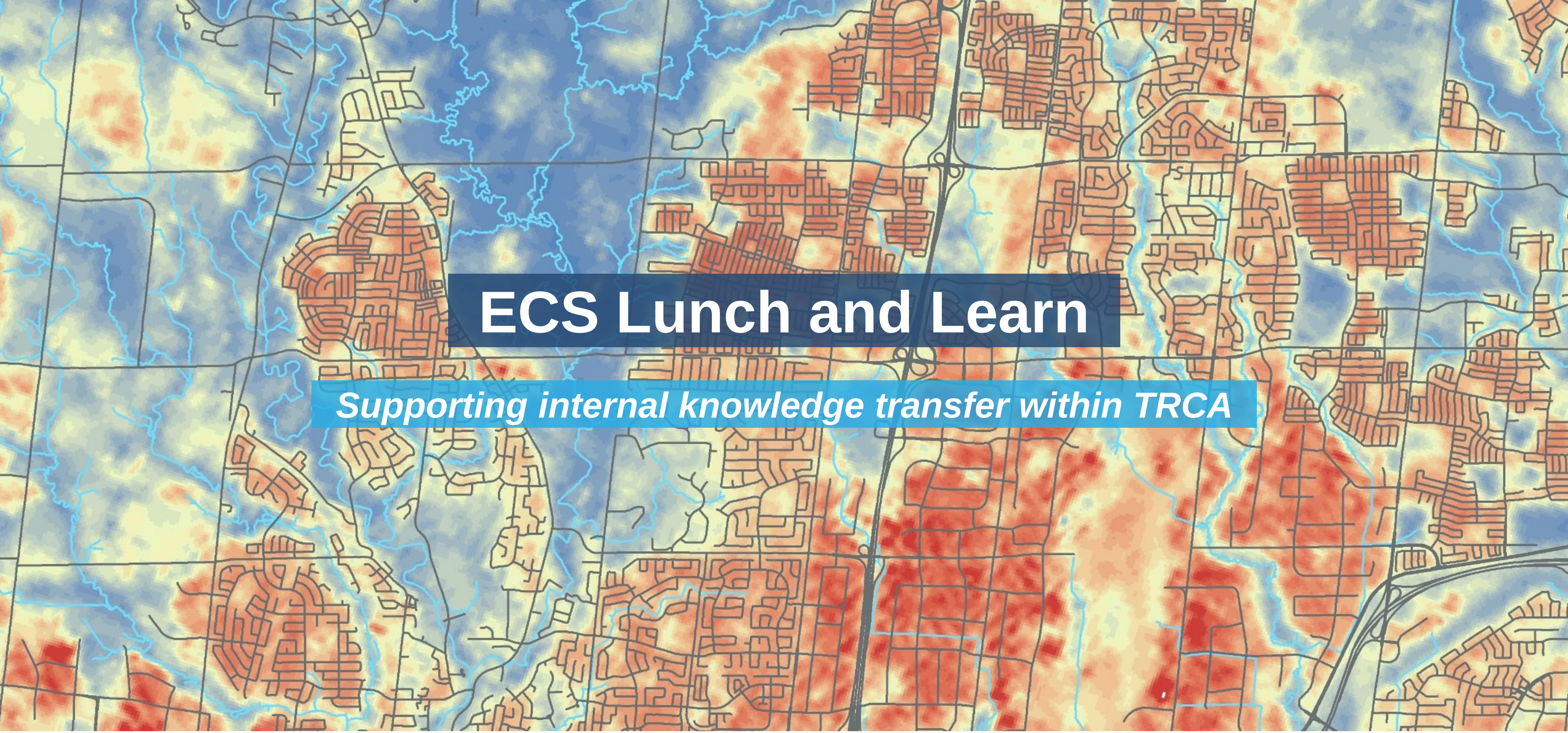


ECS Lunch and Learn

Supporting internal knowledge transfer within TRCA

April 14, 2021

Toronto and Region Conservation Authority

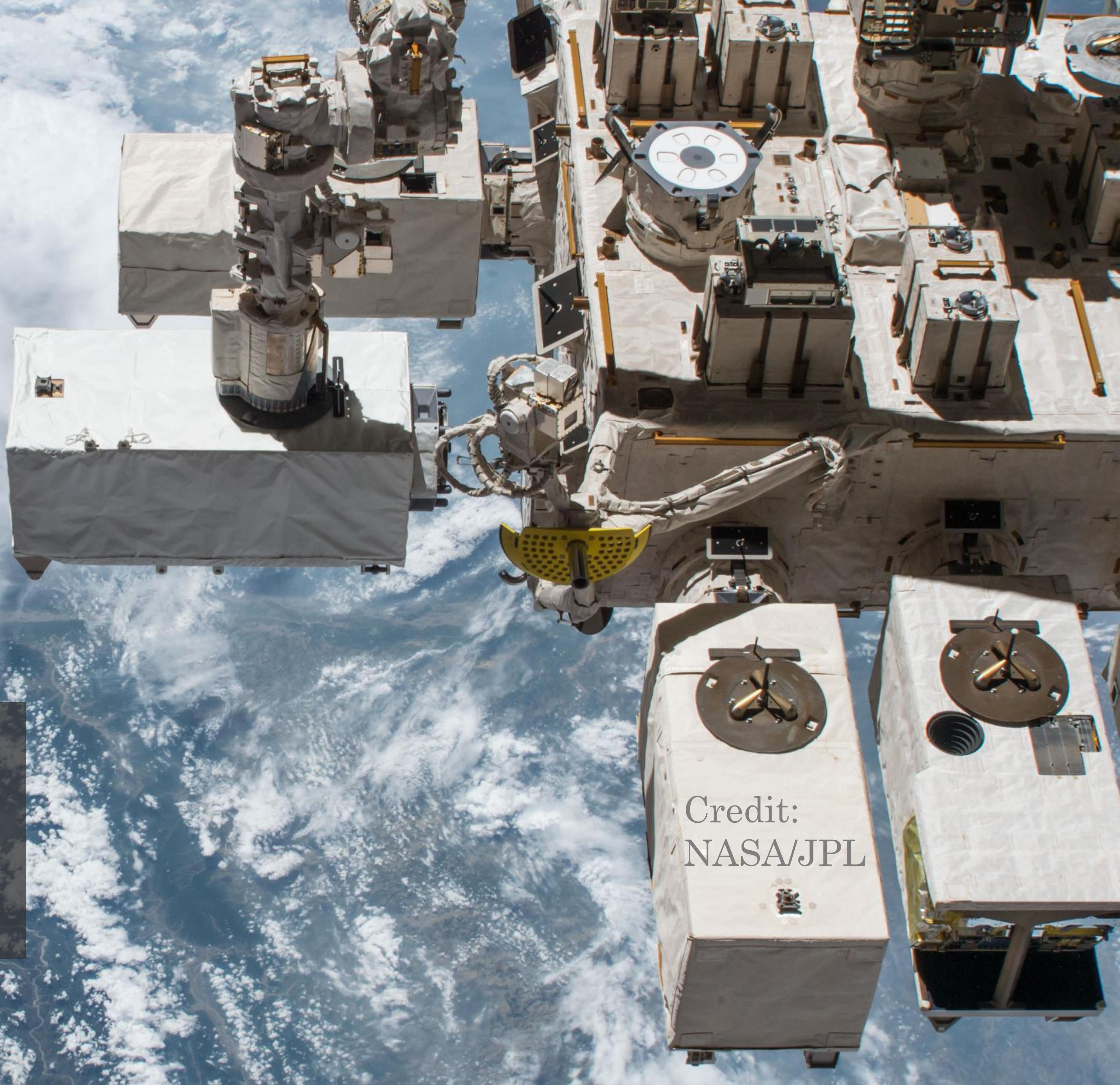

Jonas Hamberg

Thermal imaging for ecosystem conservation and restoration

Jonas Hamberg

Mitacs Postdoctoral Fellow
TRCA (ECS) & University of Toronto

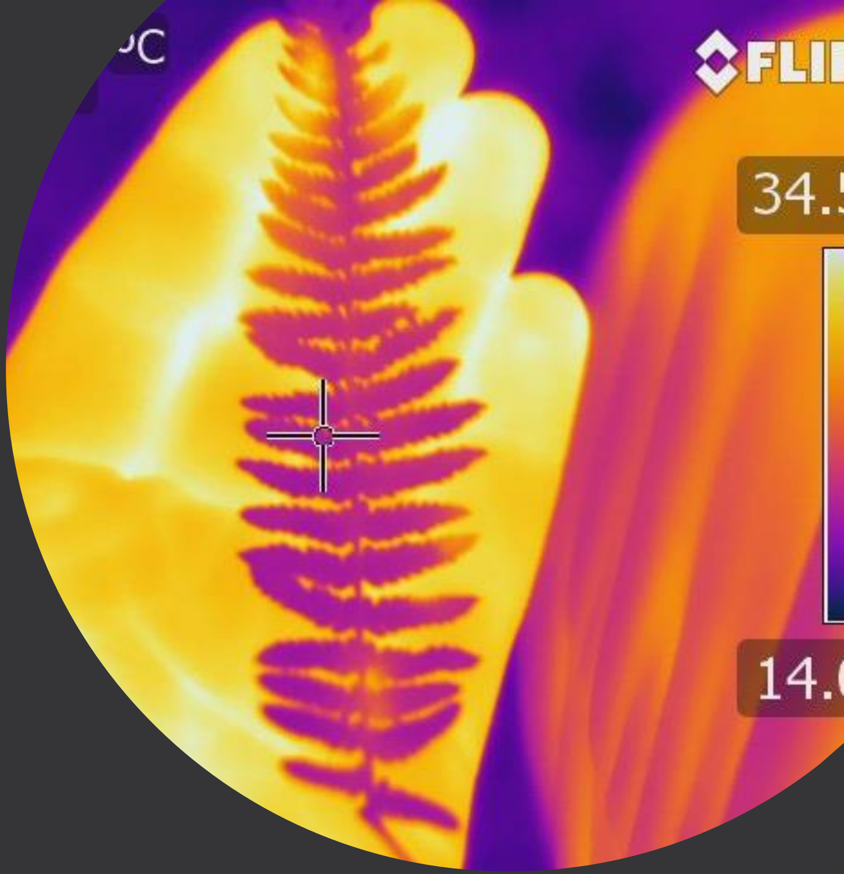
Advisors: Jonathan Ruppert & Patrick James (UofT)



Credit: NASA/JPL

Presentation outline

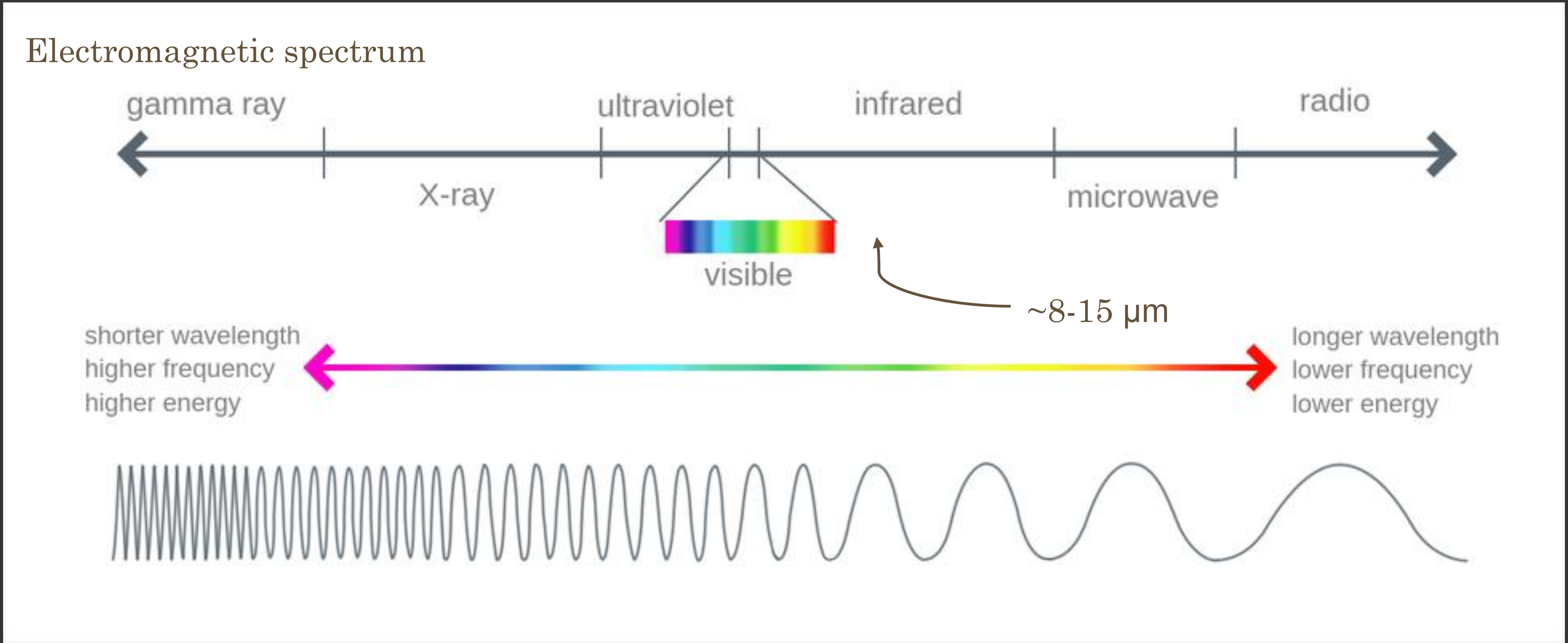
- Who is this guy?
- What is thermal imaging?
- How does thermal imaging fit into conservation and restoration management?
- Example 1: Landsat – restoration temperature over time
- Example 2: Drone thermal imaging
- Example 3: TRCA site temperatures over time of day
- Example 4: Rouge Valley mini-study
- What's next?

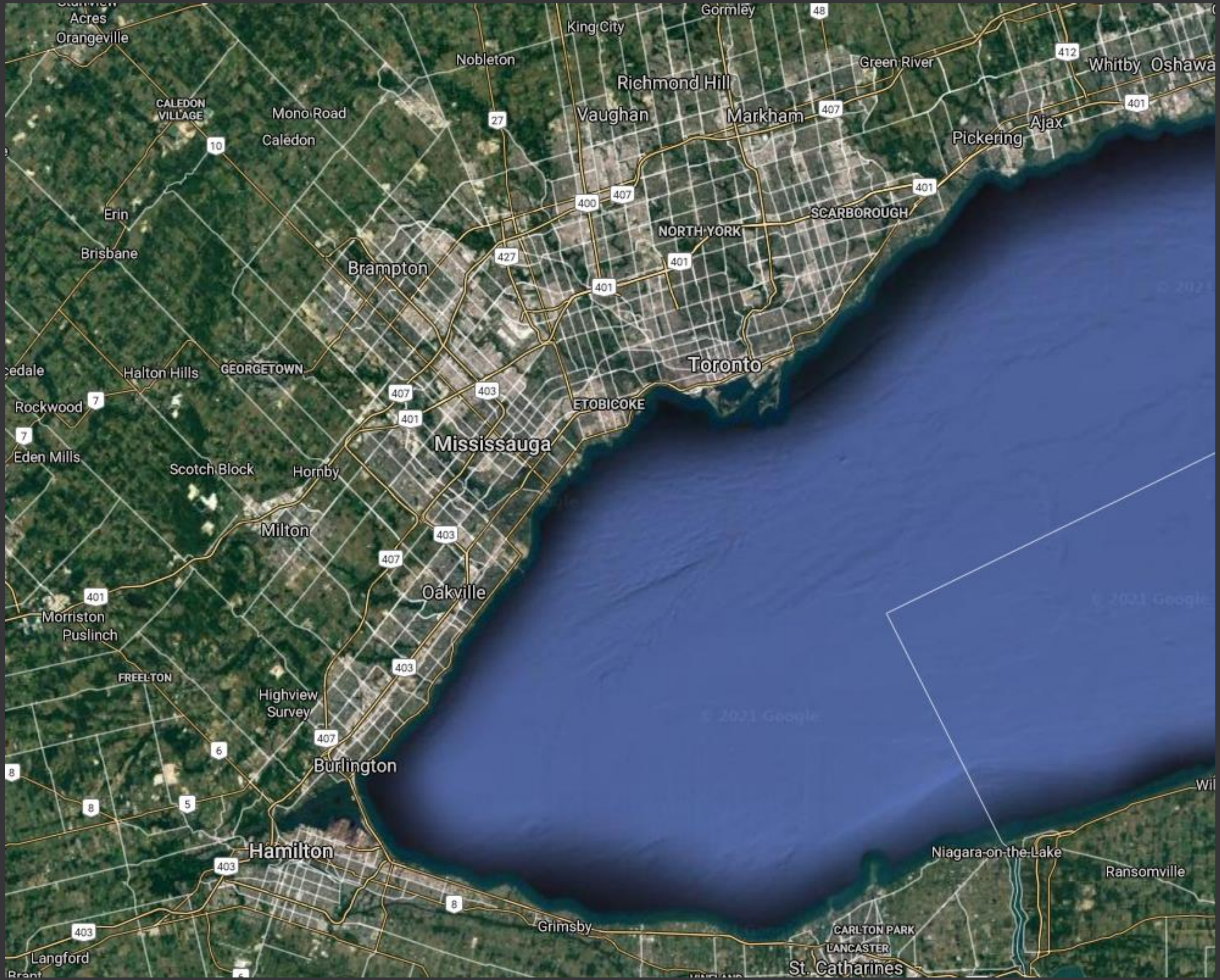


Jonas Hamberg

- Swede (can pronounce all IKEA furniture, but messes up J and Y sounds)
- M.Sc. from SUNY-ESF in Upstate New York, US
- PhD in Social and Ecological Sustainability (Restoration Ecology) from University of Waterloo
- 2 year Mitacs post-doc with University of Toronto and TRCA (ECS)

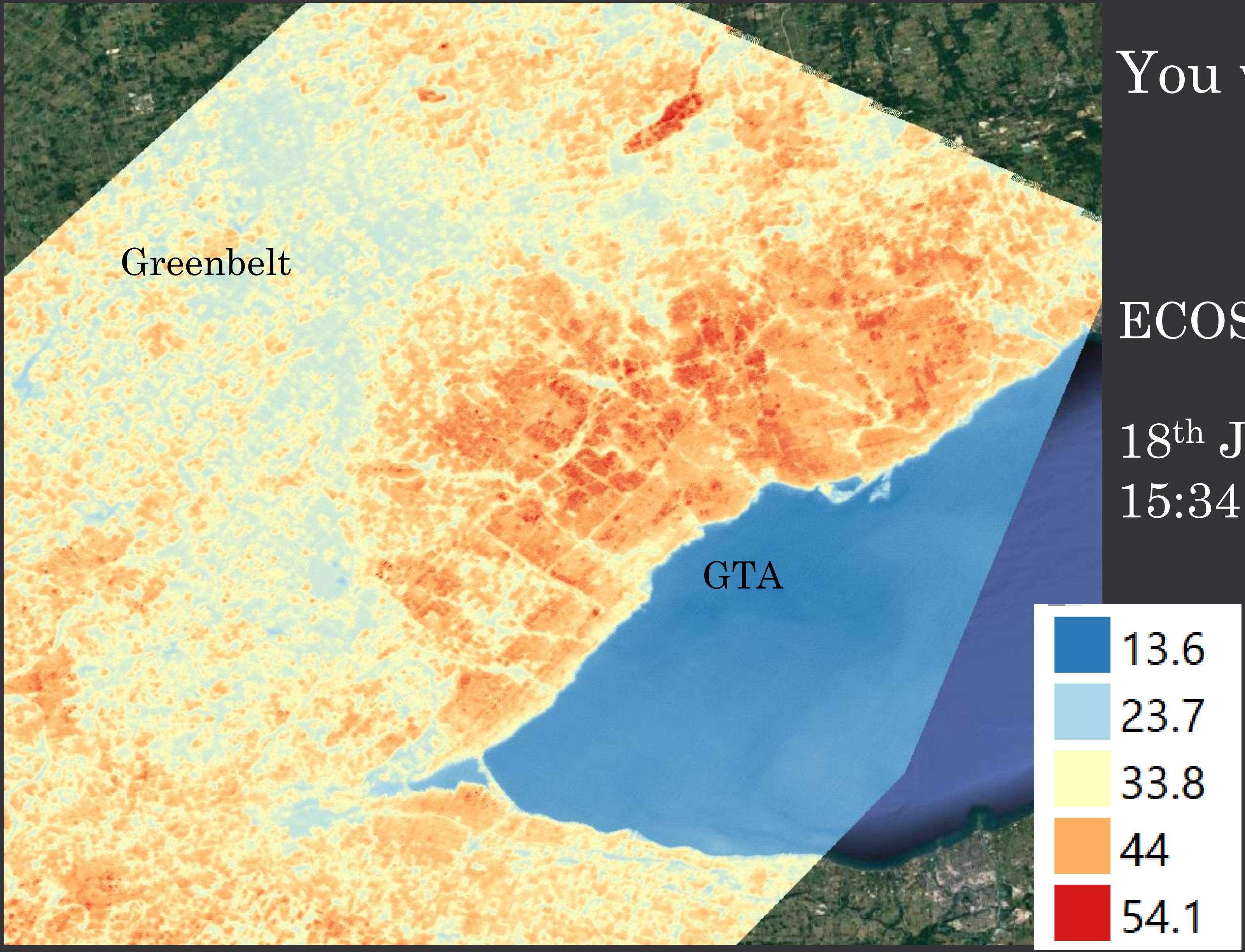
What is thermal imaging?





You <u>were</u> here

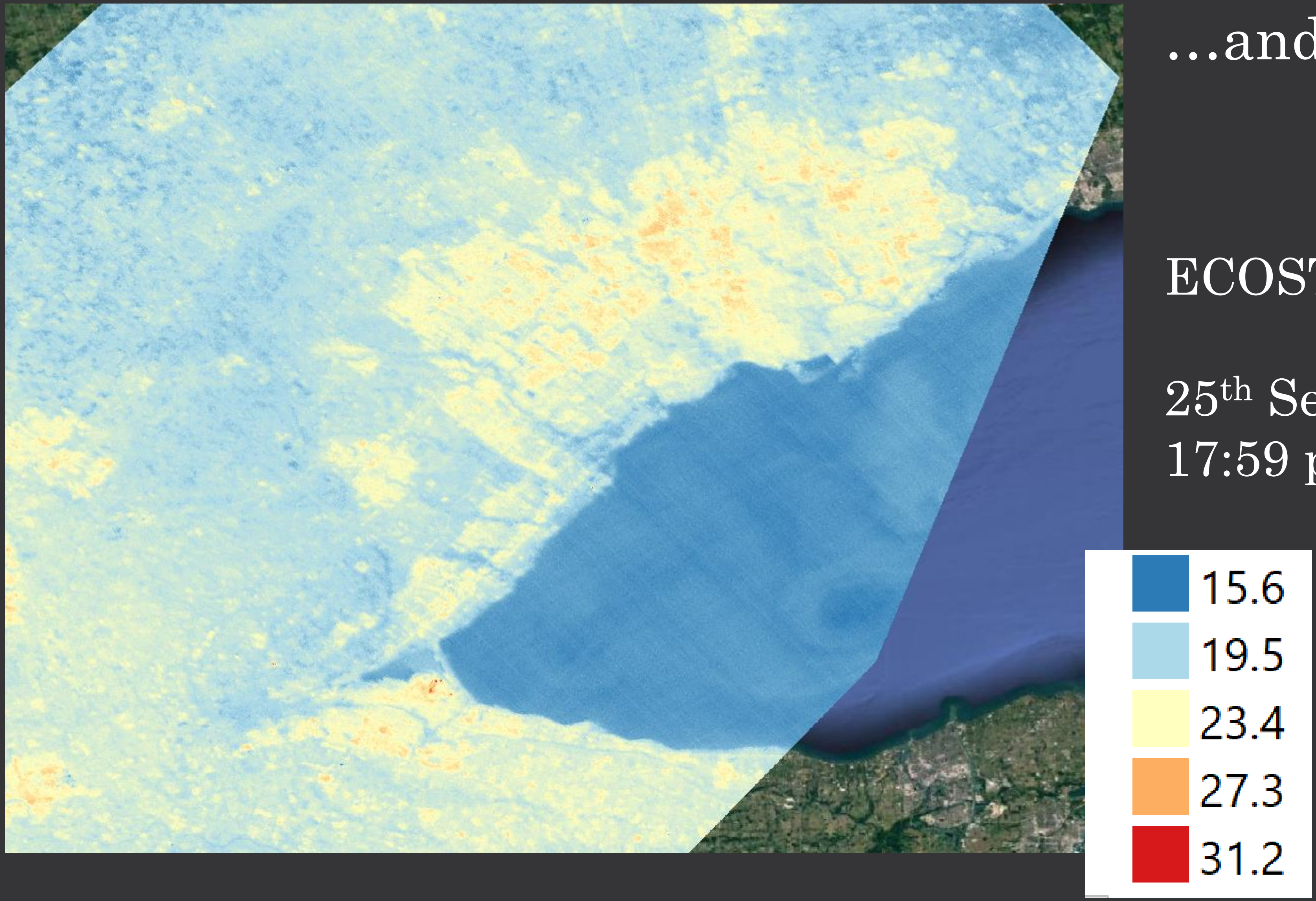
Google imagery – multiple sources ~2019-2021



You were just as much here

ECOSTRESS imagery

18th June 2020
15:34 pm



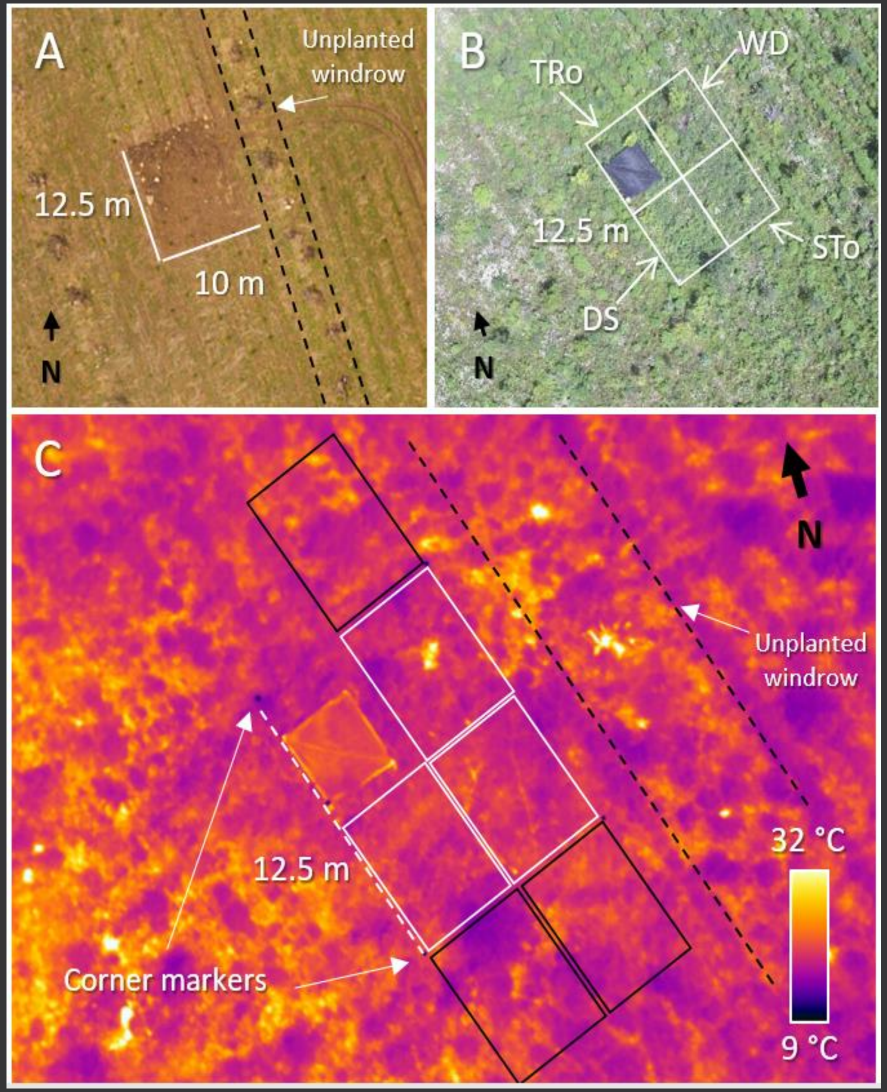
...and here

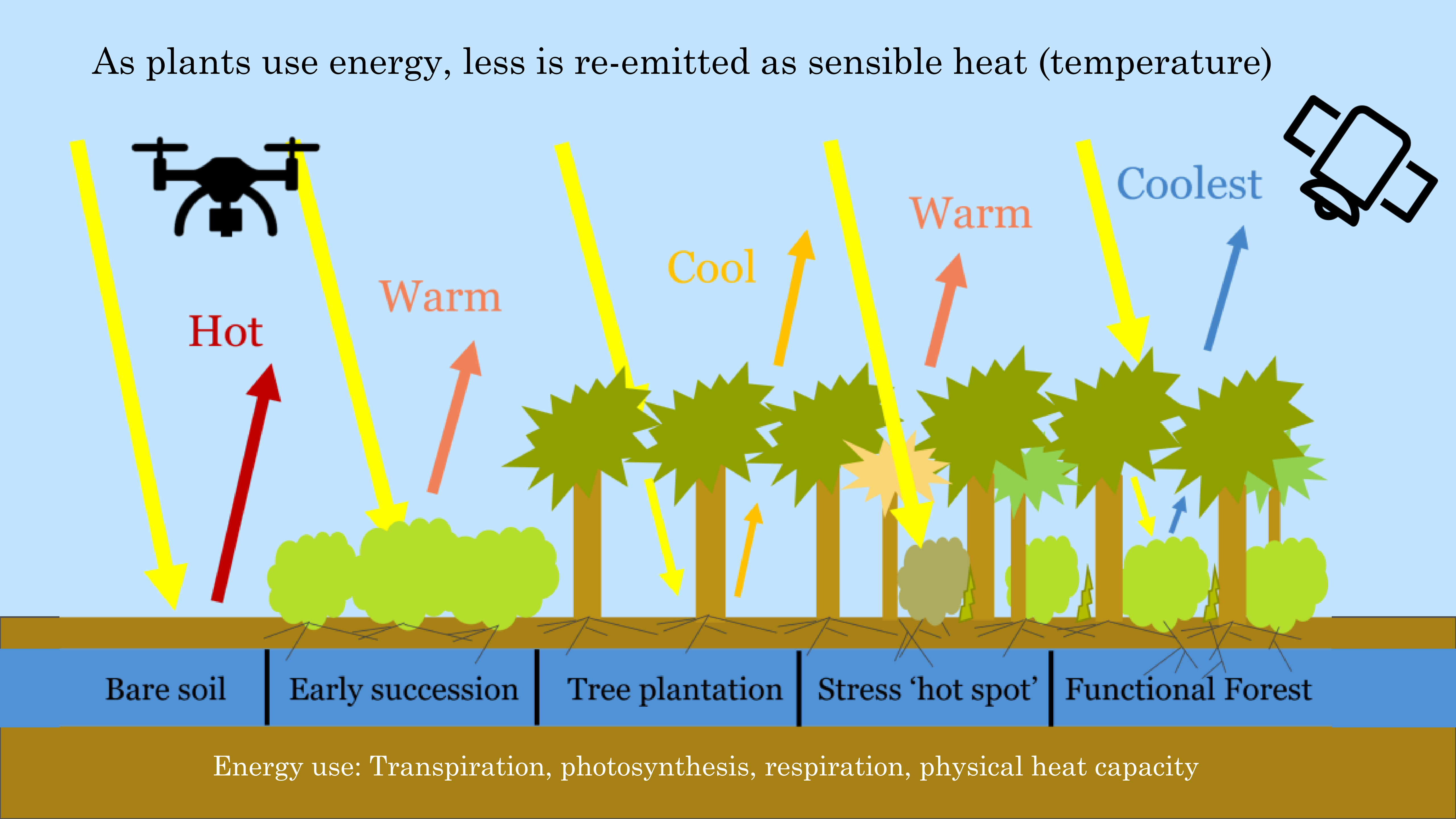
ECOSTRESS imagery

25th September 2020
17:59 pm

How is it used?

- Thermal camera (or imager, bolometer, thermographer etc.)
- Handheld, airplane, drone (RPAS), satellite, space station
- Military, search and rescue, inspection, agriculture and ecology (?)
- Ecology/Conservation: Mostly used to track larger warm-blooded animals and for urban heat island effects
- Cutting-edge: thermal imaging of ecosystem stress (e.g. disease) and energy utilization

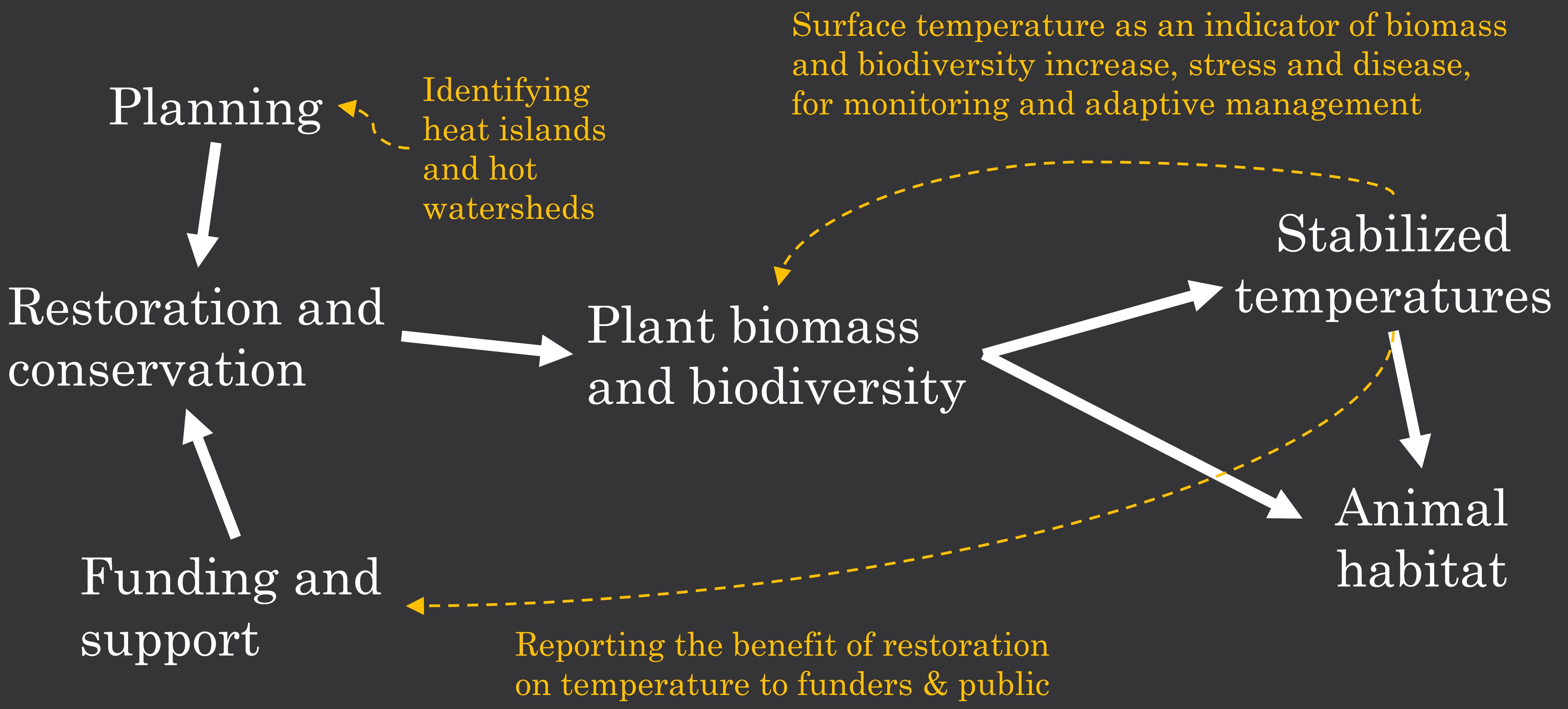



As plants use energy, less is re-emitted as sensible heat (temperature)
Hot
Warm
Cool
Warm
Coolest
Bare soil
Early succession
Tree plantation
Stress 'hot spot'
Functional Forest
Energy use: Transpiration, photosynthesis, respiration, physical heat capacity

What we (academics and practitioners) are trying to figure out

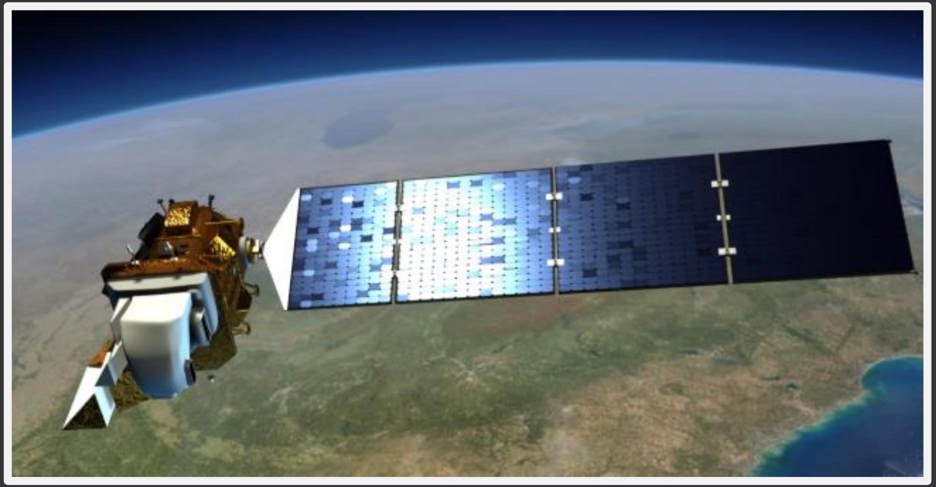
- Is there a thermal (temperature) effect, how big is the effect, how easy/useful is it to locate the effect of:
  - Differences in plant biomass
  - Differences in plant biodiversity
  - Evapotranspiration
  - Drought stress
  - Disease stress
  - Patch size of vegetation
  - Etc.

Where could thermal imaging be of use to TRCA?



Satellites & Space Station

- Free and publically available
- Large extent
- Historical global data back to 1984
- Low resolution (60-120 m)
- Clouds are a real issue (



Drone
(RPAS - Remotely Piloted Aircraft System)

- High resolution (centimeters)
- You decide when to fly
- Less error due to atmospheric conditions
- Becoming cheaper
- Requires training, certification, approval

Example 1: Agriculture to Oak-woodland restoration with Landsat satellites

Photo-credit: Mary Gartshore

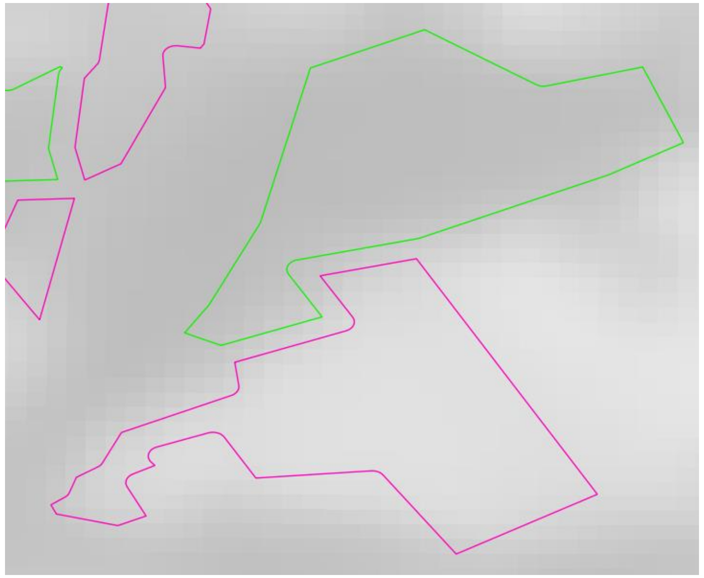
Study site

May 2006

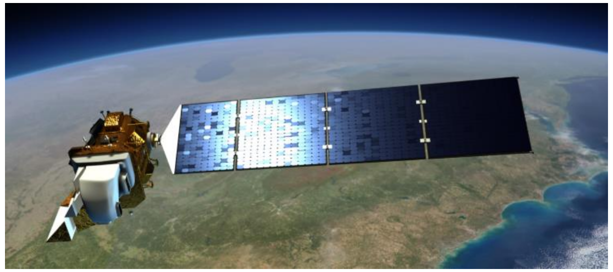
July 2018

Google maps base layer

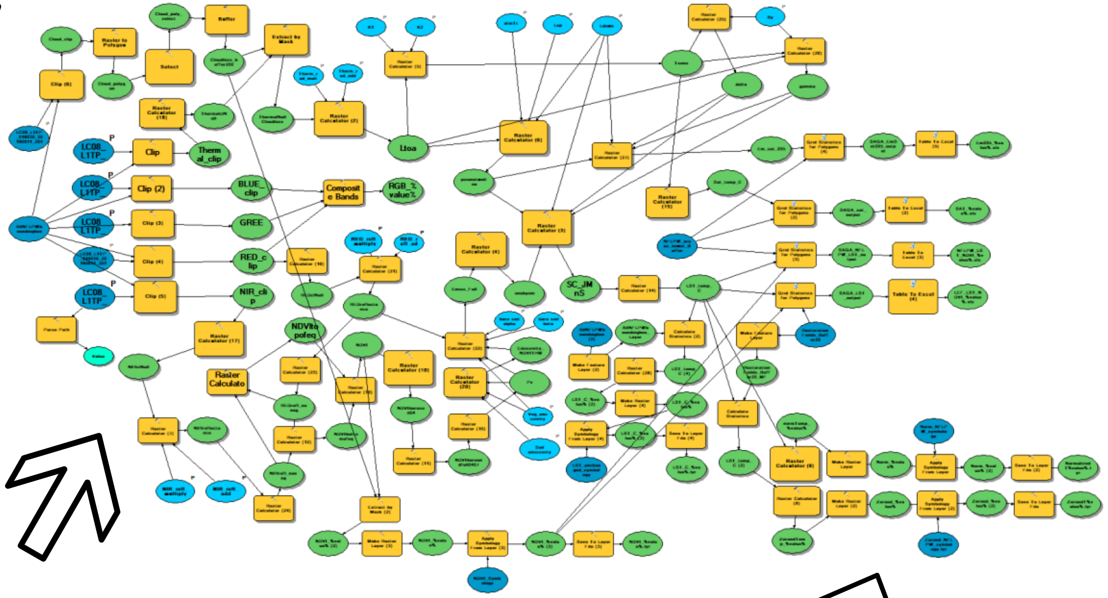
Image processing



Google maps base layer

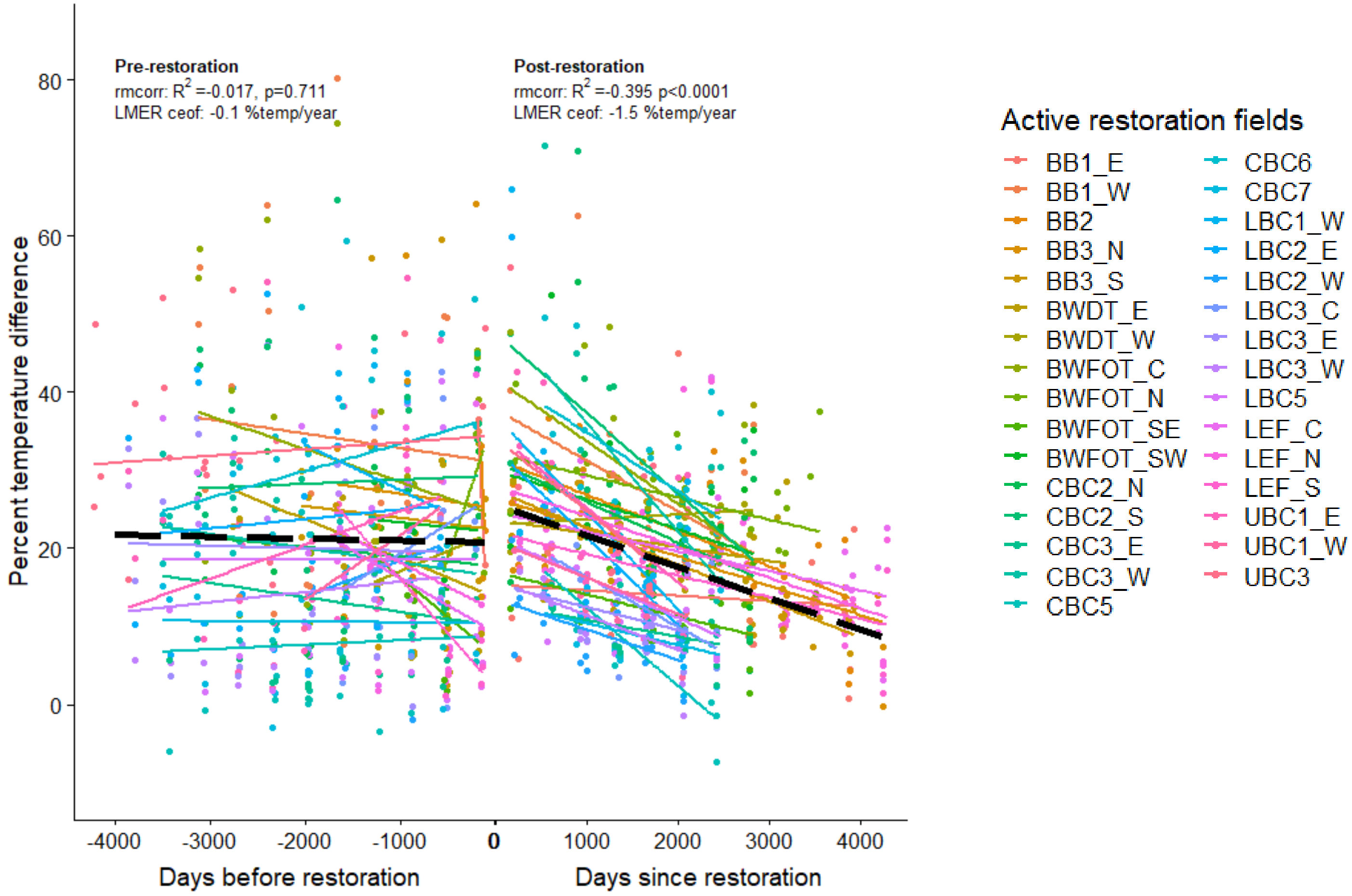


Atmospheric conditions

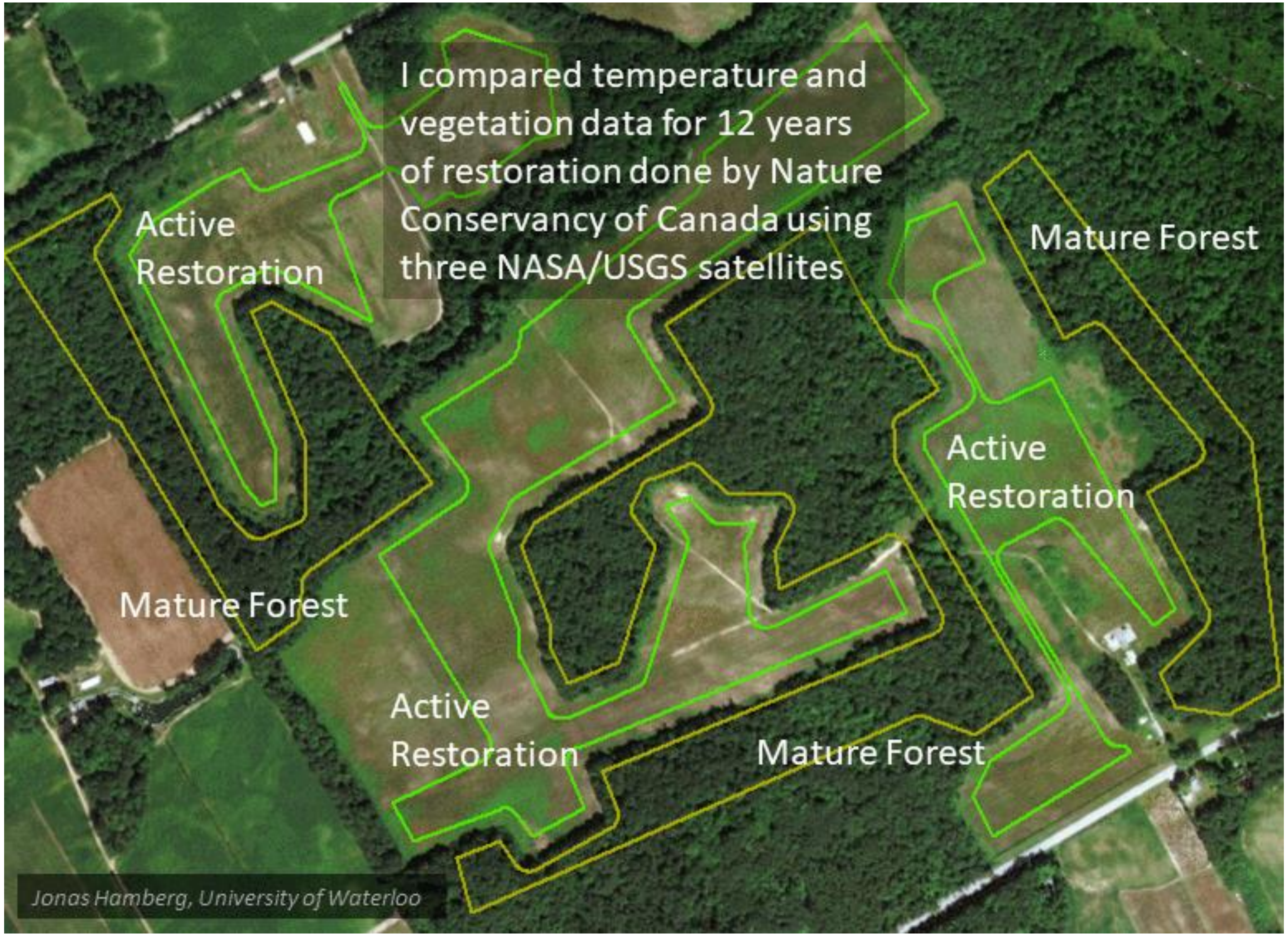


Emissivity

Normalize against paired mature forest area

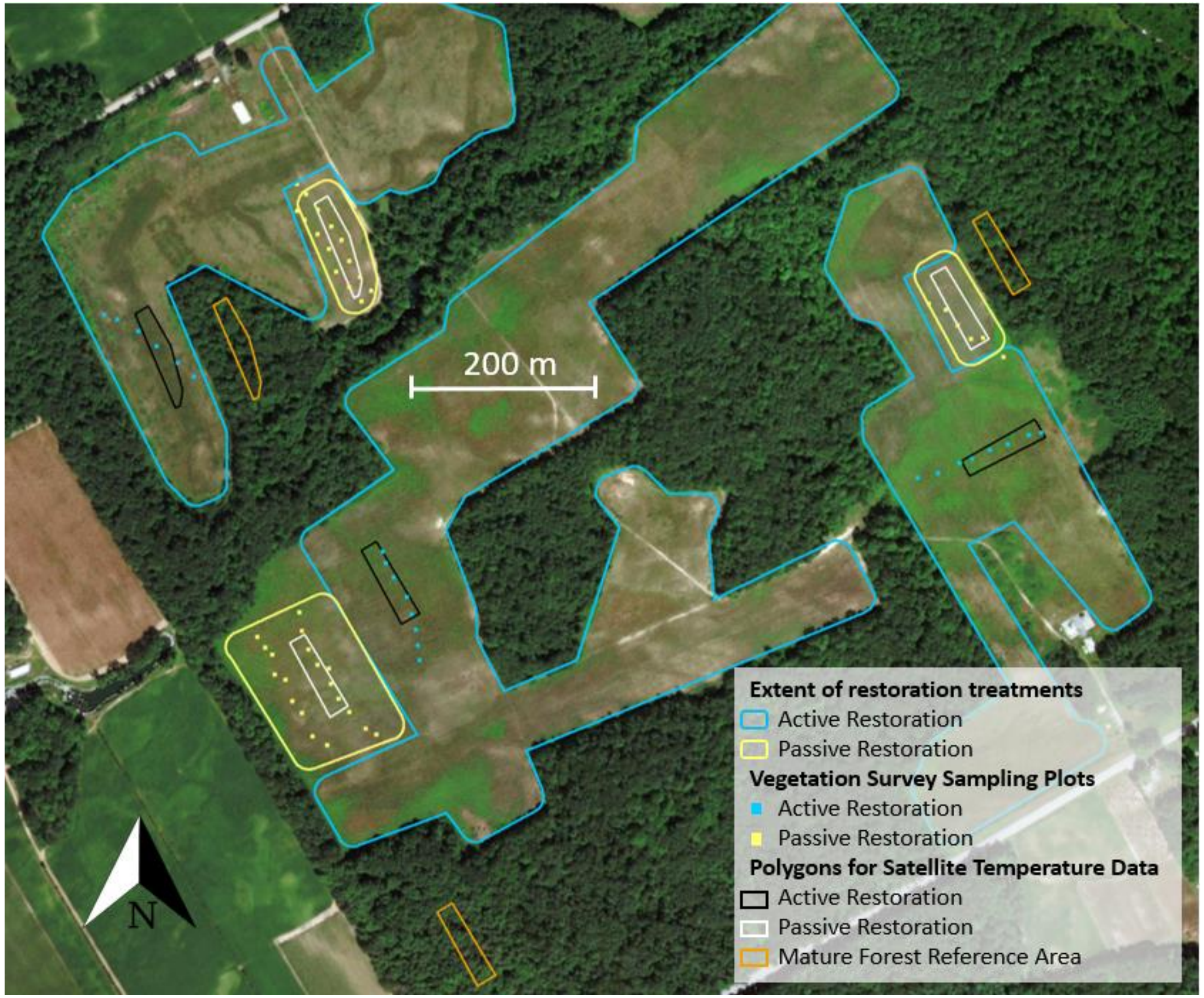


Mean temperature decrease -1.5 p.p. per year.
Equals approximately -4.5 °C in 12 years on a summer day



Google maps base layer

Comparing temperature to biodiversity and biomass



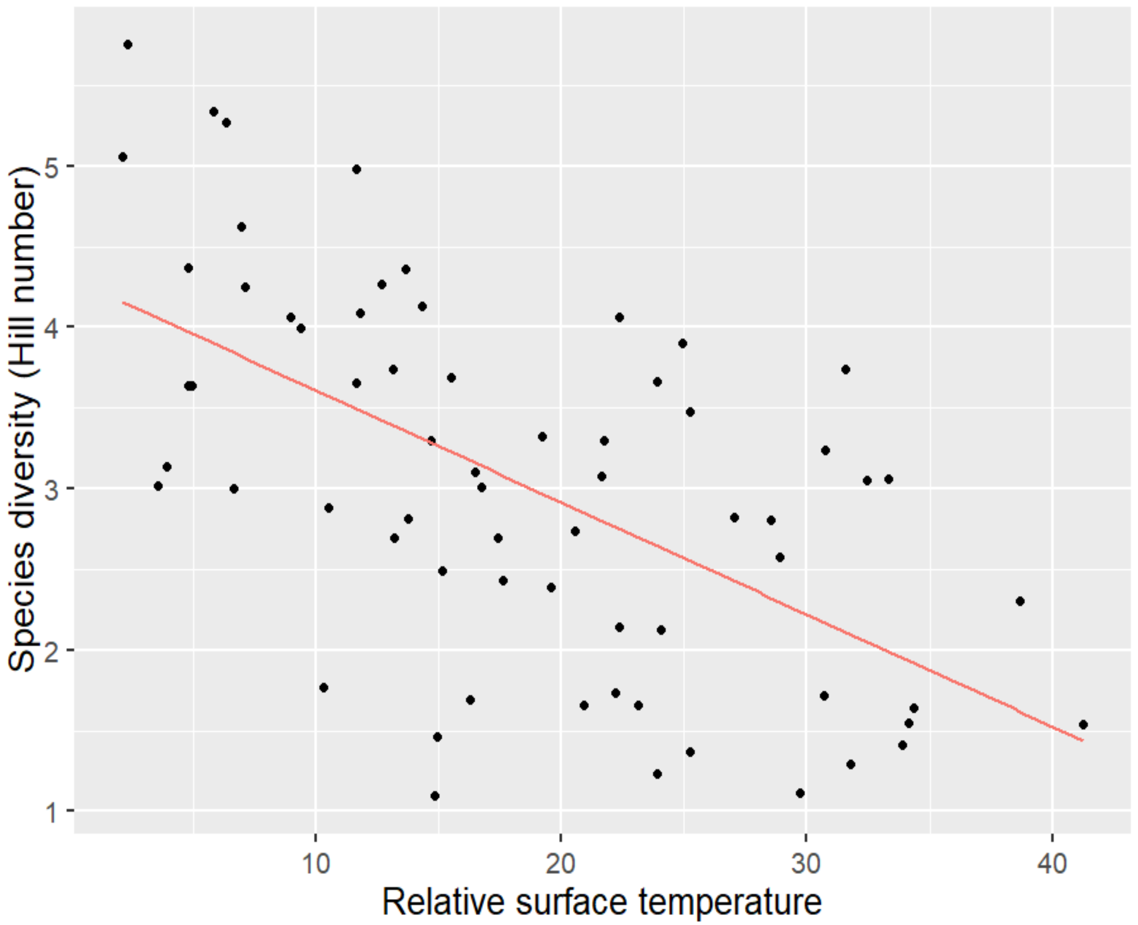
Google maps base layer

137 2x2m plots
In three fields surveyed for all plants by professionals 2007-2017

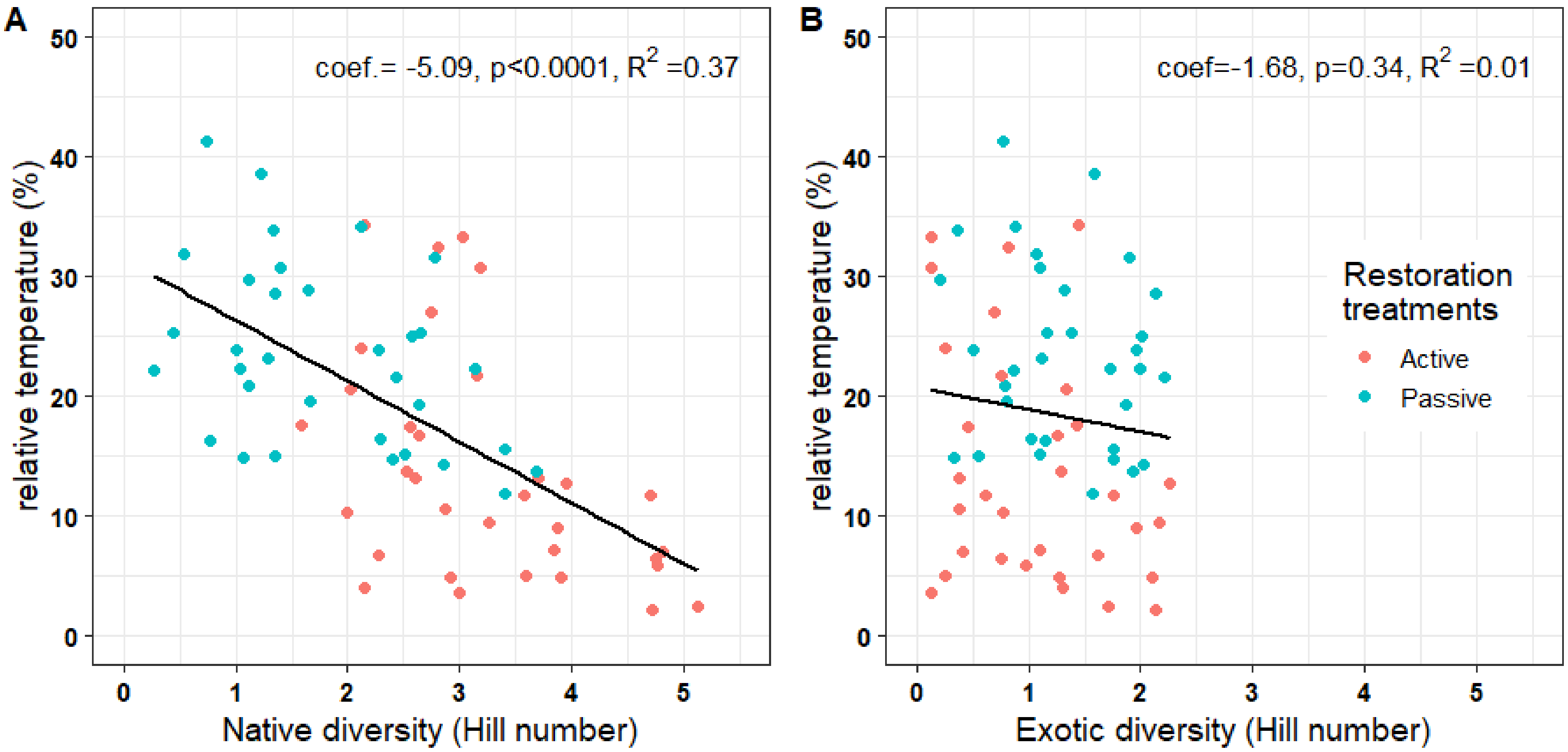
Three areas (yellow) were unseeded controls

3 paired areas were compared

When controlling for biomass, total plant cover and canopy cover – Each new species decreases temperature by about 0.5 °C



Native species may decrease temperature more than exotic ones*



*Sites may not contain enough exotic species for a fair comparison

Why would more, and more native species matter to temperature?

Ec

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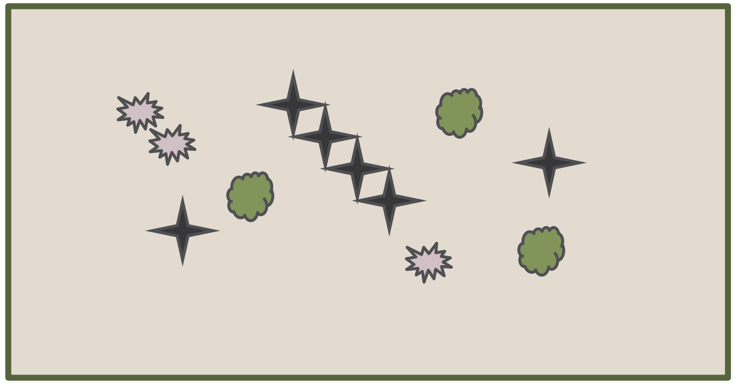
Ecosystem B

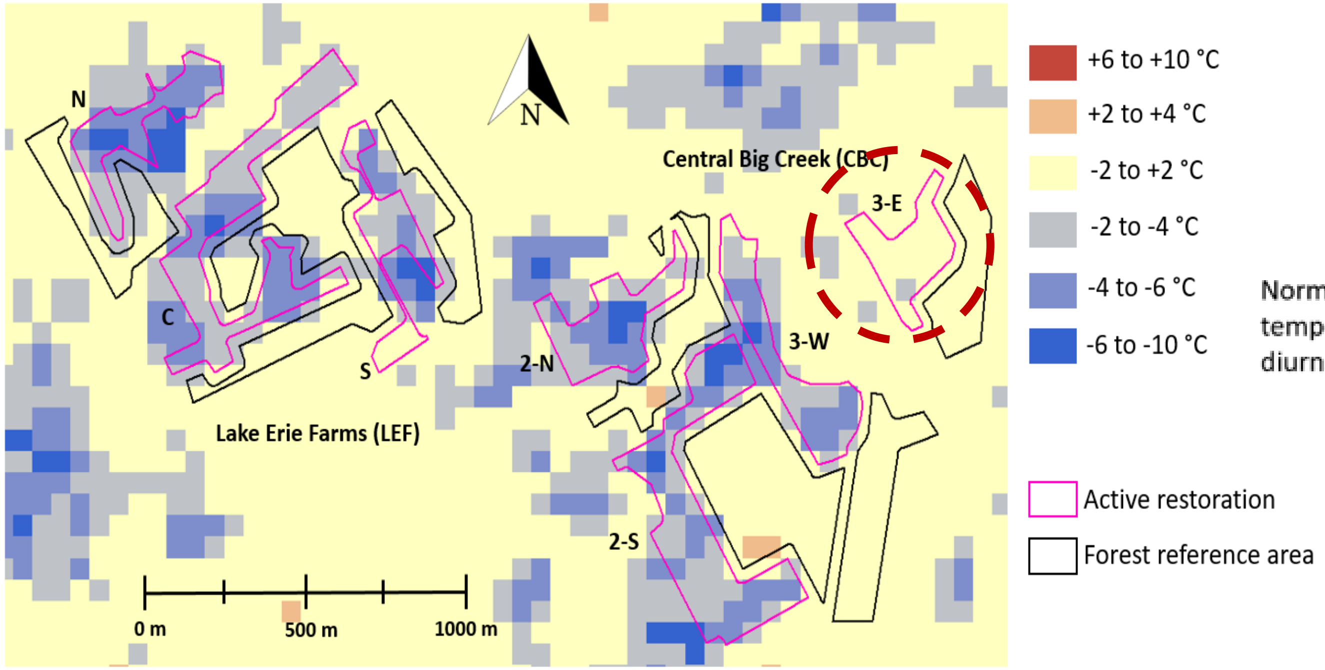
Same biomass as A, but three native species:

- Sets deeper roots to get more water
- Adapted to close and open to preserve water and keep cool
- Mycorrhizae bonds help with nitrogen uptake for more chlorophyll production



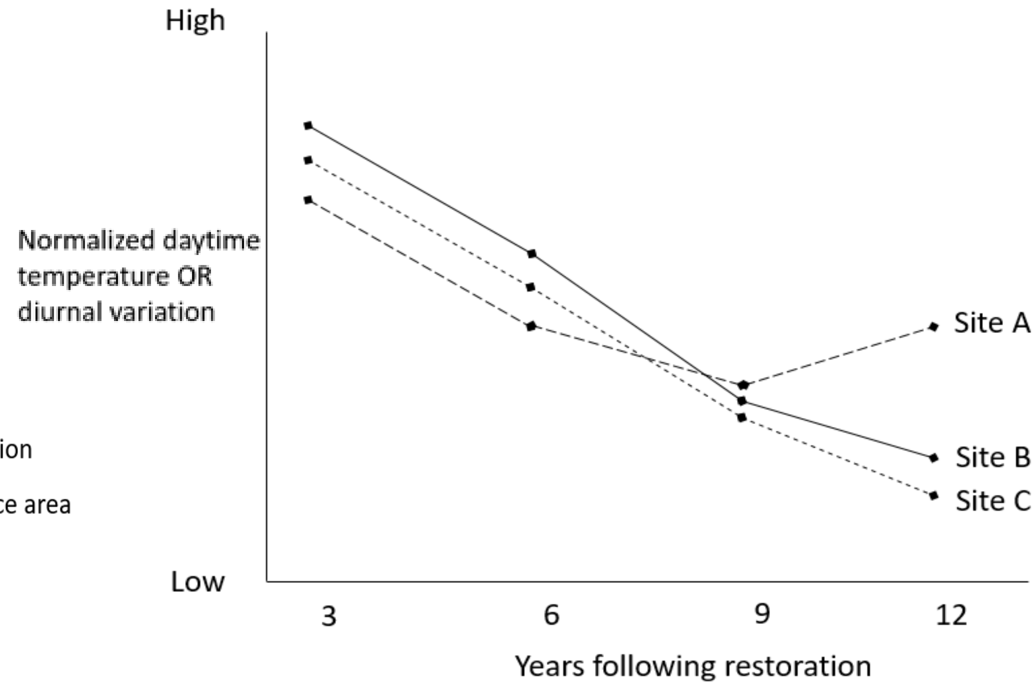
thermal monitoring and evaluation: Applications and next steps

Mapping surface temperature change over time



Summer day-time temperature change 2014-2018

Relative thermal recovery trajectory



A resolve for a solution to rectify resolution

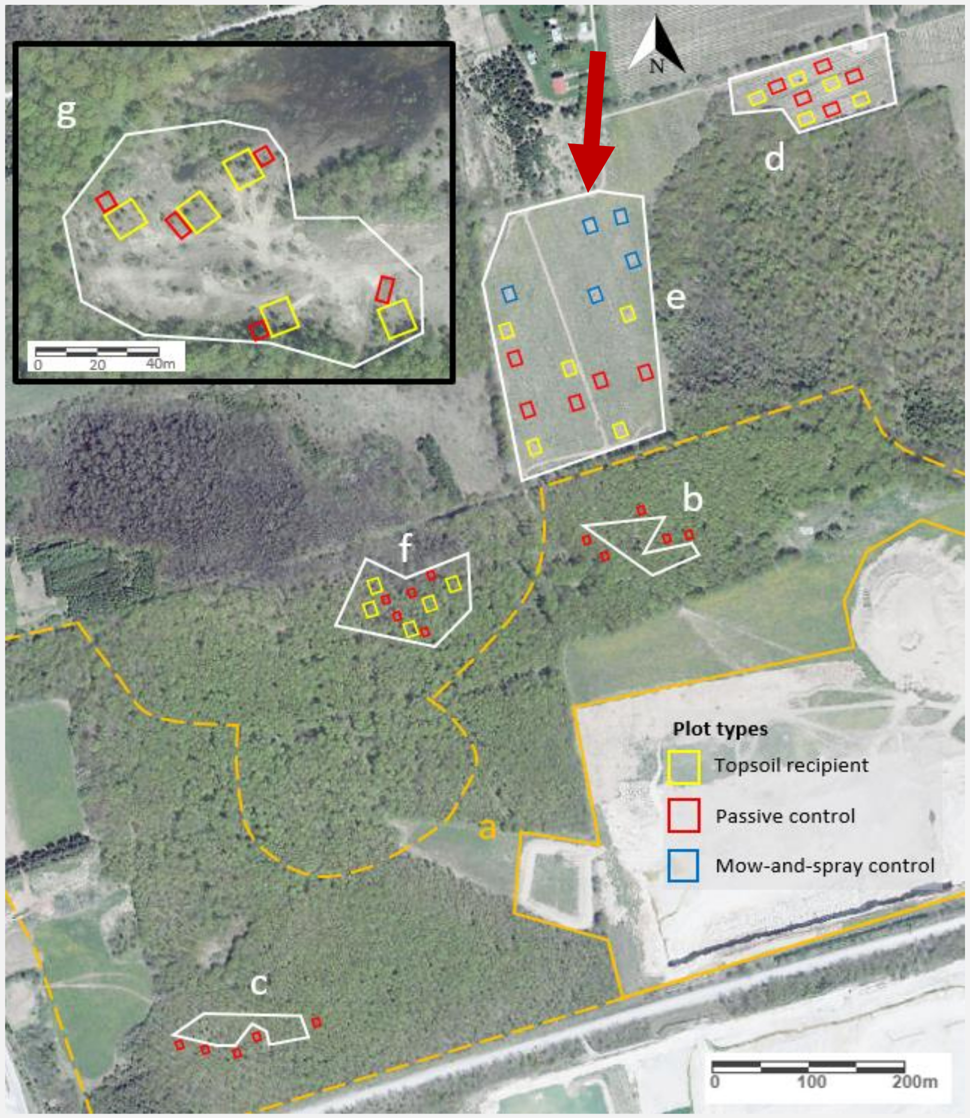
Example 2: Ag. reforestation and gravel pit restoration incl. topsoil transfer imaged with a drone (RPAS)

Methods: Implementation

875 tons of topsoil, small trees and organics moved in fall 2017

- Excavators
- Trucks
- Skid-steers
- Tractors

Study sites



OMNRF imagery 2020

Spring 2019 (UAV) – Reforestation sites

Gravel pit site plot example

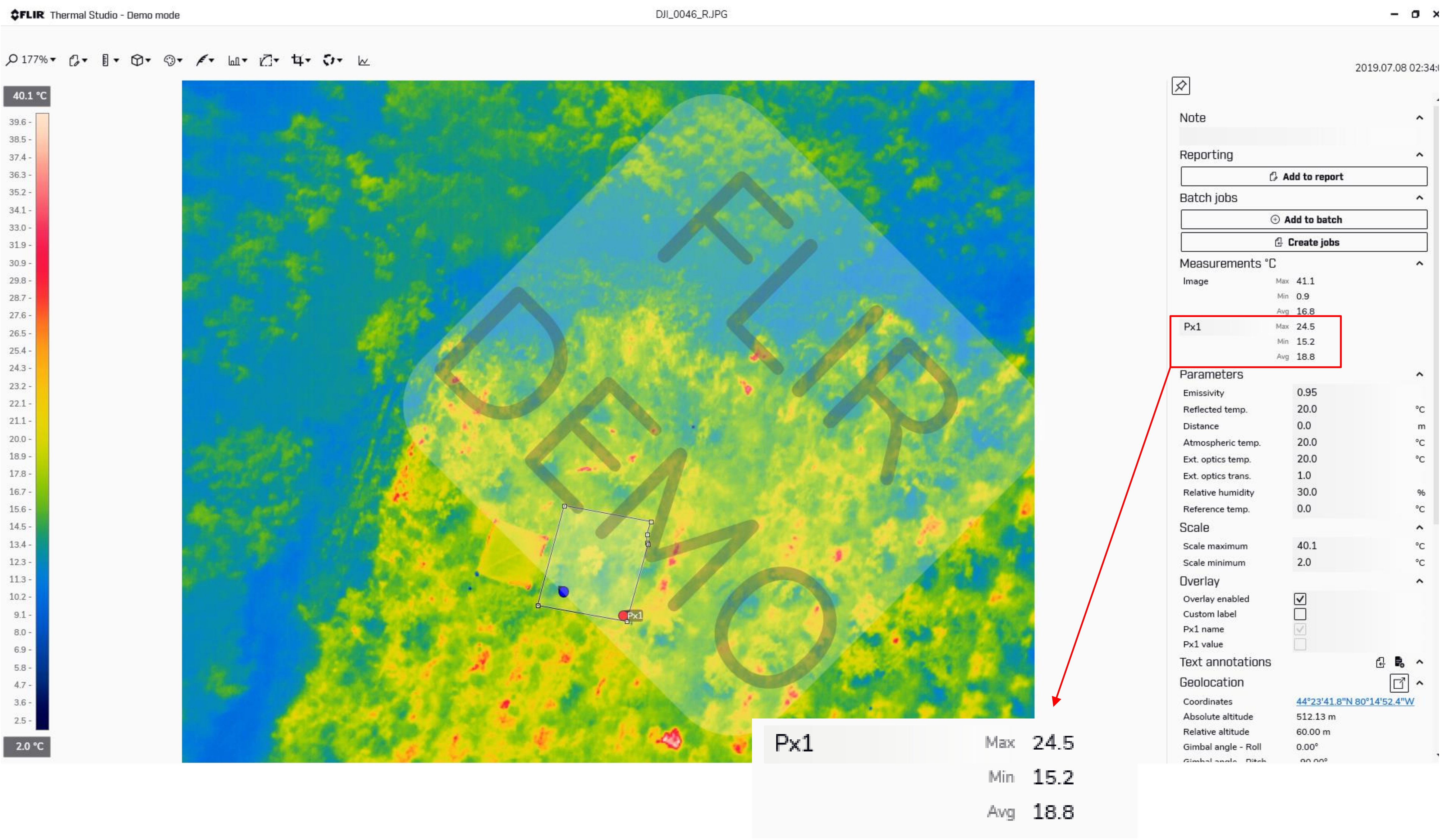
Plant species diversity and composition

- ~310 sampling frames, in spring, summer and fall 2019
- 162 total species, 50 NF species
- 44569 observations (89% identified to species)
- Tree growth and mortality measured.

Site	Plot-type	# plots/sub-plots/frames	Species richness	Native forest sp. rich.	Post-hoc grouping
S. D. Forest	Passive Control	5/1/2	17.6	13.8	A
Gravel pit	Topsoil Recipient	5/4/2	31.8	**11.2**	A, B
P. Forest	Lift-and-drop	5/3/2	11.5	9.6	A, B, C
P. Forest	Passive control	5/1/2	11.1	8.8	A, B, C, D
N. D. Forest	Passive Control	5/1/2	10.6	8.6	A, B, C, D
RF 2016	Topsoil Recipient	5/4/2	25.3	8.1	B, C, D
RF 2015	Topsoil Recipient	5/4/2	25.8	6.7	C, D
Gravel pit	Passive Control	5/1/2	14.7	**3.8**	D, E
RF 2015	Passive control	5/1/2	21.3	1.9	E
RF 2016	Passive control	5/1/2	18.4	1.8	E
RF 2015	Mow-and-spray	5/4/2	18.7	1.8	E

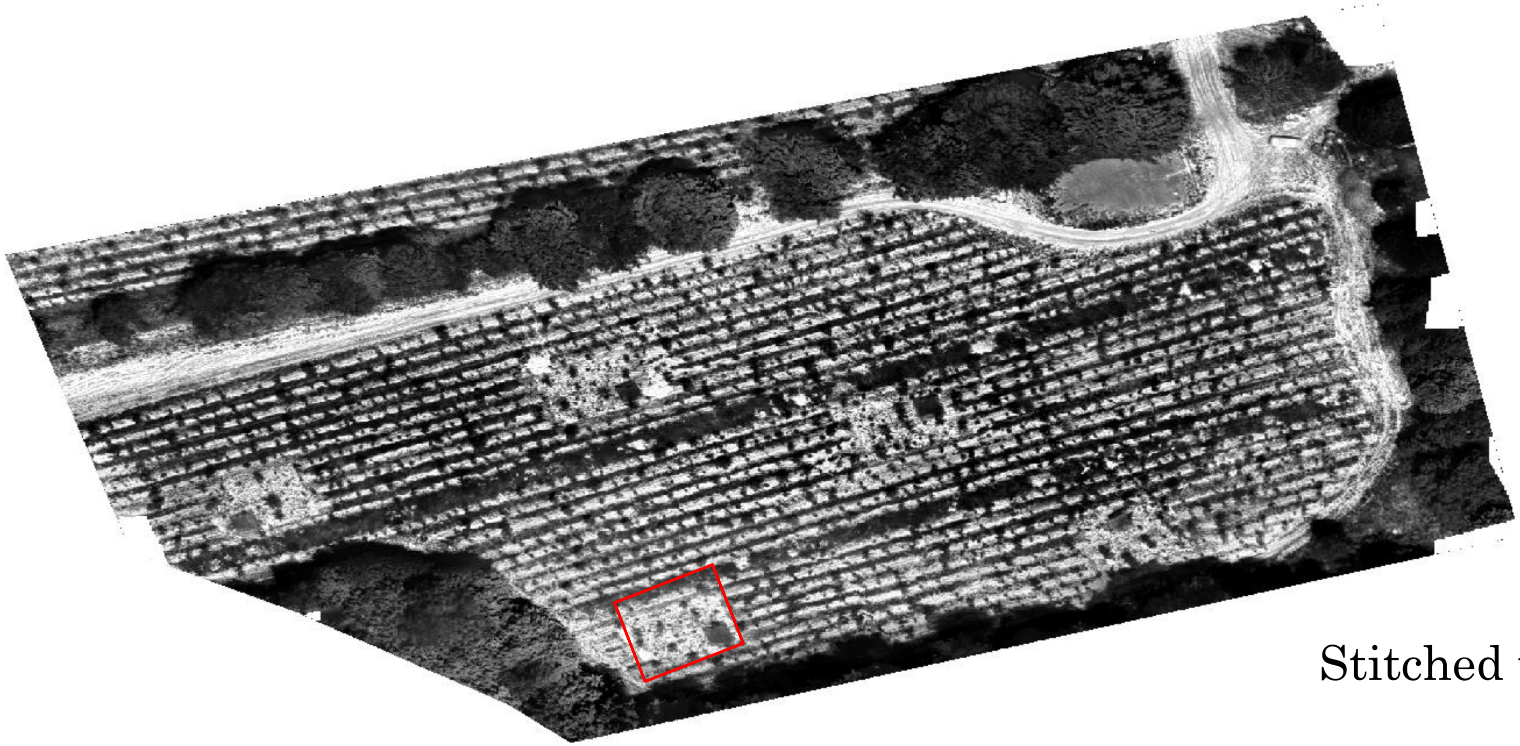
Two years after soil transfer:

1. **Topsoil transfer had increased native forest plant species diversity significantly**
2. **Plant species composition of recipient plots closer to donor forest**


FLIR Thermal Studio - Demo mode
DJI_0046_R.JPG
177%
2019.07.08 02:34:
40.1 °C
2.0 °C
Px1
FLIR DEMO
Note
Reporting
Add to report
Batch jobs
Add to batch
Create jobs
Measurements °C
Image Max 41.1
Min 0.9
Avg 16.8
Px1 Max 24.5
Min 15.2
Avg 18.8
Parameters
Emissivity 0.95
Reflected temp. 20.0 °C
Distance 0.0 m
Atmospheric temp. 20.0 °C
Ext. optics temp. 20.0 °C
Ext. optics trans. 1.0
Relative humidity 30.0 %
Reference temp. 0.0 °C
Scale
Scale maximum 40.1 °C
Scale minimum 2.0 °C
Overlay
Overlay enabled
Custom label
Px1 name
Px1 value
Text annotations
Geolocation
Coordinates 44°23'41.8"N 80°14'52.4"W
Absolute altitude 512.13 m
Relative altitude 60.00 m
Gimbal angle - Roll 0.00°
Px1 Max 24.5
Min 15.2
Avg 18.8

Spring 2018

Stitched visual



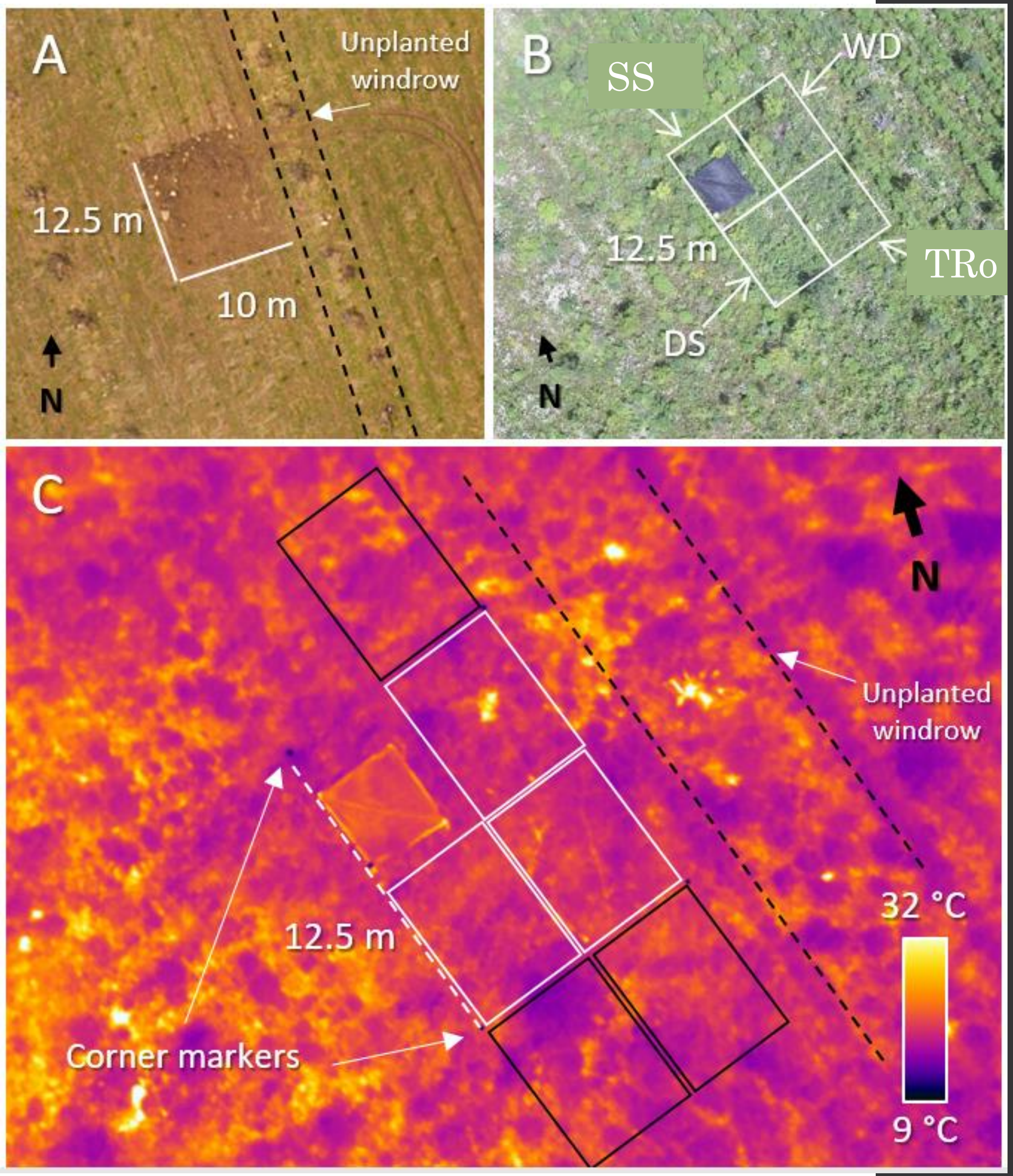
Stitched thermal

Drone thermal imaging methods

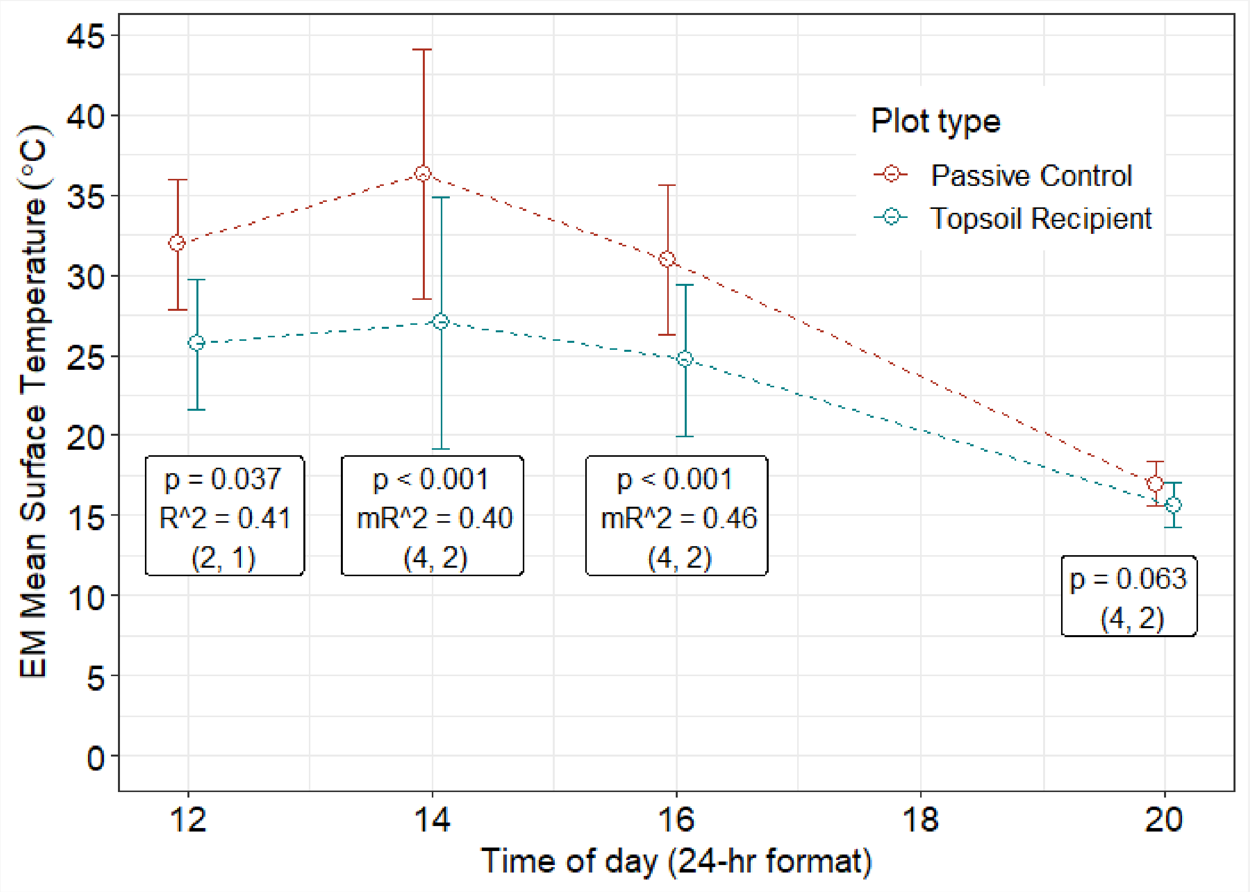
- 9 days of thermal imaging with UAV in 2019
- Mid and late season - July and September
- 8 flights per day at 12, 2, 4 and 8 pm
- 1080 thermal images

- Comparison 1: Between treatments at same site at same hour through ANOVA

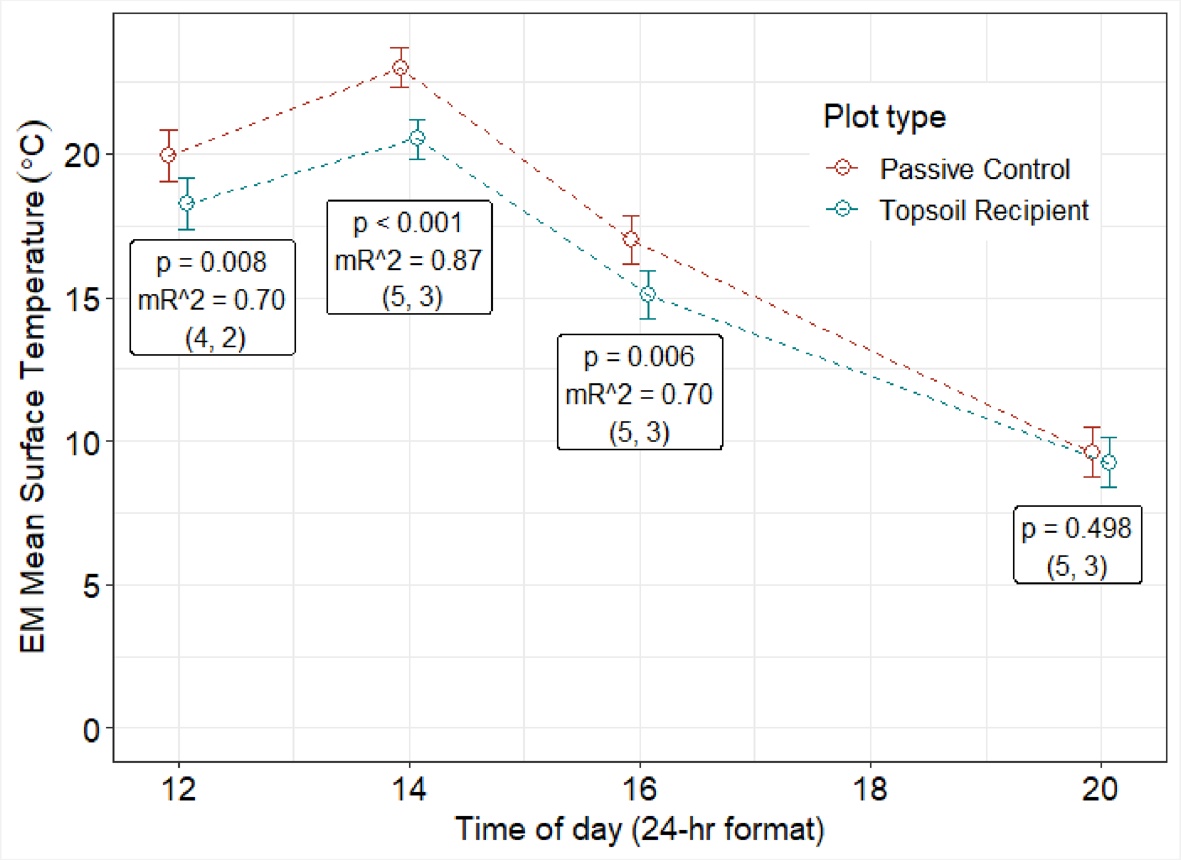
- Comparison 2: Between normalized temperature and vegetation attributes using Spearman rank correlation analysis



Temperature over time-of-day results



Gravel pit – in July 2019



Ag. reforestation – in July 2019

Temperature and vegetation attributes

The only attribute that is sig. correlated with lower temperatures at all sites is native forest plant species richness

Reforestation 2016

	Temp. norm.	Tree diameter	Tree height	Tree gen. rich.	All sp. diversity	All sp. rich.	NF. sp. rich
% ground cover	**-0.63****	-0.22	-0.27	0.23	0.27	0.3	**0.46***
NF sp. rich.	**-0.64****	-0.13	-0.16	0.39	0.34	**0.76****	
All sp. rich.	**-0.58****	-0.21	-0.20	0.23	**0.47***		
Sp. diversity	-0.39	-0.22	-0.19	-0.01			
Tree gen. rich.	-0.31	0.27	0.06				
Tree height	0.19	**0.88*****					
Tree diameter	0.02						

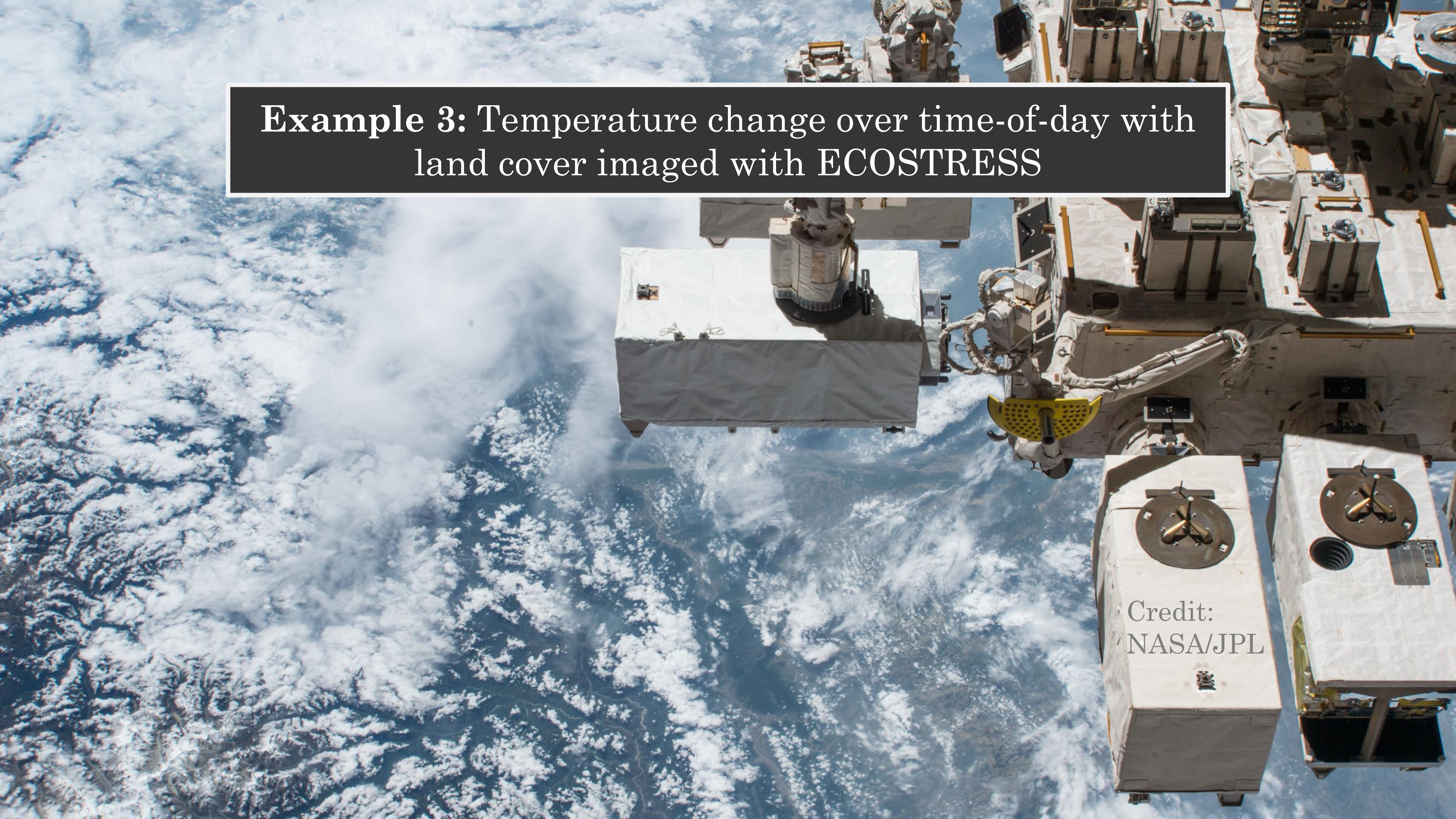
	Temp. norm.	Tree diameter	Tree height	Tree gen. rich.	Sp. diversity	All Sp. rich.	NF. sp. rich
% ground cover	-0.02	0.05	-0.08	-0.05	0.23	0.31	**0.34***
NF sp. rich	**-0.37***	0.21	0.01	0.04	**0.81*****	**0.84*****	
All sp. rich.	-0.22	0.17	-0.02	0.09	**0.92*****		
Sp. diversity	-0.15	0.03	-0.16	-0.06			
Tree gen. rich.	-0.14	**0.48****	**0.52****				
Tree height	**-0.57*****	**-0.93*****					
Tree diameter	**-0.57*****						

Reforestation 2015

	Temp. norm.	Sp. diversity	All. sp. rich.	NF. sp. rich
% ground cover	**-0.6****	0.28	0.37	**0.79*****
NF sp. rich.	**-0.47***	**0.57****	**0.70*****	
Sp. rich.	-0.29	**0.92*****		
Sp. diversity	-0.28			

Gravel pit

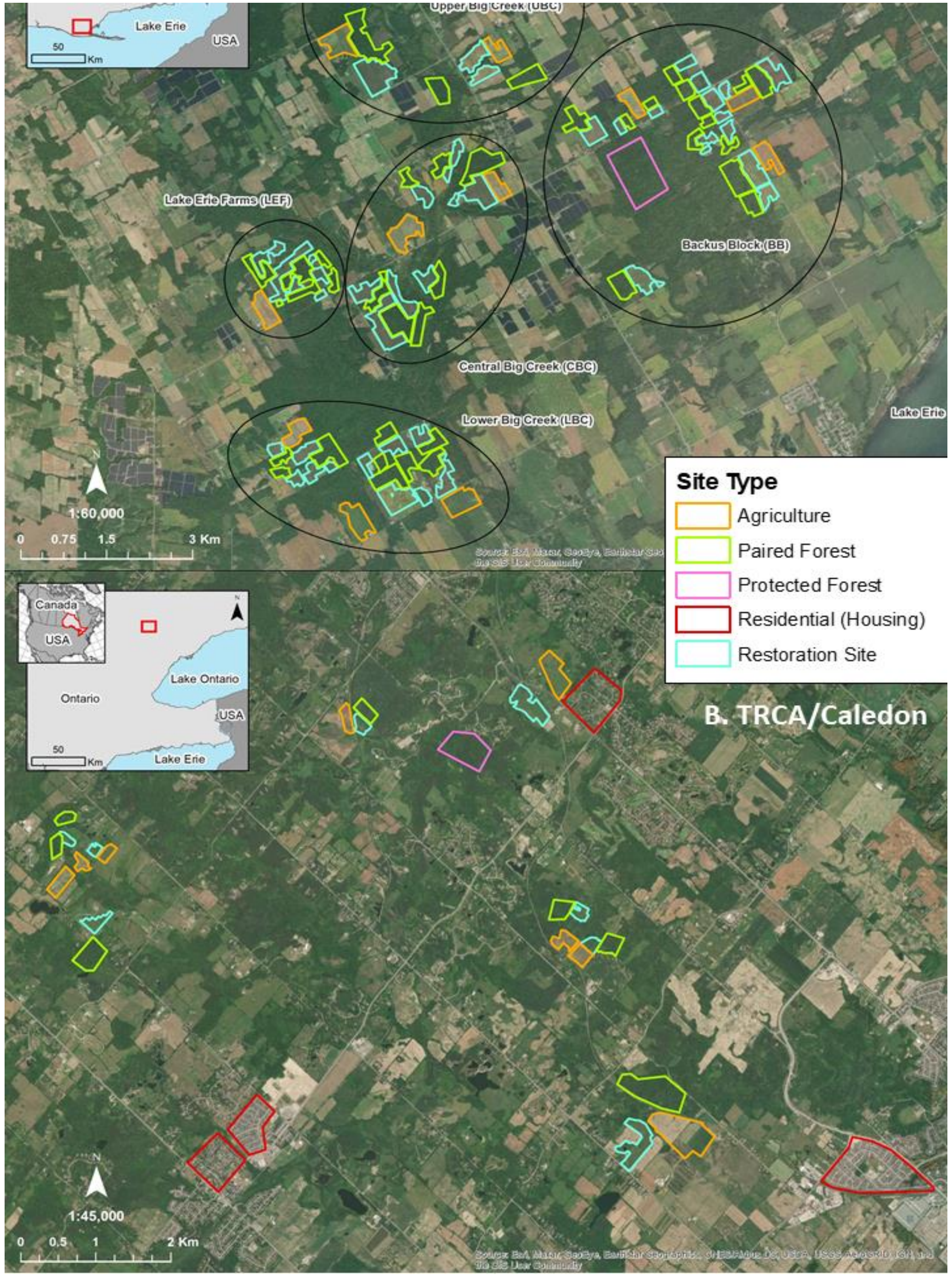
Example 3: Temperature change over time-of-day with land cover imaged with ECOSTRESS

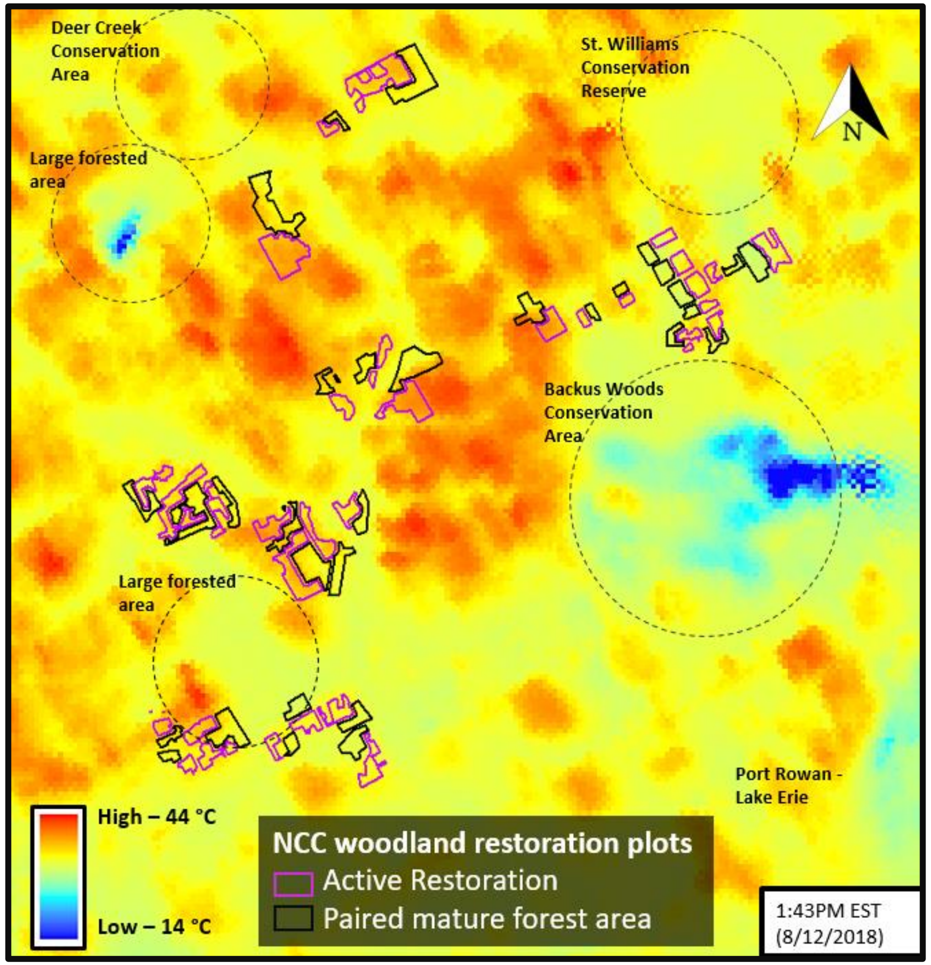


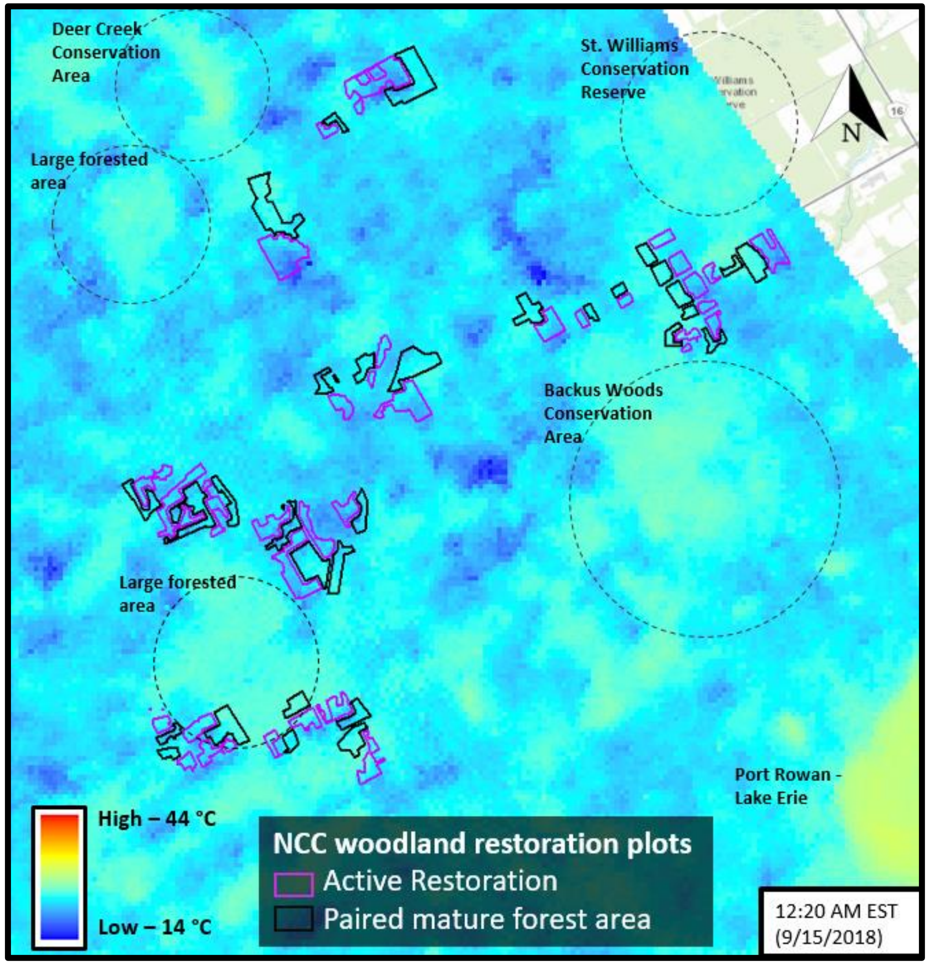
Credit: NASA/JPL

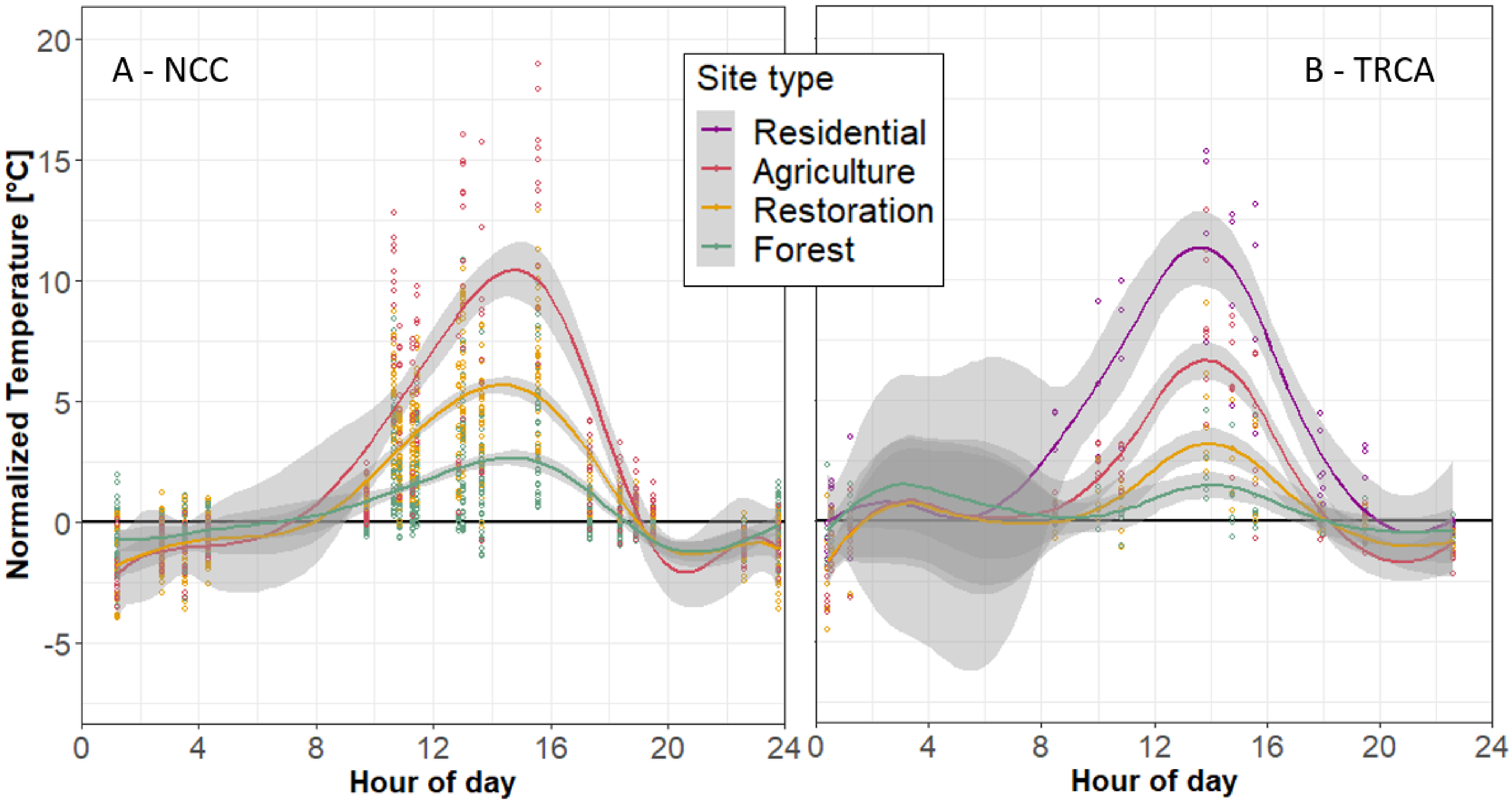
Methods

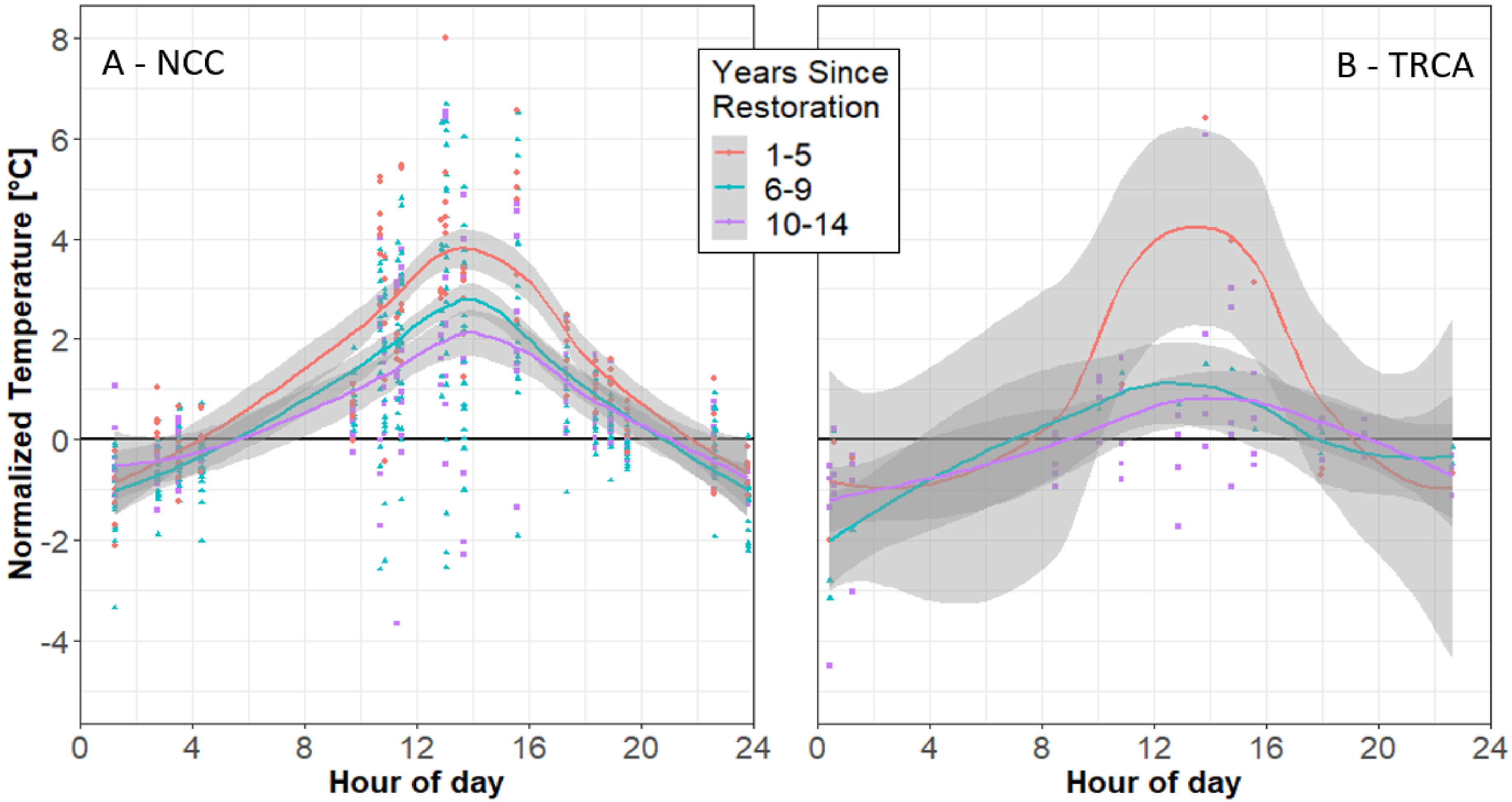
- Joint project with NASA-JPL, TRCA and UofT
- Sites:
  - NCC Norfolk County (same as example 1)
  - TRCA Albion Hills/Caledon
- Diurnal temperature change
- Four site types:
  - Pre-restoration: Agriculture
  - Reforestation
  - Post-restoration: Mature forest
  - Alternative land cover: Sub/Ex-urban residential
- June – September 2020
- NCC: 19 images, TRCA: 15 images




Deer Creek Conservation Area
St. Williams Conservation Reserve
N
Large forested area
Backus Woods Conservation Area
Large forested area
Port Rowan - Lake Erie
High – 44 °C
Low – 14 °C
NCC woodland restoration plots
Active Restoration
Paired mature forest area
1:43PM EST (8/12/2018)

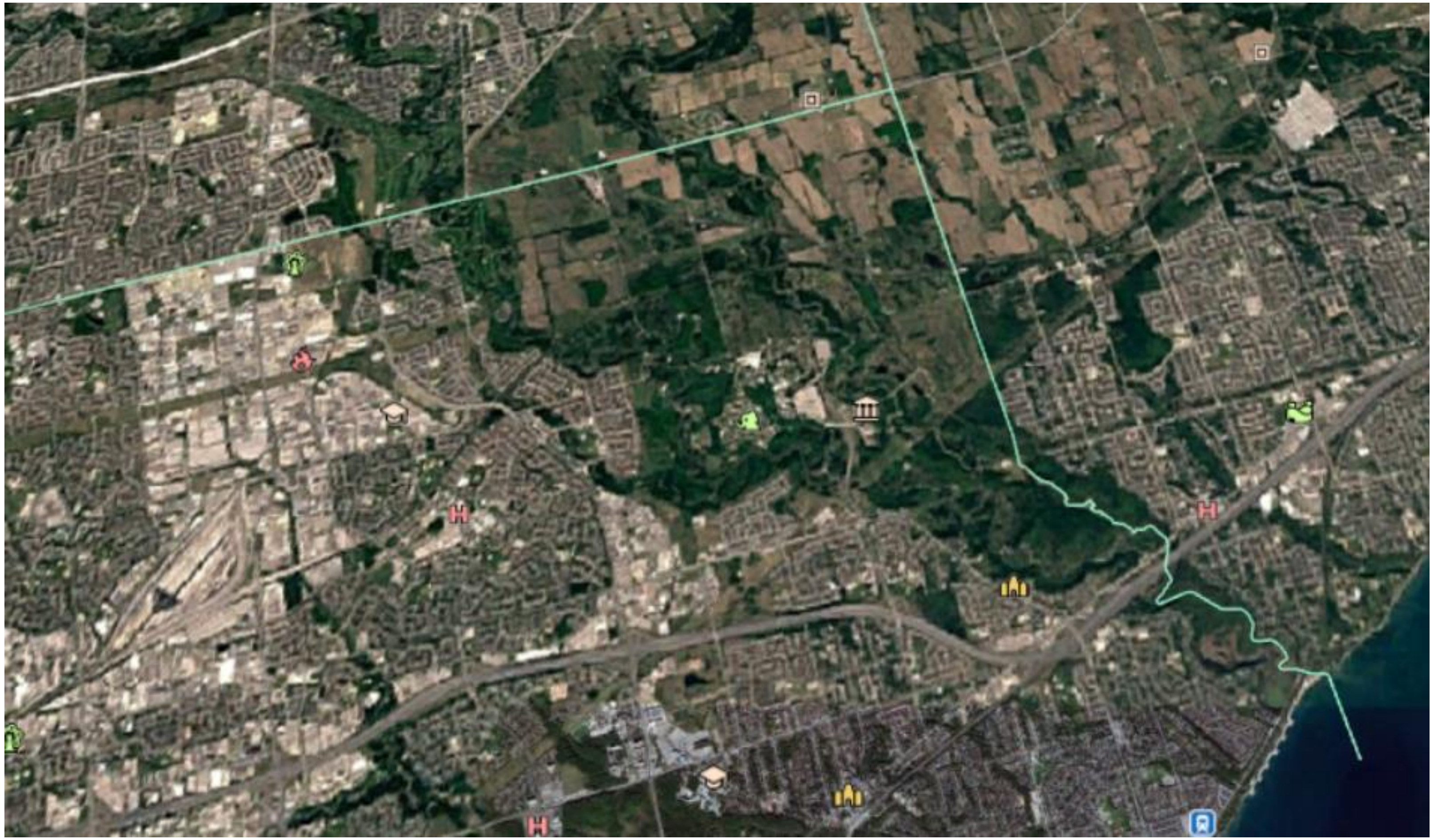

Deer Creek Conservation Area
St. Williams Conservation Reserve
N
Large forested area
Backus Woods Conservation Area
Large forested area
Port Rowan - Lake Erie
High – 44 °C
Low – 14 °C
NCC woodland restoration plots
Active Restoration
Paired mature forest area
12:20 AM EST (9/15/2018)


A - NCC
B - TRCA
Site type
Residential
Agriculture
Restoration
Forest
Normalized Temperature [°C]
Hour of day
Hour of day
20
15
10
5
0
-5
0
4
8
12
16
20
24

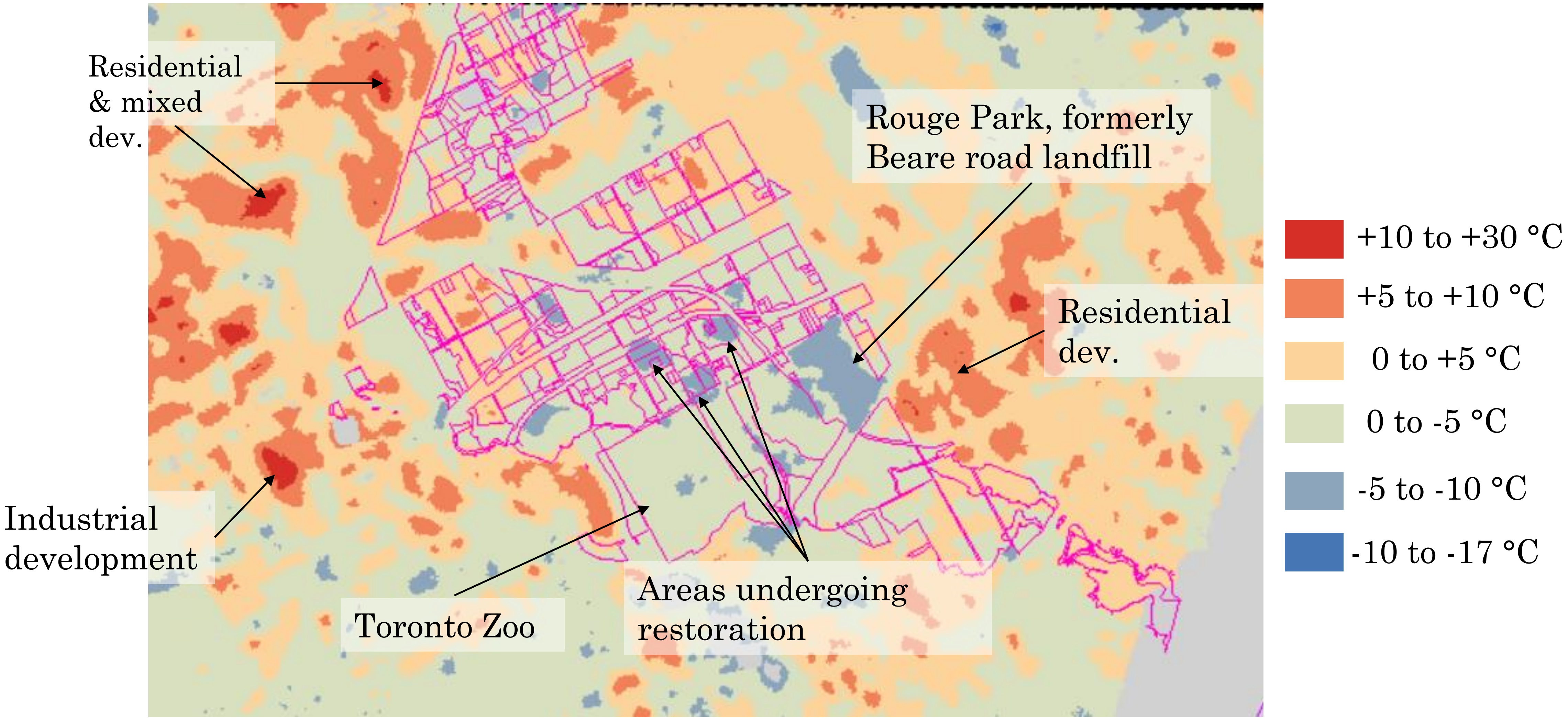


0.067 °C decrease by year since restoration

Example 4: Rouge Valley mini-study



Rouge valley surface temperature change – 1985 to 2019



2-year post-doc with TRCA and U of T
What’s next?

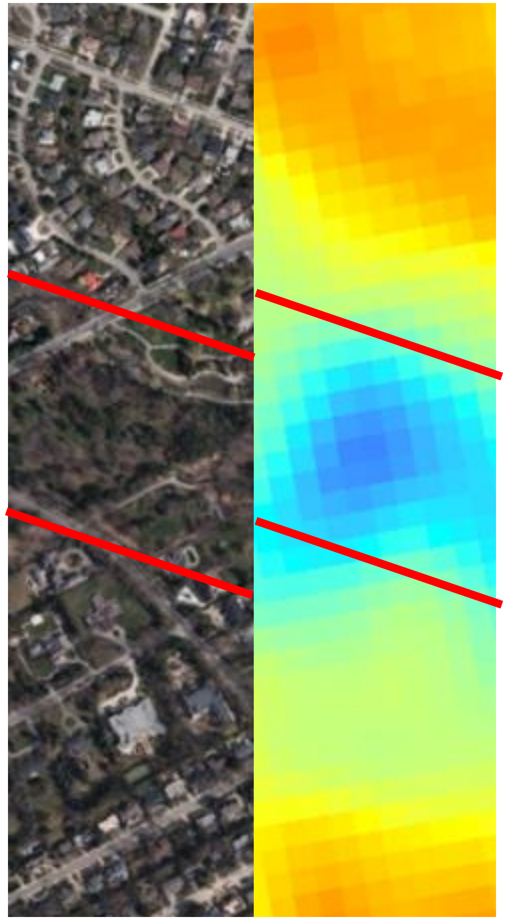
Potential projects with TRCA & UofT

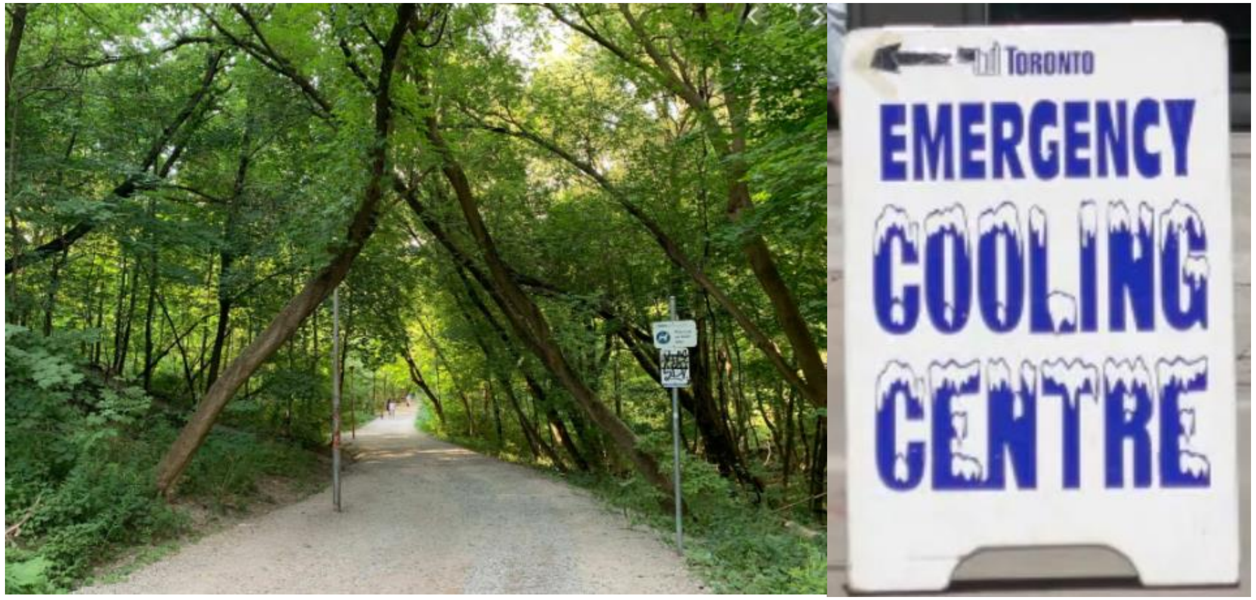
- Thermal signature of terrestrial landscapes (e.g. conifer vs. deciduous)
- The effect of tree disease on temperature due to evapotranspiration stress
- Thermal signature of native vs. invasive species (e.g. dog-strangling vine, phragmites)
- The thermal edge effect of restoration (e.g. added benefits of projects like The Meadoway and ravine/riparian restoration)
- Will depend on site access, feasibility, equipment, scientific interest and TRCA interest

Hot days ahead

- S. Ontario is predicted to have an increase of air-temperature of **0.6 degrees** by 2030 compared to today
- This results in an extra **week** of 30+ degree days by 2030
- The heat-wave in 2018 **killed** over **70 people** in Montreal
- Heat stresses, kills and displaces both wild animals and pets
- Heat helps spread ticks with **Lyme-disease**, invasive **carp** and mosquitos with **West-Nile virus**

But thermal imaging can show, evaluate and monitor GTA's natural cooling centers!





- PLANNER: Locate ‘heat-deserts’ and hot watersheds for restoration planning
- MANAGER: Monitor restoration success and biodiversity based on temperature
- GRANT-WRITER: Show funders how your restoration decreases temperatures
- PUBLIC: Are you in a ‘heat-desert’? How far does someone have to walk to get to a cool greenspace on a 30°C day?
- Advocate for and plant more native and diverse greenery. Protect parks and street-trees as ‘cool islands.

Thanks! Questions?

jonas.hamberg@trca.ca

TRCA Teams chat

Upcoming ECS Lunch and Learns!

Wednesday, April 21
11:00am-12:00pm

Lake Ontario Fish and Aquatic Ecosystem Health

By Valerie Francella, Angela Wallace, and Jan Moryk

Tuesday, April 27
11:00am-12:00pm

Lake Ontario Restoration Initiatives

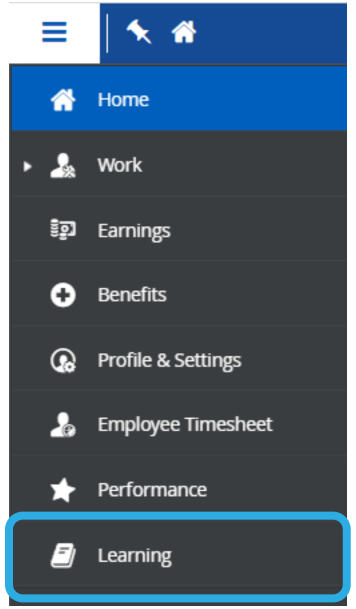
By Andrew Ramesbottom, Colleen Gibson, John Stille, and Jennifer Smith

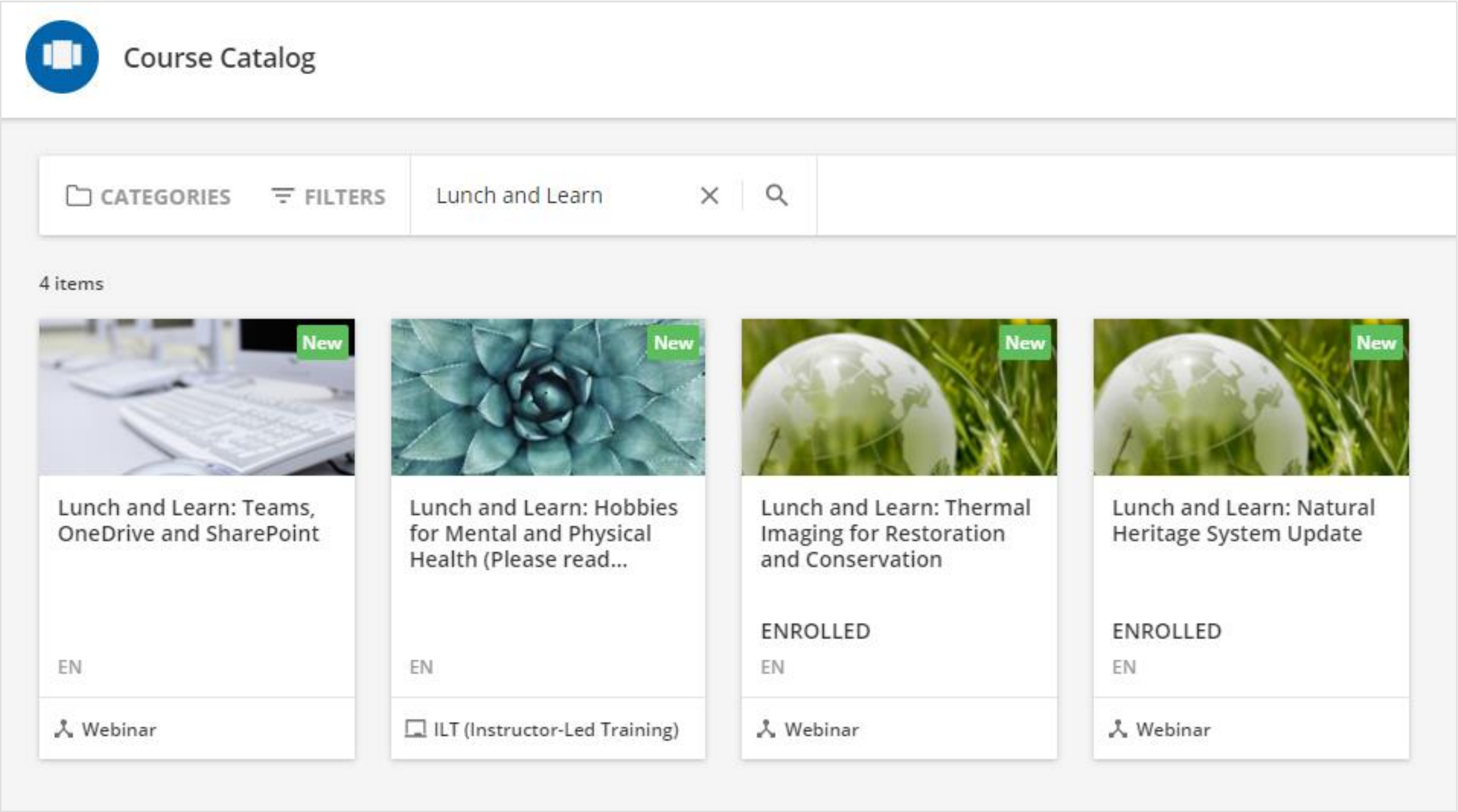
Thursday, May 16
1:00-2:00pm

Intro to eDNA: Applications, Advantages, and Implications

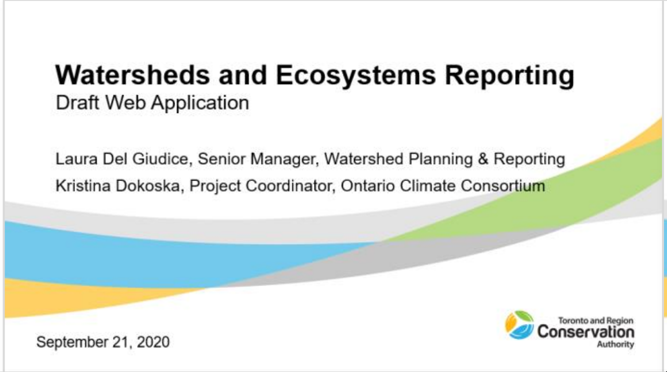
By Precision Biomonitoring

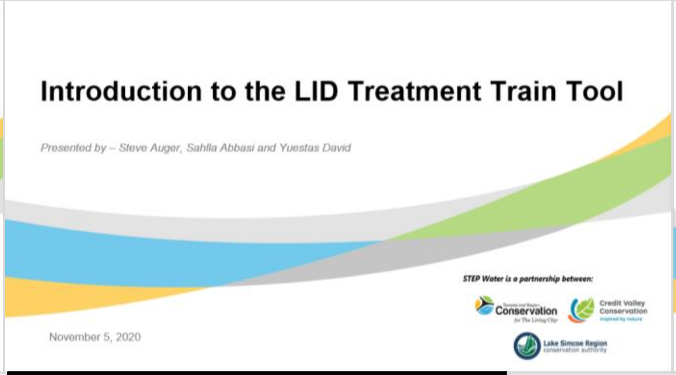
New Learning Management System!

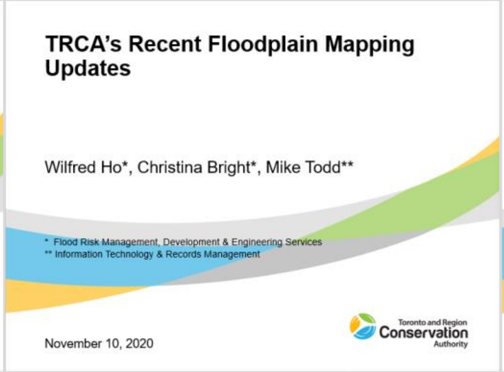


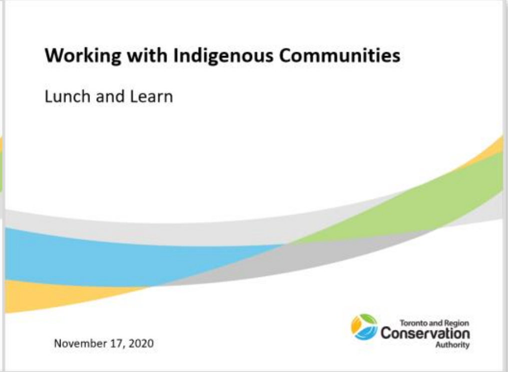


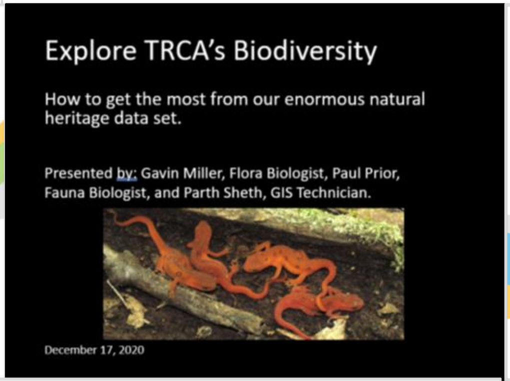
Past Recordings

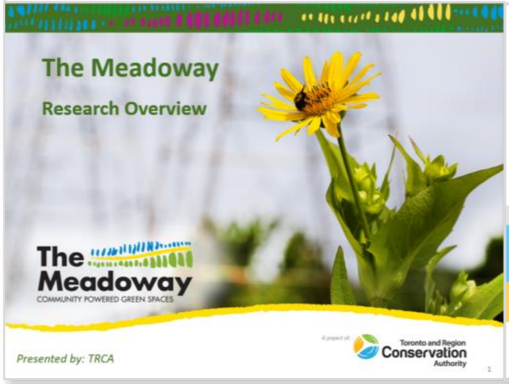












Thank you

For questions about the ECS Lunch and Learn Series, please contact:

Sharon Lam
sharon.lam@trca.ca