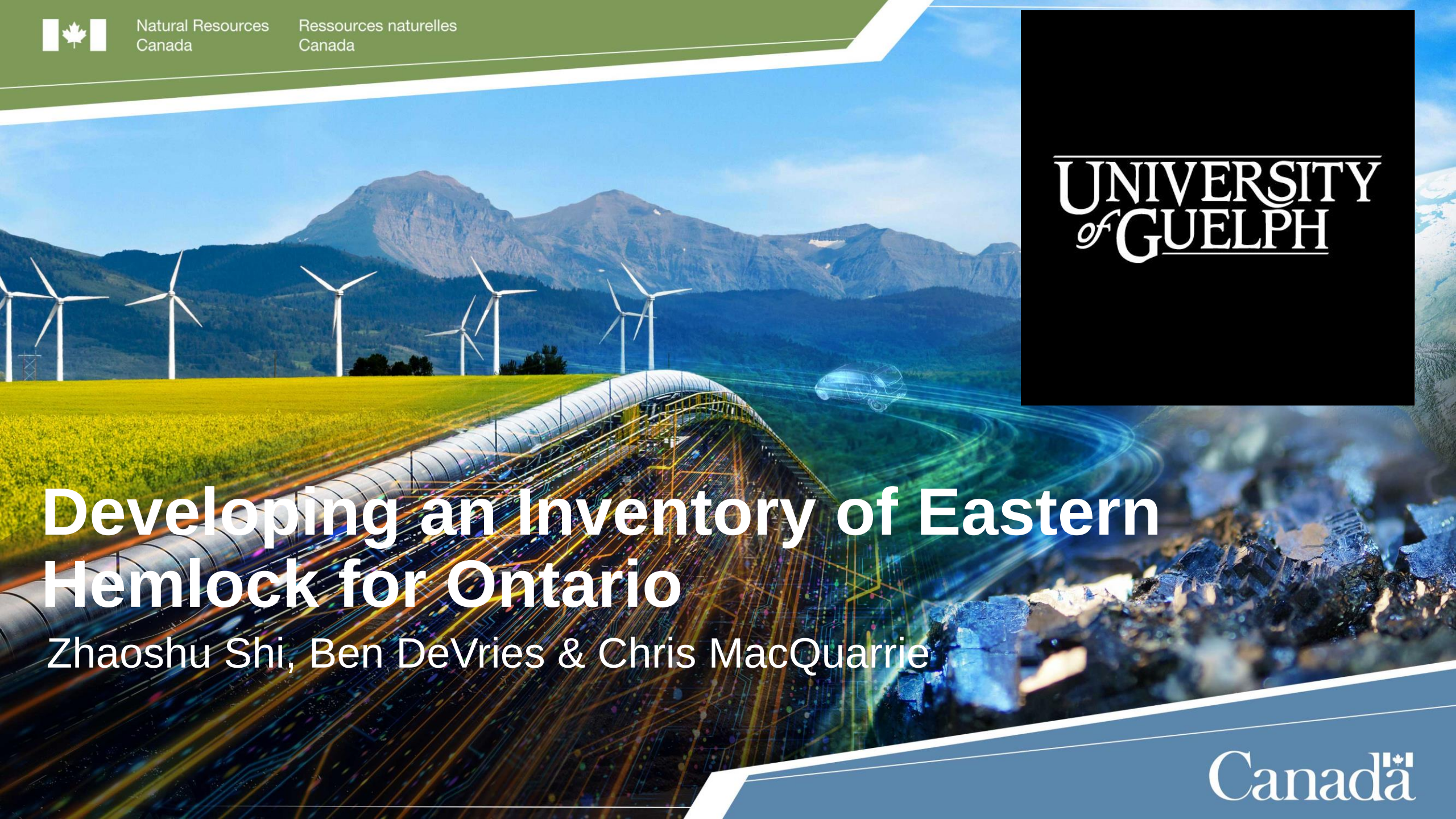
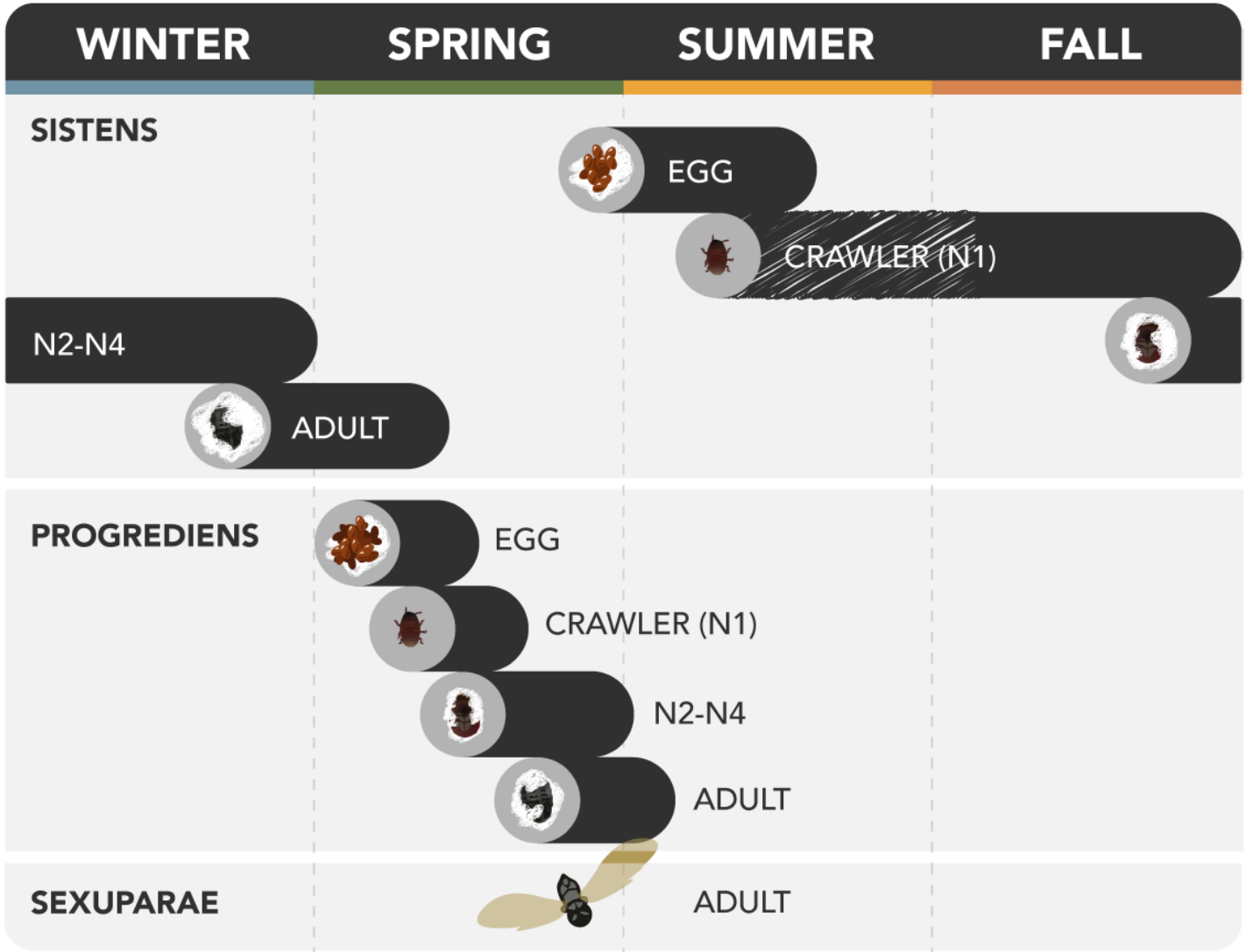
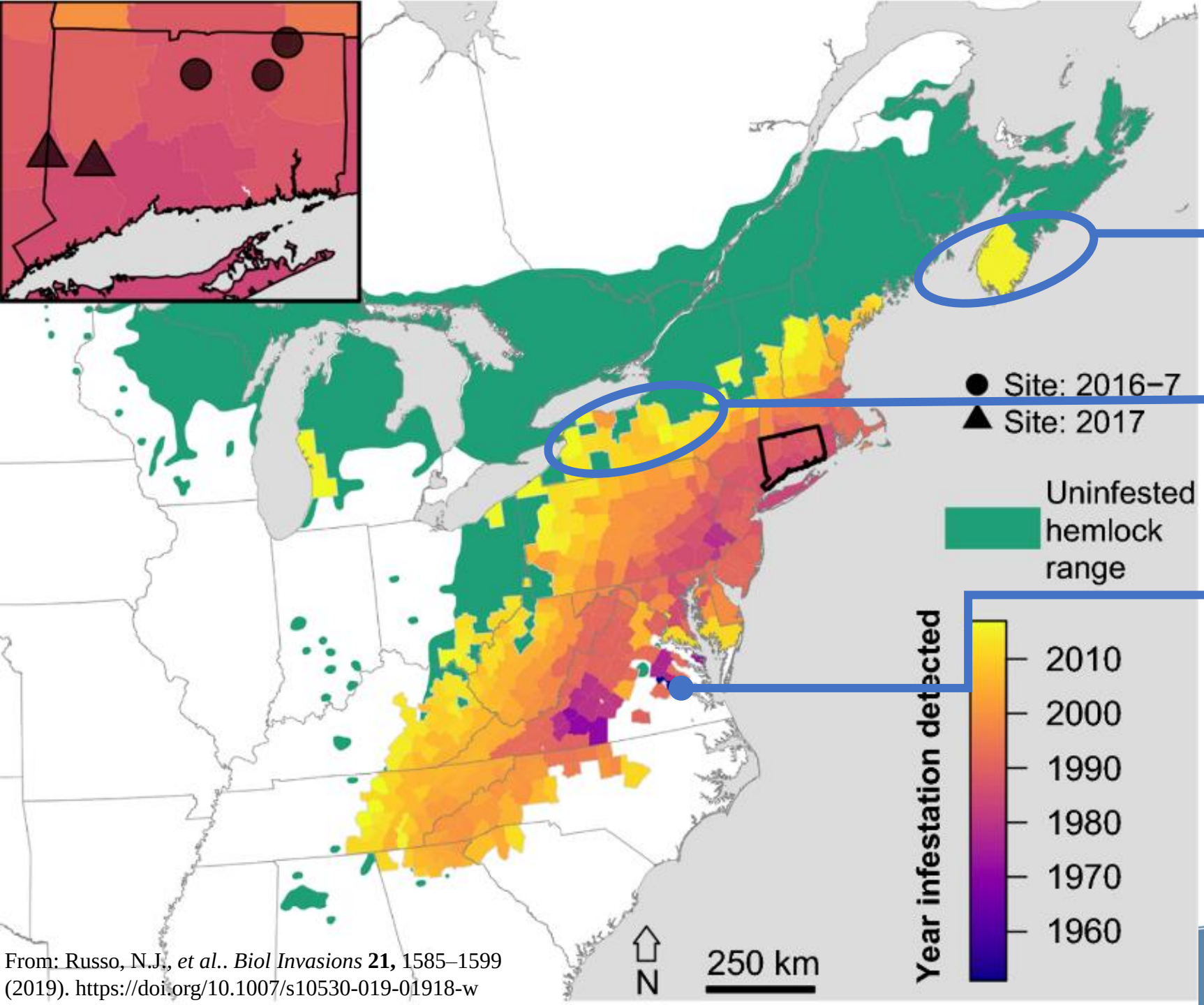

Natural Resources Canada
Ressources naturelles Canada
UNIVERSITY of GUELPH
Developing an Inventory of Eastern Hemlock for Ontario
Zhaoshu Shi, Ben DeVries & Chris MacQuarrie
Canada



Created by the Invasive Species Centre in collaboration with the Canadian Forest Service.



Nova Scotia detected in 2017

Upper New York state in 2000s

Initial detection in Virginia in 1950s

From: Russo, N.J., *et al.*. *Biol Invasions* **21,** 1585–1599 (2019). https://doi.org/10.1007/s10530-019-01918-w

Canada

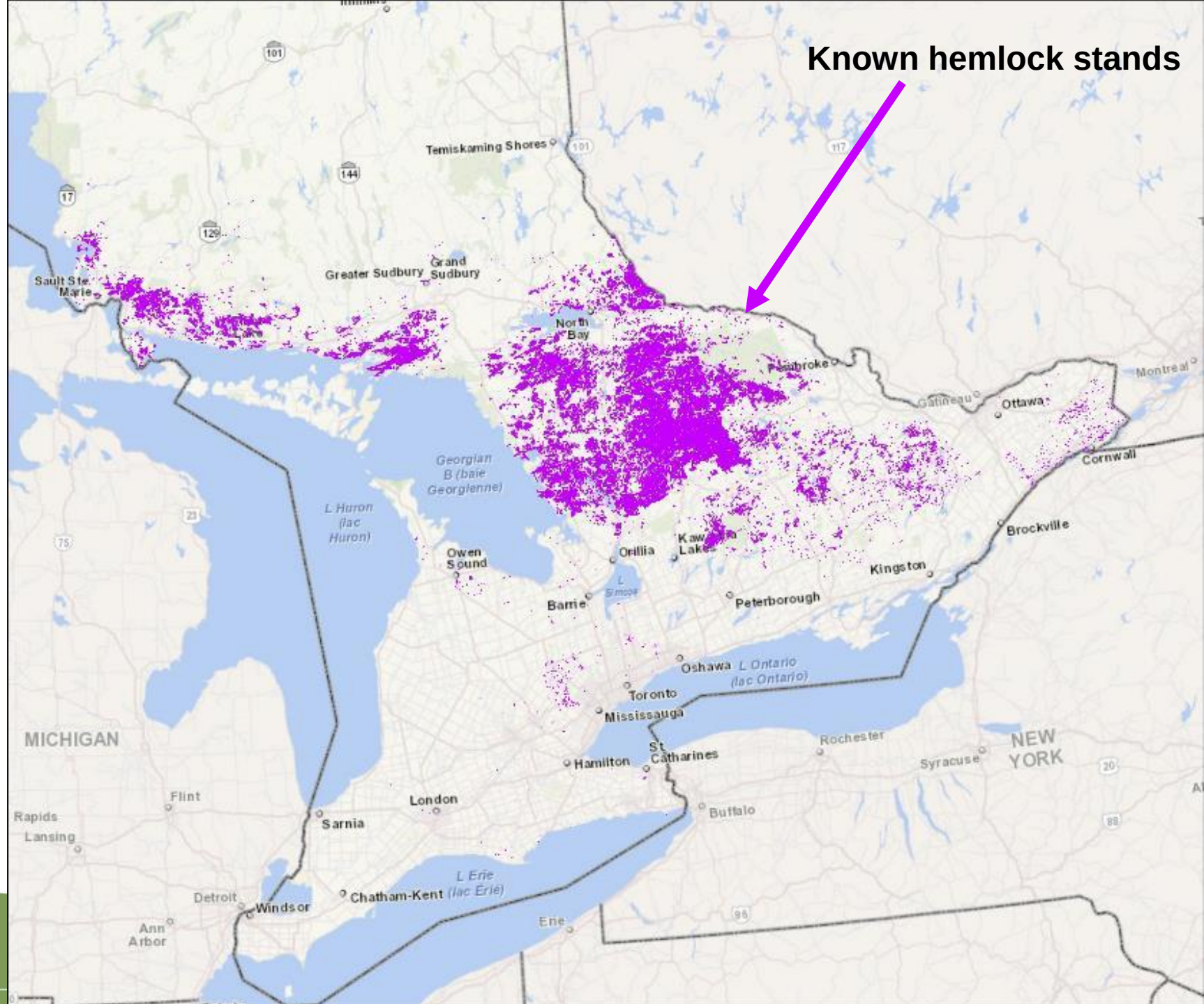
Risk

Hemlock occurs on > 1 million hectares in Ontario

1% of the growing stock of trees

Significant component of riparian and old-growth forest communities

20,000 cu meters harvested for saw logs, pulp, fuel wood & composite wood products



The Decade of HWA in ON

Graphic by V. Derry

Risk

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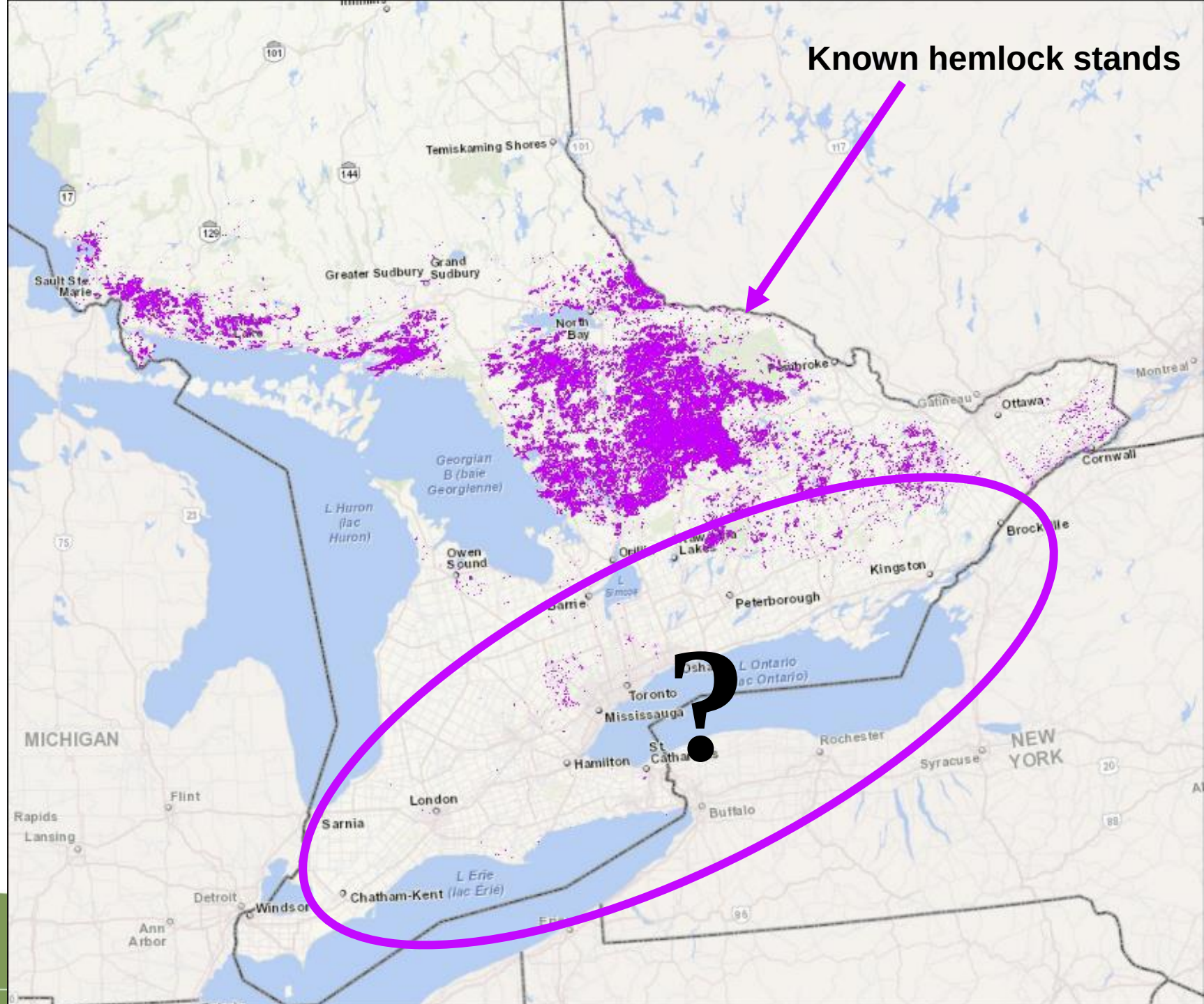
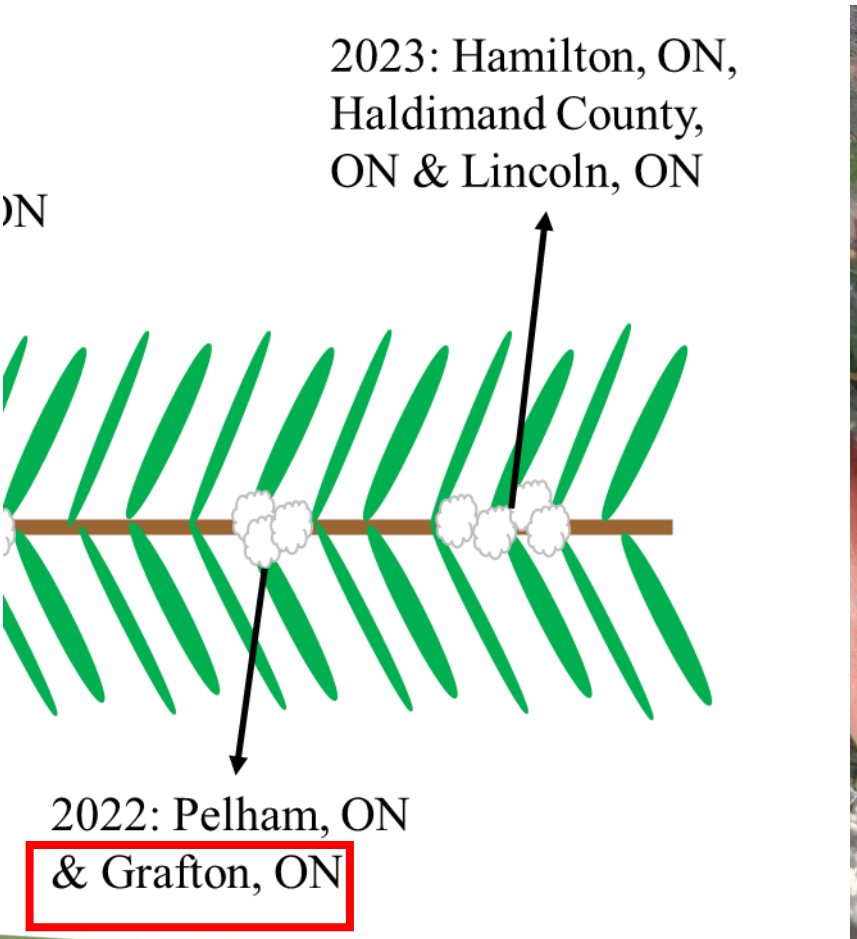


The Decade of HWA in ON



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And now, over to Zhaoshu!

The Forestry Chronicle

FREE ACCESS

Applying three decades of research to mitigate the impacts of hemlock woolly adelgid on Ontario's forests

William C. Parker, Victoria Derry, Ken A. Elliott, Chris J.K. MacQuarrie, and Sharon Reed

Vol. 99 • No. 2 • pp. 205–225

Over the past 70 years, the introduced, invasive hemlock woolly adelgid (*Adelges tsugae* Annand) has become established and caused considerable decline and mortality of eastern hemlock (*Tsuga canadensis* (L.) Carr.) across much of the tree's natural range. Hemlock is a foundation tree species with little inherent resistance to this exotic species and infestation by this sap-feeding insect results in progressive crown decline and tree mortality within 4 to 15 years. Continued climate warming favours the spread of this insect to Ontario and other areas at the northern edge of hemlock's range. More than 30 years of basic and applied research directed towards control and mitigation of damage by this insect indicates that the rate of development of hemlock decline and mortality depends on climate, site, and stand factors that affect both insect performance and hemlock vigour. Here we synthesize these research findings to provide science-based management recommendations to (1) increase the resilience of Ontario's hemlock forest resource to this insect before it spreads, (2) mitigate hemlock woolly adelgid damage once it gets established, and (3) facilitate degraded hemlock forest restoration.

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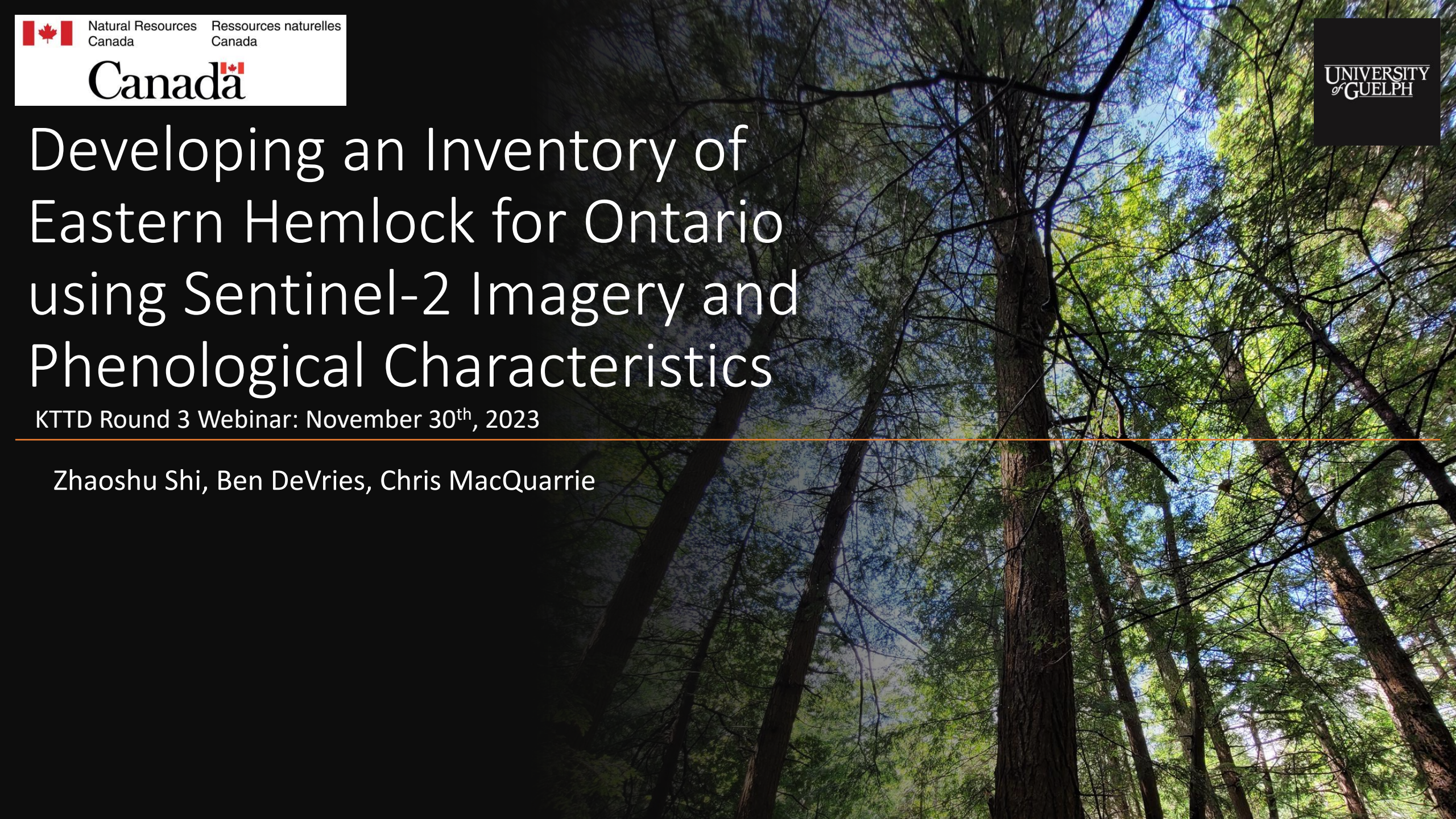
Canada

University of Guelph

Developing an Inventory of Eastern Hemlock for Ontario using Sentinel-2 Imagery and Phenological Characteristics

KTTD Round 3 Webinar: November 30th, 2023

Zhaoshu Shi, Ben DeVries, Chris MacQuarrie



Outline

- Background Information
- Objective
- Method
  - Pre-classification study
  - Hemlock classification model
- Result
- Discussion

Ontario Hemlock Inventory Background

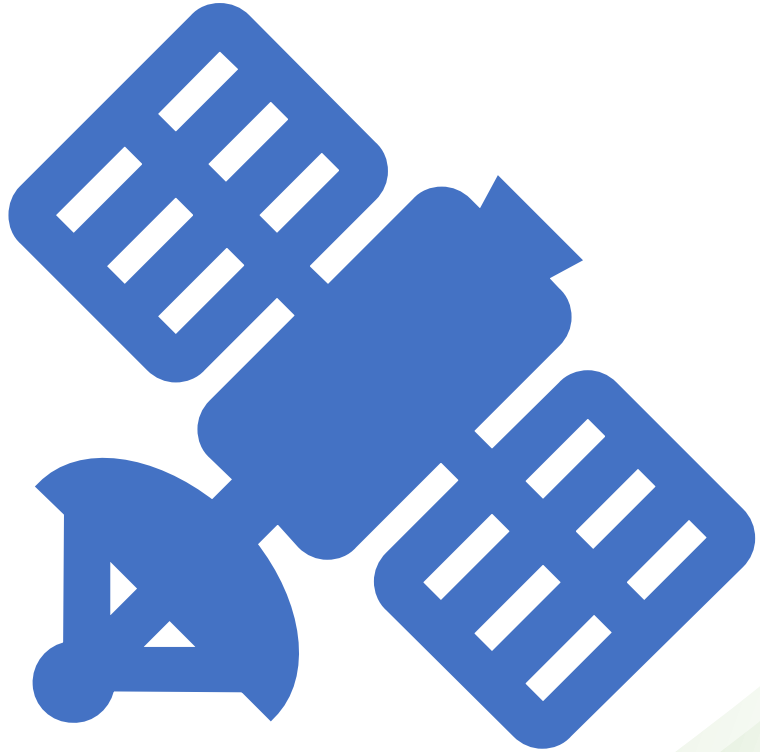
- Hemlock database developed by Silv-Econ Ltd
  - Only covers part of the Ontario forest
  - Multi-source database- inconsistent format

Satellite forest classification maps

- Canada wide leading species map
  - Low accuracy for hemlock classification
- Forest resource planning composite inventory
  - Not at species level, especially for minor coniferous species

Objective

- Create a classification method for eastern hemlock in Ontario using Sentinel-2 satellite imagery



Method: Pre-classification study

Field plots

Sentinel-2 Satellite image and Spectral Index

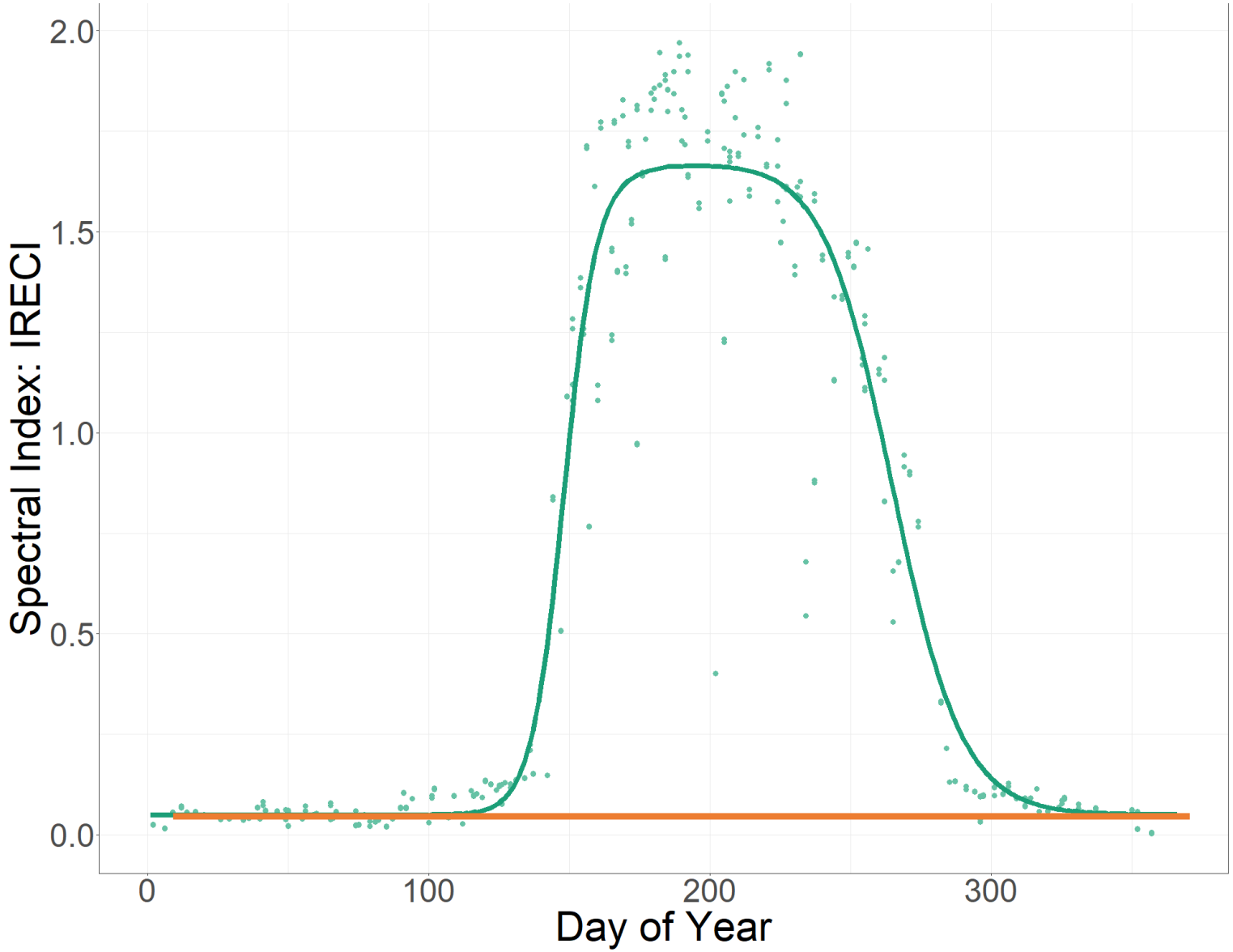
IRECI
SAVI
MCARI_2
MCARI_3

Time Series and Phenology Model

Time Series Phenology Model and Parameters

- Alpha 1:

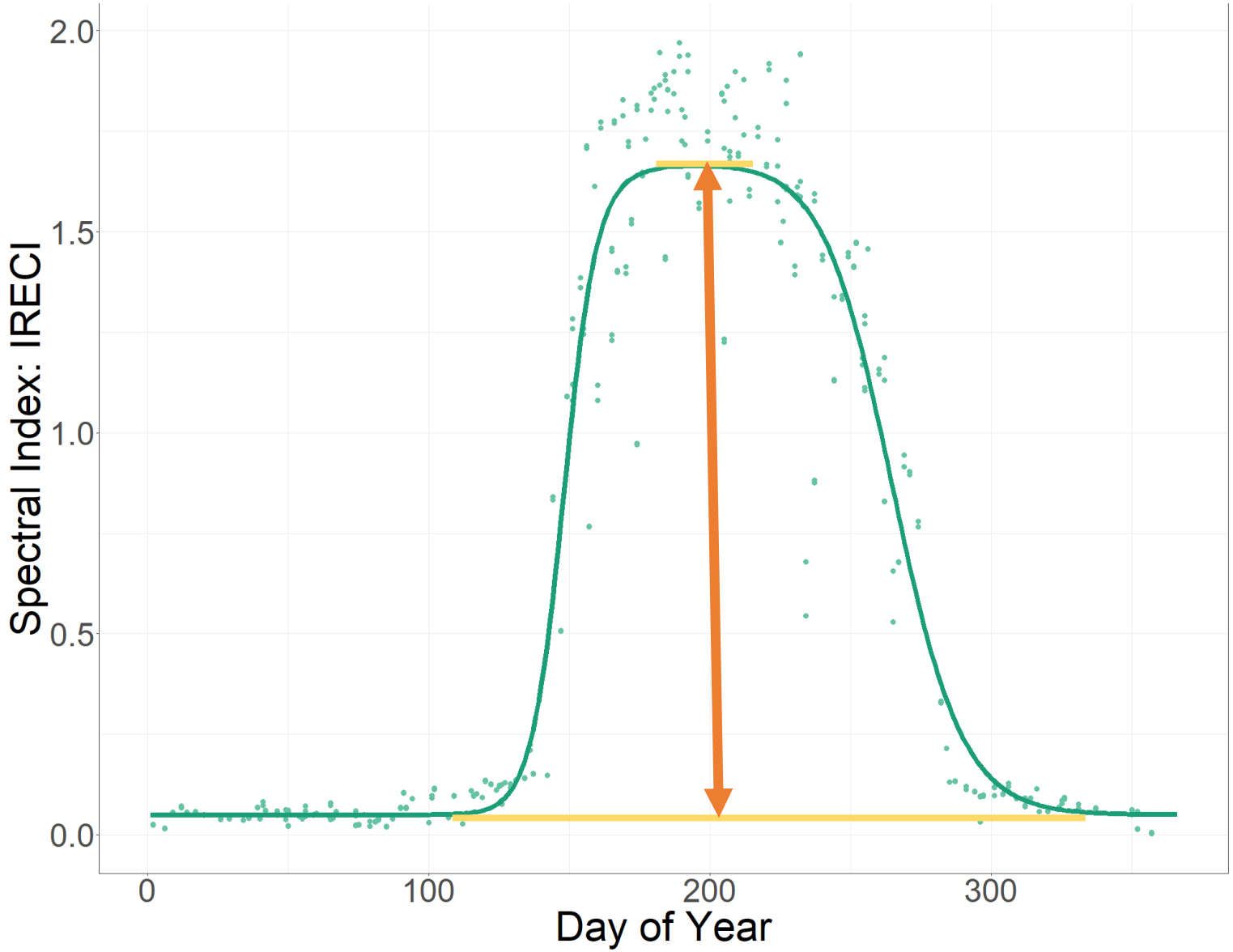
  Seasonal Minimum



Time Series Phenology Model and Parameters

- Alpha 2:

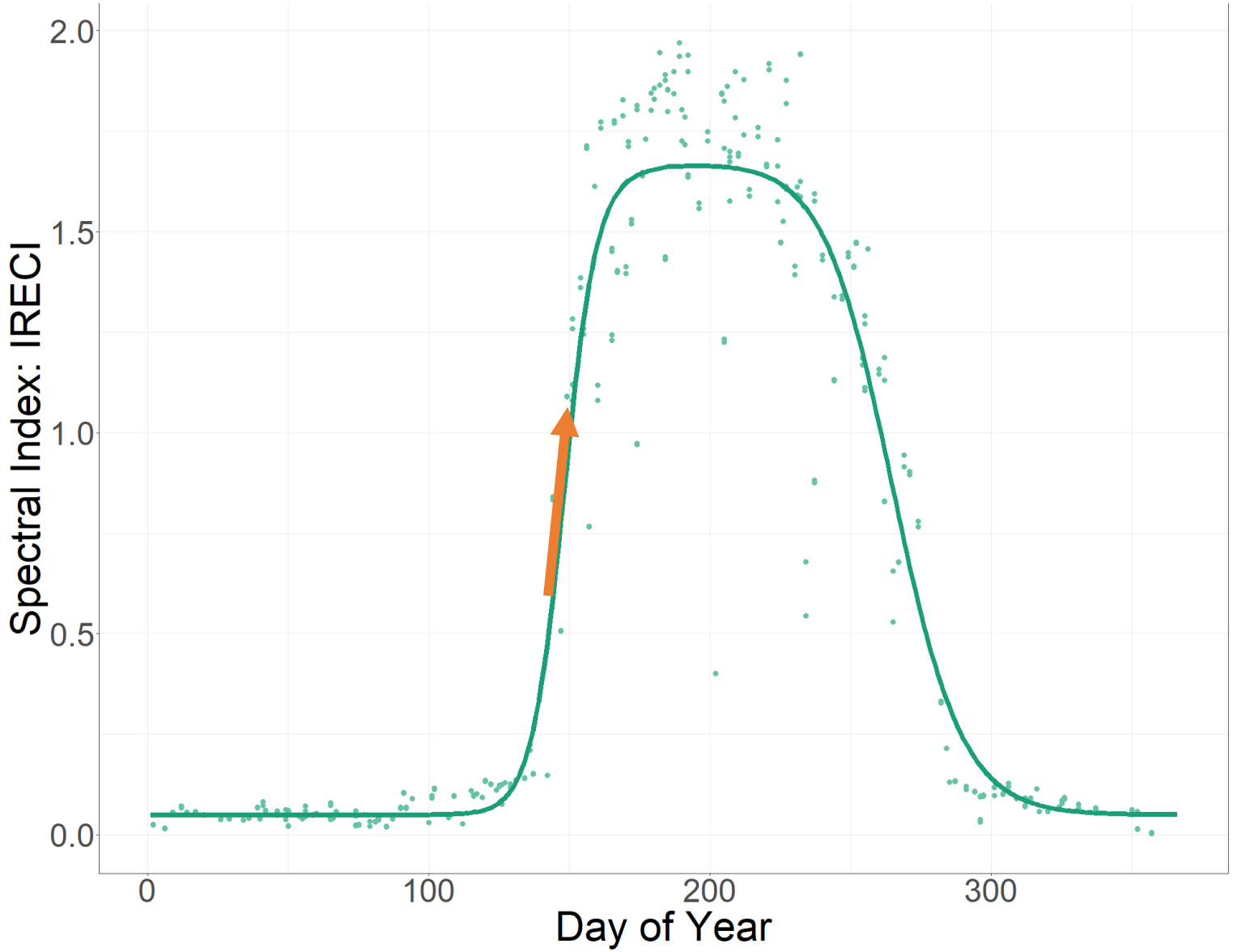
  Seasonal Difference



Time Series Phenology Model and Parameters

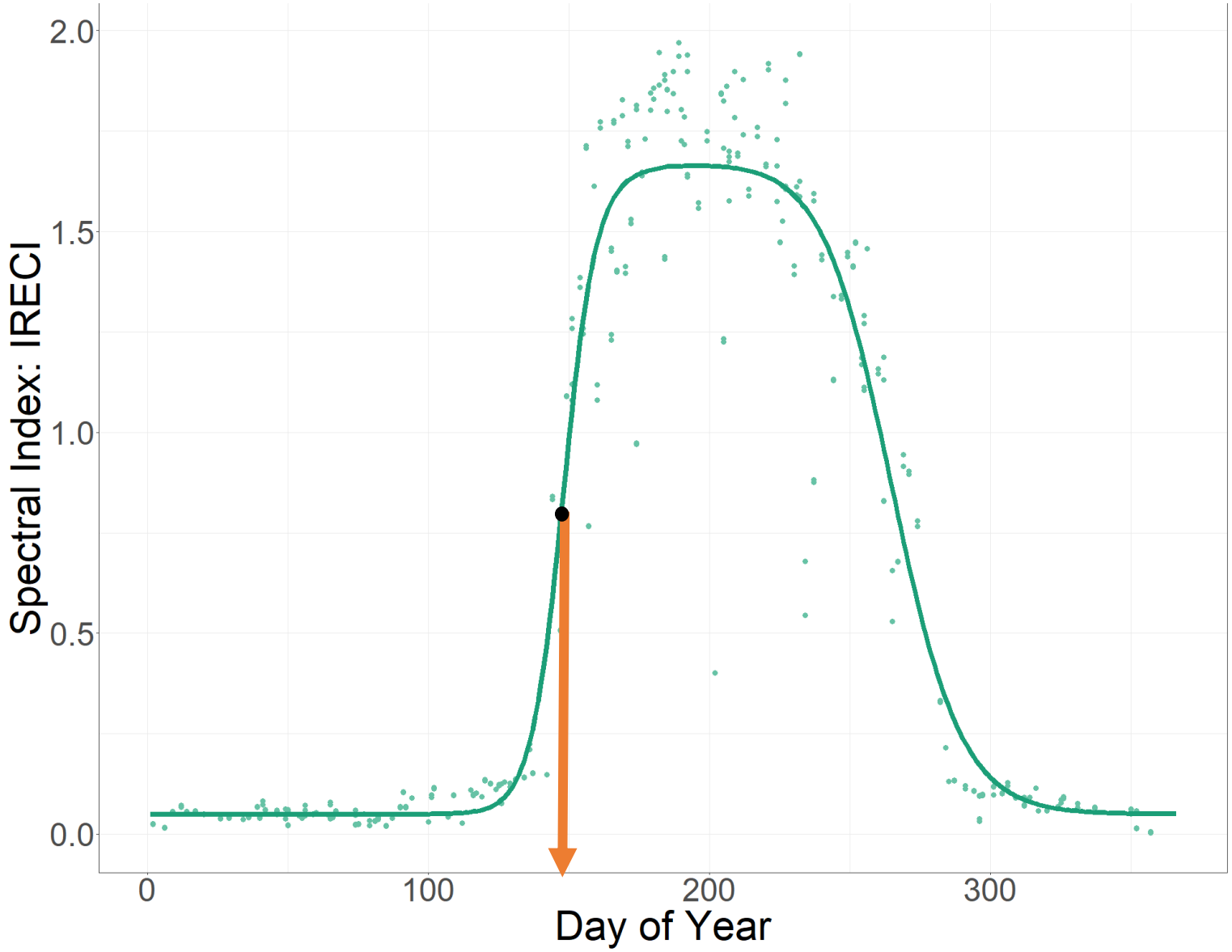
- Alpha 3:

  Green Up Slope



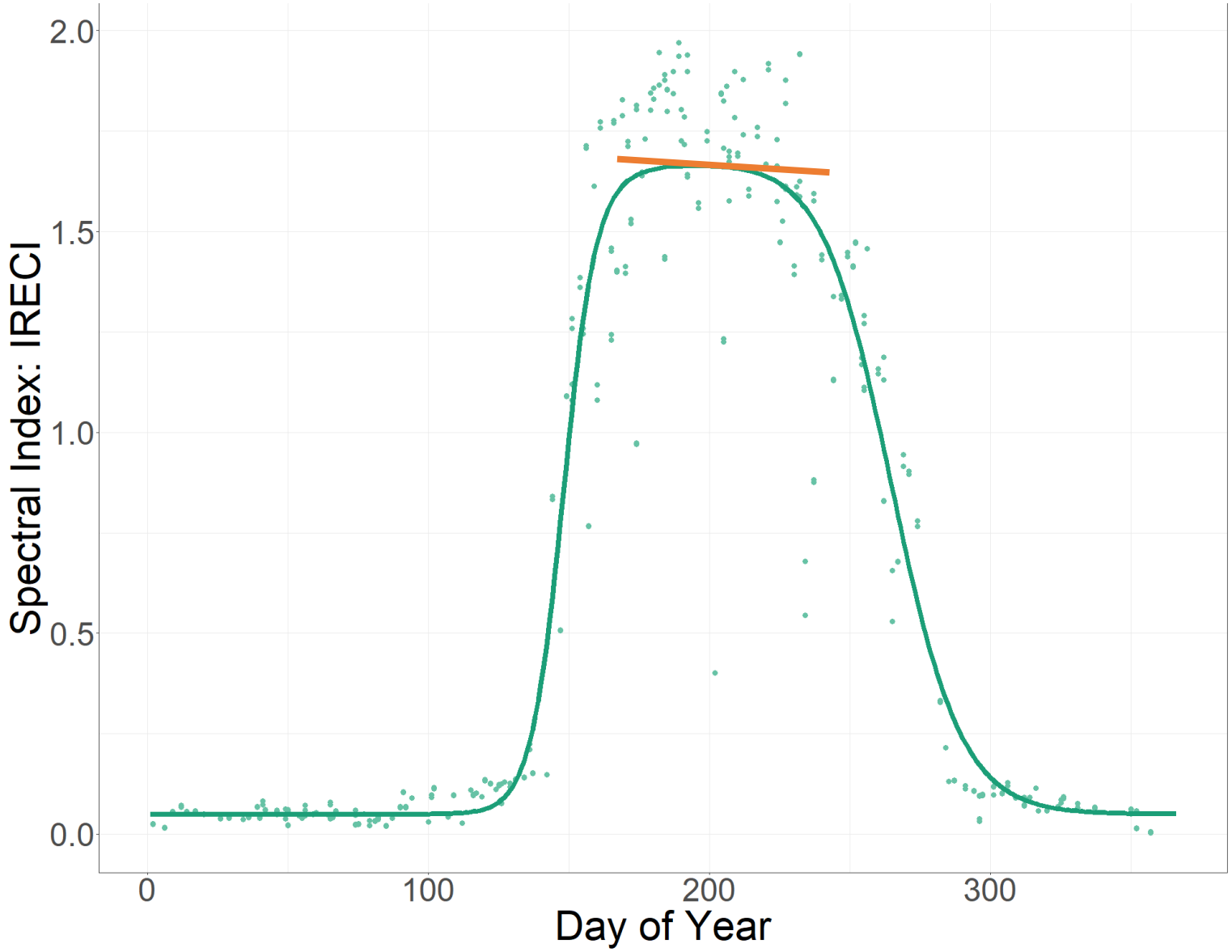
Time Series Phenology Model and Parameters

- Alpha 4:
  - Spring Inflection Day



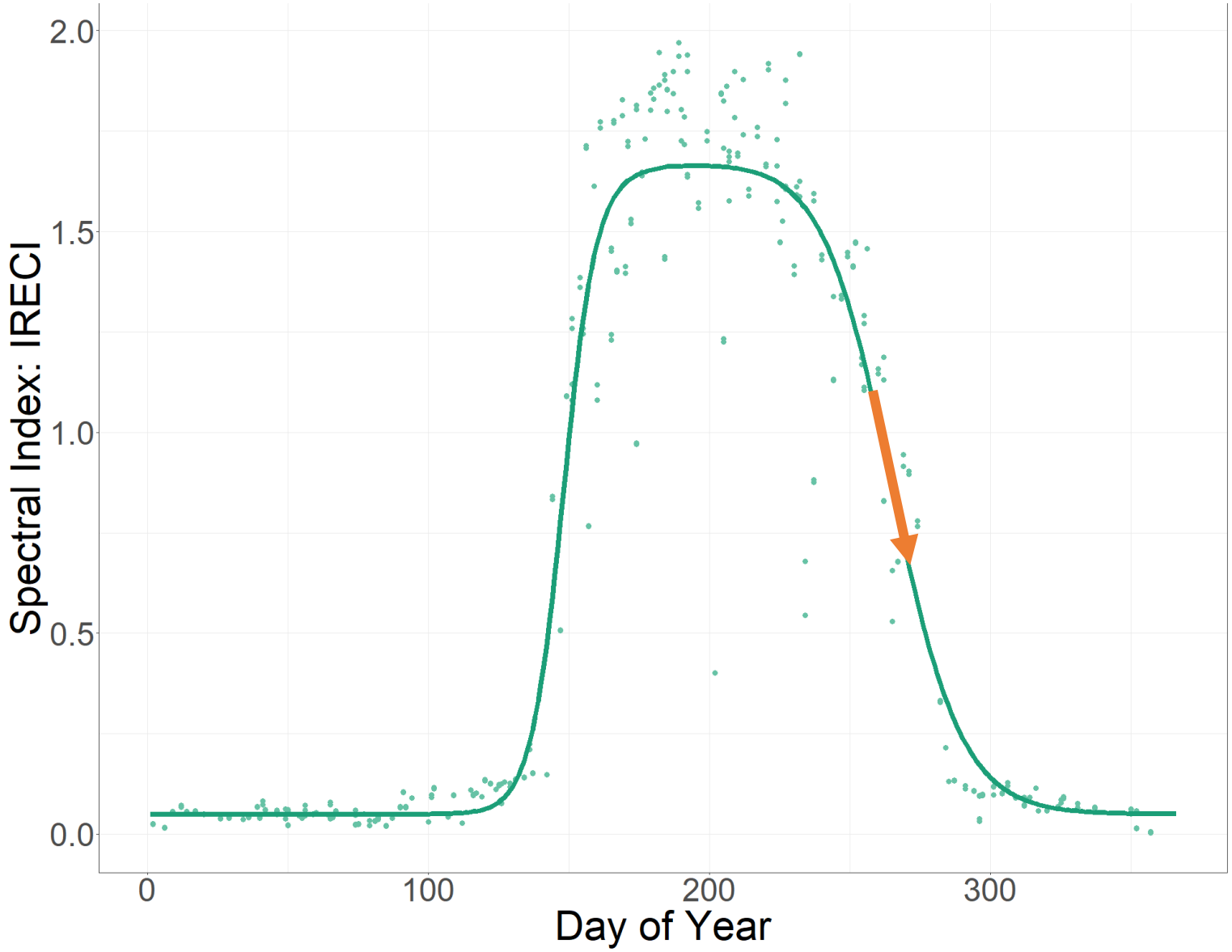
Time Series Phenology Model and Parameters

- Alpha 5:
  - Mid-growing Season Slope



Time Series Phenology Model and Parameters

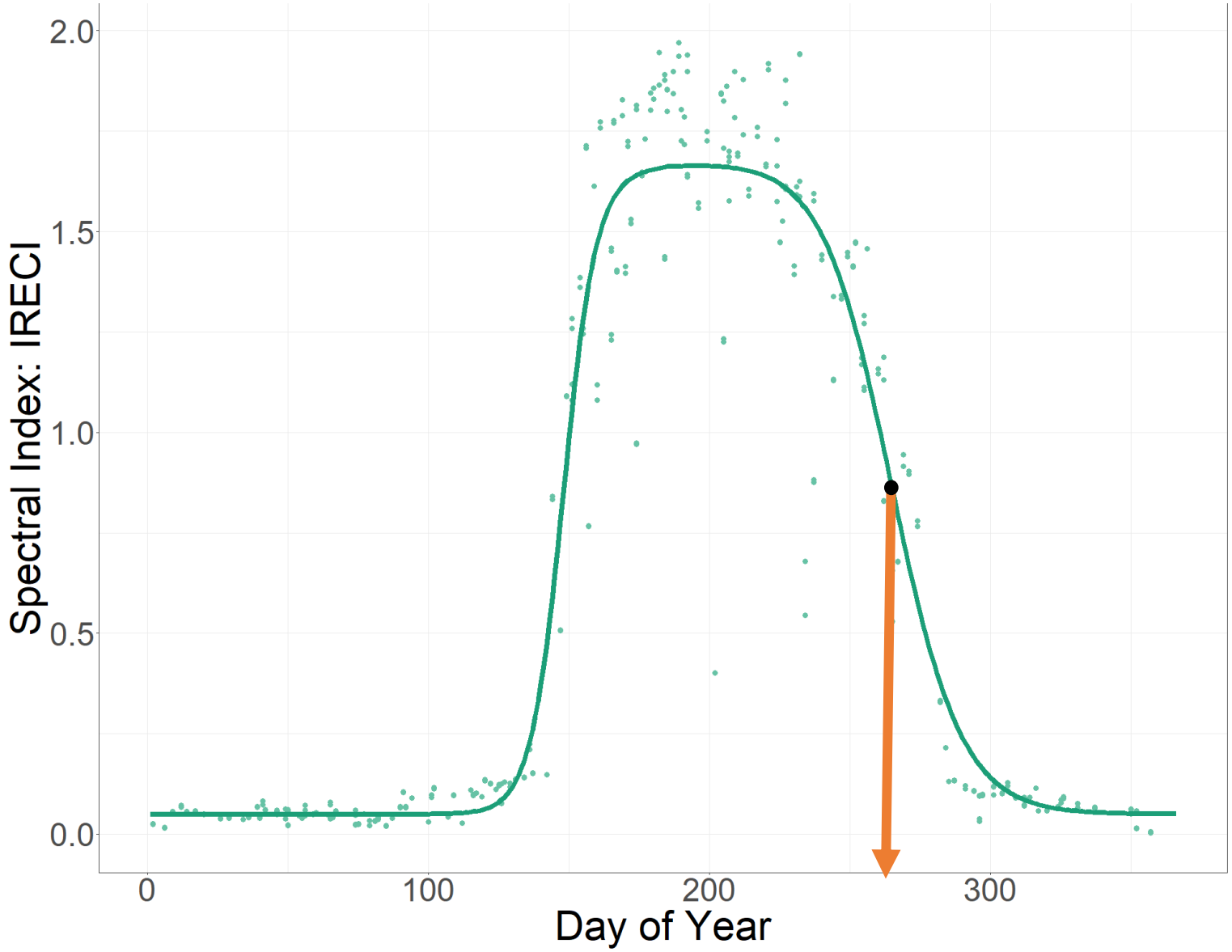
- Alpha 6:
  - Fall Green Down Slope



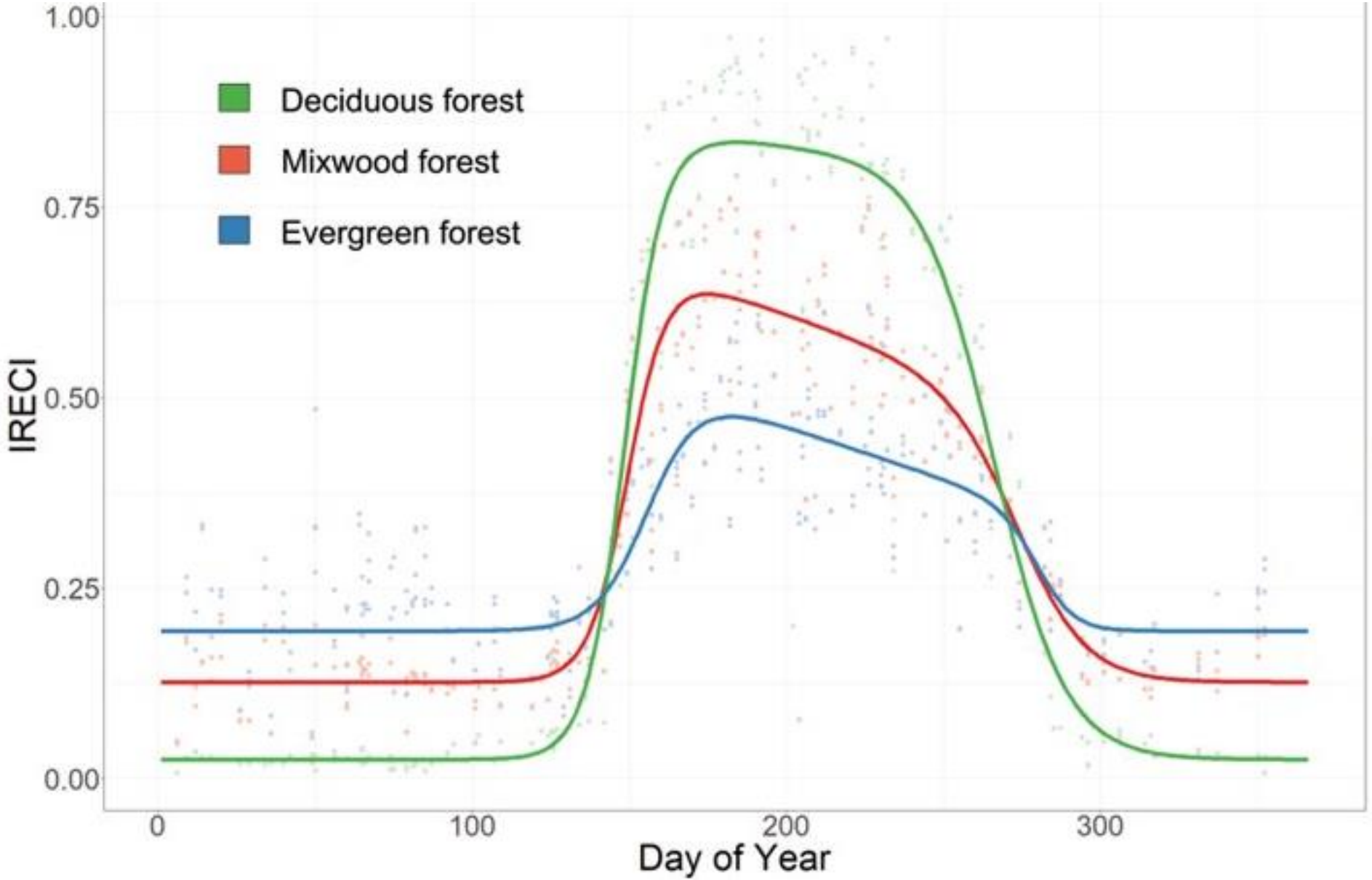
Time Series Phenology Model and Parameters

- Alpha 7:

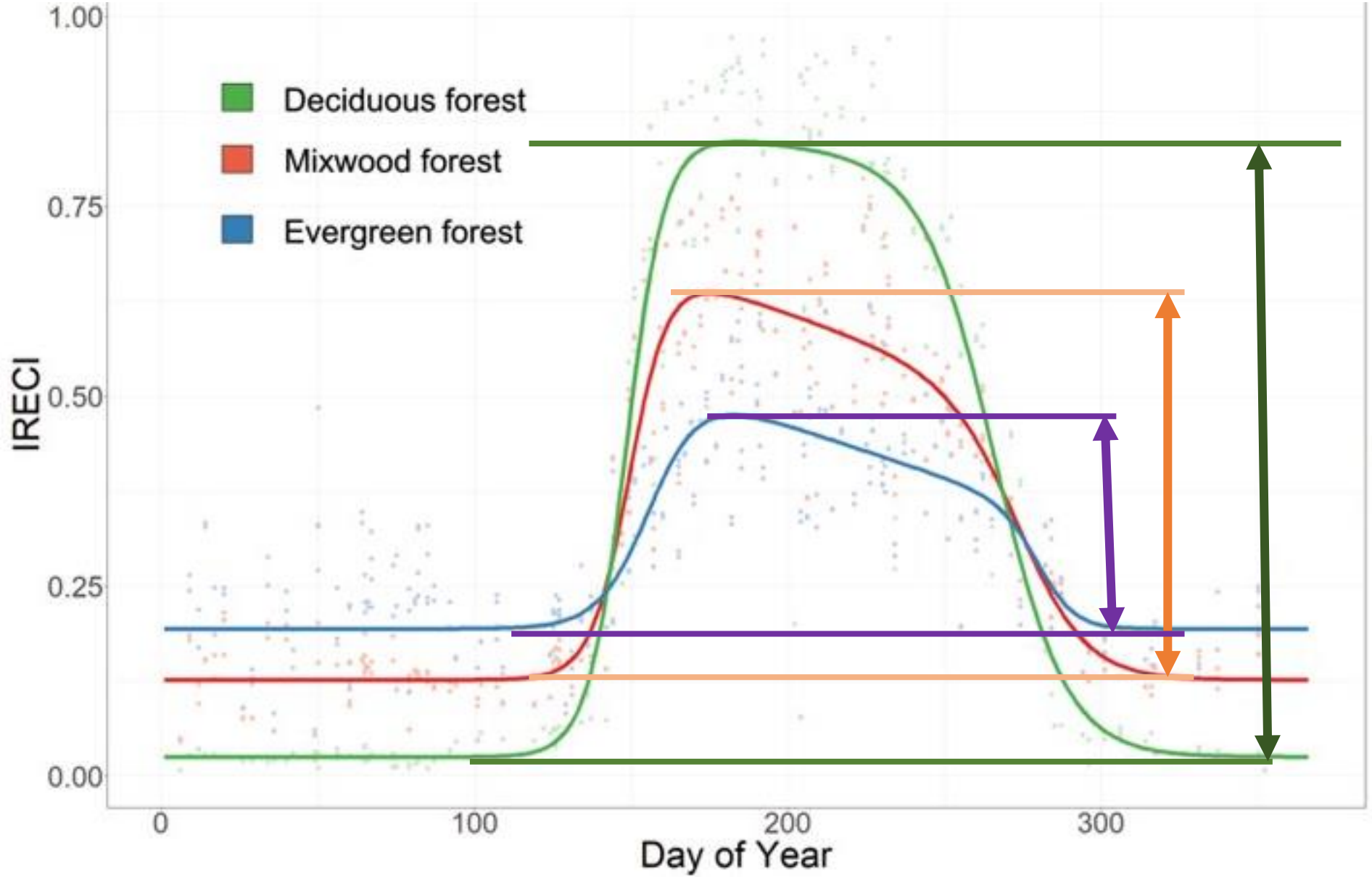
  Fall Inflection Day



Time Series and Phenological Parameters



Time Series and Phenological Parameters



Classification method

Level 1 : broad forest classes

Deciduous forest

Mixwood forest

Evergreen forest

Level 2: evergreen classes

Mono-evergreen species dominant forest

Hemlock codominant evergreen forest

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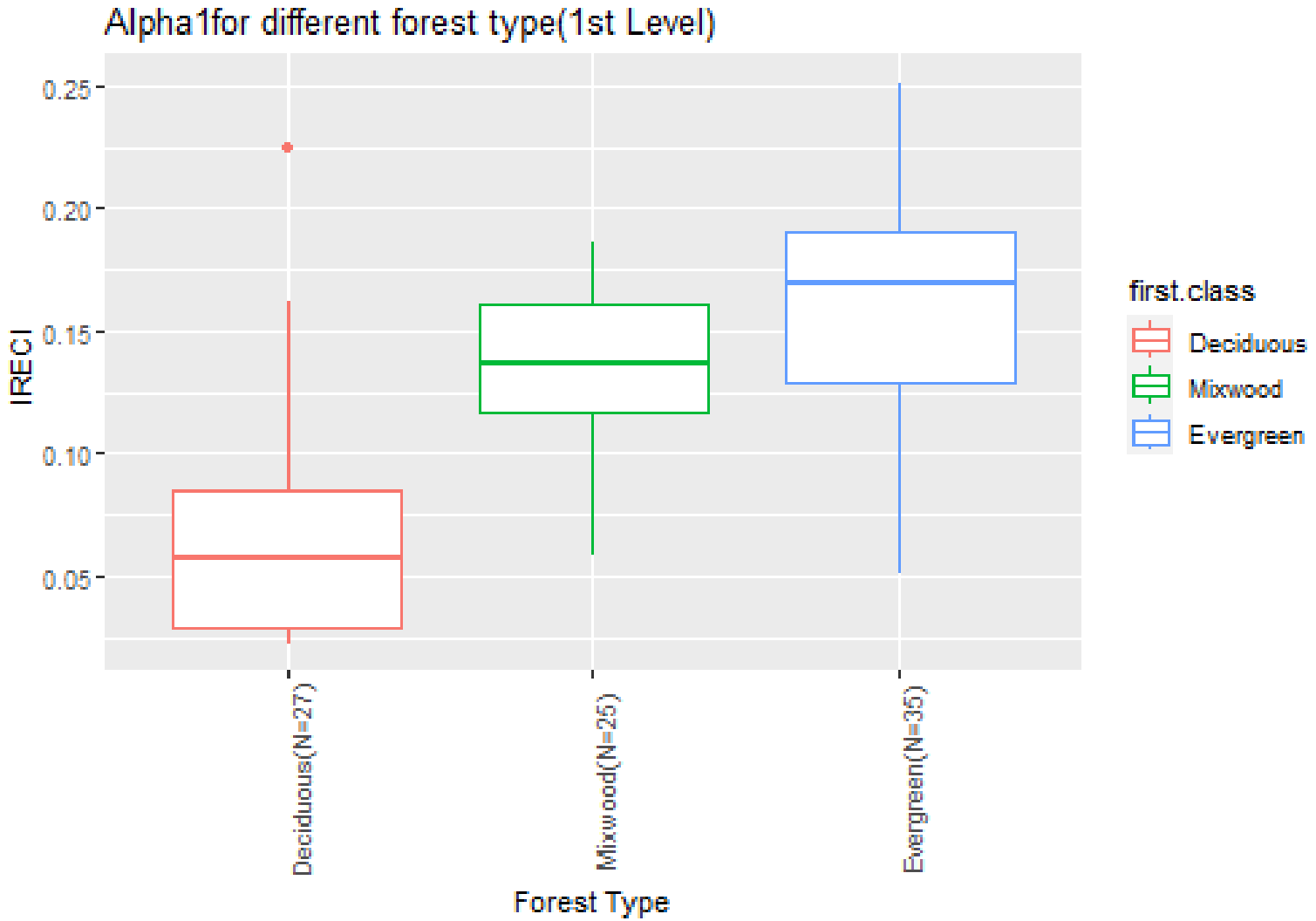
Level 1: Broad Forest Type

Spectral Index	Alpha 1	Alpha 2	Alpha 3	Alpha 4	Alpha 5	Alpha 6	Alpha 7
IRECI	7.78E-08	5.12E-03	1.92E-02	2.40E-04	0.0841	3.18E-03	0.407
MCARI_2	6.64E-07	8.53E-03	3.66E-05	7.69E-04	0.88	0.104	3.95E-02
MCARI_3	1.83E-06	0.0984	1.01E-04	1.41E-03	0.0689	0.134	9.82E-03
SAVI	1.90E-08	6.21E-06	0.134	7.18E-06	5.84E-01	2.84E-02	0.169

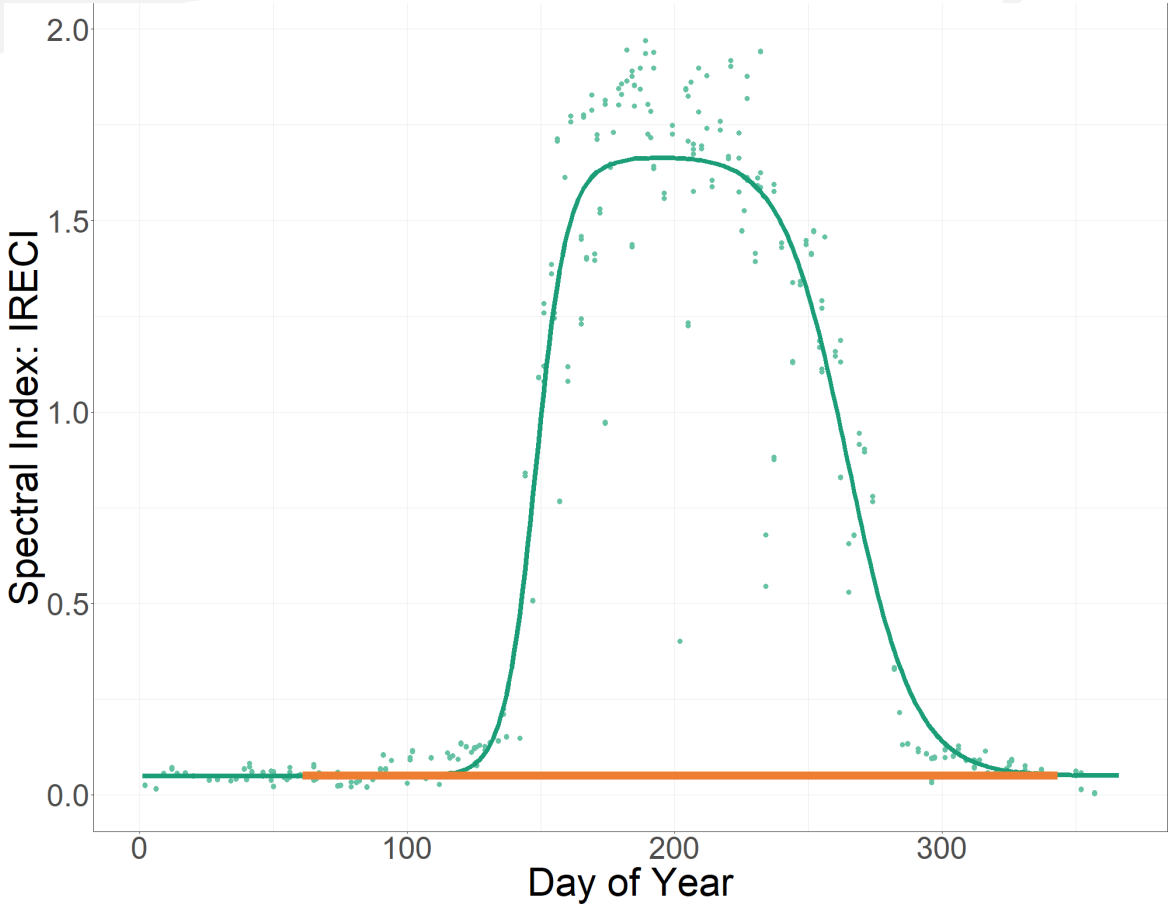
Broad Forest Type Difference

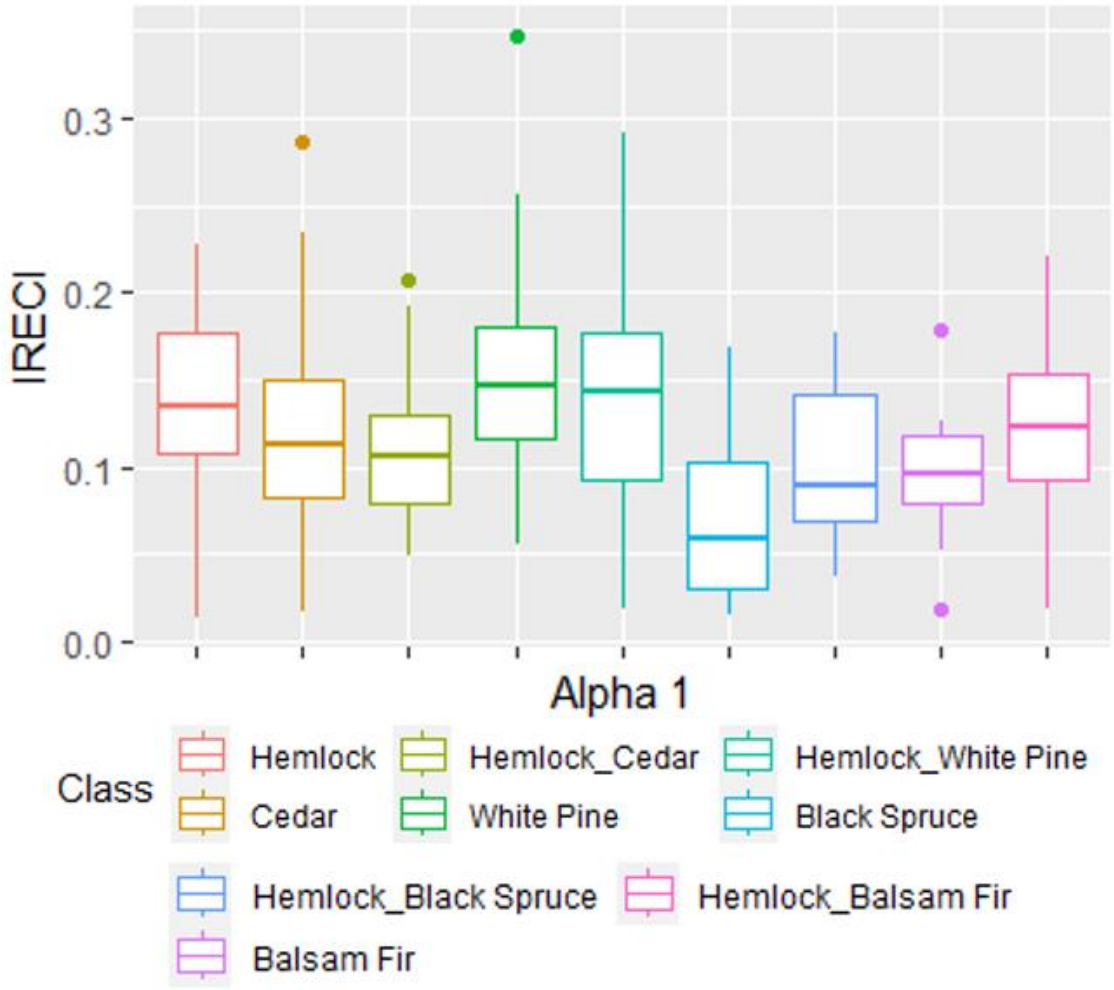


Level 2: Difference Among Evergreen Species

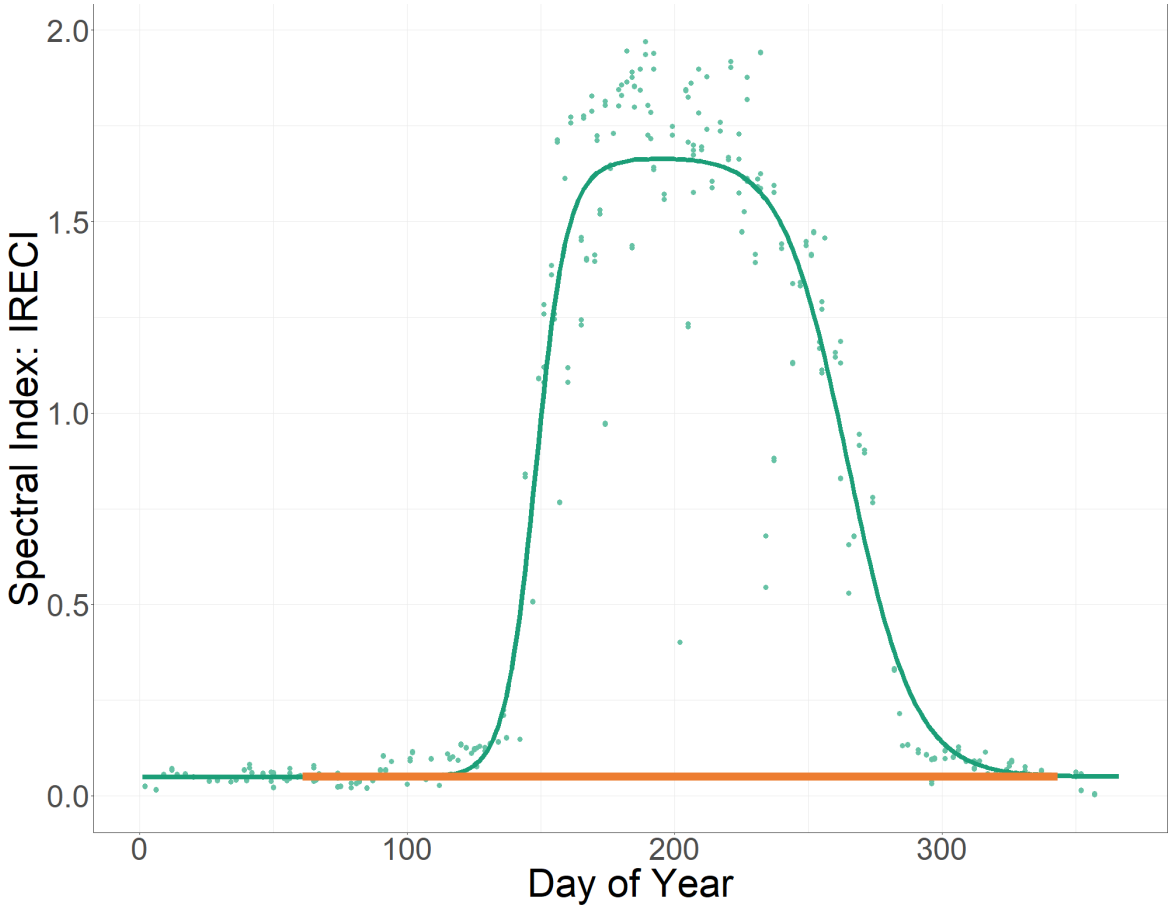
Hemlock and co-dominant evergreen species classification							
	Alpha 1	Alpha 2	Alpha 3	Alpha 4	Alpha 5	Alpha 6	Alpha 7
IRECI	2.35E-07	0.617	6.00E-04	0.349	0.261	0.308	0.399
MCARI_2	6.31E-08	3.05E-03	2.14E-02	0.1654	1.31E-02	0.1437	0.1911
MCARI_3	4.36E-09	0.07412	0.5373	5.86E-03	0.2581	1.35E-02	0.4177
SAVI	2.00E-11	4.11E-01	1.30E-03	5.98E-01	5.20E-01	9.39E-02	8.33E-01

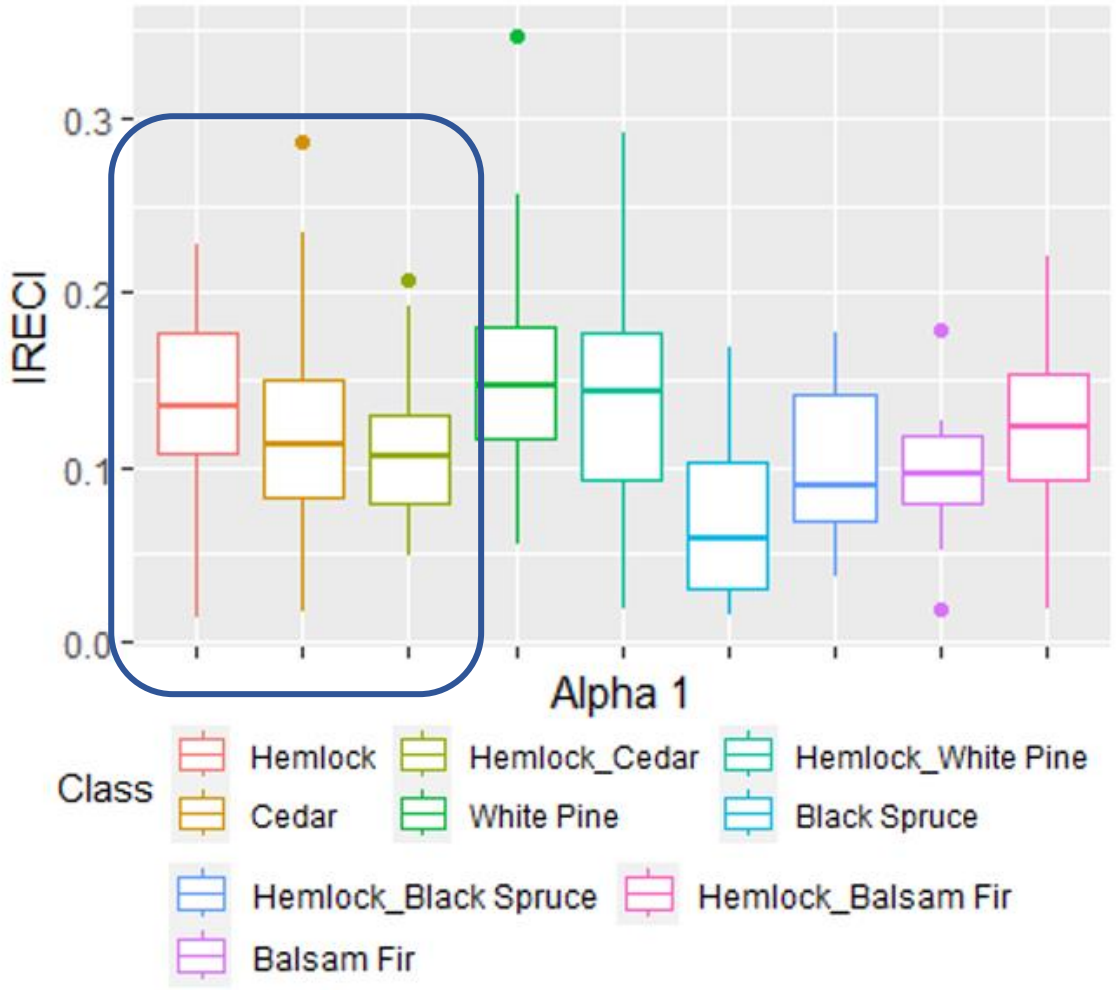
Evergreen Species Seasonal Minimum Difference

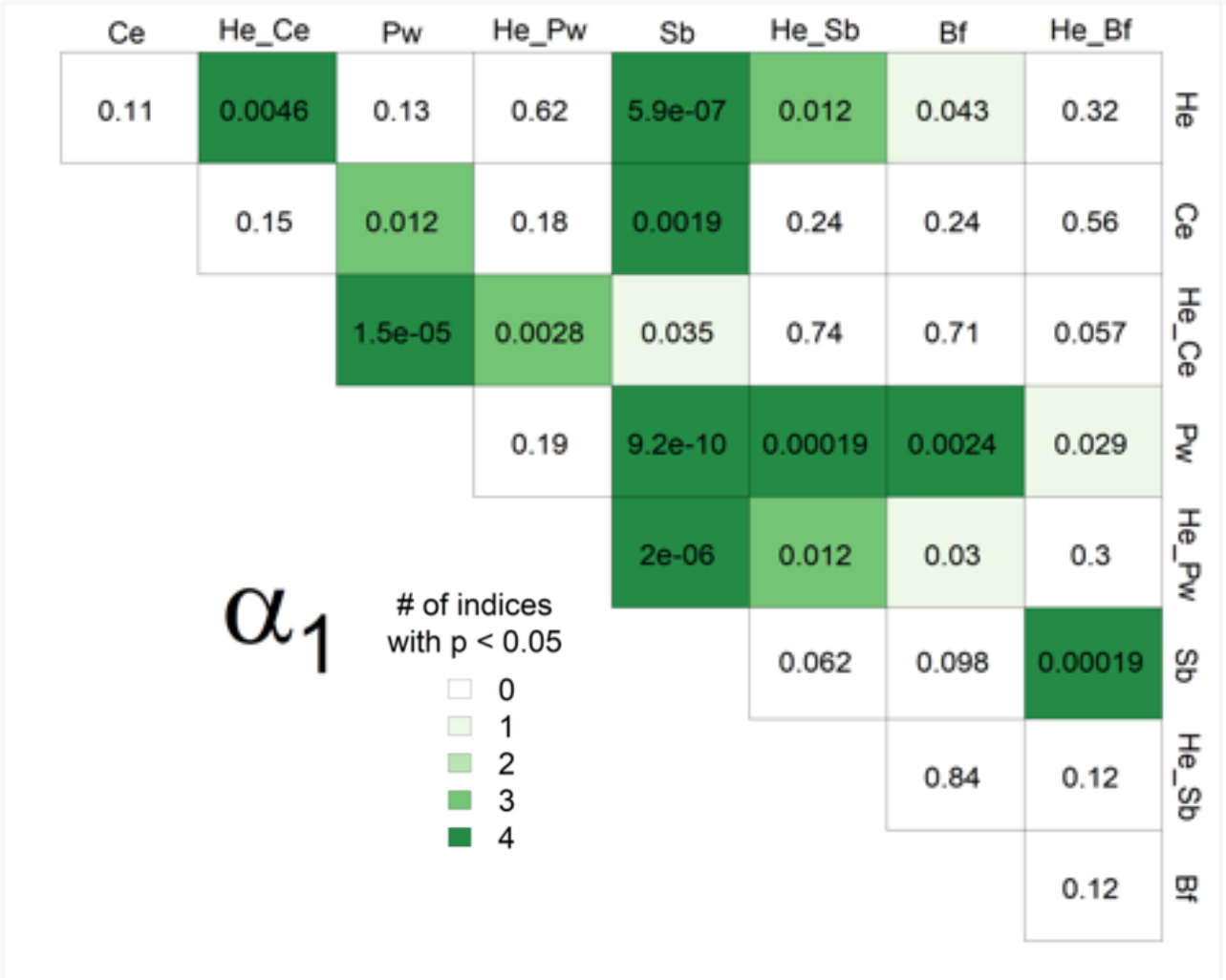


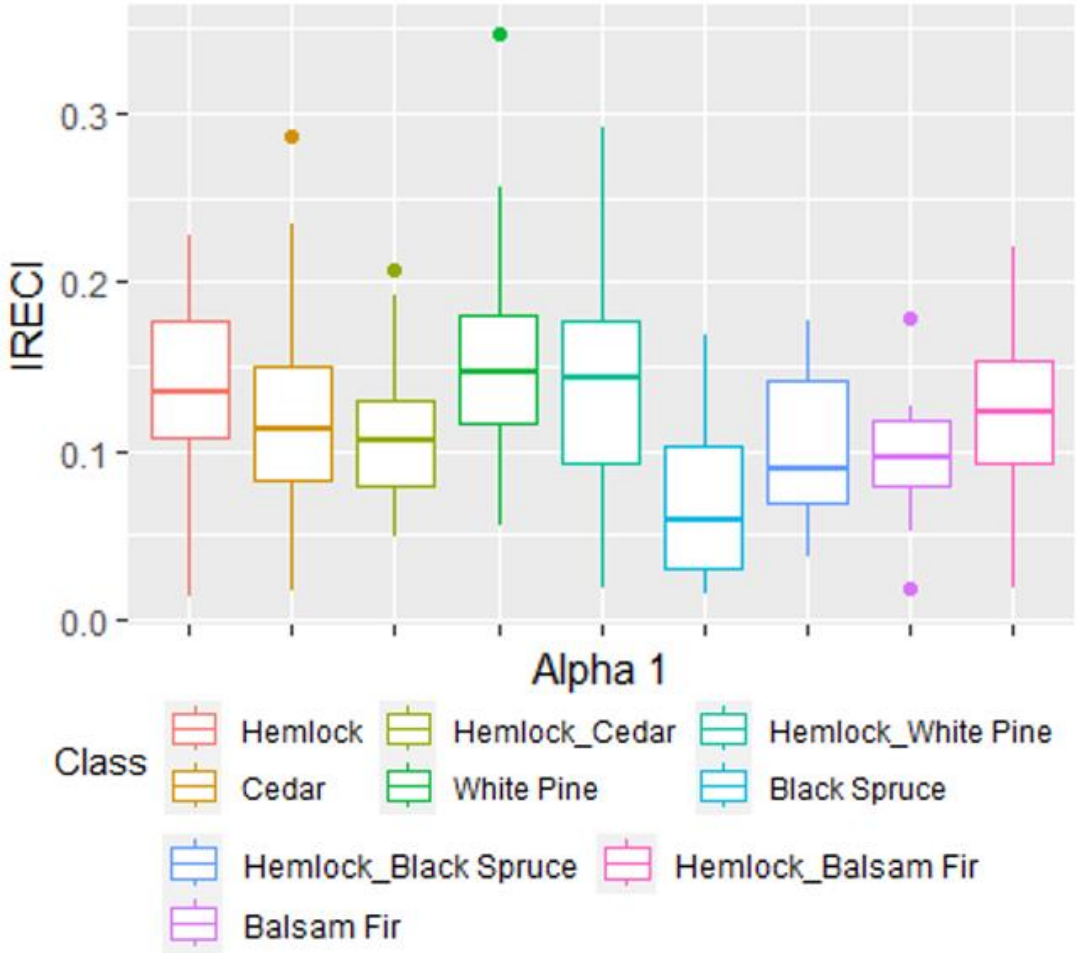


Evergreen Species Seasonal Minimum Difference









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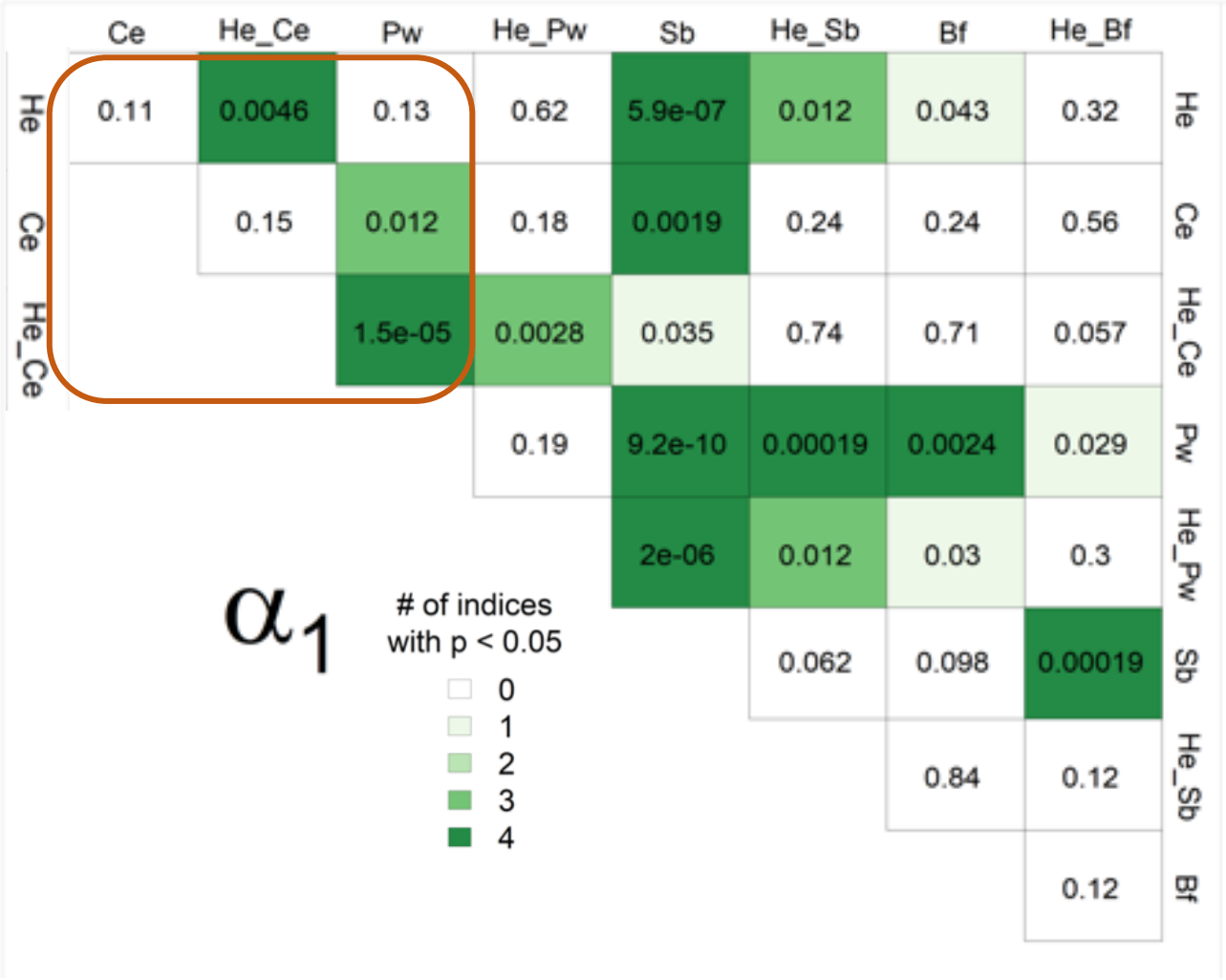
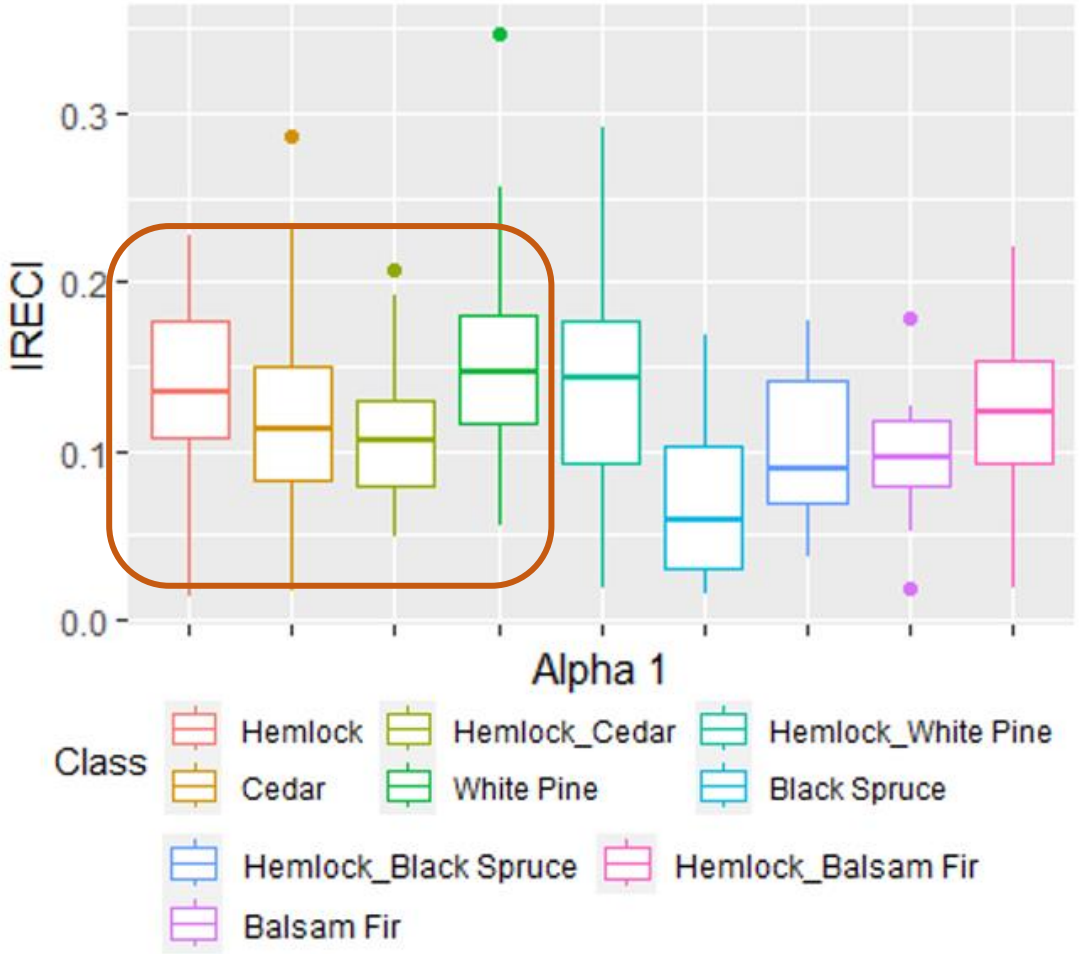
Evergreen Species Seasonal Minimum Difference





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Evergreen Species Seasonal Minimum Difference

Eastern Hemlock Classification Model

Training data source:

- Hemlock database (Silv-Econ Ltd)
- NFI data from southern and central Ontario

Classifier: Random Forest Model

- Phenological parameters from difference spectral indices
  - Sentinel-2 satellite imagery (20m spatial resolution)
- Topographical features: Slope, Aspect, TWI (topographic wetness index)

Study area

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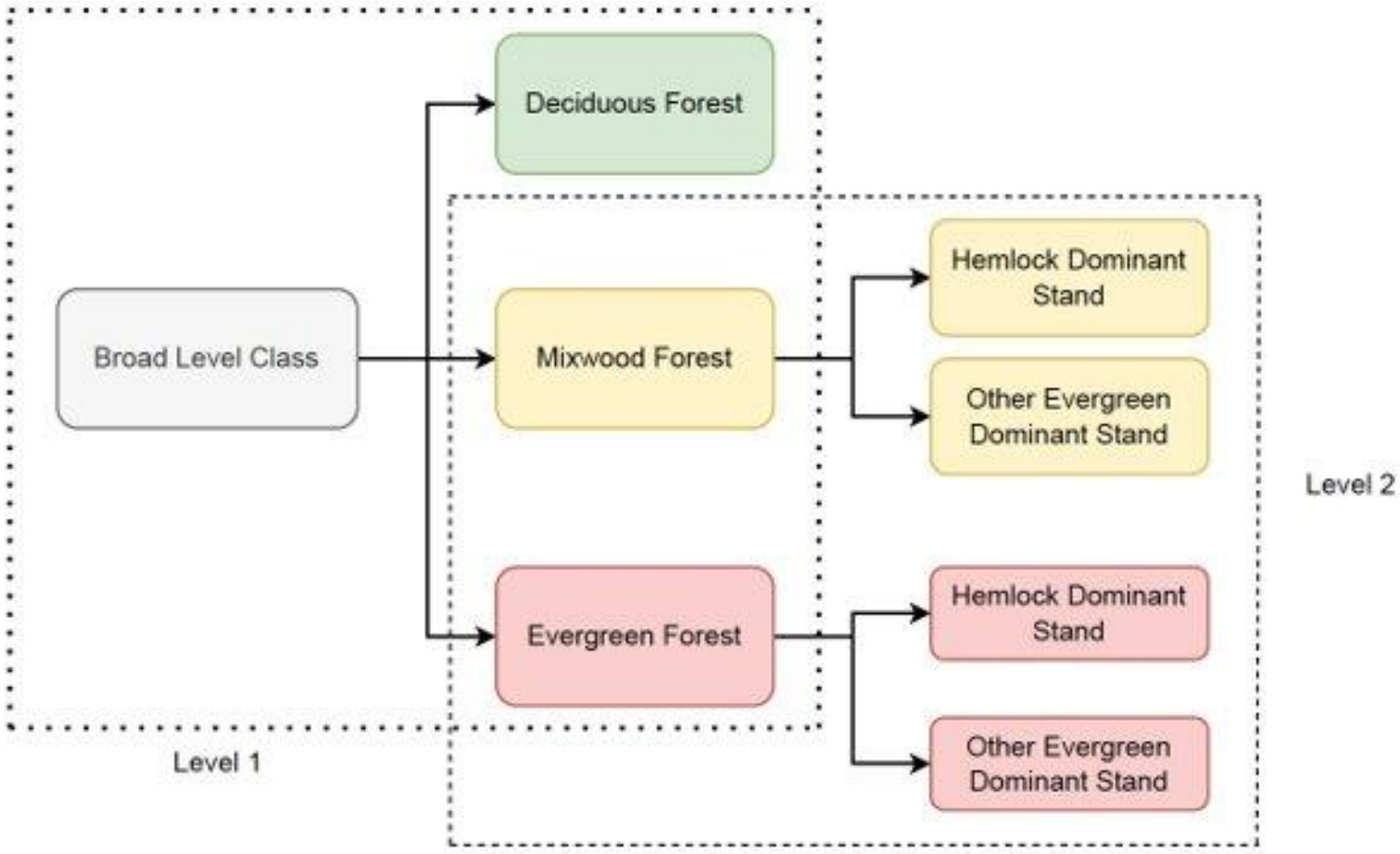
Model Structure



Level 1: Accuracy for Broad Forest Type

		model 2
Deciduous	Precision	76%
	Recall	52%
Mixwood	Precision	28%
	Recall	36%
Evergreen	Precision	41%
	Recall	76%
Evergreen/Mixwood combined accuracy	Precision	58%
	Recall	89%

	Evergreen	Mixwood	Deciduous
Evergreen	2175	633	344
Mixwood	1751	1451	912
Deciduous	1125	2521	3972

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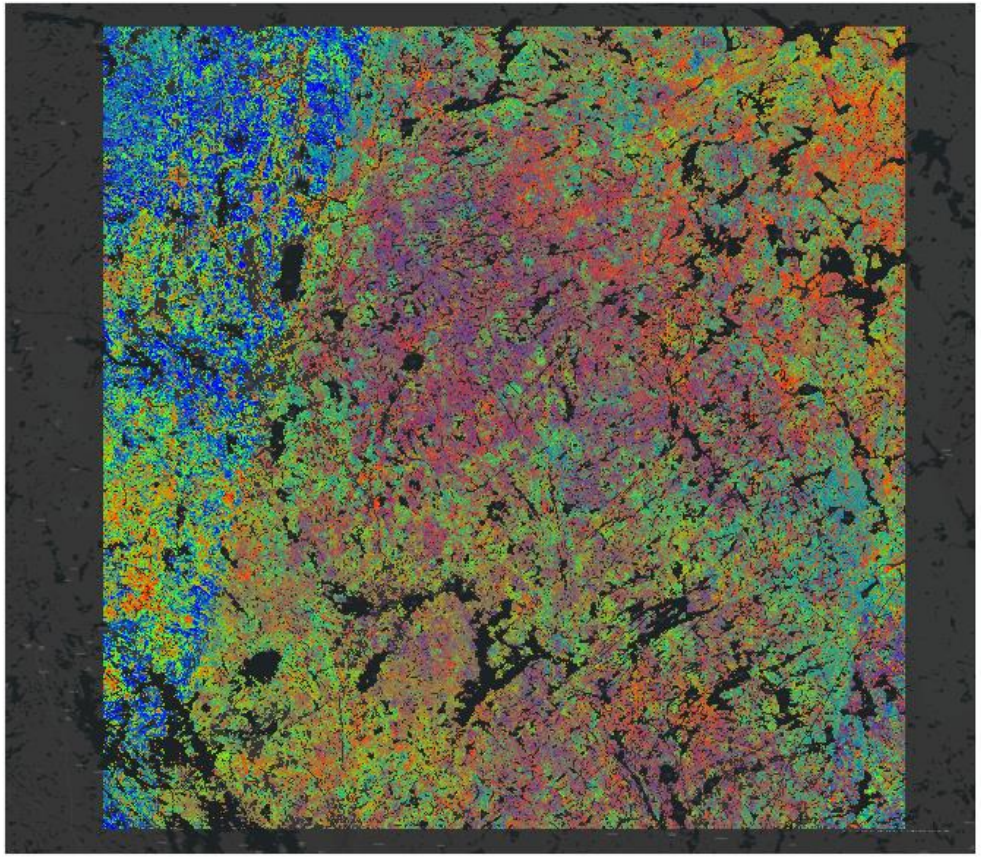
Level 1: Broad Forest Type Distribution Map

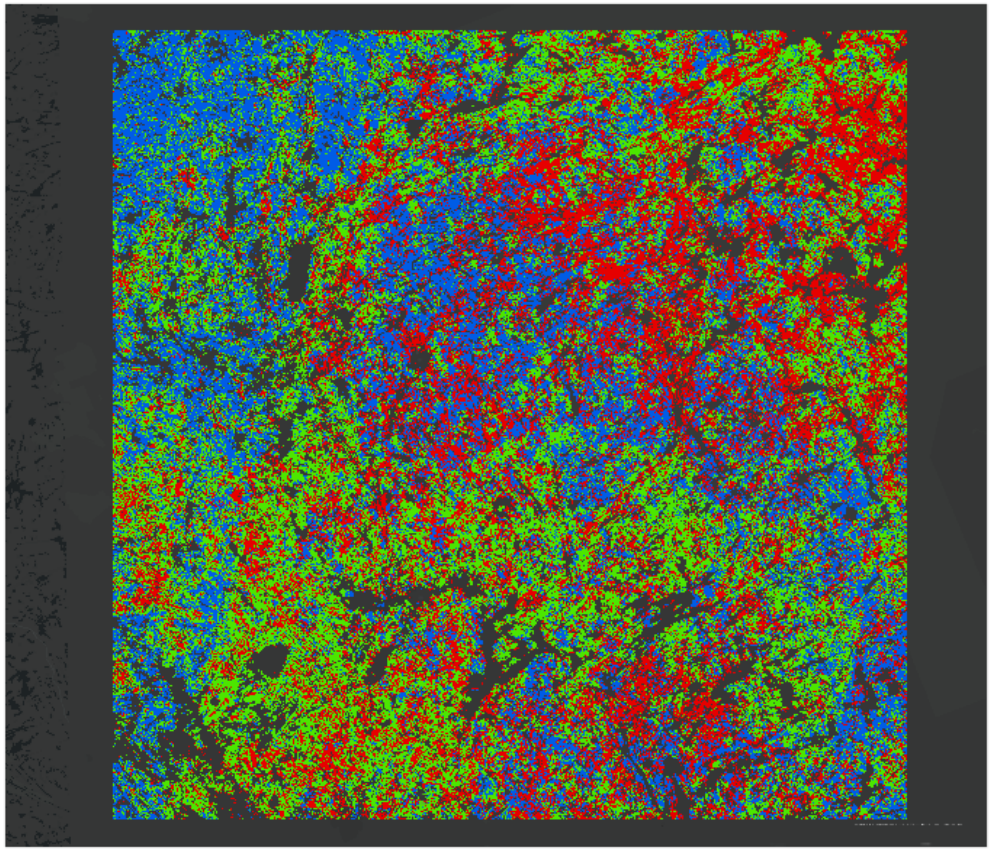
Level 1 Broad Forest Type Random Forest Model 2 Tri-color Probability Map for 17TPL



0 5 10 20 30 40 50 60 Kilometers

Forest Type
Value
Evergreen
Mixwood
Deciduous

Level 1 Broad Forest Type Random Forest Model 2 Result for 17TPL



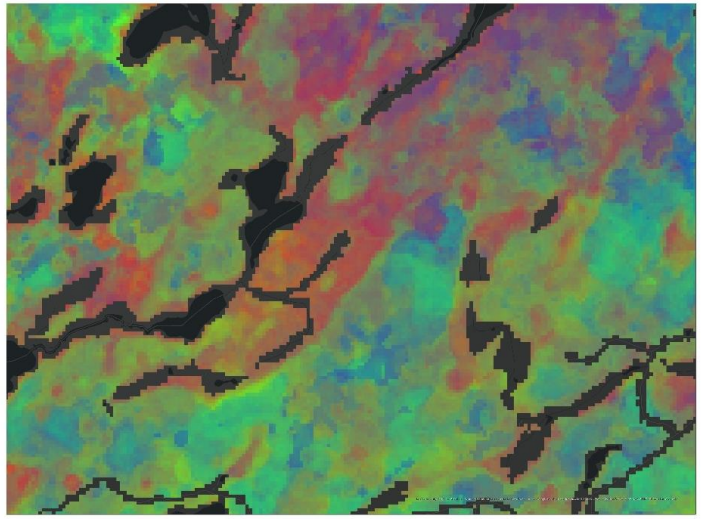
N

0 5 10 20 30 40 50 60 Kilometers

Level 1 Random Forest Model 2 Result 17TPL - Zoomed In

Ground Image from ArcPro GIS

Tri-Color Probability Map

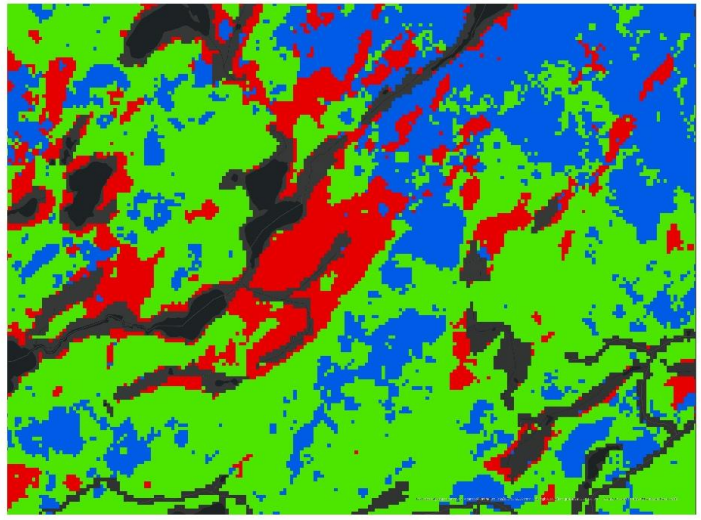


N

Forest Type
Value
Evergreen
Mixwood
Deciduous

0 0.4 0.8 1.5 2.3 3
Kilometers

Forest Type Map



Level 2 Accuracy for Hemlock Classification

	Precision	Recall
Hemlock evergreen	19%	9%
Non-hemlock evergreen	16%	45%
Hemlock mixwood	38%	47%
Non-hemlock mixwood	3%	15%
Deciduous	60%	14%
Hemlock overall accuracy	60%	51%

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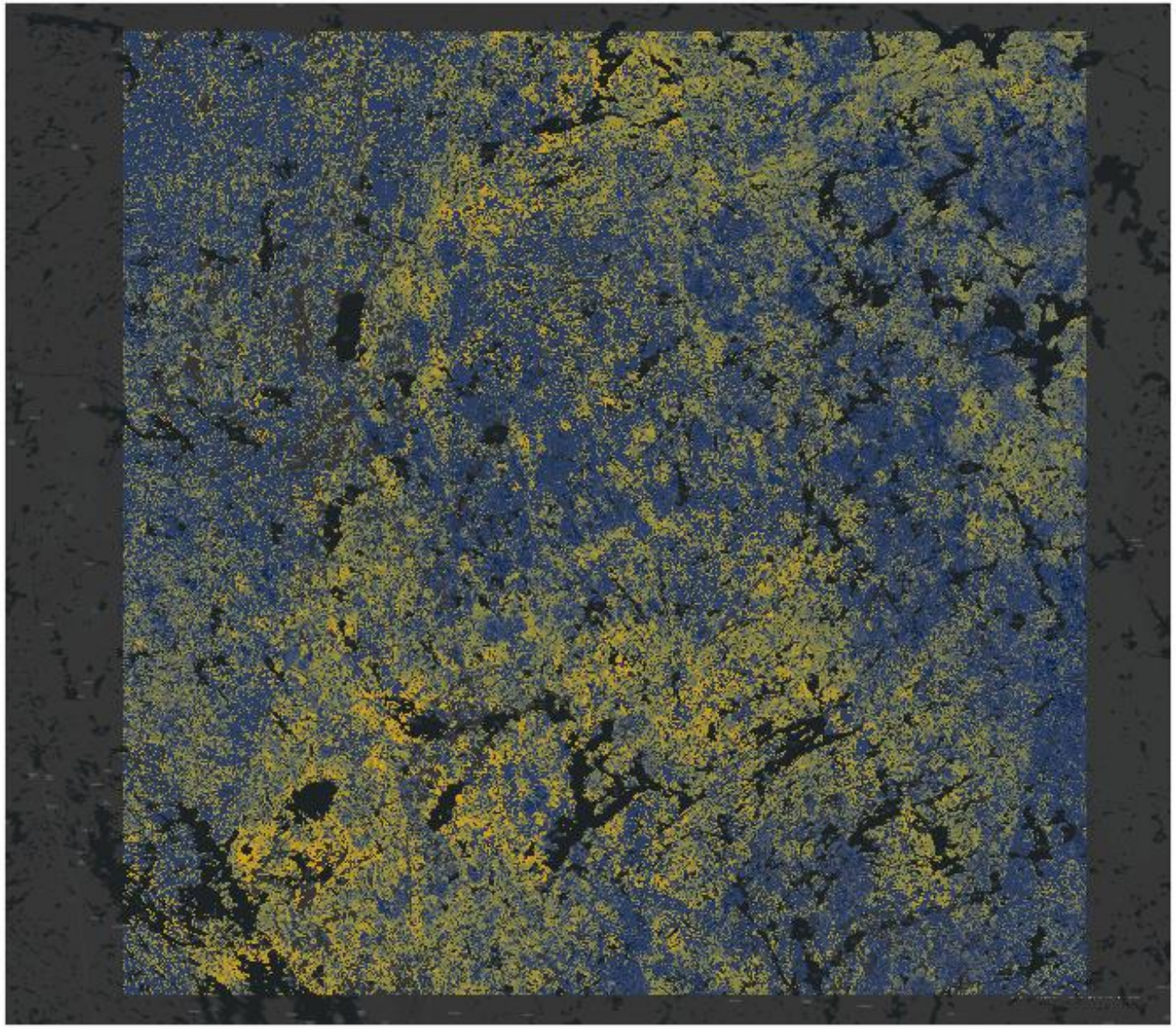
Level 2 Hemlock Probability Heat Map for 17TPL



N

Hemlock Probability Value

0.81

0.75

0.5

0.25

0.01

0 5 10 20 30 40 50 60 Kilometers

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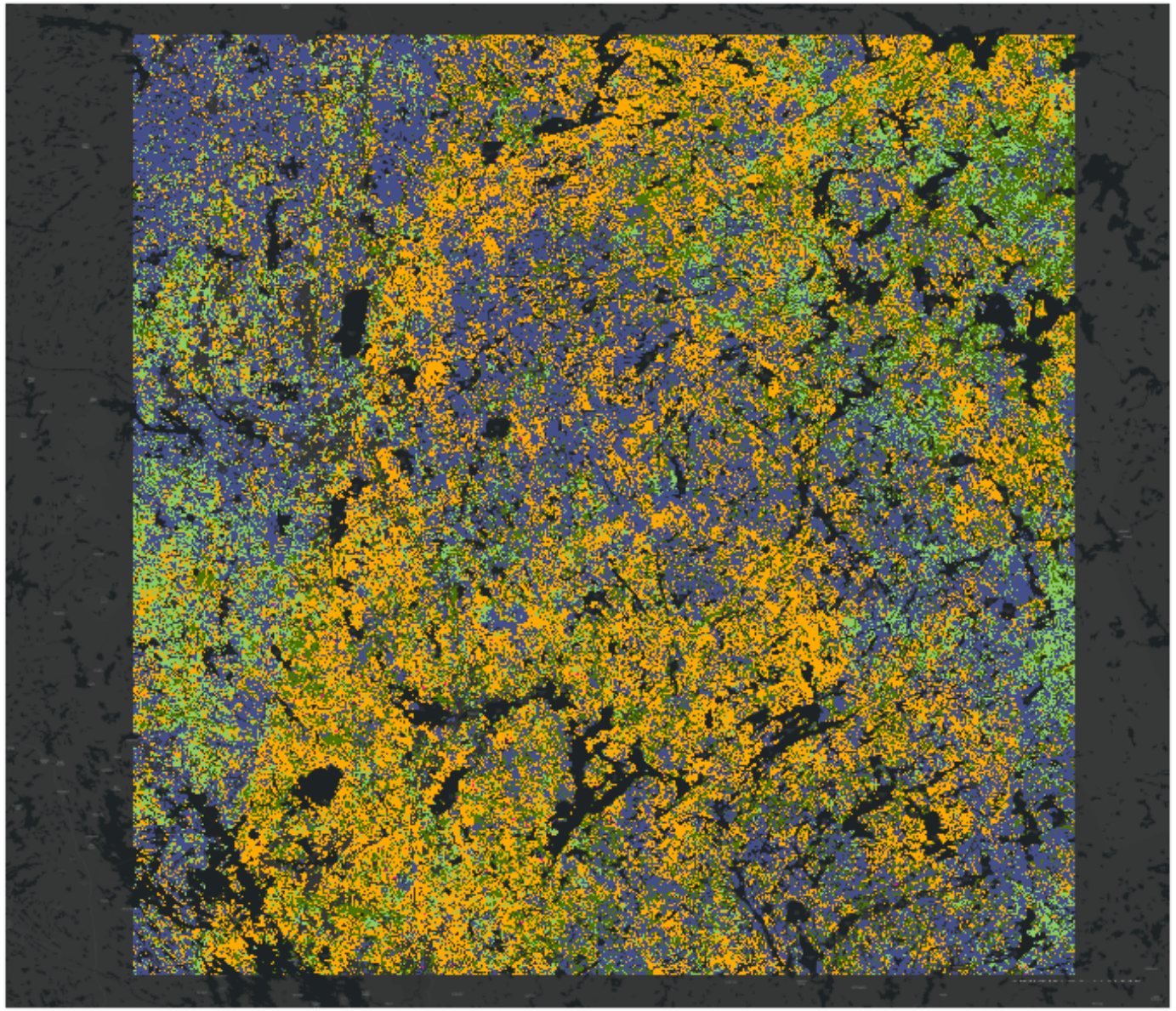
Level 2 Hemlock Distribution Map for 17TPL



N

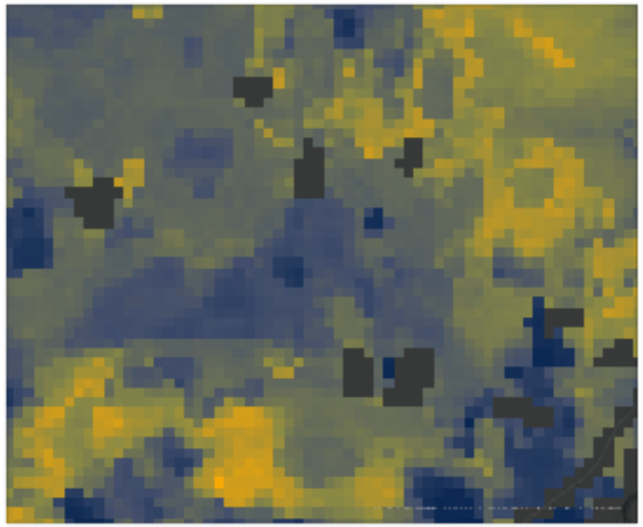
Forest Type
Value
- Hemlock evergreen
- Non-hemlock evergreen
- Hemlock mixwood
- Non-hemlock mixwood
- Deciduous

0 5 10 20 30 40 50 60 Kilometers

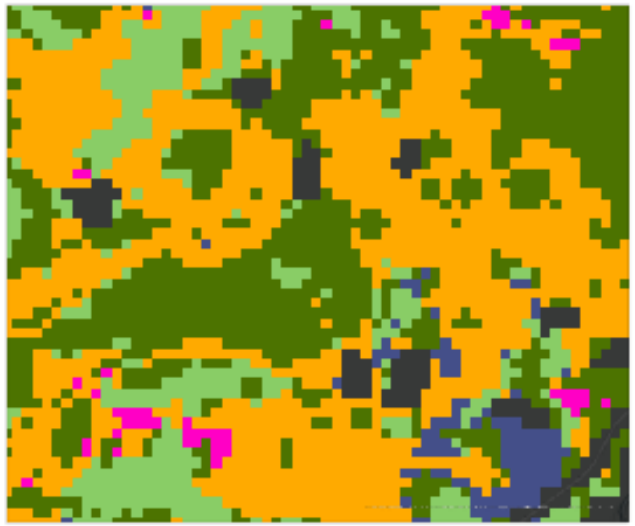
Level 2 Random Forest 17TPL - Zoomed In

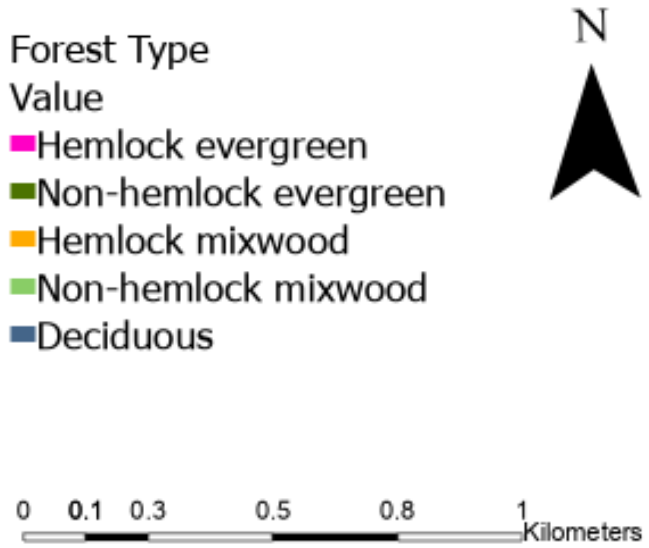
Ground Image from ArcPro GIS

Hemlock Probability Heat Map

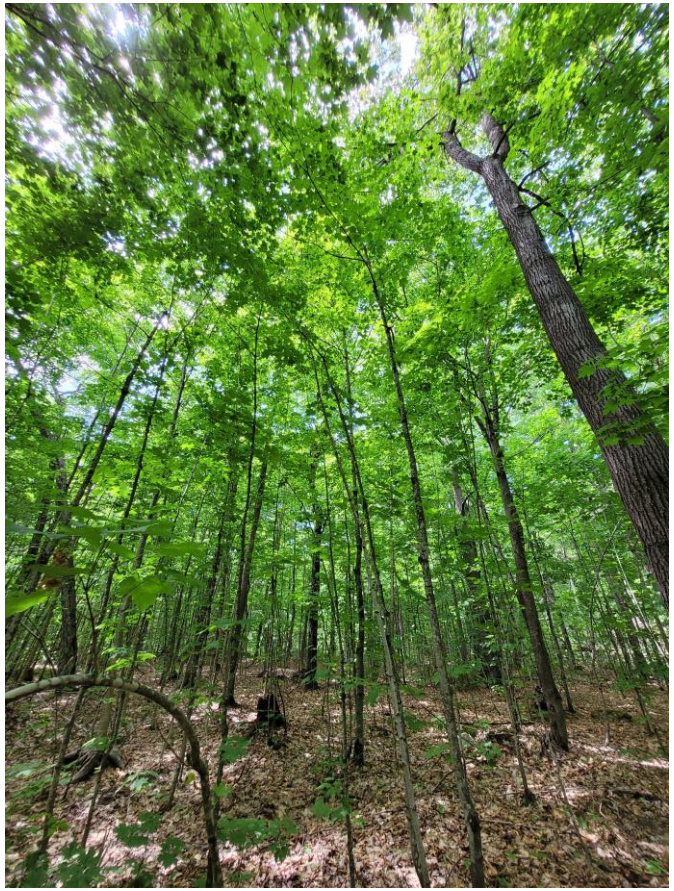


Hemlock Distribution Map



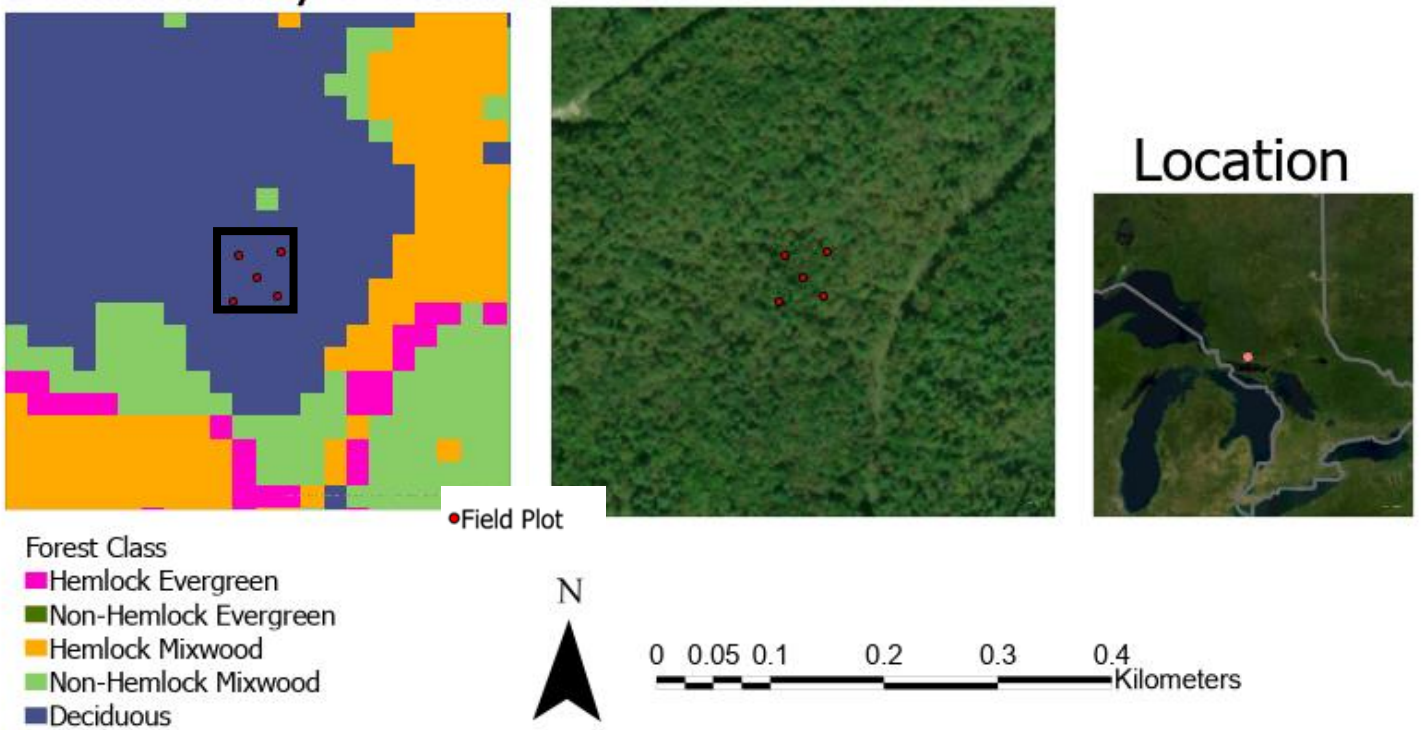


Example: Correct Predication

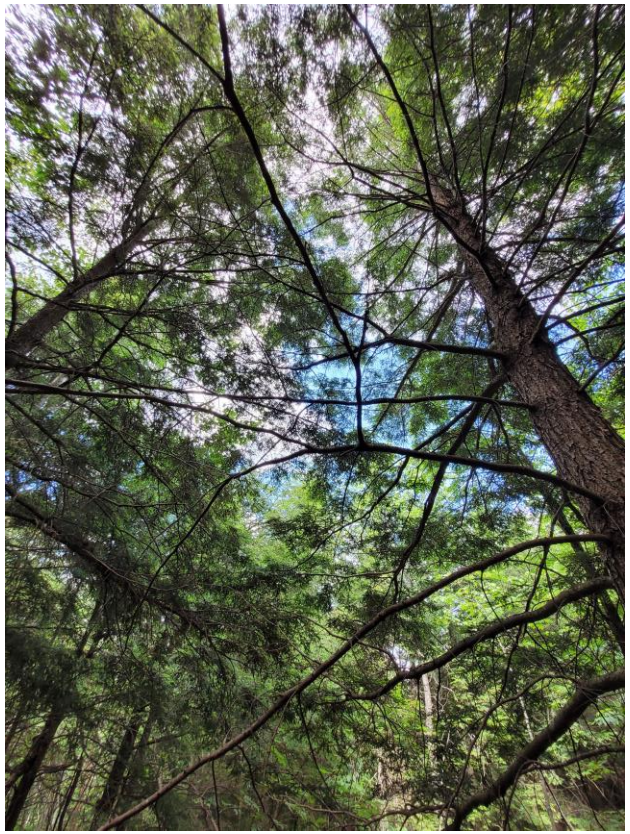


Plot# 149 - West of Eliot Lake

Field data:
Dominant by Deciduous Forest

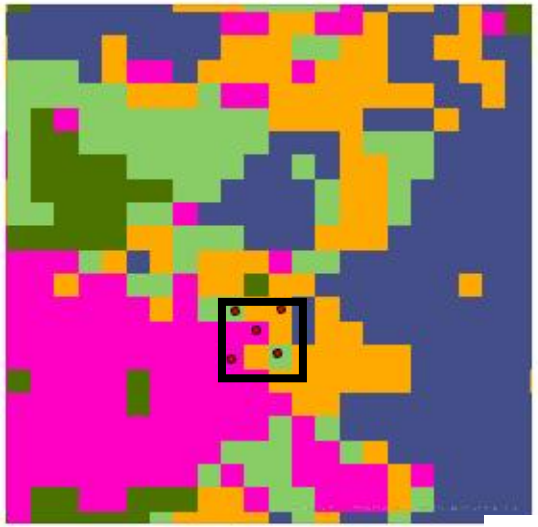


Example: Correct Predication



Plot# 5- Eliot Lake

Field data:
Dominant by Hemlock mixwood, and Hemlock evergreen



Location

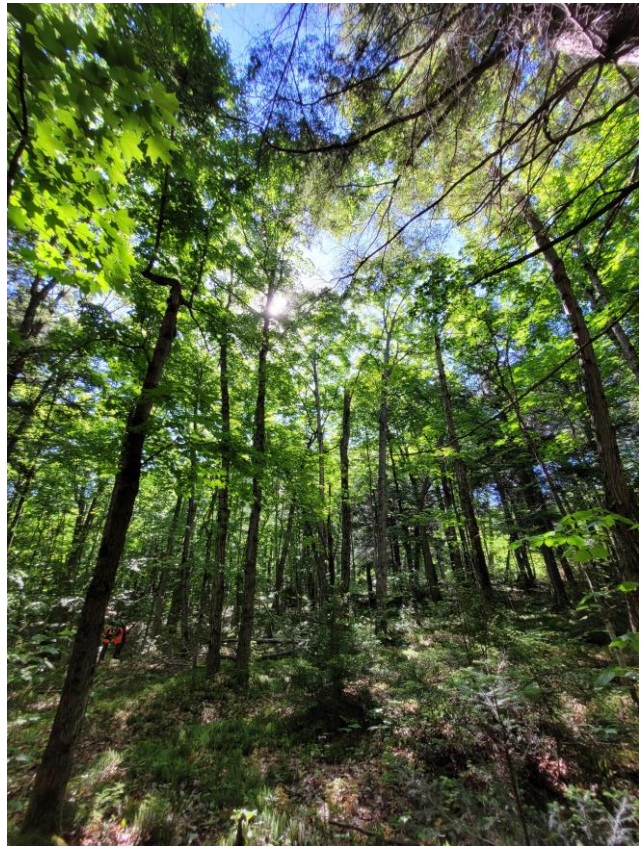
Forest Class
- Hemlock Evergreen
- Non-Hemlock Evergreen
- Hemlock Mixwood
- Non-Hemlock Mixwood
- Deciduous

Field Plot

N

0 0.05 0.1 0.2 0.3 0.4 Kilometers

Example: Wrong Predication

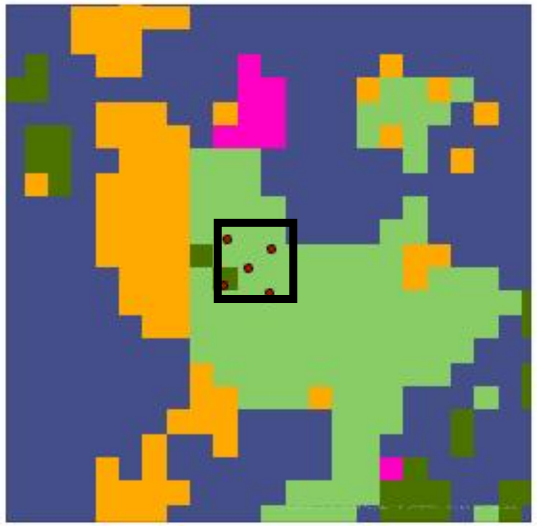


Plot# 29 has more canopy opening compares to other two plots

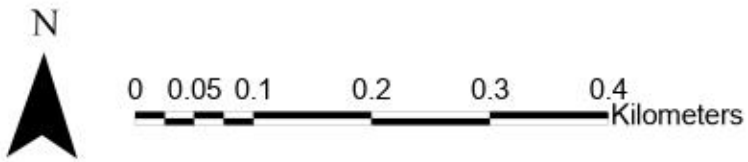
Plot# 29- West of Eliot Lake

Field data:

Dominant by Hemlock evergreen, and Hemlock mixwood



Location



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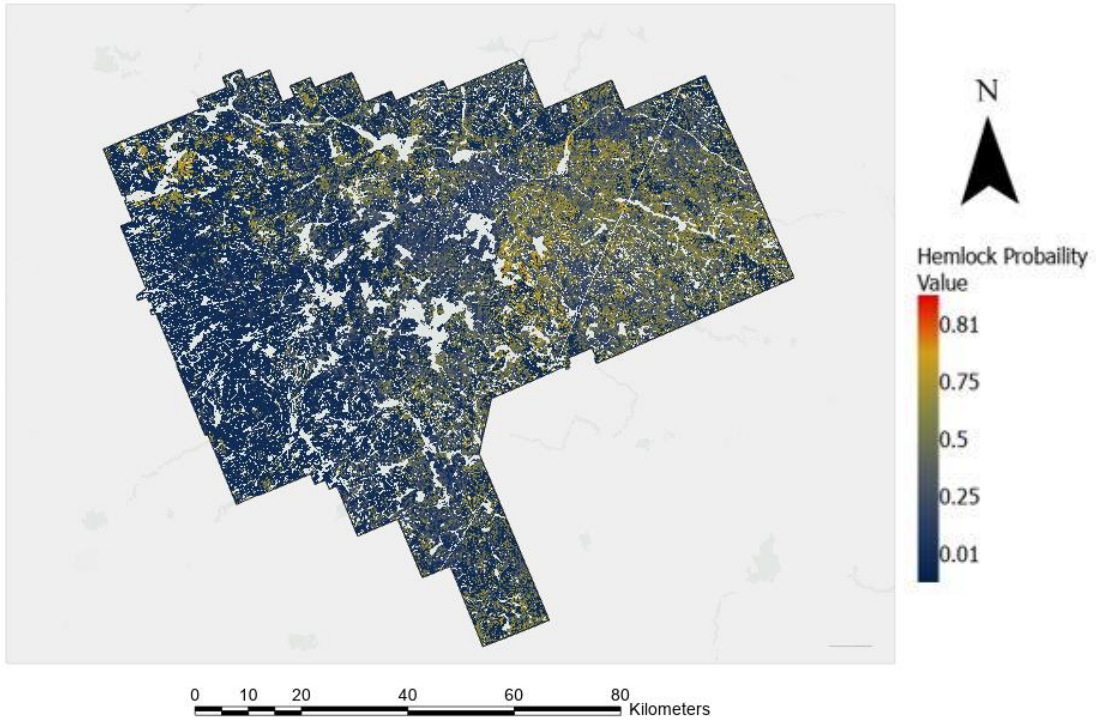
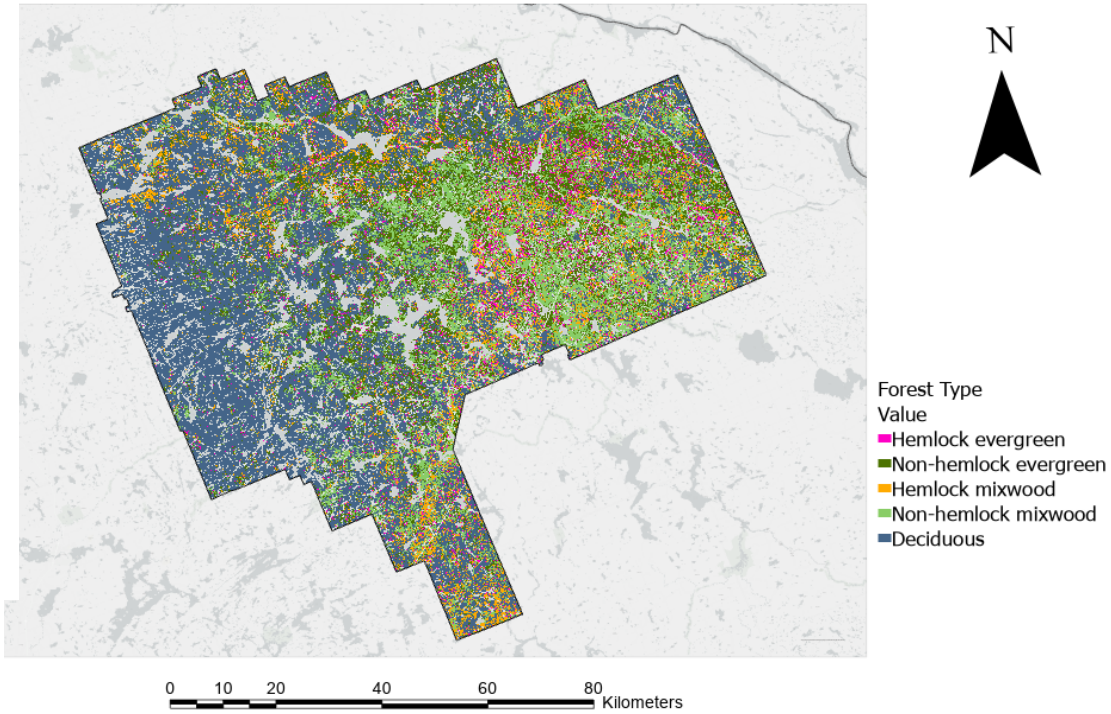
Algonquin Park Hemlock Probability Map



Algonquin Park Hemlock Distribution Map



Limitation and Future Improvement

Model Limitation

- Plot canopy cover limitation
- Clustered training data

Future Improvement

- High quality training data
- High spatial and spectral resolution data
- Lidar data
- Other ecological information

Future Application

Guide the HWA survey

Provide information for other conservation project

Ex: White tail deer conservation

Developed a classification method that may apply for other species

Summary

Constructed and evaluated the first hemlock classifier in Ontario using satellite imagery and phenological parameters.

It is hard to classify a minor species in a mixed stand with complex species interaction.

Better training data is needed for higher accuracy, Sentinel-2 imagery might be too coarse for detailed species classification.

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Contact:

Zhaoshu Shi: zhaoshu@uoguelph.ca

Ben DeVries: bdv@uoguelph.ca

Chris MacQuarrie: christian.macquarrie@nrcan-rncan.gc.ca

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