Risk Proofing Nova Scotia Agriculture: A Risk Assessment System Pilot (AgriRisk)

Mapping and Web-Enabling Nova Scotia's Expanding Wine Grape Industry
Final Report

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Nova Scotia Federation of Agriculture would like to recognize the collaborative relationships that exist among Agriculture and Agri-Food Canada and the Nova Scotia Departments of Agriculture and Environment

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Executive Summary

This project was funded through Agriculture and Agri-Food Canada's (AAFC) AgriRisk Initiative, Growing Forward II Business Management Risk Initiative, as well as the Nova Scotia Department of Environment (NSE), Nova Scotia Department of Agriculture (NSDA) and administered by the Nova Scotia Federation of Agriculture (NSFA). The Nova Scotia Community College's Applied Geomatics Research Group (AGRG) was engaged by the NSFA to produce the GIS component of the project, including the creation of spatial datasets relevant to the grape and wine industry, a suitability model to predict optimal areas to grow wine grapes in the province, and an online web-based viewer to showcase these datasets and those from other data providers.

A provincial inventory of vineyards was constructed from scratch by carrying out air photo and satellite imagery analyses, database querying and field validation. Spatial gaps in the analyses were identified by comparing mapped acreage to the 2016 Census of Agriculture reported acreage by county; additional validation from Perennia closed these gaps. At the end of this process, a total of 240 vineyard polygons were digitized representing 1,000 acres of land, with the majority of these areas located in the Annapolis Valley, specifically Kings and Annapolis counties.

The construction of soil characteristic maps derived from the Detailed Soil Survey Version 3 (DSSV3) dataset produced by AAFC included the development of a process to repair abrupt discrepancies between county boundaries evident in the original dataset. Baseline mean climate datasets spanning from 1970-2013, in addition to projected climate data for 2035 and 2050, were provided to AGRG by the Reflecting Society. The variables represented growing degree days (base 10°C), frost-free days (base 0°C) and mean number of days < -19°. These datasets were downsampled from their original coarse resolution (ca 6 km) to a finer resolution (100 m). Topographic datasets of slope, orientation of slope (aspect), and distance to coastline were derived from the 20 m provincial digital elevation model (DEM). These datasets were constructed for the purposes of integration into the suitability model as well as to be displayed in the GIS web-viewer.

A suitability model using fuzzy logic was developed to determine the optimal geographic locations to grow wine grapes in the province. A questionnaire was composed to target expert opinion to rank the individual criteria applicable to each input variable of the model. A mask was created to incorporate regulatory and land-use constraints into the output suitability maps.

Results of the suitability analyses indicated that Nova Scotia currently has an abundance of highly suitable land in the counties of Annapolis, Kings and Lunenburg; around ~66,950 acres, of which 53,482 are currently not being used for agricultural purposes. A decrease in the amount of most suitable land was evident in the 2035 model suitability map from the inclusion of projected land use-zoning layer. However, the amount of most suitable acreage available in 2050 increases again due to the effects of the increased favourability of climate conditions in more areas across the province. The addition of the suitability maps to the GIS web-viewer, as well as datasets generated from other data providers for this project,

make the web-viewer an effective tool to mitigate potential threats to the agriculture industry now and looking forward to the future.

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1 Introduction

1.1 Project Background

This project was focused on raising awareness of the potential threats to the Nova Scotia agriculture industry in the long term, and focused specifically on the expanding wine and grape industry in the province. The overall goal was to develop a user-friendly risk-assessment tool for industry stakeholders which allows for the assessment of current and future risks associated with climate change and the changing socio-economic and agricultural landscape in Nova Scotia. The project consisted of three main components: a risk assessment tool, a Geographic Information System (GIS) portion, and a dyke system vulnerability element. The Applied Geomatics Research Group (AGRG), part of the Applied Research department within the Nova Scotia Community College (NSCC), was contracted to complete the GIS component of the project. The GIS portion included the acqusition and construction of data layers, creation of a suitability model to determine the most ideal locations to grow wine grapes, and the creation of a web-viewer as a risk assessment tool to conduct spatial analyses in the context of the wine and grape industry. The GIS web-viewer will provide stakeholders with access to a wide variety of GIS datasets pertinent to the agricultural industry, allowing them to perceive a visual framework for conceptualizing and comprehending different geographic patterns and relationships, therefore enabling more efficient decision making.

1.2 Project Objectives

The project required the acquisition and generation of GIS data layers pertinent to the growth and development of wine grape growing in the province, as well as layers in the context of expediting efforts to mitigate the risks of climate change to Nova Scotia's agriculture industry. AGRG was specifically tasked with the following mapping objectives:

1) Identify and map all current wine grape growing areas in the province;
2) Generate GIS layers pertinent to the growth and development of wine grapes;
3) Develop a suitability model integrating various GIS layers to identify current suitable areas for grape growing as well as future suitable areas for grape growing;
4) Develop a web-based mapping tool including functionality for analyzing, retrieving and displaying agricultural data along with other provincial datasets that will inform participants and interested parties in the grape and wine industry within the province of current and future land suitability and availability, and any current and future risks to this industry.

In terms of the scope of the work, or study area, all mapping, data layers produced and subsequent analyses were to be carried out for the entire province of Nova Scotia. The generation and assemblage of multiple GIS data layers for these specific objectives had not been completed prior to this project. While some data layers relevant to the agriculture industry existed, these datasets presented short-comings such as scale and temporal resolution, and did not reflect the current agricultural landscape of the province; these datasets are discussed in Section 1.3. The list of datasets generated by AGRG for this project and their specifications are listed in Appendix A and the methodologies adopted to produce these layers are detailed in Section 2.0 of this report.

1.3 Review of Current Agricultural Datasets

1.3.1 National Datasets

The Canada Land Inventory (CLI) produced by Agriculture and Agri-Food Canada (AAFC) at a scale of 1: 250,000 is a multi-disciplinary land inventory of rural Canada created between the 1960s and 1980s. It contains seven classes used to rate agricultural land capacity; Class 1 lands have the highest capacity and Class 7 lands have the lowest capacity (AAFC, 2016).

The Ecological Land Classification (ELC) dataset produced by the Nova Scotia Department of Natural Resources (NSDNR) classifies land from an ecological perspective, with areas of similar ecology identified and mapped as a hierarchy of ecosystems based on features such as climate, elevation, topography, bedrock formation, and vegetation. Within the classification, specific levels of detail are presented on a series of scale dependent maps, with ecoregions at a scale of 1: 650,000, ecodistricts at a scale of 1: 500,000, and ecosections averaging a scale of 1: 50,000 (Neily et al., 2005). However, within the dataset itself, only categories for drainage, texture (soil) and topography are present; there is no indication of vegetation cover type.

1.3.2 Provincial Datasets

The Agricultural Land Identification Program (ALIP) layer completed in 1998 details agricultural land use in the province at a scale of 1: 10,000 (Moerman and Swim, 1998). Mapping was conducted on a municipal level and based on field surveys and analyses utilizing the Department of Natural Resources Forest Inventory File (described on the next page). Digitized polygons were classified into three broader categories, followed by subcategories:

- Active Agricultural Lands
  - **AL** – Agricultural Long Term: fields which are in long term crops, not likely to be rotated in an 8-10 year period (pastures, tree fruits, blueberries)
  - **AR** – Agricultural Rotation: fields which are in rotation crops and are likely to be tilled and/or seeded to other crops within 8-10 years (grains, vegetables, forages, small fruits)
  - **AS** – Agricultural Support: Support services for agricultural operations located within farming areas (feed or equipment dealers, research facilities)
- Inactive Agricultural Lands
  - **I** – Inactive: Lands which appear to have once been farmed, but are no longer in active use yet have the potential for readily being returned to agricultural use
  - **IT** – Inactive Transition: Lands newly cleared from forested conditions which may be in the process of conversion to agricultural production
- Other Codes

- **UN** – Unknown: lands which field staff were unable to verify due to access limitations (Moerman and Swim, 1998).

Until recently, this 20-year old dataset provided the most detailed information regarding the spatial scope of Nova Scotia's agricultural landscape. The ALIP layer is currently being updated as part of another ongoing project by the Environment and Agricultural Technology Lab (EATLab), part of NSCC's Applied Research department. To date, the counties of Annapolis, Digby, Hants, Kings, Lunenburg, Pictou, Queens, Shelburne and Yarmouth have been completed (EATLab, 2017).

The NSDNR Forest Inventory dataset includes polygons representing water bodies, forested and non-forested areas, and additional identification of fresh water wetlands and coastal habitat areas (NSDNR, 2017). The file was last updated in 2016 using new aerial photographs, satellite imagery, and field surveys. This dataset includes a "FOR_NON" class which distinguishes non-forest type land classes. Within this specific class there are two subclasses of "agriculture" and "blueberries". The agriculture subclass contains any hay field, pasture, tilled crop, or orchard, which contains no merchantable species, while the blueberry subclass contains areas which appear to have been or are being used for blueberry production (NSDNR, 2017). These two sub-classes were delineated using air photographs whose vintages range from 2001 – 2012. Although this dataset is detailed, the crop type is unspecified; for a given polygon, there is no information on whether that polygon represents either a hay field, pasture, tilled crop or orchard.

The deficiencies and lack of detail in the existing agricultural datasets further highlighted the need to produce accurate and updated maps of the province, particularly regarding existing vineyards as this is a relatively new sector in the province and has never been properly documented.

2 Methods

2.1 Winery and Vineyard Mapping

The identification of areas currently growing grapes in the province was required for several reasons. First, the accurate locations and property sizes of vineyards in the province is not widely known and not recorded/available publicly, thus this dataset was stated as a deliverable for the project and subsequent GIS-web viewer. Second, the mapping of these areas was required for validation of the suitability modelling work. The Atlantic Food and Horticulture and Research Centre, a branch of AAFC, has mapped and identified types of vines planted for all growers with a membership in the Grape Growers Association of Nova Scotia (GGANS). This research conducted by AAFC assured confidentiality for all participants. Growers and wineries had the option to obtain their data from AAFC and share these data for use within the AgriRisk project if they wished. However, due to the anticipation of a lengthy process to obtain these data, a thorough process for mapping current grape growing areas within the project timeline had to be independently adopted.

Dr. Deborah Moreau of AAFC stated in her presentation at the 2017 Atlantic Canada Wine Symposium (June 12 and 13, 2017 in Halifax, NS) that at that point in time, ~1,000 acres of land producing wine grapes existed in NS, located within seven main growing regions (Annapolis Valley, the Gaspereau Valley, the Avon Valley, the Bear River Valley, the Malagash Peninsula, the LaHave River Valley and Cape Breton Island) (Moreau et al., 2017). This information provided a baseline for grape growing distribution, and focused the initial mapping process on these broad regions.

2.1.1 Mapping Process

All mapping, subsequent analyses and suitability modelling for this project was completed using ArcMap 10.5.1 GIS software. The first task was to map the vineyards located on properties of the established wineries in the province. To aid in the mapping process, The Nova Scotia Civic Address File, a shapefile storing addressed point geometry (Province of Nova Scotia, 2015) was downloaded from GeoNova's Geographic Data Directory. Winery websites were explored to determine the civic address/addresses of each property. The civic address shapefile was overlaid on the most current 1:10,000 orthophoto map service from NSDNR. Google Earth and ESRI basemaps within ArcMap 10.5.1 were used in addition to the orthophotos in order to get the most complete picture of land occupied by grape vines as the orthophoto imagery had differing temporal resolution depending on the area of the province being investigated. A polygon shapefile was created to store the geometry of each digitized vineyard and the associated attributes of area (m^2), acreage, winery name, civic address and county were recorded for each mapped vineyard. Civic addresses were queried within the file and a total of 21 wineries with grape vines planted on their properties occupying roughly 413 acres were digitized from the imagery. Given the current estimate of ~1,000 acres of grape growing land in the province stated by Dr. Moreau, further investigation was required to adequately map the remaining acreage.

Access Nova Scotia contains a database available for inquiries and review of the public record maintained by the Registry of Joint Stock Companies (Province of Nova Scotia, 2018). This database allows the public to query active and inactive registered businesses within the province. Keyword searches of "winery", "grapes", and "vineyard" were conducted and 125 records were returned. A listed civic address within each record was queried within the civic address shapefile and image analysis determined whether a vineyard or potential vineyard was located on or near the listed property. Once this process was completed, the search for potential growing areas was further expanded by conducting Google searches of amateur wine making websites, social media platforms, Kijiji, Viewpoint, and Canada411.ca. Other potential growing areas were identified on the orthophotos and satellite imagery and were tagged to be validated in the field.

2.1.2 Ground Truth Data Collection and Validation of Vineyard Mapping

Field validation was crucial to the accuracy of the vineyard mapping. This was largely due to the similarities between apple orchards and grape vineyards on the imagery, which are both characterized by multiple long, narrow rows, most often oriented in a north-south direction (Figure 2-1). In addition to similarities on the imagery, newly established young apple orchards are now also using trellis systems for support, which added to further misidentification of this crop.

Field validation for the 2017 season was conducted in Annapolis, Digby, Kings and Hants counties between July 25 and August 1, 2017 by the AGRG AgriRisk team, and the remaining counties in southwestern NS were field validated between July and September of 2017. A Garmin GPSMap76CSX unit was used to collect GPS points of vineyards, and photographs were taken in tandem with the points and later merged in ArcMap 10.5.1 (Figure 2-2). The vineyard inventory was updated using the GPS points and accompanying orthophotos and/or satellite imagery.

Figure 2.1: The image on the left is an apple orchard, while the image on the right is a vineyard. Field validation was required to differentiate these two crops.

Figure 2.2: Example of field validation process. Red dots represent GPS points where photographs were taken of the vineyards, which allowed researchers to differentiate them from apple orchards.

The attributes of area (m^2) and acreage were calculated for each mapped polygon, and this mapped acreage was broken down by county. These figures were compared to reported data from the 2016 Census of Agriculture (grapes total area). By doing this comparison, gaps by county were easily recognized, as was the need for additional mapping and validation.

Additional validation of grape growing areas was carried out through meeting with Rachael Cheverie of Perennia on September 13, 2017. Perennia is a non-profit corporation which provides land assessment services to evaluate a piece of land's potential for various crops, including wine grapes, for anyone considering purchasing land in Nova Scotia or who has existing land (Perennia, 2016). Vineyards which were not identified during air photo analysis and field work (most often regions in eastern NS) were added to the inventory after meeting with Perennia. Acreage (NS total, and by county) was recalculated for the mapped polygons and compared to the Census of Agriculture data (Table 2.1). A total of 1,000 acres of vineyards were mapped; of this number, 106 acres were recorded as being newly planted within the past 1-2 years, which accounts for the difference (157) between the mapping done for this project and the 2016 census data.

As the total acreage of mapped vineyards compared very well with Dr. Moreau's estimate, and the vineyard inventory was well-validated using fieldwork and Perennia data, the vineyard mapping process was considered complete for 2017. Figure 2-3 depicts the distribution of the digitized grape growing areas across the province; this dataset is present in the GIS web viewer. The complete dataset including attributes for the mapped vineyard polygons can be found in Appendix B.

County	Acres mapped	Acres reported on 2016 Census of Agriculture
Annapolis	85.4	59
Antigonish	1.3	X
Cape Breton	0.2	X
Colchester	7.2	19
Cumberland	109.3	73
Digby	22.2	X
Hants	134.4	100
Inverness	15.7	X
Kings	553.3	500
Lunenburg	50.2	17
Pictou	10.5	X
Queens	2.0	X
Yarmouth	8.3	X
TOTAL	**1,000**	**843**

Table 2.1: Comparison of mapped acreage to acreage reported on the 2016 Census of Agriculture (grapes total area). Source: Statistics Canada. Table 004-0214 - Census of Agriculture, fruits, berries and nuts, every 5 years, CANSIM (database) (accessed: 08/21). Values of X are suppressed to meet the confidentiality requirements of Statistics Canada.

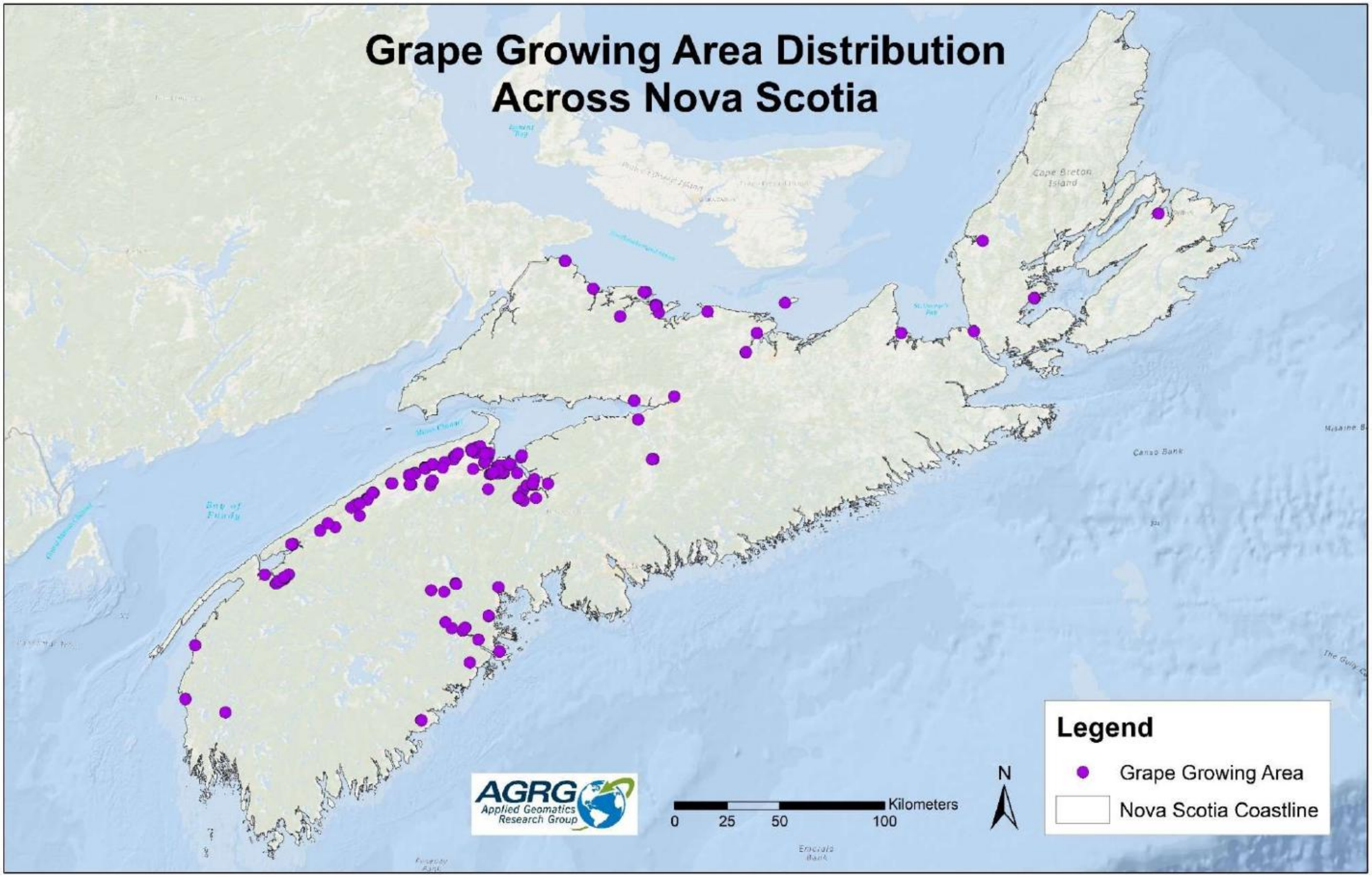


Figure 2.3: Distribution of grape growing areas (vineyards) across the province of Nova Scotia. These areas are highly concentrated in the Annapolis Valley, Gaspereau Valley, Avon Valley, Bear River Valley, LaHave River Valley, as well along the Northumberland Strait.

2.2 Data Acquisition and Preparation for Wine Grape Suitability Modelling

2.2.1 Soils Data

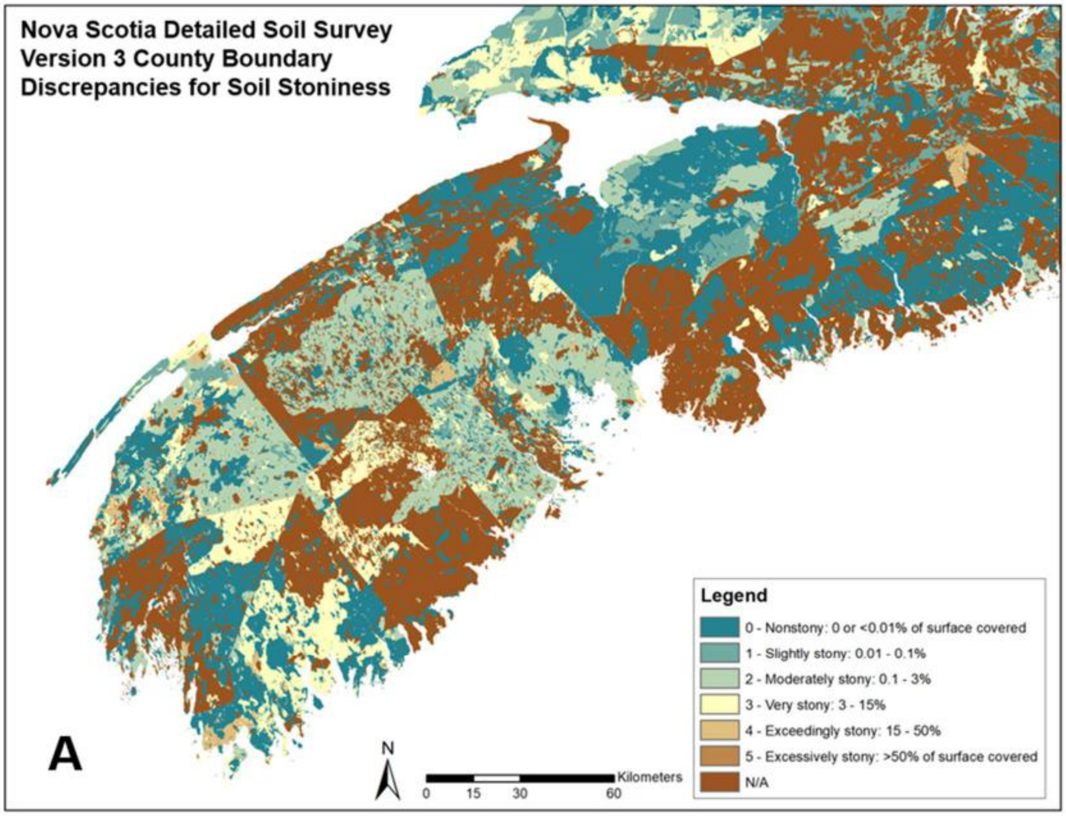
The Detailed Soil Survey Version 3 (DSSV3) dataset produced by AAFC for Nova Scotia at a scale of 1:75,000 was acquired for use in this project. Upon visual inspection of this file, it was determined that the dataset in its current state would be insufficient due to abrupt discrepancies between county borders (Figure 2-4). It became evident that this dataset required repairing in order to produce an accurate representation of the soil landscape across the province. In consultation with Perennia, it was recommended that the four variables of soil capability, soil drainage, soil stoniness and root restrictions be extracted from the map sheets for each county based on soil series (Perennia, 2017).

2.2.1.1 Data Processing

Soil survey reports in PDF form were downloaded for each county (Table 2.2). The attribute of "SOIL_CODE" representing soil series name was extracted from the original DSSV3 dataset and new fields representing soil capability for agriculture, soil drainage, soil stoniness and soil root restriction were created within the dataset attribute table. Individual soil series were assigned a classification for each of the four variables based on the map sheet legends, with the exception of rooting restrictions. Rooting restrictions were identified by querying individual soil series found within the Soils of Nova Scotia website (Agriculture and Agri-Food Canada, 2013). Once the classifications for each variable were complete, the vector dataset was converted to individual rasters at a 100 m spatial resolution representing soil capability for agriculture, soil drainage, soil stoniness (Figure 2-4) and soil rooting restriction. The classification of the soil series can be found in Appendix C.

County	Soil Survey Report Number	Scale	Vintage
Annapolis	16	1: 63,360	1969
Cape Breton Island*	12	1: 100,000	1963; reprinted in 1981
Colchester	19	1: 126,720	1948
Cumberland	17	1: 126,720	1948
Digby	11	1: 63,360	1962
Guysborough	14	1: 63,360	1964
Halifax	13	1: 63,360	1963; reprinted in 1981
Hants	5	1: 126,720	1954; reprinted in 1978
Kings	15	1: 63,360	1966
Lunenburg	7	1: 63,360	1958
Pictou	18	1: 50,000	1990
Queens	8	1: 63,360	1959; reprinted in 1978
Shelburne	10	1: 63,360	1961
Yarmouth	9	1: 63,360	1960

Table 2.2: List of soil survey paper maps and their associated specification. *Aggregated within the Cape Breton Island soil survey includes the counties of Cape Breton, Inverness, Richmond, and Victoria.



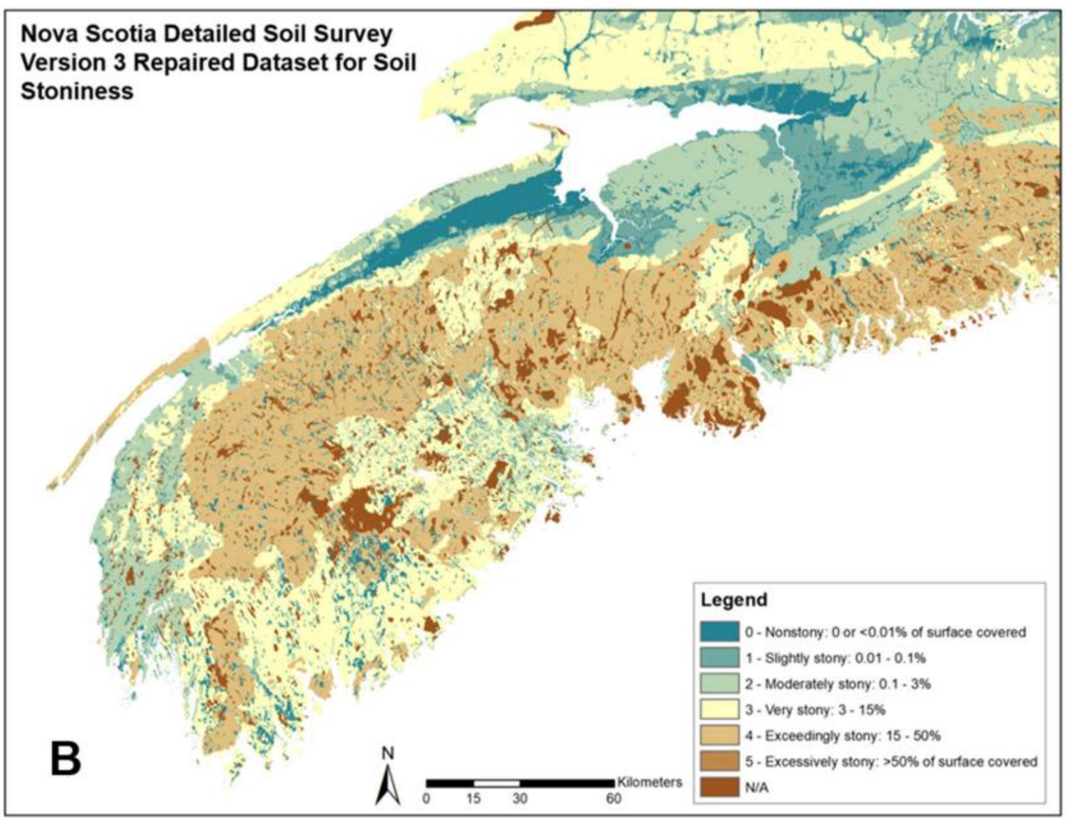


Figure 2.4: Image A represents soil stoniness from the original DSSV3 dataset; abrupt discrepancies between county boundaries are evident. Image B is the repaired soil stoniness dataset based on soil series and classified from the soil survey paper maps.

2.2.2 Climate and Climate Projection Data

2.2.2.1 Baseline Climate Surfaces

Baseline daily climate grids on at ~6.6 km spatial resolution for minimum and maximum temperature and precipitation were provided by Natural Resources Canada (NRCan) through the Reflecting Society; methods used to generate these datasets are described in Pedlar et al. (2015). Grids for each day of the year between 1970 and 2013 were used to derive estimates of variables pertinent to wine grape growing including growing degree days (GDDs) (Figure 2.5), frost-free days (FFDs) and days exceeding specific thresholds (mean number of days with minimum temperatures less than -19°C, -23°C and -26°C) on a ~6.6 km grid. The methods used to derive these datasets from the daily grids are described in Lynam (2017).

GDDs are defined as the amount of heat accumulated during the day as obtained by subtracting the plant's (in this case, grape vine) base temperature from the mean temperature for the day (Agriculture and Agri-Food Canada, 1977):

$$GDD = \frac{Max\ Temp - Min\ Temp}{2} - Base\ Temp\ (10°\mathrm{C})$$

During discussions with Francisco Diez and Rachael Cheverie of Perennia, it was agreed that the GDD period for the baseline dataset would be calculated from March 1st to November 31st of each year, with a base temperature of 10°C. Typically, the growing season is measured from April 1st – October 31st but the extended period of March to November was chosen as having the potential to provide useful information on the likely extension of the growing season which could result from warmer periods under projected future climates (Diez, 2017).

FFDs were calculated by counting the number of days where the temperature exceeded 0°C; this climate variable is particularly important because the variability in the number of FFDs is crucial for planting and harvesting (Environment and Climate Change Canada, 2018), while the impact of a strong frost can become devastating for certain varieties of grapes, especially at sustained periods. Winter damage was observed by the Perennia team in the 2016 season in some hybrid varieties in the province. A warm period observed in February potentially started the de-acclimation process of the hybrid variety prematurely, as this period of mild weather was followed by a cold snap that subsequently damaged the grape vines (Cheverie, 2017).

For the number of days exceeding extreme low temperatures, the thresholds of -19°C, -23°C and -26°C were provided to AGRG. It was advised by Perennia that in order to encompass all wine grape varieties (*Vitus vinifera* and hybrids), and in the case of the *Vinifera*, it was best to be more conservative and cautious and to use the mean number of days less than -19°C for the suitability model (Diez, 2017).

2.2.2.2 Projected Climate Surfaces

Statistically downscaled climate scenario grids produced by the Pacific Climate Impacts Consortium (PCIC) were provided for daily minimum and maximum temperature and precipitation from the Reflecting Society. Rasters were provided at a gridded resolution of 300-arc seconds (~6.6 km grid) (PCIC, 2014) representing the Intergovernmental Panel on Climate Change (IPCC) fifth assessment report (AR5) Representative Concentration Pathways (RCP's) scenarios 4.5 and 8.5 for the projected years of 2020, 2025, 2030, 2035 and 2050. Due to the little variance between the 2020, 2025 and 2030 datasets, it was decided that the use of the 2035 and 2050 datasets would suffice for the projected suitability mapping; these datasets were also prepared for implementation into the GIS web-viewer.

2.2.2.3 Data Processing

Due to the coarse spatial resolution, it was deemed necessary to develop a methodology to downsample these datasets from a 6.6 km grid size to the desired 100 m grid for input into the suitability model. Within ArcGIS 10.5.1, the "Create Fishnet" tool was used to create a fishnet of rectangular cells (polygons) and associated centroid points over top of the original GDD, FFD, and days less than -19°C datasets. A cell size width and height of 4,000 (representing 4,000 m^2) was selected to ensure the resulting polygon fishnet would be square shaped and not rectangular. Once the fishnet was created, the resulting points were clipped to the Nova Scotia coastline shapefile to remove any erroneous points outside of this boundary, as the original datasets included data for the provinces of New Brunswick and Prince Edward Island in addition to NS. Next, the "Extract Values to Points" tool was used to extract the cell values of each of the three climate rasters based on the generated fishnet points and to record these underlying values in the attribute table of each output feature class. Once these values were extracted for each dataset, the "Topo to Raster" tool was executed to interpolate the points to a 100 m grid. The bilinear interpolation method is the most suitable averaging method for continuous datasets such as these (ESRI, 2017), and was therefore applied to calculate the value of each raster cell by averaging (weighted for distance) the values of the surrounding four cells. The resulting rasters were then clipped to the NS coastline shapefile to remove the cells outside of NS which were generated from the interpolation process (Figure 2-5).

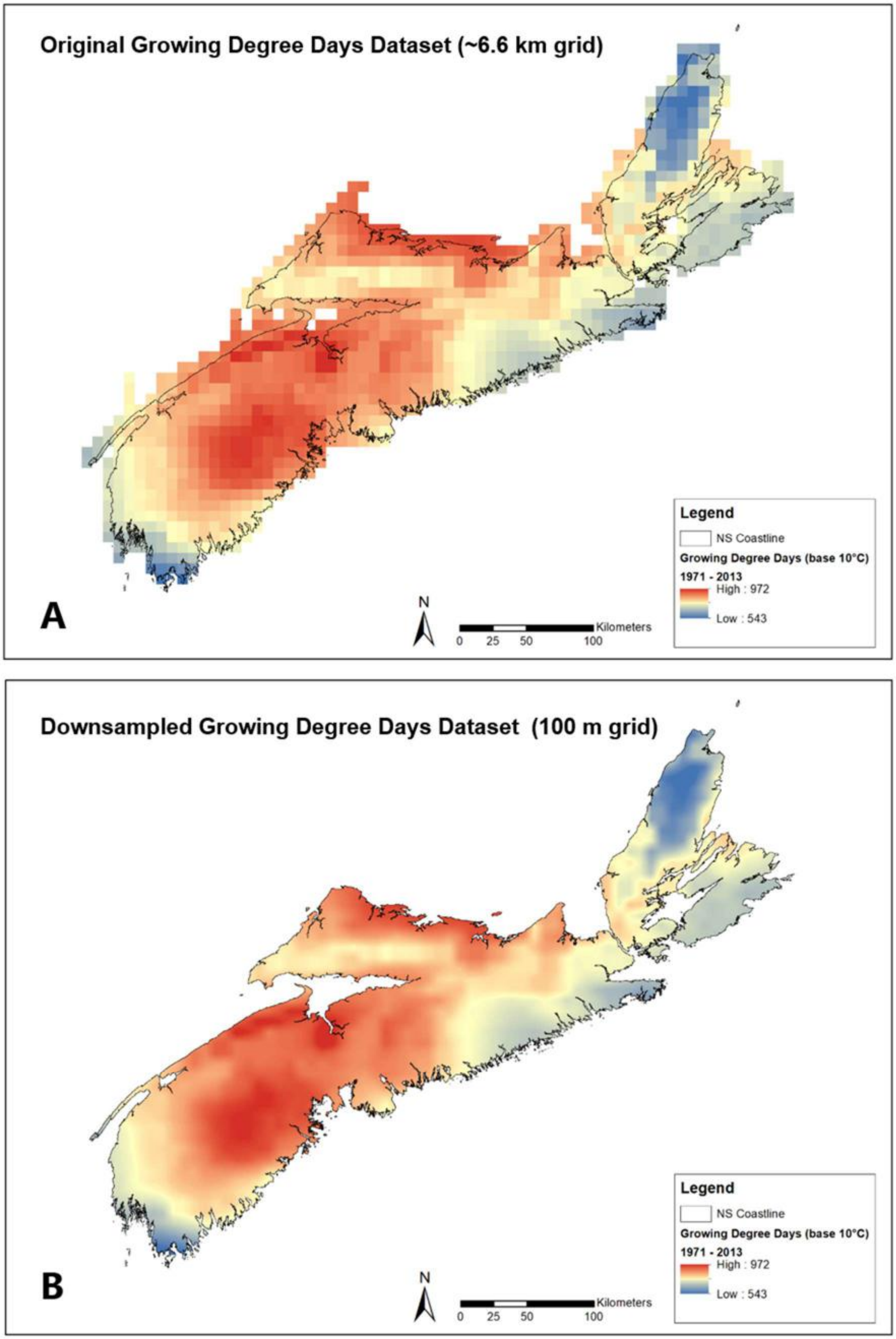


Figure 2.5: Image A depicts the growing degree day (GDD) dataset in its original form at a coarse ~6.6 km grid. Image B represents the downsampled GDD dataset at a 100 m grid.

2.2.3 Topographic Data

Topographic datasets pertinent to wine grape growing including elevation, slope, orientation of slope (aspect) and distance to coastline rasters were derived from the 20 m provincial digital elevation model (DEM). This dataset was acquired from Service Nova Scotia and Municipal Relations, Registry and Information Management Services. The Nova Scotia Geomatics Centre produced the DEM in conjunction with the Department of Natural Resources, the Department of Environment, and the Department of Agriculture and Fisheries (Province of Nova Scotia, 2017).

2.2.3.1 Data Processing

The slope of the DEM raster was produced by using the “Slope” tool in ArcGIS 10.5.1 which identifies the slope of each cell of the raster. The orientation of slope (aspect) raster was created using the “Aspect” tool which identifies the compass direction that the downhill slope faces for each cell of the raster. The DEM, slope and aspect rasters were then resampled to a 100 m spatial resolution using bilinear interpolation.

The distance to coastline raster was generated by using the “Euclidean Distance” tool which calculates the distance from each cell in the raster (in this case, the DEM) to the closest source (in this case, the Nova Scotia coastline polygon shapefile). The output raster dataset produced at a 100 m spatial resolution represents the number of metres a particular cell is located away from the NS coastline.

2.2.4 Regulatory and Constraint Data

In order to represent areas where wine grapes cannot grow due to land use or regulatory constraints, a variety of datasets were acquired. Previous work conducted by AGRG in 2014 (Webster et al., 2014) to map impervious surfaces across the province was utilized; components within this dataset were particularly useful for the purposes of generating a constraint dataset. Specifically, any urban areas including cities, towns, villages and other urbanized areas were extracted, as any crop would be unable to grow in these areas.

Delimiters, also known as administrative boundaries, are part of the NSTDB and obtained from various sources including the Nova Scotia Department of Natural Resources, Property Records Database, or Parks Canada (Province of Nova Scotia, 2015). These areas include military reserves, national parks, provincial parks, protected areas, national historic sites, and game management areas/wildlife sanctuaries. The delimiter dataset was acquired in vector (polygon shapefile) format from GeoNOVA and was also used as a constraint dataset.

2.2.4.1 Data Processing

Little preparation was needed for the impervious surface dataset; the extracted urban areas were resampled from their original 30 m spatial resolution to the desired 100 m resolution to match the model output. The delimiter polygon shapefile was converted to raster format by using the “Polygon to Raster” tool. To produce one cohesive constraint “mask”, the “Mosaic” tool was employed to merge together the urban areas with the delimiters.

2.3 Suitability Modelling and Model Selection

Suitability modelling, also known as site selection or overlay analysis, involves the combination of spatial data from diverse sources which satisfy a set of criteria to produce an output map of potential(Bonham-Carter, 1994). Suitability models identify the best location for specific phenomena; in this case, the most ideal locations for wine grape growing in the province. In raster overlay analyses, each cell or pixel of each input layer references the same geographic location, which makes combining characteristics of numerous layers into a single output map appropriate (ESRI, 2017). Numeric values, or weights, are assigned to each characteristic or variable, allowing the user to mathematically combine the layers and assign a new value to each cell in the output layer (ESRI, 2017).

Different types of suitability models exist including simple Boolean logic, Weighted Index Overlay, and Fuzzy Logic. For this project, a Fuzzy Logic approach was employed, as the Boolean Logic and Weighted Index Overlay models were deemed inappropriate for the input layers of this project. Many phenomena show a degree of uncertainty which cannot be properly expressed with crisp sets of class boundaries, as with simple Boolean logic, where a binary output map is produced with pixels having a value of either 0 or 1, signifying that a pixel is either suitable (1) or it is not suitable (0) and there is no in-between (Bonham-Carter, 1994). The Weighted Index Overlay approach is also based on crisp sets where each pixel is either in a class or not. Map classes occurring on each input map are assigned different scores or weights, as well as the maps themselves, and these input maps are then added together and divided by the sum of their weights (Bonham-Carter, 1994). Due to the additive nature of this approach, the resulting output map is often very liberal and abundant in "suitable" areas.

Fuzzy Logic suitability analyses allows for more flexible combinations of weighted maps with the rules or weights of fuzzy membership being assigned subjectively (based on expert opinion or knowledge) to estimate the relative significance of the input maps (Bonham-Carter, 1994). Whether something belongs to a class or not is subjective, and things are not always clear-cut; class boundaries can be "fuzzy", and fuzzy logic performs overlay analyses more like natural human thinking (ESRI, 2017). Using linguistic modifiers to describe how a certain variable belongs to a class is difficult to translate computationally, as it is very difficult for computers to work with vague concepts, which are easily comprehended by humans (Yanar and Akyürek, 2006). For example, to numerically represent the slope of the topography by the label ''gentle'', it is necessary to define the meaning of the term ''gentle." Once these criteria are defined, this approach then involves assigning membership values to a fuzzy set (input map) on a continuous scale from 0 (no membership) to 1 (full membership) (Bonham-Carter, 1994). A fuzzy membership value of 0.5, for example, implies that the original phenomenon may or may not be a member of the fuzzy set. As the membership value migrates below or above 0.5, is it less likely or more likely, respectively, that the phenomenon is a member of the fuzzy set (ESRI, 2017).

To determine locations which have a high likelihood of membership in all sets, or in the context of this project, the geographic locations which are most suitable for wine grape growing, a number of different fuzzy operators, or mathematical functions are available (Table 2.3).

Fuzzy Operator	Description	Formula
Fuzzy AND	The minimum of the fuzzy memberships from the input rasters	$\mu_{combination} = MIN(\mu_A, \mu_B, \mu_C, \ldots)$, Where μ_A is the membership value for map A at a particular location, and so on
Fuzzy OR	The maximum of the fuzzy memberships from the input rasters	$\mu_{combination} = MAX(\mu_A, \mu_B, \mu_C, \ldots)$ Where μ_A is the membership value for map A at a particular location, and so on
Fuzzy Algebraic Product	The multiplication of input maps producing a "decreasive" output	$\mu_{combination} = \prod_{i=1}^{n} \mu_i$, Where μ_i is the fuzzy membership function for the i-th map and i=1, 2…, n maps are to be combined
Fuzzy Algebraic Sum	Complementary to the fuzzy algebraic product resulting in an "increasive" output	$\mu_{combination} = 1 - \prod_{i=1}^{n} (1 - \mu_i)$. Where μ_i is the fuzzy membership function for the i-th map and i=1, 2…, n maps are to be combined
Fuzzy Gamma	The algebraic product of the fuzzy sum and fuzzy product, both raised to the power of gamma (γ)	$\mu_{combination} = (Fuzzy\ algebraic\ sum)^{\gamma} * (Fuzzy\ Algebraic\ product)^{1-\gamma}$, γ is a parameter chosen by the user

Table 2.3: Description of the fuzzy operators. Adapted from Bonham-Carter, 1994.

The fuzzy gamma operator was selected as the operator for the wine grape suitability modelling for this project. The judicious choice of the gamma value by the user produces an output map that ensure a flexible compromise between the decreasive effects of the fuzzy algebraic operator, and the increasive tendencies of the fuzzy algebraic sum operator, as described in Table 2.3 (Bonham-Carter, 1994). What also makes the gamma operator advantageous is the elimination of having to re-classify the input datasets when it comes time to make modifications to the model. By choosing a gamma value the user has control over how abundant (liberal) or restrained (conservative) the output map will be.

2.3.1 Fuzzy Logic Model Parameters

Four broad variables encompassing numerous metrics pertinent to successful wine grape growing identified for Nova Scotia were taken into account to identify potential suitable areas for wine grape growing. The suitability mapping component takes into account climate variables, soil characteristics, topographic characteristics, and regulatory and land use constraints (Figure 2.6 and Figure 2.7). This preliminary phase of the wine grape suitability map is not limited to a specific type of wine grape vine at this time, it is inclusive of both hybrid and *Vitus vinifera*. The selection of these variables was discussed with Perennia before the model and input layers were developed to ensure no significant variable was excluded from the analysis. These variables were represented as individual layers within ArcMap to be used as inputs to the fuzzy model described in the following section.

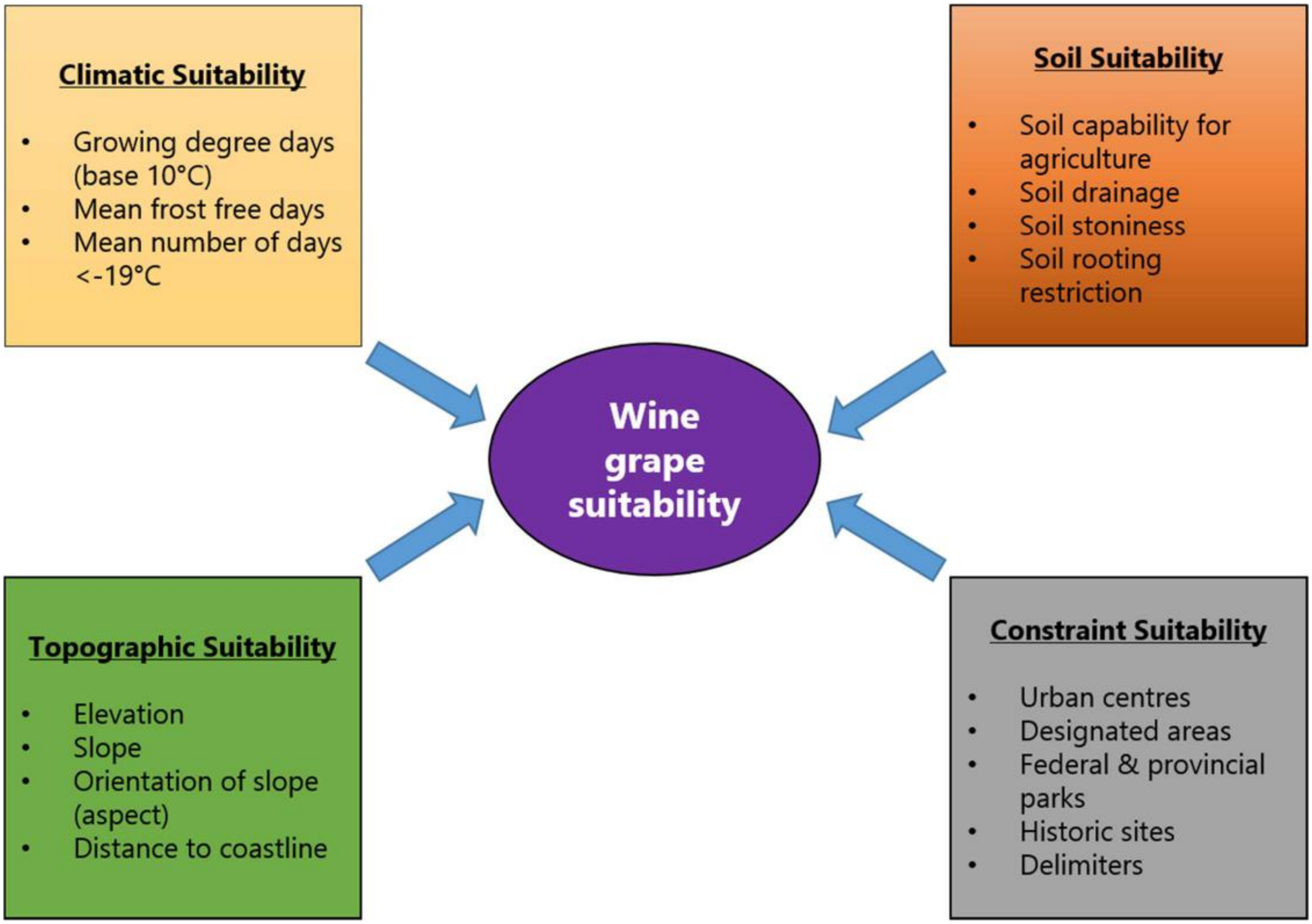


Figure 2.6: Diagram of the wine grape suitability model for 2018. The model takes into account four broader variables relevant to wine grape growing and their individual input layers contributing to overall suitability.

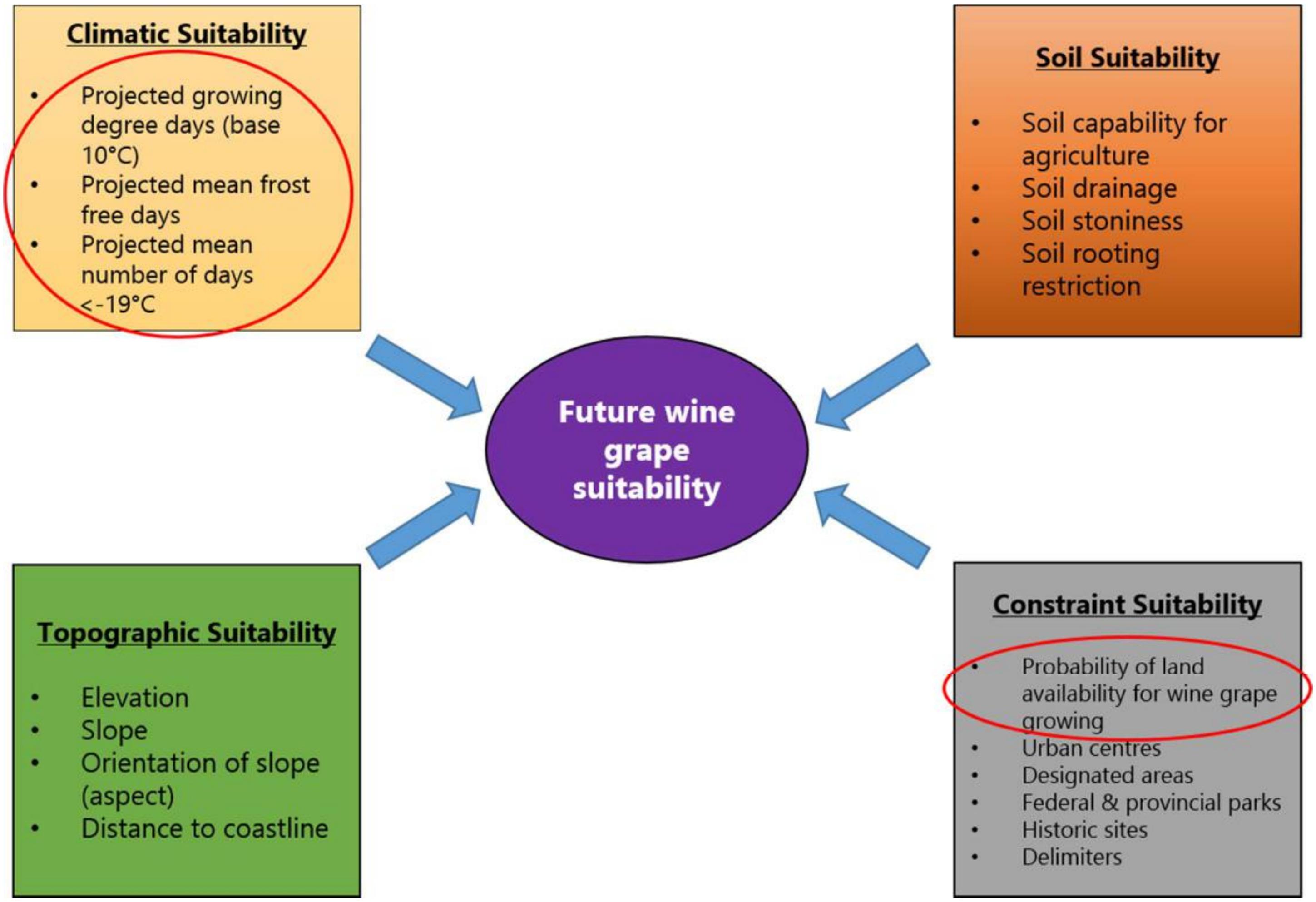


Figure 2.7: Diagram of the projected (future) wine grape suitability models for 2035 and 2050. The model takes into account four broader variables relevant to wine grape growing and their individual input layers contributing to overall suitability. The red circles highlight the differences between the 2018 suitability map inputs. Climatic suitability is based on projected climate data instead of historical baseline data, and the addition of the probability of land availability for wine grape growing produced by Dalhousie adds a land use constraint component to the model.

2.3.2 Variable Weighting and Translation into Fuzzy Membership Values

Expert knowledge was required to facilitate the ranking or weighting of each input variable. A questionnaire, included as Appendix D, was developed to survey experts in the grape and wine industry to gain insight on how to weight the characteristics of each input map layer, or variable. With recommendations from NSFA and NSDA, specific professionals in the industry were contacted to complete the questionnaire. Of the eight people contacted, five responded and completed the questionnaire. Respondents were asked to rank the characteristics of each variable from the least suitable to most suitable condition.

The rankings of the climate, soil, and topographic variables are listed in Tables 2.4 – 2.6 The constraint variable is omitted from the ranking process and these areas were automatically assigned a value of “0” indiciating no suitability.The approach by which each set of variables were assigned membership from 0 to 1 depended on whether the datasets were continuous (climate and topography) or discrete (soils and regulatory/constraint); continuous datasets were linearly scaled from 0 to 1, while discrete datasets were assigned classes manually.

Climate Variable	Dataset Range	Weight/Rank (Linearly Scaled between 0 and 1)
Baseline mean GDD (base 10°C) from 1970-2013	544 GDD – 972 GDD	< 800 GDD = 0 (least suitable) 800 – 972 GDD = 1 (most suitable)
Baseline mean FFD (base 0°C) from 1970-2013	185 FFD – 256 FFD	Low number of FFD's (185) = 0 (least suitable) High number of FFD's (256) = 1 (most suitable)
Baseline mean days < -19°C from 1970-2013	0 days – 15 days	High number of days (15) = 0 (least suitable) Low number of days (0) = 1 (most suitable)

Table 2.4: Baseline climate variable weighting criteria.

Soil Variable	Weight/Rank
Soil capability for agriculture	Unsuitable crop land = 0 (least suitable) Poor to unsuitable crop land = 1 Poor crop land = 2 Fair to poor crop land = 3 Fair crop land = 4 Good to fair crop land = 5 Good crop land = 6 (most suitable)
Soil drainage	Very poorly drained and poorly drained = 0 (least suitable) Imperfectly drained = 1 Moderately well drained = 2 Excessively drained = 5 Well drained and rapidly drained = 6 Well to rapidly drained = 7 (most suitable)
Soil stoniness	Excessively stony: >50% of surface covered = 0 (least suitable) Exceedingly stony: 15-50% of surface covered = 3 Very stony: 3-15%of surface covered = 4 Moderately stony: 0.1-3% of surface covered = 5 Slightly stony: 0.01-0.1% of surface covered = 5 Non-stony: 0 or <0.01% of surface covered = 5 (most suitable)
Soil rooting restriction	Growth restricted to second layer (0-20 cm) = 0 (least suitable) Growth restricted third layer (20-40 cm) = 1 Growth restricted to fourth layer (40-60 cm) = 2 Growth restricted to fifth layer (60-80 cm) = 3 No root restricting layer (80+ cm) = 4 (most suitable)

Table 2.5: Soil variable pre-scaled (initial) weighting criteria.

Topographic Variable	Dataset Range	Weight/Rank
Elevation above mean sea-level (MSL)	-11 m - 535 m above MSL	-11 m – 0 m = 0 Any elevation between 0 m and 150 m = 1 Any elevation > 150 m = 0 (least suitable)
Slope	0° - 60°	Any slope > 20° = 0 (least suitable) Slope of 0°(flat) – 5°= 1 Slope of 5° - 20° = 2 (most suitable)
Orientation of Slope (Aspect)	All cardinal directions (N,S,E,W)	North = 0 (least suitable) Northwest = 1 Northeast = 2 West = 3 East = 4 Southwest = 5 Southeast = 6 South = 7 (most suitable)
Distance to Coastline	0 m – 46,878 m	Proximity to coast scaled linearly: Far/inland areas (46,878 m) = 0 (unsuitable) Close/coastal areas (0 m) = 1 (most suitable)

Table 2.6: Topographic variable weighting criteria.

These weighted, reclassified datasets were then translated or scaled into fuzzy membership values ranging from 0-1 by using the "Fuzzy Membership" tool, with values of 0 or near 0 representing the least suitable conditions, and values closest to 1 or 1 representing the most ideal conditions for wine grape growing.

2.3.3 Variable Weighting and Translation into Fuzzy Membership Values for projected suitability maps

For the projected 2035 and 2050 suitability maps, the assumption was made that there would be no changes in the input variables with the exception of the derived climate variables of GDD, FFD, and days < -19°C, as these datasets are based on climate projections and not historical baseline data. The criteria used to weight these variables are detailed in Table 2.7 below.

Climate Variable	Dataset Range	Weight/Rank (Linearly Scaled)
Projected mean GDD (base 10°C) for 2035	734 GDD – 1190 GDD	< 800 GDD = 0 (least suitable) 800 – 1190 GDD = 1 (most suitable)
Projected mean FFD (base 0°C) for 2035	207 FFD – 281 FFD	Low number of FFD's (207) = 0 (least suitable) High number of FFD's (281) = 1 (most suitable)
Projected mean days < -19°C for 2035	0 days – 7 days	High number of days (7) = 0 (least suitable) Low number of days(0) = 1 (most suitable)
Projected mean GDD (base 10°C) for 2050	795 GDD – 1267 GDD	< 800 GDD = 0 (least suitable) 800 – 1267 GDD = 1 (most suitable)
Projected mean FFD (base 0°C) for 2050	214 FFD – 287 FFD	Low number of FFD's (214) = 0 (least suitable) High number of FFD's (287) = 1 (most suitable)
Projected mean days < -19°C for 2050	0 days – 4.7 days	High number of days = 0 (least suitable) Low number of days = 1 (most suitable)

Table 2.7: Projected climate variable weighting criteria

The provided projected GDDs were calculated using the April 1st – October 31st growing season. The projected suitability maps (2035 and 2050) also included the additional input layer created by Dalhousie University outlining municipal land use zoning (Figure 2.7, probability of land availability for wine grape growing). The objective of the analysis was to classify land into plausible outcomes of land availability for agriculture use in the short to mid-term future based on land use policies, by-laws, regulations, and changes in agricultural land use over time (Rapaport et al., 2018). Table 2.8 outlines the categories of the analysis. The scores listed in the category class were directly translated into Fuzzy Membership values from 0-1, as the category "0" in their analyses directly translates to representing an unsuitable area for wine grape growing, where the other end of the spectrum (1) indicates prioritization of agricultural land use. The output of the suitability model is detailed in Section 3.0.

Category	Rationale
0	Land use zoning does not allow for agricultural uses; and,
	No agricultural land use is currently occurring
0.25	Land use zoning does not permit agricultural use; and,
	Agricultural use is currently occurring
0.5	Land use zoning permits agricultural uses amongst other uses; and,
	No agricultural land use is currently occurring
0.75	Land use zoning permits agricultural uses amongst other uses; and,
	Agricultural use is currently occurring
1	Land use zoning prioritizes agricultural use; and,
	Agricultural use is or is not currently occurring

Table 2.8: Zoning and agricultural land use categories for the probability of land availability for wine grape growing layer produced by Dalhousie University for use in the 2035 and 2050 suitability maps. Table adapted from Rapaport et al., 2018.

2.4 GIS Web-Viewer Development

A web viewer was developed to showcase the GIS datasets generated from this project and from other data providers projects to inform decision makers and parties interested in the grape and wine industry of possible threats to current and future land suitability and availability. The development of a web-based mapping tool was required for analyzing, retrieving, and displaying agricultural data along with other provincial datasets, to help expedite efforts to mitigate the risks of climate change to Nova Scotia's agriculture industry. The primary goal was to create a single page dynamic website consisting of an interactive, user-friendly map and allow for such actions as:

- Displaying multiple layered spatial datasets grouped by theme or common type;
- Allowing for the individual toggling on/off of each layer;
- Allowing for the adjustment of opacity of each layer;
- Allowing for a level of secured access to proprietary data.

Data providers tasked with generating layers to be implemented into the web-viewer included AGRG, the Reflecting Society, Dalhousie University and Saint Mary's University. Additional datasets of confidential and sensitive nature were provided to NSDA to be spatially enabled for restricted use of specific managers within the NSDA. NSDA datasets were received throughout January and February of 2018 and the processes developed to transform these datasets into GIS datasets are detailed in Appendix E. Collaboration between all data providers facilitated the successful implementation of each data provider's layers into the GIS web-viewer. The list of datasets generated for use in the web-viewer can be found in Appendix F.

A standard template for the web viewer was provided by GeoNOVA for use in this project, with modifications made by AGRG (Figure 2.8). The following functionality is present within the viewer:

- Zoom in and out on map, pan around map
  - Basemap options - background maps for context
- Toggle layers on and off
  - Search tool - Search by place name, civic address, coordinate location or PID
- Identify tool - Allows for the user to click on vector datasets (points, lines or polygons) and bring up additional attributes about the specific feature
- Adjust opacity/transparency of layers
- Print/save image tool
  - Measure tool - measure by distance, area or location (latitude and longitude)

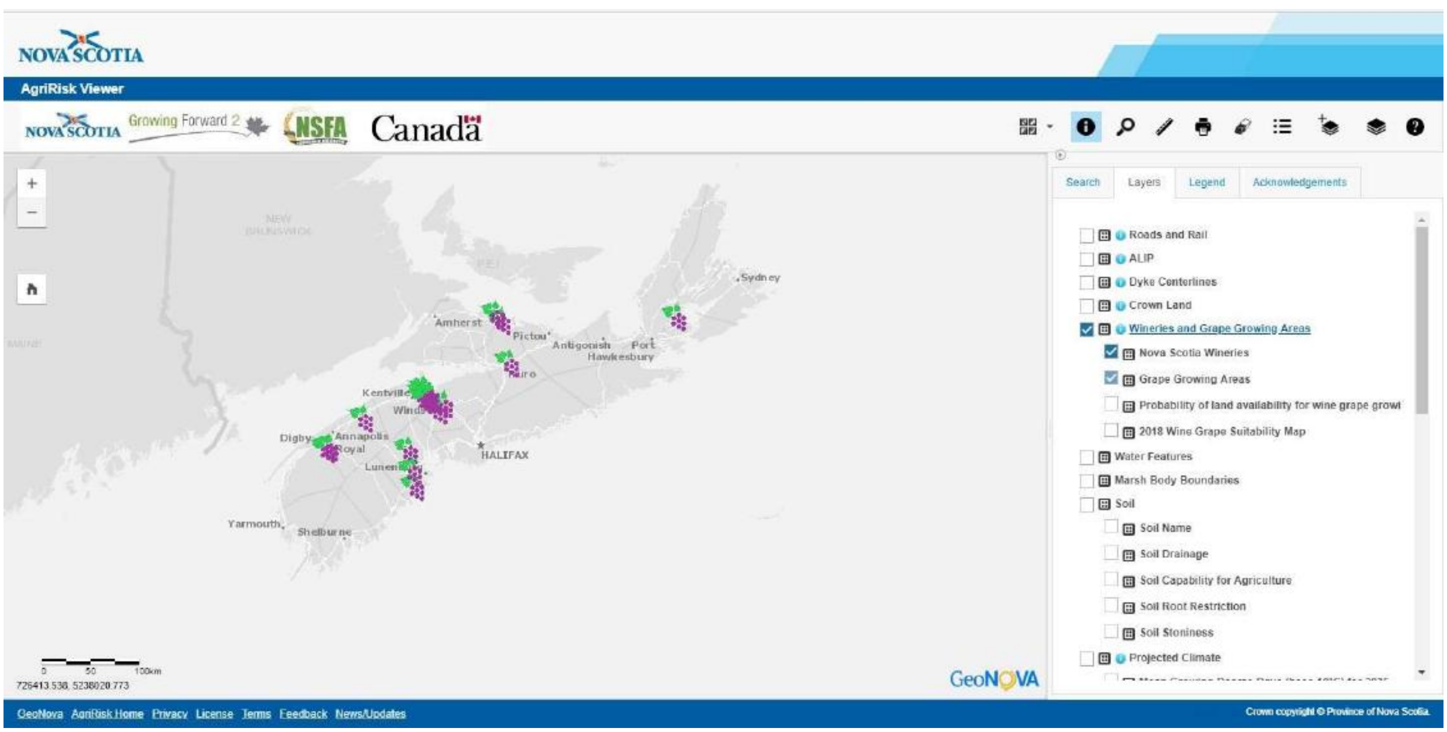


Figure 2.8: Screenshot of the GIS web-viewer template.

3 Model Results

3.1 Model Output

The gamma values implemented to complete the fuzzy gamma models for the 2018, 2035, and 2050 Suitability Maps were determined empirically by comparing suitability maps to areas where grape-growing is known to be well-established. Gamma values for each climate scenario (2018, 2035, and 2050), and the range of the fuzzy gamma model output suitability map are shown in Table 3.1.

The regulatory/constraint mask was imposed on the output suitability map by using the following conditional statement in the “Raster Calculator” tool:

Final Suitability Raster = Con(IsNull(Constraint Mask), Suitability Map, 0)

which meant that the final suitability raster was set to 0 in areas overlapping with the constraint mask. The resulting maps from this calculation then was re-classified into 10 classes ranging from 1 – 10 representing areas of land least suitable to most suitable for wine grape growing (Figure 3.1, Figure 3.2, Figure 3.3).

Suitability Map	Gamma Value	Output suitability map range
2018	0.93	0 – 0.93
2035	0.92	0 – 0.92
2050	0.93	0 – 0.93

Table 3.1: Gamma values for 2018, 2035, and 2050 Suitability Maps.

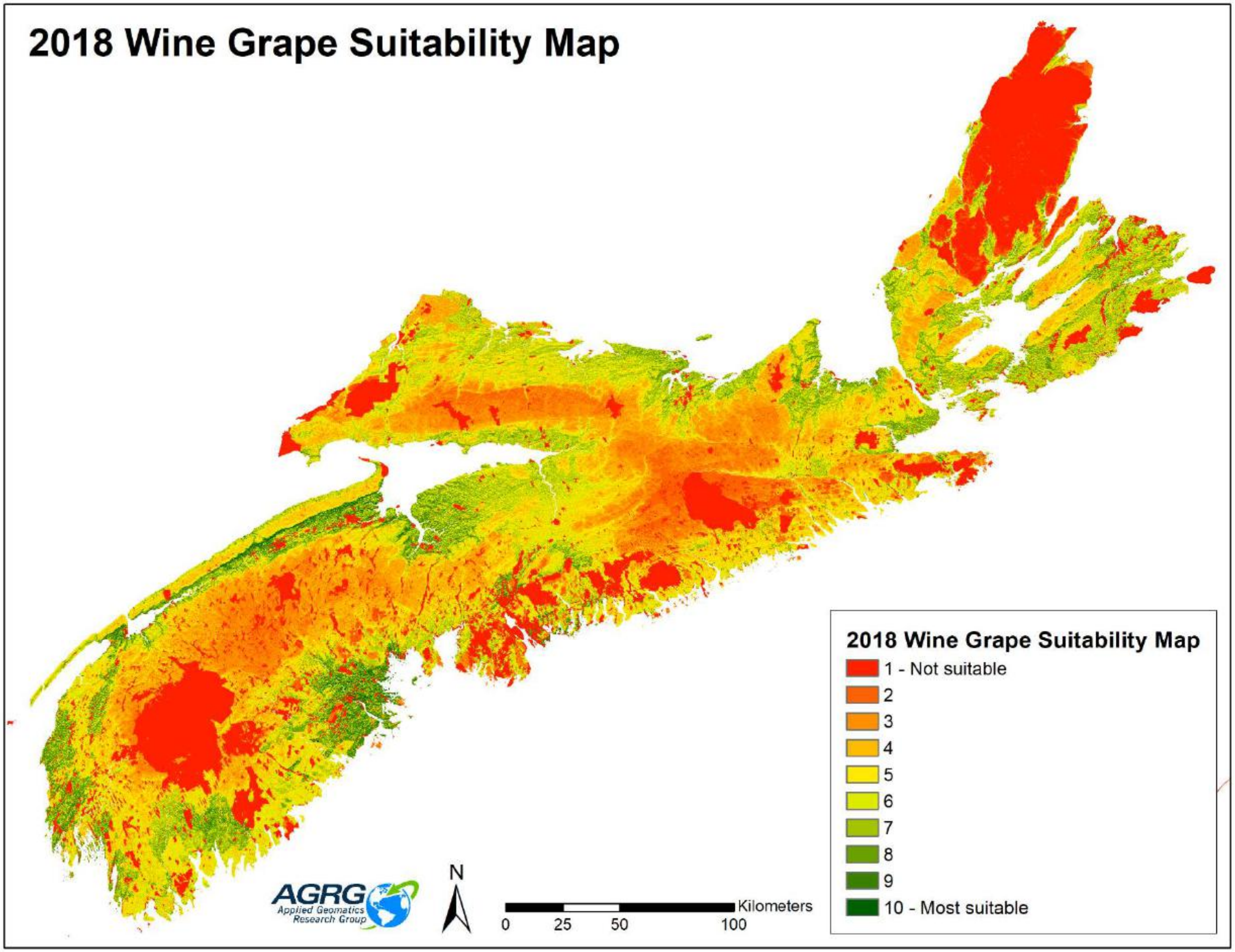


Figure 3.1: 2018 Wine Grape Suitability map for Nova Scotia. Areas in deep red represent unsuitable areas for wine grape growing, while areas in dark green represent the most suitable areas based on 11 input variables

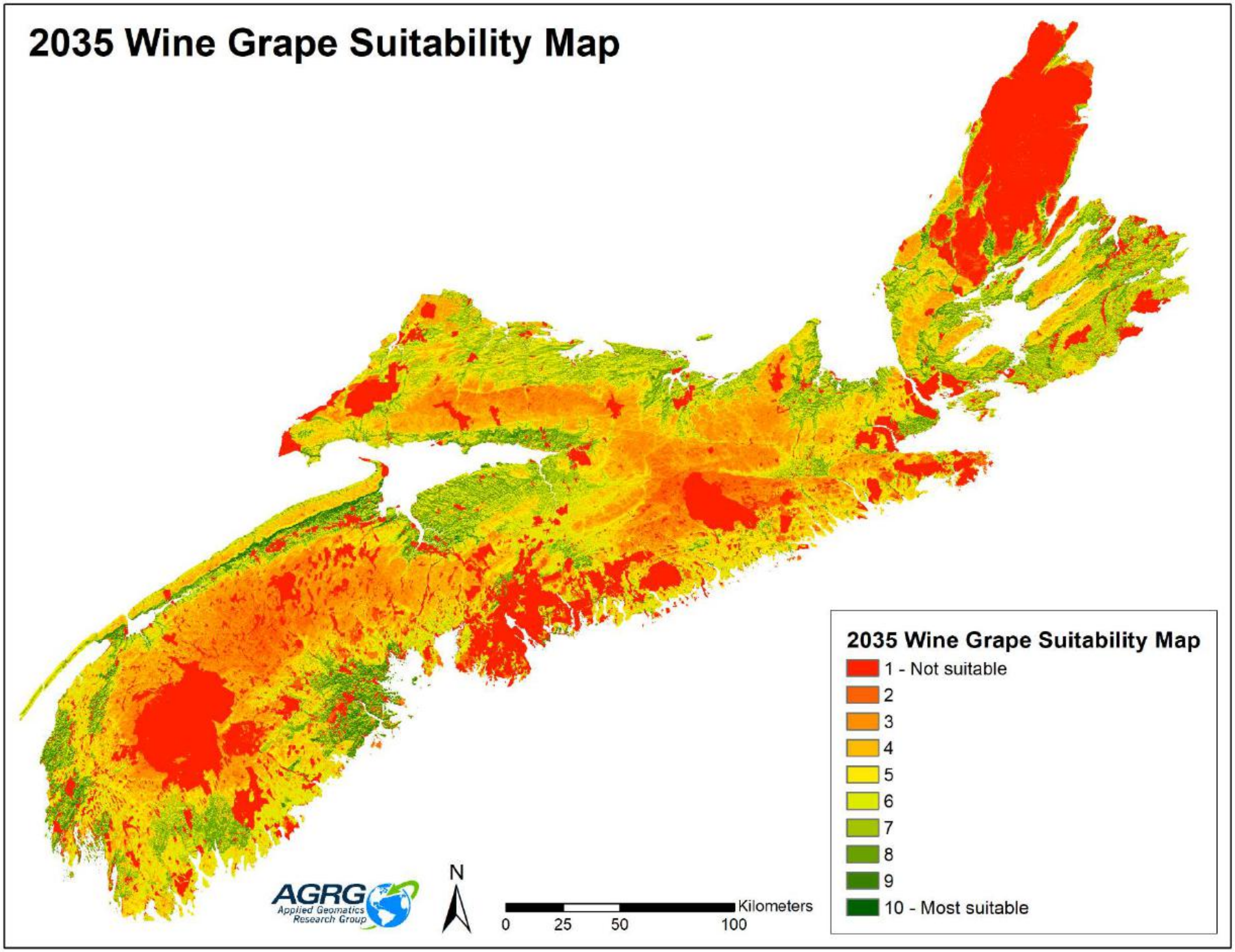


Figure 3.2: 2035 Wine Grape Suitability map for Nova Scotia. Areas in deep red represent unsuitable areas for wine grape growing, while areas in dark green represent the most suitable areas based on 12 input variables.

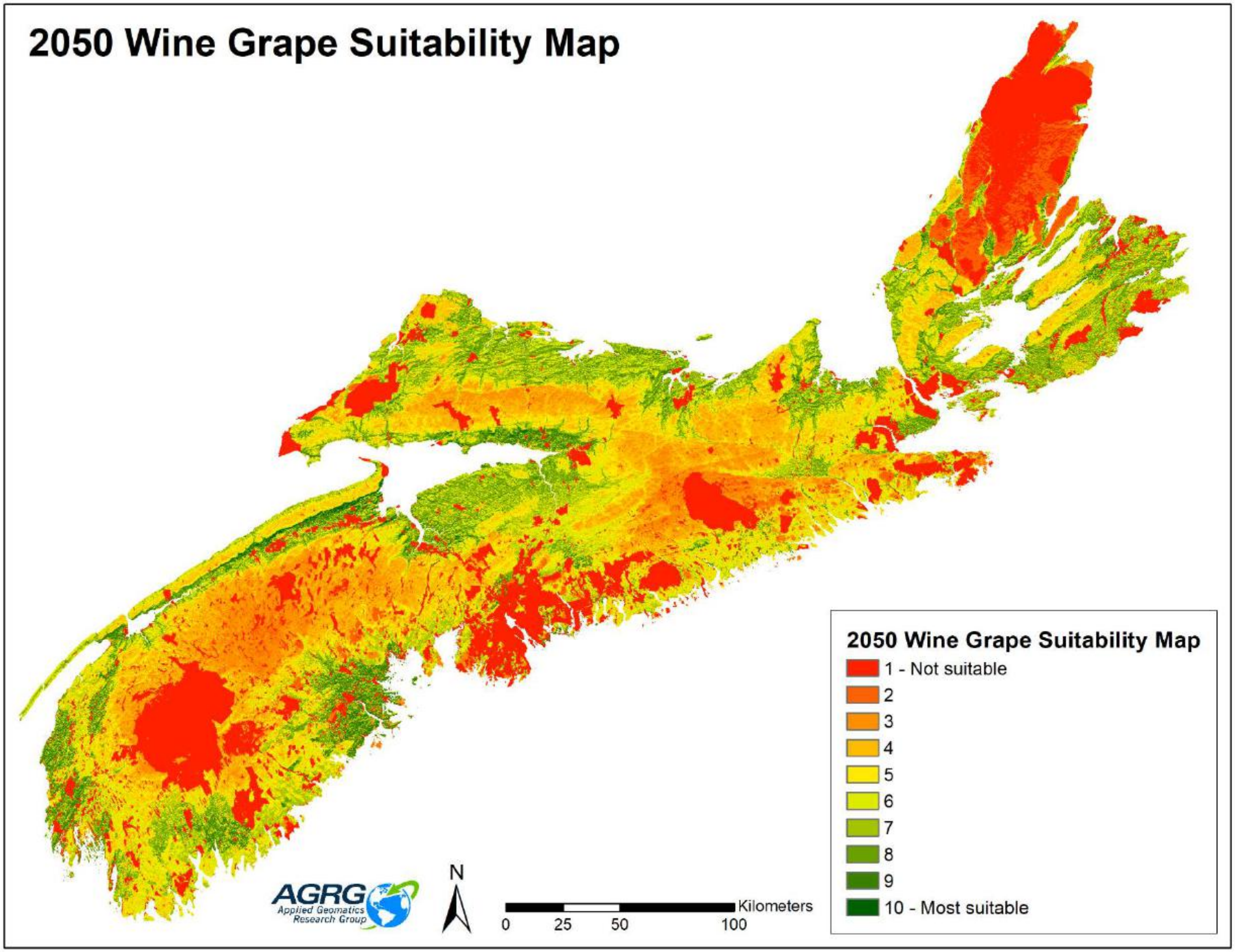


Figure 3.3: 2050 Wine Grape Suitability map for Nova Scotia. Areas in deep red represent unsuitable areas for wine grape growing, while areas in dark green represent the most suitable areas based on 12 input variables.

3.2 Model Validation

The mapped vineyard polygons (n=240) were used for validation of the output suitability maps. Due to the variance in size of these polygons, with some being much less than the 100 m cell size of the output map, the resulting suitability maps had to be resampled to a 5 m resolution in order to capture every vineyard. The suitability values were extracted for each polygon by using the “Zonal Statistics” tool in ArcGIS 10.5.1, which calculated statistics for each vineyard polygon. The mean suitability score was used to represent the overall suitability of the polygon due to the differing sizes of the polygons. The resulting statistics for each vineyard polygon can be found in Appendices G-I.

For the 2018 suitability map, the mean suitability score for all 240 polygons was 7.9 (out of a maximum of 10). The frequency of mean suitability scores for all polygons is depicted in Figure 3.4, and the percentage breakdown per class for the polygons is highlighted in Table 3.2.

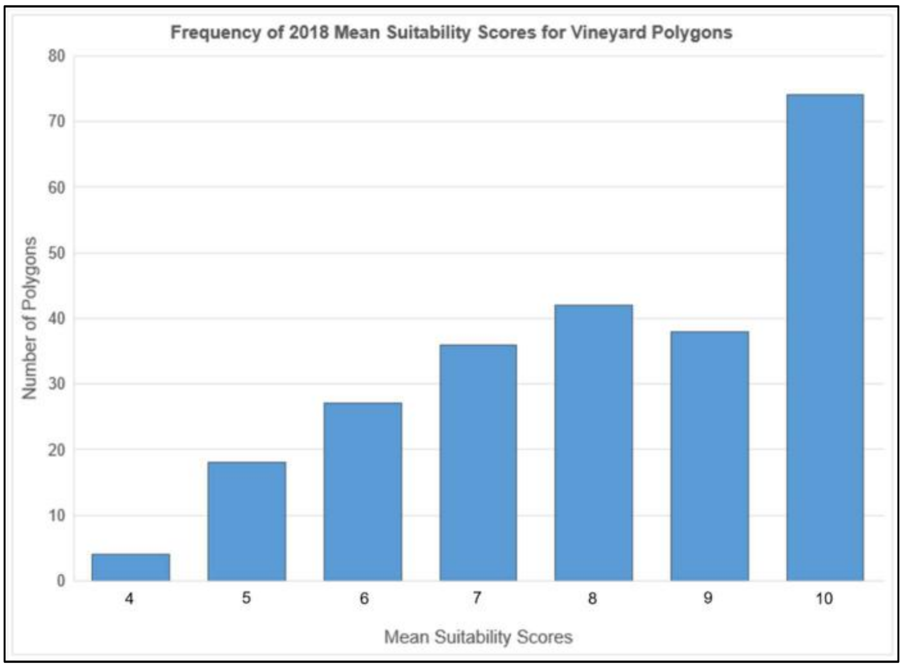


Figure 3.4: Frequency of mean suitability scores for mapped vineyard polygons for the 2018 suitability map.

Mean Suitability Score	% of Polygons
4	1.7%
5	7.5%
6	11.3%
7	15.0%
8	17.6%
9	16.0%
10	30.9%

Table 3.2: Percentage of vineyard polygons which fall into each mean suitability score for the 2018 suitability map

The majority of the vineyard polygons fell within the highest three classes of suitability (classes 8-10), totaling ~64% (about 153 out of 240 polygons) of the dataset.

For the 2035 suitability map, the mean suitability score for all 240 polygons was 7.73. The frequency of mean suitability scores for all polygons is depicted in Figure 3.5, while the percentage breakdown per class for the polygons is highlighted in Table 3.3. The majority of the vineyard polygons fell within the highest three classes of suitability (classes 8-10), totaling 50.4% (121 out of 240 polygons) of the dataset.

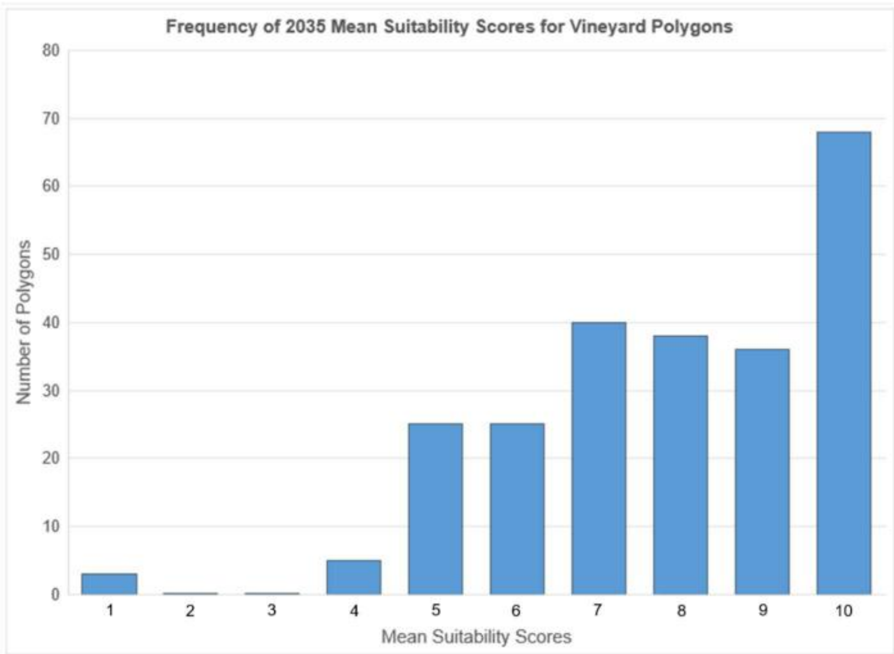


Figure 3.5: Frequency of mean suitability scores for mapped vineyard polygons for the 2035 suitability map

Mean Suitability Score	% of Polygons
< 5	4.6%
5	11.7%
6	14.2%
7	18.9%
8	14.7%
9	25.9%
10	10%

Table 3.3: Percentage of vineyard polygons which fall into each mean suitability score for the 2035 suitability map

For the 2050 suitability map, the mean suitability score for all 240 polygons was 8.01. The frequency of mean suitability scores for all polygons is depicted in Figure 3.6, while the percentage breakdown per class for the polygons is highlighted in Table 3.4. The majority of the vineyard polygons fell within the highest 3 classes of suitability (classes 8-10), totaling 55.8% (134 out of 240 polygons) of the dataset.

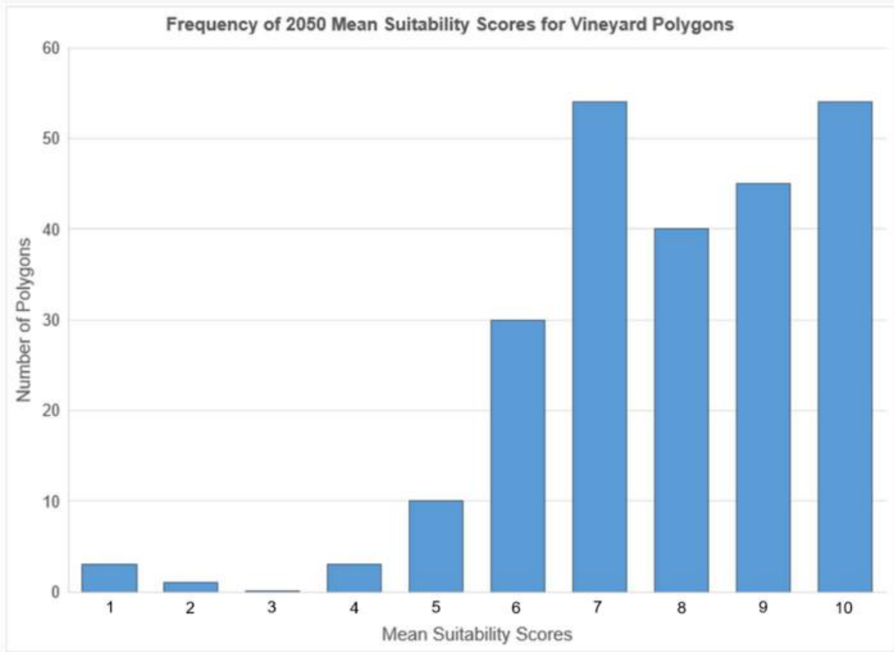


Figure 3.6: Frequency of mean suitability scores for mapped vineyard polygons for the 2050 suitability map

Mean Suitability Score	% of Polygons
< 5	2.9
5	5.4
6	14.2
7	21.7
8	17.9
9	22.0
10	15.9

Table 3.4: Percentage of vineyard polygons which fall into each mean suitability score for the 2050 suitability map

3.3 Interpretation, Assumptions and Limitations

3.3.1 Interpretation

The suitability maps produced from spatial analysis techniques highlighted some clear trends in terms of regional distribution of potentially suitable land. Coastal areas and river valleys appeared to contain the most suitable lands across the province. Generally, river valleys can provide shelter from strong winds which can be experienced at higher elevations. Annapolis and Kings counties possess the majority of the most suitable grape growing areas in the province. These counties are located in the Annapolis River Valley, sandwiched between the North and South Mountains; 60% of the mapped vineyard polygons are located within these two counties. According to the baseline mean climate datasets, this region displays a trend of higher mean GDDs, lower FFDs and a low number of days less than -19°C which makes it very suitable for wine grape growing. In the southern portion of southwest Nova Scotia, Lunenburg County also accounts for a significant portion of suitable land and currently hosts 8.7% of the current vineyards in the province. This county also historically experiences higher GDDs, lower FFDs and a low number of days <-19°C. Areas of high suitability (including class 8 and 9) are also seen in Antigonish, Digby, Yarmouth, Cumberland, Pictou counties, and on Cape Breton Island.

The results of the suitability mapping show that there are 66,950 acres of land in NS that scored a 10 on the suitability spectrum. A comparison of the most suitable areas (66,950 acres) compared to the updated ALIP layer revealed that 77% (51,923 acres) are are either forested area or are not being used for agricultural purposes, and 20% (13,468 acres) are contained within rotational or long term crops (e.g., apples, berries, or grapes). The remaining acreage (3%) falls within the classes of "inactive agriculture" or "inactive transition."

It is important to note that the probability of land availability for wine grape growing dataset produced by Dalhousie University (detailed in section 2.3.2) was not used as a constraining component for the current (2018) suitability map, and as a result, the afore mentioned total acreage of highly suitable land could be affected. However, the ability to overlay this land use layer on top of the 2018 suitability map has been implemented in the GIS web-viewer. When comparing the projected suitability maps for 2035 and 2050 to the 2018 suitability map, the same patterns emerge. Large areas of unsuitable land are found around Kejimkujik National Park, Halifax Regional Municipality and Halifax county, Cumberland County, and Inverness and Victoria Counties on Cape Breton Island. These vast areas are either due to the existence of land use zoning which is not conducive to agricultural activities, or a delimiter (such as a National Park or wildlife reserve).

The results for the 2035 suitability analysis estimated a total of 31,387 acres of the most ideal land (score of 10) for wine grape growing, while the analysis for 2050 produced 64,002 acres of the most suitable land. The addition of Dalhousie's land use zoning layer most likely contributed to the decrease in highly suitable available land for wine grape growing for 2035 compared to 2018. The increase in this acreage visible in the 2050 suitability map compared to 2035 is presumably due to the increase in mean number of GDDs, an increase in the mean number of FFDs, and also a decrease in the mean number of days <-19°C. Between 2035 and 2050, the number of GGDs are projected to increase by 77 days, the mean number of FFDs are projected to increase by 6 days, and the number of days <-19°C is suspected to decrease by 2.3 days.

3.3.2 Assumptions

A few assumptions were made in respect to the wine grape suitability mapping and subsequent validation of this work. Regarding the weighting of the variables for the projected suitability maps (2035 and 2050), modifications were only made to the input climate datasets and their weighting. The weighting of the topographic and soil variables did not change and the regulatory/constraint mask created from the impervious surface and delimeter datasets also remained set to "0" indicating no suitability**.** The projected suitability map for 2035 does not take into account lower-lying areas that could possibly be inundated due to flooding from sea-level rise or storm surge events. Both the 2035 and 2050 suitability maps also assume that there will be no change in agricultural land-use zoning in this 15-year span; it is very difficult to predict how or which counties or municipalities will change or adapt land use zoning and policies. The projected suitability maps also assume no change in the current topographic landscape; coastal erosion (or otherwise) is unaccounted for. There is also the assumption that the soils maps are static and will not experience change between now and 2035/2050.

When utilizing the mapped vineyard polygons for validating the suitability map, the assumption was made that each polygon represented an ideal geographic location for growing wine grapes; which is not always the case. Discussions with Perennia revealed that accurately predicting the ideal location for wine grape is very difficult as they have seen grapes growing in places where, in theory, should not be able to grow (Perennia, 2018). In February of 2018, the AgriRisk project held various workshops for growers and wineries. Discussions at these workshops with grape growers provided useful information on the importance of how selecting the right variety of wine grapes to grow in the right location is vital to how productive a site will be (Moran, 2018). For example, a vineyard that is located in a low-lying area may experience frosts in September and June, making the area unsuitable for more cold-intolerable varieties. Late frosts can cause damage to the bud, while early frost will kill the leaves on the plant and consequently, the grapes will not ripen. This information highlights the importance of choosing the right variety of wine grape to plant based on the microclimate and local topography. For this project, grape variety was not taken into account.

3.3.3 Limitations

The spatial resolution, and the processing of input datasets implemented to ensure each dataset matched the desired 100 m output resolution can be seen as a limitation of this work. Due to the coarse resolution of the output map, and having to resample the topographic datasets (from a 20 m spatial resolution up to a 100 m spatial resolution), valuable data tends to get diluted, and therefore any topographic intricacies which were present in the 20 m DEM would be lost when resampling from a fine spatial resolution to a coarse spatial resolution. The same point translate to the climate data; in starting off with a very coarse resolution (~6.6 km grid), the regional and local microclimates present within the province would not be captured even when the data has been downsampled to a 100 m grid, as these intricacies within the data did not exist in the first place. However, there are trade-offs and considerations to be made when working with data at different spatial resolutions. To produce a suitability map (or maps) or the entire province of Nova Scotia at a spatial resolution of 20 m, or even 50 m, for example, would require a substantial amount of computational power and processing time. Each input dataset at a finer resolution would be quite large in size (in terms of storage), and performing even very simple tasks on these datasets would be very time consuming.

Time constraints did now allow for on-the-ground validation of the suitability map. Although extremely valuable, this process would be very time consuming, as permission would be required to approach each grower or winery and obtain specific data about their vineyards. Validation of the suitability map is also not as clear-cut as comparing the score a certain vineyard plot receives (in terms of the suitability map) to yield data. It is much more complex, as different growers do not record their yield data using the same methods, nor would they manage their vineyards in the same way. The amount of yield that a specific vineyard could potentially produce is highly dependent on how the vineyards themselves are managed; yield is not solely a result of a particular crop of wine grapes growing on the most suitable land. Obtaining data on the specific varieties of wine grapes growing on each plot would also be advantageous to the validation process, but again, could potentially be a time-consuming process to acquire.

The suitability maps are not specific to any particular variety of wine grape; rather, the way in which the climate variables were weighted encompassed both *Vitus vinifera* and hybrid varieties. Generally, vinifera are more risky to grow in a cold climate province such as Nova Scotia, as historically, they are native to the Mediterranean region and Europe, which receive much warmer climates. The decision to set the temperature threshold for mean number of days less than -19°C was made to include these more cold-sensitive varieties into the work, so that the suitability maps could encompass a broad range of wine grape varieties that could grow across the entire province.

The suitability maps do not take into account other climatic variables such as precipitation (rainfall), wind and fog.

4 Discussion

Based on the suitability modelling carried out from this work, there exists a vast amount of landscape capable of being highly prosperous and productive in terms of wine grape growing, both at present day and in the future. Although a decrease in potentially highly suitable lands are seen in 2035 (most likely due to land use zoning constraints), an increase in highly suitable areas is seen again in the year 2050. When comparing the baseline mean (1970-2013) datasets to the 2050 mean projected datasets, we see an increase in range of GDDs from 241 – 295, an increase in range of FFDs of 29 – 31 and a decrease of 10 days <-19°C. These respective increases and decreases evident in the projected climate datasets are very much in line with what Dr. David Philips insinuated during his talk at the 2017 Atlantic Canada Wine Symposium. Dr. Philips, a renowned Environment and Climate Change Canada climatologist, gave a “wine weather forecast” for Nova Scotia in which he conveyed that wine grape growers in the province would reap the benefits of climate change. He spoke of Nova Scotia being the warmest province in the country, predicting projected a growth in GDDs by 40% and a growth in the frost-free period by about 30 days (Philips, 2017). It is in this respect that climate change could be beneficial for the wine industry in Nova Scotia.

On the other end of the spectrum, climate change threatens to negatively impact some vineyards already established in the province. Figure 4.1 illustrates the potentially endangered grape growing areas resulting from the high-high water large tide (HHWLT), 2050/2055 sea-level rise and 100-year storm surge scenario produced by the Maritime Provinces Spatial Analysis Research Centre at Saint Mary’s University. This static flood layer and other climate change related scenarios have been implemented in the web viewer. Spatial analysis of these two layers revealed that nearly 10% of existing grape growing areas (23 vineyard polygons) are directly affected by this scenario. In terms of the most suitable grape growing areas (cells which scored 10) produced by the suitability modelling, 815 acres of land are directly affected by this flood layer, while 4,746 acres of highly suitable land are located within 100 m of the extent of the flooding. It is necessary to note that the flood layers do not incorporate culverts, are the product of a bathtub model (they do not incorporate wave run-up or hydrodynamics) and they are limited to areas with dykelands (van Proosdij, Ross, and Matheson, 2018), so it is very possible that this analysis represents a conservative estimate of the areas which could potentially be affected by the effects of climate change including sea-level rise and storm surge events. This analysis highlights the significance of establishing mitigation efforts in terms of current growers and wineries as even though the changing climate may be beneficial for some in terms of optimization of growth and development, consequences for others could be quite devastating if climate change adaptation strategies are not implemented sooner than later.

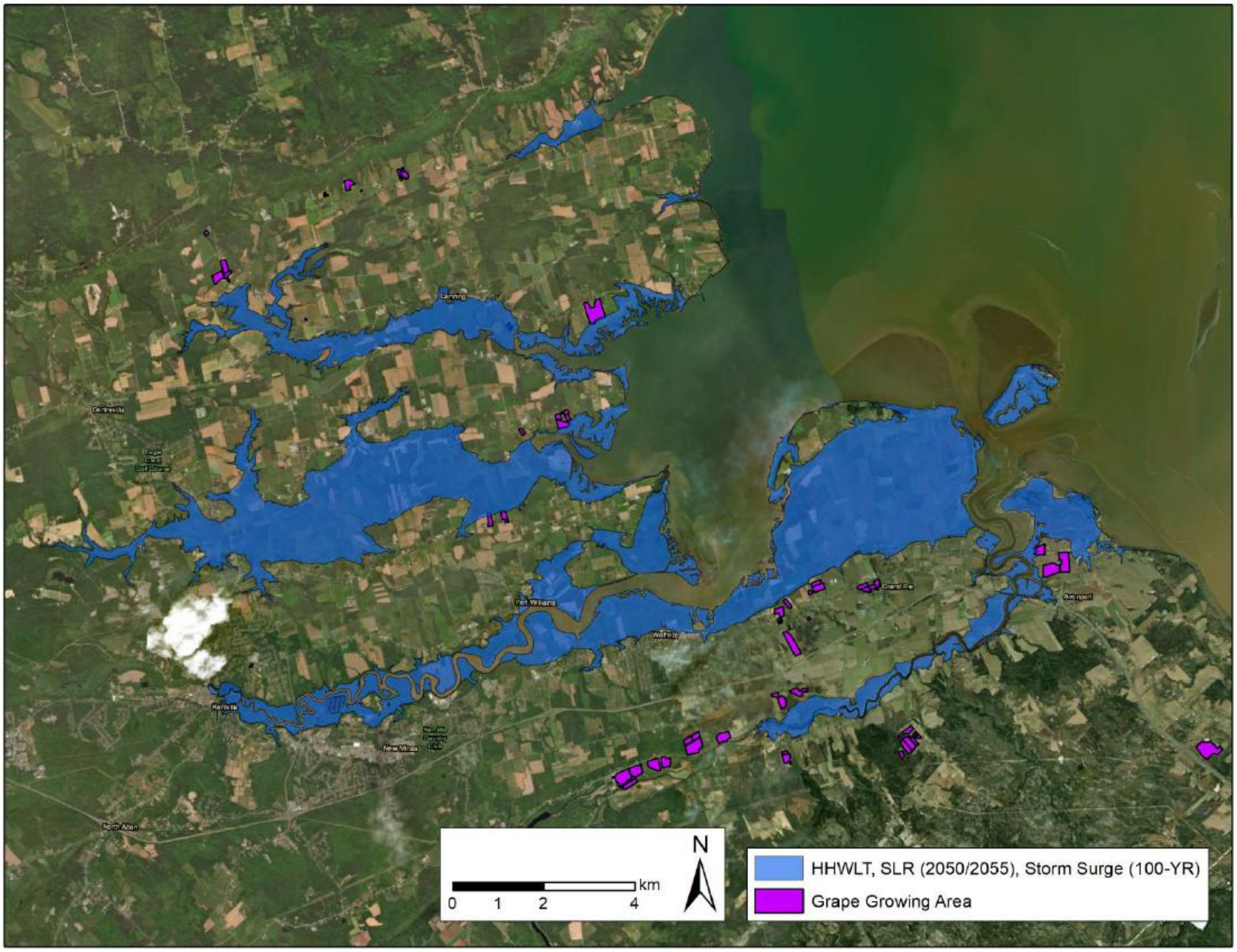


Figure 4.1: High-high water large tide (HHWLT), 2050/2055 sea-level rise and 100-year storm surge scenario (SMU, 2018) in relation to the current vineyards in the Wolfville, Gaspereau, Canning and Grand Pre areas.

5 Future Work and Conclusions

5.1 Conclusions

There were many different yet related and agriculturally-significant GIS datasets generated for this project. The majority of these datasets will be showcased in the AgriRisk GIS-web viewer which will be hosted by GeoNOVA. A combination of aerial photograph and satellite imagery analyses, along with field validation allowed for the construction of a new spatial dataset consisting of vineyards located in the province. Now established, this dataset has the capacity to be maintained going forward, and also houses the potential for new attributes (such as variety and yield) to be incorporated in the future.

This dataset enriches spatial knowledge and awareness of the distribution of vineyards, as geographical patterns are prominent across the province. Access to accurate soil and soil characteristic map, topographic maps, as well as historical baseline climate mean maps and projected mean maps is critical for decision makers to be more effective in their processes in terms of creating policies and planning around the expanding grape and wine industry, now, and in the face of climate change.

The suitability mapping conducted based on a number of input variables pertinent to the successful growth and development of wine grapes demonstrated that this province has tremendous potential to house more vineyards currently and in the future. The various methodologies adopted to produce the required GIS datasets and subsequent suitability maps could be easily applied to other agricultural commodities in the future.

5.2 Recommendations for Future Work

On a larger, provincial scale, working with more coarse datasets is sufficient in terms of efficiency, and, the output suitability model does a very good job of representing ideal areas for wine grape growing based on the criteria defined for the effective growth and development of this crop. A vast inventory of high-resolution, lidar-derived DEM's collected and generated by AGRG currently exists for numerous study areas in the province, including the entire Annapolis Valley, Avon Valley and Bear River valley regions (Figure 5.1). Moreover, as efforts to collect high-resolution lidar data are underway for the province in the near future, it would be desirable to conduct suitability analyses at a smaller scale. Utilizing elevation models generated from lidar data would be advantageous for examining smaller study areas as these datasets generally possess a spatial resolution of < 5 m. Therefore, topographic intricacies which contribute to the microclimate in an area would be captured within these datasets to produce a more precise, detailed output product. The same principal can be applied to the climate datasets; utilizing higher-resolution data would enable for the capturing of microclimates which exist within smaller, local regions. AGRG also owns and operates a network of weather stations which span across southwest Nova Scotia (Figure 5.2). This network has been in operation since 2011 and data from these stations could provide more detailed information regarding microclimates in this region. Having access to these data is also appealing because the majority of current and suitable areas for wine grape growing area located in this area of the province. By honing in on smaller or local study areas for suitability analyses, there would be no need of trade-offs between the physical size of the dataset and the resolution of the input datasets.

Having access to yield and variety data would add depth to not only the vineyard inventory created from this work, but would better enable the comparison between the output of the suitability model and the mapped vineyard polygons used for model validation. Knowledge of each type of wine grape vine planted within each polygon would add an overall picture of the most common type of varieties currently growing in the province, and how successful each variety is at adapting and flourishing in our cool climate. The assumption made of "all vineyard polygons are productive" for the validation portion of this work would able to be eliminated to a large extent as having yield data would give a better understanding of how productive and prosperous a particular polygon is, which would make for a tighter, more precise model. Of course, with this there is the assumption that all vineyard managers or growers record their yield data in the same way, which is most likely not the case. There would still be some assumptions made in order to use these data as part of the model validation; but nevertheless, these data would be very crucial to have if a second phase of this project is commissioned.

The addition of other historical and projected climate variables including precipitation (specifically rainfall) would be beneficial to both the suitability mapping and the GIS web-viewer component. Potential growers of wineries investigation a particular parcel or parcels of land would be interested in these data as it would provide give them an idea of whether or not they would need to make the investment of irrigation systems if a vineyard were to be established.

The criteria used to weight each individual metric within the four broader variables of climate, soil, topography and constraint components to the model could be easily adapted to examine more sensitive varieties, or to make the model output (suitability maps) either more or less liberal, depending on how the criteria was altered. The addition of other climate metrics such as precipitation, wind and fog would also contribute to the tightening of the model. The creation of the GIS datasets used as model inputs, as subsequent creation of the suitability model could also be very easily applied to other agricultural commodities.

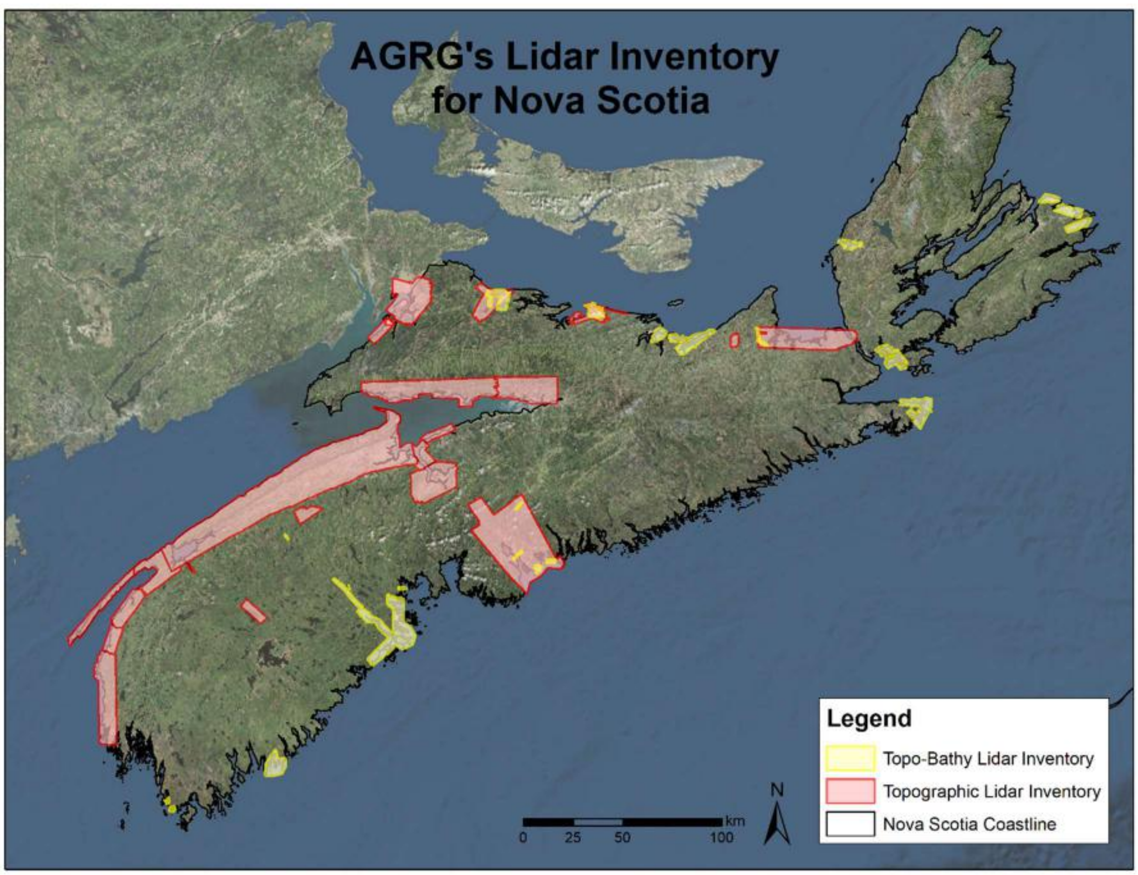


Figure 5.1: AGRG's lidar inventory for both topographic and topo-bathy datasets.

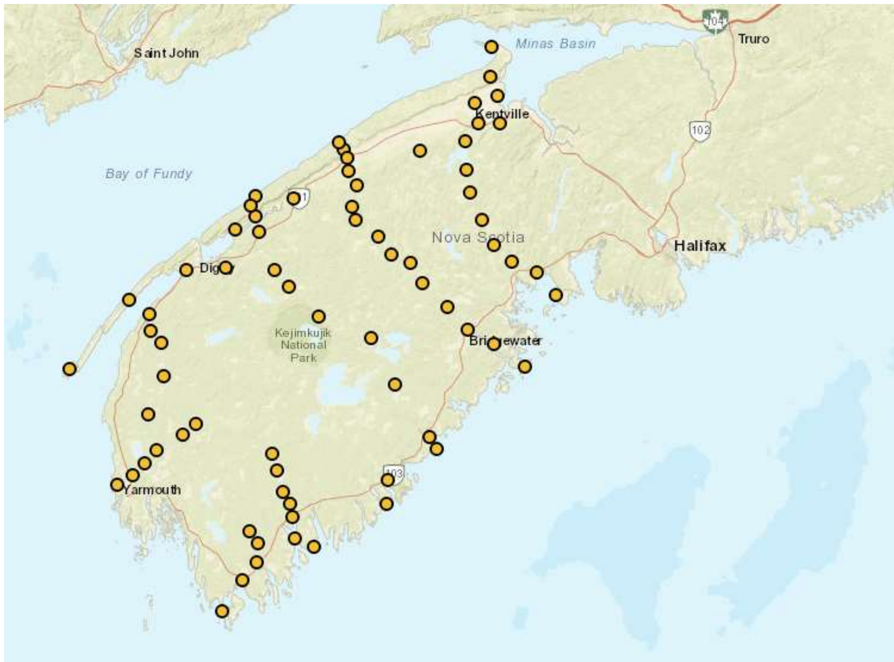


Figure 5.2: AGRG's weather network system distribution across southwest Nova Scotia.

6 Glossary of Terms

ArcMap 10.5.1 – GIS software that is used to create maps, perform spatial analysis and manage geographic data

Basemap – Background map used for context.

Bilinear Interpolation – Resample the raster while viewing it by taking the distance-weighted average from the four nearest cell centers. Best used for continuous rasters like elevation.

Centroid – The geometric center of a feature.

Clip – A tool in ArcMap that extracts features from one feature class that are entirely within a boundary defined by features in another feature class.

Coarse spatial resolution – Image contains less pixels; cell size is bigger. Only large features are visible.

Continuous data – Data that varies without discrete steps and is usually stored as a TIN, raster, or contour lines. An example of continuous data is elevation and temperature.

Digital elevation model (DEM) – Represents the continuous elevation values (z-values) over a topographic surface void of vegetation and manmade features.

Digitize – The process of converting a picture or paper map into a digital format that includes a spatial reference.

Discrete data – Data that has distinct boundaries. Also known as thematic data. An example of discrete data is property boundaries and streets.

Downsample – The process of converting a raster's cells to a smaller size.

ESRI – Provider of GIS software, web GIS, and geodatabase management applications.

Feature class – Consists of geographic features with the same geometry type (point, line, or polygon), the same attributes, and the same spatial reference.

Fishnet – A feature class that contains a net of rectangular cells.

Geographic Information System (GIS) – Software designed to capture, store, analyze, manage, and display spatial/geographic data.

Grid – A spatial data model consisting of equally sized cells arranged in rows and columns. The model can be composed of single or multiple bands. Each cell contains an attribute value and location coordinates. Cells that contain the same value represent the same type of geographic feature. Also known as a raster.

Interpolate – Estimation of surface values at unsampled points based on known values of the surrounding points.

Lidar – Acronym for light detection and ranging. A remote-sensing technique that uses lasers to measure distances to reflective surfaces.

Mask – A data layer which can either be a raster or feature class and is used to identify areas to be included or excluded in spatial analysis.

NAD83 CSRS UTM Zone 20N - Spatial reference system.

Nova Scotia Topographic Database (NSTDB) – A digital map file that completely covers all of Nova Scotia and contains a database of natural features (water bodies, topography, and forested areas) and cultural features (roads, buildings, and administrative boundaries).

Orthophoto – An aerial photograph that has been adjusted for topographic relief, camera tilt and lens distortion.

Raster – A spatial data model consisting of equally sized cells arranged in rows and columns. The model can be composed of single or multiple bands. Each cell contains an attribute value and location coordinates. Cells that contain the same value represent the same type of geographic feature.

Resample – The process of converting to a raster with a different cell size.

Shapefile – A vector data file that stores the location, shape, and attributes of geographic features.

Spatial resolution – Refers to the number of pixels/cells used to make an image.

Suitability Modelling – Suitability analyses involves a process of combining a set of input maps with mathematical functions to produce an output map based on certain criteria.

Topography – Refers to the surface of the land, including relief and the location of natural and constructed features.

Vector – Geographic features displayed as points, lines, and polygons based on coordinates. Each vector feature has an attribute associated with it.

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Appendix A – Data Dictionary

Dataset Title	Dataset File Name	Dataset Type	Spatial Resolution	Dataset Description
Mean days < -19°C from 1970-2013	Clim_days_less_minus_19_1970_2013_100m_UT83	Raster (.tif)	100 m	Mean number of days less than -19°C from 1970-2013 derived from Natural Resources Canada daily data grids at an original spatial resolution of ~6.6 km. Dataset provided by the Reflecting Society and downsampled to 100 m resolution by AGRG.
Mean days < -19°C for 2035	Clim_days_less_minus_19_2035_100m_UT83	Raster (.tif)	100 m	Projected mean number of days less than -19°C for 2035 derived from climate change projection grids at an original spatial resolution of ~6.6 km. Dataset provided by the Reflecting Society and downsampled to 100 m resolution by AGRG.
Mean days < -19°C for 2050	Clim_days_less_minus_19_2050_100m_UT83	Raster (.tif)	100 m	Projected mean number of days less than -19°C for 2050 derived from climate change projection grids at an original spatial resolution of ~6.6 km. Dataset provided by the Reflecting Society and downsampled to 100 m resolution by AGRG.
Mean Frost Free Days (base 0°C) for 2035	Clim_mean_days_greaterthan_0_2035_100m_UT83	Raster (.tif)	100 m	Projected mean number of frost free days (base 0°C) for 2035 derived from climate change projection grids at an original spatial resolution of ~6.6 km. Dataset provided by the Reflecting Society and downsampled to 100 m resolution by AGRG.
Mean Frost Free Days (base 0°C) for 2050	Clim_mean_days_greaterthan_0_2050_100m_UT83	Raster (.tif)	100 m	Projected mean number of frost free days (base 0°C) for 2050 derived from climate change projection grids at an original spatial resolution of ~6.6 km. Dataset provided by the Reflecting Society and downsampled to 100 m resolution by AGRG.
Mean Frost Free Days (base 0°C) from 1970-2013	Clim_mean_days_greaterthan_0_1970_2013_100m_UT83	Raster (.tif)	100 m	Mean number of frost free days (base 0°C) from 1970-2013 derived from Natural Resources Canada daily data grids at an original spatial resolution of ~6.6 km. Dataset provided by the Reflecting Society and downsampled to 100 m resolution by AGRG.
Mean Growing Degree Days (base 10°C) for 2035	Clim_gdd_gamma_base10_2035_100m_UT83	Raster (.tif)	100 m	Projected mean growing degree days (base 10°C) for 2035 calculated for the April 1 to October 30th growing season and derived from climate change projection grids at an original spatial resolution of ~6.6 km. Dataset provided by the Reflecting Society and downsampled to 100 m resolution by AGRG.
Mean Growing Degree Days (base 10°C) for 2050	Clim_gdd_gamma_base10_2050_100m_UT83	Raster (.tif)	100 m	Projected mean growing degree days (base 10°C) for 2050 calculated for the April 1 to October 30th growing season and derived from climate change projection grids at an original spatial resolution of ~6.6 km. Dataset provided by the Reflecting Society and downsampled to 100 m resolution by AGRG.
Mean Growing Degree Days (base 10°C) from 1970-2013	Clim_gdd_gamma_base10_Mar_Nov_1970_2013_100m_UT83	Raster (.tif)	100 m	Mean growing degree days (base 10°C) from 1970-2013 calculated for the March 1st to November 30th growing season and derived from Natural Resources Canada daily data grids at an original spatial resolution of ~6.6 km. Dataset provided by the Reflecting Society and downsampled to 100 m resolution by AGRG.
Nova Scotia Colour Shaded Relief (20m DEM)	Elev_NS_CSR_DEM_20m_UT83	Raster (.tif)	100 m	Colour Shaded Relief (CSR) of the provincial 20 m digital elevation model (DEM), vertically exaggerated 5X.

Nova Scotia Grape Growing Areas	Farm_NS_Grape_UT83	Polygon shapefile (.shp)	N/A	Digitized polygons encompassing current grape growing areas (vineyards) in the province at a 1:1,000 scale
Nova Scotia Greyscale Hillshade (20m DEM)	Elev_NS_DEM_20m_HS_UT83	Raster (.tif)	100 m	Greyscale shaded relief of the provincial 20 m digital elevation model (DEM), vertically exaggerated 5X.
Nova Scotia Slope Aspect (100m DEM)	Elev_NS_Slope_Degrees_DEM_100m_UT83	Raster (.tif)	100 m	The orientation of the slope (aspect) derived from the 20 m provincial digital elevation model (DEM), in cardinal directions.
Nova Scotia Slope Degrees (100m DEM)	Elev_NS_Slope_Degrees_DEM_100m_UT83	Raster (.tif)	100 m	The degree (°) of slope for each raster cell derived from the 20 m provincial digital elevation model (DEM).
Nova Scotia Wineries	Farm_NSWineries_UT83	Point shapefile (.shp)	N/A	Point locations of Nova Scotia wineries.
Soil Drainage	Geol_Soil_Drainage_UT83	Raster (.tif)	100 m	Soil drainage based on individual soil series, derived from the Detailed Soil Surveys (DSS) of Nova Scotia Version 3 produced by Agriculture and Agri-Food Canada (AAFC) with modifications made by the Applied Geomatics Research Group (AGRG).
Soil Stoniness	Geol_Soil_Stoniness_100m_UT83	Raster (.tif)	100 m	Soil stoniness based on individual soil series, derived from the Detailed Soil Surveys (DSS) of Nova Scotia Version 3 produced by Agriculture and Agri-Food Canada (AAFC) with modifications made by the Applied Geomatics Research Group (AGRG).
Soil Capability for Agriculture	Geol_Soil_Capability_UT83	Raster (.tif)	100 m	Soil capability for agriculture derived from a combination of soil survey map sheets by county, and classified by soil series extracted from the Detailed Soil Surveys (DSS) of Nova Scotia Version 3 produced by Agriculture and Agri-Food Canada (AAFC)
Soil Name	Geol_Soil_Name_UT83	Raster (.tif)	100 m	Soil name derived from the Detailed Soil Surveys (DSS) of Nova Scotia Version 3 produced by Agriculture and Agri-Food Canada (AAFC).
Soil Root Restrictions	Geol_Soil_Root_Restriction_UT83	Raster (.tif)	100 m	Soil root restriction classified by individual soil series extracted from the Detailed Soil Surveys (DSS) of Nova Scotia Version 3 produced by Agriculture and Agri-Food Canada (AAFC)
Wine Grape Suitability Map - 2018	Farm_Wine_Suitability2018_UT83	Raster (.tif)	100 m	Provincial thematic map depicting areas of low to high suitability for wine grape growing based on 11 input variables.
Wine Grape Suitability Map - 2035	Farm_Wine_Suitability2035_UT83	Raster (.tif)	100 m	Provincial thematic map depicting areas of low to high suitability for wine grape growing based on 12 input variables.
Wine Grape Suitability Map - 2050	Farm_Wine_Suitability2050_UT83	Raster (.tif)	100 m	Provincial thematic map depicting areas of low to high suitability for wine grape growing based 12 input variables.

Appendix B – Nova Scotia Grape Growing Areas (extracted from Farm_NS_Grape_UT83): Mapped polygons and their attributes

FID	Area (m^2)	Acres	Address	County	Source
0	41955	10.37	1655 Lansdowne Road, Bear River	Digby	AGRG field validation
1	19713	4.87	1655 Lansdowne Road, Bear River	Digby	Winery website
2	977	0.24	2717 Highway 221, Aylesford	Kings	AGRG field validation
3	963	0.24	2717 Highway 221, Aylesford	Kings	AGRG field validation
4	1415	0.35	2717 Highway 221, Aylesford	Kings	AGRG field validation
5	473	0.12	2717 Highway 221, Aylesford	Kings	AGRG field validation
6	27938	6.90	88 Gates Mountain Road, Middleton	Annapolis	Winery website
7	4670	1.15	2787 Highway 376, Lyons Brook	Pictou	Winery website
8	4132	1.02	938 Goodwin Road, Amherst	Cumberland	Winery website
9	3983	0.98	938 Goodwin Road, Amherst	Cumberland	Winery website
10	32496	8.03	391 Thorpe Road, Centreville	Kings	AGRG field validation
11	71133	17.58	391 Thorpe Road, Centreville	Kings	AGRG field validation
12	36648	9.06	391 Thorpe Road, Centreville	Kings	AGRG field validation
13	7672	1.90	391 Thorpe Road, Centreville	Kings	AGRG field validation
14	27111	6.70	391 Thorpe Road, Centreville	Kings	AGRG field validation
15	8679	2.14	391 Thorpe Road, Centreville	Kings	AGRG field validation
16	1729	0.43	391 Thorpe Road, Centreville	Kings	AGRG field validation
17	2408	0.60	391 Thorpe Road, Centreville	Kings	AGRG field validation
18	5287	1.31	391 Thorpe Road, Centreville	Kings	AGRG field validation
19	7732	1.91	391 Thorpe Road, Centreville	Kings	AGRG field validation
20	4018	0.99	391 Thorpe Road, Centreville	Kings	AGRG field validation
21	25156	6.22	543 Brooklyn Road, Middleton	Annapolis	AGRG field validation
22	12206	3.02	543 Brooklyn Road, Middleton	Annapolis	AGRG field validation
23	13302	3.29	543 Brooklyn Road, Middleton	Annapolis	AGRG field validation
24	7418	1.83	543 Brooklyn Road, Middleton	Annapolis	AGRG field validation
25	7838	1.94	543 Brooklyn Road, Middleton	Annapolis	AGRG field validation
26	3766	0.93	284 Lamont Road, Centreville	Kings	Winery website
27	53453	13.21	187 Highway 221, North Kingston	Kings	Winery website
28	20641	5.10	187 Highway 221, North Kingston	Kings	Winery website

29	15592	3.85	3735 Highway 221, Berwick	Kings	Winery website
30	15955	3.94	3735 Highway 221, Berwick	Kings	Winery website
31	4437	1.10	3735 Highway 221, Berwick	Kings	Winery website
32	3138	0.78	3735 Highway 221, Berwick	Kings	Winery website
33	5450	1.35	3735 Highway 221, Berwick	Kings	Winery website
34	8114	2.01	628 Canard Street, Port Williams	Kings	AGRG field validation
35	11144	2.75	628 Canard Street, Port Williams	Kings	AGRG field validation
36	1502	0.37	628 Canard Street, Port Williams	Kings	AGRG field validation
37	14133	3.49	628 Canard Street, Port Williams	Kings	AGRG field validation
38	36527	9.03	628 Canard Street, Port Williams	Kings	AGRG field validation
39	21493	5.31	4601 Highway 221, Welsford	Kings	Winery website
40	6805	1.68	4601 Highway 221, Welsford	Kings	Winery website
41	7810	1.93	4601 Highway 221, Welsford	Kings	Winery website
42	14309	3.54	4601 Highway 221, Welsford	Kings	Winery website
43	8096	2.00	7565 Highway 6, Port Howe	Cumberland	Winery website
44	21811	5.39	3151 Clementvale Road, Clementsvale	Annapolis	AGRG field validation
45	3442	0.85	915 LaHave Street, Bridgewater	Lunenburg	Registry of Joint Stocks
46	2135	0.53	915 LaHave Street, Bridgewater	Lunenburg	Registry of Joint Stocks
47	3385	0.84	915 LaHave Street, Bridgewater	Lunenburg	Registry of Joint Stocks
48	2160	0.53	97 Belmont Road, Newport	Hants	Registry of Joint Stocks
49	557	0.14	1001 Windsor Back Road, Windsor	Hants	Registry of Joint Stocks
50	4299	1.06	2576 Clementsvale Road, Bear River East	Annapolis	Registry of Joint Stocks
51	30901	7.64	2576 Clementsvale Road, Bear River East	Annapolis	AGRG field validation
52	824	0.20	1140 Highway 1, Lower Wolfville	Kings	Registry of Joint Stocks
53	2151	0.53	120 West Old Post Road, Smiths Cove	Digby	Registry of Joint Stocks
54	2782	0.69	5895 Highway 215, Kempt Shore	Hants	Registry of Joint Stocks
55	23920	5.91	6055 Highway 215, Kempt Shore	Hants	Registry of Joint Stocks
56	9718	2.40	418 Canard Street, Port Williams	Kings	AGRG field validation
57	7861	1.94	2234 Clementsvale Road, Bear River	Annapolis	AGRG field validation
58	23832	5.89	3551 Clarence Road, Clarence East	Annapolis	Registry of Joint Stocks
59	7327	1.81	2669 Clarence Road, Bridgetown	Annapolis	Registry of Joint Stocks/Kijiji
60	5976	1.48	1358 Davidson Street, Wolfville	Kings	Registry of Joint Stocks
61	32273	7.97	481 Woodside Road, Woodside	Kings	AGRG field validation

62	677	0.17	481 Woodside Road, Woodside	Kings	Registry of Joint Stocks
63	4509	1.11	6248 Highway 332, Upper LaHave	Lunenburg	Registry of Joint Stocks
64	1218	0.30	50 Angus Hiltz Road, Chester Basin	Lunenburg	Registry of Joint Stocks
65	3844	0.95	141 Robinson Road, Maitland	Hants	Registry of Joint Stocks
66	12191	3.01	90 Ramey Road, Barss Corner	Lunenburg	Registry of Joint Stocks
67	625	0.15	1972 Woodville Road, Woodville	Kings	Facebook
68	391	0.10	8477 Highway 3, Mahone Bay	Lunenburg	Amateurwine.ca
69	12293	3.04	8477 Highway 3, Mahone Bay	Lunenburg	Amateurwine.ca
70	3239	0.80	8477 Highway 3, Mahone Bay	Lunenburg	Amateurwine.ca
71	3491	0.86	327 Woodside Road, Canning	Kings	Amateurwine.ca
72	1006	0.25	327 Woodside Road, Canning	Kings	Amateurwine.ca
73	12609	3.12	2111 Melanson Road, Wolfville	Kings	AGRG field validation
74	35178	8.69	2111 Melanson Road, Wolfville	Kings	AGRG field validation
75	21368	5.28	603 Belmont Road, Belmont	Hants	Air photos
76	14643	3.62	4473 Highway 14, Windsor	Hants	AGRG field validation
77	12876	3.18	294 Falmouth Back Road, Falmouth	Hants	AGRG field validation
78	7565	1.87	98 Shore Road, Lower Debert	Colchester	Facebook
79	19323	4.77	98 Shore Road, Lower Debert	Colchester	Registy of Joint Stocks
80	15749	3.89	718 Windermere Road, Berwick	Kings	Annapolis Valley Vinters
81	8813	2.18	718 Windermere Road, Berwick	Kings	Annapolis Valley Vinters
82	18555	4.59	659 Woodside Road, Woodside	Kings	AGRG field validation
83	13560	3.35	659 Woodside Road, Woodside	Kings	AGRG field validation
84	2990	0.74	659 Woodside Road, Woodside	Kings	AGRG field validation
85	961	0.24	659 Woodside Road, Woodside	Kings	AGRG field validation
86	4636	1.15	306 Windermere Road, Berwick	Kings	Facebook
87	3122	0.77	237 Belcher Street, Kentville	Kings	AGRG field validation
88	4353	1.08	135 Eye Road, Lower Wolfville	Kings	AGRG field validation
89	5265	1.30	1106 Old Port Mouton Road, Liverpool	Queens	Annapolis Valley Vinters
90	2895	0.72	1106 Old Port Mouton Road, Liverpool	Queens	Annapolis Valley Vinters
91	2062	0.51	718 Windermere Road, Berwick	Kings	Annapolis Valley Vinters
92	14366	3.55	across from 118 Gates Mountain Road, Middleton	Annapolis	AGRG field validation
93	16750	4.14	11205 Highway 1, Lower Wolfville	Kings	AGRG field validation
94	53158	13.14	across road from 3053 Greenfield Rd	Kings	AGRG field validation

95	6886	1.70	6787 Highway 1, Bellisle	Annapolis	AGRG field validation
96	11593	2.86	3874 Highway 201, Bridgetown	Annapolis	AGRG field validation
97	20591	5.09	3169 Clarence Road, Lawrencetown	Annapolis	AGRG field validation
98	4156	1.03	2051 Highway 221, Welton's Corner	Kings	AGRG field validation
99	731	0.18	2051 Highway 221, Welton's Corner	Kings	AGRG field validation
100	1225	0.30	9035 Highway 221, Canning	Kings	AGRG field validation
101	12733	3.15	1704 Landsdown Road, Bear River	Digby	AGRG field validation
102	1343	0.33	391 Thorpe Road, Centreville	Kings	AGRG field validation
103	19389	4.79	391 Thorpe Road, Centreville	Kings	AGRG field validation
104	12265	3.03	391 Thorpe Road, Centreville	Kings	AGRG field validation
105	25367	6.27	3551 Clarence Road, Clarence East	Annapolis	AGRG field validation
106	6932	1.71	3551 Clarence Road, Clarence East	Annapolis	AGRG field validation
107	130819	32.33	13474 Highway 1, Lockhartville	Kings	AGRG field validation
108	78408	19.38	1741 Maple Ridge Road, Lower Wolfville	Kings	AGRG field validation
109	82740	20.45	625 Oak Island Road, Avonport	Hants	AGRG field validation
110	5515	1.36	1353 Highway 1, Mount Denson	Hants	AGRG field validation
111	5039	1.25	1355 Highway 1, Mount Denson	Hants	AGRG field validation
112	4850	1.20	201 Auburndale Road, Auburndale	Lunenburg	Registry of Joint Stocks
113	25155	6.22	1365 Church Street, Port Williams	Kings	Registry of Joint Stocks
114	14437	3.57	2271 Highway 221, Dempsey's Corner	Kings	AGRG field validation
115	145277	35.90	10318 Highway 221, Canning	Kings	Winery website
116	25314	6.26	1441 Church St, Port Williams	Kings	Winery website
117	17421	4.30	133 Chute Rd, Bear River	Annapolis	AGRG field validation
118	8342	2.06	2635 Clementsvale Road, Bear River	Annapolis	Winery website
119	17324	4.28	2635 Clementsvale Road, Bear River	Annapolis	Winery website
120	8864	2.19	2635 Clementsvale Road, Bear River	Annapolis	Winery website
121	28746	7.10	1300 Italy Cross Road, Crousetown	Lunenburg	Winery website
122	1231	0.30	105 Craig Chadler Drive, Bridgewater	Lunenburg	Winery website
123	1894	0.47	105 Craig Chadler Drive, Bridgewater	Lunenburg	Winery website
124	56090	13.86	813 Walburne Road, Mahone Bay	Lunenburg	Winery website
125	41068	10.15	813 Walburne Road, Mahone Bay	Lunenburg	Winery website
126	11011	2.72	813 Walburne Road, Mahone Bay	Lunenburg	Winery website
127	69472	17.17	11 Dudley Park Lane, Falmouth	Hants	Winery website

128	18948	4.68	80 Avondale Cross Rd, Newport	Hants	Winery website
129	1523	0.38	80 Avondale Cross Rd, Newport	Hants	Winery website
130	17503	4.33	80 Avondale Cross Rd, Newport	Hants	Winery website
131	56678	14.01	80 Avondale Cross Rd, Newport	Hants	Winery website
132	4645	1.15	13719 Highway 215, Rines Creek	Hants	Winery website
133	2402	0.59	592 Highway 311, Truro	Colchester	Winery website
134	23561	5.82	48 Vintage Lane, Malagash	Cumberland	Winery website
135	11715	2.89	48 Vintage Lane, Malagash	Cumberland	Winery website
136	26116	6.45	48 Vintage Lane, Malagash	Cumberland	Winery website
137	44827	11.08	48 Vintage Lane, Malagash	Cumberland	Winery website
138	21966	5.43	48 Vintage Lane, Malagash	Cumberland	Winery website
139	1872	0.46	48 Vintage Lane, Malagash	Cumberland	Winery website
140	7532	1.86	48 Vintage Lane, Malagash	Cumberland	Winery website
141	7774	1.92	48 Vintage Lane, Malagash	Cumberland	Winery website
142	9518	2.35	48 Vintage Lane, Malagash	Cumberland	Winery website
143	41456	10.24	48 Vintage Lane, Malagash	Cumberland	Winery website
144	35097	8.67	48 Vintage Lane, Malagash	Cumberland	Winery website
145	13184	3.26	1293 Grand Pre Road, Wolfville	Kings	Winery website
146	22773	5.63	1293 Grand Pre Road, Wolfville	Kings	Winery website
147	4087	1.01	1293 Grand Pre Road, Wolfville	Kings	Winery website
148	1421	0.35	1293 Grand Pre Road, Wolfville	Kings	Winery website
149	31087	7.68	1293 Grand Pre Road, Wolfville	Kings	Winery website
150	39402	9.74	1293 Grand Pre Road, Wolfville	Kings	Winery website
151	15448	3.82	1293 Grand Pre Road, Wolfville	Kings	Winery website
152	27917	6.90	310 Slayter Road, Gaspereau	Kings	Winery website
153	8776	2.17	310 Slayter Road, Gaspereau	Kings	Winery website
154	1477	0.36	310 Slayter Road, Gaspereau	Kings	Winery website
155	83477	20.63	1842 White Rock Road, Wolfville	Kings	Winery website
156	28358	7.01	1842 White Rock Rpad, Wolfville	Kings	Winery website
157	21194	5.24	2239 White Rock Road, Wolfville	Kings	Winery website
158	87071	21.52	2239 White Rock Road, Wolfville	Kings	Winery website
159	6209	1.53	88 Dyke Road, Wolfville	Kings	Winery website
160	36568	9.04	88 Dyke Road, Wolfville	Kings	Winery website

161	2929	0.72	11611 Highway 1, Grand Pre	Kings	Winery website
162	16416	4.06	11611 Highway 1, Grand Pre	Kings	Winery website
163	11301	2.79	11611 Highway 1, Grand Pre	Kings	Winery website
164	11712	2.89	5349 Marble Mountain Road, River Denys	Inverness	Winery website
165	10558	2.61	5349 Marble Mountain Road, River Denys	Inverness	Winery website
166	7457	1.84	5349 Marble Mountain Road, River Denys	Inverness	Winery website
167	14795	3.66	5349 Marble Mountain Road, River Denys	Inverness	Winery website
168	1478	0.37	496 Carleton Road, Lawrencetown	Annapolis	Winery website
169	10363	2.56	48 Vintage Lane, Malagash	Cumberland	Winery website
170	1272	0.31	1842 White Rock Road, Wolfville	Kings	Winery website
171	55979	13.83	1842 White Rock Road, Wolfville	Kings	Winery website
172	54491	13.47	1842 White Rock Road, Wolfville	Kings	Winery website
173	5087	1.26	1293 Grand Pre Road, Wolfville	Kings	Winery website
174	1796	0.44	1293 Grand Pre Road, Wolfville	Kings	Winery website
175	1425	0.35	105 Craig Chadler Drive, Bridgewater	Lunenburg	Winery website
176	6946	1.72	1293 Grand Pre Road, Wolfville	Kings	Winery website
177	30739	7.60	11199 Evangeline Trail, Wolfville	Kings	Winery website
178	4743	1.17	11199 Evangeline Trail, Wolfville	Kings	Winery website
179	4775	1.18	11199 Evangeline Trail, Wolfville	Kings	Winery website
180	16501	4.08	88 Dyke Road, Wolfville	Kings	Winery website
181	584	0.14	11611 Highway 1, Grand Pre	Kings	Winery website
182	15223	3.76	11611 Highway 1, Grand Pre	Kings	Winery website
183	19423	4.80	11611 Highway 1, Grand Pre	Kings	Winery website
184	60207	14.88	13719 Highway 215, Rines Creek	Hants	Winery website
185	11213	2.77	13719 Highway 215, Rines Creek	Hants	Winery website
186	4792	1.18	11 Dudley Park Lane, Falmouth	Hants	Winery website
187	4999	1.24	11 Dudley Park Lane, Falmouth	Hants	Winery website
188	7874	1.95	1337 Fox Harbour Rd, Wallace	Cumberland	Winery website
189	103251	25.51	1337 Fox Harbour Rd, Wallace	Cumberland	Winery website
190	35664	8.81	2106 Melanson Road, Wolfville	Kings	AGRG field validation
191	3763	0.93	4613 Granville Road, Granville Breach	Annapolis	AGRG field validation
192	362	0.09	938 Beaconsfield Road, Beaconsfield	Annapolis	AGRG field validation
193	4287	1.06	124 George Whynot Rd, New Germany	Lunenburg	AGRG field validation

194	4745	1.17	124 George Whynot Rd, New Germany	Lunenburg	AGRG field validation
195	16207	4.00	771 Thorpe Road, Billtown	Kings	AGRG field validation
196	7925	1.96	919 Bains Road, Atlanta	Kings	AGRG field validation
197	4382	1.08	across from 184 Canning Aboiteau Road, Habitant	Kings	AGRG field validation
198	3734	0.92	across from 184 Canning Aboiteau Road, Habitant	Kings	AGRG field validation
199	4869	1.20	26 Musgrave Rd, Auburn	Kings	AGRG field validation
200	3148	0.78	3374 Highway 332, Rose Bay	Lunenburg	AGRG field validation
201	41453	10.24	1842 White Rock Rd, Gaspereau	Kings	AGRG field validation
202	1858	0.46	245 Pictou Island Rd, Pictou Island	Pictou	Winery website
203	4190	1.04	43 Burton Drive, Upper Malagash	Cumberland	Google Earth
204	9348	2.31	5765 Highway 1, Grafton	Kings	AGRG field validation
205	3359	0.83	5349 Marble Mountain Rd, River Denys	Inverness	Winery website
206	16943	4.19	396-408 Cape John Road, River John	Pictou	AGRG field validation
207	3961	0.98	5349 Marble Mountain Rd, River Denys	Inverness	Winery website
208	29038	7.18	48 Vintage Lane, Malagash	Cumberland	Air photos
209	5828	1.44	48 Vintage Lane, Malagash	Cumberland	Air photos
210	19628	4.85	2239 White Rock Road, Wolfville	Kings	AGRG field validation
211	84542	20.89	across from 625 Oak Island Road, Avonport	Kings	AGRG field validation
212	44429	10.98	725 Oak Island Road, Avonport	Kings	AGRG field validation
213	2669	0.66	5185 Highway 1, Salmon River	Digby	Perennia
214	5431	1.34	5185 Highway 1, Salmon River	Digby	Perennia
215	30023	7.42	168 Highway 215, Union Corner	Hants	Perennia
216	2869	0.71	4715 Granville Road, Granville Ferry	Annapolis	Perennia
217	9530	2.35	4613 Granville Road, Granville Beach	Annapolis	Perennia
218	21037	5.20	4438 Highway 1, South Berwick	Kings	Perennia
219	5332	1.32	804 Highway 1, Comeauville	Digby	Perennia
220	33773	8.35	4139 Highway 340, Carleton	Yarmouth	Perennia
221	8297	2.05	771 Highway 19, Troy	Inverness	Perennia
222	3670	0.91	532 Rankinville Road, Mabou	Inverness	Perennia
223	608	0.15	2817 Point Edward Highway, Point Edward	Cape Breton	Perennia
224	363	0.09	2817 Point Edward Highway, Point Edward	Cape Breton	Perennia
225	5271	1.30	1805 South Side Harbour Road, Southside Harbour	Antigonish	Perennia
226	6831	1.69	3955 West River East Side Road, Durham	Pictou	Perennia

227	12229	3.02	3955 West River East Side Road, Durham	Pictou	Perennia
228	32634	8.06	658 Middleboro Road, Middleboro	Cumberland	Perennia
229	1574	0.39	658 Middleboro Road, Middleboro	Cumberland	Perennia
230	3415	0.84	141 Robinson Road, Maitland	Hants	Perennia
231	1382	0.34	925 Bains Road, Atlanta	Kings	Valley Vinters/Perennia
232	15912	3.93	925 Bains Road, Atlanta	Kings	Valley Vinters/Perennia
233	42601	10.53	925 Bains Road, Atlanta	Kings	Valley Vinters/Perennia
234	32794	8.10	925 Bains Road, Atlanta	Kings	Valley Vinters/Perennia
235	4736	1.17	1112 Falmouth Dyke Road, Falmouth	Hants	Perennia
236	80341	19.85	1112 Falmouth Dyke Road, Falmouth	Hants	Perennia
237	12828	3.17	1027 Palmer Road, Auburn	Kings	Perennia
238	5267	1.30	1027 Palmer Road, Auburn	Kings	Perennia
239	1866	0.46	2084 Upper Branch Road, Midville Branch	Lunenburg	Perennia

Appendix C- Classification of soil characteristics based on soil series

GOOD (1)	GOOD TO FAIR (2)	FAIR (3)	FAIR TO POOR (4)	POOR (5)	POOR TO UNSUITABLE (6)	UNSUITABLE (7)
Acadia (ACA)	Bryden (BYN)	Avonport (AVP)	Diligence (DGC)	Cobequid (CBQ)	Bayswater (BEY)	Aspotogan (APG)
Berwick (BWK)	Cumberland (CBR)	Bridgetown (BWT)	Hansford (HFD)	Cornwallis (CNW)	Castley (CSY)	Coastal Beach (ZCB)
Bridgewater (BDW)	Fash (FSH)	Farmville (FMV)	Hebert (HBT)	Kirkmount (KKM)	Dufferin (DFN)	Economy (ECY)
Canning (CNG)	Glenmont (GMO)	Kingsport (KGP)	Horton (HTN)	Nictaux (NUX)	Gibraltor (GIB)	Eroded (ZER)
Debert (DRT)	Hantsport (HTP)	Perch Lake (PLK)	Joggins (JGG)	Port Hebert (PHB)	Halifax (HFX)	Folly (FLY)
Gulliver (GLV)	Kirkhill (KKL)	Portapique (PPQ)		Rossway (RAY)	Hopewell (HWL)	Masstown (MSW)
Kentville (KTV)	Lawrencetown (LWR)			Wyvern (WYV)		Millar (MLL)
Merigomish (MGM)	Middleton (MDD)					Mine Tailings (ZMT)
Pelton (PLT)	Millbrook (MLO)					Not Surveyed (ZNS)
Pugwash (PGW)	Morristown (MRW)					Rockland (ZRL)
Stewiacke (STW)	Queens (QUE)					Rodney (RNY)
Tormentine (TRM)	Shulie (SUI)					Rossignol (RGO)
Truro (TUO)	Somerset (SME)					Salt Marsh (ZSM)
Wolfville (WFV)	Springhill (SGL)					Swamp (ZSW)
Woodville (WOV)	Thom (THM)					Water (ZZZ)
Yarmouth (YUH)	Torbrook (TBO)					
	Westbrook (WBO)					
	Woodbourne (WOB)					

Soil capability for agriculture classification based soil surveys from individual NS counties.

WELL	MODERATELY WELL	WELL TO RAPID	RAPID	IMPERFECT	POOR	VERY POOR	N/A
Bridgetown (BWT)	Glenmont (GMO)	Berwick (BWK)	Gulliver (GLV)	Acadia (ACA)	Aspotogan (APG)	Lawrencetown (LWR)	Eroded (ZER)
Cumberland (CBR)	Stewiacke (STW)	Canning (CNG)	Torbrook (TBO)	Avonport (AVP)	Millar (MLL)	Masstown (MSW)	Swamp (ZSW)
Middleton (MDD)	Woodbourne (WOB)	Gibraltar (GIB)	Hebert (HBT)	Bayswater (BEY)	Economy (ECY)	Castley (CSY)	Rockland (ZRL)
Morristown (MRW)	Folly (FLY)	Somerset (SME)		Debert (DRT)	Joggins (JGG)	Rossignol (RGO)	Eroded Land (ZER)
Pelton (PLT)	Pugwash (PGW)			Fash (FSH)		Dufferin (DFN)	Mine Tailings (ZMT)
Rossway (RAY)	Millbrook (MLO)			Hantsport (HTP)			Not Surveyed (ZNS)
Wolfville (WFV)	Hansford (HFD)			Kentville (KTV)			Water (ZZZ)
Woodville (WOV)	Bryden (BYN)			Kingsport (KGP)			Salt Marsh (ZSM)
Bridgewater (BDW)				Diligence (DGC)			Coastal Beach (ZCB)
Farmville (FMV)				Queens (QUE)			
Westbrook (WBO)				Kirkhill (KKL)			
Yarmouth (YUH)				Shulie (SUI)			
Cobequid (CBQ)				Thom (THM)			
Truro (TUO)				Springhill (SGL)			
Merigomish (MGM)				Port Hebert (PHB)			
Tormentine (TRM)				Wyvern (WYV)			
Portapique (PPQ)				Kirkmount (KKM)			
Rodney (RNY)				Hopewell (HWL)			
				Horton (HTN)			
				Perch Lake (PLK)			
				Halifax (HFX)			

Soil drainage classifications based on soil name.

No root restricting layer (0)	Second Layer (2)	Third Layer (3)	Fourth Layer (4)	Fifth Layer (5)	N/A (-999)
Cornwallis (CNW)	Nictaux (NUX)	Middleton (MDD)	Halifax (HFX)	Hopewell (HWL)	Eroded (ZER)
Cumberland (CBR)		Morristown (MRW)	Rossway (RAY)		Swamp (ZSW)
Portapique (PPQ)		Pelton (PLT)	Farmville (FMV)		Rockland (ZRL)
Stewiacke (STW)		Wolfville (WFV)	Westbrook (WBO)		Eroded Land (ZER)
Canning (CNG)		Woodville (WOV)	Cobequid (CBQ)		Mine Tailings (ZMT)
Gulliver (GLV)		Yarmouth (YUH)	Rodney (RNY)		Not Surveyed (ZNS)
Torbrook (TBO)		Truro (TUO)	Folly (FLY)		Water (ZZZ)
Hebert (HBT)		Merigomish (MGM)	Bryden (BYN)		Salt Marsh (ZSM)
Kingsport (KGP)		Tormentine (TRM)	Gibraltar (GIB)		Coastal Beach (ZCB)
Wyvern (WYV)		Glenmont (GMO)	Debert (DRT)		
Millar (MLL)		Woodbourne (WOB)	Kirkhill (KKL)		
Castley (CSY)		Pugwash (PGW)	Shulie (SUI)		
Rossignol (RGO)		Millbrook (MLO)	Thom (THM)		
Dufferin (DFN)		Hansford (HFD)	Kirkmount (KKM)		
Acadia (ACA)		Somerset (SME)	Horton (HTN)		
Avonport (AVP)		Fash (FSH)	Perch Lake (PLK)		
		Hantsport (HTP)	Aspotogan (APG)		
		Kentville (KTV)	Bridgetown (BWT)		
		Diligence (DGC)			
		Queens (QUE)			
		Springhill (SGL)			
		Port Hebert (PHB)			
		Economy (ECY)			
		Joggins (JGG)			
		Lawrencetown (LWR)			
		Masstown (MSW)			
		Bridgewater (BDW)			
		Berwick (BWK)			
		Bayswater (BEY)			

Soil rooting restriction based on soil name.

Appendix D – Grape Suitability Mapping Questionnaire for AgriRisk Project

Grape Suitability Mapping Questionnaire for AgriRisk Project

Applied Geomatics Research Group, Nova Scotia Community College

Background

Four significant broader variables encompassing numerous metrics pertinent to successful wine grape/vine growing have been identified for Nova Scotia, which will be taken into account to identify potential suitable areas for wine grape growing. These variables include topographic suitability, climatic suitability, soil suitability, and regulatory/constraint suitability. These variables will be represented as specific layers within a Geographic Information System (GIS), and a model will determine areas of highest suitability, to areas of lowest suitability, based on the feedback received from this questionnaire and associatefd literature. Below are a set of questions pertaining to individual variables; some require ranking from the least ideal (rank of 0) to most ideal condition (highest rank depending on individual dataset), whereas others require the answer to a question. Please consider all varieties of grapes (hybrids and *Vitus vinifera*) when ranking the variables, as the preliminary or first phase of the model will encompass all grape varieties and is not limited to a specific type of wine grape vine at this time.

Topographic Suitability

1) What is the ideal elevation or range of elevation for wine grape growing? What is the least ideal elevation or range of elevation for this purpose?

   ____
   ____

2) What, if any, is the ideal slope or slope range for wine grape growing?

   ____
   ____

3) In terms of the aspect (orientation of the slope) of which a site is situated affecting sun exposure, please rank the least ideal (0) to most ideal (7) condition:

   North facing ____
   Northeast facing ____
   Northwest facing ____
   South facing ____
   Southeast facing ____
   Southwest facing ____
   East facing ____
   West facing ____

4) Large bodies of water have been identified as having an effect on the mesoclimate of specific sites and microclimate of different regions. This question has two parts:
    a. At what threshold (in m^2) would a body of water have an effect on a potential grape growing site? (At what point would a water body be considered a "large body of water?")

____

____

    b. What distance, in metres or kilometres, would a site have to be situated from a large body of water in order for that body of water to have an influence on the site's mesoclimate?

____

____

<u>Climatic Suitability</u>

The datasets provided for this project are derived from Natural Resources Canada baseline means from 1970-2013. Variables of growing degree-days (base 10°C and calculated from March 1st to November 30th growing season), frost free days (FFD's – base 0°C), and mean number of days less than -19°C, -23°C and -26°C.

5) The values for the mean number of growing degree-days (GGD's) between 1970 and 2013 range from 544 – 972. When classifying these data into equal intervals, which are presented below, does this presented classification represent the least ideal to most ideal conditions in terms of wine grape growing? Yes/No

    544-629 ___
    630-715 ___
    716-801 ___
    802-886 ___
    887-972 ___

    If no, please rank the classes accordingly (0 = least ideal, 4= most ideal)

6) The values for the frost-free days dataset range from 185-256. When classifying these data into equal intervals, which are presented below, does this presented classification represent the least ideal (lowest number of FFD's) to most ideal conditions (highest number of FFD's) in terms of wine grape growing? Yes/No

    185-199 ___
    200-213 ___
    214-227 ___
    228-241 ___
    242-256 ___

    If no, please rank the classes accordingly (0 = least ideal, 4= most ideal)

7) Some wine grape varieties are more tolerant of extreme cold temperatures than others, but when considering all varieties of grapes (hybrids and *Vitis vinifera*), which dataset would make the most sense to utilize as an input for the site suitability model? Mean days less than -19°C, -23°C or -26°C and why?

____
____
____

Soil Suitability

Version 3 of the Detailed Soil Surveys for Nova Scotia has visible discrepancies between counties. To eliminate these discrepancies and to create a more cohesive dataset, in an earlier consultation with Perennia, it was recommended that the variables of soil capability for agriculture, soil drainage, soil stoniness and rooting restrictions be extracted from the map sheets for each county based on soil series. The following items concern the individual soil variables:

8) In terms of soil drainage, please rank the following conditions from least ideal (0) to most ideal (7):

Excessively Drained ____
Rapidly Drained ____
Well to Rapidly Drained ____
Well Drained ____
Moderately Well Drained ____
Imperfectly Drained ____
Poorly Drained ____
Very Poorly Drained ____

9) In terms of soil stoniness, the occurrence of stones at the surface of the soil, please rank the following conditions from least ideal (0) to most ideal (5):

Non-stony: 0 or < 0.01% of surface covered ____
Slightly stony: 0.01 -0.1% of surface covered ____
Moderately stony: 0.1 - % of surface covered ____
Very stony: 3-15% of surface covered ____
Exceedingly stony: 15-50% of surface covered ____
Excessively stony: > 50 % of surface covered ____

10) In terms of soil rooting restriction, the soil layer which restricts root growth, please rank the following conditions from least ideal (0) to most ideal (4):

No root restricting layer _____
Growth restricted to second layer ____
Growth restricted to third layer ____
Growth restricted to fourth layer ____
Growth restricted to fifth layer ____

Thank you very much for taking the time to populate this questionnaire. If you have any comments, please express them below:

____
____
____

____

____

Your feedback is much appreciated. If you have any further comments or questions, please contact Charity Robicheau from the Applied Geomatics Research Group at 902-825-5478 or Charity.Robicheau@nscc.ca

Appendix E – Workflow to spatially enable NSDA datasets

Farm Registry Process

The following text describes the steps taken to modify the Farm Registry dataset provided by NSDA in order to prepare it for the AgriRisk GIS Web-Viewer.

Preparation of datasets

The column headings in a local copy of the Farm Registry Excel document provided by NSDA were modified to prepare the data for ArcMap. Column headings were required to have maximum 10 characters, no special characters, and no spaces. Civic point data acquired from GeoNOVA for NS were used to add spatial information to the Farm Registry data. In ArcMap 10.5.1, a new field was created in the civic point data that contained the address in a format similar to the Farmer Registry data. Formatting changes were made to the Farm Registry spreadsheet to ensure consistency between the two datasets. The modified Farm Registry excel data was added to ArcMap to be joined with the civic address data.

Join Data in ArcMap

A "Join & Relate was performed in ArcMap to link the Farm Registry and Civic Address data. The results were reviewed for missing and duplicate record. Various manual changes were made to both datasets were made in order to correct errors in the join, such as spacing or spelling errors. Some farms were excluded from the join if address information was too incomplete to match with civic address information. The Join was re-computed following the modifications. The results were exported as a shapefile containing spatially enabled farm registry data. Various quality control techniques were conducted to ensure accurate linking of Farm Registry spreadsheet and Civic Address information. The small number of farms that were excluded from the join were documented in a separate file.

Farm Registry Issues

The most common errors with assigning spatial information to the Farm Registry data were related to inconsistencies in address spelling, suffixes (e.g., ROAD vs RD. vs RD), discrepancies between mailing addresses and civic (e.g., listing PO Box vs street name), data in wrong fields, missing data (e.g., county name, which could have assisted with duplicate addresses, missing civic number), use of property ID vs civic address. In general, it was noted that Quality Assurance practices should be applied to the Farm Registry data in the future; NSCAF is an excellent source of confirmation of civic addresses.

Traceability, Fox and Mink Farm Data Process

The Traceability, Fox, and Mink Farm data were assigned spatial information in ArcMap following a similar methodology as was used for the Farmer Registry data. However, the join was generated between the property ID numbers (PIDs) from the NS PID Database and the farm data rather than using civic addresses, as above.

Common issues in the assigning of spatial information to the Traceability, Fox and Mink Farm data were related to duplicate PIDs that were caused by land having been subdivided and not modified, or multiple polygons resulting from a stream/river dividing a polygon. These were corrected manually and the join was recomputed. The join was examined using quality control process similar to above, and Nova Scotia properties from the farm excel data that were not joined were documented in a separate file. The successfully joined data were exported as shapefiles containing spatially enabled Traceability, Fox and Mink farm data.

Traceability Issues

Common issues in assigning spatial data to Traceability, Fox and Mink Farm data were related to the character length of the PID field, out of province or out of date PIDs, PID in the farm file with no corresponding PID in the PID database due to recent land subdivision.

Noxious Weeds Process

A total of five Noxious Weeds shapefiles were provided in GCS WGS 1984 coordinate system. They were each projected into NAD 1983 CSRS UTM Zone 20N. The projected shapefiles were then merged together to form one Noxious Weeds shapefile.

Noxious Weeds Issues

The data contained within the Noxious Weeds file is historical data from 1999. At that time, some of the data were tagged using a GPS unit and the remainder was manually entered into an Excel document. The data that were manually entered have spatial coordinates (latitude and longitude) set to zero, which places the data outside of Nova Scotia. It was decided to leave these outside points as is so that the data would not be lost since the features do contain attribute information that can be useful even though they are not spatially located in Nova Scotia.

Appendix F – Datasets generated for GIS web-viewer from all data providers

Dataset Title	Data Provider	Purpose
Mean days < -19°C from 1970-2013	AGRG	Provided by the Reflecting Society to AGRG to produce as a dataset and map service
Mean Frost Free Days (base 0°C) from 1970-2013	AGRG	Provided by the Reflecting Society to AGRG to produce as a dataset and map service
Mean Growing Degree Days (base 10°C) from 1970-2013	AGRG	Provided by the Reflecting Society to AGRG to produce as a dataset and map service
Mean days < -19°C for 2035	AGRG	Provided by the Reflecting Society to AGRG to produce as a dataset and map service
Mean days < -19°C for 2050	AGRG	Provided by the Reflecting Society to AGRG to produce as a dataset and map service
Mean Frost Free Days (base 0°C) for 2035	AGRG	Provided by the Reflecting Society to AGRG to produce as a dataset and map service
Mean Frost Free Days (base 0°C) for 2050	AGRG	Provided by the Reflecting Society to AGRG to produce as a dataset and map service
Mean Growing Degree Days (base 10°C) for 2035	AGRG	Provided by the Reflecting Society to AGRG to produce as a dataset and map service
Mean Growing Degree Days (base 10°C) for 2050	AGRG	Provided by the Reflecting Society to AGRG to produce as a dataset and map service
Nova Scotia Colour Shaded Relief (20m DEM)	AGRG	Derived from 20m provincial DEM
Nova Scotia Grape Growing Areas	AGRG	This layer is an AgriRisk product by AGRG; locations where grapes are currently growing
Nova Scotia Greyscale Hillshade (20m DEM)	AGRG	Derived from 20m provincial DEM
Nova Scotia Slope Aspect (100m DEM)	AGRG	Derived from 20 m provincial DEM
Nova Scotia Slope Degrees (100m DEM)	AGRG	Derived from 20m provincial DEM
Nova Scotia Wineries	AGRG	This layer is an AgriRisk product by AGRG; point locations of Nova Scotia wineries
Soil Capability for Agriculture	AGRG	This layer is an AgriRisk product by AGRG
Soil Drainage	AGRG	This layer is an AgriRisk product by AGRG
Soil Stoniness	AGRG	This layer is an AgriRisk product by AGRG
Soil Name	AGRG	This layer is an AgriRisk product by AGRG
Soil Root Restrictions	AGRG	This layer is an AgriRisk product by AGRG
Wine Grape Suitability Map - 2018	AGRG	This layer is an AgriRisk product by AGRG

Wine Grape Suitability Map - 2035	AGRG	This layer is an AgriRisk product by AGRG
Wine Grape Suitability Map - 2050	AGRG	This layer is an AgriRisk product by AGRG
Land Use Planning and Agricultural Use	Dalhousie University	Shows likelihood of land being available for grape growing in the short to medium term future based on land use policies and land use by-laws
Nova Scotia Farm Registration	NSDA/Programs & Risk Management	This has been identified through the NSDA data solicitation as key data available for the AgriRisk GIS viewer as a risk assessment tool
Traceability	NSDA/Agricultural Protection	This has been identified through the NSDA data solicitation as key data available for the AgriRisk GIS viewer as a risk assessment tool
Fox Farm	NSDA/Agricultural Protection	This has been identified through the NSDA data solicitation as key data available for the AgriRisk GIS viewer as a risk assessment tool
Mink Farm	NSDA/Agricultural Protection	This has been identified through the NSDA data solicitation as key data available for the AgriRisk GIS viewer as a risk assessment tool
Noxious Weeds	NSDA/Agricultural Protection	This has been identified through the NSDA data solicitation as key data available for the AgriRisk GIS viewer as a risk assessment tool
Apple Maggot	NSDA/Agricultural Protection	This has been identified through the NSDA data solicitation as key data available for the AgriRisk GIS viewer as a risk assessment tool
Dyke Centrelines	Saint Mary's University	Allows users to identify dyke centrelines
Flood Layers	Saint Mary's University	Shows users flood inundation extent based on various elevations and is limited by lidar extent
Foreshore Change Rates	Saint Mary's University	Allows users to view foreshore change rates associated with dykes
Foreshore Marshes	Saint Mary's University	Allows users to identify the present day extent of salt marshes
Legislated Marsh Boundaries	Saint Mary's University	Allows users to identify marshland boundaries
Probability of Dyke Overtopping	Saint Mary's University	Displays dyke centerlines probability of breach and/or overtopping

Appendix G – Suitability score statistics for mapped vineyard polygons for 2018

FID	Area (m²)	Min	Max	Range	Mean	Std	Majority	Minority	Median
0	41875	7	10	3	7.79	0.74	8	10	8
1	19725	7	8	1	7.42	0.49	7	8	7
2	1000	10	10	0	10.00	0.00	10	10	10
3	950	10	10	0	10.00	0.00	10	10	10
4	1450	10	10	0	10.00	0.00	10	10	10
5	400	9	10	1	9.56	0.50	10	9	10
6	27900	9	10	1	9.63	0.48	10	9	10
7	4725	8	8	0	8.00	0.00	8	8	8
8	4150	6	7	1	6.23	0.42	6	7	6
9	4025	6	8	2	6.20	0.60	6	8	6
10	32450	9	10	1	9.25	0.43	9	10	9
11	71125	9	10	1	9.09	0.29	9	10	9
12	36650	9	10	1	9.18	0.38	9	10	9
13	7625	9	10	1	9.30	0.46	9	10	9
14	27075	9	10	1	9.40	0.49	9	10	9
15	8625	6	10	4	9.68	0.80	10	6	10
16	1775	9	10	1	9.83	0.37	10	9	10
17	2425	10	10	0	10.00	0.00	10	10	10
18	5275	10	10	0	10.00	0.00	10	10	10
19	7775	6	10	4	9.24	1.57	10	6	10
20	4050	6	10	4	9.85	0.76	10	6	10
21	25225	8	10	2	9.49	0.70	10	8	10
22	12225	9	10	1	9.80	0.40	10	9	10
23	13300	9	10	1	9.27	0.44	9	10	9
24	7400	8	9	1	8.13	0.34	8	9	8
25	7875	8	9	1	8.09	0.29	8	9	8
26	3750	8	9	1	8.89	0.32	9	8	9
27	53500	5	10	5	7.42	2.01	5	6	8
28	20675	6	10	4	9.41	0.92	10	6	10
29	15650	5	10	5	8.37	1.72	10	5	9
30	15900	7	10	3	8.86	1.20	10	8	9
31	4400	5	7	2	5.13	0.48	5	7	5
32	3175	10	10	0	10.00	0.00	10	10	10
33	5450	9	10	1	9.01	0.10	9	10	9
34	8075	9	10	1	9.02	0.14	9	10	9
35	11175	7	10	3	9.73	0.47	10	7	10
36	1525	9	10	1	9.66	0.48	10	9	10
37	14125	10	10	0	10.00	0.00	10	10	10
38	36600	3	10	7	7.73	2.26	9	3	9
39	21425	7	10	3	9.18	0.50	9	7	9

40	6750	9	10	1	9.29	0.45	9	10	9
41	7800	9	10	1	9.25	0.43	9	10	9
42	14275	8	10	2	9.97	0.24	10	8	10
43	8100	3	5	2	3.71	0.95	3	4	3
44	21825	5	7	2	6.97	0.23	7	5	7
45	3450	8	10	2	9.16	0.99	10	8	10
46	2100	10	10	0	10.00	0.00	10	10	10
47	3425	10	10	0	10.00	0.00	10	10	10
48	2175	8	8	0	8.00	0.00	8	8	8
49	500	6	7	1	6.20	0.40	6	7	6
50	4300	5	5	0	5.00	0.00	5	5	5
51	31100	5	7	2	5.87	0.93	5	6	5
52	850	7	7	0	7.00	0.00	7	7	7
53	2175	7	7	0	7.00	0.00	7	7	7
54	2800	6	8	2	6.02	0.19	6	8	6
55	23875	7	9	2	8.22	0.51	8	7	8
56	9775	8	10	2	9.62	0.53	10	8	10
57	7875	7	10	3	8.20	1.14	8	10	8
58	23850	8	10	2	8.95	0.47	9	10	9
59	7275	9	9	0	9.00	0.00	9	9	9
60	5975	4	5	1	4.93	0.25	5	4	5
61	32300	7	10	3	8.83	1.14	10	9	9
62	650	9	9	0	9.00	0.00	9	9	9
63	4525	8	10	2	9.45	0.89	10	8	10
64	1225	7	7	0	7.00	0.00	7	7	7
65	3825	6	6	0	6.00	0.00	6	6	6
66	12225	6	6	0	6.00	0.00	6	6	6
67	625	7	9	2	8.28	0.96	9	7	9
68	375	8	10	2	8.80	0.98	8	10	8
69	12300	4	10	6	9.18	1.06	10	4	10
70	3250	6	7	1	6.61	0.49	7	6	7
71	3600	9	10	1	9.93	0.25	10	9	10
72	975	10	10	0	10.00	0.00	10	10	10
73	12625	9	10	1	9.95	0.22	10	9	10
74	35200	10	10	0	10.00	0.00	10	10	10
75	21200	7	9	2	7.98	0.71	8	9	8
76	14600	7	9	2	7.87	0.55	8	9	8
77	12900	6	9	3	8.64	0.96	9	8	9
78	7600	7	7	0	7.00	0.00	7	7	7
79	19275	7	7	0	7.00	0.00	7	7	7
80	15800	6	8	2	6.34	0.75	6	8	6
81	8775	5	9	4	6.96	1.53	6	5	6
82	18525	7	10	3	9.05	0.71	9	7	9
83	13625	8	10	2	8.90	0.55	9	10	9

84	3075	9	10	1	9.38	0.49	9	10	9
85	950	9	10	1	9.53	0.50	10	9	10
86	4650	6	8	2	7.99	0.15	8	6	8
87	3150	7	8	1	7.34	0.47	7	8	7
88	4350	7	9	2	7.02	0.21	7	9	7
89	5250	5	5	0	5.00	0.00	5	5	5
90	2875	4	5	1	4.09	0.28	4	5	4
91	2075	5	7	2	5.39	0.76	5	6	5
92	14300	8	10	2	9.45	0.55	9	8	9
93	16750	7	10	3	9.14	0.90	10	7	9
94	53100	9	10	1	9.70	0.46	10	9	10
95	6850	7	8	1	7.82	0.39	8	7	8
96	11500	6	9	3	7.92	0.86	8	6	8
97	7625	9	10	1	9.68	0.47	10	9	10
98	4225	8	10	2	8.79	0.98	8	10	8
99	725	5	5	0	5.00	0.00	5	5	5
100	1250	6	8	2	7.16	0.99	8	6	8
101	12625	9	10	1	9.68	0.47	10	9	10
102	1325	10	10	0	10.00	0.00	10	10	10
103	19325	9	10	1	9.45	0.50	9	10	9
104	12300	9	10	1	9.60	0.49	10	9	10
105	25250	8	10	2	9.38	0.50	9	8	9
106	7000	9	10	1	9.09	0.29	9	10	9
107	130975	5	9	4	6.65	0.87	7	9	7
108	78525	7	9	2	7.50	0.77	7	8	7
109	82725	6	10	4	9.25	1.22	10	6	10
110	5525	8	8	0	8.00	0.00	8	8	8
111	5025	8	8	0	8.00	0.00	8	8	8
112	4925	8	10	2	8.88	0.96	8	9	8
113	25125	6	10	4	7.17	0.99	7	9	7
114	14375	7	10	3	9.11	1.37	10	7	10
115	145350	6	10	4	9.10	1.39	10	8	10
116	25275	6	8	2	7.15	0.70	7	6	7
117	17475	8	10	2	9.12	0.49	9	8	9
118	8350	7	8	1	7.11	0.32	7	8	7
119	17300	5	7	2	6.64	0.77	7	5	7
120	8850	5	7	2	5.23	0.63	5	7	5
121	28675	9	9	0	9.00	0.00	9	9	9
122	1225	10	10	0	10.00	0.00	10	10	10
123	1925	9	10	1	9.22	0.41	9	10	9
124	56100	3	6	3	4.68	0.74	4	3	5
125	41050	3	6	3	5.88	0.56	6	4	6
126	10950	4	6	2	5.86	0.51	6	4	6
127	69525	6	9	3	8.33	0.86	9	6	9

128	18950	7	9	2	8.07	0.87	9	8	8
129	1500	8	8	0	8.00	0.00	8	8	8
130	17500	6	8	2	6.15	0.52	6	8	6
131	56700	6	9	3	7.79	1.33	9	7	8
132	4500	5	6	1	5.60	0.49	6	5	6
133	2400	6	8	2	7.71	0.71	8	6	8
134	23550	5	6	1	5.20	0.40	5	6	5
135	11700	5	7	2	6.36	0.53	6	5	6
136	26000	5	6	1	5.51	0.50	6	5	6
137	44875	5	6	1	5.12	0.33	5	6	5
138	22000	5	5	0	5.00	0.00	5	5	5
139	1875	5	5	0	5.00	0.00	5	5	5
140	7525	5	5	0	5.00	0.00	5	5	5
141	7825	5	8	3	5.74	0.57	6	8	6
142	9525	5	6	1	5.05	0.22	5	6	5
143	41450	5	8	3	7.78	0.72	8	5	8
144	34975	5	8	3	7.49	1.06	8	6	8
145	13150	5	6	1	5.05	0.22	5	6	5
146	22650	6	7	1	6.99	0.09	7	6	7
147	3975	7	9	2	7.50	0.87	7	9	7
148	1425	9	9	0	9.00	0.00	9	9	9
149	31150	5	9	4	6.76	1.26	7	5	7
150	39425	5	9	4	5.91	0.83	6	9	6
151	15425	5	9	4	6.14	0.95	6	9	6
152	27925	7	8	1	7.19	0.40	7	8	7
153	8700	7	8	1	7.57	0.49	8	7	8
154	1500	7	8	1	7.10	0.30	7	8	7
155	83425	3	10	7	9.19	1.66	10	8	10
156	28375	7	10	3	8.86	1.07	9	7	9
157	21175	3	10	7	7.37	2.07	8	3	8
158	87200	6	10	4	9.33	0.72	9	8	9
159	6200	7	8	1	7.95	0.21	8	7	8
160	36725	7	10	3	8.40	1.34	7	8	9
161	2950	9	10	1	9.86	0.35	10	9	10
162	16450	7	9	2	8.11	0.86	9	8	8
163	11275	9	10	1	9.49	0.50	9	10	9
164	11650	6	7	1	6.56	0.50	7	6	7
165	10575	6	7	1	6.68	0.47	7	6	7
166	7475	6	7	1	6.43	0.50	6	7	6
167	14900	7	7	0	7.00	0.00	7	7	7
168	1475	7	7	0	7.00	0.00	7	7	7
169	10375	5	7	2	5.57	0.89	5	6	5
170	1250	6	10	4	9.76	0.95	10	6	10
171	56000	3	10	7	9.13	1.79	10	4	10

172	54475	3	10	7	8.90	1.38	10	3	9
173	5050	6	9	3	6.68	1.25	6	7	6
174	1650	7	9	2	8.36	0.93	9	7	9
175	1425	9	10	1	9.14	0.35	9	10	9
176	6875	6	9	3	7.64	1.49	9	6	9
177	30725	7	10	3	7.61	0.80	7	10	7
178	4800	9	10	1	9.49	0.50	9	10	9
179	4750	9	10	1	9.53	0.50	10	9	10
180	16550	7	9	2	7.83	0.81	7	9	8
181	600	10	10	0	10.00	0.00	10	10	10
182	15125	7	10	3	9.58	1.04	10	7	10
183	19475	7	10	3	9.65	0.88	10	7	10
184	60025	4	6	2	5.58	0.70	6	4	6
185	11400	4	6	2	5.62	0.75	6	5	6
186	4775	6	8	2	6.97	0.20	7	8	7
187	5025	6	8	2	7.92	0.39	8	6	8
188	8000	4	5	1	4.00	0.06	4	5	4
189	93825	3	5	2	4.22	0.49	4	3	4
190	35725	8	10	2	9.46	0.72	10	8	10
191	3825	9	9	0	9.00	0.00	9	9	9
192	350	9	9	0	9.00	0.00	9	9	9
193	4325	6	6	0	6.00	0.00	6	6	6
194	4750	5	6	1	5.05	0.21	5	6	5
195	16250	8	10	2	8.79	0.83	8	10	9
196	7975	8	10	2	9.56	0.83	10	8	10
197	3900	6	9	3	6.33	0.93	6	9	6
198	3750	6	9	3	6.18	0.71	6	9	6
199	4900	6	7	1	6.77	0.42	7	6	7
200	3100	9	9	0	9.00	0.00	9	9	9
201	41375	6	10	4	9.36	0.91	10	6	10
202	1850	8	8	0	8.00	0.00	8	8	8
203	4225	7	7	0	7.00	0.00	7	7	7
204	9225	7	10	3	9.49	0.92	10	7	10
205	3425	6	6	0	6.00	0.00	6	6	6
206	16925	6	8	2	7.44	0.90	8	6	8
207	3900	6	6	0	6.00	0.00	6	6	6
208	28950	5	8	3	6.83	1.46	8	5	8
209	5800	5	6	1	5.95	0.22	6	5	6
210	19650	3	10	7	6.53	2.16	8	9	8
211	84375	7	10	3	8.46	1.17	8	9	8
212	44375	7	9	2	7.73	0.61	8	9	8
213	2675	8	9	1	8.08	0.28	8	9	8
214	5275	4	9	5	8.22	1.06	8	4	8
215	29950	7	9	2	8.48	0.66	9	7	9

216	2850	7	10	3	7.03	0.28	7	10	7
217	9575	7	8	1	7.57	0.50	8	7	8
218	20975	6	9	3	8.35	1.24	9	6	9
219	5325	9	9	0	9.00	0.00	9	9	9
220	33650	8	9	1	8.46	0.50	8	9	8
221	8200	7	7	0	7.00	0.00	7	7	7
222	3675	6	7	1	6.96	0.20	7	6	7
224	300	7	7	0	7.00	0.00	7	7	7
225	5275	8	8	0	8.00	0.00	8	8	8
226	6775	6	7	1	6.48	0.50	6	7	6
227	12150	6	7	1	6.72	0.45	7	6	7
228	32700	5	6	1	5.23	0.42	5	6	5
229	1575	5	6	1	5.32	0.47	5	6	5
230	2000	6	7	1	6.34	0.47	6	7	6
231	1375	10	10	0	10.00	0.00	10	10	10
232	15975	8	10	2	9.55	0.77	10	9	10
233	42650	9	10	1	9.62	0.49	10	9	10
234	32825	9	10	1	9.87	0.33	10	9	10
235	4775	7	8	1	7.85	0.36	8	7	8
236	80400	7	9	2	8.13	0.55	8	7	8
237	12800	7	9	2	8.16	0.82	9	7	8
238	5300	6	9	3	8.84	0.67	9	6	9
239	1850	9	9	0	9.00	0.00	9	9	9
Mean		**6.90**	**8.60**	**1.70**	**7.90**	**0.54**	**7.97**	**7.53**	**7.97**

Appendix H – Suitability score statistics for mapped vineyard polygons for 2035

FID	Area (m²)	Min	Max	Range	Mean	Std	Majority	Minority	Median
0	41875	7	10	3	7.02	0.20	7	10	7
1	19725	7	7	0	7.00	0.00	7	7	7
2	1000	10	10	0	10.00	0.00	10	10	10
3	950	10	10	0	10.00	0.00	10	10	10
4	1450	10	10	0	10.00	0.00	10	10	10
5	400	9	9	0	9.00	0.00	9	9	9
6	27900	9	10	1	9.14	0.35	9	10	9
7	4725	8	8	0	8.00	0.00	8	8	8
8	4150	5	7	2	6.14	0.61	6	5	6
9	4025	7	7	0	7.00	0.00	7	7	7
10	32450	9	10	1	9.33	0.47	9	10	9
11	71125	9	10	1	9.44	0.50	9	10	9
12	36650	9	10	1	9.00	0.06	9	10	9
13	7625	9	10	1	9.01	0.11	9	10	9
14	27075	9	10	1	9.30	0.46	9	10	9
15	8625	7	10	3	9.38	1.18	10	9	10
16	1775	10	10	0	10.00	0.00	10	10	10
17	2425	10	10	0	10.00	0.00	10	10	10
18	5275	10	10	0	10.00	0.00	10	10	10
19	7775	8	10	2	9.61	0.79	10	8	10
20	4050	5	10	5	9.32	1.06	10	5	10
21	25225	8	10	2	9.41	0.61	10	8	9
22	12225	9	10	1	9.78	0.42	10	9	10
23	13300	7	10	3	9.69	0.63	10	7	10
24	7400	8	9	1	8.18	0.39	8	9	8
25	7875	8	9	1	8.08	0.28	8	9	8
26	3750	9	9	0	9.00	0.00	9	9	9
27	53500	4	10	6	7.56	2.54	10	8	10
28	20675	5	10	5	9.98	0.30	10	5	10
29	15650	5	10	5	8.25	1.91	10	9	10
30	15900	5	10	5	8.74	1.76	10	5	9
31	4400	5	7	2	6.67	0.74	7	5	7
32	3175	9	10	1	9.91	0.29	10	9	10
33	5450	9	10	1	9.42	0.49	9	10	9
34	8075	9	10	1	9.62	0.49	10	9	10
35	11175	4	10	6	9.93	0.63	10	4	10
36	1525	10	10	0	10.00	0.00	10	10	10
37	14125	10	10	0	10.00	0.00	10	10	10
38	36600	2	10	8	7.51	2.80	10	2	9
39	21425	8	10	2	9.47	0.59	10	8	10
40	6750	8	10	2	9.10	0.88	10	9	9
41	7800	9	10	1	9.26	0.44	9	10	9

42	14275	9	10	1	9.91	0.29	10	9	10
43	8100	3	5	2	4.55	0.84	5	3	5
44	21825	4	7	3	6.82	0.59	7	4	7
45	3450	1	9	8	7.20	3.34	9	1	9
46	2100	9	9	0	9.00	0.00	9	9	9
47	3425	9	9	0	9.00	0.00	9	9	9
48	2175	1	7	6	1.07	0.64	1	7	1
49	500	1	1	0	1.00	0.00	1	1	1
50	4300	5	5	0	5.00	0.00	5	5	5
51	31100	5	7	2	5.30	0.53	5	7	5
52	850	8	8	0	8.00	0.00	8	8	8
53	2175	6	7	1	6.28	0.45	6	7	6
54	2800	6	6	0	6.00	0.00	6	6	6
55	23875	7	9	2	8.35	0.72	9	7	8
56	9775	9	10	1	9.77	0.42	10	9	10
57	7875	7	9	2	7.11	0.46	7	9	7
58	23850	9	10	1	9.29	0.45	9	10	9
59	7275	7	9	2	8.53	0.85	9	7	9
60	5975	4	4	0	4.00	0.00	4	4	4
61	32300	7	10	3	8.85	1.31	10	9	10
62	650	9	9	0	9.00	0.00	9	9	9
63	4525	7	10	3	9.82	0.62	10	7	10
64	1225	5	7	2	6.55	0.83	7	5	7
65	3825	7	8	1	7.34	0.47	7	8	7
66	12225	5	6	1	5.35	0.48	5	6	5
67	625	9	9	0	9.00	0.00	9	9	9
68	375	9	9	0	9.00	0.00	9	9	9
69	12300	6	9	3	7.87	1.22	9	6	9
70	3250	6	6	0	6.00	0.00	6	6	6
71	3600	7	10	3	9.71	0.89	10	7	10
72	975	10	10	0	10.00	0.00	10	10	10
73	12625	9	10	1	9.83	0.37	10	9	10
74	35200	10	10	0	10.00	0.00	10	10	10
75	21200	6	9	3	7.78	0.97	8	6	8
76	14600	5	8	3	6.63	1.28	8	7	7
77	12900	6	7	1	6.88	0.33	7	6	7
78	7600	7	8	1	7.12	0.32	7	8	7
79	19275	8	8	0	8.00	0.00	8	8	8
80	15800	6	9	3	7.24	1.32	6	7	7
81	8775	6	7	1	6.63	0.48	7	6	7
82	18525	10	10	0	10.00	0.00	10	10	10
83	13625	10	10	0	10.00	0.00	10	10	10
84	3075	10	10	0	10.00	0.00	10	10	10
85	950	10	10	0	10.00	0.00	10	10	10

86	4650	6	9	3	8.23	1.31	9	6	9
87	3150	1	1	0	1.00	0.00	1	1	1
88	4350	7	7	0	7.00	0.00	7	7	7
89	5250	4	5	1	4.98	0.14	5	4	5
90	2875	5	5	0	5.00	0.00	5	5	5
91	2075	6	6	0	6.00	0.00	6	6	6
92	14300	9	10	1	9.60	0.49	10	9	10
93	16750	5	10	5	9.34	0.72	9	5	9
94	53100	10	10	0	10.00	0.00	10	10	10
95	6850	6	8	2	7.23	0.97	8	6	8
96	11500	5	9	4	6.61	1.63	6	5	6
97	20600	9	10	1	9.91	0.29	10	9	10
98	4225	5	10	5	8.15	1.34	8	5	8
99	725	5	5	0	5.00	0.00	5	5	5
100	1250	7	7	0	7.00	0.00	7	7	7
101	12625	8	10	2	9.10	0.87	10	9	9
102	1325	10	10	0	10.00	0.00	10	10	10
103	19325	9	10	1	9.52	0.50	10	9	10
104	12300	9	10	1	9.83	0.38	10	9	10
105	25250	9	10	1	9.47	0.50	9	10	9
106	7000	10	10	0	10.00	0.00	10	10	10
107	130975	1	7	6	5.47	1.45	6	4	6
108	78525	6	9	3	7.70	1.08	9	6	8
109	82725	6	10	4	9.06	1.18	10	6	10
110	5525	8	8	0	8.00	0.00	8	8	8
111	5025	8	8	0	8.00	0.00	8	8	8
112	4925	8	9	1	8.07	0.26	8	9	8
113	25125	6	10	4	7.07	0.50	7	6	7
114	14375	10	10	0	10.00	0.00	10	10	10
115	145350	3	10	7	8.81	1.51	10	3	9
116	25275	6	7	1	6.93	0.25	7	6	7
117	17475	8	10	2	8.89	0.76	9	10	9
118	8350	4	7	3	6.99	0.16	7	4	7
119	17300	7	7	0	7.00	0.00	7	7	7
120	8850	4	7	3	5.52	1.47	4	6	6
121	28675	9	9	0	9.00	0.00	9	9	9
122	1225	10	10	0	10.00	0.00	10	10	10
123	1925	9	10	1	9.27	0.45	9	10	9
124	56100	3	5	2	4.61	0.50	5	3	5
125	41050	4	5	1	4.97	0.18	5	4	5
126	10950	5	6	1	5.59	0.49	6	5	6
127	69525	8	9	1	8.15	0.36	8	9	8
128	18950	6	8	2	7.21	0.92	8	7	8
129	1500	6	7	1	6.72	0.45	7	6	7

130	17500	5	7	2	6.04	0.42	6	5	6
131	56700	5	9	4	7.41	1.32	8	5	8
132	4500	7	7	0	7.00	0.00	7	7	7
133	2400	8	8	0	8.00	0.00	8	8	8
134	23550	5	6	1	5.15	0.36	5	6	5
135	11700	5	6	1	5.65	0.48	6	5	6
136	26000	5	6	1	5.98	0.15	6	5	6
137	44875	5	6	1	5.21	0.41	5	6	5
138	22000	5	6	1	5.45	0.50	5	6	5
139	1875	5	6	1	5.15	0.35	5	6	5
140	7525	5	7	2	5.08	0.38	5	6	5
141	7825	5	6	1	5.41	0.49	5	6	5
142	9525	6	6	0	6.00	0.00	6	6	6
143	41450	5	8	3	7.50	1.10	8	6	8
144	34975	5	9	4	7.76	1.59	9	6	9
145	13150	5	6	1	5.43	0.50	5	6	5
146	22650	6	8	2	7.01	0.69	7	6	7
147	3975	6	8	2	7.31	0.53	7	6	7
148	1425	7	7	0	7.00	0.00	7	7	7
149	31150	5	8	3	6.24	1.17	6	7	6
150	39425	5	8	3	5.89	1.03	5	8	5
151	15425	5	7	2	5.50	0.56	5	7	5
152	27925	7	7	0	7.00	0.00	7	7	7
153	8700	7	7	0	7.00	0.00	7	7	7
154	1500	7	8	1	7.13	0.34	7	8	7
155	83425	5	10	5	9.59	1.23	10	7	10
156	28375	7	10	3	9.08	1.22	10	9	10
157	21175	6	10	4	8.29	0.75	8	10	8
158	87200	8	10	2	9.65	0.48	10	8	10
159	6200	7	8	1	7.66	0.47	8	7	8
160	36725	6	10	4	8.26	1.17	7	6	9
161	2950	7	10	3	9.75	0.58	10	7	10
162	16450	8	10	2	8.51	0.87	8	10	8
163	11275	8	10	2	9.89	0.46	10	8	10
164	11650	6	7	1	6.26	0.44	6	7	6
165	10575	6	8	2	7.37	0.60	7	6	7
166	7475	6	8	2	6.26	0.67	6	8	6
167	14900	6	8	2	7.61	0.49	8	6	8
168	1475	6	7	1	6.41	0.49	6	7	6
169	10375	5	5	0	5.00	0.00	5	5	5
170	1250	6	10	4	9.22	0.64	9	6	9
171	56000	2	10	8	9.70	0.60	10	2	10
172	54475	6	10	4	9.75	0.52	10	6	10
173	5050	5	7	2	6.23	0.96	7	6	7

174	1650	6	7	1	6.91	0.29	7	6	7
175	1425	1	9	8	8.86	1.05	9	1	9
176	6875	5	8	3	6.66	1.00	6	5	6
177	30725	6	9	3	7.47	0.67	7	6	7
178	4800	7	10	3	9.02	1.29	10	9	10
179	4750	7	10	3	9.18	1.34	10	7	10
180	16550	7	9	2	7.58	0.91	7	9	7
181	600	10	10	0	10.00	0.00	10	10	10
182	15125	6	10	4	9.02	1.38	10	6	10
183	19475	9	10	1	9.75	0.43	10	9	10
184	52350	4	7	3	5.38	1.00	6	7	6
185	11400	4	7	3	5.79	1.37	7	5	7
186	4775	6	8	2	7.35	0.94	8	6	8
187	5025	1	9	8	6.61	3.66	9	1	9
188	8000	4	4	0	4.00	0.00	4	4	4
189	103025	3	5	2	4.48	0.61	5	3	5
190	35725	8	10	2	9.57	0.67	10	8	10
191	3825	8	8	0	8.00	0.00	8	8	8
192	350	9	9	0	9.00	0.00	9	9	9
193	4325	5	5	0	5.00	0.00	5	5	5
194	4750	5	5	0	5.00	0.00	5	5	5
195	16250	7	10	3	8.44	1.34	7	9	9
196	7975	10	10	0	10.00	0.00	10	10	10
197	4375	6	7	1	6.26	0.44	6	7	6
198	3525	6	6	0	6.00	0.00	6	6	6
199	4900	6	6	0	6.00	0.00	6	6	6
200	3100	9	9	0	9.00	0.00	9	9	9
201	41375	6	10	4	9.48	0.93	10	6	10
202	1850	8	8	0	8.00	0.00	8	8	8
203	4225	7	7	0	7.00	0.00	7	7	7
204	9225	8	10	2	9.17	0.85	10	9	9
205	3425	6	6	0	6.00	0.00	6	6	6
206	16925	6	8	2	7.61	0.79	8	6	8
207	3900	6	6	0	6.00	0.00	6	6	6
208	28950	5	9	4	7.18	1.68	9	6	8
209	5800	5	6	1	5.42	0.49	5	6	5
210	19650	6	10	4	8.01	0.82	8	10	8
211	84375	6	10	4	8.77	1.32	10	9	8
212	44400	6	8	2	6.97	0.56	7	8	7
213	2675	8	8	0	8.00	0.00	8	8	8
214	5275	3	9	6	4.45	2.36	3	9	3
215	29950	6	9	3	8.56	0.84	9	6	9
216	2850	7	10	3	9.76	0.81	10	7	10
217	9575	6	8	2	7.00	1.00	6	7	7

218	20975	3	9	6	8.52	0.88	9	3	9
219	5325	6	9	3	8.84	0.67	9	8	9
220	33650	7	9	2	8.49	0.53	9	7	9
221	8200	3	8	5	7.50	1.48	8	5	8
222	3675	6	6	0	6.00	0.00	6	6	6
223	100	7	7	0	7.00	0.00	7	7	7
225	5275	8	8	0	8.00	0.00	8	8	8
226	6775	7	8	1	7.00	0.06	7	8	7
227	12150	6	6	0	6.00	0.00	6	6	6
228	32700	5	6	1	5.28	0.45	5	6	5
229	1575	5	5	0	5.00	0.00	5	5	5
230	3400	7	7	0	7.00	0.00	7	7	7
231	1375	10	10	0	10.00	0.00	10	10	10
232	15975	7	10	3	9.76	0.82	10	7	10
233	42650	10	10	0	10.00	0.00	10	10	10
234	32825	10	10	0	10.00	0.00	10	10	10
235	4775	7	8	1	7.98	0.12	8	7	8
236	80400	5	9	4	7.87	0.85	8	7	8
237	12800	4	6	2	5.20	0.62	5	4	5
238	5300	5	7	2	6.19	0.44	6	5	6
239	1850	6	9	3	8.07	1.39	9	6	9
Mean		**6.61**	**8.34**	**1.73**	**7.73**	**0.53**	**7.87**	**7.14**	**7.85**

Appendix I – Suitability score statistics for mapped vineyard polygons for 2050

FID	Area (m^2)	Min	Max	Range	Mean	Std	Majority	Minority	Median
0	41875	7	10	3	7.33	0.49	7	10	7
1	19725	7	8	1	7.69	0.46	8	7	8
2	1000	10	10	0	10.00	0.00	10	10	10
3	950	10	10	0	10.00	0.00	10	10	10
4	1450	10	10	0	10.00	0.00	10	10	10
5	400	9	9	0	9.00	0.00	9	9	9
6	27900	9	10	1	9.14	0.35	9	10	9
7	4725	7	9	2	7.11	0.42	7	8	7
8	4150	6	7	1	6.87	0.33	7	6	7
9	4025	7	7	0	7.00	0.00	7	7	7
10	32450	10	10	0	10.00	0.00	10	10	10
11	71125	10	10	0	10.00	0.00	10	10	10
12	36650	10	10	0	10.00	0.00	10	10	10
13	7625	10	10	0	10.00	0.00	10	10	10
14	27075	10	10	0	10.00	0.00	10	10	10
15	8625	7	10	3	9.43	1.18	10	7	10
16	1775	10	10	0	10.00	0.00	10	10	10
17	2425	10	10	0	10.00	0.00	10	10	10
18	5275	10	10	0	10.00	0.00	10	10	10
19	7775	8	10	2	9.61	0.79	10	8	10
20	4050	5	10	5	9.32	1.06	10	5	10
21	25225	8	10	2	9.18	0.87	10	9	9
22	12225	9	10	1	9.78	0.42	10	9	10
23	13300	8	10	2	9.72	0.51	10	8	10
24	7400	8	9	1	8.18	0.39	8	9	8
25	7875	8	9	1	8.08	0.28	8	9	8
26	3750	9	9	0	9.00	0.00	9	9	9
27	53500	5	10	5	7.72	2.37	10	8	10
28	20675	6	10	4	9.99	0.24	10	6	10
29	15650	5	10	5	8.44	1.83	10	9	10
30	15900	6	10	4	8.92	1.40	10	6	9
31	4400	6	7	1	6.84	0.37	7	6	7
32	3175	10	10	0	10.00	0.00	10	10	10
33	5450	10	10	0	10.00	0.00	10	10	10
34	8075	10	10	0	10.00	0.00	10	10	10
35	11175	4	10	6	9.93	0.63	10	4	10
36	1525	10	10	0	10.00	0.00	10	10	10
37	14125	10	10	0	10.00	0.00	10	10	10
38	36600	4	10	6	7.64	2.63	10	5	9
39	21425	10	10	0	10.00	0.00	10	10	10
40	6750	8	10	2	9.32	0.95	10	8	10

41	7800	10	10	0	10.00	0.00	10	10	10
42	14275	9	10	1	9.91	0.29	10	9	10
43	8100	4	6	2	4.61	0.88	4	5	4
44	21825	5	7	2	6.82	0.57	7	5	7
45	3450	1	9	8	7.20	3.34	9	1	9
46	2100	1	9	8	2.90	3.41	1	9	1
47	3425	9	9	0	9.00	0.00	9	9	9
48	2175	1	8	7	1.08	0.75	1	8	1
49	500	1	1	0	1.00	0.00	1	1	1
50	4300	5	6	1	5.96	0.20	6	5	6
51	31100	5	7	2	5.38	0.57	5	7	5
52	850	8	8	0	8.00	0.00	8	8	8
53	2175	7	7	0	7.00	0.00	7	7	7
54	2800	7	7	0	7.00	0.00	7	7	7
55	23875	7	9	2	8.43	0.61	9	7	8
56	9775	10	10	0	10.00	0.00	10	10	10
57	7875	7	10	3	7.87	0.64	8	9	8
58	23850	9	10	1	9.29	0.45	9	10	9
59	7275	8	9	1	8.77	0.42	9	8	9
60	5975	5	5	0	5.00	0.00	5	5	5
61	32300	7	10	3	8.88	1.32	10	8	10
62	650	10	10	0	10.00	0.00	10	10	10
63	4525	8	8	0	8.00	0.00	8	8	8
64	1225	7	7	0	7.00	0.00	7	7	7
65	3825	7	9	2	7.68	0.95	7	9	7
66	12225	6	6	0	6.00	0.00	6	6	6
67	625	9	9	0	9.00	0.00	9	9	9
68	375	9	9	0	9.00	0.00	9	9	9
69	12300	7	9	2	8.35	0.75	9	7	9
70	3250	7	7	0	7.00	0.00	7	7	7
71	3600	7	10	3	9.71	0.89	10	7	10
72	975	10	10	0	10.00	0.00	10	10	10
73	12625	9	10	1	9.90	0.30	10	9	10
74	35200	10	10	0	10.00	0.00	10	10	10
75	21200	7	9	2	7.93	0.75	8	9	8
76	14600	7	8	1	7.40	0.49	7	8	7
77	12900	6	8	2	7.67	0.68	8	7	8
78	7600	8	9	1	8.06	0.23	8	9	8
79	19275	8	9	1	8.42	0.49	8	9	8
80	15800	6	9	3	7.36	1.25	9	6	7
81	8775	7	7	0	7.00	0.00	7	7	7
82	18525	10	10	0	10.00	0.00	10	10	10
83	13625	10	10	0	10.00	0.00	10	10	10
84	3075	10	10	0	10.00	0.00	10	10	10

85	950	10	10	0	10.00	0.00	10	10	10
86	4650	7	9	2	8.48	0.88	9	7	9
87	3150	1	1	0	1.00	0.00	1	1	1
88	4350	7	7	0	7.00	0.00	7	7	7
89	5250	5	5	0	5.00	0.00	5	5	5
90	2875	5	5	0	5.00	0.00	5	5	5
91	2075	7	7	0	7.00	0.00	7	7	7
92	14300	9	10	1	9.60	0.49	10	9	10
93	16750	6	10	4	9.35	0.67	9	6	9
94	53100	10	10	0	10.00	0.00	10	10	10
95	6850	7	9	2	8.23	0.97	9	7	9
96	11500	6	9	3	7.31	1.19	7	6	7
97	20600	9	10	1	9.91	0.29	10	9	10
98	4225	6	10	4	8.25	1.11	8	6	8
99	725	5	5	0	5.00	0.00	5	5	5
100	1250	7	7	0	7.00	0.00	7	7	7
101	12625	8	10	2	9.37	0.59	9	8	9
102	1325	10	10	0	10.00	0.00	10	10	10
103	19325	10	10	0	10.00	0.00	10	10	10
104	12300	9	10	1	9.99	0.10	10	9	10
105	25250	9	10	1	9.47	0.50	9	10	9
106	7000	10	10	0	10.00	0.00	10	10	10
107	130975	1	8	7	6.31	1.00	7	1	7
108	78525	7	9	2	7.72	0.74	7	9	8
109	82725	6	10	4	9.14	1.08	10	6	10
110	5525	9	9	0	9.00	0.00	9	9	9
111	5025	8	8	0	8.00	0.00	8	8	8
112	4925	8	9	1	8.07	0.26	8	9	8
113	25125	7	10	3	7.08	0.49	7	10	7
114	14375	10	10	0	10.00	0.00	10	10	10
115	145350	3	10	7	9.16	1.52	10	3	10
116	25275	6	7	1	6.93	0.25	7	6	7
117	17475	8	10	2	9.22	0.46	9	8	9
118	8350	5	8	3	7.99	0.18	8	5	8
119	17300	7	8	1	7.01	0.11	7	8	7
120	8850	5	7	2	6.00	0.98	5	6	6
121	28675	9	9	0	9.00	0.00	9	9	9
122	1225	10	10	0	10.00	0.00	10	10	10
123	1925	9	10	1	9.27	0.45	9	10	9
124	56100	3	6	3	4.56	0.51	5	6	5
125	41050	5	6	1	5.93	0.26	6	5	6
126	10950	6	6	0	6.00	0.00	6	6	6
127	69525	8	9	1	8.66	0.47	9	8	9
128	18950	7	8	1	7.55	0.50	8	7	8

129	1500	7	8	1	7.72	0.45	8	7	8
130	17500	6	8	2	7.04	0.42	7	6	7
131	56700	6	9	3	7.71	0.96	8	6	8
132	4500	7	7	0	7.00	0.00	7	7	7
133	2400	9	9	0	9.00	0.00	9	9	9
134	23550	6	7	1	6.02	0.15	6	7	6
135	11700	6	7	1	6.65	0.48	7	6	7
136	26000	6	7	1	6.75	0.43	7	6	7
137	44875	6	7	1	6.04	0.20	6	7	6
138	22000	6	6	0	6.00	0.00	6	6	6
139	1875	6	7	1	6.09	0.29	6	7	6
140	7525	6	7	1	6.04	0.19	6	7	6
141	7825	6	7	1	6.41	0.49	6	7	6
142	9525	7	7	0	7.00	0.00	7	7	7
143	41450	6	9	3	8.27	1.08	9	7	9
144	34975	6	9	3	8.15	1.19	9	8	9
145	13150	5	5	0	5.00	0.00	5	5	5
146	22650	6	9	3	7.88	1.01	7	6	7
147	3975	7	7	0	7.00	0.00	7	7	7
148	1425	7	7	0	7.00	0.00	7	7	7
149	31150	5	9	4	7.38	1.10	7	6	7
150	39425	5	9	4	6.52	1.08	7	9	7
151	15425	5	7	2	6.32	0.71	7	5	6
152	27925	7	7	0	7.00	0.00	7	7	7
153	8700	7	8	1	7.07	0.25	7	8	7
154	1500	7	8	1	7.50	0.50	7	7	7
155	83425	5	10	5	9.60	1.21	10	7	10
156	28375	7	10	3	9.08	1.22	10	9	10
157	21175	6	10	4	8.29	0.75	8	10	8
158	87200	8	10	2	9.83	0.38	10	8	10
159	6200	7	8	1	7.66	0.47	8	7	8
160	36725	6	10	4	8.26	1.17	7	6	9
161	2950	8	10	2	9.78	0.47	10	8	10
162	16450	8	10	2	8.51	0.87	8	10	8
163	11275	8	10	2	9.89	0.46	10	8	10
164	11650	6	8	2	7.58	0.82	8	6	8
165	10575	8	8	0	8.00	0.00	8	8	8
166	7475	8	8	0	8.00	0.00	8	8	8
167	14900	8	8	0	8.00	0.00	8	8	8
168	1475	6	7	1	6.49	0.50	6	7	6
169	10375	6	6	0	6.00	0.00	6	6	6
170	1250	7	10	3	9.24	0.55	9	7	9
171	56000	3	10	7	9.70	0.59	10	3	10
172	54475	7	10	3	9.76	0.47	10	7	10

173	5050	6	7	1	6.62	0.48	7	6	7
174	1650	7	7	0	7.00	0.00	7	7	7
175	1425	1	9	8	8.86	1.05	9	1	9
176	6875	6	9	3	8.85	0.63	9	7	9
177	30725	7	9	2	7.51	0.61	7	9	7
178	4800	7	10	3	9.17	1.34	10	7	10
179	4750	7	10	3	9.18	1.34	10	7	10
180	16550	7	9	2	7.60	0.91	7	8	7
181	600	10	10	0	10.00	0.00	10	10	10
182	15125	6	10	4	9.02	1.38	10	6	10
183	19475	9	10	1	9.75	0.43	10	9	10
184	52350	5	7	2	5.71	0.55	6	7	6
185	11400	5	7	2	6.10	0.99	7	5	7
186	4775	8	8	0	8.00	0.00	8	8	8
187	5025	1	9	8	6.61	3.66	9	1	9
188	8000	5	5	0	5.00	0.00	5	5	5
189	103025	5	5	0	5.00	0.00	5	5	5
190	35725	8	10	2	9.57	0.67	10	8	10
191	3825	9	9	0	9.00	0.00	9	9	9
192	350	9	9	0	9.00	0.00	9	9	9
193	4325	5	6	1	5.14	0.35	5	6	5
194	4750	5	6	1	5.83	0.37	6	5	6
195	16250	8	10	2	9.11	0.99	10	8	10
196	7975	10	10	0	10.00	0.00	10	10	10
197	4375	6	8	2	6.83	0.81	6	8	7
198	3525	6	7	1	6.96	0.18	7	6	7
199	4900	6	7	1	6.41	0.49	6	7	6
200	3100	9	9	0	9.00	0.00	9	9	9
201	41375	7	10	3	9.53	0.75	10	7	10
202	1850	9	9	0	9.00	0.00	9	9	9
203	4225	8	8	0	8.00	0.00	8	8	8
204	9225	8	10	2	9.17	0.85	10	9	9
205	3425	6	8	2	6.07	0.38	6	8	6
206	16925	6	9	3	7.68	0.91	7	6	7
207	3900	6	6	0	6.00	0.00	6	6	6
208	28950	6	9	3	7.82	1.35	9	8	9
209	5800	6	7	1	6.42	0.49	6	7	6
210	19650	6	10	4	8.01	0.82	8	10	8
211	84375	6	10	4	8.59	1.44	10	9	8
212	44400	7	7	0	7.00	0.00	7	7	7
213	2675	8	8	0	8.00	0.00	8	8	8
214	5275	3	9	6	4.45	2.36	3	9	3
215	29950	6	9	3	8.56	0.84	9	6	9
216	2850	7	10	3	9.76	0.81	10	7	10

217	9575	6	8	2	7.05	0.97	8	7	8
218	20975	4	9	5	8.87	0.72	9	4	9
219	5325	7	9	2	8.90	0.44	9	7	9
220	33650	8	9	1	8.57	0.49	9	8	9
221	8200	3	8	5	7.51	1.47	8	6	8
222	3675	6	6	0	6.00	0.00	6	6	6
223	100	7	7	0	7.00	0.00	7	7	7
225	5275	8	8	0	8.00	0.00	8	8	8
226	6775	7	9	2	7.19	0.40	7	9	7
227	12150	7	9	2	7.50	0.87	7	9	7
228	32700	6	7	1	6.31	0.46	6	7	6
229	1575	6	6	0	6.00	0.00	6	6	6
230	3400	8	8	0	8.00	0.00	8	8	8
231	1375	10	10	0	10.00	0.00	10	10	10
232	15975	10	10	0	10.00	0.00	10	10	10
233	42650	10	10	0	10.00	0.00	10	10	10
234	32825	10	10	0	10.00	0.00	10	10	10
235	4775	7	9	2	8.69	0.50	9	7	9
236	80400	6	9	3	8.52	0.78	9	7	9
237	12800	5	7	2	6.62	0.78	7	5	7
238	5300	5	7	2	6.96	0.27	7	5	7
239	1850	7	9	2	8.38	0.93	9	7	9
Mean		**7.04**	**8.58**	**1.54**	**8.01**	**0.47**	**8.13**	**7.56**	**8.11**