# Climate Change Effects on New England's Forests

Dr. Pamela Templer

Boston University
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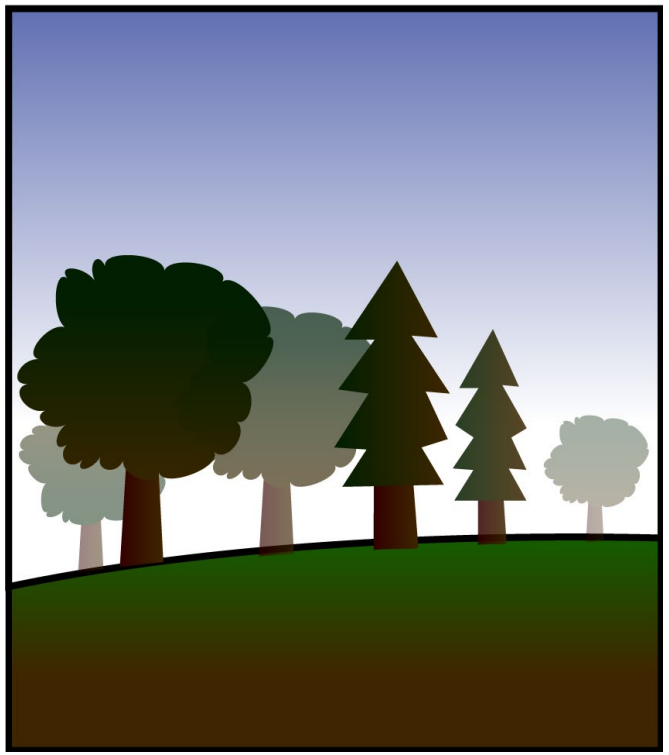
Climate Change

Air Pollution

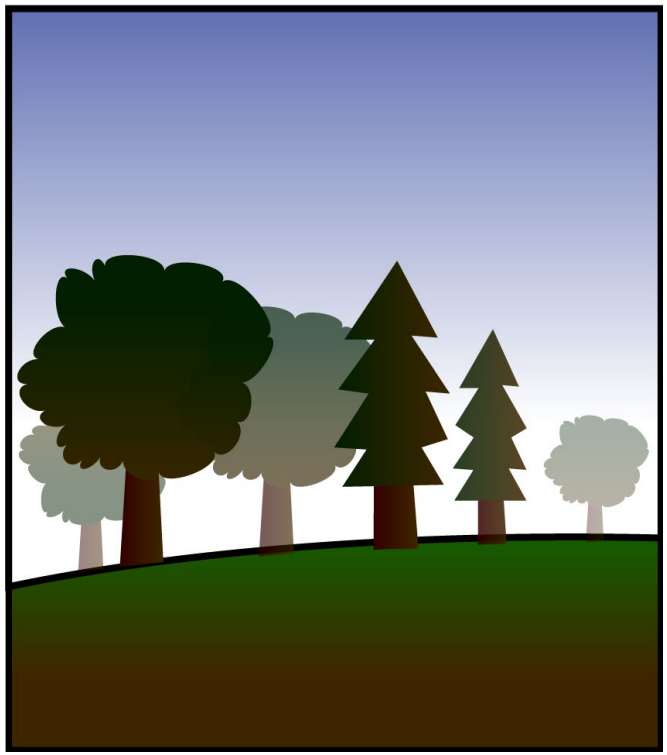


Land-Use Change
Urbanization

Introduced Pests

Climate Change

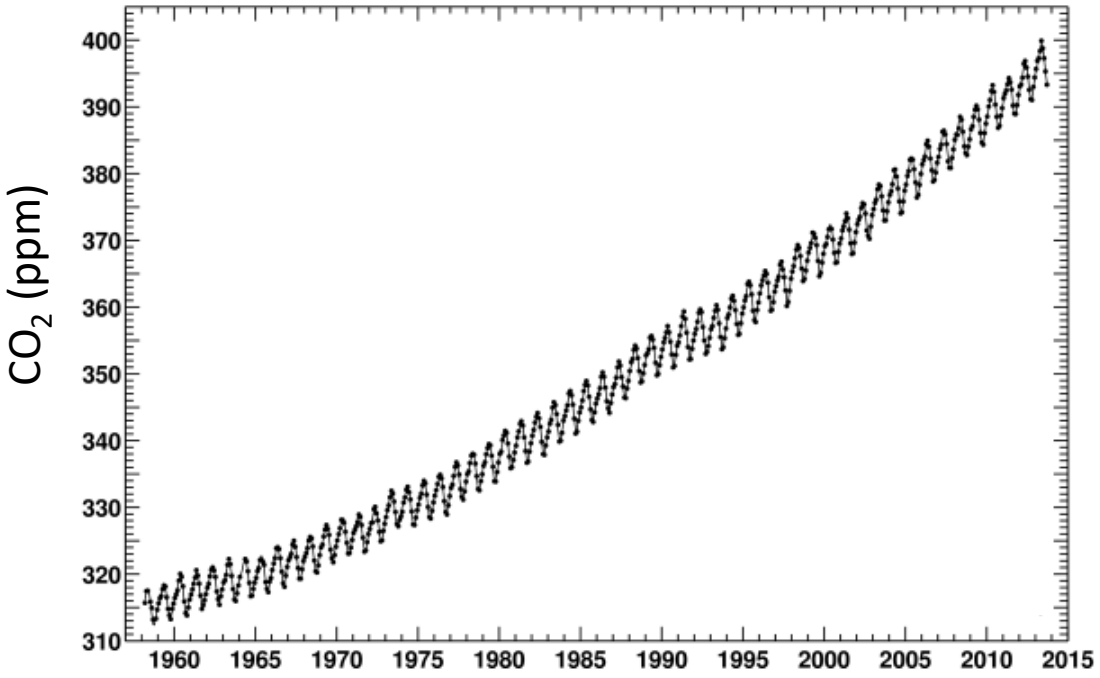
Air Pollution



Land-Use Change
Urbanization

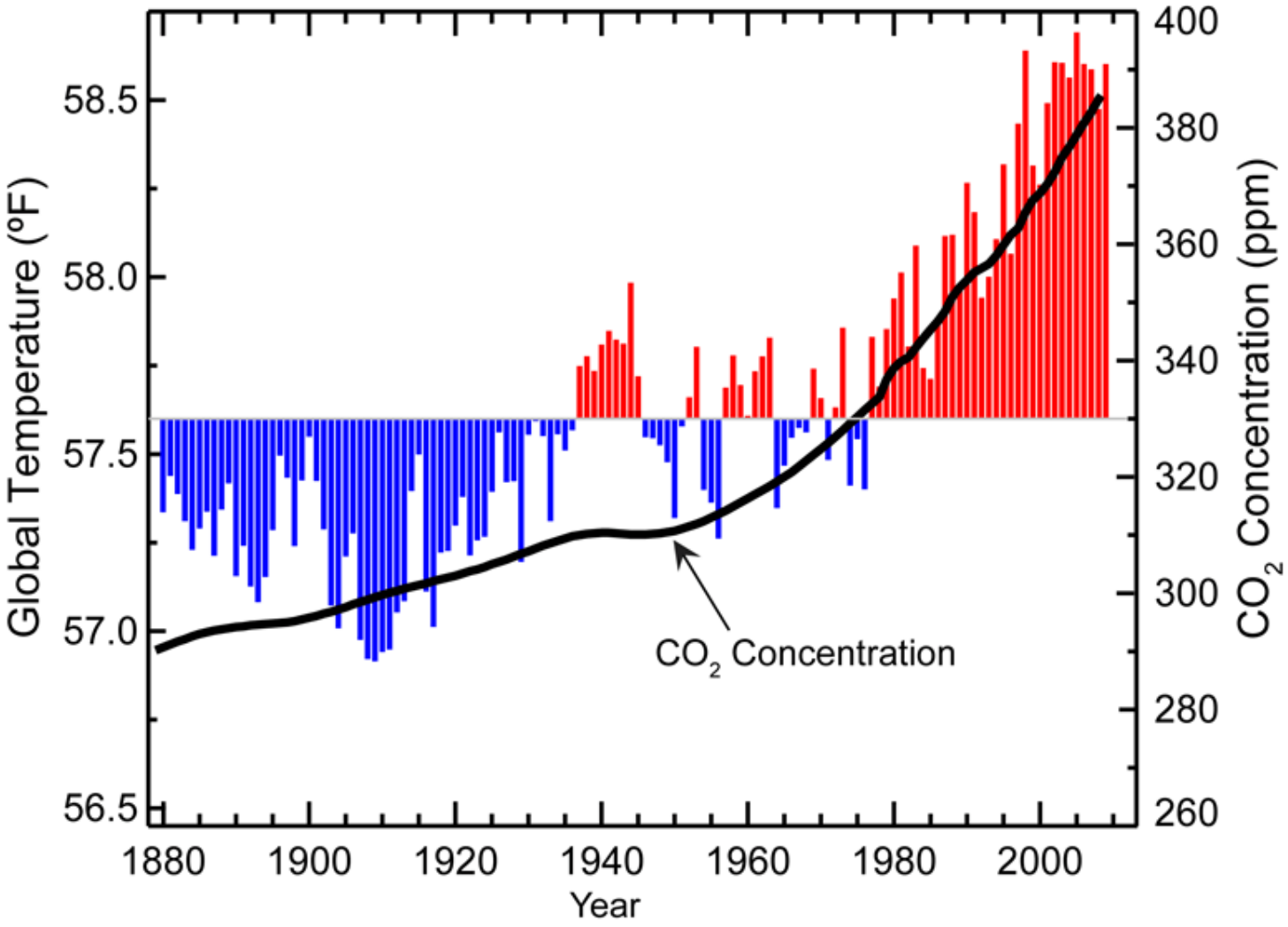
Introduced Pests

# Atmospheric $CO_2$ at Mauna Loa Observatory, Hawaii

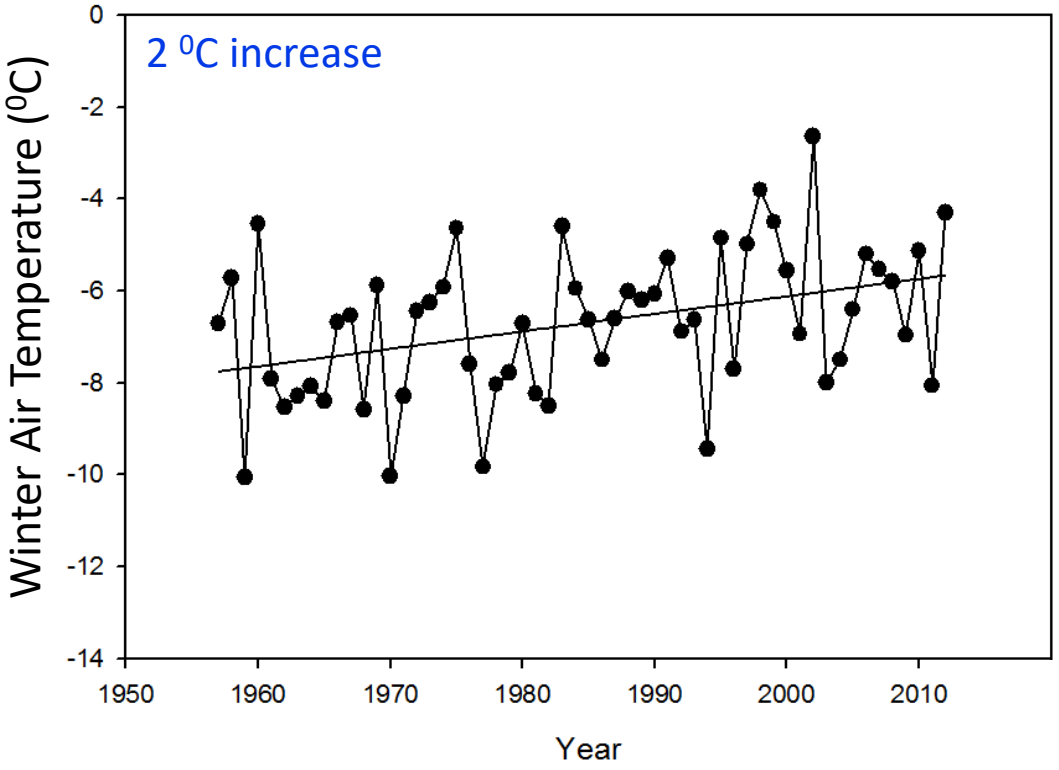



Scripps Institution of Oceanography

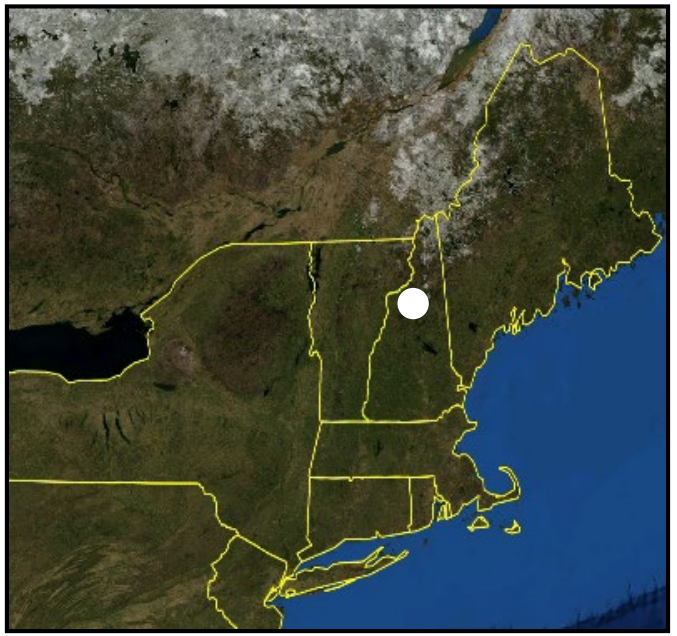
# Global Temperatures Rising



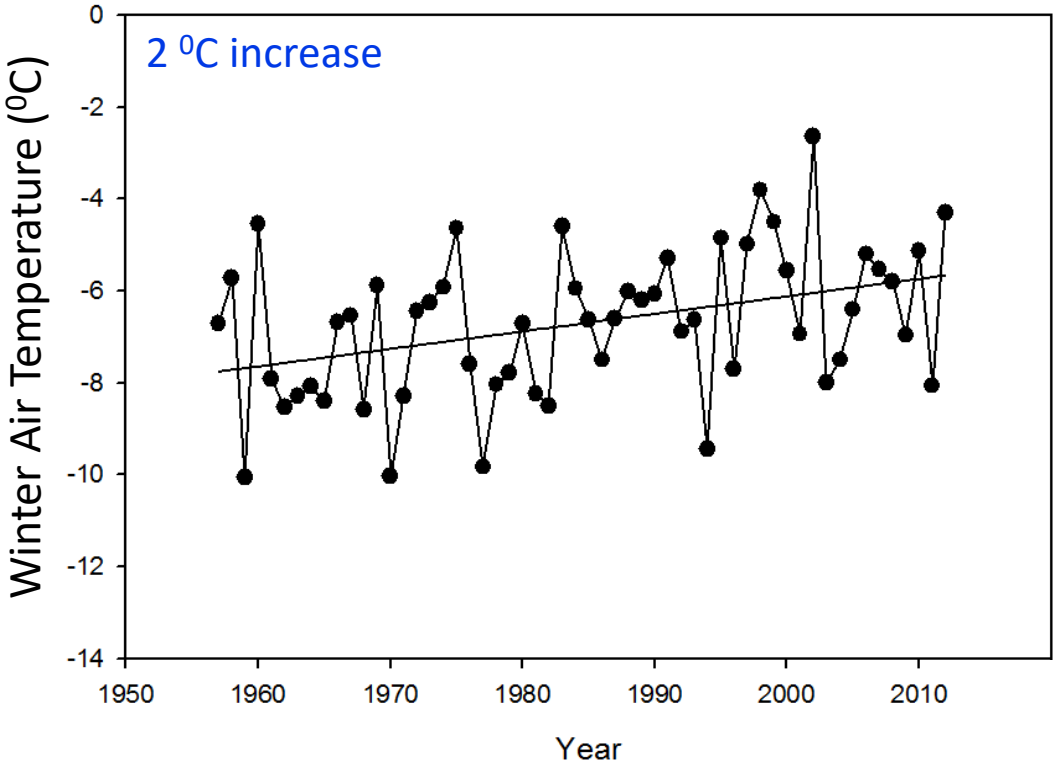

www.epa.gov/sites/production/files/2015-12/sea-level-northeast-large.jpg

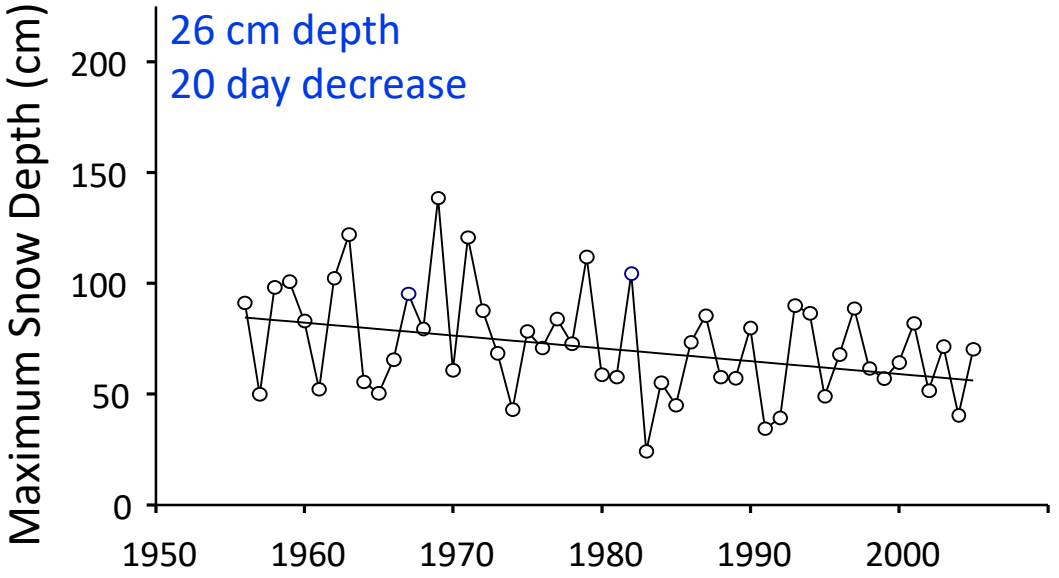



# Winter Air Temperatures Rising and Snowpack Shrinking



Hubbard Brook

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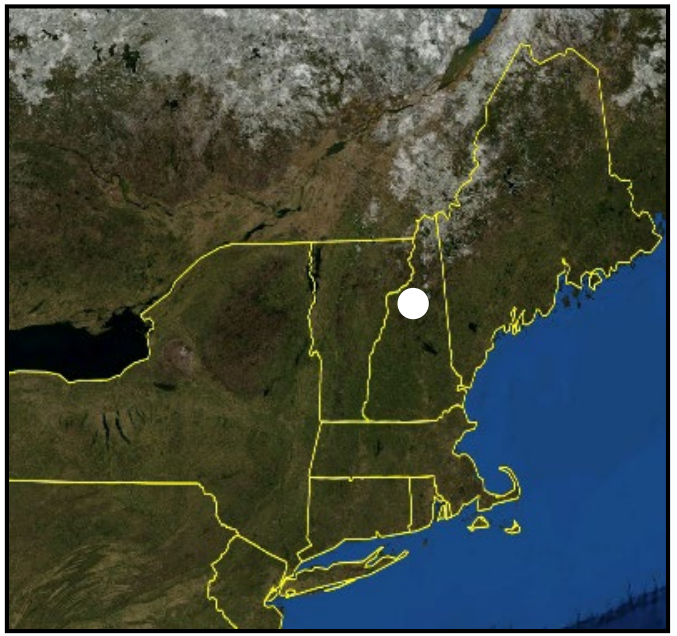

Hubbard Brook

THE PHOENIX

# Help, the mountains are melting!

## The case of the disappearing ski slopes

By NOAH SCHAFFER | November 7, 2012 Like 26

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Cornell University

CHRONICLE ONLINE

Nov. 10, 2010

# In 100 years, maple sap will flow a month earlier

**By Krishna Ramanujan**

As the climate warms this century, maple syrup production in the Northeast is expected to slightly decline by 2100, and the window for tapping trees will move earlier by about a month, reports a Cornell study.

Currently, the best times to tap maple trees are within an eight-week window from late winter to early spring when temperatures cause freezing at night and thawing by day.

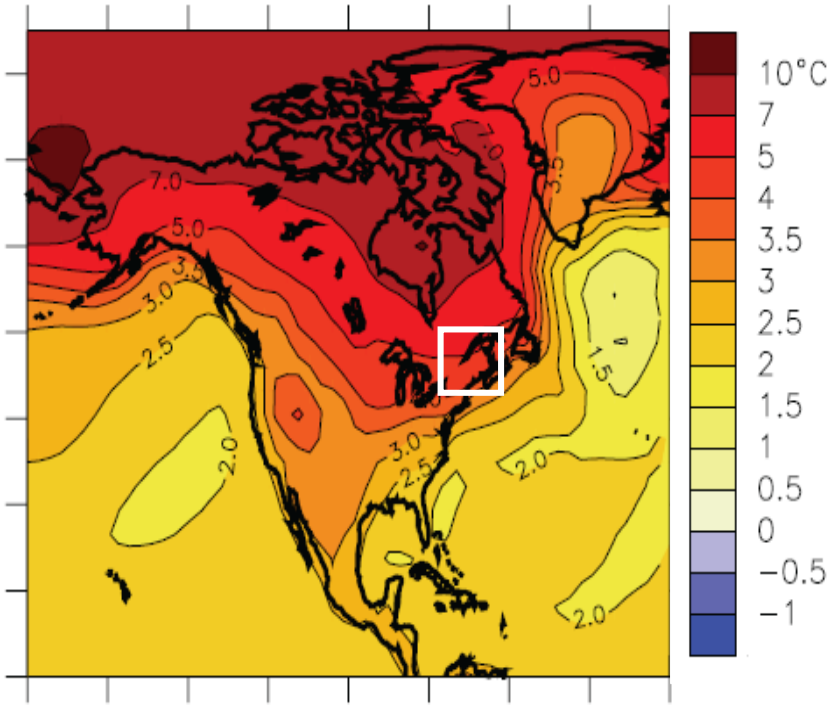
"By 2100, we can expect to begin tapping maples closer to Christmas in the Northeast," said Brian Chabot, professor of ecology and evolutionary biology and a co-author of a paper on climate changes and maple sugar production that appeared earlier this year in the journal Climate Change.

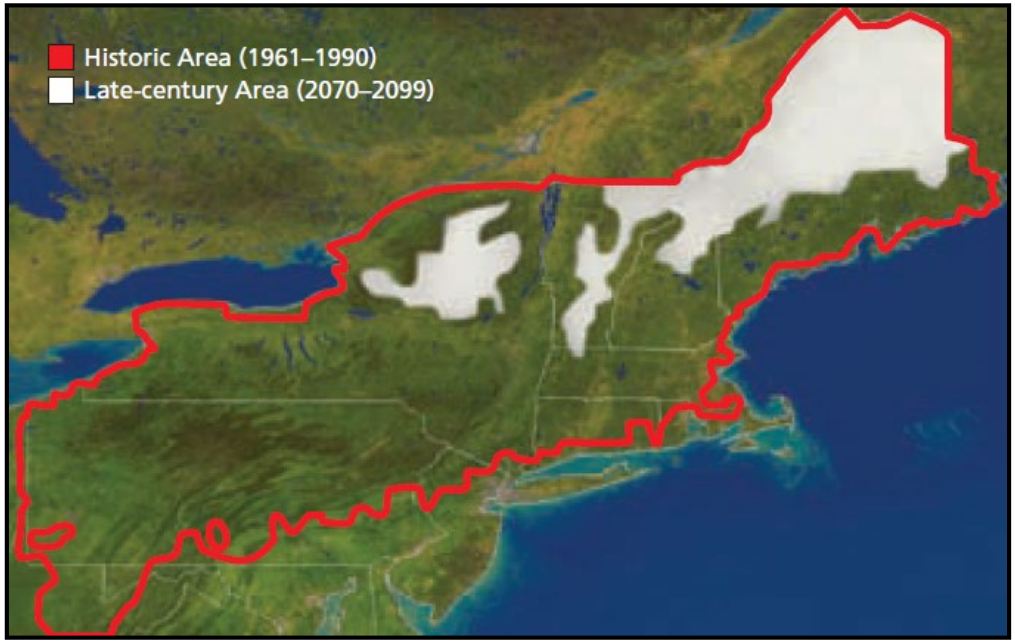
Sap flow is related to pressure changes in the trees' xylem, which are tubes beneath the bark that carry sap from the maple's roots up to the leaves. As maple trees freeze in winter, gases are pushed out of the xylem into surrounding tissues, and negative pressure is created within the xylem compared with atmospheric pressure. When the trees thaw, the gases expand and dissolve back into the sap


*Brian Chabot*

**Mike Farrell, director of the Uihlein Sugar Maple Research and Extension Field Station in Lake Placid, N.Y., taps a maple tree.**

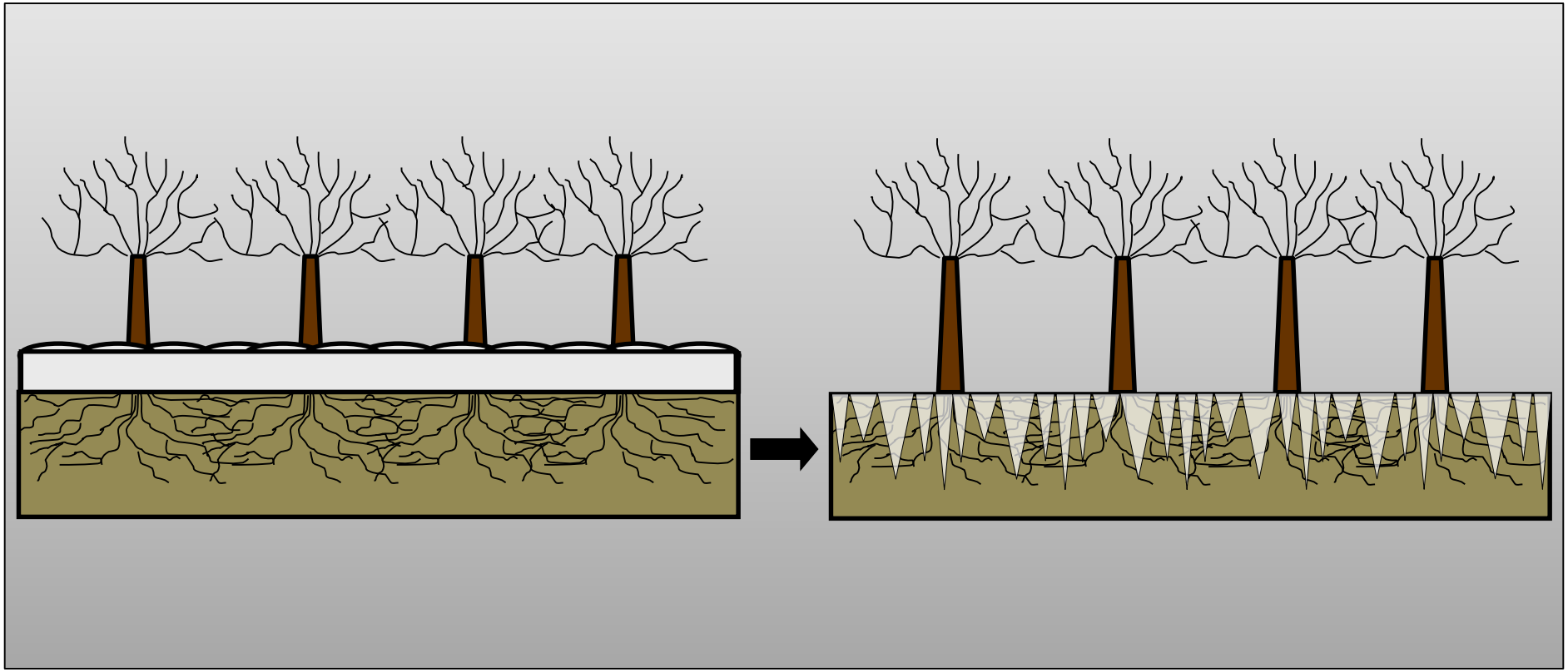
# Increased Winter Temperatures and Reduced Snowpack Extent Over Next 100 Years in Northeastern United States




IPCC

# Reduced Snowpack Leads to Soil Freezing



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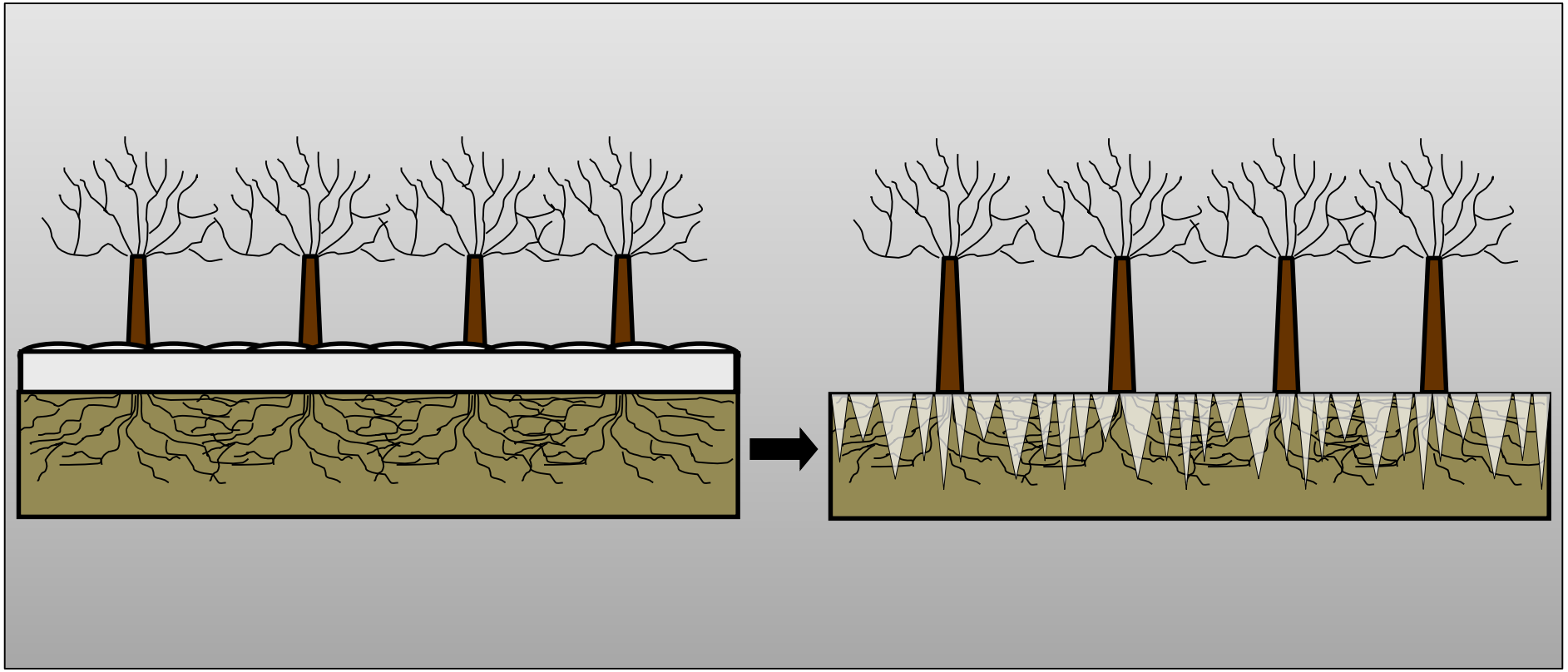

Wikipedia.org

# Why Focus on Soil Freezing?

Could damage biota in forests:

Plant Roots

Microbes

Arthropods

↓

Water & Air Quality

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Carbon Storage in Forests

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Why does this matter?

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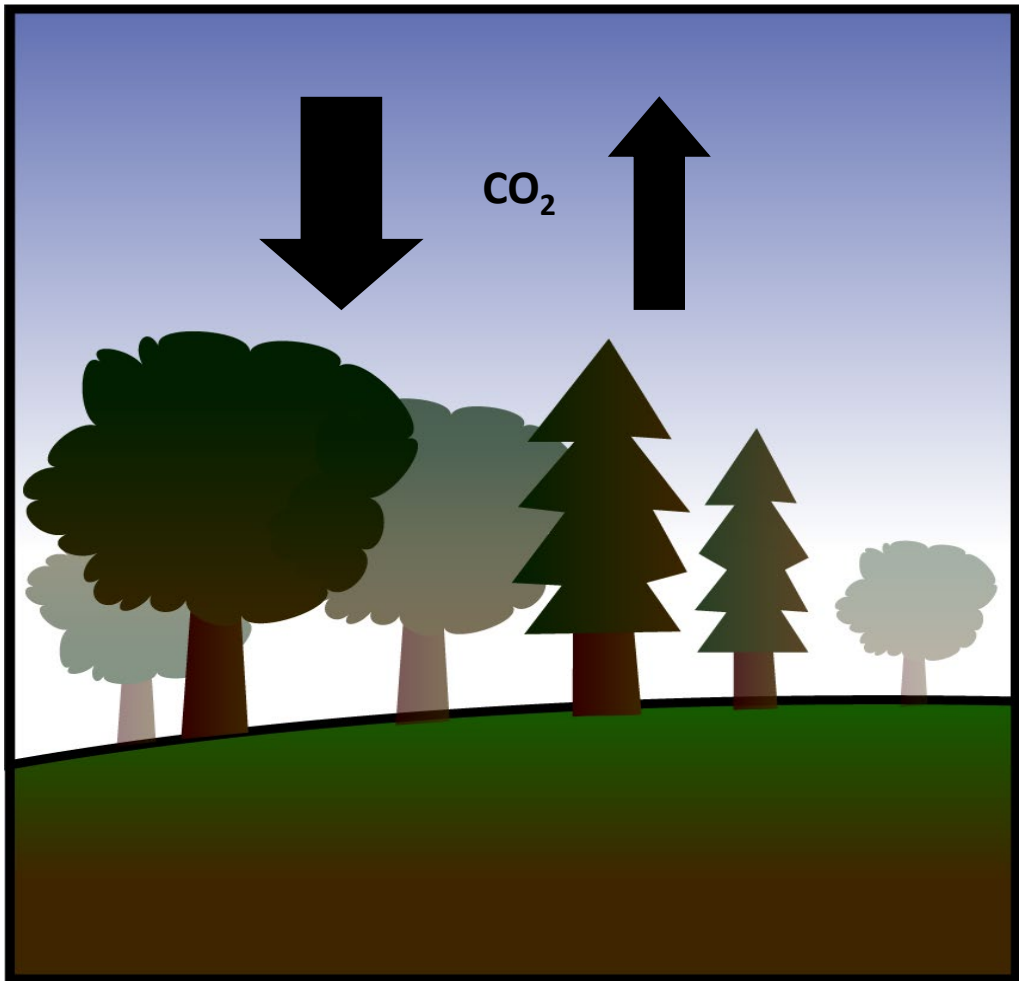
Carbon Storage in Forests

Why does this matter?

Carbon uptake by ecosystems offsets fossil fuel emissions of $CO_2$ by ~30%

# Carbon Uptake by Forests Offsets 30% of $CO_2$ Emissions from Fossil Fuel Combustion



# Do reduced snowpack and increased soil frost decrease nutrient uptake by trees and ecosystem carbon storage in forests?

# Snow-Removal Experiments at Hubbard Brook and Harvard Forest


Sugar maple - American beech

Red maple - Red oak

# Snow-Removal Experiments at Hubbard Brook and Harvard Forest

n = 4 reference and 4 treatment plots at Hubbard Brook
n = 3 reference and 3 treatment plots at Harvard Forest

# Snow and Soil Frost Depth Measurements


Snow Depth

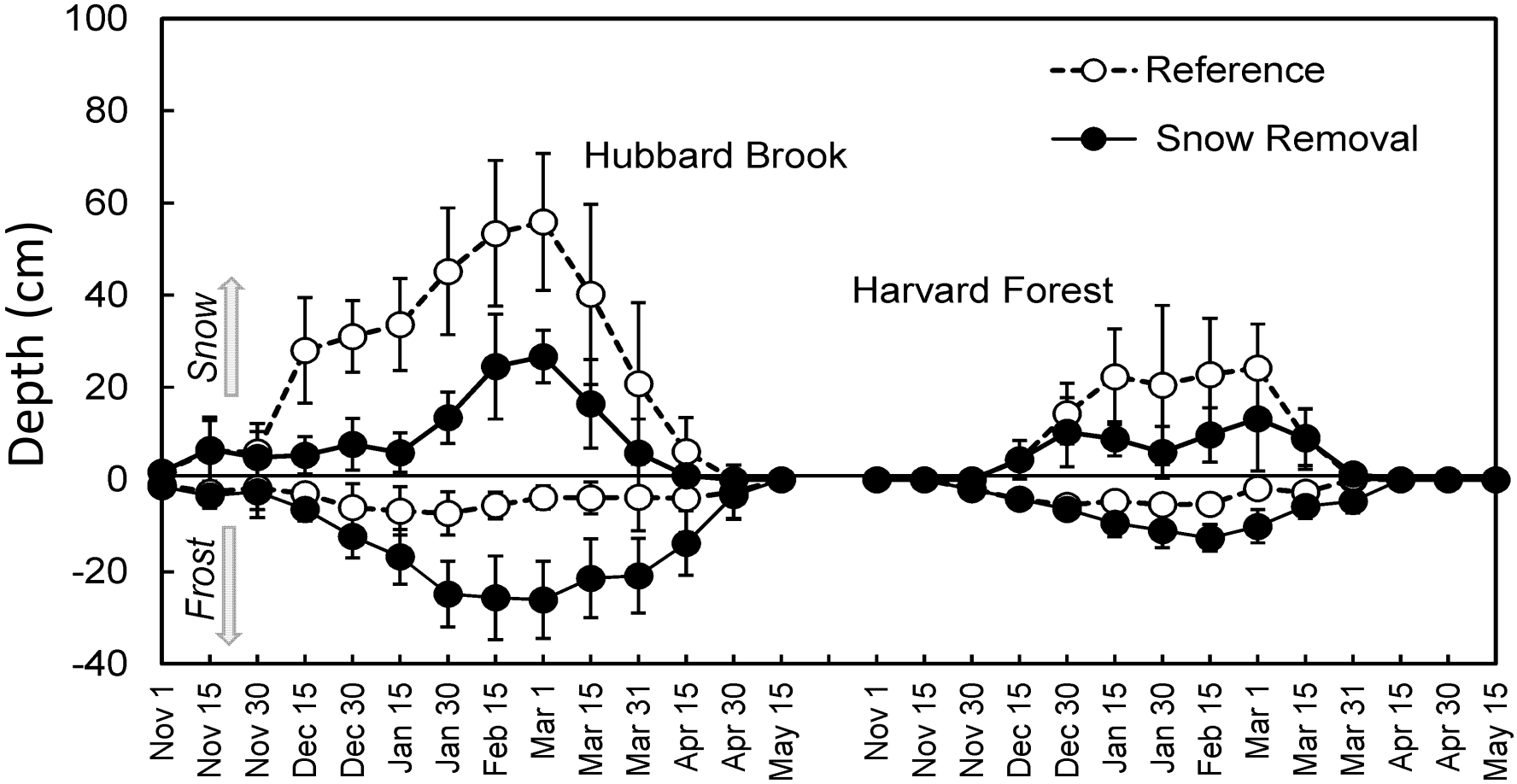
Frost tubes with
methylene blue dye

# Snow and Soil Frost Depth Measurements


Snow Depth

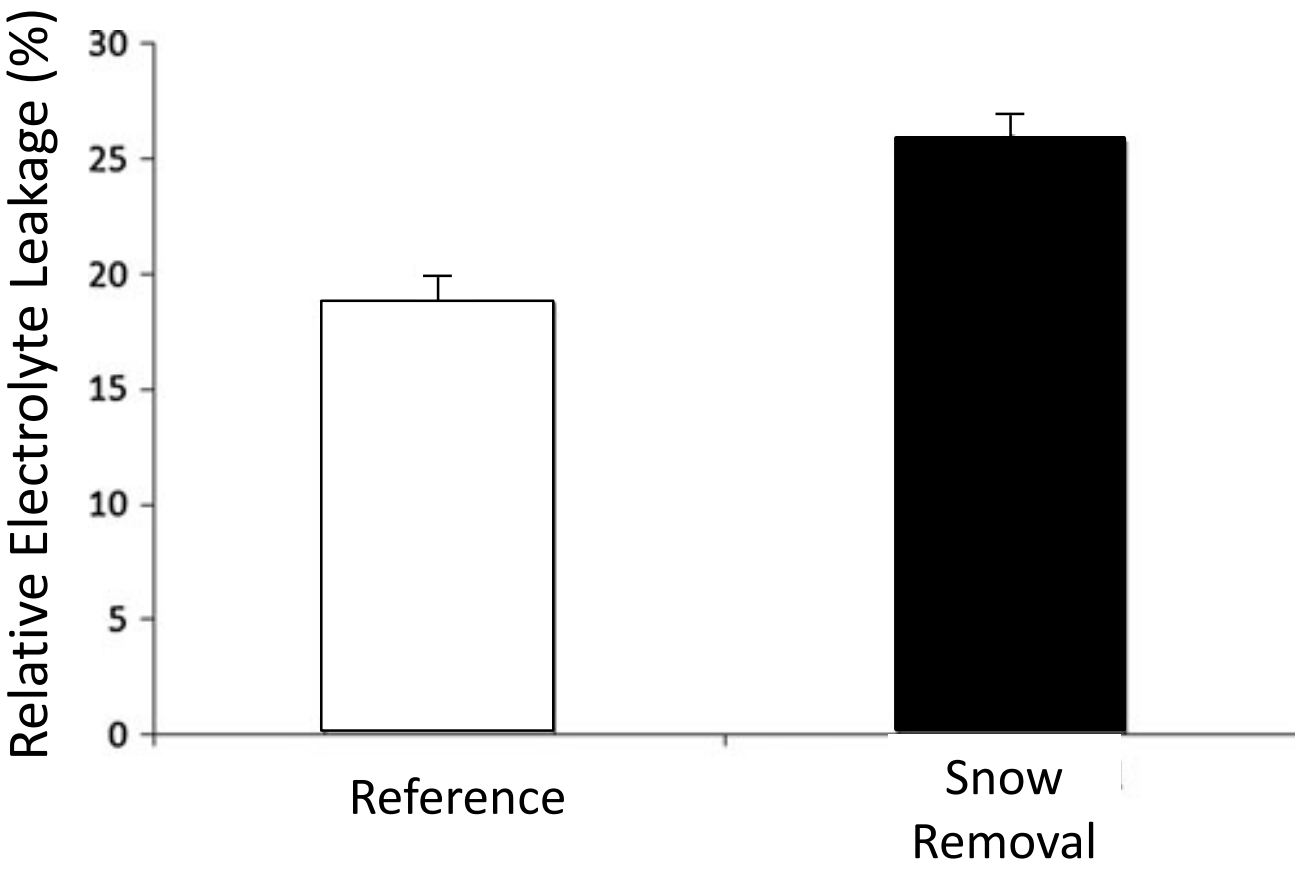

Frost tubes with
methylene blue dye

# Smaller Snowpack Increases Soil Frost Depth




Sorensen et al. (2016) *Biogeochemistry*

# Soil Frost Induces Root Injury of Sugar Maple Trees




Commerford et al. (2013) *Oecologia*

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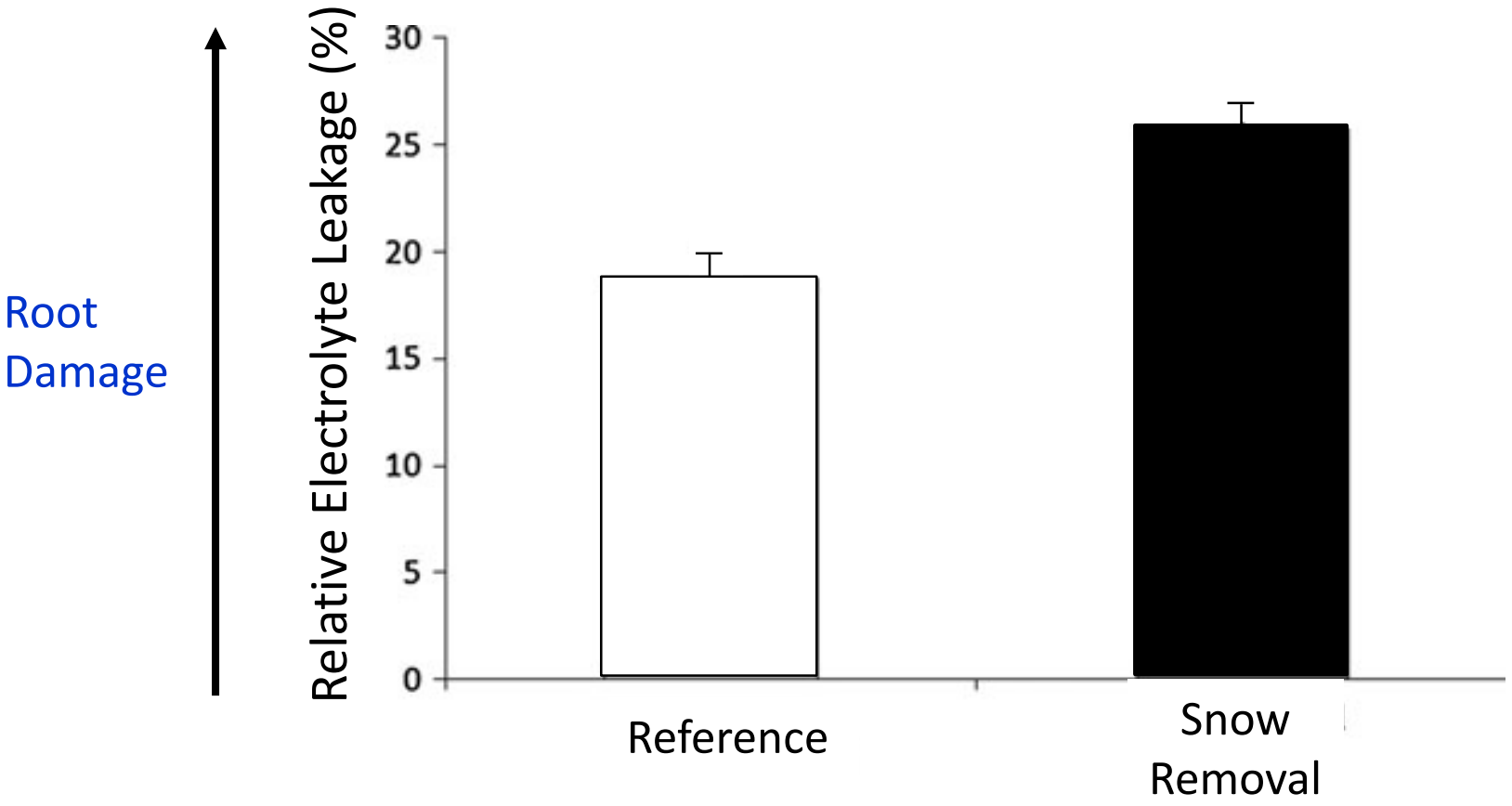


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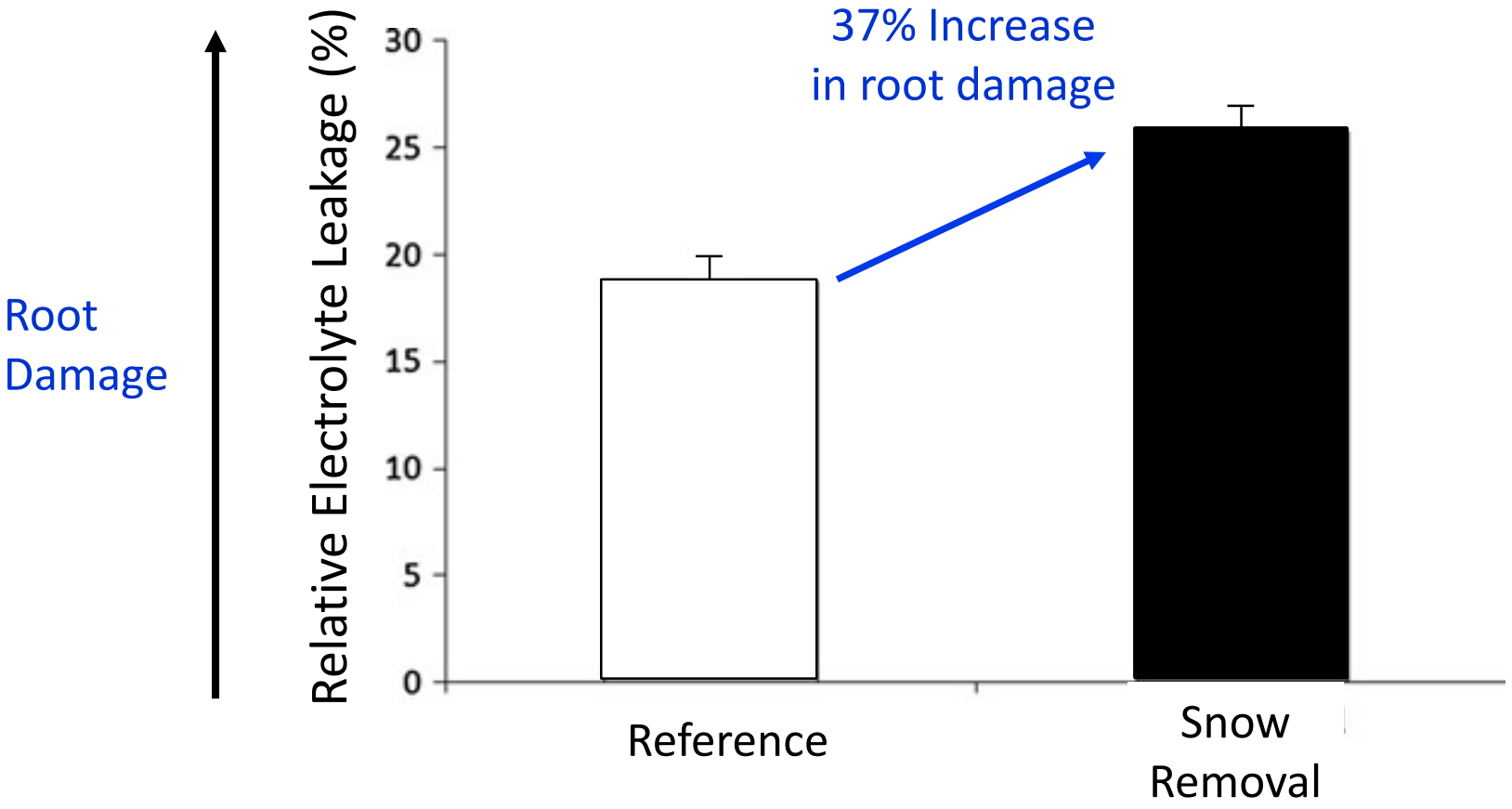


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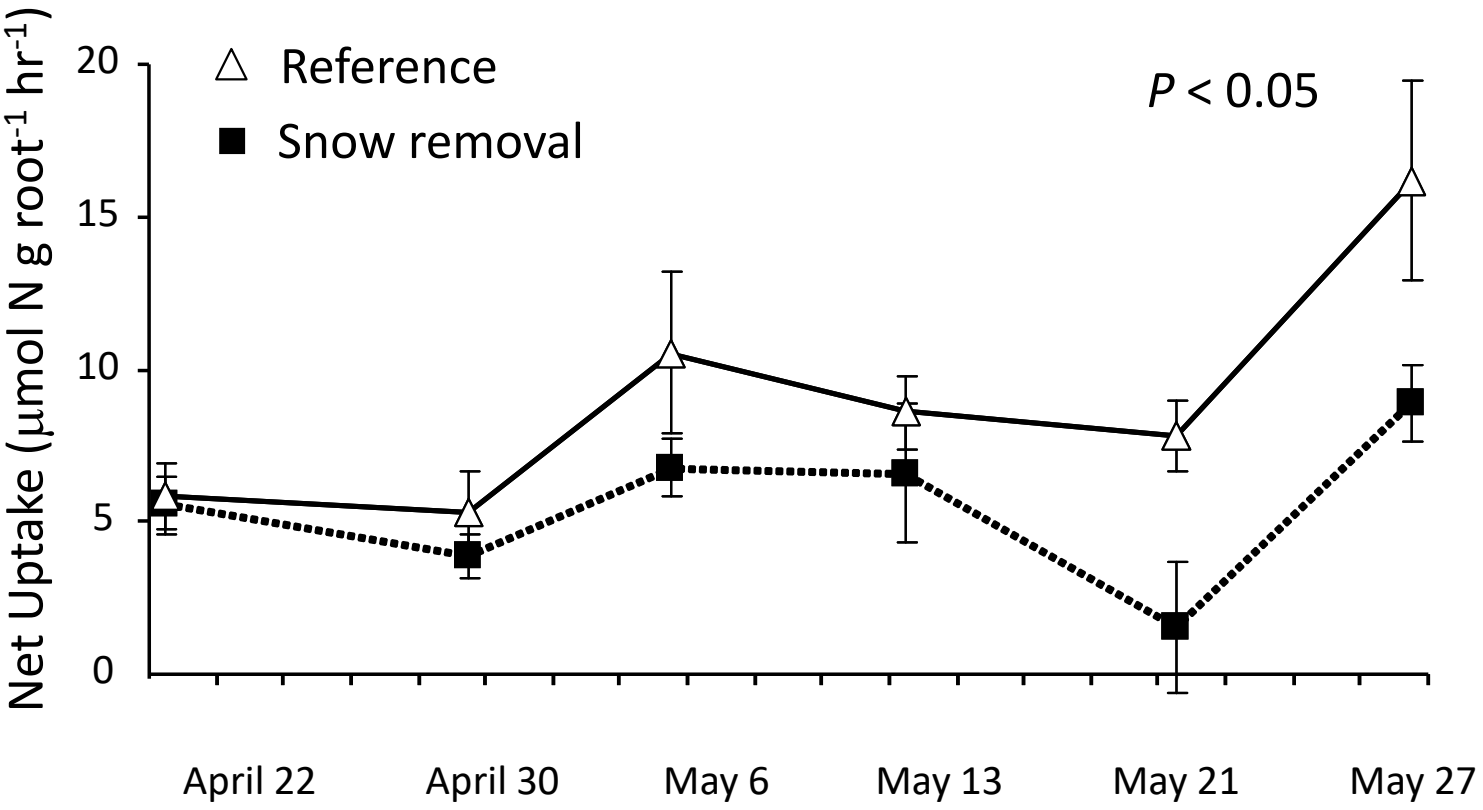
# Soil Frost Reduces Nitrogen Uptake by Sugar Maple Trees




Socci and Templer (2011); Campbell et al. (2014)

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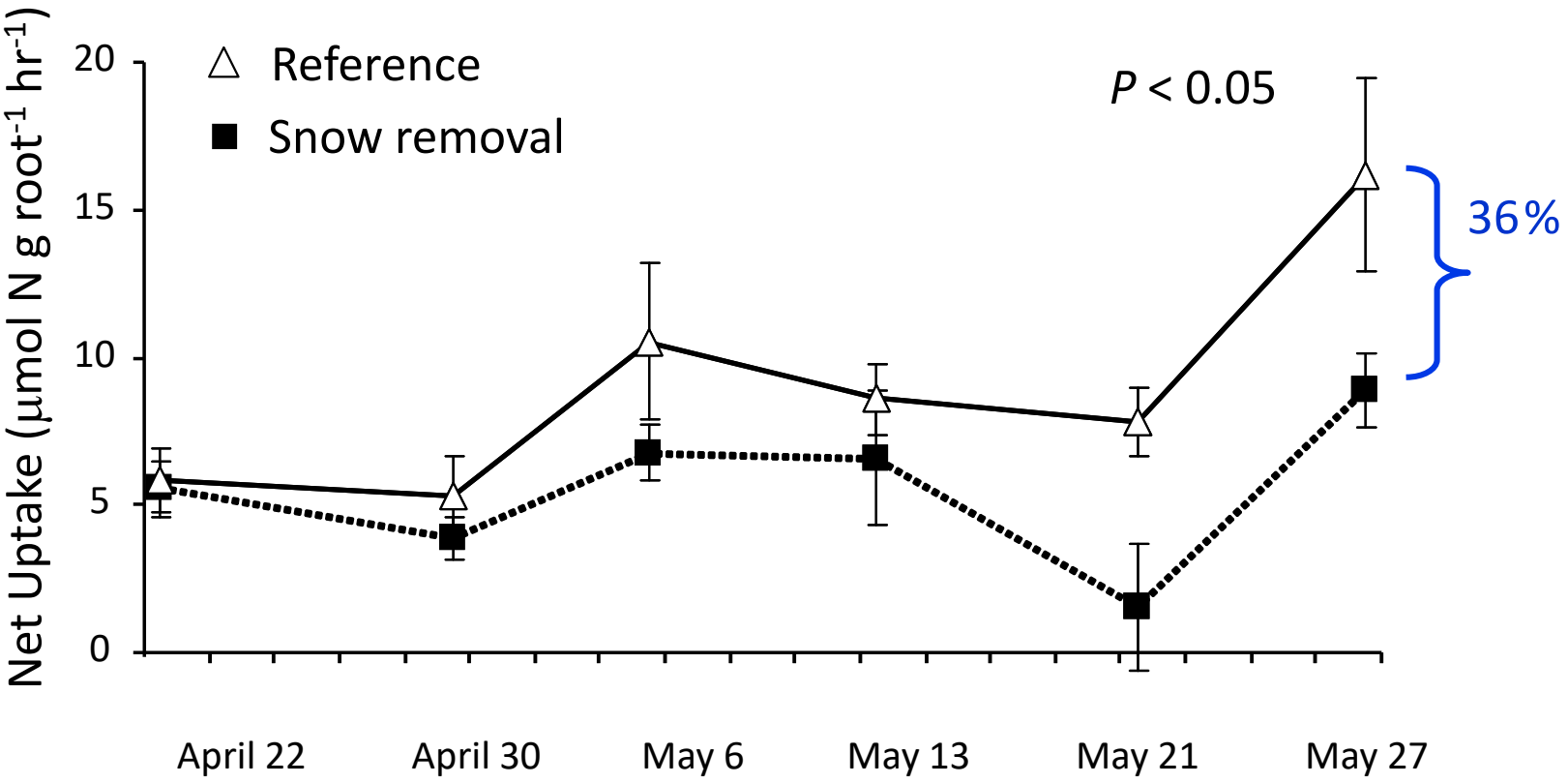
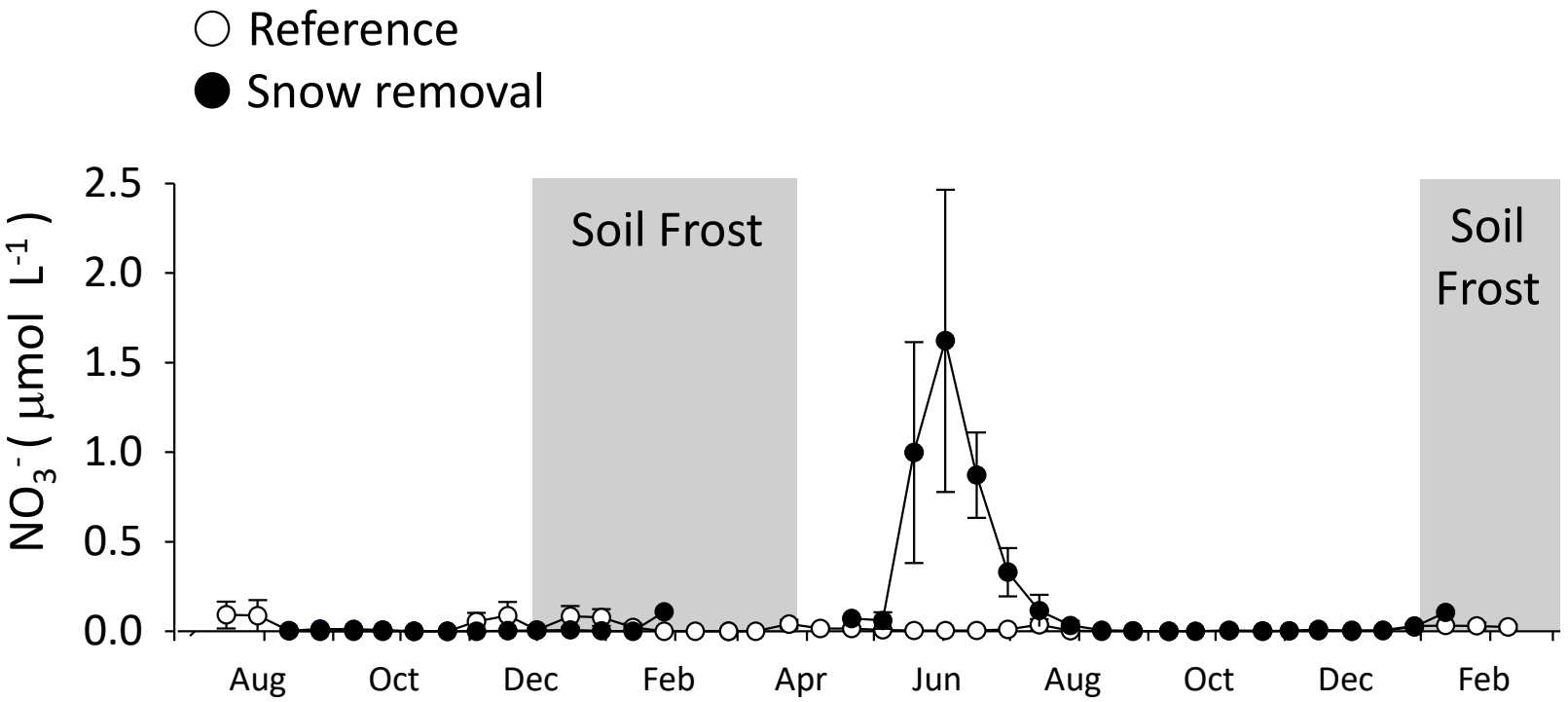


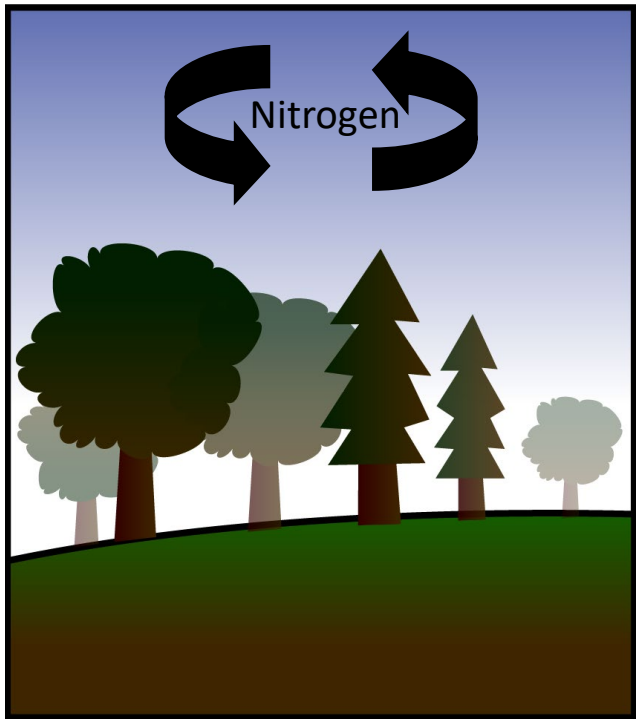

Socci and Templer (2011); Campbell et al. (2014)

# Soil Frost Induces Elevated $NO_3^-$ in Leachate




Campbell et al. (2014) *Global Change Biology*

# Why Care about Nitrogen Leaching?




$NO_3^-$ Leaching

- Release of $N_2O$
- Reduced forest productivity
- Acidification of stream water
- Eutrophication (algal blooms)
- Human health effects

# Reduced Snowpack and Increased Soil Freezing

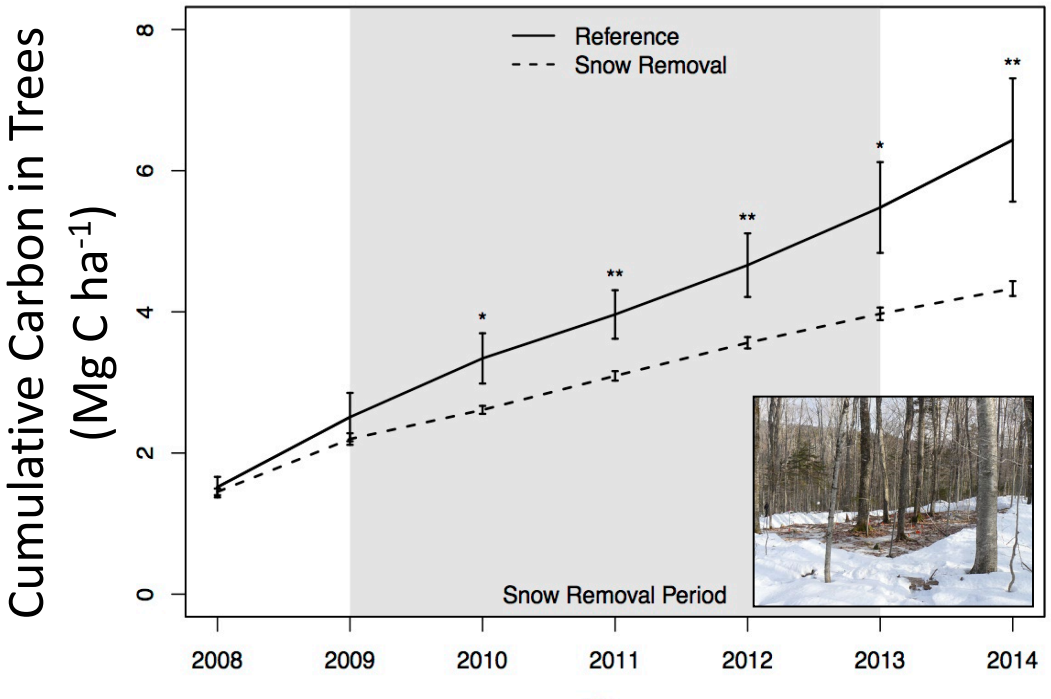
- damage roots and reduce nitrogen uptake by maple trees
  (Comerford et al. 2013, Campbell et al. 2014)

# Reduced Snowpack and Increased Soil Freezing

- damage roots and reduce nitrogen uptake by maple trees
  (Comerford et al. 2013, Campbell et al. 2014)
- increase nitrogen leaching
  (Campbell et al. 2014)

# Do reduced snowpack and increased soil frost decrease ecosystem carbon storage in forests?

# Snowpack Declines Decrease C Storage in Forests



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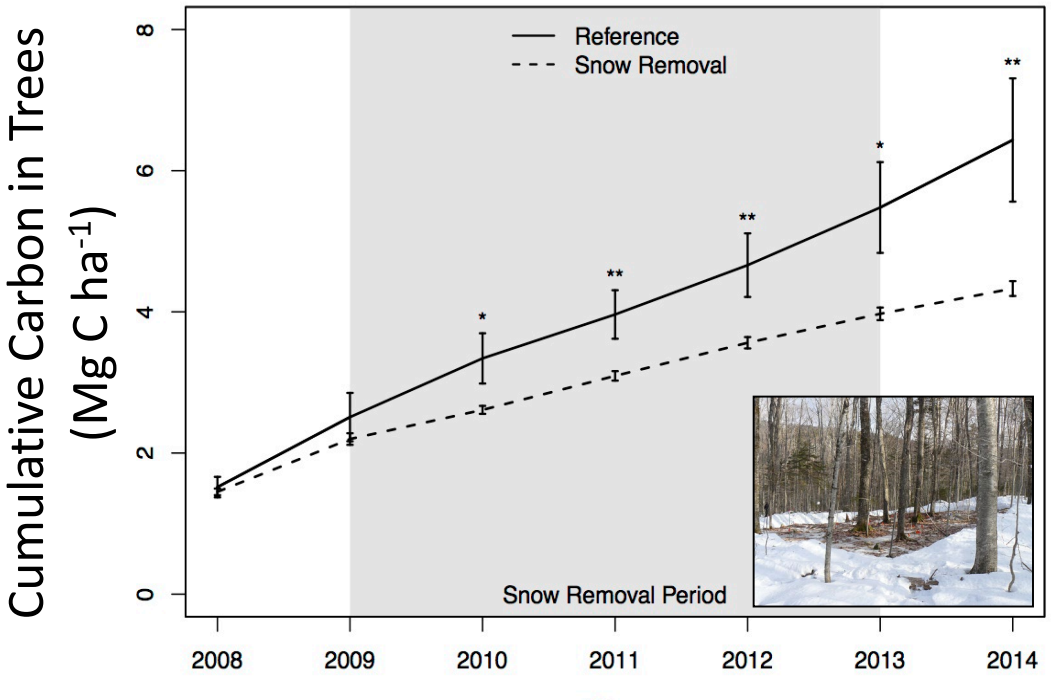
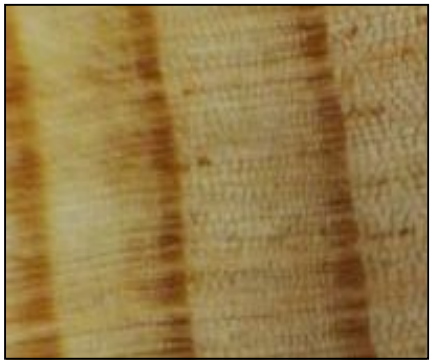
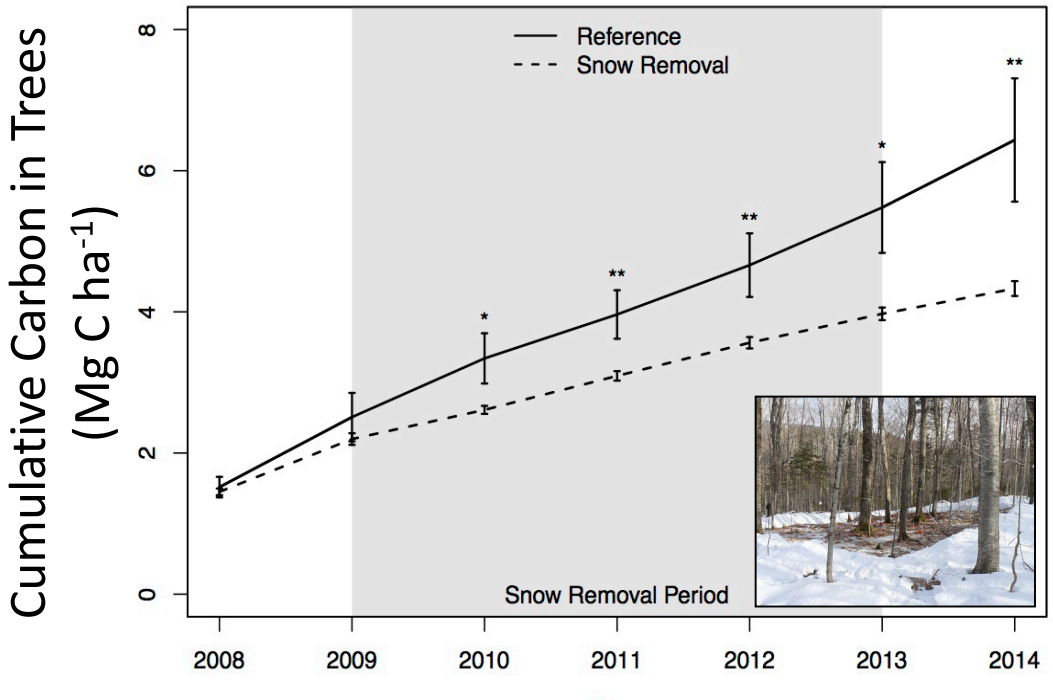



Photosynthesis
($CO_2$ Uptake)



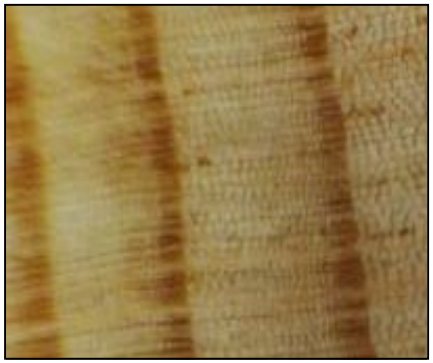
Tree Growth
($CO_2$ Uptake)

# Snowpack Declines Decrease C Storage in Forests




Climate change in winter:
40% decrease carbon storage

Photosynthesis
($CO_2$ Uptake)



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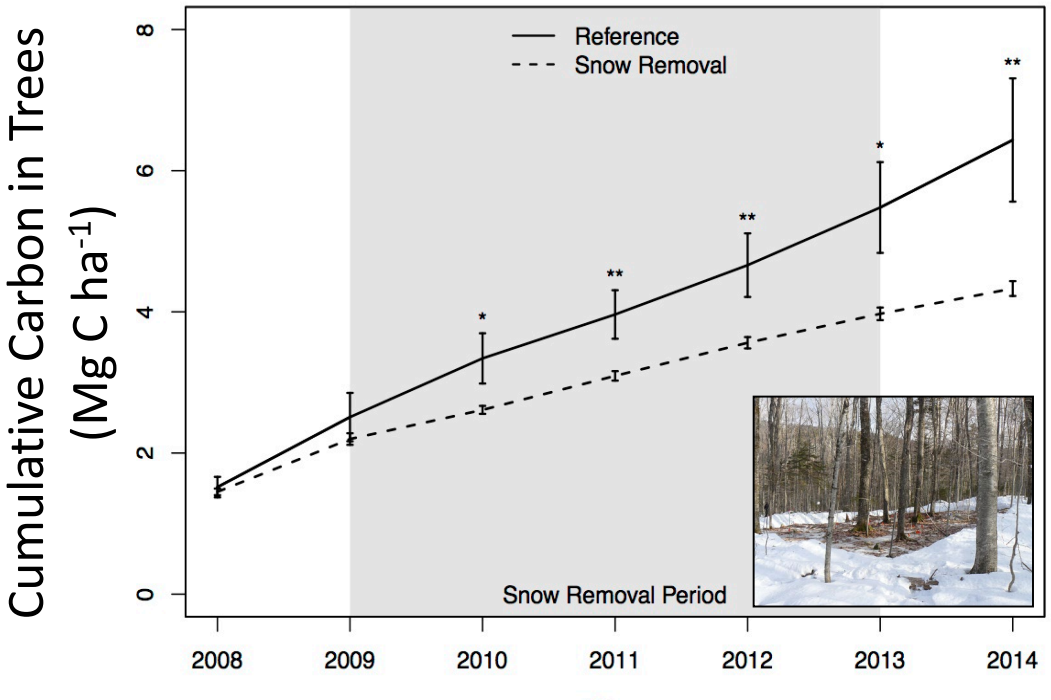
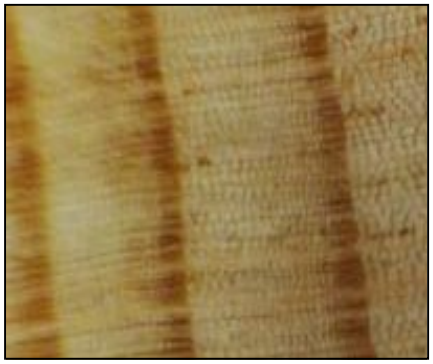



Stem Respiration ($CO_2$ Losses)

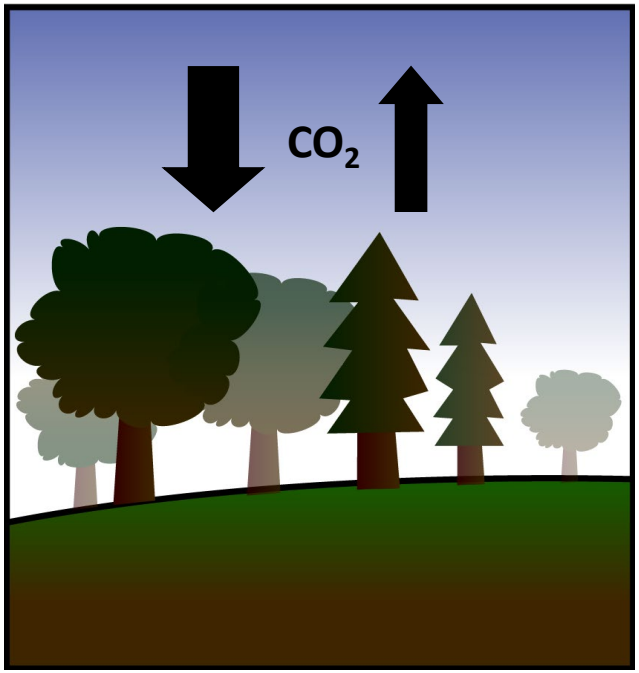
Photosynthesis
($CO_2$ Uptake)



Tree Growth
($CO_2$ Uptake)

Soil Respiration ($CO_2$ Losses)

# Do reduced snowpack and increased soil frost decrease ecosystem carbon storage in forests?




Large Snowpack
Little soil frost

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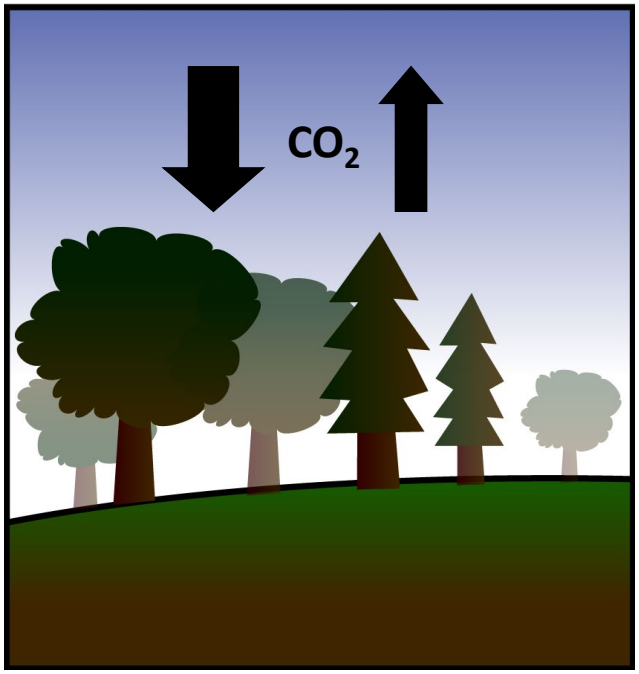


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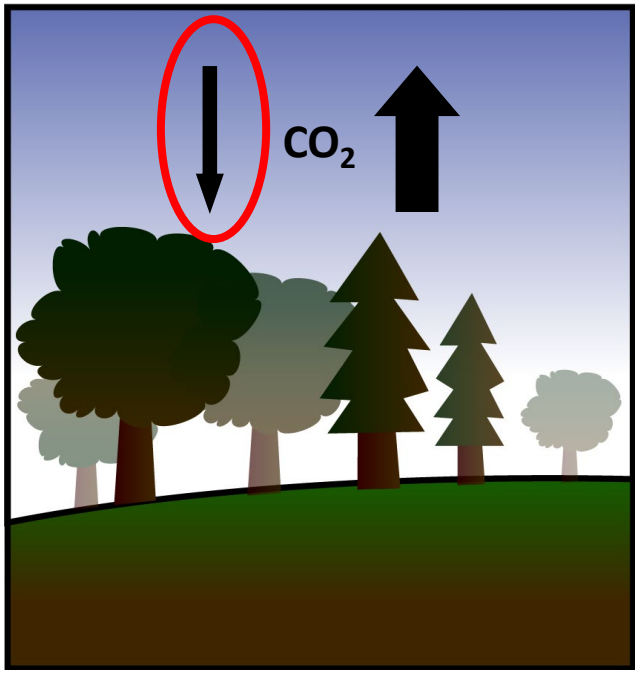


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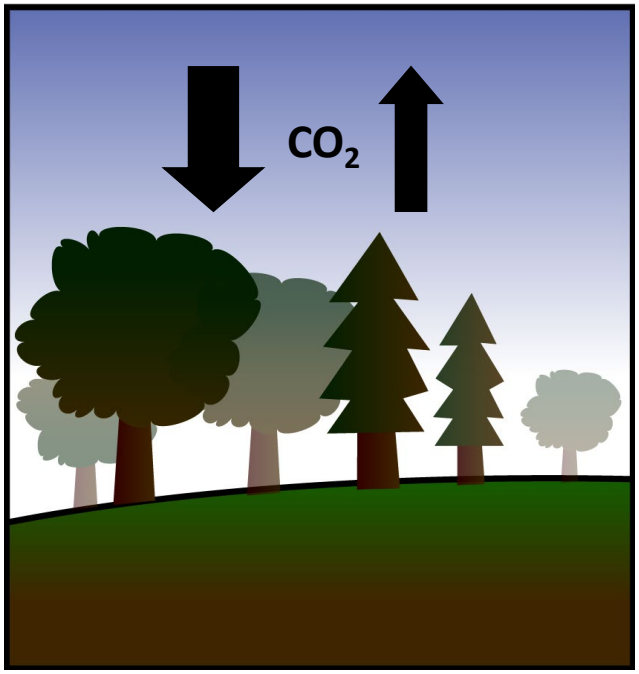


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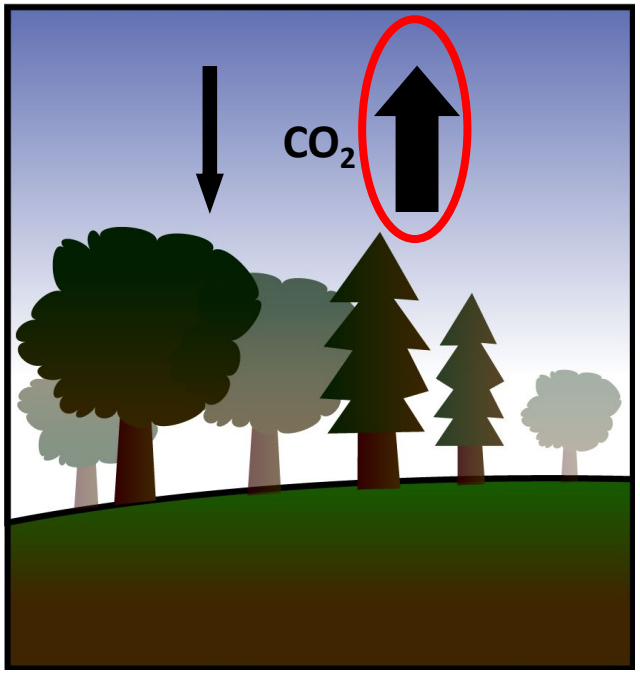


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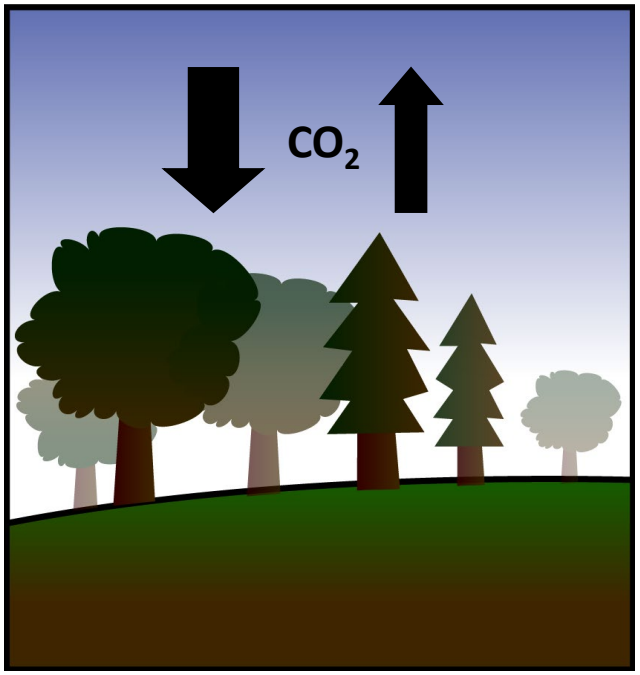
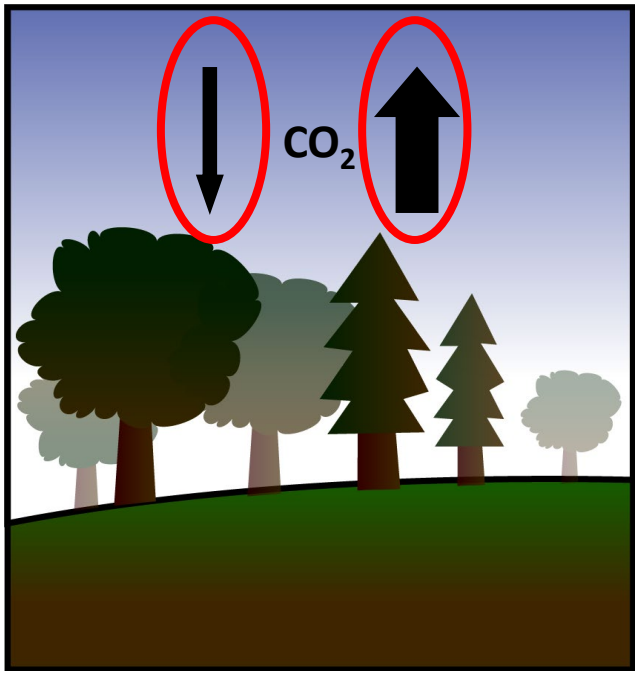



15% reduction
C storage across
northern forest

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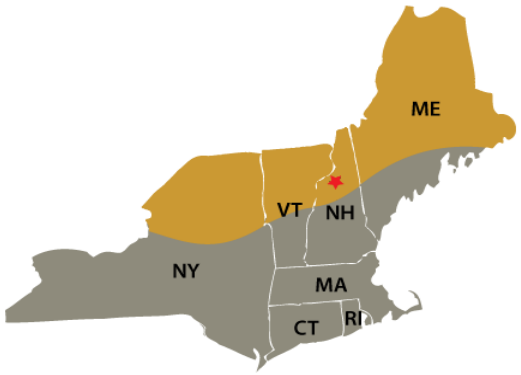


* Hubbard Brook

# What are combined effects of colder soils in winter + warmer soils in the growing season?

# Climate Change Across Season Effects Experiment

# Climate Change Across Season Effects
# CCASE

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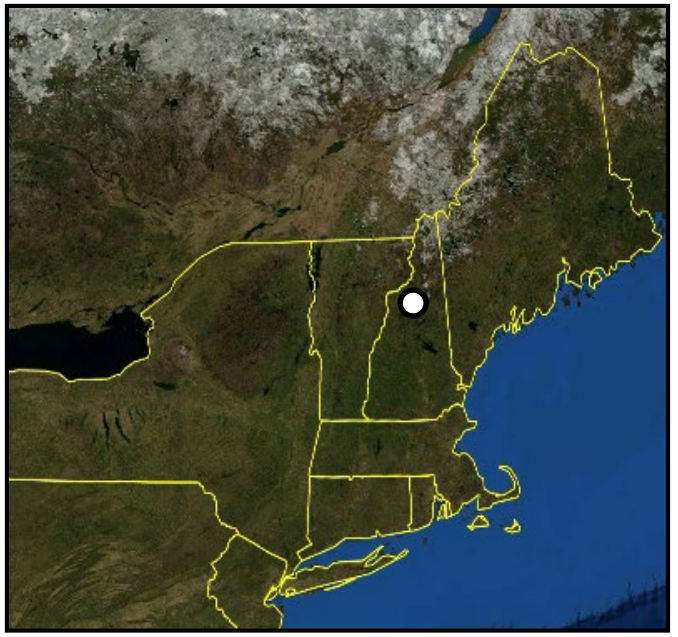
Determine how warmer temperatures in the growing season and smaller snowpack affect carbon sequestration in northern forests

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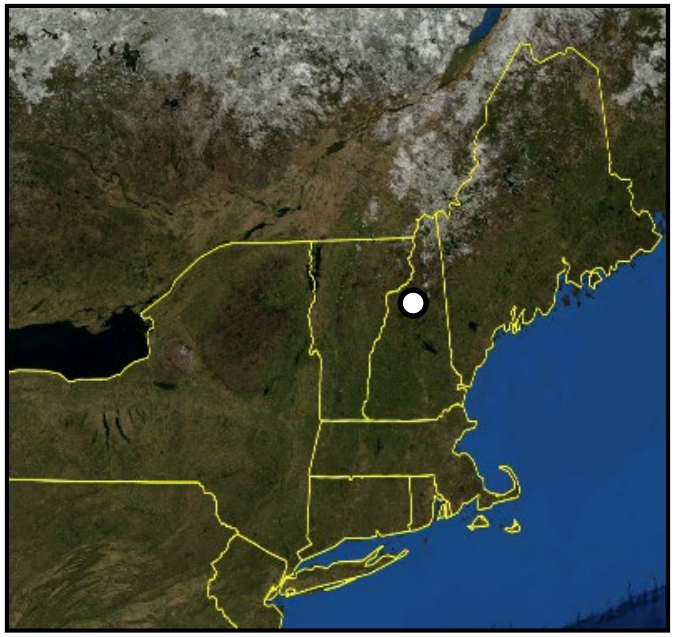
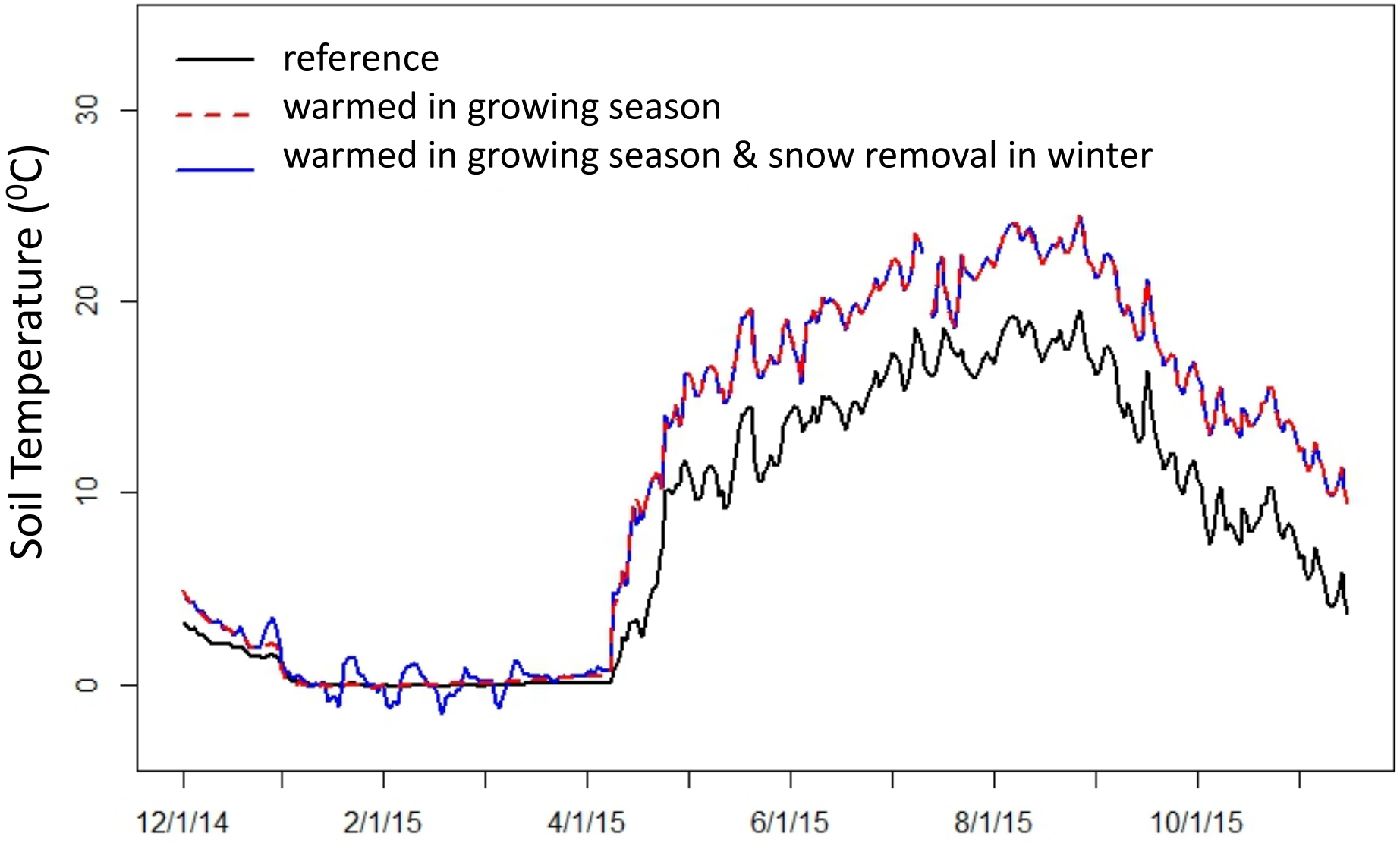


14 X 11m$^2$ plots in hardwood forest

- 2 plots: reference
- 2 plots: soils warmed 5$^0$C in growing season
- 2 plots: soils warmed 5$^0$C in growing season and less snow in winter

# CCASE Experiment at Hubbard Brook

# Soil Temperature at CCASE




Templer et al. (2017) *PLOS One*

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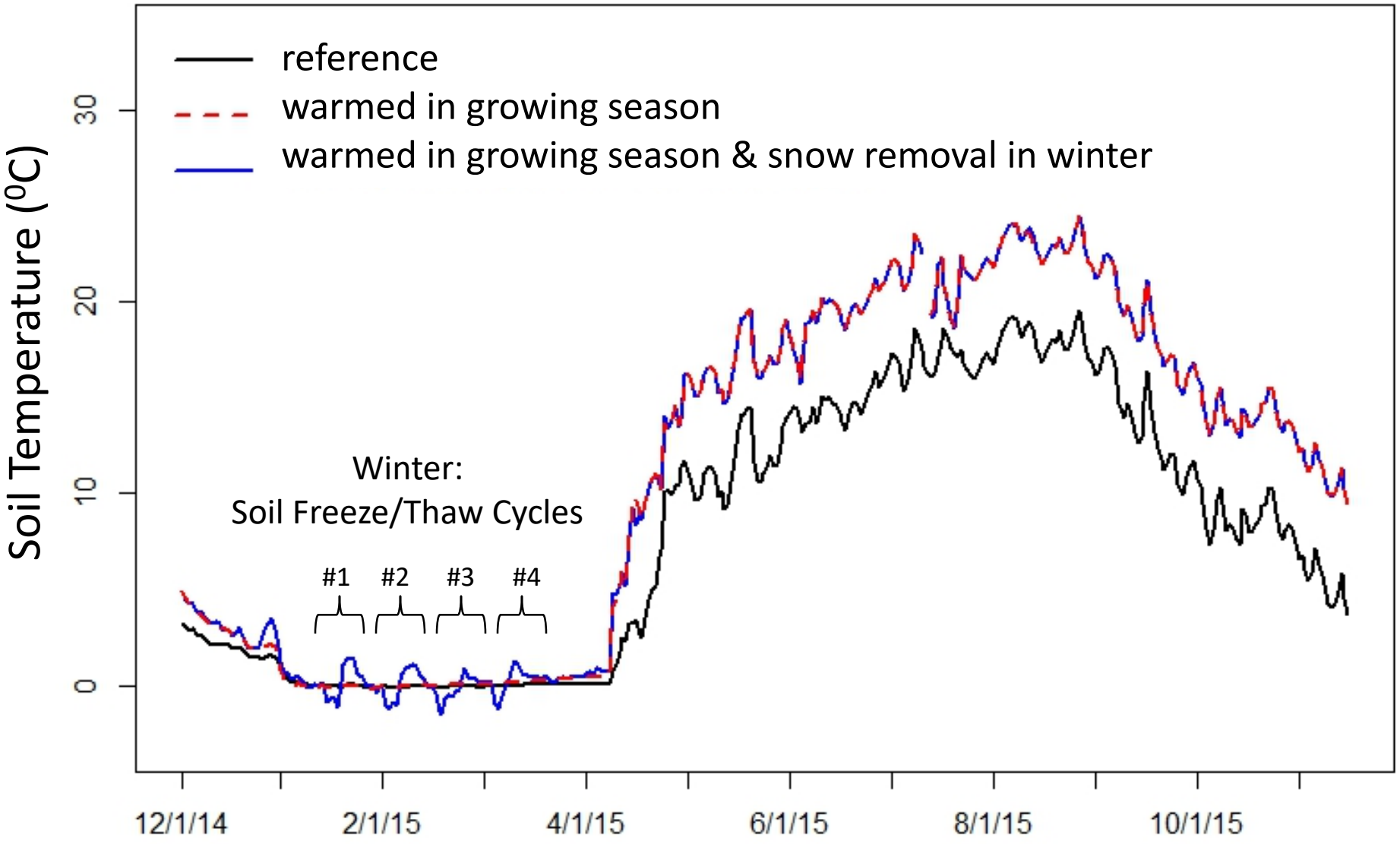


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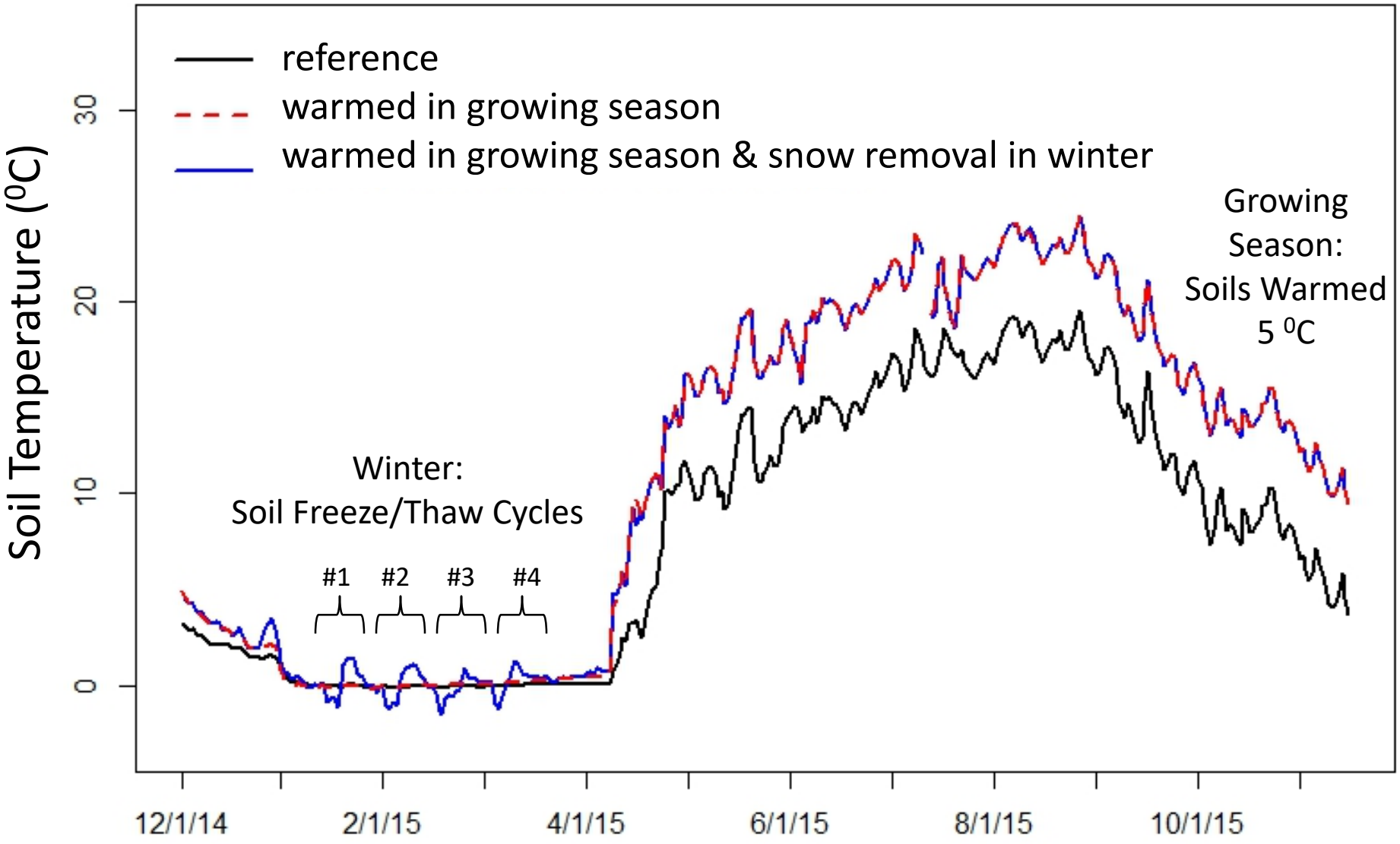


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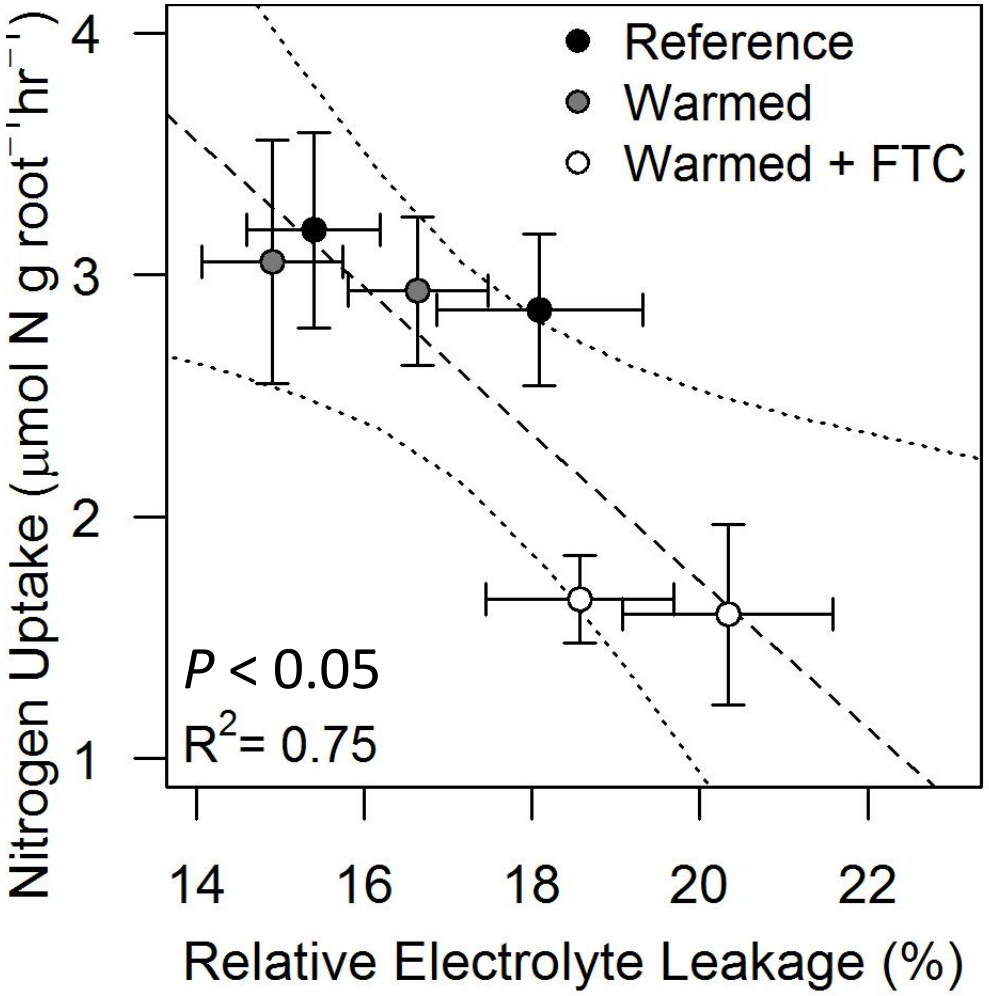
# Soil Frost Damages Roots and Reduces N Uptake




Rebecca Sanders-Demott (PhD)

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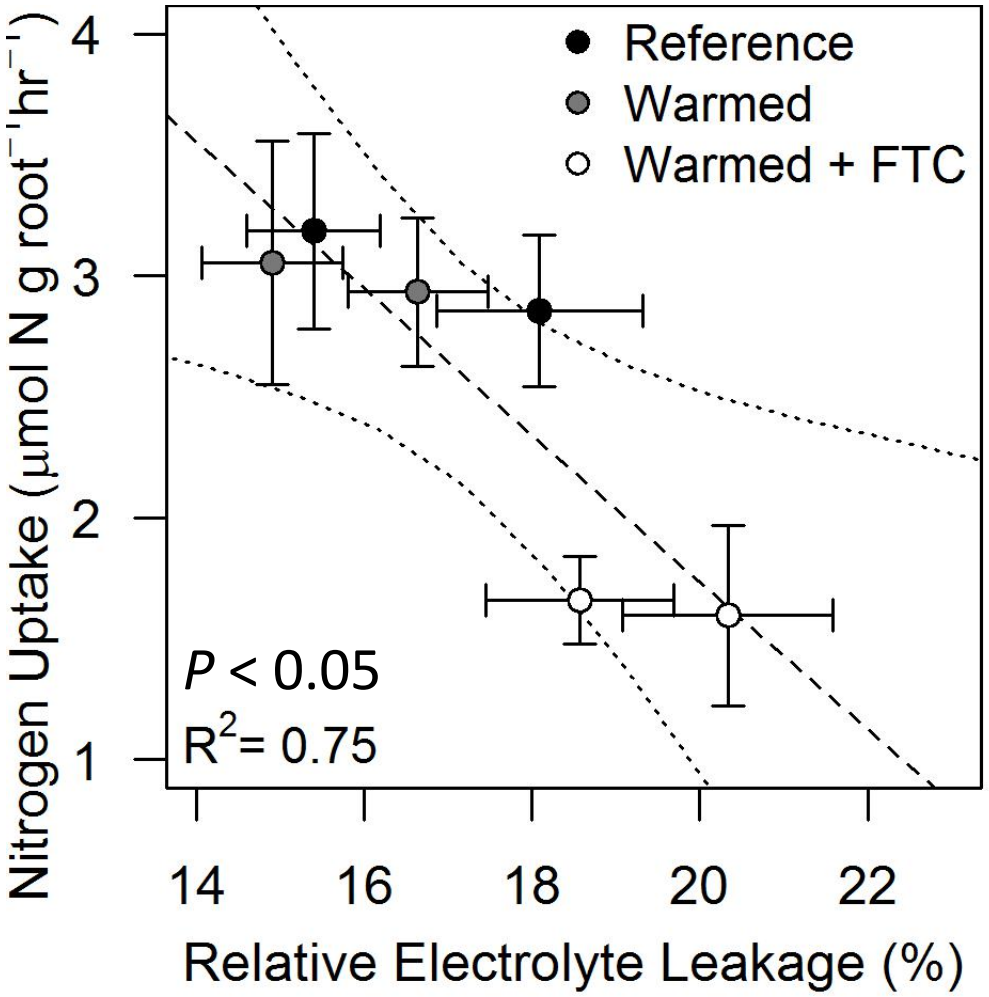


Root Damage →

Rebecca Sanders-Demott (PhD)

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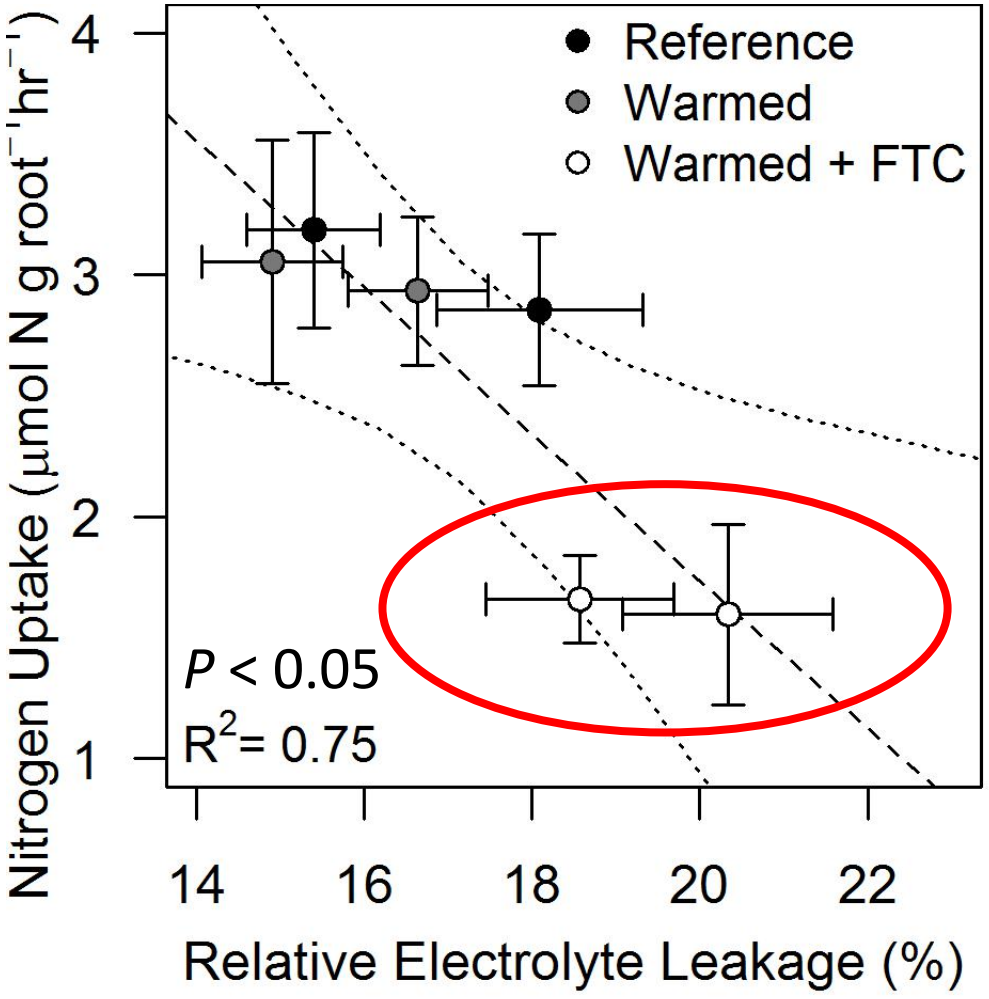


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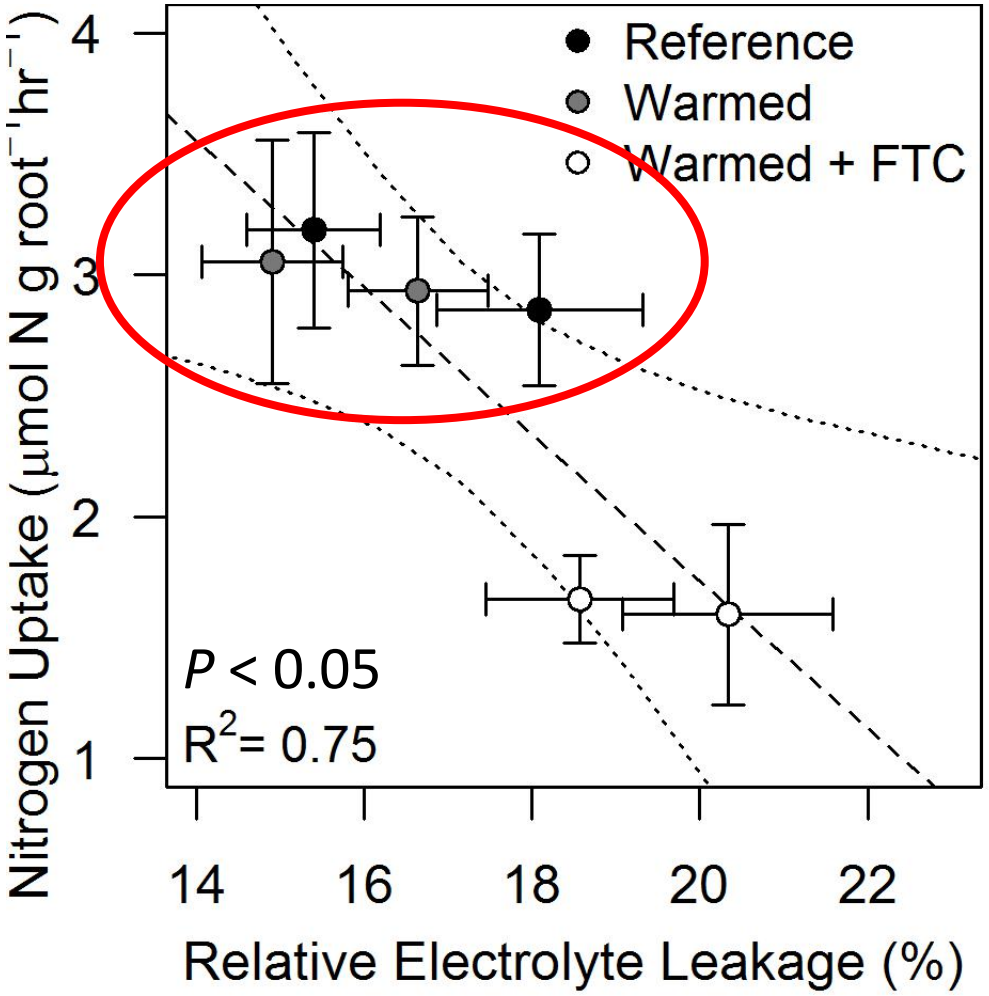
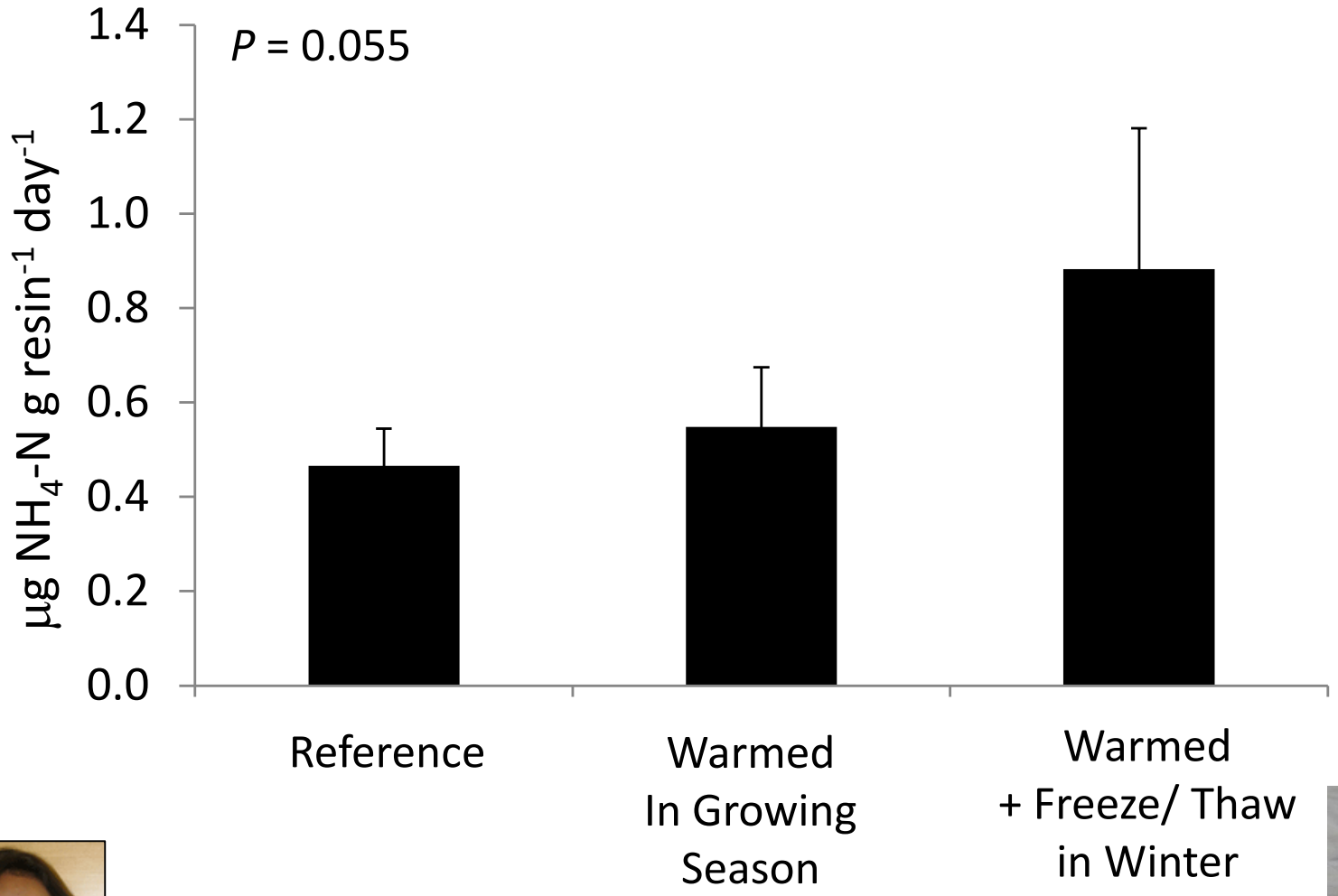



Root Damage →

Rebecca Sanders-Demott (PhD)

# Soil Frost Induces Nitrogen Losses

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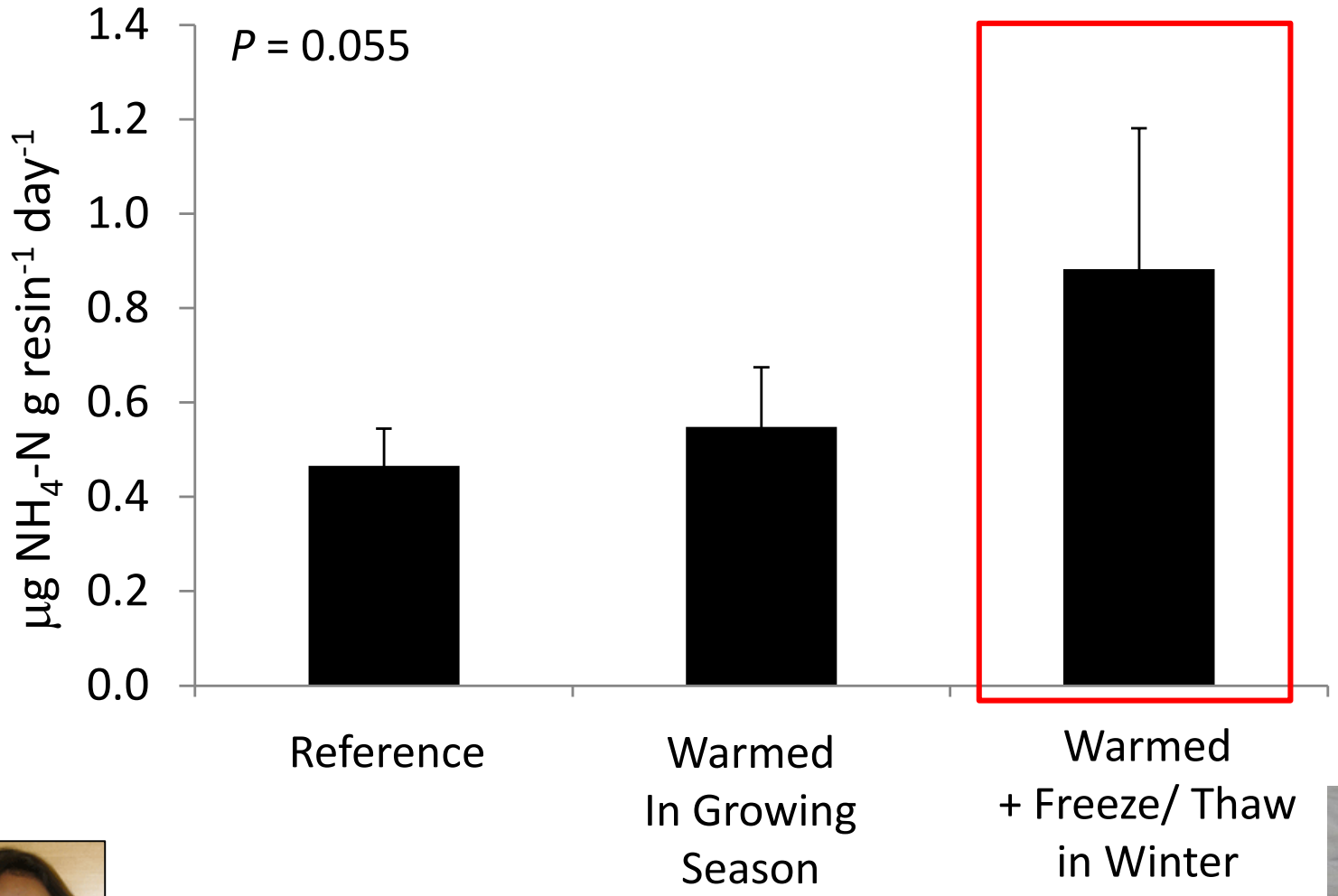


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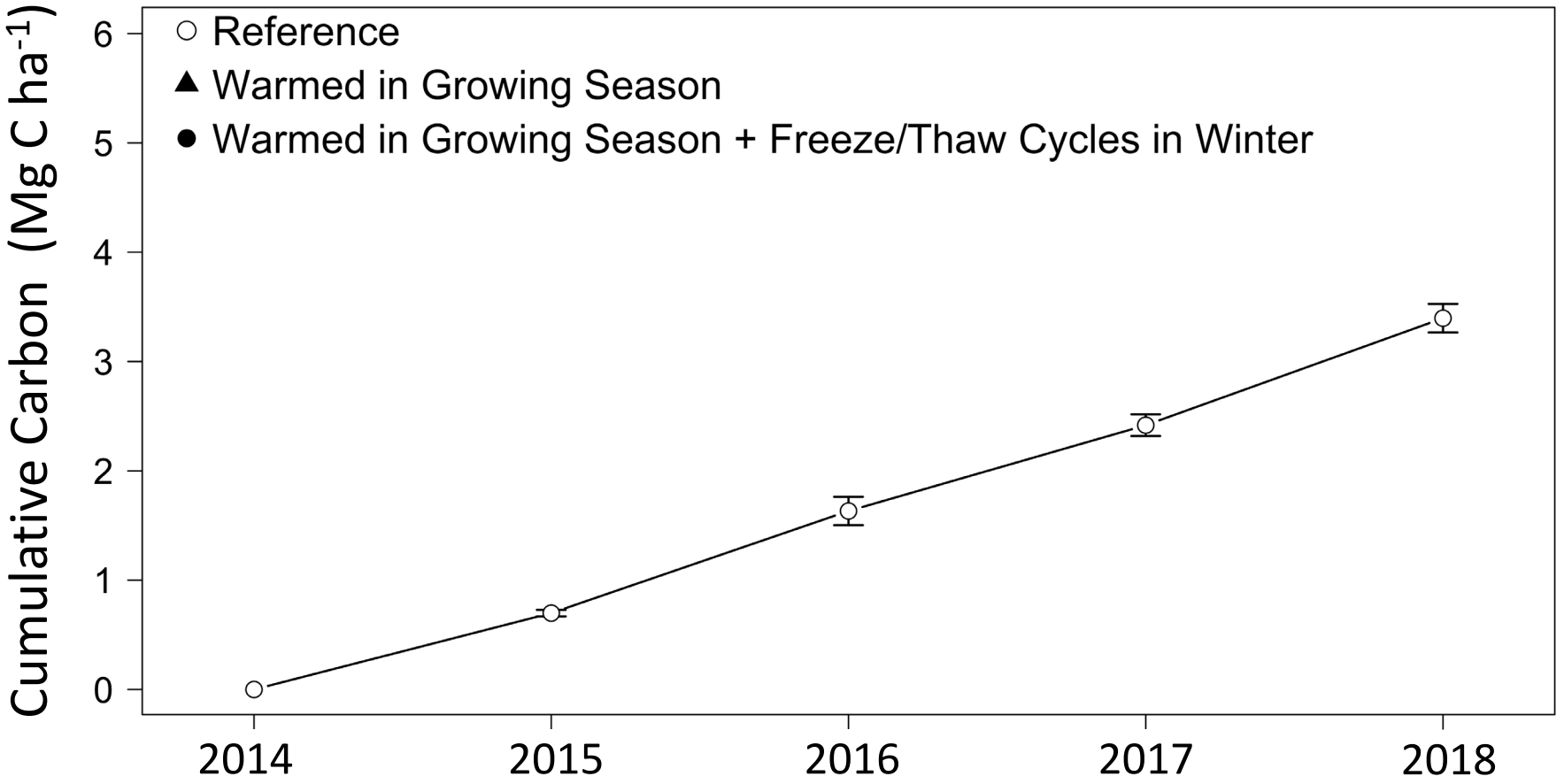
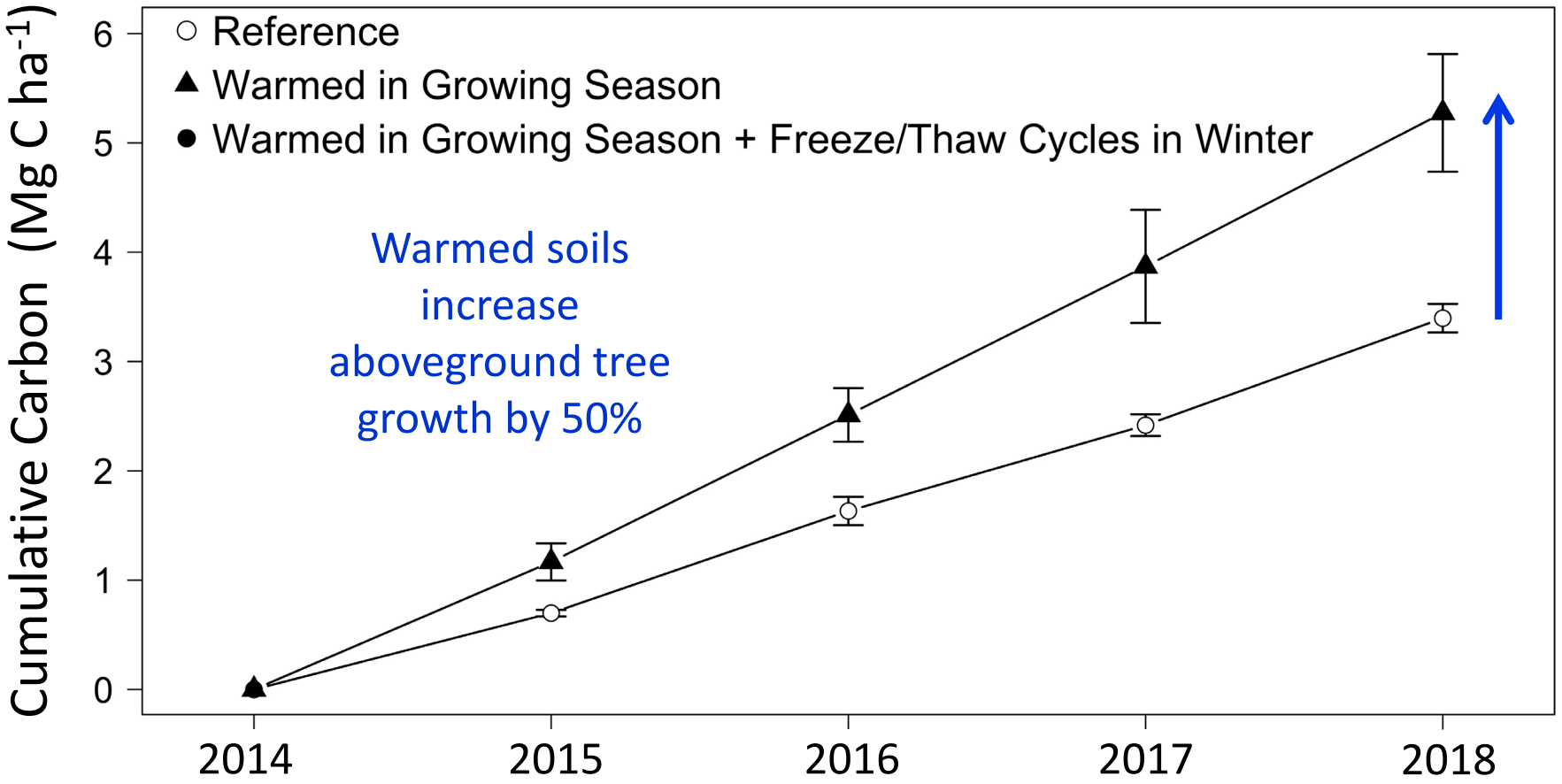
# Aboveground Productivity & Carbon Uptake by Trees

- Litterfall baskets: 4 per plot
- Dendrometer bands on all trees ≥10 cm diameter
- 21-24 trees per plot: mixed hardwood stand

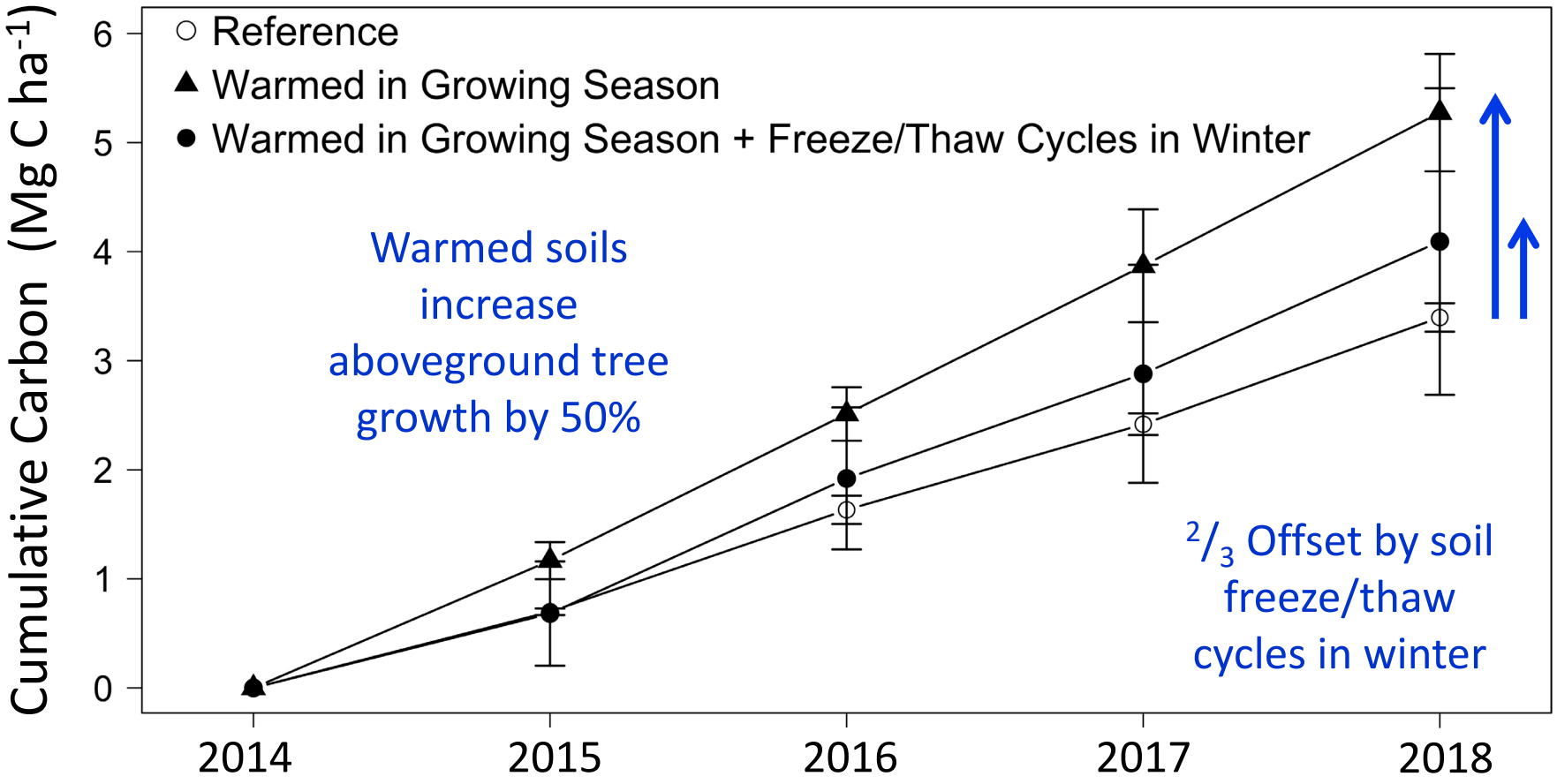
# Cumulative Aboveground Carbon Since 2014




# Cumulative Aboveground Carbon Since 2014




# Cumulative Aboveground Carbon Since 2014




# Conclusions

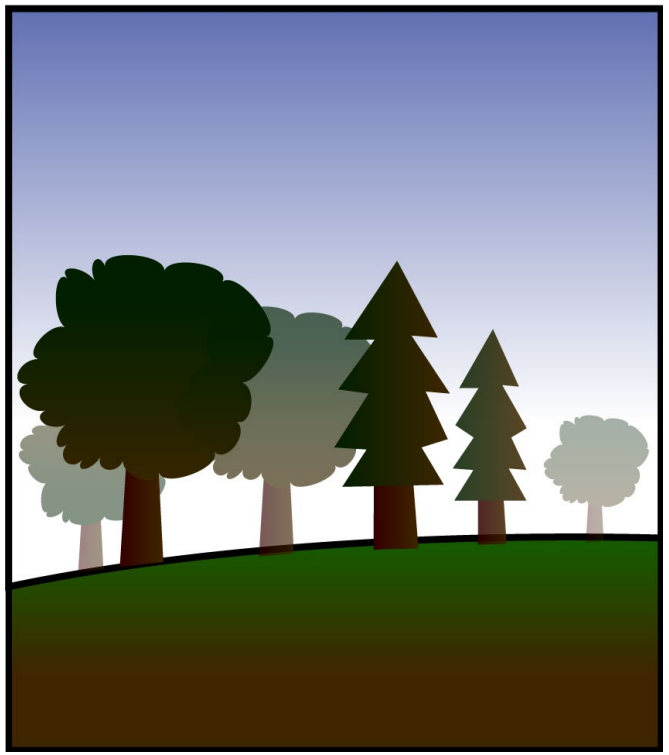
- Winter freeze-thaw cycles injure roots and reduce nitrogen uptake by trees, not offset by growing season warming

# Conclusions

- Winter freeze-thaw cycles injure roots and reduce nitrogen uptake by trees, not offset by growing season warming
- Growing season warming leads to greater tree growth and carbon uptake, but offset by soil freeze-thaw cycles in winter

Climate Change

Air Pollution



Land-Use Change
Urbanization

Introduced Pests

# Acknowledgements

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# Climate Change Effects on New England's Forests

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