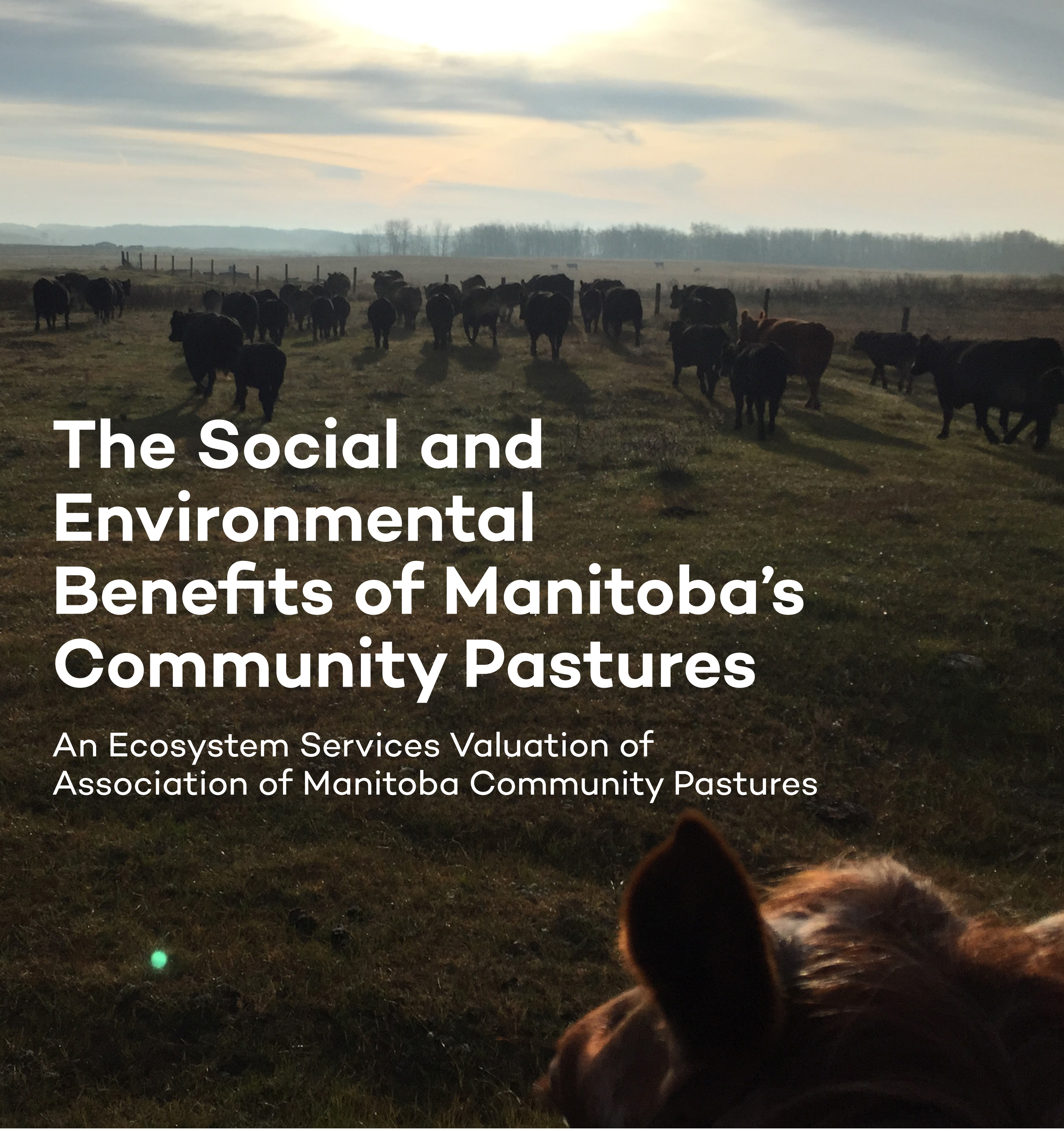

The Social and Environmental Benefits of Manitoba's Community Pastures

An Ecosystem Services Valuation of Association of Manitoba Community Pastures

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Association of Manitoba Community Pastures

The AMCP is a producer-led not-for-profit organization governed by an elected Board of patrons from pastures across the province. It was first organized by concerned pasture patrons in Manitoba after the federal government announced it would discontinue operating community pastures (formerly the Prairie Farm Rehabilitation Administration). The transition process is now complete and AMCP is operating 20 community pastures as of 2016.

The AMCP is committed to ensuring that Manitoba's community pastures continue to provide valuable grazing land for local cattle producers as well as protect some of the last remaining natural prairie ecosystems in the province. These two priorities can be reached at the same time: a well managed grazing rotation system removes woody growth and plant litter, allowing native prairie species to thrive.

The Manitoba Government lent its support by providing transitional funding as well as leasing provincial Crown Lands in community pastures to the AMCP, and, in exchange, the ACMP will manage the lands in accordance with the following objectives: utilize the resource to complement livestock production and to manage a productive, bio-diverse rangeland and promote responsible land use programs.

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Cover photo: Langford Community Pasture (AMCP)

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The project team acknowledges inputs from the Manitoba Forage and Grassland Association

Glossary

AMCP: Association of Manitoba Community Pastures

AUD: Animal Unit Days

AUE: Animal Unit Equivalents

CPs: Community pastures

CPP: Community pasture program

EGS: Ecological Goods and Services

Ha: Hectare (1 hectare = 2.47 acres)

MCPs: Manitoba Community Pastures

TEV: Total Economic Value

Tonne: Metric tonne (1 tonne = 1,000 kg = 2,204.62 lbs)

All monetary amounts are 2016 Canadian Dollars (CAD) unless otherwise specified.

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Executive Summary

This study summarized the benefits and related economic values from community pastures (CPs) managed by the Association of Manitoba Community Pastures (AMCP) in Manitoba, Canada. Based on data and information directly from the CPs and information available through a search of relevant literature, the total economic value (TEV) of Manitoba community pastures (MCPs) was calculated. Benefits that were not included in the TEV were highlighted as gaps that could be the focus of further research.

Based on available data and information, this research determined that the ecological goods and services from Manitoba community pastures is valued at $13,349,646 per year (based on a price of $25 per tonne for CO_2). The largest components of this value are forage production and carbon sequestration, and also include soil formation, biodiversity, recreation and hunting, community development, and timber. Some components—including species at risk, pollination and long-term carbon storage—were excluded due to insufficient data or significant variation across pasture landscapes. This value therefore represents an incomplete estimate of ecological goods and services from the Manitoba community pastures studied but does incorporate major service contributions.

Based on this research, the author's recommendations include the maintenance of CPs and the concentrated benefits that they provide producers and society. These large tracts of natural or naturalized land protect habitat, store carbon, and improve water retention and quality. There are gaps in existing research, data and information that inhibit more precise valuation of community pastures and grasslands in Western Canada. Current grazing management encourages sustainable delivery of commercial and non-commercial value to the landscape. At the same time, enhanced monitoring systems to qualify and quantify ecosystem goods and services benefits from pastures should be developed to measure and assess specific public benefits provided by community pastures. Quantification of total value of benefits informs policy and can help sustain community pastures in the future. Further examination of the relationships between management systems and their impacts and values would also improve our overall understanding of these valuable, but fast disappearing landscapes and provide more guidance into adaptive management.

Table of Contents

Context

Ecosystems are the basis for human life, livelihoods and economies. Indeed—the processes that make life possible are regulated by living systems. The continued health of these natural systems depends, in turn, on how humans use and care for them. The Millennium Ecosystem Assessment—a global study of the state of ecosystems conducted between 2001 and 2005— found significant loss of global biodiversity, significant increase in global atmospheric carbon emissions, and a significant loss of diversity in terrestrial biomes through land-use change, primarily to agriculture (MEA, 2005). Loss of temperate grasslands was associated with significant loss of habitat as well as pollution related to nitrogen and phosphorus (MEA, 2005).

While many landscapes are assessed in terms of commercial value, this perspective fails to capture the many ecosystem goods and services (EGS), or other benefits they provide, the quantities that they provide them in and their value to human communities. EGS considerations include not only benefits reflected in current markets, but others that we depend on or enjoy, but may not buy in a marketplace.

While these are not the only considerations for improved management, they play an important role in targeting investment, identifying management systems and improving ecosystem management and health.

Grassland Ecosystems and Benefits

Globally, temperate grasslands are considered one of the most altered ecosystems on the planet, with fewer than half remaining in an intact, natural condition (Heidenreich, 2009). Forty one per cent of the world's temperate grasslands are now agricultural lands, while another 13.5 per cent have been converted to urban, industrial and other land uses. A United States Geological Survey (USGS) study estimates 99.9 per cent of Manitoba's prairie grasslands have been lost (USGS, 1998).

Grassland provide us with a range of EGS; tangible benefits that we understand and only sometimes value in existing markets. The total economic value of grasslands includes their quantifiable market value to society, incorporating both "direct use" values of grassland commodities included in existing markets, and broader societal values that may not be captured in any market of formalized payment systems.

Well-understood benefits of grasslands include food, feed for forage livestock and wildlife, biodiversity, carbon storage, water management, and tourism and recreation (White, Murray, & Rohweder, 2000). Across the world, and particularly in parts of the North American prairies, commercial grazing of native and domestic herbivores on rangelands is necessary for the production and sale of meat, dairy, leather and other commodities. Other prominent benefits of grasslands include non-cultivated foods such as honey and berries, the biomedical use of vegetation, provision of genetic resources for relatives of crops and pasture plants, seed and biomass for restoration purposes, and recreational uses such as trails, ATVs, hunting and fishing. Grasslands store soil carbon, prevent erosion and nutrient runoff and improve the sustainability and resilience of agricultural systems more broadly. The extensive root systems of well-managed perennial forages and grasslands contribute very positively to water storage on the landscape thus reducing the risk of both floods and droughts. These root systems also improve soil health, thereby improving overall productivity. Finally, among the most prominent benefits of grasslands is their support for biodiversity. "Grasslands provide habitat for breeding, migrating, and wintering birds; ideal conditions for many soil fauna, and rangelands for wild herbivores" (White, et al., 2000, p. 7). These open landscapes also provide recreational benefits such as bird watching, tourism and aesthetic and spiritual benefits more broadly.

Manitoba Grasslands

Based on estimates, approximately 2.4 million hectares of Manitoba farmlands are grasslands of various types, including tame, naturalized and native pastures. These grasslands provide goods and services that have direct and indirect monetary value. Past studies have identified 18 ecological goods and services associated with grasslands.

However, the challenges of quantifying all these benefits and articulating their values mean that we often illustrate the value of grasslands using a smaller subset of EGS for which data and information are more available. Commonly highlighted benefits for the Manitoba context include forage production, carbon storage, water regulation, erosion control, nutrient cycling, waste treatment, pollination, wildlife habitat and recreation.

Community Pastures in Canada and Manitoba

Balkwill (2002, p.12) traces the concept of community pastures to a conference discussing dryland farming that took place in Swift Current in 1920. At the time, agronomists, farmers, and government officials expressed concern about the potential for soil erosion and the rapid decline in livestock grazing in favour of cereal production. The importance of community grazing, alongside increased federal research to enhance farming practices, were two of the conclusions arising from the conference. While not widely believed, some experts concluded the relatively moist decades of the early 20th century might not continue and were concerned about a multi-year drought.

When that drought hit, it coincided with a global economic depression. Many homesteaders abandoned unproductive lands, while others continued to try to make their operations work. As a response to the crisis, the Government of Canada established the Prairie Farm Rehabilitation Association (PFRA), which among other programs established the Community Pasture Program (CPP) to diversify Manitoba and Saskatchewan's agricultural systems with more livestock production, remove unproductive land from annual cultivation, and create opportunities to test and demonstrate sustainable farming practices (Balkwill, 2002).

Rising agricultural land prices in the late 1990s prompted academic and public research into the full benefits of PFRA pastures, and analyses such as that of Kulshreshtha et al. (2008) demonstrated the benefits pastures provided to private users (on a cost-recovery basis) and the general public in the form of ecosystem services. The authors of the study noted a sense of increasing understanding of the breadth of benefits provided by community pastures noting that (p. 3) "[a]lthough the [CPP] program was developed for both conservation and livestock production purposes, there is a realization of CPP lands' value and contribution to other sectors of society." Since establishment, community pastures restored degraded lands to grass cover, contributed to agricultural resilience, and as delivered benefits to the community such as natural resources, recreational opportunities, biodiversity and habitat for species at risk. Unlike much of the prairies, these lands are representative of the grassland ecosystems on the prairies before European settlement. They also serve as reference sites for long-term soil impacts of cultivation having different use histories than most of the agricultural landscape.

In 2012, the Government of Canada announced the end of the PFRA Community Pasture Program. In practice, this process meant a staged management transfer to the provincial governments of Saskatchewan and Manitoba beginning in 2014. The provinces diverged in administrative approach: the Government of Saskatchewan opted to sell or lease the lands to private holders, some of which will continue to have easements or liens to limit drainage or cultivation (Shield, 2017).

In Manitoba, the Association of Manitoba Community Pastures (AMCP) was formed (with the support of the provincial government) in 2014 as an umbrella organization to operate most of the community pastures throughout the province, including two that overlap into Saskatchewan (AMCP, 2016). Outside of AMCP management, there are four independent community pastures operated by municipalities not considered explicitly in this study.

AMCP is a producer-led, not-for-profit organization governed by an elected board of patrons from pastures across the province. It seeks to support the livestock industry by providing custom grazing services for local producers balanced with sustainable rangeland stewardship practices, where the diversity and productivity of the prairie ecosystems are managed using livestock grazing as the primary tool. AMCP now manages 20 community pastures with over 141,000 hectares of land, 90 per cent of which are provincial crown lands. These lands represent some of the largest contiguous blocks of native prairie remaining in Manitoba and maintained as diverse landscapes representative of natural functional prairie ecosystems. These AMCP-managed pastures continue to support Manitoba's livestock industry: approximately 41,000 head of livestock grazed the community pasture in 2016, representing 4.1 per cent of Manitoba's beef herd (AMCP, personal communication January 2018; Statistics Canada 2016). Apart from grazing, livestock management and other ecological benefits, the AMCP also supports 38 employees in rural areas dedicated to animal care, cattle rotations, infrastructure and land and water maintenance, and range management (AMCP, 2016). Due to their size and management practices that aim to prevent idling, brush encroachment and fragmentation—while providing livestock grazing and economic returns—the community pastures sustain the ecological functions of grasslands, woodlands and wetlands, biodiversity and connectivity across the landscape.

Manitoba community pastures (MCPs) represent a range of land uses. Their primary service is cattle grazing; however, many pastures are also used for hunting, trapping, fishing, traditional food harvesting, recreation and research. The AMCP also undertakes sustainable range management of the community pastures. Management practices include twice-over rotational grazing, conservative stocking rates, prescribed burns, reclamation following surface disturbance, drainage improvements, water management, noxious weed controls, mineral distribution, fencing, water source maintenance (both pipelines and aboveground) and addition of new water sources.

The grazing season lasts from approximately mid-May to mid-October, with cattle typically rotated throughout the pastures using a twice-over rotational grazing system that is adjusted throughout the season as needed. When making adjustments, considerations include management goals, vegetation type, and available forage supply and water, with a focus on the number of livestock that may be sustained while maintaining or improving vegetation and other land resources. Animal unit months (AUMs) is the unit of measurement used to express stocking rates for the community pastures, both overall and for each field. Stocking rates are based on grazing reports completed at the end of each grazing season, and are set to ensure the continued sustainability and productivity of the lands, and to mitigate any impacts of drought/dry conditions (AMCP, personal communication, January 2018).

Management systems on community pastures have the following features (Source, AMCP, 2017, unless otherwise mentioned):

- Lands are not cultivated or subject to fertilizer application.
- Stocking rates based on management goals are maintained for each field at the community pastures. Grazing intensity is adapted for each paddock to encourage grass regrowth and long-term productivity while ensuring resilience in the face of droughts, floods or other disturbances. Water and minerals are placed strategically throughout fields to ensure even cattle distribution.
- Twice-over rotational grazing, where paddocks are divided and each grazed twice over a 4- to 5-month season. This practice has been shown to increase grassland productivity, allow greater stocking rates and economic returns, while also supporting biodiversity and habitat (Ranellucci et al., 2012).
- Prescribed burns are carried out on community pastures. If used with other sound management practices, prescribed fires in grasslands can increase grass nutritive quality, palatability, availability and yield (Stubbendieck et al., 2007). Managed cattle grazing and prescribed burns on community pastures aim at improving the germination of native prairie plants, stimulating new growth, controlling invasive plant species and providing key habitat for a variety of wildlife.
- Most work is done by horseback to protect the lands, ensure vegetative cover, and reduce habitat fragmentation caused by motorized vehicle and trails.

This report reviews the ecological goods and services of 19 community pastures under AMCP management: Alonsa, Bield, Birch River, Cote San Clara, Ellice-Archie, Ethelbert-Dauphin, Ethelbert-Duck Mountain, Spy Hill-Ellice, Gardenton, Langford, Lenswood, Libau, McCreary, Mulvihill, Narcisse, Pansy, Sylvan Dale, Turtle Mountain and Wallace.

This Research: A brief introduction

This research seeks to quantify and value the existing ecological goods and services of AMCP community pastures and propose recommendations to better quantify, value and communicate these in the future.

IISD, in collaboration with grasslands valuation expert Suren Kulshreshtha, Manitoba Agriculture and others, conducted a science-based, policy-relevant study on the societal value of grassland grazing ecosystems that represent the ecosystems of 19 AMCP community pastures, which include native grasslands (rangelands), as well as tame pasture lands.

This study aimed to summarize market and non-market values of grassland ecosystems and associated agricultural production systems based on EGS and life-cycle principles. The total value of grassland production systems encompasses environmental and social parameter. These included, for example, feed and livestock production, carbon storage, habitat value, alternative uses (such as cultural, recreational, historic significance) and additional income from sale of timber, etc. Within the context of current priorities and programming, the study describes possible policy options to realize the value of EGS in grassland regions of Manitoba, including the AMCP lands.

The project includes a review of literature, oversight and validation by an expert steering committee, and an analysis of economic parameters to construct a robust valuation of AMCP-managed pastures including non-market valuations.

Given the short timescale for the project, it focuses on four steps for a rapid EGS assessment:

1. Conduct a literature review summarizing the range of benefits and their values from community pastures, including rangelands and tame pasturelands. Literature was selected based on relevance to the AMCP lands, including ecological and management conditions. This included relevant literature from other parts of Canada and around the world on management systems and ways to optimize EGS benefits and values.
2. Prioritize management systems associated with pastures where the literature provides robust information that is comparable to AMCP pastures. Provide an estimate of potential value of priority management systems based on benefits and values articulated through the literature. Where possible, locally relevant costs were used for this assessment, including AMCP management costs.
3. Assess the total economic value from community pastures as operated by AMCP, looking at how these pastures currently benefit society as a whole. Including both commercial and non-commercial components of value, total economic well-being contributions of a natural asset were aggregated using the Total Economic Value (TEV) methodology.
4. With the steering committee, indicate means of operationalizing EGS values through markets, targeted payments or other policy mechanisms.

Project partners created a small steering committee to evaluate the literature review and analysis and make recommendations for AMCP for the following:

1. The benefits from managed grasslands under AMCP, including the management systems that optimize across various EGS benefits. Recommendations include target audiences and build on the possible reasons that grasslands are being lost, including reasons why they are given lower values by society than other land uses.
2. Policy mechanisms and market options that could enable opportunities to manage these lands for optimum public and private benefits.
3. Future research and other steps needed for more clearly defining and maintaining economic value of AMCP pastures.

This report compiles the research findings and recommendations for AMCP and other interested audiences.

EGS Characterization of AMCP-managed Pastures

This section describes the geographic characteristics of 19 AMCP community managed pastures. The pastures are distributed throughout southern Manitoba, from Pansy and Gardenton in the southeast to Birch River and Lenswood in the northwest (Figure 1). Pastures are divided between the prairie and boreal plain ecozones, along the transition from the North American Great Plains to the southern margins of the continental boreal forests. Total area under management is approximately 147,249 hectares (363,860 acres). The climate of the pastures is warm-summer humid continental (Köppen Dfb). All pastures discussed are in the Lake Winnipeg basin.

Most pastures are located in rural areas of the province and relatively far from Manitoba's largest cities. Libau Community Pasture is approximately 30 km from Winnipeg while Langford and Wallace are 50 and 70 km from Brandon. The pastures are divided between Treaty 1, Treaty 2, and Treaty 4 territories, and all are within the homeland of the Metis Nation.

According to the Prairie Climate Centre (2017), most of the pastures will experience less summer precipitation in summer and more in winter and spring. At the same time, the number of days greater than 30°C could double by 2050 and dramatically increase evaporation and transpiration, adding to water stress. However, the growing season may also lengthen and alter plant communities by the end of the 21st century.

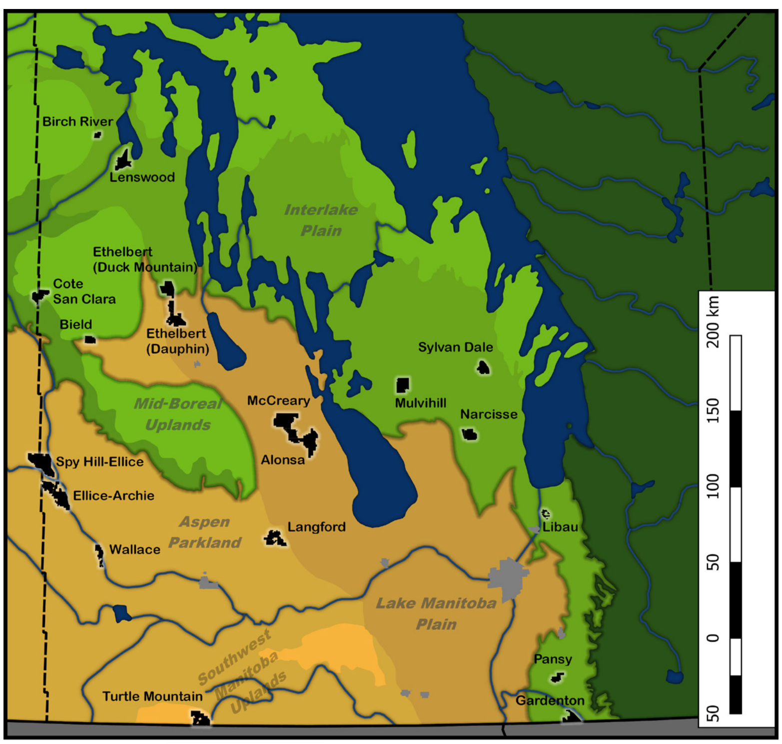

Figure 1. Amcp-Managed Pastures and Manitoba's Ecoregions

Source: AMCP

According to remote sensing data from 2016, the predominant land cover of the pastures is grasslands and forage/pasturelands, with broadleaf forests, wetlands and shrublands making up much of the remainder (Figure 2). Small amounts of open water, coniferous/mixed forests are present along with very limited areas of exposed rock and paved roads. The Aspen Parkland is home to a number of pastures in the rolling prairie, with notable river valleys and bluffs of deciduous trees. Toward the longitudinal centre of Manitoba, the ancient Glacial Lake Agassiz left a flat plain surrounding Lake Manitoba including the Interlake region to the east. Wetlands are more common in the low-relief Interlake. Turtle Mountain Community Pasture is the most distinct pasture, dominated by broadleaf forests typical of the Southwest Manitoba Uplands—a glacial remnant much like Riding Mountain and Duck Mountain to the north.

Individual pastures range from about 16,000 ha (McCreary Community Pasture and Spy Hill-Ellice) to the 1,400 ha Libau Community Pasture.

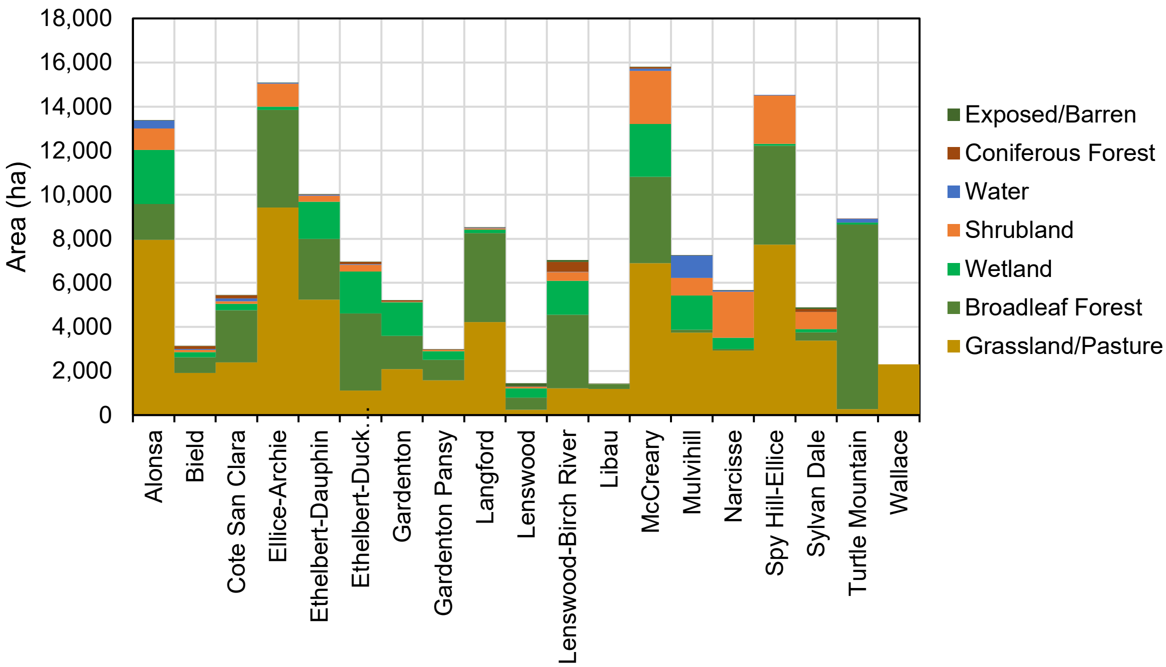

Figure 2. Land Cover Data For 2016 Growing Season

Source: AAFC Crop Inventory[1]

In pasture and grasslands areas, perennial grasses include native and introduced species. Reported native grasses include wheatgrasses (intermediate and slender), little bluestem, needle grasses, North American fescues and blue grama grass. Introduced species such as Kentucky bluegrass, smooth brome, timothy, crested wheatgrass and sheep fescue are common in naturalized or tame areas. Plant species composition at individual pastures are a mix of cool season and warm season grasses. Native forbs on community pastures include many with medicinal, historical or cultural uses, including sage, clover, Seneca root, Labrador tea, Indian breadroot, prairie turnip, dandelion, stinging nettle, raspberry, thistle, wild mint, wild onion, wild rose, wild licorice and wild strawberry. Forests and shrublands are areas dominated by woody species including Aspen poplar, chokecherry, saskatoon, paper birch, hazelnut, Manitoba maple and snowberry. Sedges and cattails (bulrushes) grow in lowlands or wet meadows. The community pastures also contain threatened or rare plant species such as early yellow locoweed, smooth blue beardtongue and Riddell's goldenrod.

The pastures provide a habitat for vertebrate and invertebrate wildlife. Larger fauna include black bears, whitetail deer, red foxes, coyotes and moose. The pastures are home to species at risk such as the red-headed woodpecker, prairie skink, golden-winged warbler, burrowing owl, common nighthawk, northern leopard frog, Sprague's pipit, loggerhead shrike, bobolink and chestnut lamprey.

[1] Available from the Government of Canada: https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9?sort=time_ascend&pagelimit=50

In 2016, approximately 41,000 livestock individuals used AMCP-managed pastures (Figure 3). Over 80 per cent of livestock individuals are cows or calves (17,370 cows; 16,474 calves) followed by 10 per cent heifers, 3.7 per cent steers, 1.6 per cent bulls, and a small number of horses and foals.

Most pastures (approximately 90 per cent) are managed using adaptive rotational grazing. Managers have divided pastures into multiple paddocks, which are grazed intermittently with regular "rest" periods to allow groundcover to regenerate. For most pastures, this means paddocks are grazed twice during the growing season. Pasture managers and staff adapt grazing plans to vary grazing intensity and duration of rotations to ensure long-term pasture productivity. Pastures with continuous grazing only represent 1.5 per cent of the livestock head and report low stocking rates. AMCP's fee structure encourages a minimum of 100 days of grazing, and 135 was assumed to be 'typical' for a stocking season.

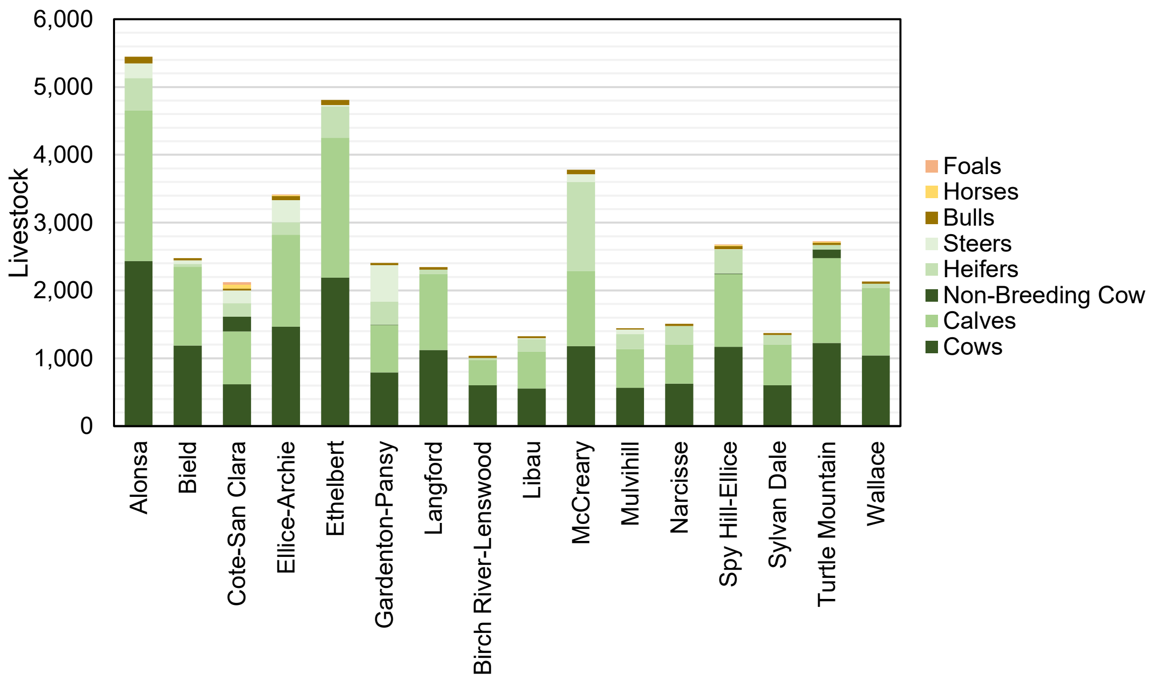

Figure 3. 2016 Livestock by Pasture

Source: AMCP

Most pastures carry some form of invasive plant species and have strategies to control or reduce spread. Reported noxious or problematic weeds on community pastures include common tansy, common burdock, purple loosestrife, tall buttercup, red bartsia and leafy spurge. These species can degrade grazing quality if not controlled: consequently pasture managers choose to control these weeds with physical (mowing or intensive grazing) or chemical (herbicide) methods.

In addition to their commercial purpose, most pastures are also used for recreational, cultural and spiritual activities. Known recreational uses of pastures include big game and fowl hunting, snowmobiling, ATV riding, horseback riding, wagon riding, hiking, camping and general sightseeing. Turtle Mountain Community Pasture is adjacent to a provincial park and receives visitors using designated trails, while others are part of the Snoman provincial snowmobile trail system.[2] Spy Hill-Ellice historic sites include the Metis community of Ste. Madeline: annual celebrations and events occur in the managed area. Estimates of the number of users in most cases is limited.

[2] Please see https://snoman.mb.ca/.

Some pastures have been explored or exploited for mineral or timber resources. Sylvan Dale, McCreary, Narcisse and Ellice-Archie have active quarries. Lenswood supplies a nearby wood products facility[3] with hardwood timber, while both the Ellice-Archie and Spy Hill-Ellice pastures have been explored for potash potential in Manitoba, and potash extraction has occurred at Spy Hill-Ellice in Saskatchewan. Spy Hill-Ellice, Wallace, and Ellice-Archie are actively explored for oil and gas extraction, with oil and gas development and extraction currently occurring at the latter two pastures.

The pastures are also used as sites for scientific research, particularly on the unique species of birds, reptiles, amphibians and mammals. Recent studies include a biodiversity and range health survey at Spy Hill-Ellice, bird studies at both Ellice-Archie and Spy Hill-Ellice. Langford has been the site of recent research on the prairie skink, a small reptile listed as endangered in Canada. Sylvan Dale Community Pasture is the site of an alvar, a landscape with a shallow limestone bedrock that enables unique ecosystems to develop, which has been studied by the Manitoba Alvars Initiative (2012).

Due to overall losses of native grasslands in North America, community pastures provide important remaining habitat for grassland birds. To that end, research on prairie songbirds of conservation concern has taken place on many pastures, including 2017 studies monitoring grassland songbirds on Ellice-Archie recording a number of Baird's sparrows, a species previously undocumented in the area since the 1980s (RIMG 2017). Similarly 2016 surveys on the open grassland portions of the Ellice-Archie Community Pasture noted high concentrations of Sprague's Pipit (Threatened in Manitoba, Threatened in Canada) and Chestnut-collared Longspur (Endangered in Manitoba, Threatened in Canada) (RIMG 2016). 2016 transects on the nearby Spy Hill-Ellice Community pasture revealed as many as 50 Sprague's pipit, 2 Baird's sparrow and 57 chestnut-collared longspur, all of which are considered at-risk species by both provincial and federal legislation as noted above (RIMG 2016). 2017 surveys undertaken to record grassland bird species-at-risk at the Spy Hill-Ellice Community Pasture revealed 140 Sprague's pipits, 73 chestnut-collared longspurs, and 28 sharp tail grouse lek sites. Other species listed in Schedule 1 of the Species at Risk Act that were observed during these surveys included common nighthawk, Baird's sparrow, short-eared owl, and olive-sided flycatcher.

[3] Louisiana-Pacific Smart Siding Facility at Swan Valley, MB https://lpcorp.com/about-lp/locations/.

Literature Review

We reviewed a diverse set of literature to summarize the range of benefits provided by rangelands, and specifically pasturelands on or relevant to the Canadian prairies. Clear shortcomings in research were discovered, both from a provisioning perspective and a valuation perspective. In some part, this is due to considerable diversity of service provision arising from diverse ecosystem communities, physical differences and grazing management systems. A selected bibliography can be found in Appendix 1.

Some of the prominent benefits recorded in literature are discussed in sections below.

Forages

Provision of forages as an ecosystem service can expressed as the yield of forage plants, or in the actual use of grazing livestock with typical intake requirements. The former allows representation of broad, uniform regions (e.g., an arid mixed-grass ecoregion) while the latter may be more appropriate for understanding commercial provision.

Kulshreshtha et al. (2015) obtained typical yields in Manitoba of 5.91 tonnes per ha per year for tame/seeded hay and 3.92 tonnes per ha per year for native or naturalized lands based upon communications with specialists at Manitoba Agriculture. Further communication with Manitoba Agriculture for this study informed us these are likely underestimated, since a well-managed community pasture with moderate grazing intensity will yield greater forage amounts.

As an alternative to quantifying utility and value of forages, it is possible to estimate the actual fodder consumed by a known number of livestock. According to Stewart (2008), cattle consume 1.5 to 3 per cent of their body weight in dry matter per day. Using typical values for livestock types, a value for forage production and provisioning can be arrived at with the assumption that sustainable grazing management is in effect. Transferring the benefits is also more simplified with this approach, as lower-quality fodder requires the animals consume more, and therefore ensuring a roughly equivalent value (nutritional and commercial) of forage is consumed.

The Animal Unit Equivalent (AUE) method can be used to calculate appropriate stocking rates for herds with a mixture of cow/calf pairs, steers, heifers and bulls to account for different sizes and feed requirements. This method can serve as a proxy for forage use, as this is the amount provided from pastures for economic use. Table 1 demonstrates suggested AUE values for Manitoba.

Table 1. Suggested AUE Parameters for Manitoba Livestock Production. Values can be found In Appendix 3.

Animal	Approximate Weight (lbs)	Animal Unit Equivalent (AUE)
Cow (low)	1,000	1.00
Cow (high)	1,500	1.50
Heifer	700	0.80
Steer	700	0.85
Bull	1,700	1.40
Horse	1,300	1.20
Sheep	120	0.20

Source: Manitoba Agriculture (N.D.)

Soil Carbon—Air quality, climate regulation, soil quality

Carbon sequestration refers to the rate and amount of carbon removed from the atmosphere. A number of land-use changes—deforestation, cultivation, urbanization—release stored carbon in the form of carbon dioxide or methane to the atmosphere, exacerbating emissions from fuel combustion. According to Houghton et al. (2012), land-use land cover changes due to deforestation and cultivation of grasslands accounted for 12.5 per cent of anthropogenic climate emissions from 1990 to 2010.

Native and naturalized grassland ecosystems provide value by holding sequestered carbon and rejuvenating depleted soil carbon stocks, respectively. Native pastures—those that have never been cultivated—hold considerable amounts of carbon that would be released due to cultivation, while restored grassland ecosystems can take in and hold carbon from the atmosphere (Follet & Reed, 2010; Bell et al., 2012). In a study in Alberta, Henderson et al. (2006) found that grazing does not reduce soil organic carbon on native grass ecosystems and that management systems leaving litter carryover likely help maintain the soil organic carbon pool. Frank (2004) conducted a study near Mandan, North Dakota and found moderate grazing improved net carbon uptake by 30 $g/m^2/yr$. Naeth et al. (1991a) also found little impact of grazing on soil organic carbon, particularly if rangeland quality was kept in the "poor" to "good" range. These figures correspond to those discussed in a meta-analysis by Zhou et al. (2017), which found that moderate and intense grazing depletes soil stocks of carbon and nitrogen most in temperate areas, with less or no effect in semi-arid and arid regions such as the Canadian prairies.

Teague et al. (2011) conducted a study measuring multiple parameters under different grazing conditions (light continuous, heavy continuous, mixed paddock adaptive, and excluded) in north Texas tallgrass prairie. The authors found that mixed paddock adaptive strategies had considerable benefits to soil health over light or heavy continuous grazing and even to areas excluded from grazing. They found mixed paddock adaptive grazing improved water holding capacity and nutrient retention, while having no negative impact on soil resilience to erosion.

There are seasonal elements impacting the rate of carbon sequestration. For example, the rate of carbon sequestration follows the amount of photosynthesis in green plant material peaking in late June and early July. Heavy grazing in the late spring will reduce this growth and therefore the rate of sequestration. Haferkamp and MacNeil (2004) noted this effect, but also that moderate grazing allows more light to reach the soil surface and can balance reduced sequestration due to biomass removal.

Research shows soil organic carbon is more strongly affected by soil type and soil water availability. Henderson et al. (2004) and Bell et al. (2012) both find that smaller soil particle sizes encourage greater soil organic carbon uptake. This may be influenced by the soil's ability to hold more water and produce better growing conditions than loamy, well-drained soil. MacNeil et al. (2008) found low rates of carbon sequestration on native ecosystems, but fluxes were heavily controlled by soil water, with more water leading to greater CO_2 fluxes.

Financial compensation for sequestration and maintenance of carbon sinks could provide the incentive to protect the land from cultivation (or other development) or adopt new grazing management techniques. Growing pasturelands under native—as opposed to tame—grasses, can increase carbon sequestration and improve soil health. Bell et al. (2012) found a re-established native grassland on clay soils resulted in higher soil organic carbon than cultivated reference fields, although the same management of a sandy loam soils did not show a difference. Dodds et al. (1998) found that restored lands provide similar services as undisturbed lands; however, they may not return to full functionality on human timescales.

These findings show the continued lack of site-specific carbon sequestration or flux measurements across Canadian prairie landscapes as noted in Kulshreshtha et al. (2015). Fluxes—the rate of carbon sequestration on an annual basis—can range from 0 to 8 tonnes per hectare per year in temperate grasslands depending on management and physical characteristics (Jones & Donnelly, 2004).

Recent federal and provincial policies have emerged that set targeted prices on carbon emissions in an effort to mitigate the worst effects of climate change. These policies may come to represent common views on the benefit of sequestration (or storage) of carbon or carbon dioxide equivalent. At the time of writing, there is a range of potential carbon values within the Canadian context. The Pan-Canadian Framework on Clean Growth and Climate Change proposes a price on carbon emissions at $10 per tonne in 2018 and increasing by $10 per tonne per year to $50 per tonne in 2022 (Environment and Climate Change Canada, 2016). The Government of Manitoba has agreed, in principle, by proposing a flat $25 per tonne price beginning in 2018 (Squires, 2018).

Water and Nutrients—Water quantity, quality and erosion.

Human landscapes and land-use changes have affected the provision of clean water and altered the speed at which it moves downstream, making both floods and droughts worse depending on the time and context. Agricultural landscapes add risk to water resources, as use for irrigation, chance of fertilizer misapplication or spills, drainage alteration to speed flow off of cultivated fields, and enhanced erosion are all risks imparted to downstream water users. The necessity of agriculture requires careful planning and management of these risks.

In a study on sub-watersheds in the upper Red River, Gerla (2007) found conversion from cropland to naturalized prairie reduced peak runoff from 1 in 5- and 25-year rainfalls by 55 per cent and up to 45 per cent respectively. This reduction points to a change in infiltration—water moving into the soil rather than remaining on the surface and travelling rapidly to streams and rivers. Past research by Naeth (1991b) found that heavy grazing—leading to reduced litter and more compacted soil—reduces infiltration and increases runoff. Mechanisms for enhanced infiltration are likely deep rooting of perennial grasses, along with the physical effects of organic particles in the soil (Asbjornsen et al., 2014).

Snowmelt and major rain events are viewed as the main pathway by which phosphorus is moved from the landscape and into waterbodies, decreasing water quality and leading to harmful algal blooms (McCullough et al., 2012). Potentially harmful bacteria along with large quantities of phosphorus and nitrogen can move overland into surface waters or leach into groundwater. Cade-Menun et al. (2013) compared snowmelt runoff nutrient flows from crops and pastures, finding distinct differences between croplands and pastures in southeastern Saskatchewan. The authors found similar total phosphorus losses, though pastures lost more particulate phosphorus while crops lost more dissolved phosphorus: nitrogen species tended to favour ammonium from pastures while crops lost more dissolved organic nitrogen. Many beneficial management practices may reduce these water quality concerns. Limiting cattle access to surface water by fencing, such as discussed by Rees et al. (2015) and Shukla et al. (2017) which are likely in place by pasture managers.

Hanuta (2006) reports that before extensive cultivation, wetlands occupied approximately 10 per cent of southern Manitoba, where they now occupy less than 1 per cent. Wetlands—most often marshes in southern Manitoba—provide considerable water retention services and water quality improvements, particularly nutrient removal and sediment retention (Olewiler, 2004).

The above processes—increased infiltration, reduced nutrient losses—combine with the biodiversity of native plant communities to enhance nutrient cycling. Native pastures cycle nutrients more effectively, especially with grazing, which reduces risk of fertilizer over-application or spills.

Biodiversity

Pastures are diverse landscapes, with human-managed grazing filling the role once occupied by the Plains and Woodlands Bison in North America. Habitat fragmentation and pest control reduced many species populations, some of which—such as the plains grizzly bear—are no longer found on the prairies. Pastures create similar landscapes to what existed before European settlement and can create suitable habitat for many plant and animal species.

Liebman, Helmers, Schulte, & Chase (2013) and Walk, Kershner, Benson, & Warner (2010) found even small patches of native perennial vegetation within a larger cropping system in Iowa dramatically increased species richness of birds in the American Midwestern states of Illinois and Iowa. In the former case, establishment of perennial patches enhanced plant biodiversity, including in ditches and other non-cropped spaces. Within four years, the conversion of 10 to 20 per cent of cropland to native prairie resulted in a 240 per cent increase in plant species richness while also demonstrating the hydrologic and nutrient benefits listed above—the authors also noted now native weeds were observed in the adjacent crop fields.

Havstad et al. (2007) note that biodiversity in rangeland is often enhanced by disturbances such as grazing or fire, which happen less frequently (or not at all) on more intensively managed landscapes. Two important aspects of rangelands (including pastures dominated by native species) are resilience to disturbance and continued provision of forages, even during shocks and stressful periods.

Species at risk add value to landscapes since people—often through governments, non-profit organizations or philanthropists—are willing to expend resources to conserve surviving examples of species and protect their habitats. Within the context of Canadian law, the Species at Risk Act (federal) and Endangered Species and Ecosystems Act (Manitoba) encourage conservation of ecosystems to support designated species, including pastures which retain many characteristics of functioning prairie ecosystems. Economic valuations of species at risk are few and subject to widely-divergent values depending on species, survey strategy, and public interest or awareness in their plight.

Richardson and Loomis (2009) conducted a meta-analysis on Total Economic Valuations of species at risk and found that species values are highly divergent. For example, multiple studies on wolves in the United States and Sweden returned a range from USD 20 (2006 USD) to USD 123 annually, with most values on the lower end. Differences in respondent affluence, sample randomness and cultural differences are considered principle factors in the diversity of responses. Posing questions to the public as a choice between two options (a dichotomous survey) generated higher values than an open-ended question asking about willingness-to-pay annual or lump sum amounts. The authors find that general understanding of valuation methods for species at risk is lacking, and more research on methods and surveys for species is needed.

Pasture biodiversity includes pollinators such as birds and bees, which in turn provide services to local horticultural and agricultural production. In a European study, Orford et al. (2016) found that increased plant richness (including legumes and forbs) increased the diversity of pollinator communities through greater reach and more plant visitation. While cereals are wind-pollinated, this service can support greater success in vegetable or fruit (as well as canola and sunflower) production. A recent thesis by Olynyk (2017) found that increased habitat fragmentation harms bee communities as did decreased litter depth in grasslands. With greater research it may be possible to estimate the distance of effect of native pastures to understand the economic impact of pollinators supported by pastures.

Recreation and Cultural Uses

Recreation and cultural uses may be reflected in commercial terms, such as tourism, or less formal uses not reflected in the market. Despite not being reflected in markets, they are recognized as important elements of human and ecosystem well-being. Costanza et al. (1997)—as well as following global ecosystem services assessments such as the Millennium Ecosystem Assessment (2005)—note the importance of cultural and amenity services in valuation frameworks, but also discuss the challenges of measuring and assessing values. These services also include spiritual services, inspiration, aesthetic appreciation of landscape, heritage values, and cultural identity. In practical terms, these values are derived from what a society considers meaningful, the parts of the landscape with significant cultural meaning (towns, cemeteries, spiritual sites), scientific research potential (unique environments, threatened habitats), or in the essence or aesthetics related to a distinct way of life (maintaining agricultural businesses, rural ways of living).

Assessment of the provision of these services is extremely localized, due to the diversity of provision of human known and understood sites and the differences in cultural meaning and appreciation. Tengberg et al. (2012) propose a framework to identify and understand the provision of these services, although they provide little direction on implementation.

One way of valuing cultural services is to measure commercial or benefits transferred values from recreational uses. Hunting, snowmobiling, hiking, and birdwatching are all activities undertaken at some cost to the participant (from gear to transportation to commercial tourism). For example, Olewiler (2004) notes that in British Columbia residents paid $112 million in 1996 to engage in hunting activities. An analysis for the Upper Assiniboine Basin, which straddles the Manitoba/Saskatchewan border, estimated that conversion from cropland to naturalized areas would remit $5.36 to $19.11 per ha per year in enhanced hunting opportunities.

Spiritual and historical sites (such as cemeteries or archeological burial grounds) carry tremendous value, though it is difficult to apply broad valuations from the literature without extensive community consultations. Other values, such as those of historical landscapes and communities, typically require surveys or other strategies to assess value from interested parties and broader society.

Valuation

While ecosystem services are complex to quantify, valuation incorporates the abilities and desires of people to use resources (or to obtain or use services). In our society, value is mostly understood through market transactions in which a consumer and producer each have a range of prices for which they would respectively buy or sell a product. Many ecosystem services are non-consumptive and may benefit individuals and society, so the one-to-one transactional relationship of a market breaks down and the estimation of value becomes challenging, since users are not paying to obtain a product or service from a supplier.

To solve this market failure, environmental economists have developed approaches to assess value of ecosystem services—to make informed decisions about land management—and to account for the perception of benefit provided to society. De Groot et al. (2010) synthesize the literature to that point and define Total Economic Value (TEV) as "[t]he sum total of use and non-use values associated with a resource or an aspect of the environment…." TEV is calculated by quantifying the state of ecosystem processes that provide services (i.e., quantity of benefit) and indicators of sustainable performance of the services (i.e., how much of the benefit can be used, if consumptive, without detriment to the system). TEV analyses are attempts to describe actual value derived from a mix of market and non-market values to obtain full value of a landscape.

Non-market values are often approximated using benefit transfer methods (see Rolfe et al., 2015 for more detail). This method uses studies (e.g., surveys, questionnaires, interviews) to understand the public's (or specific interested party's) Willingness-to-Pay (WTP) or similar variable, often imagining market-type situations where one does not actually exist. This research ascertains the resources that an individual may spend to retain a benefit (such as conservation of threatened species, as above), thereby assigning a value. Given similar populations, this benefit valuation may be assumed as an apt assessment for another region or context. Geographical and cultural contexts can be the source of error; however, this method is widely accepted when resources for primary research are not available.

Beyond valuation, a considerable amount of research examines the cost of policies and delivery of funding to encourage management to maximize ecological goods and services (Nolet et al., 2009). Opportunity cost—another method of landscape valuation—incorporates the cost to the public or individuals if a given service was not provided. This method factors into policies attempting to sustainably support beneficial management practices (BMPs): investments in practices that are expected to benefit both ecosystem services and long-term economic sustainability. Research into these programs provides further insight to the benefit of certain beneficial landscapes including wetlands, forests and naturalized areas. These programs include Alternative Land Use Services (ALUS) and the Conservation Reserve Program (CRP) (Nolet et al., 2009).

These programs seek to provide landowners with an incentive to restore highly functional ecosystems to their land. To minimize costs (and maximize service delivery), a number of payment options were studied by Nolet et al. (2009). These include annual payments, one-time payments, reverse auctions and water quality trading for water quality improvements— market-based solutions (reverse auctions and water quality trading) proved to be the most effective. Programs like ALUS (modelled in Manitoba and implemented in Ontario and Prince Edward Island) uses fixed annual payments to subsidize restoring wetlands.

Agricultural management strategies have provided subsidies to grain production in both Canada and the United States, potentially unbalancing support for pastures and perennial plant-based agriculture (Nykoluk, 2013). Accounting for multifunctionality of pastures requires valuation of benefits beyond livestock production alone and must account for the benefits to society provided by these landscapes (Galler, von Haaren, & Albert, 2015). Many private landowners have personal incentives to manage their lands efficiently, as described by a participant in a study of Manitoban landowner attitudes toward ecological goods and services programming in Woltman (2017, p. 104). Woltman finds many users in southwest Manitoba have strong connection to the land and attempt to manage sustainably, but limited resources and strong pressures from economic uncertainty may prevent sustainable management. Short-term shocks and stressors—whether economic or environmental—test this commitment and can lead to the prioritizing of short-term operational survival over long-term sustainable management.

Manitoba Community Pastures: An assessment of total value

Estimation (TEV) of Manitoba Community Pastures

As mentioned above, a natural resource (such as a community pasture) can be valued either in terms of benefits it provides now to Manitoba society or in terms of lost benefits if these resources did not exist. This section follows the former approach to value Manitoba's community pastures. Table 2 lists these pastures and their areas. Together, these MCPs have a total area of 144,621 ha with 141,001 ha (97 per cent) available for grazing. In addition, these pastures contain 10,014.6 ha of wetlands.

Table 2. List of Manitoba Community Pastures Included for Estimation of Total Economic Value

	Areas of Pastures (in ha)*			
Pasture	**Native**	**Naturalized**	**Tame**	**Total**
Alonsa	11,848	1,316	0	13,164
Bield	789	2,366	0	3,155
Cote San Clara	3,457	1,578	381	5,416
Ethelbert (Dauphin)	5,027	3,117	0	8,144
Ethelbert (Duck Mountain)	6,977	0	0	6,977
Ellice - Archie	13,284	1,476	0	14,760
Gardenton-Pansy	8,250	0	0	8,250
Langford	7,935	600	0	8,535
Lenswood-Birch River	5,645	3,129	0	8,774
Libau	329	1,101	0	1,430
McCreary	16,007	162	0	16,169
Mulvihill	7,256	0	0	7,256
Narcisse	4,450	1,196	0	5,646
Spy Hill - Ellice	14,372	1,597	0	15,969
Sylvan Dale	1,974	2,289	0	4,263
Turtle Mountain	8,933	0	0	8,933
Wallace	3,328	832	0	4,160
Total	**119,861**	**20,759**	**381**	**141,001**

* *This area excludes other uses of the land such as forested and shrub lands, forested lands, wetlands, under water bodies, or just barren lands.*

The first approach—Total Economic Value (TEV)—is based on the notion of benefit for the society. Value is placed on the natural asset because it is a source of some benefit to individuals, with a benefit defined as an increase in the well-being of an individual. Members of society can derive benefits from MCP in different ways: some are commercial in nature (leading to economic well-being) while other benefits may arise when emotional, spiritual or social desires are met. The Total Economic Value (TEV) is a method to compare all of these values as monetary figures.

The TEV is a sum of two major categories of value placed by various members of a society:[4] use-related values and non-use related values. Each of these categories has two or more sub-categories of benefits, as shown in Figure 4. Use values are related to actual use of a community pasture. These uses may take different forms, and values can be a result of one of three types of uses:

[4] "Society" can refer to different scales: local communities, regions, sub-national units, nations, or the global community. This analysis is limited to the province of Manitoba.

a) Direct use of services provided by the community pasture

b) User of environmental services provided by community pastures

c) Option value.

The direct use is primarily for commercial (market) goods and services. A typical community pasture provides its patrons grazing services. In addition, the community pastures have some forested land or mineral lands, revenue from these are also a part of the benefit. Besides commercial uses, community pastures provide a number of ecological goods and services (EGS). These include—based on availability of information around their quantities and values on CPs—carbon sequestration, maintenance of soil health, and improvements in water and air quality.

Besides direct use values, a community pasture could bring some satisfaction to members of society through non-use values. Two types of non-use related values are commonly recognized: existence value and bequest value. The former is the value associated with knowing that a certain resource (community pastures) exists and provides benefits to some members of the society. This satisfaction is not related to either past, current or future use. The bequest value is derived from the satisfaction of leaving the benefits of the natural ecosystem (in this case the community pastures) to the next generation for their use. Like existence values, there is no use required by the member of the society that is valuing the resource.

In addition to the above benefits, a community pasture may provide benefits from other use- and non-use-related services. A workshop of PFRA community pasture stakeholders held in Saskatoon in 2002 identified many specific benefits from CPs. A summary of these benefits, based on Kulshreshtha (2005), included a total of 19 such benefits categorized into seven types. These are listed below.

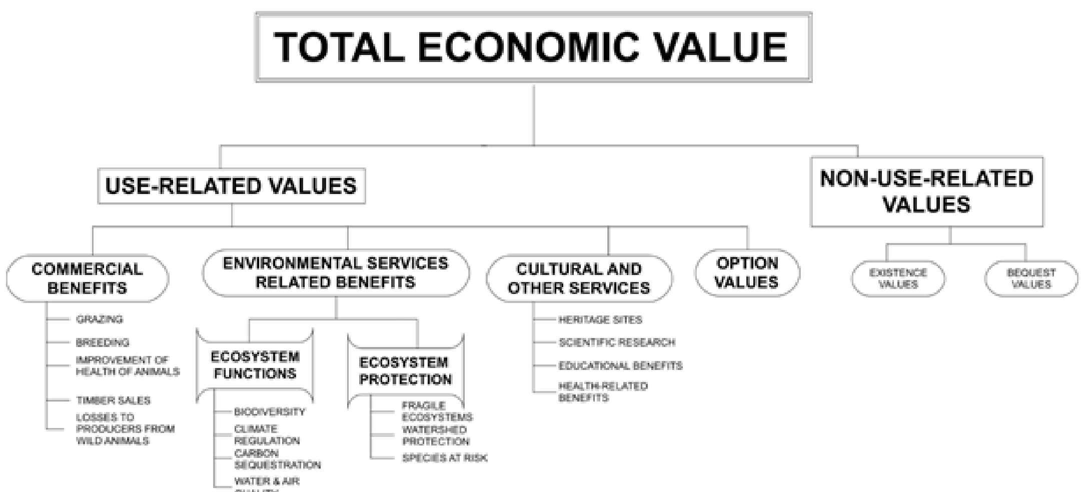

Figure 4. Components of Total Economic Value of a Community Pasture

Category One: Pasture Productivity Related and Farm-Level Impact Benefits

1. Drought proofing
2. Ease of promoting the industry on account of a single contact
3. Reduced pressure on private lands
4. Increased flexibility to producers through increased opportunity for diversification

Category Two: Provision of Environmental Services

5. Groundwater quality
6. Higher environmental standards on community pastures
7. Flood retention

Category Three: Social Aspects

8. Income distribution
9. Benefits to First Nations People
10. Higher recreational value on a large tract of land

Category Four: Educational Benefits

11. Technology transfer
12. Access for research

Category Five: Fiscal Benefits to Provincial and Federal Governments

13. Savings on crop insurance payments
14. Lower administrative cost for Rural Municipalities for tax collection

Category Six: Regional Economic Benefits

15. Diversification opportunities
16. Damage to local area through fires, insects, etc.
17. Social and community viability
18. Economic spinoffs from pasture expenditures

Category Seven: Intrinsic Value

19. Intrinsic value of a large tract of land

Estimation of some of these benefits is complex, and may not be estimated due of lack of data. For benefits that are estimated, the following procedure is used:

1. Identification of social (commercial use and non-commercial) benefits that may be provided by the community pastures.
2. Estimate level/quantity of benefits provided by a given community pasture.
3. Determine value placed by Manitoban society on the benefits provided by a given community pasture.
4. Estimation of the total value by aggregating all community pastures services' values for Manitoban society.

Societal values for many of these services—typically estimated with a survey—was not available for Manitoba. This common setback is mitigated by using a "benefit transfer" method. Table 3 demonstrates studies done in other jurisdictions that evaluate measurement of ecosystem service benefits and values ascribed by communities. Assuming similarity between societies and ecosystems, the benefits can be appropriately "transferred" from one situation to another.

A key message from this study is the gap in existing research and knowledge related to community pastures' non-use values from CPs is not well understood. Often, this gap exists both in terms of magnitude of benefit provided and perceived value. Many existing studies were not suitable due to dramatic differences in landscape or society. Even existing studies—including those outside of the CPs context—did not focus on or report a benefit estimate. However, this review continues to support the hypothesis that grasslands, including community pastures, do provide several types of benefits to society.

An Estimation of the Total Economic Value of Manitoba Community Pastures

Our review of the literature focused on studies undertaken specifically in the context of community pastures. One such study was reported by Kulshreshtha and Pearson (2006), and another one on grasslands by Kulshreshtha et al. (2015). The latter study was concerned with all grasslands in Manitoba, and did not report any values specific to community pastures. For this reason, the federal community pastures study by Kulshreshtha and Pearson (2006) was considered one of the most relevant among literature sources found and reviewed. The major reason for this choice was that these values reflect a community pasture setting (as opposed to all grasslands or nature as a whole) and have been accepted by major stakeholders of the community pastures for the Prairie Provinces.

Table 3. Types of Social Values Relevant to the Estimation of Total Economic Value of Manitoba Community Pastures

Major Source of Value	Sub-category of Value	Description of Benefit	Study Suggesting
Use Values	Consumptive Values	Provision of Forage to small livestock producers	Bailey et al. (2010); Kulshreshtha et al. (2008); Kulshreshtha et al. (2015); Miistakis Institute (2012); Dodds et al. (2008); Roy et al. (2011); Nusse et al. (2017); Manitoba Agriculture, Food and Rural Initiatives (2012);
		Additional insurance during a drought period	Gilmanov et al. (2017);
		Improved health of animals	No study was found
		Timber Harvest	No study was found
	Non-Consumptive Value	Recreational Use	Bird Impacts (Briske et al., 2011); Whelan et al. (2008);
		Aesthetics	No study was found
		Soil Quality	Water infiltration (Naeth et al. 1990a; 1990b); Teague et al. (2011);
		Pollinating services	NSERC-CANPOLIN (2015); Whelan et al. (2008);
		Air Quality	(1) Carbon Sequestration: Naeth et al. 1990a; 1990b); Bell et al. (2012); Conant et al. (2017); Eagle & Olander (2012); Follett & Reid (2010); Gascoigne et al. (2011); Haferkamp & Macneil (2004); Kulshreshtha et al. (2008); Liebig et al. (2005); Wilson et al. (n.d.); MacNeil et al. (2007); Morgan et al. (2016); Teague et al. (2011); Gilmanov et al. (2017); Nusse et al. (2017); (2) Climate Regulation: Haferkamp & Macneil (2004); Asbjornsen et al. (2014); Galler et al. (2015); Morgan et al. (2016); Morgan et al. (2016) (3) Greenhouse GAS Emissions: Alemu et al. 2017); Asbjornsen et al. (2014)
		Water Quality	(1) Hydrological Functioning: Briske et al. (2011); Bechmann et al. (2005); Chen et al. (2017); Galler et al. (2015); Gerla (2007); Liebman et al. (2013); Little et al. (2007); McCandless et al. (2008); Shukla et al. (2017); Timmons and Holt (1977); Venema et al. (2010); Liu et al. (2014); Water Quantity: Weber & Gokhale (2011)
		Erosion prevention	Galler et al. (2015);
		Biodiversity	(1) Pollinator services: Orford et al. (2016) Biodiversity: Orford et al. (2016); Duru et al. (2015)
		Nutrient Cycling	Asbjornsen et al. (2014); Dougherty et al. (2007)
		Species at Risk	No study was found
		Other Environmental Functions	Ten services evaluated: Kulshreshtha et al. (2015); Olewiler (2004); Roy et al. (2011); Costanza et al. (1977); de Groot et al. (2010); Stromberger et al. (2015); Van Berkel & Verburg (2014); Voora & Venema (2008);
		Cultural Functions	Tengberg et al. (2012); Fisher & Turner (2008); Hernández-Morcillo et al. (2013); Swinton et al. (2007); Havstad et al. (2007); Van Berkel & Verburg (2014);
		Option Value	No study was found
Non-Use Values	Altruistic Value		No study was found
	Existence Value		
	Bequest Value		

In this study, TEV of the MCPs were estimated using the following benefits, divided into four distinct categories:

Category 1: Commercial (Private) Use-Related Benefits

1. Grazing
2. Sale of timber

Category 2: Environmental Services

3. Soil conservation
4. Biodiversity
5. Carbon sequestration

Category 3: Cultural and Other Services

6. Wildlife and waterfowl recreation
7. Hunting
8. Scientific research, heritage sites, endangered species and watershed protection

Category 4: Other Benefits

9. Resource extraction (particularly gravel)
10. Local community development

The method of estimation of TEV was as follows: (1) Values of these services were obtained from Kulshreshtha and Pearson (2006); (2) Since the obtained values pertained to the year 2004, they were updated to reflect 2016 prices using the consumer price index, based on 2002=100; (3) Scale of various activities on the MCP were collected through a survey of MCP managers; and, (4) Total benefits were a product of estimated values in Step 2 above, and the scale of activities in Step 3 above for individual pastures. (5) All 19 pastures (per list in Table 2) values were aggregated to produce a total TEV of MCP in 2016 dollars.

Estimated values used for estimation of TEV and the total value for each of the sources of benefits are shown in Table 4. As noted above, these values are in 2016 dollars, and thus approximately reflect the current value of all MCPs.

Table 4. Total Economic Value of Manitoba Community Pastures, by Source of Benefit, 2016

Source of Benefit	Value per year (Canadian Dollars)
Grazing	5,667,277
Timber harvest	2,208
Net Carbon Sequestration valued @$10/tonne of CO_2	**1,888,396**
Net Carbon Sequestration valued @$25/tonne of CO_2	**4,720,991**
Net Carbon Sequestration valued @$30/tonne of CO_2	**4,851,654**
Net Carbon Sequestration valued @$50/tonne of CO_2	**10,255,516**
Soil Formation / Conservation	788,211
Biodiversity	37,901
Recreation	706,299
Hunting	477,243
Other benefits	86,666
Community Development	862,850
Total ($10/tonne of CO_2)	**10,517,051**
Total ($25/tonne of CO_2)	**13,349,646**
Total ($30/tonne of CO_2)	**13,480,309**
Total ($50/tonne of CO_2)	**18,884,171**

Using AUE calculations, MCPs produce approximately 6,513 tonnes of forage per year consumed by cattle. The analysis excludes forage consumed by horses, foals and donkeys representing approximately 0.2 per cent of total livestock. Although value of this forage is one way to determine the value of a community pasture, in this study benefit estimation was based on a producers' point of view. In other words, the value of the community pastures for grazing was determined by the carrying capacity of the pasture, reflected in pasture productivity. Values for AUE calculations are presented in Appendix 3. Native and naturalized pastures typically produce less forage than tame pastures—which is why many native areas were reseeded with tame species. Accordingly, value was estimated at $40.62 per hectare for the native and naturalized pastures, and at $119.75 per hectare for the tame pastures. Both of these values were initially obtained from Kulshreshtha and Pearson (2006) while accounting for inflation. Using these values (along with area of grazing lands) in each of the community pastures, TEV for grazing was estimated at $5.67 million annually. Having the option of using community pastures for the grazing season by producers might leave their land for other uses, which may lead to further diversification on the farm. However, this value is not included in the total grazing value of the MCPs.

Only one of the 19 Manitoba community pastures reported timber harvesting. Using the amount of timber harvested and sold and corresponding market price, this benefit was estimated to be rather small at $2,208 per year. Summing all the commercial use related benefits leads us to a value of $5.67 million, which represents 30 to 55 per cent of the total economic value of the 19 MCPs.

In addition to commercial use-related benefits, MCPs provide several non-commercial use-related benefits to Manitoban society, specifically through the provision of ecosystem services or socioeconomic benefits. One of the most significant benefits from MCP is their capacity to sequester carbon in the soil.

Forages on permanent pastures can accumulate soil through perennial growth of root matter which remains unbroken by cultivation. The rate of carbon sequestration use (measured as carbon dioxide equivalent) for this estimation was at 1.68 tonnes per hectare per year for native and naturalized, and 1.15 tonnes per hectare per year tame pastures based upon the expert panel commissioned for Kulshreshtha and Pearson (2006). To test the sensitivity of the total economic value of this function of Manitoba community pastures, this analysis includes four price scenarios: $25 per tonne as a flat rate proposed by the Government of Manitoba (Squires, 2018), and incremental rates of $10 per tonne, $30 per tonne, and $50 per tonne representing carbon dioxide emissions prices in 2018, 2020, and 2022 proposed by Environment and Climate Change Canada (2016) (Figure 5). For the gross (not including GHG emissions from cattle) carbon sequestration in the soil, the $10 per tonne scenario reaches an annual value of $2.3 million, while at $25 per tonne, it increases to $5.74 million, and at the $30 per tonne the benefit to Manitoban society reaches $6.88 million. These benefits increase to $11.48 million with the $50 per tonne price scenario. Following carbon pricing implementation and wider acceptance, these values may increase as they start to include greater understanding of future costs of climate change and reflect mature low-carbon economies. In addition, these do not include carbon sequestration from shrub and forested lands and from water bodies and wetlands.

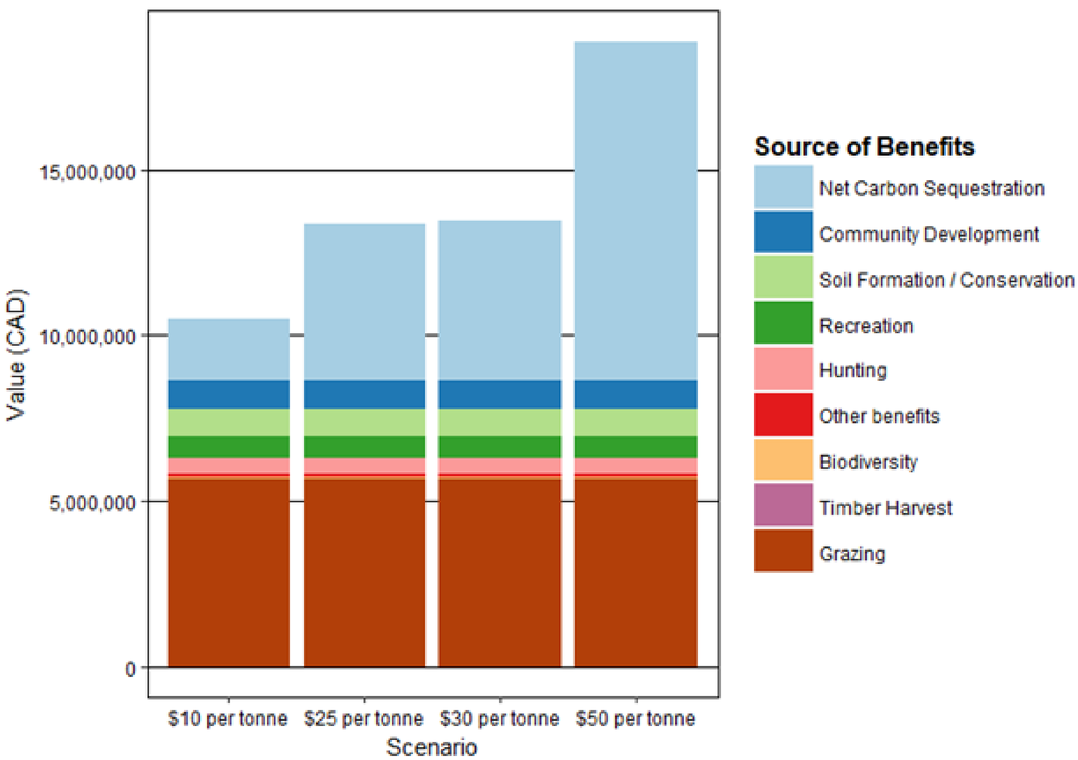

Figure 5. Impact of Carbon Pricing Scenarios on Annual Total Economic Value

Although the pastures themselves sequester carbon, livestock at the surface release carbon-containing greenhouse gases via respiration (carbon dioxide) and digestive emissions (methane). Since this is an environmental cost created by the MCPs, the analysis includes net emissions by reducing sequestration rate at a calculated emission rate similar to that of Kulshreshtha and Pearson (2006).

The cost of livestock emissions total $406,770 at the base price of $10 per tonne, leading to a net carbon sequestration value of $1.89 million per year under this scenario. These cattle-produced emissions' cost increases to $1,016,919, $1,220,303, and $2,033,838 under the $25, $30 and $50 per tonne scenarios, respectively. Net values of grazed landscapes, subtracting emissions costs from sequestration benefits, led to a total net value of carbon sequestration at $4.72, $4.85, and $10.26 million under the $25, $30 and $50 per tonne price, respectively. Figure 5 demonstrates how variable prices on carbon emissions can dramatically change the total economic value of landscapes that are net sinks of carbon.

Two other ecosystem services—soil formation/conservation and biodiversity—were included in the total economic value of MCPs following Kulshreshtha and Pearson (2006). Soil formation refers to the physical and chemical processes that produce healthy soil (which cultivation practices perform). Biodiversity refers to general provision of landscape for habitat. Using coefficients suggested by Kulshreshtha and Pearson (2006) for western Canadian grasslands, combined total economic value was estimated at $826,112 per year.

In addition to the two categories of benefits (commercial use and ecosystem services), MCPs also provide social benefits through wildlife viewing and hunting opportunities. They also house heritage sites important to the local residents around the community pastures, and provide opportunities for scientific research. Using value reported by Kulshreshtha and Pearson (2006)—updated for 2016—the total value was estimated to be $1.2 million worth of benefits to the Manitoba society (roughly 10 per cent of TEV). The value of scientific research was similarly calculated to be $17,000 per year.

Resource extraction activities—including gravel mining—take place on some MCPs. A gravel lease held by a local RM led to extraction of 12,000 cubic yards extracted from one community pasture. While the market or in-kind value of the gravel was not reported because it was solely for municipal use and not sold, the value may be estimated using conservative parameters. Assuming a cost of $1.80 per yard for loading, and $0.35 per yard per mile for hauling, a royalty to the Manitoba government of $0.50 per yard, and a hauling distance of 10 miles, the value of this gravel was estimated at $69,600. Together with benefits from heritage sites and scientific research, yielded a value of $86,600 for the 19 MCPs grouped as other benefits.

The MCPs also spend money for maintaining and undertaking various community pasture-related activities. Some these expenditures are spent locally, and local employment is created. These expenditures ultimately lead to local economic development and sustenance of some rural communities. Kulshreshtha and Pearson (2006) reported this benefit as $6.18 per ha in 2016 dollars. Using this value and the area of the MCPs, an estimated value of $862,850 per year was calculated for all 19 community pastures.

Total Economic Value of the 19 MCPs is simply a sum of the above 11 types of benefits, and ranges from $10.52 million per year to $18.88 million per year depending on the price of carbon scenarios. They provide a benefit of $76.91 per hectare of grazing land if carbon is priced at $10/tonne. This value increases to $97.63, $98.59, $138.11 per ha when price of carbon is $25, $30, and $50 per tonne, respectively.

These estimated benefits of the MCPs should be understood as the lower end of their value to Manitoban society. Many environmental services were not estimated either because of lack of data on the magnitude of benefits from MCPs, the values related to them, or due to lack of knowledge of how community pastures create them.

Wetlands are a good example: MCPs in total have a wetland area of 10,014.6 ha. This asset has a very high economic value, with growing recognition of the multiple benefits provided to society. One method of valuating wetlands is a tool developed by ÉcoRessources (2013) to support Alternative Land Use Services (ALUS) programming in Ontario and Prince Edward Island. Based upon primary research in Pattison et al. (2011), Loomis et al. (2000), and Christie et al. (2000), the tool uses benefit transfer methods to apply survey results from the research (often in terms of dollars per household) to landscape values ($ /acre) with biodiversity indicators (in terms of net primary productivity, or amount of carbon sequestered in plant material), the local population density and frequency of wetlands in a local region. For the Rural Municipality of Norfolk in the Aspen Parkland ecoregion the value of wetlands was calculated at $857 per acre per year ($2,117.6 per hectare per year). Assuming that all these values could be connected to Manitoba community pastures, these wetlands are worth $21.2 million. These values may inform further research into wetlands; however, in terms of methodology there is a risk of double-counting benefits calculated above (e.g., access to water, biodiversity).

The present analysis includes annual carbon sequestration; however, a large benefit of perennials is the long-term (years to decades) storage potential of perennial grasslands. According to White et al. (2000), grasslands can store

100 to 300 tonnes of carbon per ha in the soil. Applying the lower value of this range to native and naturalized pastures, and the upper value to tame pastures, some 13.7 million tonnes of carbon would be lost. If released as carbon dioxide, this would be equivalent to 367 to 1,101 tonnes of CO_2 from each hectare. If this carbon is totally released through dramatic land-use change, assuming a $50 per tonne carbon price, it would cost society $2.5 billion dollars. In addition, carbon sequestered in forested lands, which was not included here, would add more value to the MCPs. Teague et al. (2016) suggest overgrazing or unsustainable management practices can cause pastures to become net emitters of carbon while sustainable practices, such as those used by AMCP, ensure these landscapes continue to remain carbon sinks. Conversion of pasture to cultivated land can cause rapid release of carbon due to disturbance of deeper soil sinks (Jones & Donnelly, 2004). This property is not well understood in terms of multiple environmental attributes (soil type, climate, grazing intensity, topography, hydrology) with high diversity on the landscape. The unknown physical and biological impact on fluxes suggest further research is required to build more robust valuations of the carbon storage of pastures. Local characteristics of particular importance are soil type, plant community structure, and grazing intensity within the Manitoba context.

Pastures also provide significant social values to people of Manitoba. These benefits include therapeutic value to humans through aesthetics and large landscapes, cultural and recreational activities that they provide, as well as other regulating services. Health benefits from aesthetics and open spaces are important to people. Although we did not find any value for non-use of these pastures, it is conceivable that the option value, existence value and bequest value might also be high enough to warrant the existence of MCPs.

Given the uncertainty inherent to most aspects of this valuation, Table 5 suggests an ordinal structure of the variety of benefits discussed within this study and interpretation of 'Likely Value of Benefit.' Even though precise values have large uncertainties, it is likely that carbon stocks and stacked wetland benefits (including water quality and quality, habitat, and materials provisioning) have very high values. Future research on valuation may use this framework to prioritize valuation of these parameters to continue to improve understanding of these benefits.

Table 5. Examples of Other Ecosystem Service Benefits Provided by Manitoba Community Pastures

Type of Benefit	Likely Value of Benefit
Ecosystem Services at Present	
Pollination	High
Protection of fragile ecosystems and species at risk	High
Improved water quality – Surface and Groundwater	High
Carbon Stocks	Very High
Ecosystem Services in the Future	
Drought proofing	Medium to High
Flood Reduction	Medium to High
Ecosystems	
Wetlands	Very High
Private Benefits	
Improved income distribution	Low
Reduced pressure on private lands	Low
Diversification opportunities	Medium
Social Benefits	
Non-Use values (existence value and Bequest values)	Low
Option values	Low
Value of preserving a large tract of contiguous landscape	Medium to High
Fiscal Benefits	
Reduced cost of subsidy paid to producers for crop and pasture lands	High
Savings on crop insurance	Medium
Less administrative cost to rural municipalities	Medium

Findings and Recommendations

The community pastures managed by AMCP cover 144,000 ha of Manitoba's landscape, much of which is on public lands. These lands represent some of the largest contiguous blocks of native prairie remaining in Manitoba and maintain diverse landscapes representative of natural functional prairie ecosystems. They support approximately 40,000 head of grazing livestock annually from 350 local livestock producers and contribute to the prosperity and resilience of Manitoba's agricultural industry. This study compiles context-specific analysis based on spatial data and survey responses from the AMCP and some of its managers to determine specific quantities of EGS benefits from specific lands, land uses and management systems.

Community pastures remain relevant in a changing climate. Community pastures were created in Canada in the 1930s as a federal government response to drought and soil erosion in the prairies. While those critical drought conditions are not present today, this research shows the continuing—perhaps even increasing—relevance, of community pastures today. This research qualifies and quantifies (where possible) the critical role that community pastures and grasslands play in carbon sequestration, water retention, nutrient cycling, soil organic carbon management, biodiversity support and other services in Manitoba. All these services are in addition to their important grazing service to producers and livestock managers. In the context of a changing climate, accelerating loss of biodiversity, species migration, the need for water retention for water quality and other trends, community pastures are important components of the landscape that enable agriculture sector and rural adaptation, maintain and even enhance the landscape's resilience and support the productivity of our vital agricultural sector.

Understanding the Benefits from Community Pastures and Grasslands

Key benefits from grasslands enumerated in the reviewed literature include a range of **provisioning services**, including livestock forage, biomass, medicinal plants and genetic material; **supporting services** such as nutrient cycling, water retention, soil health, biodiversity and native habitat; **regulating services** including carbon sequestration, water purification and nutrient sequestration; and **cultural services** such as trapping, fishing, recreation, as well as spiritual and aesthetic services. Of these valuable services, the provisioning and regulating services are most understood and quantified in the regional context relevant to the MCPs. Supporting and cultural services are less researched and must be targeted for improved understanding.

Prominent benefits from community pastures include perennial forages and carbon sequestration (AMCP, 2016; Bell, et al., 2012; Conant, et al., 2017; Eagle, et al. 2012, etc.). In addition, Kulshreshtha et al. (2015) highlighted community pastures in Canada providing benefits such as nutrient cycling, water regulation, soil erosion control and water treatment. Kulshreshtha et al., (2008) also confirm that the overall economic benefits from community pastures in Canada outweighed the costs associated with maintaining them (by the federal government). Apart from carbon sequestration, the literature also highlights water quality and nutrient sequestration benefits of native grasslands as well as well-managed rangelands (Bechmann et al., 2005; Chen, et al., 2017; Flaten, D., 2016; Galler, et al. 2015). Biodiversity and habitat support provided by grasslands (specifically community pastures in the case of some literature) were highlighted, especially pollination services (Orford, et al., 2016; Ranchers Stewardship Alliance Inc, 2013; NSERC-CANPOLIN, 2015; Whelan, et al., 2008). While other services were mentioned, only a few were repeatedly confirmed within the reviewed literature. Gaps in the literature, particularly related to the benefits mentioned but not fully articulated, quantified or confirmed need to be further studied in order to improve the state of knowledge around community pastures and ensuring the best management systems for overall optimization of benefits.

In addition to the EGS they provide, community pastures act as a critical region for research, education and demonstration of management practices, showcasing land use and adaptive management systems that maintain and/or improve EGS related to land and water ecosystems. These larger tracts of ecologically valuable lands not only provide these public and private ecological services, they also support rural employment (AMCP, 2016) and rural cohesion through communal management systems and practices.

Value of Community Pastures in Manitoba

Based on current knowledge and data related to the benefits from MCPs and their values in markets and to society, the AMCP-managed pastures included in this study provide a TEV ranging from $10.57–$18.88 million per year. This included values related to benefits from CPs that were backed by data and information related to the quantity and values of benefits, either directly in the CP context or from relevant literature. Different prices for carbon sequestration note some of the variability and sensitivity of the valuation to policy decisions, but also highlight the importance of community pastures to the reduction of net carbon emissions in Manitoba.

This study used a TEV system to articulate the total value to Manitobans of the AMCP-run community pastures. This incorporated both direct use values (including commercial benefits and EGS), as well as non-use values (e.g., existence and bequest values). Based on existing data and information, only some use and non-use values were included in this study. These related to grazing, timber harvest (sales), carbon sequestration (with two pricing scenarios), soil formation/conservation, biodiversity, recreation, hunting, community development and other benefits.

While TEV is a useful methodology that provides a snapshot of the benefits and values from CPs today, another important economic assessment would be the opportunity costs related to CPs in Manitoba. These would quantify the values lost if the CPs were to be destroyed (or not managed properly) and would include benefits such as crop insurance costs related to currently mitigated damage, or costs related to downstream flooding or water quality improvements. A more complete understanding of the societal value of these lands would include the TEV and nuances associated with opportunity costs, taking care not to double-count values or benefits. Of particular interest in Manitoba are current priorities related to the role of grasslands and pastures in mitigating the impacts of flooding, as well as the potential role of these lands in offsetting nutrient emissions from point and non-point sources. Methods and parameters required for an opportunity cost valuation can be found in Appendix 2.

Finally, the TEV of community pastures is incomplete in that not all the benefits highlighted in the literature and through the survey with CP managers were valued due to a lack of data and information about the level of these benefits, as well as their locally relevant prices or values. Values related to carbon sequestration were most readily available in the literature, and values related to certain provisioning benefits (such as forage and timber) were available from local sources. Values related to recreational benefits and biodiversity were the hardest to quantify for a variety of reasons. The extent of recreational use of the CPs was not easily quantifiable and therefore hard to ascribe an economic value to. Similarly, for biodiversity, while there are some values described in the literature, these were focused on species not common to the Canadian prairies. It is clear that there are greater benefits provided by recreational and cultural services and biodiversity and a tremendous opportunity to better understand these values.

Management Systems Determine the Level of Benefits from Community Pastures

Our review of literature strongly supported the role of specific land management systems that enhanced EGS, specifically carbon sequestration, soil organic carbon and soil moisture retention. Management systems highlighted as advantageous to EGS provision include grazing management (Bailey, et. al., 2010; Briske, et. al. 2011; Dunn, et. al. 2010; Haferkamp and McNeil, 2004; Miistakis Institute, 2012; Alemu, et. al, 2017; Chen, et. al., 2017)—other authors highlight the importance of maintaining appropriate stocking rates (Bailey, et. al, 2010; Briske, et. al., 2011; Teague, et. al., 2011; Weber & Gokhale, 2011; Kemp & Michalk, 2007).

Community pastures in Manitoba are managed using systems such as rotational grazing, management of stocking rates, limited pesticides and use of prescribed fires to improve overall EGS from these lands. While the specific amount of the benefits from these lands is not precisely quantified in this report, the preliminary benefits based on existing data suggest that the lands are ecologically and economically valuable—they must be maintained in a such a way a to retain and even enhance benefits to producers and broader society. A key recommendation based on this research is the continued (or even enhanced) focus on management systems particularly linked to EGS benefits, such as rotational grazing and sustainable management explicitly tied to the community pasture concept.

Due to limitations of time and resources in this project, detailed quantities of AMCP-related benefits are not part of this study. However, the information received did allow us to provide some quantitative and some qualitative characterization of the AMCP lands that may help future researchers quantify benefits and their values. In order to get more information related to the specific quantity and value of EGS related to CPs in Manitoba, there needs to be monitoring of benefits, especially those that are markedly missing in the literature. These include the rate of CP use for recreational purposes, including ATV driving, wildlife viewing, hunting, etc. Also, an effort to collect the quantity and costs related to local products such as timber, medicinal plants, and other products not in mainstream markets would improve the quality of any future study exploring the value of CPs in Manitoba.

Improvement Engagement and Communications

The benefits, values and impacts of community pastures to Manitobans and others are not well understood. Better communications related to the key benefits from the CPs is needed, not only for improved societal understanding of land management, but for the continued interest and public sector investment currently provided through the provision of provincial lands for use as CPs. Planned communications must target not just local beneficiaries, such as the agricultural sector, but also the environmental sector, urban stakeholders and the broader public. Engagement and communications could involve tours and programs including bird watching and wildlife viewing, combined with educational information and broader insights about these lands. Citizen science programming could encourage engagement while quantifying some of the parameters necessary for further valuation studies while improving engagement with the community.

Communicating the vulnerability of these lands under growing pressure for productivity means that efforts need to be focused on communicating the value of these lands for continued overall productivity, include how these lands contribute to the improved productivity of neighbouring lands through supporting pollinators, improving flood/drought management, and improving soil health.

Conclusion

Community Pastures were a policy response in a time of crisis. The pastures provide patrons with tangible benefits to their operations, yet the sustainable management practices used have provided benefits to the wider society. Some of these benefits are only now becoming valued by society through policy: carbon sequestration, for example, was until recently a benefit without clear value, yet in the near future the mitigation potential of pastures and other uncultivated landscapes could reach a broader audience and inform understanding of the complete value of these places. Our collective ignorance of many of the environmental processes on pastures inhibits a more complete understanding of some values, but further research and investigation will allow improved studies. This analysis attempts to reveal some of the greater economic benefits provided by pastures managed with community in mind.

The $10.52–$18.88 million per year range determined by the valuation herein represents a large proportion of the total value provided by community pastures in Manitoba. Greater understanding of local benefits (such as pollination), regional benefits (community development), and global benefits (stored carbon) will add further understanding about the role of community pastures and continue to help policy-makers understand the true value of Manitoba's community pastures.

References

Alemu, A. W., Janzen, H., Little, S., Hao, X., Thompson, D. J., Baron, V., … Kröbel, R. (2017). Assessment of grazing management on farm greenhouse gas intensity of beef production systems in the Canadian Prairies using life cycle assessment. *Agricultural Systems, 158*, 1–13. https://doi.org/10.1016/j.agsy.2017.08.003

Association of Manitoba Community Pastures (AMCP). (2016). About us. Retrieved from http://www.pastures.ca/about-us-1.html

Association of Manitoba Community Pastures (AMCP). (2017). *2016-2017 Annual Report*. Minnedosa, MB: AMCP.

Asbjornsen, H., Hernandez-Santana, V., Liebman, M., Bayala, J., Chen, J., Helmers, M., Ong, C.K., Schulte, L. A. (2014). Targeting perennial vegetation in agricultural landscapes for enhancing ecosystem services. *Renewable Agriculture and Food Systems, 29*(2), 101–125. https://doi.org/10.1017/S1742170512000385

Bailey, A. W., McCartney, D., & Schellenberg, M. P. (2010). Management of Canadian prairie rangeland. Agriculture and Agri-Food Canada. Retrieved from http://www.beefresearch.ca/files/pdf/fact-sheets/991_2010_02_TB_RangeMgmnt_E_WEB_2_.pdf

Balkwill, D. M. (2002). *The Prairie Farm Rehabilitation Administration and the Community Pasture Program, 1937-1947*. University of Saskatchewan.

Bechmann, M. E., Kleinman, P. J. A., Sharpley, A. N., & Saporito, L. S. (2005). Freeze–thaw effects on phosphorus loss in runoff from manured and catch-cropped soils. *Journal of Environment Quality, 34*(6), 2301. https://doi.org/10.2134/jeq2004.0415

Bell, L. W., Sparling, B., Tenuta, M., & Entz, M. H. (2012). Soil profile carbon and nutrient stocks under long-term conventional and organic crop and alfalfa-crop rotations and re-established grassland. *Agriculture, Ecosystems and Environment, 158*, 156–163.

Briske, D. D., Derner, J. D., Milchunas, D. G., & Tate, K. W. (2011). An evidence-based assessment of prescribed grazing practices. *Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge Gaps*, pp. 21–74. Retrieved from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1045796.pdf

Cade-Menun, B. J., Bell, G., Baker-Ismail, S., Fouli, Y., Hodder, K., McMartin, D. W., Perez-Valdivia, C., & Wu, K. (2013). Nutrient loss from Saskatchewan cropland and pasture in spring snowmelt runoff. *Canadian Journal of Soil Science, 93*(4), 445–458. https://doi.org/10.4141/cjss2012-042

Christie, M., Hyde, T., Cooper, Fazey, I., Dennis, P., Warren, J., … Hanley, N. (2011). *Economic valuation of the benefits of ecosystem services delivered by the UK Biodiversity Action Plan. Final Report to DEFRA*. Retrieved from http://users.aber.ac.uk/mec/Publications/Reports/Value%20UK%20BAP%20FINAL%20published%20report%20v2.pdf

Chen, G., Elliott, J. A., Lobb, D. A., Flaten, D. N., Braul, L., & Wilson, H. F. (2017). Changes in runoff chemistry and soil fertility after multiple years of cattle winter bale feeding on annual cropland on the Canadian prairies. *Agriculture, Ecosystems and Environment, 240*, 1–13. https://doi.org/10.1016/j.agee.2017.02.003

Conant, R. T., Cerri, C. E. P., Osborne, B. B., & Paustian, K. (2017). Grassland management impacts on soil carbon stocks: a new synthesis. *Ecological Applications, 27*(2), 662–668. https://doi.org/10.1002/eap.1473

Costanza, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., … Sutton, P. (1998). The value of the world's ecosystem services and natural capital. *Ecological Economics, 387*(1), 3–15.

de Groot, R. S., Alkemade, R., Braat, L., Hein, L., & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity, 7*(3), 260–272. https://doi.org/10.1016/j.ecocom.2009.10.006

Derner, J. D., Lauenroth, W. K., Stapp, P., & Augustine, D. J. (2009). Livestock as ecosystem engineers for Grassland Bird habitat in the Western Great Plains of North America. *Rangeland Ecology and Management, 62*(2), 111–118. https://doi.org/10.2111/08-008.1

Dodds, W. K., Wilson, K. C., Rehmeier, R. L., Knight, G. L., Wiggam, S., Falke, J. A., Dalgleish, H. J., & Bertrand, K. N. (2008). Comparing ecosystem goods and services provided by restored and native lands. *BioScience, 58*(9), 837. https://doi.org/10.1641/B580909

Dougherty, W. J., Nicholls, P. J., Milham, P. J., Havilah, E. J., & Lawrie, R. a. (2007). Phosphorus fertilizer and grazing management effects on phosphorus in runoff from dairy pastures. *Journal of Environmental Quality, 37*(2), 417–28. https://doi.org/10.2134/jeq2007.0049

Dunn, B. H., Smart, A. J., Gates, R. N., Johnson, P. S., Beutler, M. K., Diersen, M. A., & Janssen, L. L. (2010). Long-term production and profitability from grazing cattle in the Northern Mixed Grass Prairie. *Rangeland Ecology & Management, 63*(2), 233–242. https://doi.org/10.2111/REM-D-09-00042.1

Duru, M., Therond, O., Martin, G., Martin-Clouaire, R., Magne, M. A., Justes, E., … Sarthou, J. P. (2015). How to implement biodiversity-based agriculture to enhance ecosystem services: a review. *Agronomy for Sustainable Development, 35*(4), 1259–1281. https://doi.org/10.1007/s13593-015-0306-1

Eagle, A. J., & Olander, L. P. (2012). Greenhouse gas mitigation with agricultural land management activities in the United States-a side-by-side comparison of biophysical potential. *Advances in Agronomy* (1st ed., Vol. 115). Elsevier Inc. https://doi.org/10.1016/B978-0-12-394276-0.00003-2

Écoressources. (2013). A Benefit Transfer Tool for Valuing Nature's Benefits to Society from ALUS Farmlands Study undertaken for Delta Waterfowl Foundation. Retrieved from http://alus.ca/wpsite/wp-content/uploads/2013/06/Assessment-of-Potential-Biodiversity-Market-Partnerships-in-Ontario.pdf

Environment and Climate Change Canada (2016). Pan-Canadian Framework on Clean Growth and Climate Change. Retrieved from http://publications.gc.ca/site/eng/9.828774/publication.html

Fisher, B., & Kerry Turner, R. (2008). Ecosystem services: Classification for valuation. *Biological Conservation, 141*(5), 1167–1169. https://doi.org/10.1016/j.biocon.2008.02.019

Flaten, D. (2016). Soluble phosphorus losses in spring snowmelt runoff in the Northern great plains. *North Dakota Soil and Water Conference*, (March 2014), 1–8. Retrieved from https://www.ndsu.edu/fileadmin/soils/pdfs/Flaten_P_loss_in_snowmelt_runoff_ND_Soil___Water_Conf_2016.pdf

Follett, R. F., & Reed, D. A. (2010). Soil carbon sequestration in grazing lands: Societal benefits and policy implications. *Rangeland Ecology & Management, 63*(1), 4–15. https://doi.org/10.2111/08-225.1

Frank, A. B. (2004). Six years of CO2 flux measurements for a moderately grazed mixed-grass prairie. *Environmental Management, 33*(SUPPL. 1), 426–431. https://doi.org/10.1007/s00267-003-9150-1

Galler, C., von Haaren, C., & Albert, C. (2015). Optimizing environmental measures for landscape multifunctionality: Effectiveness, efficiency and recommendations for agri-environmental programs. *Journal of Environmental Management, 151*, 243–257. https://doi.org/10.1016/j.jenvman.2014.12.011

Gascoigne, W. R., Hoag, D., Koontz, L., Tangen, B. A., Shaffer, T. L., & Gleason, R. A. (2011). Valuing ecosystem and economic services across land-use scenarios in the Prairie Pothole Region of the Dakotas, USA. *Ecological Economics, 70*(10), 1715–1725. https://doi.org/10.1016/j.ecolecon.2011.04.010

Gerla, P. J. (2007). Estimating the effect of cropland to prairie conversion on peak storm run-off. *Restoration Ecology, 15*(4), 720–730. https://doi.org/10.1111/j.1526-100X.2007.00284.x

Gilmanov, T. G., Morgan, J. A., Hanan, N. P., Wylie, B. K., Rajan, N., Smith, D. P., & Howard, D. M. (2017). Productivity and CO2 exchange of Great Plains ecoregions. I. Shortgrass Steppe: Flux Tower Estimates. *Rangeland Ecology and Management, 70*(6), 700–717. https://doi.org/10.1016/j.rama.2017.06.007

Haferkamp, M. R., & MacNeil, M. D. (2004). Grazing effects on carbon dynamics in the northern mixed-grass prairie. *Environmental Management, 33*(SUPPL. 1), 462–474. https://doi.org/10.1007/s00267-003-9154-x

Hanuta, I. (2006). Land cover and climate for part of Southern Manitoba: A reconstruction from Dominion Land Survey maps and historical records of the 1870s. PhD Thesis. University of Manitoba.

Havstad, K. M., Peters, D. P. C., Skaggs, R., Brown, J., Bestelmeyer, B., Fredrickson, E., … Wright, J. (2007). Ecological services to and from rangelands of the United States. *Ecological Economics, 64*(2), 261–268. https://doi.org/10.1016/j.ecolecon.2007.08.005

Henderson, D. C., Ellert, B. H., & Naeth, M. A. (2004). Grazing and soil carbon along a gradient of Alberta rangelands. *Rangeland Ecology & Management, 57*(4), 402–410. https://doi.org/10.2111/1551-5028(2004)057[0402:GASCAA]2.0.CO;2

Heidenreich, B. (2009). What are global temperate grasslands worth? A case for their protection. Retrieved from https://www.iucn.org/sites/dev/files/import/downloads/grasslandssocioeconomicreport.pdf

Hernández-Morcillo, M., Plieninger, T., & Bieling, C. (2013). An empirical review of cultural ecosystem service indicators. *Ecological Indicators, 29*, 434–444. https://doi.org/10.1016/j.ecolind.2013.01.013

Houghton, R. A., House, J. I., Pongratz, J., Van Der Werf, G. R., Defries, R. S., Hansen, M. C., … Ramankutty, N. (2012). Carbon emissions from land use and land-cover change. *Biogeosciences, 9*(12), 5125–5142. https://doi.org/10.5194/bg-9-5125-2012

Johnson, J. M. F., Reicosky, D. C., Allmaras, R. R., Sauer, T. J., Venterea, R. T., & Dell, C. J. (2005). Greenhouse gas contributions and mitigation potential of agriculture in the central USA. *Soil and Tillage Research, 83*(1 SPEC. ISS.), 73–94. https://doi.org/10.1016/j.still.2005.02.010

Johnston, R. J., & Rosenberger, R. S. (2015). *Benefit Transfer of Environmental and Resource Values* (Vol. 14). https://doi.org/10.1007/978-94-017-9930-0

Jones, M. B., & Donnelly, A. (2004). Carbon sequestration in temperate grassland ecosystems and the influence of management , climate and elevated CO 2. *New Phytologist*, 423–439. https://doi.org/10.1111/j.1469-8137.2004.01201.x

Kemp, D. R., & Michalk, D. L. (2007). Towards sustainable grassland and livestock management. *The Journal of Agricultural Science, 145*(6), 543–564. https://doi.org/10.1017/S0021859607007253

Kulshreshtha, S. N. (Ed.) 2005. *Public and private benefits and costs on federal community pastures: A summary of stakeholders' panel discussion*. Saskatoon: Department of Agricultural Economics, University of Saskatchewan.

Kulshreshtha, S. N. & Pearson, G.G. (2006). Determination of a cost recovery framework and fee schedule formula for the Agriculture and Agri-Food Canada – Prairie farm Rehabilitation Administration Community Pastures. Saskatoon: Department of Agricultural Economics, University of Saskatchewan.

Kulshreshtha, S. N., Undi, M., Zhang, J., Ghorbani, M., Wittenberg, K., Stewart, A., Salvano, E., Kebreab, E., Ominski, K. (2015). The economic value of goods and services from temperate grasslands in Manitoba, Canada. Rijeka, Croatia: InTech Publisher.

Liebig, M. A., Morgan, J. A., Reeder, J. D., Ellert, B. H., Gollany, H. T., & Schuman, G. E. (2005). Greenhouse gas contributions and mitigation potential of agricultural practices in northwestern USA and western Canada. *Soil and Tillage Research, 83*(1 SPEC. ISS.), 25–52. https://doi.org/10.1016/j.still.2005.02.008

Liebman, M., Helmers, M. J., Schulte, L. A., & Chase, C. A. (2013). Using biodiversity to link agricultural productivity with environmental quality: Results from three field experiments in Iowa. *Renewable Agriculture and Food Systems, 28*(2), 115–128. https://doi.org/10.1017/S1742170512000300

Little, J. L., Nolan, S. C., Casson, J. P., & Olson, B. M. (2007). Relationships between soil and runoff phosphorus in small Alberta watersheds. *Journal of Environment Quality, 36*(5), 1289. https://doi.org/10.2134/jeq2006.0502

Loomis, J., Kent, P., Strange, L., Fausch, K., & Covich, A. (2000). Measuring the total economic value of restoring ecosystem services in an impaired river basin: Results from a contingent valuation survey. *Ecological Economics, 33*(1), 103–117. https://doi.org/10.1016/S0921-8009(99)00131-7

MacNeil, M. D., Haferkamp, M. R., Vermeire, L. T., & Muscha, J. M. (2008). Prescribed fire and grazing effects on carbon dynamics in a northern mixed-grass prairie. *Agriculture, Ecosystems and Environment, 127*(1–2), 66–72. https://doi.org/10.1016/j.agee.2008.02.015

Manitoba Agriculture (n.d.) Animal unit months, stocking rate and carrying capacity. Retrieved from https://www.gov.mb.ca/agriculture/crops/production/forages/animal-unit-months-stocking-rate-and-carrying-capacity.html

Manitoba Agriculture, Food and Rural Initiatives. (2012). *Forage and Rangeland Restoration Reference Guide*. Retrieved from http://mbfc.s3.amazonaws.com/wp-content/uploads/2012/05/forage_restoration_guide.pdf

Manitoba Alvar Initiative. 2012. *Alvars in Manitoba: A description of their extent, characteristics & land use*. Nature Conservancy of Canada, Manitoba Region, Winnipeg, Manitoba and Manitoba Conservation and Water Stewardship.

McCandless, M., Venema, D., & Barg, S. (2008). *Full cost accounting for agriculture – Final report. Valuing public benefits accruing from agricultural beneficial management practices: An impact pathway analysis for Tobacco Creek, Manitoba*. Retrieved from https://www.iisd.org/pdf/2008/measure_fca_2008.pdf

McCullough, G. K., Page, S. J., Hesslein, R. H., Stainton, M. P., Kling, H. J., Salki, A. G., & Barber, D. G. (2012). Hydrological forcing of a recent trophic surge in Lake Winnipeg. *Journal of Great Lakes Research, 38*(SUPPL. 3), 95–105. https://doi.org/10.1016/j.jglr.2011.12.012

Miistakis Institute. (2012). Grassland Stewardship Conservation Programming on Natural Grasslands Used for Livestock Production: Payment for Ecosystem Services Program Review, (November). Retrieved from http://www.rockies.ca/project_info/Grassland_Stewardship_Conservation_Programming_PES2.pdf

Millennium Ecosystem Assessment (MEA). (2005). *Volume 1: Current state and trends*. Hassan, R., Scholes, R. & Ash, N. (Eds). Washington, D.C.: Island Press.

Morgan, J. A., Parton, W., Derner, J. D., Gilmanov, T. G., & Smith, D. P. (2016). Importance of early season conditions and grazing on carbon dioxide fluxes in Colorado Shortgrass Steppe. *Rangeland Ecology & Management, 69*(5), 342–350. https://doi.org/10.1016/j.rama.2016.05.002

Naeth, M. A., Bailey, A. W., Pluth, D. J., Chanasyk, D. S., & Hardin, R. T. (1991a). Grazing impacts on litter and soil organic matter in mixed prairie and fescue grassland ecosystems of Alberta. *Journal of Range Management, 44*(1), 7–12. https://doi.org/10.4141/cjss91-031

Naeth, M. A., Chanasyk, D. S., Rothwell, R. L., & Bailey, A. W. (1991b). Grazing impacts on soil water in mixed prairie and fescue grassland ecosystems of Alberta. *Canadian Journal of Soil Science, 71*(3), 313–325. https://doi.org/10.4141/cjss91-031

NSERC-CANPOLIN. (2015). Pollination nation: Research highlights from the Canadian Pollination Initiative (2009-2014), 111. Retrieved from http://www.uoguelph.ca/canpolin/New/NSERC-CANPOLIN%20Pollination%20Nation_print%20version.pdf

Nüsse, A., Linsler, D., Kaiser, M., Ebeling, D., Tonn, B., Isselstein, J., & Ludwig, B. (2017). Effect of grazing intensity and soil characteristics on soil organic carbon and nitrogen stocks in a temperate long-term grassland. *Archives of Agronomy and Soil Science, 63*(12), 1776–1783. https://doi.org/10.1080/03650340.2017.1305107

Nykoluk, C. (2013). *What are native prairie grasslands worth?* Retrieved from http://www.pcap-sk.org/rsu_docs/documents/Native_Grassland_EGS_RSA-sm.pdf

Olewiler, N. (2004). *The value of natural capital in settled areas of Canada*. Retrieved from http://www.cmnbc.ca/sites/default/files/natural%2520capital_0.pdf

Olynyk, M. (2017). *Effects of habitat loss, fragmentation, and alteration on wild bees and pollination services in fragmented Manitoba grasslands*. University of Manitoba. Retrieved from https://mspace.lib.umanitoba.ca/handle/1993/32744

Orford, K. A., Murray, P. J., Vaughan, I. P., & Memmott, J. (2016). Modest enhancements to conventional grassland diversity improve the provision of pollination services. *Journal of Applied Ecology, 53*(3), 906–915. https://doi.org/10.1111/1365-2664.12608

Pattison, J., Boxall, P. C., & Adamowicz, W. L. (2011). The Economic Benefits of Wetland Retention and Restoration in Manitoba. *Canadian Journal of Agricultural Economics, 59*(2), 223–244. https://doi.org/10.1111/j.1744-7976.2010.01217.x

Phillips, D. (2015). *PFRA Pastures Transition Study*, 48. Retrieved from http://www.naturesask.ca/rsu_docs/pfra-final-report.pdf

Prairie Climate Centre. (2017). *Prairie Climate Atlas*. Retrieved from http://climateatlas.ca/

Ranchers Stewardship Alliance Inc. (2013). What are native prairie grasslands worth? Retrieved from http://www.pcap-sk.org/rsu_docs/documents/Native_Grassland_EGS_RSA-sm.pdf

RIMG. (August 2016). Range Implementation Management Group 2016 Annual Report. Unpublished.

RIMG. (2017). Range Implementation Management Group Summary of Biodiversity Monitoring at Ellice-Archie and Spy Hill-Ellice. Unpublished.

Ranellucci, C. L., Koper, N., & Henderson, D. C. (2012). Twice-over rotational grazing and its impacts on grassland songbird abundance and habitat structure. *Rangeland Ecology and Management, 65*(2), 109–118. https://doi.org/10.2111/REM-D-11-00053.1

Rees, G., Tech, V., Stephenson, K., & Taylor, D. B. (2015). Reducing agricultural nonpoint source pollution in Virginia. In *Southern Agricultural Economics Association Annual Meetings*. Atlanta, GA.

Richardson, L., & Loomis, J. (2009). Total Economic Valuation of Endangered Species: A Summary and Comparison of United States and Rest of the World Estimates. In *Conserving and Valuing Ecosystem Services and Biodiversity: Economic, Institutional and Social Challenges*. Ninan, K.N. (Ed). London: Earthscan.

Rolfe, J., Johnston, Robert J., Rosenberger, Randall S., & Brouwer, R. (2015). Introduction: Benefit transfer of environmental and resource values. In *Benefit transfer of Environmental and Resource Values*. Johnston, R., and Rosenberger R. (Eds). Dordrecht: Springer.

Roy, D., Venema, H. D., & McCandless, M. (2011). *Ecological goods and services: A review of best practice in policy and programming*. Winnipeg: International Institute for Sustainable Development. Retrieved from http://www.iisd.org/pdf/2011/egs_policy_programing.pdf

Sayre, N. F., deBuys, W., Bestelmeyer, B. T., & Havstad, K. M. (2012). "The range problem" After a century of rangeland science: New research themes for altered landscapes. *Rangeland Ecology & Management, 65*(6), 545–552. https://doi.org/10.2111/REM-D-11-00113.1

Shield, D. (2017). Sask. Pastures Program being phased out. CBC News. Retrieved from http://www.cbc.ca/news/canada/saskatoon/saskatchewan-pastures-program-1.4036408

Shukla, S., Graham, W. D., Hodges, A., & Knowles, J. M. (2017). *Cattle fencing BMP can reduce phosphorus loads from Florida ranches*. Retrieved from http://edis.ifas.ufl.edu/ae501

Squires, R. (2018). Government of Manitoba letter announcing adoption of the Pan-Canadian Framework on Clean Growth and Climate Change. Retrieved from https://www.canada.ca/en/environment-climate-change/news/2018/02/government-of-manitoba-letter-announcing-adoption-of-the-pan-canadian-framework-on-clean-growth-and-climate-change.html

Statistics Canada. 2016. Table 004-0221 - *Census of Agriculture, cattle and calves on census day (number)*. CANSIM. Retrieved from http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=0040221&tabMode=dataTable&p1=-1&p2=31&srchLan=-1&pattern=004-0200..004-0246

Stewart, F. (2008). *Pasture Planner - A guide for developing your grazing system*.

Stromberger, M., Comerford, N., & Lindbo, D. (2015). *Ecosystem Services and Natural Capital: Pierrefonds-West development project*. Canada. Retrieved from http://ocpm.qc.ca/sites/ocpm.qc.ca/files/pdf/P85/5.8.2_2015_05_ecosystem_services_and_natural_capital_pierrefonds-west_development_project.pdf

Stubbendieck, J., & Volesky, J. (2007). Grassland Management With Prescribed Fire (No. EC148). *University of Nebraska - Lincoln: Extension (No. EC148)*. Lincoln, NE. Retrieved from http://extensionpublications.unl.edu/assets/pdf/ec148.pdf

Swinton, S. M., Lupi, F., Robertson, G. P., & Hamilton, S. K. (2007). Ecosystem services and agriculture: Cultivating agricultural ecosystems for diverse benefits. *Ecological Economics, 64*(2), 245–252. https://doi.org/10.1016/j.ecolecon.2007.09.020

Teague, W. R., Dowhower, S. L., Baker, S. A., Haile, N., DeLaune, P. B., & Conover, D. M. (2011). Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie. *Agriculture, Ecosystems and Environment, 141*(3–4), 310–322. https://doi.org/10.1016/j.agee.2011.03.009

Tengberg, A., Fredholm, S., Eliasson, I., Knez, I., Saltzman, K., & Wetterberg, O. (2012). Cultural ecosystem services provided by landscapes: Assessment of heritage values and identity. *Ecosystem Services, 2*, 14–26. https://doi.org/10.1016/j.ecoser.2012.07.006

Timmons, D. R., & Holt, R. F. (1977). Nutrient losses in surface runoff from a native prairie. *Journal of Environment Quality, 6*(4), 369–373.

Undi, M., Stewart, A., Kebreab, E., Zhang, J., Ghorbani, M., Kulshreshtha, S., Wittenberg, K. M & Ominski, K. H. (2011). *The socio-economic value of Manitoba grasslands*. Draft Report.

Venema, H. D., Oborne, B., & Neudoerffer, C. (2010). *The Manitoba challenge: Linking water and land management for climate adaptation*. Retrieved from http://www.iisd.org/pdf/2009/the_manitoba_challenge.pdf

Walk, J. W., Kershner, E. L., Benson, T. J., & Warner, R. E. (2010). Nesting Success of Grassland Birds in Small Patches in an Agricultural Landscape. *The Auk*, *127*(2), 328–334. https://doi.org/10.1525/auk.2009.09180

Weber, K. T., & Gokhale, B. S. (2011). Effect of grazing on soil-water content in semiarid rangelands of southeast Idaho. *Journal of Arid Environments, 75*(5), 464–470. https://doi.org/10.1016/j.jaridenv.2010.12.009

Whelan, C. J., Wenny, D. G., & Marquis, R. J. (2008). Ecosystem services provided by birds. *Annals of the New York Academy of Sciences 1134*. Washington D.C.: Island Press. https://doi.org/10.1196/annals.1439.003

Wilson, L., Wilson, C., Roy, D., & Otfinowski, R. (n.d.). Ecological goods and services provided by rangelands and lands producing perennial forages in Manitoba. *Carbon Sequestration, 1*, 3–7.

Woltman, S. (2017). *Application of an ecological goods and services model in the Whitewater Lake sub-watershed: An analysis of options and landowner attitudes*. MEnv Thesis. University of Manitoba.

Wood, S., Sebastian, K., & Scherr, S. (2000). *Pilot analysis of global ecosystems: Agroecosystems*. Washington, DC: World Resources Institute. Retrieved from https://www.researchgate.net/publication/2934748_Pilot_Analysis_of_Global_Ecosystems_Agroecosystems

USGS. (1998). Status and trends of the nation's biological resources. Olpher, P.A., Puckett Haecker, C.E. & Dorean, P.D. (eds). Washington D.C.: U.S. Dept. of the Interior. Retrieved from https://www.nwrc.usgs.gov/sandt

Van Berkel, D. B., & Verburg, P. H. (2014). Spatial quantification and valuation of cultural ecosystem services in an agricultural landscape. *Ecological Indicators, 37*(PART A), 163–174. https://doi.org/10.1016/j.ecolind.2012.06.025

Voora, V., & Venema, H. D. (2008). *An Ecosystem Services Assessment of the Lake Winnipeg Watershed. Phase 1 Report: Southern Manitoba Analysis*. Winnipeg: International Institute for Sustainable Development. Retrieved from https://www.iisd.org/pdf/2008/ecosystem_assessment_lake_wpg.pdf

White, R., Murray, S. Rohweder, M. (2000). *Pilot analysis of global ecosystems: Grassland ecosystems*. Washington D.C.: World Resources Institute.

Zhang, L., Wylie, B. K., Ji, L., Gilmanov, T. G., & Tieszen, L. L. (2010). Climate-driven interannual variability in net ecosystem exchange in the Northern Great Plains Grasslands. *Rangeland Ecology & Management, 63*(1), 40–50. https://doi.org/10.2111/08-232.1

Zhou, G., Zhou, X., He, Y., Shao, J., Hu, Z., Liu, R., … Hosseinibai, S. (2017). Grazing intensity significantly affects belowground carbon and nitrogen cycling in grassland ecosystems: a meta-analysis. *Global Change Biology, 23*(3), 1167–1179. https://doi.org/10.1111/gcb.13431

Appendix 1: Selected bibliography of past research

Citation	Topic	Region
Alemu, A. W., Janzen, H., Little, S., Hao, X., Thompson, D. J., Baron, V., ... Kröbel, R. (2017). Assessment of grazing management on farm greenhouse gas intensity of beef production systems in the Canadian Prairies using life cycle assessment. *Agricultural Systems, 158*, 1–13. https://doi.org/10.1016/j.agsy.2017.08.003	Life-cycle assessment over 8 years on beef farm. Calves raised on rangeland with finishing on grain for market. Four scenarios varying grazing intensity for different cattle group (all, cow calf, backgrounded cattle).	Canadian prairies
Asbjornsen, H., Hernandez-Santana, V., Liebman, M., Bayala, J., Chen, J., Helmers, M., ... Schulte, L. A. (2014). Targeting perennial vegetation in agricultural landscapes for enhancing ecosystem services. *Renewable Agriculture and Food Systems, 29*(2), 101–125. https://doi.org/10.1017/S1742170512000385	Previous agriculture regimes placed disproportionate value on product production rather than ES; perennialization can enhance EGS. Strategic opportunities in American Midwest.	Midwestern United States
Bailey, A. W., McCartney, D., & Schellenberg, M. P. (2010). Management of Canadian Prairie Rangeland. *Agriculture and Agri-Food Canada*. Retrieved from http://www.beefresearch.ca/files/pdf/fact-sheets/991_2010_02_TB_RangeMgmnt_E_WEB_2_.pdf	Managing Natural Rangelands. Natural grasslands are vulnerable to repeated heavy grazing pressure; Serious overgrazing management practices can devastate ecosystems and leave them more vulnerable to long-term damage. Light to moderate use, adequate animal distribution can reduce risks of livestock disease. Riparian management is needed but challenging. Recent research points to mimicking natural grazing. Three systems: continuous, seasonal and rotational grazing. Four rotational subsystems; switchback, deferred rotation, short duration rotation and complementary.	Canadian grasslands
Balkwill, D. M. (2002). *The Prairie Farm Rehabilitation Administration and the Community Pasture Program, 1937-1947.* University of Saskatchewan.	Establishment rationale for PFRA. Originally meant to last 5 years, the first decade of the PFRA's half-century of existence applied federal policy to prairie farming techniques. Community pasture program reflected understanding that broadly based land-use policy had to be flexible in order to accommodate ecological and social diversity of the prairies.	Canadian grasslands
Bechmann, M. E., Kleinman, P. J. A., Sharpley, A. N., & Saporito, L. S. (2005). Freeze–thaw effects on phosphorus loss in runoff from manured and catch-cropped soils. *Journal of Environment Quality, 34*(6), 2301. https://doi.org/10.2134/jeq2004.0415	Non-point source P losses from agricultural lands in cold climates comes from freeze-thaw of crops (and other biomass) at surface in springtime.	Cold climates
Bell, L. W., Sparling, B., Tenuta, M., & Entz, M. H. (2012). Soil profile carbon and nutrient stocks under long-term conventional and organic crop and alfalfa-crop rotations and re-established grassland. *Agriculture, Ecosystems and Environment, 158*, 156–163.	Comparison of deep SOC, TN, and Olsen-P between alfalfa crop rotation and re-established grassland.	Manitoba - Glenlea Research Station
Briske, D. D., Derner, J. D., Milchunas, D. G., & Tate, K. W. (2011). An evidence-based assessment of prescribed grazing practices. *Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge Gaps*, 21–74. Retrieved from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1045796.pdf	Research shows consistent relationships between stocking rate, plant production, animal production and species composition of pastures. Very detailed literature review on rotational grazing systems and impacts.	United States

Citation	Topic	Region
Chen, G., Elliott, J. A., Lobb, D. A., Flaten, D. N., Braul, L., & Wilson, H. F. (2017). Changes in runoff chemistry and soil fertility after multiple years of cattle winter bale feeding on annual cropland on the Canadian prairies. *Agriculture, Ecosystems and Environment, 240*, 1–13. https://doi.org/10.1016/j.agee.2017.02.003	Export of P and N were monitored on same fields with and without winter bale grazing and compared with confined feeding. WBG improved soil fertility, however caused higher nutrient pollution runoff (but lower concentrations).	Manitoba
Conant, R. T., Cerri, C. E. P., Osborne, B. B., & Paustian, K. (2017). Grassland management impacts on soil carbon stocks: a new synthesis. *Ecological Applications, 27*(2), 662–668. https://doi.org/10.1002/eap.1473	Meta-analysis of grassland management impacts to soil organic carbon stocks.	Global
Derner, J. D., Lauenroth, W. K., Stapp, P., & Augustine, D. J. (2009). Livestock as ecosystem engineers for Grassland Bird habitat in the Western Great Plains of North America. *Rangeland Ecology and Management, 62*(2), 111–118. https://doi.org/10.2111/08-008.1	Concept of livestock as ecosystem engineers to improve habitat for songbirds.	North America
Dodds, W. K., Wilson, K. C., Rehmeier, R. L., Knight, G. L., Wiggam, S., Falke, J. a., … Bertrand, K. N. (2008). *Comparing Ecosystem Goods and Services Provided by Restored and Native Lands. BioScience, 58*(9), 837. https://doi.org/10.1641/B580909	Comparison of restored vs intact landscapes in North America.	North America
Dunn, B. H., Smart, A. J., Gates, R. N., Johnson, P. S., Beutler, M. K., Diersen, M. A., & Janssen, L. L. (2010). Long-term production and profitability from grazing cattle in the Northern Mixed-Grass Prairie. *Rangeland Ecology & Management, 63*(2), 233–242. https://doi.org/10.2111/REM-D-09-00042.1	Questioning long-term sustainability metrics for production optimization.	South Dakota
Eagle, A. J., & Olander, L. P. (2012). Greenhouse gas mitigation with agricultural land management activities in the United States-a side-by-side comparison of biophysical potential. *Advances in Agronomy* (1st ed., Vol. 115). Elsevier Inc. https://doi.org/10.1016/B978-0-12-394276-0.00003-2	Survey and comparison between pasture and rangeland, signifying heavily managed grazing lands and less managed grazing lands respectively.	North America
Fisher, B., & Kerry Turner, R. (2008). Ecosystem services: Classification for valuation. *Biological Conservation, 141*(5), 1167–1169. https://doi.org/10.1016/j.biocon.2008.02.019	Proposal to think of services and benefits as intermediate, final and benefits in separate frameworks.	Global
Flaten, D. (2016). Soluble phosphorus losses in spring snowmelt runoff in the Northern great plains. *North Dakota Soil and Water Conference*, (March 2014), 1–8. Retrieved from https://www.ndsu.edu/fileadmin/soils/pdfs/Flaten_P_loss_in_snowmelt_runoff_ND_Soil___Water_Conf_2016.pdf	Phosphorus losses from spring snowmelt cause considerable issues.	Manitoba
Follett, R. F., & Reed, D. A. (2010). Soil carbon sequestration in grazing lands: Societal benefits and policy implications. *Rangeland Ecology & Management, 63*(1), 4–15. https://doi.org/10.2111/08-225.1	Globally grazing lands occupy 3.6 billion ha and account for 1/4 of potential for CO_2 sequestration in soils.	Global; United States
Galler, C., von Haaren, C., & Albert, C. (2015). Optimizing environmental measures for landscape multifunctionality: Effectiveness, efficiency and recommendations for agri-environmental programs. *Journal of Environmental Management, 151*, 243–257. https://doi.org/10.1016/j.jenvman.2014.12.011	Comparison of co-ordinated with unco-ordinated management strategies in terms of EGS optimization.	Germany
Gascoigne, W. R., Hoag, D., Koontz, L., Tangen, B. A., Shaffer, T. L., & Gleason, R. A. (2011). Valuing ecosystem and economic services across land-use scenarios in the Prairie Pothole Region of the Dakotas, USA. *Ecological Economics, 70*(10), 1715–1725. https://doi.org/10.1016/j.ecolecon.2011.04.010	Focus on carbon sequestration, sedimentation reduction and waterfowl production.	North Dakota; South Dakota

Citation	Topic	Region
Gerla, P. J. (2007). Estimating the effect of cropland to prairie conversion on peak storm run-off. *Restoration Ecology, 15*(4), 720–730. https://doi.org/10.1111/j.1526-100X.2007.00284.x	Conducts analysis of sub-watersheds to determine curve number-the impact of each watershed on flood duration and intensity.	North Dakota
Haferkamp, M. R., & Macneil, M. D. (2004). Grazing effects on carbon dynamics in the northern mixed-grass prairie. *Environmental Management, 33*(SUPPL. 1), 462–474. https://doi.org/10.1007/s00267-003-9154-x	Site-scale experiment over 3 y ears analyzing grazing impact on CO_2 flux and soil respiration using closed chambers.	Eapa fine loam, northern Mixed-grass prairie, Montana
Hernández-Morcillo, M., Plieninger, T., & Bieling, C. (2013). An empirical review of cultural ecosystem service indicators. *Ecological Indicators, 29*, 434–444. https://doi.org/10.1016/j.ecolind.2013.01.013	Pressing issues require we build global frameworks for assessing cultural ecosystem benefits and indicators for the services that provide them.	Global
Johnson, J. M. F., Reicosky, D. C., Allmaras, R. R., Sauer, T. J., Venterea, R. T., & Dell, C. J. (2005). Greenhouse gas contributions and mitigation potential of agriculture in the central USA. *Soil and Tillage Research, 83*(1 SPEC. ISS.), 73–94. https://doi.org/10.1016/j.still.2005.02.010	Summarizing soil organic carbon sequestration on cropping systems and ways to optimize sequestration.	Central United States
Johnston, R. J., & Rosenberger, R. S. (2015). Benefit Transfer of Environmental and Resource Values (Vol. 14). https://doi.org/10.1007/978-94-017-9930-0	Textbook on benefit transfer.	Global
Kulshreshtha, S., Pearson, G., Kirychuk, B., & Gaube, R. (2008). distribution of public and private benefits on federally managed community pastures in Canada. *Rangelands, 30*(1), 3–11.	Framework for separating public and private benefits from managed pastures.	Canadian prairies
Kulshreshtha, S., Undi, M., Zhang, J., Ghorbani, M., Wittenberg, K., Stewart, A., ... Ominski, K. (2015). Challenges and opportunities in estimating the value of goods and services in temperate grasslands — A case study of prairie grasslands in Manitoba, Canada. *Agroecology*.	Process valuation of Manitoba's grassland ecosystems.	Manitoba
Liebig, M. A., Morgan, J. A., Reeder, J. D., Ellert, B. H., Gollany, H. T., & Schuman, G. E. (2005). Greenhouse gas contributions and mitigation potential of agricultural practices in northwestern USA and Western Canada. *Soil and Tillage Research, 83*(1 SPEC. ISS.), 25–52. https://doi.org/10.1016/j.still.2005.02.008	Accounting for soil organic carbon, CO_2, N_2O and CH4 fluxes in cropland and rangeland.	North America
Liebman, M., Helmers, M. J., Schulte, L. A., & Chase, C. A. (2013). Using biodiversity to link agricultural productivity with environmental quality: Results from three field experiments in Iowa. *Renewable Agriculture and Food Systems, 28*(2), 115–128. https://doi.org/10.1017/S1742170512000300	Analysis of data from three cropping system experiments focusing on impacts to water quality, reducing carbon use and improving soil health.	Iowa
Little, J. L., Nolan, S. C., Casson, J. P., & Olson, B. M. (2007). Relationships between soil and runoff phosphorus in small Alberta watersheds. *Journal of Environment Quality, 36*(5), 1289. https://doi.org/10.2134/jeq2006.0502	A study to model relationship between soil test phosphorus (STP) and phosphorus lost to runoff.	Alberta
MacNeil, M. D., Haferkamp, M. R., Vermeire, L. T., & Muscha, J. M. (2008). Prescribed fire and grazing effects on carbon dynamics in a northern mixed-grass prairie. *Agriculture, Ecosystems and Environment, 127*(1–2), 66–72. https://doi.org/10.1016/j.agee.2008.02.015	Given relationship between prescribed fire and grazing with carbon dynamics is not understood, this study examined plots on mixed-grass prairie in eastern Montana with undisturbed, burned and grazed treatments.	Eastern Montana
McCandless, M., Venema, D., & Barg, S. (2008). *Full cost accounting for agriculture – Final report. Valuing public benefits accruing from agricultural beneficial management practices: An impact pathway analysis for Tobacco Creek, Manitoba*. Retrieved from https://www.iisd.org/pdf/2008/measure_fca_2008.pdf	Benefits of pastures to nutrients.	Manitoba

Citation	Topic	Region
Miistakis Institute. (2012). *Grassland Stewardship Conservation Programming on Natural Grasslands Used for Livestock Production: Payment for Ecosystem Services Program Review, (November)*. Retrieved from http://www.rockies.ca/project_info/Grassland_Stewardship_Conservation_Programming_PES2.pdf	Review of payments for ecosystem services programs from around the world, focused on livestock production in grassland ecosystems.	Global
Morgan, J. A., Parton, W., Derner, J. D., Gilmanov, T. G., & Smith, D. P. (2016). Importance of early season conditions and grazing on carbon dioxide fluxes in Colorado Shortgrass Steppe. *Rangeland Ecology & Management, 69*(5), 342–350. https://doi.org/10.1016/j.rama.2016.05.002	Impact of weather and grazing on carbon dioxide fluxes.	Colorado
NSERC-CANPOLIN. (2015). Pollination nation: Research highlights from the Canadian Pollination Initiative (2009-2014), 111. Retrieved from http://www.uoguelph.ca/canpolin/New/NSERC-CANPOLIN%20Pollination%20Nation_print%20version.pdf	Summary of pollination research in Canada.	Canada
Olewiler, N. (2004). The value of natural capital in settled areas of Canada. *Public Policy, 36*. Retrieved from http://www.cmnbc.ca/sites/default/files/natural%2520capital_0.pdf	Evaluation of natural capital in southern Canada.	Canadian ecumene
Orford, K. A., Murray, P. J., Vaughan, I. P., & Memmott, J. (2016). Modest enhancements to conventional grassland diversity improve the provision of pollination services. *Journal of Applied Ecology, 53*(3), 906–915. https://doi.org/10.1111/1365-2664.12608	Field-scale experiment to test how biodiversity of pastures impacts pollinator communities.	Devon, United Kingdom
Phillips, D. (2015). PFRA Pastures Transition Study, 48. Retrieved from http://www.naturesask.ca/rsu_docs/pfra-final-report.pdf	Principles of community pasture management, risks of transition from PFRA to associations/user groups/management groups.	Prairies
Ranchers Stewardship Alliance Inc. (2013). What are native prairie grasslands worth? Retrieved from http://www.pcap-sk.org/rsu_docs/documents/Native_Grassland_EGS_RSA-sm.pdf	A literature review to scan recent studies pertaining to EGS valuation, and a opportunity cost approach for assessment.	Great Plains
Roy, D., Venema, H. D., & Mccandless, M. (2011). *Ecological goods and services : A review of best practice in policy and programming*. Winnipeg: International Institute for Sustainable Development. Retrieved from http://www.iisd.org/pdf/2011/egs_policy_programing.pdf	EGS framework for landowners in Manitoba.	Manitoba
Sayre, N. F., deBuys, W., Bestelmeyer, B. T., & Havstad, K. M. (2012). "The range problem" After a century of rangeland science: New research themes for altered landscapes. *Rangeland Ecology & Management, 65*(6), 545–552. https://doi.org/10.2111/REM-D-11-00113.1	The range problem is the consistent degraded state of rangeland in the American Southwest. Future research and policy must get out of that rut and target research and policy development away from reductionist approaches to more holistic ones.	American Southwest
Shukla, S., Graham, W. D., Hodges, A., & Knowles, J. M. (2017). Cattle Fencing BMP Can Reduce Phosphorus Loads from Florida Ranches 1, 2–4. Retrieved from http://edis.ifas.ufl.edu/ae501	Evaluating efficacy of livestock exclusion by fencing streams and riparian areas for reducing phosphorus loading in surface waters.	Lake Okeechobee watershed, Florida
Swinton, S. M., Lupi, F., Robertson, G. P., & Hamilton, S. K. (2007). Ecosystem services and agriculture: Cultivating agricultural ecosystems for diverse benefits. *Ecological Economics, 64*(2), 245–252. https://doi.org/10.1016/j.ecolecon.2007.09.020	Overview of ecosystem services in agriculture and outline of various approaches to non-market valuation.	Global; crops and rangelands

Citation	Topic	Region
Teague, W. R., Dowhower, S. L., Baker, S. A., Haile, N., DeLaune, P. B., & Conover, D. M. (2011). Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie. *Agriculture, Ecosystems and Environment, 141*(3–4), 310–322. https://doi.org/10.1016/j.agee.2011.03.009	Comparison of multi-paddock grazing and continuous grazing at high stocking rates (in multi-paddock) and light and heavy continuous grazing. 9-year study with rest.	Texas
Tengberg, A., Fredholm, S., Eliasson, I., Knez, I., Saltzman, K., & Wetterberg, O. (2012). Cultural ecosystem services provided by landscapes: Assessment of heritage values and identity. *Ecosystem Services, 2*, 14–26. https://doi.org/10.1016/j.ecoser.2012.07.006	Two case studies evaluating cultural/heritage ecosystem services: Sweden and Arafura-Timor Seas.	Sweden, oceans
Timmons, D. R., & Holt, R. F. (1977). nutrient losses in surface runoff from a native prairie. *Journal of Environment Quality,* 6(4), 369–373.	5-year study on nutrient losses from native prairie runoff. Little bluestem dominated on a Barnes loam soil in west-central MN.	Minnesota (loam soil, bluestem dominated)
Venema, H. D., Oborne, B., & Neudoerffer, C. (2010). *The Manitoba challenge: Linking water and land management for climate adaptation*. Retrieved from http://www.iisd.org/pdf/2009/the_manitoba_challenge.pdf	Manitoba needs to link land and water management to adapt to a changing climate.	Manitoba
Weber, K. T., & Gokhale, B. S. (2011). Effect of grazing on soil-water content in semi-arid rangelands of southeast Idaho. *Journal of Arid Environments, 75*(5), 464–470. https://doi.org/10.1016/j.jaridenv.2010.12.009	Analysis of grazing management alternatives (simulated holistic grazing, rest-rotation, and total rest) at three stocking rates (36,6,0 animal days/ha) with measurements of soil water content.	Idaho
Whelan, C. J., Wenny, D. G., & Marquis, R. J. (2008). Ecosystem services provided by birds. *Annals of the New York Academy of Sciences 1134*. Washington D.C.: Island Press. https://doi.org/10.1196/annals.1439.003	Birds contribute to four types of ES recognized by UN MEA. Specific services include pollination, predation, scavenging, seed dispersal and engineering.	Global
Wilson, L., Wilson, C., Roy, D., & Otfinowski, R. (n.d.). Ecological Goods and Services Provided by Rangelands and Lands Producing Perennial Forages in Manitoba Carbon sequestration, 1, 3–7.	Survey of literature discussing 3 EGS: carbon sequestration, water regulation and biodiversity.	Manitoba
Zhang, L., Wylie, B. K., Ji, L., Gilmanov, T. G., & Tieszen, L. L. (2010). Climate-driven interannual variability in net ecosystem exchange in the Northern Great Plains Grasslands. *Rangeland Ecology & Management, 63*(1), 40–50. https://doi.org/10.2111/08-232.1	Long-term eddy covariance flux tower measurement of net ecosystem exchange of CO_2 for 2000-2006.	Towers in Montana, North Dakota, South Dakota, and Colorado
Zhou, G., Zhou, X., He, Y., Shao, J., Hu, Z., Liu, R., ... Hosseinibai, S. (2017). Grazing intensity significantly affects belowground carbon and nitrogen cycling in grassland ecosystems: a meta-analysis. *Global Change Biology, 23*(3), 1167–1179. https://doi.org/10.1111/gcb.13431	Meta-analysis of 115 studies to examine global impacts of grazing intensity on C and N fluxes in soil.	Global

Appendix 2: Estimation of Opportunity Cost of Manitoba Community Pastures

The opportunity cost approach looks at the MCPs as they now exist and compares it with a situation if the community pastures were to be dismantled and perhaps sold to private ownership. This requires a slightly different type of estimation of the social value, as shown in Table A1. The basic principle here is that of change in the nature and level of commercial and non-commercial services from the MCPs. For example, if the MCPs are sold to private owners, what would happen to the land use—would it change? If yes, would that affect greenhouse gas emissions, productivity or other benefits from them? This type of evaluation is done for each of the stated benefits used for the estimation of the TEV.

Table A1. A Conceptual Framework for Estimating Opportunity Cost of Community Pastures

Particular	Current	Future	Change
Identify Types of Benefits from Community Pastures	A	B	(A-B)
Estimate Quantity of Benefits by Type	Current Level (C)	Under Altered Condition (D)	(C-D)
Determine valuation of Manitobans to change in Benefits by Type	Current Level (E)	Altered Level (F)	
Total Value (Weighted by type of benefit)	G = C * E	H = D * F	
Opportunity Cost of Manitoba Community Pastures			= H - G

Appendix 3: Animal Unit Equivalent Parameters

Cow/Calf

- Total Weight: 1,000 lbs
- Feed (% of body weight): 2.5 per cent
- Stocking days: 135

Heifer

- Total Weight: 550 lbs
- Feed (% of body weight): 2.5 per cent
- Stocking days: 135

Steer

- Total Weight: 600 lbs
- Feed (% of body weight): 2.5 per cent
- Stocking days: 135

Bull

- Total Weight: 2,000 lbs
- Feed (% of body weight): 2.5 per cent
- Stocking days: 135

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