Determining forest recruitment change through the integration of NASA Earth observation data and predictive modeling

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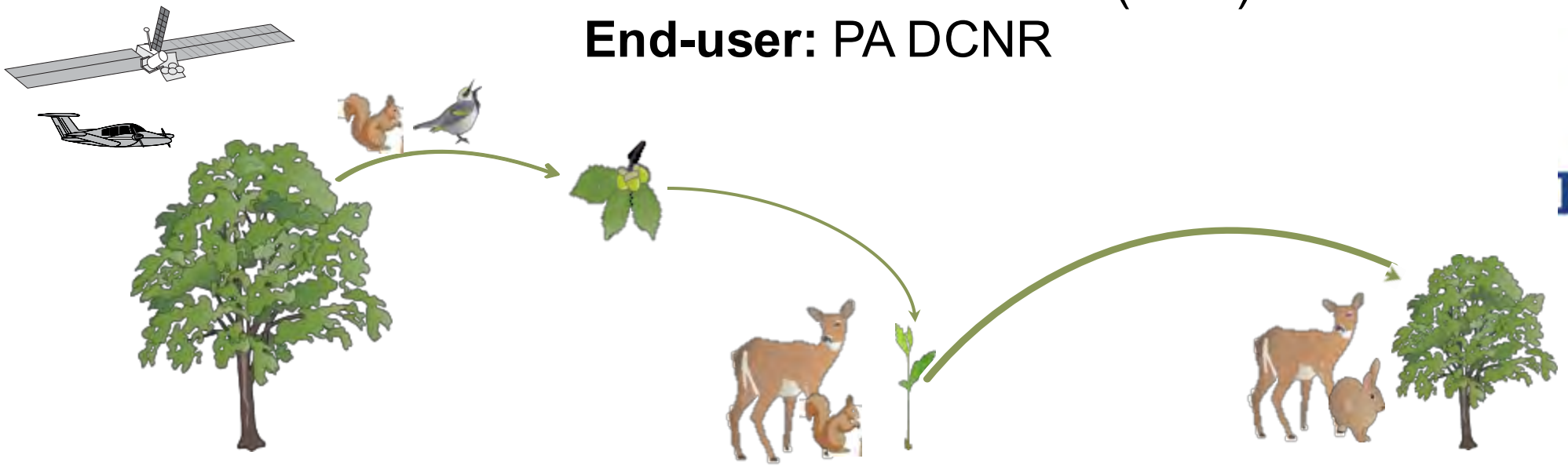
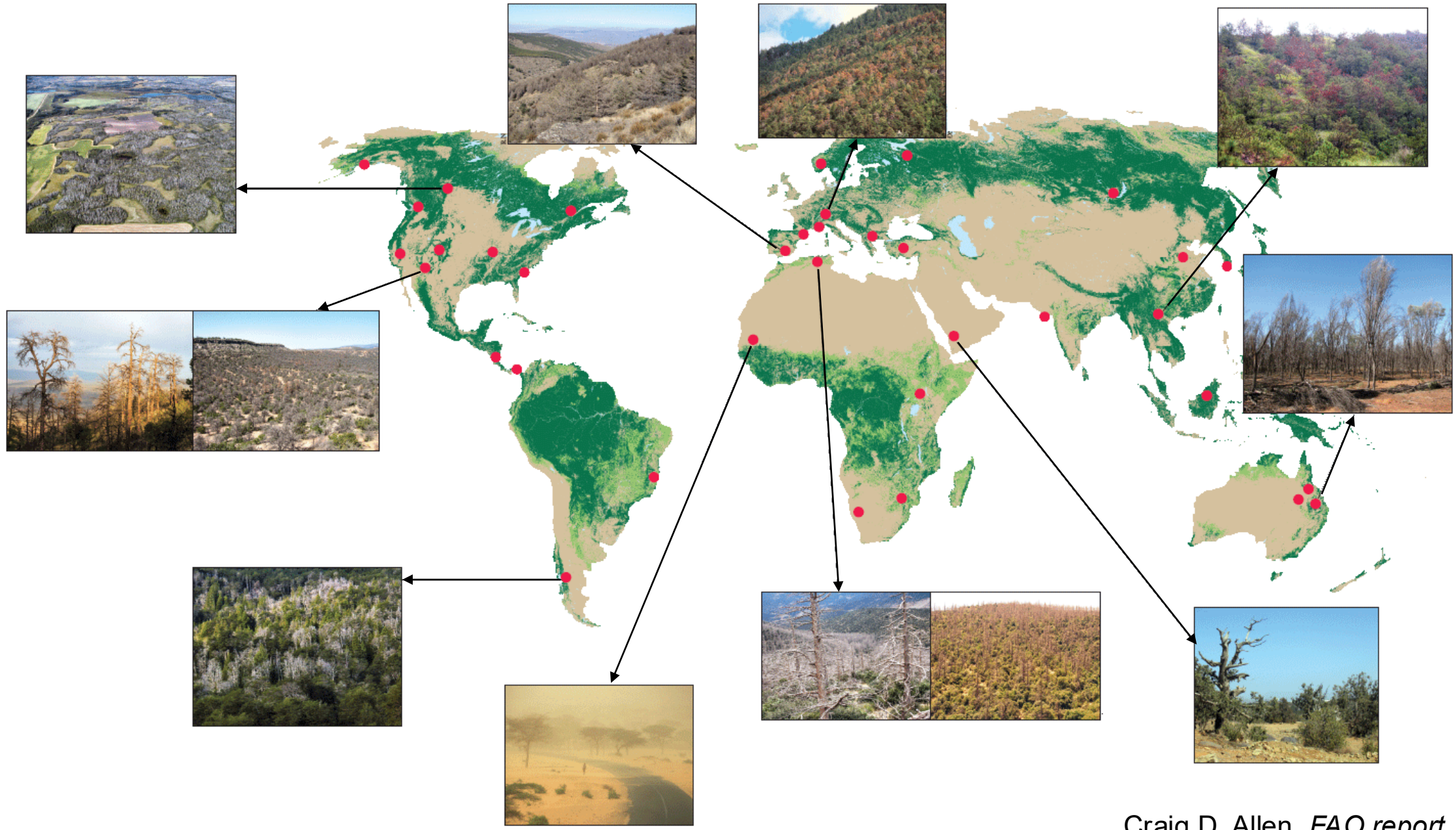
Co-PIs: James S. Clark (Duke),
Marc E. McDill (PSU)
End-user: PA DCNR



Today's agenda

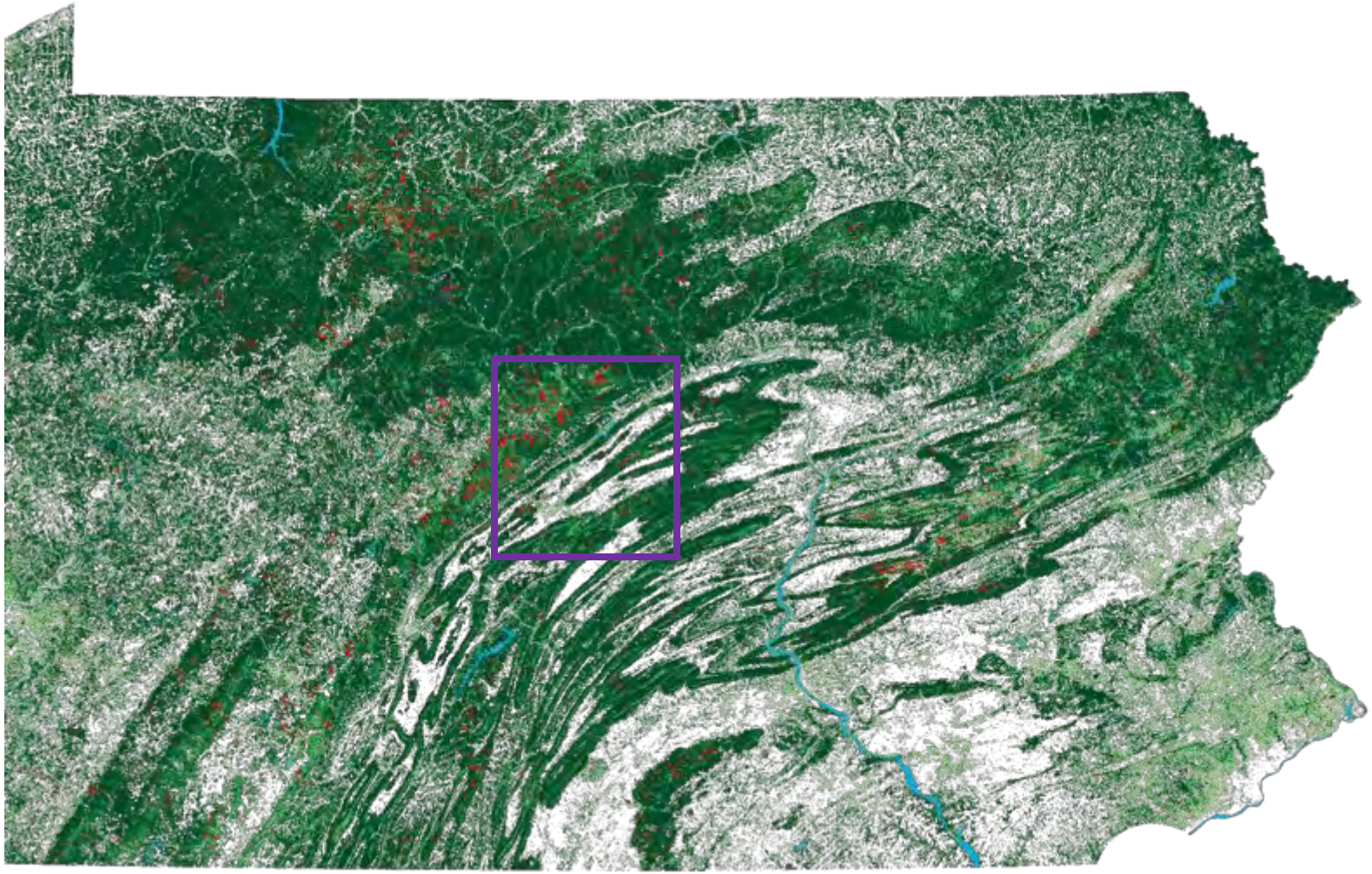
- Motivations and backgrounds
- Decision-making challenges
- Methods
- Current progress
  - Seeding & planting projects
  - Assisted migrations
  - Mitigate climate extremes
- Summary

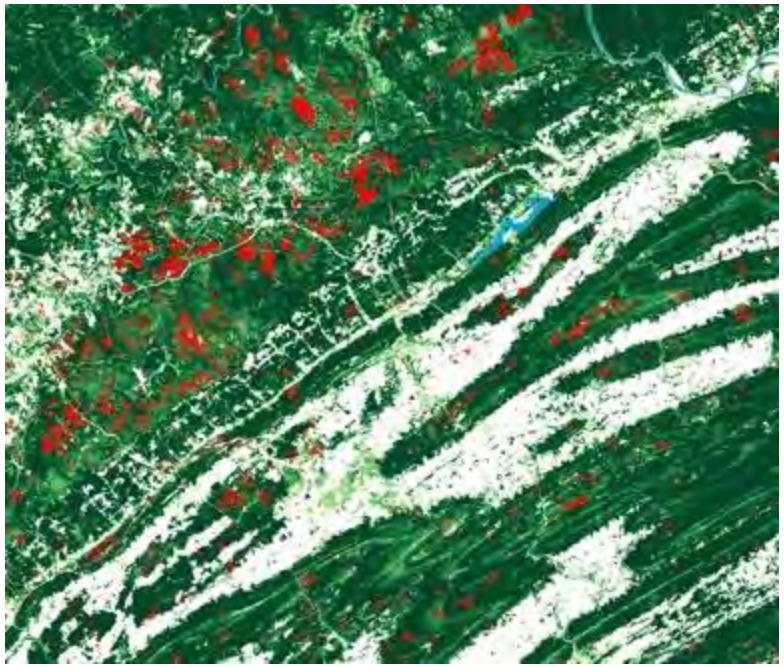
Motivations: Global forest dieback under climate change



Craig D. Allen, *FAO report*, 2009

Motivations: Regional forest loss in Pennsylvania in 2024





Invasive species & Frost

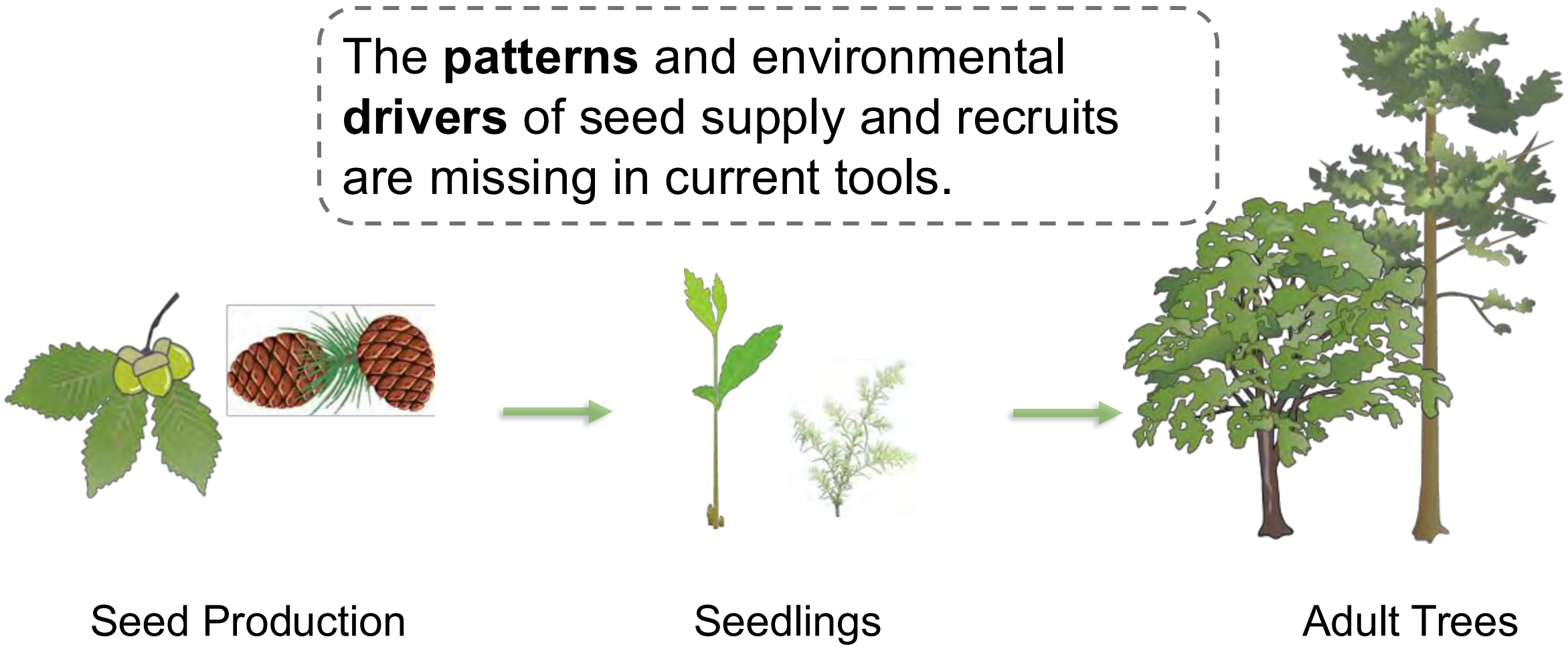
Data from: Hansen et al., and
PA DCNR Division of Forest health

Motivations: PA DCNR Bureau of Forestry

Seeding/planting:
Meredith Seltzer
Conservation genetics:
Amanda Penn
Deer-forest specialist:
Jim Julian
Emily Domoto
Foresters:
Brandon Brantner
Chris Firestone
Benjamin Gamble
Managers:
Shawn Lehman
Christian Nicholas

Decision-making challenges: how to quantify regeneration?

The **patterns** and environmental **drivers** of seed supply and recruits are missing in current tools.

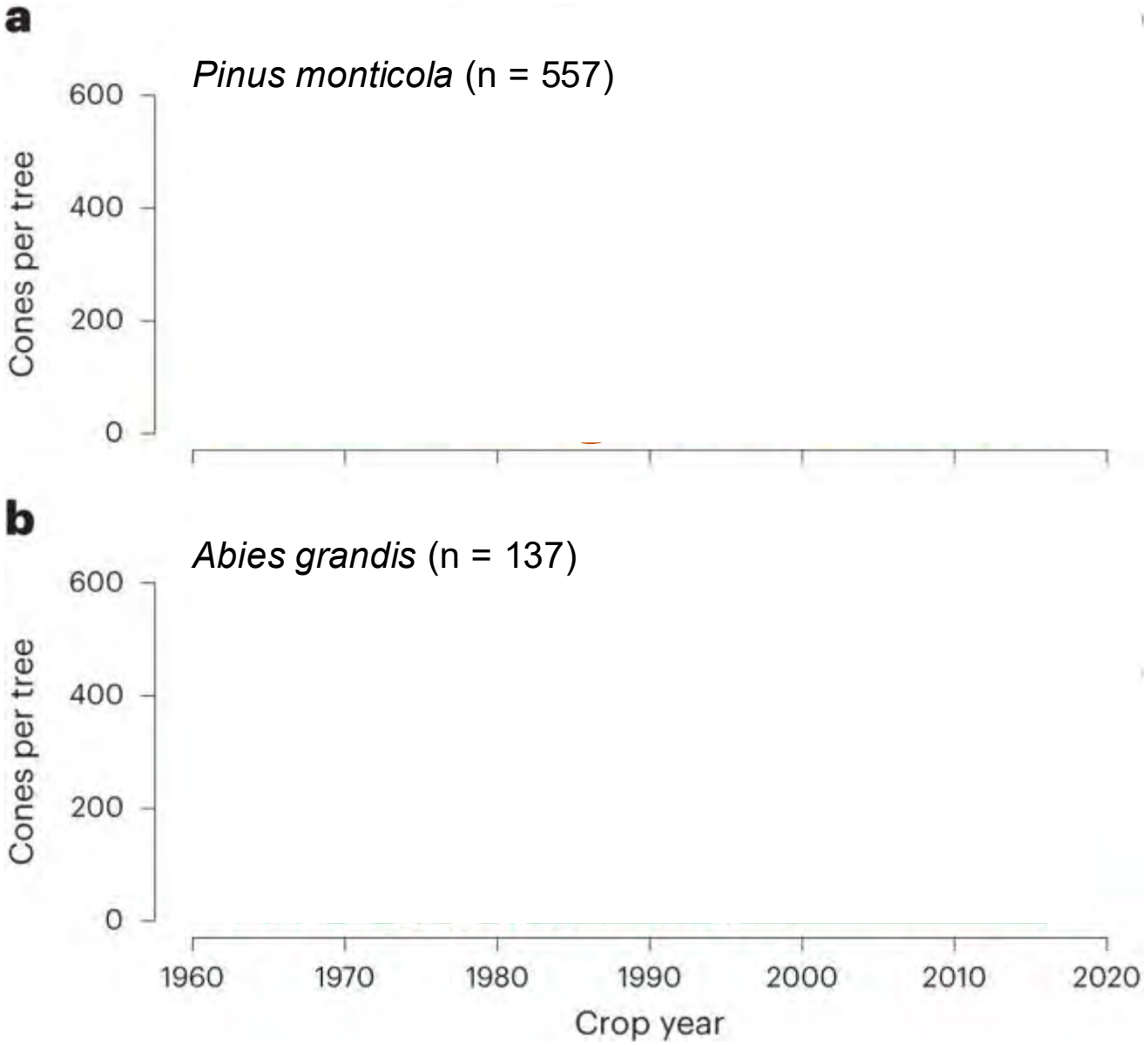


Seed Production

Seedlings

Adult Trees

Decision-making challenges: fecundity data

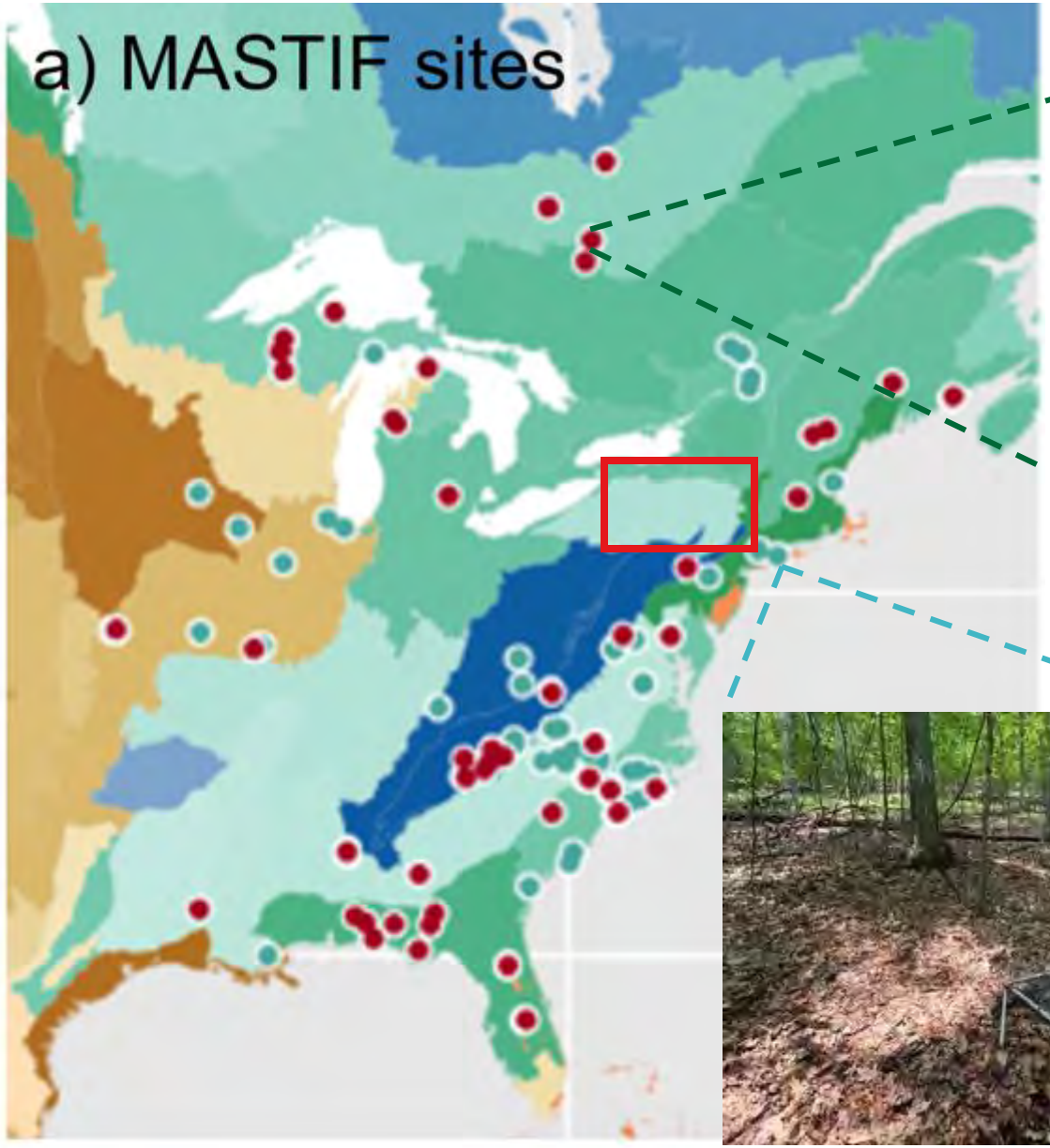


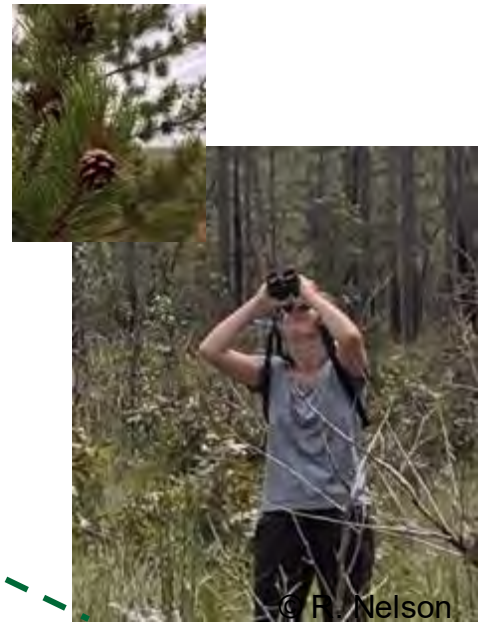
Order-of-magnitude variations

- between individuals
- between years
- between species

Qiu et al., *Nature Plants,* 2023

Decision-making challenges: sampling gaps





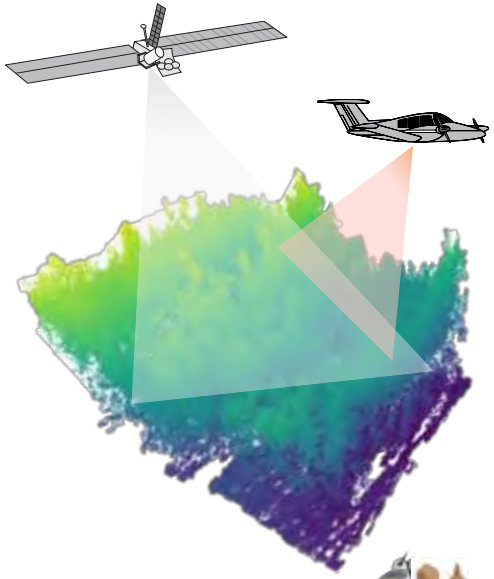
Crop count

Seed traps

Masting inference and forecast (MASTIF)
1M+ trees,
5M+ tree years
100+ species

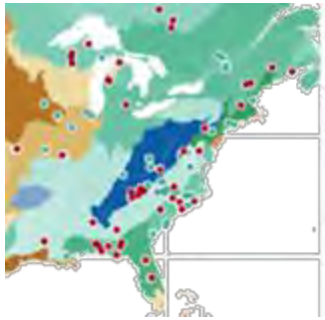
Clark et al., *Ecol. Monogr.* 2019
Clark et al., *Nature Comm.,* 2020
Qiu et al., *PNAS,* 2021
Qiu et al., *Nature Comm., 2022*
Qiu et al., *Nature Plants*., 2023

Project overview and objectives: 2024 to 2028

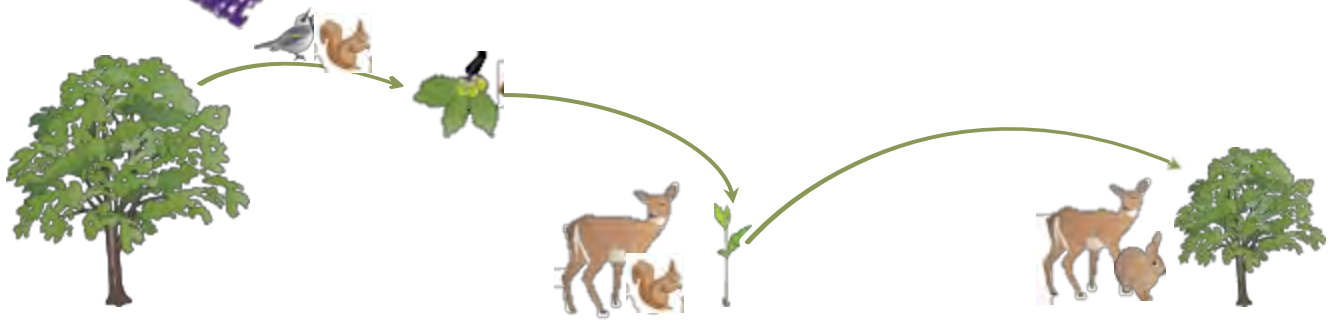


GEDI ECOSYSTEM LIDAR

ECOSTRESS
ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
NASA | JPL



Sampling on seeds/seedlings

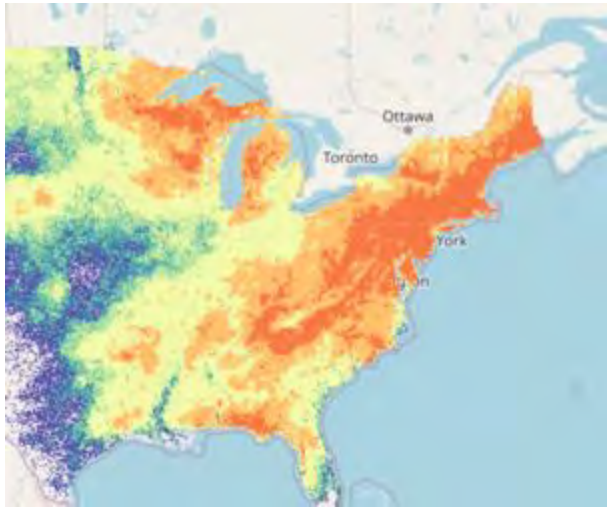


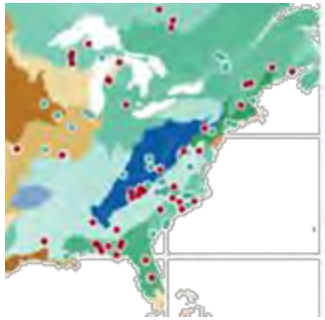
Seed production | Seedling recruits | Survival, growth

- **Translate satellite and airborne remotely sensed products into fecundity, recruitment, and vertebrate abundance at biogeographic scales**.
- **Develop predictive models of recruitment changes as a function of seed supply and environment-vertebrate interactions.**

Project overview and objectives: 2024 to 2028

- **Evaluate how different management practices and climate change scenarios affect the migration capacity for each species across the eastern U.S.**

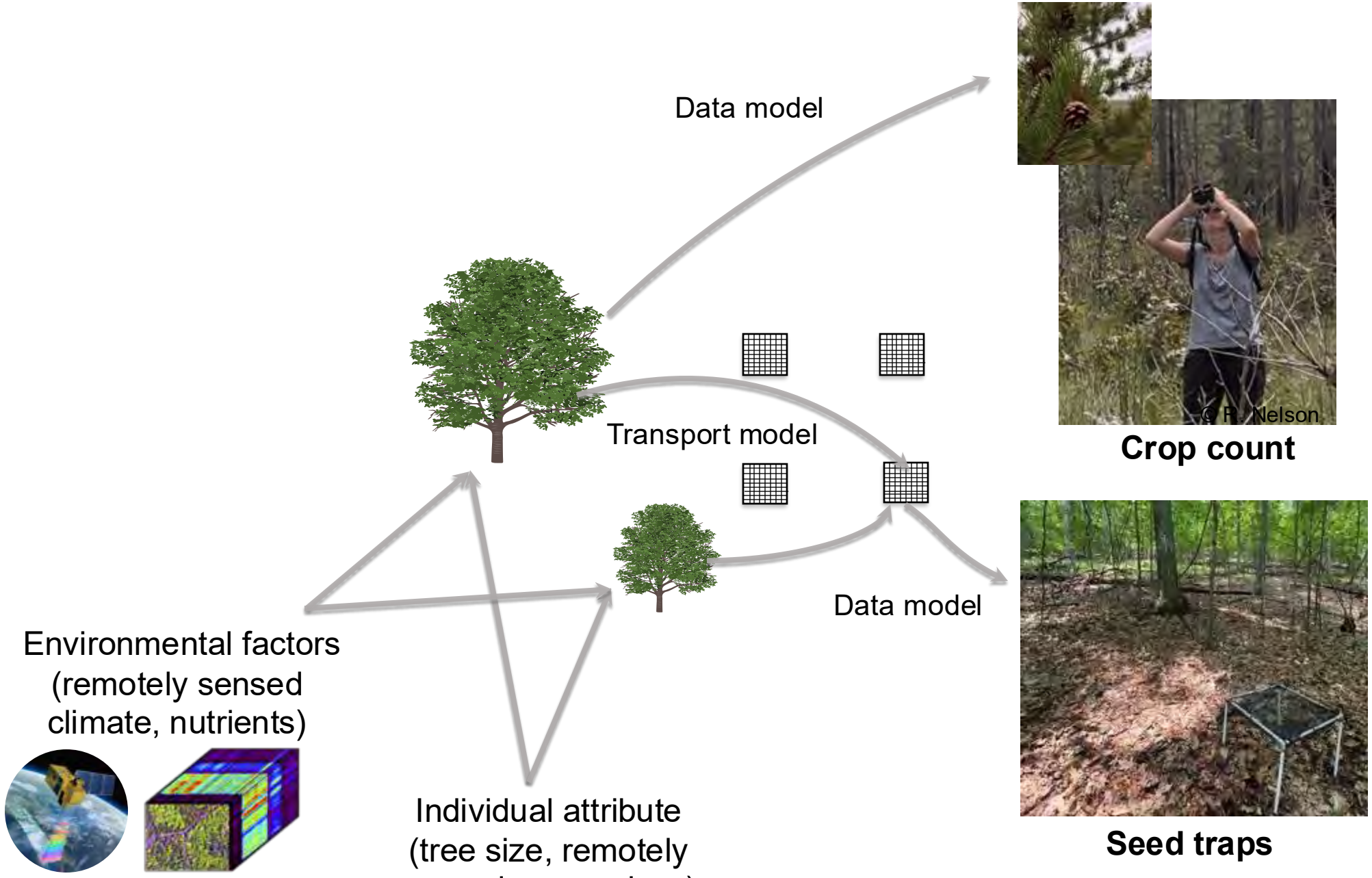




Sampling on seeds/seedlings

- **Develop an interactive R Shiny web-based tool that will guide sustainable forest practices and protected area management.**
  - Seeding/Planting
  - Assisted migration
  - Mitigate climate extreme
  - Landscape-level management
  - etc.

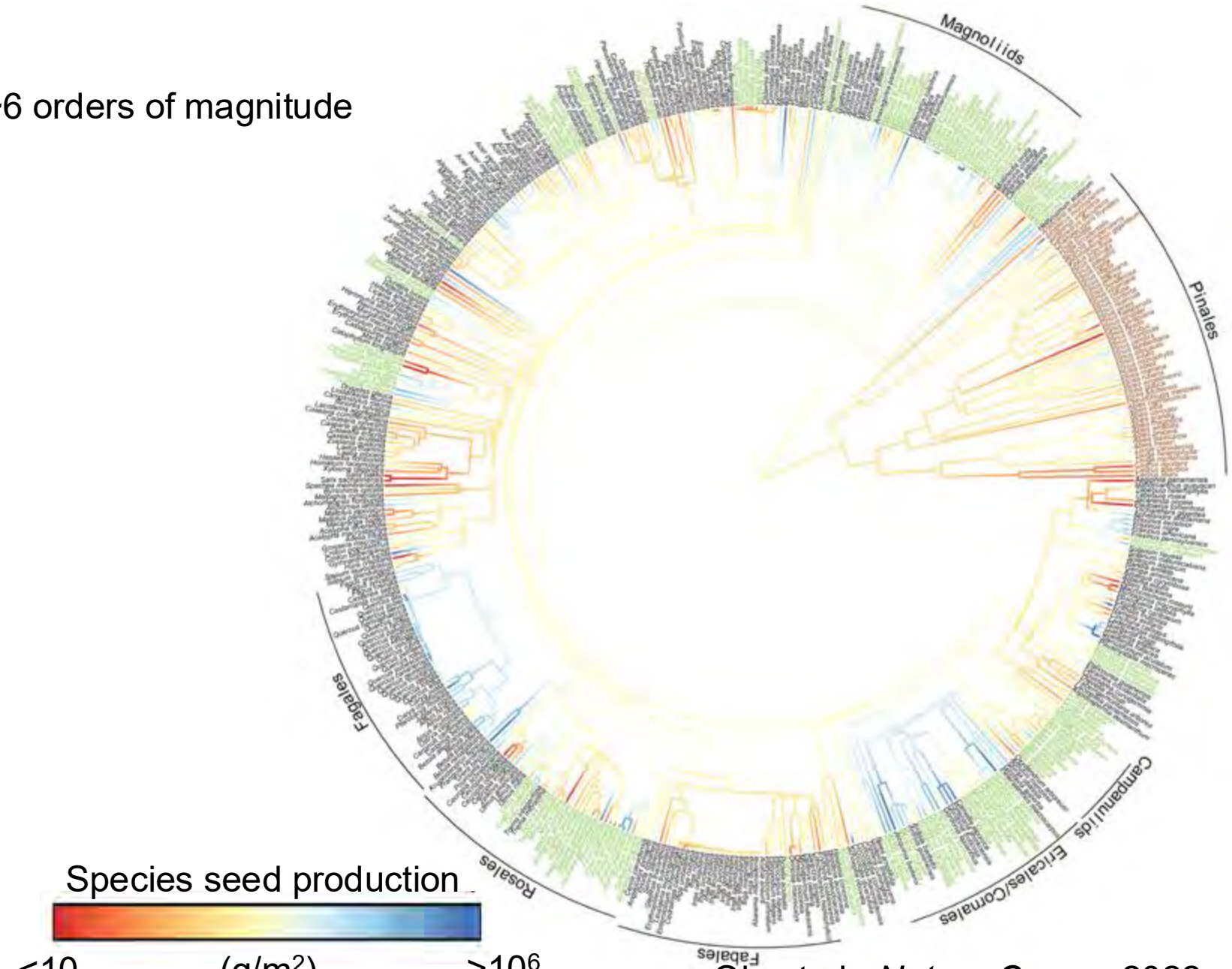
Methods: Synthesis of ecological big data and remote sensing



Simplified from Clark et al., *Ecol. Monogr.* 2019

Seeding project: variations across species

- Species seed production varies ~6 orders of magnitude



Qiu et al., *Nature Comm.* 2022

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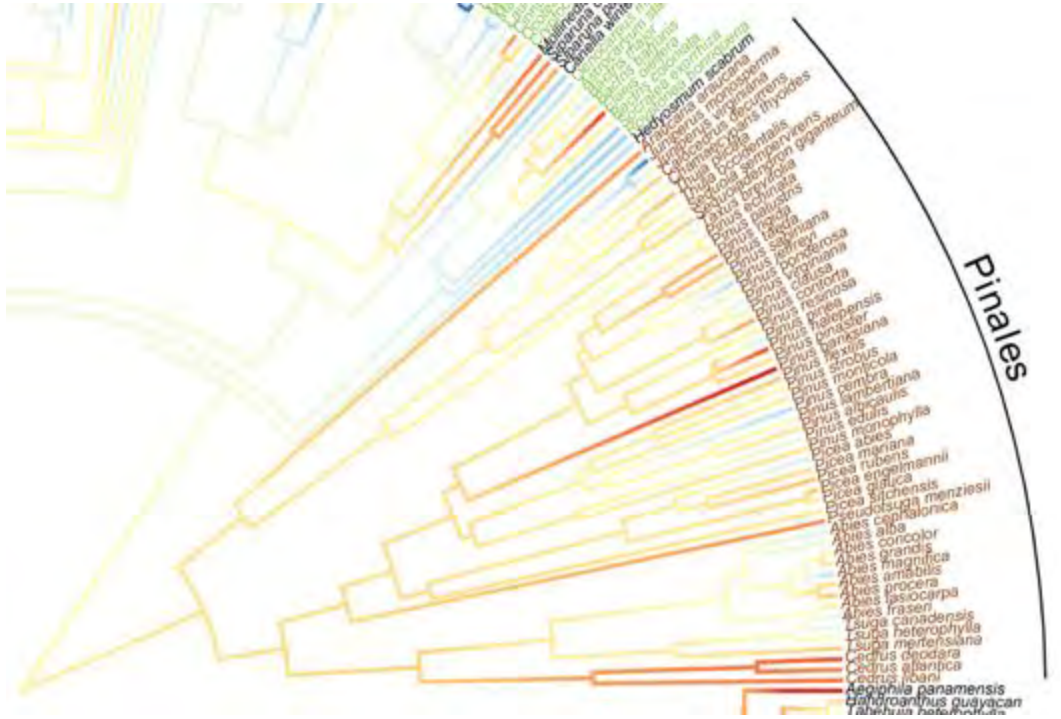

Species seed production

<10 (g/m^2) >10^6

Qiu et al., *Nature Comm.* 2022

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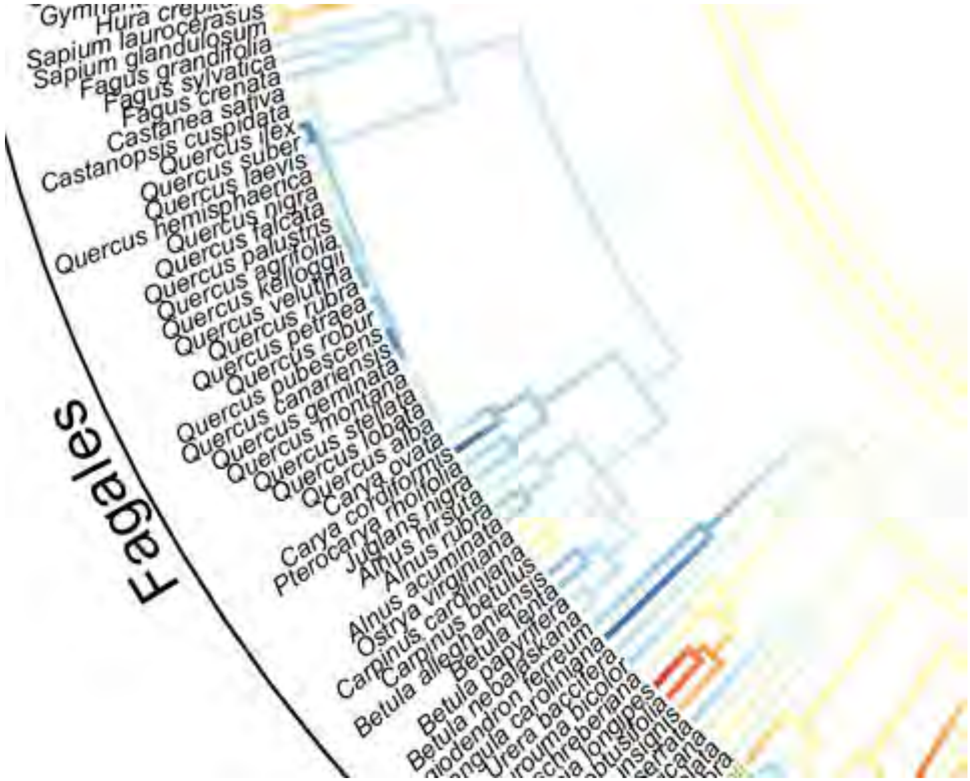

Species seed production

Qiu et al., *Nature Comm.* 2022

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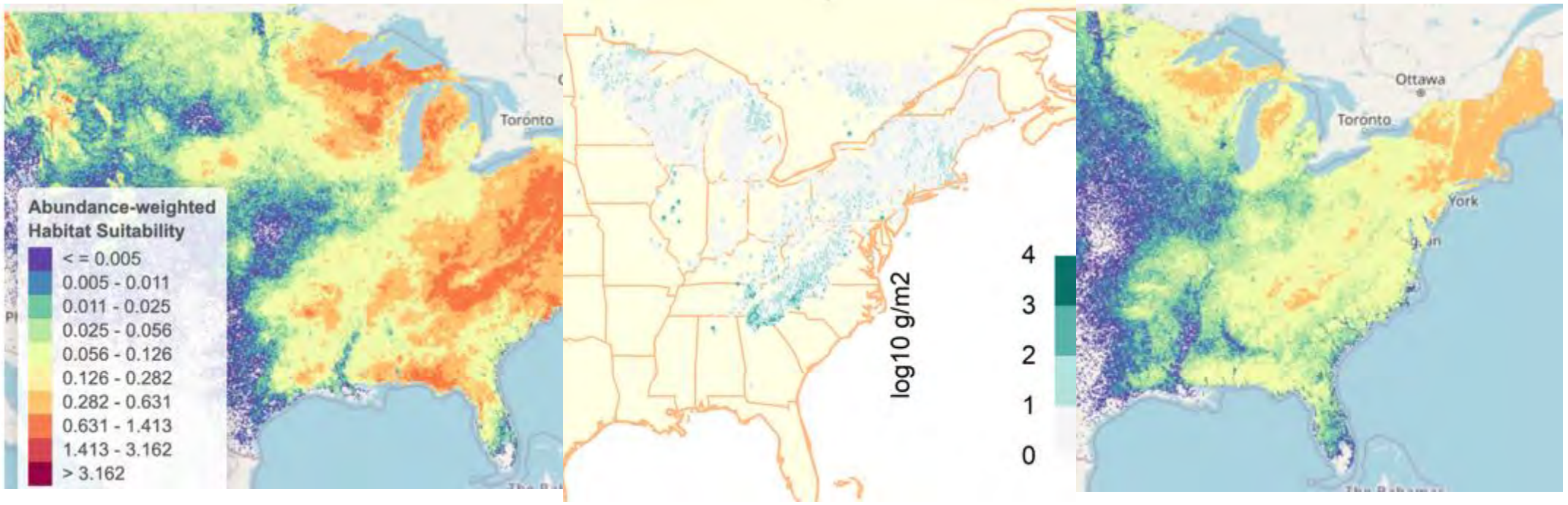
Prioritize active seeding or planting for conifer-dominated stands

Qiu et al., *Nature Comm.* 2022

Assisted migration: fill the data gaps of fecundity data

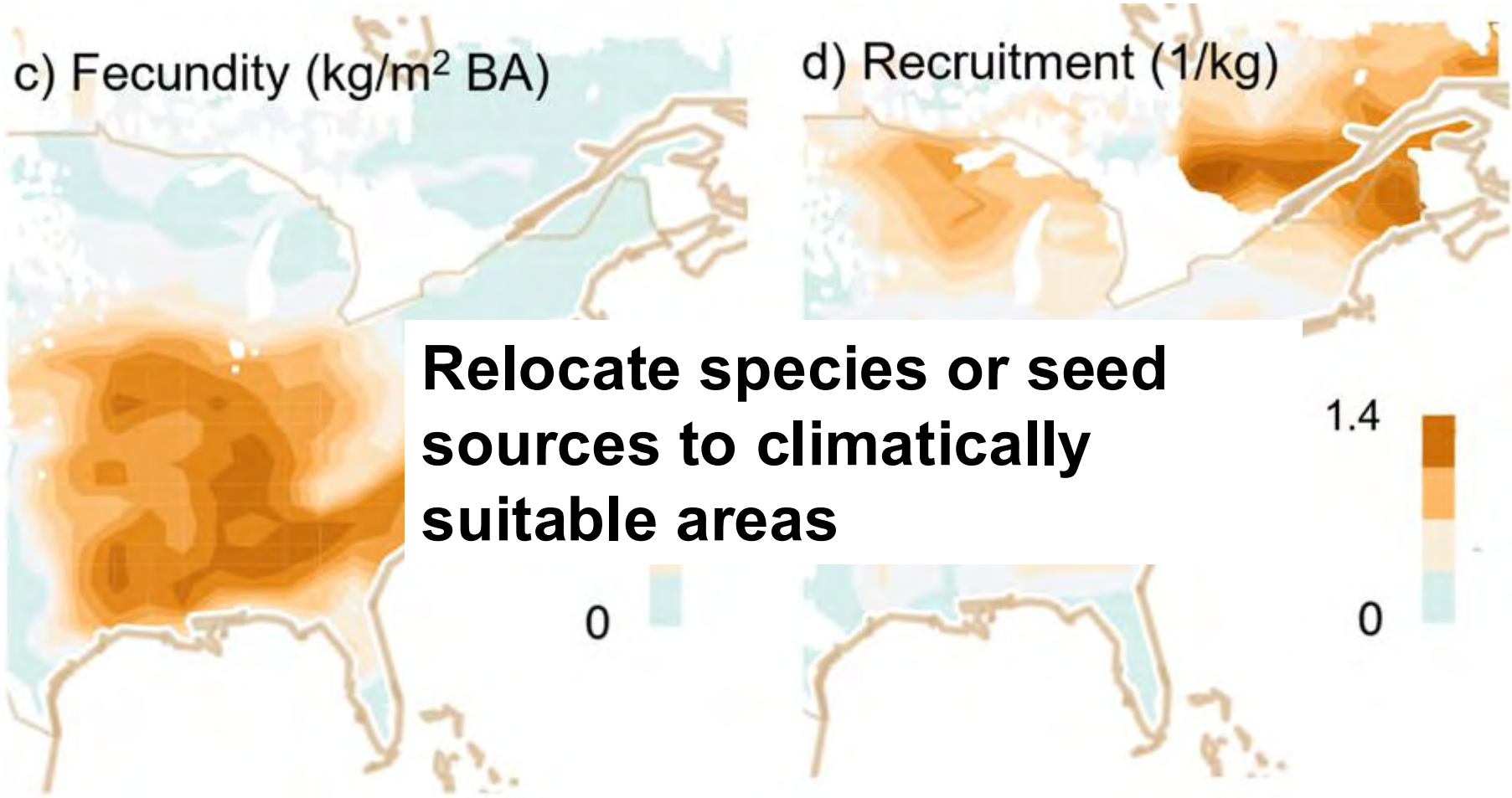


Pinus strobus (current)

Pinus strobus (future)

Qiu et al., *in prep*

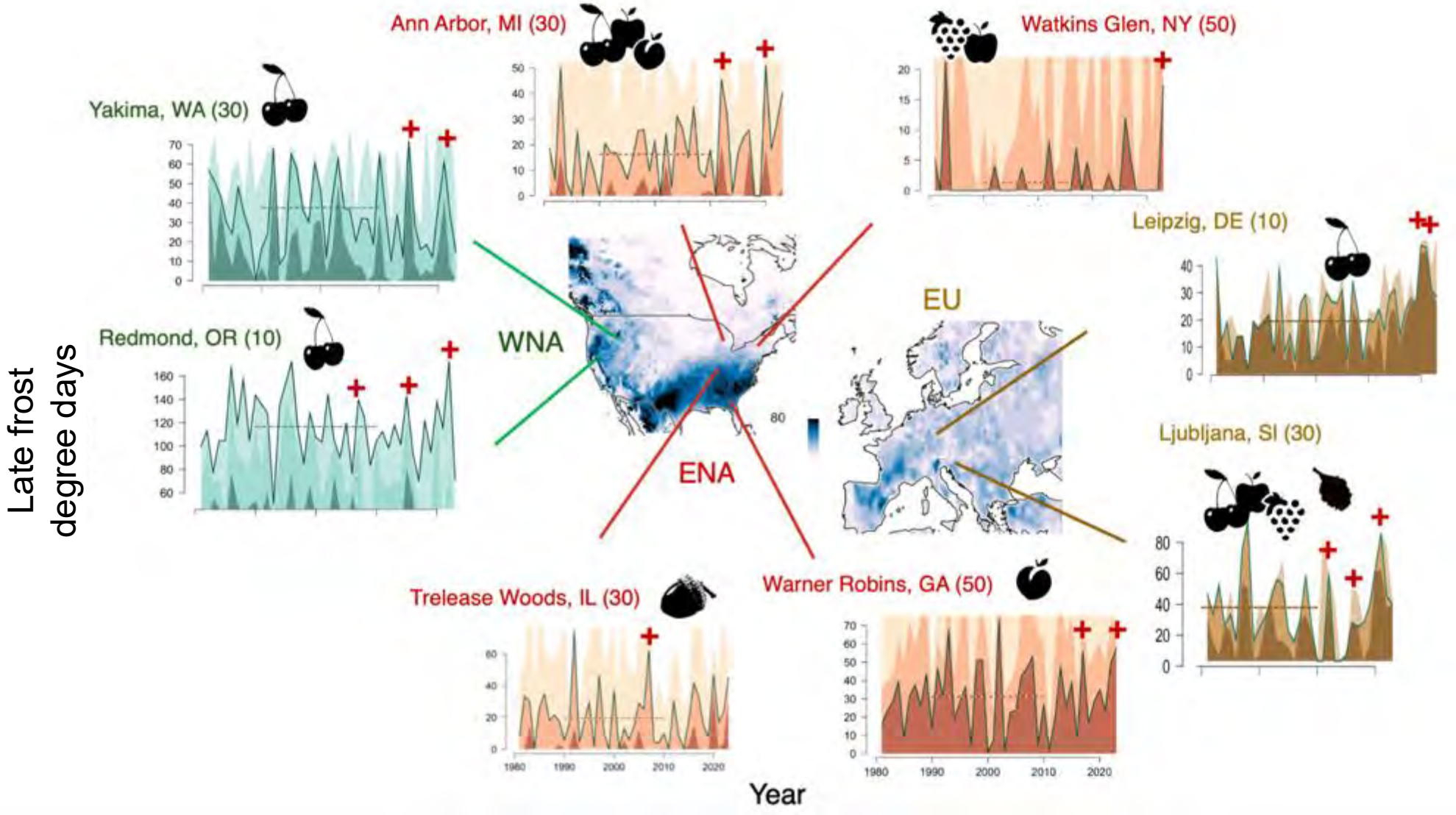
Assisted migration: fill the data gaps of fecundity data



Relocate species or seed sources to climatically suitable areas

Qiu et al., *in prep*

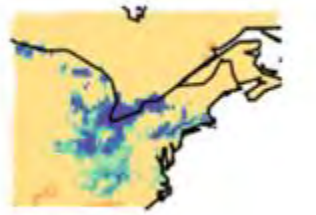
Mitigate and predict extremes: frost and drought events



Clark et al., *in revision*

Mitigate and predict extremes: frost and drought events

Late frost degree days

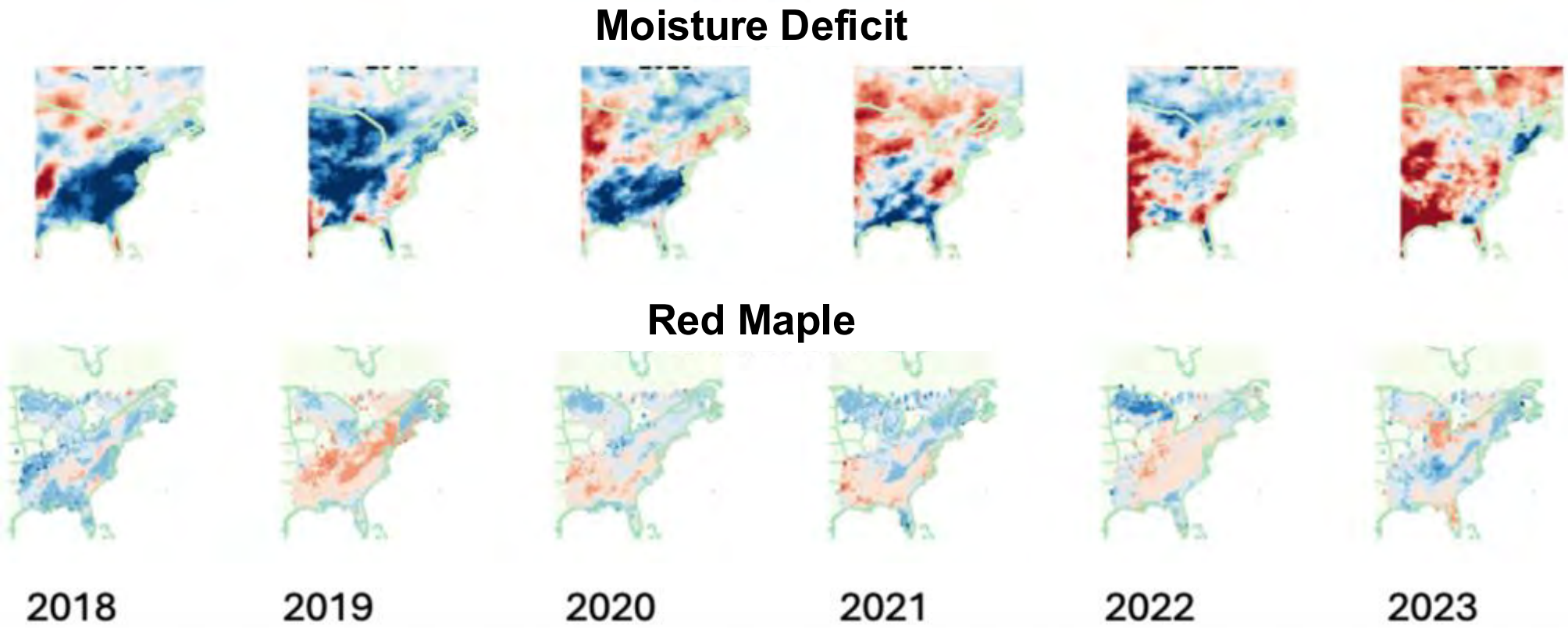


2012 2016 2017 2020 2023

Anticipate and prioritize which areas are at greatest risk of reproductive failure

Clark et al., *in revision*

Mitigate and predict extremes: frost and drought events



Clark et al., *in revision*

Summary of adaptive management

- Seeding and planting project: which species are most productive? Winner or loser species?
- Failure to migrate? incorporate the fecundity data to inform assisted migration
- Understanding the extremes: tracking fecundity over years