U.S. Then, in phase two between November 2022 and January 2023, the SAG started a tournament of strategies to define which strategies are most feasible in reducing emissions. Phase three occurred between February and April 2023 and involved interviews with two producer focus groups per sector with the main goals of discussing what producers consider feasible for the sector and refining the original strategies proposed by the SAG. Finally, phase four was conducted between April and June 2023 and included the SAG categorizing strategies according to their potential contribution to emission reduction, return to investment, and market availability, resulting in a final list of top- and mid-term strategies that have the potential of leading the beef and dairy sectors to a NetZero goal in the future. The final product of this research defined a roadmap based on feasible strategies and established a research agenda for strategies that are not ready to be implemented by producers yet.

Results:

To ensure accuracy of strategy definition and evaluation, the SAG divided strategies into three different types of operation: cow-calf, dairy, and finishing. Then, the list of strategies related to each sector were separated between top- and mid- tier alternatives. The priority criteria for strategies were based on i) GHG reduction potential, ii) likely positive returns on investment, and iii) market readiness. Additionally, barriers, solutions, and research needs related to each strategy were discussed and included in the final results for the roadmap.

The final phase of this project is not completed yet. The final roadmap outline will be defined after the AgNext Summit in June 2023, on which occasion the SAG will propose a stakeholder activity to strengthen the strategy proposal.

Acknowledgements: The authors would like to thank all the producers that participated in the focus group interviews.

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Effects of growth implant and tannin supplementation on methane emissions and estimated nitrogen excretion in grazing stocker steers

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Introduction:

Grazing beef cattle contribute 70 to 80% of total greenhouse gas (GHG) emissions from the US beef sector, specifically cow-calf and stocker cattle. However, grazing systems supply 34% of global beef production. The ability of ruminants to convert complex carbohydrates with high fiber content on untillable land into useable end products, such as meat or milk, is a unique service of the livestock industry.

A need to develop strategies to reduce methane (CH_4), nitrous oxide (N_2O), and ammonia (NH_3) emissions without impacting the net return to beef cattle producers challenges the livestock industry. Potential mitigation strategies have been reviewed, including the use of tannins and various management strategies. Tannins are a diverse group of secondary plant compounds that exert effects on ruminal N and fiber fermentation. Tannins can diminish enteric CH_4 emissions by their ability to bind proteins and carbohydrates within the rumen. This binding action inhibits microbial attachment, reducing ruminal fiber fermentation while increasing the availability of bypass protein. Although the literature on tannins reducing CH_4 production has been variable, studies have concluded that including tannins in the ruminant diet shows promise for decreasing ruminant CH_4 emissions. Employing performance-enhancing technology, such as using anabolic implants, is common practice for beef cattle producers. Over 75% of cattle in the stocker/background segment are implanted due to the benefit of increased individual average daily gain (ADG). Revalor-G (REV-G, Merck Animal Health, Madison, NJ) is a medium-potency implant administered in a slow-release delivery system that contains 40 mg of trenbolone acetate and 8 mg of estradiol 17-beta. As ADG increases due to implantation, emissions intensity (g CH_4/kg gain) is expected to decrease with the heightened conversion of forage to gain (e.g., feed efficiency). Considering the large contribution of the grazing sector to total GHG emissions (i.e., enteric CH_4 emissions), this experiment's primary objective is to understand how implanting with REV-G and supplementing with tannins may impact enteric CH_4 and N utilization.

Objectives:

The objective of this experiment is to understand how implanting with a growth-promoting implant (Revlor-G, Merck Animal Health., Rahway, NJ) and supplementing tannin (Silvafeed BX, Silva Team., San Michele Mondovi CN, Italy) will impact enteric CH_4 and estimated nitrogen excretion in stocker cattle.

Methods:

Grazing stocker steers (n=20; initial BW = 343 ± 14 kg) were housed on an 82-ha irrigated pivot at the Colorado State University Agricultural Research, Development and Education Center (ARDEC were trained for 3 weeks to use a portable automated head-chamber system (Greenfeed; C-Lock Inc., Rapid City, SD). Steers were then offered ad libitum access to sweet feed mix for 3 weeks through the SmartFeed Pro (C-Lock Inc., Rapid City, SD) while acclimating to allow for supplemental feeding. Steers were randomly assigned to four treatments, no tannin and no implant (CON), tannin supplement and no implant (TAN), implant and no tannin (IMP), and tannin and implant (TAN+IMP). The tannin supplement was fed at the rate of 0.30% DM tannin intake with 0.5 kg/hd/d using sweet mix (Sweet Mix, Agfinity., Eaton, CO). Treatment groups without tannin (CON and IMP) received the same sweet mix ration at 0.5

kg/hd/d without the tannin supplementation. Despite satisfactory acclimation, during the grazing period no animal consistently consumed all the offered supplement. In response, we looked at the effect of tannin inclusion on its own and the effect of implantation on its own. The tannin effect included: CON (n=9; 5 animals were implanted) and TAN (n=9; 5 animals were implanted). The implant effect included: CON (n=10) and IMP (n=8). Forage intake was estimated using the NRC 1996 intake equation for cattle consuming an all-forage diet. Total intake included the estimated forage intake, actual bait (alfalfa pellets from the GreenFeed) intake, and actual supplement intake (from the SmartFeed).

Results:

Tanin Effect - Total dry matter intake (DMI) tended (P=0.08) to be lower in tannin-supplanted animals. There were no final BW or ADG differences between treatments (P>0.64). CH_4 production, emission intensity (EI; g CH_4/kg gain), and methane yield (MY; g CH_4/kg total DMI) were not different among treatments (P>0.05). There were no interactions between treatment and time for BUN, urine N, creatinine, or fecal N (P>0.36).

Implant Effect - Total DMI tended (P=0.06) to be greater in implanted steers than no implant steers. ADG tended to be greater for IMP steers (0.92 ± 0.03) in period 1 (d 0 to d 45) when compared to the CON (0.83 ± 0.04; P=0.10). Although numerically different, daily CH_4 production was not different for CON (220 ± 4.21) compared to IMP (211 ± 3.71; P=0.15). MY tended to be greater for CON (24.4 ± 0.51) compared to IMP (23.2 ± 0.45; P=0.09). Methane EI was not different for CON (234 ± 9.71) compared to IMP (218 ± 8.57; P=0.19) for 90 d of the study. However, EI was significantly lower for IMP (250 ± 10.3) compared to CON (285 ± 14.4; P=0.03) in period 1 of the study (Fig. 1). Urine N, creatinine, and fecal N were not different among treatments (P>0.30). However, BUN tended (P=0.08) to be greater in implanted cattle.

The inclusion of tannin in the diet tended to reduce DMI and did not reduce CH_4 emissions. The lack of effect of tannin inclusion on CH_4 production may have resulted from steers not consuming the full target tannin intake threshold. In the literature, the type of tannin used and the level of tannin supplementation varies between studies and thus, the results from tannin inclusion in the diet to reduce CH_4 emissions is variable. Revalor-G implantation tended to increase total DMI and ADG in the first 45 days of the study and tended to decrease CH_4 production, emission intensity, and methane yield in grazing stocker steers, indicating this performance-enhancing technology may benefit sustainable livestock production management strategies.

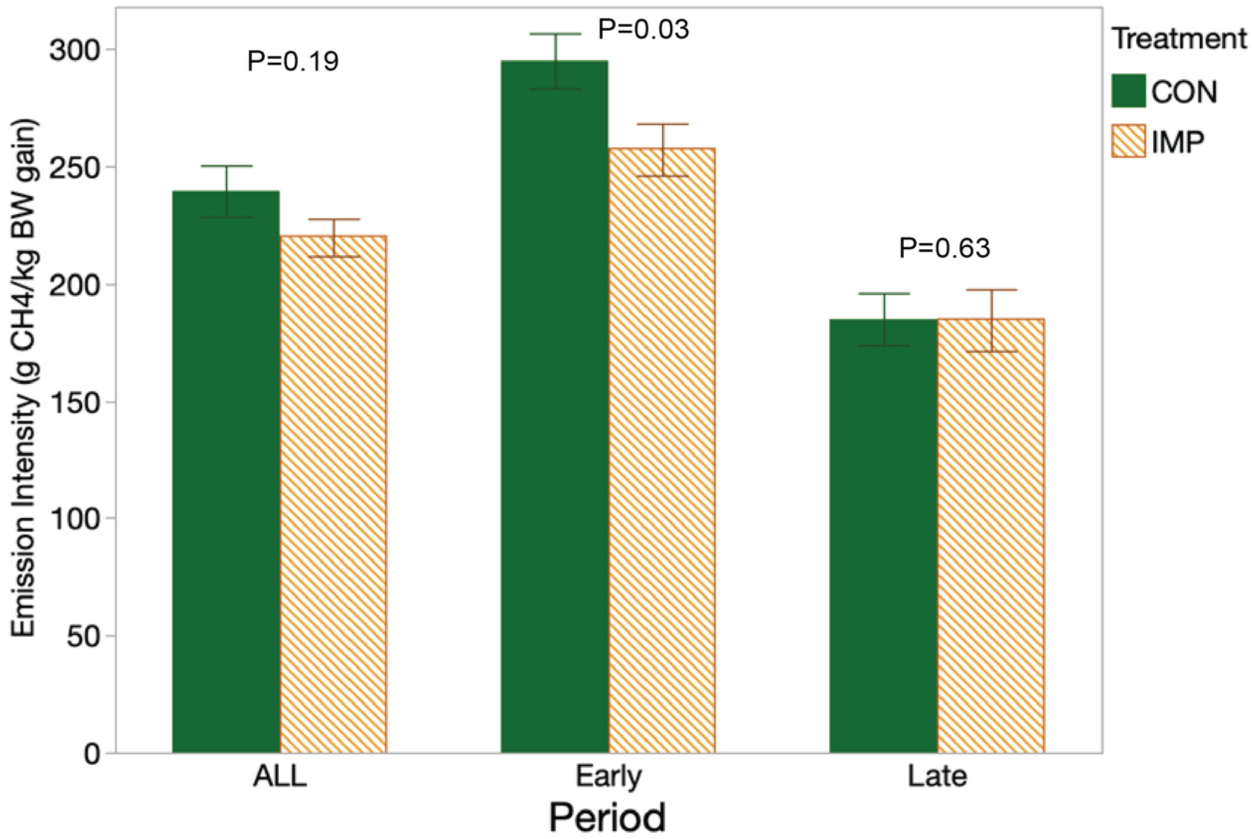

Figure 1. Emission Intensity (g CH_4 / kg gain) of steers with implant (IMP) and without implant (CON) for the whole 90 d study, the early period (d 0 to d 45), and the late period (d 45 to d 90).

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Funded by: Merck Animal Health.

Enteric Methane Emissions for Post-Weaning, Stocking, and Finishing Phases of Steers from Distinct Origins Across the High Plains Region of the United States

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Introduction:

Animal agriculture accounts for approximately 5.4% of global greenhouse gas emissions (GHG). Most of the GHG emissions are from cattle enteric methane (CH_4), which approximately 70-80% of those emissions are from cattle in grazing systems. However, how enteric emissions varies across animal life stages, such as post-weaning and finishing is not clear. Therefore, developing an understanding of enteric emissions at different stages of a beef steer's life presents a significant opportunity in the process of developing emissions mitigation strategies.

Objectives:

Determine steer enteric emissions on post-weaning and finishing stages of beef cattle from different origins in the western Great Plains, to enhance the understanding of potential variation in enteric emissions from steers across life stages.

Methods:

Enteric emissions and animal performance were measured at different life stages: post-weaning and finishing from 120 beef steers. Enteric gas emissions were measured using a GreenFeed Emissions Measurement system and cattle growth performance was assessed through the collection of individual body weight at the start and end of each phase and will be measured at the beginning and end of the finishing phase. Forage intake was estimated during the each grazing period using a titanium dioxide-marker approach. While in confinement, individual animal intake will be measured using SmartFeedPro intake measurement bunk systems (C-Lock Inc., Rapid City, SD).

Post-weaning Stage 1 (dormant season January to April, 2023)
Stage 1 included the evaluation of 40 British-breed yearling steers from Crow Valley Livestock Cooperative, LLC at Nunn, Colorado, 40 yearling steers at the USDA Meat Animal Research Center (MARC) in Clay Center, Nebraska, and 40 yearling steers at the CSU John E. Rouse Beef Improvement Center in Saratoga, Wyoming. The objective was to evaluate enteric emissions and animal performance from the animals in their native (born) environment. The yearling steers at Nunn, CO were grazed at a private ranch (grazing system) in Grover, Colorado from the 17th of January to the 15th of March. The steers at USDA-MARC were fed in a backgrounding feedlot system from the 15th of February until the 15th of April. Steers born at the high elevation CSU John E. Rouse Beef Improvement Center in Saratoga, Wyoming were housed in a backgrounding feedlot system at the CSU ARDEC facility in Fort Collins, Colorado from the 17th of November (2022) until the 14th of January. After completion of the backgrounding stage, each of the three herds were transported to the USDA – Agricultural Research Service's Central Plains Experimental Range (CPER) near Nunn, Colorado where they will be stocked on shortgrass rangeland from May to August 2023.

Results:

Stocker Stage 2 (May to August, 2023)
In stage 2, the 120 seers (from the three different origins) are grazing together at CPER near Nunn Colorado shortgrass rangeland from the 16th of May to August 1st or before (depending on the forage availability). The multi-origin herd will graze two blue grama-dominated shortgrass rangeland pastures (320 acres) sequentially for approximately 5 weeks each. Quantity and quality of forage will be measured the day before the cattle enter the pasture and the day after they leave it, with the objective of calculating the forage that the cattle consumed and its quality.

Finishing Phase (Stage 3; September 2023 to January, 2024)
Lastly, these 120 animals will be finished at ARDEC, where they will occupy the Climate Smart Research facility until they reach their finishing weight. Each pen is also equipped with Smartfeed (to measure individual intake per animal) and GreenFeed emissions monitoring systems (to measure animal greenhouse gas emissions).

Acknowledgements: USDA – ARS, Colorado State University, and Crow Valley Livestock Cooperative for their continuous support of this research. Inés Mesa was supported by the Fulbright Foreign Student Program. The Fulbright Foreign Student Program is administered by binational Fulbright Commissions/Foundations or U.S. Embassies.

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Evaluation of Methane Emissions Predictions from Observed Methane Emissions Data in Beef Steers, Heifers, and Bulls

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Introduction:

Enteric methane emissions from cattle are the largest source of agricultural methane emissions; however, measuring enteric methane emissions is costly and infeasible in many environments. Consequently, prediction of enteric methane emissions for greenhouse gas emissions inventories for reporting and carbon market purposes is an important alternative to measurement. By assessing emissions outputs directly from cattle, prediction equations can be evaluated and improved.

Objectives:

The objective of this experiment was to evaluate the relationship between feed intake and methane emissions, as well as compare the observed methane emissions with commonly used enteric methane emissions prediction equations.

Methods:

One-hundred ninety-two (steers n =99, heifers n=57, bulls n=36) cattle were housed at the Colorado State University Climate Smart Research pens equipped with Smartfeed feed intake measurement and Greenfeed emissions monitoring systems (C-Lock, Rapid City, SD). Body weight, body weight gain, dry matter intake, and methane emissions were collected over 37 days for each individual animal. Cattle were fed a backgrounding diet with a NEg concentration of 0.86 Mcal/kg. Observed methane emissions were compared to three extant methane prediction equations: IPCC tier 2 (IPCC)[1], Moraes et al. (2014) animal-level (MAL)[2], and Mills et al. (2003) non-linear equation 2 (MNL)[3].

Results:

Mean observed methane emissions were 185.3 g animal/day (standard deviation (SD) = 31.1), 135.0 g animal/d (SD = 29.3), and 177.4 g/animal/day (SD = 20.2), for steers, heifers, and bulls, respectively. Across all 192 animals mean total mixed ration feed intake was 6.33 kg/d (SD = 1.65) and mean methane emissions were 169 g/animal/day (SD =36.3; Pearson correlation coefficient r = 0.65).

When comparing observed vs. predicted methane emissions (Table 1), MNL predicted emissions were not different from observed emissions (mean = 168.2 g/animal/day; $P = 0.72$), whereas MAL (mean 123.0 g/animal/day) and IPCC (mean = 138.5 g/animal/day) underpredicted methane emissions ($P < 0.01$).

Of the 3 prediction equations, MAL had the lowest root mean square error (RMSE) of 21.4 (R square = 0.44), followed by IPCC (RMSE = 27.6, R square = 0.42), and MNL (RMSE = 30.6, R square = 0.42). The current preliminary data suggests further refinement of enteric methane emissions prediction equations could improve inventories and estimates of enteric methane emissions on commercial cattle operations.

Sex	Statistic	Observed methane emissions, g/d	MNL predicted methane emissions, g/d[3]	IPCC predicted methane emissions, g/day[1]	MAL predicted methane emissions, g/d[2]
Bull	Mean	177.4	169.4	139.1	125.8
	Median	176.2	172.7	141.5	126.5
	Std Dev	20.2	29.2	26.9	21.9
	Min	137.2	108.1	84.6	79.7
	Max	226.7	240.4	207.5	178.9
Heifer	Mean	135.0	145.4	117.7	108.3
	Median	130.0	150.7	121.5	109.2
	Std Dev	29.3	37.1	32.7	26.5
	Min	85.6	58.0	43.9	49.6
	Max	228.1	230.6	197.5	172.7
Steer	Mean	185.3	180.9	150.2	130.5
	Median	181.6	186.5	154.4	134.5
	Std Dev	31.1	39.8	36.3	28.9
	Min	100.9	30.3	22.6	26.4
	Max	253.4	269.7	238.5	195.3

[1]Methane in MJ/d = dry matter intake, kg/d x gross energy concentration of diet, MJ/d x 0.065 (% of diet energy lost as methane)

[2]Methane in g/d (heifers, high forage diet) = (-1.487+0.046 x gross energy intake, MJ/d+0.032 x NDF, % of dry matter + 0.006 x body weight in kg) x 1,000/55.65

Methane in g/d (steers, high forage diet) = (-0.221 + 0.048 x gross energy intake, MJ/d + 0.005 x body weight in kg) x 1,000/55.65

[3]Methane in MJ/d = 45.98 - (45.98 x $e^{-0.003 \times \text{metabolizable energy intake, MJ/d}}$*)*

Table 1. Summary statistics for observed vs. predicted methane emissions for steers (n = 99), heifers (n = 57), and bulls (n = 36) fed a common backgrounding diet for three different prediction equations.

Acknowledgements: The authors would like to thank the AgNext undergraduate research interns and ARDEC staff for their help in collecting these data.

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Lifecycle Assessment

Image of the foothills from the Climate-Smart Research Facility at the Agricultural Research, Development and Education Center (ARDEC).

Stakeholder Engaged Modeling, Data Science, and Machine Learning for More Resilient and Sustainable Animal Protein Food Systems

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Introduction:

Today's defining challenge for the U.S. Food System is to provide an affordable, nourishing, and balanced diet to the entirety of society in a manner that addresses the major resource constraints imposed upon agriculture: labor, water, climate, and other environmental concerns, including biodiversity and soil health. We must combat existing malnutrition and obesity related health problems while not further transgressing the planetary boundaries of biophysical processes, especially the imperatives of carbon and freshwater neutrality. Because food supply chains collectively represent a complex adaptive system, interventions can have unintended consequences, making it essential to assess all aspects of system performance when proposing or monitoring the effectiveness of any such actions.
The animal protein system (APS) provides around 2/3 of U.S. dietary protein, more than $100B of total economic value to producers, and provides employment for millions of Americans, most of whom live in rural communities. This study aims to develop a model that can be used to more fully understand the resilience of the APS under increasingly frequent shocks, such as COVID, drought or cyber-attacks. The outcomes will support policy decisions to decrease supply chain disruptions in the future.

Objectives:

Our long-term goal is to develop an innovative data-based modeling framework for evaluation of interventions in the APS as companies and the government continue to mitigate tradeoffs between resilience and sustainability (defined broadly to include socioeconomic factors).

Methods:

We have defined five objectives in support of this goal:
1. Collect stakeholder input on data sources and metrics appropriate for quantifying the resilience and sustainability of the U.S. APS.
2. Advance data science capabilities to model APS supply chains.
3. Advance data science capabilities to measure and monitor APS environmental impacts.
4. Add socioeconomic performance metrics to APS modeling capabilities.
5. Demonstrate use of the new modeling framework by simulating APS response to interventions that are proposed by stakeholders for mitigating resilience and sustainability tradeoffs.

Our long-term goal is to develop an innovative data-based modeling framework for evaluation of interventions intended to mitigate tradeoffs between resilience and sustainability (defined to include socioeconomic factors). Stakeholder-input on important problem definition issues, including the identification of relevant data sources at appropriate spatial and temporal scales, must be gathered, to ensure that the resultant modeling framework is measuring APS performance and tradeoffs in a meaningful way. As detailed below, this input will be gathered as the primary deliverable of Objective 1. Under Objective 2, we will develop new advances in data science that will make it possible to enhance the capabilities of FoodS^3 to model APS supply chains and to simulate supply and demand shocks. Objective 3 is focused on the advancement of data science capabilities to measure and monitor farm management practices deployed in the APS, including from crop and livestock production, and again implement these within FoodS³ to improve spatially explicit environmental impact models. Objective 4 involves expansion of FoodS³ capabilities to report on regional and demographic patterns in socioeconomic response to the COVID shock. Lastly, under Objective 5, the new modeling framework will be used to simulate APS response to interventions that are proposed by stakeholders for mitigating resilience and sustainability tradeoffs in the APS (see Figure 1).

Pending Results:

The project was initiated in February 2023 and does not yet have results to be reported. The team has held a kickoff meeting and is in the process of developing prototypical models that can be used as a tool for engaging with stakeholders in the model development process. Our current plan is to hold a workshop at the Sustainable Agricultural Systems meeting in December 2023 to solicit feedback regarding the types of questions that stakeholders wish to explore using the tools under development.

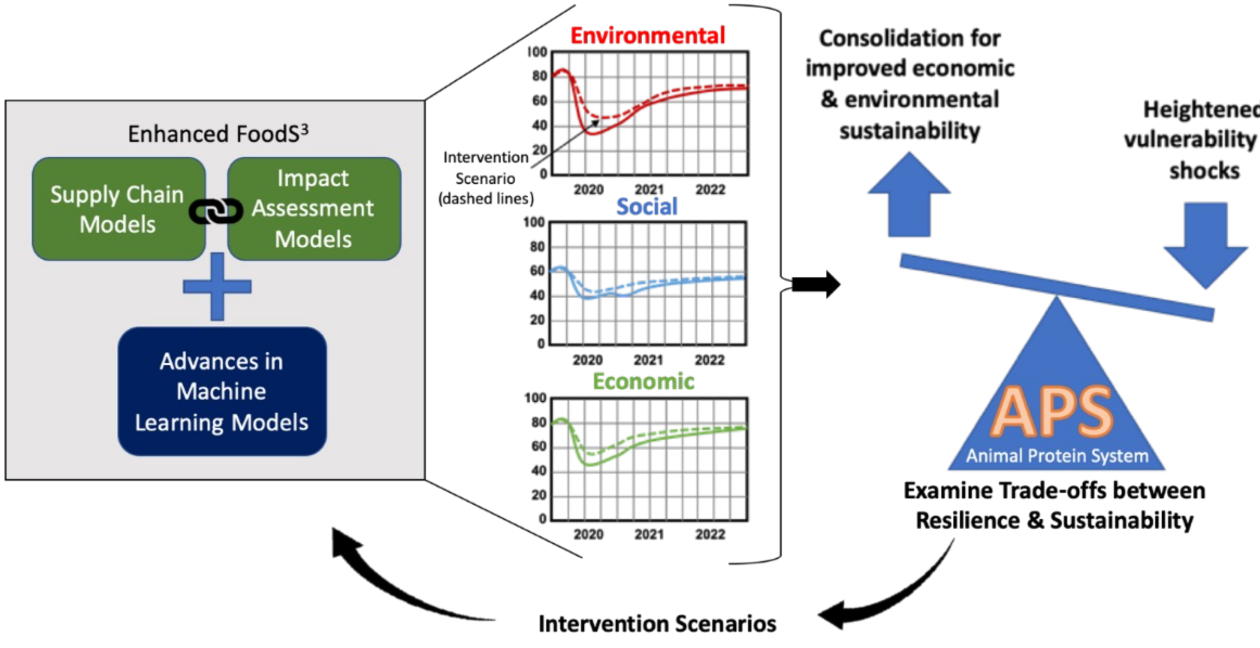

Figure 1: The enhanced version of FoodS³ will be used to model interventions intended to mitigate tradeoffs between resilience and sustainability in the Animal Protein System (APS).

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Retrospective and Current Life-Cycle Assessment of U.S. Wheat Production

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Introduction:

Growing concern among consumers and large retail organizations regarding the sustainability of the production systems underscores the need to characterize and quantify multiple metrics within the food production system. Wheat is one of the major row crop commodities produced in the U.S. and consists of several varieties including spring, winter, red, white and Durum wheat varieties. Understanding the intersection of management, location, and variety on the environmental performance of wheat production systems is a foundational effort in defining the sustainability of production.

Objectives:

1. Characterizing past sustainability progress of the U.S. wheat production: We are conducting a technical analysis of environmental key performance indicators (KPIs) based on peer-reviewed literature and historic production data from NASS and ARMS and professional publications for U. S. wheat production. This analysis supports benchmarking for the identified KPIs and will provide U.S. wheat growers with the information necessary to understand the state of knowledge of sustainability KPIs and characterize the primary contributing factors. This retrospective comparison of U.S. wheat production in the 1980s (prior to adoption of no-till and conservation-tillage systems) and current cultivation practices will identify and assess the improvements made of the last 40+ years of wheat production and will characterize the contributions of various technologies to those improvements. This life-cycle assessment will highlight the changes in production practices that have modulated environmental stresses. We propose a functional unit of 1 bu (60 lb/bu) of 86.5% dry matter (13.5% moisture) wheat grain at the farm gate ready for transport to a regional grain elevator. The KPIs will include greenhouse gas emissions, water consumption, energy consumption, and land use.

2. Measuring sustainability for U. S. wheat production: Production practices are highly variable across the U.S. and defining a national-scale suite of environmental impacts has utility in policy-level discussions or for communication with retailers or consumers. However, management decisions are made on a much smaller scale and therefore require a more granular assessment that differentiates between alternative practices, which may be based on local environmental conditions including available rainfall, soil type, and other factors. To assist with this, we are developing high-level demographic information regarding production practices on a regional basis using available public data including NASS, ARMS, FRIS, and the ERS. This information will inform detailed process models of production, which in turn will enable the creation of archetypical LCAs linked to specific production practices, including regional effects. A model-validation step will compare model-predicted yields against historically reported yields for important production regions.

Methods:

An existing process model, APEX, will be adapted to simulate wheat production. A framework has been developed (a) to automate the simulation process including input and output management and (b) to widen the scope of field-based models to a regional scale. The model simulation results will be used to create life-cycle inventory (LCI) for LCA development. The life-cycle inventory to life-cycle models of the production chain will be constructed using the OpenLCA software platform.

When the archetypical simulations have been completed during the summer of 2023, these results will be used to establish environmental KPIs (GHG emissions, energy use, water use, and land use). The LCA will be performed according to ISO 14040 in the following four stages: 1) goal and scope definition; 2) life cycle inventory (generation, using process models as described above, of data needed to perform the LCA calculations); 3) impact assessment; 4) analysis and interpretation of the results. The wheat supply chain will be divided into 4 stages: 1) pre- farm supply chain; 2) planting; 3) fertilizer application, disease and pest control, irrigation; 4) harvest and drying. For each stage, a separate analysis will be performed, and results will be combined to provide overall environmental indicators of U. S. wheat production.

The system boundaries will include the energy and greenhouse gas (GHG) emissions starting from production of seeds, fertilizers, and pest and disease control chemicals and will end with production of the functional unit at the farm gate. Some specific emissions like phosphorus (P) and nitrogen (N) from fertilizer application will also be included in assessment to enable estimation of secondary particulates (NH3) and freshwater and marine eutrophication. LCA results will be analyzed using stochastic methods to enable quantification and characterization of uncertainty. Pairwise comparisons will be presented to minimize covariance between scenarios.

Results:

An exhaustive review of available public data combined with feedback from stakeholders has allowed us to identify approximately 110 producing counties in the U.S. that provide a representative sample of production practices across primary production varieties. The sampling protocol included an evaluation of the relative production across various eco-regions, which are intended to represent similar geographies and weather patterns to minimize variability. We are currently in the process of collecting data from state agencies and other organizations regarding the specific management practices associated with each of the archetypical production systems. This includes information such as fertilization rates, planting density, planting and harvest dates as well as the use of irrigation and potentially tile drainage systems.

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Climate Smart Grasslands – the Root of Agricultural Carbon Markets

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Introduction:

Grasslands are the largest agricultural land use in the U.S., with over 265 million ha, and within the eastern U.S. (east of the Great Plains), are among the most important agricultural land uses with approximately 20 million ha within the Tall Fescue Belt (TFB) (Figure 1). The TFB grasslands are estimated to support approximately 40% of US cow-calf operations. However, pasture area has declined within this region by 738,000 ha between 2012 and 2017. This loss represents a substantial reduction in C-storage capacity, especially to the extent these lands were converted to more carbon-intensive practices such as hay production, row crops, or development. In fact, during this same period, land devoted to hay production within the TFB increased by approximately 100,000 ha. Regardless, both outcomes contribute to reduced soil carbon accretion and likely higher carbon emissions.

Objectives:

Colorado State University is partnering with the University of Tennessee and others to evaluate the potential for enhancing carbon sequestration in Eastern grasslands. Our contribution to this Climate Smart Commodity project is to coordinate modeling and experimental work with lifecycle assessment (LCA). The LCA will be conducted using the ISO 14040 and 14044 standards for LCA using a quantitative approach, with results presented in terms of resource use and environmental impacts per unit of beef produced. We anticipate that there may be different functional units that account for different phases of production. For example, when evaluating the cow calf sector, the functional unit may be a kg of live weight for a weaned calf, while for the processing stage an appropriate functional unit would be 1 kg of either hot carcass weight or lean, bone free meat for retail distribution.

Methods:

Data collection: The LCA will be based on data collected from a representative sample of beef production operations in the eastern grasslands region and subsequently simulated using process models to enable broader application of the results. Data will include information on inputs (e.g., feed, water, energy, pesticides), outputs (e.g., greenhouse gas emissions, waste), and other environmental impacts (e.g., land use, water quality).

Life cycle modeling: The collected data will be used to develop a life cycle inventory (LCI) model of beef production in the Eastern grasslands. The model will link the stages of the production process, from input materials and feed production to animal rearing, in the openLCA modeling platform. It is anticipated that a programmatic interface between COMET Farm and openLCA will be developed to enable rapid calculation of life cycle impact at a variety of aggregation scales from individual farms to regional assessments.

Environmental impact assessment: The life cycle inventory model will be used to assess the environmental impacts of beef production in the region, focusing on greenhouse gas emissions as influenced by soil carbon cycling associated with various management practices.

Decision support: work with the web-tool decision support team to incorporate the results of the LCA. The tool will allow users to input data about their beef production operation, including the types of feed and inputs used, the management practices employed, and the transportation distances involved. The tool will then calculate the environmental impacts of the user's operation and compare them to alternate scenarios.

The CSU team will primarily engage with the COMET Farm modeling team since the LCA acts as the final integrator of data which can inform carbon markets. We anticipate that the modeling team will also interact with the experimentalists in support of validation of the simulations.

Results:

This project is expected to begin in Summer 2023. Our anticipated deliverables include a final report summarizing the results of the LCA and the development and testing of the decision support tool. The report will include a description of the scope and methodology of the LCA, an inventory of resource use and environmental impacts for each stage of beef production, an evaluation of the overall environmental performance of alternative beef production systems in the Eastern grasslands, and recommendations for improving the environmental performance of beef production as well as understanding the role of carbon management from a systems perspective.

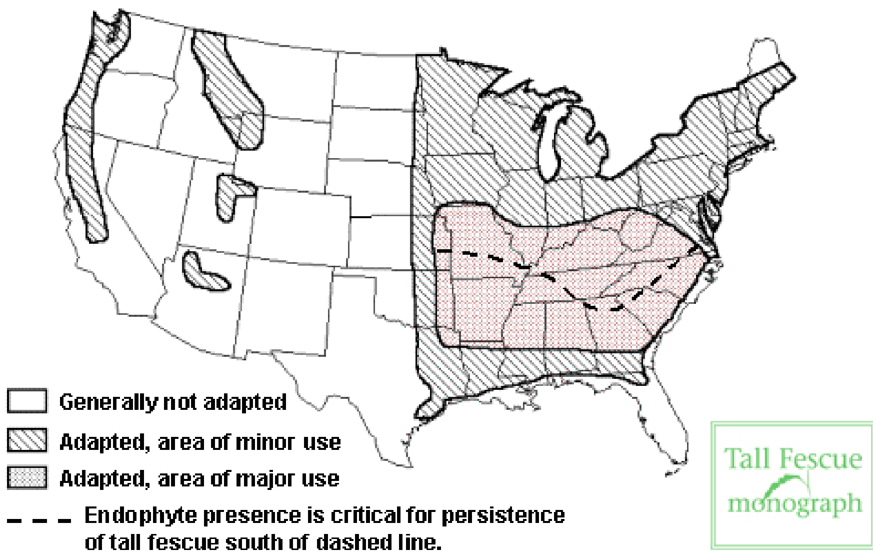

Figure 1: Zone of adaptation and use of tall fescue.
Source: forages.oregonstate.edu/tallfescuemonograph

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The Meaning and Measure of "Net Zero" Animal Agriculture: A System Dynamics Perspective

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Introduction:

Under the 2015 Paris Agreement on climate change,196 nations are aiming to reduce the net flow of greenhouse gases to the atmosphere from all human activity to zero. News articles with titles like "Cow burps drive global warming" (WBUR, Boston, 2022) encourage the idea that eliminating methane (CH_4) from livestock (and other sources) should be a top priority. It is not obvious that this is the right priority. We contend that the public and policy debate about CH_4 emissions, from livestock in particular, is broken. We tackle this problem by addressing the confusion and controversy surrounding our understanding of how to properly account for the contribution of livestock CH_4 to climate change using simple concepts and modeling tools of system dynamics.

Objectives:

Apply systems thinking and user-friendly modeling tools to establish a sound but simplified scientific basis for agreeing on goals to reduce the climate impact of animal agriculture.

Methods:

We began by building a stock-and-flow model that is used to describe the dynamics of the three main GHGs (carbon dioxide; CO_2, CH_4, and nitrous oxide; N_2O) in the atmosphere. The atmosphere is modeled (metaphorically) as a bathtub (stock) with an inflow of water (GHGs) and a drain (mechanism for removing the gases). The amount of water in the tub at any given time depends on the relationship between the flows in and out (Figure A). The amount of water (GHGs) in the tub at any time determines the rate at which heat is 'reflected' back to the earth's surface.

Figure 2A shows how this simple model is implemented using an intuitive graphical interface in the Stella® system dynamics software package (ISEE Systems, Inc., Lebanon, NH USA). The inflow is controlled (as shown by the red arrow) by GHG emissions from human activity. The outflow is controlled by the amount of water (stock of GHGs) divided by the average residence time of the water (GHGs) in the tub. Longer residence time translates to slower outflow at a given level (stock) of water and a larger stock causes faster outflow at a given residence time.

Climate scientists have estimates for the atmospheric residence time of each GHG, that is the average duration that a gas emission remains in the atmosphere before removal by any mechanism. CO_2 residence time is a little more complicated, in that it has four different mechanisms for removal, and is therefore treated as four separate bathtub models. A similar model is then used to track the increased stock of heat (increased temperature) as a function of the stock of each gas in the atmosphere (not shown here). What is important to note is that the heating potential of a kg of CH_4 is much greater than that of a kg of CO_2, but that CH_4 has a much smaller residence time (faster removal rate) in the atmosphere.

Results:

Prioritizing mitigation strategies. We used this simple model to show non-climate scientists the effect of prioritizing CH_4 over CO_2 reductions. The model has a dashboard with a section for users to set timing and removal rates of the gases (Figure 2B) and a section that displays climate response (Figures 2C and D). Emissions of each gas in phase 1 correspond to current global estimates. A comparison of Figures 2C and D shows that prioritizing CH_4 over CO_2 removal in this simple scenario leads to a much higher global temperature rise than prioritizing CO_2 over CH_4 removal. This comes as no surprise to the climate science community but runs counter to the intuitive notion that the more potent CH_4 gas should be the first priority for removal. Note that this does not mean that advocates of prioritizing CH_4 are wrong. Figure 2D shows that if CH_4 is not rapidly removed there will be a significant peak in climate response compared to the long-term temperature rise, which may not be desirable. Users can play with the model to seek out combinations of CO_2 and CH_4 mitigation that keep both peak and long-term temperatures within desired limits.

New and more detailed model. A more advanced version of the model described above is already available. We have used it to shed light on the controversies surrounding a newly proposed way to track CH_4 as CO_2 warming equivalents. Some have accused advocates of this new metric (known as GWP star, GWP*) of trying to make some livestock sectors in the world appear less damaging to the climate, and that the new metric gives a free pass to historically high CH_4 emitters. This new model transparently evaluates the pros and cons for both GWP* and the currently accepted method for calculating CH_4 GHG equivalents. It also explores an alternative approach that may be both more correct and fairer.

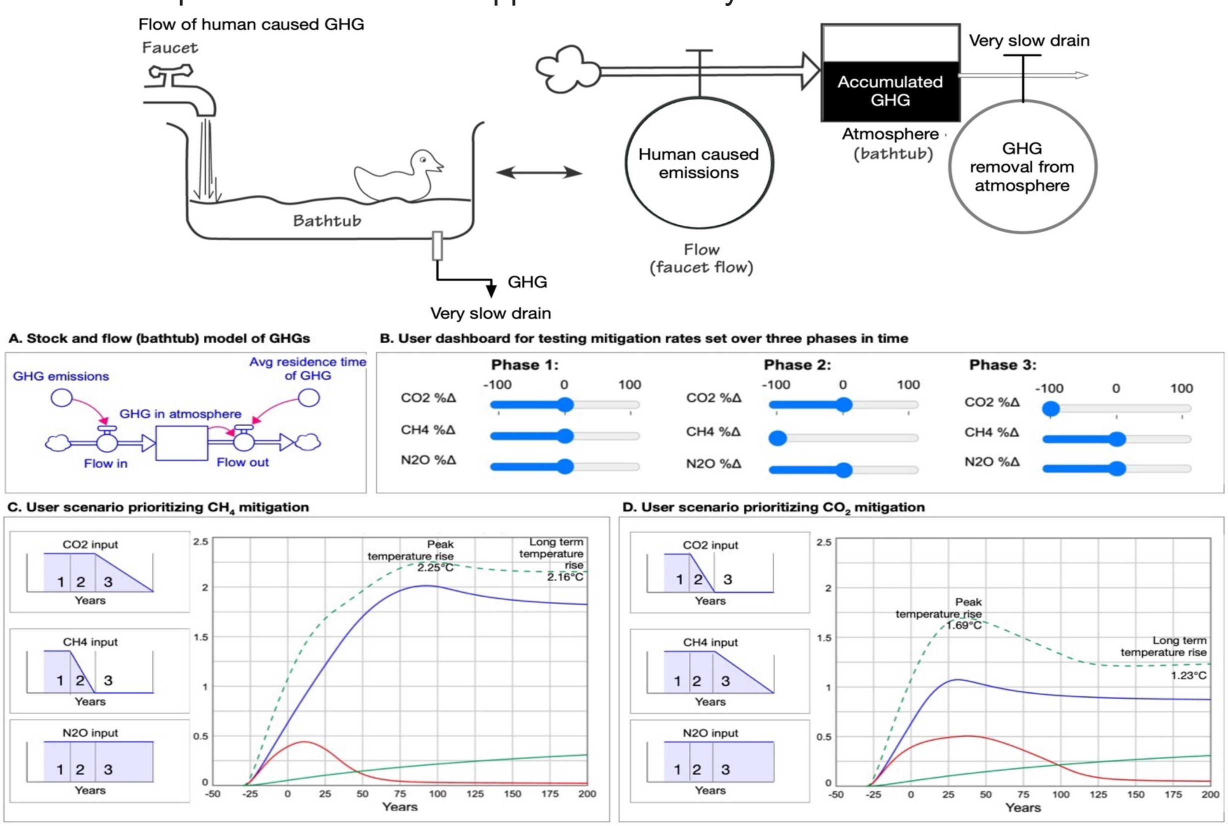

Figure 2. Intuiting the dynamics of greenhouse gases and climate change using simple stock and flow models

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Corporate Sustainability Efforts

Industry partners at the Climate-Smart Research Facility.

National Beef Packing Company Sustainability Program Development & Reporting

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Introduction:

A strong corporate sustainability program is an important business element of food companies in the U.S. and globally. Yet the steps required to implement a sustainability program are not immediately clear. Due to the complex nature of beef production systems, it is imperative that National Beef's sustainability approach considers potential unintended consequences. Specifically, they must balance aggressive goals that are focused on reducing a specific environmental impact, like reducing greenhouse gas emissions, without sacrificing and ideally improving issues related to water quality, water use, food security, animal health and well-being, worker safety and satisfaction, impacts on public health and value chain profitability.

Finally, it is imperative that National Beef's strategy is science-based. As such, they have partnered with CSU AgNext, to assist in developing and implementing a sustainability program and reporting on progress toward sustainability related goals and initiatives.

Objectives:

The objectives of this collaboration are to 1) implement a sustainability program and reporting schedule for National Beef and 2) enhance the visibility of sustainability through the National Beef supply-chain.

Methods:

In 2021-2022, AgNext performed a competitor and customer analysis, assisted National Beef in the identification of material topics, provided guidance in the completion of CDP reporting for Climate and Forests, and established a GRI reporting strategy for the company. Over the next year, CSU AgNext will assist National Beef in furthering the work completed in 2021-2022 by 1) enhancing the visibility of sustainability throughout National Beef operations, 2) reporting Environment, Social, and Governance (ESG) data-based progress on sustainability related activities via a minimum three reporting frameworks such as CDP, GRI, UNSDGs, SASB, TCFD, etc., and 3) providing strategic council and direction on scope 3 emission reduction opportunities within the NBP supply chain.

Acknowledgements: CSU AgNext would like to extend our sincerest appreciation to National Beef for their continued support and collaboration.

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Funded by: National Beef Packing, LLC.

Superior Farms, LLC Company Sustainability Program Development

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Introduction:

The significance of sustainability is rapidly growing, placing increasing expectations on companies from investors and consumers to play their part in improving our society and planet. However, the method required to accomplish this is not immediately evident. Given the complex nature of sustainability, it is vital that Superior Farms adopt a strategy that is firmly grounded in science and driven by data. In today's world, sustainability has become a massive concern, and businesses must recognize the need to align their practices with scientific principles. By basing their decisions and actions on robust scientific evidence, Superior Farms can effectively address the challenges associated with sustainability. A data-driven approach will enable Superior Farms leadership to make well-informed decisions, identify areas for improvement, and implement targeted strategies. A science-based and data-driven strategy not only enhances Superior Farms' credibility and reputation, but it also contributes to their long-term success. By utilizing scientific knowledge and the power of data, Superior Farms can proactively tackle environmental and social concerns, reduce its ecological footprint, and remain profitable. In a world where sustainability plays a pivotal role in business, Superior Farms can position itself as a market leader by embracing a sustainability strategy firmly rooted in science and driven by reliable data.

Objectives:

The objective is to assist Superior Farms in establishing a robust sustainability program by conducting a competitor and customer analysis to identify opportunities for differentiation, determining an appropriate framework for a facility-level sustainability program, and providing guidance on data collection methodologies, material topics, goals, metrics, and policies.

Methods:

First, we will conduct a comprehensive competitor and customer analysis to gain insights into the commercial lamb industry sustainability landscape. This will allow us to identify opportunities for differentiation for Superior and help us understand shared values along the supply chain to develop an appropriate approach. Next, we will collaborate with the Superior Farms Leadership Team to develop a framework for implementing a comprehensive robust sustainability program. This will include evaluating current data collection methodologies, identifying material topics, and considering the need for goals within the program. We will also develop shared facility metrics to benchmark performance and provide guidance on developing policies related to environmental performance, diversity and inclusion, animal welfare, and traceability. Throughout the process, we will facilitate two workshops with the Superior Farms leadership team and AgNext to present findings, discuss progress, and determine next steps. Our aim is to create a strong internal sustainability framework while advancing human, animal, and ecosystem health, promoting food security, and optimizing natural resource use in the supply chain.

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Funded by: Superior Farms, LLC

National Lamb Quality Audit – 2022 Phase One and Two Producer Perceptions and In-Plant Survey of Carcass Characteristics Related to Quality and Value of Fed Lambs and Mutton

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Introduction:

The U.S. lamb industry faces competition from imported lamb from countries like Australia and New Zealand, and producers are also experiencing increased production costs, raising concerns for the industry's future. The National Lamb Quality Audit (NLQA) is a tool that have been used to benchmark the industry's current production state and identify opportunities to improve lamb quality attributes to enhance the value of U.S. lamb. The three previous NLQAs evaluated management strategies related to quality attributes for foodservice but have had minimal in-plant evaluations. Overall, the U.S. lacks data on lamb carcass characteristics, especially data captured in the production settings. Therefore, the current NLQA evaluates producer perceptions and conducts an in-plant audit to quantify carcass characteristics associated with carcass yield and value. Another tool that lamb producers can utilize to improve the value of their product is the Sheep Quality Assurance (SQA) program, which provides guidance on best practices to improve or maintain product quality and safety, animal health and well-being, and marketability. This program uses research and education to improve management practices to maximize consumer confidence in sheep products. Therefore, including the information from the current NLQA will provide a more effective platform to enhance producers' adoption of best practices. Moreover, the revisions of the SQA manual could lead to increased producer adoption of the SQA program.

Objectives:

1. Quantify and benchmark U.S. producer perceptions of the lamb industry.
2. Conduct in-plant audits and quantify characteristics associated with carcass yield and value.

Methods:

The producer perception survey was administered using software package (Qualtrics®) customized to develop a structured order of questions and was distributed via social media and emails between May 2022 and June 2022. Respondent demographic information, the rank of lamb quality attributes, and answers to open-ended questions related to sustainability, and future challenges and opportunities the industry has, were collected from each respondent. Based on results and themes from the 2015 NLQA, respondents were asked to rank from 1 (least important) to 10 (most important) topics based on importance to their operation. Respondents were then prompted the ranking of significant challenges currently present within the industry from 1 (most significant) to 10 (least significant).
In-plant cooler assessments were conducted at four federally inspected lamb processing facilities, selected to represent the entire fed lamb industry across the U.S. These assessments occurred from June 2022 to September 2022 and were completed by personnel from Colorado State University and the University of Idaho. Each facility was surveyed for 50% of a typical day's production. Lamb and sheep carcasses (n=2,464) were evaluated for breed type, mud score, wool length, contamination, sex, presence of horns, hot carcass weight (HCW), United States Department of Agriculture (USDA) yield and quality grades (YG and QG), measured fat thickness (probe), and maturity indicators (dentition or ossified joints).

Results:

One hundred fifty-five producers completed an online survey with producer representatives from 32 states and Canada. Animal welfare (8.9), lamb quality (8.4) and sustainability (7.6) were the most important factors for the survey respondents. Further, the respondents indicated that operation costs (3.04), and lamb supply and market volatility (3.70), and labor (4.08) were their most significant challenges. Among carcasses audited, 63.0% were wethers, 32.0% ewes, and 5.4% rams, and 2.0% of them had horns. Of those, 40.2% were speckle-faced (white-face and black-face cross), 38.8% were white-faced, 18.3% were black-faced, 1.4% had natural characteristics, and 1.2% were hair sheep. The average mud score was 2.12, and the average wool length was 1.98. Additionally, 81.5% of the sheep audited presented two break joints (lamb), 5.7% with one break joint (yearling mutton), and 7.2% with no break joints (mutton). The average HCW was 39.9 kg, whereas the fat thickness was 0.97 cm. The USDA stamped yield grade was 2.71, of those carcasses 68.5% were graded Choice, 22.6% Prime, and 8.9% were not graded. The 2022 NLQA in-plant survey of carcass characteristics is the first one to provide a benchmark for carcass characteristics of lamb processed in the U.S. The data from this study can be used by all industry segments to understand and develop strategic initiatives to improve the quality of fed lamb and mutton.

Acknowledgements: Ashley Schilling, Colton Smith, Hannah Cochran, Sara Gonzalez, Micheal Sintharakao Hernandez, Chris Poppy, University of Idaho, Abby Ruch, Superior Farms, Colorado Lamb, Double J Lamb, and survey respondents

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Funded by: American Lamb Board