January 25, 2011

Pre-settlement Vegetation Mapping for the Greater Toronto Area, Including the Regions of Hamilton, Halton, Peel and York, and the Credit Valley Watershed

Danijela Puric-Mladenovic

with assistance from Julia Buck, and Alex MacIntosh

Table of Contents

Acknowledgements:

We would like to acknowledge the support and contributions of the following organizations and institutions:

- Region of Peel, Region of Hamilton, Halton Region, York Region, Credit Valley Conservation, University of Toronto, Ontario Ministry of Natural Resources.

We would also like to acknowledge the support and contributions of the following individuals to the pre-settlement mapping project:

- Iain Rayner, Geoff Clark, James McHattie, David Bradley, Nayna Khalatkar, Gergin Naoumov, and Ryan Large at the Southern Science and Information Section, Ontario Ministry of Natural Resources
- Andy Kenney and Shawar Aslam at the Faculty of Forestry, University of Toronto
- Wasyl Bakowsky at the Natural Heritage and Information Section, Ontario Ministry of Natural Resources
- Eric Ansel, Jim Macdonald, Deborah Scott, and Donna Gertridge at the Crown Land Surveyor`s Office, Government of Ontario.
- Dan McKenney at the Canadian Forestry Service, Natural Resources Canada.
- Cover photos provided by the Archives of Ontario

This report can be referenced as:

Puric-Mladenovic, D. Pre-settlement Vegetation Mapping for the Greater Toronto Area, including the Regions of Hamilton, Halton, Peel and York and the Credit Valley Watershed. Faculty of Forestry, University of Toronto, January 2011.

Contact us:

If you have any questions about the methodologies or analysis that were used to produce the pre-settlement mapping, or applications of the product or if you want to discuss expanding the scope and / or geographic area of pre-settlement vegetation mapping coverage please contact:

Dr. Danijela Puric-Mladenovic
danijela.puricmladenovic@ontario.ca
or
d.puric@utoronto.ca

Introduction

Pre-settlement vegetation mapping is based on statistically derived models that map tree species distributions and landscape characteristics as they were prior to European Settlement. Before the first major waves of European settlement in southern Ontario, information on land and vegetation characteristics was collected by land surveyors to support and direct land settlement. These historical records permit reconstruction of the composition and distribution of historical vegetation cover.

Prior to European settlement, the landscape of southern Ontario was a mosaic of prairie, savanna, and marsh amidst predominately forested vegetation. In the 1800s, the region was described as a “landscape of hardwood with species such as beech, basswood, oak, walnut and maple, to be of the most beautiful growth” (Jameson, 1838). Species such as elm, and the occasional pine were also present, and mixed hardwood stands were scattered with balsam fir (Strickland, 1853). The amount of original vegetation cover that has been lost, disturbed, or altered over the last 200 years in southern Ontario as a result of land clearing, logging, development and agriculture, can be determined through gap-analysis using pre-settlement vegetation modeling and mapping. This process shows us, for example, that historically, early successional forest made up about 4% of the total forest cover, while today it represents greater than 30% of all forest cover.

Spatially mapped historical vegetation is vital for helping us appreciate the landscape that existed prior to the arrival of settlers, and why certain species decreased while others increased. It also gives us an understanding of the origins and reasons for the present distribution and representation of vegetation on the landscape and helps us predict and shape the direction of future vegetation growth.

This document reviews the history of pre-settlement landscape mapping in southern Ontario, the methodology used to produce pre-settlement landscape mapping for the Municipalities of Halton, Hamilton, Peel and York and the entire Credit Valley watershed, the results of this mapping effort, and potential applications for this mapping product.

Figure 1. Early scenes from southern Ontario, including (above) men sawing down a tree in 1910, west of Guelph (Ontario Archives), and (below) a scene from Bathurst Street, Toronto in 1912 (City of Toronto Archives).

History of Pre-Settlement Vegetation Mapping in Ontario

In Ontario, pre-settlement surveyors' information and vegetation mapping have been referred to in a number of reports and addressed in a few comparative studies. Apart from the pre-settlement vegetation mapping initiative documented in this report, pre-settlement mapping has also been generated for Algonquin Park, Temagami and York Region (Figure 2).

Also, for northeastern and central Ontario, information from pre-settlement surveyors' records was converted into a digital spatial data base by the Ontario Ministry of Natural Resources (OMNR) to support Crown Forest management (Pinto at al., 2003; Pinto and Ferguson, 2008). A portion of this digital land surveyor information from 1856 to 1958, which contained descriptions of tree taxa along township boundaries, was used to model vegetation distribution in un-surveyed portions of Algonquin Provincial Park and the Temagami Sustainable Forest License as shown in Figure 3 and Figure 4 (Puric-Mladenovic and Pinto, 2005). Pre-settlement vegetation has also been statistically modeled and mapped across the Regional Municipality of York (Figure 5) utilizing spatially finer vegetation descriptions that were recorded by surveyors along concession lines (Puric-Mladenovic, 2003).

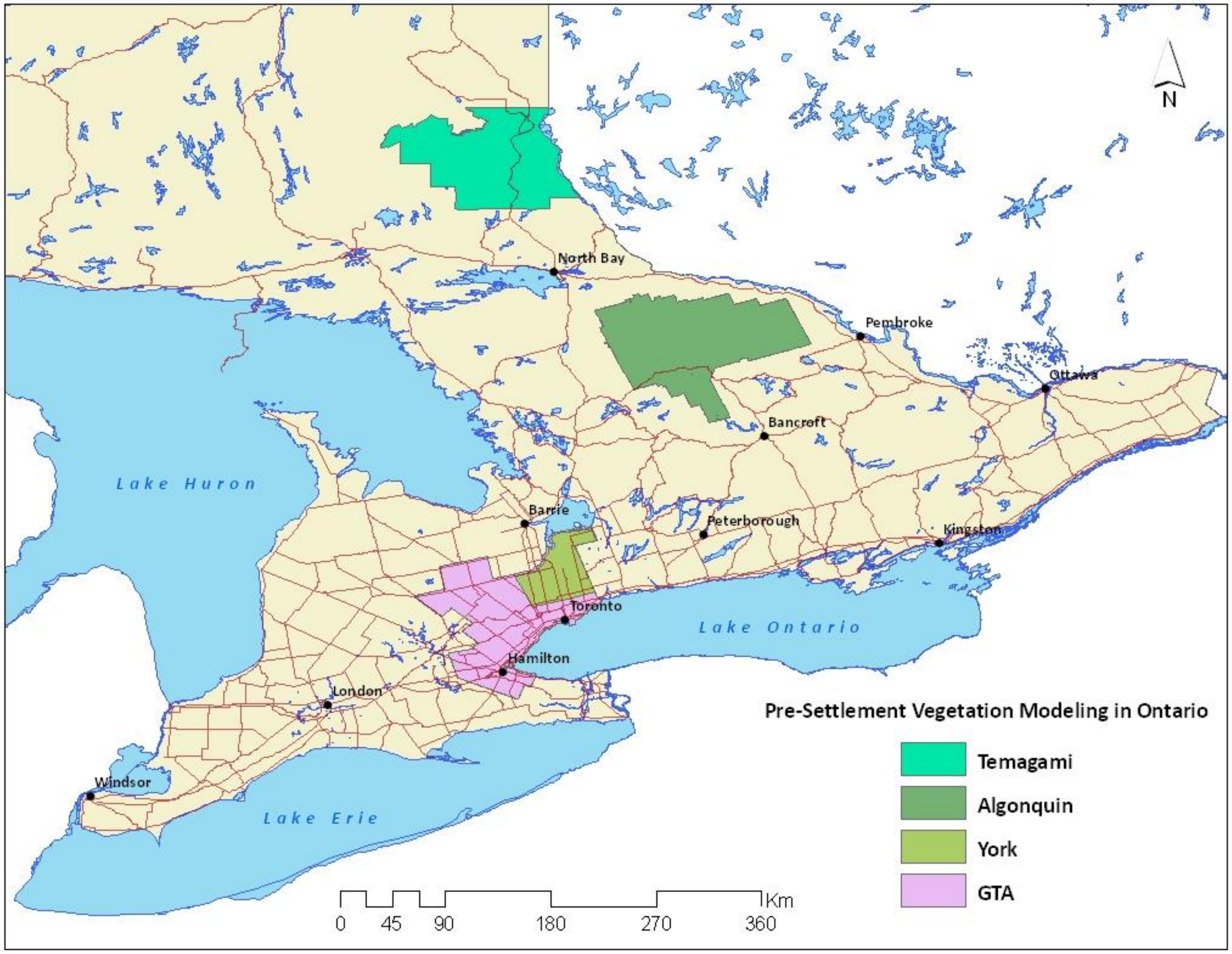


Figure 2. Locations of pre-settlement vegetation mapping initiatives in Ontario, including Temagami, Algonquin Park and the Greater Toronto Area (including York, Peel, Hamilton and Halton Regions and the Credit Valley Watershed). Note that pre-settlement vegetation mapping was completed for York Region in 2003, and was updated in 2011.

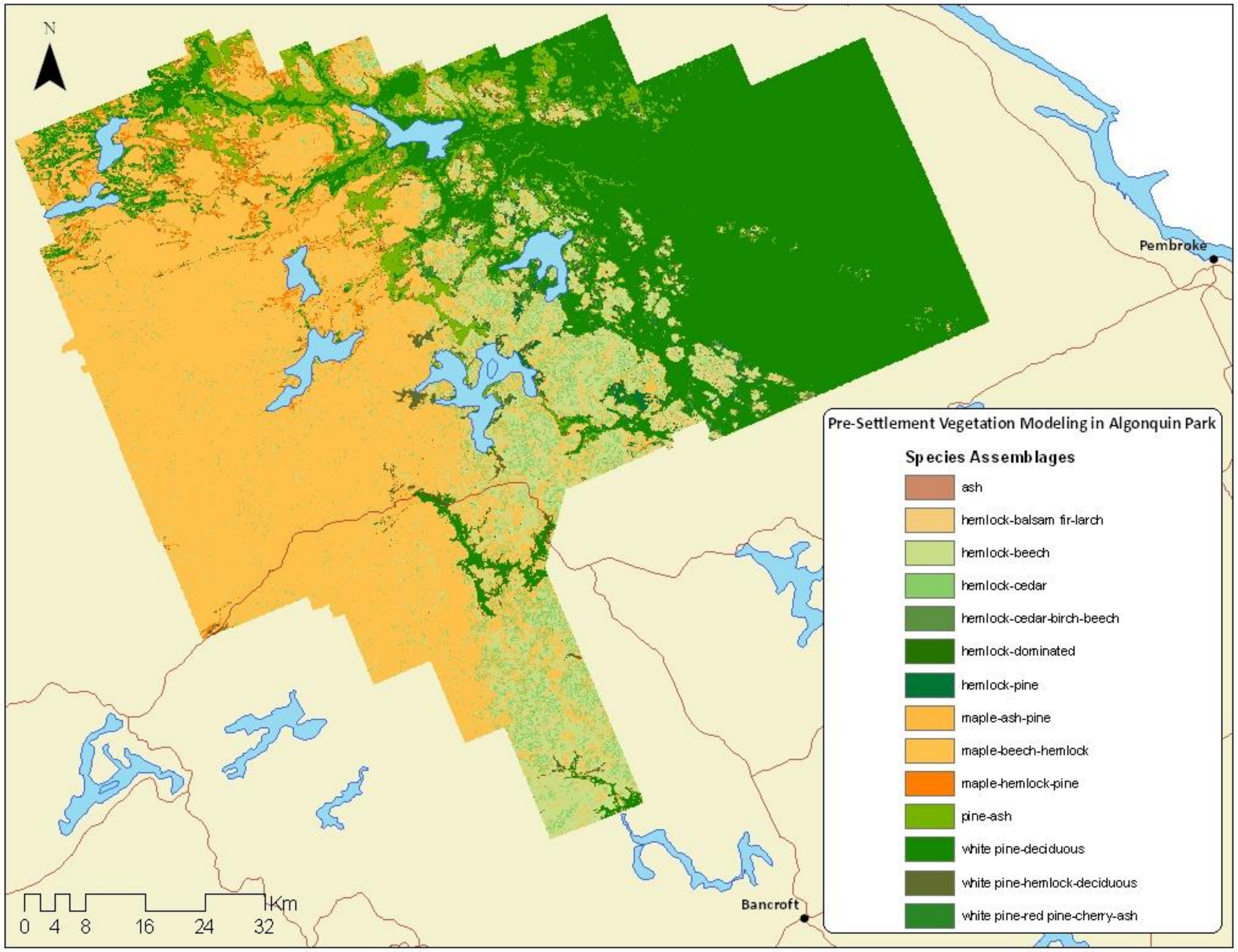


Figure 3. Pre-settlement vegetation mapping for Algonquin Provincial Park was completed in 2005 (Puric-Mladenovic and Pinto, 2005) based on land surveyors' information collected between 1856 and 1958. The abrupt contrast in forest species composition between western and eastern Algonquin Park provides guidance for today's Park's Forest Management Plan.

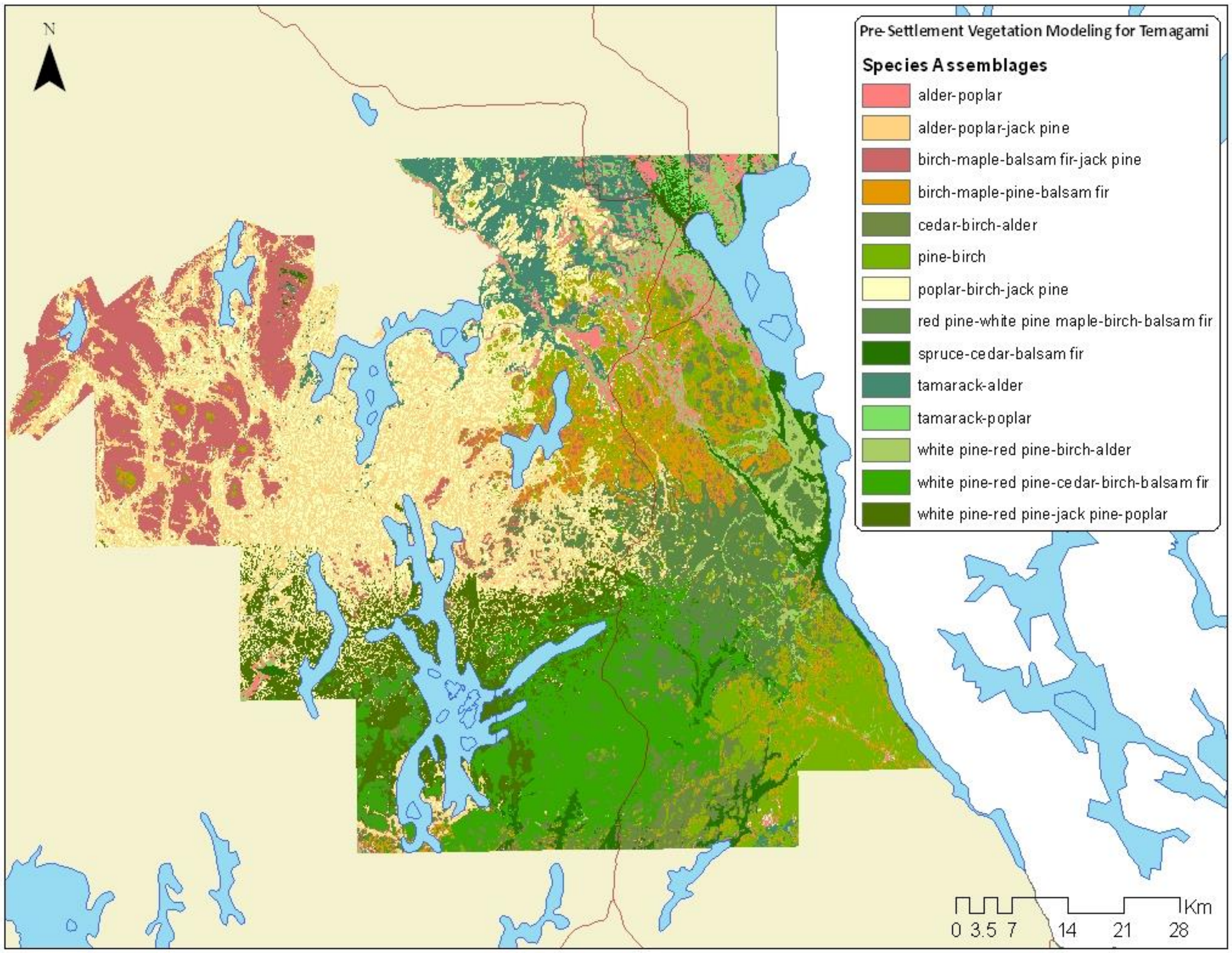


Figure 4. Pre-settlement vegetation mapping for the Temagami Sustainable Forest License was completed in 2005 (Puric-Mladenovic and Pinto, 2005) based on land surveyors' information collected between 1856 and 1958.

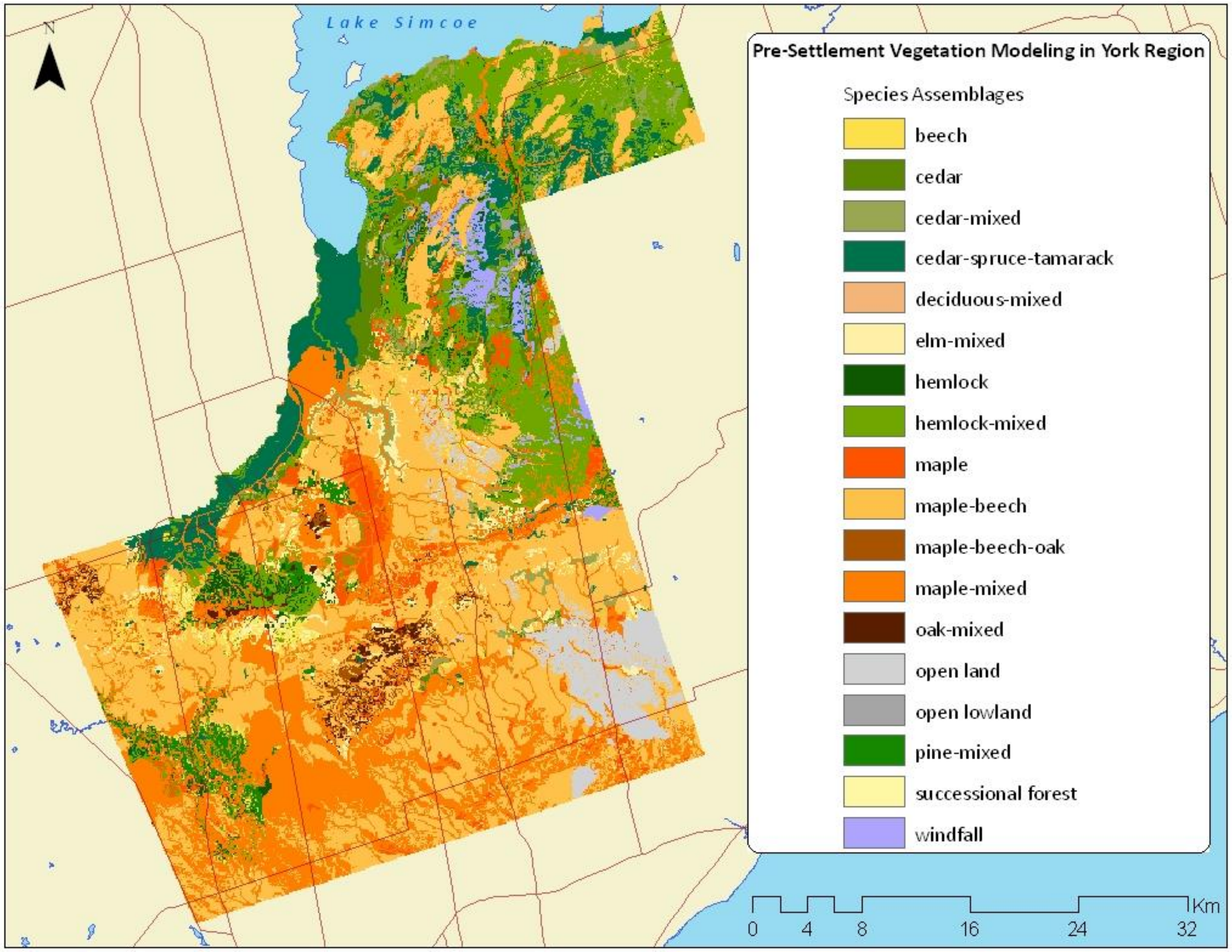


Figure 5. Pre-settlement vegetation mapping for the Regional Municipality of York was initially completed in 2003 (Puric-Mladenovic, 2003), and updated mapping for the area accompanies this report.

Methodology

Historical surveyors' records contain unique and extremely valuable qualitative information about southern Ontario's pre-European settlement forests and biophysical features, which permits the reconstruction of the pre-settlement vegetation composition and structure. The information used to support the production of pre-settlement mapping in Greater Toronto Area was collected approximately two centuries ago from 1793 to 1838 (Figure 6 and Appendix A), just prior to dramatic human-induced changes in natural vegetation cover. During this time surveyors traveled along concession lines, marking lot corners, and paying particular attention to natural features, vegetation cover and forest composition. They noted dominant species composition, soil type, topography, streams, lakes and ponds, swamps, and made observations about the suitability of the land for agriculture and timber production (Ladell et al., 1993).

The original surveyors' records cannot be moved from the Surveyor General's office in Peterborough, and as such, data from these notebooks was transcribed into a digital format on site (Figure 7). To do this, a data entry form was created (see image below) in Microsoft Access. Data recorded from the surveyors' notebooks included species information, surveyor information, segment information and length (e.g. townships) and other features such as soil type, terrain, and disturbances. Once this data was recorded digitally and tied spatially to lots and the original geographic townships, data accuracy tests were performed to reduce surveyor bias. Such tests generally involve comparing surveyor data to enduring features, records of heritage trees, or other available data. Conducting vegetation modeling over a large geographic extent also facilitates the removal of biased data.

In addition to surveyor record data, other available information was used to support pre-settlement modeling and validation, including readily available vegetation data and environmental data. To eliminate the cost of field data collection, various existing vegetation datasets were collected and used, OMNR Forest Resource Inventory (FRI) paper and digital maps, OMNR and Conservation Authority Ecological Land Classification (ELC) inventories and mapping, existing plant databases, and various government and environmental non-governmental organization (ENGO) reports. Environmental information used to support model development included surficial geology and soil data, digital elevation models (DEM) and various DEM derivatives, and historical climate averages for 1900-1931. Figure 9 outlines the general process that was used to create the pre-settlement vegetation mapping product.

Figure 6. Historical survey dates by geographic township ranged from 1793 to 1838 for the survey information that was used to produce pre-settlement mapping for Hamilton, Halton, Peel, and York Regions, and the Credit Valley watershed.

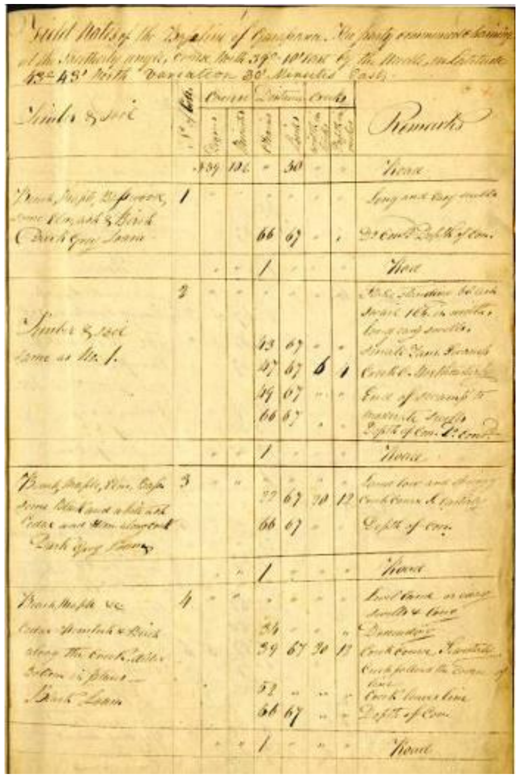
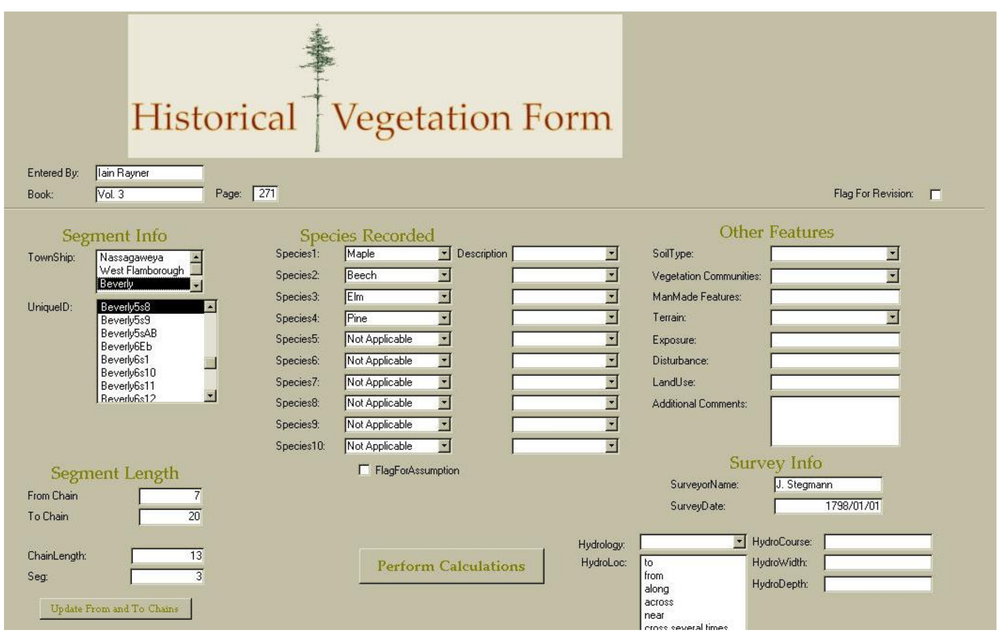


Figure 7. An example of one page from a surveyor's notebook (above). Each page comprised numerous data records, which were transcribed using the data input form below, to support pre-settlement vegetation mapping for the Greater Toronto Area. The original copies of these records are stored at the Surveyor General's Office in Peterborough, and cannot be removed.

.



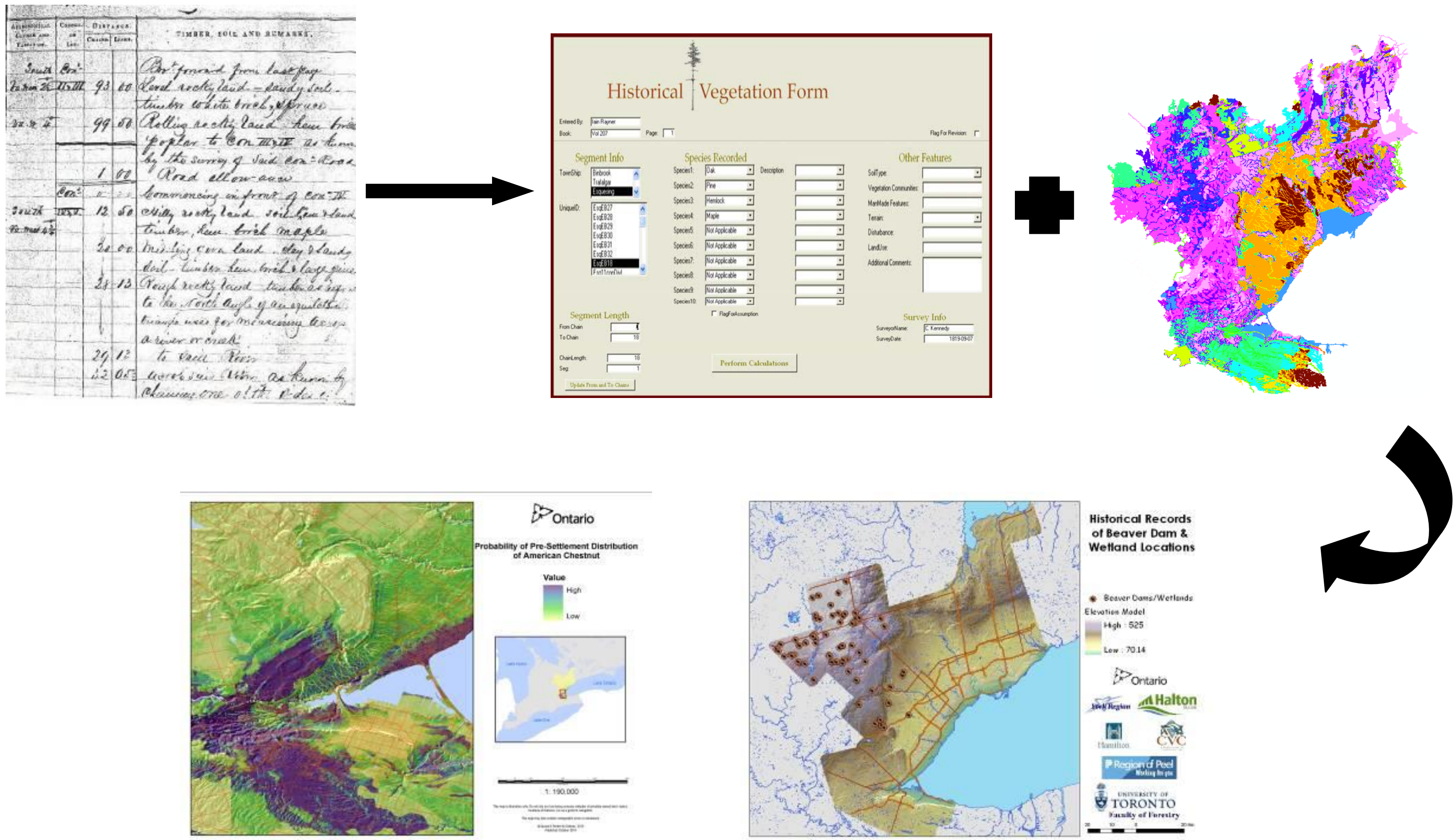


Figure 8. A simplified diagram showing how pre-settlement vegetation maps are created: surveyors notes (top-left) are converted into digital format (top-center), and used in combination with existing data (e.g. environmental or spectral datasets) to produce pre-settlement mapping products (bottom row).

Results

Species Assemblages

Statistically-based cluster analysis was used to derive 21 vegetation clusters from dominant species information and landscape characteristics (see Figure 8 and Figure 9 for examples and Appendix B for a list of the species found in each vegetation cluster). Each of these clusters are statistically significant species assemblages that correspond to dominant pre-settlement vegetation. It should be noted that the species order in the vegetation clusters does not imply relative species dominance or abundance (i.e. species 1 is not more abundant than species 2 or maple-beech does not mean that maple was more prominent than beech).

For each vegetation assemblage, a model, using a random forest algorithm, was developed, validated, and then extrapolated across the entire study area. Each species assemblage is represented as a probability map in raster format (i.e. each map unit is associated with a value indicating the probability that the particular species assemblage occurred on the pre-settlement landscape at a particular location). Each of these vegetation grids have been clipped to each of the partners' areas of interest. The continuous probability maps (values from 0 to 1) can be converted to a map of species presence or absence based on a threshold probability indicative of species presence.

Probability threshold values above which the different species assemblages are likely to be present have not yet been statistically defined for the pre-settlement vegetation maps presented with this report. However, to create species assemblage presence-absence maps, one should not use a 0.5 probability. It is suggested that species presence/absence maps are derived by reclassifying the provided probability maps into two classes (i.e. create a binary map) based on the natural breaks method that is available in GIS software.

Wetland and Upland Probability Grids

Using a methodology similar to that used to create maps of vegetation species assemblages, pre-settlement landscape and vegetation information was used to produce wetland and upland vegetation probability grids (Figure 10 and Figure 11). Suggested threshold values above which wetland/upland are likely to be present have not yet been defined. However, as noted above, when creating wetland or upland presence-absence maps, one should not use a 0.5 probability. It is suggested that such presence/absence maps are derived by reclassifying the provided probability maps into two classes (e.g. wetland and non-wetland) based on the natural breaks method that is available in GIS software.

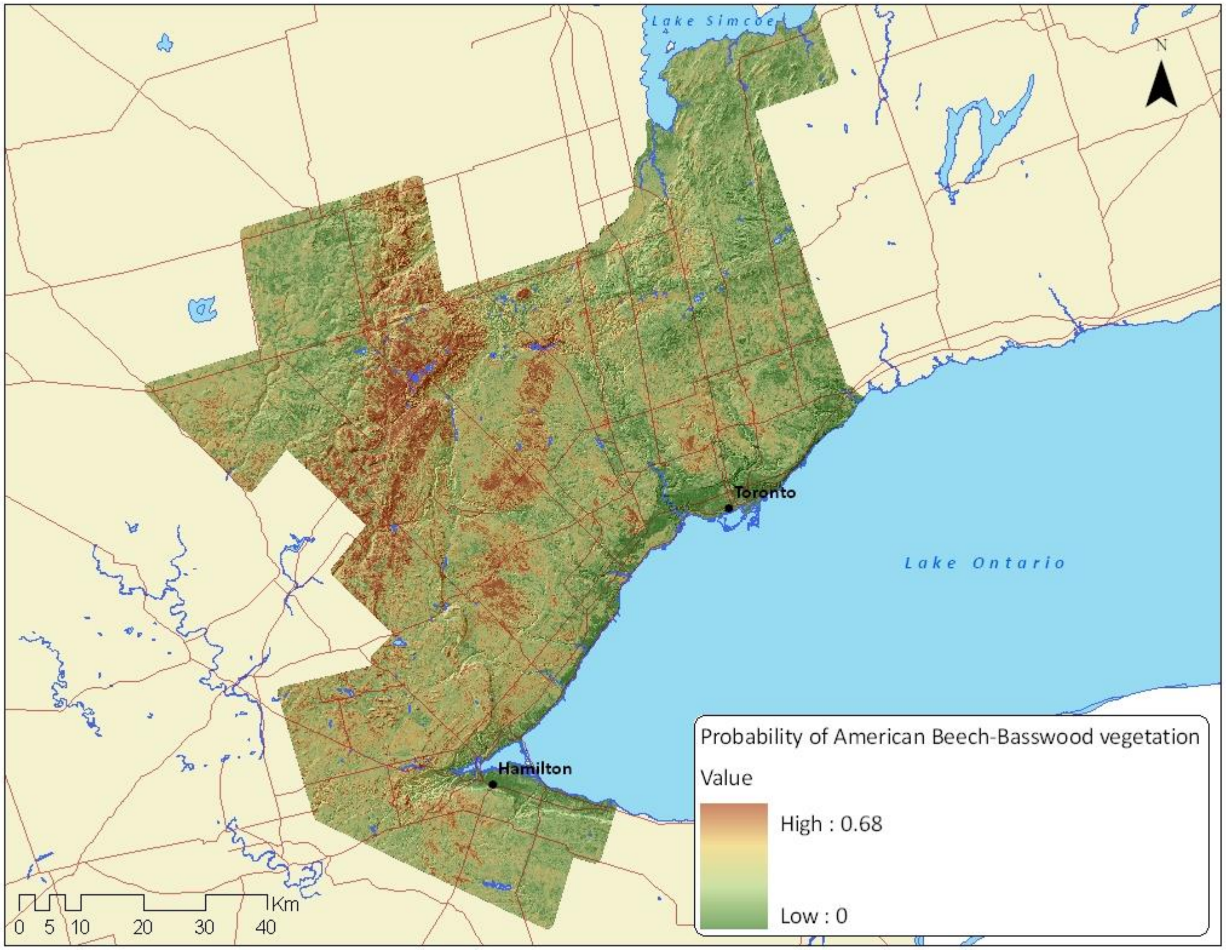


Figure 8. The pre-settlement vegetation mapping product for the Greater Toronto Area contains 21 vegetation clusters or grids. The above map is an example of one of these grids showing the probability of encountering upland American beech-basswood forest across the Greater Toronto Area pre-settlement landscape. Red indicates areas where American beech-basswood forests were more likely to have occurred, while green indicates areas where this forest type was unlikely.

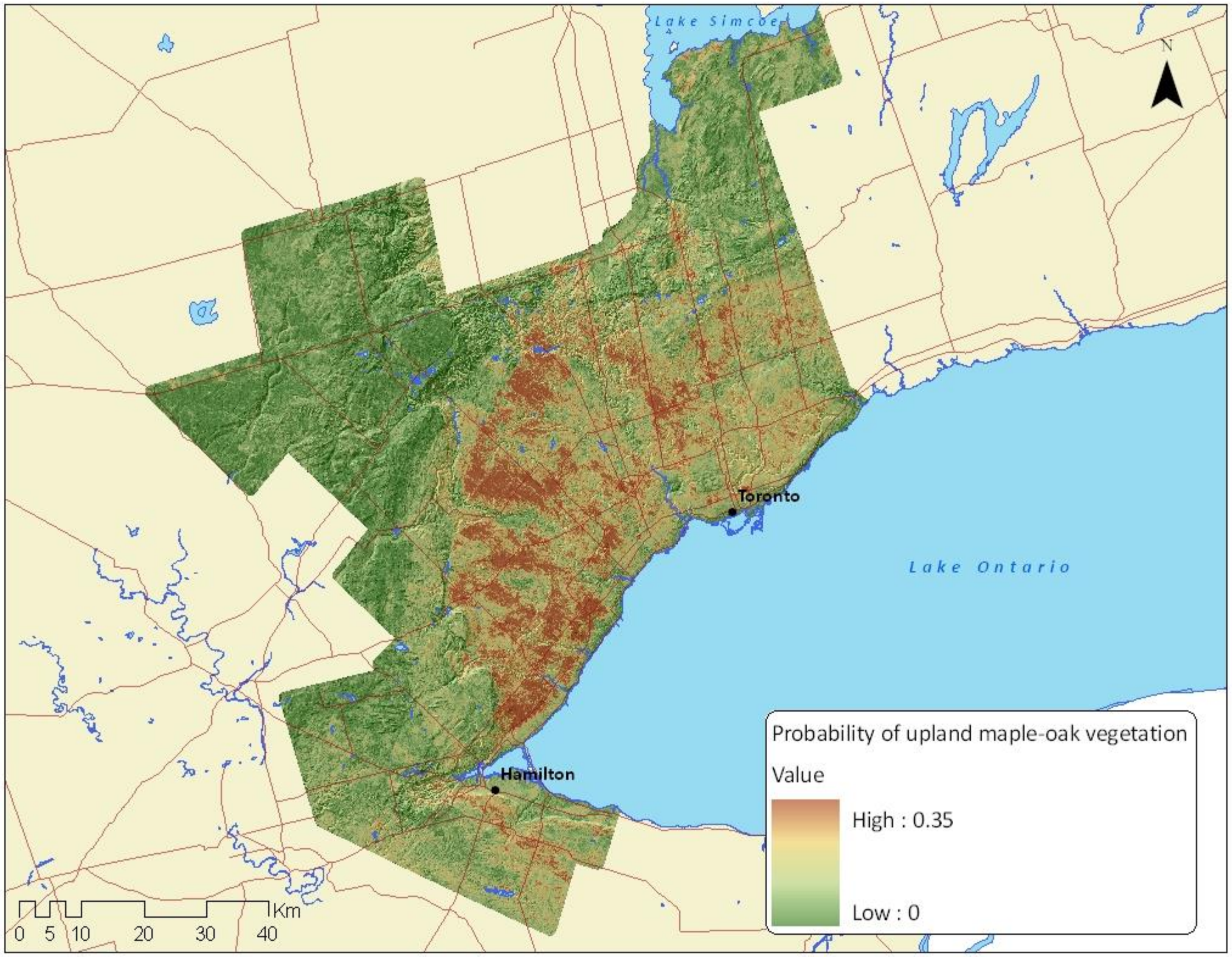


Figure 9. The pre-settlement vegetation mapping product for the Greater Toronto Area contains 21 vegetation clusters or grids. The above map is an example of one of these grids showing the probability of encountering upland maple-oak forest across the Greater Toronto Area pre-settlement landscape. Red indicates areas where maple-oak forests were more likely to have occurred, while green indicates areas where this forest type was unlikely.

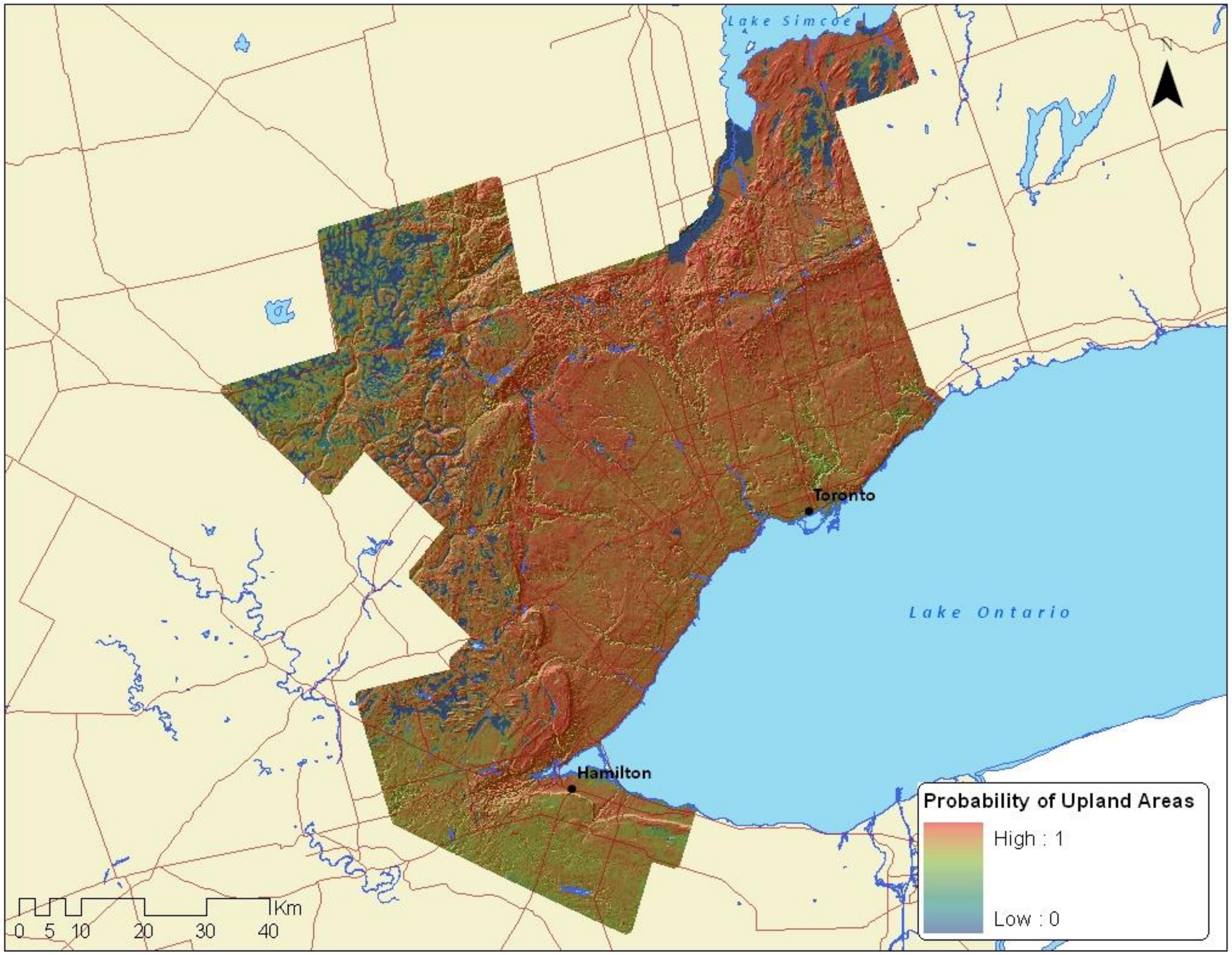


Figure 10. The probability of encountering upland vegetation across the Greater Toronto Area's pre-settlement landscape is shown in darker shades of red while darker shades of blue represents areas where upland vegetation was least likely to have occurred.

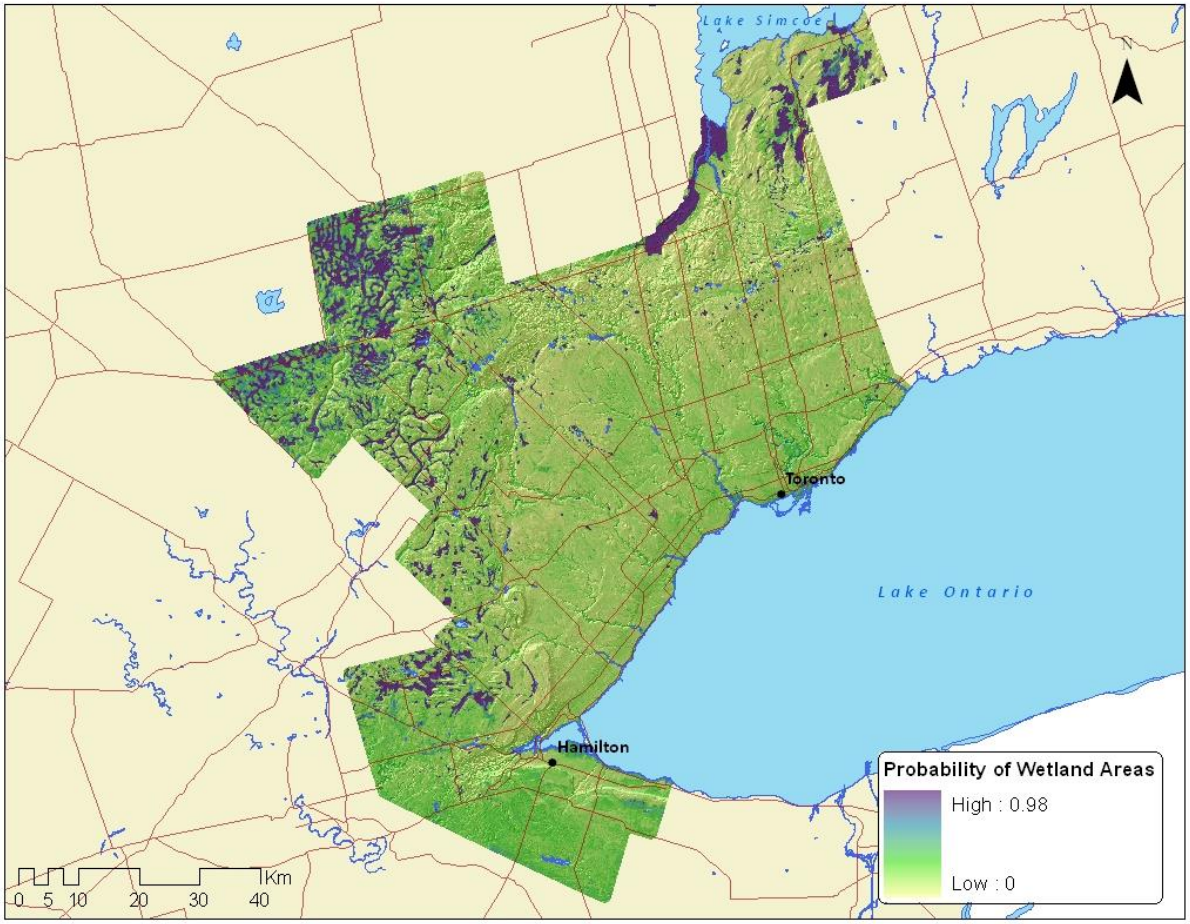


Figure 11. Probability maps of pre-settlement wetland vegetation areas across the Greater Toronto Area, including Hamilton, Halton, Peel and York Regions, and the Credit Valley watershed. Darker shades of purple represent areas where wetland vegetation was most likely to have occurred, while lighter shades of yellow represent areas where is was least likely to have occurred.

Applications for Pre-settlement Vegetation Mapping

In human impacted landscapes, where natural vegetation cover competes with other land uses, and has been changed spatially, structurally, and compositionally, resource management and conservation activities can benefit from knowledge about the vegetation reference condition, which can be provided by pre-settlement vegetation mapping. The following is a list of possible applications for pre-settlement vegetation mapping.

a) Directing forest management and silvicultural practices. For example, long-term management of mid-aged to mature stands can be directed towards silviculturally-based thinning prescriptions that restore the pre-settlement vegetation cover (Figure 12).

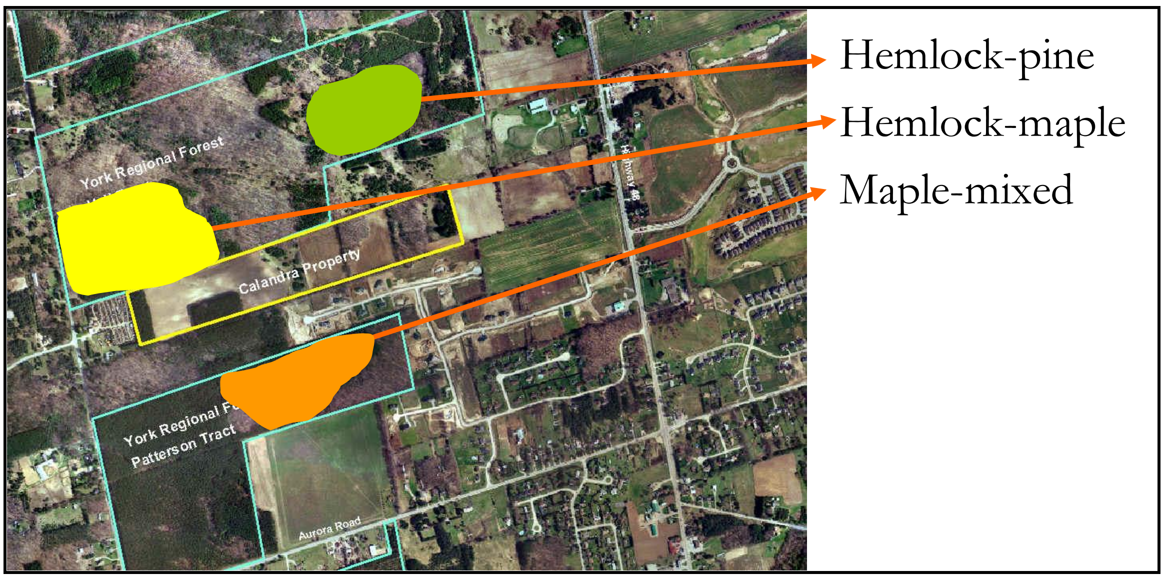


Figure 12. This figure shows pre-settlement vegetation assemblages (e.g. hemlock-pine) superimposed on existing forest stands in York Region, demonstrating how long-term management of existing forest stands can be directed towards silviculturally-based thinning prescriptions that restore the pre-settlement vegetation cover.

b) Defining appropriate restoration practices for an area (e.g. planting, seeding, or natural regeneration). For example, if the pre-settlement vegetation of a site that is being reforested is maple-oak forest and there are no adjacent oak trees for seeding, then restoration practices might include tree planting with oak seedlings from an appropriate seed zone.

c) Setting restoration objectives to achieve aesthetic and scenic values. For example, pre-settlement mapping can be used to justify protecting or setting restoration targets at focal scenic points on the landscape (e.g. topographic peaks, ridgelines, lakes, river valleys) or scenic heritage areas (e.g. picturesque rural landscapes or farmscapes). Further, pre-settlement mapping can direct restoration or conservation efforts designed to hide undesirable views (e.g highways, industrial areas, land-fills) in a manner that protects or enhances scenic values while satisfying many ecological needs (e.g. increasing natural forest cover, improving and establishing wildlife habitat).

d) Guiding gene conservation. Pre-settlement maps can be used in combination with maps of existing forest cover to determine the location of remnant stands or stands with unique species composition which can act as regional seed sources and gene preserves.

e) Assessing existing forest conservation and protection plans. Conservation plans that do not take pre-settlement vegetation into account may result in an unbalanced protection of forest types; access to vegetation reference condition mapping can help ameliorate this by providing information about the historic proportions of vegetation assemblages in a regional landscape.

f) Wildlife habitat protection and planning. Pre-settlement mapping provides spatial data that can be used to target, protect and restore wildlife habitats. For example, when used in combination with existing vegetation cover mapping, wildlife habitats that are underrepresented on the landscape can be protected, or areas that formerly contained a specific habitat can be restored.

g) Directing land use planning. Pre-settlement vegetation maps, by providing knowledge of historical natural vegetation distribution and representation, can be used during the land use planning process to define areas that should be protected or restored to increase the ecological goods and services they provide.

References:

Jameson, A. B. 1838. Winter Studies and Summer Rambles in Canada. New Canadian Library. Saunders and Otley, London.

Ladell, John L. 1993. They Left Their Mark: Surveyors and Their Role in the Settlement of Ontario. Dundurn Press, Toronto & Oxford.

Pinto, F. S. R. and Ferguson, M. 2008. Changes to pre-industrial forest tree composition in central and northeastern Ontario, Canada. Canadian Journal of Forest Research. 38(7): 1842–1854.

Pinto, F. and Romaniuk, S.M. 2003. Changes in tree species composition from pre-settlement to present: a case study of the Temagami forest, Ontario. In Emulating natural disturbances. Edited by A. Perera, M. Weber, and L. Buse. Fitzroy & Sons, Toronto, Ont.

Puric-Mladenovic, D. 2003. Predictive vegetation modeling for forest conservation and management in settled landscapes. Ph.D. Thesis. Faculty of Forestry, University of Toronto. 281 + 112

Puric-Mladenovic, D. and Pinto, F. S. R. 2005. Modeled historical vegetation distribution across Temagami and Algonquin Provincial Parks. OMNR, Southern Science and Information, Peterborough.

Strickland, S. 1853. Twenty-seven years in Canada West; or the experience of an early settler. Richard Bentley, London.

Appendix A

Table 1. This table presents the historical townships that were surveyed from 1793 to 1838 and used to produce pre-settlement vegetation mapping for Hamilton, Halton, Peel and York Regions and the Credit Valley watershed, along with the dates that they were surveyed, and the names of the surveyors.

Township	Survey Date	Surveyor Name
ALBION	1819	Hewett
AMARANTH	1822	Hugh Black
ANCASTER	1793, 1796	A. Jones
BARTON	1796, 1799, 1834	Jones, Burwell
BEVERLY	1798	J. Stegman
BINBROOK	1810	S. Wilmot
CALEDON	1819, 1820	James Hewett, S. Ryckman
CHINGUACOUSY	1819	Richard Bristol
EAST FLAMBOROUGH	1795	A. Fredell, Stegman
EAST GWILLIMBURY	1800	Hambly, Stegman, Wilmot
ERAMOSA	1819	Ryckman
ERIN	1819, 1821	C. Kennedy, Samuel Ryckman
ESQUESING	1819	Bristol, C. Kennedy
ETOBICOKE	1975	A. Iredelle
GARAFRAXA	1821	S. Ryckman
GEORGINA	1817, 1818	McDonnall
GLANFORD	1793, 1794, 1799	A.Jones, J. Stegman
KING	1800, 1838	Stegman, Callaghan
MARKHAM	1794, 1801	Iredell, Stegman
MONO	1820, 1822	Benson, Black
NASSAGAWEYA	1819	R. Sherwood
NELSON	1806, 1819	R. Sherwood, S. Wilmot
NORTH GWILLIMBURY	1800	Hambly, Stegman
SALTFLEET	1831	A. Jones
TORONTO	1806, 1819, 1828	John Goessman, Richard Bristol, S. Wilmot
TORONTO GORE	1819	R. Sherwood
TRAFALGAR	1819	R. Bristol
VAUGHAN	1795, 1798	Iredell, Stegman
WEST FLAMBOROUGH	1793, 1794	A. Jones, J. Stegman, W. Grant
WHITCHURCH	1800, 1802	Stegman
YORK	1811	A. Jones. S. Wilmot, W. Hambly, S. Wilmot

Appendix B

The pre-settlement mapping product contains 21 vegetation species assemblage grids. The different species contained in each species assemblage are shown in Table 2, and Table 3 is a key for the species codes shown in Table 2. None of these assemblages could be related to currently used Ecological Land Classification ecosites.

Table 2. The table shows the different grid names found in the pre-settlement landscape mapping product, and the specific species contained in each species assemblage. Note that the numbers (i.e. species 1, species 2) do not imply relative species dominance.

Grid Name	Cluster Number	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species Assemblages	Species Assemblages (Detailed)
Vg1_1	1_1	ULMUAME	ACERSPEC	FAGUGRA	TILIAME			UPLAND ULMUAME-ACERSPEC	UPLAND ULMUAME-ACERSPEC-FAGUGRA-TILIAME
Vg1_2	1_2	ACERSPEC	ULMUAME	BETUSP	FAGUGRA			UPLAND ACERSPEC-ULMUAME	UPLAND ACERSPEC-ULMUAME -BETUSP-FAGUGRA
Vg1_4	1_4	FAGUGRA	TILIAME	ACERSPEC				UPLAND FAGUGRA-TILIAME	UPLAND FAGUGRA- -TILIAME-ACERSPEC
Vg2		FAGUGRA	ACERSPEC	QUERSPEC	TILIAME	FRAXSPEC	PINUSPEC	UPLAND-FAGUGRA-ACERSPEC	UPLAND-FAGUGRA-ACERSPEC-QUERSPEC-TILIAME-FRAXSPEC-PINUSPEC
Vg3		THUJOCC						UPLAND-THUJOCC	UPLAND-THUJOCC
Vg4		ULMUAME	FRAXSPEC	ACERSPEC	TILIAME			UPLAND-ULMUAME-FRAXSPEC	UPLAND-ULMUAME-FRAXSPEC-ACERSPEC-TILIAME
Vg5		TSUGCAN	THUJOCC	BETUSP				WETLAND-TSUGCAN-THUJOCC	WETLAND-TSUGCAN-THUJOCC-BETUSP
Vg6		PINUSPEC	ACERSPEC	FAGUGRA	TILIAME			UPLAND-PINUSPEC-ACERSPEC	UPLAND-PINUSPEC-ACERSPEC-FAGUGRA-TILIAME
Vg7		FRAXSPEC						UPLAND-FRAXSPEC	UPLAND-FRAXSPEC
Vg8		PINUSPEC	QUERSPEC					UPLAND-PINUSPEC-QUERSPEC	UPLAND-PINUSPEC-QUERSPEC
Vg9		THUJOCC	LARILAR					WETLAND-THUJOCC-LARILAR	WETLAND-THUJOCC-LARILAR

Grid Name	Cluster Number	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species Assemblages	Species Assemblages (Detailed)
Vg10		LARILAR	THUJOCC	PICESP	TSUGCAN	PINUSPEC		UPLAND-LARILAR-THUJOCC	UPLAND-LARILAR-THUJOCC-PICESP-TSUGCAN-PINUSPEC
Vg11		ACERSPEC	ULMUAME	FAGUGRA	TILIAME	TSUGCAN		WETLAND-ACERSPEC-ULMUAME	WETLAND-ACERSPEC-ULMUAME-FAGUGRA-TILIAME-TSUGCAN
Vg12		TSUGCAN	THUJOCC	PINUSPEC				UPLAND-TSUGCAN-THUJOCC	UPLAND-TSUGCAN-THUJOCC-PINUSPEC
Vg13		THUJOCC	TSUGCAN	BETUSP	ACERSPEC	FRAXSPEC		UPLAND-THUJOCC-TSUGCAN	UPLAND-THUJOCC-TSUGCAN-BETUSP-ACERSPEC-FRAXSPEC
Vg14		POPUSPEC	PINUSPEC					UPLAND-POPUSPEC-PINUSPEC	UPLAND POPUSPEC-PINUSPEC
Vg15		ACERSPEC	QUERSPEC	TILIAME	CARYSP			UPLAND-ACERSPEC-QUERSPEC	UPLAND-ACERSPEC-QUERSPEC-TILIAME-CARYSP
Vg17		TILIAME	ACERSPEC	PINUSPEC	ULMUAME			UPLAND-TILIAME-ACERSPEC	UPLAND-TILIAME-ACERSPEC-PINUSPEC-ULMUAME
Vg18		JUGLCIN	JUGLSPEC	TILIAME	ULMUAME	ACERSPEC	FAGUGRA	UPLAND-JUGLCIN-JUGLSPEC	UPLAND-JUGLCIN-JUGLSPEC- TILIAME-ULMUAME-ACERSPEC-FAGUGRA
Vg19		CARYSP	QUERSPEC	PINUSPEC	ACERSPEC			UPLAND-CARYSP-QUERSPEC	UPLAND-CARYSP-QUERSPEC-PINUSPEC-ACERSPEC
Vg20		ACERSPEC	FAGUGRA	TSUGCAN				UPLAND-ACERSPEC-FAGUGRA	UPLAND-ACERSPEC-FAGUGRA-TSUGCAN

Table 3. Key to species codes found in the pre-settlement mapping product.

Species Codes	Common Name	Latin Name
ACERSPEC	Maple Species	*Acer sp.*
BETUSP	Birch Species	*Betula sp.*
CARYSP	Hickory Species	*Carya sp.*
FAGUGRA	American Beech	*Fagus grandifolia*
FRAXSPEC	Ash Species	*Fraxinus sp.*
JUGLCIN	Butternut	*Juglans cinerea*
JUGLSPEC	Walnut Species	*Juglans sp.*
LARILAR	Tamarack	*Larix laricina*
PICESP	Spruce	*Picea sp.*
PINUSPEC	Pine Species	*Pinus sp.*
POPUSPEC	Poplar Species	*Populus sp.*
QUERSPEC	Oak Species	*Quercus sp.*
THUJOCC	Eastern White Cedar	*Thuja occidentalis*
TILIAME	Basswood	*Tilia americana*
TSUGCAN	Eastern Hemlock	*Tsuga canadensis*
ULMUAME	American Elm	*Ulmus americana*