

SENSITIVITY MAPPING FOR CLIMATE CHANGE IMPACT ON THE AGRICULTURAL SECTOR
IN THE LAKE SIMCOE REGION

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- The Technical Working Team responsible for assessing the Provincial Groundwater Monitoring Network (PGMN) and Stream Monitoring Network (PWQMN) with respect to climate change.

Summary

A climate change sensitivity score was assigned to each quaternary watershed in the Lake Simcoe Region. The score was based on the agricultural sector's current sensitivity to climate change. To achieve a sensitivity score the quaternary watershed needed a current sensitivity rating for three indicators. There were three possible sensitivity ratings for each indicator; low, medium and high. The three indicators were number of animals, number of irrigated hectares and water erosion potential. The Schomberg River quaternary watershed is most sensitive to climate change based these three indicators. The high score was driven by the large number of irrigated hectares and the high potential for water erosion. It is anticipated that climate change will lead to more frequent droughts and more frequent intensive rainstorms. If true, these changes will have an impact on water demand and soil erosion. In addition, this report provides recommendations further refining the datasets used and suggests some other possible indicators to consider in a future type of assessment.

1.1 Introduction

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Despite technological advances, such as improved varieties, genetically modified organisms, and irrigation systems, weather is still a key factor in agricultural productivity, as well as soil properties and natural communities. The effect of climate on agriculture is related to variability in local climates rather than in global climate patterns. Locally, Ontarians can anticipate the following impacts as a result of climate change:

Summary of climate change impacts (ref. "From Impacts to Adaptation: Canada in a Changing Climate 2007"; MNR 2007;

- Temperature: increases in summer and winter temperatures; maximum warming will occur in winter in the northern subregion
- Precipitation: increases in annual totals - winter increases and summer and fall decreases; changes in extreme daily amounts, duration of season and form of precipitation
- Evaporation: increased evaporation and evapotranspiration rates due to warmer temperatures and longer growing season
- Ice Cover/Snow Melt: Less overall snow and ice coverage; more winter melt events and earlier spring melt
- Extreme Weather: more frequent and more extreme weather events; eg. more intense precipitation, more extreme hot days, floods and droughts

The aforementioned changes in climate conditions will impact agriculture in both a positive and negative way. Summary of impacts (ref. "Agriculture and Climate Change 2005")

Positive impacts

- Increased productivity from warmer temperatures
- Possibility of growing new crops
- Longer growing seasons
- Increased productivity from enhanced CO₂
- Accelerated maturation rates
- Decreased moisture stress

Negative impacts

- Increased insect infestations
- Crop damage from extreme heat
- Planning problems due to less reliable forecasts
- Increased soil erosion
- Increased weed growth and disease outbreaks
- Decreased herbicide and pesticide efficacy
- Increased moisture stress and droughts

1.2 The Study Approach

The vulnerability assessment will focus on the negative impacts of climate change on agriculture. A positive impact does not involve a constraint evoking a need for a mitigation strategy, but rather provides an opportunity for the sector to recognize and seize. Any opportunities will depend on shifts in global markets and although it is easy to say the impacts of climate change may have a larger negative effect in other agricultural jurisdictions, a significant shift will depend on many other factors than just climate change. As a result, this will remain out of scope for this vulnerability assessment.

The approach used in this report is modelled after the approach used by the technical working team responsible for assessing the Provincial Groundwater Monitoring Network (PGMN) and Stream Monitoring Network (PWQMN) with respect to climate change. The approach designed by the technical working team and vetted through a panel of experts on climate change.

Approach Principles (ref.: Final Report: Sensitivity Mapping and Local Watershed Assessments for Climate Change Detection and Adaptation Monitoring, 2010)

- Use available provincial scale data for the mapping of sensitivity factors. Due to limited time and resources, there was a need to use existing data;
- Use a simple scoring system of high, medium, and low for the indicators. A system for weighting the indicators was not employed but could be considered for future sensitivity analyses;
- Issues of scale – although the sensitivity mapping is conducted on a regional / provincial scale, the quaternary watershed level is considered to be the optimum scale for sensitivity assessment and for evaluating the monitoring networks;
- Use MNR temperature and precipitation projections to provide an indication of potential exposure to climate change at the regional watershed level. It is recognized that these projections are based on a number of scenarios, each with its own assumptions.

The following definitions were used to guide the development of the approach:

Vulnerability to climate change is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability to climate change is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity" (IPCC, 2007).

Sensitivity: The degree to which a system has the potential to be affected, either adversely or beneficially, by climate-related stimuli.

Adaptive Capacity: The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007).

The adaptive capacity of the agricultural sector is very difficult to quantitatively assess because there are so many variables to consider (e.g. resources available, market fluctuations). As a result, an adaptive capacity factor was not considered in the assessment of the watershed. This report, however, will address possible data sets, if improved, that could be used to assess the adaptive capacity of a watershed.

1.3 Assumptions and Rationale for Selected Indicators used in the Sensitivity Analysis

Assumption 1: The 'No Regrets' Approach

The success or failure of the agricultural sector is influenced by several factors and it is likely not possible to attribute any trends directly to climate change. The focus of this assessment is identifying vulnerable agricultural watersheds within the Lake Simcoe region and therefore a "no regrets" approach is taken. That is any prioritization of vulnerable agricultural watersheds will be valuable even if climate change does not happen.

Assumption 2: Current Problems Exacerbated by Climate Change

Current environmental problems will be exacerbated by climate change. Under climate change there will be an intensification of the hydrologic cycle with more floods and drought, more intense

storms, changes in precipitation distribution, changes in seasonal stream flow patterns. (*IPCC 2007; MNR 2007*).

2.1 Rationale for Indicators for Sensitivity

The task for this project is to develop between three and five indicators and assess the vulnerability of Lake Simcoe watershed to climate change. In this instance, the data available dictated the assessment be based on the sensitivity of the agricultural section within the watershed only.

Three indicators were selected for use in the watershed sensitivity analysis based on the following rationale:

Number of Animals

- Based on the number of animals per quaternary watershed.
- Livestock production can be affected by heat stress (Chase, 2006). If warmer summer temperatures are expected then issues around heat stress on livestock will be exacerbated.
- The greater the density of animals the greater the problem of heat stress will occur.

Number of Irrigated Hectares

- Based on the number of irrigated hectares per quaternary watershed.
- This was used as a proxy for agricultural water use. Generally, irrigated agriculture uses more water than livestock production and therefore the number of irrigated hectares will show where a greater amount of agricultural water use occurs in the watershed.
- It is expected that climate change will lead to more extreme droughts, which impact the water availability under these conditions.

Soil Erosion

- Based on the potential soil erosion in kg/ha per quaternary watershed
- It is expected that climate change will lead to more frequent intense rainstorms. As intensity increase the potential for soil loss is greater.

2.2 Assessment of Sensitivity using GIS Mapping

As stated, the purpose of this project is to assess the sensitivity and vulnerability of the Lake Simcoe watershed to climate change. Seeing as this project could lead to the province assessing the vulnerability of other watersheds to climate change, it was important to select datasets that are available on a provincial scale. It should be recognized that OMAFRA's Agricultural Resource Inventory project has collected a significant amount of agricultural land use data in the Lake Simcoe Region. To date, the data layer created in the Lake Simcoe region is only a research layer and does not have provincial coverage. The hope is to use remote sensing to expand the layer to a provincial layer (Agricultural Resource Inventory, 2010).

The largest agricultural provincial data set available is the information collected in the agricultural census. The agricultural census dates back to 1871 and only covered the Prairie Provinces. It was initially taken every 10 years. In 1896, the time between agricultural censuses was reduced from 10 to 5 years. In 1956, the agricultural census was extended to the whole country. The agricultural census is often criticized as a reliable source of information because the results are based on an individual's response to questionnaire. The criticism is warranted, however, there is no other data set that contains as much information on such a large scale.

The other large data set available is the National Agri-Environmental Health Analysis and Reporting Program (NAHARP), which was developed under the federal government's Growing Forward initiative. Under NAHARP a series of science based agri-environmental indicators were developed to help guide policy and program design.

These two data sets were used to generate the following indicators on quaternary watershed level:

- Number of animals
- Number of irrigated hectares
- Water erosion potential

Once the data sets were established the approach used by the technical working team responsible for assessing the Provincial Groundwater Monitoring Network (PGMN) and Stream Monitoring Network (PWQMN) with respect to climate change was employed.

The general approach used was to first assess each individual indicator (i.e. GIS dataset) in terms of sensitivity to climate change. This was achieved by applying a three category classification to each input GIS dataset at a quaternary watershed level. The three categories based on relative sensitivity to climate change were:

- (1) – low sensitivity to climate change;
- (2) – moderate sensitivity to climate change;
- (3) – high sensitivity to climate change.

Each quaternary watershed was assigned a value of 1, 2, or 3 for each of the three input layers. Once these values were established for each input layer, they could be combined into the overall relative sensitivity to climate change map for Lake Simcoe.

Detailed descriptions on how each of the three input layers was reclassified into the three categories are found below. The following sections of this chapter also provide the source for each input layer, as well as potential data gaps and sources of error.

2.3 Number of Animals

The source of the data is the 2006 Agricultural Census. In addition to the standard geographical reporting areas, OMAFRA requested the census data be organized on a quaternary watershed level. The total number of animals per quaternary watershed is the sum of the following agricultural census categories:

- Total Number of Cattle
- Total Number of Swine
- Total Number of Chickens
- Total Number of other livestock

The next step was to select an appropriate range for each sensitivity rating. This GIS layer was then classified into 3 categories based on the following criteria:

- 0 – 100,000 animals = 1, low
- 100,001 – 200,000 animals = 2, moderate
- >200,001 animals = 3, high

See Figure 2.1 Number of Animals per Quaternary Watershed

Data Gaps/Limitation/Sources of Error

- The number of animals in a tertiary watershed will differ significantly across the province and therefore these ranges may not be appropriate to use in other regions across the province.
- The agricultural census data will always be out of date or unlikely a true reflection of what is happening on the ground.
- If there is small number of active farms in quaternary watershed it could lead to suppression issues and therefore it may be difficult to gather any information for a given quaternary watershed.
- It is assumed that the effect of heat stress is equal across all livestock commodities. This we know, however, is not true, so with more time and resources this effect could be built into this data layer. There would be a need to develop a heat stress coefficient for each livestock commodity and apply it to the census data.

2.4 Number of Irrigated Hectares

The source of the data is the 2006 Agricultural Census. The sum of irrigated hectares in each quaternary watershed was calculated. The next step was to select an appropriate range for each sensitivity rating. This GIS layer was then classified into 3 categories based on the following criteria:

- 0 - 500 Hectares of irrigated land = 1, low
- 500 – 1000 Hectares of irrigated land = 2, moderate
- >1000 Hectares of irrigated land = 3, high

Data Gaps/Limitation/Sources of Error

- The data set does not give a true representation of agricultural water use. It does, however, show the intensity of high agricultural users.
- This data set could be improved to include all agricultural water uses. A more detailed run of census data has occurred in the past. The exercise was attaching water coefficients to census information (e.g. A dairy cow uses X number of L/day; the number of dairy cows in the geographical region is Y). This type of exercise has not happened with the latest census information.
- The number of irrigated hectares in a tertiary watershed will differ significantly across the province and therefore these ranges may not be appropriate to use in other regions across the province. This indicator may be better on a provincial vulnerability assessment using a range appropriate for the entire province because not every larger tertiary watershed will have a significant amount of irrigation.
- The Tier 2 budgets prepared as part of the Clean Water Act could provide a more accurate assessment of the agricultural water demand.
- Many of the northern quaternary watersheds had the data suppressed and therefore they were assumed to have less than 500 hectares of irrigated land. The suppression issues in these watersheds are because we typically don't expect to see a lot of irrigated agriculture in these areas.
- The last census was taken in 2005 and it could be argued this data is dated.

See Figure 2.2 Number of Irrigated Hectares per Quaternary Watershed

2.5 Water Erosion Potential

This layer was developed as part of an OMAFRA led project to develop a decision support framework for agri-environmental priority issues. This layer is based on the NAHARP Indicator for the risk of soil erosion due to water erosion represented on a quaternary watershed scale. The layer uses the Universal Soil Loss Equation to develop the erosion potential. This requires

knowledge of land uses, tillage practices and inherent field properties (slope and soil conditions). The land use and tillage practice were generated using the agricultural census data. The slope and soil conditions were based on the Soil Landscape of Canada (SLC) polygons. To convert the SLC polygons to quaternary watershed polygons spatial manipulation was required. The methodology outlined below is how the data layer was created:

Excerpt from “Development of a Decision Support Framework for Agri-Environmental Priority Issues and Watersheds in the Great Lakes Basin: Final Report” 2010.

- Step 1: Unioned NAHARP Indicator with the quaternary watersheds and recalculated the area – this created a new boundary layer that is based on both polygons.
- Step 2: Multiplied the NAHARP Indicator (raw values) for the 2006 Census year by the area of the new polygon boundaries – this gives a value of the indicator multiplied by the new area.
- Step 3: Joined the attributes of the unionized layer to the quaternary watersheds; while doing so summed the values of the polygons contained within each quaternary watershed; then divided the value created in step 2 by the quaternary watershed area to obtain the final product on a quaternary watershed scale.

This GIS layer was then classified into 3 categories based on the following criteria:

- 0-10 tonne/ha = 1, low
- 10-20 tonne/ha = 2, moderate
- >20 tonne/ha = 3, high

Data Gaps/Limitation/Sources of Error

- The SLC data is on such a large scale that prevents a good variation of parameters over a large geographic area.
- The potential for water erosion in a tertiary watershed will differ significantly across the province and therefore these ranges may not be appropriate to use in other regions across the province.
- The last census was taken in 2005 and it could be argued this data is dated.

See Figure 2.3 Water Erosion Potential per Quaternary Watershed

3.1 Results of Quaternary Watershed Climate Change Vulnerability Assessment

Once the input layers were classified into three categories, it was possible to overlay the input layers and calculate a sensitivity score based on the sum of the input layers for each quaternary watershed. Each quaternary watershed had a value for each of the three input layers. The numbers from all three input layers were added for each quaternary watershed to arrive at a Sensitivity Score. The Sensitivity Score is a dimensionless number which represents the sum of the values of all the input layers. The resulting Sensitivity Scores can be viewed on Figure 3.1.

On a general level, it was not surprising to see the watersheds with the largest amount of agricultural activity show up as the most sensitive to climate change. The northern quaternary watersheds do have some agricultural activity, but the activity in these watersheds is less intensive than the southern quaternary watersheds. Out of all the southern quaternary watersheds, the Schomberg River quaternary watershed turns out to be the most sensitive to climate change. The high score was driven by the large number of irrigated hectares and the high potential for water erosion. It is anticipated that climate change will lead to more frequent droughts and more frequent intensive rainstorms. If true, these changes will have an impact on water demand and soil erosion.

4.1 Discussion and Recommendations

The assessment of sensitivity of agriculture to climate change was the first of its kind in Ontario and should be seen as a first step only. The following recommendations on future development of this assessment should be considered:

Recommendation #1

The sensitivity scoring should remain on a quaternary level because data sets used in this report are available at that level of scale. There are suppression issues with census data at a quaternary level. The problem exacerbates the smaller the scale. There are, however, methods of dealing with these issues if time and cost are not an issue.

Recommendation #2

In Ontario, the agricultural sector is very diverse both by commodities grown and spatial distribution. The sensitivity assessment should be conducted on a provincial level with a single set of ranges for each sensitivity indicator.

Recommendation #3

A sensitivity assessment on a provincial level should include the drought frequency indicator used by the technical working team responsible for assessing the Provincial Groundwater Monitoring Network (PGMN) and Stream Monitoring Network (PWQMN) with respect to climate change. The drought frequency indicator was based on the Low Level Response provincial program. The data set is only available on a tertiary watershed scale and so it was not considered in the Lake Simcoe Region assessment.

Recommendation #4

A single set of ranges for each indicator should be vetted by an expert committee to ensure that classifications of properly represent the fluctuation in numbers across the province.

Recommendation #5

A more accurate province wide agricultural land use data set, such as the one the Agricultural Resource Inventory is attempting to capture, should be obtained. An assessment such as this will be dictated by available data sets and with a more accurate data set the indicators in this report could be improved. The 2011 agricultural census is mandatory, but the future of a mandatory agricultural census is uncertain. This uncertainty stresses the importance of continuing projects such as the Agricultural Resource Inventory.

Recommendation #5

In lieu of a provincially complete Agricultural Resource Inventory, this assessment should be re-run with 2011 agricultural census data. The agricultural census data is 5 years old and large fluctuations in commodities grown have occurred in Ontario. (e.g. hog industry).

Recommendation #6

The water demand indicator should be developed for a province wide assessment using a revised set of water demand coefficients. The number of irrigated hectares was used a proxy for water demand. If water demand is to be considered as an indicator then it should consider other water demands then just irrigated hectares.

Recommendation #7

An adaptive capacity piece should be included to move this exercise from a sensitivity assessment to a vulnerability assessment. A data layer has been created demonstrating the distribution of projects funded under the Environmental Farm Plan (EFP) program in the Lake Simcoe Region. This layer, however, is based on 2009-2010 projects only. Furthermore, the layer shows all EFP projects, which includes everything from soil erosion projects to purchasing GPS equipment. A data layer should be created showing the distribution of EFP projects that will directly mitigate the sensitivity indicators (e.g. erosion control measures). The layer should also encompass a greater period of record.

Recommendation #8

This report did not consider the climate change impact on pests. There is an expectation that climate change will lead to a greater amount of pests (Wolfe, 2006). In the past, OMAFRA in conjunction with Ridgetown Campus of the University of Guelph has conducted a Pesticide Use Survey. The last survey was conducted in 2008. The results show the amount of active ingredients used per crop. The results of the survey were then expanded to demonstrate the amount of active ingredients used per crop on provincial scale. This data could be used, but there would need some more thought into using it in the context of climate change. For example, the data shows that field corn uses the greatest variety of pesticide and so does this show corn as being more or less resistant to pest.

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Figure 2.1 Number of Animals per Quaternary Watershed

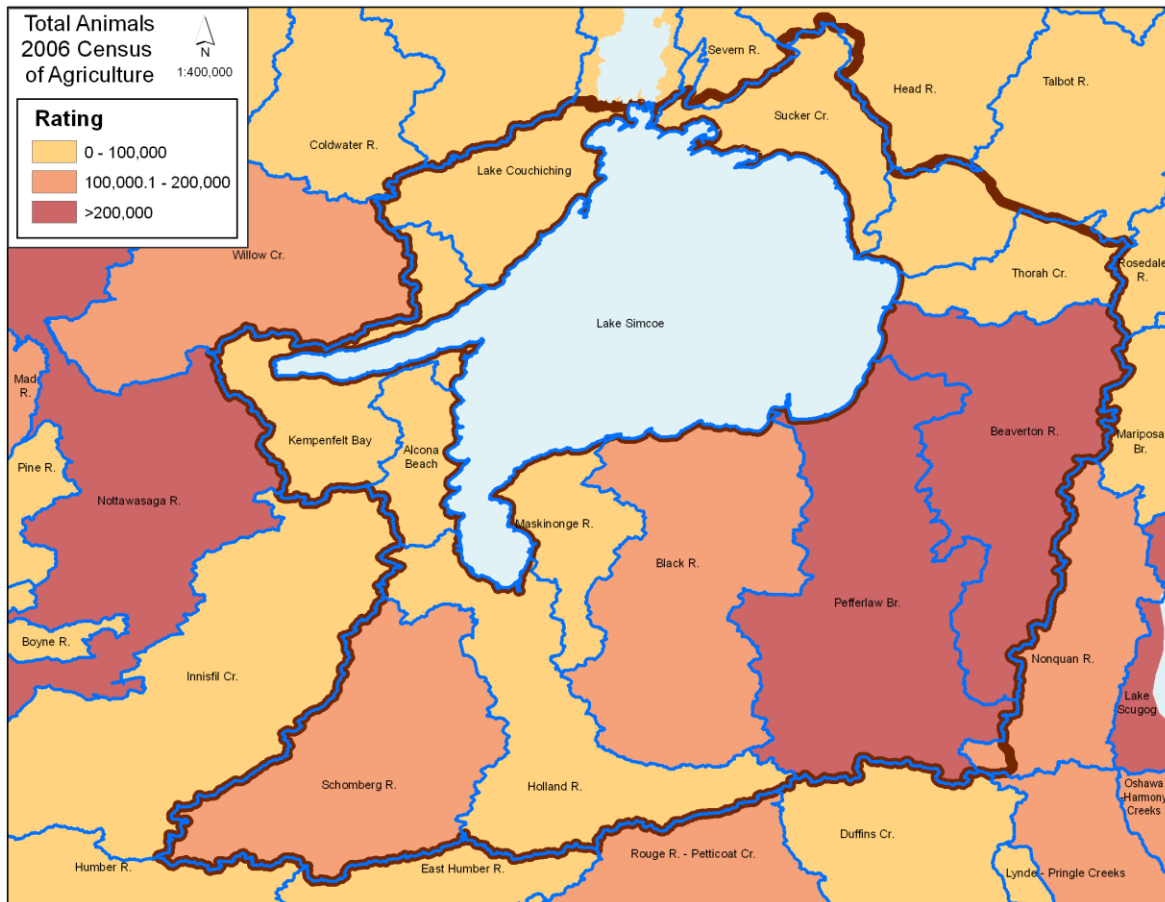


Figure 2.2 Number of Irrigated Hectares per Quaternary Watershed

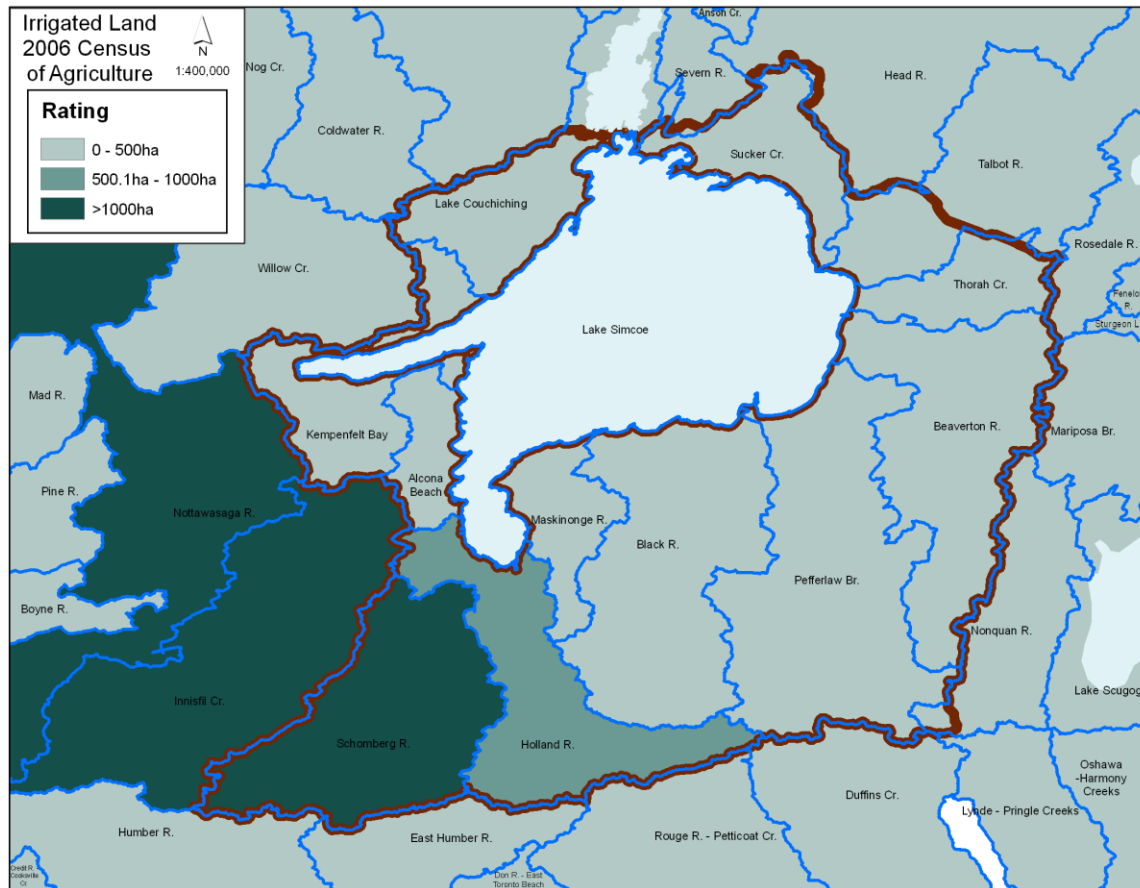


Figure 2.3 Water Erosion Potential per Quaternary Watershed

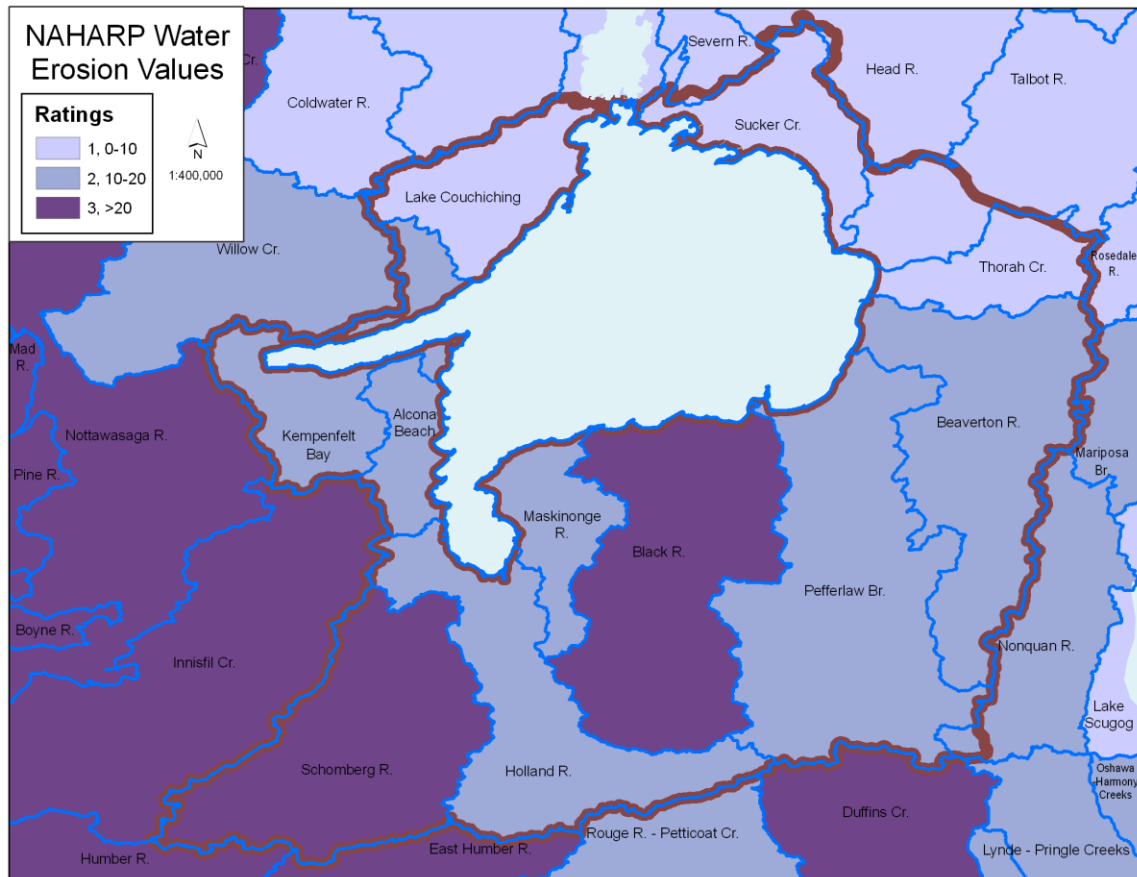


Figure 3.1 Climate Change Sensitivity Score per Quaternary Watershed

