**USER’S MANUAL**

*Wetland Drainage Decision Web App*

*(Version 3)*

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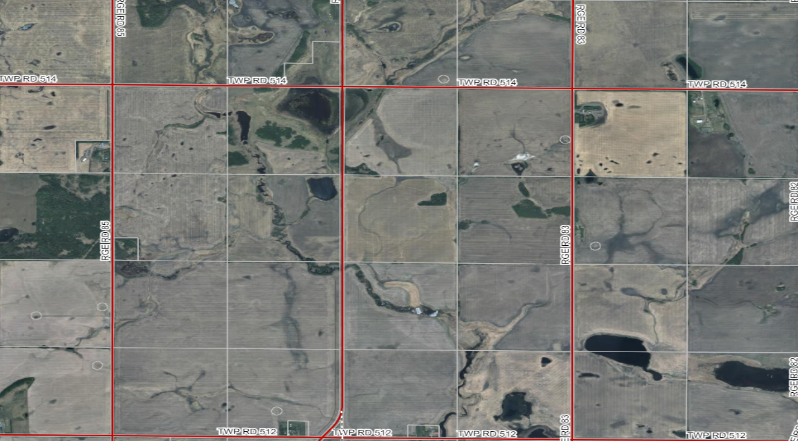
## 1.0. System Overview

Our App, which is developed for agricultural landscapes in Saskatchewan, answers the following questions:

1. What is the benefit to the landowner if wetlands on the quarter-section are converted to cropland?
2. How many acres of wetlands can society save given a conservation budget?
3. How will questions (1) and (2) change and by what magnitude if crop prices change by a certain percentage?

Figure 1 shows an example of a landscape comprising many quarter-sections, QS, (1 QS = 160 acre). We qualify the landscape as an agricultural landscape if the predominant economic activity is agriculture. We assume that farmers who cultivate the quarter-sections have property rights to (own) the land.

**Figure 1. Relationship between a Landscape and Quarter-section.**



Spatial View of Landscape

Zoomed Quarter-section in a Landscape

Wetland

In the zoomed quarter-section in Figure 1 we have a wetland, which is a land depression that holds water either permanently or seasonally. These wetlands could be found in many quarter-sections in the landscape which could be converted to a cropland.

There are functions at the back-end (the codes that drive the App) that work in concert to answer questions (1)-(3). The arguments or parameters of the functions or the information we need in the functions to answer the questions are grouped into default, fixed values and user-defined values. The default values are used at the App’s back-end as arguments or parameters to the functions to answer the questions above which are displayed to the user of the App. The user-defined values are the information users or visitors of the App could put in defined spaces on the App’s front-end (the interactive phase) to over-ride the default values. Fixed values are the default values which users of the App cannot change.

In the App’s front-end, we have three main sections. They are the Overview, the Field-level and Landscape-level. Overview presents a summarized structure of the App, including how the user will navigate the App. The Field-level presents the results on wetland drainage at the per-acre level on a quarter-section. The Landscape-level presents the results on wetland drainage on an agricultural landscape or watershed, which is comprised of many quarter-sections.

**2.0. Field level Analysis**

Let us assume there is an acre of wetland on a quarter-section in a landscape or watershed. The wetland is an important ecosystem, which provides essential services, such as flood control, that benefits society; but it incurs cost to the producer which are:

1. forgone farm profit which the farmer could have earned if it has been converted to a cropland,
2. reduced field efficiency when farm-machinery operate around wetlands and input wastage from overlap.

The producer gains (i) and (ii) above if the wetland is drained which we will call benefit of drainage. Also, there is a one-time wetland drainage cost, which includes drainage construction and maintenance cost, if the producer decides to drain the wetland. The producer will have an economic incentive to drain the wetland if the net-present benefit of wetland drainage is positive, that is if the drainage cost is less than the present value of benefit of drainage given a farm planning horizon (how many years producer intend to operate the farm) and a discount rate. In the sub-sections below, we will explain how our App calculates the Net-present benefit of wetland drainage, including the default, user-defined, and fixed values that will drive the App’s system. Also, we will show how changes in crop price could affect the Net-present value of wetland drainage.

**2.1. Net Present Benefit of Wetland Drainage**

Net present benefit (NPB, $/Acre) of wetland drainage is the benefit that accrues to the landowner from cultivating crops on a drained wetland area. Also, it can serve as the opportunity cost of wetlands on agricultural lands or the forgone benefit to the producer for retaining wetlands on the farmland. It is the present value, at an appropriate discount rate, of the streams of profits that accrue to the farm business when the wetland is drained and cultivated over a planning horizon less total drainage cost. Mathematically, it is given as:

where,

= farm-profit of drained wetland ($/Acre)

= Drainage cost

T = planning horizon

r = discount rate

It is assumed that the annual farm profit of drained wetland is constant over the planning horizon.

**2.2. Farm-profit of Drained Wetland**

The farm profit of drained wetland, when it is cultivated with crops, is made up of three components, which are total revenue, increased field efficiency gains and total cost of production. Total revenue is the product of yields of crops cultivated on the drained wetland and their respective prices. The increased field efficiency gain is the cost savings to the farm when farm-machinery operates in straight lines and avoid input wastage from overlap when there are no wetlands. The total cost of production is the sum of the products of production inputs and their respective prices. Therefore, the total farm profit of drained wetland is the total gains from wetland drainage (total revenue plus increased field efficiency gain) net total cost of production; it is given as:

(2)

where,

= Total farm profit

= Yield for the nth crop

= Price for the nth crop

= Cost of production for the nth crop

= Increased field efficiency gain

N = total number of crops

For this App we impose the following structure on crop cultivation on a drained wetland:

1. a producer can choose from these crops: Canola, Spring Wheat, Malt Barley, Feed Barley, Flax, Oats, Peas, Soybean and Corn to cultivate a drained wetland. We chose the crops because they are the common cultivated crops in Saskatchewan,
2. assume that the yield of cultivated crops will vary depending on the type of soil (black, brown, and dark brown) of the quarter-section (QS) where the wetland is located,
3. producers follow a proportional acreage cultivation, such that a proportion of the wetland drained acreage is used to cultivate a given crop and farming season/year; it is repeated for the annually over the planning horizon. For instance, since we consider 9 crops in the App, each crop will be cultivated on 1/9th of the drained wetland area (1 acre).

Moreover, there are two main components of production costs, which are:

1. Variable cost – they change 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 – they do 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.

Table 1 presents the different inputs under variable cost and fixed cost which are considered in this App.

**Table 1. Components of Variable and Fixed cost of Production**

|  |  |
| --- | --- |
| **Variable cost** | **Fixed cost** |
| Seed cost | Building repair |
| Seed Treatment | Property taxes |
| Fertilizer cost | Business overheads |
| Herbicide cost | Machinery depreciation |
| Insecticide cost | Building Depreciation |
| Fuel Cost | Machinery inventory |
| Machinery repairs | Building inventory |
| Insurance premiums | Land inventory |
| Loan interest payments |  |
| Miscellaneous costs |  |

**2.3.** **Default Parameters**

We use information on crop prices, crop yields on different soil zones, and cost of production from different soil zones from the Provincial Ministry of Agriculture Crop Panning Guide, 2021, as default information in the farm profit function. The farm production information is presented in Table 2. We also assume a discount rate of 8.3% and a planning horizon of 50-years (Asare et al. 2020) for the farm profit present value function.

**Table 1. Farm Production Information**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Black Soil** | | **Brown Soil** | | **Dark Brown** | |
| **Crops** | **Crop price**  **($/Bushel)** | **Crop Yield**  **(Bushel/Acre)** | **Cost**  **($/Acre)** | **Crop**  **Yield** | **Cost** | **Crop**  **Yield** | **Cost** |
| Feed Barley | 3.94 | 91.9 | 354.56 | 76.7 | 297.47 | 81.8 | 325.94 |
| Malt Barley | 4.7 | 74.6 | 407.43 | 62.7 | 351.03 | 67 | 380.88 |
| Canola | 10.7 | 53.8 | 503.55 | 48.5 | 412.89 | 50.3 | 480.07 |
| Corn | 4.7 | 108.2 | 486.6 | 100 | 437.33 | 72 | 430.53 |
| Flax | 13.78 | 34.3 | 358.94 | 30.3 | 309.69 | 33.1 | 338.73 |
| Oats | 3.02 | 139.4 | 348.91 | 79.1 | 252.07 | 103.7 | 310.77 |
| Yellow Peas | 6.85 | 58.4 | 402.94 | 43.7 | 342.76 | 51.1 | 376.35 |
| Soybean | 10.66 | 37.1 | 414.33 | 31.6 | 373.33 | 33.4 | 395.31 |
| Spring Wheat | 6.42 | 64.7 | 391.07 | 38.9 | 312.62 | 57 | 360.47 |

*Default Value of Increased Field Efficiency Gain*

The estimate of the gain to the producer from increased field efficiency from drained wetlands is assumed to be dependent on the wetland location in the quarter-section. We assume that wetlands located at the margins of the quarter-section will have $0/acre field efficiency gain, otherwise they will have a positive field efficiency gain. The estimate of field efficiency gains from wetlands not at the margins of the field will be obtained from the results of a parallel study, “Canadian Prairie producers’ land preference”. In that study, we estimate the producers’ willingness to pay for quarter-sections not at the margins of the field. The difference between the land rental price and the WTP estimate will be used as a proxy for the field-level efficiency gain ($/acre) from drained wetlands. As default, we will assume the wetlands are not located at the margin of the field.

*Default Value for Drainage Cost*

For the drainage construction cost, we use $409/acre, which is the mean drainage for agricultural producers (respondents) from Saskatchewan who participated in the Canadian Prairie land preference survey, 2021. Also, we assumed a wetland drainage maintenance cost of $200 to allow the continuous cultivation of the drained wetland over the crop production planning horizon.

*Effect of Crop Price Changes on Field-level Outputs*

To assess the effect of crop prices changes on field-level App outputs, we will assume prices over the planning horizon changes by 25%.

**2.3.1 Fixed Parameters**

The only fixed-parameter is the type of crop rotation which we assumed to be proportional acreage cultivation annually.

**2.3.2. User-defined Parameters**

The user will be presented with a selection (based on soil zone) of Table 2, which could be edited with user-defined values to override the App’s default values. Specifically, the user will take these steps to edit the Table 2:

1. Select from a drop-down the soil zone that applies to his/her farm,
2. Select crops the producer intends to cultivate on the drained wetland,
3. Edit the parameters in Table 2 for selected soil zone and crop choices.

We will present information in Table 1 to the user, in the Overview section of the App, to guide their estimations of total production costs in Table 2. Again, the user will be able to provide values for discount rate and planning horizon in input-forms. The system will use the new information to recalculate the functions and present results that reflect the circumstances of users.

*User-defined Increased Field Efficiency Gain*

The user will be asked this questions, “are the wetlands you intend to drain located at the margin of your field?” If the user responds yes to the question, the value of field efficiency gain from wetland drainage will be 0, otherwise, the value will be the same as the default value for efficiency gain for wetlands not located at the margins of the field.

*User-defined Drainage Cost*

In the App, the user will be able to change the components of the drainage cost as follows:

1. Put the cost of drainage construction per acre in an input form,
2. Put the maintenance cost per acre in an input form.

*Effect of Crop Price Changes on Field-level Outputs*

To assess the effect of crop prices changes on field-level App outputs (section 2.3), the user will put the expected percentage change in crop prices over the planning horizon in an input form.

**2.4. Field-Level App Outputs**

The Field-level analysis outputs that are shown on the App are the following:

1. Graphical summary of the present-value of farm profits of cultivated crops on the wetland,
2. The Net-present benefit of drained wetland
3. Percentage change in Net-present benefit of drainage given percentage change in crop prices.

**3.0. Landscape-level Analysis**

The landscape level analysis investigates what happens to an agricultural landscape when wetlands on it are drained. Specifically, it will show the following:

1. wetland supply curve, which is the acreage of wetland areas that maybe drained given different levels of net present benefit of wetland drainage.
2. wetland conservation calculator, which will show the acreage of wetlands that could be save on the landscape given a wetland conservation budget.
3. the percentage of quarter-sections with positive NPB of wetlands.
4. How results (1) – (3) will change when crop prices change by a certain percentage over the planning horizon.

We create a function, called WetlandLandscape, that returns or produces a data-frame on the information we need to estimate the net present benefit of wetland drainage for each quarter-section in the landscape. The information we will use in the function or function arguments are number of quarter-sections on the landscape, the distribution of wetland acreage, the location of wetlands in a quarter-section, soil zones, information on crop yields and cost of production in each soil zone, and information on crop prices. To estimate the net-present benefit of wetland drainage, we will need information on discount rate and planning horizon. Also, to estimate the magnitude of the changes in results (1) – (3) above, we will need information on the expected percentage changes in crop prices over the planning horizon.

**3.1. Landscape Wetland Drainage Default Parameters**

The default values for the WetlandLandscape function, including their definitions are provided in Table 3.

**Table 3. Default Values for Wetland Characteristics**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Description** |
| Number of Quarter-sections (QS) | 14,000 | We assume a 100km by 100 km agricultural landscape will contain about 14,000 quarter-sections |
| Wetland acreage |  |  |
| Minimum acres | 0.5 | Minimum wetland acre in the landscape |
| Maximum acres | 37 | Maximum wetland acre in the landscape |
| Location of wetlands |  |  |
| Prop\_margin | 0.4 | Proportion of quarter-sections in the landscape where wetlands are located at the margins; this means 0.6 (1-Prop\_margin) will be the proportions of QS with wetlands not at their margins. |
| Soil zone |  |  |
| Prop\_black | 33% | 33% of QS in landscape fall in the black soil zone |
| Prop\_brown | 33% | 33% of QS in landscape fall in the brown soil zone |
| Prop\_darkbrown | 34% | 34% of QS in landscape fall in the dark brown soil zone |

Additionally, information on crop yields and cost of production in each soil zone, and crop prices is taken from Table 2 in section 2.4. We will assume that crop prices will increase by 25% over the planning horizon to estimate how outputs (1)-(3) will change. The default values for discount rate and planning horizon are taken from the field-level analysis.

**3.2. Landscape Wetland Drainage User-defined Parameters**

We will provide an opportunity for the user to download Table 2, edit it and upload it back into the App; this will provide us information on crop production variables. We think there will be information burden on the user if they must edit Table 2 in the App. Moreover, to characterize the wetland distribution in the landscape, a list of forms will be presented to the producer to provide the information in Table 3; the forms will be:

1. Input form that will allows the user to provide information on the number of quarter-sections on the landscape.
2. Input forms that will allow the user to provide information on minimum and maximum wetland acreage on the landscape.
3. Input form that allows the user to provide information on the proportion of quarter-sections in the landscape which have wetlands located at their margins.
4. Input forms that allow the user to state the proportion of quarter-sections in the landscape that are in the black, brown, and dark brown soil zones.

Information on discount rate, planning horizon and the expected percentage increase in crop prices over the planning horizon will be taken from the appropriate field level analysis user-defined parameters.

**3.0. Landscape Wetland Drainage Analysis**

The landscape level analysis investigates what happens to an agricultural landscape when wetlands on it are drained. Specifically, it will show the following:

1. wetland supply curve, which is the acreage of wetland areas that maybe drained given different levels of net present benefit of wetland drainage.
2. wetland conservation calculator, which will show the acreage of wetlands that could be save on the landscape given a wetland conservation budget.
3. the percentage of quarter-sections with positive NPB of wetlands.
4. results of a Monte Carlos simulation that analyze the effect of changes in crop prices on outputs (1) – (3) above.

We create a function, called WetlandLandscape, that returns or produces a data-frame on the information we need to estimate the net present benefit of wetland drainage for each quarter-section in the landscape. The information we will use in the function or function arguments are number of quarter-sections on the landscape, the distribution of wetland acreage, the location of wetlands in a quarter-section, soil zones, information on crop yields and cost of production in each soil zone, and information on crop prices to define the landscape and prepare it for the wetland drainage analysis. Also, for we will need discount rate and planning horizon. When conducting the Monte Carlos simulation, we will fix all the NPB parameters an change on crop prices.

**5.1. Landscape Wetland Drainage Default Parameters**

The default values for the WetlandLandscape function, including their definitions are provided in Table 3.

**Table 3. Default Values for Wetland Characteristics**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Description** |
| Number of Quarter-sections (QS) | 14,000 | We assume a 100km by 100 km agricultural landscape will contain about 14,000 quarter-sections |
| Wetland acreage |  |  |
| Minimum acres | 0.5 | Minimum wetland acre in the landscape |
| Maximum acres | 37 | Maximum wetland acre in the landscape |
| Location of wetlands |  | Categorical variable which is 1 when Prop\_middle\_4 applies to wetlands in QS; 2 when Prop\_middle\_5 applies to wetlands in QS; and 3 when Prop\_corner applies to wetlands in QS |
| Prop\_middle\_4 | 33% | 33% of the QS in the landscape have at least 4 wetlands are scattered in the middle |
| Prop\_middle\_5 | 33% | 33% of the QS in the landscape have at least 5 relatively smaller wetlands are scattered in the middle |
| Prop\_corner | 34% | 34% of the QS in the landscape have at 1 relatively bigger wetland at the corner (margin) |
| Soil zone |  |  |
| Prop\_black | 33% | 33% of QS in landscape fall in the black soil zone |
| Prop\_brown | 33% | 33% of QS in landscape fall in the brown soil zone |
| Prop\_darkbrown | 34% | 34% of QS in landscape fall in the dark brown soil zone |

Additionally, information on crop yields and cost of production in each soil zone, and crop prices is taken from Table 1 in section 2.3. Regarding the crop price Monte Carlos Simulation, we will assume crop prices varies between +/- (2\*standard deviation of price for the past 30 years); the parameters for the simulation analysis will be fixed parameter which cannot be changed by the user. The default values for discount rate and planning horizon are taken from the field-level analysis.

**5.2. Landscape Wetland Drainage User-defined Parameters**

Tables 1 and 3 will be presented to the user on the App (landscape section) to edit based on conditions on that applies to them. Information on discount rate and planning horizon will be taken from the appropriate field level analysis user-defined parameters.