Rotational grazing in beef cattle pasture-based systems as a soil health practice to support climate change mitigation and biodiversity: protocol for a systematic review

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Author contributions

Lucia Sanguinetti: Protocol/ search strategy development, reviewer resolving conflict, manuscript preparation/revision

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Guillaume Lhermie: Project/student supervision, acquisition of funding, project administration,protocol and search strategy development, third reviewer resolving conflicts, and manuscript editing/revision

Registrations

The protocol will be archived in PRISM: the University of Calgary Digital Repository (http://prism.ucalgary.ca). The protocol will follow the Guidelines and Standards for Evidence Synthesis in Environmental Management. Version 5.1 (AS Pullin, GK Frampton, B Livoreil & G Petrokofsky, Eds, 2022)

Support

This research is funded by the Simpson Chair project, Simpson Centre, School of Public Policy, University of Calgary.

Amendments

In case any amendments are made to this protocol after its registration, they will be adequately documented in the systematic review as Protocol Deviations.

Abstract

Background: The rise in population and industrial practices are causing negative impacts on our environment, leading to climate change. This phenomenon triggers extreme weather events, increasing soil evaporation and lowering water availability for plants. It requires the attention of every economic sector, and agriculture has the potential to mitigate its effects. The Canadian government has recently launched the Sustainable Agriculture Strategy plan, whose goal is to encourage the use of eco-friendly practices and the implementation of new technologies. One of the strategies promoted is rotational grazing, for supporting soil health. Rotational grazing is a practice that involves residency and rest periods of pastures for grazing cattle. This study aims to conduct a systematic review to identify the current rotational grazing systems used worldwide and their impact on GHG emissions, biodiversity, soil health, and productivity. Our findings will inform the value of rotational grazing in beef systems in Canada. Evaluating the cost/benefit relationship of implementing recommended rotational grazing systems with different levels of intensification. Focusing on arid, semi-arid and continental climates, considering both tame and native grassland that pre-exist in Canada.

Methods: This systematic review will include all types of rotational grazing studies under beef grazing operations. As well as articles that estimate GHG emissions from native and tame pastures (Poaceae and Fabaceae) with any type of intensification, the climate of interest (continental, semi-arid, arid), relevant plant species to Canada, biodiversity, and *Bos Taurus* cattle population**.** If possible, articles will be included in a meta-analysis examining the impacts of the different rotational practices.

Keywords: ecosystem services, cattle, livestock grazing, greenhouse gas emission, biodiversity, carbon sequestration, legumes, forage and fodder crops, ruminants, carbon stock, intensive grazing, controlled grazing, management intensive grazing, rotational stocking, multi-paddock (MP) grazing, strategic-rest grazing, and adaptive multi-paddock grazing (AMP).

INTRODUCTION

Background

There is an expectancy that the global population will rise to 9.7 billion by 2050, boosting the whole food supply chain(1), which directly impacts the environment and has negative consequences for climate change (1) (2) (3). This causes frequent extreme weather events(4) and agricultural production has been damaged. To counter this, the government of Canada is developing a sustainable Agriculture strategy, supporting long-term vitality, in order to make the food system resilient and innovative, that focuses on our environment, society, and economy (1).

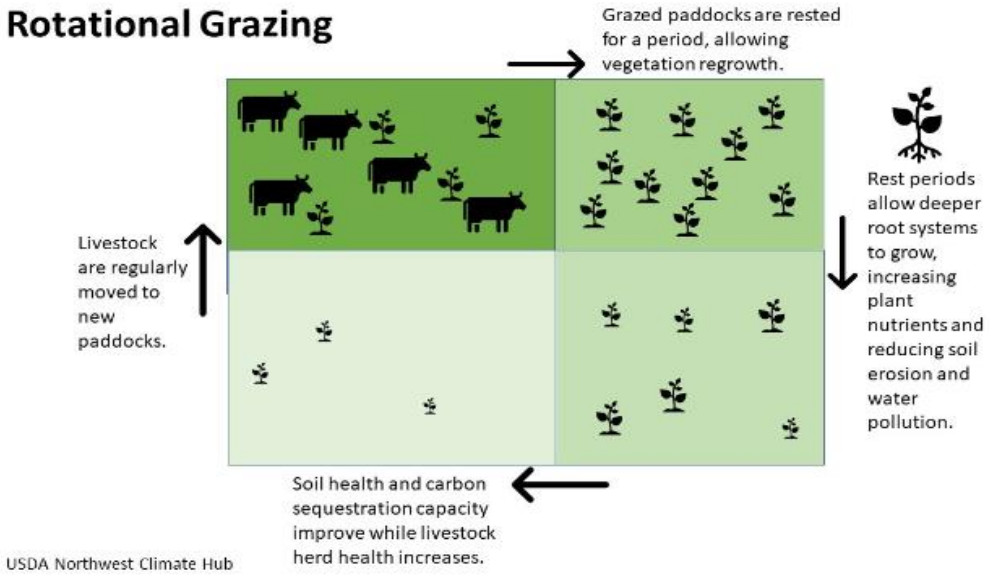
Decreasing greenhouse gas (GHG) emissions is a worldwide concern and priority in all sectors(5)(1). Agriculture is one of the main sources of Canada's total methane emissions, contributing approximately 30% (1). Ruminant production is responsible for significant greenhouse gas emissions internationally(6), livestock emits methane (CH_4) from enteric fermentation as well as both CH_4 and nitrous oxide (N_2O) from livestock manure management systems(7), and they occupy the highest percentage of CH_4 emissions in the Canadian agricultural sector (8).

Mitigation strategies for GHG emissions in the agricultural sector include several changes in farming operations and practices as well as the implementation of new technologies(9)(10)(11). Various strategies of forage and feeding or herd management can be included(3), and it is necessary to evaluate the entire production system as a whole, rather than individual activities (12) (10). The emission decrease strategies must be consistent with the economic viability of the

producer (9). Rotational grazing is a Best Management Practice (BMP) that consists in changing livestock from paddock to paddock, allowing rest and residency periods for improving forage quantity and quality (13)(14). Moderate intensification of livestock might be an effective strategy to mitigate GHG emissions(15). Although intensive production systems decrease methane emission intensities, they can increase N2 O and CO2 emissions (16). Therefore, an equilibrium must be established when utilizing technologies that mitigate GHG emissions.

Biodiverse ecosystems benefit agricultural production through nutrient cycling, soil formation, water purification, pest management (17) (1), and pollination. Other agricultural practices, such as the use of pesticides and herbicides, can also have an impact on biodiversity, large-scale pollination, and other ecosystem services(1) (18).

Promoting healthy soils is vital for Canadian sustainable agriculture(1), soil organic matter is an indicator of soil quality (1)(19). Increase in soil organic carbon can raise yield, plant growth, crop quality, and root growth. It can also increase resilience to drought due to higher nutrient and water-holding capacity, binds harmful substances (reduces toxicity) and acts as a storage reservoir for carbon dioxide (CO2), decreases erosion (1)(17)(20) as well as increases microbial biomass and microbial activity and protects water quality (19).



(21)

Objectives

The objective of the review is to evidence the impact of adopting RG as a beneficial management practice on the productivity and sustainability of beef farm systems within continental, arid or semi-arid climates.

METHODS

The methodology follows Guidelines and Standards for Evidence Synthesis in Environmental Management, Version 5.1 (22).

The systematic review will incorporate selected articles that include any type of rotational grazing and its effect on environmental factors (GHG emissions) or Soil health (Soil Organic Carbon, Carbon sequestration), or economic indicators (profit and productivity), or biodiversity

(Plant richness and diversity) restricted to semi-arid, arid or continental climate systems.

The review team will include four members including experts in rotational grazing (LS, MT, GL), beef cattle (GL, LS), and a librarian with experience in conducting systematic searches (HG).

The search question is defined using the PICOL format framework (Population, Intervention, Comparator, Outcomes, Location) (23).

Information sources

Articles must have complete text accessible in English and a publication date from 2006. To access the latest and updated estimation studies on greenhouse gas (GHG) emissions, it is essential to consider a commonly employed IPCC 2019 methodology, which builds upon the refinement of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (7).

The librarian (HG) will perform the literature search and import results into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia).

Population (P)	• beef cow-calf pairs or pregnant heifers
Intervention/Exposure(I)	• Grazing practices that involve rest and residency periods for livestock. • including overall management practices, livestock management, soil health management, and GHG emissions. • Include single or combination of plant species, and other BMP practices of RG.
Comparator (C)	• Between different types of rotational grazing systems and Continuous/extensive grazing.
Outcome (O)	• Soil health: Soil erosion, soil carbon/organic matter and C sequestration, drought Resilience and soil temperature • Climate indictor: CH4, NO2, C02 and C02 equivalent intensity • Biodiversity: Plant richness and diversity • Economic: Gross and Net Present Values • Policy implications
Location(L)	• Continental climate, semi-arid or arid worldwide. • Dry and humid in summer, dry and cold in winter. • Rain in spring and summer, very low precipitation in winter. • Köppen-Geiger classifications Cfb and CFc

The following databases will be searched:

- CAB Abstracts (Ebsco platform)
- Environment complete (Ebsco platform)
- BIOSIS previews (Web of Science platform)
- Web of Science Core Collection – Science Citation Index and Emerging Sources Citation Index (Web of Science platform)

Keywords and controlled vocabulary terms will be searched for the following concepts: rotational grazing, beef cattle. A complete search strategy for CAB Abstracts can be seen in Appendix A. This search will be translated to the vocabulary and syntax of the other databases.

Review question

What impact does the adoption of rotational grazing practices as a beneficial management strategy have on the efficiency and ecological aspects of beef cow-calf pair farms?

Eligibility criteria

Inclusion Criteria

The inclusion criteria have been categorized into eight sections: GHG emissions, climate of interest, rotational grazing, soil health, management, biodiversity, economic and publication source. Studies should at least include climate of interest, publication source and rotational grazing in order to be considered part of this study. May include another or multiple categories. Term variations will be accepted.

1- <u>GHG emissions</u>
-GHG emissions (CO_2, CH_4, NO_2)
- carbon sequestration, soil organic carbon stock
- total pasture emissions (including labor practices)
- tame pastures and/or legumes
- native pastures and/or legumes

2- <u>Climate of interest</u>
- Arid/Semi-arid areas
- Continental climate
- Köppen-Geiger classifications Cfb and CFc

3- <u>Rotational grazing:</u>
- Best Management Practices
- infrastructure- fencing- water supply
- number of animals with available forage supply
- forage growth: pasture quality and forage biomass
-forage potential

4- <u>Soil health</u>
- soil cover
- erosion
- soil organic carbon (SOC)
- soil organic matter
- Root biomass and root depth
- Drought Resilience and soil temperature

5- Management
   - Stocking density
   - period grazing and rest per paddock (rest and residency periods). Grazing ratio
   - Animal weight gain and animal production
   - Herd-grazing management

6- Biodiversity
   - Soil beneficial organisms
   - Mixed pastures or mixed forage systems
   -Conservation planning: species and vegetation types in the planning area.
   -Conservation targets
   -plant richness and diversity

7- Economic
   - Gross value
   - Net Present Value (NPV)
   - Sanitary, management, infrastructure costs
   -policy implications and recommendations

8- Publication source:
   Published in a peer review journal

Exclusion Criteria

1- Full text not available in English
2- Article published prior to 2006
3- Not related to rotational grazing
4- *Bos taurus indicus* or hybrids- Zebu, Nelore, Brahman, Braford, Brangus, etc.
5- Dairy cattle
6- Tropical and semi-tropical regions
7- Plant or animal species non-existing in Canada

Study records

Data management

Relevant articles will be imported into Covidence (HG), and all duplicates will be eliminated using the software. All collected studies will go through two independent stages. The screening team includes two independent reviewers (LS and MT) and a third reviewer (GL) that will resolve the conflicts between them. All investigations that comply in the first stage of inclusion criteria will continue to the second stage and later to the data extraction process. The first stage focuses on the title and abstract screening and the second is the full-text screening.

First stage: Title and abstract screening

Reviewers only read the title and abstract on this first stage. And go through the first 3 questions on the bellow order.

1) Is it available in English and is full text?
2) Was the study published in a peer-reviewed journal?
3) Does it refer to any rotational grazing practice or system?

There are three possible answers to above questions: YES, NO or UNCERTAIN. Studies that both reviewers agree as YES will continue to the second stage of screening. On the other hand, when both agree as NO they will be excluded from our study. If both agree as UNCLEAR the paper will pass to the next phase. In the case there is a conflict within both reviewers, the third reviewer will discuss with the whole team.

Second stage: full text screening

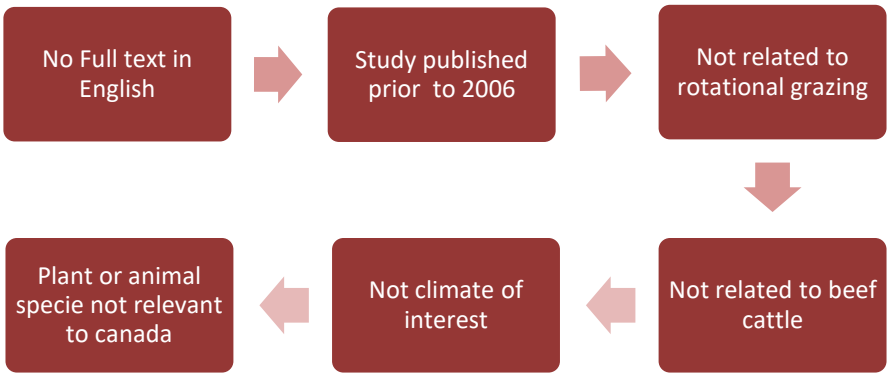
The full-text screening will be done emphasizing the methodology and results section.

1) Is the study relevant to rotational grazing in beef cattle?
2) If it includes GHG emissions, is the 2006 IPCC methodology or updates used?
3) Does the article report mention an environmental, biodiversity or economic rotational grazing practice?
4) Does the article include certain practice for Canada's farming implementation?

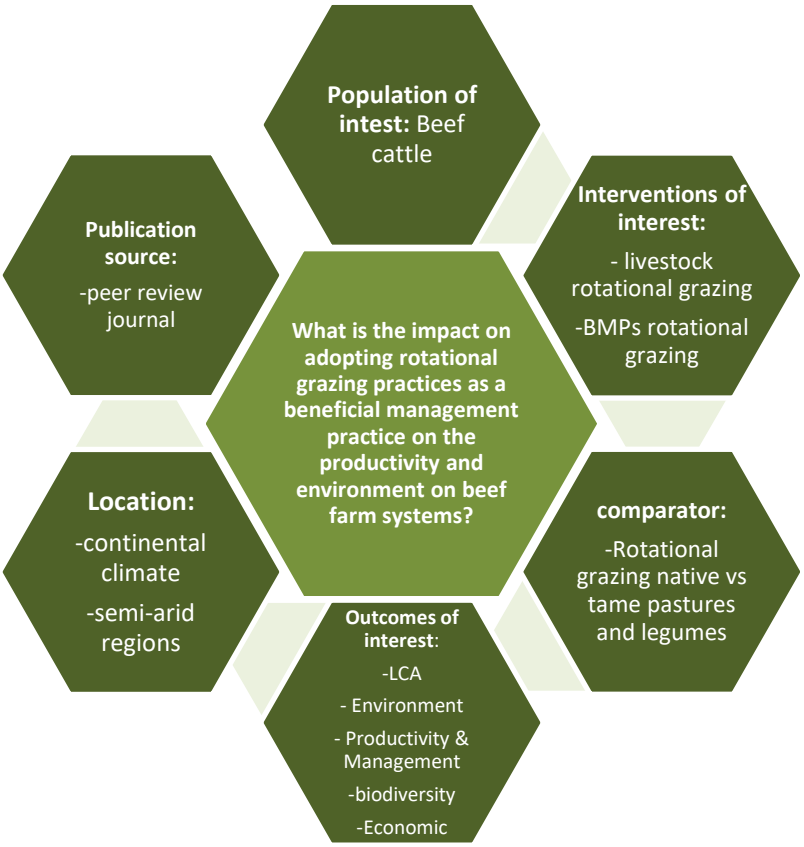
All studies that include YES or combination of YES and UNCLEAR will be included and continue to the Data extraction phase. NO articles will be excluded. Conflicts will include the opinion of the third reviewer.

Screening Criteria for a Systematic review

Exclusions



Interest


Population of intest: Beef cattle
Interventions of interest:
- livestock rotational grazing
-BMPs rotational grazing
comparator:
-Rotational grazing native vs tame pastures and legumes
Outcomes of interest:
-LCA
- Environment
- Productivity & Management
-biodiversity
-Economic
Location:
-continental climate
-semi-arid regions
Publication source:
-peer review journal
What is the impact on adopting rotational grazing practices as a beneficial management practice on the productivity and environment on beef farm systems?

Data extraction

The studies approved will be extracted using Covidence Extraction tool and exported into Microsoft Excel 365 (Microsoft Corporation, Redmond, WA).

Data extraction depends on the focus of each article (GHG emissions, BMP rotational grazing, management of pasture, soil or biodiversity).

The data to be extracted will include:

- **Bibliographic information:** Title, authors, journal name, country, published date, funding information.
- **Study design:** type of study, sample size.
- **Description of rotational grazing:** intensive/extensive or semi.
    - Location/Province- Country
    - Description of rotational system, livestock density- stocking rates, infrastructure.
    - Livestock characteristics and productivity: breed, category, livestock liveweight gain, dry matter intake
    - grassland characteristics: plant species, yield, root depth, rest and residency periods, forage biomass and quality, forage potential
    - Biodiversity: Soil beneficial organisms. diversity and richness of plant species identified
    - Soil: soil type, soil organic carbon (SOC), soil organic matter, root biomass, Carbon sequestration, drought Resilience and soil temperature
    - GHG: CO2 eq, N02, CH4, CO2
    - Economic: gross and Net Present Values. Policy implications and recommendations.

- **Outcomes:** Environmental, biodiversity and economic impact will be the main outcome of interest.
    - Climate indictor: CO2 eq, N02, CH4, CO2
    - Soil health: Soil erosion/sediment loss; soil carbon/organic matter. C sequestration. Drought Resilience and soil temperature
    - Grassland: Biomass and forage potential, resting periods according to specie recomendations
    - Biodiversity: soil beneficial organisms. Plant diversity and richness
    - Animal productivity: livestock liveweight gain (Kg/period) and per ha, stocking rates, dry matter intake
    - Economic: gross and Net Present Values. Policy implications and recommendations

Risk of Bias Assessment

The screening team includes two independent reviewers (LS and MT) and a third reviewer (GL) that will resolve the conflicts between them.

Information bias

Related to factors of precise information.

1) Does the article specify the plant(s) specie(s) of interest (*Poaceae or Fabaceae*)?
2) Does the study define correctly the level of intensification of the rotational grazing system?

Data synthesis

A narrative synthesis will be constructed based on the data collected. A Meta-analysis will be executed if the data is homogeneous and sufficient.

CONCLUSIONS

The objective of this systematic review is to examine the literature available on rotational grazing and impacts on mitigation of climate change in beef farms. This will help the Canadian sustainable Agriculture strategy to quantify rotational grazing as a soil health practice and climate change mitigation strategy considering the economic and biodiversity perspective. This systematic review will suggest gaps of information that require more research in the future.

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APPENDIX A

CAB Search strategy

This strategy will be translated to syntax and vocabulary of the other databases mentioned in the Methods.

CAB Abstracts search (Ebsco platform, no date restrictions)
Date run: March 24, 2023

Search#	Query	Results
S1	DE “beef cattle” OR DE “beef herds” OR DE “suckler herds”	29,399
S2	TI (beef OR suckler* OR cattle OR cow* OR “cow-calf”) OR AB (beef OR suckler* OR cattle OR cow* OR “cow-calf”	472,219
S3	S1 OR S2	475,068
S4	((DE “controlled grazing” OR DE “grazing intensity”) OR (DE “rotational grazing”)) OR (DE "strip grazing" OR DE "mixed grazing"	5,960
S5	TI ("rotational grazing "OR "controlled grazing" OR "continuous grazing" OR "strip grazing" OR "mixed grazing") OR AB ("rotational grazing" OR "controlled grazing" OR "continuous grazing" OR "strip grazing" OR "mixed grazing")	4,472
S6	S4 OR S5	8,623
S7	S3 AND S6, Limiters - Publication Year: 20060101-20231231	1,434