Chapter 6

Challenges and Opportunities in Estimating the Value of Goods and Services in Temperate Grasslands — A Case Study of Prairie Grasslands in Manitoba, Canada

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1. Introduction

Although the primary function of agricultural lands is to supply commodity outputs such as food, fibre and other raw materials for industrial use, these lands are also a source of many outputs that are not commodities. The non-commodity products are jointly produced and exhibit public goods[1] characteristics. Although more commonly known as externalities of agricultural production, together with the primary production functions are referred to as 'multifunctionality' [1]. Now there is a wide recognition of the services provided by various types of ecosystems [2].

Multifunctionality is important to recognize in the context of human well-being, as it depends on goods and services provided by nature in association with other forms of capital resources. These other capitals include: human capital[2], social capital[3], and manufactured capital[4] (Figure 1). In fact, humanity has always depended on the services provided by the biosphere and its

1 A public good has the characteristic that if supplied to one individual it can be provided to others at no extra cost. Furthermore, no individual can be excluded from the use of that good.

2 Refers to investments made in human resources in order to improve productivity.

3 Social capital is the expected collective or economic benefits derived from the preferential treatment and cooperation between individuals and groups, typically through social networks.

4 Manufactured capital is the infrastructure that is needed to produce various products in the economic system.

ecosystems – natural capital [3]. In order to achieve sustainability, all types of capital are required, although natural capital and economic capital are complementary, and cannot be substituted for each other. Particularly, some of the natural capital cannot even be substituted for any other type of capital (human and manufactured capitals). Furthermore, in some cases, substituting some natural capital may be economically impractical.

An ecosystem service is some attribute of an ecosystem which provides value to humankind [4]. These services are usually related to some attribute of the ecosystem but there is not necessarily a one-to-one correspondence of functions to service. Ecosystems as a provider of goods and services have a value to humankind. These values measure the importance of ecosystem services to members of the society.

The Millennium Ecosystem Assessment [3] has suggested four major types of ecosystem services: provisioning services, cultural services, regulating services, and supporting services that are related to well-being of humans (Figure 2). Provisioning services are the products that the people obtain from the ecosystem. Goods such as food, fibre, water, genetic resources, and others are typical examples. Regulating services include regulation of air quality, climate, water quality, pollination, biological control of diseases, among others. These services are related to productivity of human and non-human systems, and thus have a value. Cultural services result in non-monetary benefits to humans through recreation, aesthetics, and related services. Supporting services are those that are needed for the generation of all the above three types of ecosystem services. Their impact on people is not direct but indirect through these three services.

Figure 1. Types of capital resources relevant to human well-being

Common awareness of concerning trends in climate change and other negative externalities of human activities has recently attracted some attention towards the importance of ecosystem goods and services. Communities and governments have begun to recognize the services that are offered by nature [3]. In response to this need of societies, many researchers and research foundations have started assessing and valuating ecosystems goods and services. Reviewing such studies may shed a light on our way to recognizing the essential goods and services of grasslands in Canada and provide a better understanding of values of these goods and services for society.

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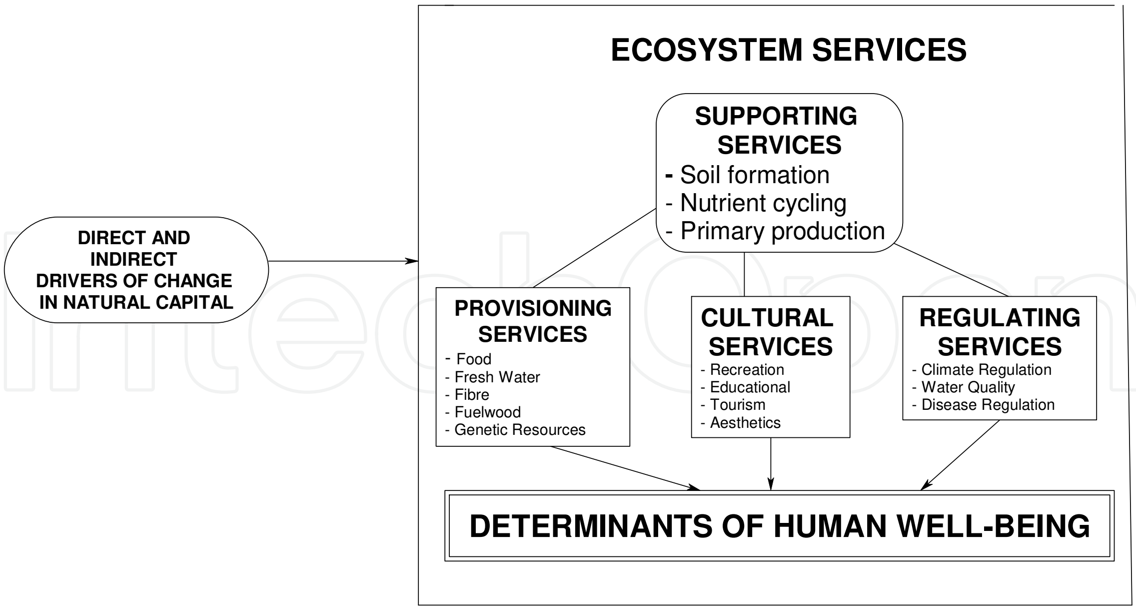

Figure 2. Ecosystems services and ecological goods and services from natural capital (Adapted from [2])

Grasslands are an important part of the rural landscape and are defined as semi-arid areas dominated by herbaceous and shrub vegetation [5]. Worldwide, grasslands fall into three categories, namely, prairie, steppe, and savanna, and cover approximately 3,500 million hectares [6]. On the Canadian prairies, grasslands cover approximately 11 million hectares, extending across southern parts of Alberta, Saskatchewan, and Manitoba, and encompass five prairie eco-regions; Dry Mixed Grass, Mixed Grass, Foothills Fescue, Parkland Northern Fescue, and Tall Grass prairie [7]. Approximately 90% of the Canadian prairie grassland area is grazed by domestic livestock and wildlife [7].

Grasslands have long played a multifunctional role, as a source of feed for wild and domestic herbivores [8,9], and have provided a range of other goods and services (non-commodity goods) such as: management of water resources, carbon sequestration, nitrogen fixation, and recreation [8]. Grasslands are a sustainable source of producing high quality meat and milk [10] and are expected to play an increasingly important role in energy production. The use of perennial grass species, such as switchgrass for ethanol production, could reduce the use of fossil fuels (a positive move in the context of climate change) while also providing producers with an avenue for diversification [11]. Grasslands also play an important role in carbon sequestration. The substantial stocks of carbon sequestered in temperate grassland ecosystems are located largely below ground in the extensive root system of grasses [12, 13]. Perennial forages improve soil quality by reducing erosion and increasing nutrient content of the soil [14]. Grasslands breakdown plant litter and animal wastes and purify water, thus ensuring land and water sustainability and health for future generations [15]. The high plant species richness makes grasslands an ideal habitat for diverse animal populations [8]. Perennial grass cover is important for recreational activities, such as hunting and wildlife viewing [14]. Grasslands provide areas for species reproduction and refuge. For example, ducks need 40% of the landscape as grass in order to achieve nesting success [16]. Grassland flora and fauna are an important genetic resource and provide material for animal and plant breeding and biotechnology [13]. Grasslands are also an important source of biochemical substances that have important medicinal uses [17]. Animal products, such as skins and shells, and flowers from grasslands are important ornamental resources [18]. Thus, the multifunctional role of grasslands provides an important argument for the protection of grasslands as either managed or natural ecosystems.

Ecosystem services through generating ecological goods and services have a value to society, as they contribute to human welfare, both directly and indirectly, and to economic viability through the sustainability of healthy ecosystems [19]. Most goods and services provided by grasslands are not paid for directly and are often overlooked in land-use decision-making processes, resulting in either over-exploitation or inefficient use of grasslands [9]. Establishing an economic value for grassland goods and services increases perception of the importance of grasslands and can lead to improvement in land use in terms of improved grassland management, conservation and protection [9]. Valuation of grasslands can also form the basis for grassland damage assessment and compensation systems [20]. One report on temperate grasslands [20] notes that, although the role of goods and services from temperate grasslands has long been identified as important, the quantitative valuation of such Goods services has not received much attention. A similar sentiment has been expressed through a survey of producers (farmers and ranchers), where recognition of grassland ecosystem services by producers was found to be low – only 25% had awareness of the term 'ecological goods and services' while another 22% indicated some familiarity [21]. To fill this void in past research, this study was undertaken to (a) provide a strategy for assessing the economic value of goods and services from grasslands, (b) identify variables that influence the value of grassland goods and services, and (c) identify gaps in knowledge which require more information to improve the valuation process.

2. Methods

This study was conducted in the Province of Manitoba in Canada. Manitoba, Alberta and Saskatchewan make up the Canadian Prairie Provinces. The Canadian prairies stretch from south-eastern Manitoba to northwestern Alberta [6].

2.1. Concept of value of good/service

Since ecosystem services are a combination of market-based commodities (food and fiber) and non-commodity based goods, their valuation needs to be comprehensive to capture all of these values. Two types of economic valuation are most commonly used: market price method, and non-market valuation. These methods are based on three types of approaches: (1) Revealed willingness to pay; (2) Imputed willingness to pay; and (3) Expressed willingness to pay [22].

Market-based valuation is an example of revealed willingness to pay. People's willingness to pay results in a demand function for that good/service. Here consumers have revealed a preference captured by the curve *DD'* for a given ecosystem service or ecological good or

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service (Figure 3). If that good or service is sold through a market, there would be a price established through interaction between buyers and sellers, shown by *PP′*. Similarly the supplier of that good/service would incur certain expenses and willing to offer that good/ service only if it covers its cost of producing it. Adding all the sellers' offers for that good/ service results in a supply curve for it marked as *SS′*. The area *DP′P* is the benefit to the consumers, called consumer surplus and can be used as the value of that good/service through the use of that ecological good/service. In contrast, the area *PP′S* is the value accruing to producers of that good/service (shaded are in Figure 3), and is equated to be the value of that good/service to them. In the context of grassland, the commercial products are not consumed directly by people, the only relevant value is that to producers.

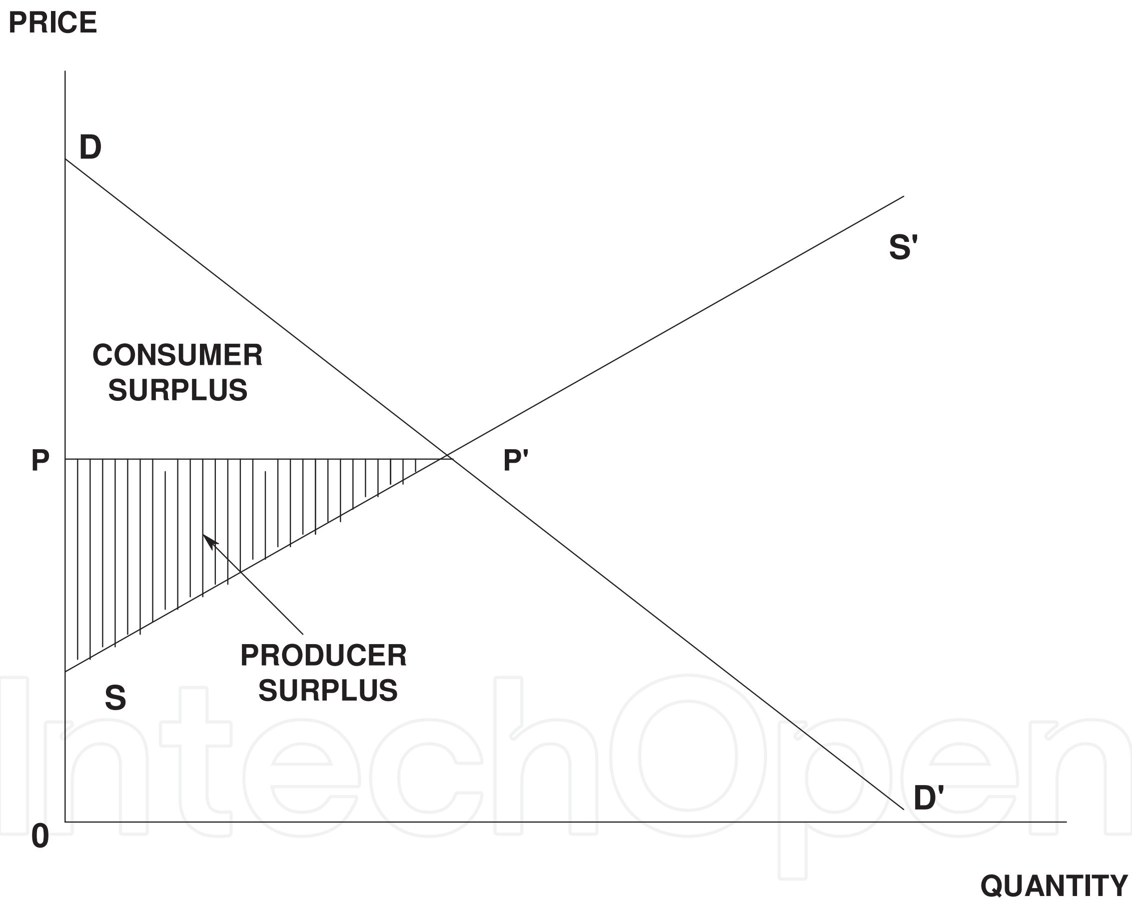

Figure 3. Concept of Consumer and Producers Value of a good/service

Unfortunately many ecological goods and services are not traded through market place. However, for valuation purposes, it is not necessary that an ecosystem service be bought and sold in a market in order to measure its monetary value. What is required under these circumstances is a measure of how much of their purchasing power (dollars) people are willing to give up to enjoy that ecological good/service. Using their revealed willingness to pay, one can use techniques such as Hedonic Pricing method, Travel Cost method or Productivity method to establish a value of the good/service in question. Here the value of a good/service is determined indirectly from the data generated by the marketplace capturing actual market based transactions.

If market based transactions are not available, ecosystem valuation can be based on two other types of approaches: Imputed willingness to pay, and Expressed willingness to pay. These approaches are typically classified as non-market valuation. In the first approach value of an ecosystem service can be imputed from the actions people are willing to take to avoid the adverse effects that could be experienced if that service was lost. Damager Cost Avoided, Replacement cost, and substitute cost are common methods included in this category of non-market valuation. The expressed willingness to pay is through asking people directly what they are willing to pay for an ecosystem service based on a hypothetical scenario. Contingent valuation and Contingent choice methods are included in this category. To undertake non-market valuation, data need to be collected through primary surveys which tends to be costly.

2.2. Process of valuation of Manitoba grassland ecosystem services

The valuation process of grassland goods and services involved several steps. Firstly, detailed information on Manitoba grasslands was collected based on grass type (native, naturalized or tame/seeded), land use (hay, pasture and other) and ownership (private, crown and non-governmental organizations). Tame/seeded grassland was defined as those grasslands which have been cultivated within the past eight years, and are frequently used as part of the crop rotation [23]. Naturalized grasslands are areas that were under cultivation or were seeded to forage and subsequently reverted to grassland, approximately eight to 15 years since last cultivation [23]. Native grasslands were defined as areas that have never been broken, or have been re-established as grassland for such a length of time that native conditions have been restored, more than 15 years since last cultivation [23]. Collection of detailed information on grasslands was followed by identification and valuation of goods and services that could be expected from Manitoba grasslands, as listed in Table 1.

Although a longer list of ecosystem services has been proposed in literature, 21 ecosystem services were identified as being relevant to grassland ecosystems. Of these ten services were excluded from estimation for reasons related to either lack of importance or non-availability of information. The remaining eleven services included all four ecosystem functions. Provisioning services included forage production from grassland, a commercial product for which markets do exist. Under regulating services, six services were identified, including carbon sequestration (thereby affecting gas regulation function), nutrient cycling, water regulation, soil erosion control, soil formation, and water treatment. Recreation and aesthetics was identified as the major cultural service of the grassland ecosystem, whereas refugium services were identified under the supporting services category.

Ecosystem Function	Detailed goods and services	Relevant to grassland in Manitoba	Valuation method
Provisioning services	Forage production	Yes	Market price
	Genetic resources	Nil to ignorable	-
	Medicinal resources	No data	-
	Raw materials	No data	-
	Ornamental resources	No data	-
Regulation services	Carbon sequestration (Gas Regulation)	Yes	Market price –based on carbon trading
	Climate regulation	Nil to ignorable (maybe some local effect, no data)	
	Disturbance prevention	Nil to ignorable	-
	Water regulation	Yes	Value transfer
	Water filtration/water supply	Nil to ignorable	-
	Soil retention/erosion control	Yes	Value transfer
	Soil formation	Yes	Value transfer
	Nutrient cycling	Yes	Market price of accumulated Nitrogen
	Waste treatment	Yes	Value transfer
	Pollination	Yes	30% of market price of food production of grassland relies on pollination
	Biological control	Yes	Value transfer
Supporting services	Wildlife habitat (refugium function)	Yes	Value transfer
	Nursery function	Nil to ignorable	-
Cultural services	Recreation and aesthetics	Yes	Value transfer
	Cultural and artistic information	No data	-
	Spiritual and historic information	No data	-

Table 1. Goods and services from natural ecosystems and methodology of estimation adopted.

Two methods were used to value identified goods and services from the Manitoba grassland ecosystem. A market-based approach was used for goods and services that are traded in the open market. For goods and services that are not traded on the open market, studies that have attempted to value ecosystem goods and services in similar eco-zones were reviewed, and using benefit transfer, values obtained from these studies were applied to non-market goods and services in Manitoba grasslands. Benefit transfer, which in other cases is called environmental value transfer, is related to the process by which a value or demand function of a characteristic or a set of environmental characteristics obtained from each valuation method in a location (original location) can be used to evaluate environmental values in another location (location transfer).

Using the estimates obtained from previous studies to evaluate the costs (or benefits) of new projects, environmental laws or other policies, is common to cost-benefit analysis and public decision making. Benefit transfer approaches are generally recommended and applied by the various institutes for economic valuation of environmental effects. Moreover, because of resource constraints and cost effectiveness, benefit transfer is recommended [24]. In fact, analysts can rarely provide the conditions and facilities of original studies. Therefore, when performing a complete study, transfer studies may provide an economical method to guidance of a researcher [25].

Sometimes the benefit transfer approach is not essentially considered as a methodology, but simply considered as transfer of estimates from one location to other location [25]. Some authors [26] believe that transfer studies involve all advanced skills required to the main research. Therefore, transfer analysts should have high judgment and innovation power of manipulating the existing data and provide results to decision-makers. They should also clearly show the relative roles of data and assumptions and help decision makers to understand the intrinsic uncertainty resources of estimates. Despite the widespread use of this approach, few professional studies exist on how the transfer of data and estimates should be done for grassland ecosystems.

In this study, the benefit transfer approach was used but was also subjected to a sensitivity analysis to account for market price fluctuations or uncertainties in benefit transfer values from other studies. The total economic value of Manitoba grasslands was obtained by summing economic values of market and non-market goods and services.

2.3. Market-based valuation

Under market-based valuation, a link between the environmental (ecosystem) service (and ecological goods and services generated by it) and society’s preference is developed. If the good is commercial in nature, it is bought and sold through the marketplace. Its demand reflects social preference (or value). If market price for a certain grassland service in the marketplace exists, the price is directly used to evaluate the goods and services [27]. Market-based valuation was used to assess the value of perennial forage production, carbon sequestration, and nutrient cycling.

2.3.1. Perennial forage production

Data on grassland area, forage yield and forage prices were obtained from consultations with individuals with in-depth knowledge of Manitoba grasslands (Bill Gardiner, MAFRI; Glenn

Friesen, MAFRI; Rick Andrews, Ducks Unlimited Canada; Wybo Vanderschuit, Riding Mountain National Park) and other sources [23]. The yield of native and naturalized hay was estimated to be 3.92 t/ha/yr whereas that for tame/seeded hay was estimated to be 5.91 t/ha/yr (Glenn Friesen, Manitoba Provincial Forage Specialist, personal communication). The tame/seeded hay yield is the average of the alfalfa and alfalfa-grass yields. It was assumed that grass hay yields were comparable to alfalfa/grass hay yields. The yield for forage seed production (0.38 t/ha/yr) was the average of the yield in 2005 and 2006 [24]. The price (2004-2008 average) utilized for native and naturalized hay was $0.042/kg (Glenn Friesen, personal communication). Grass and alfalfa/grass hay grown on tame/seeded grasslands was valued at $0.055/kg and $0.075/kg, respectively. Forage seed was valued at $1.10/kg (average price for 2005-2006). Native and naturalized pasture was valued at $34.37 ha/yr and tame/seeded pasture was valued at $101.33 ha/yr (Glenn Friesen, personal communication). Energy production, an important direct value of forages, was not included in the valuation of Manitoba grasslands as there are currently no facilities for biofuel production from grass in Manitoba. In fact, perennial grasses that can be used to produce cellulosic ethanol are not yet grown on a commercial scale [11].

2.3.2. Carbon sequestration

The economic value of carbon sequestration was based on sequestration estimates from the Pilot Analysis of Global Ecosystems (PAGE) [5]. The PAGE carbon sequestration estimate for grasslands ranges from 100 to 300 t/ha/yr, with mid-latitude grasslands having lower carbon sequestration than high- and low-latitude grasslands [9]. This study adopted a carbon sequestration value of 105 t/ha/yr for valuation of Manitoba grasslands, as suggested to be appropriate for Canadian grasslands [28]. Due to lack of data on rate of carbon sequestration for various types of grasslands, the same level was assumed for all grasslands in Manitoba. Total amount of carbon sequestered by Manitoba grasslands was estimated at 250.5 million t/yr (Table 2). About 64% of this amount is sequestered by tame or seeded pastures, and another 35% by native pastures in the province.

	Grassland type			
	Native	**Naturalized**	**Tame/seeded**	**All**
Carbon sequestration[1], t/ha/yr	105	105	105	
Area (c), ha	826,334	19,926	1,539,400	2,385,660
Total carbon sequestration, t/yr	86,765,070	2,092,230	161,637,000	250,494,300

[1]Suggested value for Canadian grasslands [32].

Table 2. Calculation of level of carbon sequestration.

Valuation of the carbon sequestered by grasslands is not a simple matter since it is not traded in a fully functional market place. A close approximation to a market is the Chicago Climate

Exchange where in 2009 carbon was trading at US$2.10 per ton. Converting it using current exchange rates leads a value of $2.67 per ton in Canadian funds. This resulted in a total value of $668.8 million. However, during the past, exchange rates between US and Canadian dollar have fluctuated. In addition trading value of carbon at the Chicago Climate Exchange has also fluctuated from $1.60 to $2.15 per ton in US dollar. To see the change in the value of carbon sequestration, a sensitivity analysis was undertaken. The value of carbon sequestration ranged from $508 to $683 million per year (Table 3). On account of higher level of carbon sequestration, value of non-native grassland was higher ranging from $326 to $438/ha/yr compared to native grassland. If one argues that rate of sequestration or its unit value as shown in these tables can vary, further sensitivity analysis needs to be undertaken, which is presented in a later section.

	Exchange rate	Trading Price		Total value	Value (Can $/ha/yr)	
		2009 US $/ton	2009 Can $/ton	2009 Can $	All grasslands	Excluding native grasslands
Base scenario	1.2718	2.10	2.67	668,819,781	280.35	428.91
Lower C price scenario	1.2718	1.60[1]	2.03	508,503,429	213.15	326.10
Higher C price scenario	1.2718	2.15[2]	2.73	683,849,439	286.65	438.55
Strong Canadian dollar	0.9984[2]	2.10	2.10	526,038,030	220.50	337.35

[1]Lowest trading price between 2003-2010 at Chicago Climate Exchange.

[2]The exchange rate on April 21, 2010.

Table 3. Sensitivity analysis of total value of carbon sequestration in Manitoba grasslands.

2.3.3. Nutrient cycling

The value of increasing soil nitrogen was determined as a product of estimated amount of nitrogen accumulation in the soil, area of grassland and the value of the accumulated nitrogen. Utilizing a 10:1 ratio of carbon to nitrogen accumulation [29] resulted in accumulation of 0 t nitrogen ha/yr in native grassland, and 0.047 and 0.056 t nitrogen ha/yr in naturalized and tame/seeded grassland, respectively. The accumulated nitrogen was valued at $1.32/kg, the value of urea fertilizer. This resulted in a value for nutrient cycling of $81.47/ha.

2.4. Non-market-based valuation

Most goods and services in grasslands are not traded in the marketplace and require valuation techniques that reflect their existence outside the market system [27]. Techniques for the valuation of such non-market goods and services have been discussed above. Most of these techniques are time-consuming and require considerable resources to complete. Selection of benefit transfer as the method of choice in this study was based on cost-effectiveness and

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previous application in the valuation of ecosystem goods and services. Benefit transfer is widely applied in the economic valuation of non-market services, often as part of cost-benefit analysis of a new project that has environmental impacts. A legitimate use of benefit transfer should meet the following conditions: a) population of both regions should be similar, b) goods and services in all locations should have about the same characteristics, and, c) initial estimated values should be current because preferences change over time [30].

The benefit transfer values utilized in this study were obtained mainly from two studies [14, 24] and are listed in Table 4. The first study [14] used four case studies from different agricultural regions across Canada to assess the ecological goods and services provided by the natural capital within settled areas. The case studies estimated that the net value of conserving or restoring natural areas varied from $65/ha/yr in the Upper Assiniboine River Basin in eastern Saskatchewan and western Manitoba, $142/ha/yr in the Mill River Watershed in Prince Edward Island, to $195/ha/yr in the Grand River Watershed of Ontario. The transfer values from this study [14] were, in turn, obtained from a report [31]. The second study [24] undertook an evaluation of the economic value of New Jersey's wetlands, marine ecosystems, forests, urban green space, beaches, agricultural land, open fresh water and riparian buffers. The transfer values from this study were only used in situations where no Canadian values exist.

Other important sources of benefit transfer values relevant to the Canadian prairies [32-34] were consulted and appropriate values were selected for this study. Benefit transfer was used to value water regulation, waste treatment, soil erosion control, soil formation, recreation, and wildlife habitat (refugium). The value of water regulation in Manitoba grasslands was calculated from total grassland area (2,385,660 ha) using the benefit transfer value of $5.14/ha/yr (Table 4). Benefit transfer values for soil formation ($10.70/ha/yr) and erosion control ($13.34/ha/yr) were transferred from two studies [24, 35] (Table 4). Waste treatment was estimated utilizing a benefit transfer value of $64.52/ha/yr (Table 4). The value of cultural services was transferred from reference [14]. The value of refugium was transferred from a study [34] which estimated willingness to pay for prairie grassland conservation for burrow owl (an endangered species) in Southern Alberta at approximately $34.07/rural household (Table 4).

In determining the preferred value to be transferred to this study, values derived from a similar eco-zone of grassland in Manitoba were used. In general, values transferred from North America grassland were preferred to the global grassland. Similarly, Canadian grassland values were preferred over the North America grassland. If a choice was available, values from Western Canada were preferred over those from Eastern Canada.

3. Results

Grasslands of various types occupy approximately 2.4 million ha of Manitoba lands (Table 5). Of this area, 64.5% is tame/seeded grassland and 34.6% is native grasslands. Naturalized grasslands make up less than 1% of the total grassland area. Almost half of Manitoba grasslands (54%) are utilized for pasture, while another 44% are utilized for hay production. Most of the grassland area in Manitoba (90%) is privately-owned (Table 5).

Single value $/ha/yr	Value range $/ha/yr	Notes	Source
		Water regulation	
5.14		Improved water quality-decreased sediment in Upper Assiniboine River Basin	[14]
7.14	1.48 – 7.14	Average of grassland in the world	[24]
		Erosion control	
2.97		Estimate is based on reduced wind erosion in Upper Assiniboine River Basin	[14]
13.34	2.97-53.45	Based on prairie soil in Canada	[34]
53.45		Average of grassland in the world	[24]
		Soil formation	
10.7	10.7	Average of grassland in the world	[19]
		Waste treatment	
64.52		Waste treatment services by forests (i.e. removal of phosphorus and nitrogen	[14]
157.03	64.52-157.03	Average of world grassland	[24]
		Recreation & aesthetics	
17.05		Assuming that cropland provides no habitat to game species of wildlife, the average hunting value for lands in permanent cover is $11.91/ha/yr, an upper bound is $23.72/ha/yr. Revenue related to wildlife viewing is about $5.14/ha/yr.	[14]
0.1	0.10-17.05	Based on discrete travel cost study in Alberta	[32]
		Refugium function	
4.6		Individual households are willing to pay $34.07 to conserve grassland habitat for burrowing owl, and there are 321,750 rural households in Manitoba	[33]
0.25	0.20-4.60	$1.48-2.69/household	[14]

[1]Preferred transfer values were derived from a similar eco-zone as grassland in Manitoba. North America grassland values were preferred to global grassland values.

Table 4. Summary of grassland goods and services values[1] reported in other studies and utilized in benefit transfer.

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3.1. Market-based valuation

3.1.1. Perennial forage production

Most perennial forage production in Manitoba occurs on native (826,334 ha) or tame/seeded grasslands (1,484,999 ha), with only small amounts of naturalized grassland (18,211 ha) being utilized for this purpose (Table 5). Forages in Manitoba are primarily utilized for grazing and preserved forage (hay and silage) but may also be used for forage seed production (Table 5). The total value of forage production in Manitoba was approximately $524 million/yr (Table 6). Sensitivity analysis of the volatility of forage prices indicated that a 20% increase in the price of hay would increase the value of seeded forage or pasture to $629.5 million/yr. An equivalent decrease in the price of hay would reduce the value of seeded forage/pastures to $419.7 million/yr.

Grassland Type	Ownership	Grassland use (ha)			Sub-total
		Hay	Pasture	Other uses[2]	
Native Grassland[3]	Private	82,537	577,754	137[6]	660,428
	Crown	10,114	152,777	2,999	165,889
	NGO	-	17	-	17
	Sub-total				**826,334**
Naturalized Grassland[4]	Private	-	-	137[6]	137
	Crown	4,098	14,113	-	18,211
	NGO	-	-	1,578	1,578
	Sub-total				**19,926**
Tame/seeded Grassland[5]	Private	945,308	498,312	53,551	1,497,171
	Crown	5,008	36,371	-	41,379
	NGO	-	-	850[6]	850
	Sub-total				**1,539,400**
Grand total					**2,385,660**

[1]Compiled from several sources [24,35-37] and personal communication with Bill Gardiner (MAFRI), Glenn Friesen (MAFRI), Rick Andrews (Ducks Unlimited Canada), and Wybo Vanderschuit (Riding Mountain National Park).

[2]Mainly forage seed production, green space and aesthetic appeal.

[3]Grasslands which have been cultivated within the past eight years and are frequently used as part of the crop rotation.

[4]Areas that were under cultivation or were seeded to forage and subsequently reverted to grassland (approximately eight to 15 years since last cultivation).

[5]Areas that have never been broken, or have been re-established as grassland for such a length of time that native conditions have been restored (> 15 yr since last cultivation).

[6]Conservation purposes (Rick Andrews, Ducks Unlimited, Canada, personal communication).

Table 5. Area of Manitoba grasslands by grass type, use and ownership[1].

Production				
Grassland type[2]	Hay	Pasture	Forage seed	Total
Native	$16,767,375	$25,109,664	0	
Naturalized	$88,984	$485,111	0	
Tame/Seeded	$402,814,401	$54,181,756	$25,166,927	
Total	$419,670,760	$79,776,531	$25,166,927	$524,614,218

[1]Areas of different grassland types are shown in Table 5.

[2]Defined in Table 5.

Table 6. Total annual value[1] of forage and seed production from Manitoba grasslands.

3.1.2. Carbon sequestration

With 19,926 ha of naturalized grassland and 1,539,400 ha of tame/seeded grassland in Manitoba, carbon sequestration in Manitoba grassland was estimated at approximately 250.5 million tons annually (Table 5). The average value of carbon sequestration was $280.35/ha/yr for all types of grasses (Table 7). Alternative values that were estimated to account for fluctuations in Canadian-US dollar exchange showed that the total value of carbon sequestration could range from approximately $508.5 million/yr to $683.8 million/yr (Table 7). The average value of carbon sequestration for all grasslands was approximately $213.35 to $286.65/ha/yr or, if native grassland is excluded, $326 to $439/ha/yr (Table 7). The value of carbon sequestration in this study lies between estimates of $267/ha/yr and $469/ha/yr reported in other studies [28,38].

Source	Price ($/ha)	Area (ha)	Total value (2009 Can $)
This study	280.35	2,385,660	668,819,781
[38]	266.94	2,385,660	636,828,080
[28]	468.84	2,385,660	1,118,492,834

Table 7. Sensitivity analysis of the total value of carbon sequestration.

3.1.3. Nutrient cycling

Perennial forages can improve land productivity by increasing the nutrient content of soil. For example, inclusion of legumes in pastures will increase soil nitrogen due fixed atmospheric nitrogen being added to the soil [39]. The increase could also be due to the ability of forages to access nitrate from soil depths of more than one meter below the surface. With a total of 1,559,326 ha of naturalized and tame/seeded grassland, the total value of nutrient cycling was estimated at $127.04 million/yr. If the price of nitrogen fluctuates by 20%, the total value of nitrogen will vary between $101.63 and $152.45 million/yr (Table 8).

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	Best value[1]		Low estimate		High estimate	
Goods and services	Total ($ million)	$/ha	Total ($ million)	$/ha	Total ($ million)	$/ha
Provisioning services						
Forage production	524.61	219.89	419.69	175.93	629.54	263.87
Regulating services						
Carbon sequestration						
Low CO_2 price	508.50	213.15	508.50	213.15	508.50	213.15
Middle CO_2 price	668.82	280.35	668.82	280.35	668.82	280.35
High CO_2 price	683.85	286.65	683.85	286.65	683.85	286.65
Nutrient cycling	127.04	81.47	101.63	65.18	152.45	97.78
Water regulation	12.26	5.14	3.54	1.48	17.04	7.14
Soil erosion control	31.85	13.34	7.07	2.97	127.51	53.45
Soil formation	25.52	10.70	8.94	3.76	29.60	12.40
Waste treatment	153.92	64.52	153.92	64.52	374.62	157.03
Cultural service						
Recreation and aesthetics	40.67	17.05	0.01	0.10	40.67	4.74
Supporting services						
Refugium function	10.96	4.60	0.25	0.20	0.46	0.37
Low CO_2 price	1,435.33	629.86	1,203.55	527.29	1,880.39	809.93
Middle CO_2 price	1,595.65	697.06	1,363.87	594.49	2,040.71	877.13
High CO_2 price	1,610.68	703.36	1,378.90	600.79	2,055.74	883.43

[1]Estimates are based on 2,385,660 ha of grassland except nutrient cycling (1,559,325 ha).

Table 8. The annual value of goods and services from Manitoba grasslands.

3.2. Non-market-based valuation

The value of water regulation was estimated to be $12.26 million/yr or $5.14/ha/yr (Table 8). The total value for erosion control in Manitoba grasslands was assessed to be $32 million/yr or $13/ha/yr while soil formation by grasslands was estimated to be $26 million/yr (Table 8). Based on 2,385,660 ha of grassland, waste treatment in Manitoba grasslands was valued at approximately $153.92 million/yr (Table 8). Cultural services from grasslands include recreation, aesthetics, and cultural information. Perennial forage cover increases recreational activities such as hunting and wildlife viewing [14]. In riparian areas, perennial forage cover can increase the use of an area for fishing, camping, swimming, and canoeing [14]. Based on approximately 2.4 million ha of grassland and benefit transfer value of $17.05/ha/yr (Table 4), the value of cultural services from Manitoba grasslands was estimated to be $40.67 million/yr

(Table 8). With 321,750 rural households in Manitoba in 2006, the total value for conserving the burrowing owl in Manitoba grasslands was estimated to be $10.96 million/yr or approximately $4.60/ha/yr (Table 4). Using these estimates, the total willingness to pay by Manitoba rural households was estimated to range from $0.25 to $0.46 million/yr or $0.20 to 0.37/ha/yr (Table 8).

3.3. Total value of Manitoba grasslands

The total economic value of Manitoba grasslands varies between $1,204 million/yr ($527/ha/yr) to $2,056 million/yr ($883/ha/yr; Table 8). This range is relatively narrow as a consequence of the sensitivity analysis conducted. The scope of research for values that were derived from benefit transfer was limited to those studies conducted in a similar eco-zone to Manitoba grasslands. Further, a 20% price fluctuation in prices was assumed for values that are derived using market price. The economic value of Manitoba grasslands obtained in this study should be taken as a minimum value which is expected to change as information specific to Manitoba grasslands becomes available.

Among all the estimated values of various ecosystem services, besides the commercial (market-based) values, carbon sequestration is an important ecosystem service (Figure 4). About a third of the total value of Manitoba grasslands is through production of forages and related goods. Under most expected conditions, the ecosystem service most important for this ecosystem is carbon sequestration. At this time, 42% of total value is credited to this service. The third most important ecosystem service for the Manitoba grassland is from waste treatment.

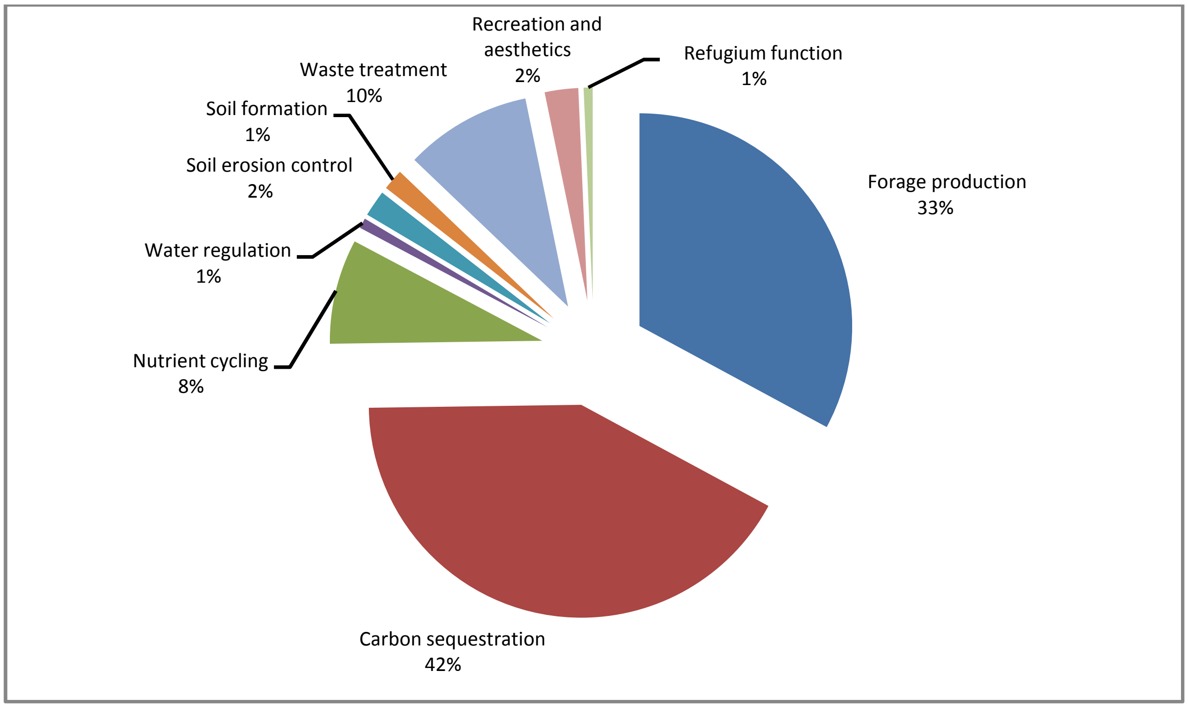

Figure 4. Distribution of total economic value of Manitoba grassland by type of ecosystem service

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4. Discussion

This study set out to provide a strategy for estimating the economic value of goods and services from Manitoba grasslands by utilizing market and non-market based approaches. Assigning value to goods and services such as perennial forage production and carbon sequestration that are traded in the open market is a matter of identifying prevailing market values. The market value of goods and services such as forage production will depend on the quality of the goods and services. The value of pasture, for example, should take into account season, pasture plant species, and pasture management since such factors will influence pasture quality. For hay, quality characteristics including nutrient content (protein and energy) as well as organoleptic characteristics, such as color, mold, and dust, to assign value would lead to a more objective price determination. Such a pricing system would give a range in prices for forage production. The strategy of assigning value based on forage quality was not employed in the current study due to inadequate information. Carbon sequestration is influenced by location of the grasslands [28] and by management practices that are imposed on the grasslands [10]. Carbon sequestration estimates reported in these studies were not measured directly and the differences in estimates among studies suggest a need for direct carbon sequestration measurements in grasslands.

Benefit transfer was used to valuate non-market goods and services in Manitoba grasslands. Challenges in applying benefit transfer analysis are mainly related to difficulties in identifying and selecting suitable studies for comparison, in combining data and in transferring data [40, 41]. It is also important to note that most studies are not designed with the aim of transferring [40, 41]. A more complex approach, which we did not use in this study, is to use meta-analysis to systematically analyze the impact of a study on estimated values [26]. The use of the benefit transfer method is not universally accepted and has been questioned. In most cases, the original studies will have valued small changes in specific and localized components of individual ecosystems, which makes it incorrect to extrapolate value estimates obtained from these localized scenarios to a much larger scale [26]. Benefit transfer has also been criticized as being dirty, quick and ugly [42]. Some economists do not consider benefit transfer as a methodology, but simply consider it as transfer of estimates from one location to other location [25]. Others (43) consider the transfer of valuations from one ecological and social context to another as dangerous because ecosystem values are highly dependent on location. Until more appropriate methods are utilized to value ecosystem goods and services, benefit transfer will likely remain the method of choice.

Genetic, medicinal, and ornamental resources, water supply and cultural services, such as cultural and artistic information, and spiritual and historic information were not included in the valuation of Manitoba grasslands due to lack of information. Such goods and services tend to be site-specific and values obtained within the region of interest, in this case, prairie grasslands, would be more appropriate. Since no valuation studies for these goods and services were identified, primary data collection would be the only method to collect such information. Techniques that can be utilized to value these goods and services have been suggested [27]. A market-based valuation (direct market pricing) is appropriate to value genetic, medicinal, and ornamental resources, water supply, and nursery function although other techniques such as factor income, replacement cost, and contingent valuation can also be applied [27]. For cultural services, techniques such as contingent valuation, travel cost, and hedonic pricing are important [27]. With growing emphasis on valuation of grassland goods and services, there is a need to conduct specific studies that will provide values for such goods and services. Such information will further improve the value of grasslands, thus further emphasizing the importance of maintaining productive grasslands.

5. Conclusion

Grasslands have a multi-functional role, providing food for herbivores as well as other goods and services such as carbon sequestration, nature conservation, and recreation. The goods and services provided by grasslands have direct and indirect monetary value. This study was conducted to a) provide a strategy for assessing the economic value of goods and services from grasslands, b) identify variables that influence the value of grassland goods and services, and c) identify gaps in knowledge which require more information to improve the valuation process. The study was conducted in three stages. Firstly, information regarding grasslands in the Province of Manitoba, Canada was collected based on grass type (native, naturalized or tame/seeded), land use (hay, pasture and other) and ownership (private, crown and non-governmental organizations). This was followed by identification of goods and services that could be expected from these grasslands. The identified goods and services were then valuated. Market prices were utilized to value grassland goods and services where transactions occur in the marketplace while the benefit transfer method was used to infer monetary values of those goods and services that are not typically sold through the marketplace. Sensitivity analysis was performed to account for market price fluctuation or uncertainties in benefit transfer. The total economic value of Manitoba grasslands was derived by summing economic values of goods and services for which supporting data was available.

Although the study identified 21 goods and services provided by Manitoba grasslands, only perennial forage production, carbon sequestration, nutrient cycling, water regulation, waste treatment, soil erosion control, soil formation, recreation, and wildlife habitat were included in the valuation. Genetic, medicinal, and ornamental resources, water supply, nursery function, biological value, and cultural services, while important, could not be assigned monetary value due to lack of data. The total economic value of Manitoba grasslands was estimated to be approximately $1,436 million/yr ($630 ha/yr), with a range of $1,203 million/yr ($527 ha/yr) to $1,880 million/yr ($810 ha/yr). The two most highly valued goods and services in Manitoba grasslands were perennial forage production and carbon sequestration. Multidisciplinary research, focusing on economic valuation of non-market goods and services will provide more relevant transfer values than those obtained from other ecosystems and will greatly improve estimates of grassland value.

This study shows that goods and services in complex ecosystems such as temperate grasslands can be valued using market and non-market based valuation methods. Improvements in market-based valuation can be accomplished by local research that will more precisely quantify goods and services such as carbon sequestration and assess forage value based on forage quality. The major challenge in valuation of grasslands lies in the development and use of methods to improve valuation of non-market goods and services. While benefit transfer, as utilized in this study, gives estimates of the value of non-market goods and services, local grassland research will be required to ground truth benefit transfer values. The limited number of studies reporting values of non-market goods and services in North America made use of benefit transfer in the current study somewhat complex. This study could not access information on the value of goods and services such as genetic, medicinal, and ornamental resources, water supply, and cultural services, which will be required for a complete valuation of grasslands. Ultimately, the valuation of grasslands will require economic values of goods and services obtained directly from grasslands. In this respect, investment into multidisciplinary research focusing on the economic valuation of grassland goods and services will provide more relevant transfer values than those obtained from other ecosystems and will greatly improve grassland valuation.

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