PEEL REGION URBAN FOREST BEST PRACTICE GUIDE 4

Potential Street and Park Tree Species for Peel in a Climate Change Context

October 2021

Region of Peel
working with you

TOWN OF CALEDON

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Peel Region Urban Forest Best Practice Guide 4

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October 2021

Working together as part of the Peel Climate Change Partnership

Acknowledgments

This document is the fourth in a series of five deliverables developed for Peel Region and its partners as part of the Peel Region Urban Forest Best Practices project. Like all the deliverables for this project, this document has been developed collaboratively with input and guidance from members of the Project Team, Peel Urban Forest Working Group, Peel Climate Change Partnership and other agency professionals with expertise in ecology, botany and arboriculture. Specific thanks are extended to:

- REGION OF PEEL: Heather Hewitt, Mark Pajot, Chris Despins, Danielle Gnoyke, Mark Head
- CITY OF MISSISSAUGA: Paul Tripodo, John MacKinnon, Scott McLeod
- CITY OF BRAMPTON: Michael Hoy, John Allison, Brian McKelvey, Ed Hunwicks, Natalia Fleishman
- TOWN OF CALEDON: Nick Pirzas, Christina Guido
- CREDIT VALLEY CONSERVATION (CVC): Yvette Roy, Aaron Day, Joe Pearson, Lisa Riederer, Dawn Renfrew, Laura Timm
- TORONTO AND REGION CONSERVATION AUTHORITY (TRCA): Michelle Sawka, Mark Funk, Courtney Den Elzen and Jacqueline DeSantis who provided technical input as well as graphic design support.

This deliverable was developed under the oversight of Margot Ursic of Beacon Environmental Limited with the bulk of the species review and compilation completed by Ash Baron with support from Sarah Zicca of Beacon, and the report content and vulnerability assessments provided by Steve Colombo of Ecoview Consulting Limited. While every attempt has been made to provide current information in an accurate manner, the authors at Beacon and Ecoview take responsibility for any errors or omissions.

Disclaimer

The guidance provided in this document is primarily intended for street and park trees in the Region of Peel and its local municipalities (i.e., the Town of Caledon, City of Brampton and City of Mississauga) as their urban forest planning evolves both in anticipation of and in response to shifts associated with climate change. Aspects of this guidance may be applicable to trees in natural areas and to other urbanizing areas in southern Ontario and beyond. The guidance in this document is intended to serve as a resource for application at the user's discretion; it does not reflect the position or direction of any of the partner agencies.

In addition, the species vulnerability assessments represent projections based on the approach described in this report, the available information and the perspectives of the consulting and Project Team members. However, the responses of the environment and of trees to climate change remains uncertain. Therefore, this document should be considered as a "working document" subject to updates as more information becomes available.

Cover image credit: A. Cunningham, City of Brampton

Executive Summary

Urban areas tend to be places where (a) the greatest concentrations of people live and (b) many of the environmental stressors associated with climate change (e.g., heat) can be exacerbated.

Enhancing the urban forest by establishing and maintaining more trees in cities is increasingly recognized as part of the solution to mitigate and adapt to climate change. However, because trees are biological organisms, using them effectively for these purposes requires an understanding of their vulnerabilities to climate change. Gaining such an understanding is no simple task. Different trees have variable tolerances to stressors depending on their inherent sensitivity, exposure to risks and capacity to cope. In addition, there are many tree species for which such data is incomplete or lacking. Assessment is further complicated by the onset of climate change which is introducing extreme environmental conditions over a relatively short period of time. Nonetheless, there is an imperative to re-consider current tree species selection practices based on the best available information now or risk having urban forests increasingly unable to adapt to the changing climate in the coming decades.

The Region of Peel and its municipal and agency partners (i.e., the City of Brampton, City of Mississauga, Town of Caledon, Credit Valley Conservation Authority [CVC] and Toronto and Region Conservation Authority [TRCA]) have worked collaboratively for over a decade to develop and implement various strategies to protect and enhance Peel's urban forest, and to help the communities in Peel both mitigate and adapt to climate change. Through the Peel Climate Change Partnership (PCCP), the partners have identified increasing green natural infrastructure in Peel's urban areas, and particularly tree canopy cover, as one of the most urgent actions needed to help the community adapt to climate change.

This report is the fourth in a series of five deliverables developed for Peel Region and its partners as part of the Peel Region Urban Forest Best Practices project. The purpose of this project was to help sustain and expand tree cover in Peel's urban areas where it can provide benefits to the greatest number of people, while also contributing to climate change mitigation and adaptation. The guides in this series are:

- Guide 1: Best Practices Guide for Urban Forest Planning in Peel
- Guide 2: Urban Forest Management Best Practices Guide for Peel
- Guide 3: Guide for Tree and Shrub Standards and Specifications for Regional Roads in Peel
- **Guide 4: Potential Street and Park Tree Species for Peel in a Climate Change Context**, and
- Guide 5: Working with Trees - Best Practices for a Resilient Future.

The best practices and opportunities identified in these guides can also support the implementation of other strategies and plans related to climate change and urban forestry developed by the partners, including: the Region of Peel's *Urban Forest Strategy* (2011); the City of Mississauga's *Urban Forest Management Plan* (2014) and *Climate Action Plan* (2019); the City of Brampton's *One Million Trees Strategy* (2019), *Community Energy and Emissions Reduction Plan* (2020) and *Urban Forest Management Plan* (in progress); and the Town of Caledon's *Tree Seedling Program* (2019) and *Community Climate Change Action Plan 2020-2050*.

This guide includes the methods for, results of, and recommendations related to vulnerability assessments for 88 selected tree (and shrub) species. The species selected are predominantly species considered "native" to southern Ontario (i.e., whose current ranges overlap with Peel Region and / or the CVC watershed or are south of Peel but still within southern Ontario). However, the assessment also included several species "non-native" to southern Ontario (e.g., with current ranges in the northeastern United States) and some species considered invasive and widespread in Peel. The rationale for this approach was to understand how a representative cross-section of native, non-native and invasive trees (and shrubs) that currently occur are projected to respond to the changing climate in Peel Region over the next 20 to 50 years.

This guide specifically includes:

- An overview of anticipated tree and urban forest vulnerabilities to climate change in Peel based on projected conditions in 2041 to 2070 under what is currently considered the "business as usual" or "worst case" scenario (referred to as RCP8.5) (**Section 2**)
- A description of the methods used for selecting species and undertaking the vulnerability assessments (**Section 3**)
- An overview of the results of these assessments (**Section 4**), and
- Guidance as to how this work could be used and concluding remarks (**Section 5**).

The application of the information contained in this guide is primarily intended for professionals with knowledge of tree species tolerances and expertise in urban tree establishment and maintenance. A glossary of key technical terms is provided in **Section 6** for the reader's reference.

It is important for anyone who intends to use the information in this guide to note that the results of the tree vulnerability assessments provided in **Appendix A** and discussed in this guide are projections based on assumptions using a specific, but not the only, possible methodology. Furthermore, these assessments are one source of information to be considered in the species selection process in conjunction with other knowledge about species' tolerances and sensitivities, as well as an understanding of the existing and anticipated site conditions.

There is currently little local guidance in terms of what trees could or should be planted in the context of a rapidly shifting climate, and so although it is not perfect it is hoped that the information generated for this guide (which has been developed with input from experts at CVC and TRCA) can start to fill this gap. This guide is intended to provide individuals already knowledgeable about trees with additional information to inform species selection of street and park trees in Peel's urban areas and guide urban forest diversification efforts across Peel over the long term in a climate change context. Specific applications include:

- Assessing current urban forest planting lists for their vulnerability to climate change
- Revising planting plans to include a greater proportion of native species that are expected to be suitable under anticipated climate conditions, and a lower proportion of species that are expected to be more vulnerable
- Designing and/or inform assisted migration trials, and
- Assessing the current composition of Peel's urban forest to vulnerability.

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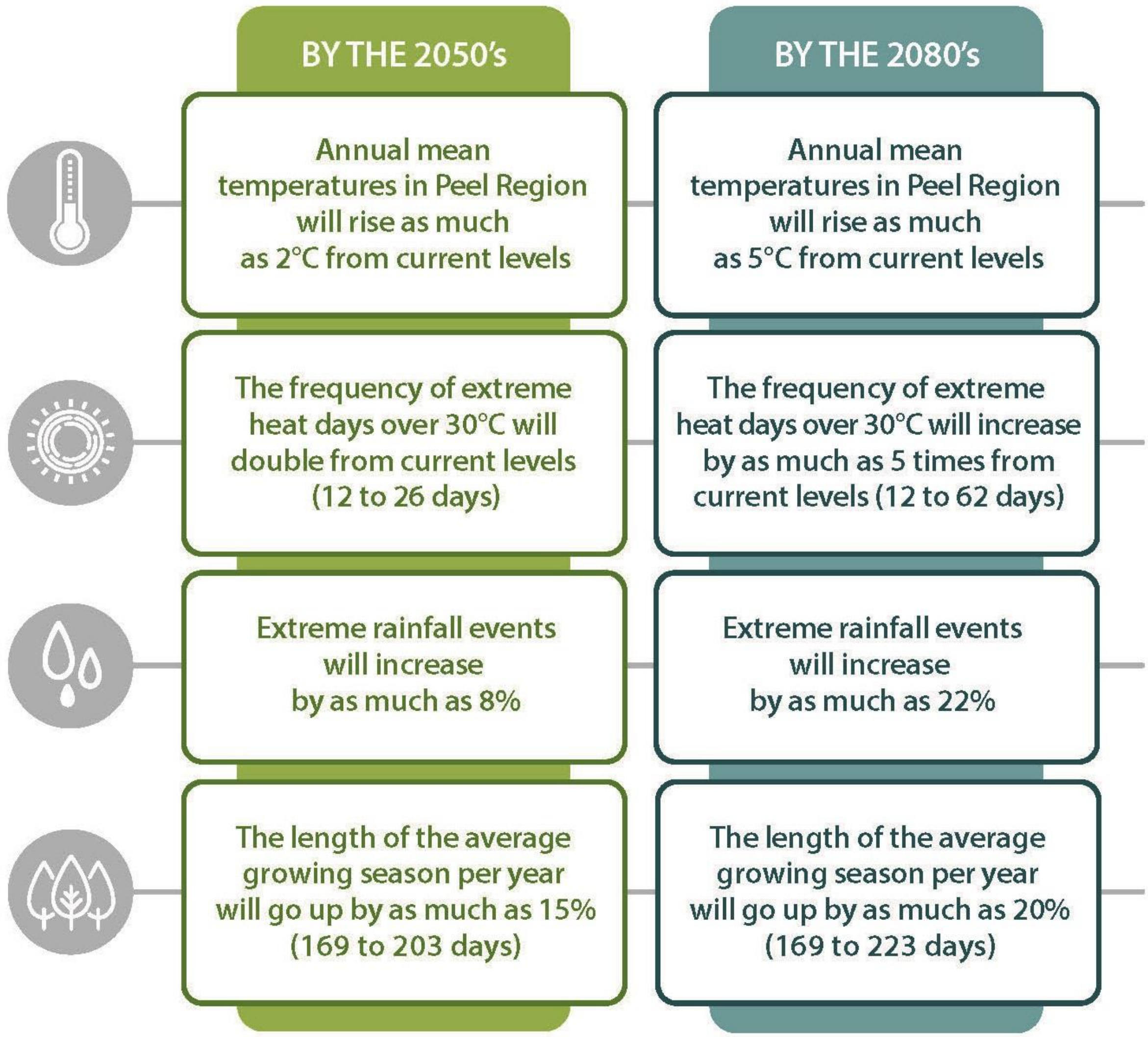
Appendices

1. Introduction

Urban areas tend to be places where (a) the greatest concentrations of people live and (b) many of the environmental stressors associated with climate change (e.g., heat, drought, flooding) can be exacerbated. Projected climate shifts anticipated in Peel Region over the next 30 to 60 years based on a "business as usual" scenario, which is the current trajectory (IPCC 2018), are summarized in **Figure 1**.



Sources: Data adapted from Auld *et al.*, 2016, Tu *et al.*, 2017 and Region of Peel 2018

Figure 1. Overview of key projected climate shifts anticipated in Peel Region over the next 30 to 50 years

Enhancing the urban forest by establishing and maintaining more trees in cities is increasingly recognized as part of the solution to mitigate and adapt to climate change. However, because trees are biological organisms, using them effectively for these purposes requires an understanding of their vulnerabilities to climate change. Gaining such an understanding is no simple task. Different trees have variable tolerances to stressors depending on their inherent sensitivity, exposure to risks and capacity to cope. In addition, there are many tree species for which such data is incomplete or lacking. Assessment is further complicated by the onset of climate change which is introducing extreme environmental conditions over a relatively short period of time. Nonetheless, there is an imperative to re-consider current tree species selection practices based on the best available information now or risk having urban forests increasingly unable to adapt to the changing climate in the coming decades.

The Region of Peel and its municipal and agency partners (i.e., the City of Brampton, City of Mississauga, Town of Caledon, Credit Valley Conservation Authority [CVC] and Toronto and Region Conservation Authority [TRCA]) have worked collaboratively for over a decade to develop and implement various strategies to protect and enhance Peel's urban forest, and to help the communities in Peel both mitigate and adapt to climate change. Through the Peel Climate Change Partnership (PCCP), the partners have identified increasing green natural infrastructure in Peel's urban areas, and particularly tree canopy cover, as one of the most urgent actions needed to help the community adapt to climate change.

This report is the fourth in a series of five deliverables developed for Peel Region and its partners as part of the Peel Region Urban Forest Best Practices project. The purpose of this project was to provide guidance that will help sustain and expand tree cover in Peel's urban areas, where it can provide benefits to the greatest number of people, while also contributing to climate change mitigation and adaptation. The guides in this series are:

- Guide 1: Best Practices Guide for Urban Forest Planning in Peel
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This guide includes the methods for, results of, and recommendations related to vulnerability assessments for 88 selected tree (and shrub) species. The species selected are predominantly species considered "native" to southern Ontario (i.e., whose current ranges overlap with Peel Region and / or the CVC watershed or are south of Peel but still within southern Ontario). However, the assessment also included several species "non-native" to southern Ontario (e.g., with current ranges in the northeastern United States) and some species considered invasive but that are relatively widespread in Peel. The rationale for this approach was to understand how a representative cross-section of native, non-native and invasive trees (and shrubs) that currently occur in southern Ontario were projected to respond to the changing climate in Peel Region over the next 20 to 50 years.

This guide specifically includes:

- An overview of anticipated tree and urban forest vulnerabilities to climate change in Peel based on projected conditions in 2041 to 2070 under what is currently considered the "business as usual" or "worst case" scenario (referred to as RCP8.5) (**Section 2**)
- A description of the methods used for selecting species and undertaking the vulnerability assessments (**Section 3**)
- An overview of the results of these assessments (**Section 4**), and
- Guidance as to how this work could be used and concluding remarks (**Section 5**).

This guide is the most technical of the five guides developed for the Peel Region Urban Forest Best Practices project, and the application of the information contained in it is primarily intended for experienced professionals with knowledge of tree species tolerances and expertise in urban tree establishment and maintenance. A glossary of key technical terms is provided in **Section 6** for the reader's reference.

It is important to note the following related to use of this guide:

- The results of the tree vulnerability assessments in this guide (**Appendix A**) are one source of information that ought to be considered in the species selection process in conjunction with other information (e.g., site context and conditions) by a professional with knowledge of tree species' management and requirements in urban areas.
- The results of the tree vulnerability assessments included in this guide are projections based on assumptions using a specific, but not the only, possible methodology[1]. Therefore, the results should not be considered definitive but rather one source of information to be used in conjunction with other knowledge about a species' tolerances and sensitivities, and an understanding of the existing and anticipated site conditions.

Nonetheless, there is currently little local guidance in terms of what trees could or should be planted in the context of a rapidly shifting climate. It is hoped that the lists generated for this guide, which have been developed with input from experts at CVC and TRCA, help fill this gap.

[1] Sansom (2020) recently completed climate change vulnerability assessment of 55 tree and shrub species in the Greater Toronto Area for CVC using a different approach than that used for this guide.

This guide is intended to provide individuals already knowledgeable about trees with additional information to inform species selection in Peel in a climate change context so that they can better:

- Assess current urban forest planting lists for their vulnerability to climate change
- Revise planting plans to include a greater proportion of native species that are expected to be suitable under anticipated climate conditions, and a lower proportion of species that are expected to be more vulnerable
- Design and/or inform assisted migration trials, and
- Assess the current composition of Peel's urban forest to vulnerability.

This information, in conjunction with other site-specific and site design considerations, is intended to help inform species selection in Peel's urban areas – particularly in some of the locations where tree establishment is most challenging (e.g., streets and rights-of-way) – and by doing so, is intended to help guide urban forest diversification efforts across Peel over the long term.

> ***As the climate changes, some individual trees or even whole local populations of a species may not prove adapted, nor have the capacity or time to evolve… So our forests' capacity to adapt, thrive and provide the many benefits our society needs, depends on the quality of today's efforts – our ability to conserve, manage and restore our forests…***
>
> **Forest Gene Conservation Association (FGCA) website, 2021**

2. An Overview of Tree and Urban Forest Vulnerabilities

Climate change in Peel has already begun to, and will continue to, contribute to: (a) increased average temperatures, (b) more frequent and extended periods of extreme heat and drought, wider temperature fluctuations, and (c) altered amounts and intensities of precipitation and high winds, including both flooding and ice storms. These are all considered "primary" environmental stressors in that their occurrence can directly impact the ability of trees, and of the urban forest, to become established, grow and survive. There are also a host of "secondary" environmental stressors that have the potential to be introduced or exacerbated by climate change. Key "secondary" stressors include: (a) increased vulnerability to tree diseases and pests (including invasive plant species) that currently occur in Peel and (b) increased risk of diseases and / or pests (including invasive plant species) moving into and spreading in Peel that were previously limited because of the generally colder conditions than areas further south.

This section includes an overview of anticipated tree and urban forest vulnerabilities to climate change in Peel based on projected conditions in 2041 to 2070 under what is currently considered the "business as usual" or "worst case" scenario (referred to as RCP8.5).

An overview of some key projected climate shifts anticipated in Peel Region drawn from the local research completed to date (Auld *et al.,* 2016; Tu *et al.,* 2017; Region of Peel 2018) are presented in **Figure 1**. How exactly these anticipated climatic changes are expected to contribute to making Peel's urban forest more vulnerable is discussed further below and summarized in **Table 1**.

2.1 Increased Average Temperatures

Temperature increases have direct effects on nearly all aspects of tree physiology, from the rates of photosynthesis in leaves to the absorption of water and mineral nutrients from the soil. Information on the responses of trees to climate warming is lacking for most species. However, some general responses can be formulated based on a species' natural range. A couple of examples are provided below.

- Species that occur in Peel and are at the southern end of their natural range (e.g., balsam fir, white spruce and trembling aspen) may experience slowed growth with increases in temperature because the species are adapted to more northerly (i.e., colder) climates.
- Species that occur in Peel and are at the northern end of their natural range may experience more growth because the species is adapted to warmer temperatures and local populations may be growing at sub-optimal temperatures (e.g., Lu *et al.,* 2015).

Climate warming has the potential to alter the timing of flowering and of budburst of vegetative shoots (i.e., buds that produce leaves). In temperate regions, most woody plants go into dormancy over the late fall and winter, and all modes of growth and reproduction are paused. Dormancy is broken after a period of chilling during the winter and growth resumes once air temperatures provide sufficient heat units in the spring, with different species and genotypes having different chilling and heat sum requirements. The reduced winter chilling and increased spring warming associated with climate change is expected to affect budburst of species in different ways, and responses may be further complicated by wider temperature variations as time progresses. Risks to the urban forest include uneven or failed flowering (and reduced seed production) due to post-bud burst frost and / or insects – or other pollinators[2] - arriving too soon or too late (Kehrberger and Holzschuh 2019).

Asynchrony between flowering and the timing of insect pollinator emergence is another potential cause of reduced seed production for some hardwood tree species. In natural forest areas, reduced seed production could affect regeneration and, over the long term, alter species composition of urban forest areas that rely on natural recruitment. Reduced seed production can also limit the amount and quality of available seed for nurseries.

A warmer climate can also make it easier for pests and diseases that damage trees to propagate and spread, and to do so for a greater part of the growing season (e.g., Lehmann *et al.,* 2020), although some of these effects might be offset by more frequent freeze-thaw cycles in Peel which may negatively impact overwintering insect populations (Sanders-DeMott *et al.,* 2019). Warmer winter temperatures in North America have been linked to extended seasons for, and more widespread impacts from, several damaging pests that occur in Canada's forests, such as mountain pine beetle and emerald ash borer (e.g., https://climateatlas.ca/forest-pests-and-climate-change).

2.2 More Frequent Extreme Heat Events

In addition to overall increases in temperature, climate change will continue to magnify pre-existing urban heat island effects. This will increase the intensity and frequency of extreme heat events in Peel's urban areas. Microclimates in urban centres already cause air temperatures to exceed 40°C, which can directly injure trees, although so long as trees (and other plants) have sufficient water to provide cooling by using transpiration, they can usually avoid or delay heat damage caused by microclimates that are temporarily intensely hot (e.g., Urban *et al.,* 2017)[3]. Direct heat damage can, however, occur when temperatures are so persistently high that the rate of transpiration cannot keep up with evaporative demand. This could occur, for example, after a long heat wave combined with low precipitation that depletes soil water (see **Figure 2**).

[2] Close to 80% of temperate hardwood species are pollinated by insects and other types of wildlife (Ollerton et al., 2011). This includes at least 15 species pollinated by bees that occur in Peel, such as apples, basswood, cherries, black and honey locust, catalpa, horse chestnut, tulip tree, and willows.

[3] Plants are cooled by transpiration in the same way as sweating cools people because the evaporation of water from a surface absorbs heat energy, which is then carried away into the air.

In addition, extreme heat may occur in some urban microclimates even when air temperatures are not extreme. For example, Trowbridge and Bassuk (2004) reported a case where air temperatures on sunny days remained under 24°C but exceeded 50°C near a concrete wall facing the sun, causing nearby trees to defoliate several times during the summer.

Credits: *Managing Your Forest in a Changing Climate* (OWA 2015)

Figure 2. Images from eastern Ontario forests showing responses to multiple droughts (left) and drought followed by windstorms (right)

2.3 More Variable Temperatures

Mild winters and warm, early springs are expected to occur more frequently as the climate warms. These conditions can cause trees and other plants to become active before the risk of late season frost has passed (Gu *et al.,* 2008). Such exposure can kill newly formed leaves, shoots, and developing flowers and fruits. The resulting damage can cause tree crowns to change from elongating shoots with enlarging leaves to red and brown dead tissues within days of freezing (Man *et al.,* 2009).

In addition to direct freezing damage to shoots and foliage, long winter thaws without snow cover followed by a drop to seasonal freezing temperatures can cause freezing injury to roots. The loss of water absorption capacity due to root death can also lead to damage to tree shoots, as insufficient root pressures will fail to remove air blockages within the trunk and stems and limit water and nutrient uptake (Zhu *et al.,* 2000).

2.4 More Frequent Droughts

Even though total annual precipitation is projected to increase above historical levels, climate change is expected to result in generally drier soils during the growing season in Peel Region (Auld *et al.,* 2016). Trees are affected more so by the length and frequency of droughts, rather than their severity (Gustafson and Sturtevant 2013) and drier soils are expected during the growing season because increased temperatures will result in more moisture loss from trees and soils than can be compensated by a few intense rain events between May and September.

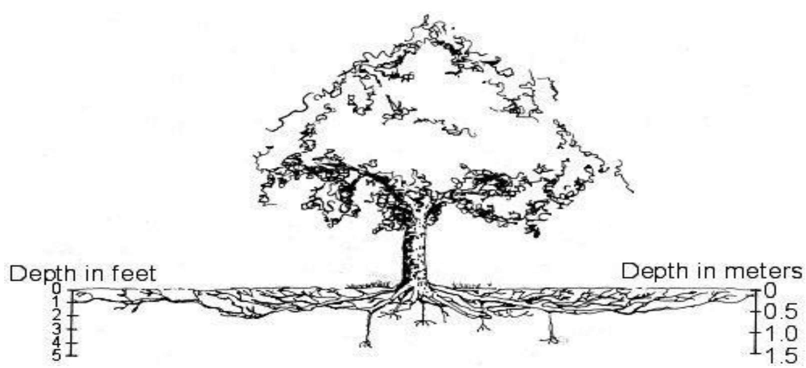
Moisture stress can have adverse effects on trees, including diminished photosynthesis, reduced leaf size and decreased tree growth. In increasingly severe instances, soil moisture deficits cause leaf curl, browning, leaf drop, branch dieback, and crown thinning. In addition to the direct impacts of moisture stress in trees, drought also increases vulnerability of trees to attack by damaging insects and disease.

In Peel's urban areas, abiotic factors that can exacerbate the risks to trees caused by extended periods with no precipitation include: the microclimate in which a tree occurs (i.e., fully sun-exposed as opposed to partially shaded); the materials of the surrounding natural or built structures (i.e., whether they absorb and reradiate solar radiation as heat as opposed to materials that largely reflect radiation); and the physical properties of the soil (i.e., a uniform compacted soil with little structure able to hold less moisture as opposed to a more "clumpy" soil that contains some organic matter and is better able to retain moisture).

Biotic factors that can affect tree responses to extended periods with no precipitation include: tolerances of certain species to drought[4], stage of tree growth (e.g., in spring and summer when the tree is growing the tissues are more susceptible to dehydration damage than in fall or winter), health of the tree and the size and nature of the tree's root system. For example, a tree with extensive fibrous roots (see **Figure 3**) that can exploit a large volume of good quality soil will be better able to withstand drought than a tree with limited root system in a poor quality substrate (Coble *et al.,* 2017).

The cumulative impacts of successive droughts over one and / or multiple summers can also reduce the overall resilience of the urban forest. For example, trees stressed by drought (as shown in **Figure 4a**) may not be able to fully replace their foliage, making them more vulnerable to pests or diseases that a healthier tree might be able to withstand. There can also be indirect impacts, such as drought inhibiting a fungus that naturally controls gypsy moth, increasing the severity of gypsy moth damage to the urban forest.

Figure 3. When unconstrained, tree roots typically extend well beyond the edge of the crown dripline and concentrate in the top few feet of soil



Credit: Lichter and McGlothlin 2011

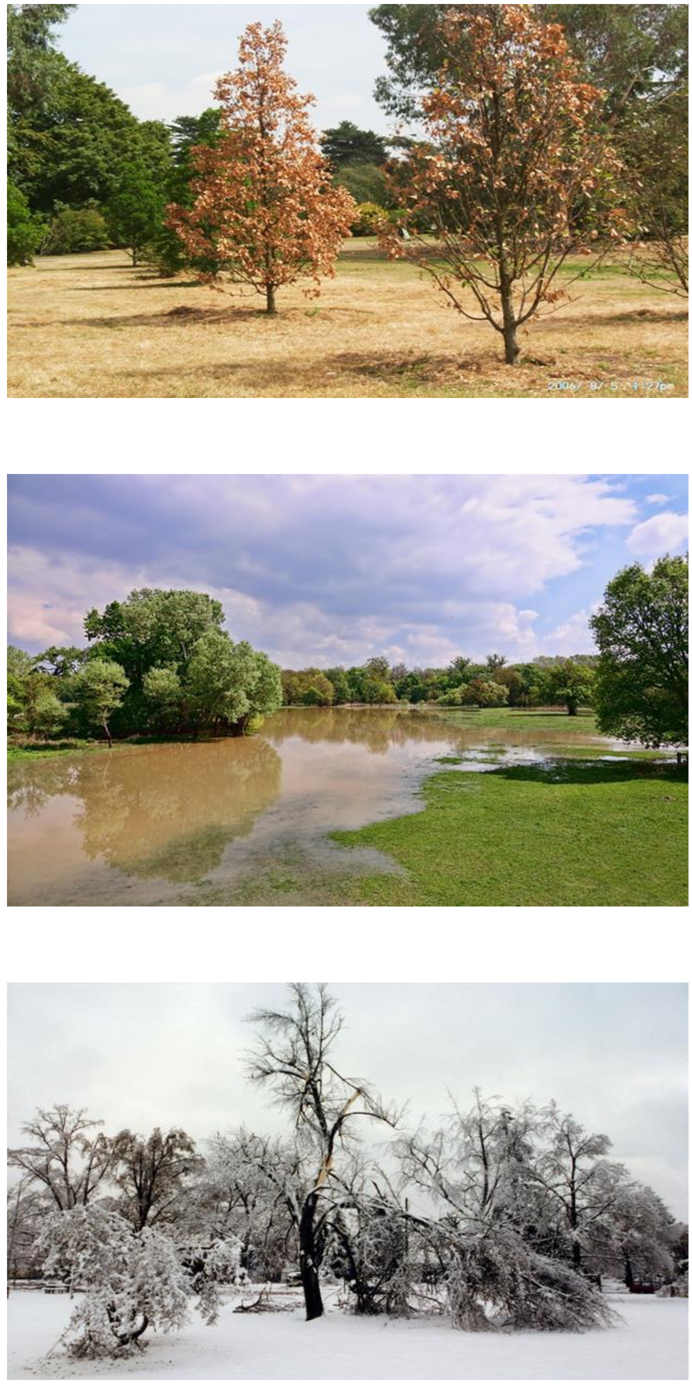
[4] Tree species with greater drought resistance tend to have the capacity to develop deep rooting systems (e.g., oaks, walnuts, hickories, black gum, sassafras, sweet gum, butternut, aspens, larches, willows and pines) in suitable soils (e.g., Crow (2005) presents ranges of root depths for different species growing in different soil types).

2.5 More Frequent High Intensity Precipitation

More frequent highly intense precipitation events can cause localized flooding and erosion in the warmer months and ice storms in the winter (as shown in **Figure 4b** and **Figure 4c**). These types of events are often accompanied by strong winds, although high winds can also occur as stand-alone events.

Riparian areas are especially susceptible to erosion from flash flooding, which can cause dieback or death of trees and shrubs that have low capacity to tolerate waterlogged soils. Symptoms of flood-stress can include: leaf chlorosis (yellowing) followed by leaf loss, reduced leaf size, early leaf drop, formation of watersprouts (i.e., small shoots emerging from the main stem) and crown dieback. Species tolerant of wet soils can grow roots during wet periods but tend to develop shallower, wider spreading root systems, which makes them more susceptible to windthrow. However, there are tree and shrub species in Peel better able to survive weeks and even months in flooded situations.

More frequent and severe ice storms over the winter have already, and are expected to continue, to increase mechanical damage to trees (e.g., branch loss, tree leaning, and tree toppling). Trees are generally more susceptible to breakage from ice accumulation if they have longer horizontal branches, fine branching that can accumulate more ice and stems that do not flex in response to the weight of ice they are carrying.



Credits: S. Colombo

Figure 4. Images from southern Ontario showing: (a) trees stressed by multiple droughts (top), (b) trees subject to flooding (middle) and (c) trees damaged by an ice storm (bottom).

Trees are also more prone to being toppled by ice loading (or strong winds) if their crown is asymmetrical, their roots are shallow and / or their roots are damaged or restricted such that they cannot provide a strong, stable base for the above-ground parts of the tree.

High winds can cause mechanical damage to trees (Purcell 2013), which can be magnified when high winds occur together with ice storms and, to a lesser extent, rainstorms. Mechanical damage also increases susceptibility to insect infestation and disease of affected trees.

2.6 More Pests and Diseases

There are many insect pests and tree diseases that currently affect southern Ontario trees, with some being more harmful than others (McGauley and Kirby 2002). One of the "primary" effects of climate change is increasing vulnerability of the urban forest to diseases and pests (including invasive plant species) that currently occur in Peel because, as described above, there are times when trees are already stressed by drought, flooding and intense wind and/or ice storm damage (e.g., Dale and Frank 2017). Additional "secondary" effects anticipated with climate change include:

- tree diseases and pests already in Ontario becoming more virulent (e.g., Boland *et al.*, 2004, Dale and Frank 2017), and
- an increased risk of diseases and / or pests (including invasive plant species) that were previously excluded from Peel (and southern Ontario) because of the generally colder conditions than areas further south.

Trees that are seriously affected by pests or diseases are also more likely to have to be removed (e.g., as part of risk management and to stop the spread of the pest or disease), further hampering the growth and expansion of the urban forest.

Table 1. Anticipated changes to the climate in Peel by 2041 - 2070[1] and potential effects on trees and risks to the urban forest

Anticipated Changes	Potential Effects on Trees	Risks to the Urban Forest
Increased average temperatures all year-round, with the greatest increases in urban areas (i.e., mainly Mississauga and Brampton)	• May increase the growth of hardwood trees, if soil moisture is not limiting, but not conifers[2], particularly for species at the northern end of their natural range • When temperatures exceed a tree's threshold, physiological functions are impaired and tissues can be permanently damaged • Uneven and even failed flowering and budburst can impact seed production	• Reduced growth of some species, but increased growth of others (if moisture is not limiting) • Uneven and even failed flowering, threatening seed production • Increased damage related to more robust populations of pests / diseases that already occur in Peel

Anticipated Changes	Potential Effects on Trees	Risks to the Urban Forest
	○ Caused by asynchrony between flowering and the timing of insect pollinator emergence or budburst followed by atypical frost	• Increases in incidences of non-native pests / diseases able to move into Peel[3]
Increased frequency and intensity of extreme heat events	• Reduced growth, stress responses (such as early defoliation) and even mortality	• Limited growth and increased mortality • Increased susceptibility to pests, diseases, other stressors
More variable temperatures	• Mild winters and warm, early springs followed by spring frost can damage or kill plant tissues that have begun to grow, including newly emerged shoots and flowers • Long winter thaws without snow cover followed by soil freezing can damage or kill roots, limiting water and nutrient uptake	• Reduced growth and increased mortality • Increased susceptibility to pests, diseases and other stressors
More frequent and extended periods of drought	• Diminished photosynthesis, reduced leaf size • In increasingly severe instances - leaf curl, browning, leaf drop, branch dieback, and crown thinning	• Limited growth and increased mortality • Increased susceptibility to pests, diseases and other stressors
More frequent and more intense precipitation and wind events (flooding and ice storms)	• In the case of flooding, leaf chlorosis, reduced leaf size, early leaf drop, formation of watersprouts and crown dieback • Increased mechanical damage from ice storms, resulting in increased dieback and mortality	• Dieback or death of trees intolerant to waterlogged soils • Increased erosion in and loss of riparian areas • Decline in tree growth and condition due to widespread mechanical damage • Increased susceptibility to pests, diseases and other stressors
More tree pests and diseases	• Variable effects depending on the pest or disease and the species and condition of the affected trees: can range from limited tissue damage to tree mortality	• Dieback or death of trees and shrubs • Loss of certain species or genera in the urban forest

[1] Based on RCP8.5
[2] Way and Oren 2010
[3] Lehmann *et al.,* 2020, Bale and Hayward 2010, Sanders-DeMott *et al.,* 2019

3. Approach for Tree Species Vulnerability Assessment

For this guide, vulnerability assessments under projected climate conditions between 2041 and 2070 under the "worst case" (or RCP8.5) scenario were completed for a suite of tree species (as discussed in **Section 3.1**).

The species selected are primarily native to the CVC watershed or those that occur south of Peel but still within southern Ontario. However, a few species with ranges within the northeastern United States, as well as a few prevalent invasive species known to occur in Peel, were also assessed (as discussed in **Section 3.2**).

The approach used for undertaking the vulnerability assessments is outlined in **Figure 5** and described in more detail in **Section 3.3**.

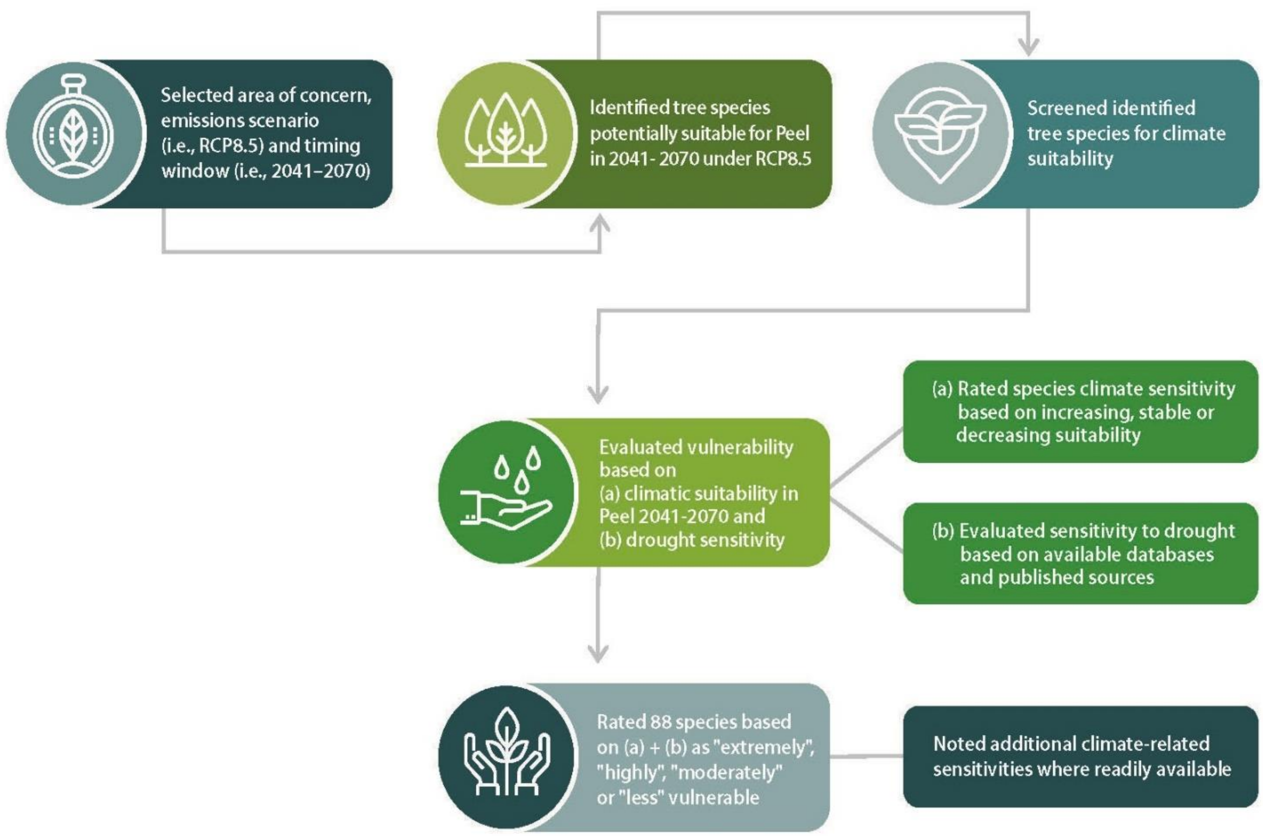


Figure 5. Process for tree species vulnerability assessments undertaken for this guide

3.1 Step 1: Selection of Area, Emissions Scenario and Timing Window

The first step in the process was to select an area of concern, an emissions scenario and a timing window for future climate change projections.

Due to the focus of this project and this guide on Peel Region, this region was confirmed as the "area of concern" for this guide, with the CVC watershed being a close surrogate when exploring the geographic ranges of tree species. The biophysical and land use context of Peel Region –particularly within the urban areas south of the Niagara Escarpment – are described in *Guide 2: Urban Forest Management Best Practices Guide for Peel*.

The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body tasked with assessing and sharing science related to climate change and has been doing so since the 1990s. Anticipating how greenhouse gases will change Earth's climate can be assessed using general circulation models (GCMs), which project future climate conditions for what are called representative concentration pathways (RCPs). The RCPs modelled to date represent different climate scenarios based on different amounts of greenhouse gas in the atmosphere, which produce what is called radiative forcing, with current projected values ranging between 1.9 and 8.5 W/m^2 (IPCC 2018). RCP8.5 is currently the model used to approximate the "worst case" scenario and is based on "business as usual".

Current science indicates that without significant and widespread changes in present practices, the planet is on a "worst case" scenario trajectory for climate change (IPCC 2018). Therefore, the project team decided this scenario was appropriate to use for projecting climate conditions.

Range maps for various plant species to assess climate change vulnerability are generally divided into different periods to compare shifts under historical, current and projected conditions. Natural Resources Canada (NRCan) uses the following four time periods:

- historical (i.e., 1970 – 2010)
- current (i.e., 2011 – 2040)
- near future (i.e., 2041 – 2070) and
- far future (i.e., 2071 – 2100).

The project team decided to undertake vulnerability assessments for the "near future" period (i.e., 2041 – 2070), to be aligned with the natural areas vulnerability assessment work already completed (Tu *et al.,* 2017), which looked towards the 2050's in Peel.

3.2 Step 2: Screening Potentially Suitable Species

For this guide, several hundred tree and shrub species whose current ranges fall within eastern North America were considered for inclusion in the vulnerability assessments. Species lists from the project partners (mainly TRCA and CVC) and municipal street tree lists from sources in the eastern United States with comparable climates to those projected for Peel in 2050 were reviewed and incorporated into a master list that was used as the basis for further consideration.

The following sources were screened as part of this process:

- Arlington County. 2020. Recommended Trees for Arlington County. Arlington County, Virginia. Available online at: https://environment.arlingtonva.us/trees/plant-trees/recommended-trees/
- Bassuk, N., Curtis, D.F., Neal, B. 2008. Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance. Urban Horticulture Institute, Dept. of Horticulture, Cornell University, Ithaca, New York.
- Borough of Chambersburg. 2010. Official List of Trees Suitable for Street Tree Planting by The Borough of Chambersburg Municipal Shade Tree Commission Est. March 1994 (revised July 2010).
- Branch Out Columbus. 2016. Recommended Tree List. 6/29/16.
- City of Alexandria. 2007. Landscape Guidelines: Recommended Planting List. City of Alexandria, Virginia.
- City of Bowling Green. 2006. Street Trees List. City of Bowling Green, Ohio. Urban Forestry Division.
- City of Charlottesville. 2016. Charlottesville Tree Packet: Master Tree List. City of Charlottesville, North Carolina; prepared January 18, 2007; updated October 2016.
- City of Chicago. 2012. City of Chicago Urban Street Tree Planting List. Available at: https://www.chicago.gov/city/en/depts/streets/provdrs/forestry/svcs/tree_planting.html/
- City of Hamilton. 2019. Tree Species Best for New Development. City of Hamilton, Butler County, Ohio.
- City of Mississauga, Ontario. 2020. Tree and Shrub Species Lists.
- City of Saratoga Springs. 2013. Urban and Community Forest Master Plan - Appendix H. City of Saratoga Springs, New York.
- Cleveland Tree Coalition. 2015. Cleveland Tree Plan - Appendix A: Guide for Species Selection. August 2015.
- CVC. 2020. Tree and Shrub Species Lists.
- Lancaster City. 2018. Lancaster City Tree Planting Program. City of Lancaster, Pennsylvania. August 28, 2018.
- New York City. Approved Species Lists. New York City Department of Parks and Recreation. Available for download at: https://www.nycgovparks.org/trees/street-tree-planting/species-list/
- Philadelphia Parks & Recreation. 2017. Approved Street Trees. City of Philadelphia Department of Parks & Recreation. November 15, 2017.

- The Morton Arboretum. Trees & Plants: Tree Recommendations. Available online at: https://www.mortonarb.org/trees-plants/tree-and-plant-advice/tree-species-list/
- TRCA. 2020. Tree and Shrub Species Lists.
- Town of Caledon. 2020. Draft Preferred Street Tree List.
- Virginia Department of Transportation. 2010. Streetscape and Landscape. Location and Design Division, Vol. 1, Appendix B. March 25, 2010.

The 88 species ultimately selected for screening were identified based on a variety of considerations, including the availability of information and the expertise of the project team members. The intent was to focus on species that currently occur in Peel Region and / or that are south of Peel but still within southern Ontario. Species were selected to include both species currently in Peel at the southern edge of their native range and species south of Peel at the northern edge of their native range. Some of the selected species are known to be able to survive and even thrive as street trees under conditions that tend to be harsher and subject to more extremes than in parks or other open spaces. Other key considerations that were used to evaluate vulnerability included tolerance to drought, tolerance to flooding and tolerance to ice damage.

The methods and results of other tree vulnerability studies in Peel and the GTA were also considered, as follows:

- Projected tree distributions in the Credit River watershed (Malcolm *et al.,* 2008)
- Vulnerability of common urban forest species (Khan 2017)
- Town of Ajax Climate Change Study (Restivo and Schofield 2019), and
- Review and consideration of the climate change vulnerability indices (CCVI) assigned for 55 tree and shrub species in the GTA (Sansom 2020).

Ultimately, 88 tree (and shrub) species were selected for assessment including the following as provided in **Appendix A**:

- 54 species categorized for this project as N1 (i.e., native to / current range overlaps with Peel Region and/or CVC watershed
- 15 species categorized for this project as N2 (i.e., native to / current range overlaps with southern Ontario, but south of and not known to be reported as naturally occurring in Peel Region/CVC watershed
- 3 species categorized for this project as N3 (i.e., native to / current range overlaps with the northeastern U.S. as far west as Michigan)
- 2 species categorized for this project as N4 (i.e., native to / current range overlaps with the southeastern U.S.), and
- 14 species categorized for this project as NN (i.e., not native to / current range does not overlap with the North America) including species considered invasive.

Invasiveness of species was also noted based on the Ontario Invasive Plants Council[5] and the Morton Arboretum[6], as well as from input by experts at CVC and TRCA. Although the emphasis

[5] www.ontarioinvasiveplants.ca/
[6] www.mortonarb.org/trees-plants/

was on species native to Peel and/or southern Ontario, one very commonly planted cultivar (Freeman's maple, *Acer x freemanii*) and several confirmed invasive species were evaluated, as listed below:

- Norway maple (*Acer platanoides*)
- Tree of heaven (*Ailanthus altissima*)
- Russian olive (*Elaeagnus angustifolia*)
- White mulberry (*Morus alba*)
- Scots pine (*Pinus sylvestris*)
- Common buckthorn (*Rhamnus cathartica*)
- Black locust (*Robinia pseudoacacia*)
- White willow (*Salix alba*), and
- Siberian elm (*Ulmus pumila*).

Species known to be invasive in Peel under current conditions are generally not recommended for planting (as noted in **Appendix A**) due to the wide range of negative impacts they can cause (i.e., threats to urban forest diversity and natural area biodiversity more broadly). However, because invasive trees and shrubs present some significant management challenges in Peel Region and have the potential to become an even greater threat to native biodiversity as climate change progresses, generating information about their vulnerability under projected climate change conditions was considered to provide valuable information for this exercise.

The species assessed are discussed in **Section 4**, with a full list of the 88 species and the assessment results provided in **Appendix A**, along with a comparison with the CCVI assessments under an RCP8.5 scenario where the same species were examined (as per Sansom 2020, Table C2). Species generally not recommended for planting due to their invasive tendencies or other risks they present (e.g., hybridization with native species) are flagged with two asterisks.

Notably, the projected climatic conditions for Peel under RCP8.5 (as per Auld *et al.,* 2016, Tu *et al.,* 2017 and Peel Region 2018) are subject to uncertainty, and there are different approaches to undertaking species vulnerability assessments, which can generate differing results (as shown in **Appendix A** and Sansom 2020). Therefore, the results provided in this guide are intended to provide one source of information to be considered in conjunction with other sources. In addition, prior to species selection, site context and conditions should be considered by a professional knowledgeable about urban horticulture, and the information in this guide should be updated as additional and / or new information becomes available.

3.3 Step 3: Tree Species Suitability Assessments

A total of 88 species were assessed for climate change vulnerability using the approach described below assuming a "worst case" (RCP8.5) climate scenario and focusing on the near future period of 2041 to 2070. Following species selection, the process consisted of evaluating vulnerability for each species based on (a) exposure to climate change and (b) sensitivity to drought, as illustrated in **Figure 5** and described in more detail below.

3.3.1 Step 3a: Rate Selected Species Based on Climate Exposure

Climate suitability evaluations for selected tree species in Peel Region were undertaken based on an evaluation of (i) 49 species by Malcolm *et al.,* (2008) for Peel Region, and (ii) the 88 species identified for this assessment, with many of these species covered by both (i) and (ii).

- In the study by Malcolm *et al.* (2008), current and future climate suitability for tree species in Peel Region were evaluated based on the climate in the species' historical range (1971-2000), which was assumed to represent the climate a species is genetically best adapted to. The climatic suitability of Peel for each species was then determined for two future climate conditions analogous to RCP6.0 and RCP8.5 for the period 2090-2100. Species with low climate suitability were considered more likely to experience climatic stress.
- Species were classified based on climatic suitability within Peel Region (as per Fourcade et al., 2014), using RCP8.5 for the period 2041 to 2070. Species were classified visually using maps obtained online from the NRCan Plant Hardiness website, as follows:
    - "low" exposure to climatic stress = species with no future loss or with a gain in climatic suitability within Peel Region; area of suitable habitat is more than 20%
    - "moderate" exposure to climatic stress = species with some loss in climatic suitability within Peel; area of suitable habitat in Peel does not fall below 20%
    - "high" exposure to climatic stress = species for which climatic suitability declines within Peel; area of suitable habitat in Peel is less than 20%.

The results of the climactic suitability mapping for the 88 species assessed and for the four time periods considered under the RCP8.5 scenario for climate change are presented in **Appendix B**.

3.3.2 Step 3b: Rate Selected Species Based on Drought Sensitivity

Sensitivity to drought was rated as low, moderate or high based primarily on documented species' drought tolerances obtained from:

- the "Tree Species Selector" available at Vineland Research and Innovation Centre website[7]
- the Morton Arboretum online plant database[8], and
- the plant list assembled by Niinemets and Valladares[9].

[7] https://www.greeningcanadianlandscape.ca/tree-species-selector/eastern-canada-tree-species

[8] https://www.mortonarb.org/trees-plants/search-trees/search-all-trees-and-plants

[9] Ecological Archives M076-020-A1 available at https://wiley.figshare.com/articles/dataset/Appendix_A_A_table_showing_shade_drought_and_waterlogging_tolerance_for_806_species_of_woody_plants_from_the_temperate_Northern_Hemisphere_/3565671/1

Where the Vineland and Morton Arboretum databases were not in agreement or where they did not provide information on drought tolerance for a particular species, the plant list assembled by Niinemets and Valladares[10] (who based plant physiological drought tolerance on the minimum soil water potential that can be tolerated over the long term with <50% damage to foliage or dieback) was consulted. Niinemets and Valladares (2006) use a five-level scale for assessing drought tolerance based on the geographical areas where species occur. The Niiniments and Vallardes numeric scale was converted to categorial values, in which high sensitivity to drought was assigned to species numerical values of from 1 to 2.19, moderate sensitivity from 2.20 to 3.39, and low sensitivity to drought for values greater than 3.4.

3.3.3 Additional Climate Tolerances and Sensitivities Considered

As discussed in **Section 2**, climate change is expected to increase the frequency of flooding and ice storms and the frequency and duration of periods of drought and heat. These stressors are also expected to increase trees' risk of damage from storms and susceptibility to harmful pests and/or diseases.

Although a comprehensive review of all the available information on species-specific tolerances and risks / sensitivities was not possible as part of this project, some targeted research was undertaken[11] and synthesized with our team's applied experience[12] to assign species-specific tolerances and sensitivities to many of the 88 species being assessed, as follows:

- TOLERANCES (to urban / climate change stressors): high level of resistance to ice damage, drought tolerant, flood tolerant, resistant to serious pest or disease, poor soils tolerant
- RISKS / SENSITIVITIES: low resistance to ice damage, drought intolerant, flood intolerant, vulnerable to serious pest or disease, hybridizes with native species.

This additional information did not factor directly into the species vulnerability rankings but was considered potentially useful for informing species selection and was noted where appropriate in **Appendix A.** This information should be amended as additional work is done and / or as additional species-specific information becomes available.

[10] Ecological Archives M076-020-A1 available at https://wiley.figshare.com/articles/dataset/Appendix_A_A_table_showing_shade_drought_and_waterlogging_tolerance_for_806_species_of_woody_plants_from_the_temperate_Northern_Hemisphere_/3565671/1

[11] Additional sources consulted include: Farrar (1995), Trees in Canada [range maps]; Hauer et al., (1993), Ice Storm Damage to Urban Trees [susceptibility to ice damage]; Hauer et al., (2006), The Development of Ice Storm–resistant Urban Tree Populations [susceptibility to ice damage]; Loucks (1987), Flood-tolerant Trees [flood tolerance]; Trees Ontario (2020). Accessed at ontariotrees.com/main/list_latin.php [source of latin and common names]; University of Tennessee (2005), Shade and Flood Tolerance of Trees [flood tolerance and sensitivities]

[12] This information has been gleaned from the experience and opinions of the experts on the consulting team (Ash Baron, Steve Colombo) and at the agencies - specifically at CVC (Lisa Riederer, Joe Pearson, Dawn Renfrew) and at TRCA (Mark Funk).

4. Results and Discussion of Tree Species Vulnerability Assessment

As per the process shown in **Figure 5**, vulnerability rankings were applied to the 88 species assessed based on (a) projected climatic suitability in 2041 – 2070, and (b) drought sensitivity, determined using the methodology described in **Section 3**. The results are illustrated in **Figure 6**, discussed further below and provided in **Appendix A**.

Species vulnerability to climate change was classified as extreme, high, moderate or low, as follows:

- **Extreme Vulnerability (EV)** = 16 of 88 (18%) species that were both "high" in climate exposure and drought sensitivity rankings
- **High Vulnerability (HV)** = 31 of 88 (35%) species that had a "high" ranking of either climate exposure or drought sensitivity
- **Moderate Vulnerability (MV)** = 21 of 88 (24%) species with two moderate rankings or with one moderate and one low ranking of either climate exposure or drought sensitivity
- **Low Vulnerability (LV)** = 20 of 88 (23%) species having low sensitivity to drought and low climatic exposure

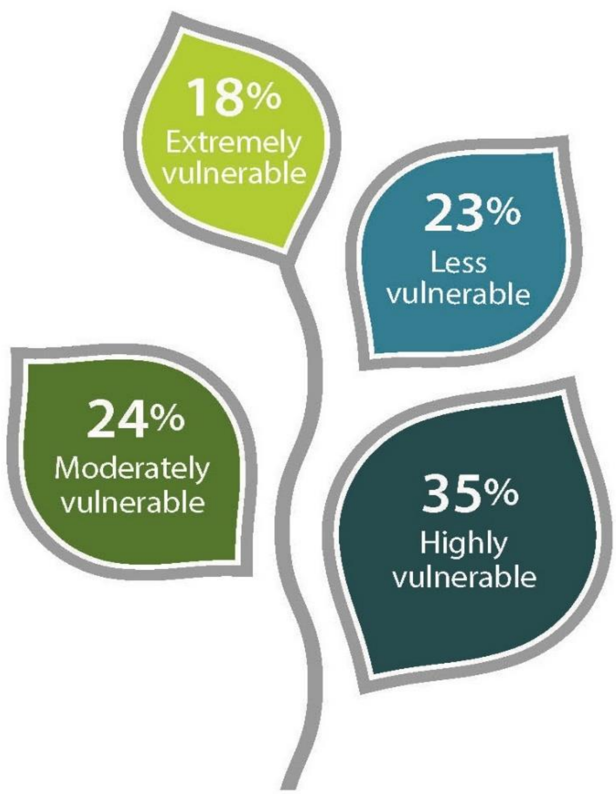


Figure 6. Illustration of tree species vulnerability assessment results for Peel

Table 2. Overview of tree (and shrub) vulnerability assessments[1] for 88 species completed for Peel Region

Peel Vulnerability Assessment (VA) Ranking	Results[2]	Notable Species[3]
Extreme Vulnerability (EV)	16 of 88 species • 8 N1 species • 6 N2 species • 0 N3 or N4 species • 2 NN species, but no invasives	• Includes one SAR – cucumber tree (*Magnolia acuminata*) and one S3 species – red spruce (*Picea rubens*)
High Vulnerability (HV)	31 of 88 species • 17 N1 species • 4 N2 species • 2 N3 species • 2 N4 species • 6 NN species, including 4 invasives and 2 potential invasives	• Includes one SAR – Kentucky coffee tree (*Gymnocladus dioicus*), one S3 species – pawpaw (*Asimina triloba*) and one S2 species – dwarf chinquapin oak (*Quercus prinoides*)
Moderate Vulnerability (MV)	21 of 88 species • 18 N1 species • 2 N2 species • 0 N3 or N4 species • 1 NN species, potentially invasive	• Includes three SAR – flowering dogwood (*Cornus florida*), Butternut (*Juglans cinerea*) and red mulberry (*Morus rubra*)
Low Vulnerability (LV)	20 of 88 species • 12 N1 species, including 1 potential invasive • 2 N2 species • 2 N3 species, including 1 invasive • 0 N4 species • 4 NN species, all invasive	• Includes one S3 species – Shumard oak (*Quercus shumardii*)

[1] Based on RCP8.5 projected for 2041 to 2070
[2]RANGE: N1 = native to (current range overlaps with) Peel Region and/or CVC watershed
N2 = native to (current range overlaps with) southern Ontario, but south od and not known to be reported as naturally occurring in Peel Region/CVC watershed
N3 = native to (current range overlaps with) the northeastern U.S. as far west as Michigan
N4 native to southeastern U.S. (I added this category based on our discussion), and
NN = not native to (current range does not overlap with) North America
[3]SAR = Species at Risk in Ontario, S2 = very rare in Ontario (5 to 20 occurrences), S3 = rare to common in Ontario (20 to 100 occurrences)

Overall, more than half of the tree species assessed (47 of 88) were rated extremely or highly vulnerable, with all species at the southern edge of their range projected to be extremely or highly vulnerable and many (but not all) species at the northern edge of their range (see **Appendix B**) projected as having moderate or low vulnerability.

Established trees of species assessed as HV or EV may be able to persist in Peel in 2041 to 2070 under RCP8.5 conditions, but they would be expected to be less likely to thrive in future conditions. In addition, although some species will be more vulnerable than others, there is still some uncertainty associated both with the anticipated conditions and with the results of this assessment. Including a diversity of species is one of the best strategies to help mitigate against this uncertainty (as discussed in Guide 2 and Guide 5) and although it is recommended that species assessed as LV or MV be favoured over those assessed as HV or EV for planting, particularly in more challenging / stressful locations (such as adjacent to busy roads, in hardscapes, etc.) where the trees are already experiencing stressors, greater diversity achieved by planting some HV and EV species is desirable.

Table 3. Tree and shrub species vulnerability to climate change in Peel Region

Scientific Name	Common Name	Range[1]	Status[2]	Peel VA-RCP8.5[3]
Abies balsamea	Balsam fir	N1		EV
Abies concolor	White fir	NN		HV
Acer pensylvanicum	Striped maple	N2		EV
Acer rubrum	Red maple	N1		MV
Acer saccharinum	Silver maple	N1		MV
Acer saccharum	Sugar maple	N1		MV
Acer x freemanii	Freeman's maple	N1		MV
Aesculus glabra	Ohio buckeye	N2		MV
Amelanchier arborea	Downy serviceberry	N1		MV
Asimina triloba	Pawpaw	N2	S3	HV
Betula alleghaniensis	Yellow birch	N1		EV
Betula papyrifera	White birch	N1		EV
Carpinus caroliniana	Blue beech	N1		HV
Carya cordiformis	Bitternut hickory	N1		LV
Carya ovata	Shagbark hickory	N1		LV
Catalpa speciosa	Catalpa	N3		HV
Celtis occidentalis	Common hackberry	N1		LV
Cercis canadensis	Eastern redbud	N3		LV
Cornus alternifolia	Alternate-leaved dogwood	N1		EV
Cornus florida	Flowering dogwood	N1	SAR	MV
Cornus sericea	Red osier dogwood	N1		HV
Crataegus mollis	Downy hawthorn	N1		LV
Crataegus punctata	Dotted hawthorn	N1		LV
Fagus grandifolia	American beech	N1		HV
Gleditsia triacanthos	Honey locust	N2		LV
Gymnocladus dioicus	Kentucky coffee tree	N2	SAR	HV
Juglans cinerea	Butternut	N1	SAR	MV
Juglans nigra	Black walnut	N1		MV
Juniperus virginiana	Eastern red cedar	N1		LV
Larix decidua	European larch	NN		EV

Scientific Name	Common Name	Range[1]	Status[2]	Peel VA-RCP8.5[3]
Larix laricina	Tamarack	N1		EV
Liquidambar styraciflua	Sweetgum	N4		HV
Liriodendron tulipifera	Tulip tree	N2		EV
Magnolia acuminata	Cucumber tree	N2	SAR	EV
Morus rubra	Red mulberry	N1	SAR	MV
Nyssa sylvatica	Black gum	N2		LV
Ostrya virginiana	Eastern hop-hornbeam	N1		LV
Picea abies	Norway spruce	NN		EV
Picea glauca	White spruce	N1		HV
Picea pungens	Colorado spruce, blue spruce	NN		HV
Picea rubens	Red spruce	N2	S3	EV
Pinus resinosa	Red pine	N1		HV
Pinus strobus	White pine	N1		HV
Platanus occidentalis	Sycamore	N1		LV
Populus deltoides	Eastern cottonwood	N1		MV
Populus grandidentata	Largetooth aspen	N1		HV
Populus tremuloides	Trembling aspen	N1		HV
Prunus pensylvanica	Pin cherry	N1		HV
Prunus serotina	Black cherry	N1		MV
Prunus virginiana	Chokecherry	N1		HV
Ptelea trifoliata	Common hoptree	N2		HV
Quercus alba	White oak	N1		MV
Quercus bicolor	Swamp white oak	N1		HV
Quercus coccinea	Scarlet oak	N3		HV
Quercus macrocarpa	Bur oak	N1		MV
Quercus palustris	Pin oak	N2		MV
Quercus prinoides	Dwarf chinquapin oak	N2	S2	HV
Quercus rubra	Red oak, northern red oak	N1		HV
Quercus shumardii	Shumard oak	N2	S3	LV
Quercus velutina	Black oak	N1		LV
Rhus glabra	Smooth sumac	N1		HV
Rhus typhina	Staghorn sumac	N1		HV
Salix amygdaloides	Peachleaf willow	N1		HV
Salix humilis	Prairie willow	N2		EV
Salix nigra	Black willow	N1		HV
Sassafras albidum	Sassafras	N1		LV
Sorbus americana	American mountain ash	N1		EV
Sorbus decora	Showy mountain ash	N2		EV

Scientific Name	Common Name	Range[1]	Status[2]	Peel VA-RCP8.5[3]
Taxus canadensis	Canada yew	N1?		EV
Thuja occidentalis	Northern white cedar	N1		HV
Tilia americana	Basswood	N1		MV
Tsuga canadensis	Eastern hemlock	N1		EV
Ulmus americana	White elm	N1		LV
Ulmus rubra	Slippery elm	N1		MV
Ulmus thomasii	Rock elm	N1		MV

[1]N1 = native to (current range overlaps with) Peel Region and/or CVC watershed
N2 = native to (current range overlaps with) southern Ontario, but south od and not known to be reported as naturally occurring in Peel Region/CVC watershed
N3 = native to (current range overlaps with) the northeastern U.S. as far west as Michigan
N4 native to southeastern U.S. (I added this category based on our discussion), and
NN = not native to (current range does not overlap with) North America
[2]SAR = Species at Risk in Ontario, S2 = very rare in Ontario (5 to 20 occurrences), S3 = rare to common in Ontario (20 to 100 occurrences)
[3] Peel Vulnerability Assessment for this project (see methodology in **Section 3**) based on RCP8.5 and 2041 to 2070; Extreme Vulnerability (EV), High Vulnerability (HV), Moderate Vulnerability (MV) and Low Vulnerability (LV)

Species assessed but generally not recommended for planting in Peel are listed in **Table 4**. Most of these 11 of the 88 species assessed are not recommended because they are confirmed or potentially invasive in Peel, with other factors being their potential for hybridization with native species and susceptibility to pests.

Appendix B includes range maps for the species listed in **Appendix A** under historical (i.e., 1970 – 2010), current (i.e., 2011 – 2040), near future (i.e., 2041 – 2070) and far future (i.e., 2071 – 2100) projected climate scenarios under RCP8.5, obtained from the on-line NRCan species-specific and climate change-informed range mapping.

In general, these rankings are comparable to those of Khan (2017) and Restivo *et al.,* (2019), who assessed vulnerability to environmental conditions for tree species in the City of Mississauga and the Town of Caledon, respectively. The results are also comparable with the CCVI assessments by Sansom (2020) in most cases, but for some species the results are very different (see **Table 5**).

Most of the species evaluated for vulnerability in this project are either already present in Peel naturally or have been introduced or occur elsewhere in southern Ontario south of Peel. However, some of the species considered are not native to Ontario. Introducing a species whose historic / current range is outside Peel constitutes assisted migration. Although assisted migration has already been happening inadvertently through municipal planting programs for decades, particularly for street and park trees which tend to be larger stock often grown in the United States for at least part of their development, it should not be knowingly undertaken without careful consideration of multiple factors, with future climatic suitability being just one consideration (Aubin *et al.*, 2011). (Further discussion and guidance related to assisted migration is provided in Guide 5 of this series).

Table 4. Tree and shrub species assessed for vulnerability generally not recommended for planting in Peel Region

Scientific Name	Common Name	Range[1]	Risks[2]	Peel VA-RCP8.5[3]
Acer negundo	Manitoba maple	N1	I?	LV
Acer platanoides	Norway maple	NN	I	HV
Aesculus hippocastanum	Horse chestnut	NN	I?	MV
Ailanthus altissima	Tree of heaven	NN	I	LV
Elaeagnus angustifolia	Russian olive	NN	I	LV
Fraxinus americana	White ash	N1	P**	MV
Maclura pomifera	Osage orange	N4	I?	HV
Morus alba	White mulberry	NN	I, H	LV
Pinus sylvestris	Scots pine	NN	I	HV
Rhamnus cathartica	Common buckthorn	NN	I	HV
Robinia pseudoacacia	Black locust	N3	I	LV
Salix alba	White willow	NN	I	HV
Ulmus pumila	Siberian elm	NN	I	LV

[1]N1 = native to (current range overlaps with) Peel Region and/or CVC watershed
N2 = native to (current range overlaps with) southern Ontario, but south od and not known to be reported as naturally occurring in Peel Region/CVC watershed
N3 = native to (current range overlaps with) the northeastern U.S. as far west as Michigan
N4 native to southeastern U.S. (I added this category based on our discussion), and
NN = not native to (current range does not overlap with) North America
[2]RISKS: I = Invasive or I? = Potentially invasive (based on the literature reviewed and local expert opinion); H = hybridizes with native species (N1, N2, N3 or N4), P = vulnerable to serious pest or disease currently widespread in Peel
[3] Peel Vulnerability Assessment for this project (see methodology in **Section 3**) based on RCP8.5 and 2041 to 2070; Extreme Vulnerability (EV), High Vulnerability (HV), Moderate Vulnerability (MV) and Low Vulnerability (LV)
** For all *Fraxinus*, if there are genetic strains with EAB resistance then planting of species in this genus that are N1 or N2 for Peel would be encouraged.

It is important to keep in mind that species ranked as having "high" or "extremely high" vulnerability to climate change should not be entirely excluded from consideration because of the uncertainties associated with climate change projections the species-specific vulnerability analyses carried out for this project. Ultimately, trees that are site-appropriate, provided with good growing conditions and appropriately maintained (as described in Guide 2) will be best positioned to respond to a range of stressors and changes in conditions. Species selection and diversification is just one piece of this puzzle.

Therefore, including some species assessed as having "high" and "extremely high" vulnerability to climate change is still recommended going forward, although they should generally be kept out of difficult growing environments and / or provided supplemental maintenance and management measures (e.g., additional watering as needed) to help bolster their resilience.

4.1 Comparison with CCVI

As noted above, there is no universal methodology for undertaking species vulnerability assessments and different approaches have been used by different researchers. However, the NatureServe Climate Change Vulnerability Index (CCVI) has been used in a wide variety of ecosystems for both plant and animal species. To illustrate the potentially different outcomes for the same species using two defensible but different approaches, the species vulnerability results undertaken for this project were compared to the results obtained by Sansom (2020) for CVC using the CCVI (**Table 5)**. Notably, comparisons are shown where the species evaluated by Sansom (2020) overlapped with those examined for this project.

Table 5. Tree and shrub species assessed for vulnerability using two different methods

Scientific Name	Common Name	Range[1]	Risks[2]	Status[3]	Peel VA-RCP8.5[4]	GTA CCVI-RCP8.5[5]
Abies balsamea	Balsam fir	N1			EV	EV
*Acer negundo***	Manitoba maple**	N1	I?		LV	HV
Acer rubrum	Red maple	N1			MV	HV
Acer saccharinum	Silver maple	N1			MV	EV
Acer saccharum	Sugar maple	N1			MV	HV
Acer x freemanii	Freeman's maple	N1			MV	MV
Betula alleghaniensis	Yellow birch	N1			EV	EV
Betula papyrifera	White birch	N1			EV	EV
Carpinus caroliniana	Blue beech	N1			HV	HV
Carya cordiformis	Bitternut hickory	N1			LV	EV
Carya ovata	Shagbark hickory	N1			LV	EV
Fagus grandifolia	American beech	N1			HV	EV
*Fraxinus americana***	White ash**	N1			MV	EV
Juglans cinerea	Butternut	N1		SAR	MV	EV
Juglans nigra	Black walnut	N1			MV	EV
Juniperus virginiana	Eastern red cedar	N1			LV	HV
Larix laricina	Tamarack	N1			EV	EV
Liriodendron tulipifera	Tulip tree	N2			EV	EV
Morus rubra	Red mulberry	N1		SAR	MV	EV
Ostrya virginiana	Eastern hop-hornbeam	N1			LV	MV
Picea glauca	White spruce	N1			HV	EV
Pinus strobus	White pine	N1			HV	EV
Populus deltoides	Eastern cottonwood	N1			MV	EV

Scientific Name	Common Name	Range[1]	Risks[2]	Status[3]	Peel VA-RCP8.5[4]	GTA CCVI-RCP8.5[5]
Populus grandidentata	Largetooth aspen	N1			HV	HV
Populus tremuloides	Trembling aspen	N1			HV	HV
Prunus serotina	Black cherry	N1			MV	HV
Quercus alba	White oak	N1			MV	EV
Quercus bicolor	Swamp white oak	N1			HV	EV
Quercus macrocarpa	Bur oak	N1			MV	EV
Quercus rubra	Red oak, northern red oak	N1			HV	HV
Quercus velutina	Black oak	N1			LV	EV
*Rhamnus cathartica***	Common buckthorn**	NN	I		HV	MV
Salix nigra	Black willow	N1			HV	EV
Sassafras albidum	Sassafras	N1			LV	HV
Thuja occidentalis	Northern white cedar	N1			HV	EV
Tilia americana	Basswood	N1			MV	HV
Tsuga canadensis	Eastern hemlock	N1			EV	EV
Ulmus americana	White elm	N1			LV	EV
Ulmus rubra	Slippery elm	N1			MV	EV
Ulmus thomasii	Rock elm	N1			MV	HV

[1]RANGE: N1 = native to (current range overlaps with) Peel Region and/or CVC watershed
N2 = native to (current range overlaps with) southern Ontario, but south od and not known to be reported as naturally occurring in Peel Region/CVC watershed
N3 = native to (current range overlaps with) the northeastern U.S. as far west as Michigan
N4 native to southeastern U.S. (I added this category based on our discussion), and
NN = not native to (current range does not overlap with) North America

[2]RISKS: I = Invasive or I? = Potentially invasive (based on the literature reviewed and local expert opinion); H = hybridizes with native species (N1, N2, N3 or N4), P = vulnerable to serious pest or disease currently widespread in Peel

[3]SAR = Species at Risk in Ontario

[4] PEEL VA-RCP8.5 = Peel Vulnerability Assessment for this project (see methodology in Guide 4) based on RCP8.5 and 2041 to 2070; Extreme Vulnerability (EV), High Vulnerability (HV), Moderate Vulnerability (MV) and Low Vulnerability (LV) (see Guide 4, Section 3 for methodology)

[5] GTA CCVI-RCP8.5 = Climate Change Vulnerability Index rankings under RCP8.5 as per Sansom (2020) for 55 trees/shrubs in the GTA from Table C2; EV = extremely vulnerable, HV = highly vulnerable, MV = moderately vulnerable, LV = less vulnerable (note: not all the same species were assessed)

The CCVI expresses climate change vulnerability based on factors related to species' exposure to climate change, the sensitivity of species to changes in climate, and species' adaptive capacity allowing it to avoid harmful outcomes. In the CCVI approach, exposure is based on projections of future temperature and moisture availability and also considers the ability of a species to migrate. Sensitivity and adaptive capacity are assessed using factors such as dispersal capability, sensitivity to changes in temperature and moisture regime, reliance on interspecific interactions, species genetic diversity, and effects of altered phenology with changing climate. The CCVI categorizes species using the same four categories adopted above (i.e., EV, HV, MV and LV).

Of the 39 species assessed in both this guide and Sansom (2020), less than 10 were assigned the same ranking, and some received rankings at the opposite ends of the vulnerability spectrum (i.e., LV versus EV), illustrating how different approaches can give quite different results. It was not within the scope of this project to analyze these differences – they have, however, been presented to clearly illustrate that different approaches can, and do, yield different outcomes.

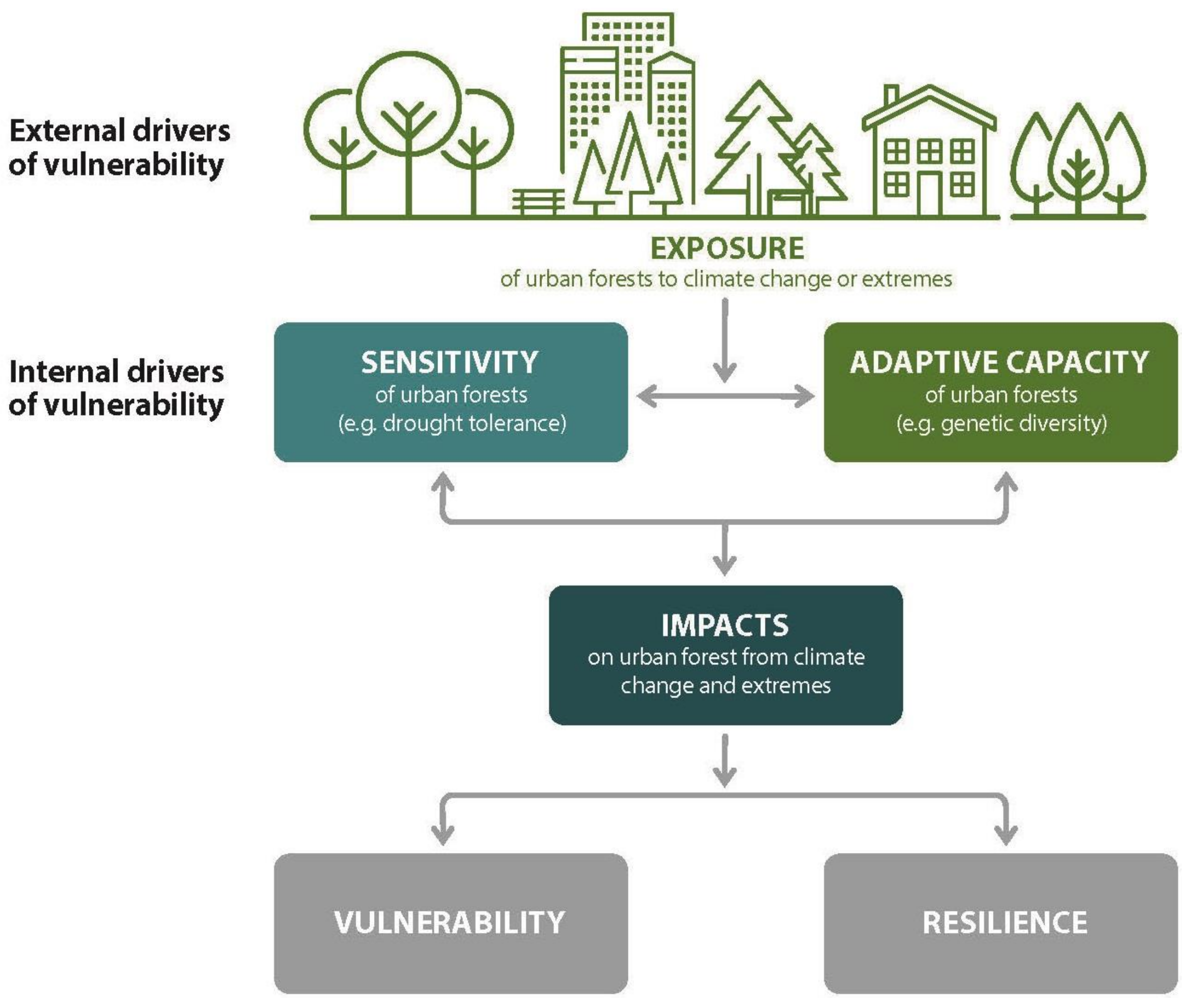


Figure 7. Illustration of how both sensitivity and adaptive capacity among and within different species can influence their response to climate change impacts

5. How to Use This Guide and Concluding Remarks

This guide describes the methods and results for vulnerability assessments completed on 88 selected trees and shrubs. These species were assessed to gain insights as to which may be better suited (or less vulnerable) to growing under projected climate conditions in 2041 to 2070 under the "worst case" climate scenario (RCP8.5 scenario). A comprehensive list of species and their projected vulnerabilities are provided in **Appendix A**.

It is important to recognize the following in using the information this guide provides:

- Established trees of species assessed as having "high vulnerability (HV)" or "extreme vulnerability (EV)" under projected conditions in 2041 to 2070 may survive, but are less likely to thrive and are expected to be more susceptible to the negative impacts of environmental and other stressors. Therefore, consideration should be given to planting a lower proportion of these species and a greater proportion of species identified as having "moderate (MV)" or "low (LV)" vulnerability, particularly in sites where trees are more exposed to urban stressors (e.g., along busy roads).

- The results of the tree vulnerability assessment in this guide are one of several important factors that ought to be considered in the process of selecting potentially suitable tree species for planting. In all cases, appropriate species selection requires an understanding or a range of extrinsic (i.e., environmental, site) and intrinsic (i.e., species-specific) variables, and should be done with input from individuals with knowledge of tree species' management, ecology and microsite requirements in urban areas.

- There are uncertainties as to how climate change will unfold and uncertainties about the tolerances of many of the species considered through this project. The results of the tree vulnerability assessments included in this guide are projections based on assumptions of a "business as usual" emissions scenario using a specific (but not the only possible) methodology. Therefore, the results provided in the appendices of this report should be considered working lists, subject to further revisions and refinements as additional data and information is collected and / or available.

Despite these uncertainties, today's science indicates that without significant and widespread changes in current practices the planet is on a "worst case" scenario trajectory for climate change (IPCC 2018). The need for action has never been more urgent. Therefore, given there is currently little local guidance in terms of what trees could or should be planted in the context of a rapidly shifting climate in Peel, the approach undertaken, and the lists generated for this document, which have been developed with input from experts at CVC and TRCA, provide valuable information.

This guide is intended to provide individuals already knowledgeable about trees with additional information to inform species selection in Peel in a climate change context, so that they can better:

- Assess current urban forest planting lists for their vulnerability to climate change
- Revise planting plans to include a greater proportion of native species that are expected to be suitable under anticipated climate conditions, and a lower proportion of species that are expected to be more vulnerable
- Design and/or inform assisted migration trials, and
- Assess the current composition of Peel's urban forest to vulnerability.

This information, in conjunction with other site-specific and site design considerations, is intended to help inform species selection in Peel's urban areas – particularly in some of the locations where tree establishment is most challenging (e.g., streets and rights-of-way) – and by doing so, is intended to help guide urban forest diversification efforts across Peel over the long term.

Credit: A. Cunningham

Figure 8. Trees shading a trail in the City of Brampton

6. Glossary of Key Terms

Most of the following terms relate to climate change. Text in italics has been quoted *verbatim* from the source indicated. Text not in italics has been adapted or provided by the authors.

(climate change) Adaptation	*Adjustment in natural or human systems in response to actual or expected climate stimuli and their effects, which moderates harm or exploits beneficial opportunities. There are various types of adaptation, including anticipatory, autonomous and planned adaptation* (Richardson 2010). Coping is not same as adaptation: coping reflects existing abilities, adaptation is a change in the framework (e.g., change in species in a forest) in which coping takes place.
Adaptive capacity	*The whole of capabilities, resources and institutions of a country, region, community or group to implement effective adaptation measures* (Richardson 2010). The capability to adapt.
Assisted migration	Assisted migration refers to human intervention to deliberately move species to new, more favorable locations, with the goal of helping them to survive and flourish in a changing climate (Ste-Marie 2014).
Assisted Migration	*Assisted migration,* human-assisted movement of species in response to climate change*, is a general term that encompasses a variety of different potential actions, which have substantial differences in terms of risk, ecological implications, and policy considerations. Here are some of the commonly used terms that distinguish between different forms of assisted migration:* • *Assisted population migration (also assisted genetic migration or assisted gene flow) – moving seed sources or populations to new locations within the historical species range.* • *Assisted range expansion – moving seed sources or populations from their current range to suitable areas just beyond the historical species range, facilitating or mimicking natural dispersal.* • *Assisted species migration (also species rescue, managed relocation, or assisted long-distance migration) – moving seed sources or populations to a location far outside the historical species range, beyond locations accessible by natural dispersal.* (Williams and Dumroese 2013)

GCM (General Circulation Models)	GCMs are used to understand how Earth's climate is being changed by greenhouse gases. GCMs represent physical processes that occur in the atmosphere, ocean, cryosphere and on land surfaces (IPCC 2018). GCMs provide projections of future climate for what are called representative concentration pathways, or RCPs.
(climate change) Impacts	*The adverse and beneficial effects of climate change on natural and human systems* (Richardson 2010). An impact of climate change on a biological system can be, for example, a change in a plant's productivity or quality, a plant population's competitive ability, or a species range.
Mitigation	*In the context of climate change, mitigation is an anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhance greenhouse gas sinks* (Richardson 2010).
Plasticity	Plasticity is a plant's ability to adapt behavior or characteristics to cope with changes in environment. Plasticity responses are physiological, but can be manifested by changes in biochemistry, physiology, morphology, behavior or life history. The timing, specificity, and speed of plastic responses are critical to their adaptive value. Phenotypic plasticity, through its ecological effects, can facilitate genetic change through mating, seed production and seedling survival.
Provenance	"Provenance" as it relates to tree seeds refers specifically to the original geographic area in which the seeds originally evolved over time (Sjöman *et al.*, 2019). A provenance is site-specific, typically represented by a local stand of trees.
Radiative Forcing	*Radiative forcing is the difference between solar irradiance (sunlight) absorbed by the Earth and energy radiated back to space. It is the scientific basis for the greenhouse effect on planets, and plays an important role in computational models of Earth's energy balance and climate* (Wikipedia, May 2021).

RCP (Representative Concentration Pathways)	*A Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC. Four pathways were used for climate modeling and research for the IPCC fifth Assessment Report (AR5) in 2014. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come. The RCPs – originally RCP2.6, RCP4.5, RCP6, and RCP8.5 – are labelled after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6, and 8.5 W/m^2, respectively). Since AR5 the original pathways are being considered together with Shared Socioeconomic Pathways: as are new RCPs such as RCP1.9, RCP3.4 and RCP7* (Wikipedia, accessed 2020-12-31). Each RCP scenario considers different the concentrations of greenhouse gases, atmospheric aerosols and other chemically active gases, as well as projected changes in land use and land cover over time (Moss *et al.*, 2008). The greatest increase in radiative forcing is given by RCP8.5, which is the scenario considered for the tree and shrub species analyses conducted for this toolkit.
Resilience	*The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the same capacity for self-organization and the same capacity to adapt to stress and change* (Richardson 2010). The strengthening of coping capacities usually builds resilience to withstand the effects of hazards.
(climate change) Risk	*A combination of the likelihood (probability of occurrence) and the consequences of an adverse event* (Richardson 2010). Risk is the potential for climate change to have an adverse consequence, determined by integrating exposure and vulnerability. For example, there is a risk that climate change will produce droughts causing mortality of some tree species. Risk of an impact is proportional to exposure to a climate change hazard and vulnerability of the system. To determine whether climate change will be damaging for any ecosystem or species requires assessing its exposure and vulnerability to specific hazards.
(climate change) Sensitivity	*Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or climate change. The effect may be direct … or indirect* (Richardson 2010). For plants, it relates to the biophysical effect of climate change, such as a change in tree growth, plant mortality, etc., caused by exposure to a change in climate. Each element, such as different tree species, has its own sensitivity to a specific aspect of climate change, and sensitivity can be changed by changes in environment.

(biological) Stress	A biological stress is any environmental factor capable of inducing a potentially injurious response (or strain) on an organism. Stress may be manifested physically (e.g., reduced cell division) or chemically (e.g., a shift in metabolism). Some changes in physiological processes caused by stress can cause injury or death. The presence of both stress avoidance and stress tolerance mechanisms increases the likelihood of survival during stress.
(biological) Stress avoidance	Stress avoidance is the extent to which a plant can reduce the level of or to postpone exposure to a stress. Stress avoidance mechanisms may allow a stress to be avoided entirely or in part or may postpone the time for which the stress is experienced.
(biological) Stress tolerance	The level of stress at which physiological impairment occurs.
Urban forest	*A dynamic system that includes all trees, shrubs and understory plants, as well as the soils that sustain them, located on public and private property* (Region of Peel 2011).
(climate change) Vulnerability	*Vulnerability is the susceptibility to be harmed. Vulnerability to climate change is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability to climate change is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity* (Richardson 2010). For plants, vulnerability to climate change is the risk of undesirable things happening (i.e., how prone a species or ecosystem is to be adversely affected by an event or change). Vulnerability is a function of three factors: exposure, sensitivity and adaptive capacity to a hazard. More exposure and sensitivity increase vulnerability, while more adaptive capacity decreases it. An assessment of vulnerability should consider all three factors. Reducing vulnerability involves altering the context in which elements are exposed to climate change hazards (e.g., high temperature, extreme precipitation events). Vulnerability is determined by the ability to cope with or adapt to climate change hazards.

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Appendix A

Tree Species Vulnerability Assessments for Peel Region

Table A. Tree Species Vulnerability Assessments Undertaken for Peel Region and its Partners

Scientific Name	Common Name	Range[1]	Risks[2]	Tolerances[3]	Sensitivities[4]	Status[5]	Peel VA-RCP8.5[6]	GTA CCVI-RCP8.5[7]
Abies balsamea	Balsam fir	N1		C*	D,F,R		EV	EV
Abies concolor	White fir	NN		D*			HV	
*Acer negundo***	Manitoba maple**	N1	I?		C		LV	HV
Acer pensylvanicum	Striped maple	N2			A,F		EV	
*Acer platanoides***	Norway maple**	NN	I				HV	
Acer rubrum	Red maple	N1		F*	D		MV	HV
Acer saccharinum	Silver maple	N1		F*	C		MV	EV
Acer saccharum	Sugar maple	N1			D		MV	HV
Acer x freemanii	Freeman's maple	N1					MV	MV
Aesculus glabra	Ohio buckeye	N2		C*,R*	D		MV	
*Aesculus hippocastanum***	Horse chestnut**	NN	I?	C*	D		MV	
*Ailanthus altissima***	Tree of heaven**	NN	I				LV	
Amelanchier arborea	Downy serviceberry	N1		D*	A		MV	
Asimina triloba	Pawpaw	N2		R*		S3	HV	
Betula alleghaniensis	Yellow birch	N1		F*	D		EV	EV
Betula papyrifera	White birch	N1			D,R		EV	EV
Carpinus caroliniana	Blue beech	N1		C*,F*	D		HV	HV
Carya cordiformis	Bitternut hickory	N1		C*,D*,R*			LV	EV
Carya ovata	Shagbark hickory	N1		C*,D*,R*	F		LV	EV
Catalpa speciosa	Catalpa	N3		D*,I*			HV	
Celtis occidentalis	Common hackberry	N1		D*,F*,R*	C		LV	

Scientific Name	Common Name	Range[1]	Risks[2]	Tolerances[3]	Sensitivities[4]	Status[5]	Peel VA-RCP8.5[6]	GTA CCVI-RCP8.5[7]
Cercis canadensis	Eastern redbud	N3		R*			LV	
Cornus alternifolia	Alternate-leaved dogwood	N1					EV	
Cornus florida	Flowering dogwood	N1		R*	D,F	SAR	MV	
Cornus sericea	Red osier dogwood	N1		F*	R		HV	
Crataegus mollis	Downy hawthorn	N1					LV	
Crataegus punctata	Dotted hawthorn	N1					LV	
*Elaeagnus angustifolia***	Russian olive**	NN	I				LV	
Fagus grandifolia	American beech	N1		F*	D,P		HV	EV
*Fraxinus americana***	White ash**	N1			F,P		MV	EV
Gleditsia triacanthos	Honey locust	N2		D*,R*,S*	C		LV	
Gymnocladus dioicus	Kentucky coffee tree	N2		C*,D*,R*,S*		SAR	HV	
Juglans cinerea	Butternut	N1		R*	C,P	SAR	MV	EV
Juglans nigra	Black walnut	N1		C*,D*,R*			MV	EV
Juniperus virginiana	Eastern red cedar	N1		C*,D*,R*			LV	HV
Larix decidua	European larch	NN		C*,U*	D		EV	
Larix laricina	Tamarack	N1		F*	D,R		EV	EV
Liquidambar styraciflua	Sweetgum	N4		F*,R*,U*	A		HV	
Liriodendron tulipifera	Tulip tree	N2		R*,U*	D		EV	EV
*Maclura pomifera***	Osage orange**	N4	I?				HV	
Magnolia acuminata	Cucumber tree	N2		R*	D,F	SAR	EV	
*Morus alba***	White mulberry**	NN	I, H	R*			LV	
Morus rubra	Red mulberry	N1		R*		SAR	MV	EV
Nyssa sylvatica	Black gum	N2		C*,D*,R*,U*	A		LV	
Ostrya virginiana	Eastern hop-hornbeam	N1		C*,D*			LV	MV
Picea abies	Norway spruce	NN		C*	F		EV	
Picea glauca	White spruce	N1		C*	F,R		HV	EV

Scientific Name	Common Name	Range[1]	Risks[2]	Tolerances[3]	Sensitivities[4]	Status[5]	Peel VA-RCP8.5[6]	GTA CCVI-RCP8.5[7]
Picea pungens	Colorado spruce, blue spruce	NN		C*,D*,U*	F		HV	
Picea rubens	Red spruce	N2			F	S3	EV	
Pinus resinosa	Red pine	N1			F		HV	
Pinus strobus	White pine	N1		D*	F		HV	EV
*Pinus sylvestris***	Scots pine**	NN	I		F		HV	
Platanus occidentalis	Sycamore	N1		D*,F*,R*			LV	
Populus deltoides	Eastern cottonwood	N1		F*,R*	C		MV	EV
Populus grandidentata	Largetooth aspen	N1			C		HV	HV
Populus tremuloides	Trembling aspen	N1			C		HV	HV
Prunus pensylvanica	Pin cherry	N1					HV	
Prunus serotina	Black cherry	N1		R*	C,F		MV	HV
Prunus virginiana	Chokecherry	N1			F		HV	
Ptelea trifoliata	Common hoptree	N2		R*	F		HV	
Quercus alba	White oak	N1		C*	F		MV	EV
Quercus bicolor	Swamp white oak	N1		C*,F*,R*			HV	EV
Quercus coccinea	Scarlet oak	N3			F		HV	
Quercus macrocarpa	Bur oak	N1		C*,D*,F*,U*			MV	EV
Quercus palustris	Pin oak	N2		F*,R*			MV	
Quercus prinoides	Dwarf chinquapin oak	N2		R*		S2	HV	
Quercus rubra	Red oak, northern red oak	N1					HV	HV
Quercus shumardii	Shumard oak	N2		R*		S3	LV	
Quercus velutina	Black oak	N1		D*,R*			LV	EV
*Rhamnus cathartica***	Common buckthorn**	NN	I				HV	MV
Rhus glabra	Smooth sumac	N1			F		HV	
Rhus typhina	Staghorn sumac	N1			F,R		HV	
*Robinia pseudoacacia***	Black locust**	N3	I	D*	F,C		LV	

Scientific Name	Common Name	Range[1]	Risks[2]	Tolerances[3]	Sensitivities[4]	Status[5]	Peel VA-RCP8.5[6]	GTA CCVI-RCP8.5[7]
*Salix alba***	White willow**	NN	I	F*	C,D		HV	
Salix amygdaloides	Peachleaf willow	N1		F*	C,D		HV	
Salix humilis	Prairie willow	N2		F*	C		EV	
Salix nigra	Black willow	N1		F*,R*	C		HV	EV
Sassafras albidum	Sassafras	N1		R*	F		LV	HV
Sorbus americana	American mountain ash	N1			F,R		EV	
Sorbus decora	Showy mountain ash	N2			R		EV	
Taxus canadensis	Canada yew	N1?			R		EV	
Thuja occidentalis	Northern white cedar	N1		C*	R		HV	EV
Tilia americana	Basswood	N1			C		MV	HV
Tsuga canadensis	Eastern hemlock	N1		C*	P		EV	EV
Ulmus americana	White elm	N1			C,P		LV	EV
*Ulmus pumila***	Siberian elm**	NN	I	R*	C		LV	
Ulmus rubra	Slippery elm	N1		R*	C,P		MV	EV
Ulmus thomasii	Rock elm	N1		R*	C,P		MV	HV

LEGEND

** = Generally not recommended for planting in Peel due to its (a) highly invasive or potentially invasive status and / or other (b) associated risk(s) / sensitivities (such as ability to hybirdize with N1 or N2 species), as noted in the "Risks" column.

[1] RANGE:N1 = native to (current range overlaps with) Peel Region and/or CVC watershed

N2 = native to (current range overlaps with) southern Ontario, but south od and not known to be reported as naturally occurring in Peel Region/CVC watershed

N3 = native to (current range overlaps with) the northeastern U.S. as far east as Michigan

N4 native to southeastern U.S. (I added this category based on our discussion), and

NN = not native to (current range does not overlap with) North America"

[2] RISKS: I = Invasive or I? = Potentially invasive (based on the literature reviewed and local expert opinion); H = hybridizes with native species (N1, N2, N3 or N4)

[3] TOLERANCES (to urban and / or climate change stressors): C* = high level of resistance to ice damage, D* = drought tolerant, F* = flood tolerant, P* = resistant to serious pest or disease, R* = species within or near Peel Region at the northern end of their current range, S* = poor soils tolerant, U* = planted successfully in other southern Ontario urban areas

[4] SENSITIVITIES: C= low resistance to ice damage, D = drought intolerant, F = flood intolerant, P = vulnerable to serious pest or disease, R = species within or near Peel Region at the southern end of their current range

[5] STATUS (IN ONTARIO): SAR = Species at Risk in Ontario, S2 = very rare in Ontario (5 to 20 occurrences), S3 = rare to common in Ontario (20 to 100 occurrences)

[6] PEEL VA-RCP8.5 = Peel Vulnerability Assessment for this project (see methodology in Guide 4) based on RCP8.5 and 2041 to 2070; Extreme Vulnerability (EV), High Vulnerability (HV), Moderate Vulnerability (MV) and Low Vulnerability (LV) (see Guide 4, Section 3 for methodology)

[7] GTA CCVI-RCP8.5 = Climate Change Vulnerability Index rankings under RCP8.5 as per Sansom (2020) for 55 trees/shrubs in the GTA from Table C2; EV = extremely vulnerable, HV = highly vulnerable, MV = moderately vulnerable, LV = less vulnerable (note: not all the same species were assessed)

SOURCES [type of information sourced]

Farrar (1995), Trees in Canada [range maps]
Hauer et al., (1993), Ice Storm Damage to Urban Trees [susceptibility to ice damage]
Hauer et al., (2006, The Development of Ice Storm–resistant Urban Tree Populations [susceptibility to ice damage]
Loucks (1987), Flood-tolerant Trees [flood tolerance]
Morton Arboretum (2020) on-line plant advice. Accessed at: www.mortonarb.org/trees-plants/tree-and-plant-advice/horticulture-care/drought-stress [drought tolerance or sensitivity]
Natural Resources Canada (2020), on-line MaxEnt species maps for 1971-2000. Accessed at: www.planthardiness.gc.ca/?m=2m [range maps]
Niinemets and Vallardes (2006) [drought tolerance or sensitivity]
Sansom (2020), Climate Change Vulnerability Assessment of 55 Tree and Shrub species in the Greater Toronto Area [CCVI]
Trees Ontario (2020). Accessed at ontariotrees.com/main/list_latin.php [source of latin and common names]
University of Tennessee (2005), Shade and Flood Tolerance of Trees [flood tolerance and sensitivities]

DISCLAIMER

Please note the tolerances and risks/sensitivities assigned to the various species that currently do or could occur in Peel have been identified based on a targeted review of the relevant literature (see Sources) as well as the experience and opinions of the experts on the consulting team (Ash Baron, Steve Colombo) and at the agencies - specifically at CVC (Lisa Riederer, Joe Pearson, Dawn Renfrew) and at TRCA (Mark Funk). This list should be amended as additional work is done and / or as additional species-specific information becomes available and as such should be treated as a working draft.

Appendix B

Range Maps Informing Tree Species Vulnerability Assessments for Peel Region

This appendix includes range maps for each of the 88 tree and shrub species assessed for climate change vulnerability for Peel. The maps are focused on southern Ontario, which includes Peel Region and areas to the south in Ontario. The maps are provided for four different periods to compare shifts under historical, current, near future and far future conditions, as defined below.

- historical (i.e., 1970 – 2010)
- current (i.e., 2011 – 2040)
- near future (i.e., 2041 – 2070), and
- far future (i.e., 2071 – 2100).

The mapping was generated using Open Source data provided by Natural Resources Canada (NRCan) and is presented using the four time periods with which they undertake climate suitability modelling.

Description of MaxEnt climatic suitability

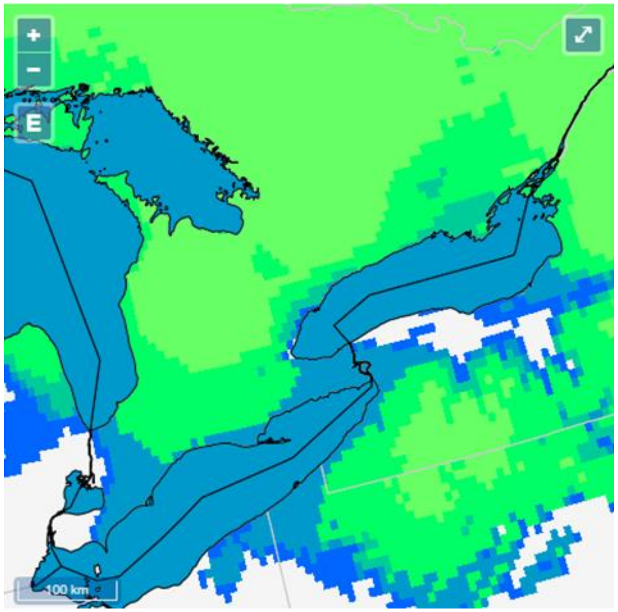
Each series of four maps shows climatic suitability as per the MaxEnt modelling used by NRCan. An area's climatic suitability for a species was based on the results of MaxEnt modelling, which is a tool that uses correlations between a species presence and the environment at locations across a geographic area where the species is found. NRCan provides maps of MaxEnt habitat suitability, with species maps showing locations in North America where environmental habitat is (or is not) suitable for a species. Maps are based on either historical climate or climate projected for future time periods for different RCPs. For this project a threshold of 0.2 was used to infer minimum climatic suitability of a map grid cell, with values less than 0.2 indicating habitat unsuitable for a species.

Additional information is provided at the following Government of Canada websites which are being updated on a regular basis:

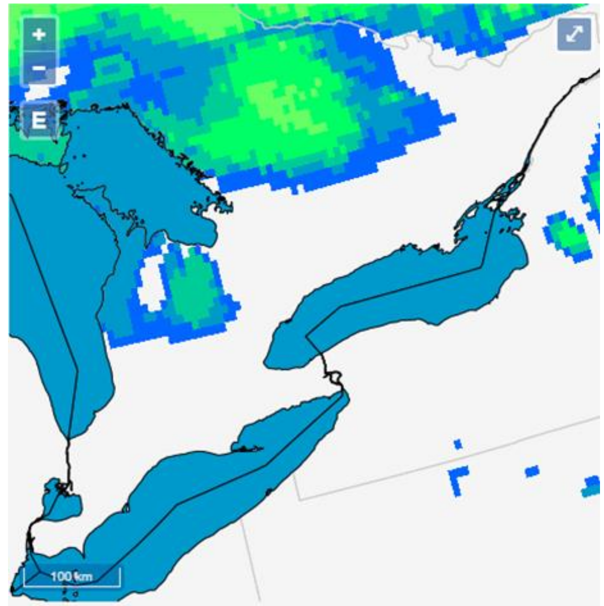
- Government of Canada, Changing Climate, Changing Forest Zones
  https://www.nrcan.gc.ca/climate-change/impacts-adaptations/climate-change-impacts-forests/impacts/changing-climate-changing-forest-zones/13093
- Government of Canada, Climate Change Maps
  https://www.nrcan.gc.ca/environment/resources/maps/11019

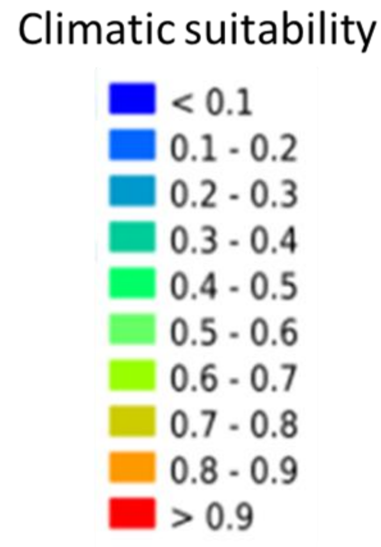
Abies balsamea (Balsam fir)

a. Historical

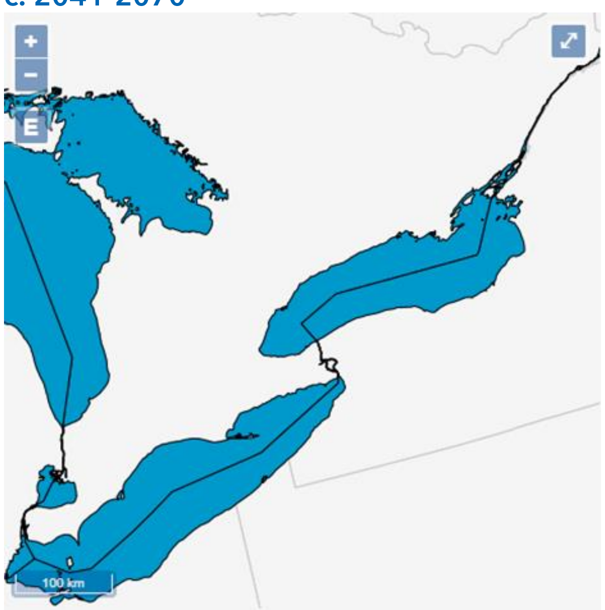


b. 2011-2040

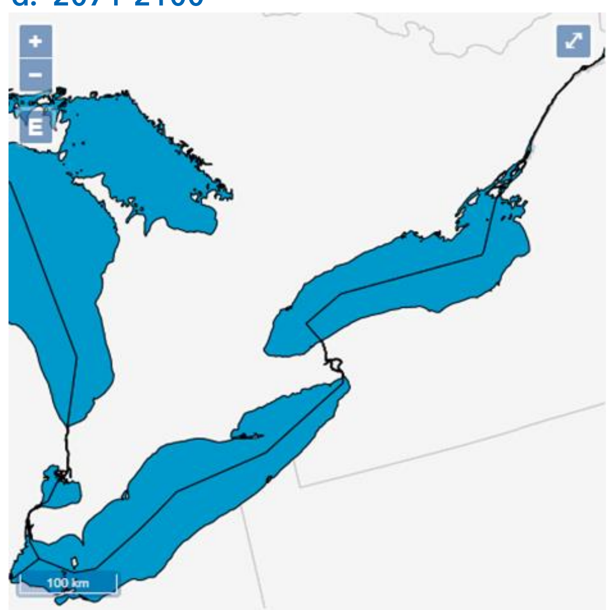




c. 2041-2070

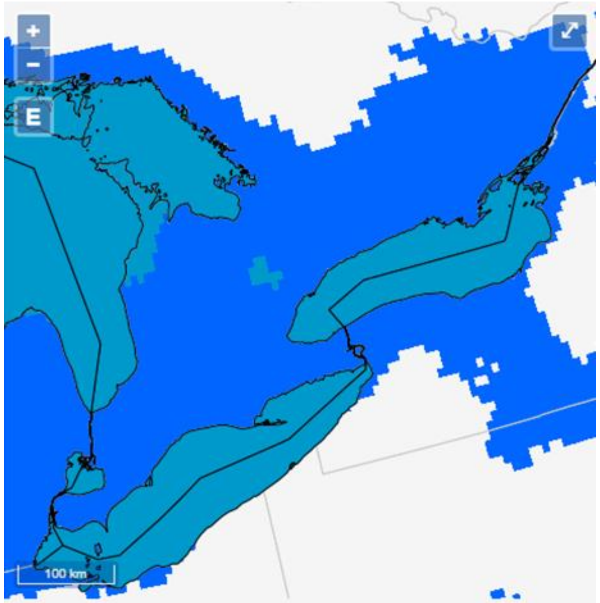


d. 2071-2100

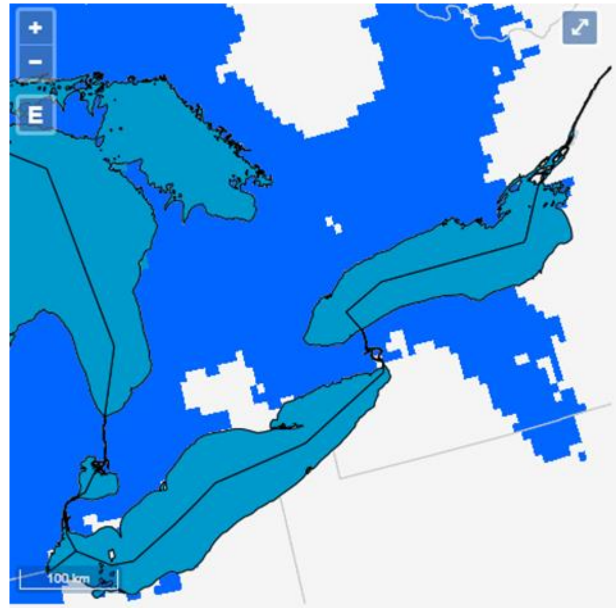


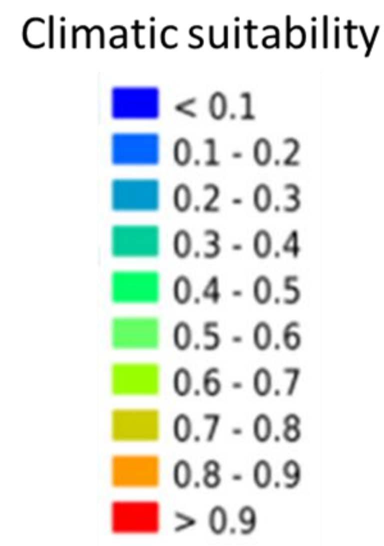
Abies concolor (White fir)

a. Historical

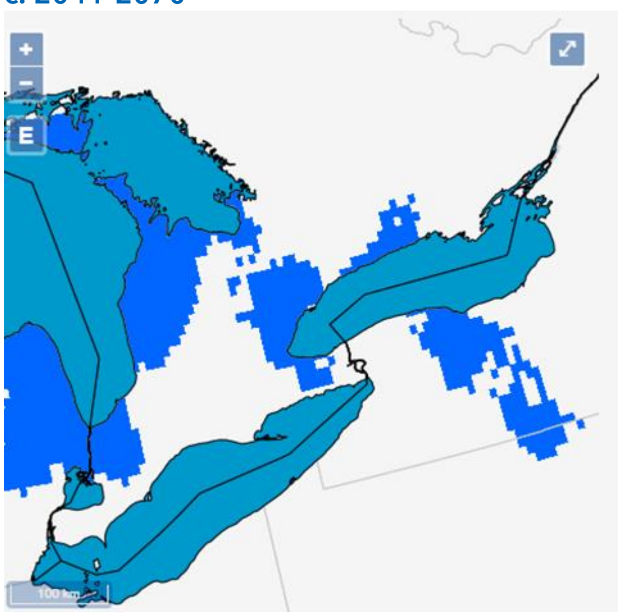


b. 2011-2040

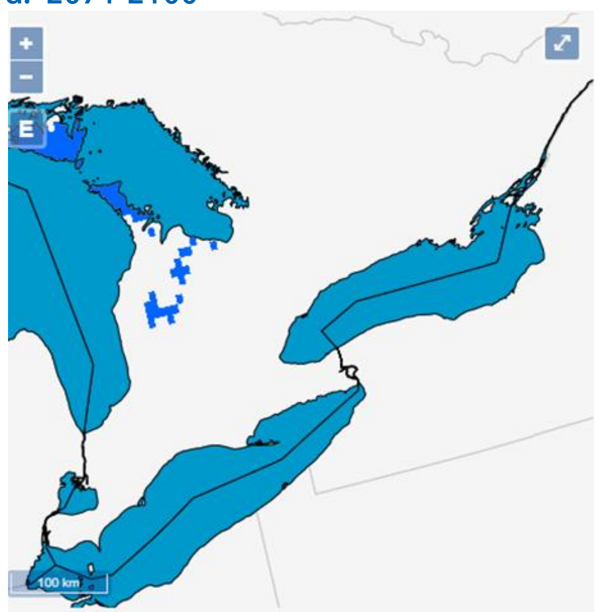




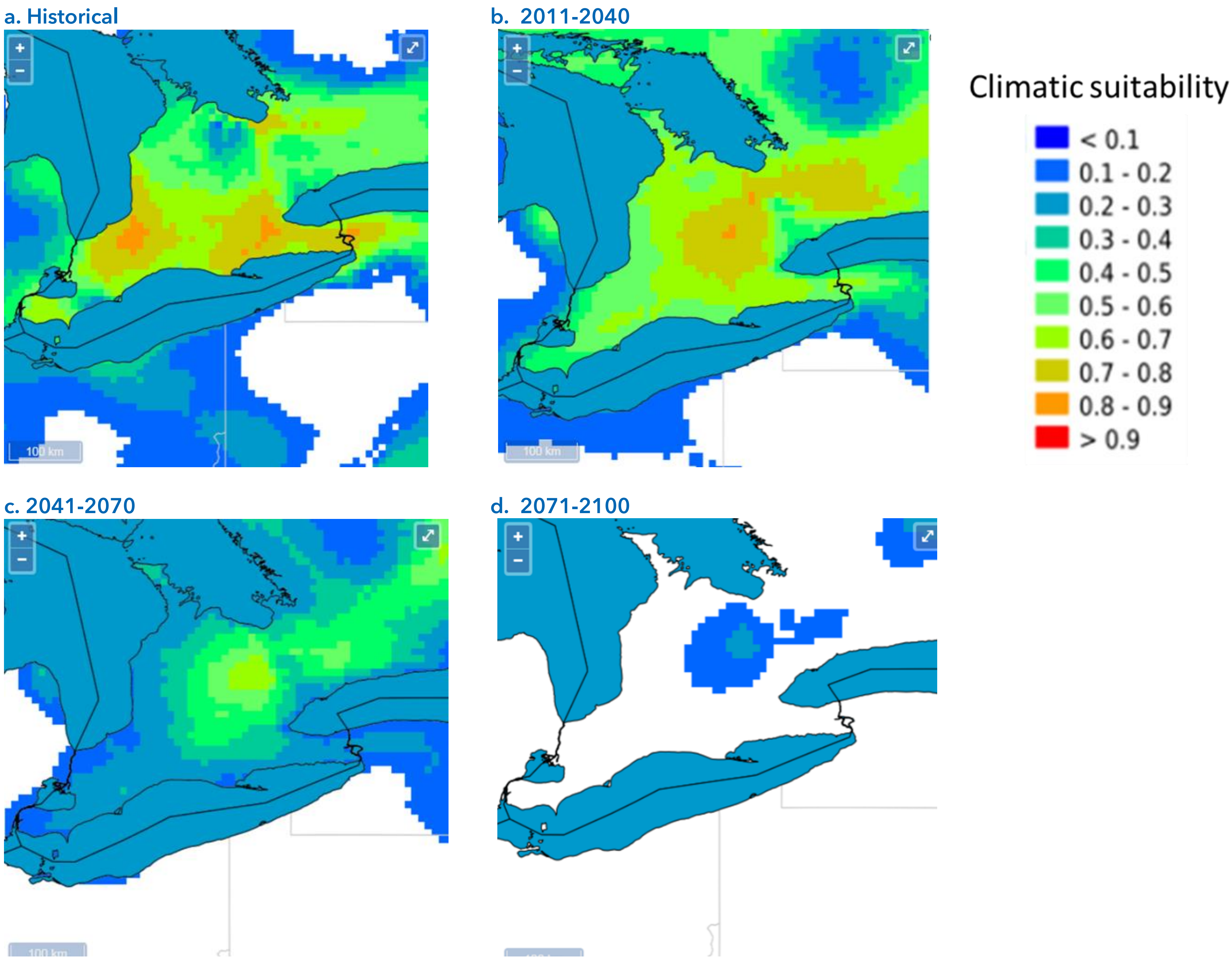
c. 2041-2070



d. 2071-2100

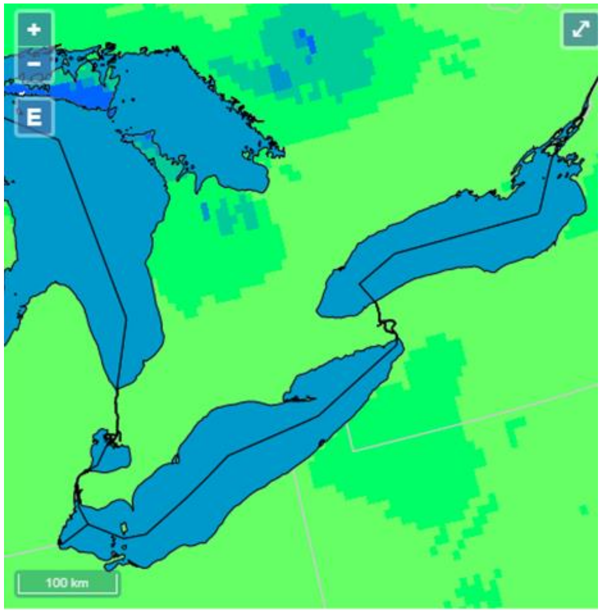


Acer x freemanii (Freeman's maple)

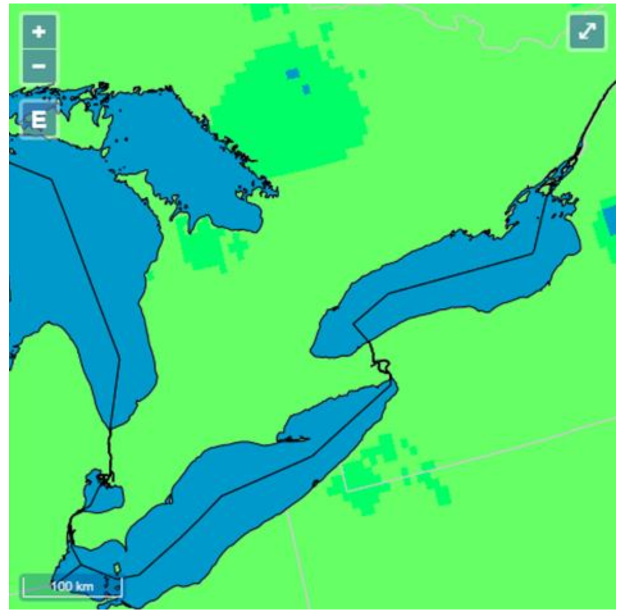


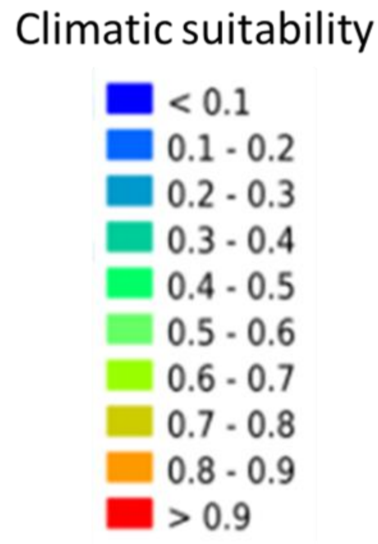
Acer negundo (Manitoba maple)

a. Historical

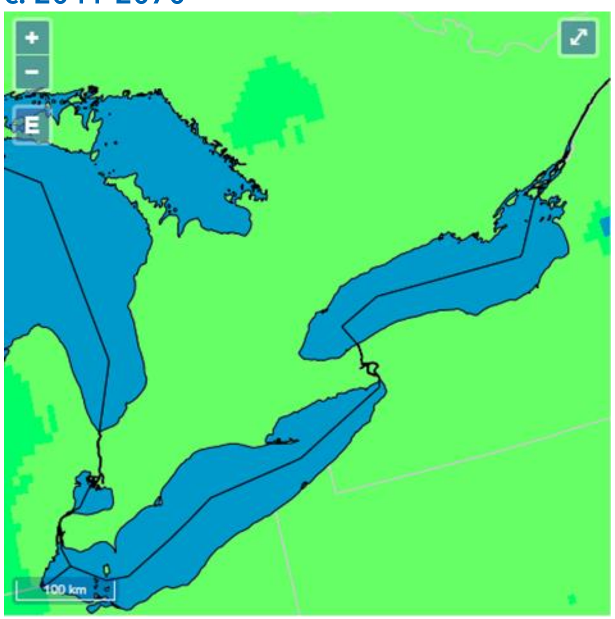


b. 2011-2040

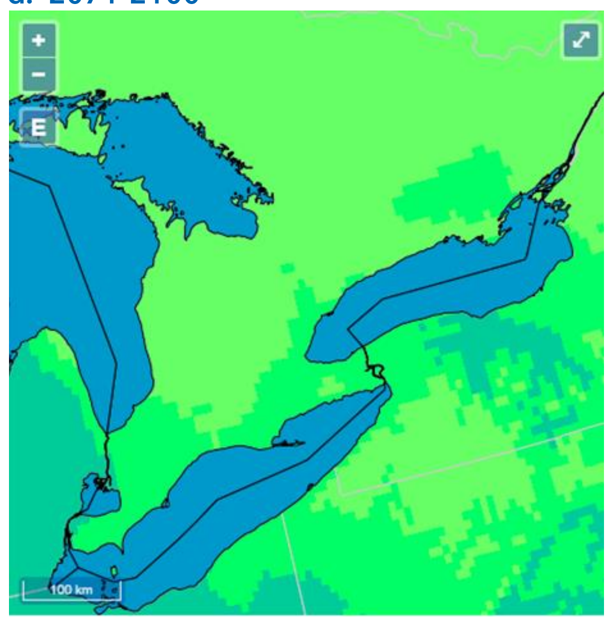




c. 2041-2070

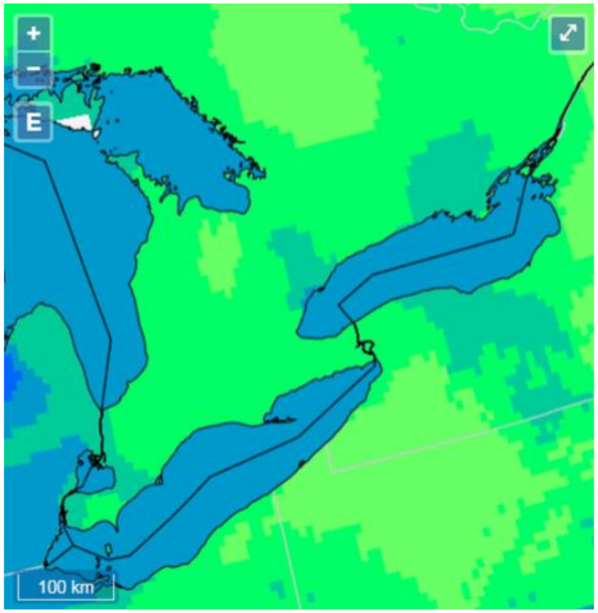


d. 2071-2100



Acer pensylvanicum (Striped maple)

a. Historical



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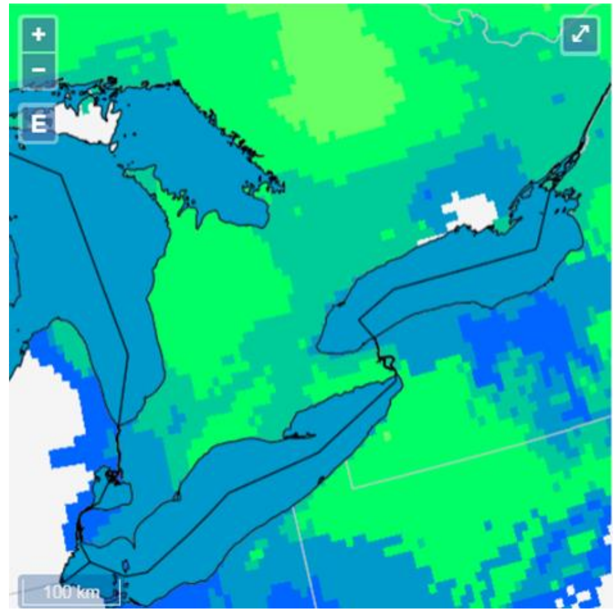
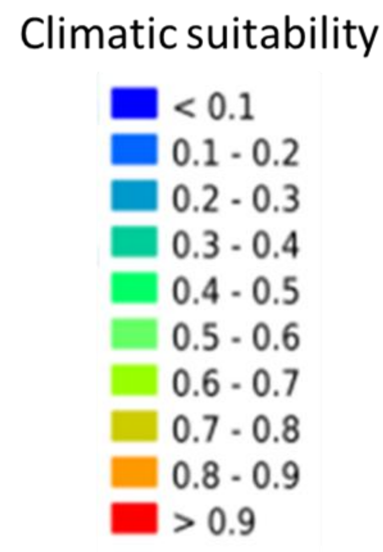
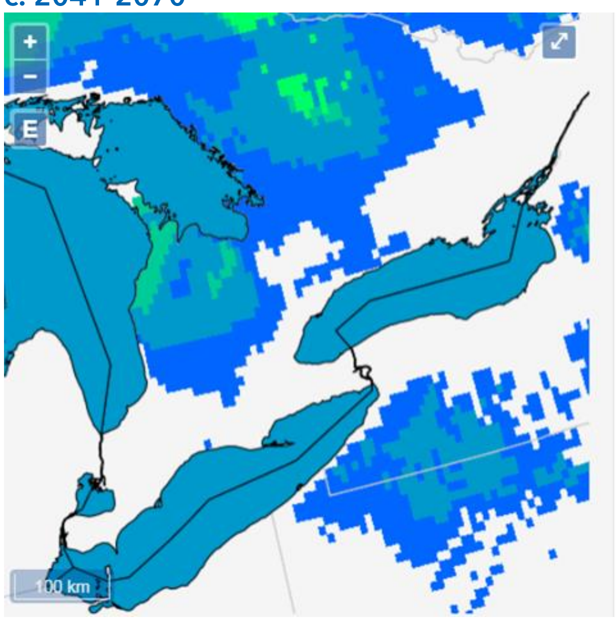
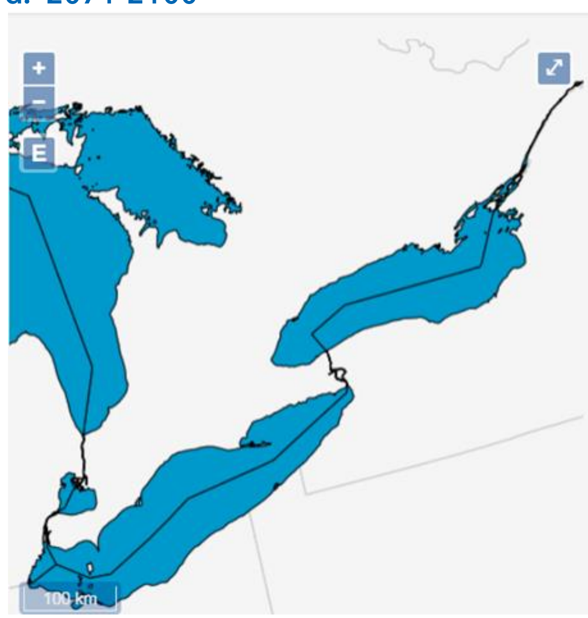




c. 2041-2070

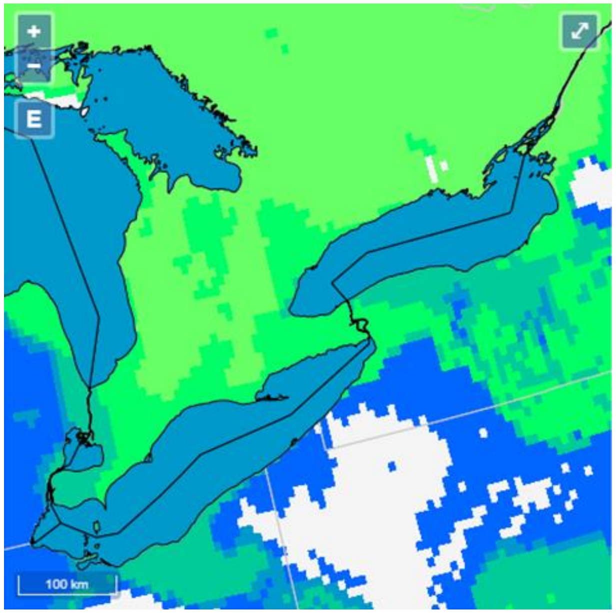


d. 2071-2100



Acer platanoides (Norway maple)

a. Historical



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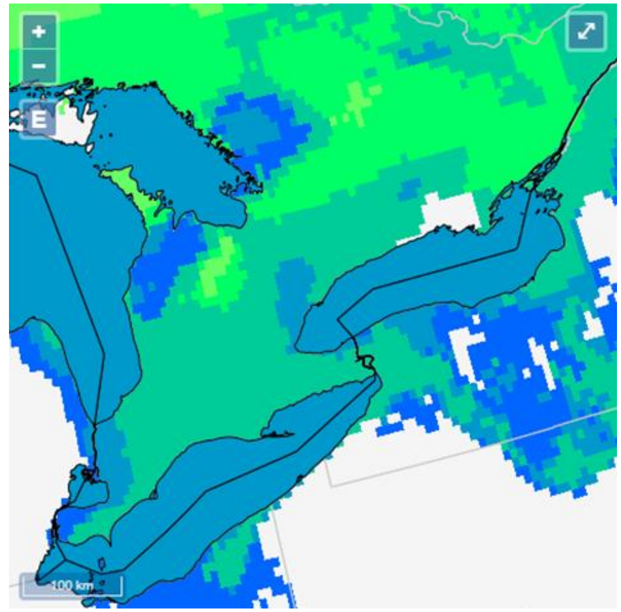
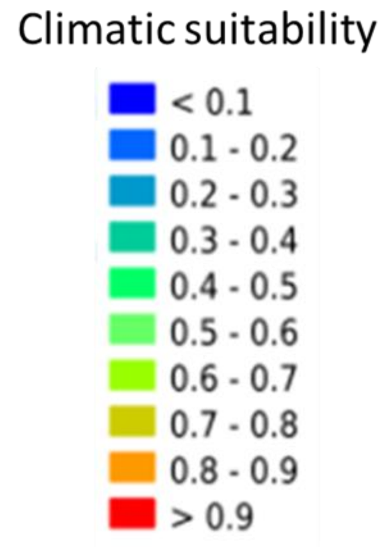
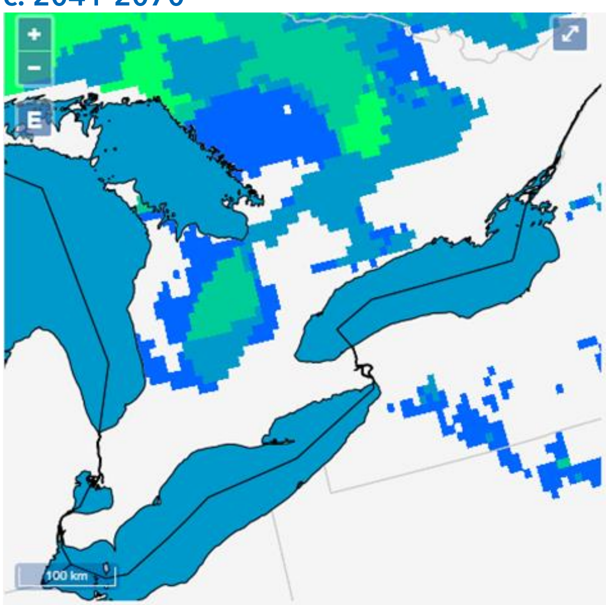
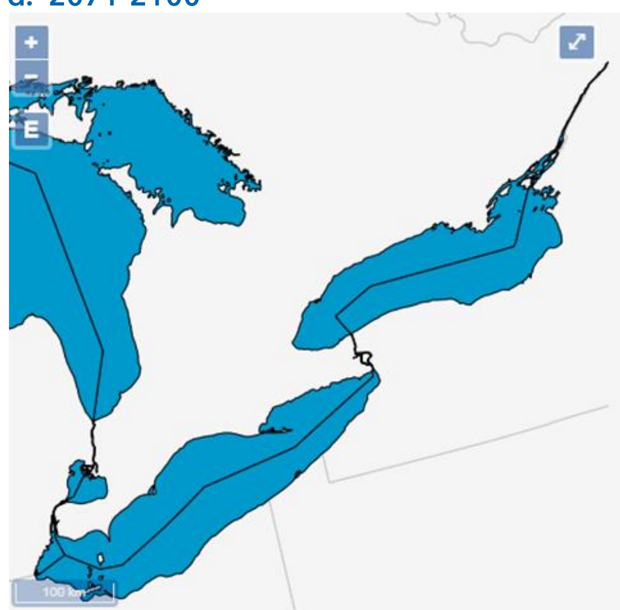




c. 2041-2070

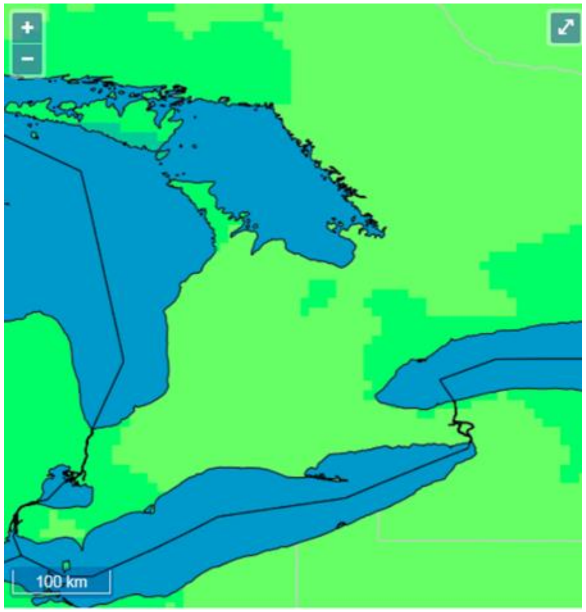


d. 2071-2100



Acer rubrum (Red maple)

a. Historical



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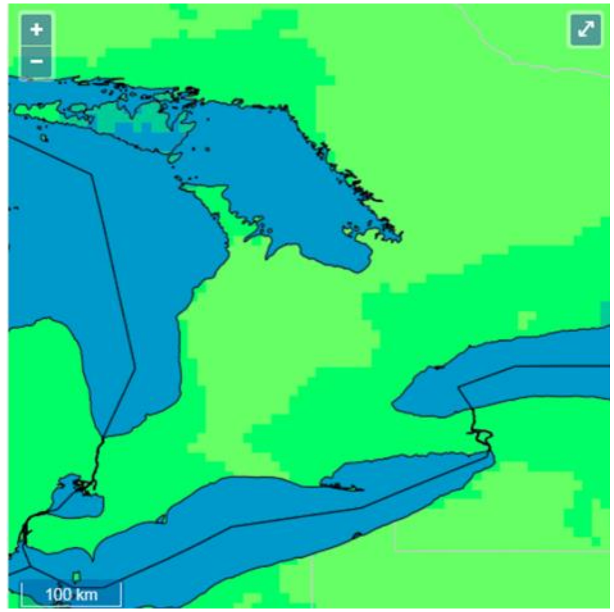

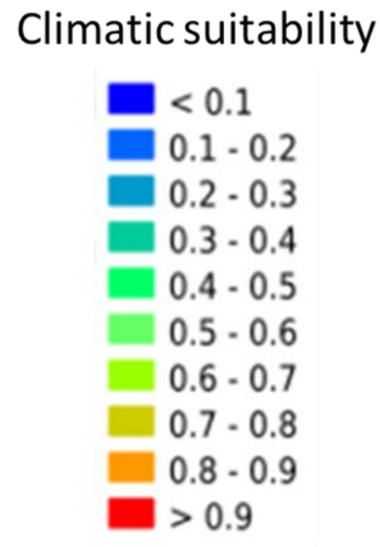

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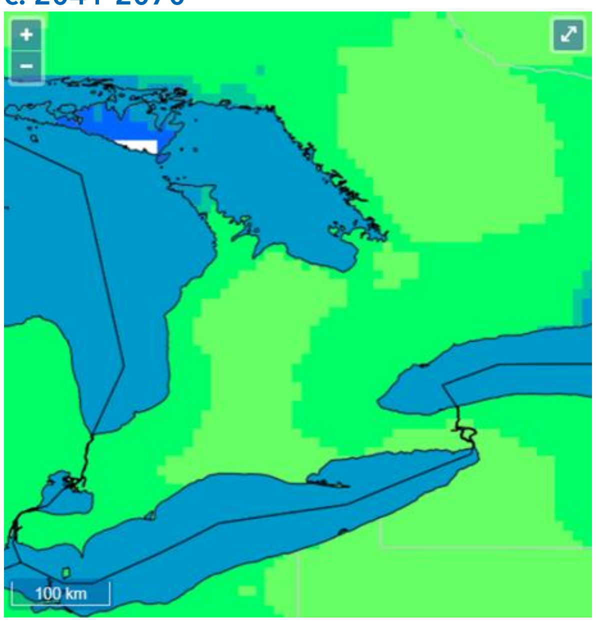
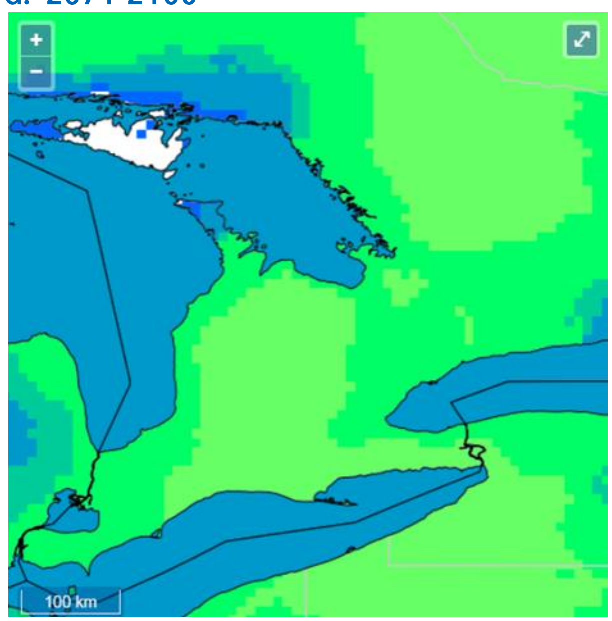
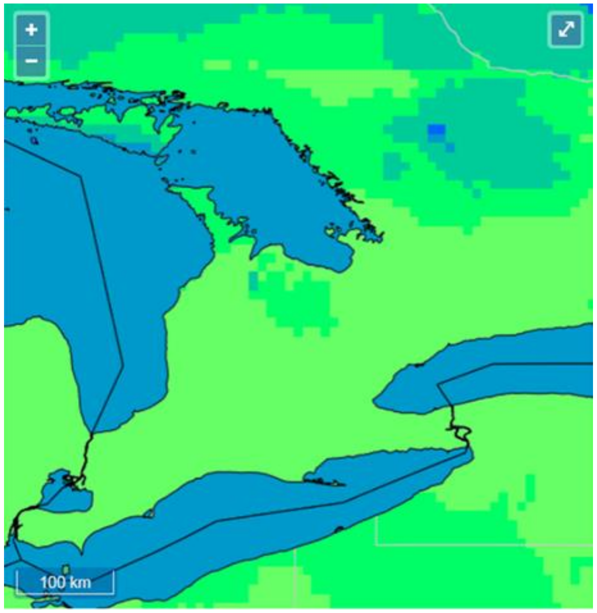


d. 2071-2100

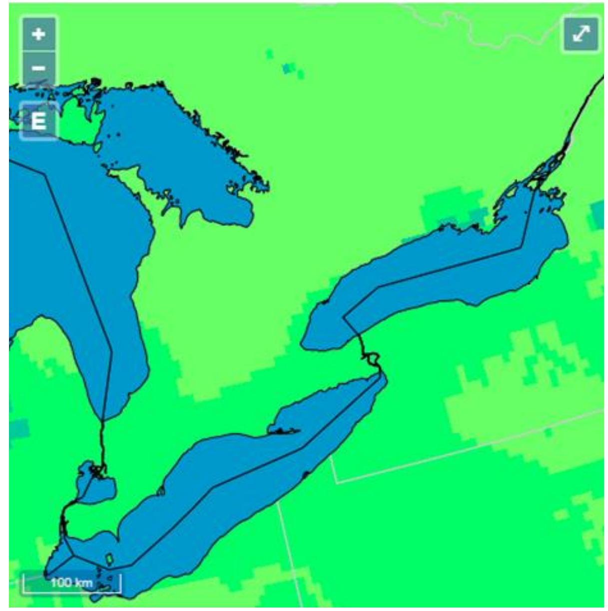


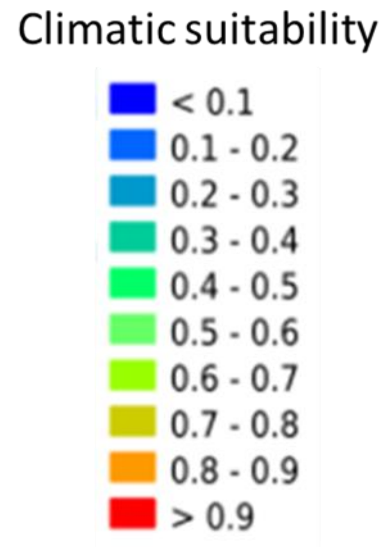
Acer saccharinum (Silver maple)

a. Historical

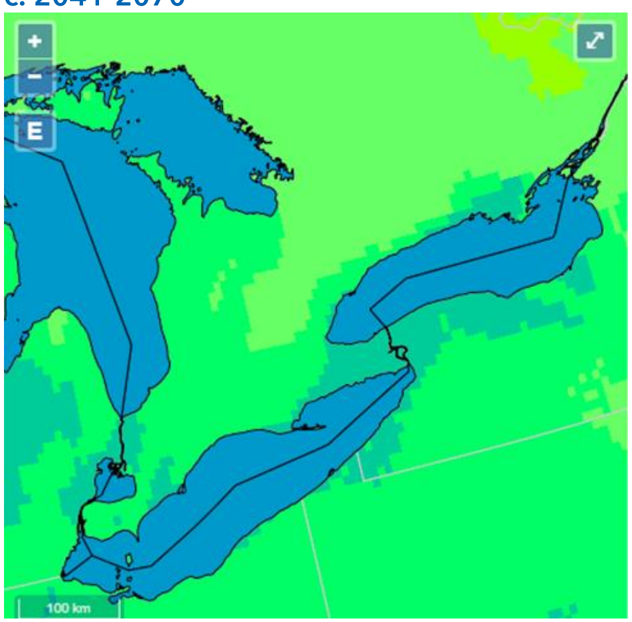


b. 2011-2040

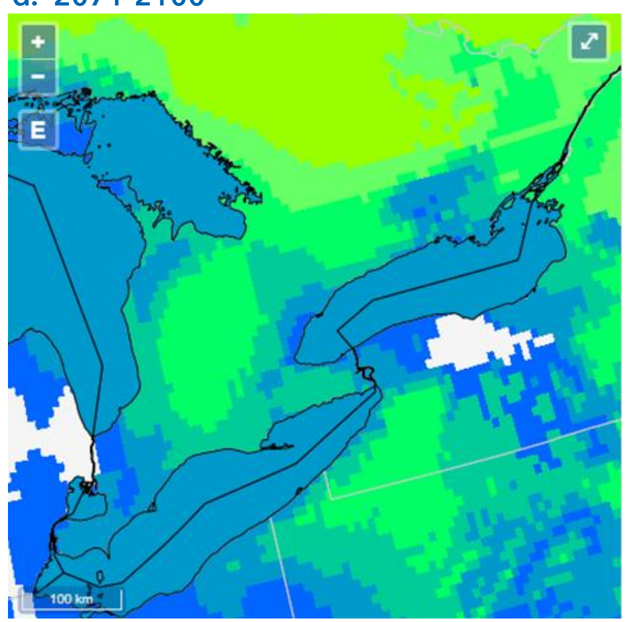




c. 2041-2070



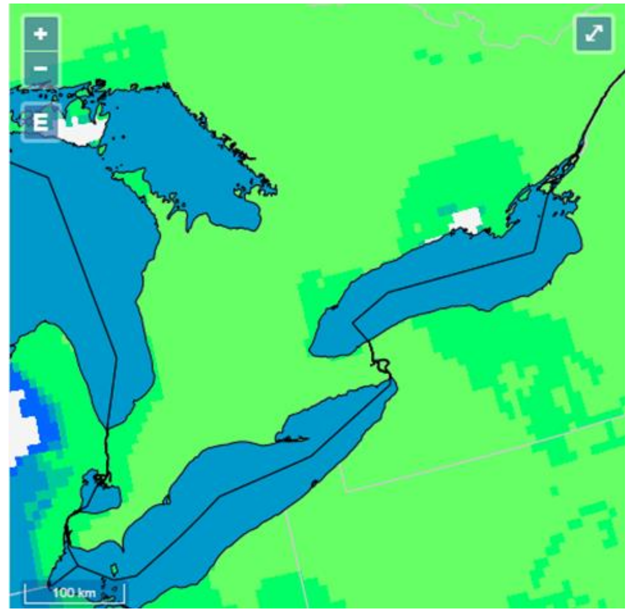
d. 2071-2100

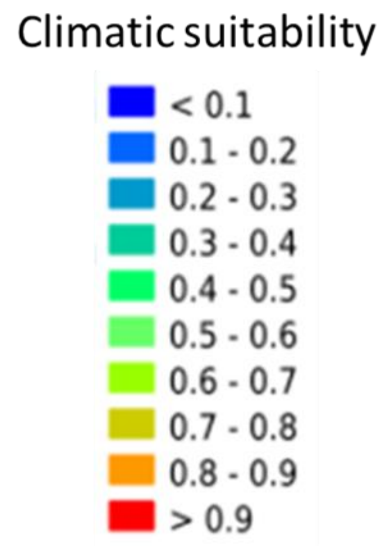


Acer sacchurum (Sugar maple)

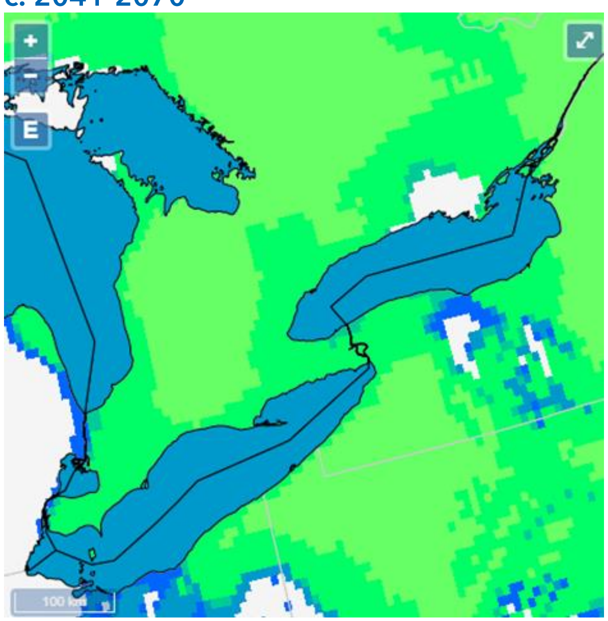
a. Historical

b. 2011-2040

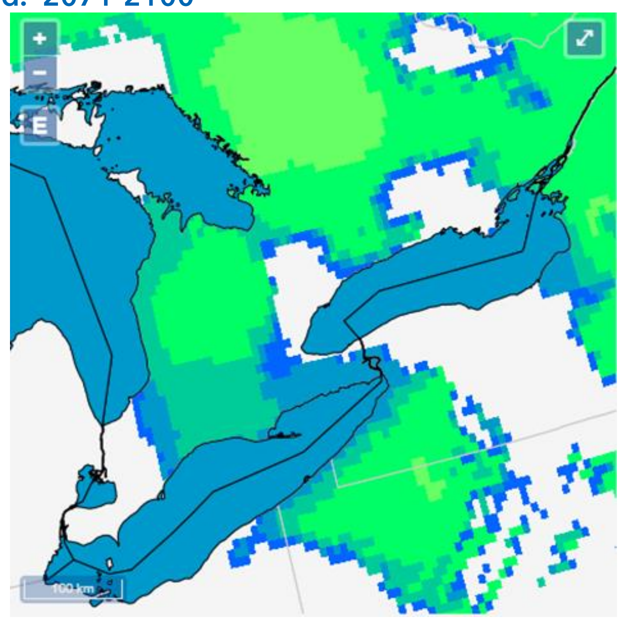




c. 2041-2070

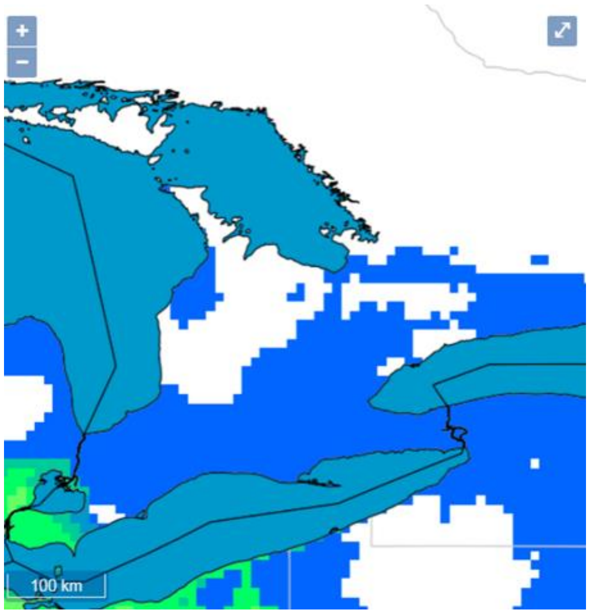


d. 2071-2100

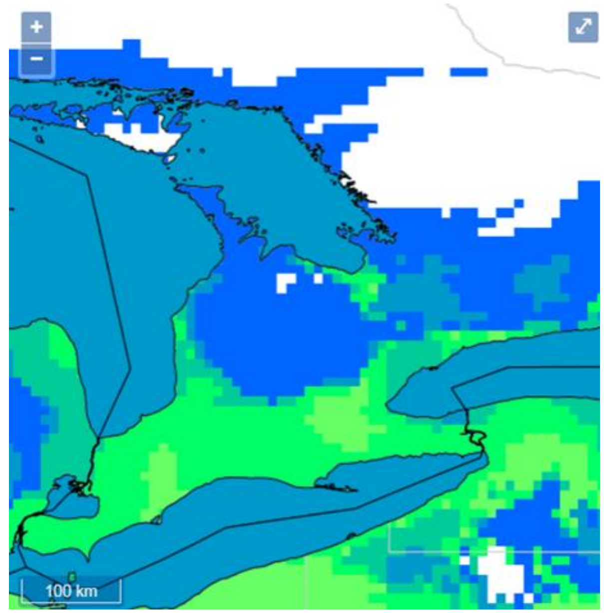


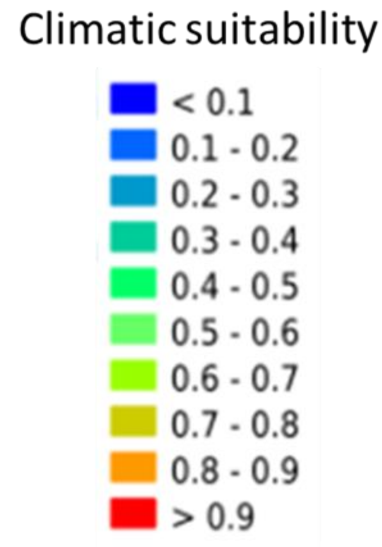
Aesculus glabra (Ohio buckeye)

a. Historical

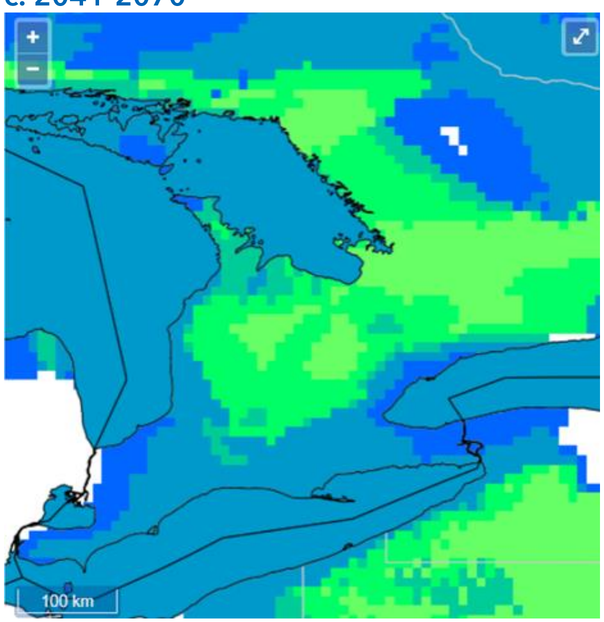


b. 2011-2040

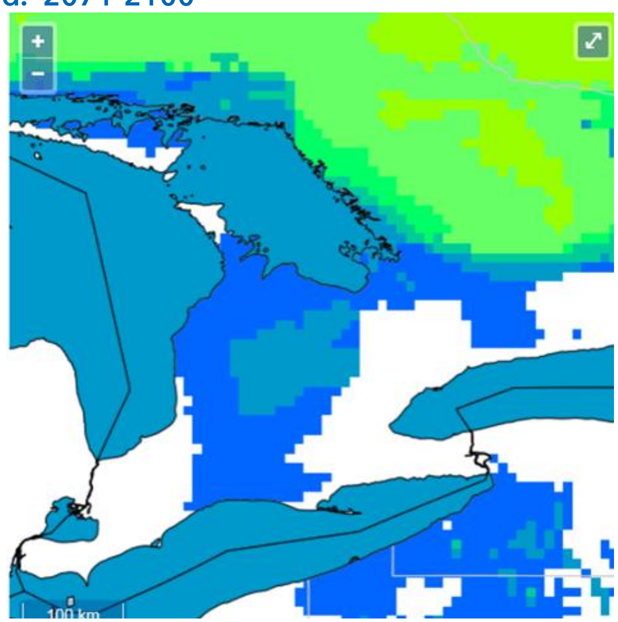




c. 2041-2070

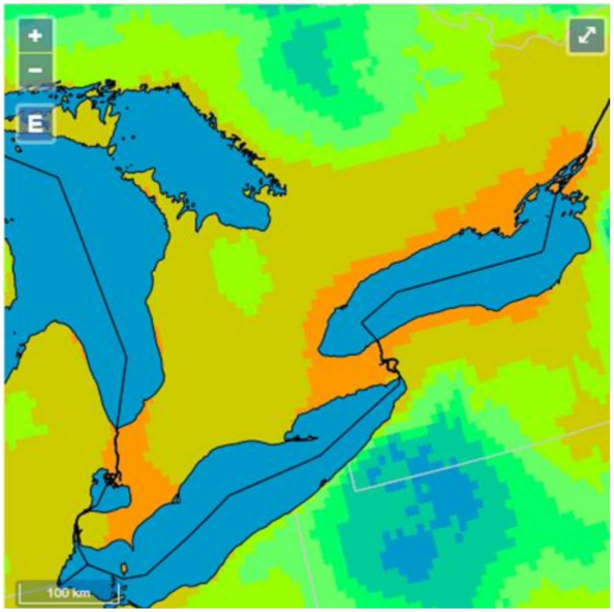


d. 2071-2100

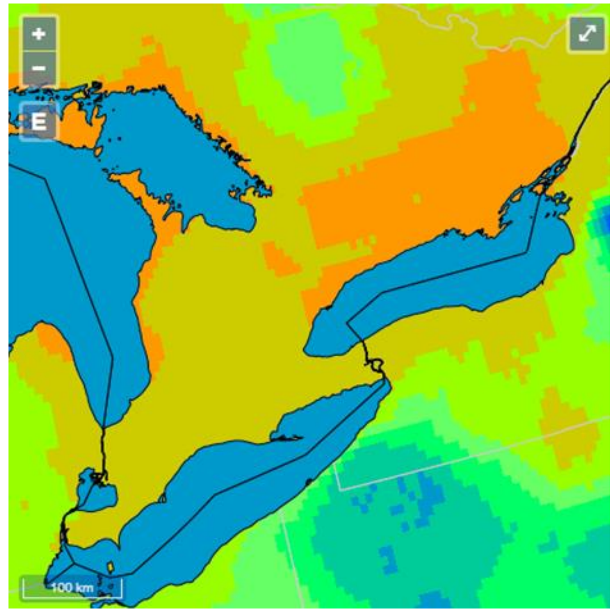


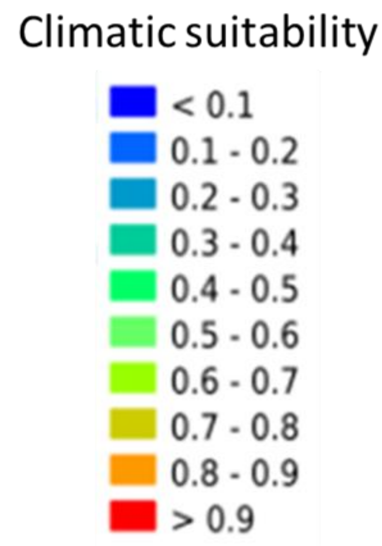
Aesculus hippocastanum (Horse chestnut)

a. Historical

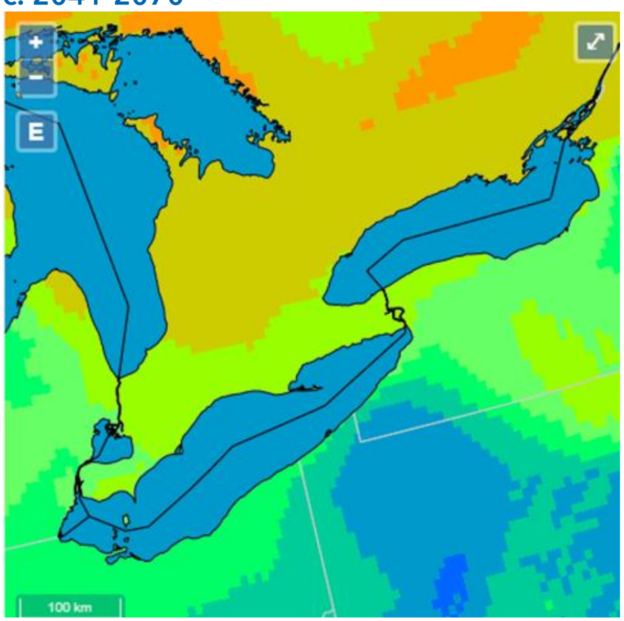


b. 2011-2040

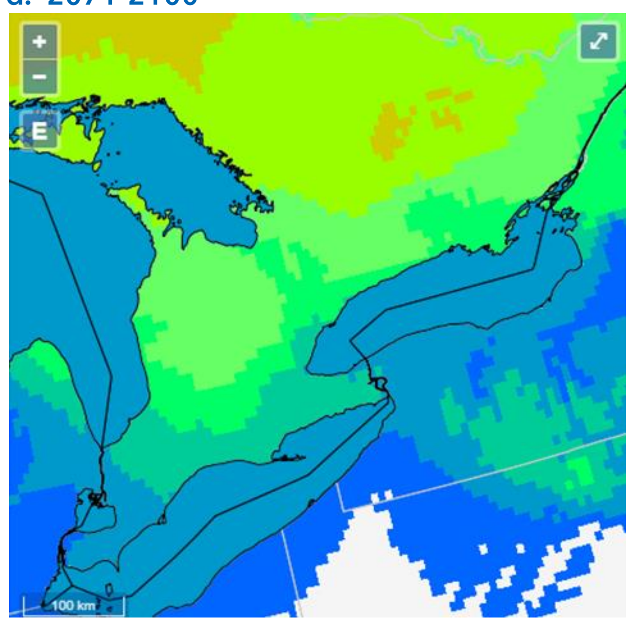




c. 2041-2070

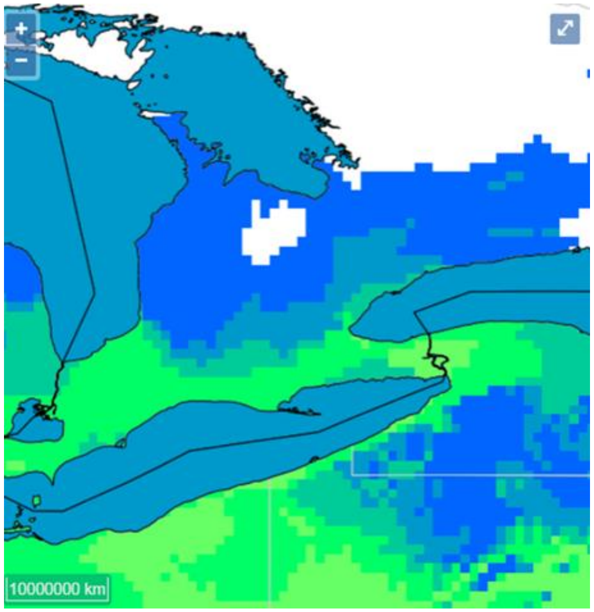


d. 2071-2100

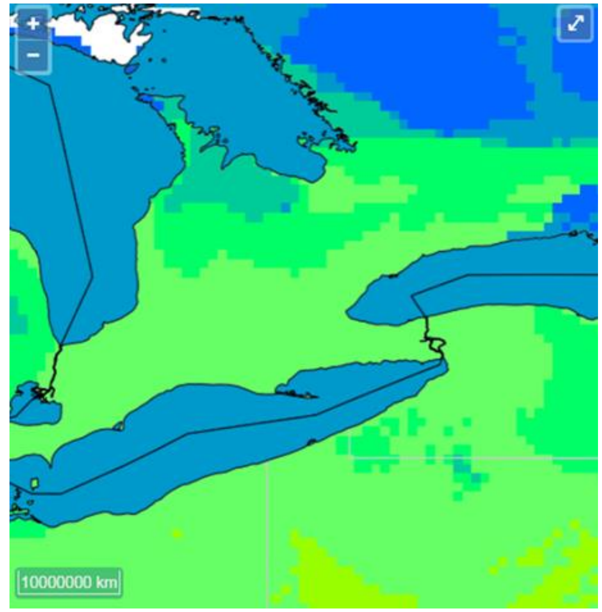


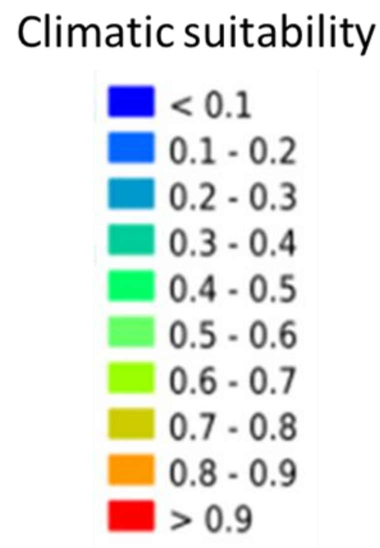
Ailanthus altissima (Tree-of-heaven)

a. Historical

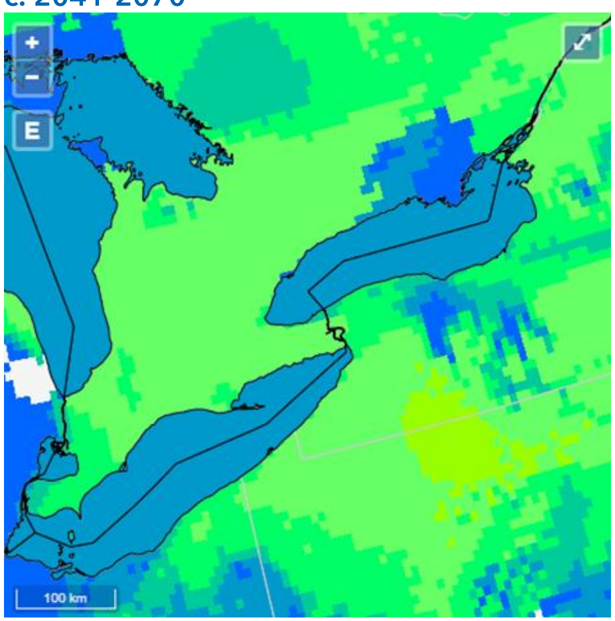


b. 2011-2040

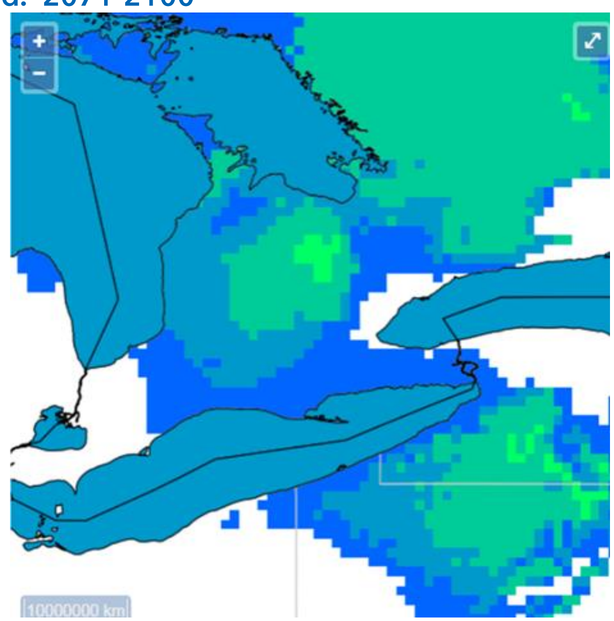




c. 2041-2070

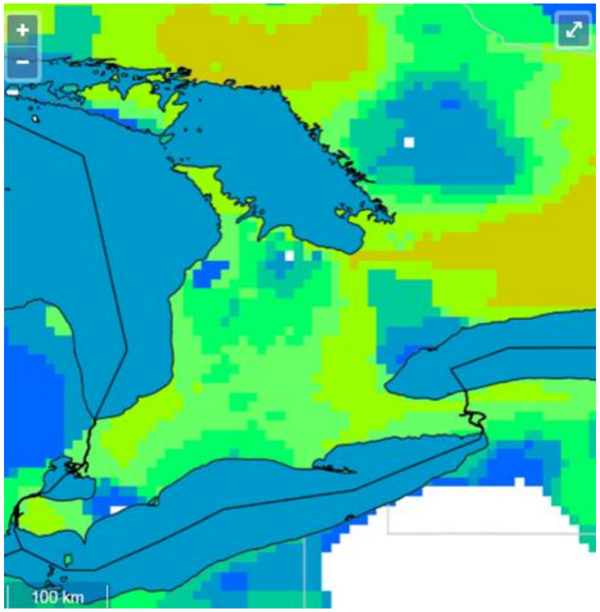


d. 2071-2100

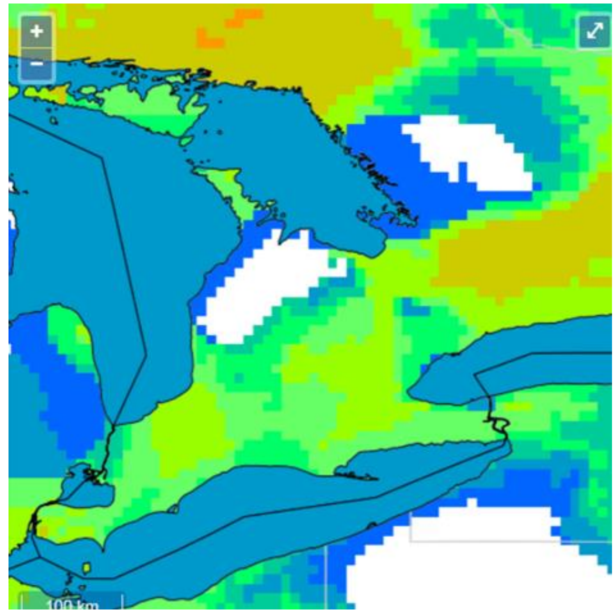


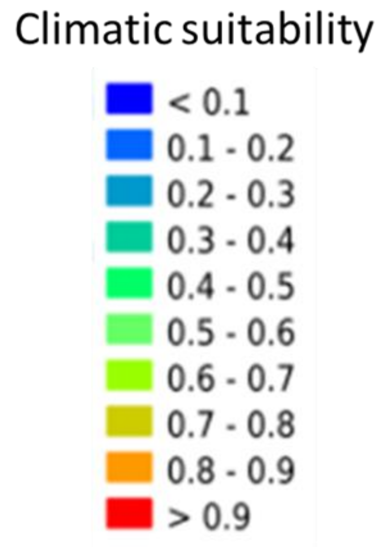
Amelenchier arborea (Downy serviceberry)

a. Historical



b. 2011-2040





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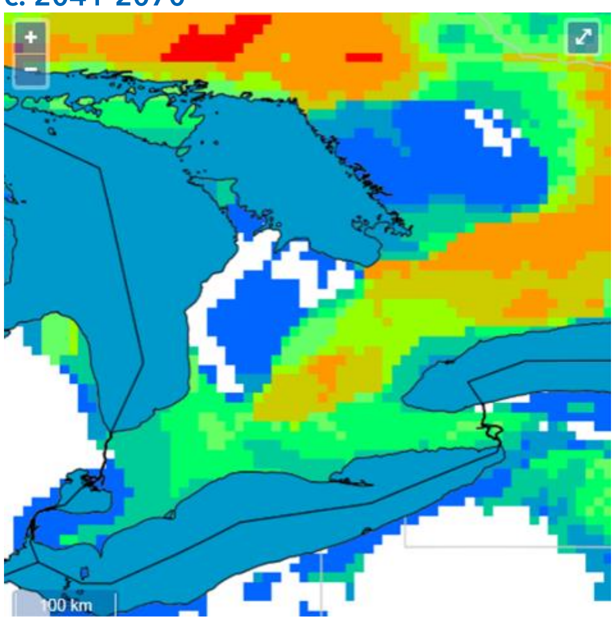
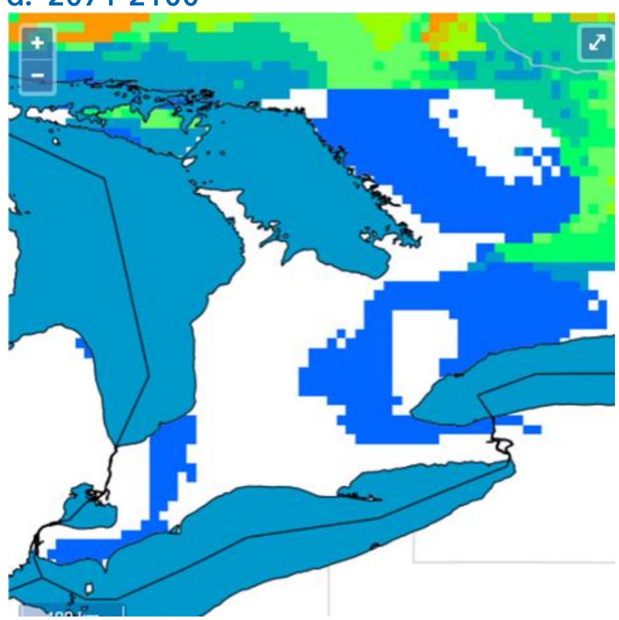
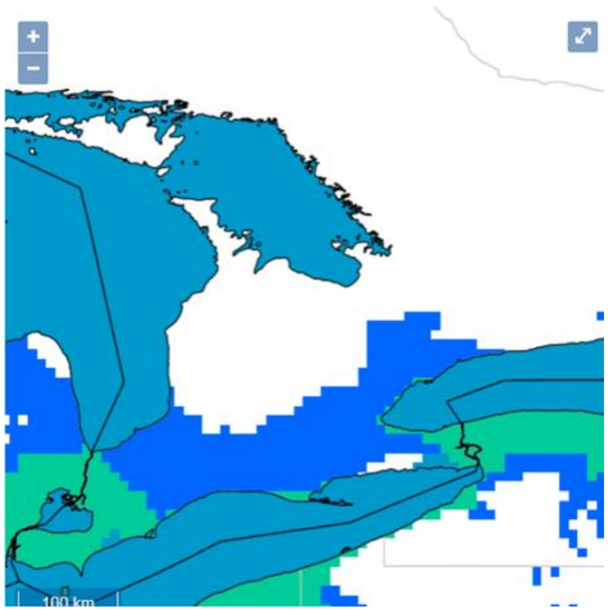


d. 2071-2100



Asimina triloba (Pawpaw)

a. Historical



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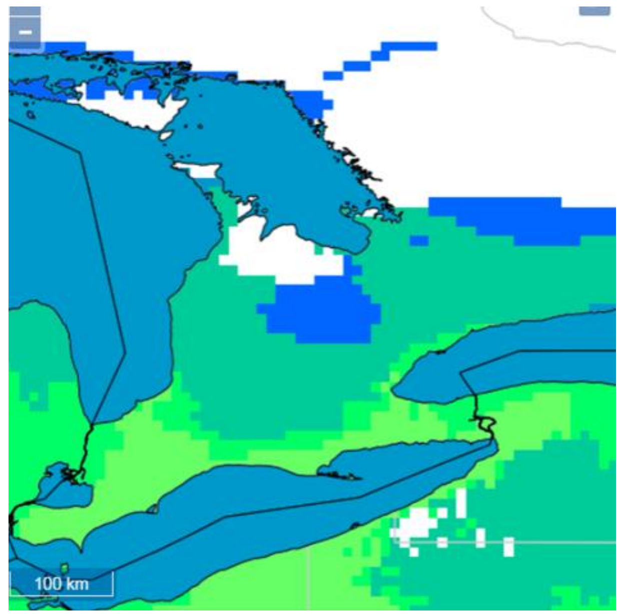

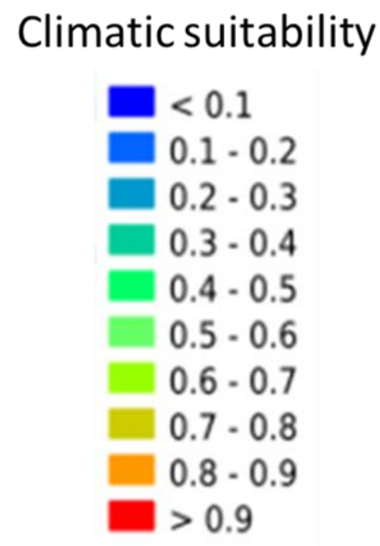

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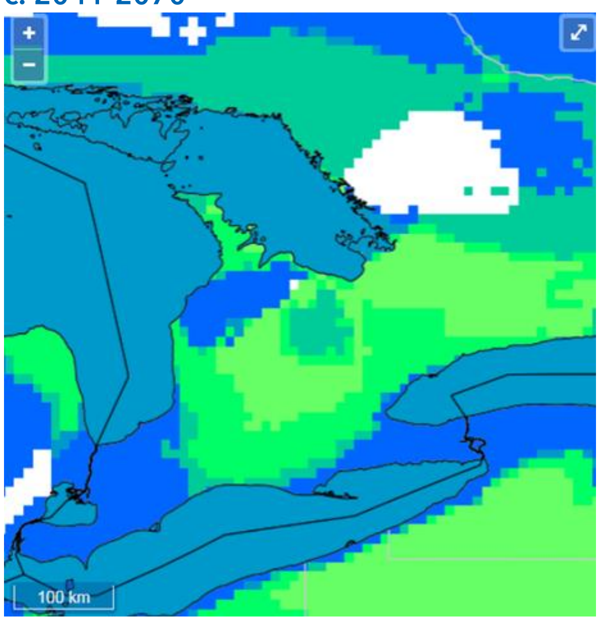
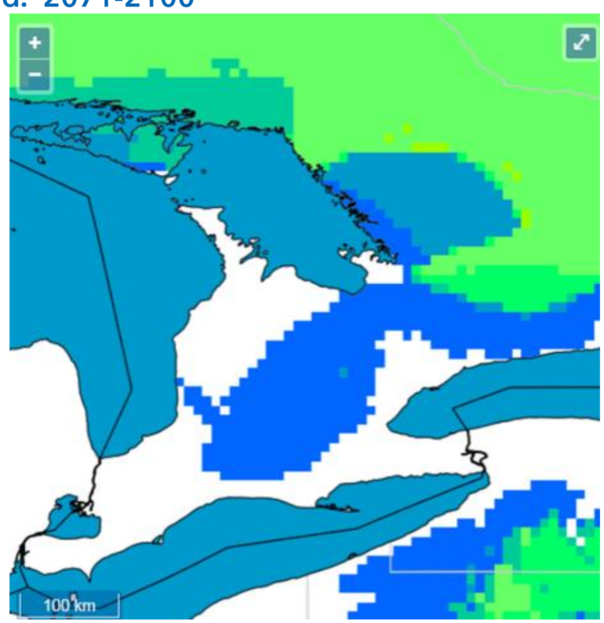
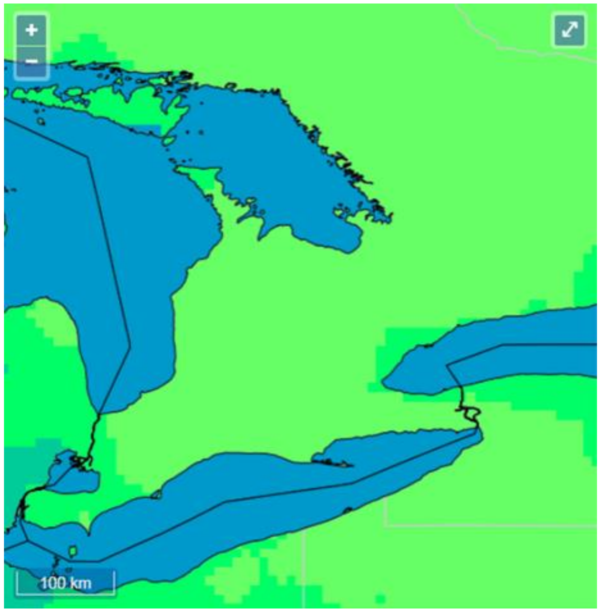


d. 2071-2100



Betula alleghaniensis (Yellow birch)

a. Historical



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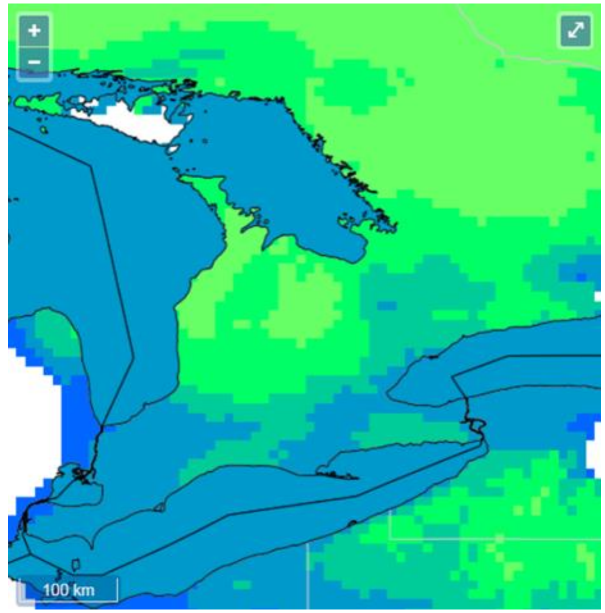

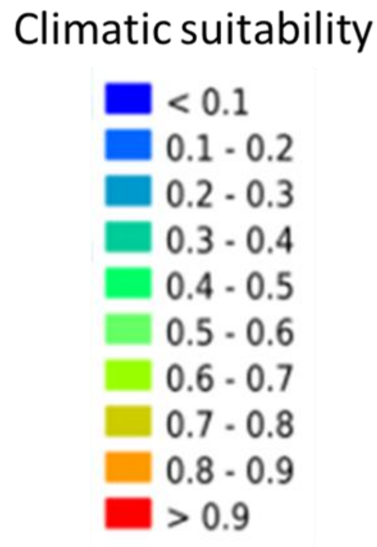

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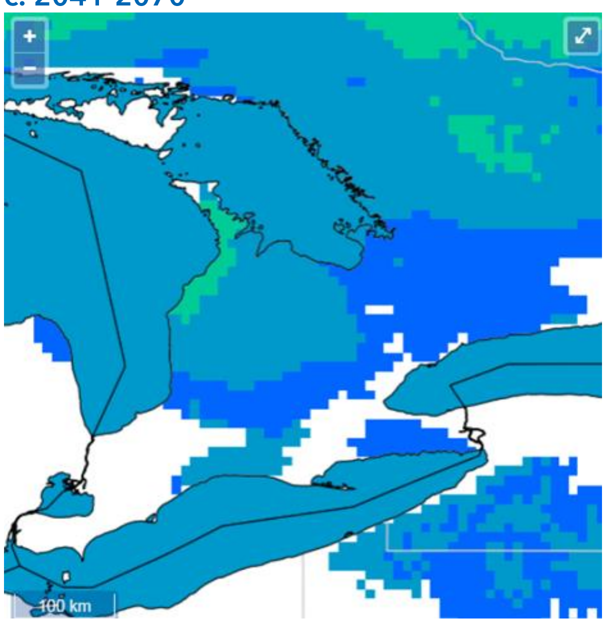
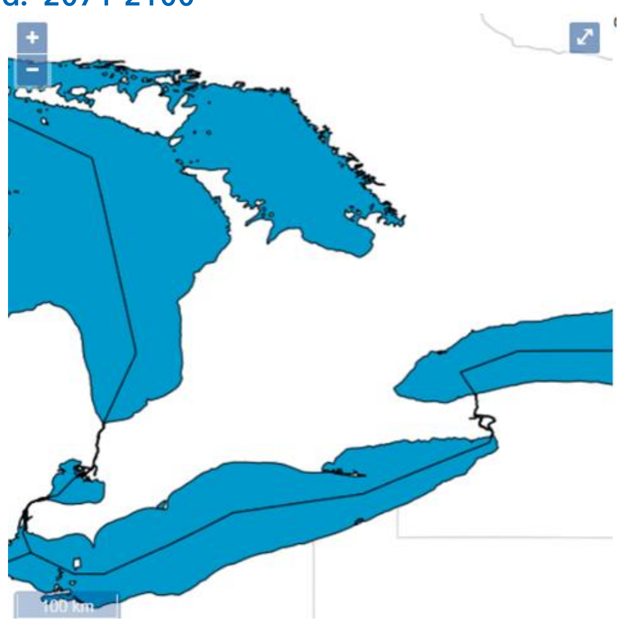
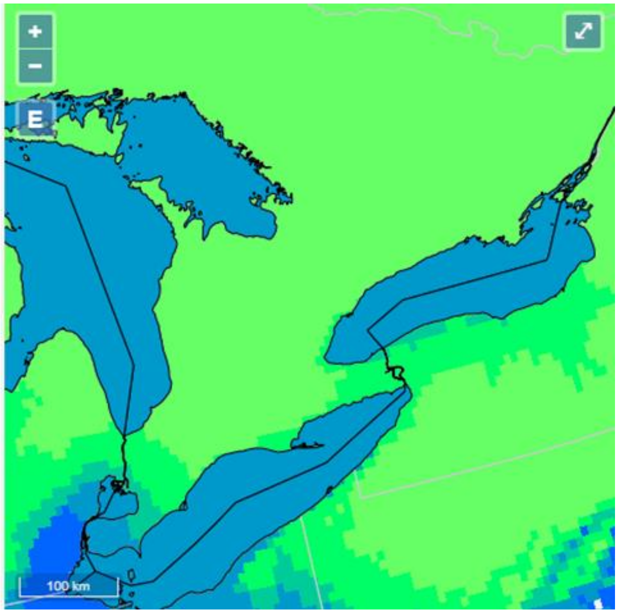


d. 2071-2100

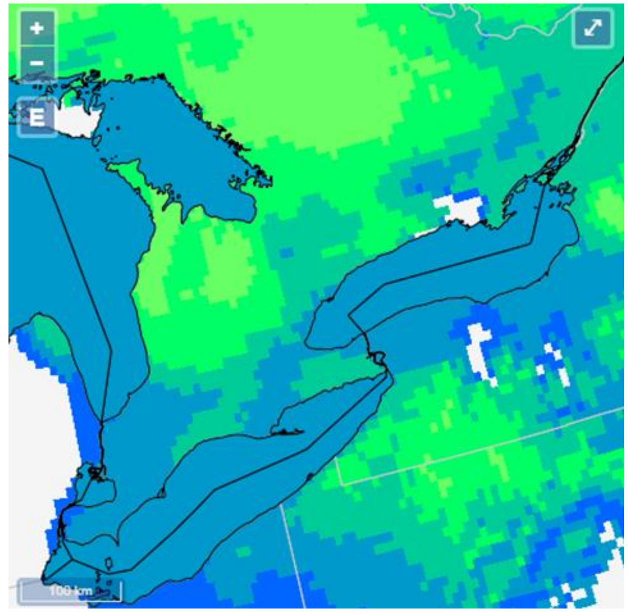


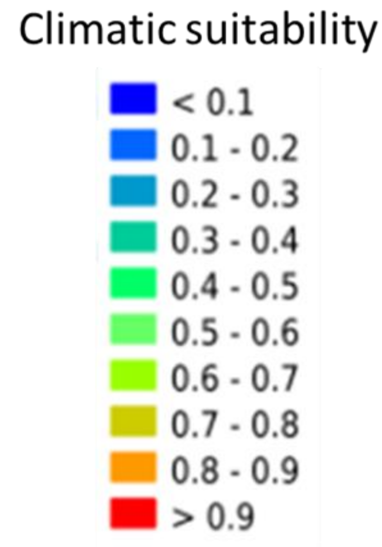
Betula papyrifera (White birch)

a. Historical

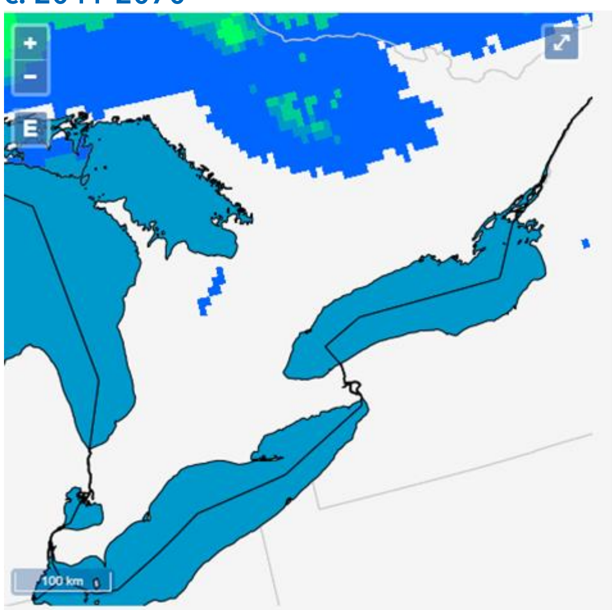


b. 2011-2040

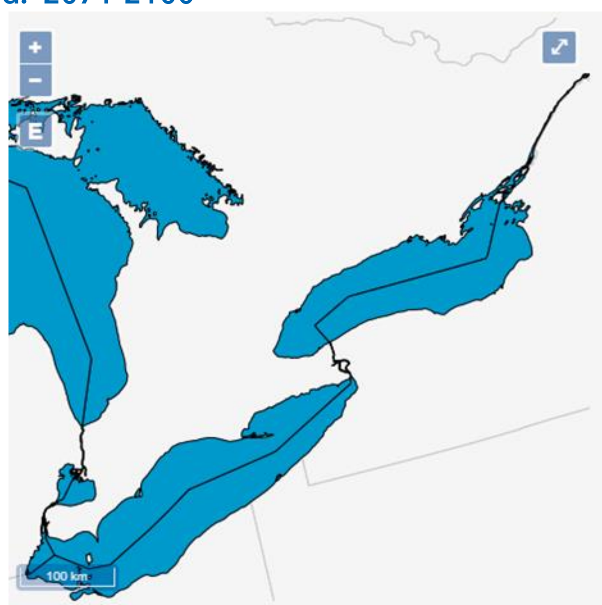




c. 2041-2070

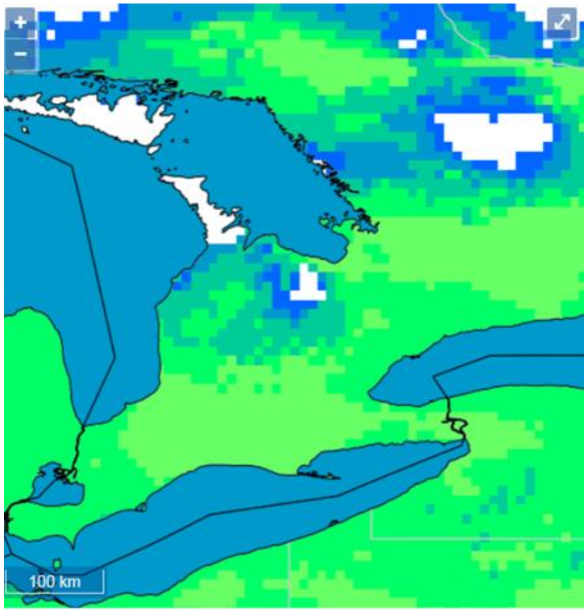


d. 2071-2100

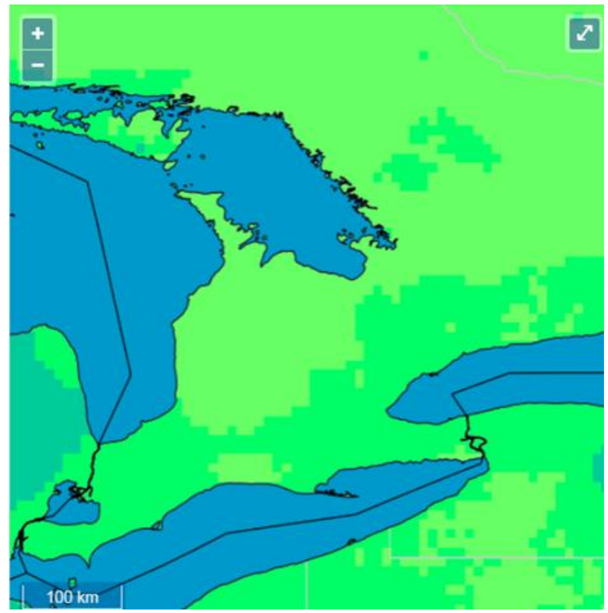


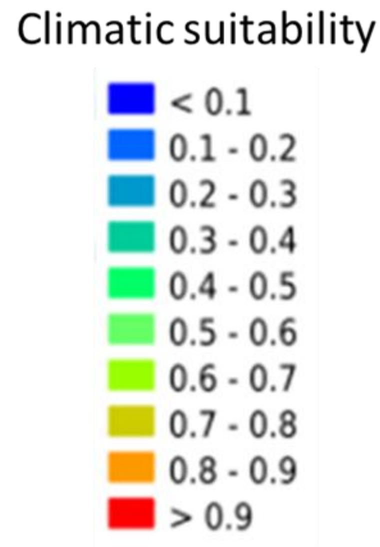
Carpinus caroliniana (American hornbeam)

a. Historical

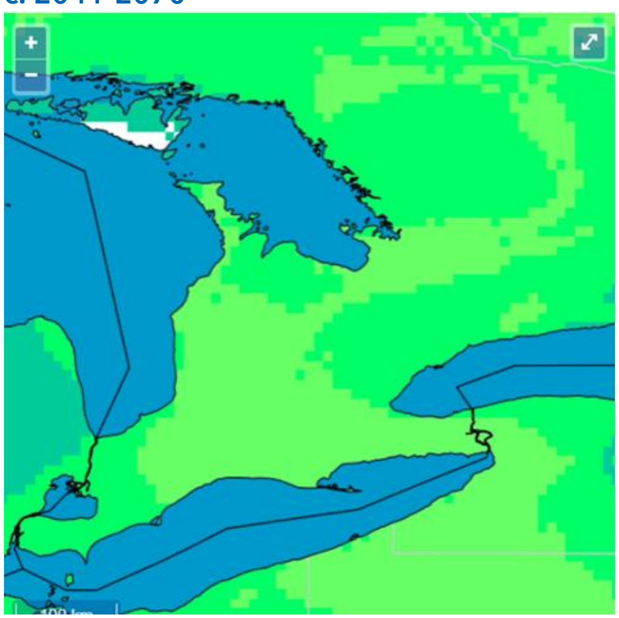


b. 2011-2040

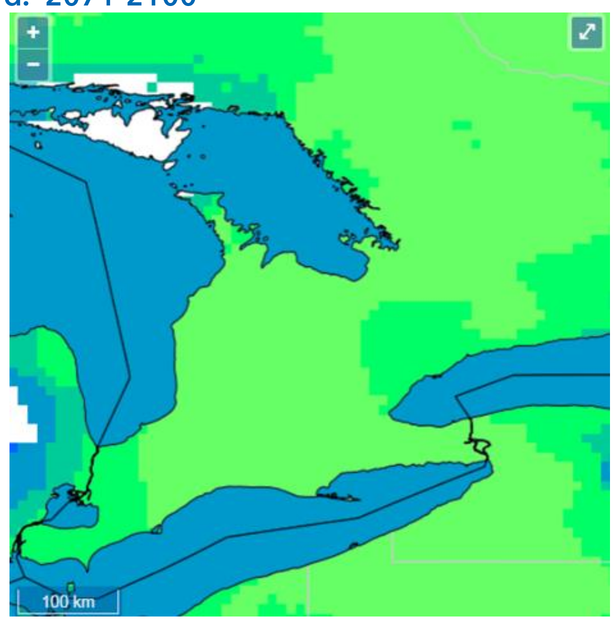




c. 2041-2070

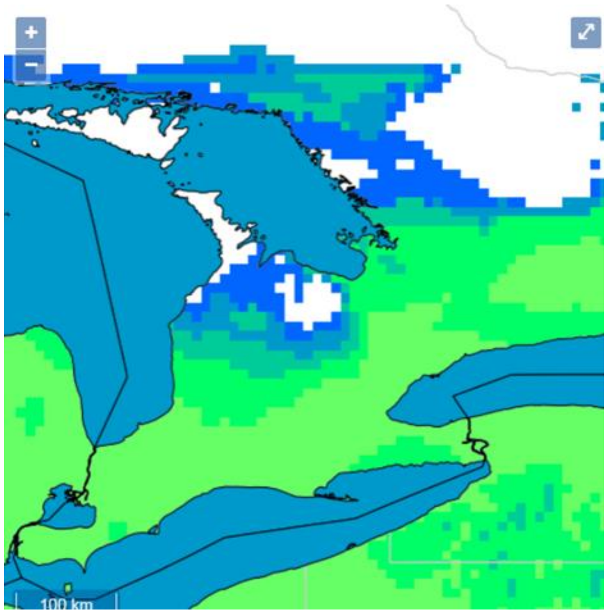


d. 2071-2100

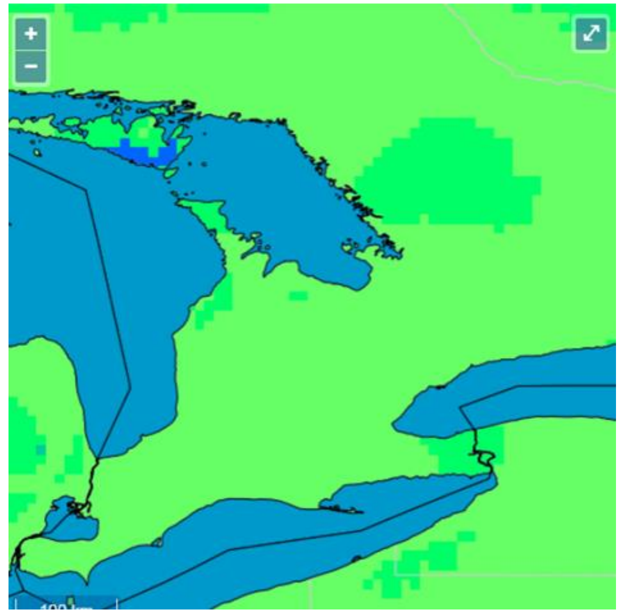


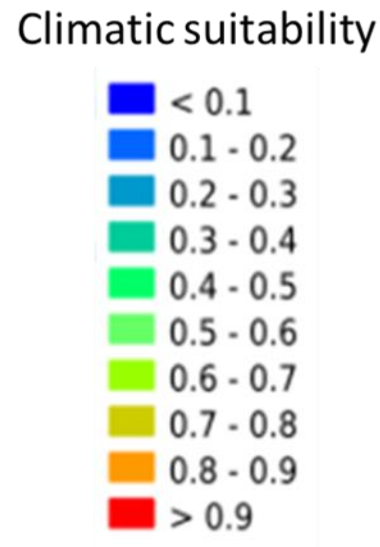
Carya cordiformus (Bitternut hickory)

a. Historical

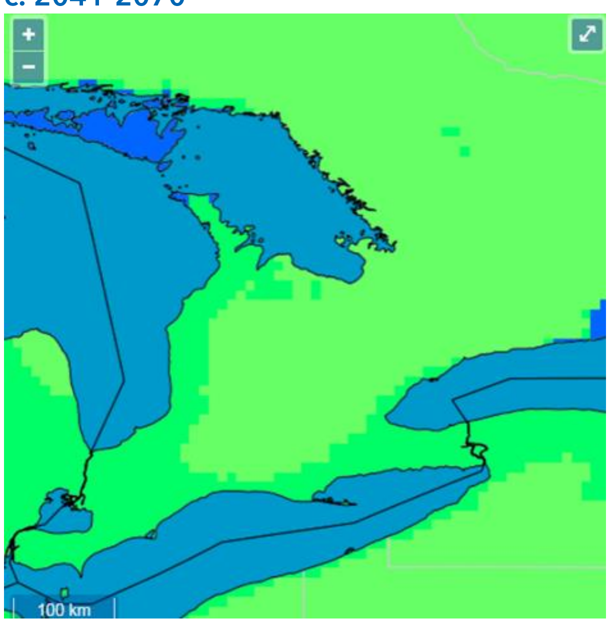


b. 2011-2040

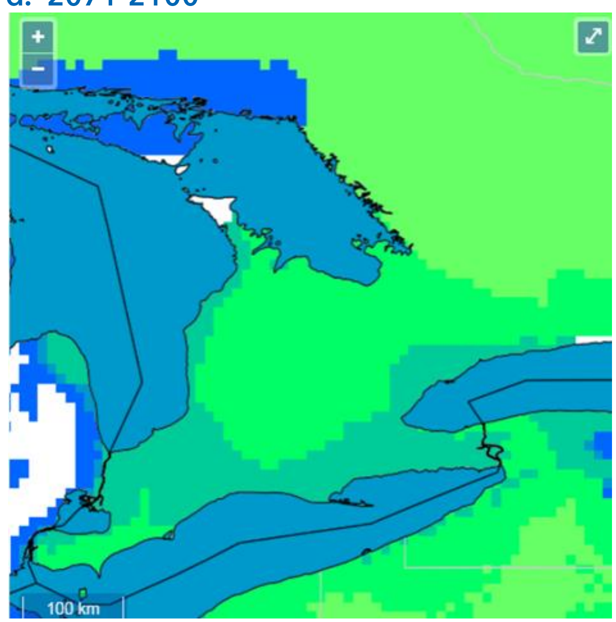




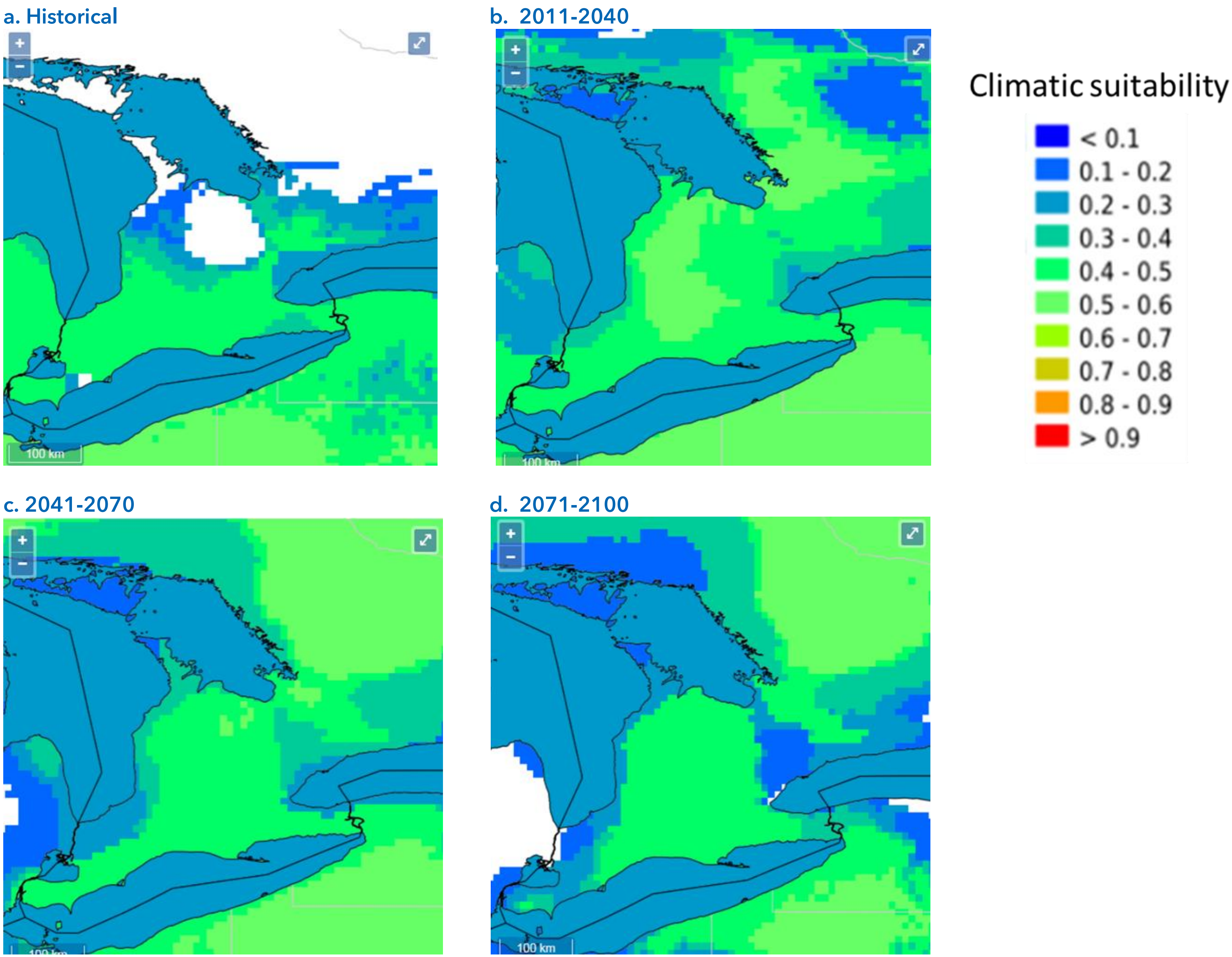
c. 2041-2070



d. 2071-2100

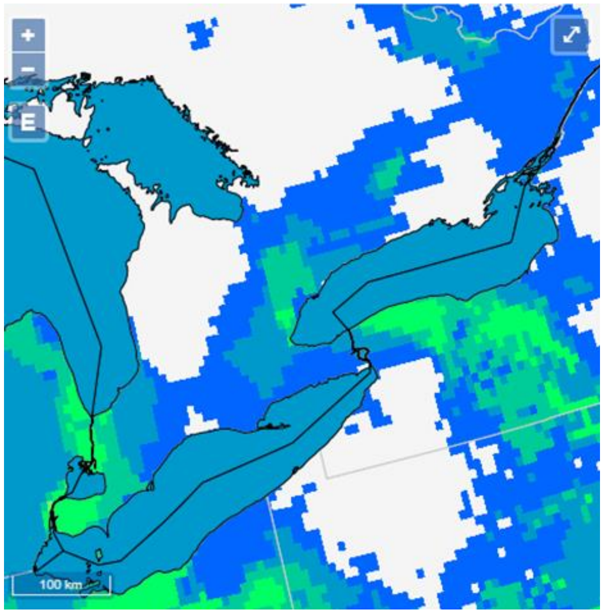


Carya ovata (Shagbark hickory)

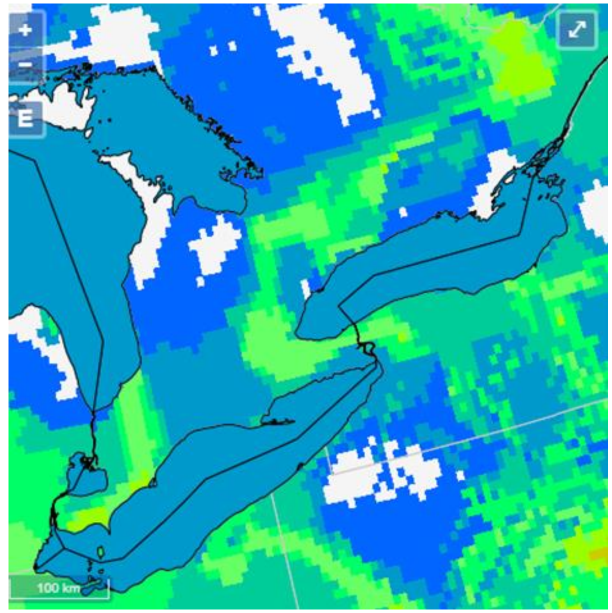


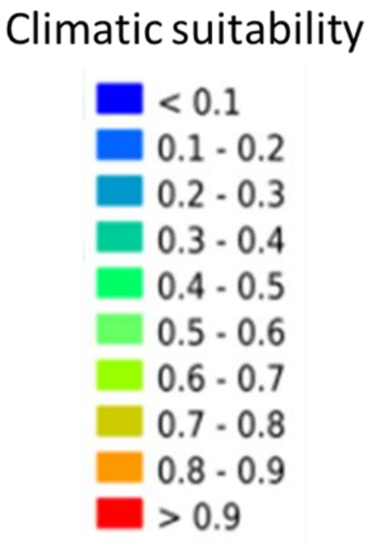
Catalpa speciosa (Catalpa)

a. Historical

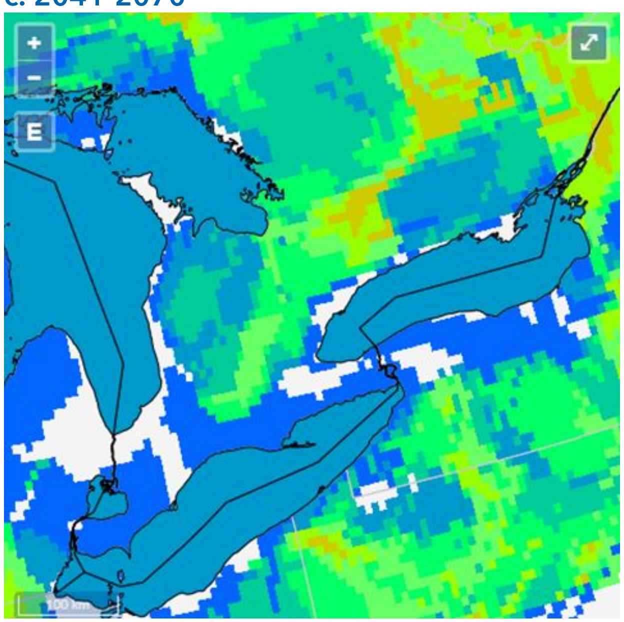


b. 2011-2040

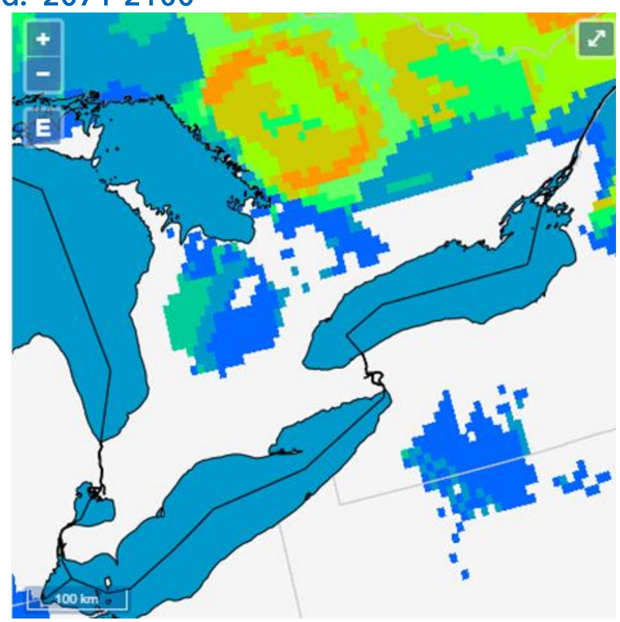




c. 2041-2070

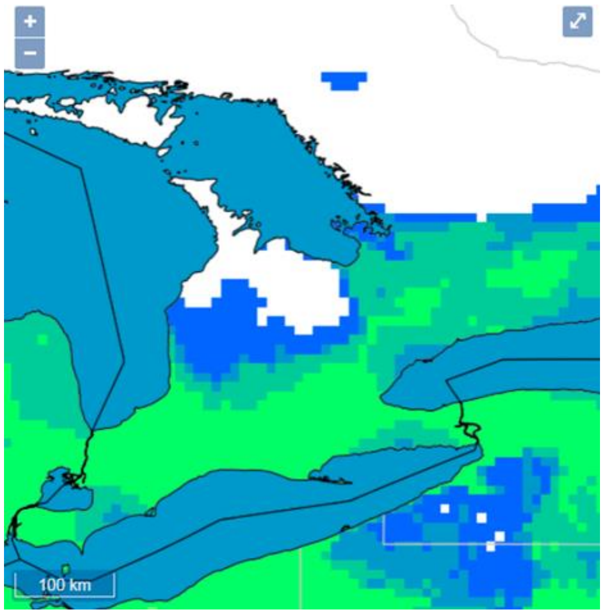


d. 2071-2100



Celtis occidentalis (Northern hackberry)

a. Historical



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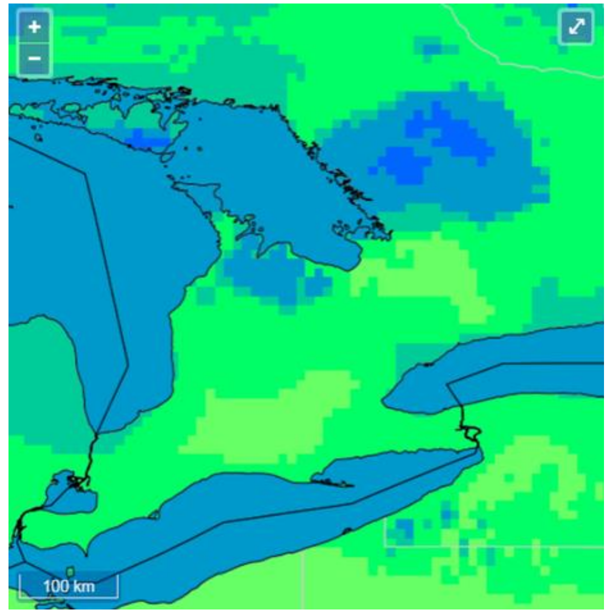
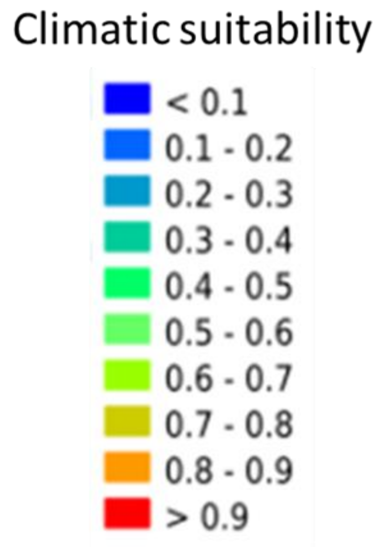
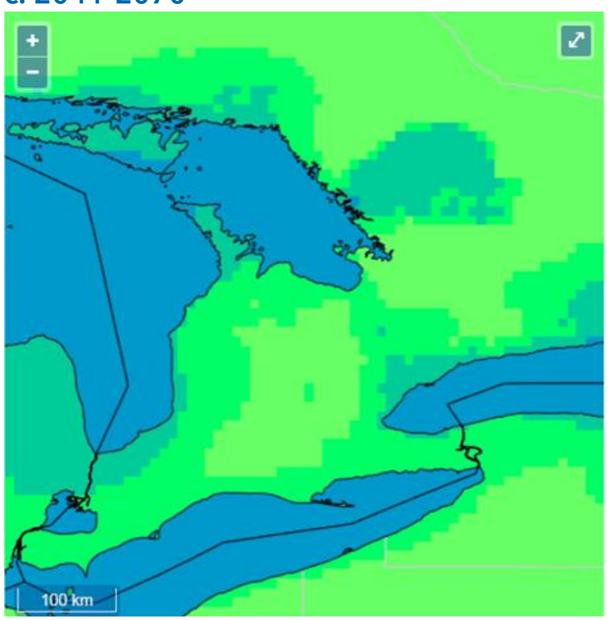
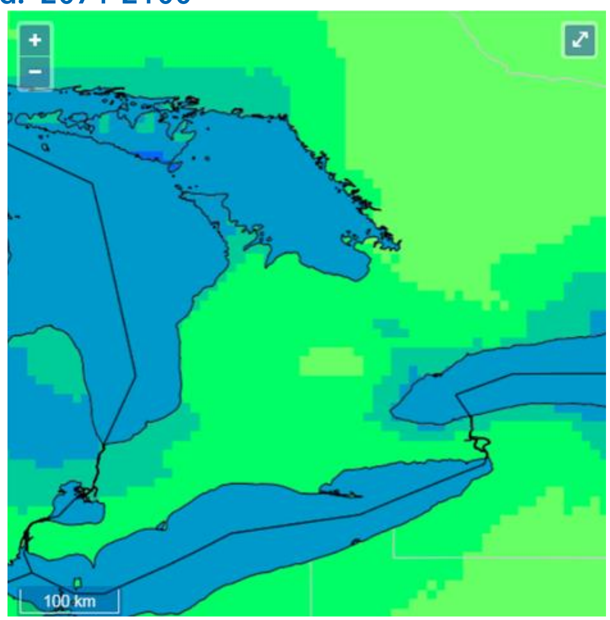




c. 2041-2070

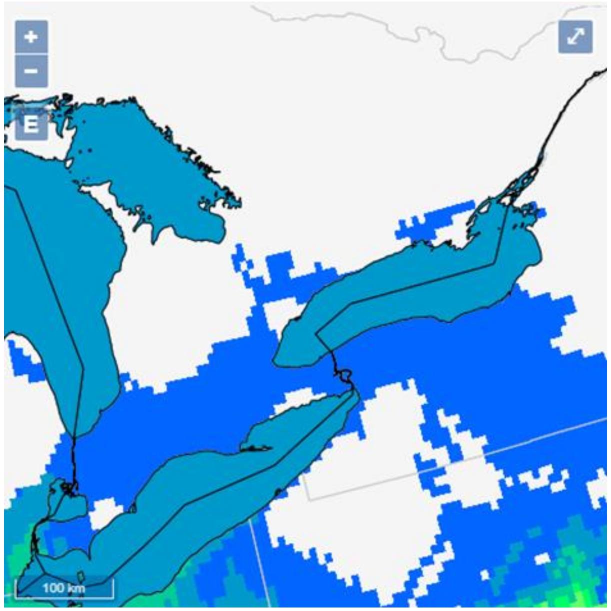


d. 2071-2100

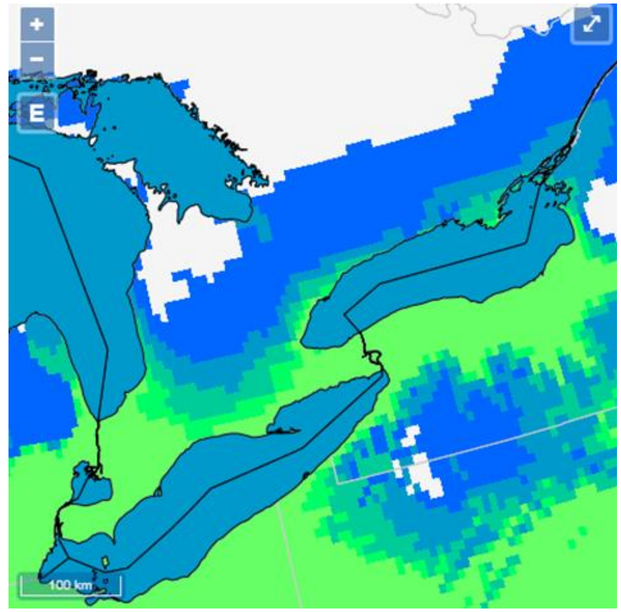


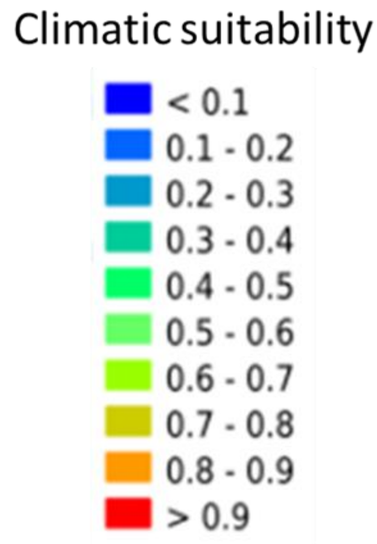
Cercis canadensis (Eastern redbud)

a. Historical

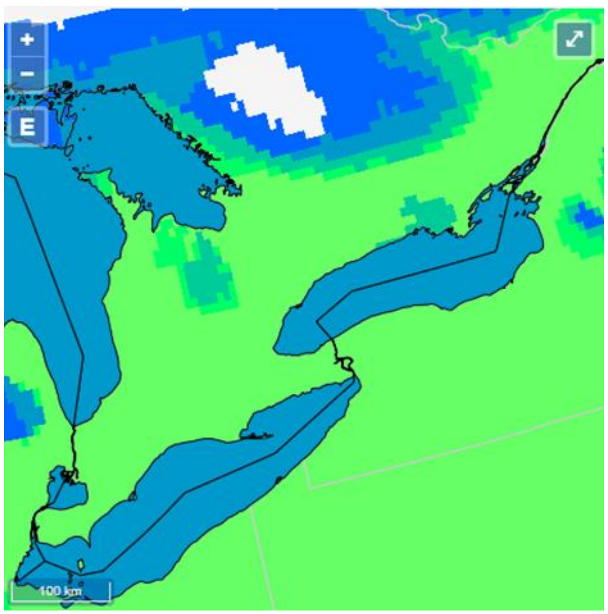


b. 2011-2040

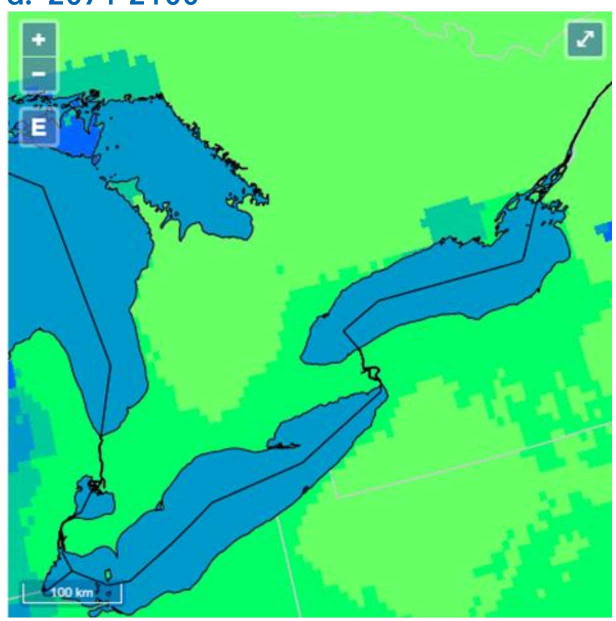




c. 2041-2070

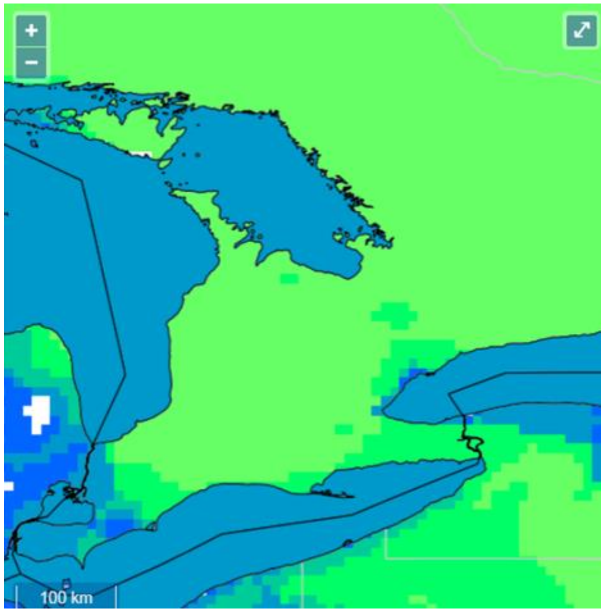


d. 2071-2100

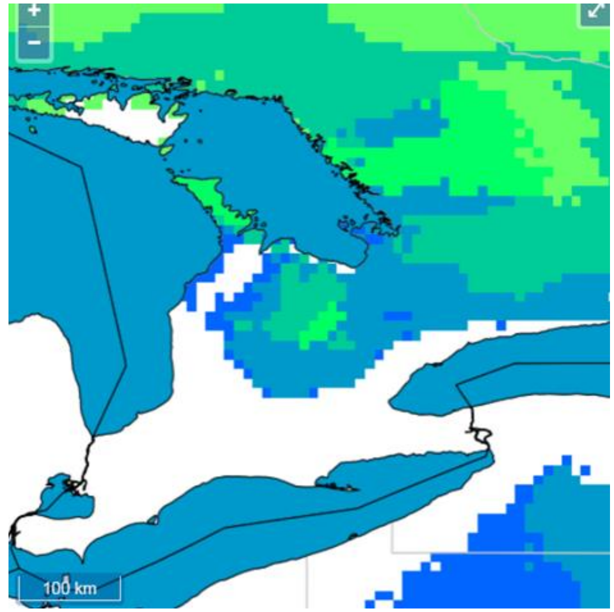


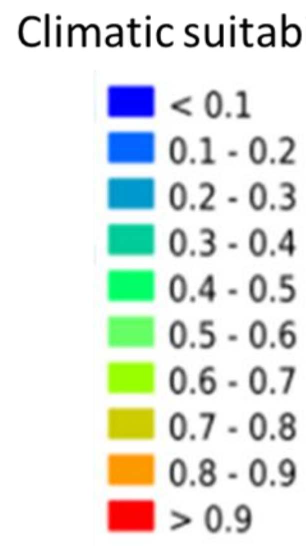
Cornus alternifolia (Alternate-leaf dogwood)

a. Historical

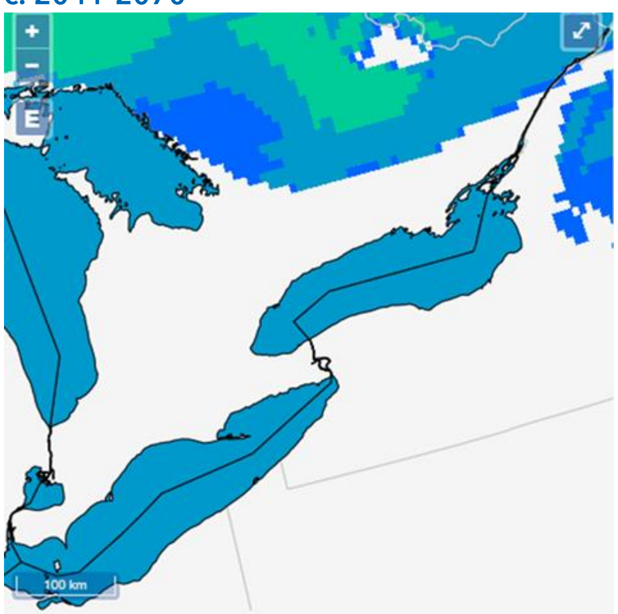


b. 2011-2040

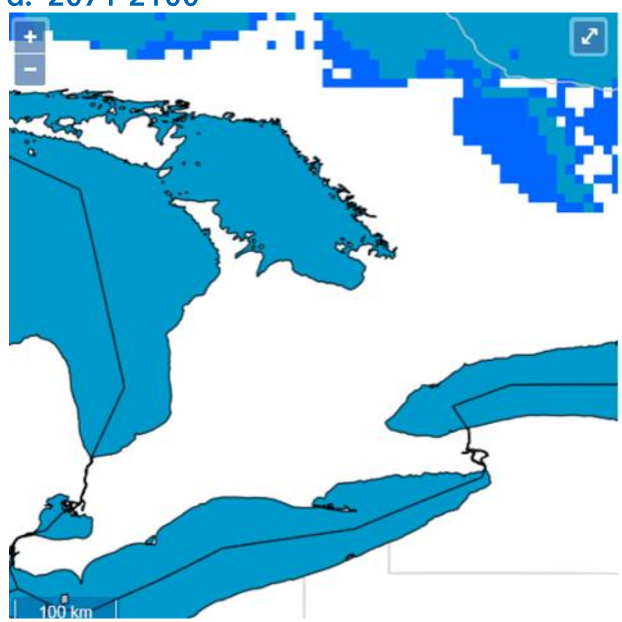




c. 2041-2070

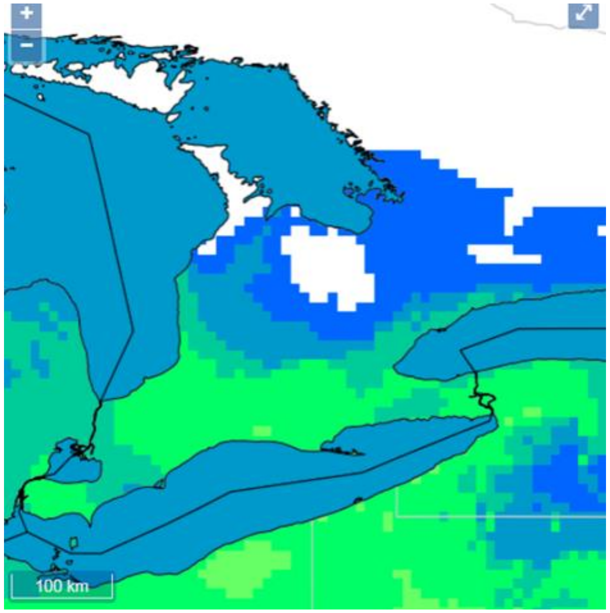


d. 2071-2100

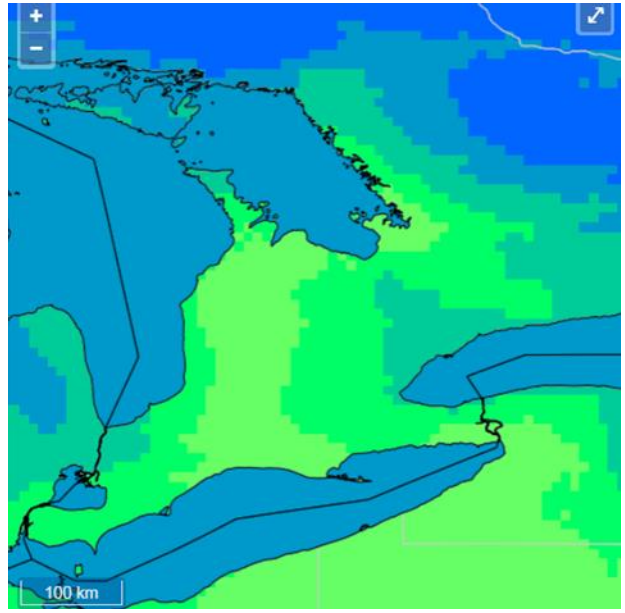


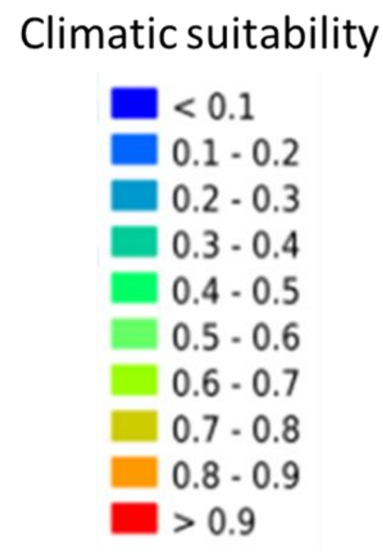
Cornus florida (Flowering dogwood)

a. Historical

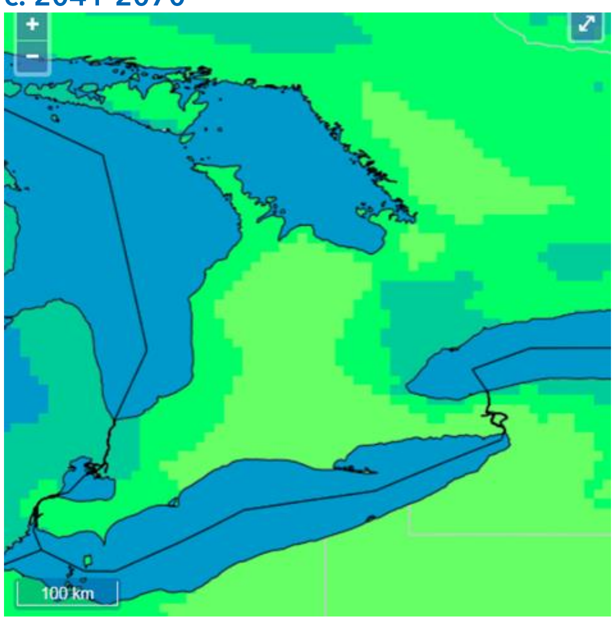


b. 2011-2040

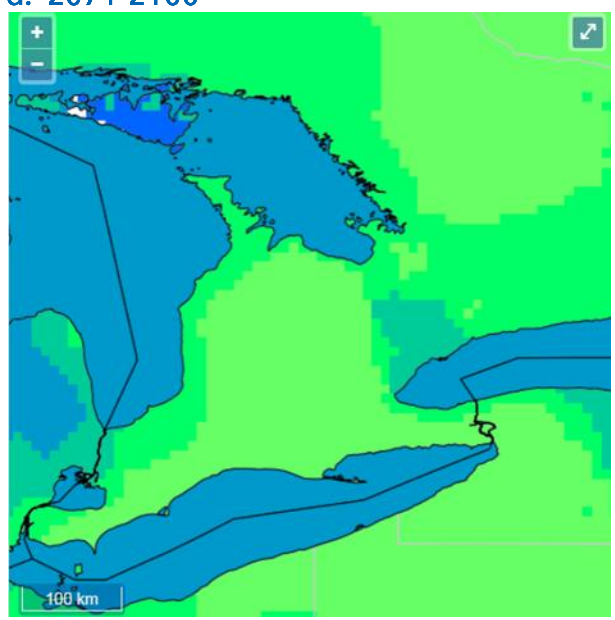




c. 2041-2070

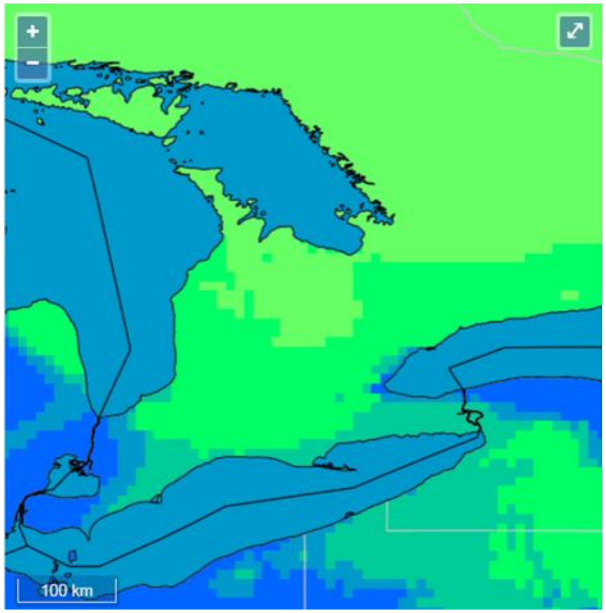


d. 2071-2100

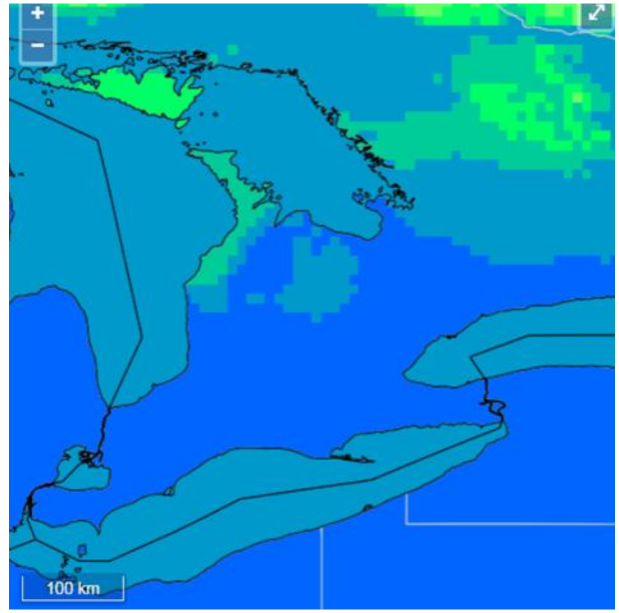


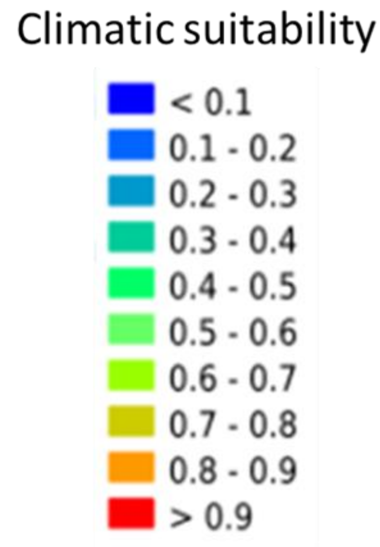
Cornus sericea (Red osier dogwood)

a. Historical

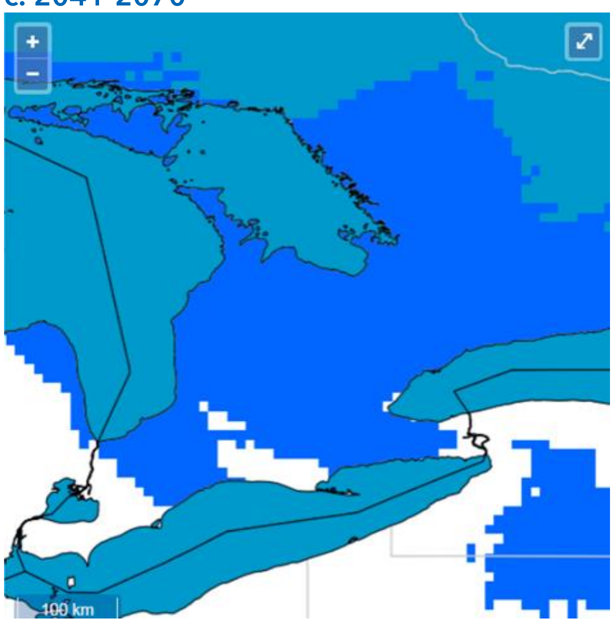


b. 2011-2040

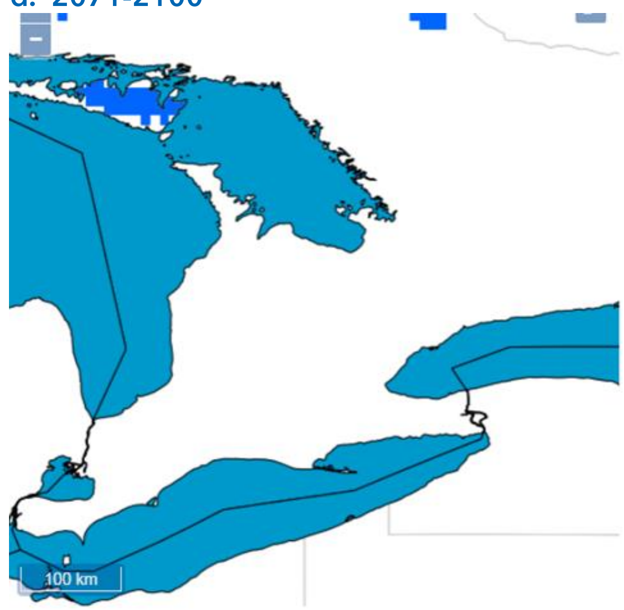




c. 2041-2070

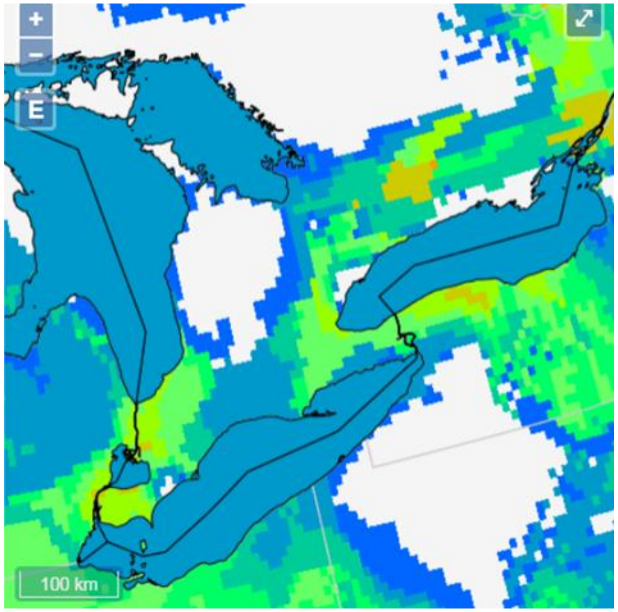


d. 2071-2100

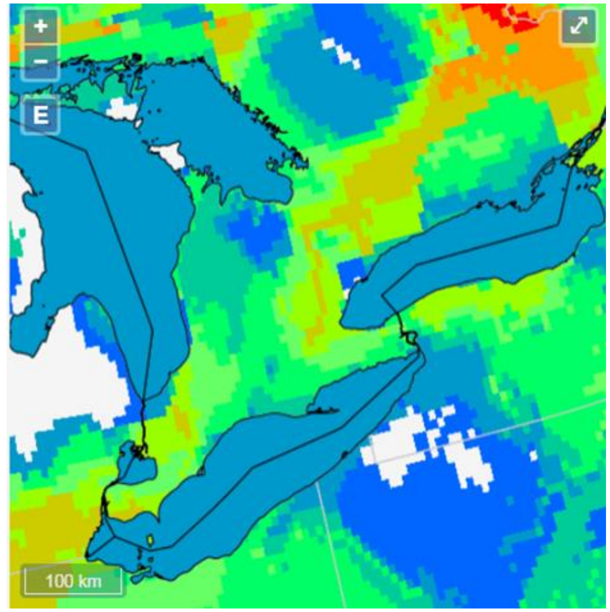


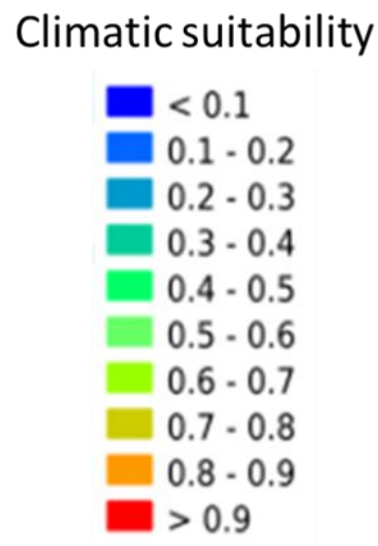
Crataegus mollis (Downy hawthorn)

a. Historical

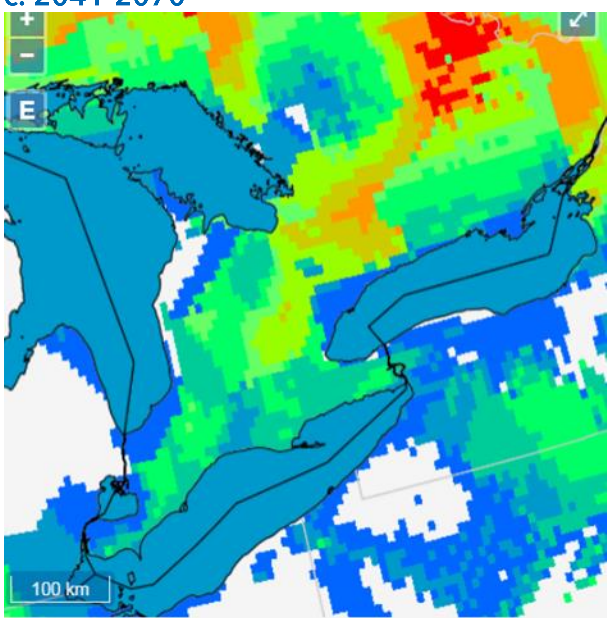


b. 2011-2040

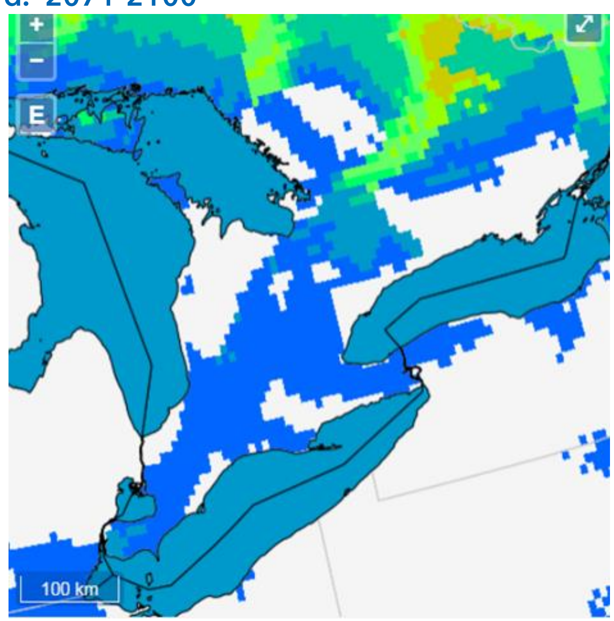




c. 2041-2070

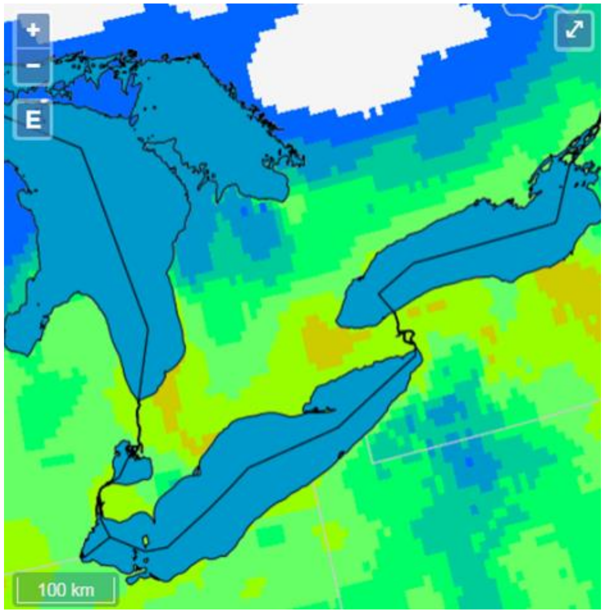


d. 2071-2100

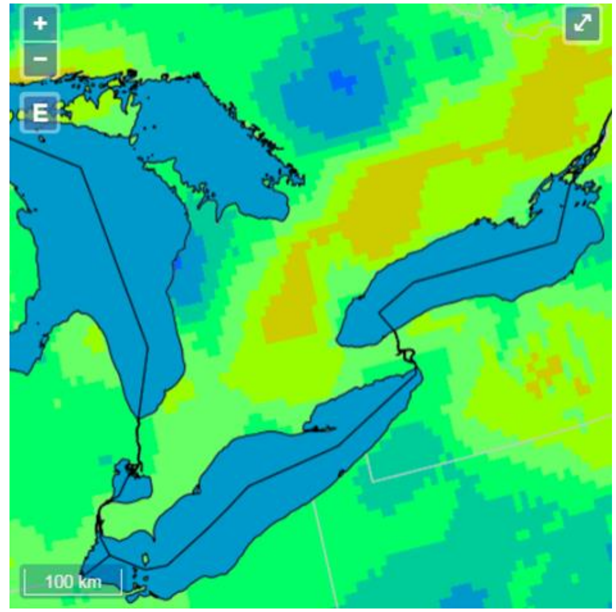


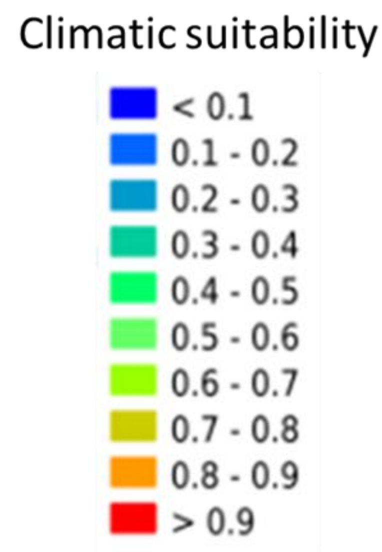
Crataegus punctata (Dotted hawthorn)

a. Historical

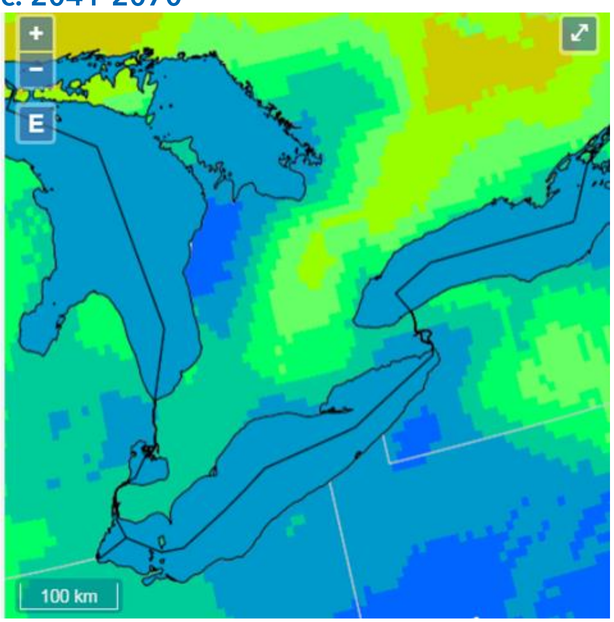


b. 2011-2040

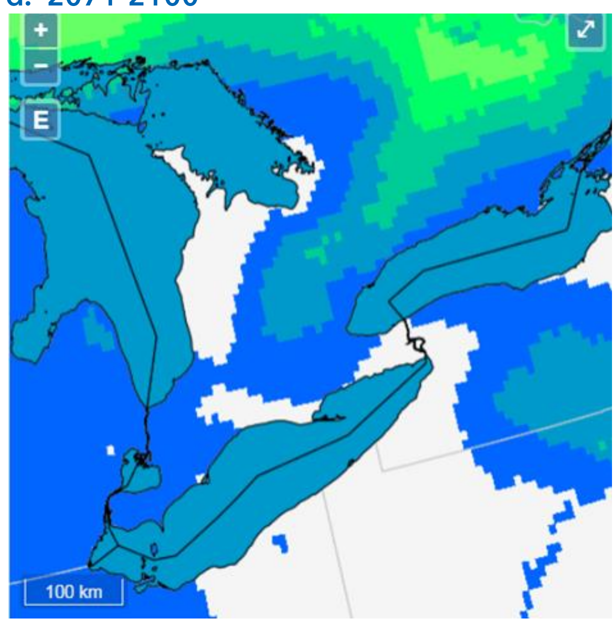




c. 2041-2070

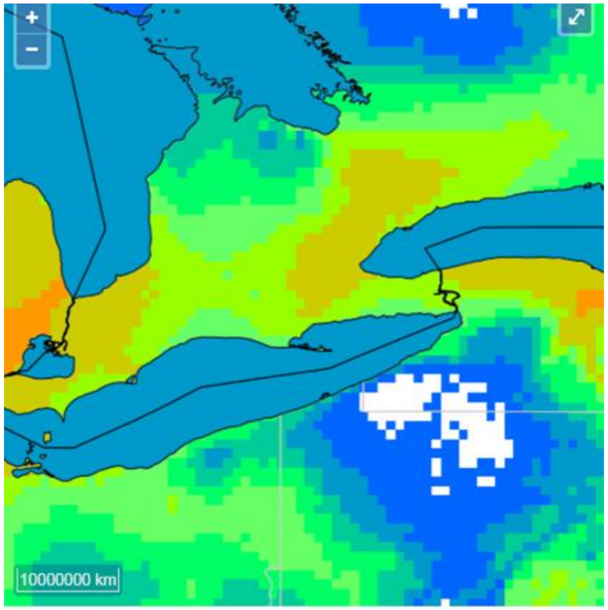


d. 2071-2100

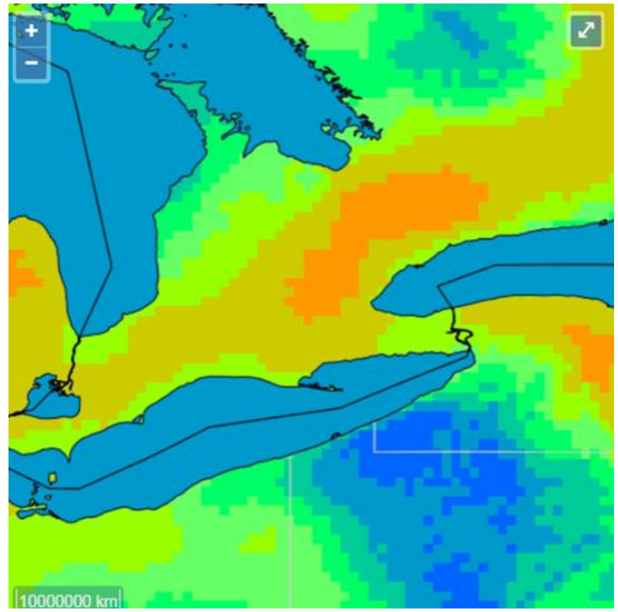


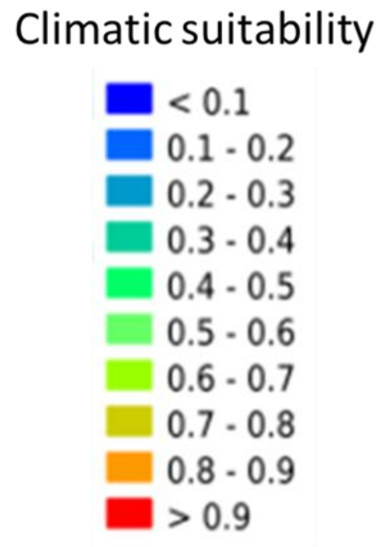
Elaeagnus angustifolia (Russian olive)

a. Historical

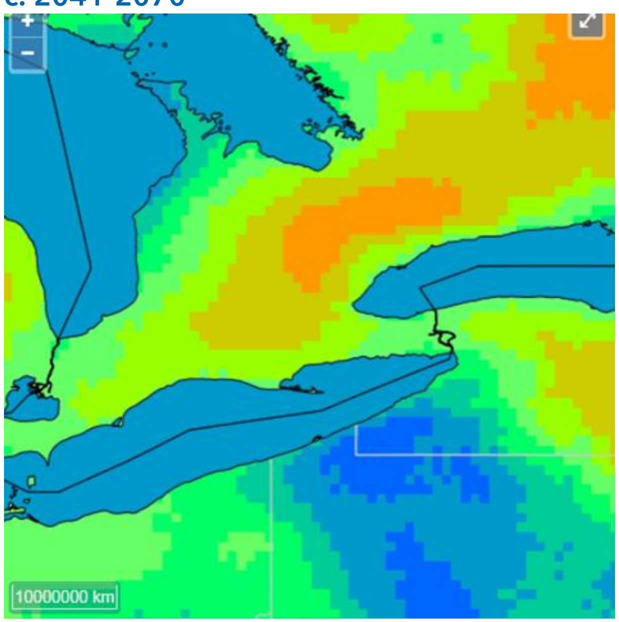


b. 2011-2040

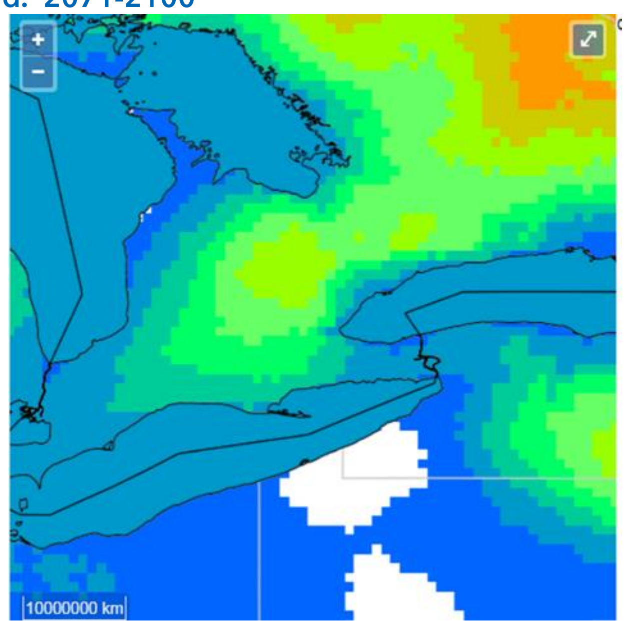




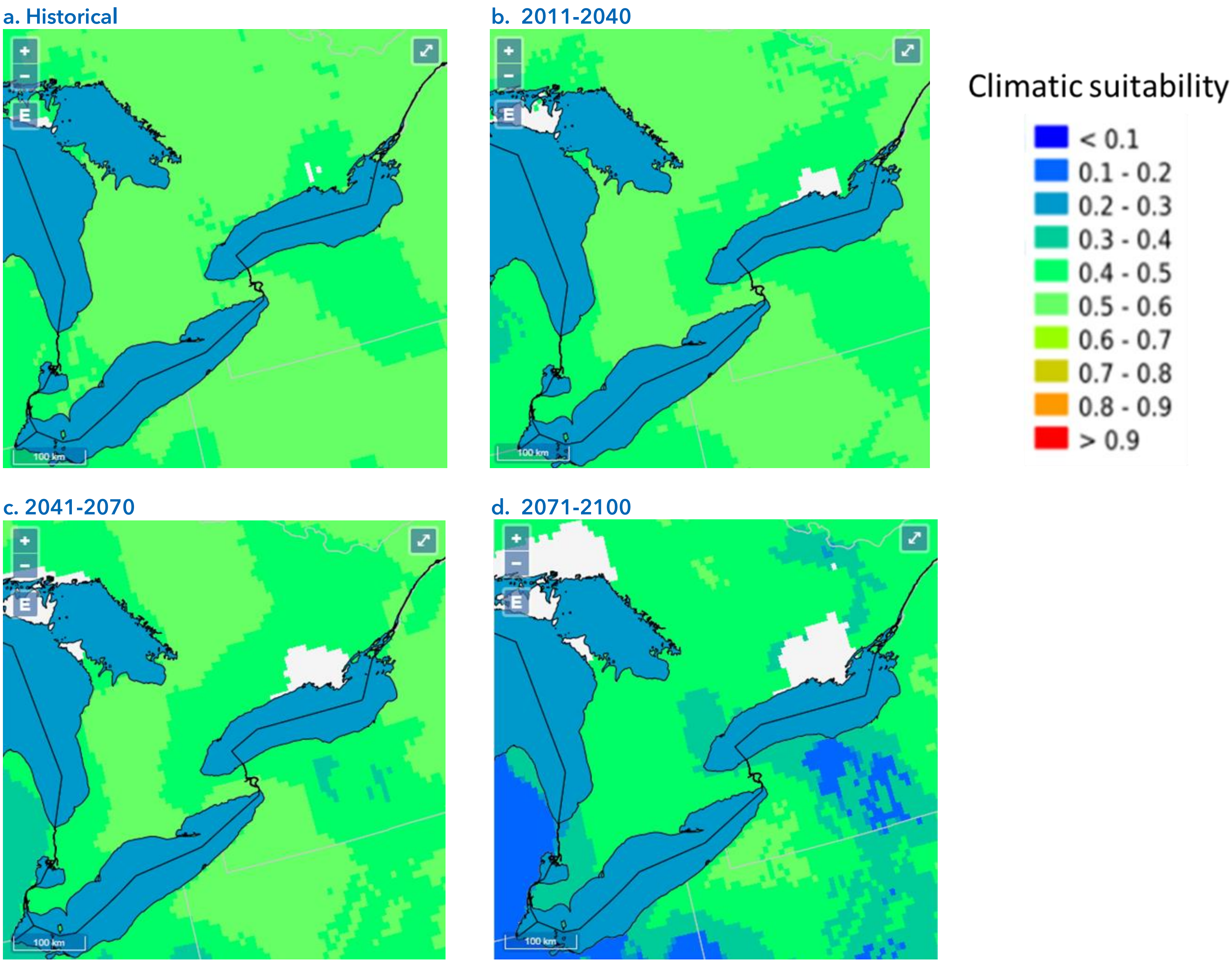
c. 2041-2070



d. 2071-2100

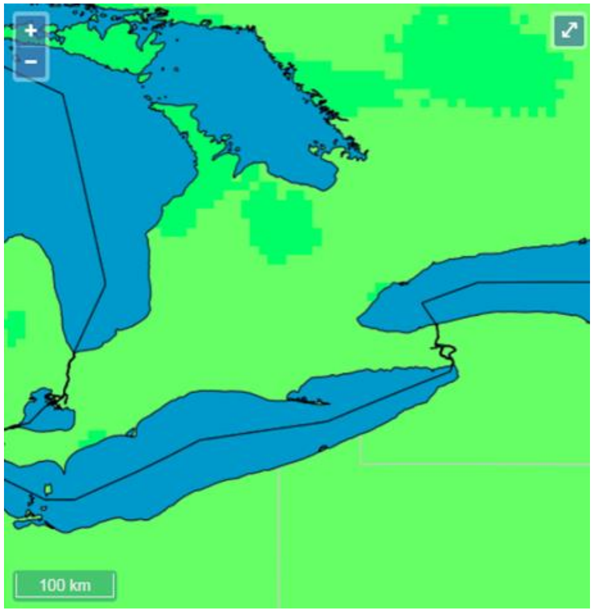


Fagus grandifolia (American beech)

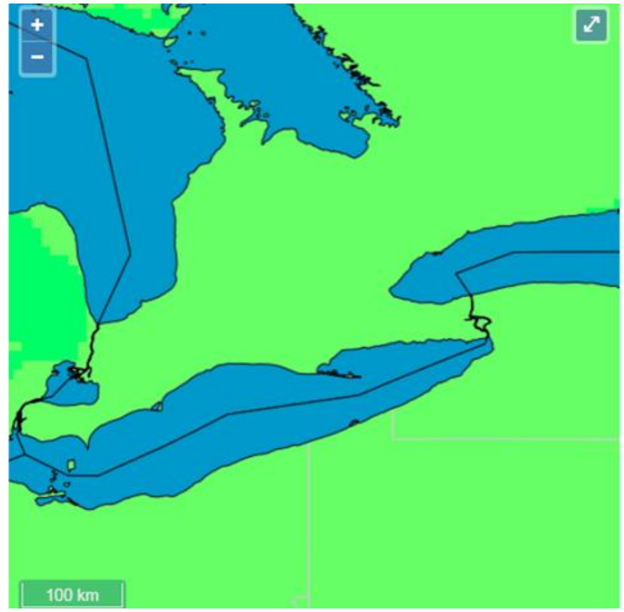


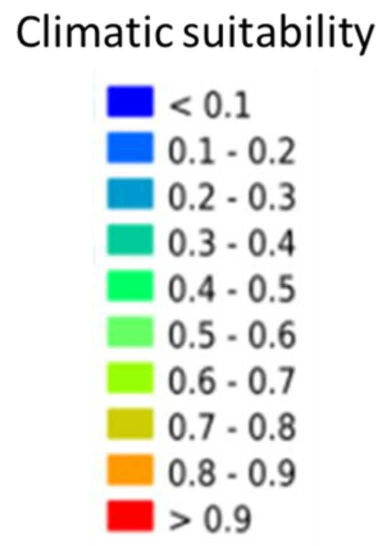
Fraxinus americana (White ash)

a. Historical

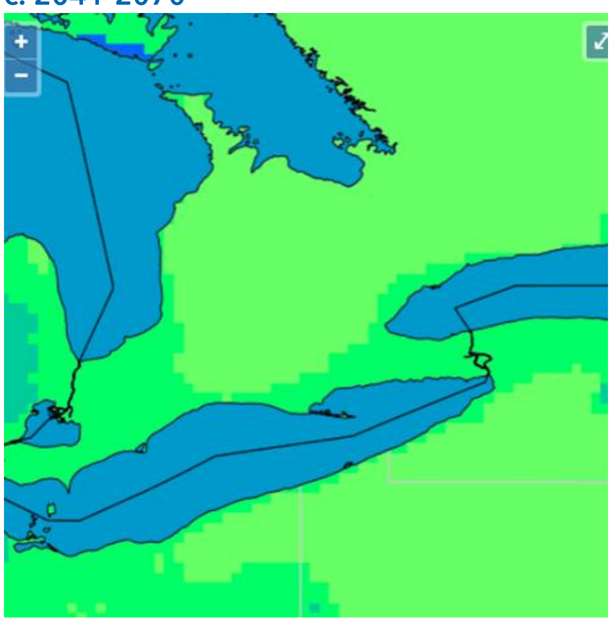


b. 2011-2040

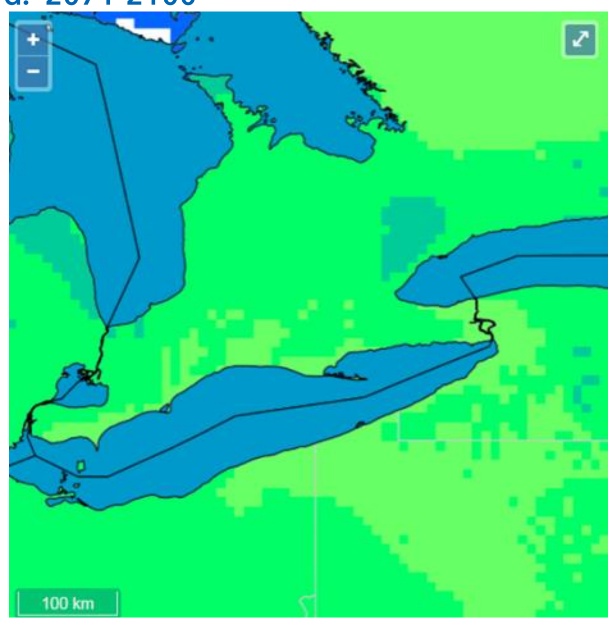




c. 2041-2070

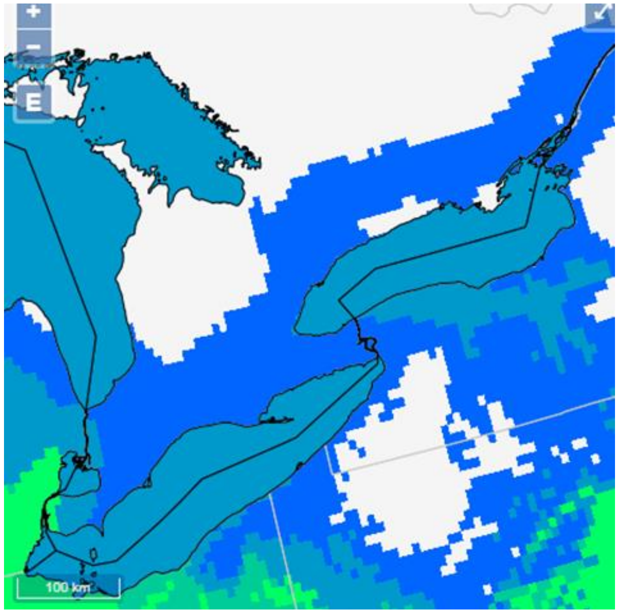


d. 2071-2100

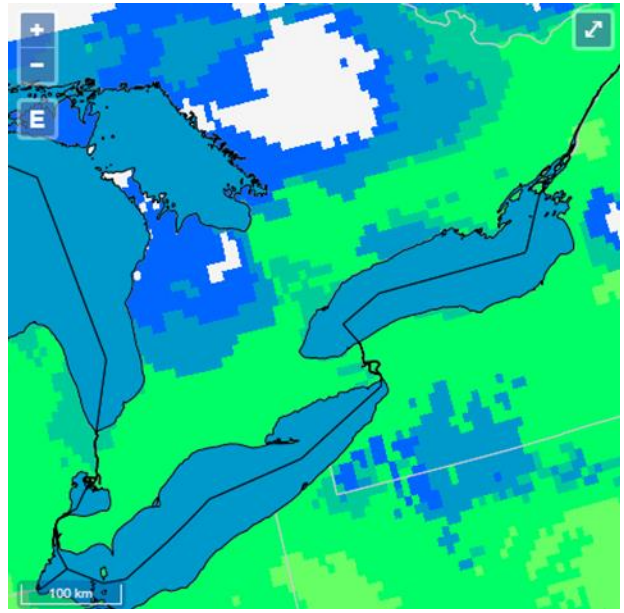


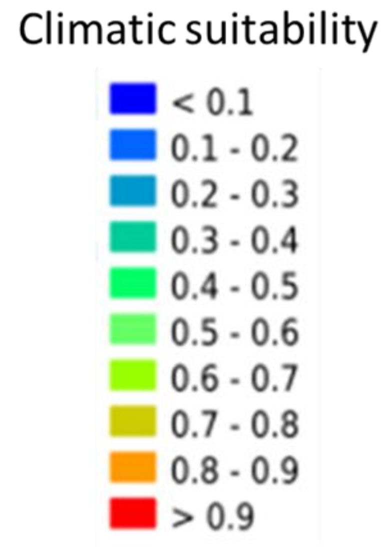
Gleditsia triacanthos (Honey locust)

a. Historical

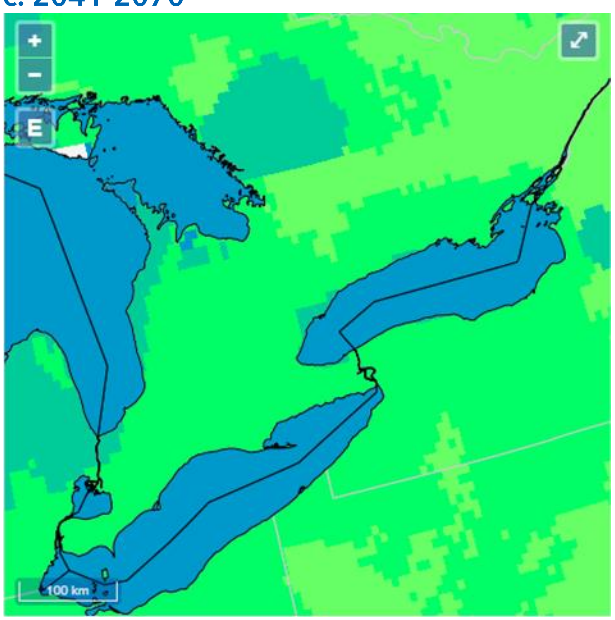


b. 2011-2040

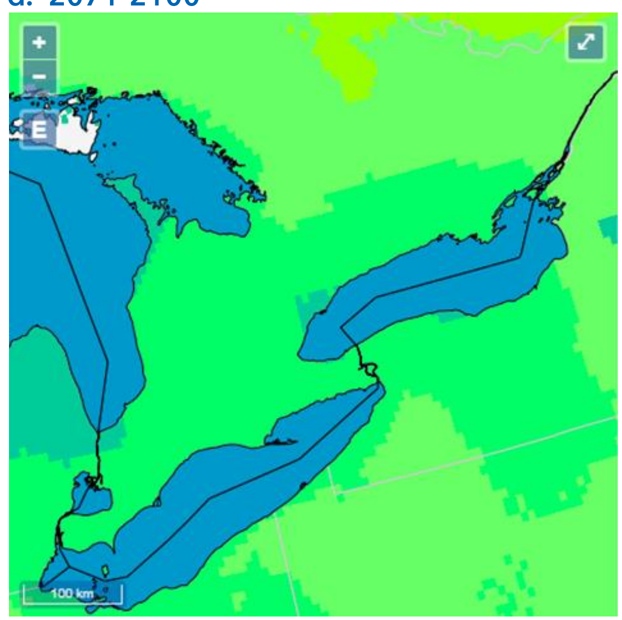




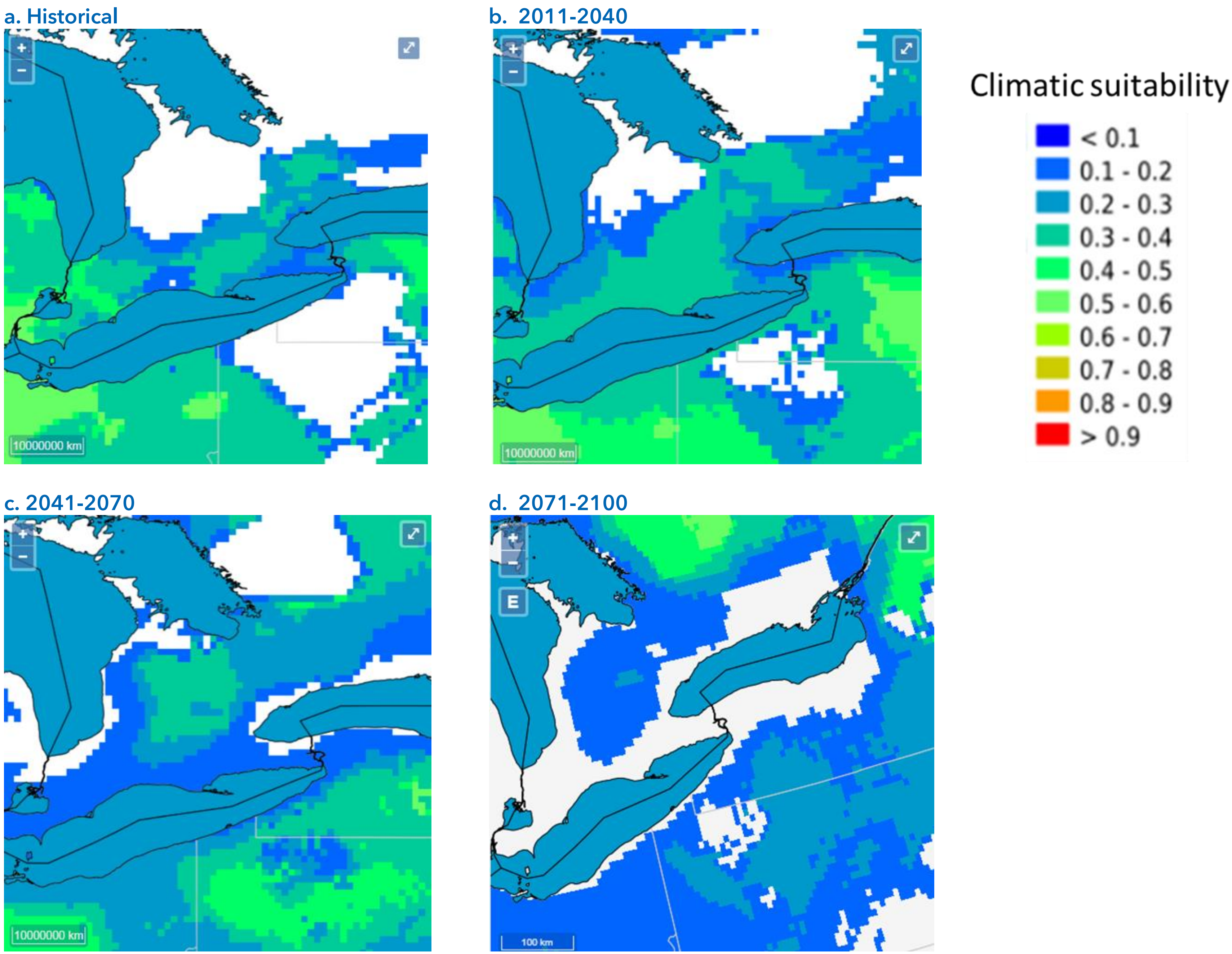
c. 2041-2070



d. 2071-2100

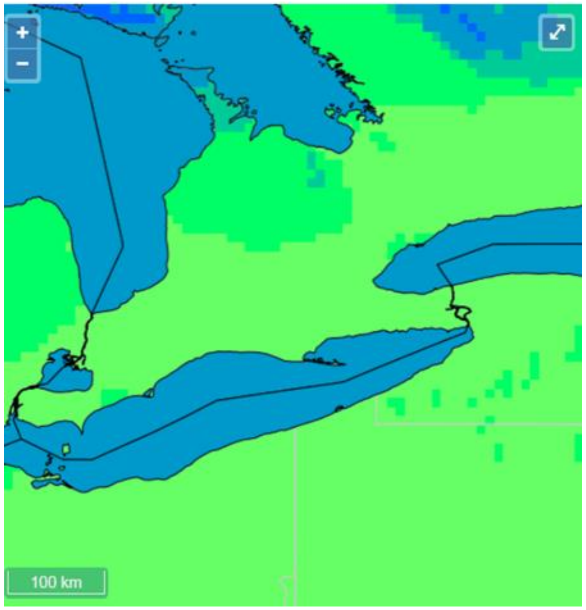


Gymnocladus diocius (Kentucky coffeetree)

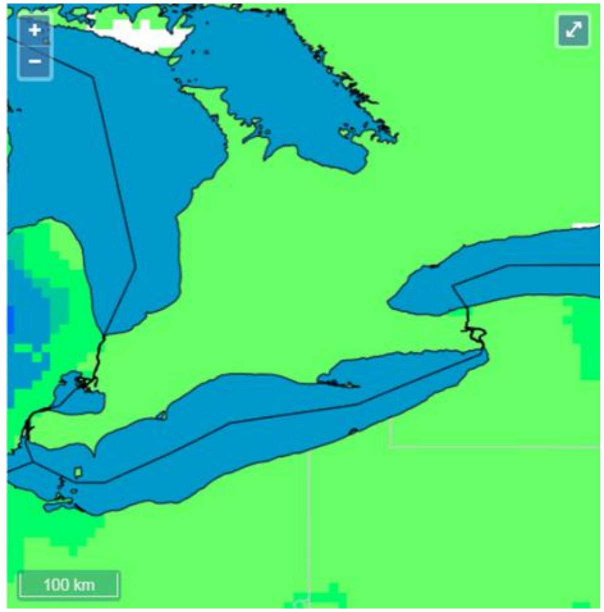


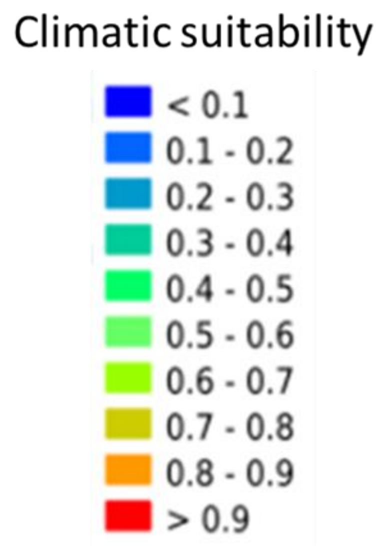
Juglans cinerea **(Butternut)**

a. Historical

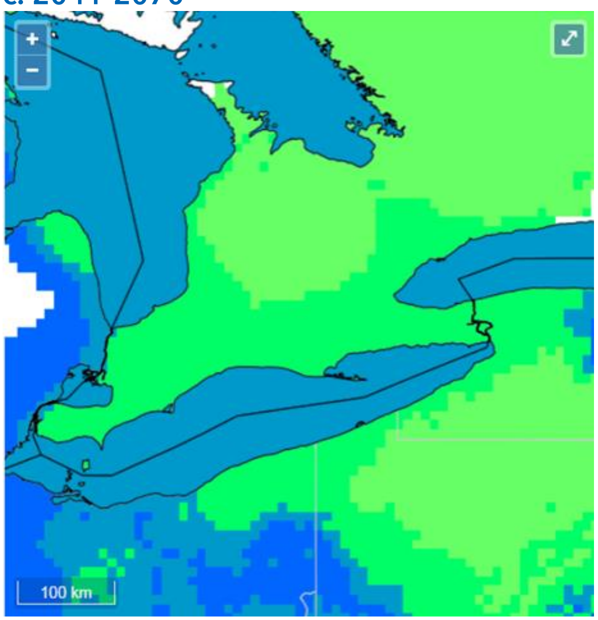


b. 2011-2040

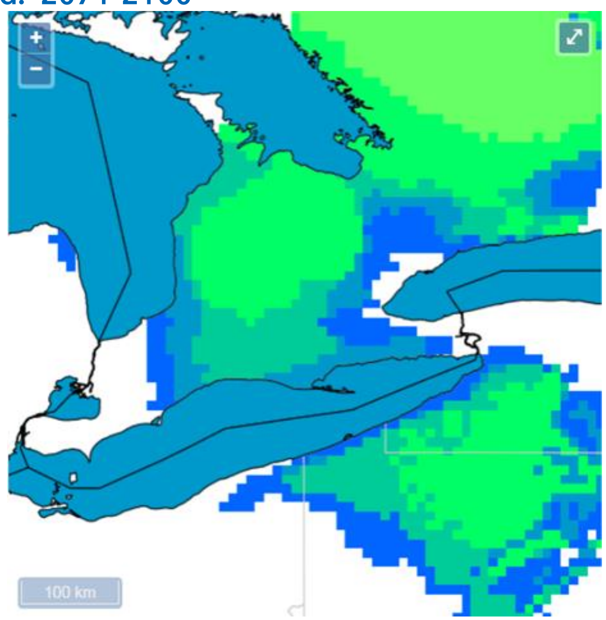




c. 2041-2070

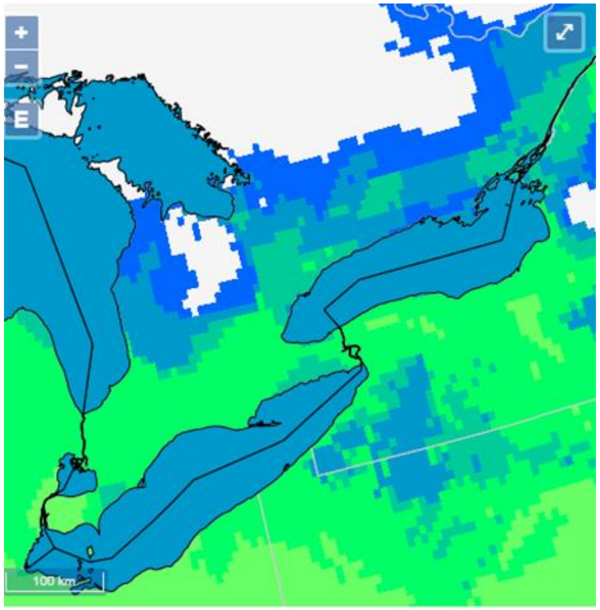


d. 2071-2100

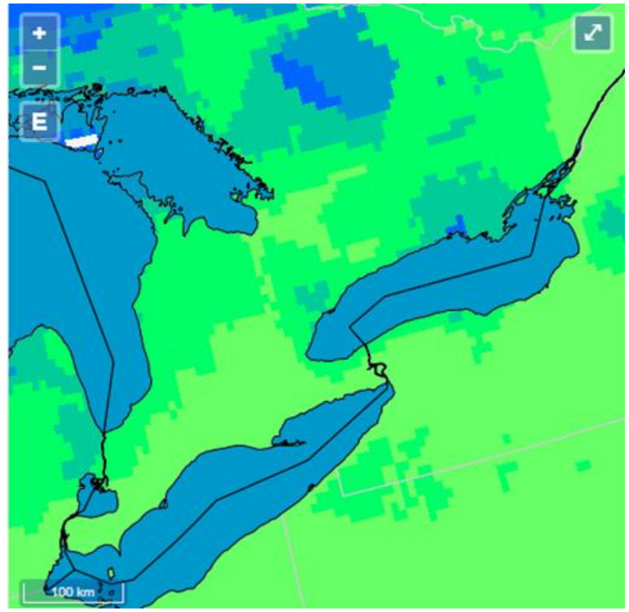


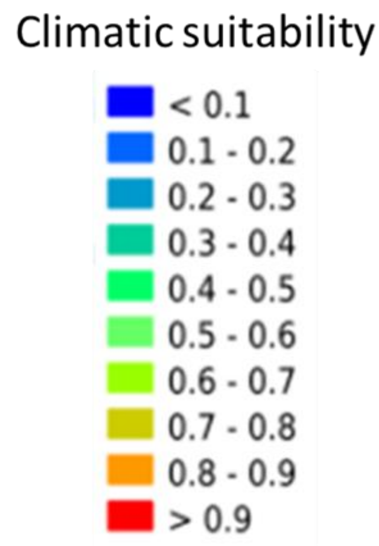
Juglans nigra (Black walnut)

a. Historical

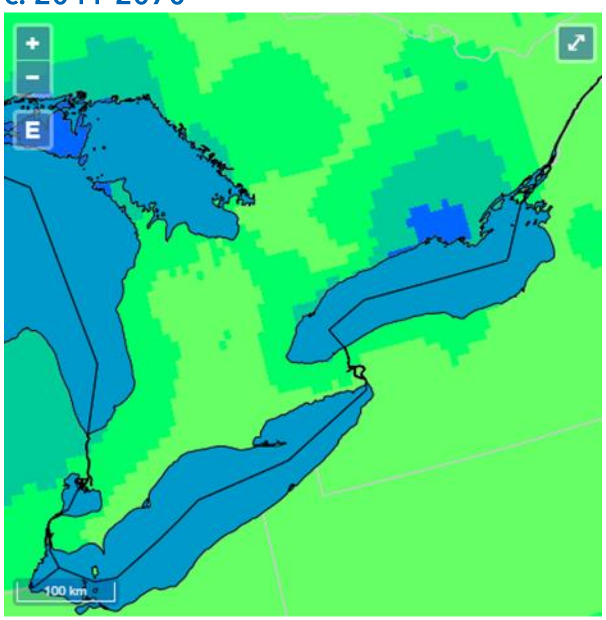


b. 2011-2040

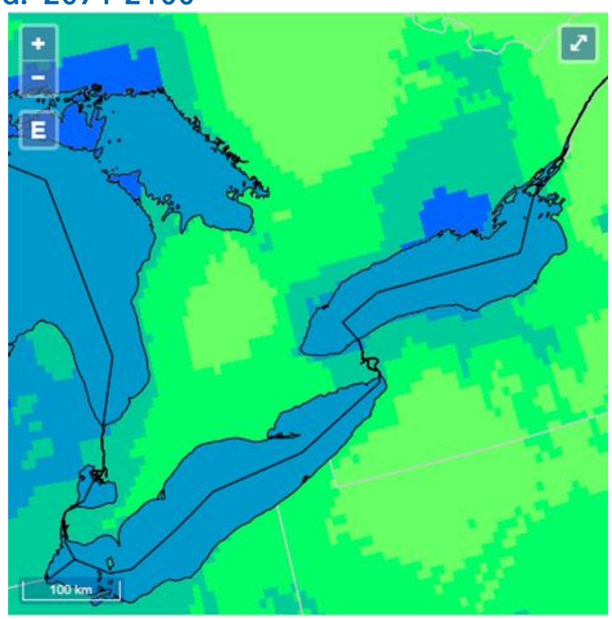




c. 2041-2070

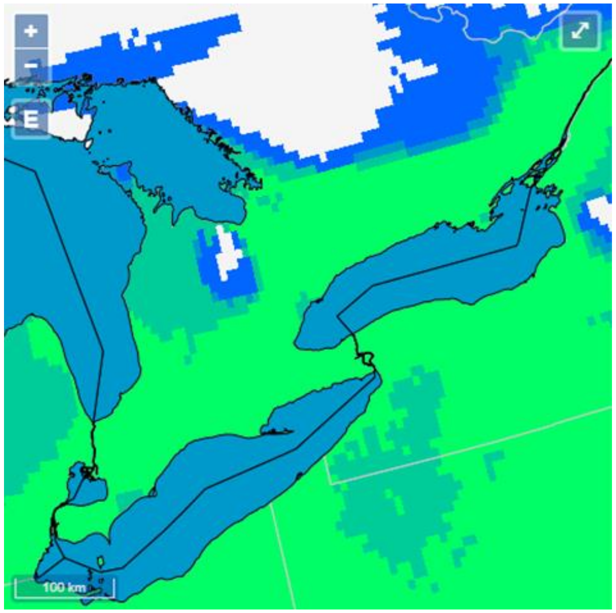


d. 2071-2100

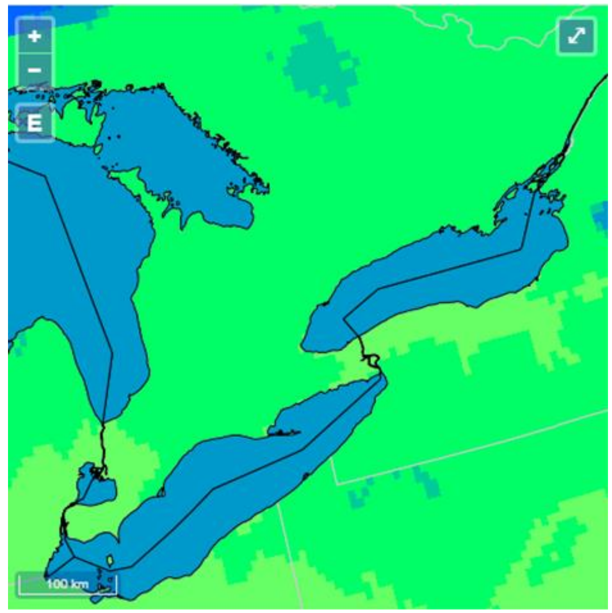


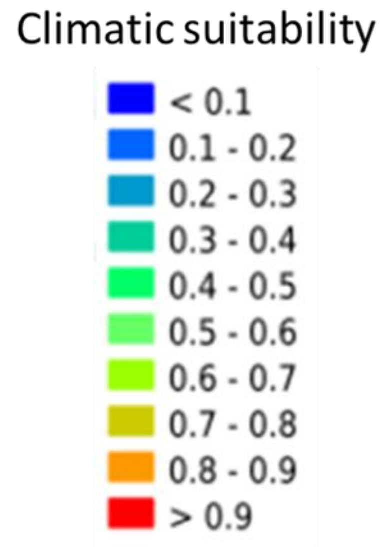
Juniperus virginiana (Eastern red cedar)

a. Historical

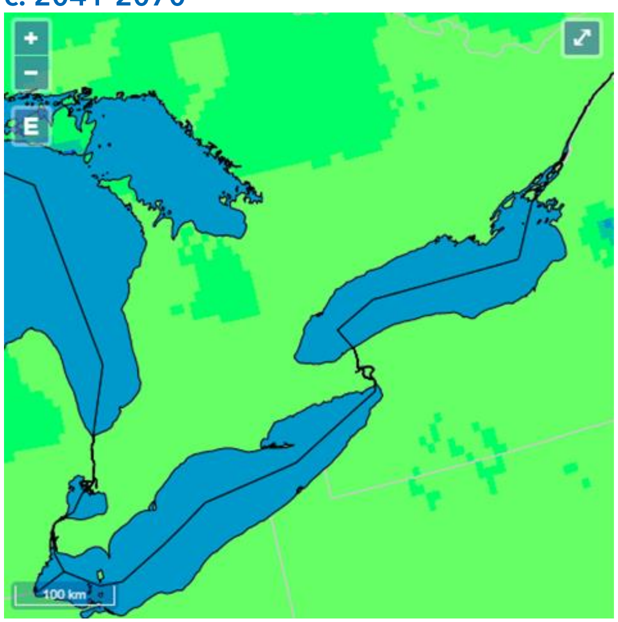


b. 2011-2040

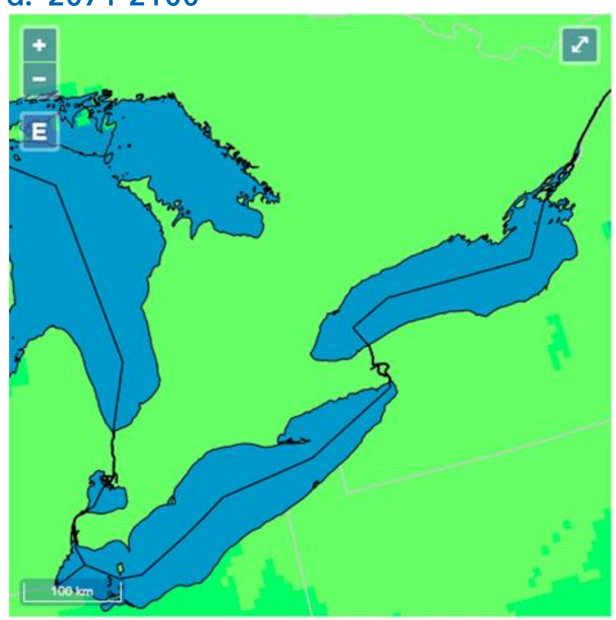




c. 2041-2070

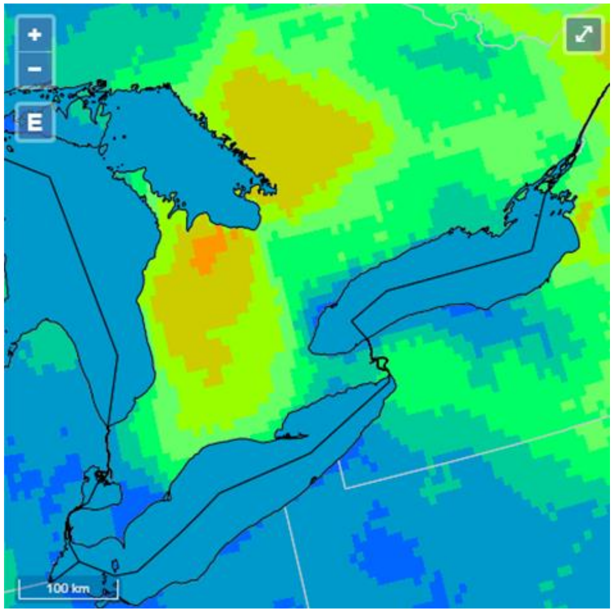


d. 2071-2100

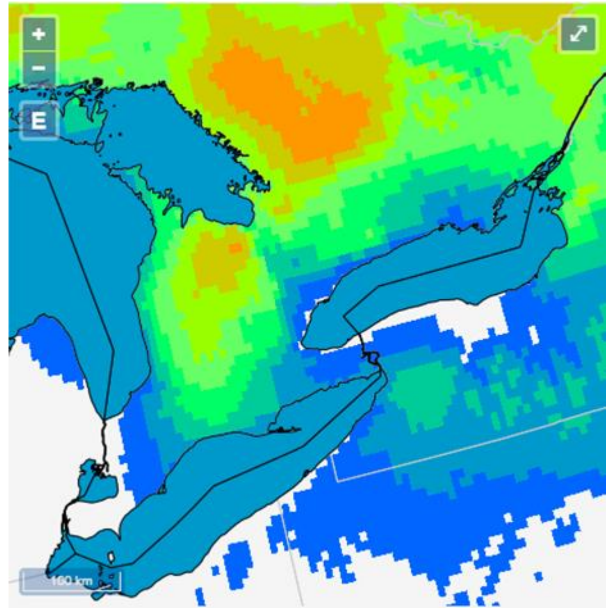


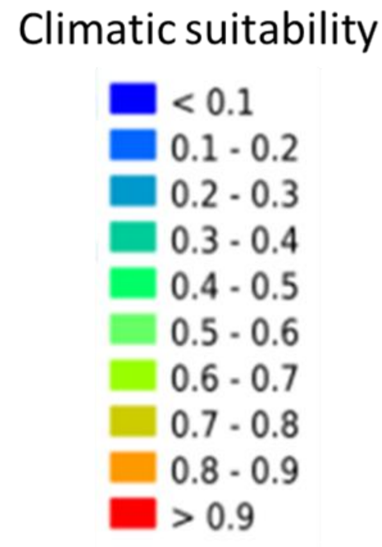
Larix decidua (European larch)

a. Historical

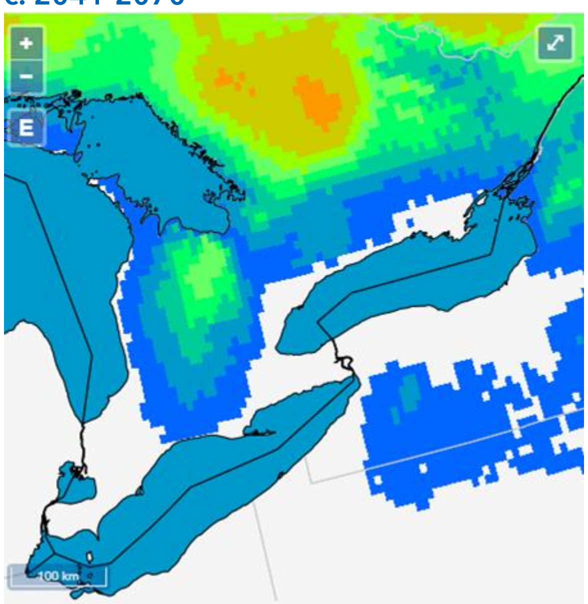


b. 2011-2040

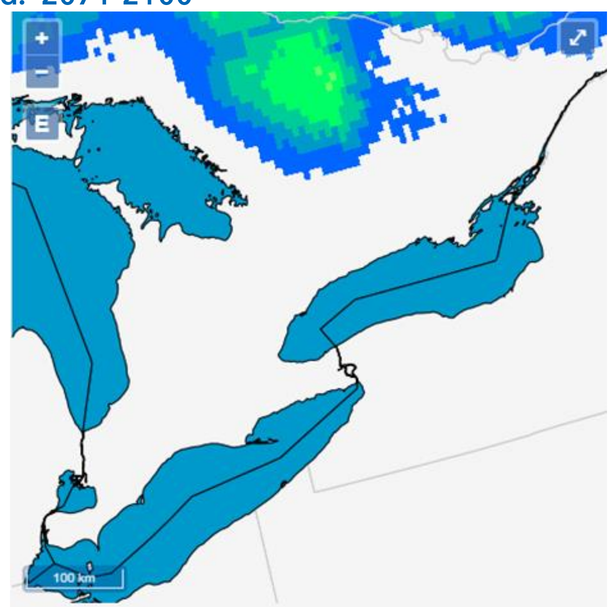




c. 2041-2070

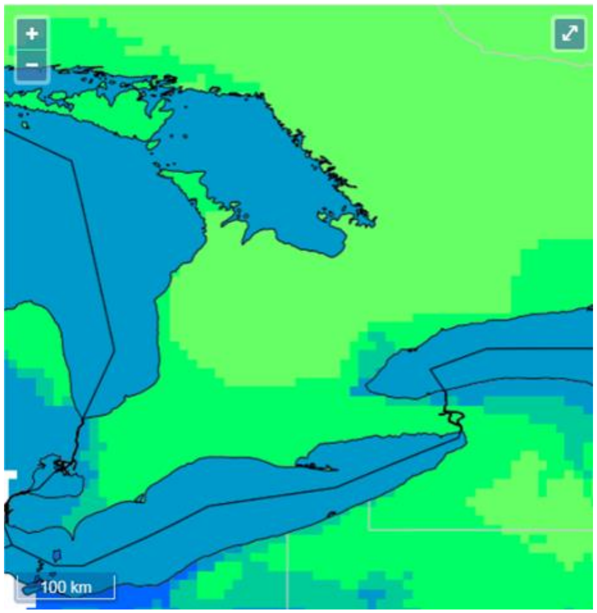


d. 2071-2100

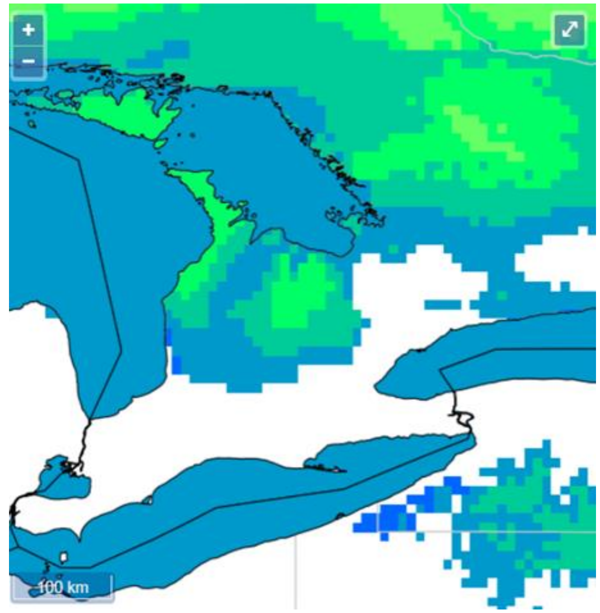


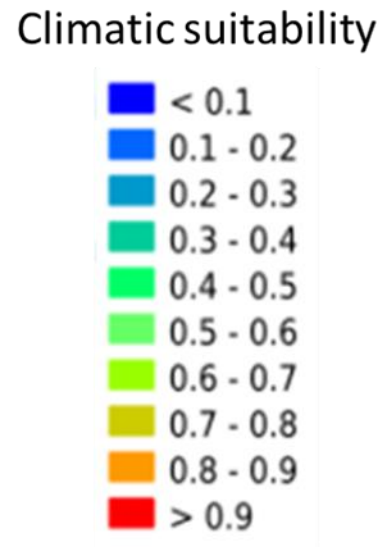
Larix laricina (Tamarack)

a. Historical

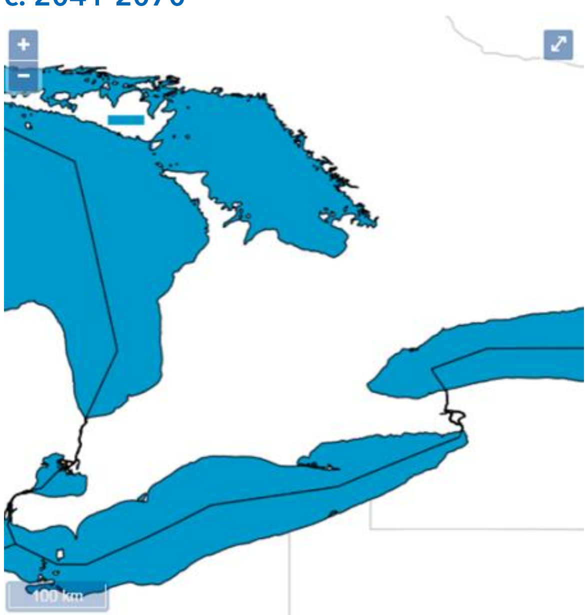


b. 2011-2040





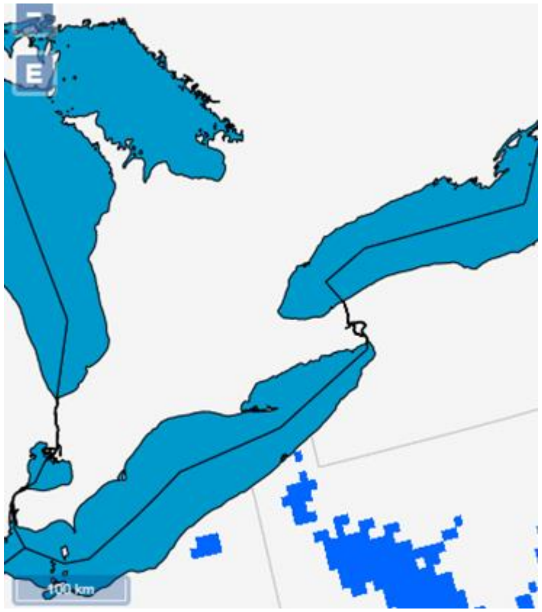
c. 2041-2070



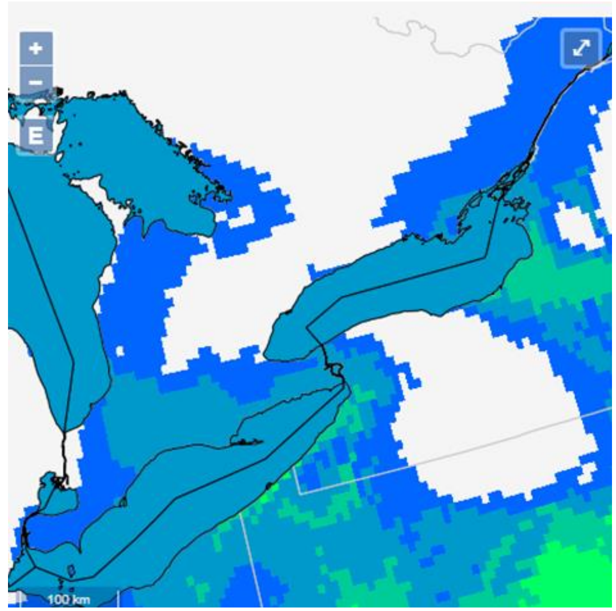
d. 2071-2100

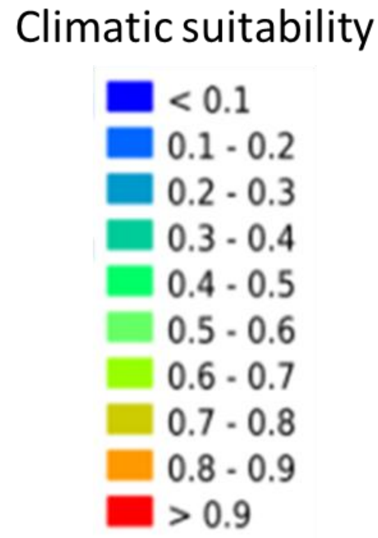
Liquidambar styraciflua (Sweetgum)

a. Historical

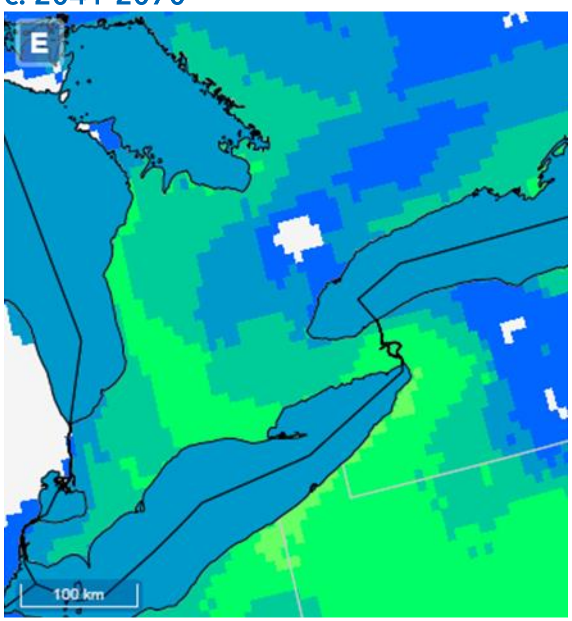


b. 2011-2040

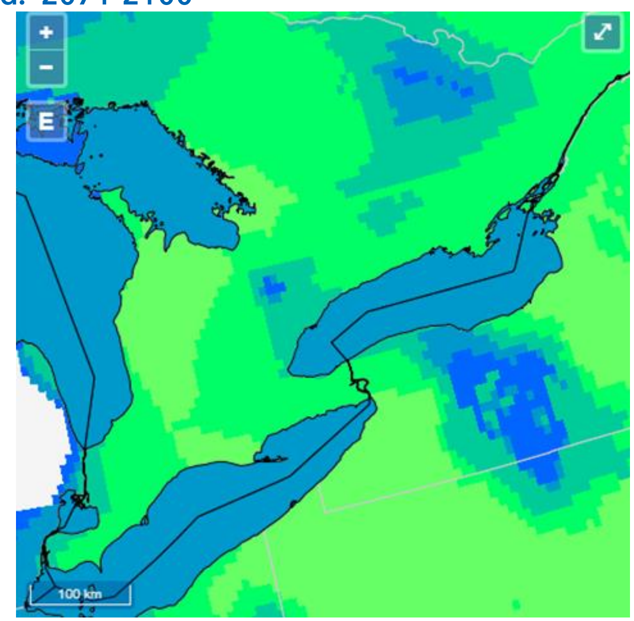




c. 2041-2070

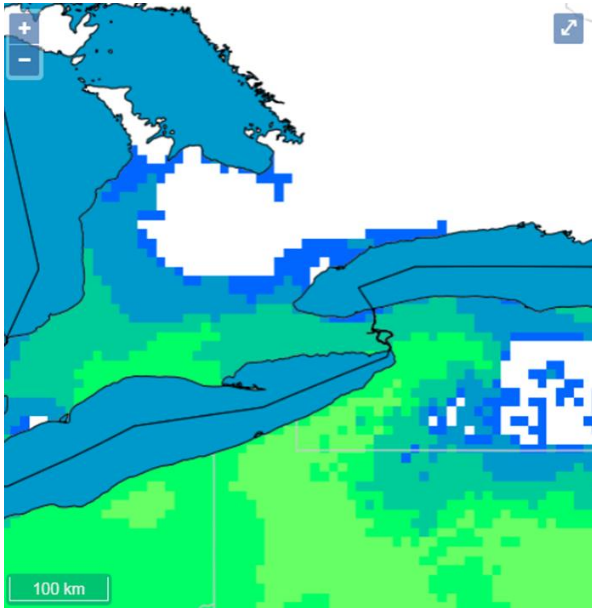


d. 2071-2100

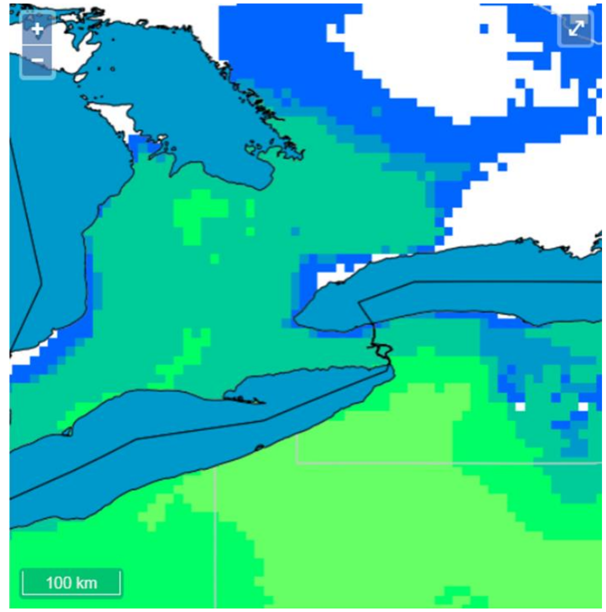


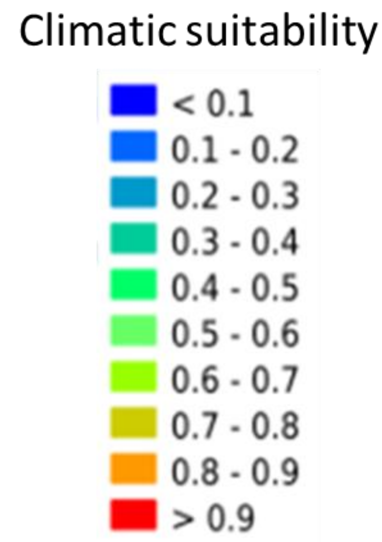
Liriodendron tulipifera (Tulip tree)

a. Historical

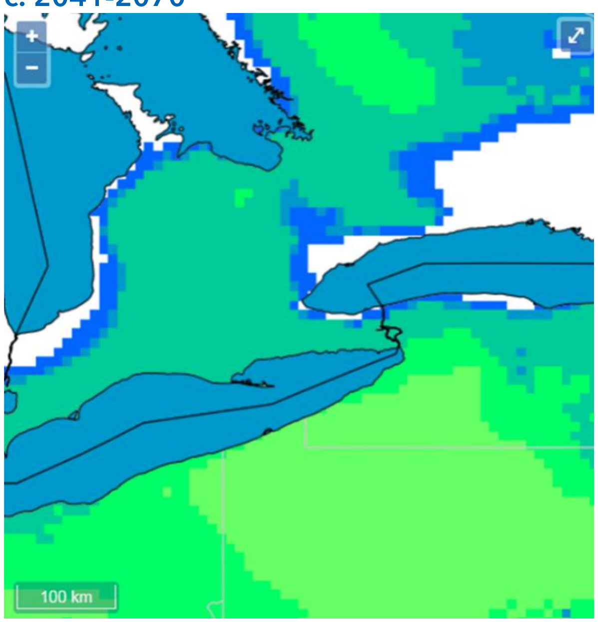


b. 2011-2040

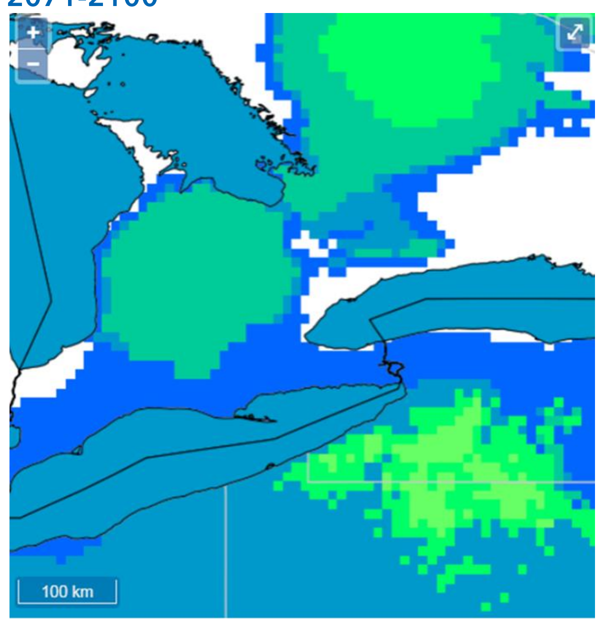




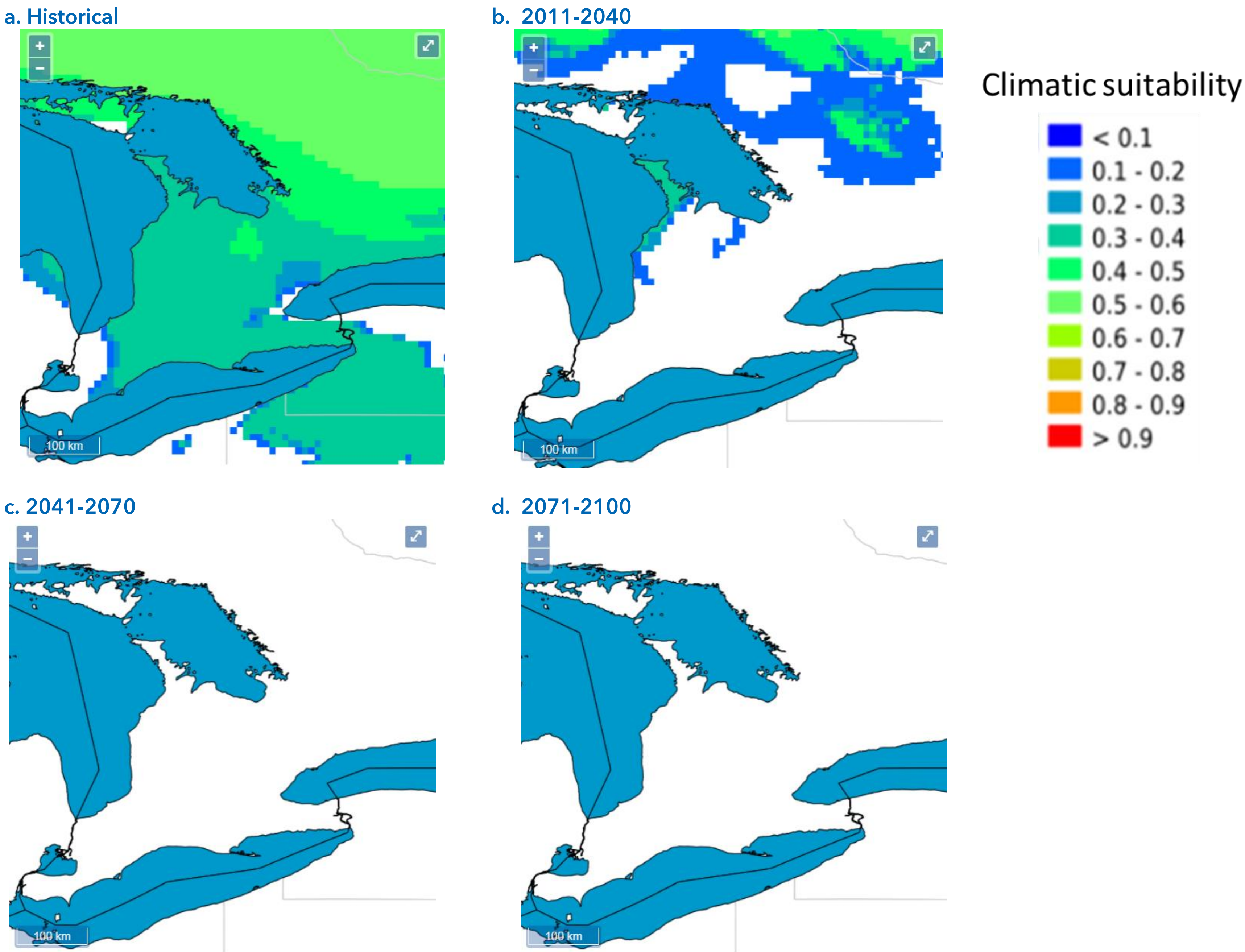
c. 2041-2070



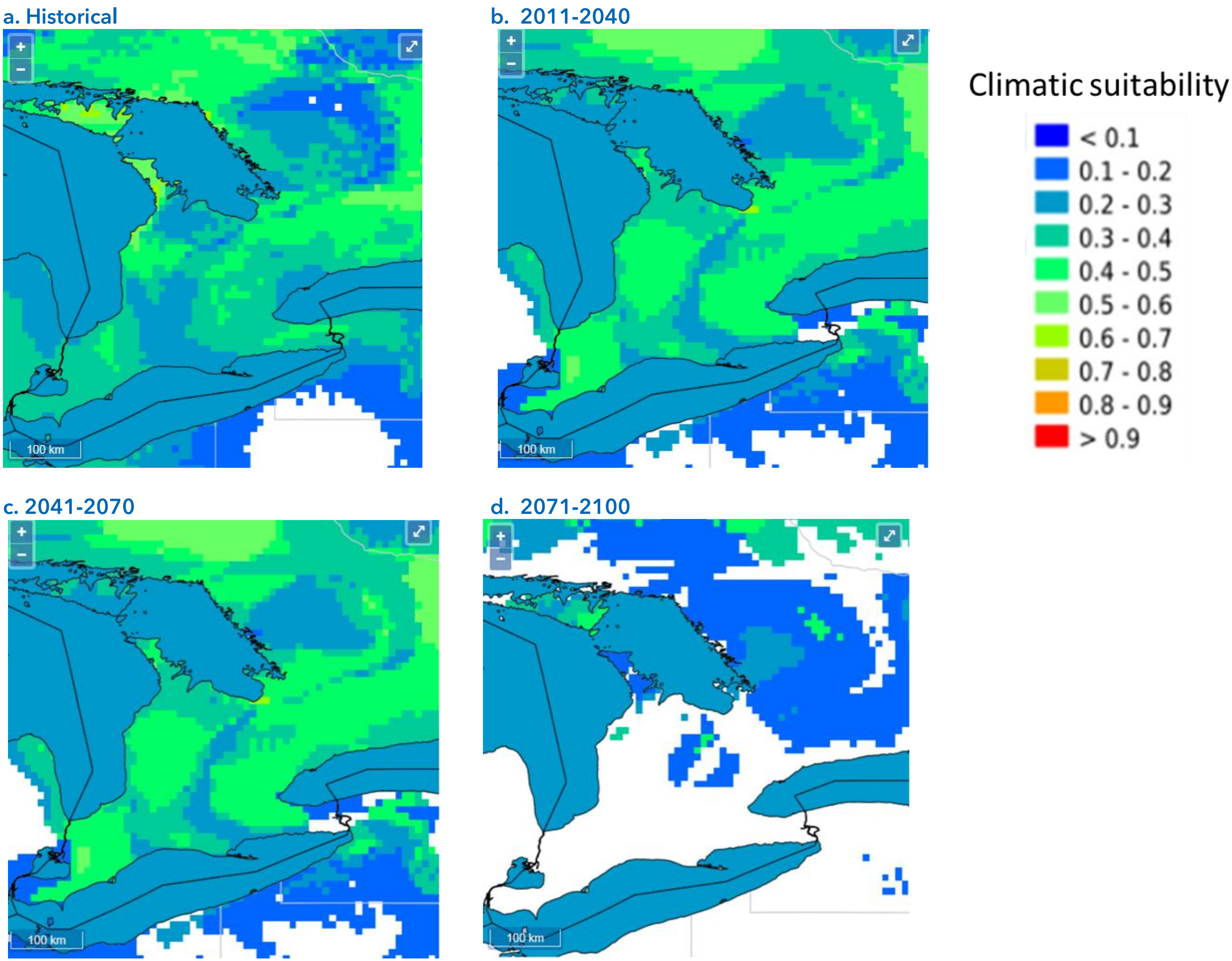
d. 2071-2100



Lonicera canadensis (American honeysuckle)

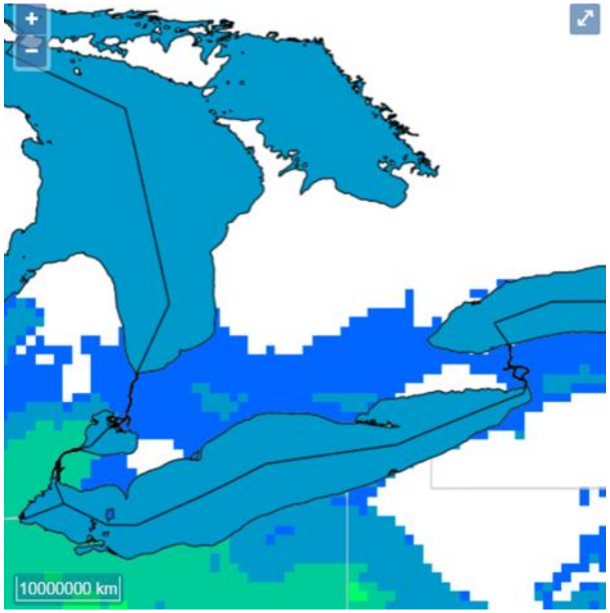


Lonicera dioica (Glaucus honeysuckle)

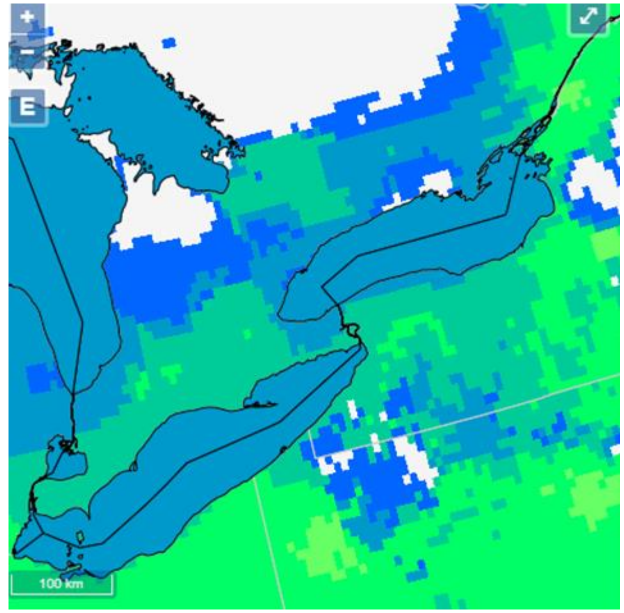


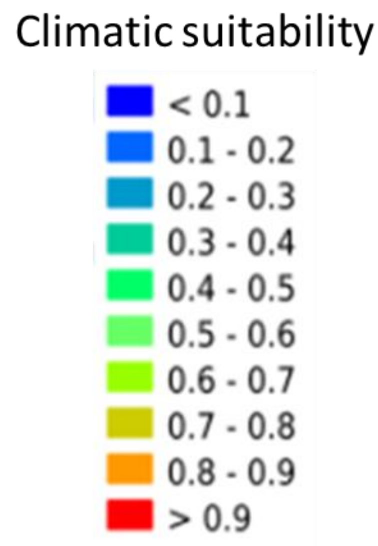
Maclura pomifera (Osage orange)

a. Historical

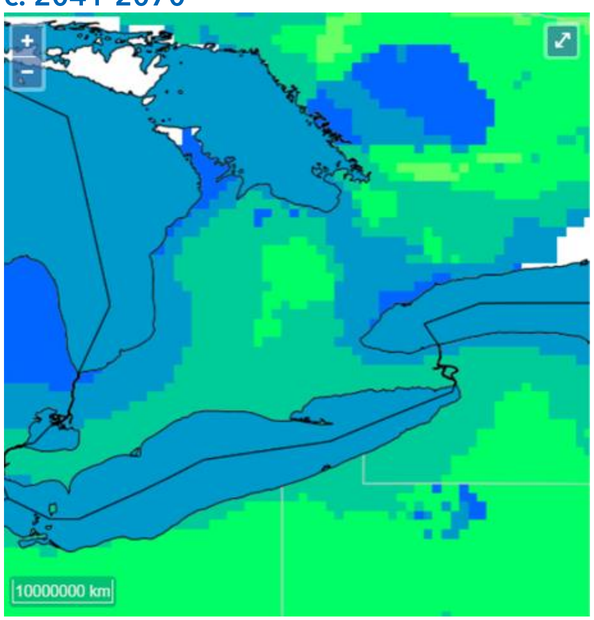


b. 2011-2040

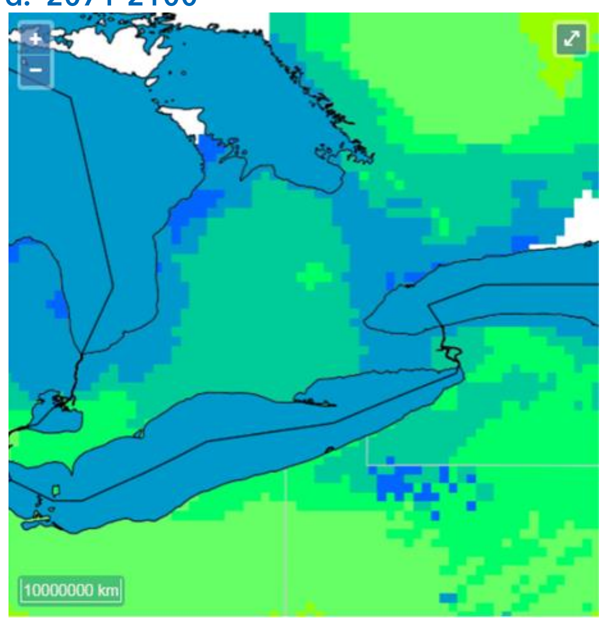




c. 2041-2070

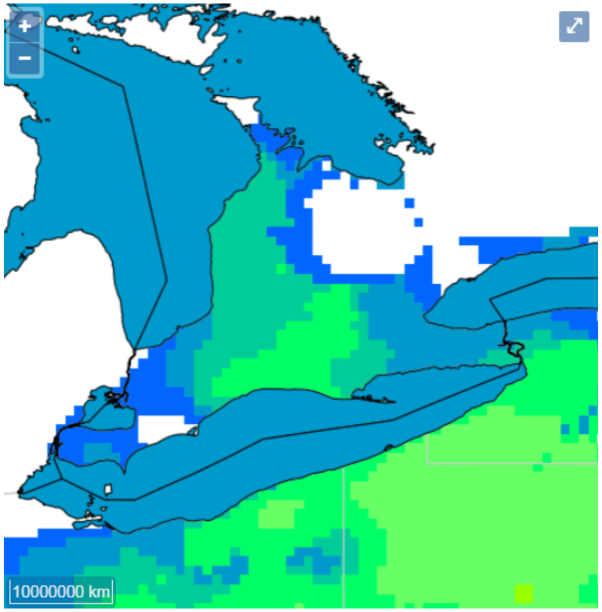


d. 2071-2100

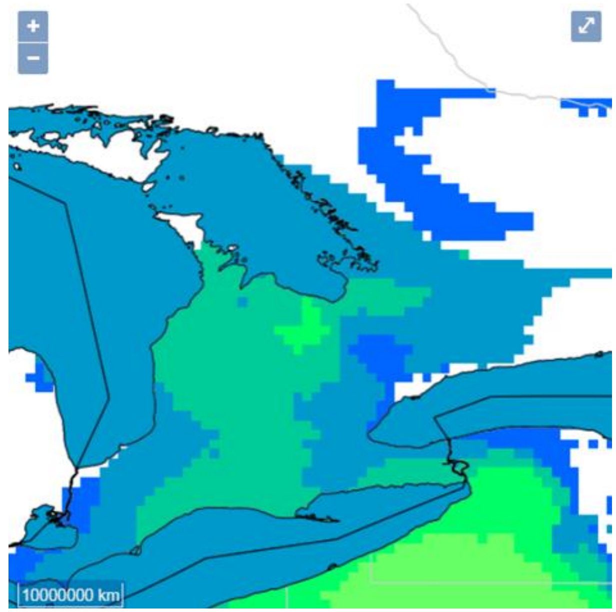


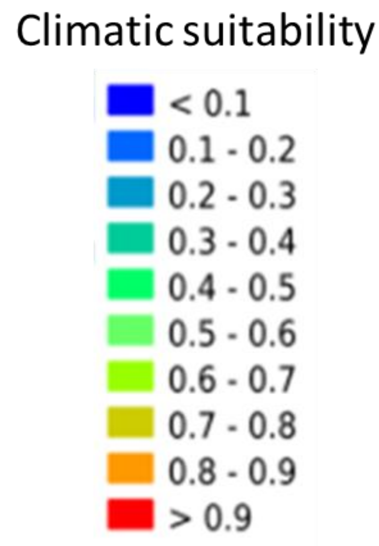
Magnolia acuminata (Cucumber tree)

a. Historical

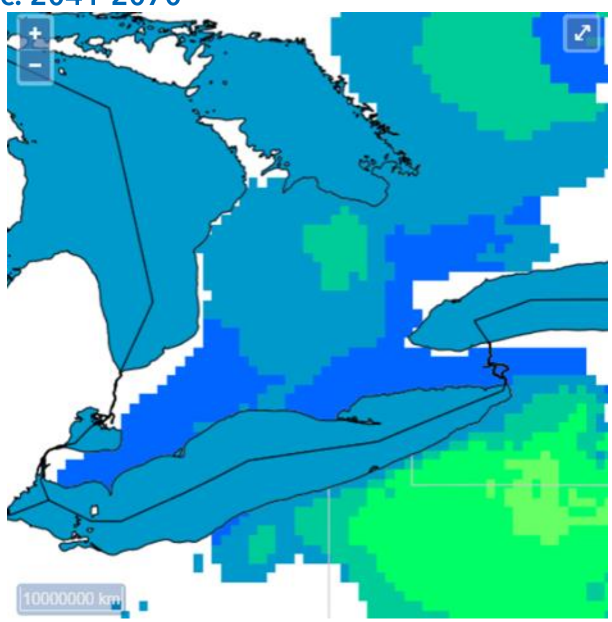


b. 2011-2040

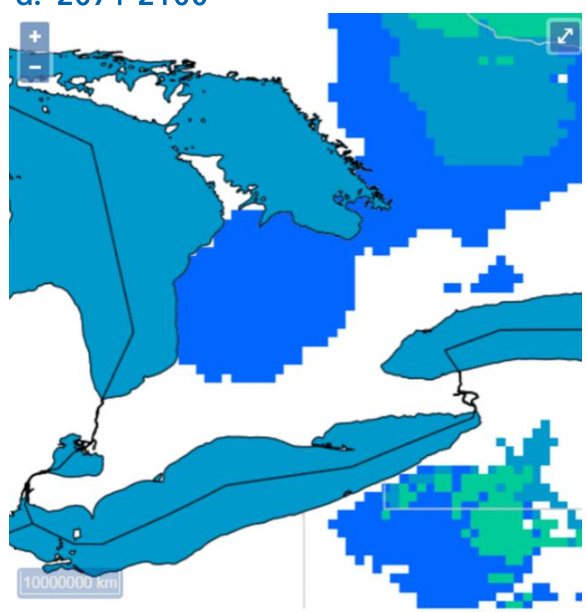




c. 2041-2070

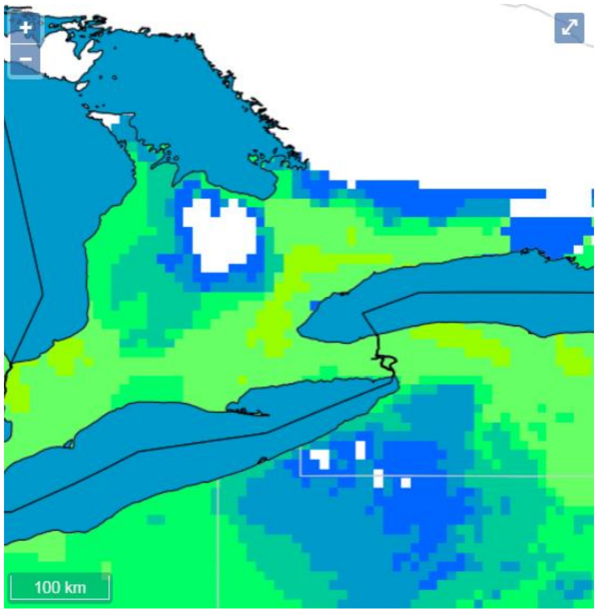


d. 2071-2100

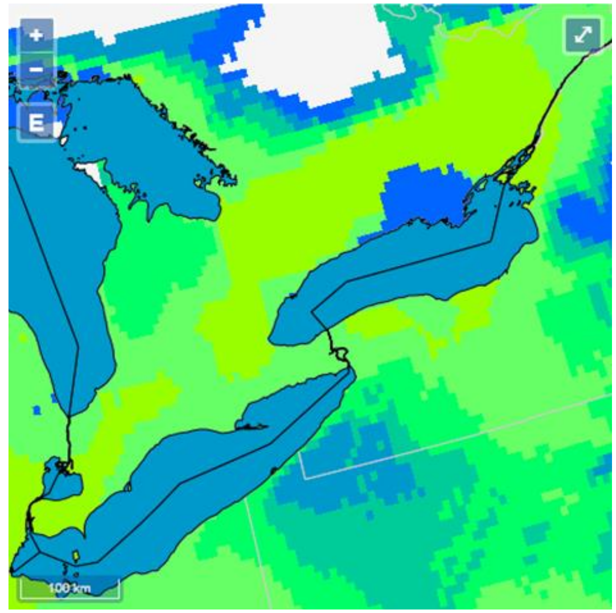


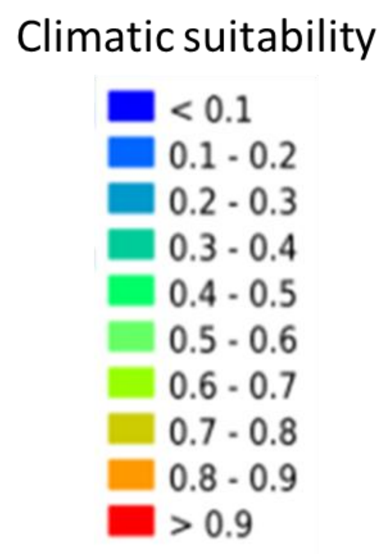
Morus alba (White mulberry)

a. Historical

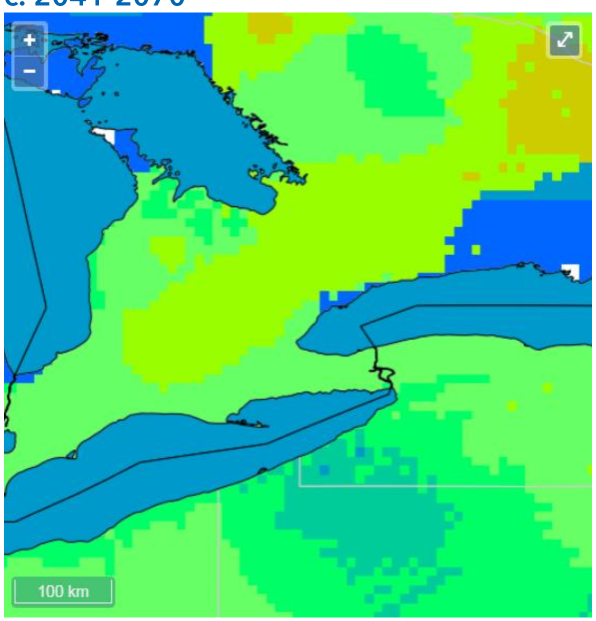


b. 2011-2040

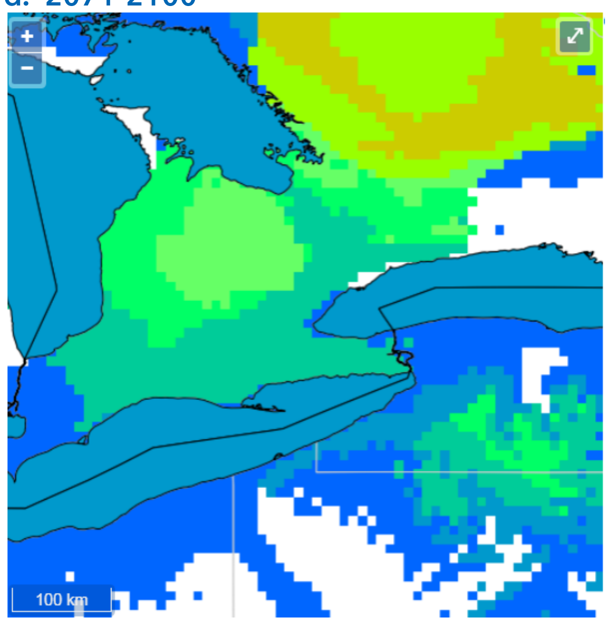




c. 2041-2070

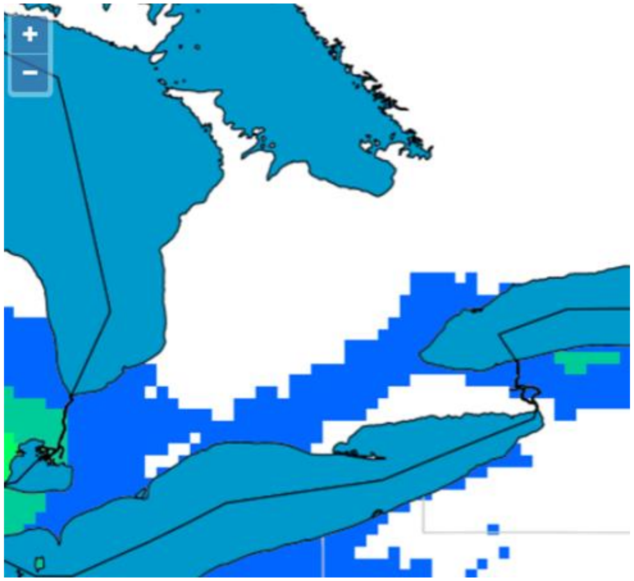


d. 2071-2100

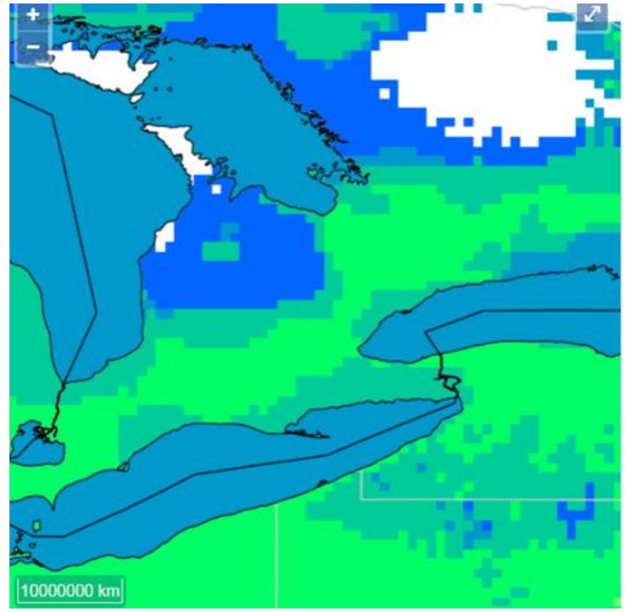


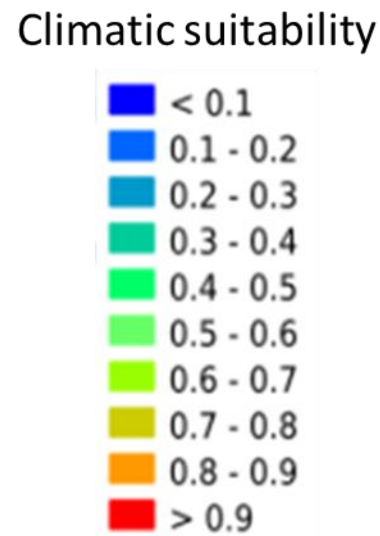
Morus rubra (Red mulberry)

a. Historical

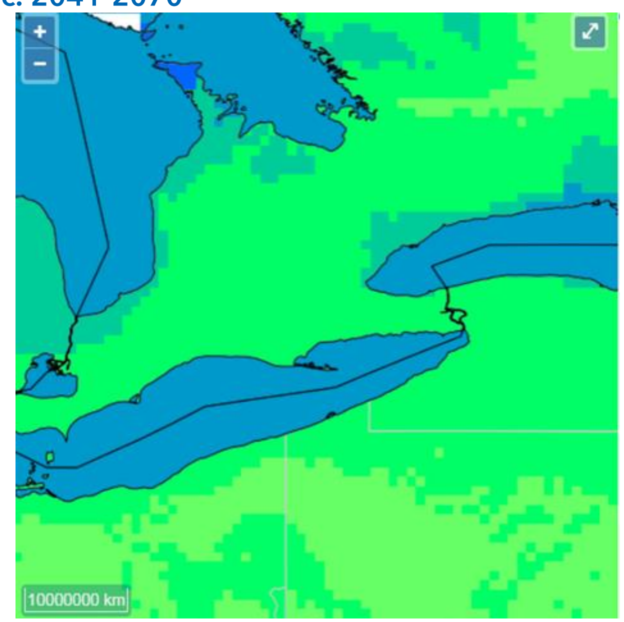


b. 2011-2040

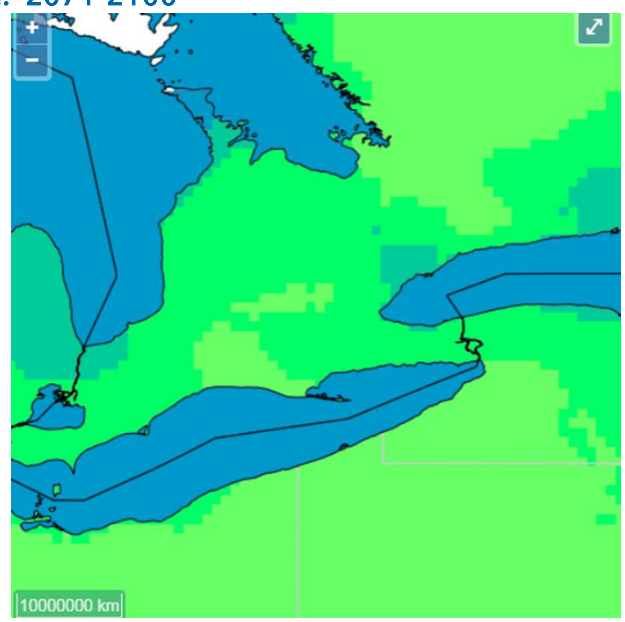




c. 2041-2070

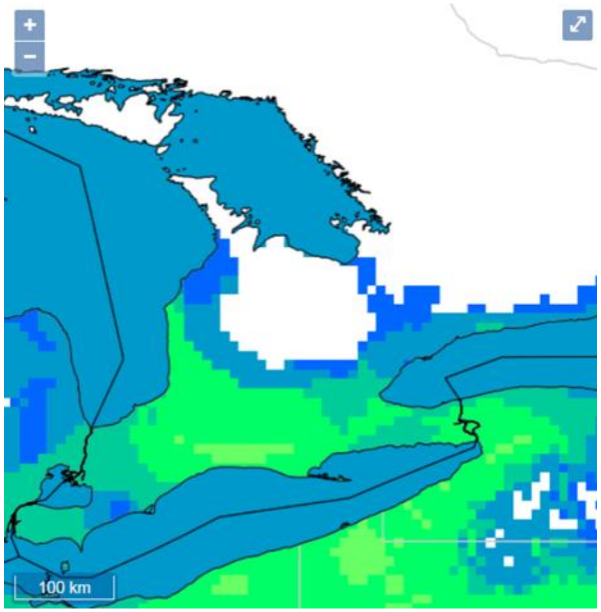


d. 2071-2100

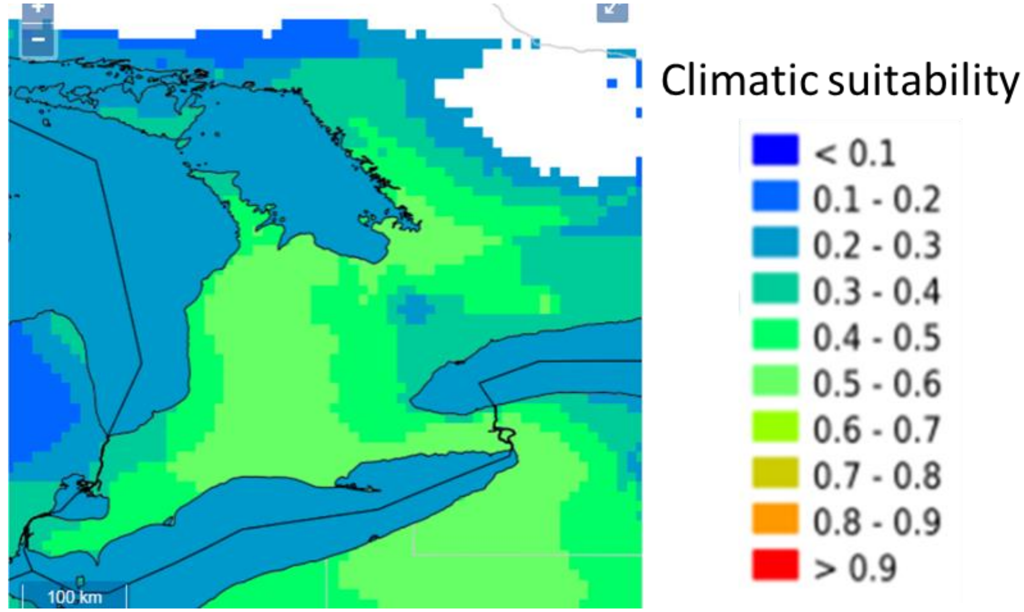


Nyssa sylvatica (Black gum)

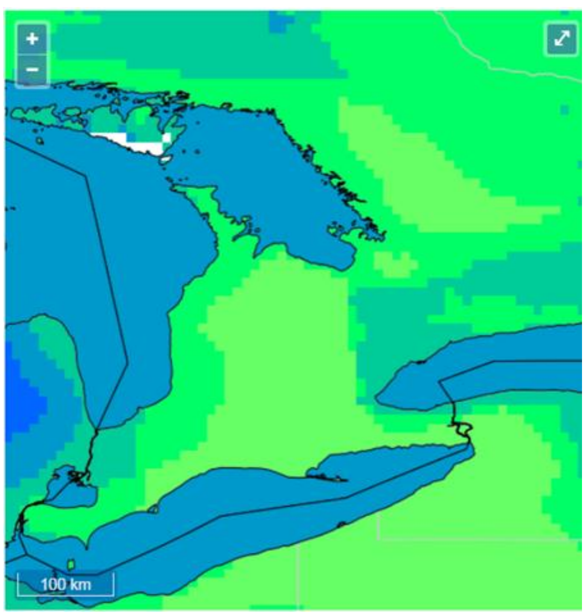
a. Historical



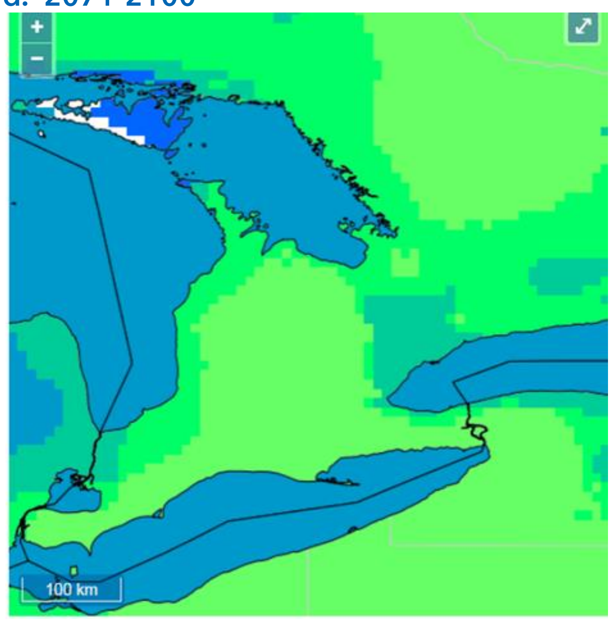
b. 2011-2040



c. 2041-2070

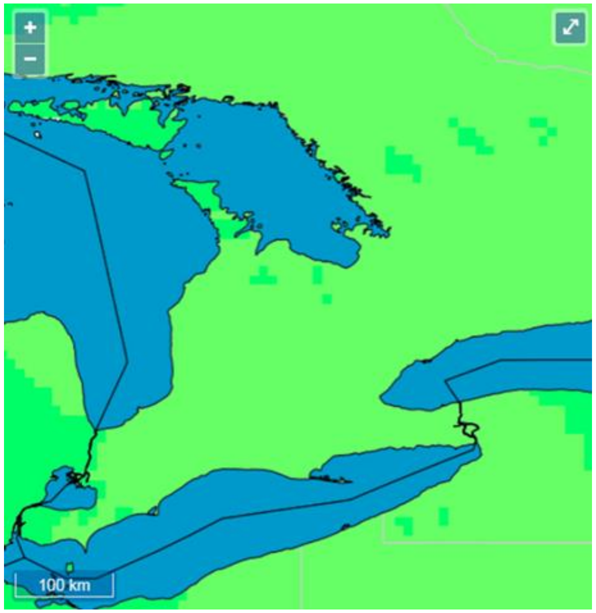


d. 2071-2100

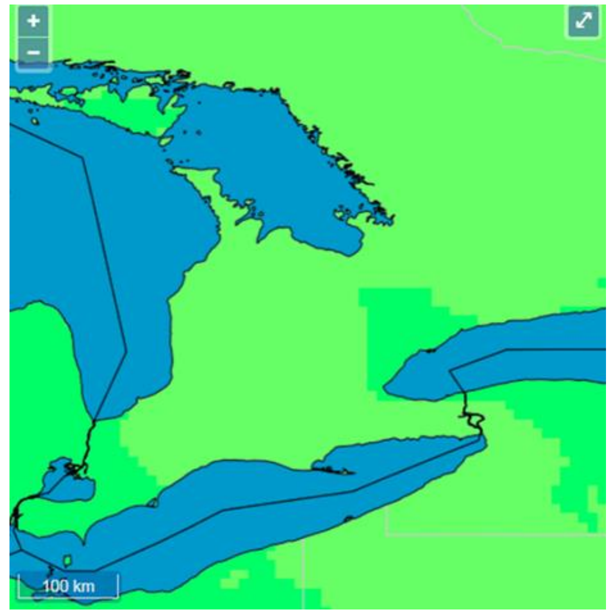


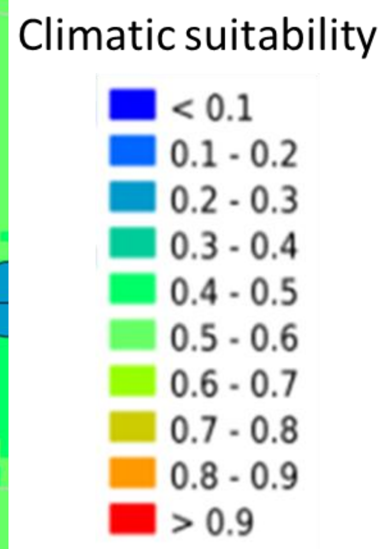
Ostrya virginiana (Hophornbeam)

a. Historical



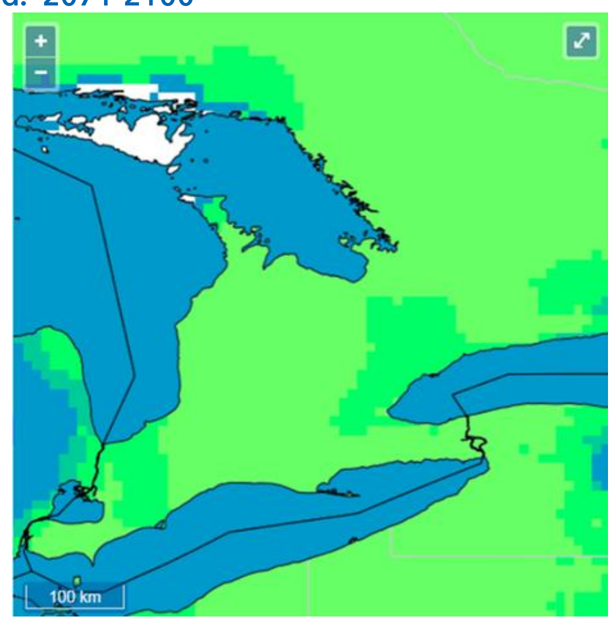
b. 2011-2040





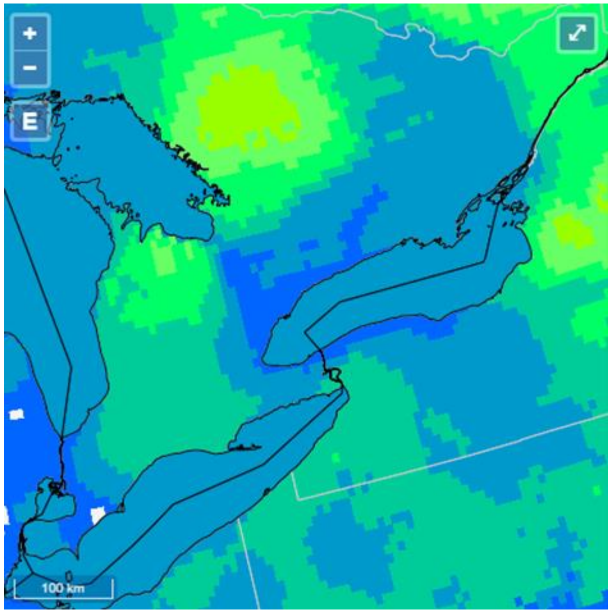
c. 2041-2070

d. 2071-2100

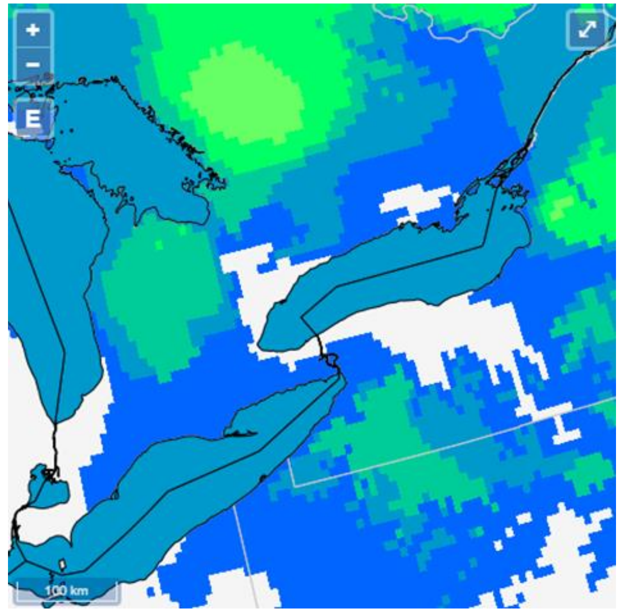


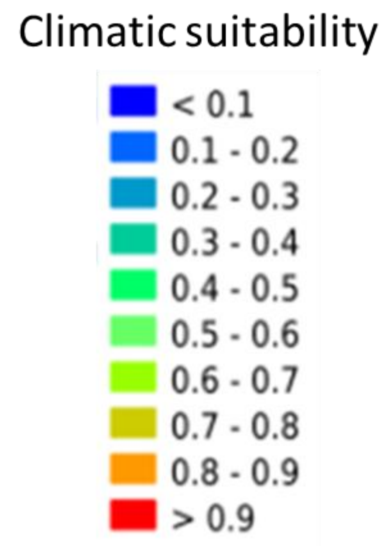
Picea abies (Norway spruce)

a. Historical

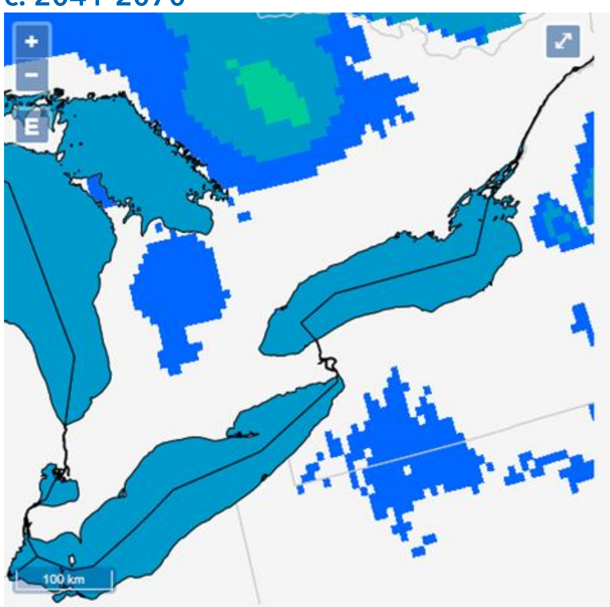


b. 2011-2040

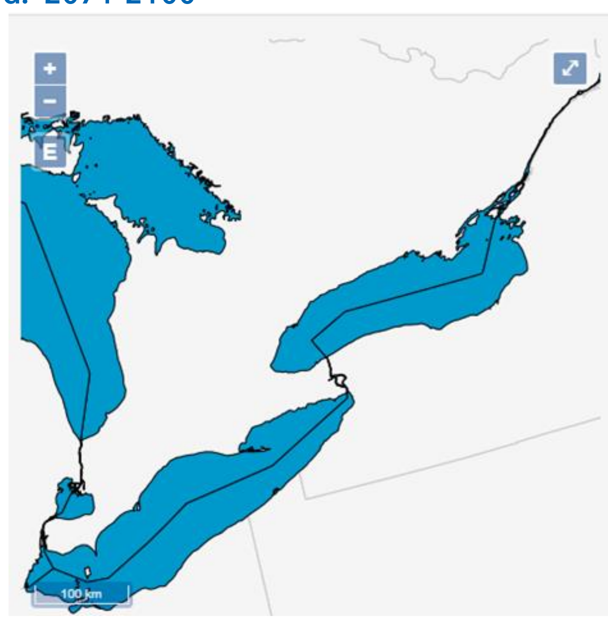




c. 2041-2070

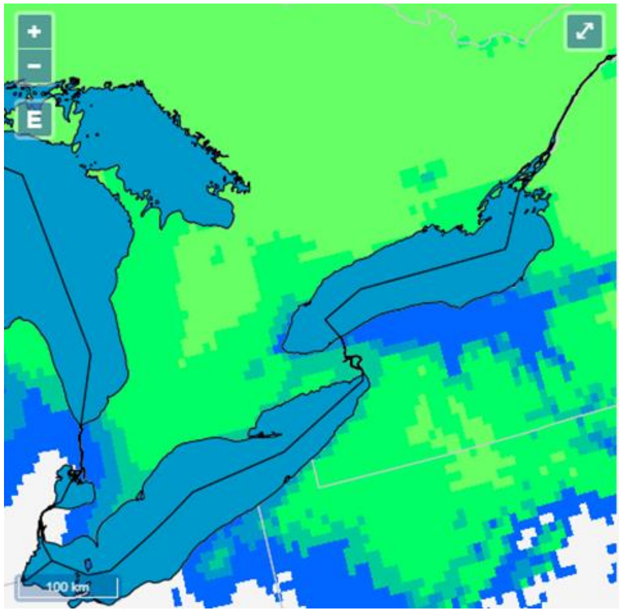


d. 2071-2100

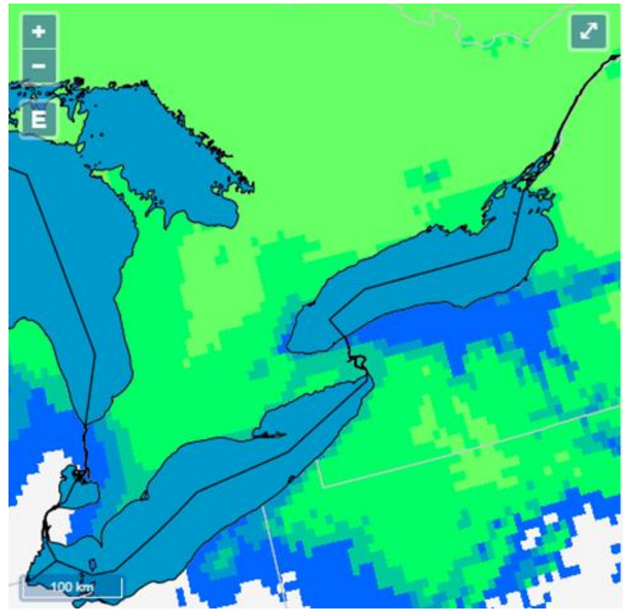


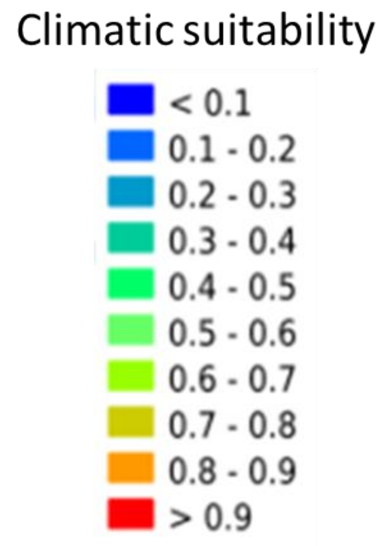
Picea glauca (White spruce)

a. Historical

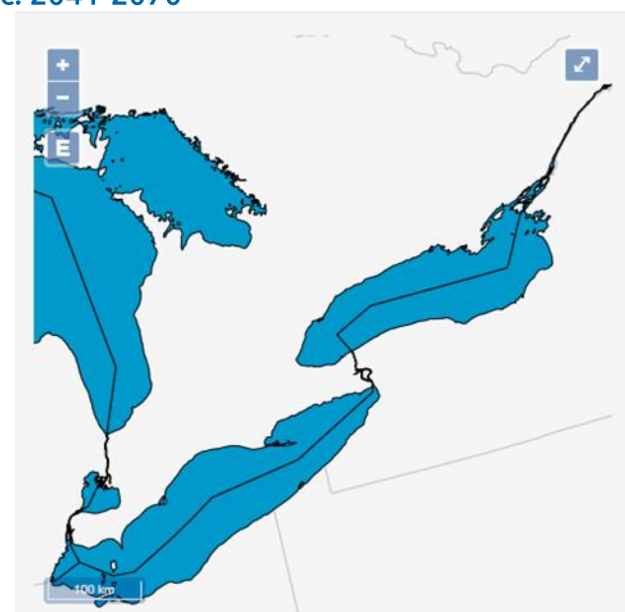


b. 2011-2040

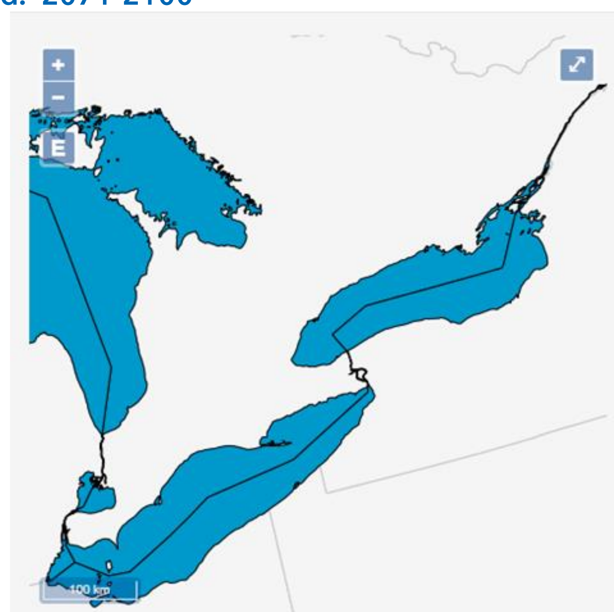




c. 2041-2070

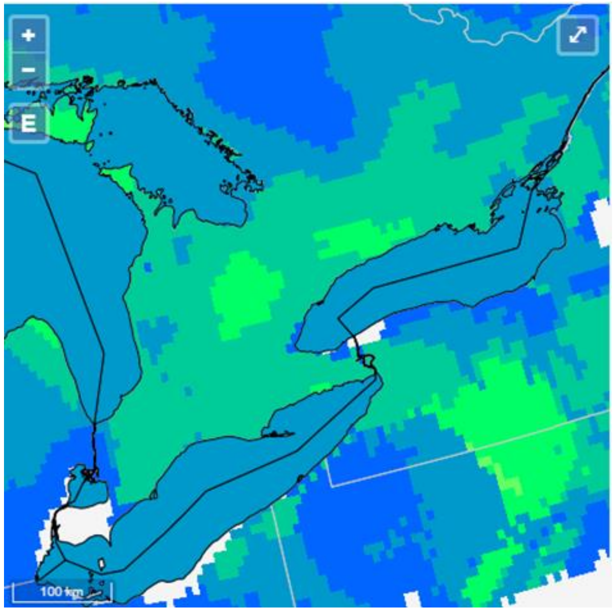


d. 2071-2100

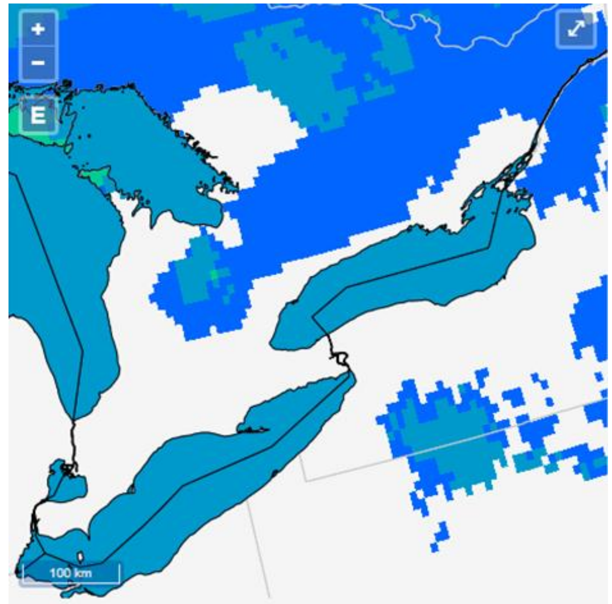


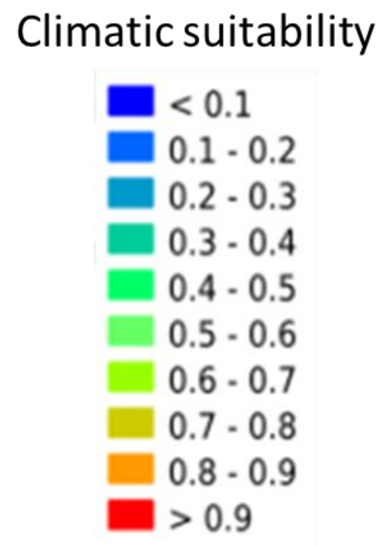
Picea pungens (Colorado spruce)

a. Historical

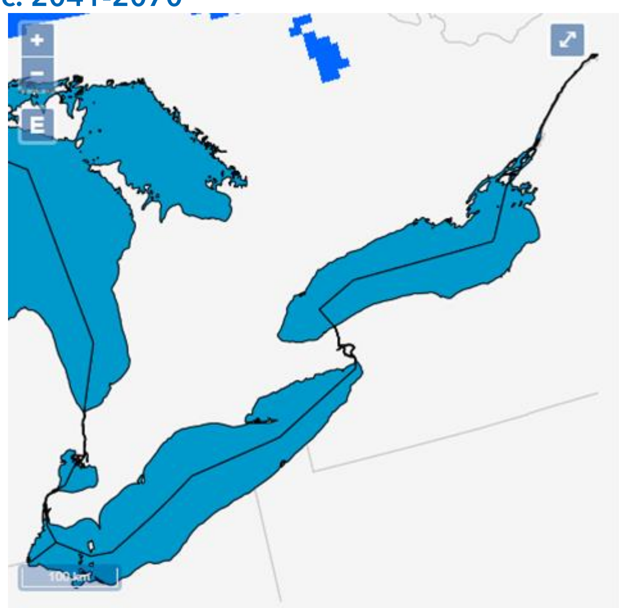


b. 2011-2040

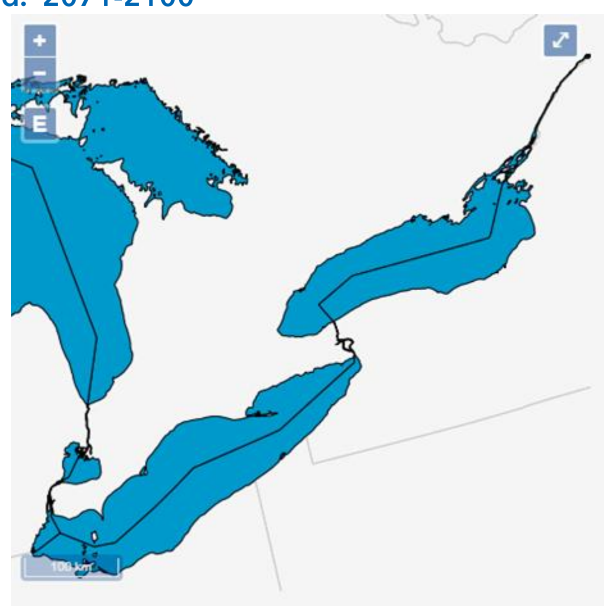




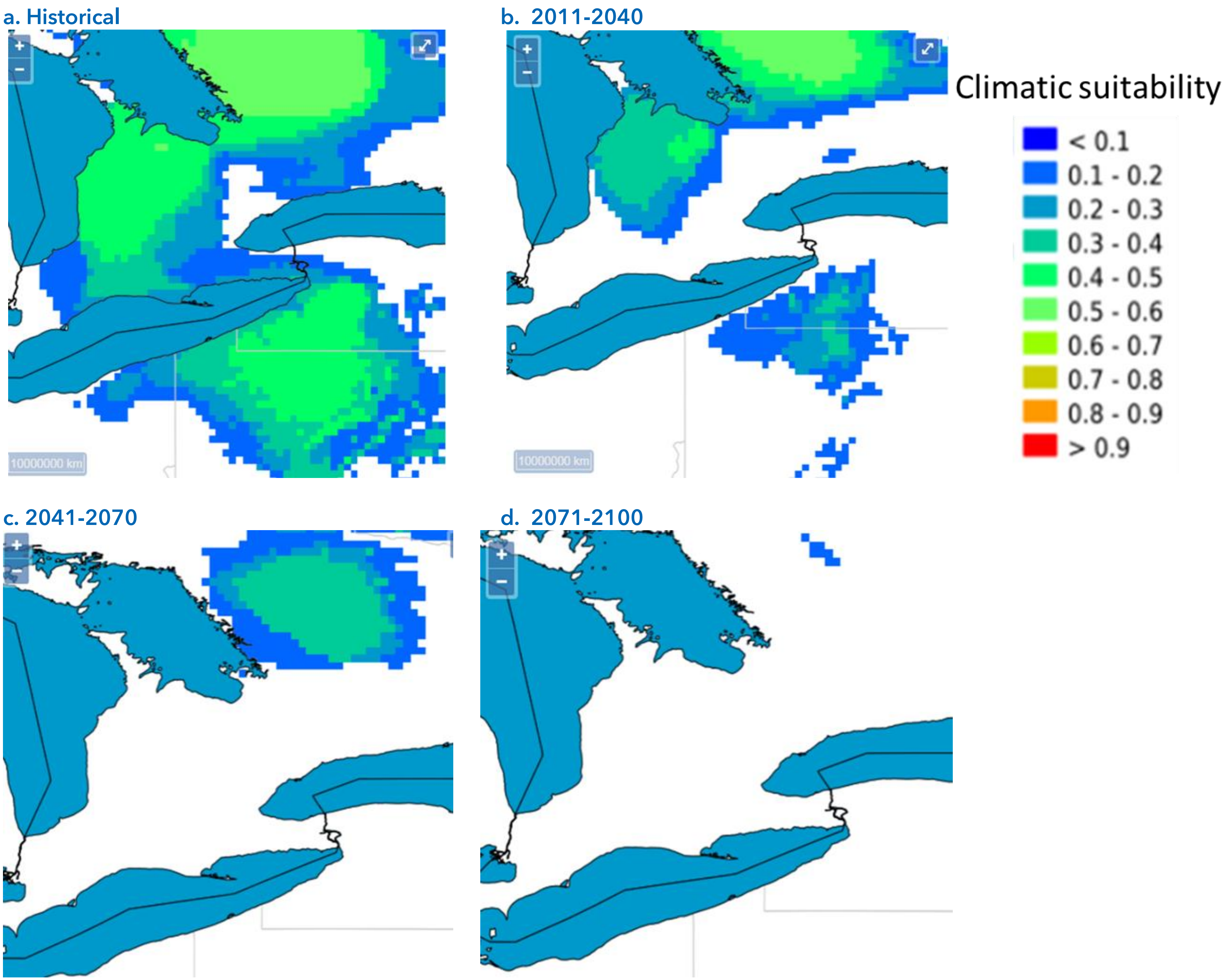
c. 2041-2070



d. 2071-2100

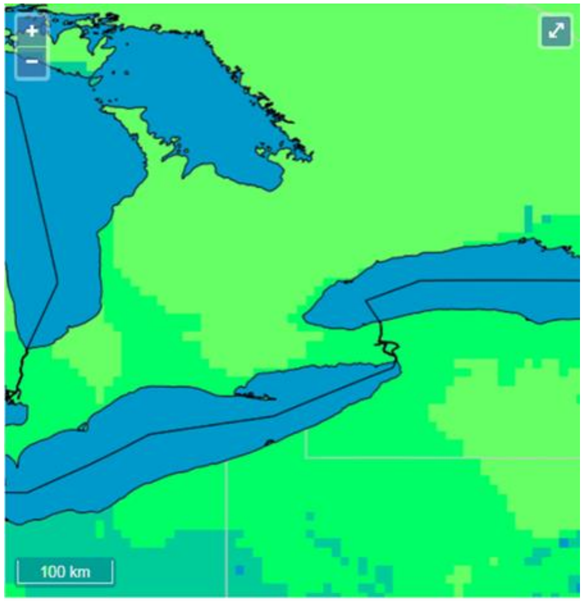


Picea rubens (Red spruce)

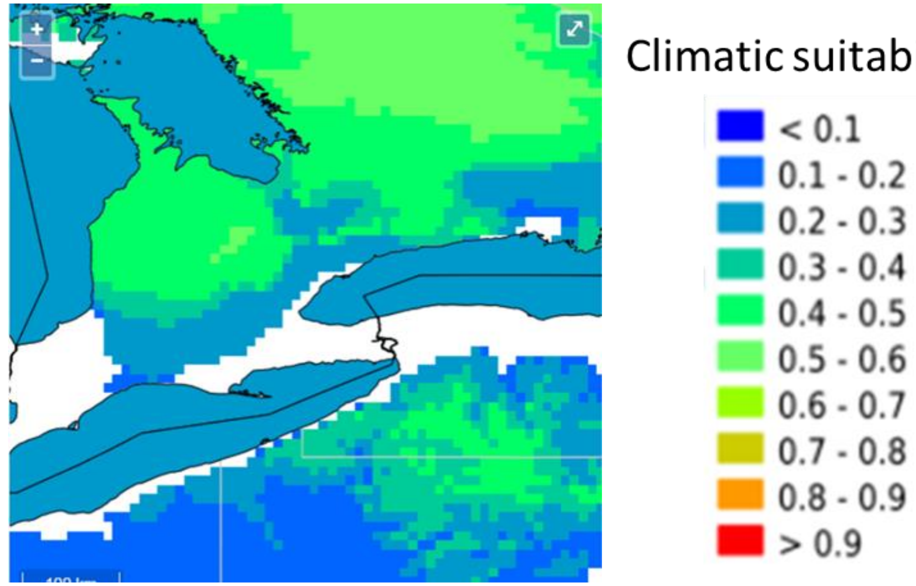


Pinus resinosa (Red pine)

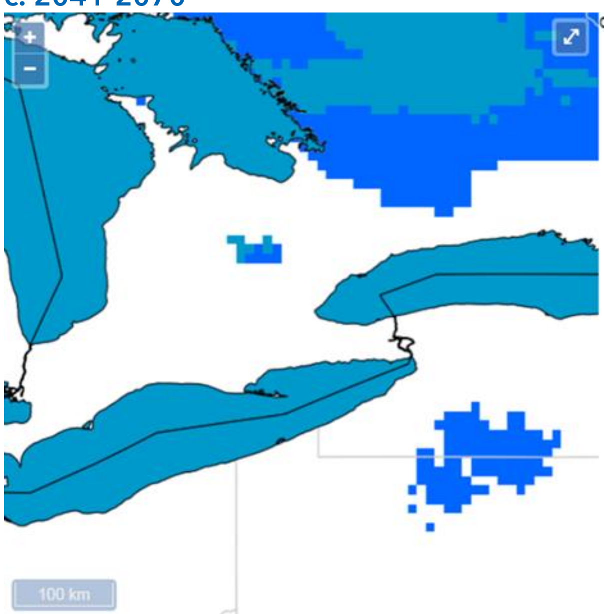
a. Historical



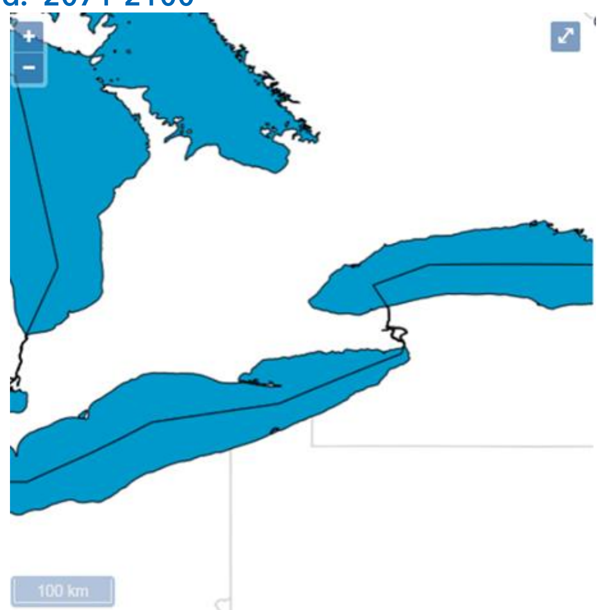
b. 2011-2040



c. 2041-2070

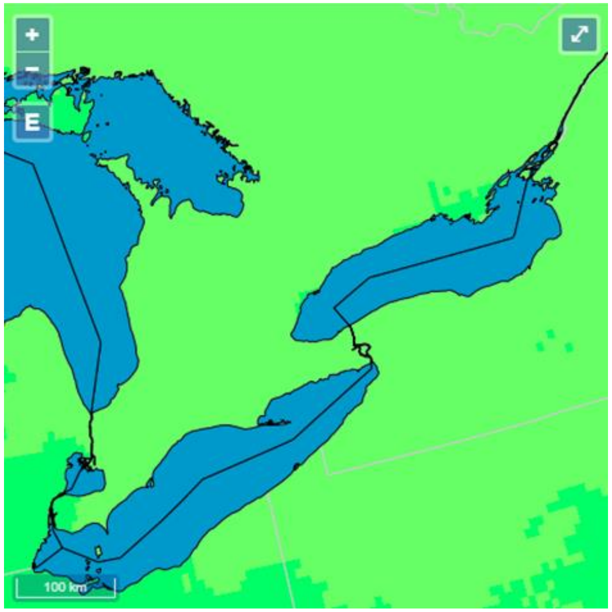


d. 2071-2100

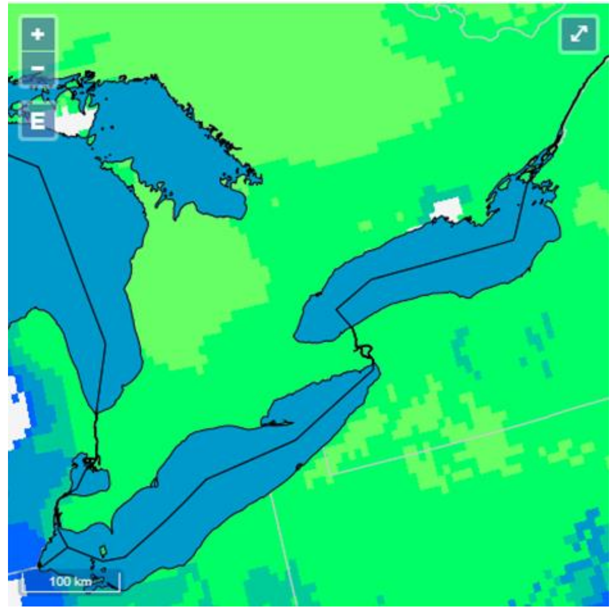


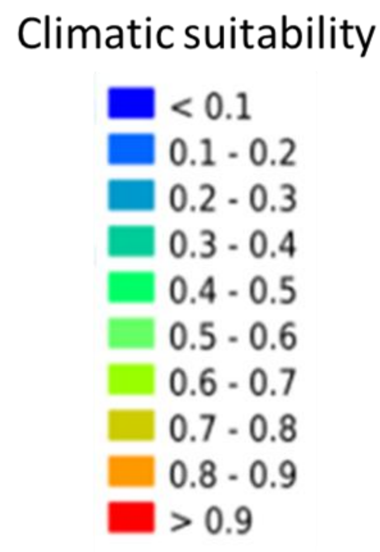
Pinus strobus (White pine)

a. Historical

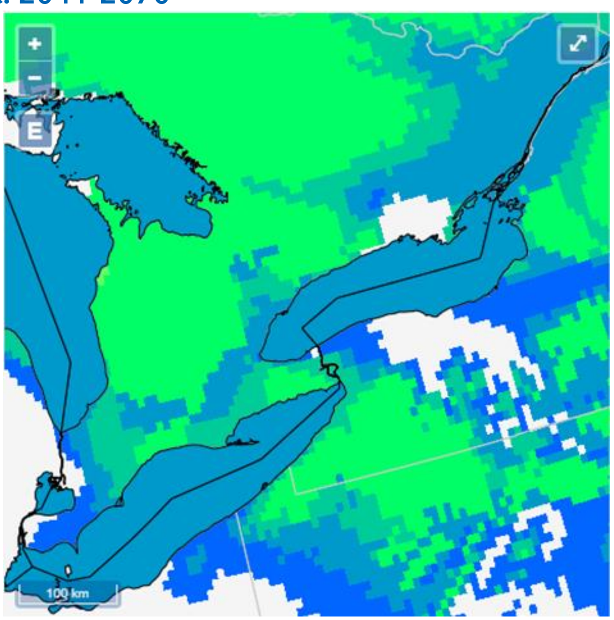


b. 2011-2040

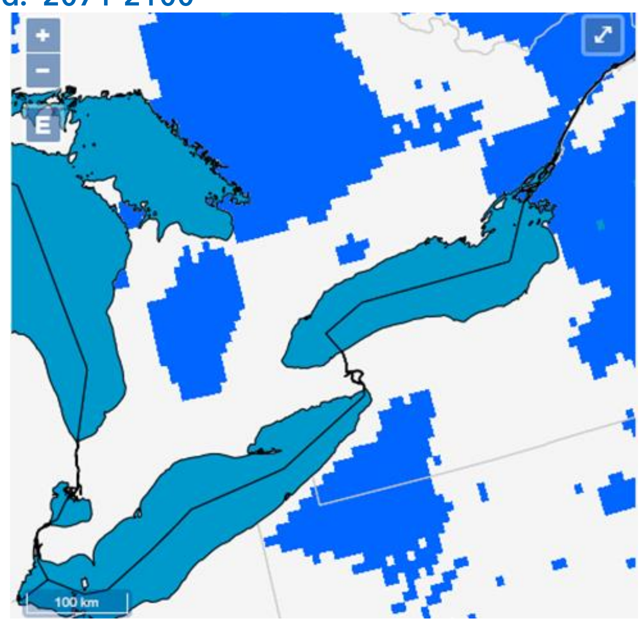




c. 2041-2070

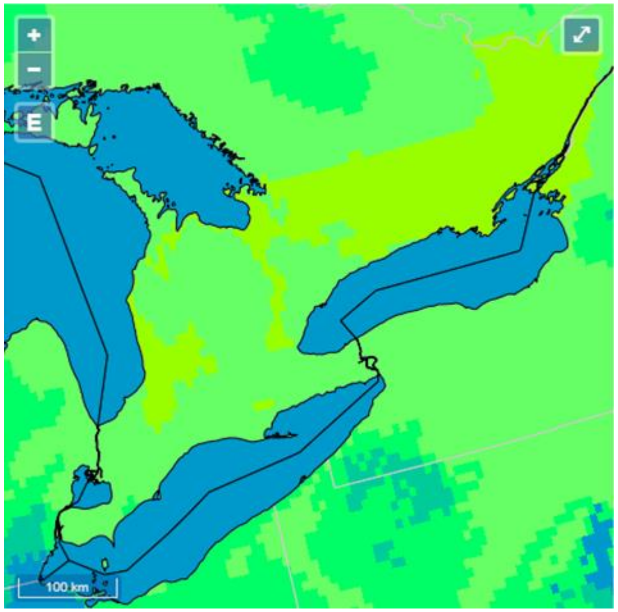


d. 2071-2100

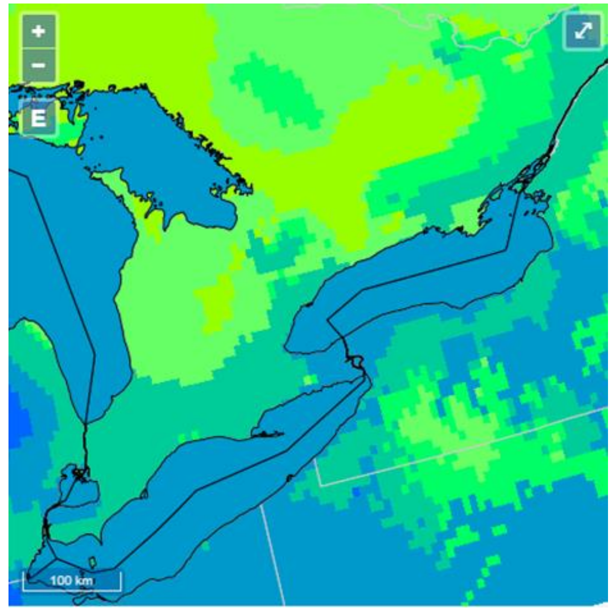


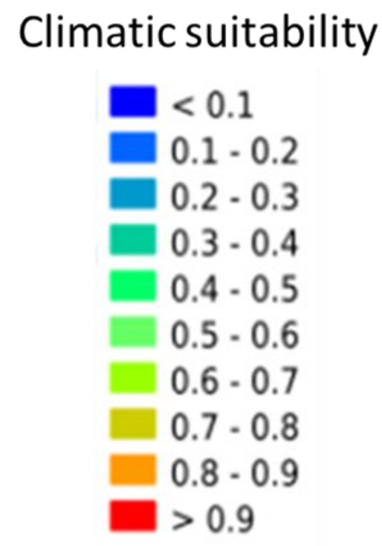
Pinus sylvestris (Scots pine)

a. Historical

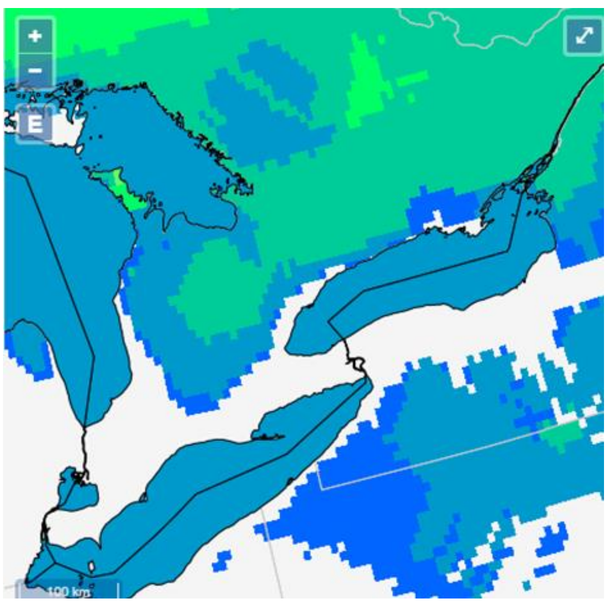


b. 2011-2040

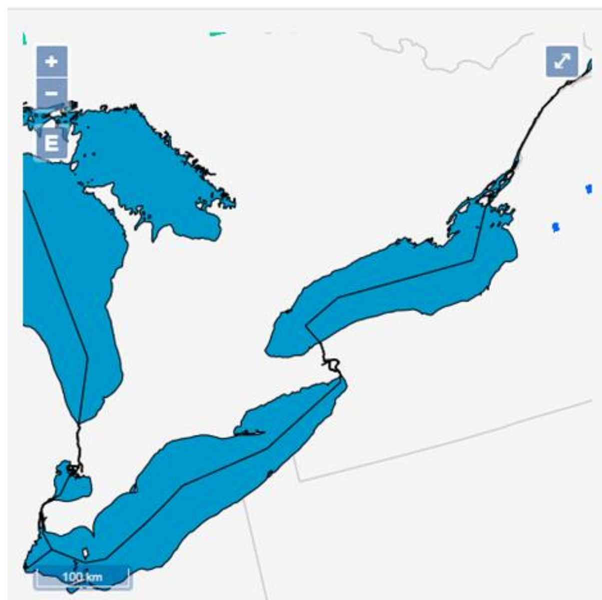




c. 2041-2070

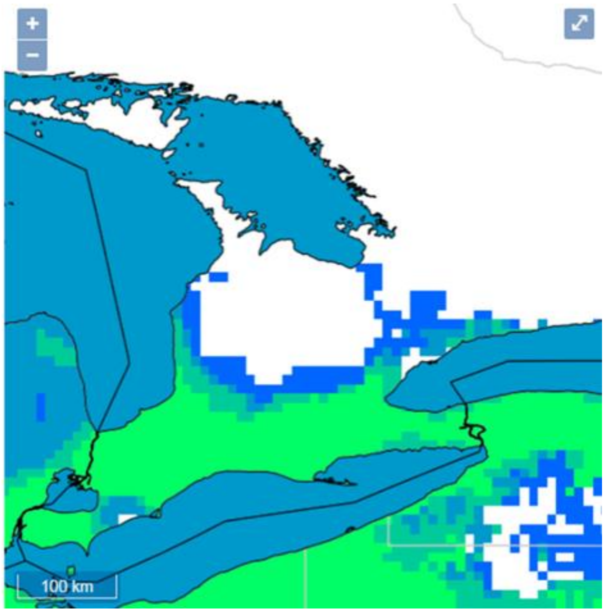


d. 2071-2100

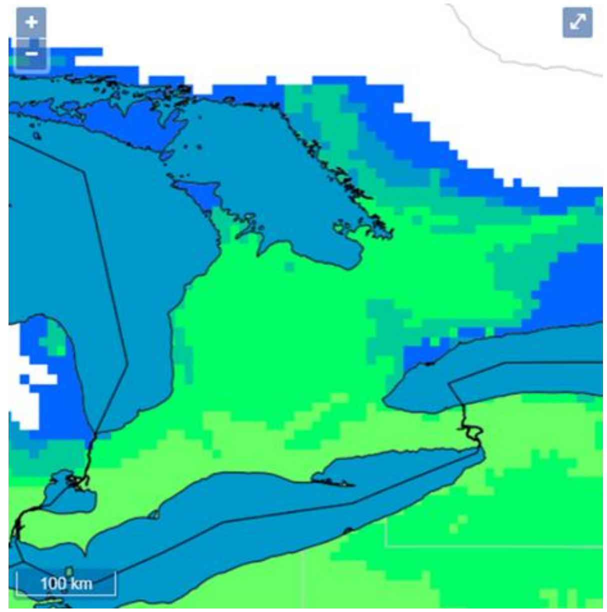


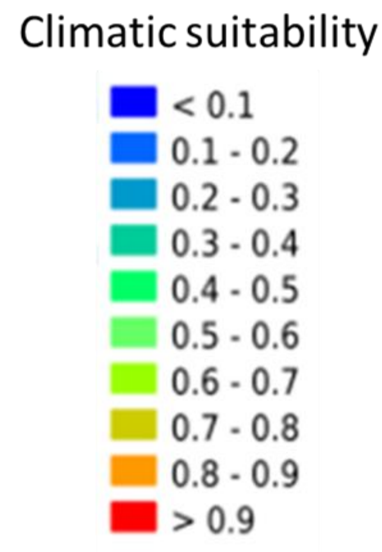
Platanus occidentalis (American sycamore)

a. Historical

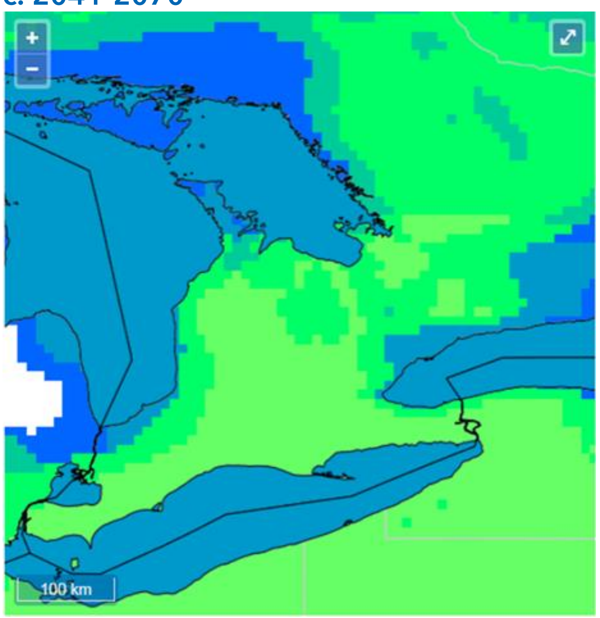


b. 2011-2040

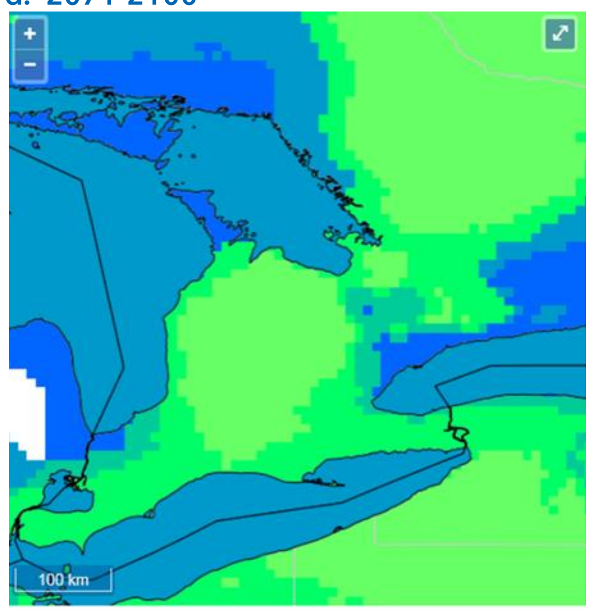




c. 2041-2070

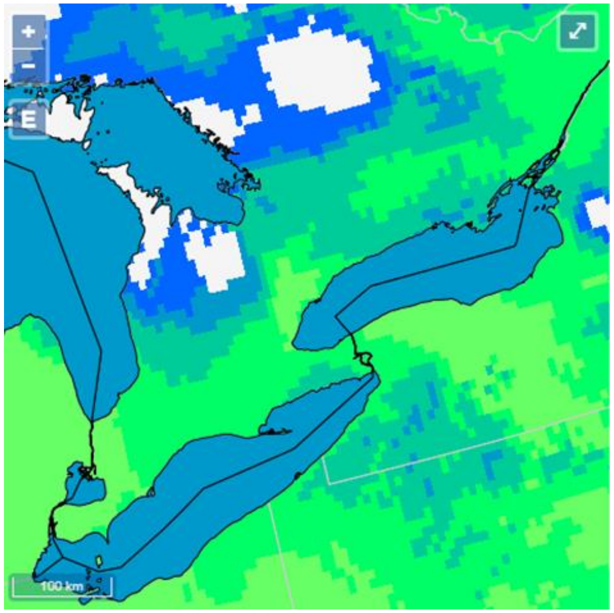


d. 2071-2100

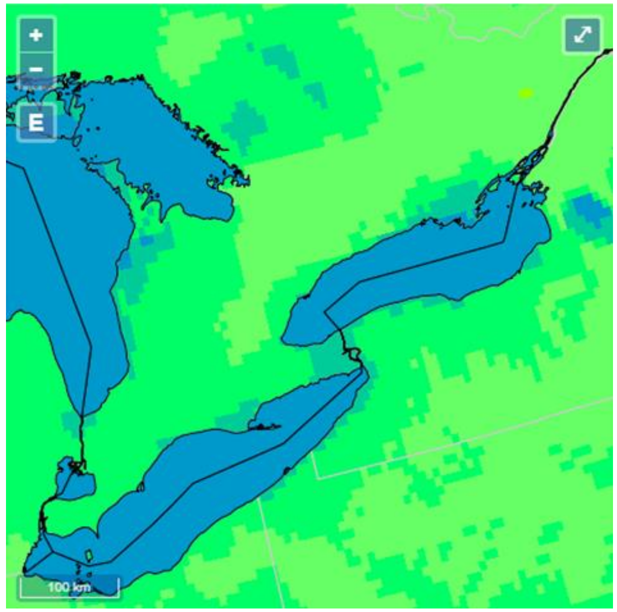


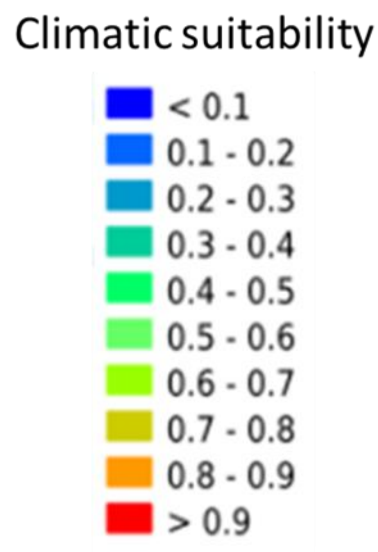
Populus deltoides (Eastern cottonwood)

a. Historical

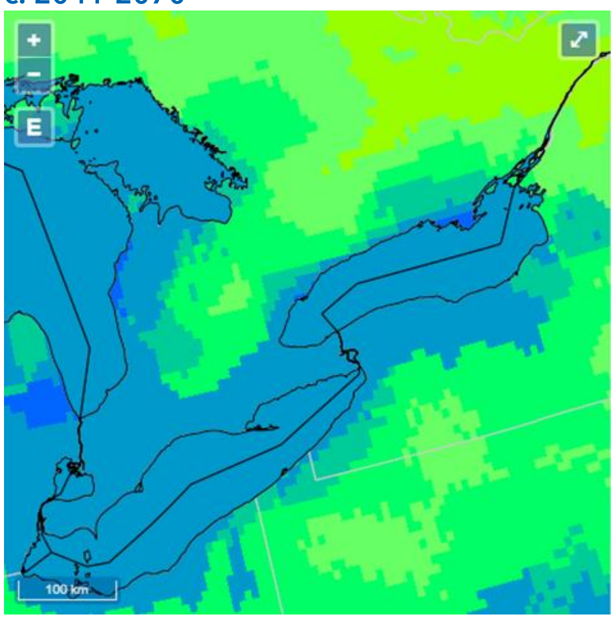


b. 2011-2040

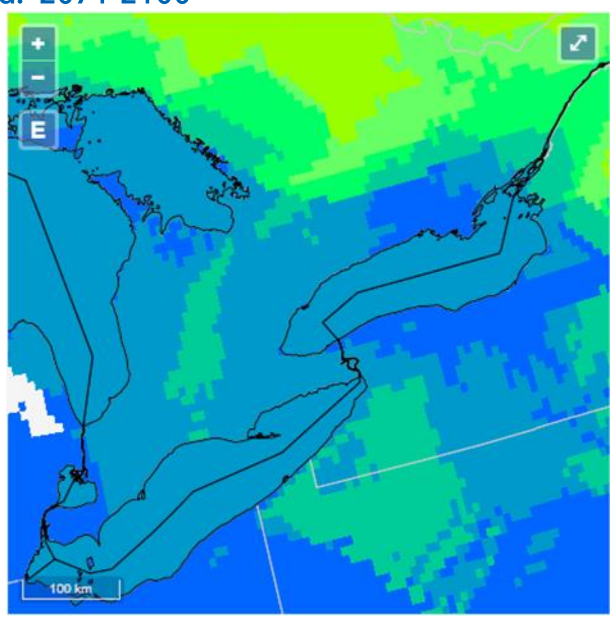




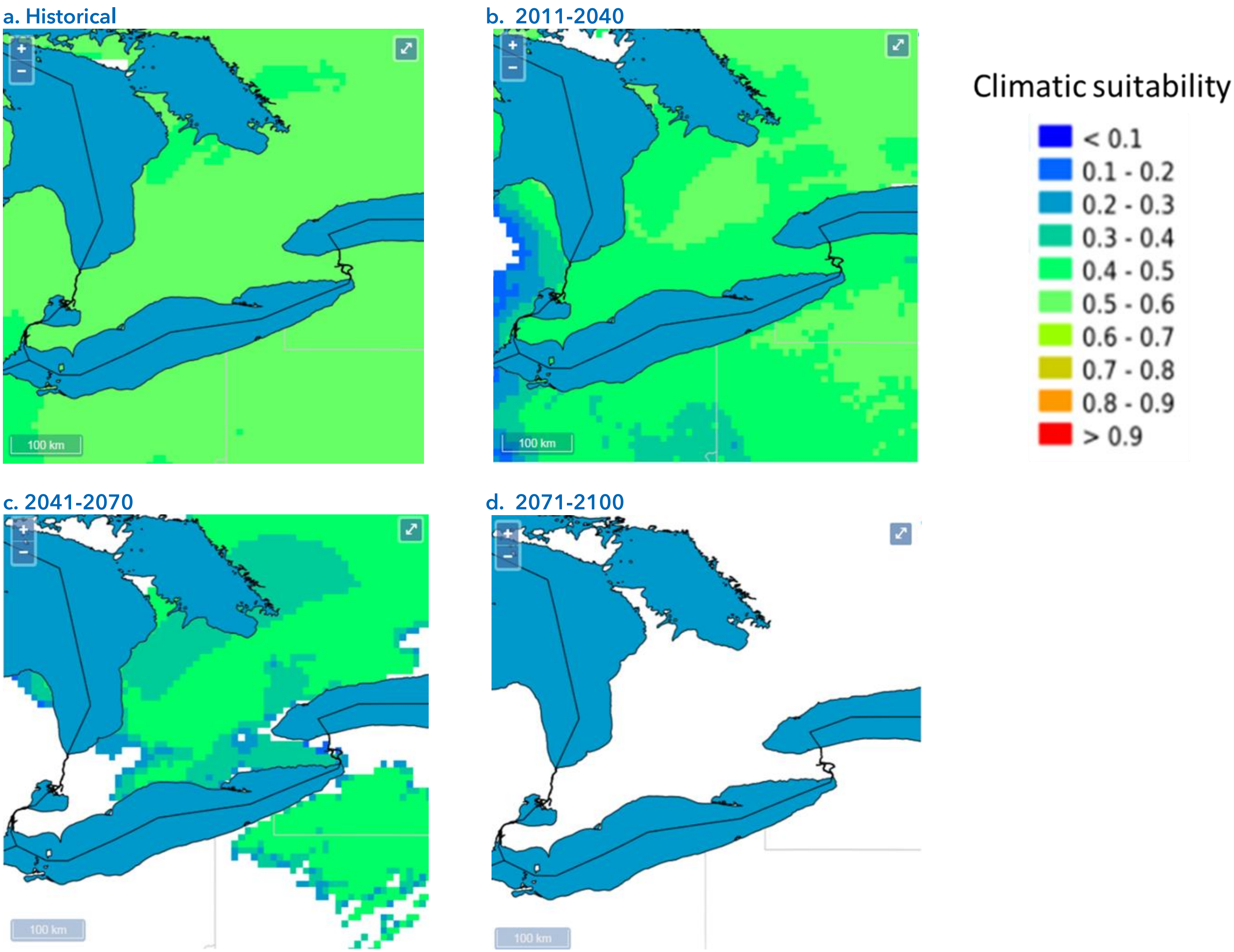
c. 2041-2070



d. 2071-2100

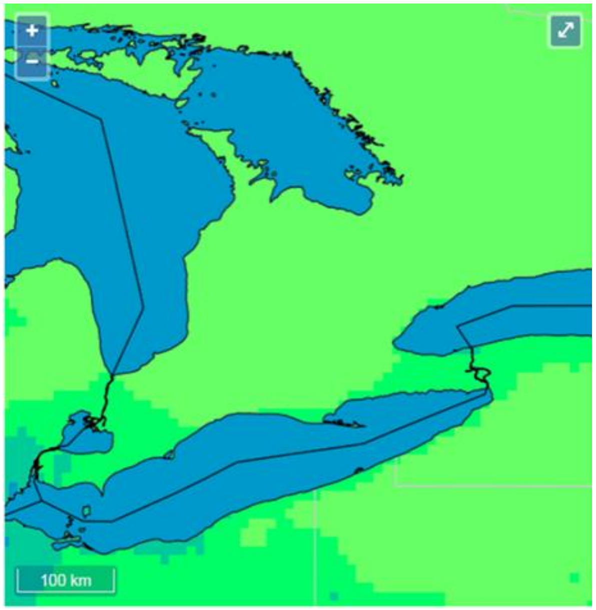


Populus grandidentata (Largetooth aspen)

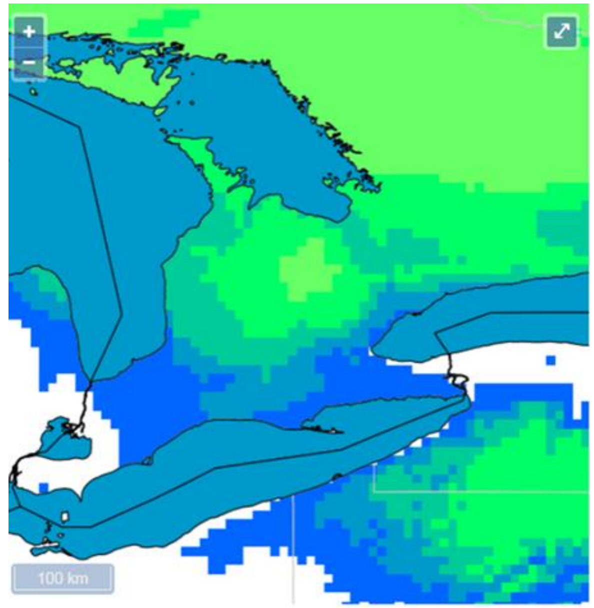


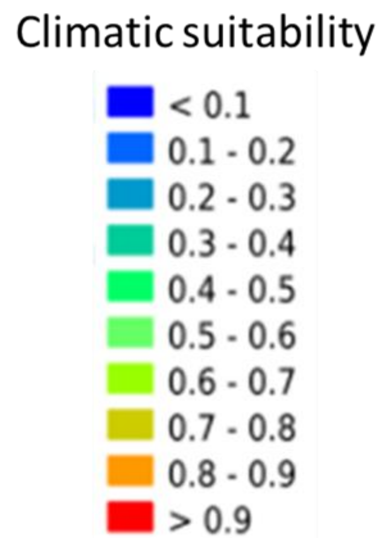
Populus tremuloides (Trembling aspen)

a. Historical

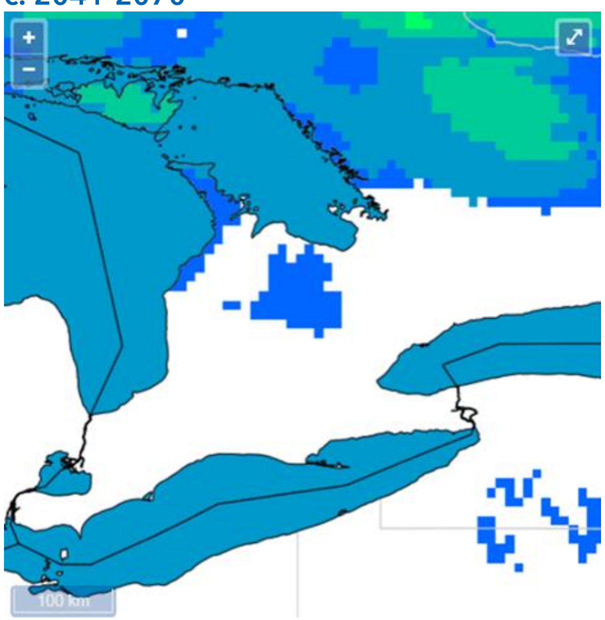


b. 2011-2040

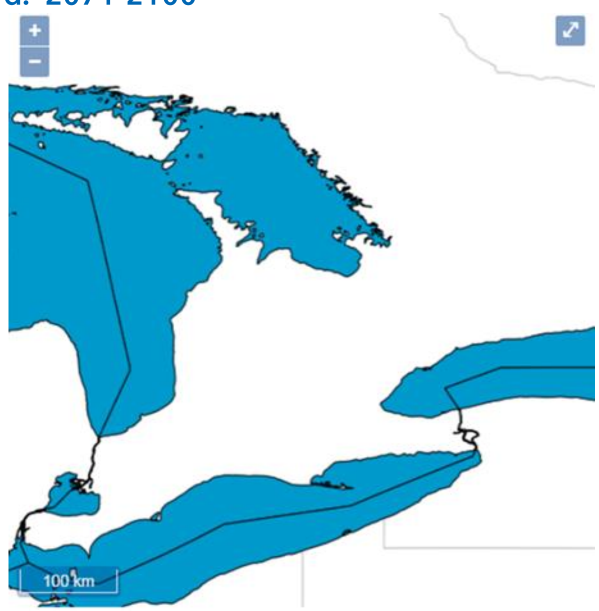




c. 2041-2070

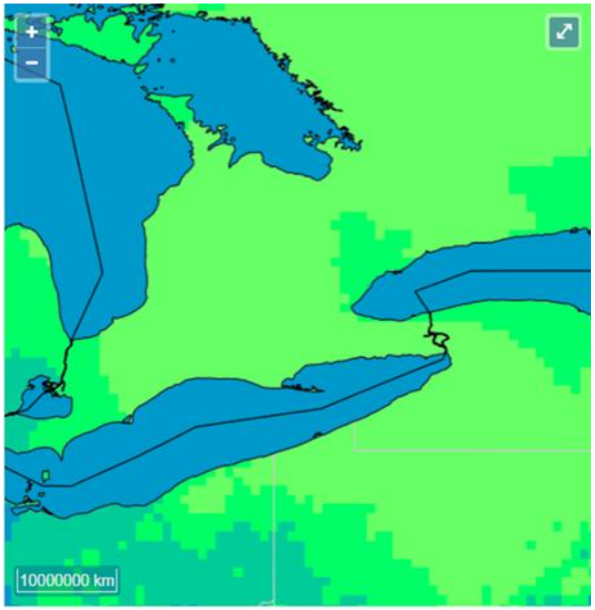


d. 2071-2100

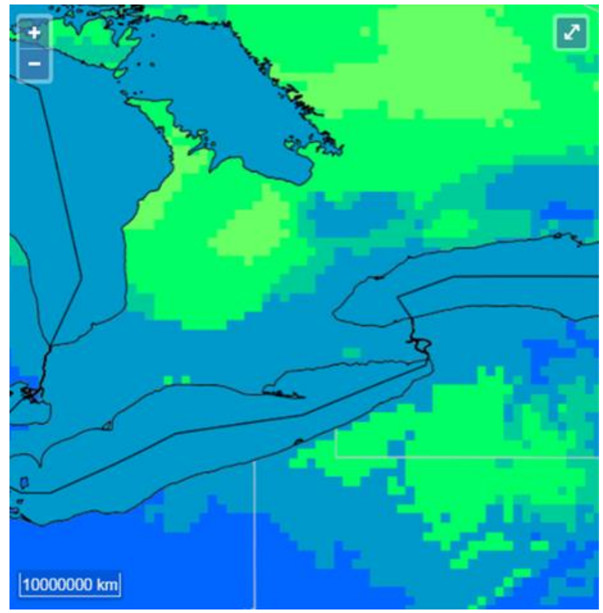


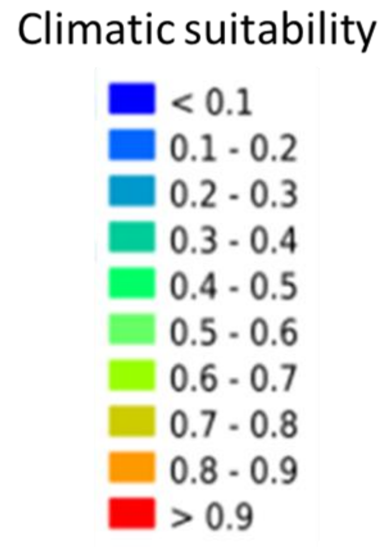
Prunus pensylvanica (Pin cherry)

a. Historical

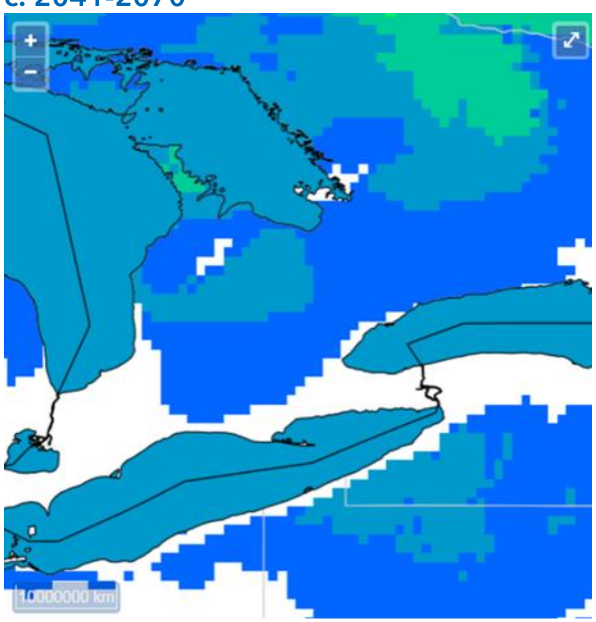


b. 2011-2040

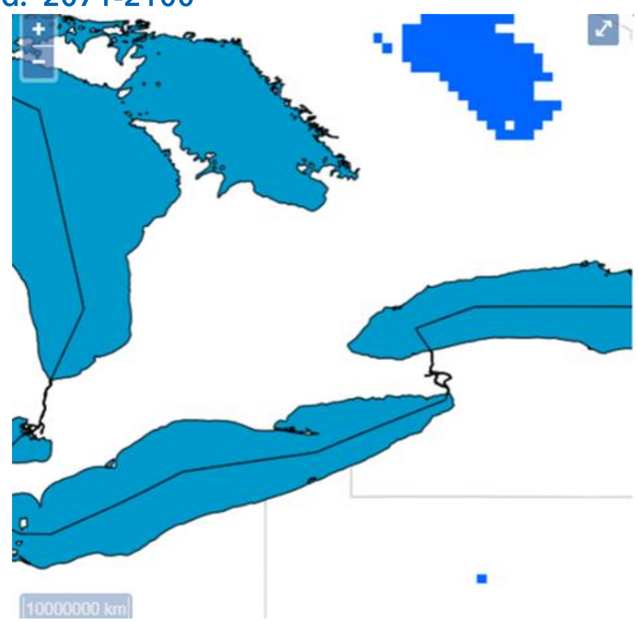




c. 2041-2070

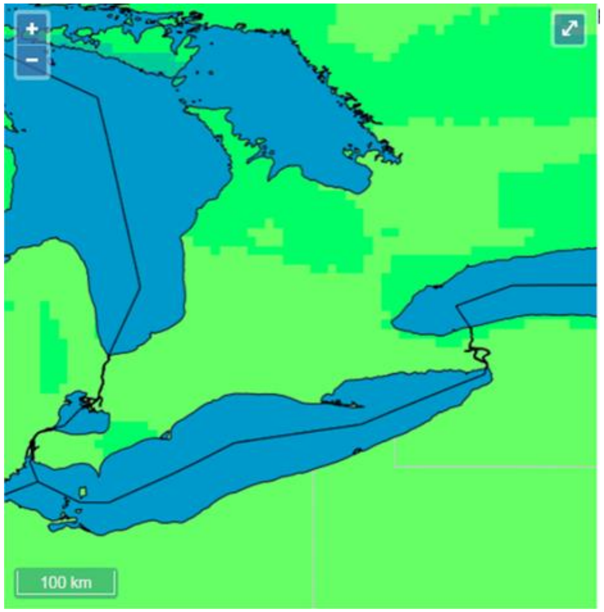


d. 2071-2100

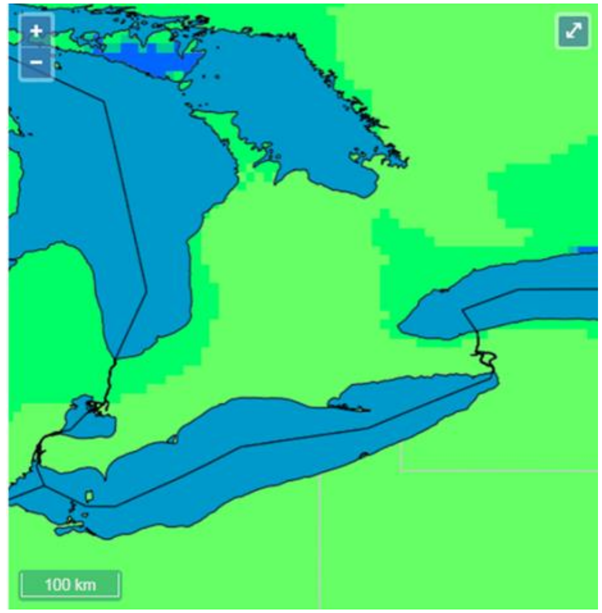


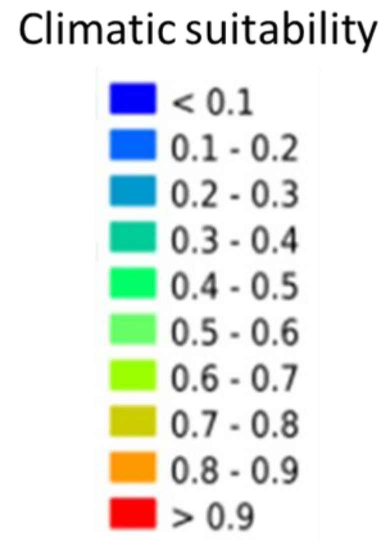
Prunus serotina (Black cherry)

a. Historical

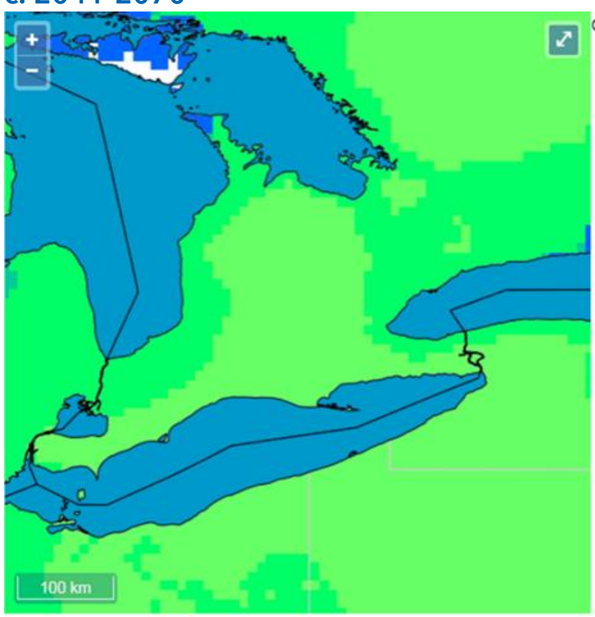


b. 2011-2040

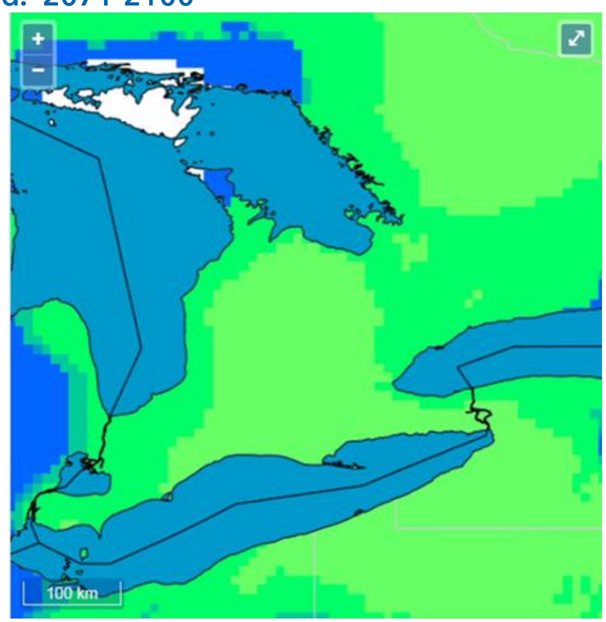




c. 2041-2070

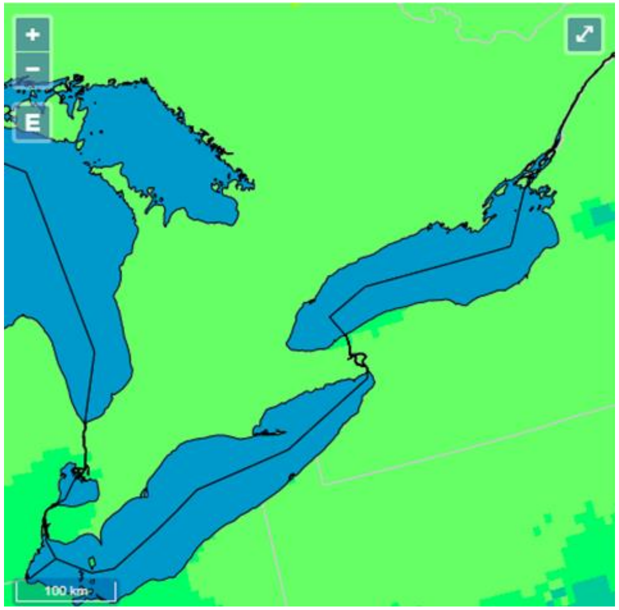


d. 2071-2100

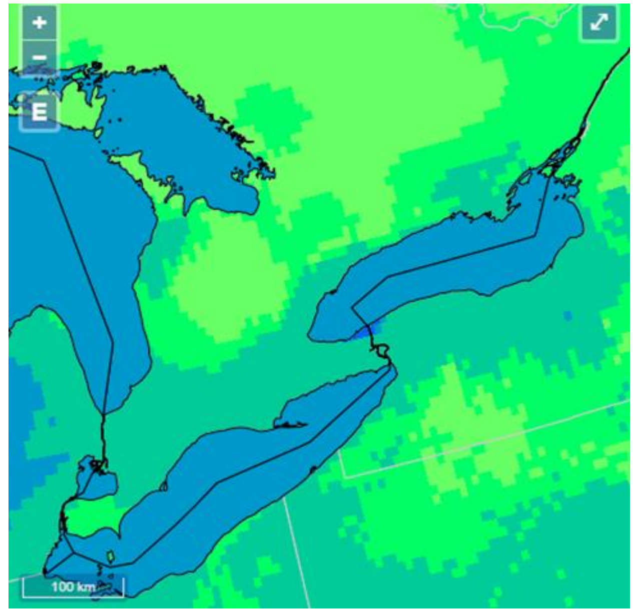


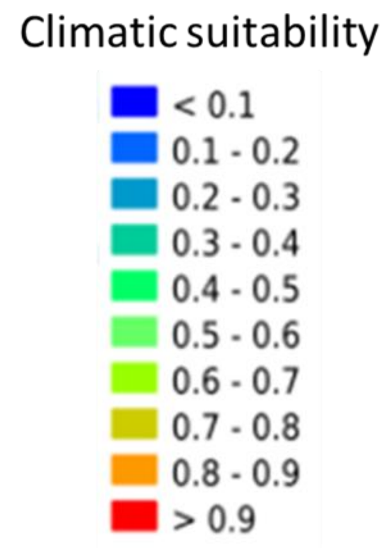
Prunus virginiana (Choke cherry)

a. Historical

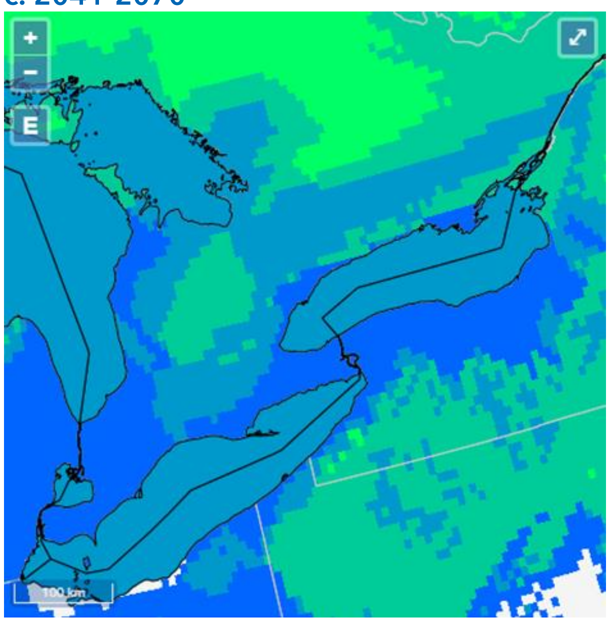


b. 2011-2040

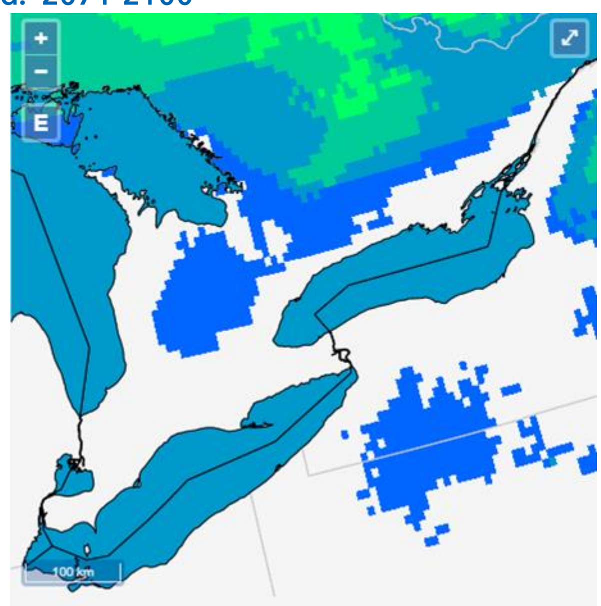




c. 2041-2070

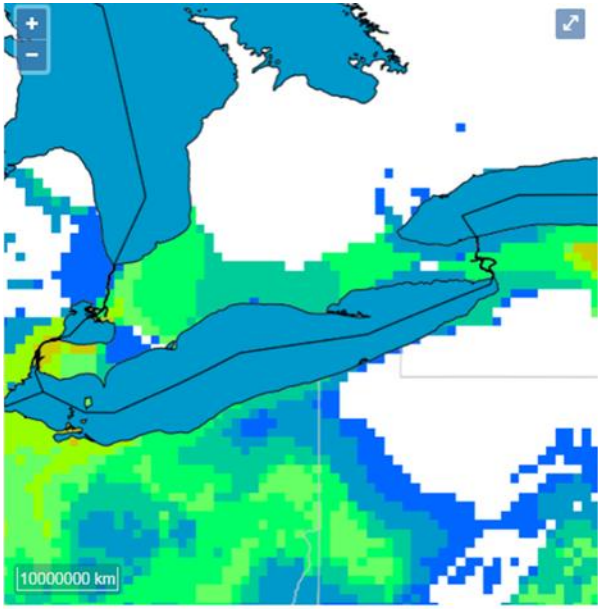


d. 2071-2100

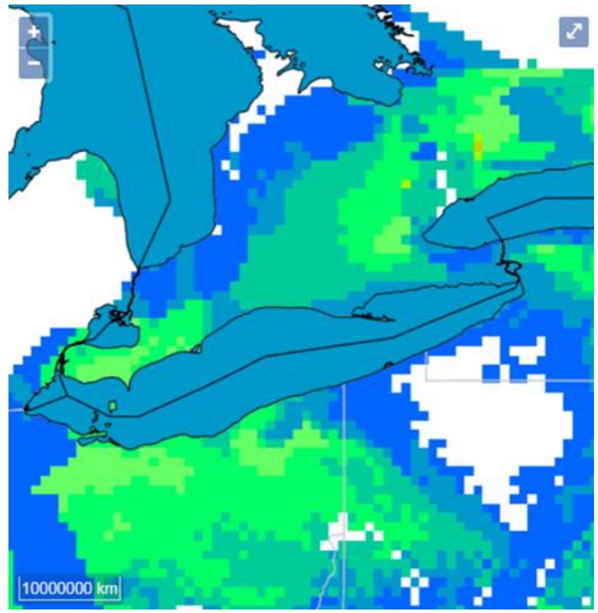


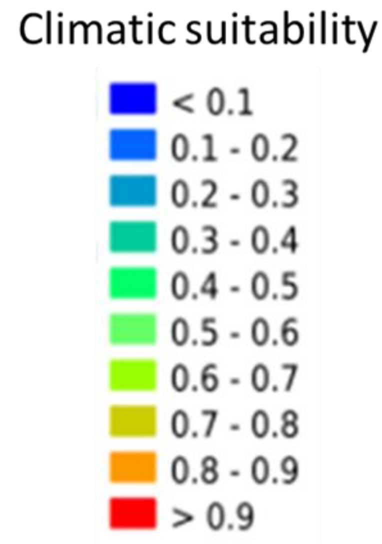
Ptelea trifoliata (Common hoptree)

a. Historical

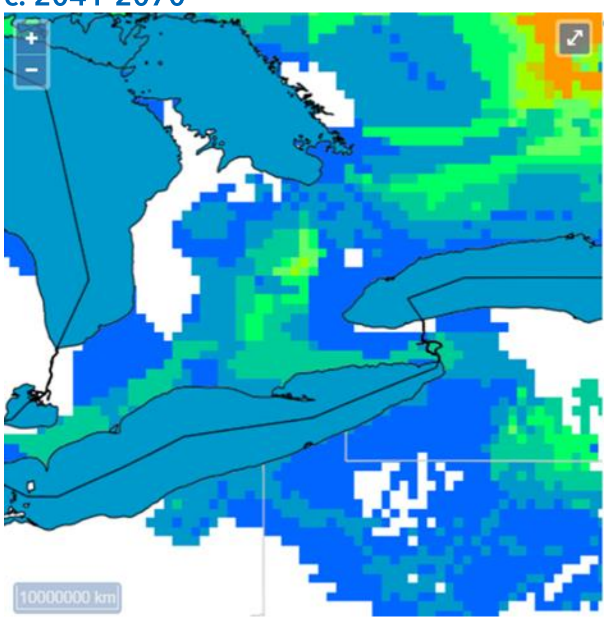


b. 2011-2040

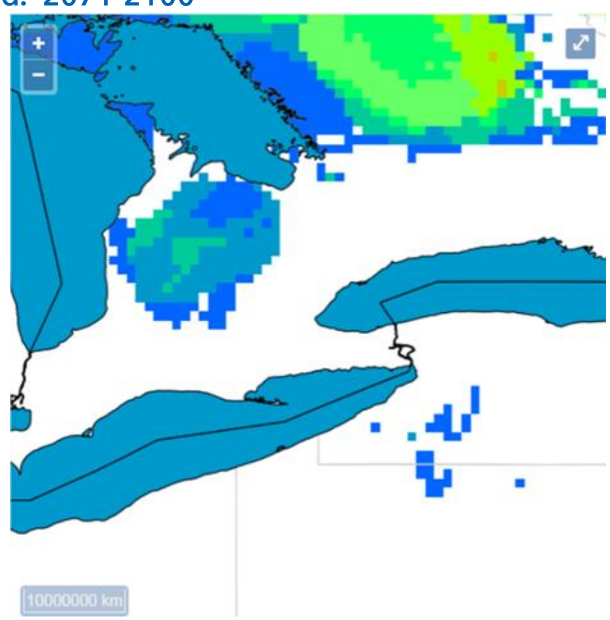




c. 2041-2070

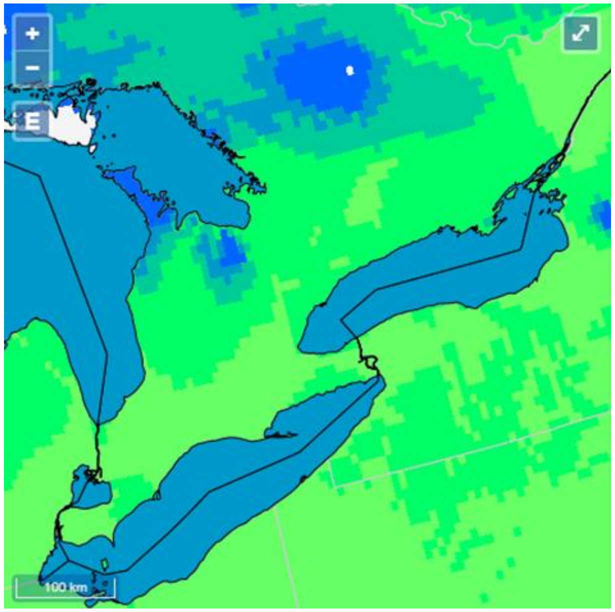


d. 2071-2100

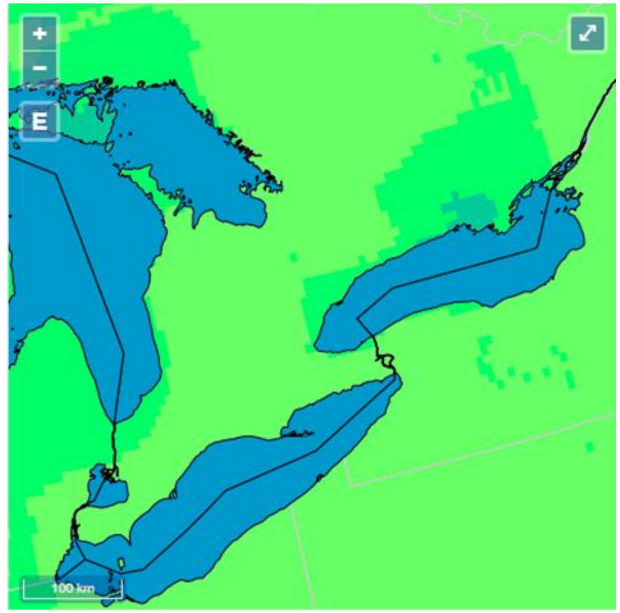


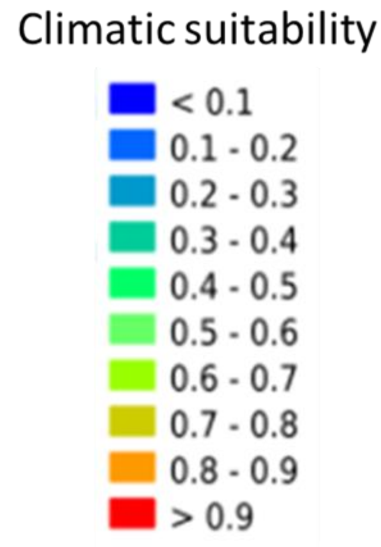
Quercus alba (White oak)

a. Historical

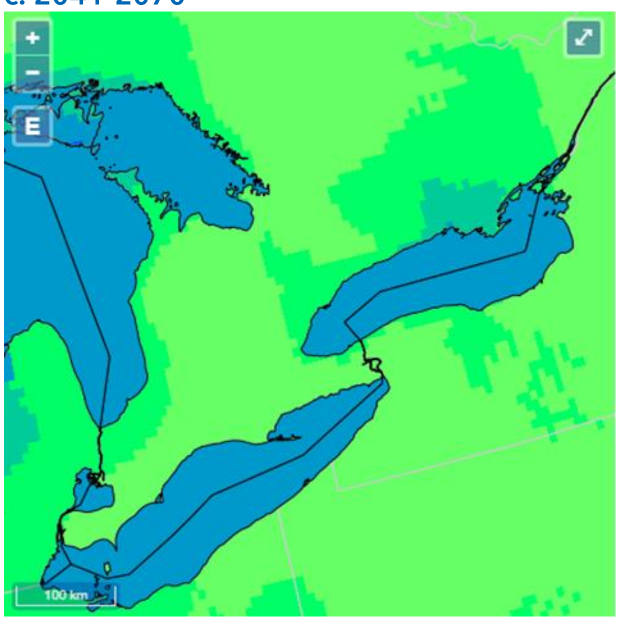


b. 2011-2040

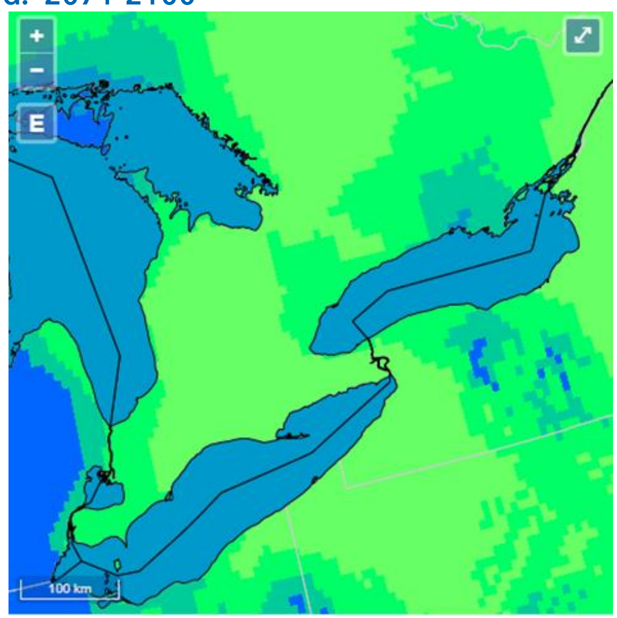




c. 2041-2070

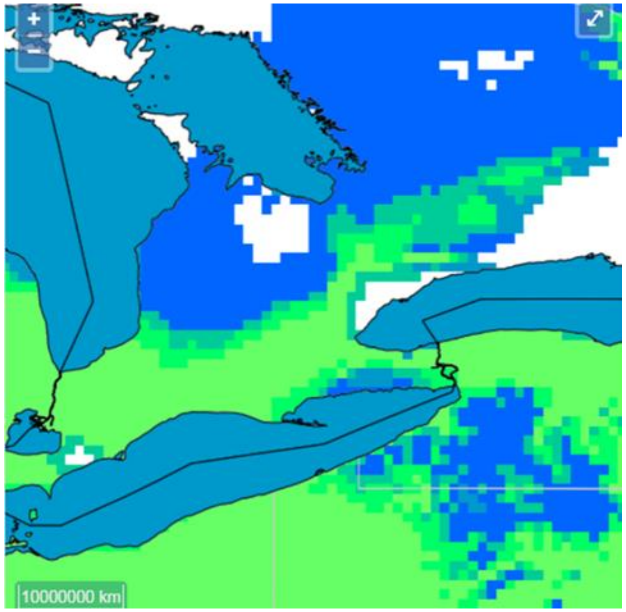


d. 2071-2100

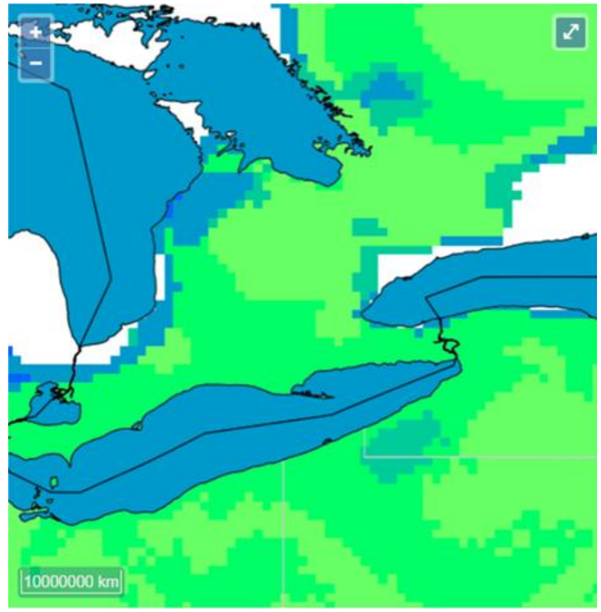


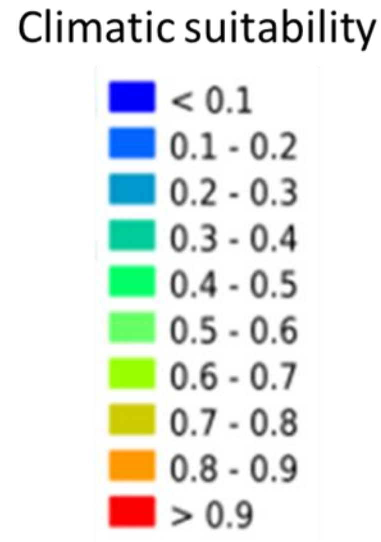
Quercus bicolor (Swamp white oak)

a. Historical

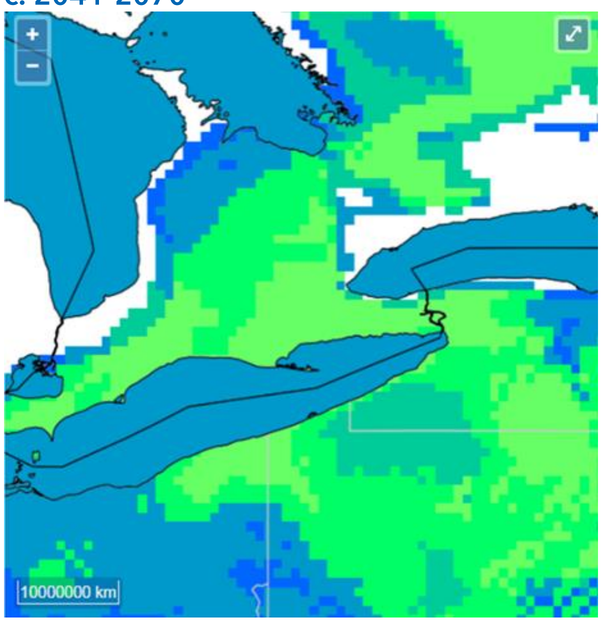


b. 2011-2040

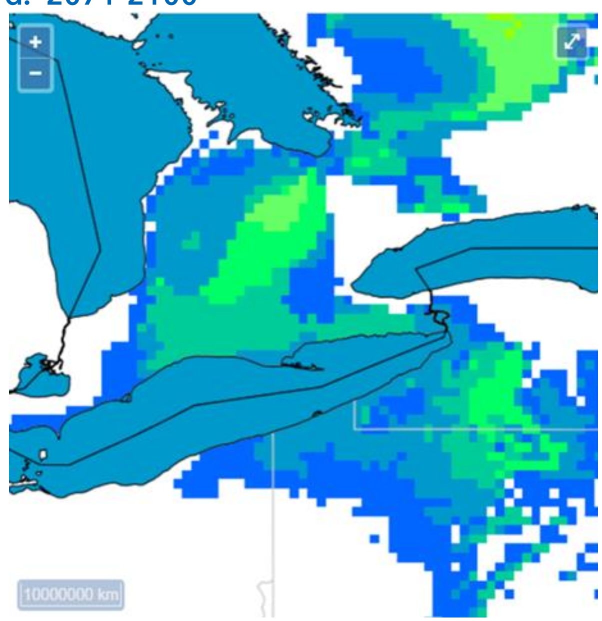




c. 2041-2070

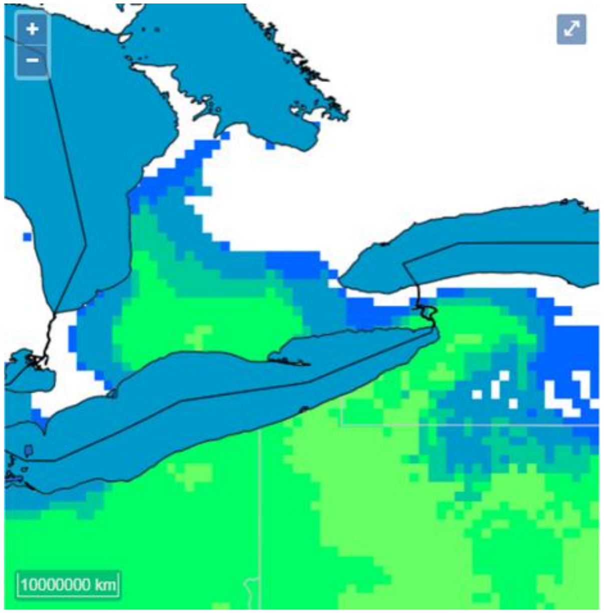


d. 2071-2100

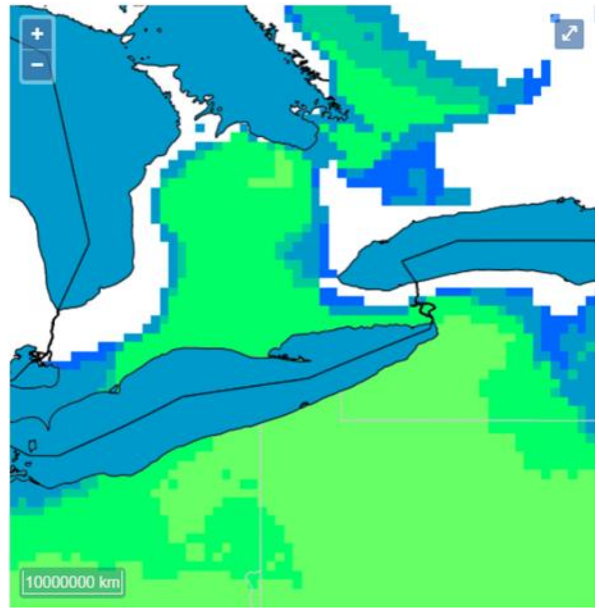


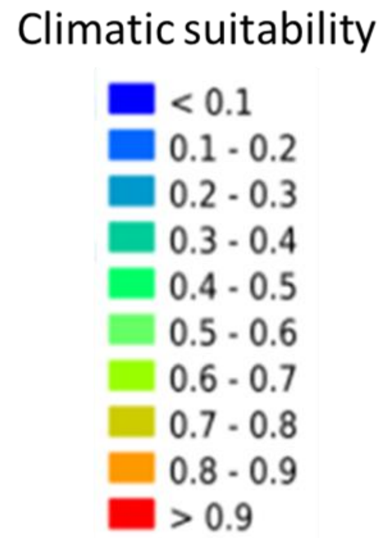
Quercus coccinea (Scarlet oak)

a. Historical

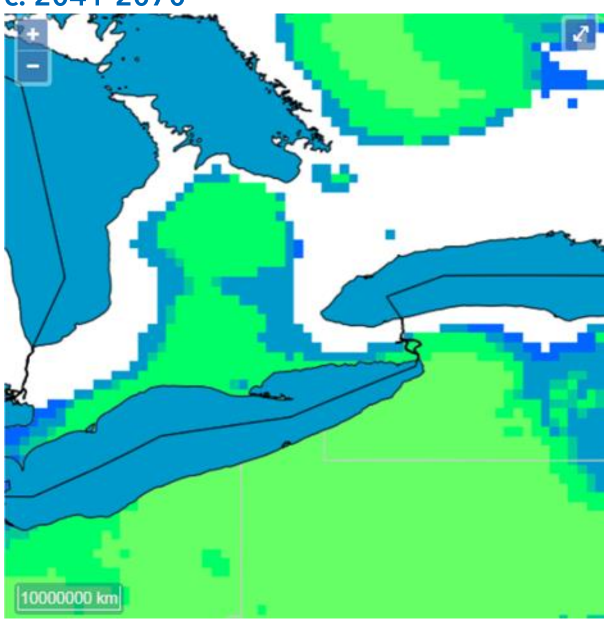


b. 2011-2040

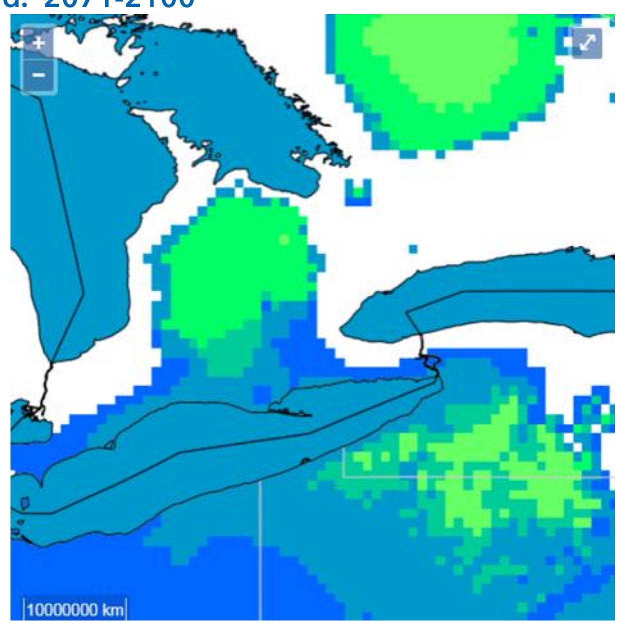




c. 2041-2070

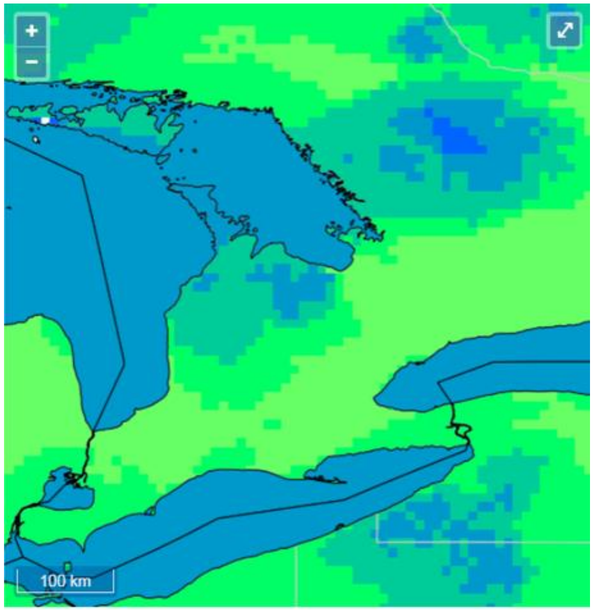


d. 2071-2100

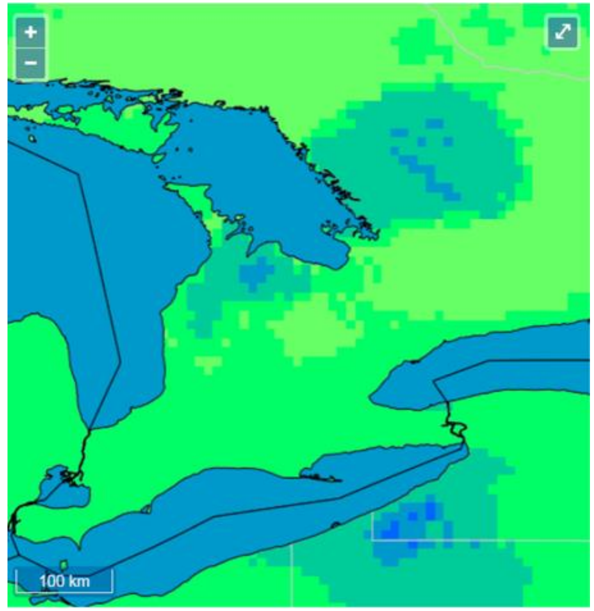


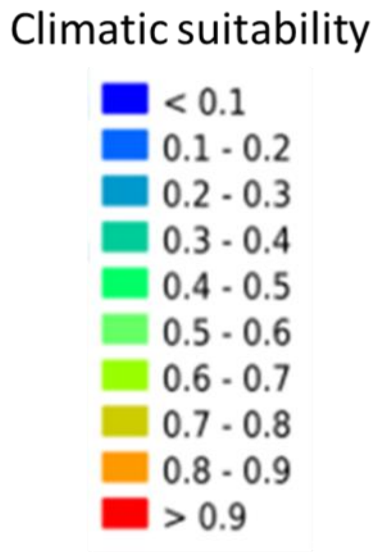
Quercus macrocarpa (Bur oak)

a. Historical

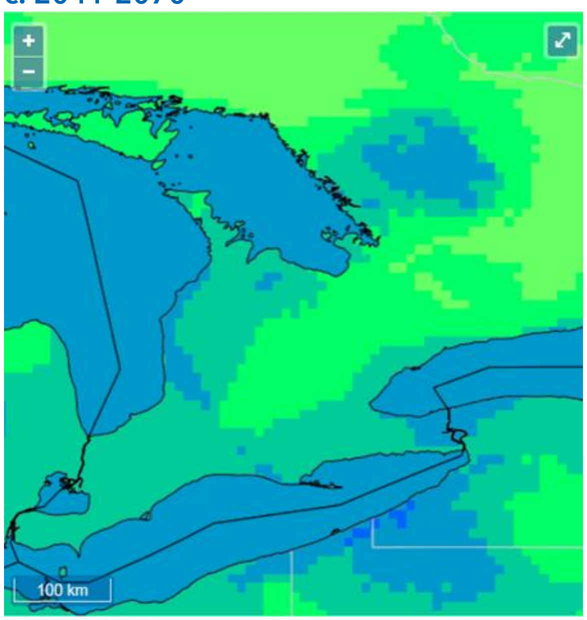


b. 2011-2040

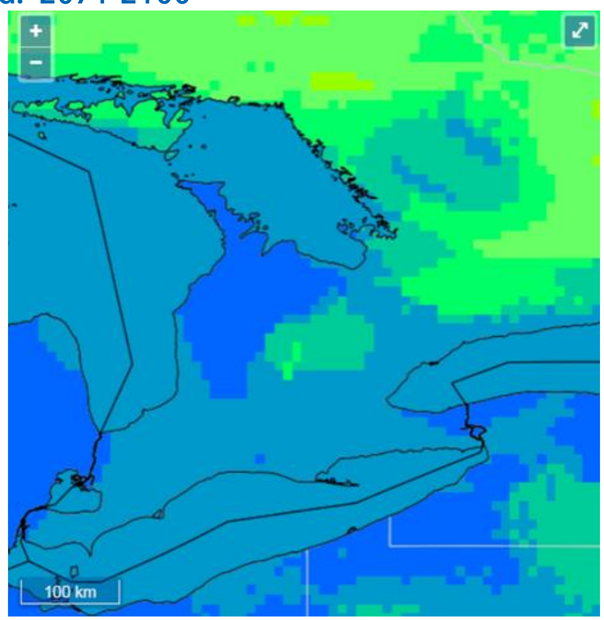




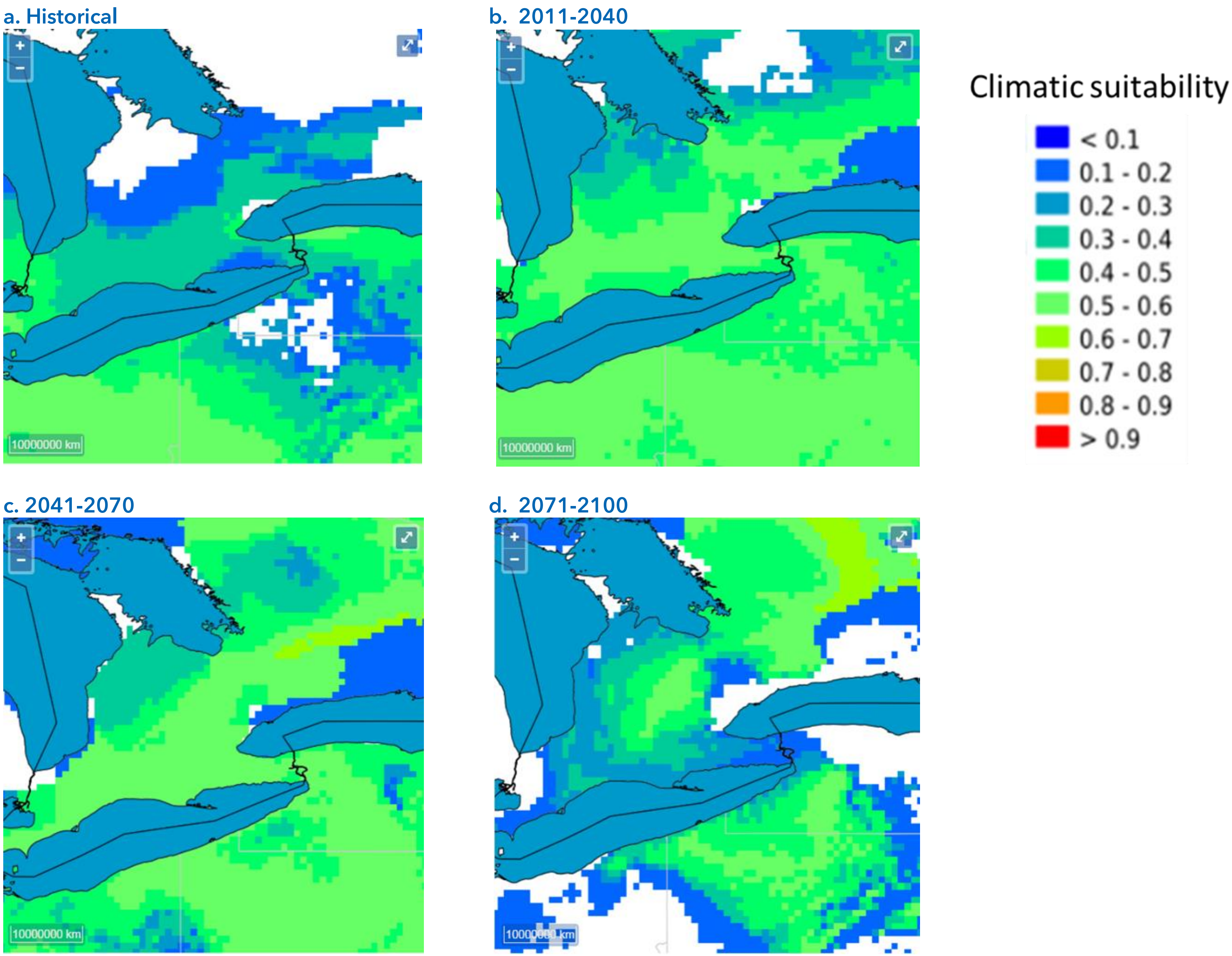
c. 2041-2070



d. 2071-2100

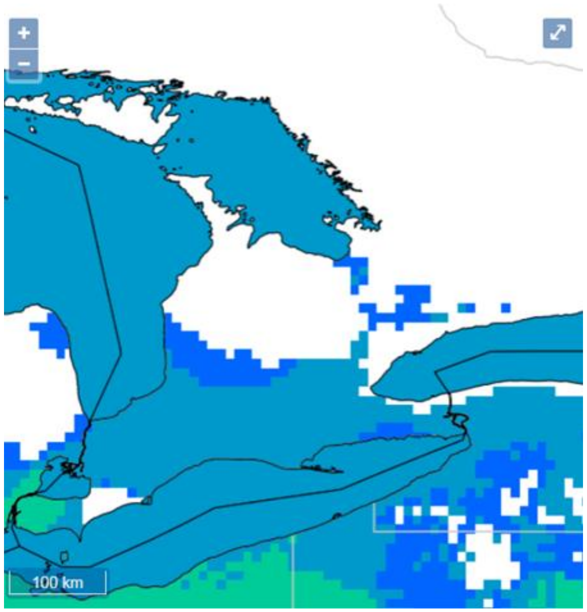


Quercus palustris (Pin oak)

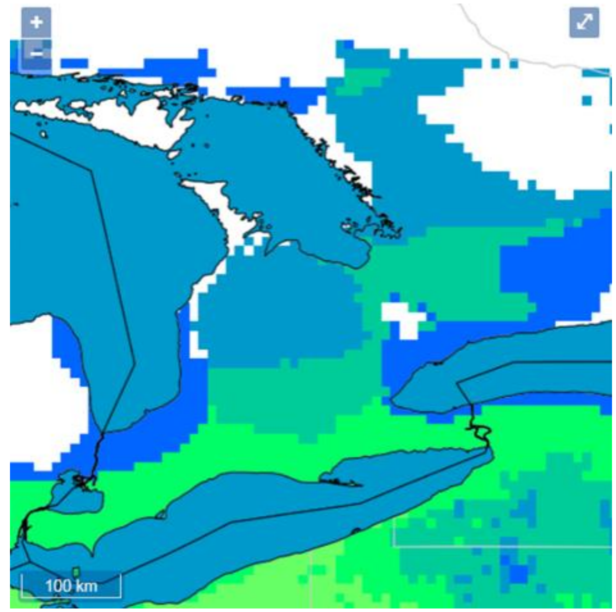


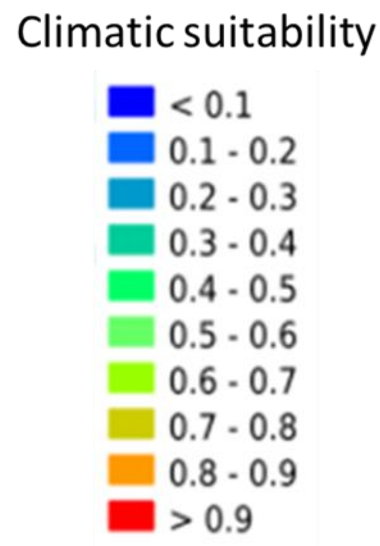
Quercus prinoides (Chestnut oak)

a. Historical

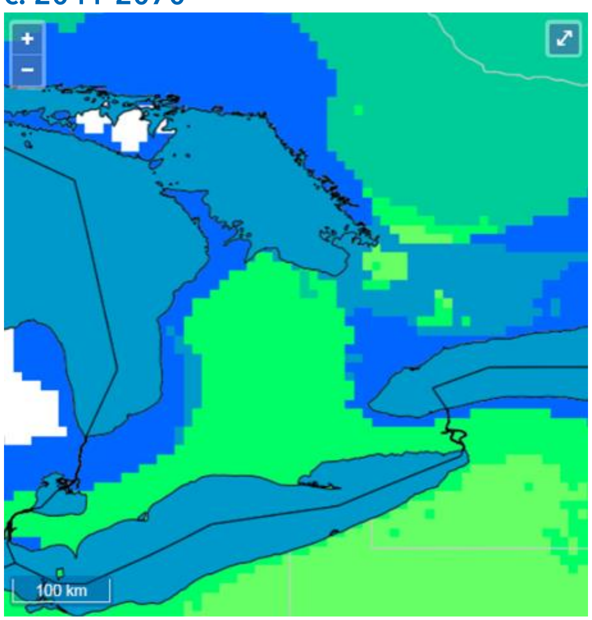


b. 2011-2040

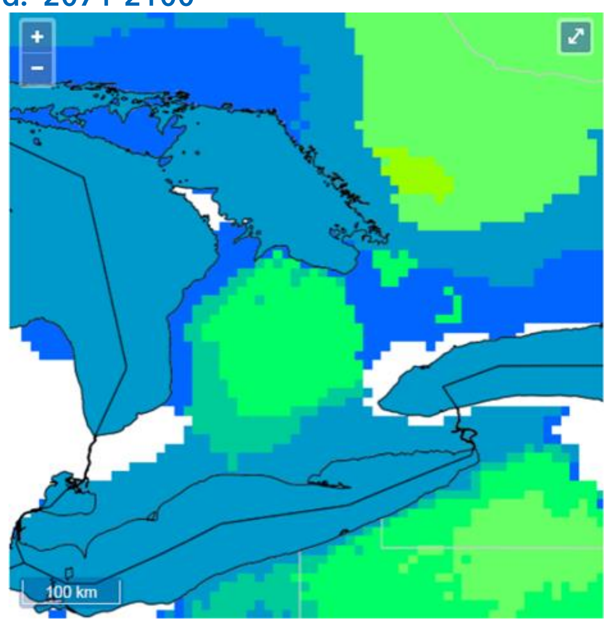




c. 2041-2070

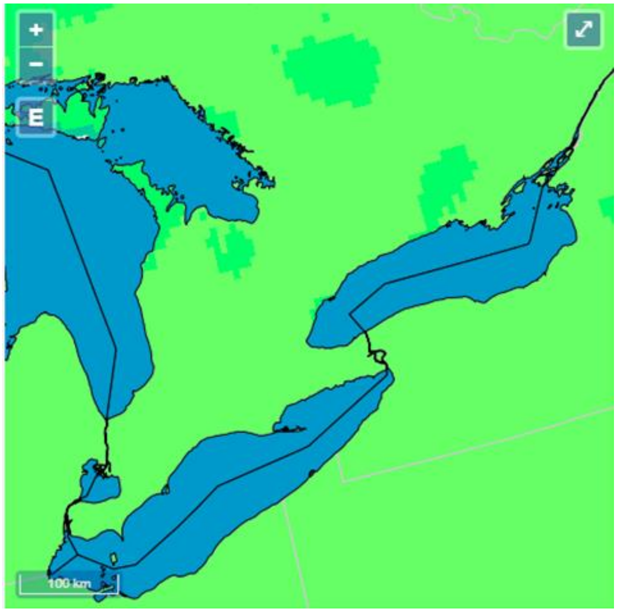


d. 2071-2100

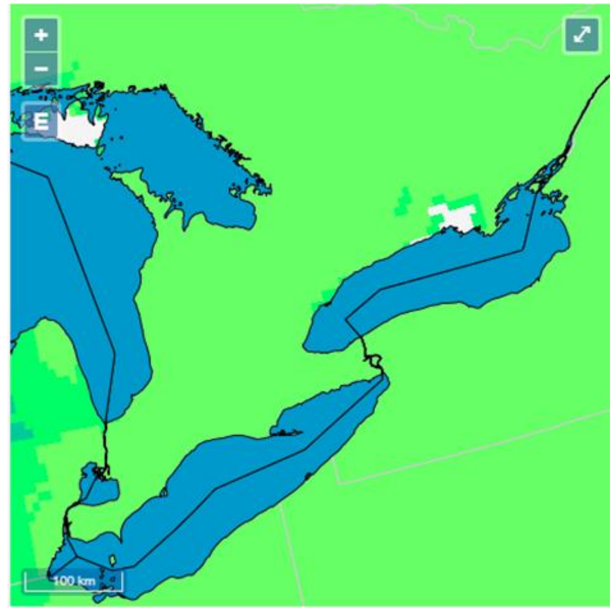


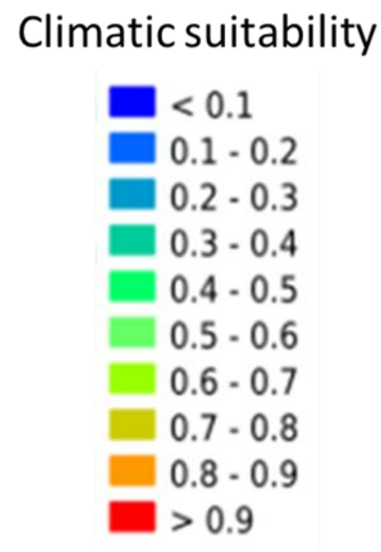
Quercus rubra (Red oak)

a. Historical

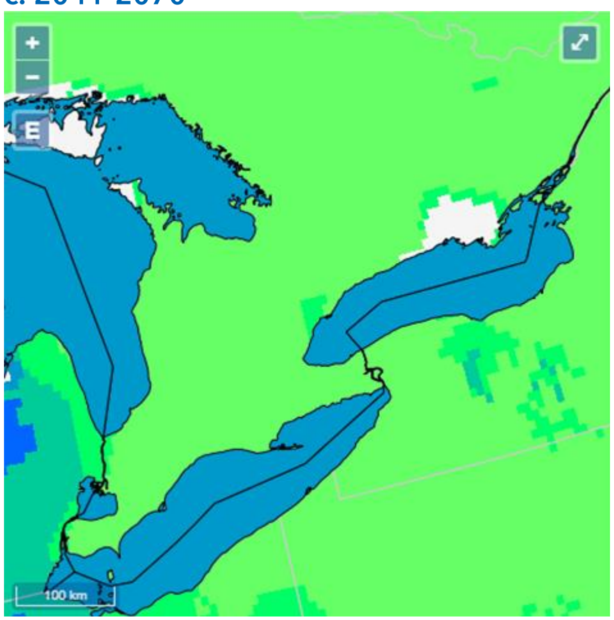


b. 2011-2040

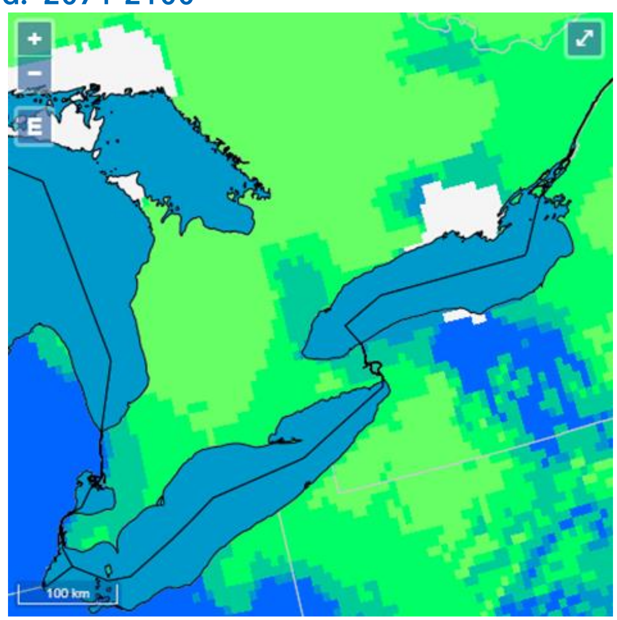




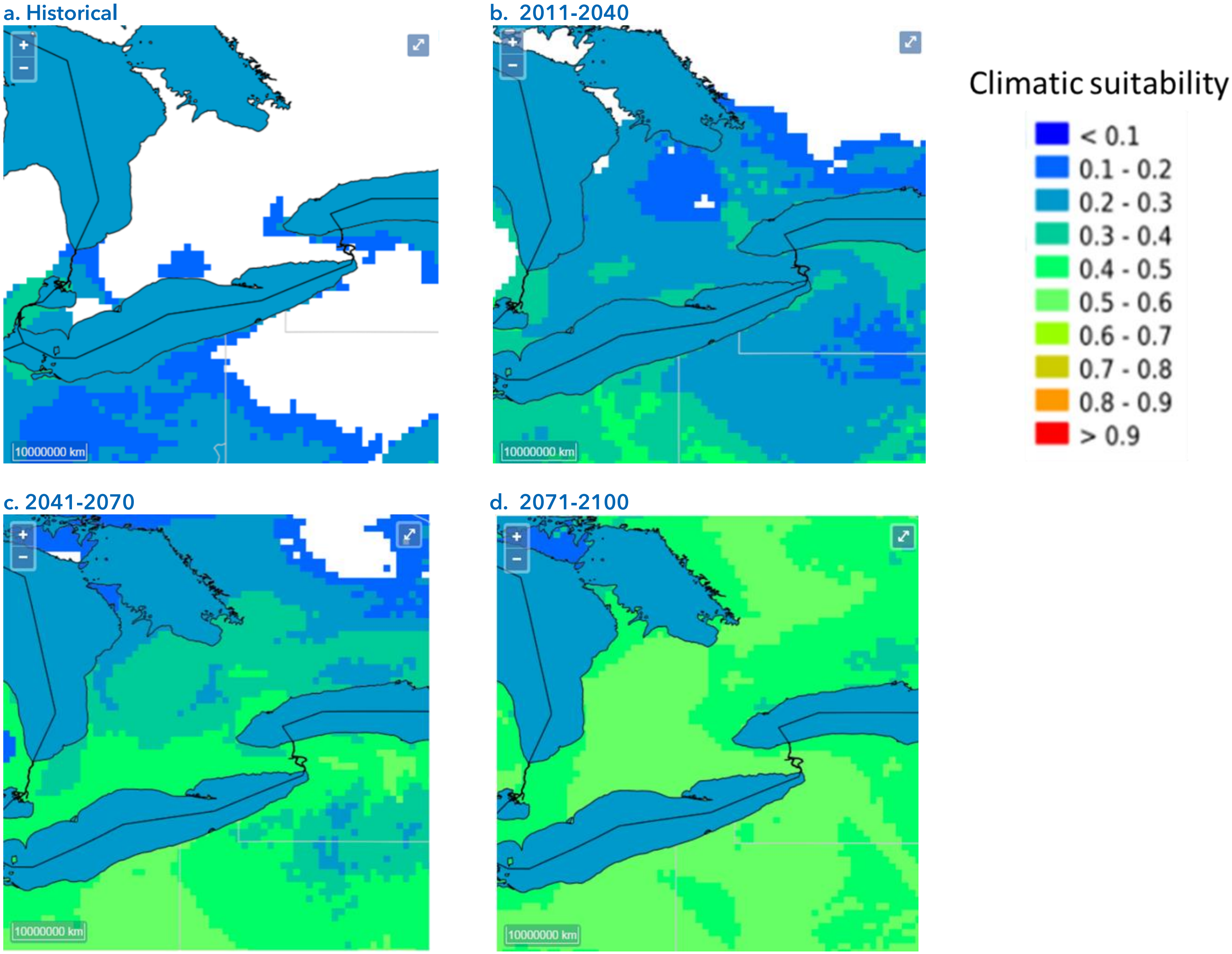
c. 2041-2070



d. 2071-2100

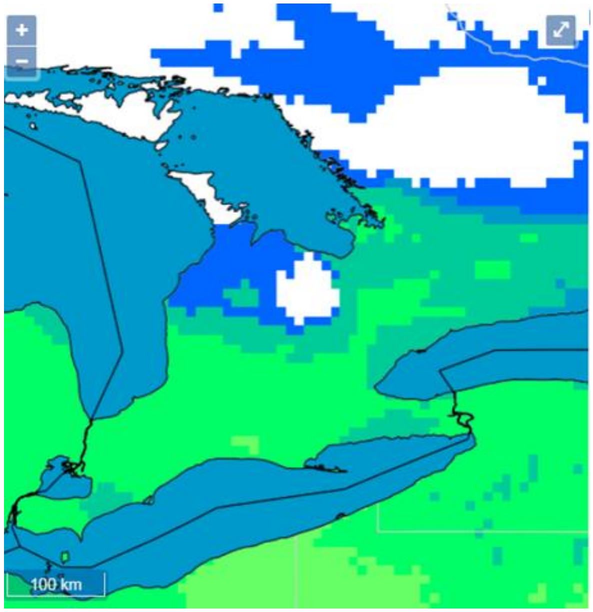


Quercus shumardii (Shumard oak)

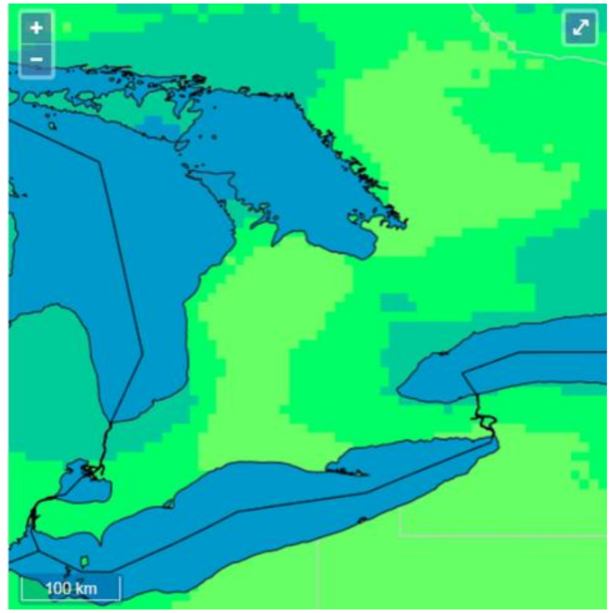


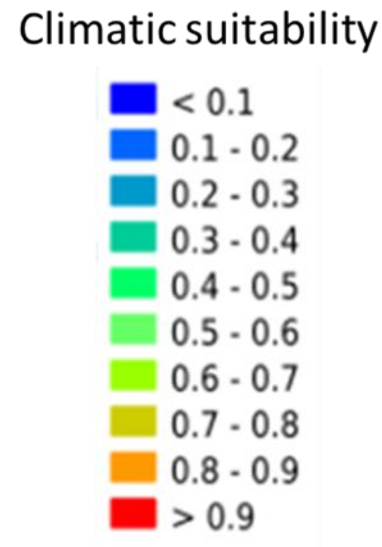
Quercus velutina (Black oak)

a. Historical

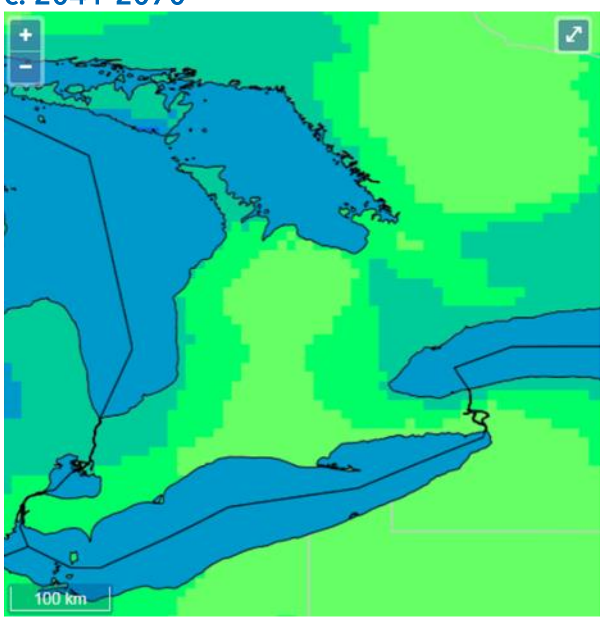


b. 2011-2040

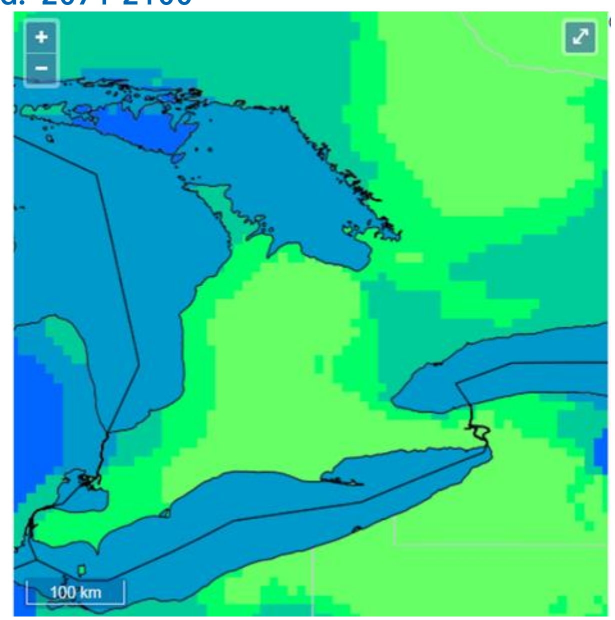




c. 2041-2070

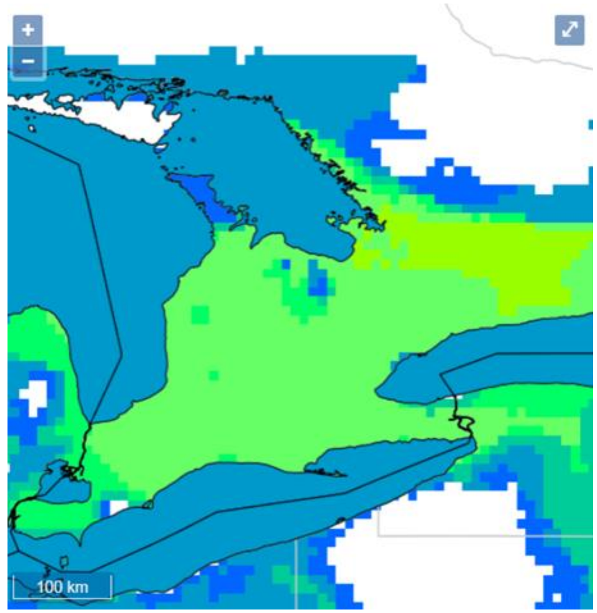


d. 2071-2100

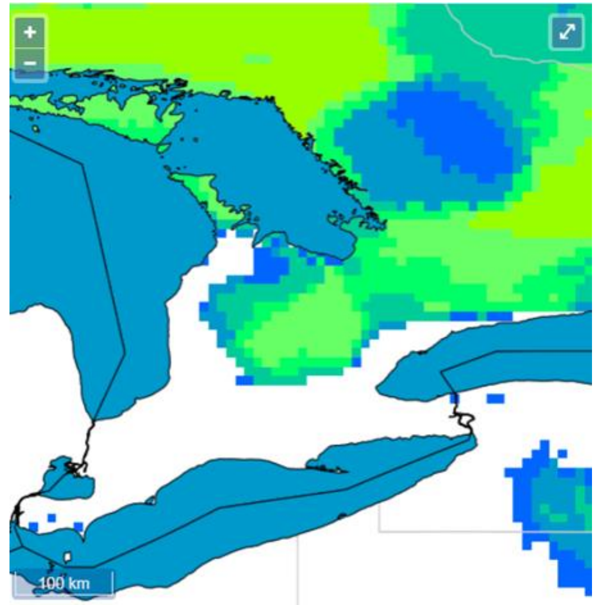


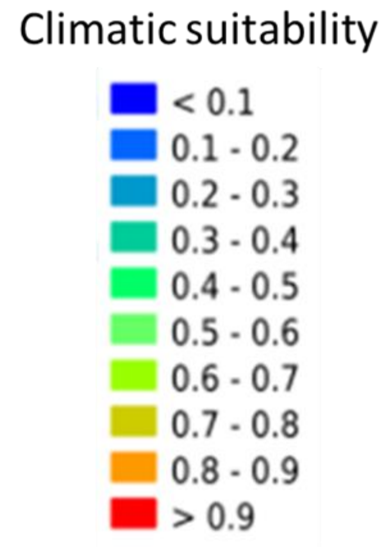
Rhamnus cathartica (Common buckthorn)

a. Historical

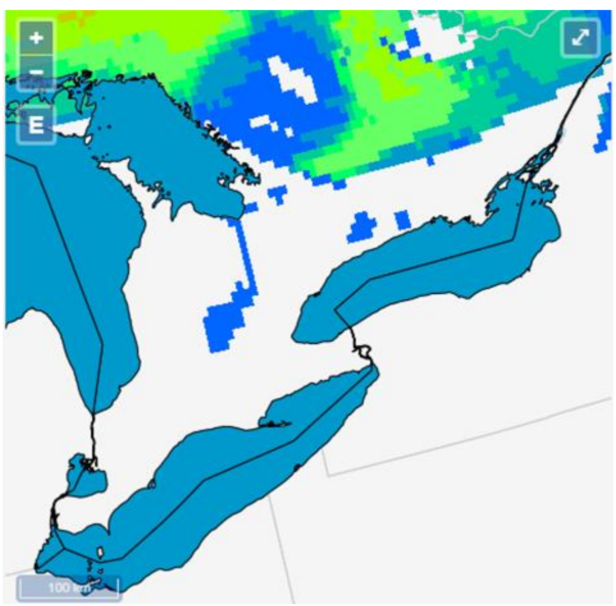


b. 2011-2040

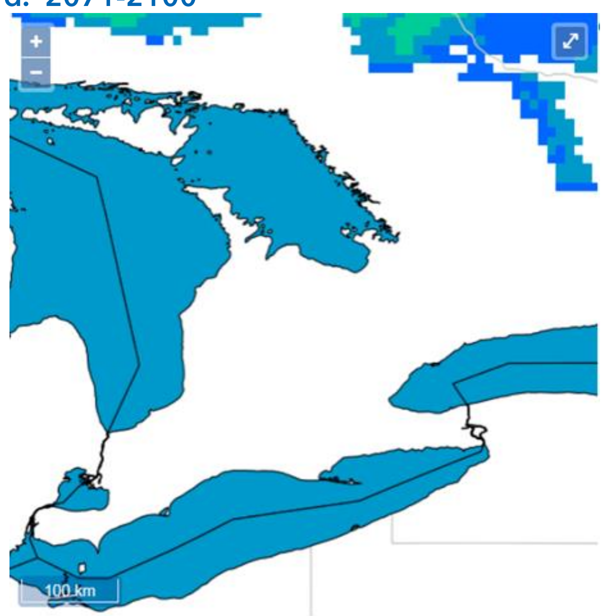




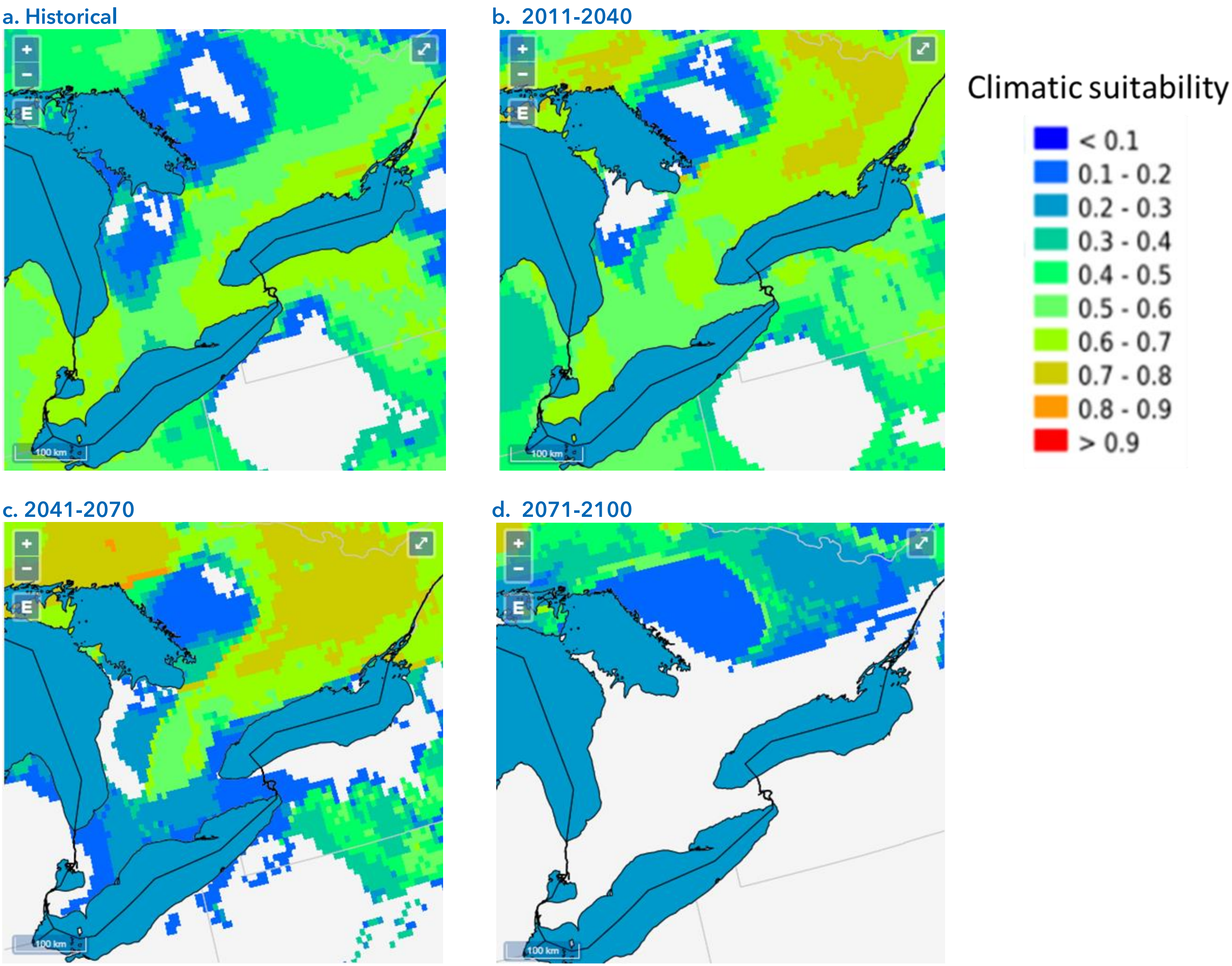
c. 2041-2070



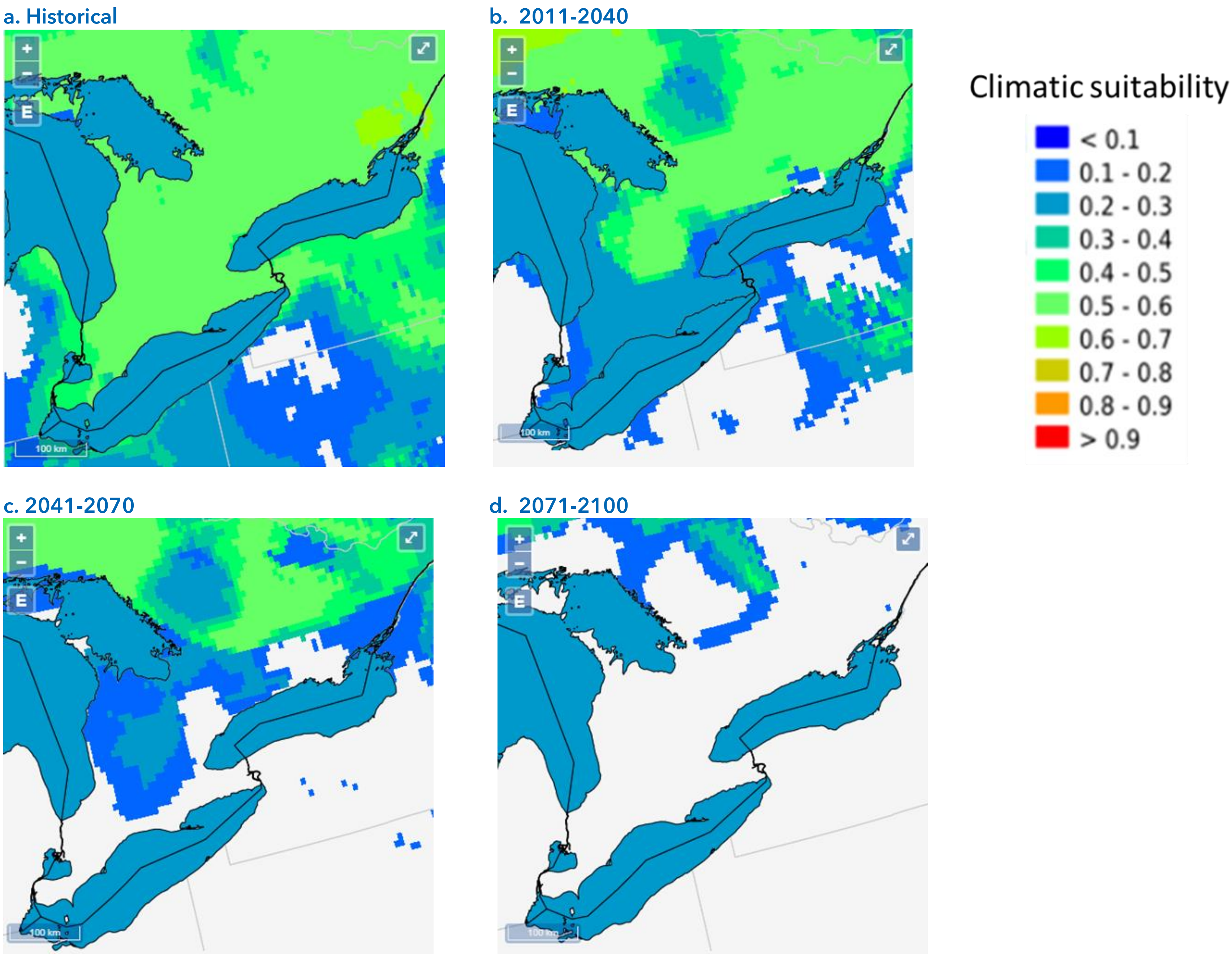
d. 2071-2100



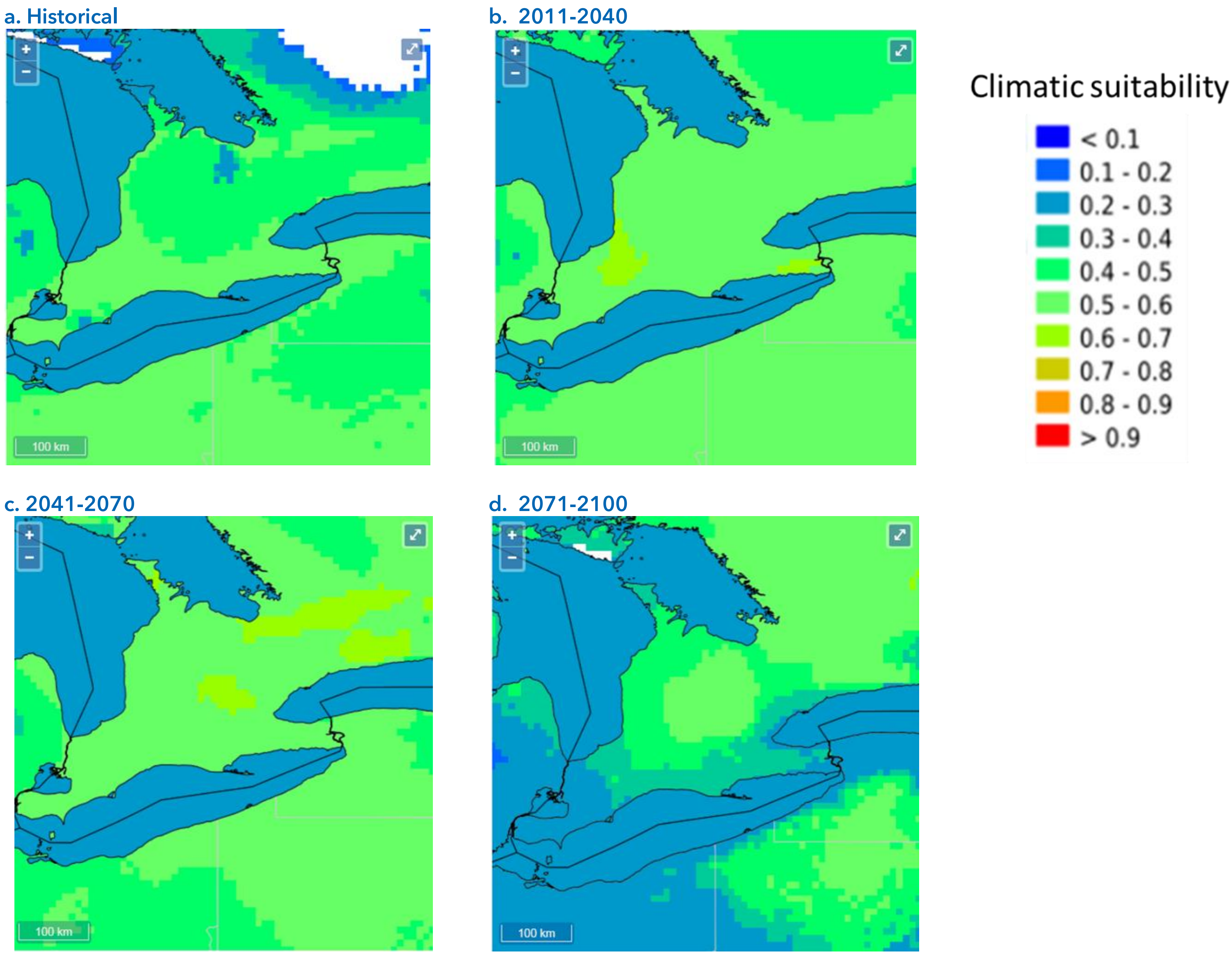
Rhus glabra (Smooth sumac)



Rhus typhina (Staghorn sumac)

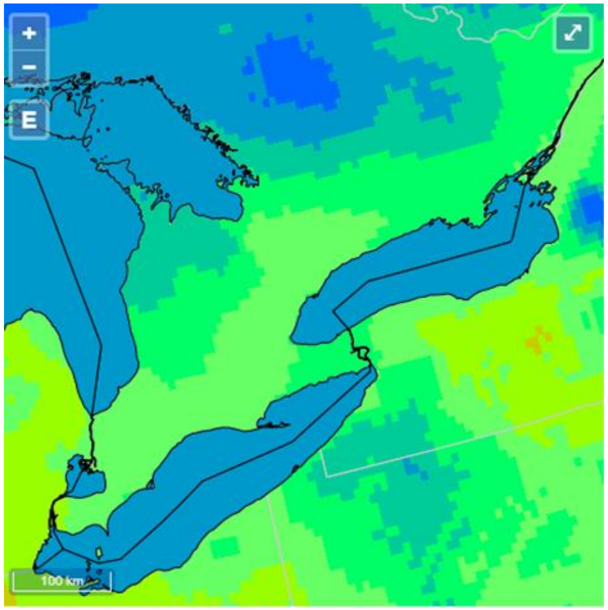


Robinia pseudoacacia (Black locust)

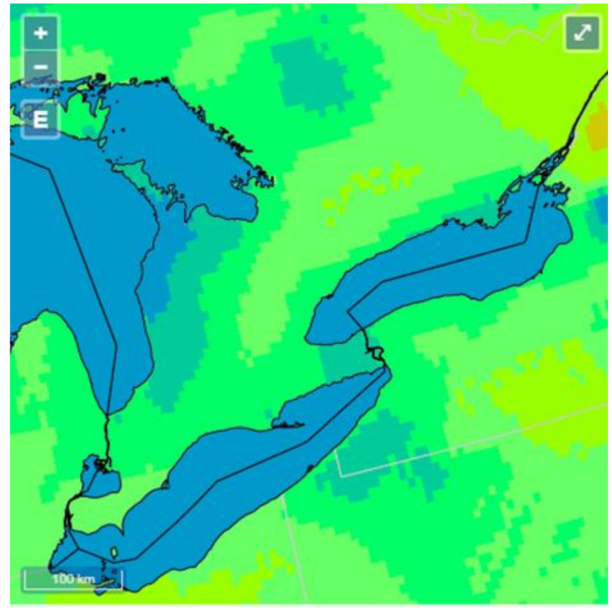


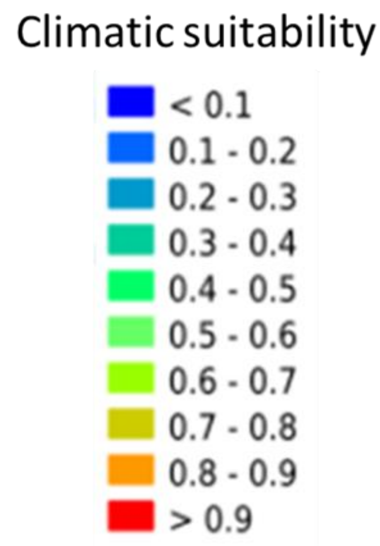
Salix alba (White willow)

a. Historical

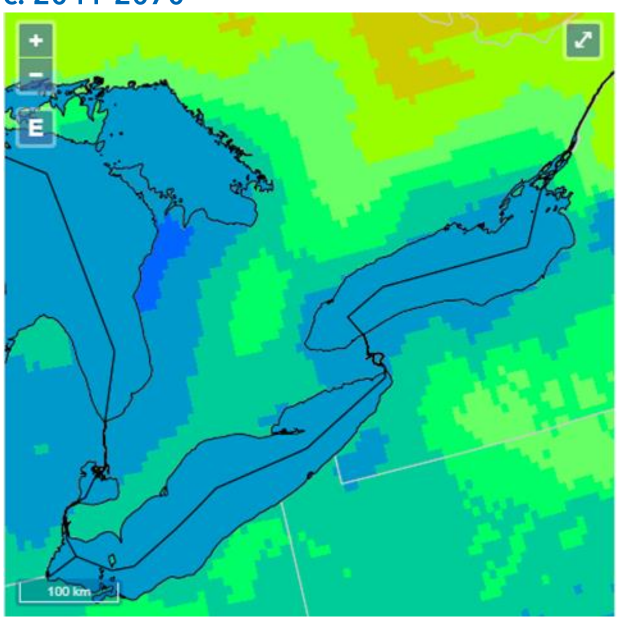


b. 2011-2040

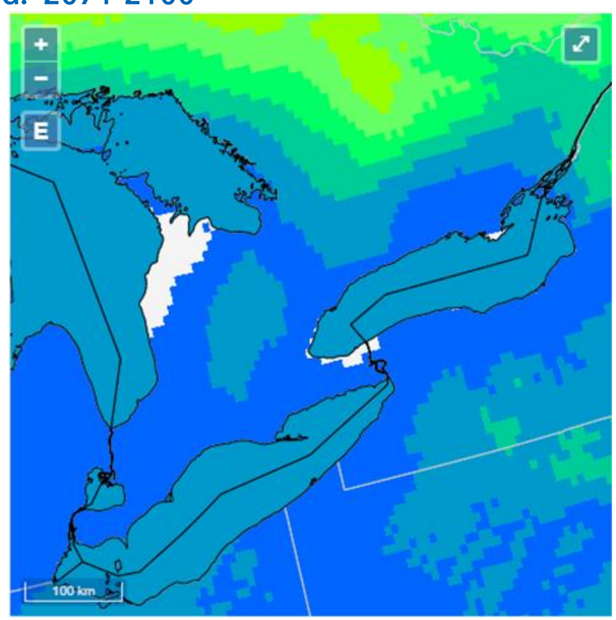




c. 2041-2070

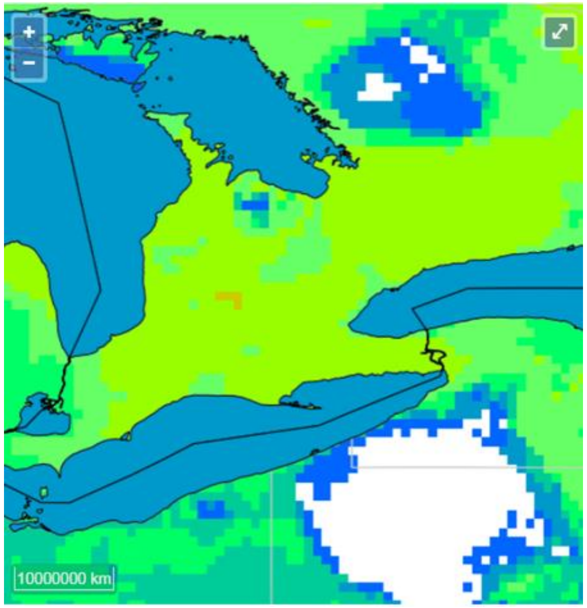


d. 2071-2100

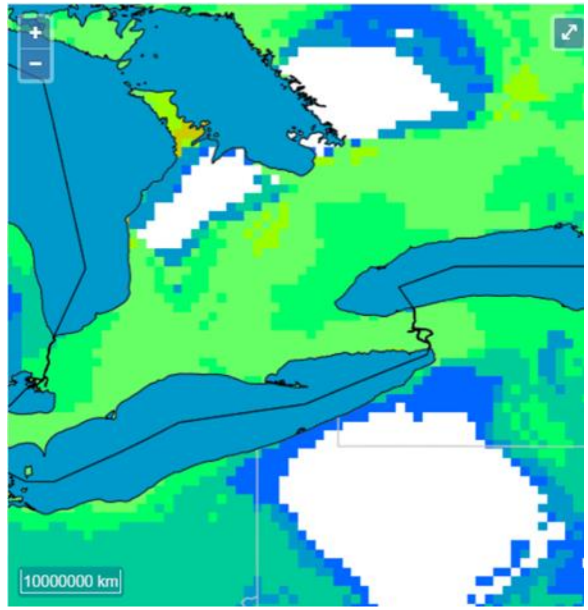


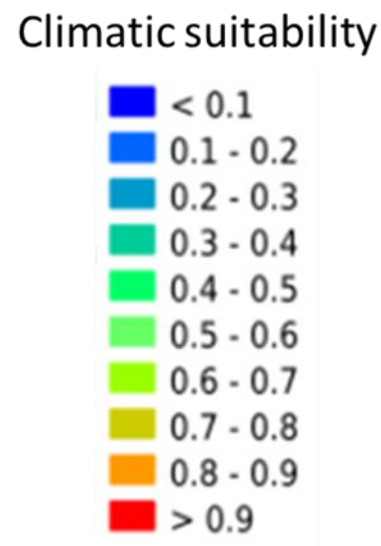
Salix amygdaloides (Peachleaf willow)

a. Historical

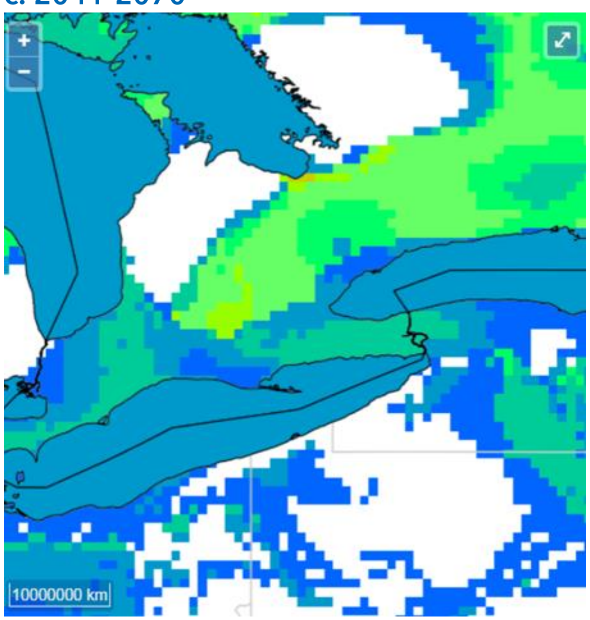


b. 2011-2040

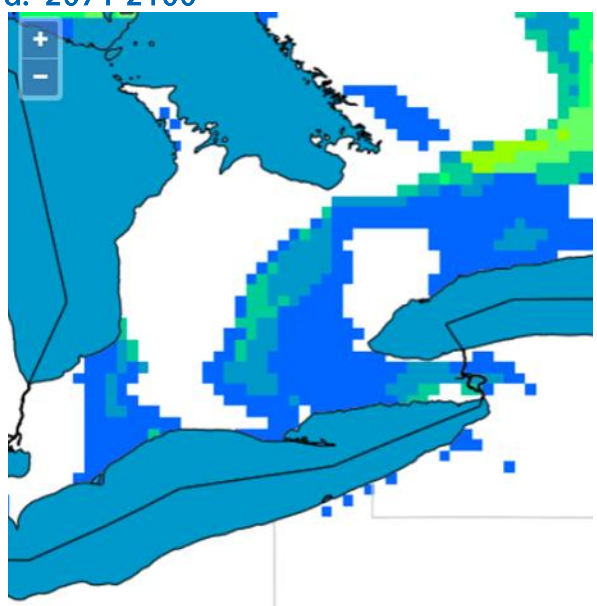




c. 2041-2070

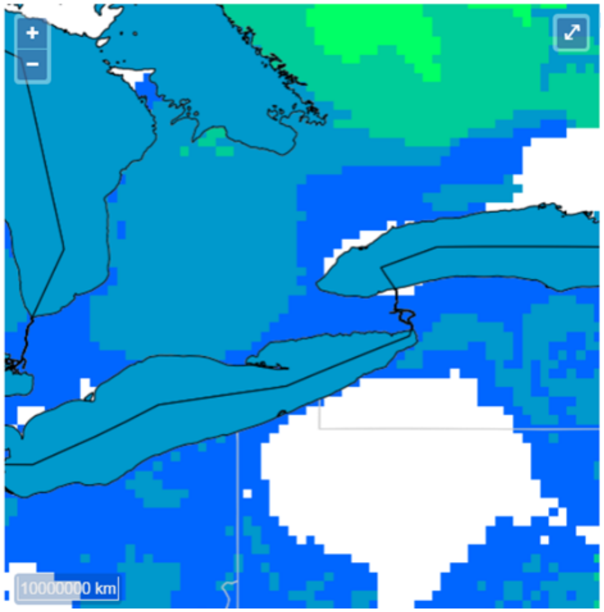


d. 2071-2100

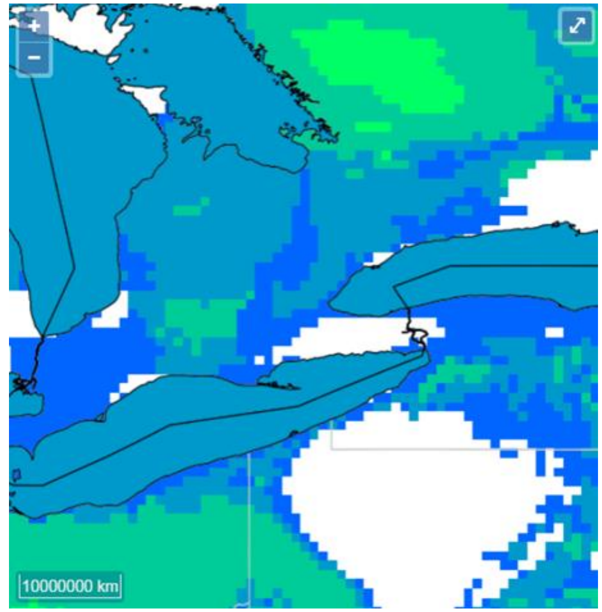


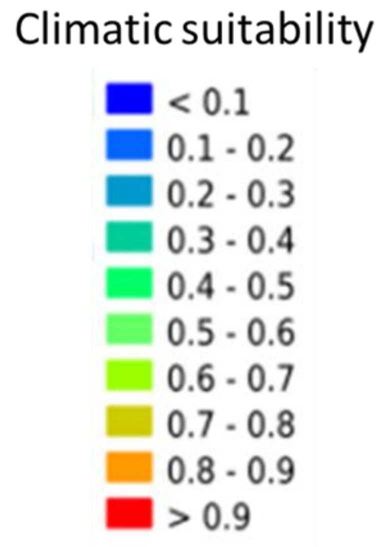
Salix humilis (Upland willow)

a. Historical

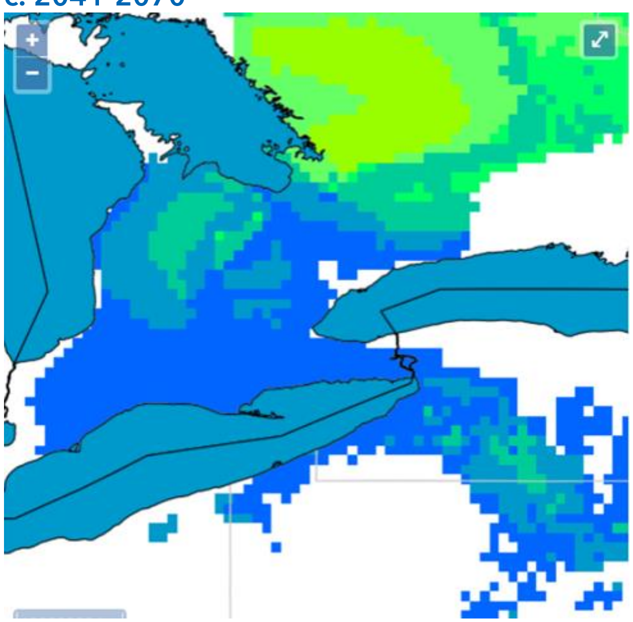


b. 2011-2040

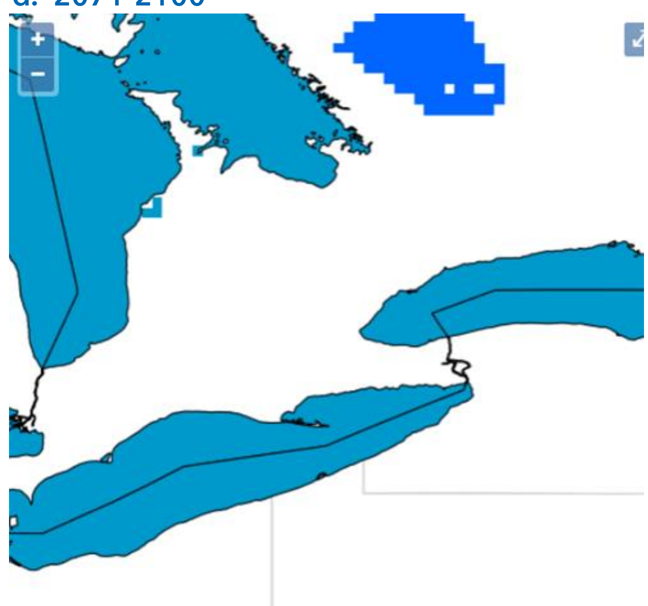




c. 2041-2070

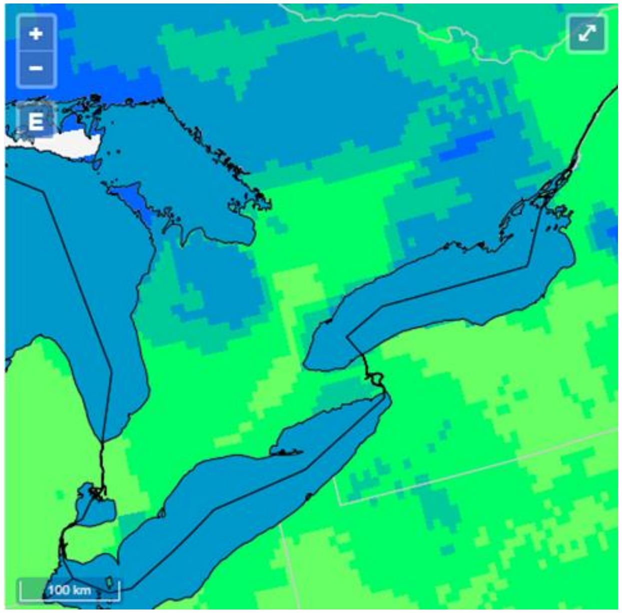


d. 2071-2100

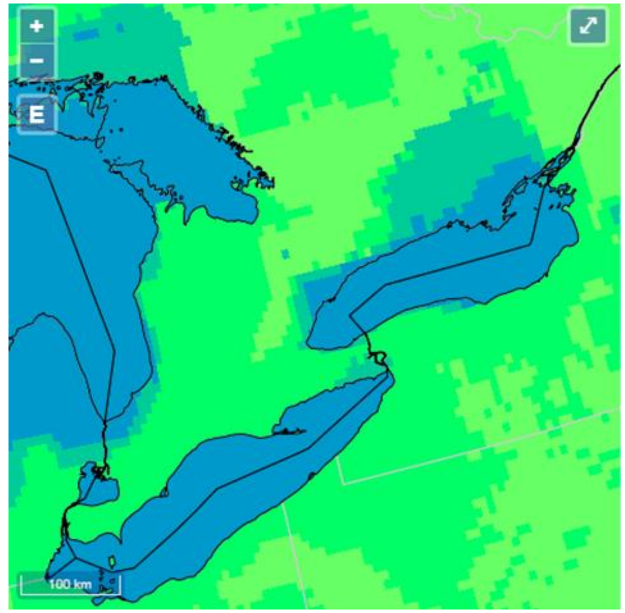


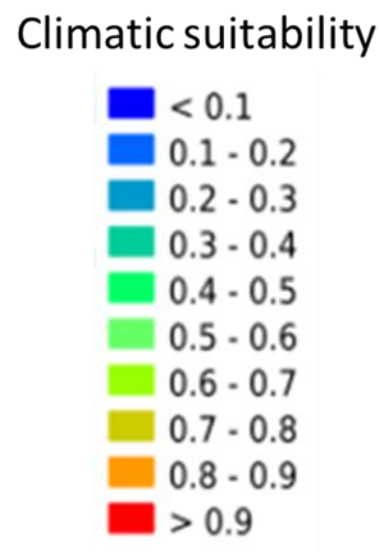
Salix nigra (Black willow)

a. Historical

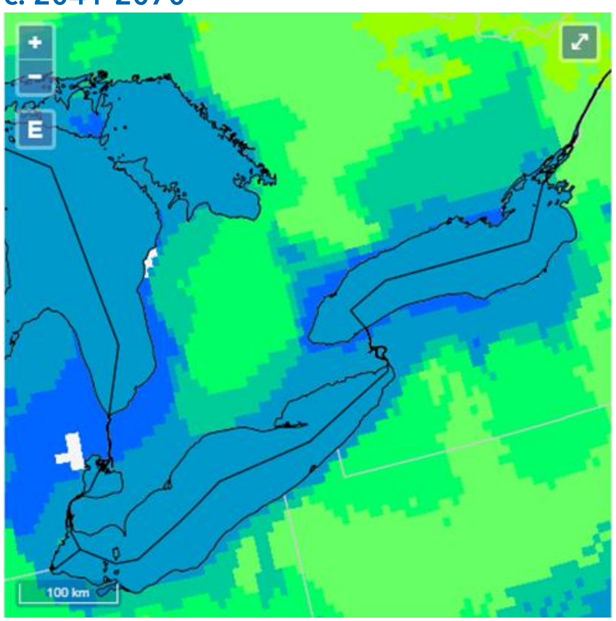


b. 2011-2040

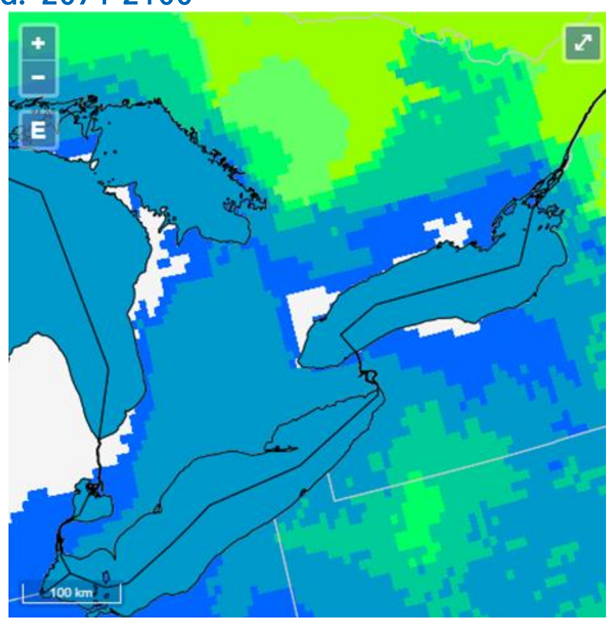




c. 2041-2070

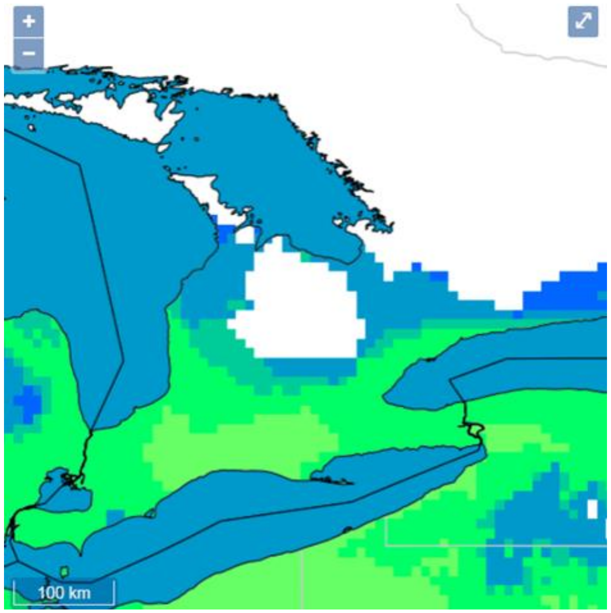


d. 2071-2100

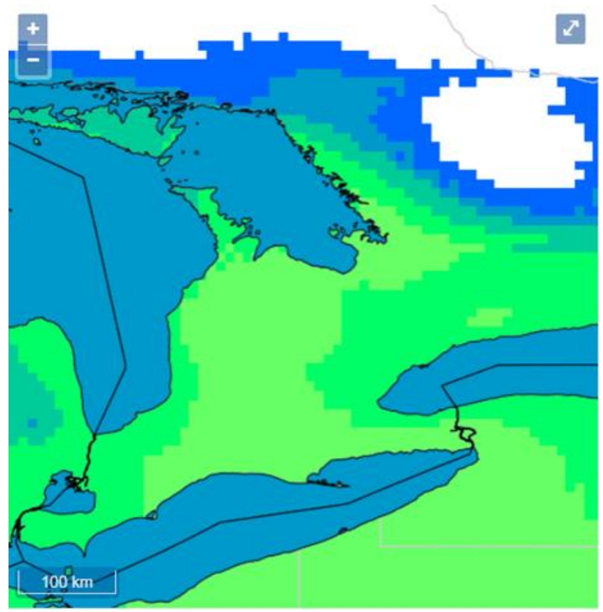


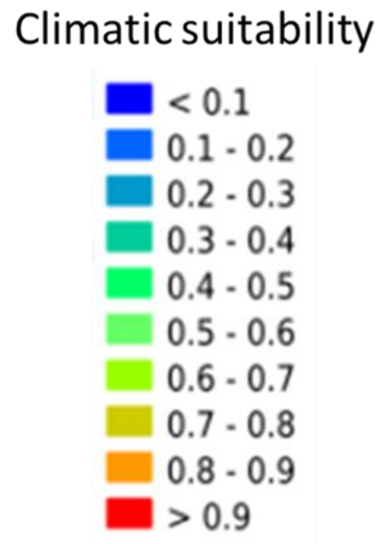
Sassafras albidum (Sassafras)

a. Historical

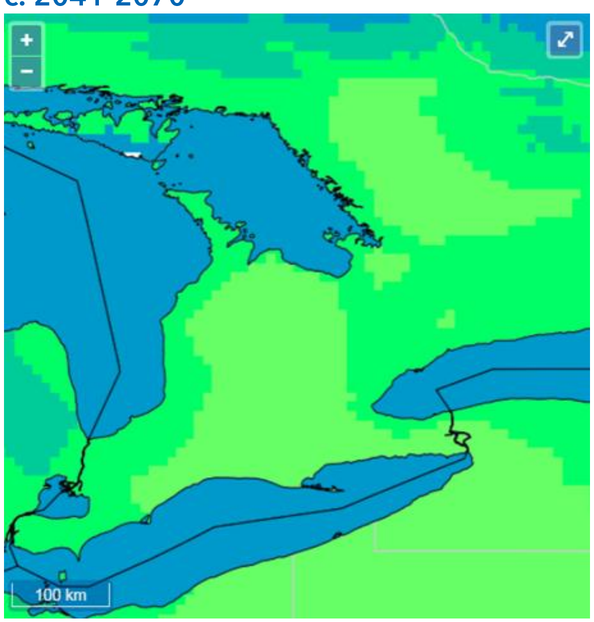


b. 2011-2040

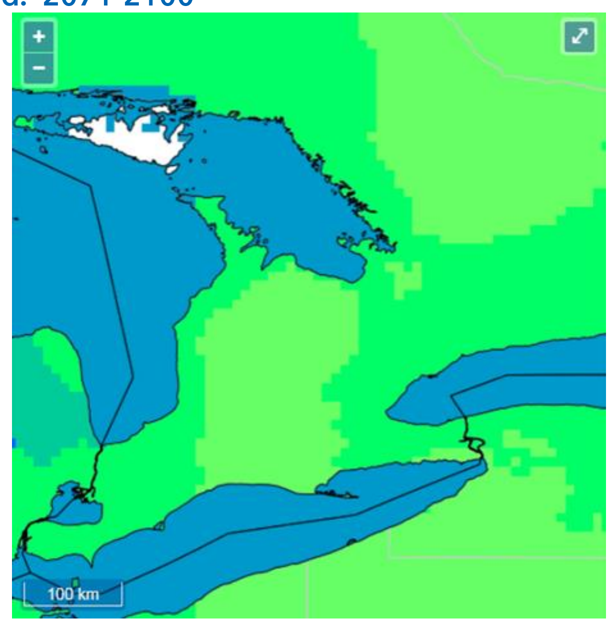




c. 2041-2070

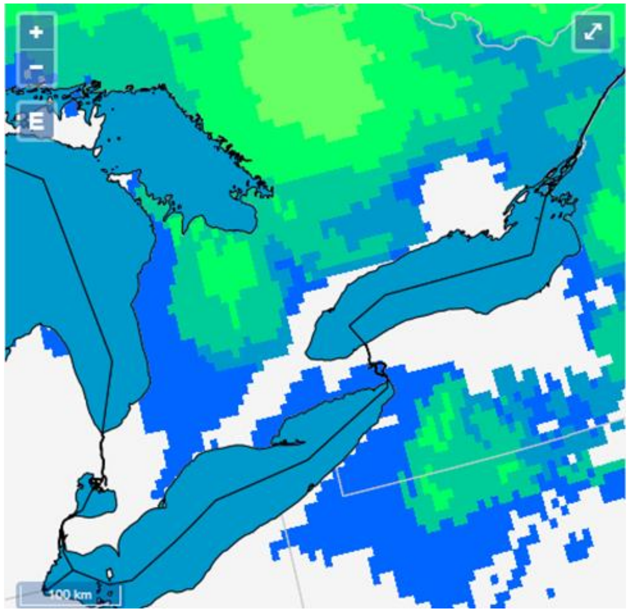


d. 2071-2100

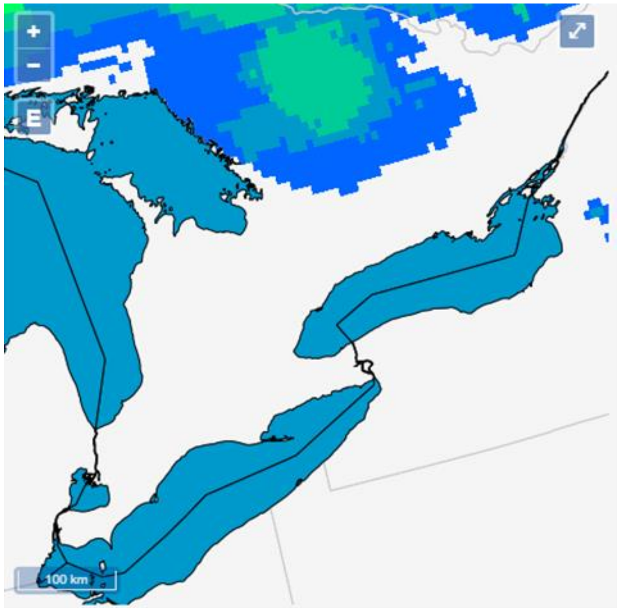


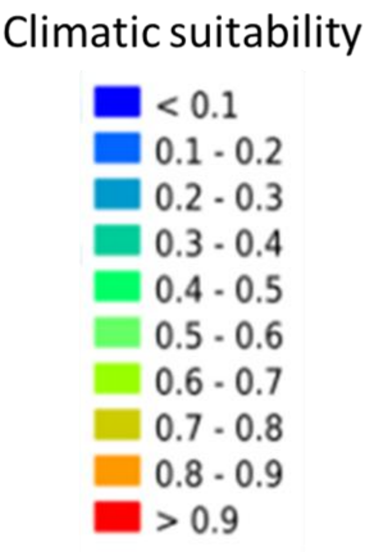
Sorbus americana (Northern mountain ash)

a. Historical

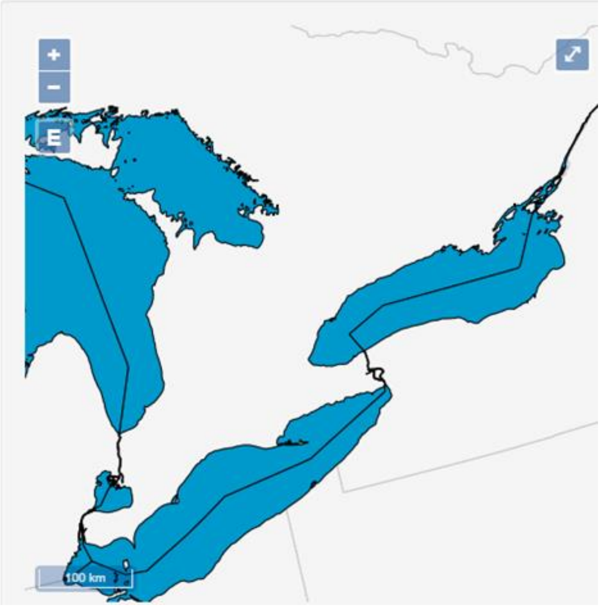


b. 2011-2040

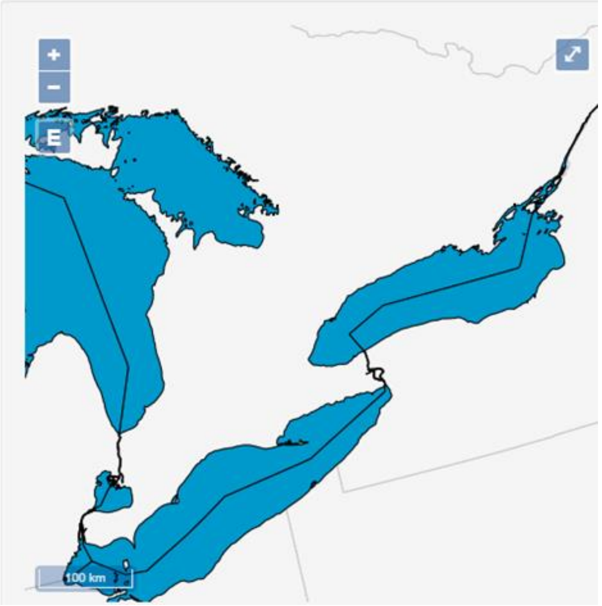




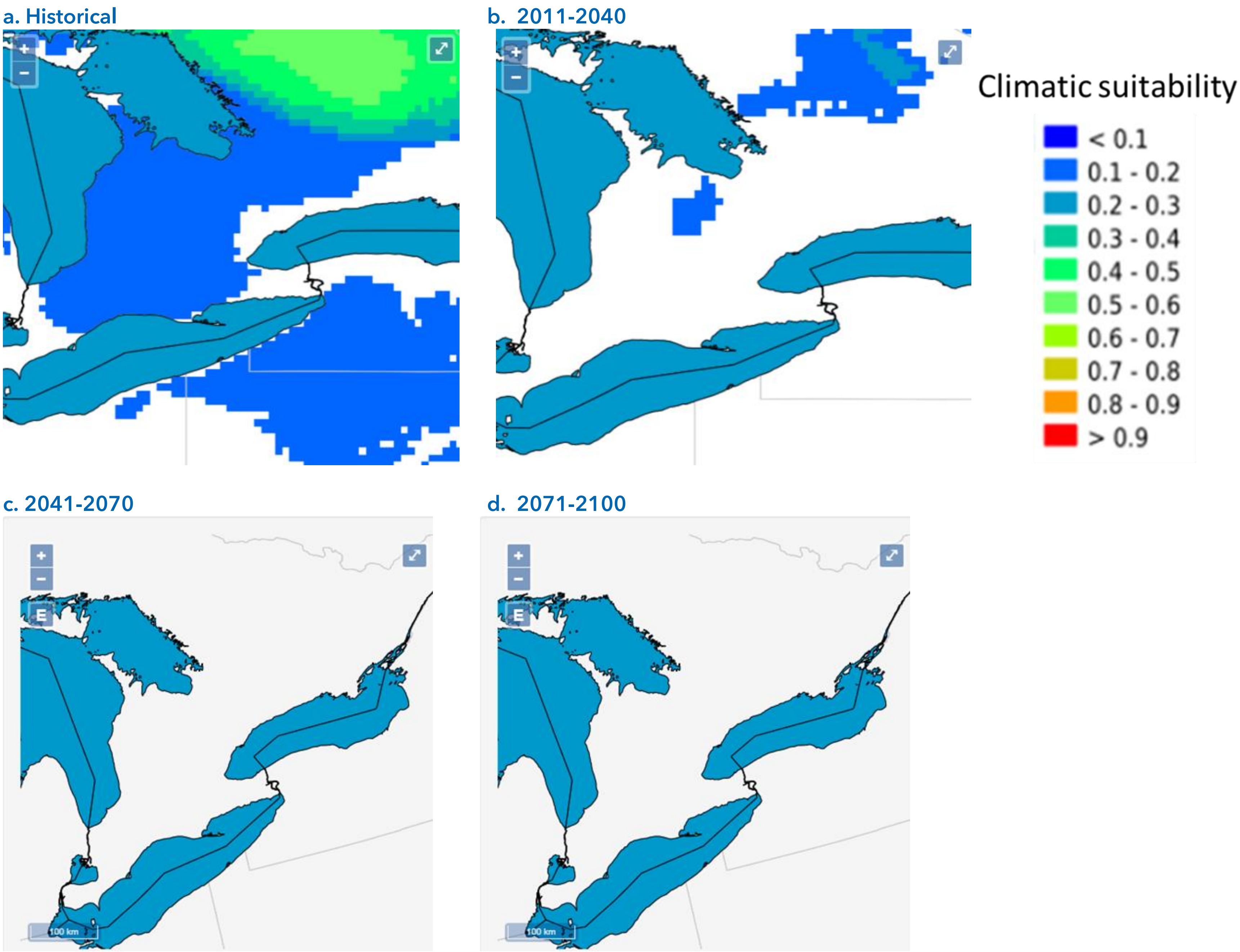
c. 2041-2070



d. 2071-2100

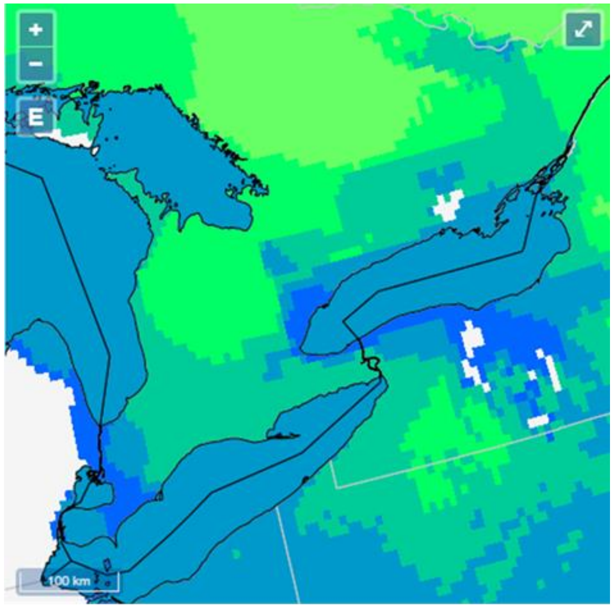


Sorbus decora (Showy mountain ash)

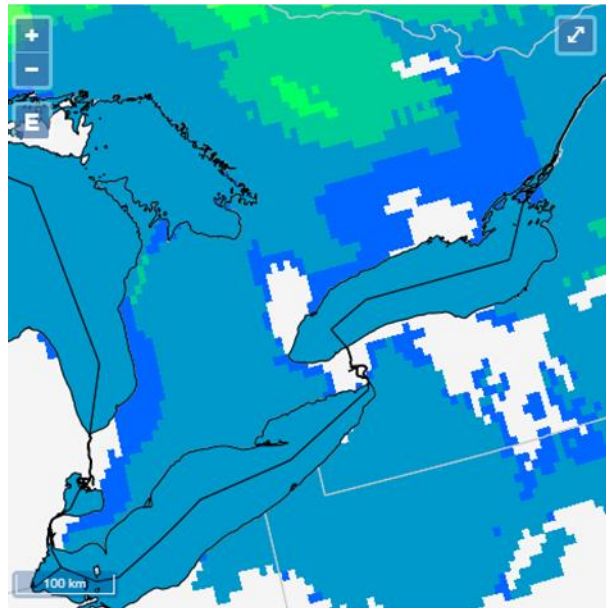


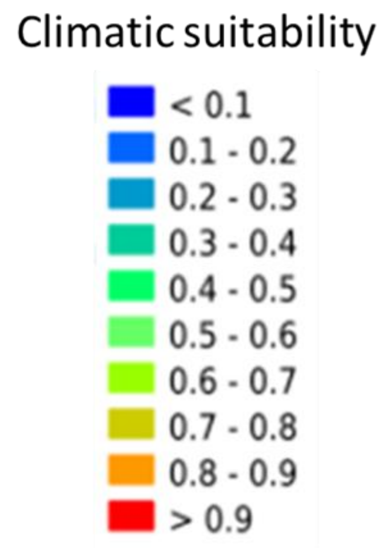
Taxus canadensis (Canada yew)

a. Historical

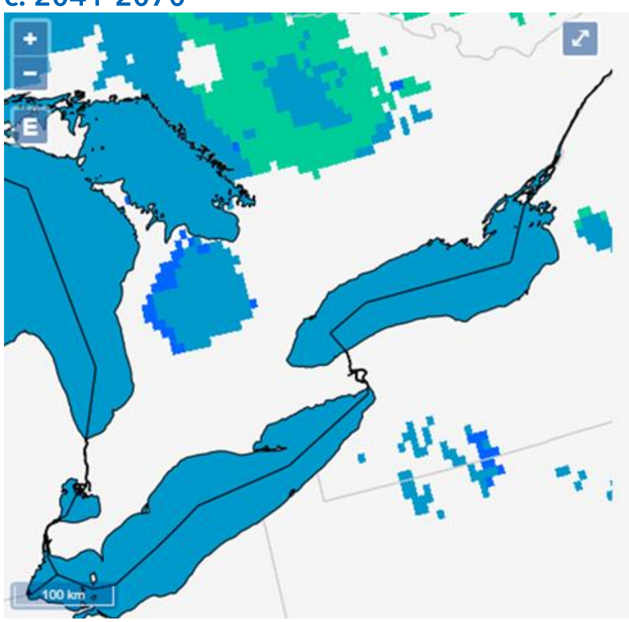


b. 2011-2040

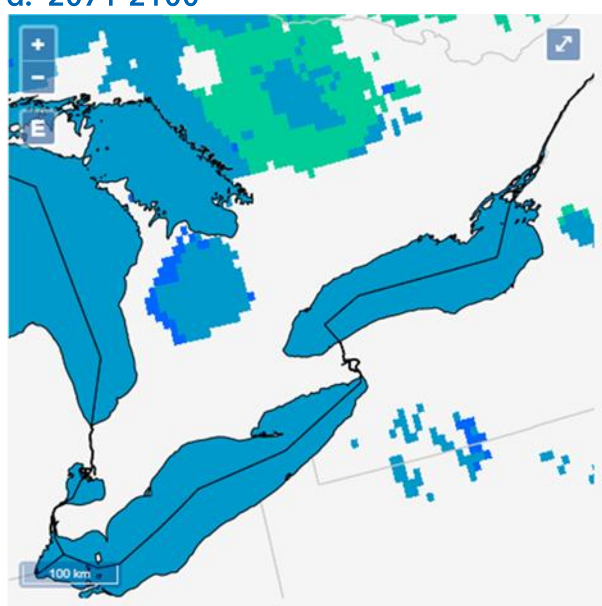




c. 2041-2070

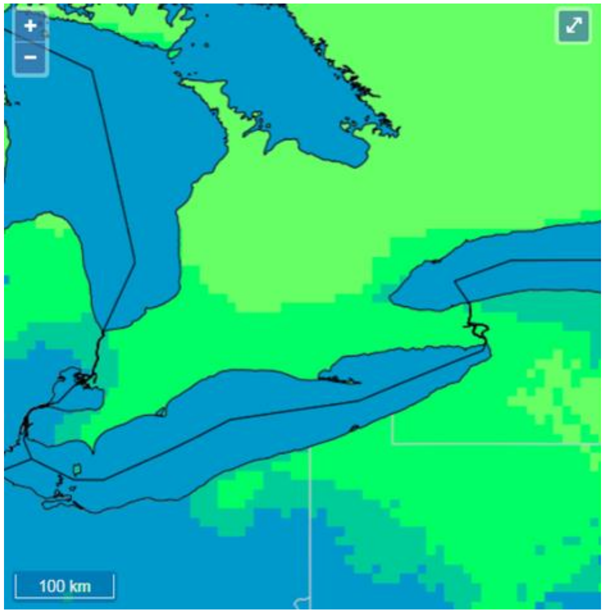


d. 2071-2100

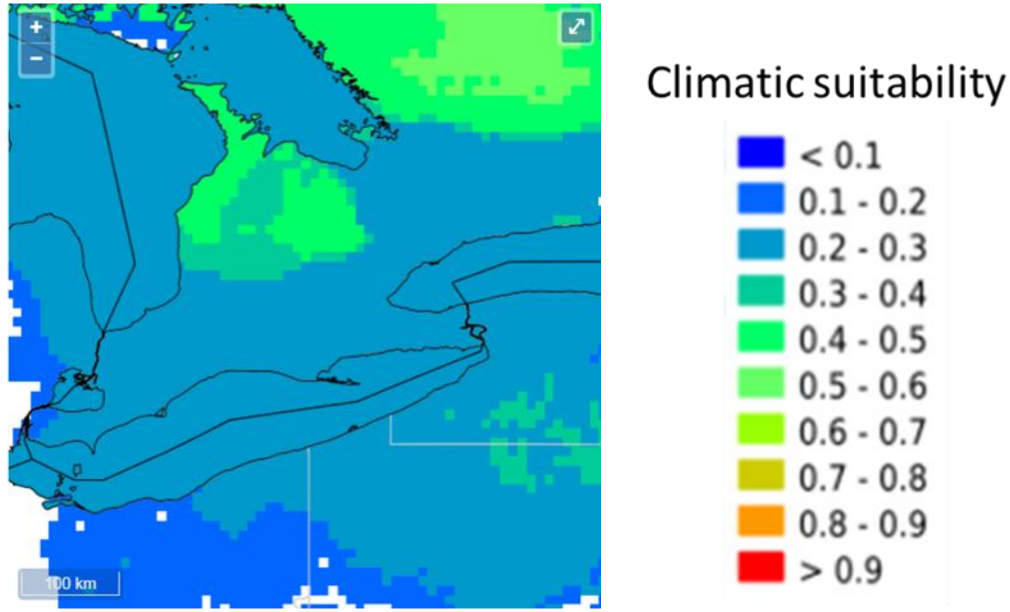


Thuja occidentalis (Eastern white cedar)

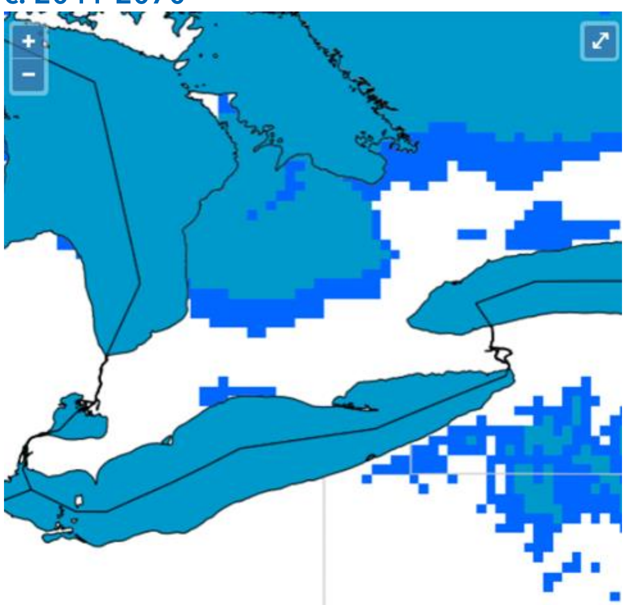
a. Historical



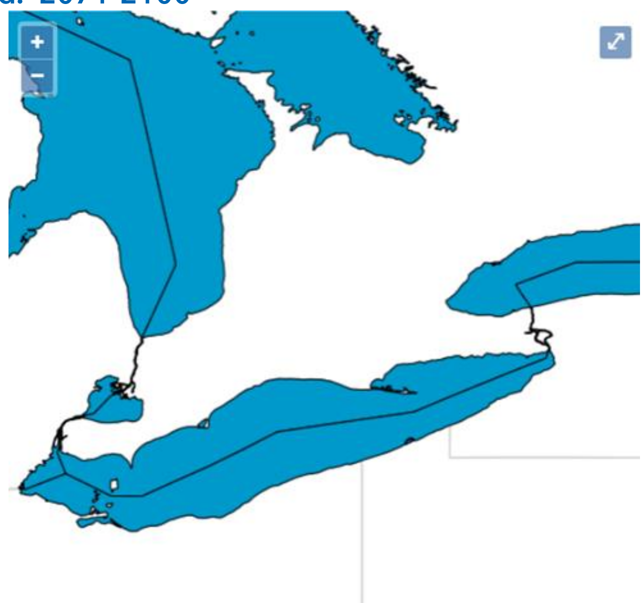
b. 2011-2040



c. 2041-2070

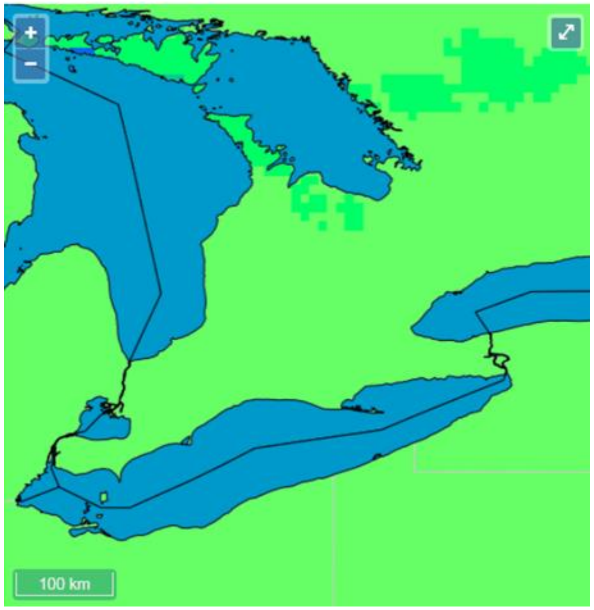


d. 2071-2100

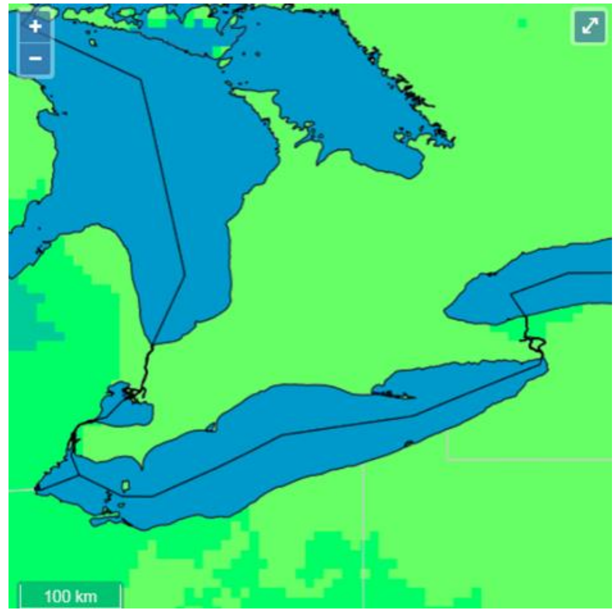


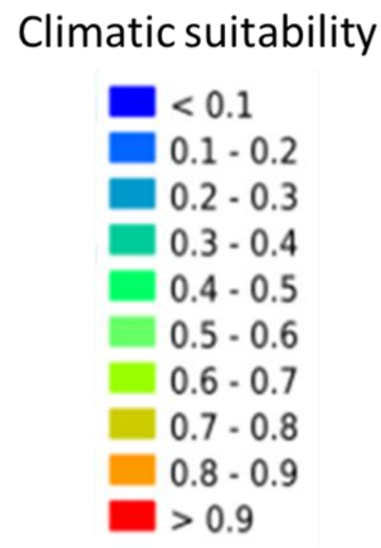
Tilia americana (American basswood)

a. Historical

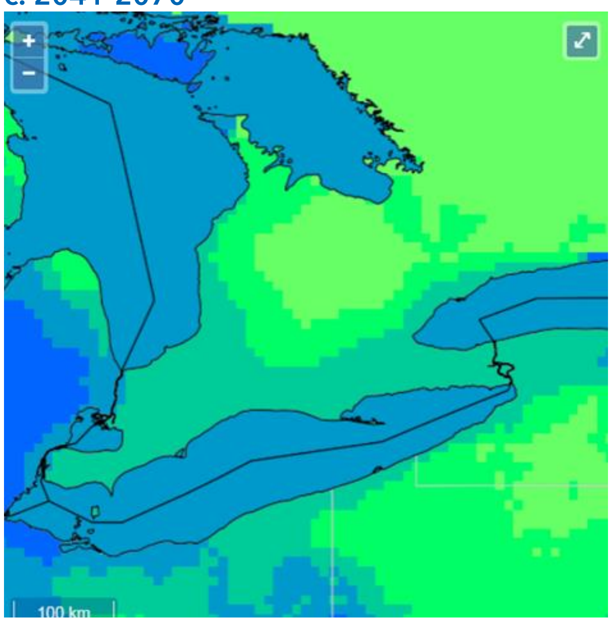


b. 2011-2040

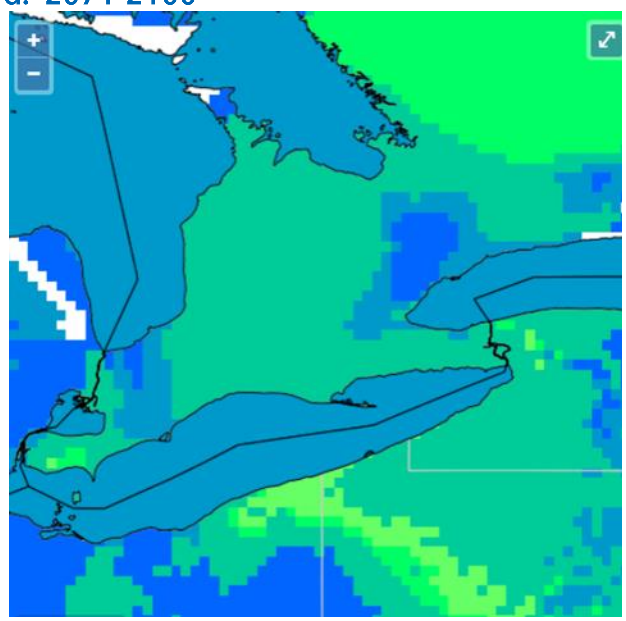




c. 2041-2070

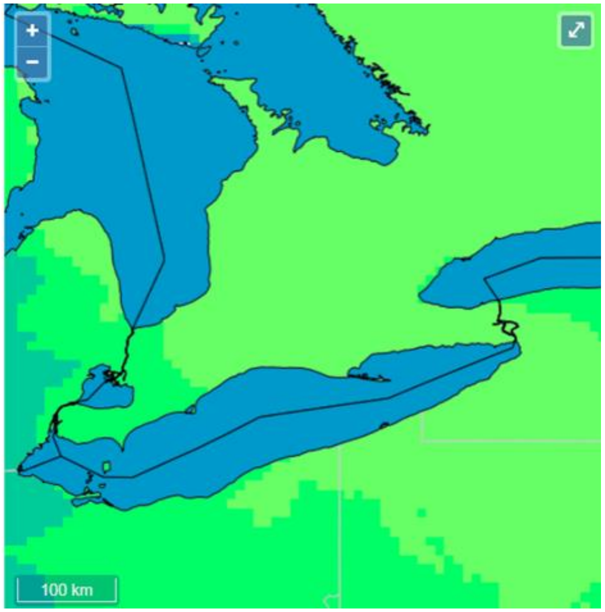


d. 2071-2100

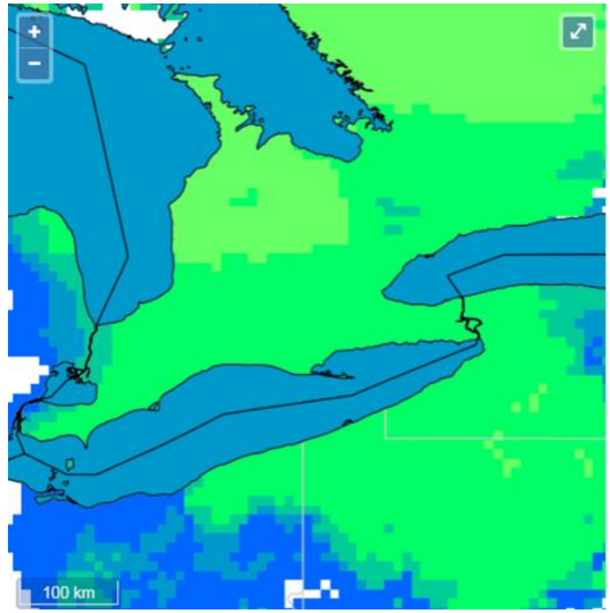


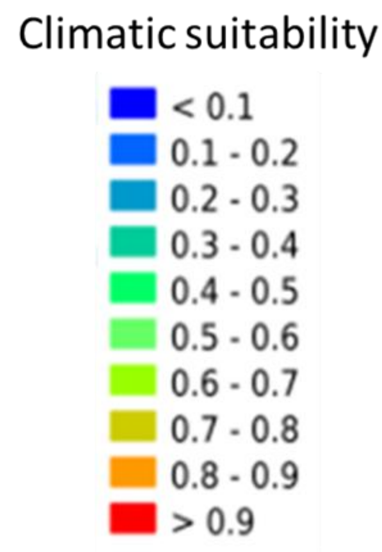
Tsuga canadensis (Eastern hemlock)

a. Historical

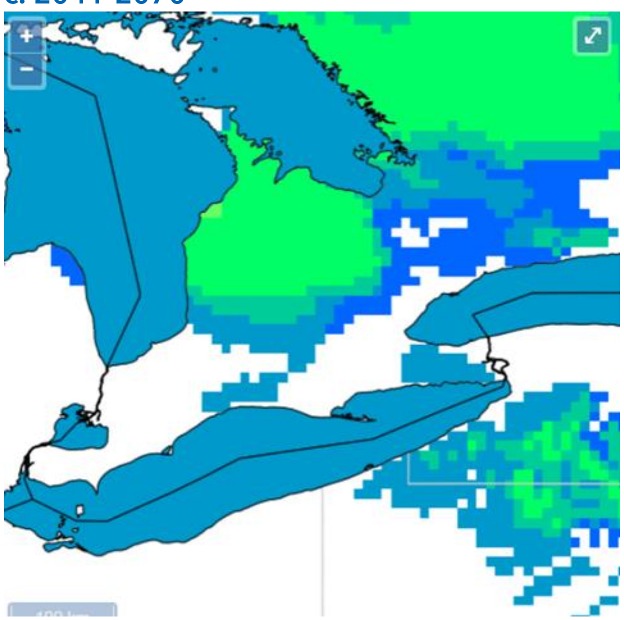


b. 2011-2040

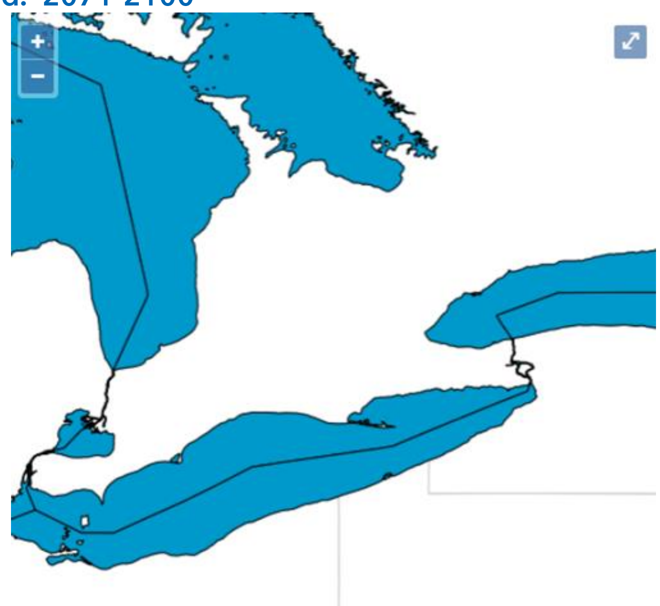




c. 2041-2070

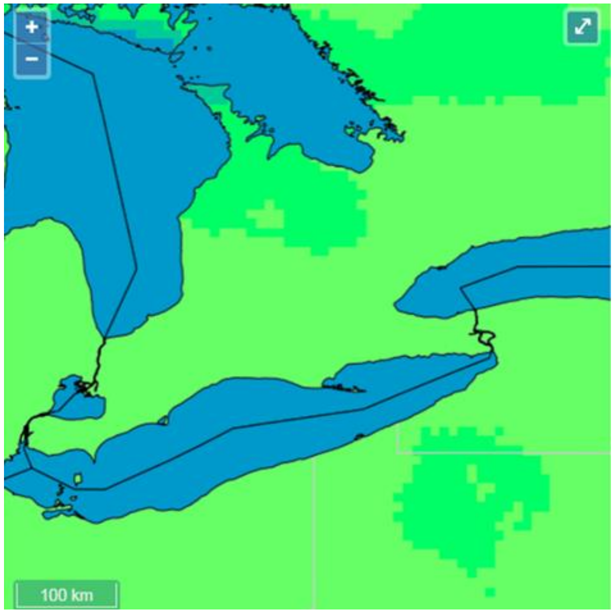


d. 2071-2100

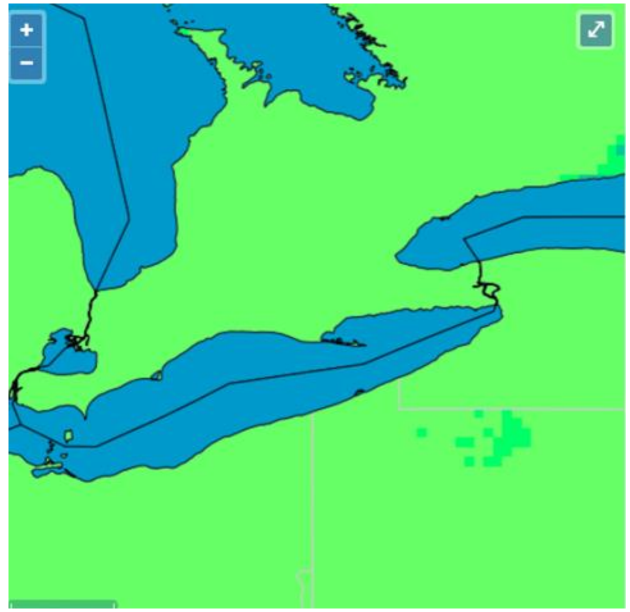


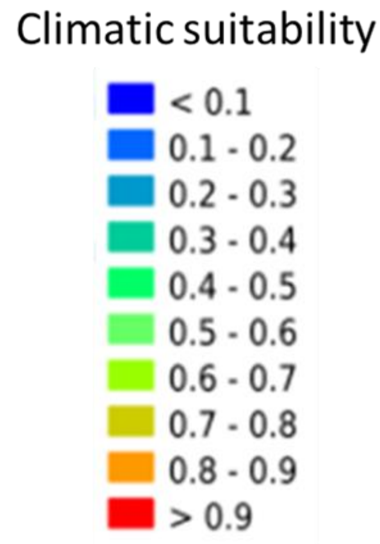
Ulmus americana (White elm)

a. Historical

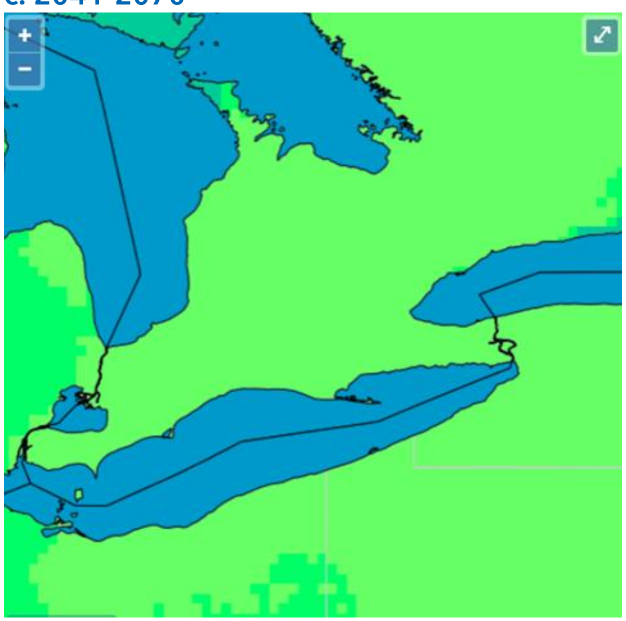


b. 2011-2040

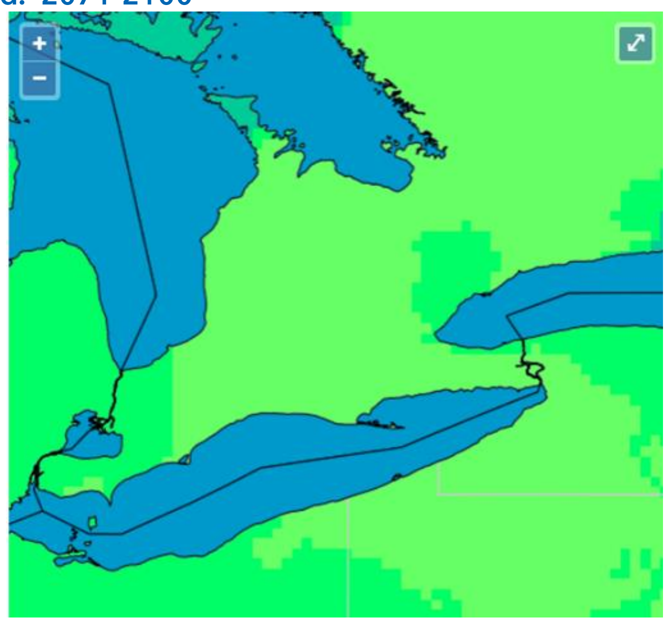




c. 2041-2070

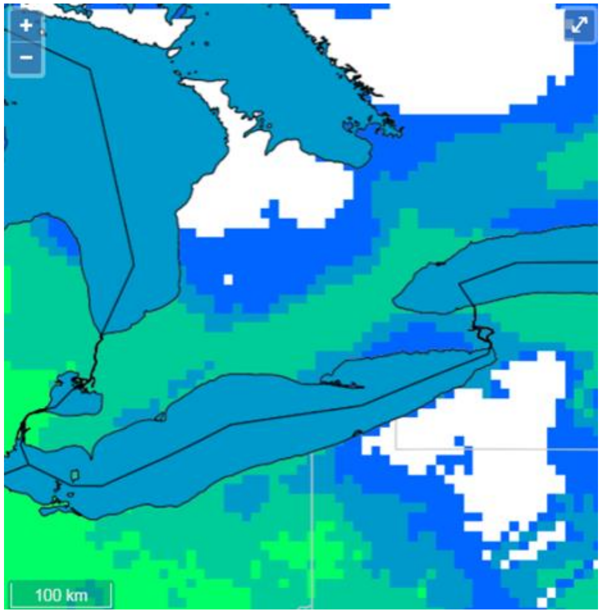


d. 2071-2100

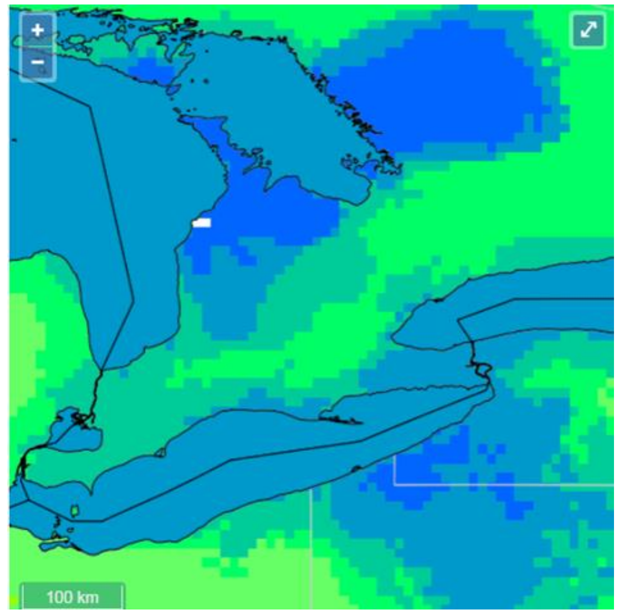


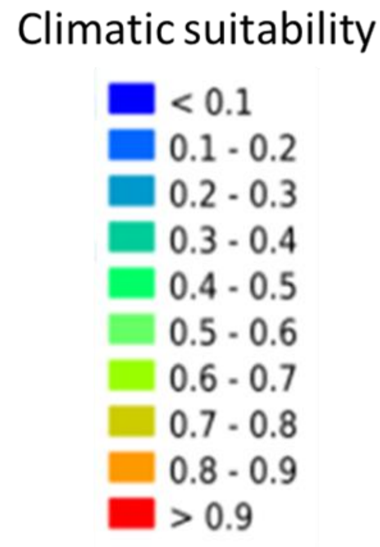
Ulmus pumila (Siberian elm)

a. Historical

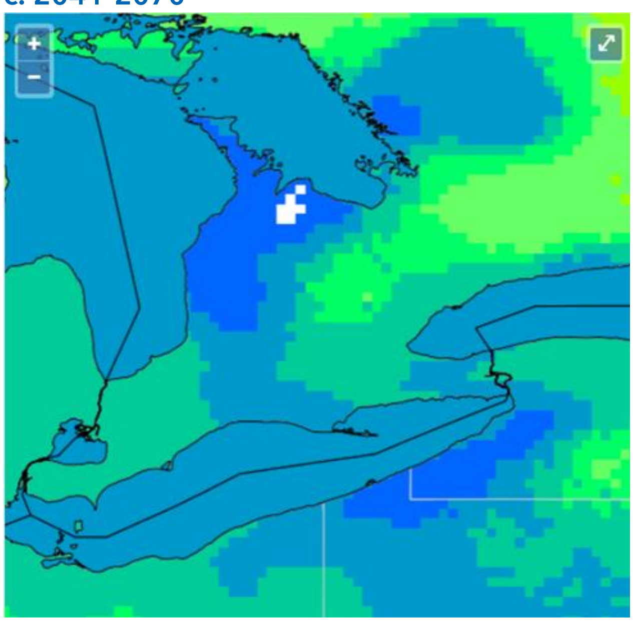


b. 2011-2040

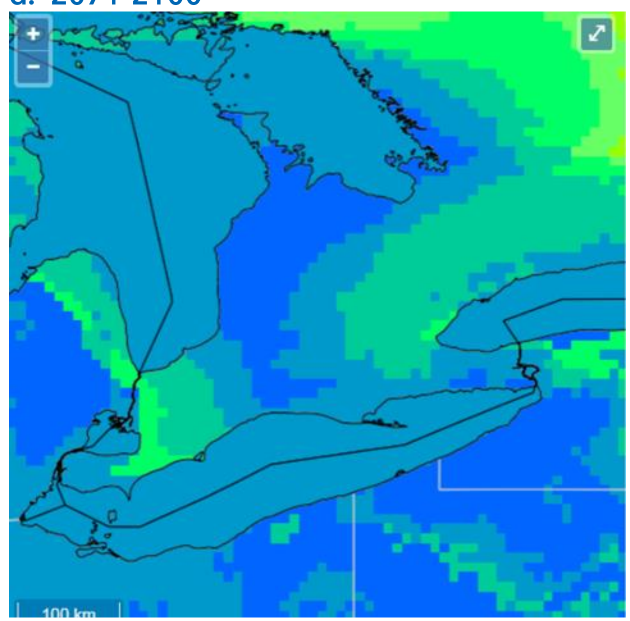




c. 2041-2070

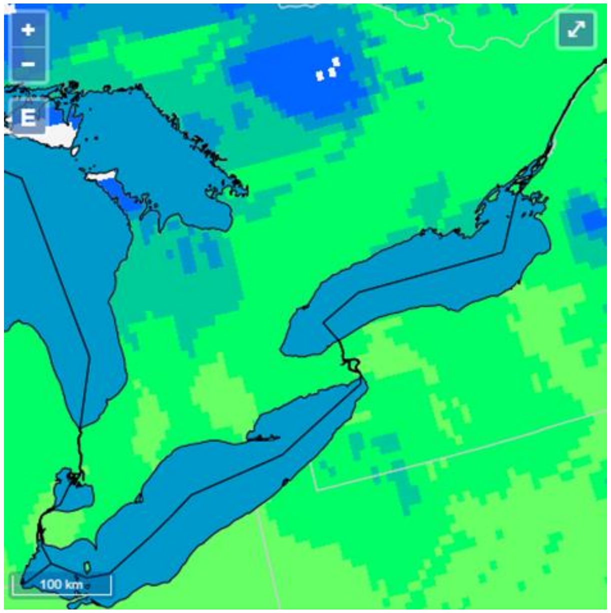


d. 2071-2100

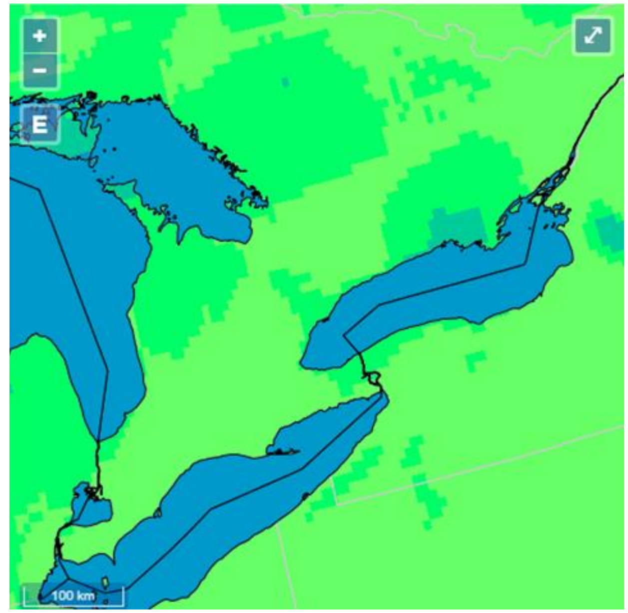


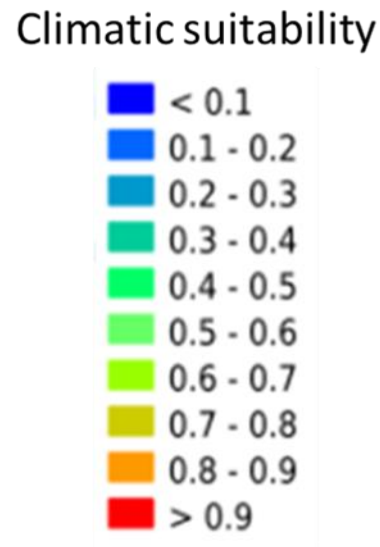
Ulmus rubra (Slippery elm)

a. Historical

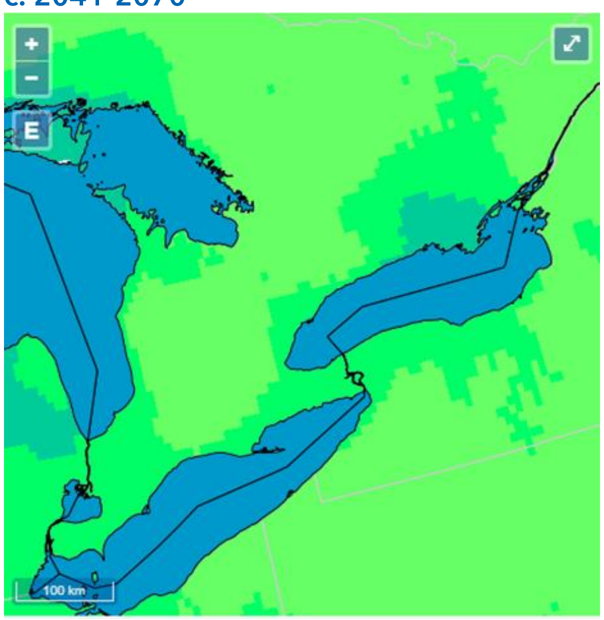


b. 2011-2040

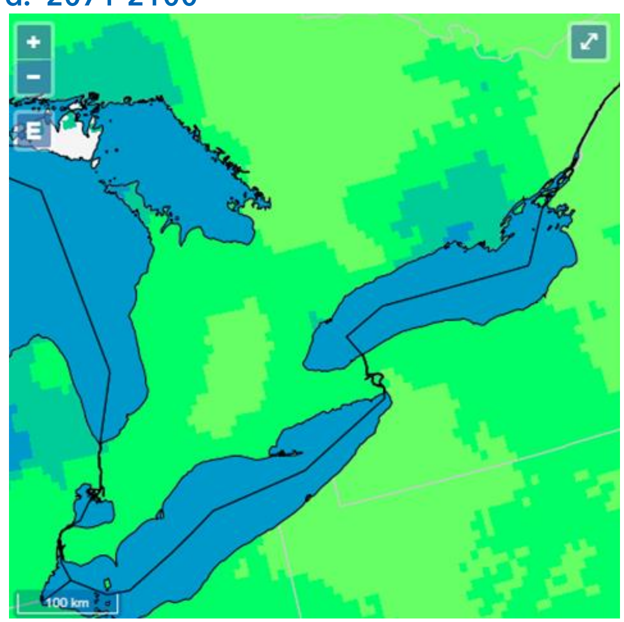




c. 2041-2070

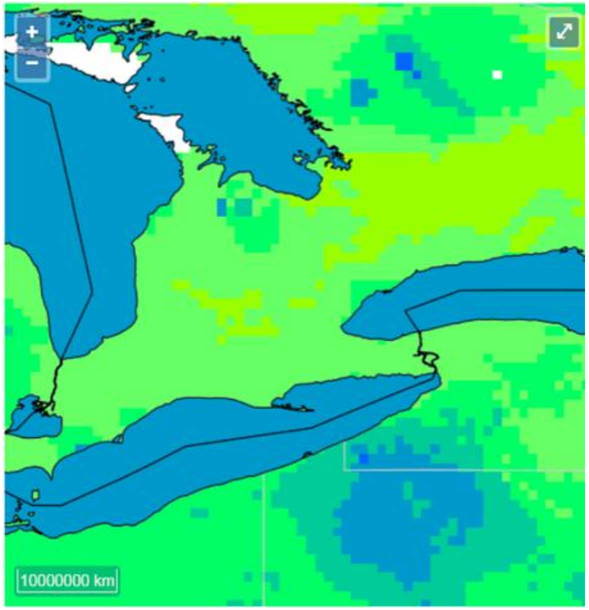


d. 2071-2100

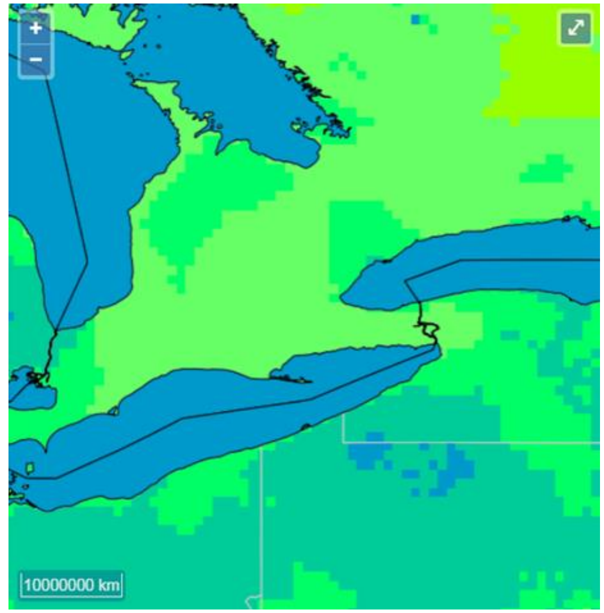


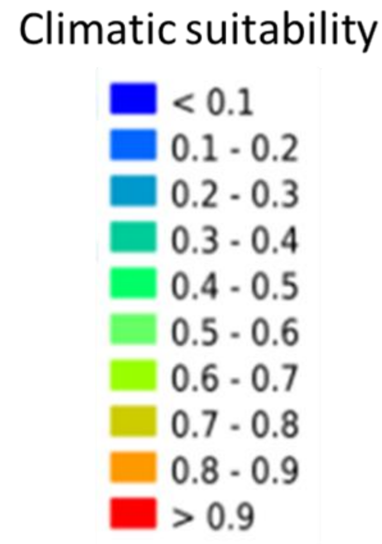
Ulmus thomasii (Rock elm)

a. Historical

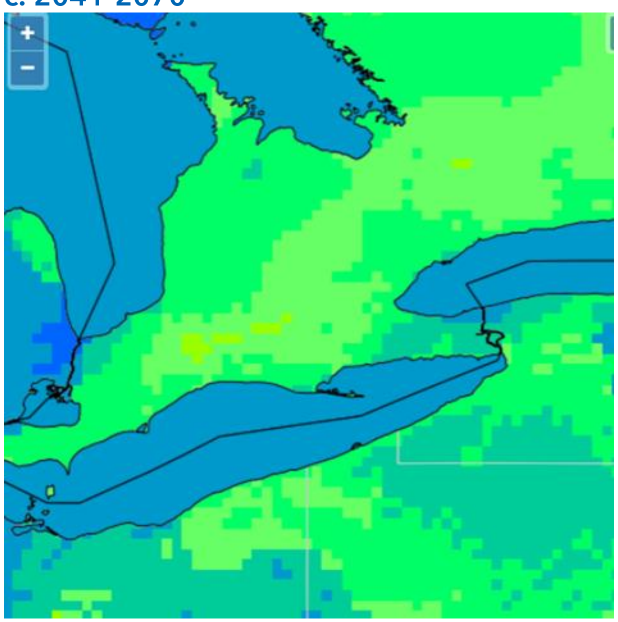


b. 2011-2040





c. 2041-2070



d. 2071-2100