Potential of Rangelands to Sequester Carbon in Alberta

Report Summary

The following is a summary of the report "Potential of Rangelands to Sequester Carbon in Alberta," prepared by Eric Bremer, PhD, P Ag, for Alberta Sustainable Resource Development.

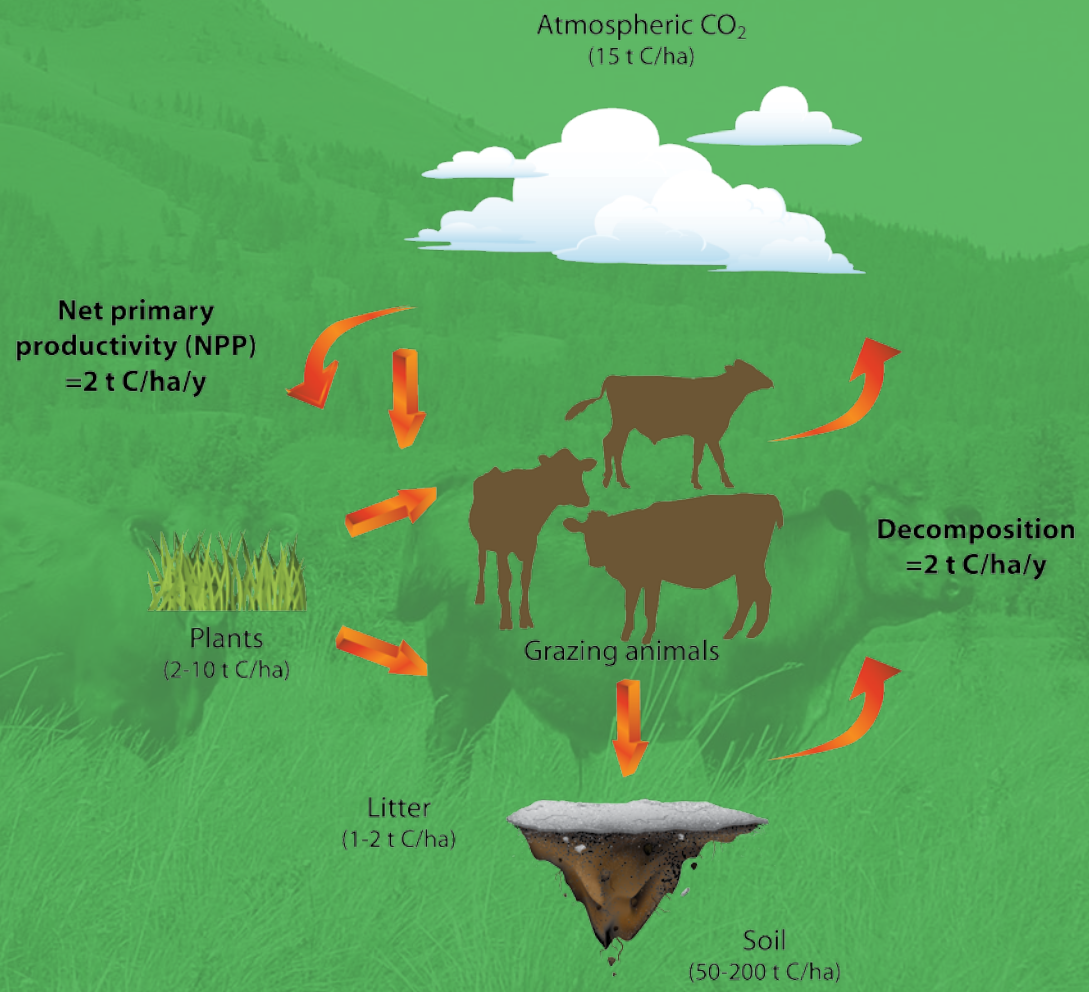
The intent of this summary is to provide a brief overview of the report's findings. Readers wanting more detailed information are referred to the original.

Government of Alberta

Report Background

International concern about greenhouse gases and their impacts on climate change has added to the need for increased understanding of carbon sequestration in rangelands. Simply defined, carbon sequestration is the process of capturing and storing carbon before it enters into the atmosphere.

Recently, a growing market for carbon credits has spurred interest in rangeland carbon sequestration projects and their potential economic upside. This has occurred largely because of the relatively low cost of achieving increased soil carbon storage. At the same time, however, documenting and verifying changes in carbon storage is proving very difficult. The success of rangeland carbon storage in the marketplace will depend on whether reliable, accurate measures of increases in carbon storage can be achieved.



Carbon Flow Diagram Carbon flows in a typical Alberta rangeland. Small amounts of carbon may also be lost via animal weight gain, soil erosion and leaching.

Current Levels of Carbon Storage In Alberta Rangelands

The organic carbon stored in Alberta's rangelands is equivalent to about three times the annual emissions of all greenhouse gases in Canada.

One hectare of rangeland contains 50 to 200 tonnes (t) of carbon in soil organic matter (to 0.3 m), 2 to 10 t carbon in plant biomass, and 1 to 2 t carbon in litter.

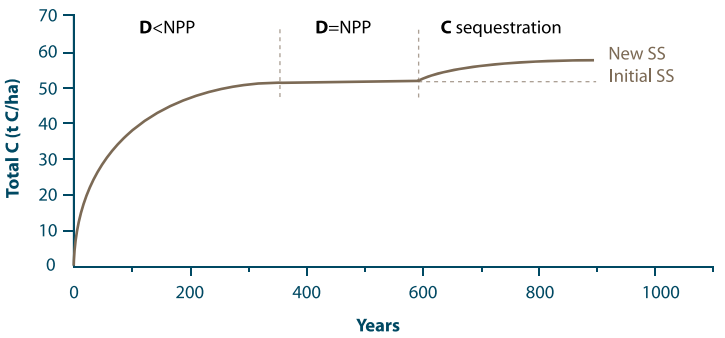
The total amount of carbon in an ecosystem (the carbon inventory) is a function of the historical relationship between plant growth (net primary productivity or NPP) and decomposition.

When the rate of plant growth is higher than the rate of decomposition, carbon accumulates in an ecosystem.

However, the more carbon there is in the system, the more decomposition occurs. Eventually, carbon losses and carbon gains become roughly equivalent and a constant value or steady state is achieved.

The length of time it takes for an ecosystem to achieve a steady-state carbon level depends on the lifespan of the carbon compounds within it. Soils contain a mixture of organic materials with lifespans ranging from a few hours to several centuries.

Carbon Dynamics Diagram
Simple model illustrating carbon dynamics in a rangeland ecosystem. During soil formation, net primary productivity (NPP, 3 t C/ha/y in example) exceeds decomposition (D) and total soil carbon increases until D ≈ 3 t C/ha/y and total C is at steady state (SS). A 10% increase in NPP at year 600 increases total C by 10% over a 200-year period (C sequestration).



Three Approaches to Increasing Carbon Storage in Rangelands

Recently, the question has been asked, Can Alberta rangelands be managed to store more carbon? Based on current research, the answer to this question is "yes," although to what extent depends on the management approach. Not all management approaches are equally effective.

Three possible management approaches to increasing the carbon storage capacity of Alberta rangelands have been examined:

1. **Converting marginal cropland to rangeland**
2. **Improving grazing management practices to restore rangeland health**
3. **Improving typical grazing practices (e.g., rotational or complementary grazing)**

All three of these management approaches are based on either increasing net plant production or decreasing decomposition. By doing either, it is possible to elevate the steady-state level of organic carbon in a rangeland ecosystem, thereby increasing the amount of carbon stored in the land.

CONVERTING MARGINAL CROPLAND TO RANGELAND

Converting marginal cropland or extremely degraded rangelands to well-managed rangelands has proven to be the most promising method of increasing carbon storage.

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Samples from 72 Alberta farms show that converting native vegetation to cropland reduces organic carbon levels by an average of 33 tonnes of carbon/hectare (t C/ha). Assuming pre-cultivation carbon levels can be achieved, this same amount of carbon (33 t C/ha) could potentially be restored to the land.

An important point to add is that potential to increase soil carbon increases with moisture. Potential gains in the brown soil zone are approximately 10 t C/ha, while potential gains in the black soil zone are 30 to 40 t C/ha.

IMPROVING GRAZING MANAGEMENT PRACTICES TO RESTORE RANGELAND HEALTH

Compared to converting cropland to rangeland, improving grazing management practices to restore rangeland health has shown much less potential to increase carbon storage in rangeland.

In studies, even extreme changes in grazing practices, such as installing exclosures (areas from which cattle are excluded), have had relatively small impacts on organic carbon levels.

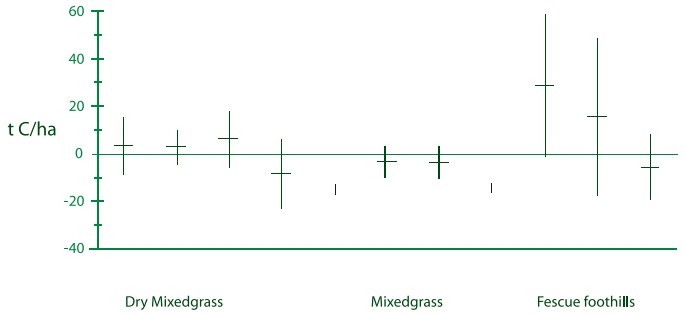
The exact impacts of grazing on rangeland carbon levels are not easy to predict. A review of 236 studies found that grazing had almost equally positive and negative effects on carbon levels.

These inconsistent responses can be attributed to the complexity of rangeland systems.

While grazing generally inhibits plant growth by reducing the plant biomass capable of photosynthesis, under certain conditions moderate grazing has been found to promote plant growth by enhancing nutrient availability and changing the plant community structure.

In the dry Alberta prairie, early studies seemed to show that heavy grazing increased soil carbon levels. Over time, however, more precise measurements showed that carbon was merely being redistributed in the soil, as deep-rooted species gave way to shallow-rooted ones.

Appropriate grazing practices improve rangeland health and sustainability. However, the potential to increase carbon storage by improving grazing management practices is low, and any small carbon gains that might result from doing so are difficult to detect.



Grazed vs. Ungrazed Diagram Gain in total organic carbon in ungrazed exclosures compared to adjacent areas with moderate grazing at nine sites in southern Alberta (derived from Henderson 2000).

A lightly grazed treatment (left) versus a heavily grazed treatment (right). Grazing has been shown to have almost equally positive and negative effects on soil organic carbon storage levels. It should be noted, however, that reductions in rangeland health can negatively affect many other values and functions.

Compared to converting cropland to rangeland, improving grazing management practices has shown much less potential to increase carbon storage in rangeland.

IMPROVING TYPICAL GRAZING PRACTICES

Improving typical grazing practices (e.g., employing rotational or complementary grazing) also appears to have limited potential to increase carbon storage in rangelands.

Rotational grazing is the practice of frequently moving livestock between subdivisions of a pasture to achieve optimum vegetation use. Research shows the impact of rotational grazing on carbon levels depends on the stocking rate and site conditions of the rangeland. When rotational grazing is employed under high stocking rates, range health declines and soil organic carbon concentrations decrease; the opposite occurs under low stocking rates.

Complementary grazing is the practice of grazing seeded pastures and native pastures in a rotational sequence. Estimates of its potential to increase carbon storage vary across different ecoregions and are very slight, with one study estimating potential carbon gains of 0.8 t C/ha over 30 years.

Considerations for Measuring Carbon Inventories

Detecting small changes in carbon levels against a large carbon background, and differentiating them from year to year fluctuations, is highly difficult. Intensive, well-designed sampling programs are required to accurately measure the small carbon level increases that might result from changes to grazing management practices.

When measuring carbon inventories, one needs to consider the following issues:

1. **Measurements need to be done based on area (t C/ha) rather than concentration (percentage of soil carbon).**
2. **When bulk densities vary between treatments, carbon inventories need to be expressed on an equivalent mass basis.**
3. **All types of organic carbon that are likely to persist need to be measured.**
4. **Sampling programs must be designed to measure small changes in carbon inventories of systems with a large carbon background.**
5. **Depth of sampling must be sufficient to account for variations in carbon distribution with depth.**
6. **Soil erosion events are hard to quantify and increase the difficulty of evaluating carbon inventories.**
7. **Background changes in carbon storage may interfere with measurements of treatment effects.**
8. **Since not all exported carbon is released as CO2, the fate of organic carbon exported in agricultural products also needs to be considered.**
9. **The impact of converting cropland on other gases that contribute to global warming (e.g., N_2O, CH_4) should also be considered.**

Conclusions

Increasing the amount of organic carbon stored in Alberta rangelands may be difficult because organic carbon levels are likely already near maximum steady-state levels.

Alberta rangelands already contain significant stores of carbon. The most certain and effective means of preserving the carbon stored in rangelands is to manage them well and maintain their health and function.

The most certain and effective method of increasing carbon storage is to convert cropland or extremely degraded rangelands to well-managed rangelands.

Validating increases in carbon levels is difficult because carbon gains are likely to be small and must be detected against a large, highly variable background.

The potential to increase carbon storage in rangelands through improved grazing practices is not as clear as the potential of converting cropland to rangeland.

Measuring the small carbon gains that might result from improving grazing practices requires intensive, well-designed sampling programs.

Suggestions for further reading

Colberg, T. J. 2007. Relationships between plant communities and soil carbon in the prairie ecozone of Saskatchewan. Ph.D. thesis, University of Saskatchewan, Saskatoon.

Bremer, E. 2009. Potential of Rangelands to Sequester Carbon in Alberta. Research Paper. Alberta Sustainable Resource Development, Lands Division. 8 pp.

De Steiguer, J.E., J.R. Brown and J. Thorpe. 2008. Contributing to the mitigation of climate change using rangeland management. Rangelands: June Issue, pages 7-11.

Dormaar, J. F. and Smoliak, S. 1985. Recovery of vegetative cover and soil organic matter during revegetation of abandoned farmland in a semiarid climate. J. Range Manage. 38:487-491.

Dormaar, J. F., Smoliak, S. and Willms, W. D. 1990. Soil chemical properties during succession from abandoned cropland to native range. J Range Manage. 43:260-265.

Dormaar, J. F., Adams, B. W. and Willms, W. D. 1994. Effect of grazing and abandoned cultivation on a Stipa-Bouteloua community. J. Range Manage. 47:28-32.

Dormaar, J. F., Adams, B. W. and Willms, W. D. 1997. Impacts of rotational grazing on mixed prairie soils and vegetation. J. Range Manage. 50:647-651.

Dormaar, J. F. and Willms, W. D. 1998. Effect of forty-four years of grazing on fescue grassland soils. J. Range Manage. 51:122-126.

Henderson, D. C. 2000. Carbon storage in grazed prairie grasslands of Alberta. M. Sc. thesis, Department of Renewable Resources, University of Alberta, Edmonton, AB.

Henderson, D. C., Ellert, B. H. and Naeth, M. A. 2004. Grazing and soil carbon along a gradient of Alberta rangelands. J. Range Manage. 57:402-410.

Janzen, H. H., Campbell, C. A., Gregorich, E. G. and Ellert, B. H. 1997. Soil carbon dynamics in Canadian agroecosystems, p. 57-80, in R. Lal, J. Kimble, R. F. Follett and B. A. Stewart, eds. Soil Processes and the Carbon Cycle. CRC Press, Boca Raton, FL.

McGill, W. B., Dormaar, J. F. and Reinl-Dwyer, E. 1988. New perspectives on soil organic matter quality, quantity, and dynamics on the Canadian prairies, p. 30-48 Land Degradation and Conservation Tillage. Proceedings of the 34th Annual Canadian Society of Soil Science/Agriculture Institute of Canada. Calgary, AB.

Web resources:

http://www.agr.gc.ca/pfra/land/fft1.htm

http://www.agric.gov.ab.ca/app21/rtw/index.jsp

Additional resources and publications available at:
www.srd.alberta.ca

For assistance by telephone, call:
310-0000 (toll free)

Alberta Sustainable Resource Development aims to ensure Alberta's public lands, including rangelands, are healthy, productive, and sustainable.

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