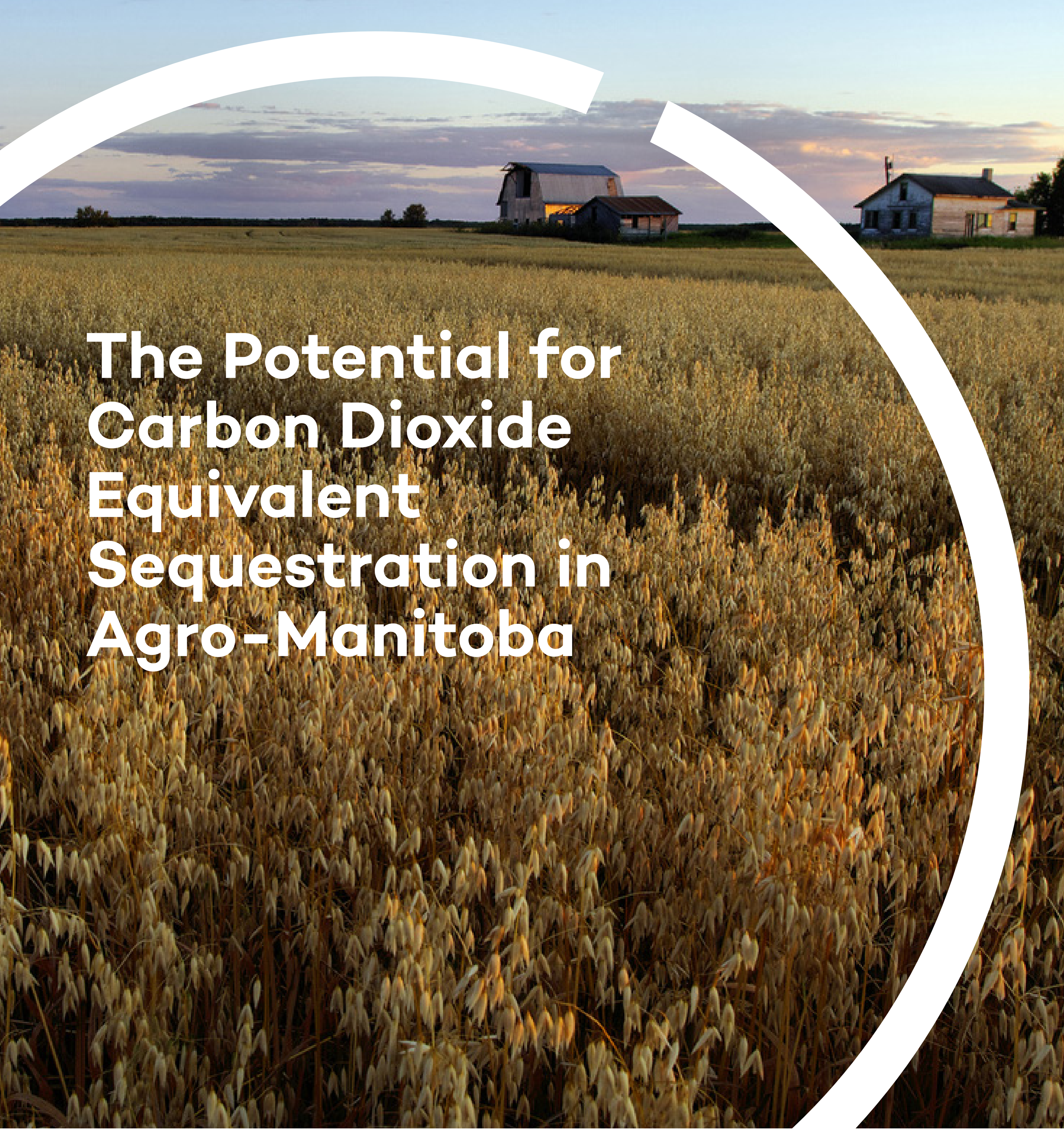

The Potential for Carbon Dioxide Equivalent Sequestration in Agro-Manitoba

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1.0 INTRODUCTION

Manitoba is a province rich in agricultural lands, where the agriculture sector is a cornerstone for the economy. It is also the second largest emitting sector in the province's greenhouse gas (GHG) emissions profile. In 2015 Manitoba's total emissions were 20.8 megatonnes of carbon dioxide equivalent ($MtCO_2e$); of these, transport sector emissions are the largest (39 per cent of total emissions) and the agricultural sector emissions were 6.5 $MtCO_2e$ (or 31 per cent of total emissions) (Environment and Climate Change Canada, 2017). Though a high emitting sector, land use practices in Manitoba over the years have become more sustainable, such as increasing land conservation and reducing emissions intensity. In the province and internationally, more and more of these practices are gaining momentum as important tools to address climate change and support environmental commitments.

Internationally, the potential to mitigate anthropogenic GHG emissions by managing terrestrial ecosystems—particularly through agriculture and forestry—has re-emerged as core climate policy since the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change in Paris (December 2015). Nationally, the Pan-Canadian Framework on Clean Growth and Climate Change highlights carbon sequestration under land use and conservation measures as contributors to reducing GHG emissions and meeting Canada's 2030 reduction target. Provincially, in the 2016 Speech from the Throne, the Government of Manitoba also highlighted land use and conservation measures as key elements for carbon sequestration (Government of Manitoba, 2016a):

> Manitoba's New Government will begin discussions with our federal partners and other jurisdictions as we develop a made-in-Manitoba climate action plan. This plan will include carbon pricing that fosters emissions reductions, retains investment capital and stimulates new innovation in clean energy, businesses and jobs. **We will consult in the development of land-use and conservation measures that sequester carbon, improve water quality and foster adaptation to climate change.** (p. 7, emphasis added).

Additionally, the provincial ministers of agriculture and sustainable development jointly received ministerial mandate letters with instructions to implement programming based on the alternative land use services model (Government of Manitoba, 2016b).

As the province moves toward a new climate policy paradigm, the land use-based practices in private, seeded lands within Agro-Manitoba[1] present an opportunity to sequester or reduce net emissions. To this end, the International Institute for Sustainable Development and the Prairie Climate Centre conducted a high-level quantitative analysis of the sequestration potential of land use practices in Agro-Manitoba that are additional to business as usual. The land use practices that were considered in this study include those related to wetlands, forestry, riparian buffers, minimum tillage, perennials and cover crops.

The paper begins by presenting the analytical framework to conduct the analysis, outlining modelling approaches, assumptions and sources used to calculate the carbon dioxide equivalent (CO_2e) sequestration potential in Agro-Manitoba, as well as identifying the limitations of the analysis. It then moves on to present the results, breaking it down from total CO_2e sequestration potential under each approach moving toward the CO_2e sequestration rates of the individual land use practices. Next, the paper outlines some of the broader ecological and social co-benefits and drawbacks of each practice, followed by opportunities for policy coherence in land use practices. The paper concludes with suggestions for next steps in analysis.

[1] Agro-Manitoba refers to privately owned agricultural land in southern Manitoba.

2.0 ANALYTICAL FRAMEWORK

The following provides information on the modelling approaches used to conduct the high-level analysis presented in this paper, outlines the assumptions used for each land use practice analyzed in this study and describes the sources used to conduct the study. Lastly, it sets out the limitation of the analysis.

2.1 Modelling Approaches

The estimates in this paper were developed using two different approaches, each considering high and low GHG mitigation scenarios (see Table 1). The first approach presents a snapshot that looks at the maximum potential one-year CO_2e sequestration rate, while the second approach presents the annual average CO_2e sequestration rate over the course of 30 years through a cumulative sequestration approach.

2.1.1 Maximum One-Year Sequestration Rate Approach

This approach captures the maximum sequestration rate that could ensue from all six practices under consideration if they were all to reach their maximum sequestration rate in a given year.

For each practice, an annual CO_2e sequestration rate was computed and applied to an estimated adoption rate across Agro-Manitoba based on surface area. Hectares of land were used as the unit of reference for the latter.

Maximum sequestration rate was explored, in part, to be cognizant of the fact that adoption of different forestry and agriculture practices by landowners is dependent on a number of variables (e.g., crop prices, incentives), in addition to considering that the soil on which these practices are implemented will eventually saturate in its capacity to sequester carbon (discussed below). The maximum sequestration rate could happen earlier or later based on how those external, independent variables play out. What the high and low scenarios of the maximum one-year approach first help illustrate is the CO_2e sequestration rate for each practice per hectare per year (see Table 2).

2.1.2 Cumulative Potential Approach

In addition to exploring the maximum one-year sequestration rate of CO_2e for the same six practices, their cumulative potential was calculated over a 30-year period. It was assumed that each practice would be implemented starting year one at the annual adoption rates found in Table 3. The cumulative potential of all six practices combined is illustrated in Figure 1.

The cumulative approach takes into account the fact that, in agriculture practices, soil saturates more quickly than forestry when sequestering carbon. Twenty years after the practices are first implemented on a certain lot of land, the capacity to sequester carbon peaks and progressively declines over the next 20 years. This means that the surface area on which the practice is implemented in year one stops sequestering carbon after year 20; in year two it stops sequestering carbon after year 21, and so on. More specifically, the total surface area in the agricultural practices under consideration would be fully saturated in carbon after 40 years.

These data, represented in Figure 1 and Figure 2 (in Section 3), provide a hypothetical picture of the sequestration potential that Agro-Manitoba could progressively harvest, assuming constant adoption of all six practices by landowners over the next 30 years.

2.1.3 High and Low Scenarios

The high and low scenarios were developed to reflect two different averages of potential CO_2e practice sequestration rates for cover crops outlined in the scientific literature. Different cover crop methods have different impacts on carbon sequestration. One form of cover cropping uses the biomass harvested for green manure, usually used during the planting season in the fallow period (typically late fall) and ploughed into the soil before seeding or mowed as a surface mulch. The other form of cover cropping harvests all or part of the aboveground biomass for use or marketing (e.g., winter wheat or livestock fodder). These different methods can dramatically alter carbon sequestration, particularly when used alongside tillage practices. Estimates of both practices are included in this study: a high sequestration estimate from VandenBygaart et al. (2008) that includes cover crop harvesting and a lower estimate from VandenBygaart et al. (2003) that only includes green manure.

2.2 Assumptions

In the case of wetlands, we assume that from 2017 no more surface area would be converted from wetlands to other land use, and that, optimistically, 10,000 hectares of land could be restored annually. The number of hectares for wetlands was derived from the Manitoba Habitat Heritage Corporation's (MHHC) most recent annual wetland conservation figures of roughly 4,700 hectares in 2015–2016 (MHHC, 2016), along with MHHC's figures of hectares protected in 2014-2015, at approximately 14,800 hectares (MHHC, 2015). From this, a rough average of 10,000 hectares of restored, protected or conserved area annually was deemed realistic under a provincial program designed through incentive measures.

Information on forestry was derived from provincial and federal incentives conducted between 2008 and 2012, such as Improved-Stock, Trees for Tomorrow, Agro-Woodlot, Forest 2020 and Manitoba Forestry Association Woodlot programs. The information provided estimated additional land area and annual sequestration rate in forestry for Agro-Manitoba. For riparian buffers, the potential practice sequestration rate included in this study is an average of the potential practice sequestration rate coming from four different species or categories, namely: aspen, green ash, hybrid poplar and white spruce. For both forestry and riparian buffers, there was no specification of tree type to derive the sequestration rate, and for forestry there was no separation between forestry practices, such as afforestation and reforestation, as the data used did not make this distinction. Afforestation and reforestation, however, are the two main practices assumed under forestry, and to a lesser extent shelterbelts.

For minimum tillage, the literature focused primarily on switching from conventional tillage to conservation tillage (some residue maintained on soil surface), with a potential practice sequestration rate of 0.4 tCO_2e/ha/year. This rate was lowered to 0.3 tCO_2e/ha/year to be more representative of minimum tillage practices that present a higher disturbance on the soil, but are also more realistic in terms of adoption in Agro-Manitoba. An increase in zero tillage hectares was not considered in this analysis because the overall uptake of this practice seems to have peaked in Manitoba and will likely vary in the future depending on prevailing soil moisture conditions (i.e., it will tend to increase during dry periods and decrease during relatively wet periods).

Information for cover and perennial crops on estimated additional adoption land area was obtained from Manitoba Agriculture experts that were consulted for this study, and the practice sequestration rates were derived from literature that focused on agricultural management in Canada. As noted before, cover crops are the measure that represents the high and low scenarios in the analysis. The higher practice sequestration rate was derived from literature that included reseeded grassland or perennial forage, while the lower practice sequestration rate looked at cover crops under green manure rotation. For perennial crops, the focus was on grassland restoration of forage cover on annual cropland.

Minimum tillage, cover and perennial crops' practice sequestration rates were converted from soil carbon sequestration to a CO_2e capture conversion rate of 3.67 tCO_2e per tonne of carbon. In addition, under the cumulative approach, for all agriculture practices it was assumed that after 20 years of implementation, soil carbon absorption capacity would be saturated. This means that the soil would hold the sequestered carbon (or CO_2e) amassed for 20 years but would no longer accumulate additional stock due to saturation in the capacity for soil to sequester carbon (see further details in Section 3).

2.3 Sources

Overall, the literature used in this study is representative of an initial illustrative study, and in all cases the practice sequestration rates were not Manitoba-specific, though most were derived from research and field experience in Western Canada and the Prairie Pothole Region, coupled with inputs from Manitoba Agriculture and Forestry Branch experts.

2.4 Limitations

Due to the high-level analysis in this study, the following are limitations in the analysis' scope:

- There is no specificity per practice; therefore, there is no granular reflection of the incremental sequestration rate of individual practices. For example, no tree type was identified for forestry and riparian buffers, where tree types have different practice sequestration rates and the uptake will vary depending on the tree stand and soil quality.
- No representative curve of the gradual sequestration rate per practice is available. The cumulative potential and annual average rate are over a 30-year period.
- There is no cost per uptake of practices, nor cost per tonne in this analysis. In order to undertake that type of study, it would be necessary to conduct a deeper analysis that includes different types of policies and incentives and types of input (such as soil type) used by farmers, etc., as such inputs would provide a more detailed, holistic picture of the political and economic landscape.

3.0 RESULTS

Table 1 presents the results for both approaches and includes scenarios illustrating the high and low ranges of tonnes of CO_2e sequestration potential per year.

Table 1. CO_2e sequestration rate

Approach	Scenario	Sequestration rate (tCO_2e/yr)
Maximum one-year	High	3,072,825
	Low	2,441,825
Annual average	High	1,707,978
	Low	1,334,636

Table 2. Maximum one-year carbon sequestration potential

Practice	Practice sequestration ($tCO_2e/ha/yr$)	Total new potential area (ha)	Maximum one-year sequestration rate (tCO_2e)	Source (practice sequestration)
Wetlands	3.25	300,000	975,000	Badiou et al., 2011
Forestry	5.25	45,000	236,250	Personal communication with Manitoba Forestry Branch (September 27, 2017)
Riparian buffers	8.56	30,000	256,890	Alberta Agriculture, Food and Rural Development, 2001
Minimum tillage	0.30	1,000,000	300,000	VandenBygaart et al., 2008, with assumption of lower practice sequestration rate than no-till practice
Cover crops (high)	1.10	1,000,000	1,101,000	VandenBygaart et al., 2008
Cover crops (low)	0.47		470,000	VandenBygaart et al., 2003
Perennial crops	2.04	100,000	203,685	VandenBygaart et al., 2008
Total (high)		**2,475,000**	**3,072,825**	
Total (low)			**2,441,825**	

Table 3. **Cumulative carbon sequestration potential of various land use practices, over 30-year time frame**

Practice	Estimated additional adoption over 30-year time frame (ha/year)	Time frame	Practice sequestration rate (tco_2e/ha/year)	Total new potential area (ha)	Cumulative sequestration potential after 30 years (tCO_2e)	Annual average sequestration rate over 30 years (tCO_2e)	Source (practice sequestration)
Wetlands	10,000	30	3.25	300,000	15,112,500	503,750	Badiou et al., 2011
Forestry	1,500	30	5.25	45,000	3,661,875	122,063	Personal communication with Manitoba Forestry Branch (September 27, 2017)
Riparian buffers establishment	1,000	30	8.56	30,000	3,981,795	132,727	Alberta Agriculture, Food and Rural Development, 2001
Minimum tillage	50,000	30	0.30	1,000,000	5,325,000	177,500	VandenBygaart et al., 2008, with assumption of lower practice sequestration rate than no-till practice
Cover crops (high)	50,000	30	1.10	1,000,000	19,542,750	651,425	VandenBygaart et al., 2008
Cover crops (low)			0.47		8,342,500	278,083	VandenBygaart et al., 2003
Perennial crops (grassland restoration of forage cover on annually cropped land)	5,000	30	2.04	100,000	3,615,409	120,514	VandenBygaart et al., 2008
Total (high)	**117,500**			**2,475,000**	**51,239,329**	**1,707,978**	
Total (low)					**40,039,079**	**1,334,636**	

3.1 Cumulative Potential and Annual Sequestration Rate

Based on the analysis, the cumulative CO_2e sequestration potential ranges between 40,039,079 and 51,239,329 tCO_2e over 30 years, as illustrated in Figure 1. This translates into an annual average sequestration rate between 1,334,636 tCO_2e using lower practice sequestration rate for cover crops, and 1,707,978 tCO_2e using higher practice sequestration rate for cover crops, as illustrated in Figure 2.

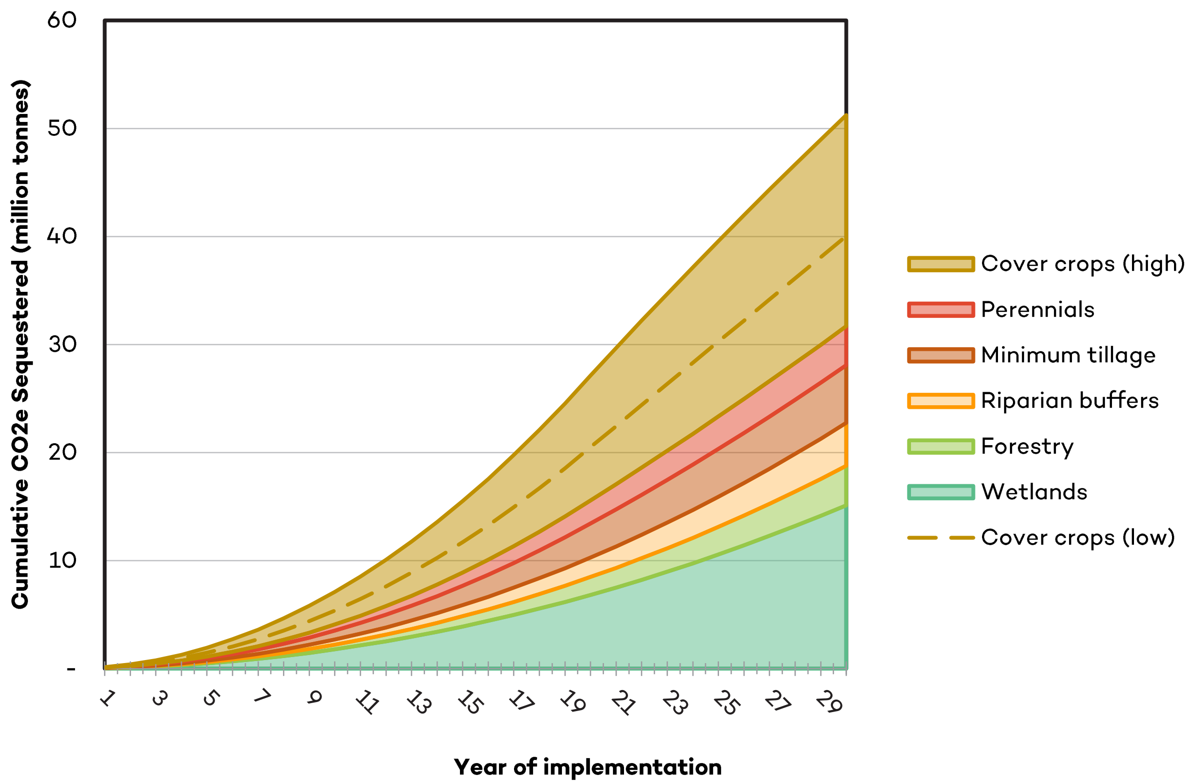

Figure 1. Cumulative CO_2e sequestration potential

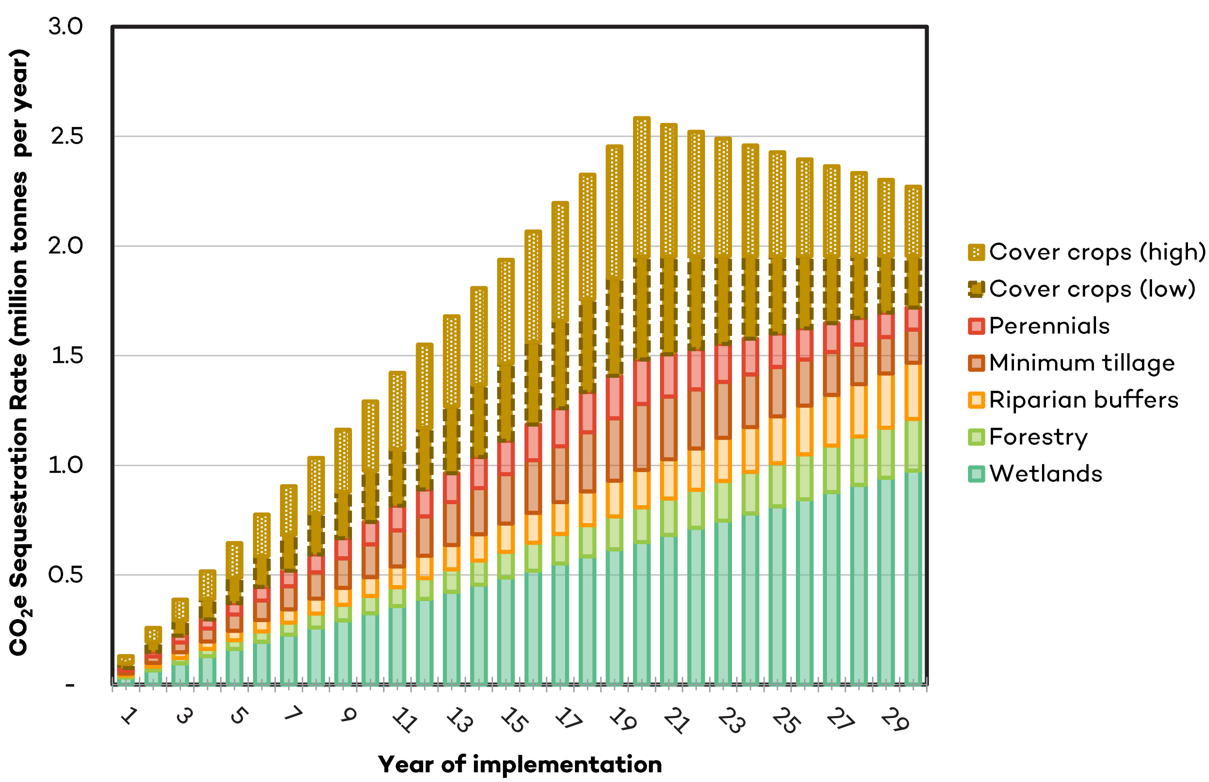

Figure 2. Annual CO_2e sequestration rate

3.2 Sequestration Rate of Individual Practices

For each practice, two figures are provided below. The first one is representative of the CO_2e sequestration rate under the maximum one-year approach, wherein it is assumed that all six practices under consideration would reach their maximum sequestration rate at the same time in a given year. The second one represents the CO_2e sequestration rate under the cumulative approach. For each practice, the cumulative potential was averaged over 30 years of implementation.

In the case of cover crops, due to the consideration of two different practice sequestration rates for reasons explained in Section 2.1, four figures are provided. The first two represent the one-year maximum approach under the high and low GHG mitigation scenarios, while the latter two figures represent the cumulative approach, also under the high and low GHG mitigation scenarios.

3.2.1 Wetlands

The qualitative analysis assumes that, if there are no losses of wetlands, an estimated 300,000 hectares could be added to the Agro-Manitoba landscape. Under the maximum one-year approach, the sequestration rate for wetlands is 975,000 tCO_2e, while under the cumulative approach the annual average sequestration rate is 503,750 tCO_2e across that land base. However, if wetlands are lost at a greater rate than new ones are added, there is a risk that wetlands may become a carbon source rather than a carbon sink.

3.2.2 Forestry and Riparian Buffers

Both forestry and riparian buffers on private land present opportunities to sequester carbon, estimating an additional 45,000 and 30,000 hectares, respectively. However, given the carbon sequestration rate of trees, despite their comparatively small number of additional hectares, their sequestration potential is significant. Under the maximum one-year approach the carbon sequestration rate for forestry and riparian forests combined is 493,140 tCO_2e, while under the cumulative approach the annual average for sequestration rate is 254,789 tCO_2e across the additional 75,000 hectares. Riparian buffers have a higher sequestration rate compared to forest given their wet natural habitats, which minimizes climatic impacts, such as forest fires and droughts that can affect their growth rates.

3.2.3 Minimum Tillage

Minimum tillage had a big uptake in Manitoba, though it has plateaued over the past few years. However, a slight uptake was observed between 2011 and 2016, demonstrating the possibility to increase adoption rates. Based on the analysis, the maximum one-year carbon sequestration rate is 300,000 tCO_2e, and under the cumulative approach the annual average rate is 177,500 tCO_2e in the 1 million hectares.

3.2.4 Cover Crops

Planting cover crops in Agro-Manitoba is a niche practice, but interest has been increasing over the past few years. In addition to sequestering carbon, cover crops present opportunities for farmers to address salinity issues and excess moisture, and can be used as grazing pastures for cattle, as well as can be practiced over minimum tillage. Cover crops present the high and low ranges under both approaches (see Table 4).

Table 4. High and low sequestration rates for cover crops for both approaches

Approach	Scenario	Sequestration rate (tCO_2e/yr)
Maximum one year	High	1,101,000
	Low	470,000
Annual average	High	651,425
	Low	278,083

3.2.5 Perennial Crops

Perennials present a smaller number of additional hectares, as they are managed differently than cultivated lands. Farmers tend to keep perennial crops, such as hay, relatively the same through the years, and their scale is determined by the size of the cattle herd. Economic factors, such as cattle versus crop prices, may influence the area of perennial crops on farmland. Notwithstanding the above-mentioned, perennial crops have a higher sequestration rate than that of minimum tillage and covered crops. Therefore, despite their lower number in additional hectares, they present attractive sequestration potential in Agro-Manitoba. Under the maximum one-year approach, the sequestration rate is 203,685 tCO_2e, while under the cumulative approach the annual average sequestration rate is 120,514 tCO_2e. There is also an opportunity to increase the net area of perennial cover in Manitoba by increasing the frequency of perennial forages within crop rotations.

Overall, all six practices present healthy sequestration potentials and, though not recorded under the agricultural national inventory report, can help offset Manitoba's second-highest emitting sector. For agricultural practices, both minimum tillage and cover crops present the highest potential of additional hectares within the agricultural practices. Perennials present a lower potential, but perennial crops have the highest sequestration rate of the three. Of the six, cover crops and wetlands present the highest sequestration potential, with a caveat of no loss in wetlands over the next three decades.

4.0 ECOLOGICAL CO-BENEFITS AND DRAWBACKS

In addition to carbon sequestration potential, land use practices present a number of co-benefits as well as some drawbacks. This section presents the different co-benefits and related drawbacks for each of the land use practices examined in this paper.

4.1 Wetlands

Overall, wetlands provide important ecological, biodiversity and social benefits, from water storage and flood retention to filtering services. Commenting recently on the loss of wetlands in Manitoba over an 8-month period in 2016–2017, Ducks Unlimited Canada indicated that the loss of 800 hectares of wetlands in Manitoba could be the equivalent of losing up to 1.8 billion litres of water storage capacity—water services that can be crucial to mitigate floods, for instance (Hoye, 2017). Additionally, these same 800 hectares were estimated to have the potential to filter roughly CAD 1.2 million worth of excess phosphorous and nitrogen leached into surface water.

4.2 Forestry

Forestry, specifically afforestation and reforestation, present a wide range of potential co-benefits. Economically, both practices could foster short-term employment required to plant and maintain the vegetation, and longer-term employment in the form of harvesting. This cycle would continue over time (Garrett et al., 2005), leading to better employment opportunities in some regions. These areas could also allow for the connection of wildlife corridors (Smith, McFarlane, Parkins, & Pohrbniuk, 2003).

4.3 Riparian Buffers

Riparian buffers and wetlands can have similar economic and social benefits. Riparian buffers can take various forms such as grass buffers or tree buffers, which provide habitats for a number of different species (Garrett et al., 2005). They can also vary in width and in their number of rows, which will provide enhanced diversity of ecological services.

Other co-benefits can include reducing chemical runoff from watersheds and reducing erosion on riverbanks, as well as enhancing the viability of the natural environment of the rivers they protect, thereby promoting biodiversity (Garrett et al., 2005). For instance, riparian buffers can be conducive to freshwater aquatic life, especially for trout, and potentially provide a means of eco-business for landowners, including farmers, who could profit from increased recreation opportunities on their land (Lynch & Tjaden, n.d.).

However, a Manitoba study has also shown that the water quality benefits provided by inadequately managed riparian buffers can have negative impacts on the environment rather than providing potential co-benefits (Lobb & Flaten, 2012).

4.4 Minimum Tillage Management

Switching to minimum tillage management presents a variety of environmental and economical co-benefits to farmers compared to intensively tilled land. It can reduce soil erosion, as well as nutrient runoff from the soil, thus improving the structure and nutrient cycling of the latter. Minimum tilled soil also has a better capacity than intensively tilled soil to store water and, in this way, to adapt to extreme precipitation events as well as droughts (Government of Manitoba, n.d.). However, increased phosphorus leaching is a possible risk of minimum tillage (Agriculture and Agri-Food Canada, 2013; Liu et al., 2014).

4.5 Perennials and Cover Crops

Potential co-benefits associated with perennial and cover crops include improved capacity to store non-organic nitrogen in the soil, thereby preventing chemicals from contaminating watersheds (Schnitkey, Coppess & Paulson, 2016). Phosphorous leakage risks exist, as noted under minimum tillage (Agriculture and Agri-Food Canada, 2013; Liu et al., 2014).

5.0 POLICY COHERENCE

In July 2017 the Province of Manitoba released a public consultation document, entitled *Growing Outcomes in Watersheds (GROW): A Home-Grown Ecological Goods and Services Program for Manitoba*. The program's objectives are: "reduced flooding, improved water quality, improved climate resiliency, improved biodiversity and habitat, **enhanced carbon storage**, enhanced sustainable food production, and improved groundwater quality" (Government of Manitoba, 2017, p. 3; emphasis added). The GROW consultation document lists the following priority beneficial management practices (BMPs) to achieve these objectives:

- Small water retention projects with controlled release of water
- Grassland restoration, enhancement and reclamation
- Wetland restoration and enhancement
- Riparian area management

The document also lists the following "additional BMPs for consideration":

- Soil health improvements – includes implementing new cropping systems to improve soil health, such as a one-time payment to establish a cover crop, inter-crop or poly-crop system
- Natural area management
- Shelterbelts/eco-buffers
- Woodlot restoration, enhancement and rejuvenation
- Aquifer recharge protection

The six land use practices analyzed in this report encompass the majority of the priority BMPs of GROW, illustrating the potential of the GROW program to incentivize carbon sequestration practices similar to those assessed in this report. In addition, there will likely be similar opportunities with other BMPs to be offered through future agri-environmental programming in the Canadian Agricultural Partnership agreement.

6.0 CONCLUSION

This analysis documents the estimated volume of GHG removals that could be harnessed from agricultural and other land use practices in Agro-Manitoba. Six practices are considered through two different methodological approaches. One practice, cover crops, is estimated using two different practice sequestration rates that are dependent on the types of crops landowners would chose to adopt. The study concludes that there is a concrete opportunity—ranging from 1.3 to 3 megatonnes of CO_2e per year—to offset GHG emissions from Agro-Manitoba, the second-highest source of emissions in the province.

Table 5. CO_2e sequestration potential

Approach	Scenario	Sequestration rate (tCO_2e/yr)
Maximum one-year	High	3,072,825
	Low	2,441,825
Annual average	High	1,707,978
	Low	1,334,636

These results also point to deeper analysis opportunities:

- Conduct a granular analysis for the agriculture and forestry practices outlined in this brief, cognizant of the fact that soil carbon will be influenced by many variables, including within options (e.g., type of riparian buffers). This would also allow for the development of a representative GHG emissions reduction curve over the 30-year period explored, as the carbon dioxide uptake will fluctuate over such a time period within practices (e.g., conservation tillage).
- Engage with other jurisdictions and through the Canadian Council of Ministers of the Environment to assess potential GHG offset opportunities in Manitoba's agriculture and forestry sectors and develop appropriate offset protocols.
- Develop Manitoba-specific carbon sequestration rates and implementation costs, which will require an in-depth analysis of literature and unpublished data. Consideration of economic factors can also strengthen the analysis, such as opportunity costs for landowners to change land practices to determine the most appropriate policy instruments.
- Develop an interaction matrix of carbon sequestration practices with other GROW program objectives for application in individual watersheds.

Overall, the high congruence of potential carbon sequestration practices with other agro-environmental objectives provides an opportunity and rationale for policy and technological leadership by Manitoba in what is increasingly a key front in the broader battle against climate change.

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