Sustainability of Grazing Beef Cattle in the Great Plains

Merri E. Day [1], Minfeng Tang [2], Phillip A. Lancaster [2], Deann Presley [3], Dustin L. Pendell [1,2], Walter H. Fick [3], Luca Doro [4], Adam Ahlers [5] and Andrew Ricketts [5]

Risk and Profit Conference

August 2023

[1]Department of Agricultural Economics, Kansas State University, Manhattan, KS 66506, USA
[2]Beef Cattle Institute, Kansas State University, Manhattan, KS 66506, USA
[3]Department of Agronomy, Kansas State University, Manhattan, KS 66506, USA
[4]Blackland Research and Extension Center, Texas AgriLife Research, Temple, TX 76502, USA
[5]Department of Horticulture and Natural Resources, Kansas State University, Manhattan, KS 66506, USA

This research was funded by the Beef Checkoff grant number 1850.

U.S. Roundtable for Sustainable Beef

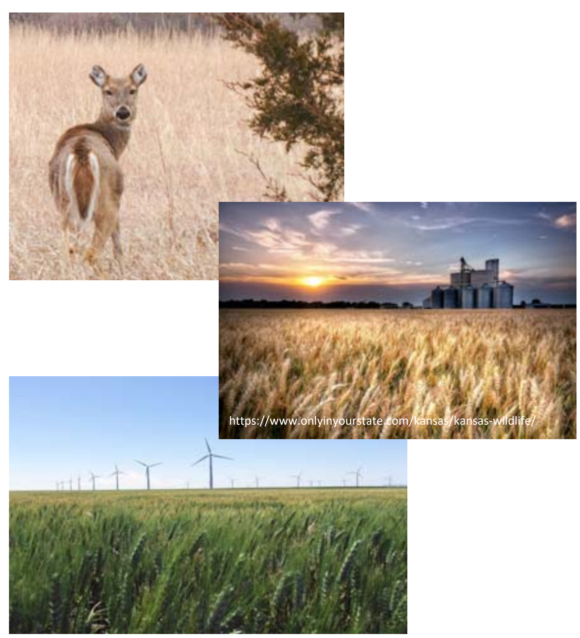
Source: U.S. Roundtable for Sustainable Beef (2023)

People, Planet, Profit

The three pillars of sustainability. Source: Based on 'sustainable... | Download Scientific Diagram (researchgate.net)

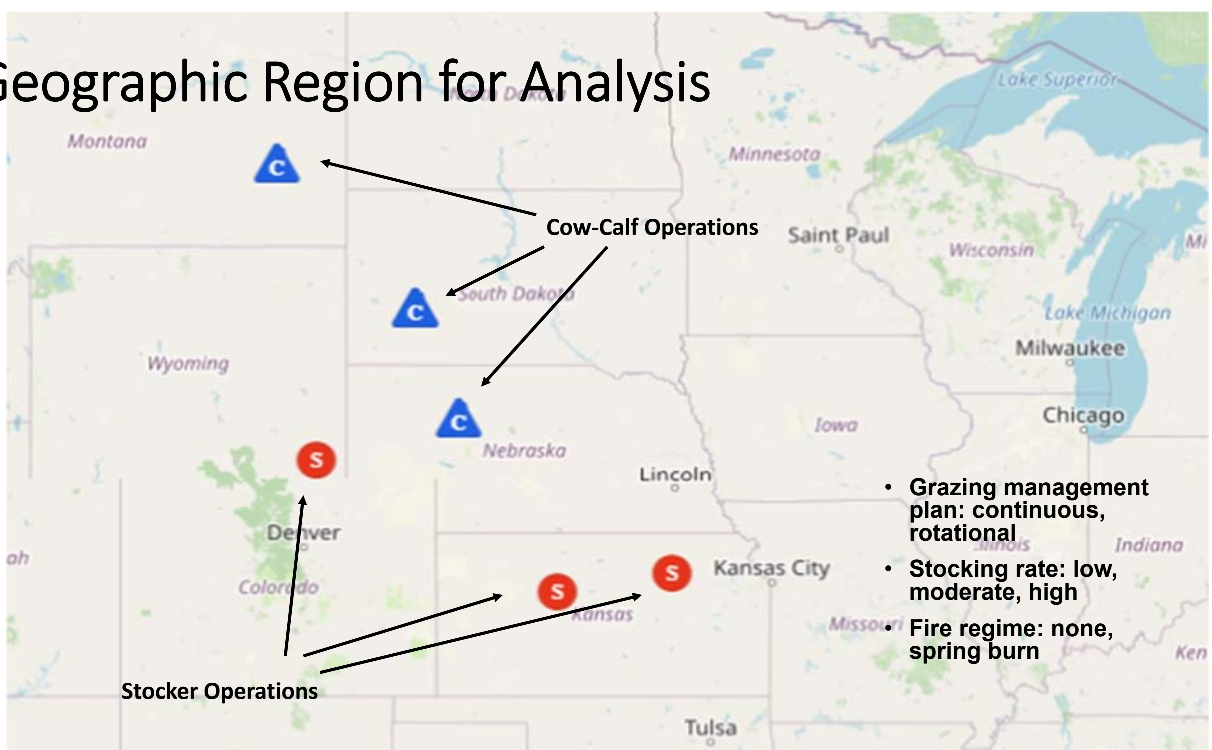
Rangelands provide many human benefits:

- Food production
- Income for rural families and communities
- Recreation
- Wildlife habitat
- Soil carbon sequestration
- Plant and animal diversity
- Water filtration



How do combinations of grazing management practices impact sustainability of rangelands in different ecoregions across the Great Plains?

Geographic Region for Analysis



- Grazing management plan: continuous, rotational
- Stocking rate: low, moderate, high
- Fire regime: none, spring burn

Agricultural Policy eXtender (APEX) Model

APEX: A WATERSHED & LAND MANAGEMENT SIMULATION MODEL

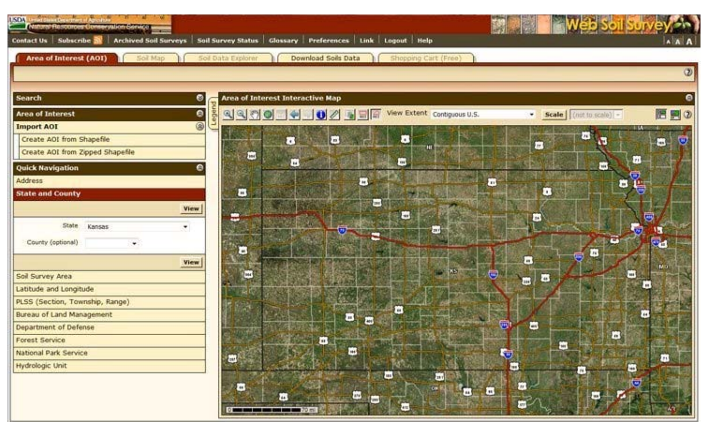
The Agricultural Policy / Environmental eXtender (APEX) model was developed to extend EPIC's capabilities of simulating land management impacts for small-medium watersheds and *heterogeneous* farms. It can be configured for land management strategies such as irrigation, drainage, furrow diking, buffer strips, terraces, waterways, fertilization, manure management, lagoons, reservoirs, crop rotation and selection, pesticide application, grazing, and tillage. The routing of water, sediment, nutrient, and pesticide capabilities are some of the most comprehensive available in current landscape-scale models.

Source: EPIC/APEX | EPIC & APEX Models (tamu.edu)

APEX

U.S. Department of Agriculture
Natural Resources Conservation Service

- Soil data: USDA-NRCS Soil Survey
- Historical weather data: on-site weather station when available, or nearest weather station available in the NASA POWER database
- Plant species composition: literature and USDA-NRCS Soil Survey



Integrated Farm System Model (IFSM)

- The IFSM is a process-level simulation tool to assess the performance, environmental impacts, and economics of cattle and feed production systems.
- IFSM tracks blue and green water use, plant growth, and animal requirements.
- Reactive nitrogen losses are estimated as ammonia volatilization, nitrous oxide via nitrification and denitrification processes, and nitrate via leaching and runoff as influenced by temperature, wind speed, precipitation and soil and management characteristics.

Source: Integrated Farm System Model : USDA ARS

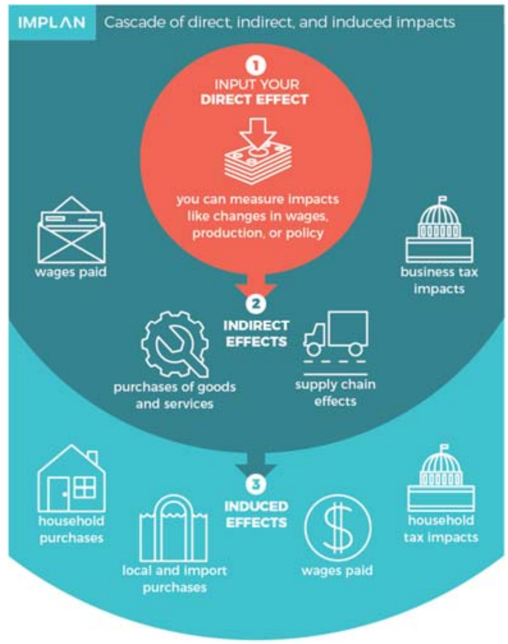
IFSM

- **Nutrition value of forages**: published literature
- **Fuel** (country region**), gas, electricity** (state) **rates**: US Energy Information Administration
- **Land rental and property tax rates**: USDA NASS (county)
- **Machine life, salvage values, interest rates**: default values
- **Cattle purchase/sale prices**: LMIC, USDA AMS
  - Feeder cattle: steers, fall 2018 purchase, fall 2019 sale, 250kg weaning weight
  - Sale weights: 340kg (KS1), 300kg … kg (WY)
- **Labor requirements**:
  - Initial requirements for mod stocking obtained from literature (Asem Hiablie et al., 2015, 2016, 2017)
  - Adjustments made to approximate requirements for low and high stocking follow (Gillespie et al., 2008)
  - Multiplier developed to estimate differences between continuous and rotational requirements
- **Custom operations costs**: KSU and UNL
- **Labor wages**: USDA NASS
- **Feedstuffs**: LMIC, USDA NASS, USDA … KSU Livestoc…

USDA Agricultural Marketing Service | eia Independent Statistics & Analysis U.S. Energy Information Administration | LMIC Livestock Marketing Information Center

IMPLAN

- Industry Impact Analysis (Detailed) Event
- Observable impacts: direct, indirect, induced
- Economic effects measured in terms of employment, labor income, value added, total output



Source: [Economic Impact Analysis for Planning | IMPLAN]

Sustainability Index

- Values for each metric were retrieved from APEX, IFSM, and IMPLAN results, with the exception of biodiversity indicators.
- A normalized scale was used to convert data to a dimensionless unit; normalized values were determined as a function of sustainability limit and standard deviation within study sites.
- Participatory approach was used to give an importance score for each indicator.
- Final index value was calculated by equally weighting each pillar.

Figure 1. Total forage yield for each rangeland management scenario at each study site.

Total forage yield was lesser with burning at KS1, WY, MT, and NE.

Total forage yield decreased with increasing stocking density at KS1, KS2, and WY under continuous grazing.

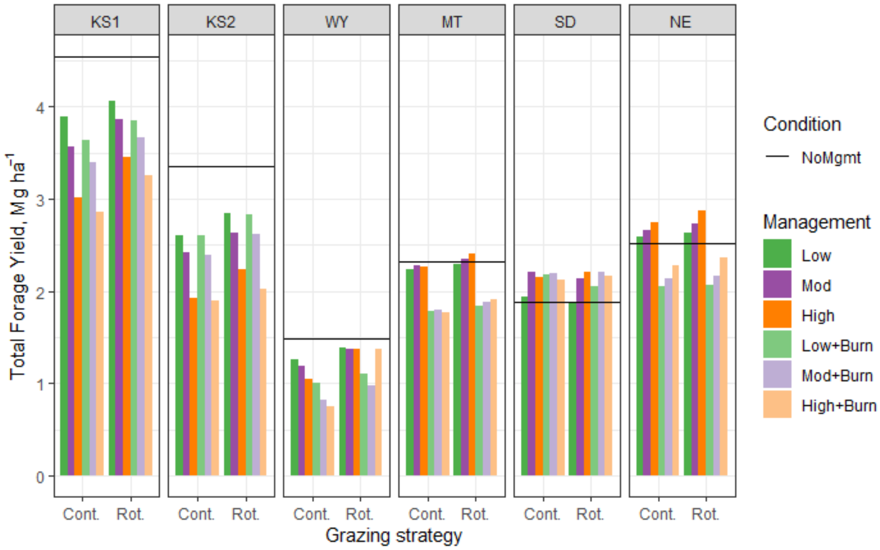


Figure 2. Peak standing crop on a singe day for each rangeland management scenario at each study site.

Peak standing crop: maximum amount of forage available on any given day

Peak standing crop follows a trend similar to that of total forage yield.

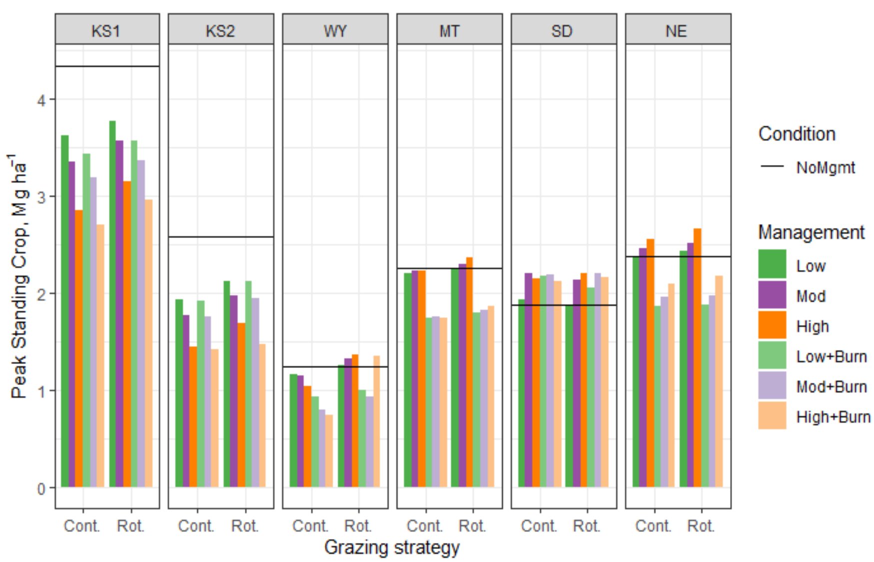


Figure 3. Final body weight of stocker calves (KS1, KS2, WY) and nursing calves (MT, SD, NE) for each rangeland management scenario at each study site.

Stocker calves:
- Rotational grazing increased final body weight at WY.
- Annual spring burning significantly decreased final body weight at WY.

Nursing calves:
- Increased stocking density decreased final body weight at MT.
- Increasing stocking density under rotational grazing decreased final body weight at NE.

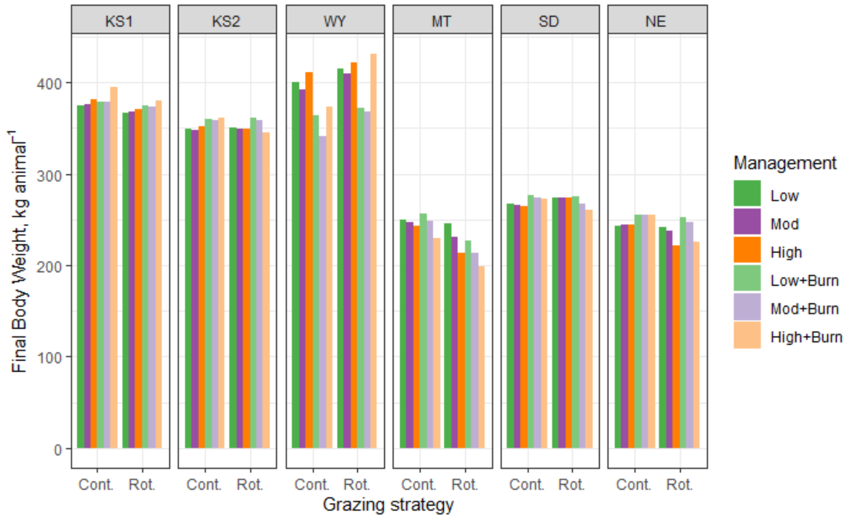


Figure 4. Number of hay feeding days for cow-calf systems (MT, SD, NE) for each rangeland management scenario.

At MT, winter hay feeding decreased at high stocking density under continuous grazing.

At SD, winter hay feeding decreased with increasing stocking density under no burn conditions.

At NE, winter hay feeding decreased with increasing stocking density.

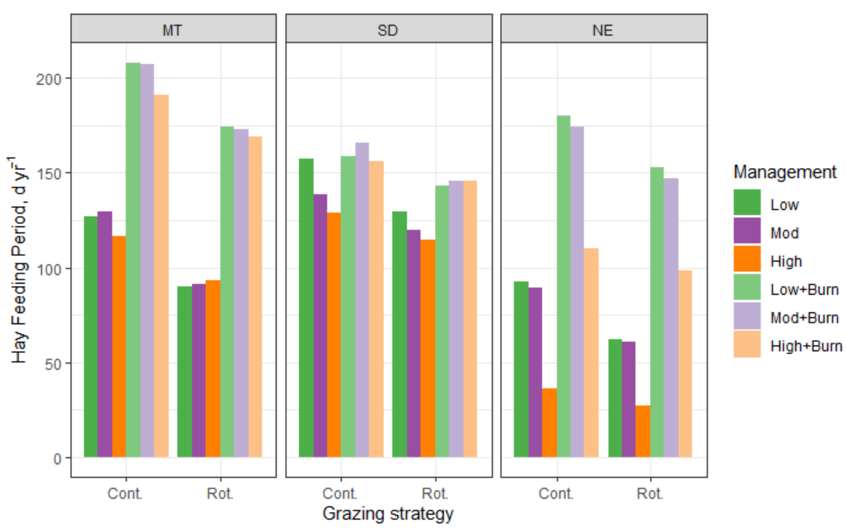


Figure 5. Soil loss from water and wind for each rangeland management scenario at each study site.

Soil loss increased at high stocking density at KS1, KS2, and WY.

Rotational grazing decreased total soil loss compared with continuous grazing at KS1.

Spring burning increased soil loss at all sites compared with no burn conditions except at NE.

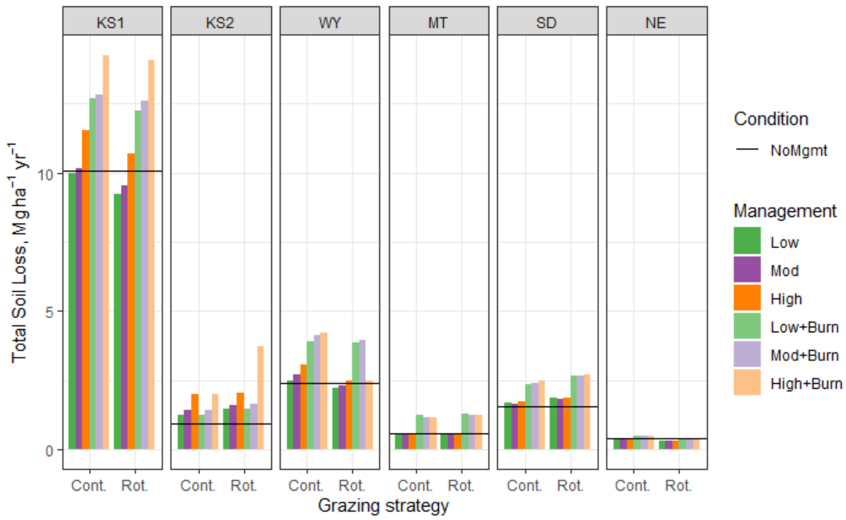


Figure 6. Nitrogen losses for each rangeland management scenario at each study site.

Total nitrogen losses increased with increasing stocking density at all sites but were unaffected by grazing management and fire regime.

The pathway of nitrogen loss was affected by rangeland management practices.

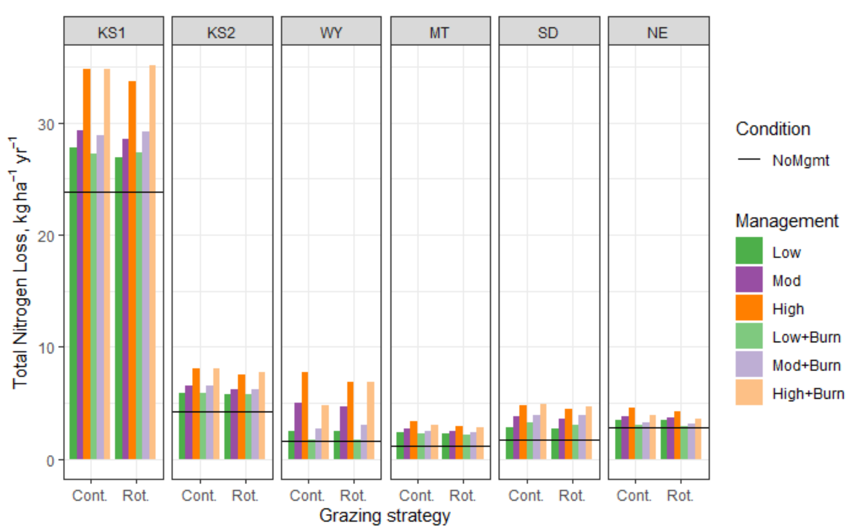


Figure 7. Phosphorus losses for each rangeland management scenario at each study site.

Phosphorus losses increased with cattle grazing compared to unmanaged rangelands.

Phosphorus losses increased with increasing stocking density at all sites.

Burning increased phosphorus losses at KS1 and decreased losses at MT.

Rotational grazing have no effect on phosphorus losses at any site.

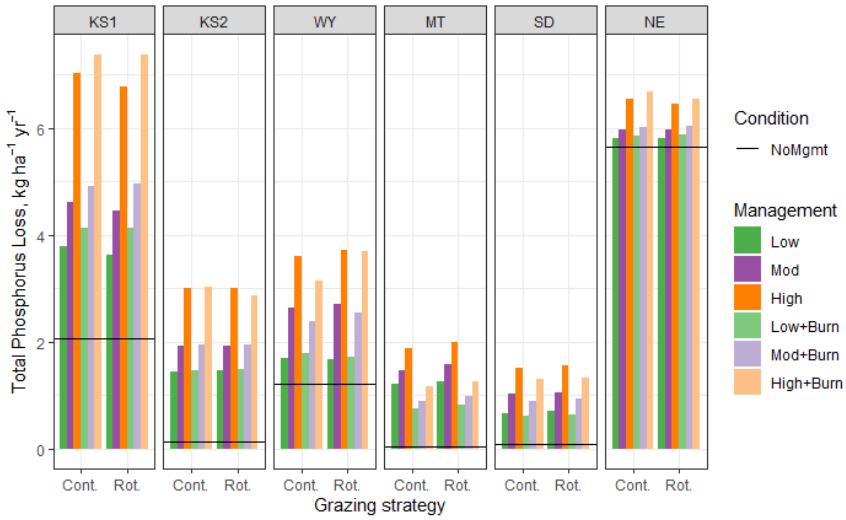


Figure 8. Initial and final soil organic carbon for each rangeland management scenario at each study site.

On average, cattle grazing resulted in less soil organic carbon at KS1, SD, and NE, but similar soil organic carbon at KS2, WY, and MT.

Increasing stocking density decreased soil organic carbon at KS1 and SD, increased at MT and NE, and had no effect at KS2 and WY.

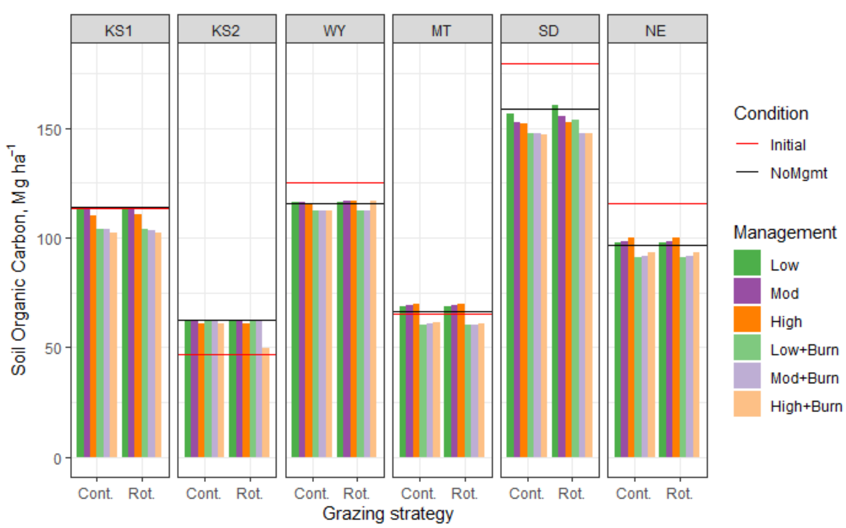


Figure 9. Blue water footprint for each rangeland management scenario at each study site.

The blue water footprint was unaffected by stocking density, grazing management, or annual fire at KS1 and KS2.

Effect of stocking density, grazing management, and annual fire on blue water footprint varied across other sites.

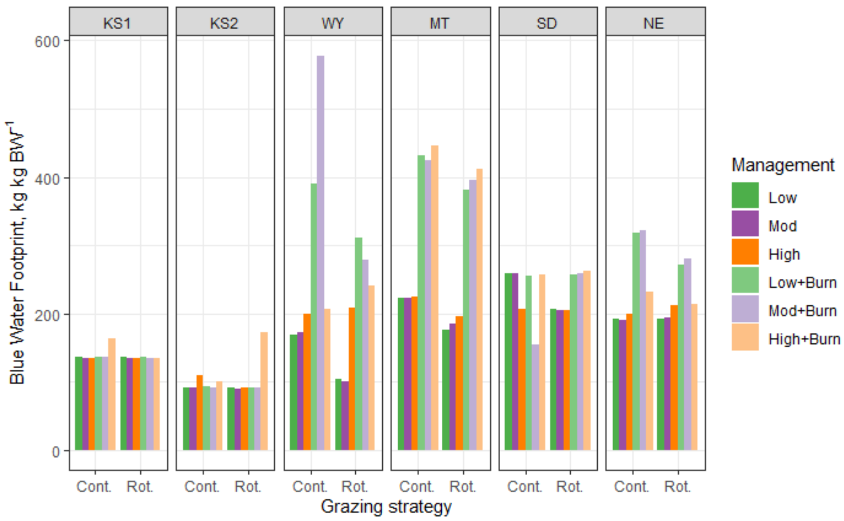


Figure 10. Reactive nitrogen footprint for each rangeland management scenario at each study site.

The reactive nitrogen footprint decreased with increasing stocking density at KS1, WY, MT, and NE.

Impact of rotational grazing management on reactive nitrogen footprint varied across sites.

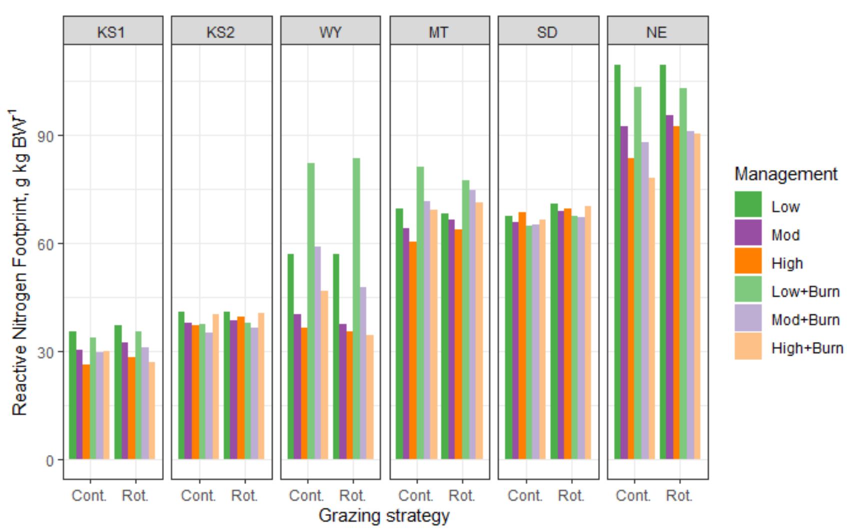


Figure 11. Energy footprint for each rangeland management scenario at each study site.

At KS1 and KS2, the energy footprint decreased with increasing stocking density except at high stocking density under continuous grazing with burning.

Rotational grazing decreased the energy footprint at WY and MT compared with continuous grazing management.

Impact of annual burning on energy footprint varied across sites.

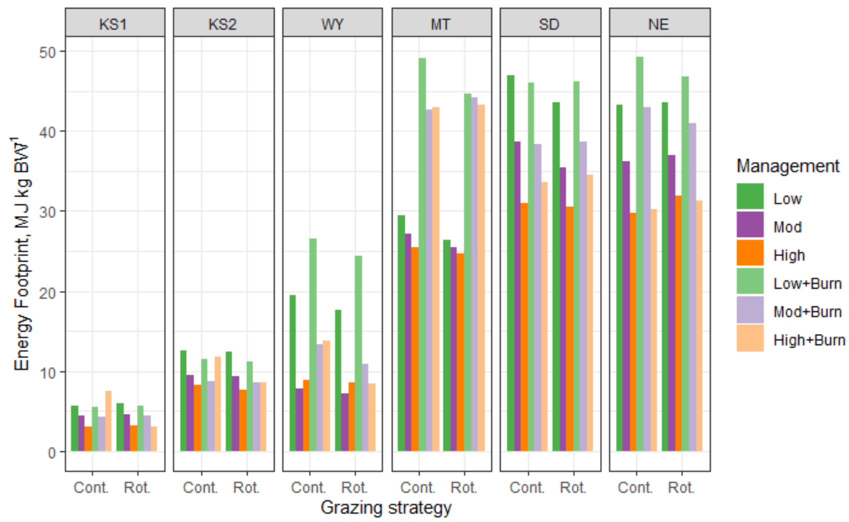


Figure 12. Carbon emissions footprint with biogenic CO2 for each rangeland management scenario at each study site.

The carbon footprint decreased with increasing stocking density at KS1, WY, and NE regardless of grazing management and fire regime.

The impacts of rotational grazing and annual burning on carbon footprint varied across sites.

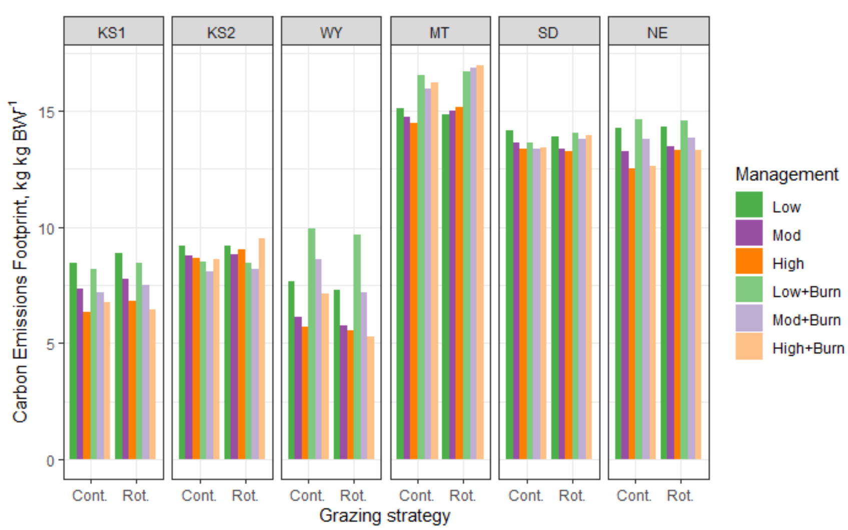


Figure 13. Total expenses for each rangeland management scenario at each study site.

Estimated total expenses from IFSM increased with increasing stocking density regardless of grazing management or fire regime at all sites.

Rotational grazing management had greater total expenses than continuous grazing management at all sites.

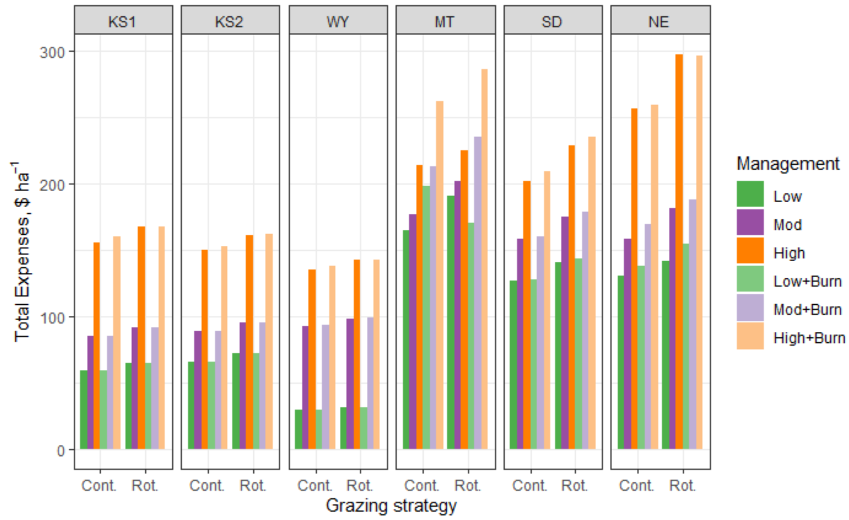


Figure 14. Income for each rangeland management scenario at each study site.

Income from animal sales also increased with increasing stocking density regardless of grazing management or fire regime at all sites.

Impact of rotational grazing and annual burning on income varied across sites.

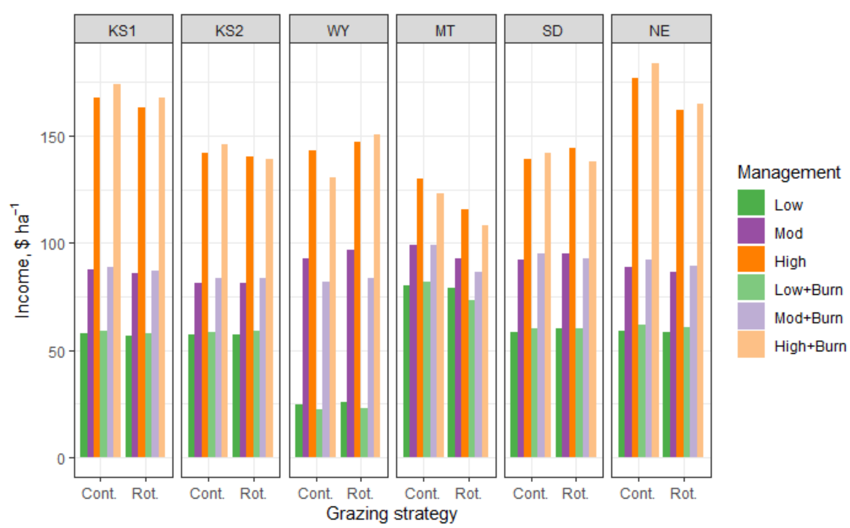


Figure 15. Returns for each rangeland management scenario at each study site.

Returns to management takes into consideration both fixed and variable costs, and input costs vary between study sites.

Returns are expected to increase from low to moderate stocking, but decrease as stocking density continues to increase due to a lack of available forage resulting in less weight gain.

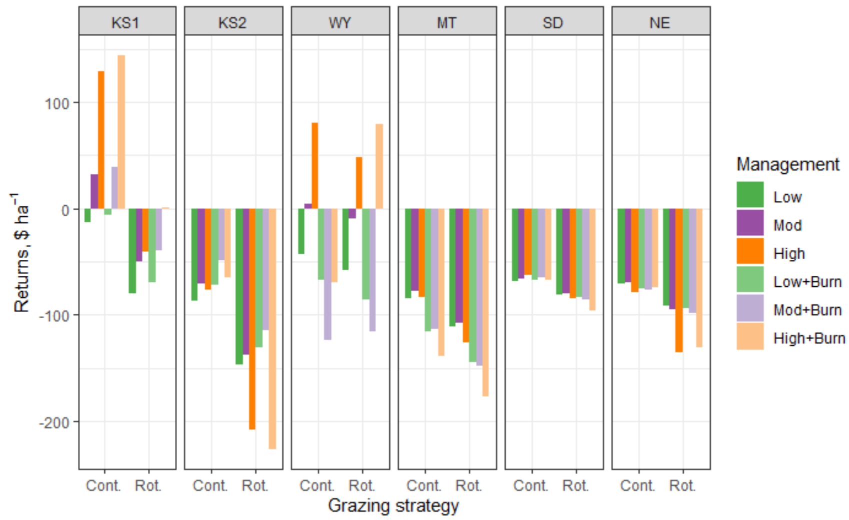


Figure 16. Value-added impacts for each management scenario at each study site from IMPLAN.

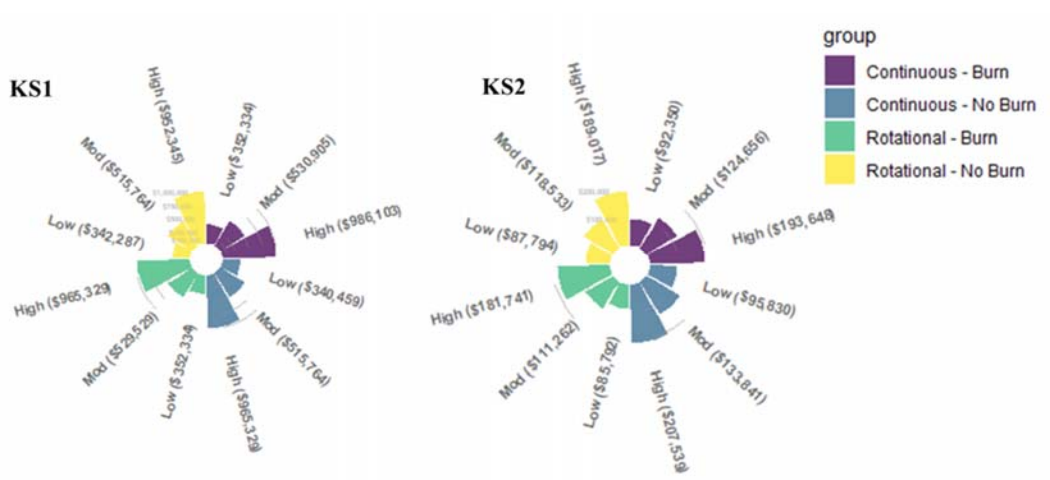


Figure 16. Value-added impacts for each management scenario at each study site from IMPLAN.

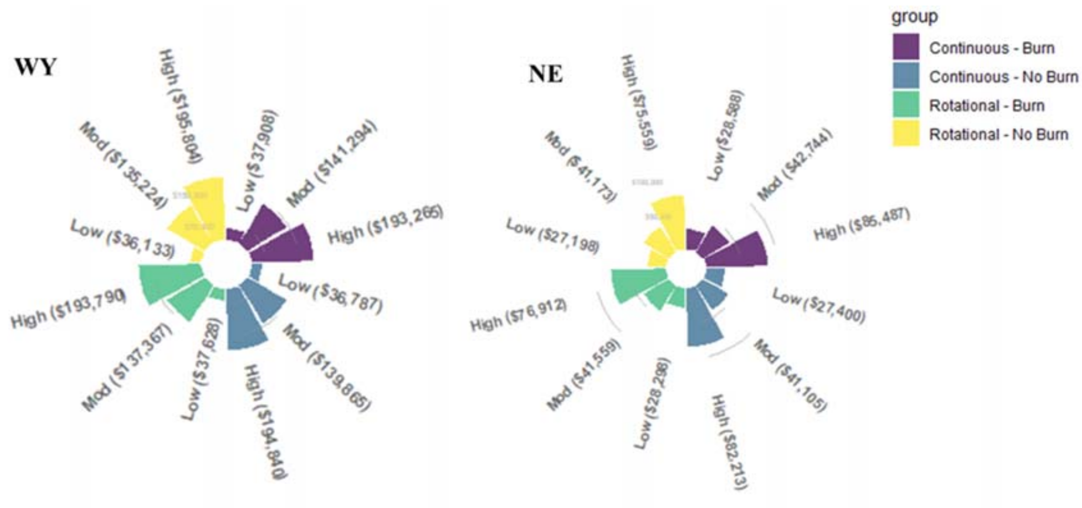
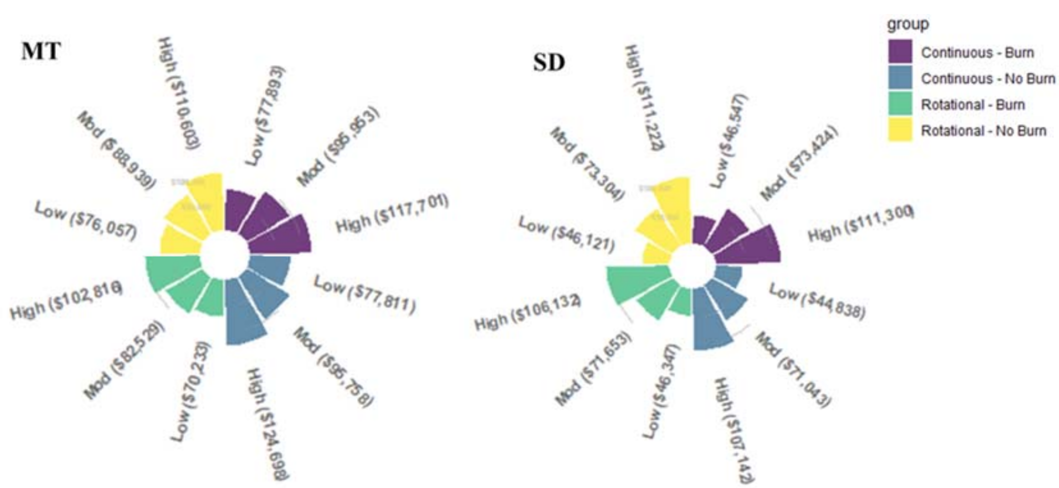
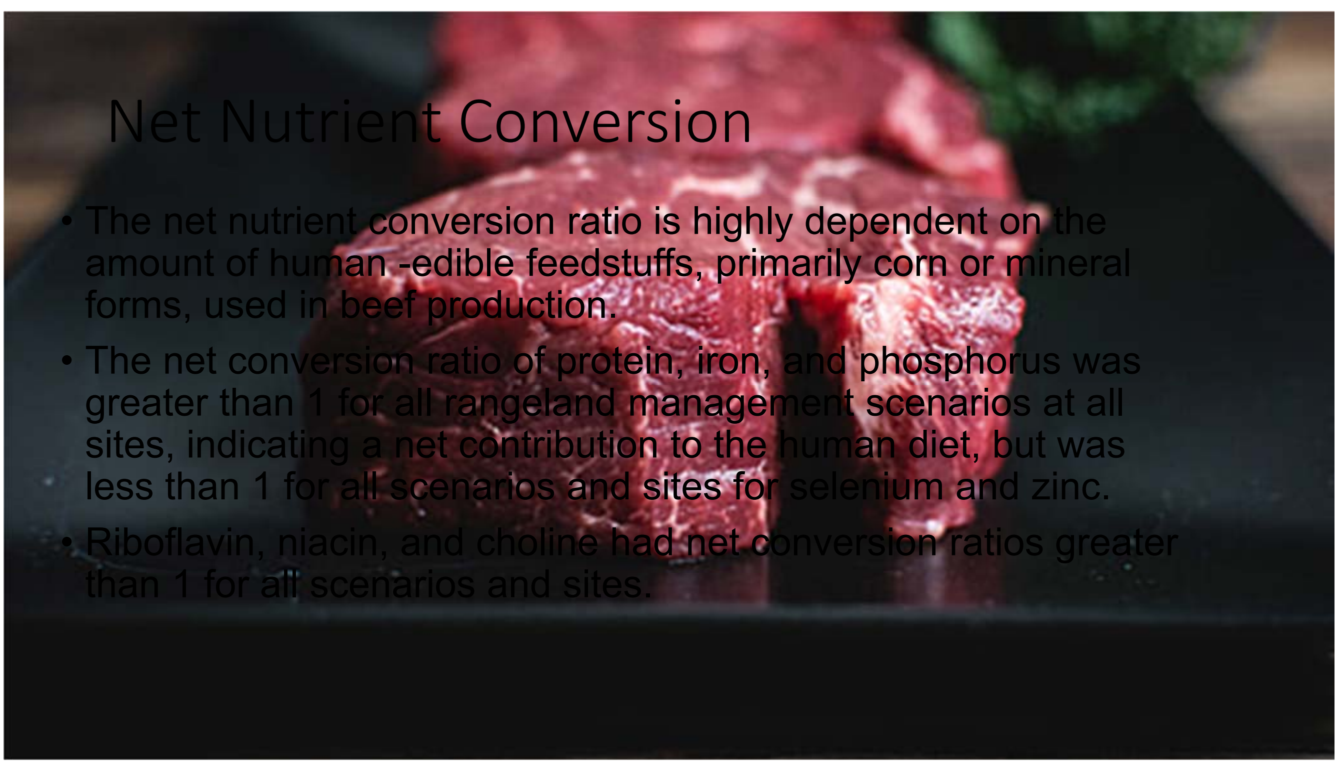


Figure 16. Value-added impacts for each management scenario at each study site from IMPLAN.



Economic Impacts – Management Scenario with Highest Impacts

Location	Impact	Fire Regime	Grazing Management	Stocking Rate
KS1	Employment	Spring Burn	Rotational	High
	Economic	Spring Burn	Continuous	High
KS2	Employment	No Burn	Rotational	High
	Economic	No Burn	Continuous	High
WY	Employment	No Burn	Rotational	High
	Economic	No Burn	Rotational	High
NE	Employment	Spring Burn	Rotational	High
	Economic	Spring Burn	Continuous	High
MT	Employment	No Burn	Rotational	High
	Economic	No Burn	Continuous	High
SD	Employment	No Burn	Rotational	High
	Economic	Spring Burn	Continuous	High



Net Nutrient Conversion

- The net nutrient conversion ratio is highly dependent on the amount of human -edible feedstuffs, primarily corn or mineral forms, used in beef production.
- The net conversion ratio of protein, iron, and phosphorus was greater than 1 for all rangeland management scenarios at all sites, indicating a net contribution to the human diet, but was less than 1 for all scenarios and sites for selenium and zinc.
- Riboflavin, niacin, and choline had net conversion ratios greater than 1 for all scenarios and sites.

Sustainability Indicators

Pillar	Indicator	Metric
Planet	Soil Health	Soil erosion/sediment loss
		Change in soil carbon/organic matter
	Climate	Carbon dioxide equivalents intensity
		Blue water use
		Reactive nitrogen loss
	Biodiversity	Small mammal populations
		Number sm. mammal species identified
		Bird populations
		Number bird species identified
		Number plant species identified
Profit	Economic	Rancher income
		Induced/indirect economic impacts
People	Food Security	Net nutrient conversion ratios

Sustainability Indicators

Pillar	Indicator	Metric	Importance Score
Planet	Soil Health	Soil erosion/sediment loss	1.8
		Change in soil carbon/organic matter	1.8
	Climate	Carbon dioxide equivalents intensity	1.4
		Blue water use	1.4
		Reactive nitrogen loss	1.4
	Biodiversity	Small mammal populations	0.5
		Number sm. mammal species identified	0.5
		Bird populations	0.5
		Number bird species identified	0.75
		Number plant species identified	1.75
Profit	Economic	Rancher income	2
		Induced/indirect economic impacts	1
People	Food Security	Net nutrient conversion ratios	1

Sustainability Index – Final Values

No Burn

	Continuous			Rotational		
Item	**Low**	**Mod**	**High**	**Low**	**Mod**	**High**
KS1	1.47	1.93	1.79	0.74	1.07	1.11
KS2	1.66	2.08	0.9	0.6	0.83	-0.01
WY	0.33	0.09	0.37	0	-0.14	0.33
MT	1.14	1.48	1.33	1.04	0.8	0.76
SD	0.85	1.41	1.32	0.65	1.46	1.27
NE	1.67	2.05	2.1	0.95	1.56	1.71

Is grazing beef cattle in the Great Plains sustainable?

- When aggregated over all three pillars of sustainability, grazing beef in the Great Plains is sustainable.
- The effect of rangeland management practices on ranch and community economics (as well as other aspects of sustainability) is highly dependent upon geographic location.
- Future research could include additional management practices in model simulations and more extensive field research in each geographic region.


Questions?
Merri Beth Day
meday@ksu.edu
Dustin Pendell
dpendell@ksu.edu
AgManager.info