Agricultural-Water Quantity Climate Change Sensitivity Assessment, NVCA Watershed

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1.0 Introduction

Climate is inherently variable. According to the Intergovernmental Panel on Climate Change (IPCC), a region's vulnerability to climate change depends on its adaptive capacity, sensitivity, and exposure to changing climatic patterns (Deressa et al., 2008). *Adaptive capacity* describes the ability of a system to adjust to actual or expected climate stresses, or to cope with the consequences. It is considered a function of wealth, technology, education, information, skills infrastructure, access to resources, and stability and management capabilities (McCarthy et al., 2001). *Sensitivity* refers to the degree to which a system will respond to a change in climate, either positively or negatively. *Exposure* refers to the degree to which a system is exposed to climate change and the nature of the climate (O`Brien, 2004). The more exposed a system is to a particular climate stimulus, the greater the system vulnerability; conversely, the greater the adaptive capacity of the system to a given climate event, the lower its vulnerability (Tubiello and Rosenzweig, 2008).

Agriculture is a land-based entrepreneurial enterprise. The capacity of a farming system to adapt to changing climate and weather conditions is based on its natural resource endowment and associated economic, social, cultural and political conditions (Wall and Smit, 2005).

The Nottawasaga Valley Conservation Authority (NVCA) watershed, located in south-central Ontario, is approximately 3,300 km^2. Agriculture dominates much of the NVCA landscape and provides significant economic and social benefits. The area has a land base, climate and a skilled farm community that make agriculture highly productive. The vast majority of this area's agricultural land is either prime agricultural lands or specialty crop (approximately 70%). The major crops from this area are: soy beans, corn, sod, wheat, barley, potatoes, carrots, and onions. Although a significant local economic engine, limited work has been completed to determine this region's sensitivity to the anticipated impacts of climate change from an agricultural water quantity perspective; however, previous sensitivity analysis has been completed for Lake Simcoe (Jamieson, unpublished report), groundwater sensitivity analysis to low water conditions (MNR and MOE, 2013), and livestock water use and future water needs (Wong, 2013) from which the NVCA could build from.

At the quaternary watershed level in the NVCA, the objective of this project is to advance the understanding of agricultural-based sensitivity to climate variability and longer-term change with the focus on water quantity. The sensitivity analysis utilizes the following indicators: 1) low water occurrence, 2) irrigated area, 3) surface water stress assessment, and 4) animal water use.

2.0 Summary of climate change impacts for Ontario

Summarized from Ministry of Natural Resources (2007), the following climate change impacts are anticipated for southern Ontario, where the Nottawasaga Valley watershed is situated:

1. Temperature: increased summer and winter temperatures
2. Precipitation: increased annual totals - winter increases and summer and fall decreases; changes in extreme daily amounts, duration of season and form of precipitation
3. Evaporation: increased evaporation and evapotranspiration rates due to warmer temperatures and longer growing season
4. Ice Cover/Snow Melt: less overall snow and ice coverage; more winter melt events and earlier spring melt
5. Extreme Weather: more frequent and more extreme weather events (e.g. more intense precipitation, more extreme hot days, floods and droughts).

In addition, the above climatic changes will impact agriculture in both a positive and negative way, as summarized below (Agriculture and Agri-Food Canada, 2005).

Positive impacts:

- Increased productivity from warmer temperatures
- Possibility of growing new crops
- Longer growing seasons
- Increased productivity from enhanced CO_2
- 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

3.0 Data sources and methodology

Using a no-regrets approach, the climate change sensitivity analysis focuses on agricultural sensitivity related to water quantity. Completed at the quaternary watershed level, the selected indicators include: 1) low water occurrence, 2) irrigated area, 3) surface water stress assessment, and 4) animal water use. The indicators represent local drought manifestations and impacts to water quantity in addition to water quantity impacts to both livestock and crop production. The selected sensitivity indicators are based on readily available data that could be utilized easily for this desktop exercise and are not deemed to be comprehensive.

Provided by OMAF, the 2011 Census of Agricultural data summarized at the quaternary subwatershed level was used for irrigated area and animal water use sensitivity indicators. The data for the low water occurrence is based on declarations made by the NVCA Low Water Response Team from 2001 to 2012. The surface water stress assessment data is from the NVSPA Assessment Report (South Georgian Bay-Lake Simcoe Source Protection Committee, 2011).

There are nine subwatersheds in the NVCA watershed: upper, lower, and middle Nottawasaga River; Mad River; Pine River; Boyne River; Innisfil Creek; Willow Creek; and the Blue Mountain subwatershed. The 2011 Census of Agriculture provided data for seven subwatersheds, with the Nottawasaga River as a single composite subwatershed. Data associated with the low water response and the surface water stress assessment sensitivity indicators were collected with the Nottawasaga River subwatershed divided into three (upper, middle, and lower); however, have been averaged to correspond to the units provided in the 2011 Census of Agriculture data (see figure 1). Table 1 provides the watershed ID and subwatershed code from the 2011 Census of Agriculture data.

The sensitivity analysis per indicator was completed by applying a three category classification based on relative sensitivity to climate change: 1 - low sensitivity to climate change, 2 - moderate sensitivity to climate change, and 3 - high sensitivity to climate change. Consistency with ranking and methodologies used in other local-scale or regional scale climate change sensitivity analysis in Ontario was desired where appropriate. Methodology and ranking matrix for the number of animals and irrigated area indicators is identical to Jamieson (unpublished report). The low water indicator is modified from the low water response indicator presented by MNR and MOE (2013). The surface water stress assessment and the animal water use indicators did not have a previously developed criterion.

Each quaternary watershed was assigned a value of 1, 2, or 3 based on the climate change sensitivity for the four indicators. These values were summed to provide overall understanding of climate change sensitivity with the focus on agricultural water quantity for the NVCA quaternary watersheds.

Table 1: Subwatershed code and associated name, NVCA Quaternary subwatersheds (from 2011 Census of Agriculture data).

WATERSHED_ID	Subwatershed code	Name
Nottawasaga	2ED-10	Pretty R.
	2ED-15	Innisfil Cr.
	2ED-14	Willow Cr.
	2ED-13	Boyne R.
	2ED-12	Pine R.
	2ED-11	Mad R.
	2ED-09	Nottawasaga R.

4.0 Results

4.1 Indicator 1: Low water occurrence

Areas historically prone to drought will experience greater occurrences of drought under projected climate change scenarios. Low water conditions are manifested through low water declarations completed by the local Water Response Team, based on the methodology set forth through the MNR Ontario Low Water Response (OLWR) Program. Based on stream flow and/or precipitation, the OLWR program consists of three levels of increasing drought/low water severity. (It is noted that a Level 3 declaration has never been officially declared in Ontario.)

The number of Level 1 and 2 declarations made by the NVCA Low Water Response Team were summarized on a quaternary watershed level for the period of 2001-2012, based on internal documentation of low water declarations. It should be noted that low water declarations (level 1 or above) were made somewhere within the tertiary watershed in only six out of the 12 years. Further, not every quaternary watershed declared a level 1 in each of the six years, and only five quaternary watersheds declared a level 2. The following rationale and ranking are used for this indicator:

- Low – score of 1 = Did not declare a level 1 in every dry year
- Medium – score of 2 = Did not declare a level 1 in every dry year and declared at least one level 2
- High – score of 3 = Declared a level 1 in every dry year and declared at least one level 2

Results of the low water occurrence sensitivity indicator are presented in Table 2.

Table 2: Low water declaration level 1 ("*1*") and level 2 ("*2*") per year, 2001-2012 for the NVCA watershed and climate change sensitivity ranking.

	2001		**2002**		**2003**		**2004**		**2005**		**2006**		**2007**		**2008**		**2009**		**2010**		**2011**		**2012**		**Sensitivity ranking**
	1	***2***	***1***	***2***	***1***	***2***	***1***	***2***	***1***	***2***	***1***	***2***	***1***	***2***	***1***	***2***	***1***	***2***	***1***	***2***	***1***	***2***	***1***	***2***	
Nottawasaga River	1	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	2
Blue Mountain	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1
Mad	1	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	2
Pine	1	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	2
Boyne	1	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	1	0	3
Willow	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1
Innisfil Creek	1	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	1	0	3

4.2 Indicator 2: Surface water stress assessment

A decrease in summer precipitation is projected to occur due to climate change. This is also the time of highest water demand. In addition to a projected decrease in precipitation, increased annual temperatures would also result in higher evapotranspiration rates which would lead to further water loss. This could result in increased frequency of water shortages and/or drought conditions.

The water budget exercise completed through the Source Water Protection process utilized a hierarchical approach based predominantly on the source of municipal demands (e.g. groundwater versus surface water). Subwatersheds that experienced demand on the municipal source were elevated to the next level of water budget corresponding to a three-tiered process. The Tier 1 water budget was completed at the watershed scale and the Tier 2 water budget was conducted at the subwatershed scale, only where stress on the municipal source was identified.

Through source water protection, a surface water stress assessment was based on water course flows vs. the maximum permitted rate of takings for surface water abstractions (South Georgian Bay-Lake Simcoe Source Protection Committee, 2011). This provides a proxy where competing demands are greatest and where there is potential for surface water scarcity: the greater the water demand vs. flow, the more stressed the system is. With the projected increase in summer and winter temperature and associated drought/low flow periods, the systems with existing stress of the surface water system are anticipated to be impacted more relative to a less stressed system. The following rationale and ranking is used for this indicator:

- No existing surface water stress assessment= 1 (low sensitivity)
- Existing surface water stress assessment, no tier 2 water budget= 2 (moderate sensitivity)
- Underwent a Tier 2 water budget= 3 (high sensitivity)

Results of the surface water stress assessment sensitivity indicator are presented in Table 3.

Table 3: Surface water stress assessment and climate change sensitivity ranking.

Subwatershed	Current surface water conditions	Stress condition (as per technical rule 32(c)(i)(ii)	Sensitivity ranking
Nottawasaga-complete	June - September	Significant	3
Blue Mountains subwatershed	June - September	Significant	3
Mad River subwatershed			1
Pine River subwatershed	July - September	Significant	3
Boyne River subwatershed	June - September	Significant	3
Willow Creek subwatershed	Various	Moderate	2
Innisfil Creek subwatershed	June - September	Significant	3

4.3 Indicator 3: Irrigated area

Climate change is anticipated to lead to more extreme droughts, which will impact the water availability under these conditions. The use of the total hectares irrigated provides a broad metric to evaluate which areas are more sensitive to climate change. It is assumed that the majority of the irrigation water is abstracted from surface water features, which are susceptible to drought/ low water conditions, and the greater the area per subwatershed the more susceptible to low water impacts it is assumed to be. The following ranking is defined:

- 0-500 hectares of irrigated land = 1 (low sensitivity)
- 501-1000 hectares of irrigated land = 2 (moderate sensitivity)
- >1000 hectares of irrigated land = 3 (high sensitivity)

Results of the irrigated area sensitivity indicator are presented in Table 4.

Table 4: Total area irrigated per quaternary watershed, NVCA and climate change sensitivity ranking.
X = data suppressed to meet the confidentiality requirements of the Statistics Act.

Subwatershed	Total farm area (ha)	Total use of irrigation (Ha)	Irrigated field crops (Ha)	Irrigated vegetables (Ha)	Other irrigated area (Ha)	% of irrigated vs. total farm area	Sensitivity ranking
Nottawasaga-complete	56,810.5	2,102.4	1,884.3	95.1	71.2	3.7	3
Blue Mountains subwatershed	10,420.0	29.8	X	X	X	0.3	1
Mad River subwatershed	21,876.9	75.4	X	X	41.2	0.3	1
Pine River subwatershed	14,392.8	227.2	X	X	56.3	1.6	1
Boyne River subwatershed	12,936.1	401.3	343.1	X	14.8	3.1	1
Willow Creek subwatershed	12,480.8	28.2	X	4.7	X	0.2	1
Innisfil Creek subwatershed	24,003.4	626.6	440.3	111.3	59.2	2.6	2

4.4 Indicator 4: Animal water demand

With the projected temperature increase, it is anticipated that animal well-being will be impacted by water availability and physiological related impacts (e.g. heat stress). To determine the water needs of livestock, water use coefficients are used to estimate the amount of water needed per animal strictly for drinking purposes. The coefficients used to determine the livestock water use per capita are based on the averaged OMAFRA coefficients (Ward and McKague, 2007). The total sum of animals per quaternary watershed is based on the following agricultural census categories: total number of poultry, cattle and calves, pigs, and other livestock (sheep, goats, and horses). The ranking for the total daily animal water use is arbitrarily defined as:

- 0-500,000 L/day= 1 (low sensitivity)
- 5001,000-1,000,000 L/day= 2 (moderate sensitivity)
- >1,000,001 L/day= 3 (high sensitivity)

Results of the animal water demand sensitivity indicator are presented in Table 5.

Table 5: Distribution of animal and associated water with climate change sensitivity ranking use per quaternary watershed, NVCA.
X= data suppressed to meet the confidentiality requirements of the Statistics Act.

	Nottawasaga -complete		**Blue Mountains subwatershed**		**Mad River subwatershed**		**Pine River subwatershed**		**Boyne River subwatershed**		**Willow Creek subwatershed**		**Innisfil Creek subwatershed**	
	animal number	**total water use**	**animal number**	**total water use**	**animal number**	**total water use**	**animal number**	**total water use**	**animal number**	**total water use**	**animal number**	**total water use**	**animal number**	**total water use**
Total poultry (0.28 L/day)	264,469	74,051	10,212	2,859	158,825	44,471	37,421	10,478	9,712	2,719	X	X	111,889	31,329
Beef breeders (27 L/day)	4,024	108,659	1,183	31,930	1,517	40,958	1,278	34,511	1,281	34,593	728	19,659	1,201	32,418
Heifers for beef herd replacement (27 L/day)	425	11,471	175	4,729	212	5,711	137	3,703	127	3,434	81	2,191	161	4,354
Dairy cows (115 L/day)	1,966	226,109	295	33,932	397	45,673	233	26,751	X	X	623	71,596	477	54,849
Heifers for dairy herd replacement (30 L/day)	1,268	38,038	125	3,743	421	12,628	134	4,026	X	X	291	8,738	343	10,292
Calves, under 1 year (15 L/day)	4,239	63,588	794	11,906	2,025	30,379	1,240	18,597	1,105	16,576	890	13,349	1,261	18,915
Steers and heifers for slaughter or feeding, 1 year and over (30 L/day)	4,882	146,457	285	8,541	7,757	232,699	2,519	75,562	3,255	97,640	1,427	42,799	758	22,738
Total pigs (20.5 L/day)	15,192	311,432	4,230	86,721	6,521	133,682	1,432	29,347	X	X	3,190	65,385	X	X

	Nottawasaga -complete		Blue Mountains subwatershed		Mad River subwatershed		Pine River subwatershed		Boyne River subwatershed		Willow Creek subwatershed		Innisfil Creek subwatershed	
	animal number	**total water use**	**animal number**	**total water use**	**animal number**	**total water use**	**animal number**	**total water use**	**animal number**	**total water use**	**animal number**	**total water use**	**animal number**	**total water use**
Pig breeders (20.5 L/day)	791	16,212	X		1,201	24,612	X	X	X	X	X	X	X	X
Nursing and weaner pigs (20.5 L/day)	4,890	100,242	X		3,874	79,427	1,081	22,151	X	X	X	X	X	X
Grower and finishing pigs (20.5 L/day)	9,511	194,978	4,215	86,400	1,446	29,643	X	X	X	X	X	X	X	X
Sheep, goats and horses (average 40L/day)	7,477	299,078	1,092	43,690	3,734	149,364	1,656	66,234	2,523	100,907	1,575	63,013	3,885	155,389
total water use (L/day)		**1,590,315**		**314,452**		**829,246**		**291,361**		**255,870**		**286,732**		**330,284**
ranking		**3**		**1**		**2**		**1**		**1**		**1**		**1**

5.0 Discussion and summary

The climate change sensitivity ranking/scoring for each of the four indicators was summarized to provide a final dimensionless sensitivity score at the quaternary watershed level. A higher score indicates a higher sensitivity. It is noted that the sensitivity for the number of animals and animal water demand were averaged in the final scoring, resulting in a final sensitivity score out of a possible 12 (Table 6). The watersheds with the largest amount of agricultural activity scored the highest (e.g. Nottawasaga River and Innisfil Creek). Not surprisingly, this area includes extensive irrigated potato and sod crop lands and noted historical low water conditions. It is also noted that the Nottawasaga River subwatershed is roughly three times the size of any of the other quaternary watersheds and, as a result, the number of animals in this area may be reflective of the area and not necessarily the density of animals. Alternatively, the watersheds that lack extensive and intensive agriculture scored the lowest – the Mad River, Blue Mountains, and Willow Creek subwatersheds. Regardless of the score, it is noted that all quaternary watersheds exhibited some degree of sensitivity to climate change.

This is the first attempt to complete a quantifiable agricultural water quantity sensitivity analysis related to the projected impacts of climate change for the NVCA watershed. Further, this project is only one focused aspect of the overall vulnerability assessment to climate change, which also includes the adaptive capacity and exposure to changing climatic patterns. Therefore, while this desktop analysis is deemed not to be extremely comprehensive, it provides a satisfactory start and could be used to target adaptation strategies or efforts. From this study, the following recommendations are noted:

- Building on this report, adaptive capacity and exposure to changing climatic patterns should be next examined for the NVCA watershed.

- Future sensitivity analysis should include the examination of water quality indicators (e.g. potential for water-based soil erosion, exceedances to PWQO for total phosphorus, etc.).

- A consistent scoring matrix should be developed that can be used at the quaternary watershed level for climate change sensitivity indicators throughout Ontario.

- The sensitivity analysis presented in this report is completed at the quaternary watershed level. The Census of Agricultural data provides a wealth of information that can be used to analyze for climate change vulnerability, sensitivity, and adaptive capacity. Adaptive capacity regarding agricultural and water quantity can be summarized from the Census of Agricultural farm business characteristics (e.g. operating arrangements, computer use, farm capital, farm machinery, gross farm receipts, operating expenses, paid agricultural work); however, this is limited to the township level and not the quaternary level. As a result, it is recommended that a consistent scaled approach be developed where the analysis for all climate change vulnerability work is to be completed at the same geographic scale.

Table 6: Summary agricultural water quantity sensitivity analysis scoring.

	low water occurrence	surface water stress assessment	irrigated areas	animal water demand	final sensitivity score (out of 12)
Nottawasaga-complete	2	3	3	3	**11**
Blue Mountains subwatershed	1	3	1	1	**6**
Mad River subwatershed	2	1	1	2	**6**
Pine River subwatershed	2	3	1	1	**7**
Boyne River subwatershed	3	3	1	1	**8**
Willow Creek subwatershed	1	2	1	1	**5**
Innisfil Creek subwatershed	3	3	2	1	**9**

6.0 Acknowledgements

The 2011 Census of Agricultural data summed at the quaternary watershed level that was used for irrigated area and number of animals and associated animal water use was provided by OMAF. Andrew Jamieson (AAFC), Jennifer Birchmore (OMAF), and Dave Bray (OMAF) provided technical guidance to this endeavor.

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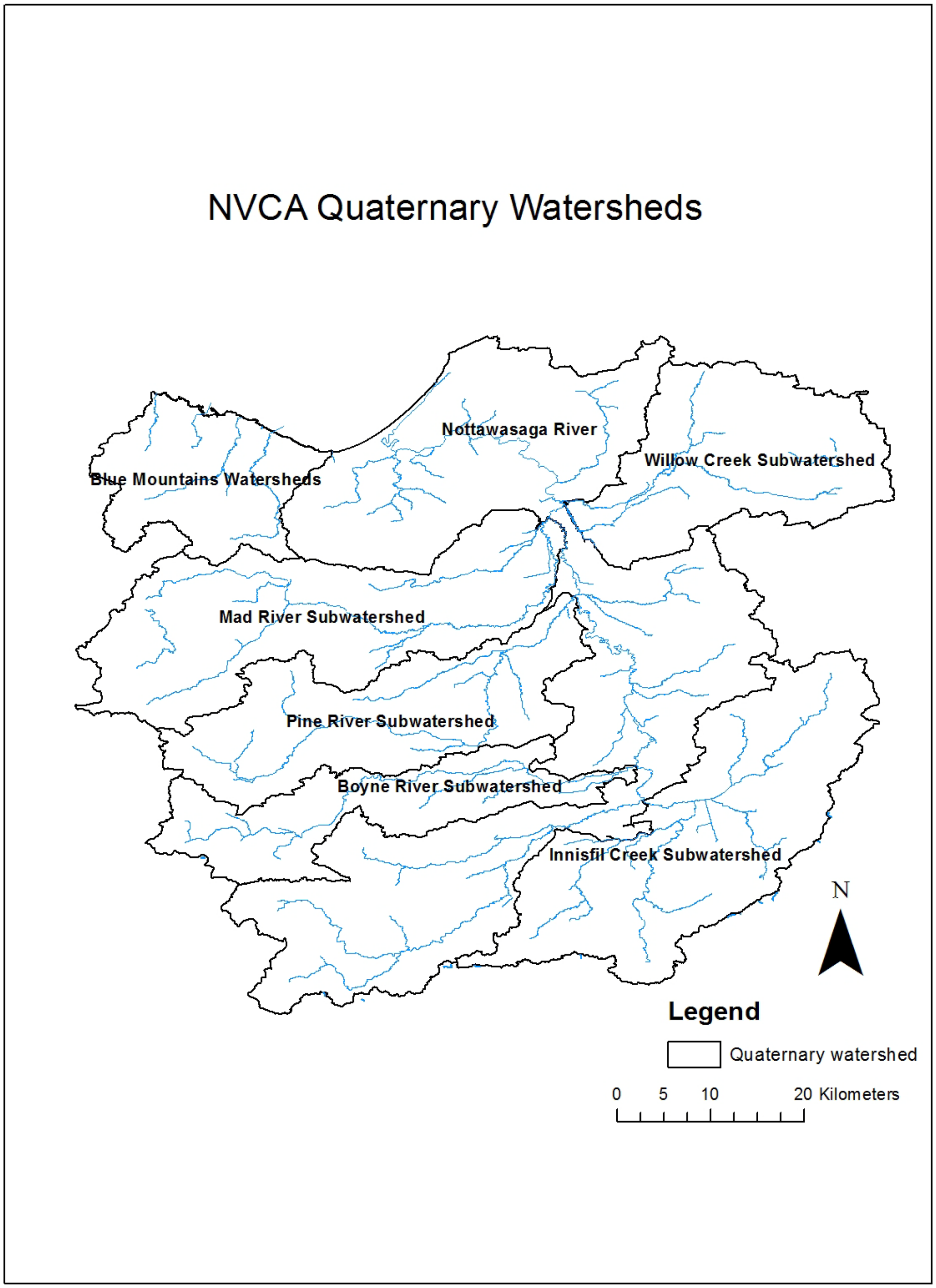

Figure 1: NVCA quaternary watersheds.