1. **Introduction**

Wetlands are land areas that are saturated with water long enough to allow for the development of hydric soils, growth of water-tolerant vegetation and biological activity adapted to wet conditions (Government of Alberta, 2013). Bogs, Peats, Fens, and Marshes are examples of naturally occurring wetlands in Canada. For instance, in Alberta Peats and Fogs account for about 90% of the wetlands in the province (Government of Alberta, 2013). Wetland ecosystems provide essential services to society, including flood control, water for domestic use and crop irrigation, recreation, habit for biodiversity, climate regulation and others, that positively impacts societal welfare.

Despite the positive contribution of wetlands to society, they continue to be degraded across the world. Davidson et al. (2014) estimate that about 64-67% of the wetland areas in the world have been lost since 1900. In Canada, about 50-70% of wetland areas have been degraded since European settlements, including the Canadian Prairie provinces such as Alberta (Environmental Canada, 1986; Tiner, 1984, Watmough and Schmoll, 2007). Many of the wetland degradations occur on agricultural landscapes (Badiou et al. 2011; Watmough and Schmoll, 2007). Agricultural producers may have an economic incentive to drain wetlands because a) wetland areas could potentially reduce the feasible land area for crop production, b) wetland areas could reduce the efficiency of farm operations (especially farm machinery operations) and c) wetland areas could increase input wastage from overlaps (Cortus et al. 2011).

To conserve wetland areas around the world, there will be a need for wetland policies that specifically protect wetlands. Wetland policies are the operational policies or rules that provide a framework for the regulation and management of wetland areas. Using data from Peimer (2017; supplementary materials) we calculate that, globally, very few countries (about 9% or 17 countries) have specific wetland policies that protect wetlands; none of these countries has a no net loss or no net gain wetland policy. Also, about 50% of countries around the world have some form of environmental laws that indirectly protects wetland areas, while 41% of the countries have no wetland policy.

In Canada, some provinces, such as Alberta, are beginning to design and implement policies to protect their wetlands. Alberta's wetland policy goal is a form of no let loss or net gain policy that seeks to manage wetlands in the province, excluding those on Federal lands, to minimize the loss and degradation of wetland areas and sustain their benefits to society. It provides a uniform framework to manage wetlands across all regions in the province; before the wetland policy, the Wetland Management in the Settled Area of Alberta: Interim Policy, (1993) managed wetlands on the settled region (White region), while other policies (including the Water Act, the Environmental Protection and Enhancement Act, and the Public Lands Act) managed wetlands on crown lands (Green Area). The Water Act forms the legislative basis for the current wetland policy. The specific objectives of Alberta's wetland policy are:

1. Protect highest valued wetlands
2. Restore wetlands and their benefits in areas where losses have been high
3. Avoid, minimize, and if necessary, replace lost wetland value.
4. Management wetlands in a regional context.

The Alberta wetland policy's goal of conserving wetlands is an important step towards reversing the trend of wetland degradation in the province and could restore wetlands areas to their levels during European settlements. However, society must also know the cost of the implementation of this policy, especially to agricultural producers who may be more affected by this policy. Therefore, the objective of this study is to estimate the cost to agricultural producers of implementing Alberta’s Wetland Policy, especially specific objectives 1-3. Most wetlands occur on agricultural landscapes in Alberta, as in most Canadian provinces. As such, if we know the cost of Alberta's Wetland Policy to agricultural producers, we could implement other policies to mitigate such costs so that the policy does not adversely impact agricultural production in the province.

The study is structured into 5 sections. In section two, we provide a background statement that describes Alberta's Wetland Policy and other related information. The methods that are used to achieve the objective of this study are presented in section 3. The results of the study and their discussions are provided in section 4. Lastly, section 5 presents the conclusion of the paper, including suggestions for future research.

1. **Background Statement**

Alberta classifies wetlands into bogs, fens, swamps, marshes, and open water; 90% of the wetlands in the province are peat. Wetlands occupy about 20% of Alberta’s land area, which translates into about 117,400 km2 (Government of Alberta, 2013). The province has lost about 50-70 per cent of its wetland area because the value of wetlands was not widely understood, and the ecosystem was seen mostly as nuisance or wastelands, especially on agricultural lands which account for most of the wetland degradation in the province. However, at the start of the 21st century, Alberta is increasing designing policies or regulations to protect these important ecosystems; some of the important wetland related policies are discussed next.

The Wetland Management in the Settled Area of Alberta: An interim Policy was designed in 1991 to protect wetlands, especially sloughs and marshes, in the settled areas (White region) of Alberta (Alberta Water Resources Commission, 1993). Specifically, the policy sought to manage wetlands by focusing on the following priorities (in descending order of importance) (Alberta Water Resources Commission, 1993):

1. to conserve wetlands in a natural state,
2. to minimize degradation or loss of the wetlands and their benefits as close to the site of disturbance as possible,
3. to restore degraded wetlands.

The policy recognized that wetlands in the province were not the same and sought to apply different wetland management rules in different parts of the province (Alberta Water Resources Commission, 1993).

The Wetland Management in the Settled Area of Alberta: An interim Policy applied to half of Alberta lands. This means wetlands in the other half of Alberta (the Green region) had no protection from drainage. Other policies, acts and regulations worked in concert to protect wetlands in the Green areas of Alberta (or Crown lands). The Water Act regulates any activity that disturbs or degrades a wetland through a permit system (Clare and Krogman, 2013). Under this Act, the government of Alberta or the Crown has the right to all water bodies, including wetlands, in Alberta. The primary goal of the Act is to “support and promote the conservation and management of water, including the wise allocation and use of water” (Government of Alberta, 2021). The Public Lands Act provides the legal basis for the governance of public lands in Alberta, which is about 60% of the land area of Alberta (Government of Alberta, 2015). Environmental Protection and Enhancement Act provide the regulatory framework for the management of air, water, land, and biodiversity in Alberta towards the protection, enhancement, and wise use of environmental resources. All projects impacting Alberta’s air, land and water environmental resources are reviewed for their potential environmental impacts and are approved or denied. Specifically, the Act mandates that projects in the following groups: conservation, potable (drinking) water, substance release, waste management and miscellaneous (pesticides, designated materials) must seek approval before their commencements (Government of Alberta, 2022). The overarching goal of all the Acts above is to protect the environment, including wetlands, for sustainable development in Alberta.

The Alberta Wetland Policy provides a unifying framework that brings together all the Acts discussed to specifically protect wetlands in all areas of Alberta (Green and White regions). This is important because the province by this policy has acknowledged and placed wetland ecosystems into a distinct environmental resource category that needs protection. The policy supports the avoidance, minimization, and restoration rule of wetland protection. Avoidance means that, if possible, all activities that may alter wetlands’ ecosystem must be avoided; minimization means that if avoidance is not possible, the potential devastation to the ecosystem must be minimized through activities such as best management practices; restoration means that if avoidance and minimization are not possible, wetland areas or portions thereof that are degraded must be replaced.

Wetland replacement requirements are influenced by the wetland area loss and relative value of that area (Government of Alberta, 2013). Wetland values are classified into A, B, C or D scales; whereby A has the highest ecosystem values and D has the lowest ecosystem values reflecting hydrological health function, water quality function, ecological health function, and human use function of wetlands (Asare et al. 2021). An agent who has degraded a wetland area or portions of it can choose to pay an in-lieu payment, which is a financial cost that will act as restitution for the loss wetland area and its functions; alternatively, the agent may choose the permittee-responsible replacement option, which involves the actual replacement of the wetland area and functions according to the requirements of Government of Alberta (Government of Alberta, 2013). Further, with the permittee-responsible replacement option, the agent must follow replacement ratios (Table 1) to know the area of wetland to restore for a given value of loss wetland area. For instance, if an acre of class A is degraded, an agent will need about 8 acres of class D wetlands to replace it; this mechanism will ensure that Alberta’s highest valued wetlands are protected for sustainable development (Government of Alberta, 2013).

**Table 1. The Wetland Replacement Matrix**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Value of Replacement Wetland** | | | | |
| **Value of Lost Wetland** |  | D | C | B | A |
| A | 8:1 | 4:1 | 2:1 | 1:1 |
| B | 4:1 | 2:1 | 1:1 | 0.5:1 |
| C | 2:1 | 1:1 | 0.5:1 | 0.25:1 |
| D | 1:1 | 0.5:1 | 0.25:1 | 0.125:1 |

**Source: Government of Alberta (2013)**

By the full implementation of the Alberta Wetland Policy, all wetlands in the province will be protected from degradation. This will ensure that Albertans will continue to enjoy the essential services that wetlands provide, but at what cost, especially to the agricultural sector in Alberta? In the next section, we will explore methods that can be used to estimate the cost of implementing the wetland policy to the agricultural producer.

1. **Methodology**

In this section, we describe the methods that will be used to evaluate the economic cost of different aspects of the Alberta Wetland Policy to the agricultural producer. First, we review farm production economics, including wetland conservation cost. Second, we show how we will estimate the economic cost, to the farmer, for adhering to the following Alberta’s wetland policy priority areas:

1. Protection of highest valued wetlands
2. Restoration of wetlands and their benefits in areas where losses have been high
3. Avoidance, minimization, and if necessary, replacement of lost wetland value.
   1. **Farm production economics on agricultural field**

Most agricultural producers seek to maximize the net returns from farming activities. That is given the crop prices and input prices, they would select the levels of production inputs, including agricultural lands, labor, fertilizer prices, to maximize crop outputs. For this study, we assume the farm activity is crop production (specifically, Canola, Spring Wheat). Also, we assume crop production follows the proportional acreage cultivation, such that a proportion of the field area is used to cultivate a given crop in farming season/year, which is repeated annually for the lifespan of farm or planning horizon. For instance, for the 2 crops we will consider in this study, 1/2 of the field area is used to cultivate a crop.

The net production returns (crop production revenue minus crop production cost) which is also called producer surplus, captures the reward to the farmer for engaging in the farming economic activity. Therefore, for the farming business to be sustained in the long-run, the net production returns must be at least greater than 0.

Another important dimension of farm production economics is the concept of economies of scale, which is the cost advantage (decreases in the cost per unit of output) to the farmer as the scale of production increases. An important measure of the scale of production in agriculture is increases in production area and/or increased use of farming technologies (intensification). Therefore, wetland areas on agricultural fields may hinder producers from benefiting from economies of scale in their businesses because they take up space which could be used to scale up crop production.

The question then is, must producers drain wetland areas to benefit from economies of scale? Yes, a producer may have an economic incentive to convert wetlands to cropland if the cost of converting the wetland area to cropland (which is a one-time drainage cost) is less than the annualized net returns of cultivating the drained wetland area over a period (planning horizon); this estimate is called wetland conservation cost. Otherwise, if the wetland conservation cost is negative, the producer may retain wetland area; in this case, it may have an economic reason to bear the potential cost of having wetlands on fields, including efficiency loss of operating farm machinery around wetland areas, input wastage and the opportunity to gain from economies of scale. For this study, we assume that when wetlands are located at the margins of the field, the efficiency loss and input wastage cost will be zero.

Mathematically, wetland conservation cost is estimated as the difference between the annualized net returns from cultivating a field with intact wetlands and a field with drained wetland areas; it is specified as equation 1 below:

= Annual net returns of cultivated field with drained wetland areas

= Annual net returns of cultivated field with intact wetland areas

= Farm profit

EL = Efficiency loss from farm machinery operations and input wastage when wetlands are present on field

AF = Annualized factor =

R = Discount factor

T= Planning horizon

DC = Drainage cost

We expect crop prices and crop yield to have a positive effects on wetland conservation cost; also, drainage cost and crop production cost are expected to have negative effects on wetland conservation cost. The cost of production is negatively affected by input prices and positively by best management practices that may improve the efficiency of crop production input use. The two main components of total cost are variable cost and fixed cost:

1. Variable cost changes with the level of farm production activity; for example, when the farmer must hire more workers to expand production, the labor cost will be a variable cost. Other examples of variable cost are seed cost, fertilizer cost and fuel cost that change with the level of production activity.
2. Fixed cost does not change with the level of production activity, for example insurance on farm machinery. Other examples of fixed cost are property tax and farm building and machinery repair.

Moreover, we assume that the farmer will not be able to harvest from the drained wetland areas 1 out of ten years due to a possible inundation of the drained wetland areas with excess water which may cause delayed seeding. The cost of production is increased by the efficiency loss estimate that is associated with using farm machinery operations around wetland areas and input wastage from overlap (Cortus et al. 2011). We followed Cortus et al. (2011: Table 3) to generate nuisance factors based on the number of wetlands on the field. We then multiplied the nuisance factor by machinery input cost (fuel cost plus repairs) and 50% of the total wetland area in the field to get the efficiency loss associated with farm machinery operations around wetland areas for the whole field; by using 50% of the wetland area in the field, we are assuming that 50% of the wetland area approximates the effective area around the wetland that affects farm machinery operations. To get the efficiency loss associated with input wastage, we assumed an input wastage factor of 0.1 (Cortus et al. 2011) and multiplied it by the total input cost (including the cost of seed, seed treatment, pesticide, fungicide, and fertilizer). The sum of the efficiency loss associated with machinery operation and input wastage is the total efficiency loss when wetlands interfere with farm operations on the field.

Again, crop yield on drained wetland areas may be lower than yields on croplands; for this study we assume that crop yields on wetland area will be about 90% of upland crop yield. We assume a discount factor and planning horizon of 8.3% and 50 years, respectively (Asare et al. 2021).

* 1. **Economic Cost of Alberta’s Wetland Policy**

In this section, we describe a typical agricultural landscape in Alberta, which will serve as the study area of for this study. Again, this section will describe the methods we will use to estimate the economic cost of Alberta’s Wetland Policy to the agricultural producer in the agricultural landscape. Specifically, we will focus on their priority areas of the policy, which are a) protect highest valued wetlands, b) restore wetlands and their benefits in areas where losses have been high, and c) avoid, minimize, and if necessary, replace lost wetland value.

* + 1. **Description of the Agricultural Landscape for this study**

An agricultural landscape is made of fields (or quarter-sections of 160 acres) which are mostly used for agricultural productions. We created the number of fields in the landscape with a “landscape\_num\_fields” function. The function uses the expected number of fields in the landscape and the selected crops to produce an agricultural landscape, such that 1/n (where n is the number of fields) proportion of the number of fields in the landscape is used to cultivate a crop. For instance, assuming we want to cultivate Canola and Spring in the landscape; if the number of fields in the landscape is 100, 50 fields (which is 1/2 \* 100) is used to cultivate one crop, say Canola, and the other 50 fields for Spring wheat.

Moreover, we assumed wetland acreage distribution in the landscape followed a uniform distribution, with minimum and maximum wetland acreage parameters of 0 and 37, respectively (Spence, 2006). Also, the number of wetlands on a field followed a uniform distribution with minimum and maximum values of 0 and 4, respectively. For this study, we assumed 50% of the wetlands interfere with farming operations because they are located at the margins of the fields in the landscape.

In Alberta, wetland values are defined according to the ecosystem functions they provide, which are hydrological health function, water quality function, ecological health function, and human use function. The wetland values are grouped into 4 classes: A, B, C or D groups; whereby Class A wetlands have the highest ecosystem values and D wetlands have the lowest ecosystem values. We will divide the number of fields in the landscape, such each quarter will contain either of Class A or B or C or D wetlands.

We assume that farmers will use a surface drainage technology to manage wetlands on their fields. We chose surface drainage because it is the most dominant wetland drainage technology is the Canadian Prairies (Asare et al. 2021). Wetland drainage cost is made up of drainage construction cost and maintenance cost; the maintenance cost involves the cost of activities such as stone removals and others, that prepares drained wetland areas for crop cultivation. For this study, we assume wetland drainage is one-time investment cost follows a triangular distribution and varies between $300/acre to $1,300/acre (…..) in the agricultural landscape.

* + 1. **Protect highest valued wetlands**

The highest priority of the Alberta’s Wetland Policy is to protect highest valued wetlands; that is a no drainage of highest valued wetland areas. We will estimate the wetland conservation cost of class A and B wetlands in the agricultural landscape using Equation 1. The sum of the wetland conservation costs for class A and B wetlands in the landscape will be the cost to farmers for retaining such wetlands on their fields.

* + 1. **Minimize degradation of wetland areas and functions**

kkk ar exemption was incorporated into the WCA of 1991. The use of Best Management Practices (BMPs) is encouraged in both acts to protect wetland values and functions. Best Management Practices provide resource managers, loggers, and landowners with the necessary tools to avoid or minimize direct and indirect impacts from activities that, if improperly conducted, can diminish the quantity, quality, and biological diversity of wetlands. With BMPs as an integral part of forest management, continuous commercial production on or near Minnesota’s wetlands is feasible without compromising environmental quality.

* + 1. **Restore degraded wetland areas**

As much possible the Alberta Wetland Policy would want to avoid any disturbance to wetlands in the province, especially high valued wetlands (Class A and B wetland). With this, the province could continue to benefit from the many valuable ecosystem services wetland offer, However, if the valuable wetlands are degraded, it is now mandatory for producer to replace it by following the replacement ratios in Table 1.

For this study, about 50% of the fields in the landscape will contain Class A or B wetlands. For instance, for each acre of Class A wetland that is drained for crop production, 8 acres, 4 acres and 2 acres of Class D, C and B wetlands, respectively, will have to be created to restore loss wetland ecosystem functions that were associated with the acreage of Class A wetland on the field. For this study, That is for each acre of hopes to continue benefiting from

**3.3. Uncertainties on Crop Yield and Prices**

The values of the main variables (including crop yields, crop prices, production cost, and drainage cost) varies in the fields of the landscape. We obtained crop yield and prices data for the Canadian Prairie provinces from Statistics Canada (2022).

The crop price data is monthly time series from 1980 to 2021; the prices reflect point of first transaction (where fees deducted before a producer is paid are excluded (for example, storage, transportation, and administration costs) and exclude commodity specific program payments (Statistics Canada, 2022). The crop yield data is annual time series from 1908 to 2021.

We fit the distributions of crop yield and crop prices with the “fitdist” function from the “fitdistrplus” R package (Delignette-Muller and Dutang, 2014). The function fits the data (a specific crop yield or crop price) to many empirical distributions (including Weibull, Normal, Gamma and Log-normal) and uses Akaike Information Criteria to suggest the best distribution fit to the data. The “fitdist” uses maximum likelihood estimation procedure. In fitting the univariate crop yield or price data, we did not account for time variant factors such as inflation and interest rates for crop prices and technological change for crop yield, because we assumed the information will be captured in the time series trends. We did not apply the procedure above to corn price and yield, drainage cost because of lack of data; instead, we assumed a uniform distribution for these variables. Moreover, we used the variable distribution information above, for crop yield, crop price, drainage cost and production cost, to estimate the uncertainty associated with annual net return of wetland drainage at the field level. The variable distribution information is summarised in Table 3 below.

**Table 3.** **Variable distributions and their parameters**

|  |  |  |
| --- | --- | --- |
| **Variable** | **Distribution** | **Parameters** |
| *Crop Yield (Bushels/Acre)* | | |
| Canola | Gamma | Shape = 7.34, Rate = 0.11 |
| Feed Barley | Weibull | Shape = 2.53, Scale = 80 |
| Malt Barley | Weibull | Shape = 2.53, Scale = 80 |
| Yellow Peas | Uniform | Minimum = 0.7\* average pea yield  Maximum = 1.3\* average pea yield |
| Soybean | Uniform | Minimum = 20, Maximum = 50 |
| Corn | Uniform | Minimum = 50, Maximum = 130 |
| Flax | Weibull | Shape=2.18, Scale = 35 |
| Spring Wheat | Weibull | Shape= 2.48, Scale=80 |
| Oat | Gamma | Shape=4.59, Rate=0.03 |
| *Crop Yield($/Bushel)* | | |
| Canola | Gamma | Shape = 10.5, Rate = 0.91 |
| Feed Barley | Gamma | Shape = 7.54Scale = 1.65 |
| Malt Barley | Gamma | Shape = 7.54Scale = 1.65 |
| Yellow Peas | Log-normal | Mean log=1.85, Standard deviation log=0.3 |
| Soybean | Gamma | Shape = 15.34, Rate = 1.34 |
| Corn | Uniform | Minimum = 0.7\* average corn price  Maximum = 1.3\* average corn price |
| Flax | Log-normal | Mean log= 2.33, Standard deviation log=0.42 |
| Spring Wheat | Log-normal | Mean log=2.0, Standard deviation log=0.13 |
| Oat | Gamma | Shape=8.52 Rate=1.86 |
| *Production cost($/Acre)* | | |
| Production Cost | Uniform | Minimum = 0.7\* average production cost  Maximum = 1.3\* average production cost |
| *Drainage Cost($/Acre)* | | |
| Drainage Cost | Uniform | Minimum = 200  Maximum = 600 |

* 1. **Results and Discussion**

**5.0. Conclusion**

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