BC Agricultural Climate Adaptation Research Network

September 2021

# Summary of Research on Management Practices for Climate Change Mitigation

## Grazing & Range Management

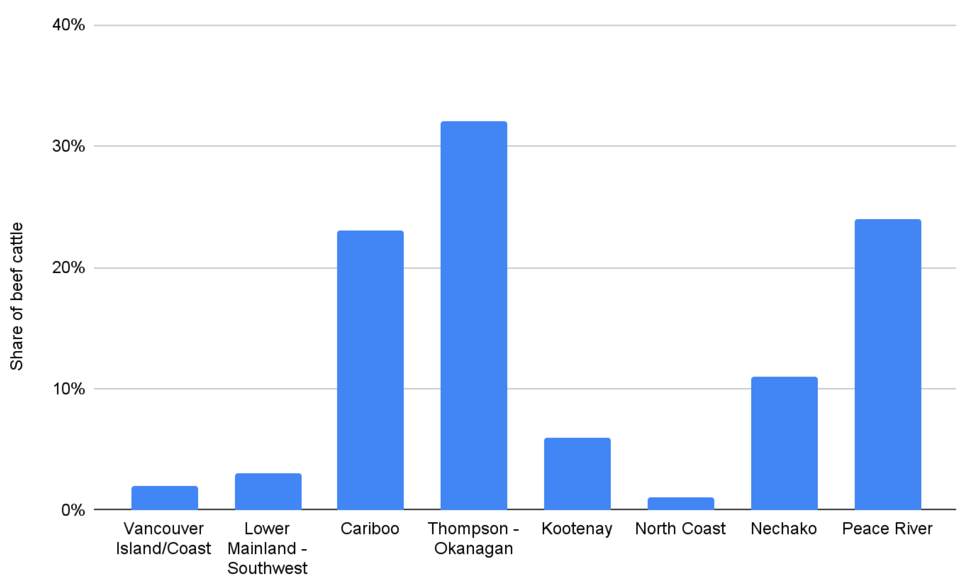
### SCOPE

This document is a high-level overview of recent, primarily BC-based, published research and research in progress investigating management practices with potential to mitigate climate change. Many practices are in early stages of evaluation for their impacts to carbon (C) sequestration and/or greenhouse gas emissions (primarily $N_2O$), and/or have not been trialled in the BC context. Therefore, the objective of this research summary is to provide a brief overview of what research has been done, where it took place, and a short description of key methods and results. This review does not include an exhaustive inventory of relevant research outside of BC. It is intended to provide an introduction to past research and research in progress.

### OVERVIEW

Grazing and land management occur on both crown and private land and includes both natural land for pasture (1.4 million hectares) and tame or seeded pasture (226,000 ha). Grazing of beef cattle predominantly takes place in the Thompson-Nicola, Cariboo-Chilcoltin, Omineca, and Peace regions, with some in the Kootenay region. Relevant management practices are described in Table 1, and the distribution of beef cattle by region is shown in Figure 1.

**FIGURE 1: Regional distribution of Beef Cattle in BC, 2018**



### TABLE 1: MANAGEMENT PRACTICE DESCRIPTIONS and MITIGATION POTENTIAL

| Management Practice Area | Description and Potential for Climate Change Mitigation |
|---|---|
| **Organic amendments and/or fertilizing** | Applications of carbon-based amendments (i.e. biosolids, compost) to increase soil C, possible impacts to $N_2O$ emissions. |
| **Grazing management** | Timing and intensity of cattle grazing on pasture lands; typically rotational grazing (also known as mob grazing or management intensive grazing) is intended to increase soil C, but will also impact $N_2O$ emissions. |
| **Grassland seeding** | Reseeding/interseeding natural grazing lands with grass and legumes, typically with re-seeding methods that minimize soil disturbance. Intended to increase soil C, possible impacts to $N_2O$ emissions. |
| **Agroforestry (excluding hedgerows and riparian buffers)** | Integrating forestry (woody perennials) and grazing systems. Includes silvopasture. For the purpose of this document, hedgerows / riparian buffers are considered in their own research summary. |

## RESEARCH SUMMARY: HIGHLIGHTS and GAPS

### RESEARCH HIGHLIGHTS

#### Organic amendments and/or fertilizing

- Using predictions from the Holos model, cattle grazing in the Lac Du Bois grasslands would become a C sink by re-seeding with alfalfa and crested wheatgrass. However, the model was not able to account for the fossil fuel consumption associated with the production of seeds and re-seeding. Using the same model, combining reseeding with fertilization (nitrogen and phosphorus) was predicted to increase C sequestration potential; this accounting included increased $N_2O$ emissions from fertilizing, but should not be considered a life cycle analysis (i.e. considering emissions from production, transport, and application of fertilizers).
- One field study did not find differences in soil C 14 years after a one-time application of biosolids to ungrazed rangeland.

#### Grazing management

- In an observational study of 6 ranches using intensive grazing (implemented one to 23 years prior to soil measurements), intensive grazing increased soil C in the 10-20cm and 20-30cm depths, but not the 0-10cm depth. Comparisons were made between rotationally grazed areas and paired comparisons where extensive grazing was still being used at the same ranch site.
- One study found higher soil C in pastures grazed in the fall vs. spring.
- A newly developed model for remote detection of changes in soil C did not find differences in soil C between grazed vs. ungrazed exclosures.

### Grassland seeding

- See the first bullet point in the 'Organic amendments and/or fertilizing' section above

### Agroforestry (excluding hedgerows and riparian buffers)

- At a site in Kelowna, a 45-year lodgepole pine stand was strip-thinned (harvested strips), planted with an agronomic seed mix, and grazed for the following two summers. Soil C did not change between the harvested and grazed strips and the un-harvested control plots. Within treatments, the 10 and 15m strips had higher soil C than the 20m strips, but none were different than the control.

### RESEARCH GAPS

- Overall, there has been limited research in BC, with a lack of long-term controlled studies.
- All field studies have focused on impacts to soil C; $N_2O$ emissions also need to be considered and field tested.
- There are potential opportunities for layering management practices (i.e. reseeding plus rotational grazing) that should be explored.

### TABLE 2: RESEARCH HIGHLIGHTS

| Management Practice Area | Research Highlights [c] | Research Limitations |
|---|---|---|
| **Organic amendments and/or fertilizing**<br><br>**[TN, 1, 2*]**<br>**[CC, 1, 1*]** | **Lac du Bois, modelling cattle grazing emissions with Holos [G2]**<br>The Holos model predicted that the cattle grazing system's net emissions (CO2e per grazing season) would be changed from a positive (C source) to a negative (C sink) by implementing no-till reseeding with alfalfa and crested wheatgrass. The model was not able to account for the fossil fuel consumption associated with production of seeds and re-seeding.<br>Combining reseeding with fertilization (nitrogen and phosphorus) was predicted to increase C sequestration potential; this accounting included increased $N_2O$ emissions from fertilizing, but should not be considered a life cycle analysis (i.e. considering emissions from production, transport, and application of fertilizers).<br><br>**Cariboo-Chilcotin, biosolids, 14yrs [G7]**<br>A one-time application of biosolids to ungrazed (with fenced exclusion) rangeland did not change soil C at follow-up 14 years later. However, biosolids increased grass biomass and protein production (although lower protein percent)<br><br>***<u>Research in Progress:</u>***<br>**Princeton (1 site) and Kamloops (1 site), restoring native grassland, 1+ yrs [*G7]**<br>Treatments: three different biosolid rates plus control, and two different cover crop treatments: 1. Annual rye grass, 2. Annual rye grass clipped and re-seeded with native plants<br>Measuring: Soil C, other soil chemical properties<br><br>**Kamloops (1 site), priority effects in grasslands, 1 yr [*G8]**<br>Treatments: three amendments (straw matting, biochar, straw/biochar mix) plus control, and 3 plant sowing orders (with annual ryegrass, perennial, and mix of native species)<br>Measuring: soil C, plant community<br><br>**Clinton (1 site), biosolids and grazing, 1 yr [*G9]**<br>Treatments:1. biosolids applied 20 years ago, 2. Grazing, 3. Drought treatment (rain-out shelters)<br>Measuring: soil C, vegetation | • Lacking studies measuring impacts $N_2O$ emissions (together with soil C and production |
| **Grazing management**<br><br>**[CC, 2, 1*]** | **Cariboo-Chilcotin and Thompson-Nicola (6 ranch sites), rotational grazing [G1]**<br>In an observational study of 6 ranches having implemented intensive grazing (one to 23 years prior to soil measurements), intensive grazing increased soil C in the 10-20cm and 20-30cm depths, but not the 0-10cm depth. Comparisons were made between rotationally grazed areas and paired comparisons where extensive grazing was still being used at the same ranch site. | • Most studies limited to grazed vs. ungrazed instead of |

| | | |
|---|---|---|
| **[TN, 3, 3*]** | **Lac Du Bois (1 site), grazing management, 2 yrs [G4]**<br>Pastures grazed in the fall had higher soil C compared to pastures grazed in the spring.<br><br>**Cariboo-Chilcotin, Thompson-Nicola, Kootenay (65 sites), field/model [G5]**<br>A newly developed model for remote detection of changes in soil C did not find differences in soil C between grazed vs. ungrazed exclosures.<br><br>***<u>Research in Progress:</u>***<br>**Merritt (1 site), intensive grazing, 2 yrs [*G6]**<br>Treatments: 1. Ten cow-calf pairs for one day, compared to 2. one cow-calf pair for ten days<br>Measuring: soil C, plant biodiversity, knapweed plant traits<br><br>**100 Mile (1 site) and Quesnel (1 site), pasture rejuvenation, 3 yrs [*G10]**<br>Treatments (applied to native grassland): grazing treatments 1. Grazed, 2. Ungrazed; brushing treatments: 1. Brushed, 2. Non-brushed; seeding treatments: 1. Seeded with agronomic and native species, 2. Unseeded.<br>Measuring: soil C, vegetation<br><br>**Thompson Nicola (~50 sites), grazing intensity trials, 1 yr [*G11]**<br>Observational study using gradients moving away from water sources as proxies for grazing intensity<br>Measuring: soil C, microbial analysis, vegetation<br><br>**Thompson Nicola (12 to 16 sites), range reference study, 1 yr [*G12]**<br>Treatments (installed in 2005): 1. Inside exclosures (ungrazed), and 2. Outside exclosures (grazed)<br>Measuring: soil C, microbial data, vegetation | enhanced management<br><br>● Research on intensive grazing is observational, lacking well-defined controls and treatments<br><br>● Lacking studies measuring impacts $N_2O$ emissions (together with soil C and production) |
| **Grassland seeding**<br><br>**[CC, 1*]**<br>**[TN, 1, 1*]** | **Lac du Bois, modelling cattle grazing emissions with Holos [G2]**<br>The Holos model predicted that the cattle grazing system's net emissions (CO2e per grazing season) would changed from positive (C source) to negative (C sink) by implementing no-till reseeding with alfalfa and crested wheatgrass. The model was not able to account for the fossil fuel consumption associated with production of seeds and re-seeding.<br>Combining reseeding with fertilization (nitrogen and phosphorus) was predicted to increase C sequestration potential; this accounting included increased $N_2O$ emissions from fertilizing, but should not be considered a life cycle analysis (i.e. considering emissions from production, transport, and application of fertilizers).<br><br>***<u>Research in Progress:</u>***<br>**Kamloops (1 site), priority effects in grasslands, 1 yr [*G8]**<br>Treatments: three amendments (straw matting, biochar, straw/biochar mix) plus control, and 3 plant sowing orders (with annual ryegrass, perennial, and mix of native species) | ● Limited data from one modelling study; requires robust field validation |

| | | |
|---|---|---|
| | Measuring: soil C, plant community<br><br>**100 Mile (1 site) and Quesnel (1 site), pasture rejuvenation, 3 yrs [*G10]**<br>Treatments (applied to native grassland): grazing treatments 1. Grazed, 2. Ungrazed; brushing treatments: 1. Brushed, 2. Non-brushed; seeding treatments: 1. Seeded with agronomic and native species, 2. Unseeded.<br>Measuring: soil C, vegetation | |
| **Agroforestry (excluding hedgerows and riparian buffers)**<br><br>**[OK, 1]** | **Kelowna (1 site), grazing strip-thinned silvopastures, 2 yrs [G3]**<br>A 45-year lodgepole pine stand was strip-thinned (harvested strips), planted with an agronomic seed mix, and grazed for the following two summers. Soil C did not change between the harvested and grazed strips and the un-harvested control plots. Within treatments, the 10 and 15m strips had higher soil C than the 20m strips, but none were different than the control. | • Limited data from one short-term study |

[a] [Agricultural region [b], number of studies in the region]
[b] BC Agricultural Regions: Vancouver Island/Coast (VC), South Coast (SC), Cariboo Chilcotin Coast (CC), Thompson Nicola (TN), Okanagan (OK), Kootenay (KT), Omenica Skeena (OS), and Peace (PC)
[c] References include both peer-reviewed publications and Master's theses and can be found in the published research and research in progress spreadsheets
* Research with an asterisk (*) is in progress or manuscripts in prep


## Acknowledgements

*This research summary was prepared by Amy Norgaard and the BC Agricultural Climate Adaptation Research Network (ACARN) technical working group on climate change mitigation. ACARN would like to thank those who shared information about their previous and continuing research projects.*

*This project was supported by the Investment Agriculture Foundation of BC, with funding provided by Agriculture and Agri-Food Canada programs.*