USER'S MANUAL

Wetland Drainage Decision Tool

(Version 5)

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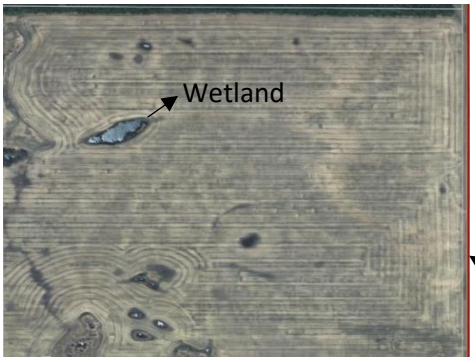
1.0. System Overview

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

1. What is the net financial 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 in an agricultural landscape?
3. How much it will cost society to conserve wetland areas in the highest quality fields in an agricultural landscape?

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 rights to manage the land as they see fit.

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



Zoomed Quarter-section in a Landscape

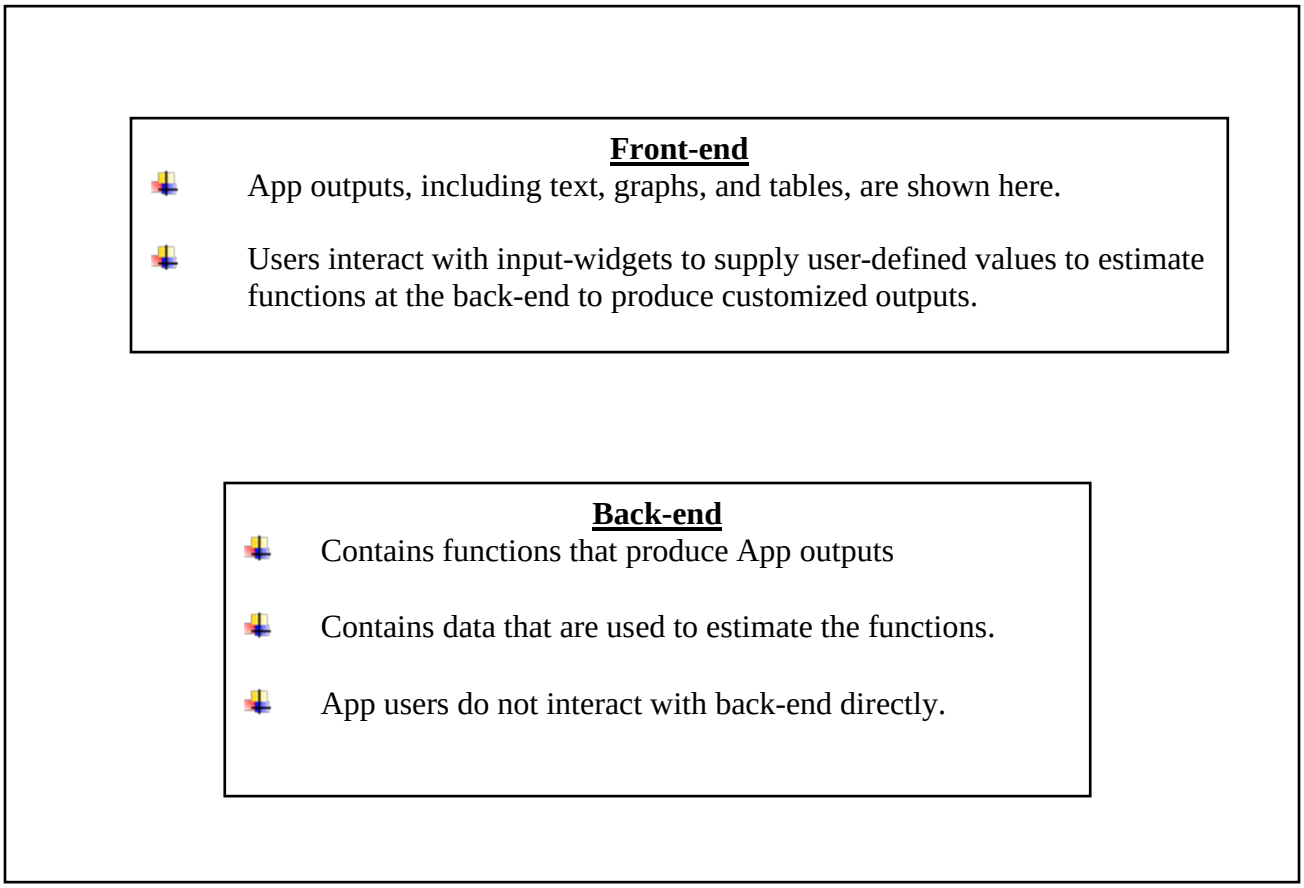
Spatial View of Landscape

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 through an investment into wetland drainage and other land clearing activities.

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 two main sections. They are 1) Field-level and 3) Landscape-level. 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. Figure 2 below shows the structure that drives the behavior of the App.

Figure 2. Front-end and Back-end structure of App



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 imposes costs on the producer which are:

i) forgone farm profit which the farmer could have earned if it has been converted to a cropland,

ii) reduced field efficiency when farm-machinery operate around wetlands and input wastage from overlap.

The producer gains the net returns from the wetland basin land (i) and increased efficiency of field operations (ii) if the wetland is drained which will be included as the benefit of drainage. Also, there is a one-time wetland drainage construction cost/acre and maintenance cost/acre, which occurs over time, if the producer decides to drain the wetland; wetland construction cost is the sum of construction and maintenance cost. 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) subject to a selected discount rate. In the sub-sections below an explanation on how the App calculates the Net-present benefit of wetland drainage, including the default, user-defined, and fixed values that will drive the App's system will be provided.

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. 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 cropped over a planning horizon, less total drainage cost. For this App, we calculated NPB as the difference between the NPB of the field with wetland drainage and the field without wetland drainage. In General, the NPB is given as:

$$NPB = \sum_{t=0}^{T} \pi * (1+r)^{-t} - DC \quad (1)$$

where,

π = farm-profit ($/Acre)

DC = Drainage cost

T = planning horizon

r = discount rate

2.2. Farm-profit

The farm profit of field is made up of two components, which are total revenue and total cost of production. Total revenue is the product of the yield of crops cultivated on the drained wetland and the respective crop prices. The total cost of production is the sum of the products of crop production inputs and their respective prices.

When wetlands are present on the field and are drained, the producer gains an increased field efficiency from the cost savings when farm-machinery operates in straight lines and limits input wastage from field operations overlap which occurs when navigating around field obstructions such as wetlands; however, the field efficiency is a loss to the producer when wetlands on fields are not drained. Also, we assume that crop yields in upland fields are greater than those on drained wetlands.

Therefore, the total farm profit of field with drained wetland is the total gains from wetland drainage (total revenue plus increased field efficiency gain) net total cost of production; the total crop yield in the drained wetland area/acre is reduced by 10% of the crop yield (this is a default value, and the user will be able to change it). In addition, there could be delayed seeding on drained wetland areas which could negatively affect the yield of crops on the drained area; for instance, if there is delayed seedling of 1 out of 10 years, crop yield on drained wetlands will reduce by 10% of the yield upland. The total farm profit of field without drained wetland is the total gains from field crop production (total revenue minus increased field efficiency gain) net total cost of production. The generic formula for farm profit is given as:

$$\pi_T = \sum_{n=1}^{N}[(Y_n * P_n) + IEG] - C_n \quad (2)$$

where,

π_T = Total farm profit

Y_n = Yield for the nth crop

P_n = Price for the nth crop

C_n = Cost of production for the nth crop

IEG = Increased field efficiency gain

N = total number of crops

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

a. a producer can choose from these crops: Canola, Spring Wheat, Malt Barley, Feed Barley, Flax, Oats, Peas, Soybean and Corn to produce on the land made available by wetland drainage. These crops represent the most common cultivated annual crops in Saskatchewan,
b. assume that the yield of cultivated crops will vary depending on the soil type (black, brown, and dark brown) of the quarter-section (QS) where the wetland is located,
c. producers follow a proportional acreage cultivation, such that a proportion of the field 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 $1/9^{th}$ of the drained wetland area (1 acre).

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

a. Variable cost – they change with the level of farm production activity; for example, changes in seed cost, fertilizer cost and fuel cost that change with the level of production activity. Another example of variable cost is when farmers hire more workers to expand production.
b. 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 machinery inventory.

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
Loan interest payments	Land inventory
Miscellaneous costs	Insurance premiums

2.3. Default Values of Farm Profit

Crop Prices, Soil Zone, Crop Yields and Production Costs

Information on crop prices, crop yields on different soil zones, and cost of production from different soil zones are sourced 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. A discount rate of 8.3% and a planning horizon of 50-years (Asare et al. 2020) was assumed for calculations of the present value of farm profit.

Table 2. 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	4.70	74.6	407.43	62.7	351.03	67	380.88
Canola	10.70	53.8	503.55	48.5	412.89	50.3	480.07
Corn	4.70	108.2	486.60	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

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 provide $0/acre field efficiency gain, otherwise they will have a positive field efficiency gain (the default value is $50/acre). Also, as default, we will assume the wetlands are not located at the margin of the field.

Default Value for Drainage Cost

It is assumed that wetland drainage cost is $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 one-time wetland drainage maintenance cost of $100 to allow the continuous cultivation of the drained wetland over the crop production planning horizon.

Default Value for Upland-Drained Land Yield Difference and Delayed Seeding

We assume that crop yields/acre is greater than those on drained wetlands. For this App we assumed that the yield associated with the drained wetland area is 90% of the reported yield data in Table 1. Also, we assumed that the delayed seeding associated with drained wetland area is 1 out of 10 years.

Effect of Changes in Crop Production and Drainage Economic Information on Field-level Outputs

We assume that crop prices, crop production cost, crop yield and drainage cost might change over the crop production planning horizon. To account for the variability of these variables on net present benefit of wetland drainage, we calculated the net present benefit estimate over several iterations. For each iteration, we selected crop prices, crop production cost, crop yield and drainage cost values from a triangular distribution. We chose a triangular distribution to allow the values to be centered at the mean with decreasing probabilities of selecting values closer to the extremes. The average values for the triangular distributions for the variables (crop prices, crop production cost and crop yield) are taken from Table 1; we chose 30% increase and 30% decrease in the values of the variables, respectively, to represent the minimum and maximum values of the triangular distribution. The same process is used to account for the variability of drainage cost.

2.4. Fixed Parameters

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

2.5. User-defined Parameters

The user-defined variables are broadly grouped into crop production variables, wetland characteristics, economic variable information, and simulation control. The make-up of the above variable groups and their definitions are summarized Tables A1, A2, and A3 in appendix.

crop Production Variables

The user will be presented with Table 2 to edit based on his/her farming circumstances. Specifically, the user will take these steps to edit the Table 2:

a. Select the relevant soil zone from a drop-down menu
b. Select crops the producer intends to produce on the drained wetland,
c. Edit the parameters in Table 2 for the selected soil zone and crop choices.

Wetland Characteristics

The user will have the opportunity to change the area of wetland on the field, the location of wetland, cost of constructing surface drainage, cost of maintaining drainage infrastructure, state whether crop yield upland is greater than yield on drained wetland and by how much (as a percentage of crop yield). Also, the user will be able to state the cost savings from draining wetlands ($/acre), which is also called efficiency gain.

Economic Variable Information

The user can change the level of discount rate and planning horizon. Also, they can state the by how much, in percentage, that crop yield, crop price, variable cost, fixed cost, drainage construction cost, drainage maintenance cost, wetland area and field area varies around their means.

Simulation Control

The user will be able to state the number of iterations to estimate net present benefit of wetland drainage. Also, he/she will be able to turn or on the variability of the key variables in the simulation. The key variables are crop yield, crop price, production cost, drainage cost and field area. drainage maintenance cost, wetland area and field area.

2.6. Field-Level App Outputs

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

i) Graphical (boxplot) comparison of the net present benefit of cultivated crops on field with wetland drainage and field without wetland drainage,

ii) The histogram and density plot of net present benefit of cultivated crops on drained wetlands.

3.0. Landscape-level Analysis

The landscape level analysis estimates the effect of wetland drainage at the agricultural landscape scale. Specifically, the following will be estimated:

1. wetland supply curve, representing the wetland area that may be drained subject to different levels of monetary benefits associated with wetland drainage.
2. wetland area that could be conserved given a conservation budget.
3. The cost of conserving wetlands in highest quality fields.

The data for the landscape level analysis is an extension of the field level data. Recall, that we estimated the net present benefit, NPB, of drained wetlands for several simulations. The NPB values for the iterations will be different because of the differences in the values of crop prices, crop yields, production cost and drainage cost for each iteration. Therefore, the number of iterations can serve as the number of fields in the landscape; that is the number of simulations will be the same as the number of fields in the landscape. Therefore, the default values, fixed values and user defined values in the field-level analysis will apply here.

Appendix

Table A1. Definition of User-defined crop production and wetland characteristics variable groups

User-defined Group	Definition	Possible choice options
1. Crop Production Variable		
a. Field area	Acreage of farm field (acres)	Values range from 1-1,000 acres.
b. Soil zone	The soil zone of your field	Options are black soil, brown soil, and dark brown soil
c. Cultivated crops	Cultivated crops on the field	Options are Feed Barley, Malt Barley, Yellow Peas, Soybean, Canola, Corn, Flax, Spring Wheat, Oats, Fallow.
d. Editable Table 1	Edit Table 1 with appropriate information on crop price, crop yield, and cost of production based on the selected soil sone and cultivated crops	
2. Wetland Characteristics		
a. Wetland acres	Wetland area(acres)	Values range from 1-37 acres.
b. Location of wetland	Location of wetland on field	Options: Corner or Not
c. Efficiency gain of wetland drainage	Cost savings from not driving around wetlands and avoiding input wastage ($/acre)	Values range from 0 – $2,000/acre
d. Is crop yield upland greater than yield on drained wetlands?	Ask whether crop yield upland is greater than those on drained wetland areas.	Options: Yes or No
e. Difference in upland and drained wetland yield as a percentage of crop yield.	How much does crop yield upland differs from those on drained wetlands as a percentage of upland crop yield.	Values range from 0 to %100.
f. Cost to construct surface drainage.	How much does it cost to construct surface drainage?	Values range from 0 to $2,000/acre
g. Cost to maintain surface drainage	How much does it cost to maintain surface drainage?	Values range from 1 to $300/acre

Table A2. Definition of User-defined economic information variable group

User-defined Group	Definition	Possible choice options
4. Economic information		
a. Discount rate	Discount factor to estimate net present benefit of wetlands	Values range from 1 to 100%
b. Planning horizon	Expected operational years of the farming business.	Values range from 1 to 200 years.
c. Dispersion of crop yield around its mean	How much (%) does crop yield vary around its mean?	Values range from 1 to 100%
d. Dispersion of variable cost around its mean	How much (%) does variable cost vary around its mean?	Values range from 1 to 100%
e. Dispersion of fixed cost around its mean	How much (%) does fixed cost vary around its mean?	Values range from 1 to 100%
f. Dispersion of crop price around its mean	How much (%) does crop price vary around its mean?	Values range from 1 to 100%
g. Dispersion of drainage maintenance cost around its mean	How much (%) does drainage maintenance cost vary around its mean?	Values range from 1 to 100%
h. Dispersion of drainage construction cost around its mean	How much (%) does drainage construction cost vary around its mean?	Values range from 1 to 100%
i. Dispersion of wetland area around its mean	How much (%) does wetland area vary around its mean?	Values range from 1 to 100%
j. Dispersion of field area around its mean	How much (%) does field area vary around its mean?	Values range from 1 to 100%

Table A3. Definition of User-defined simulation control variable group

User-defined Group	Definition	Possible choice options
5. Simulation control		
a. Number of simulations	Number of iterations	Values range from 50 to 100,000
b. Turn on yield simulation	If answer is yes, it will make the yield variable stochastic.	Options: Yes or No.
c. Turn on crop simulation	If answer is yes, it will make the crop variable stochastic.	Options: Yes or No.
d. Turn on drainage cost simulation	If answer is yes, it will make the drainage cost variable stochastic.	Options: Yes or No.
e. Turn on production cost simulation	If answer is yes, it will make the production cost variable stochastic.	Options: Yes or No.
f. Turn on field area simulation	If answer is yes, it will make the field area variable stochastic.	Options: Yes or No.