USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE


Christian Marks


Josh Wigal


Steve Matthews

Tree breeding to support forest resilience:

What, why and how

Mary Mason, Leila Wilson, Jennifer Koch, David Carey, Therese Poland, Kathleen Knight, Gus Goodwin

And many partners and collaborators

Genetic Variation is the Key To Resistance (and many other things too)

- ✓ Natural stands have LOTS of genetic variation!
- ✓ Basis for tree improvement since the early 1950's
- ✓ Many natural processes create and maintain variation in wild species, including our favorite trees
- ✓ Many trees have high diversity due to reproductive biology

Tree Improvement in the Great Lakes and Northeast US

Historically

- most hardwoods are naturally regenerated
- Natural succession in old fields gave good quality stands
- Invasive insects were more rare and less explosive
- Invasive plants dominated sites less fully

Today: Planting more trees, and different species, and for different reasons

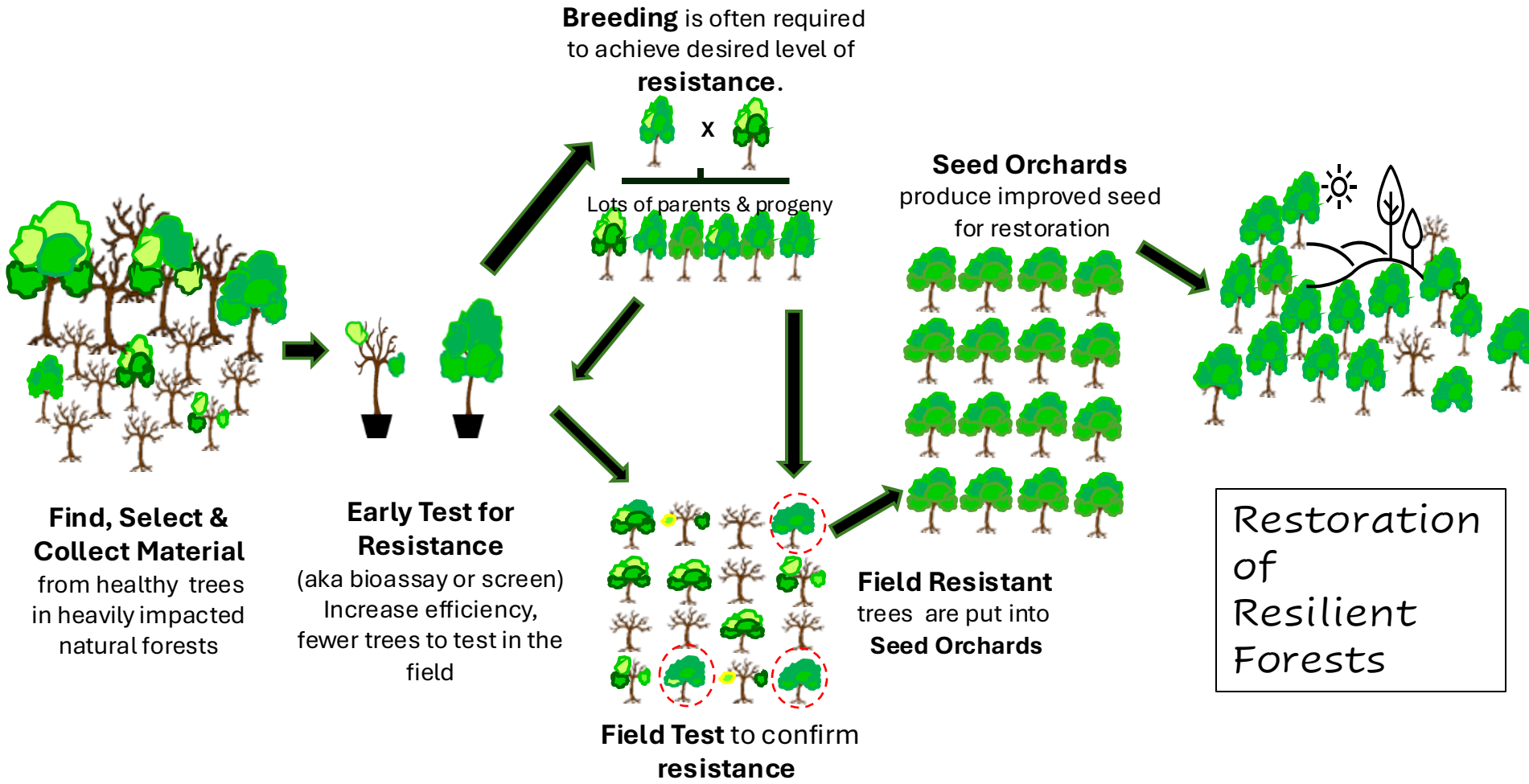
- Climate Change adaptation strategies driving planting
- Mesophication, 'oak problem'
- Breeding for resistance
  - New pests
  - Moving pests
- increased need & opportunity

Breeding Programs…

- Produce seed
  - For nurseries to grow seedlings
  - That people want to plant

1. Select Good Trees
2. Show they are Good Parents
3. Produce Good Seed

Basic Steps in Resistance Breeding



Breeding Research …
science foundation for breeding programs

- Show genetic control of trait is adequate for breeding
    - Validate good parents!
- Show seed produced has adequate genetic diversity, seed orchard crosses well and produces, etc. Tell us where the seed should be planted.
    - Validate good seed!
- Incorporates pest life cycle, genomics, metabolomics, mechanism of resistance, silviculture and ecology, restoration technologies, nursery practice, quantitative genetics, screening technologies

Insect and Disease Resistance example: Range of Phenotypes in Ash

Susceptible (Common) — **Partial Resistance** (Rare) — **Resistant** (Extremely Rare)

dead

Healing bole

Healthy bole

What does Resistance Really Look Like?

Resistance is:

- NOT immunity
- Relative to susceptible trees
- (Schneider & Ayres Nature Reviews, 2008, 889-895)

Resistant trees may eventually die but live longer than susceptible trees!

AND

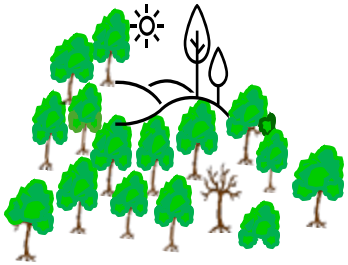
even subtle levels of partial resistance can be improved through breeding!!!!

*Rare because prior to new pest there is no selective advantage

Sources of Seed in Breeding Program

Seed Collection Area

- Especially good stand
- Includes clusters surviving pests
- Not validated, wild crossing
- “some seed”

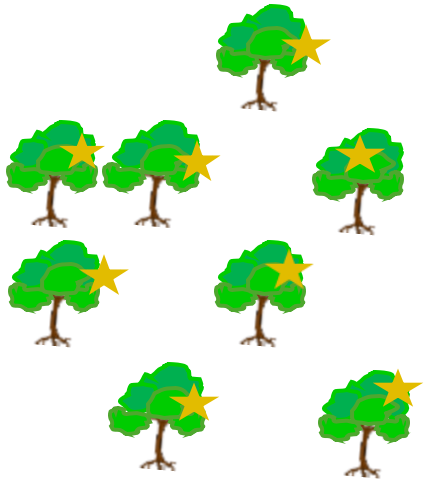


Seed Orchards

- Selected ‘Plus’ trees to one site
- Control male and female
- Managed for seed production
- Parents not validated for breeding value
- May include unconfirmed phenotypes
- May be ‘rouged’ to created improved orchard
- “Good seed”

Improved Seed Orchard

- Plus trees…
- validated for breeding value
- ‘rouged’ or poor performing parents removed
- Managed for seed production
- seed produced validated for traits and diversity!
- “best seed”



The Why

Josh Wigal

Why breed trees for pest/pathogen resistance?

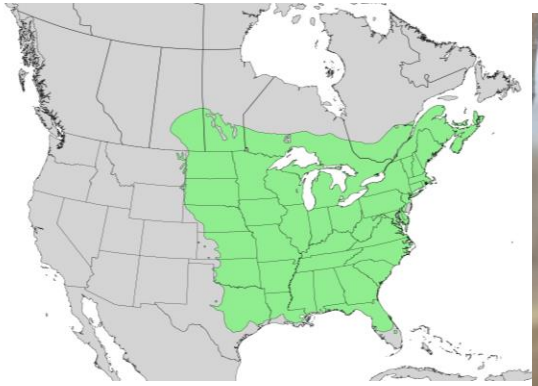
Species restoration

Ecosystem restoration

Ecosystem resilience

Species importance: American elm

- Diverse lepidoptera (215 species) including specialists
- Diverse insects (>500 species)
- Early seeds support migratory birds

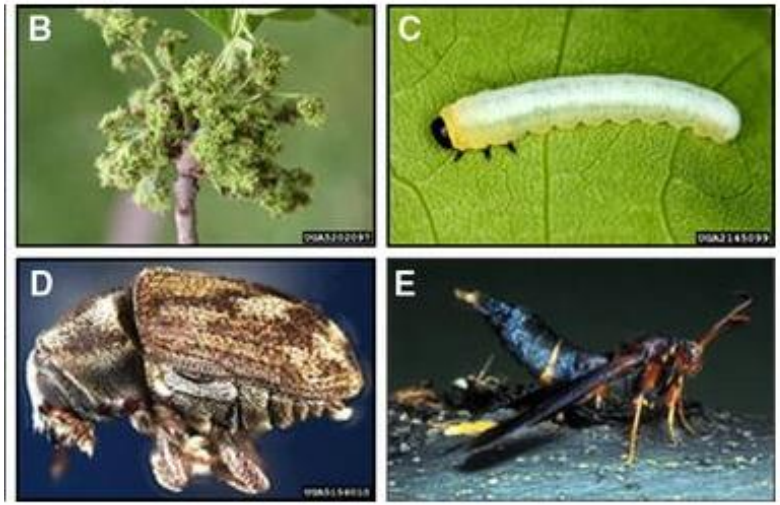


U.S. Geological Survey. 1999. Digital representation of E.L. Little 1971 "Atlas of United States Trees"

Question mark, *Polygonia interrogationis*

Elm sphinx moth, *Ceratomia amyntor*

Species importance: ash spp.



Gandhi, K. J., & Herms, D. A. (2010). *Biological Invasions*, *12*, 1839-1846.

- 43 native arthropod species are specialists on ash
- Many species consume ash seeds, including birds and small mammals

- Ecologically important riparian & wetland forest species (*green, black, pumpkin*)
- Regulation of wetland hydrology (*black)*
- Important Agroforestry species-one of very few species that can survive in the Plains states (*green*)

Resistance breeding to support ecosystem restoration

Restoring not just this species, but in doing so, contributing to the restoration of ecosystems that have seen unparalleled deterioration and change.

Planting in formerly grazed wetland

Planting after NNIP removal

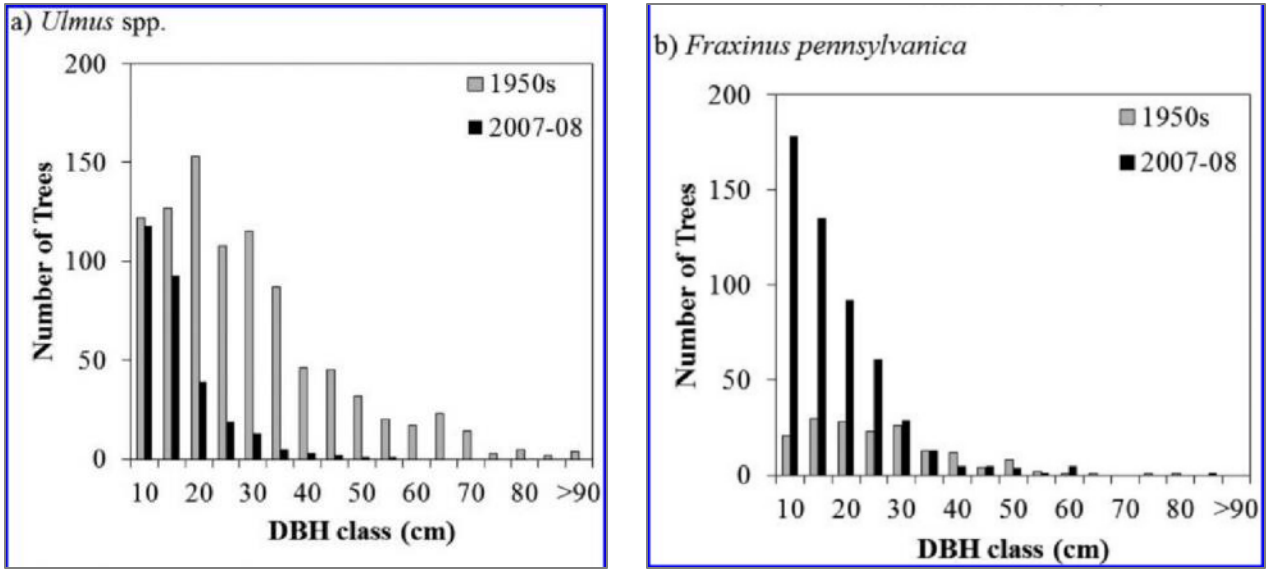
EAB impacted floodplain

Changes to floodplain forests: > 80% substantially modified

Honeysuckle removal paired with mixed-species plantings

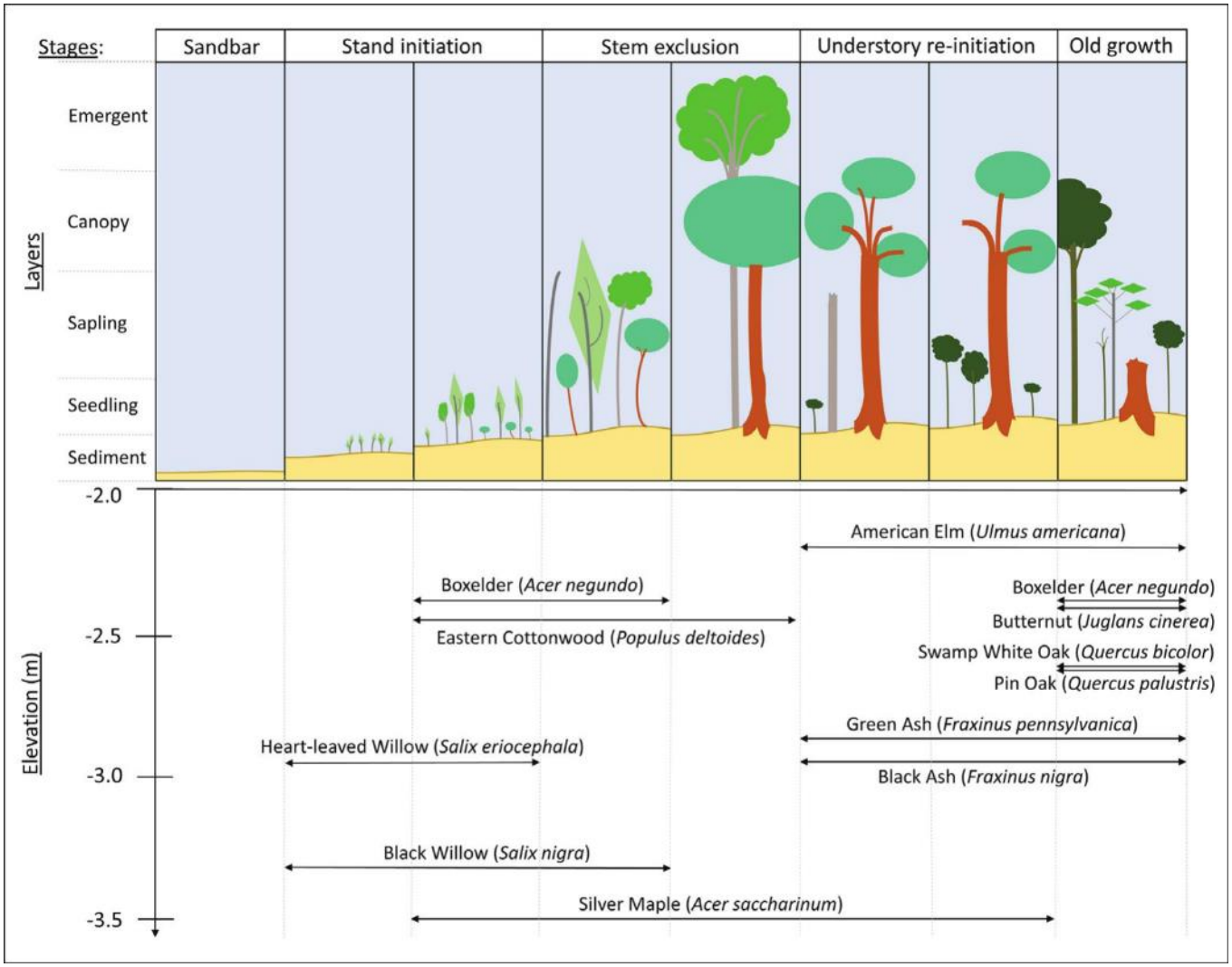
Resistance breeding to support ecosystem resilience

- **Ecosystem resilience**: facilitating the ability of ecosystems to recover from (climate change related) future disturbances
  - Species diversity and genetic diversity to increase ecosystem resilience.



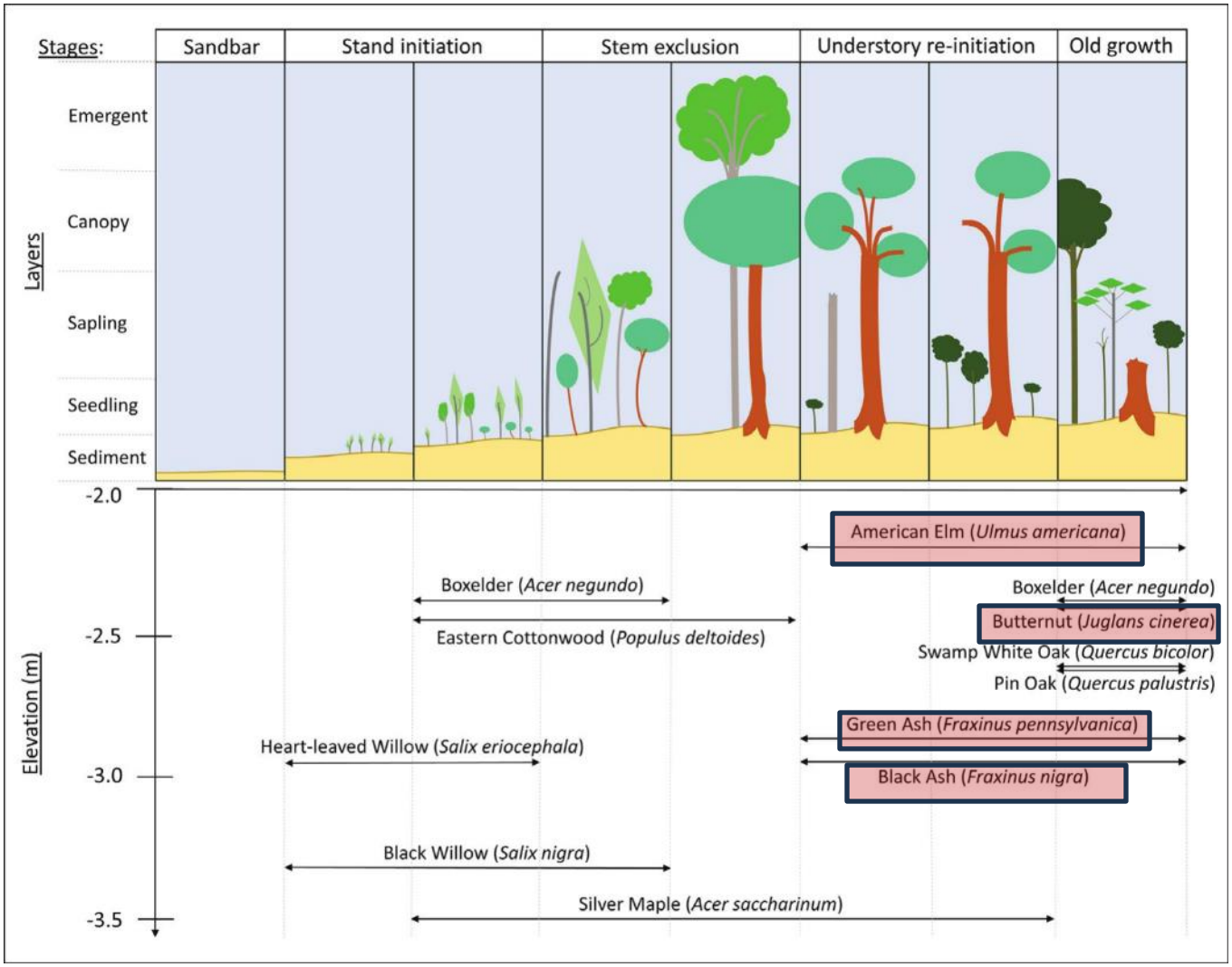
Johnson and Waller, 2012, Canadian Journal of Forest Research 43: 159-170

Resistance breeding to support ecosystem resilience



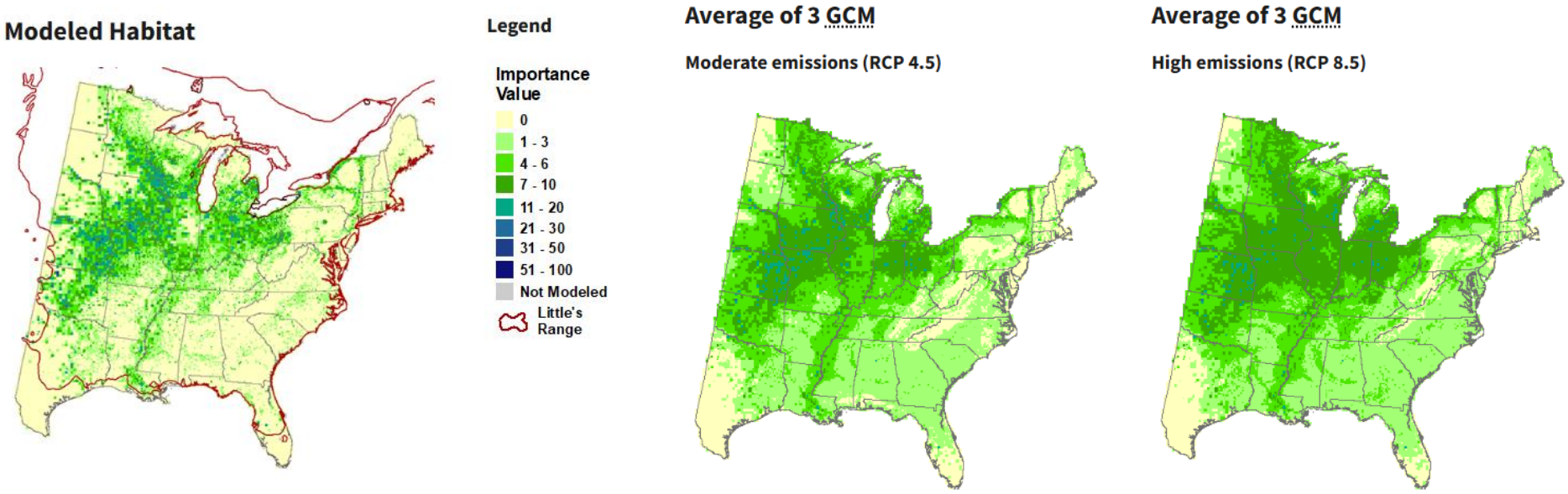
Marks, Yellen and Nislow. 2021. Northeast Naturalist.

Resistance breeding to support ecosystem resilience



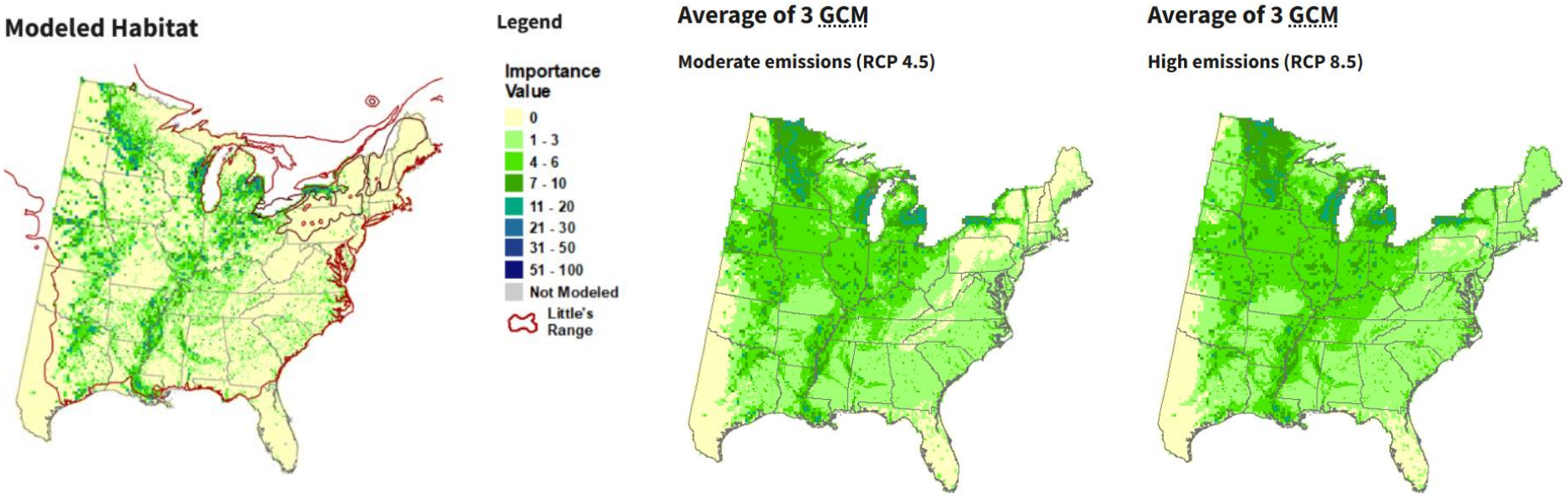
Marks, Yellen and Nislow. 2021. Northeast Naturalist.

Tree Atlas habitat quality change maps for American elm



Peters, M.P., Prasad, A.M., Matthews, S.N., & Iverson, L.R. 2020. Climate change tree atlas, Version 4. U.S. Forest Service, Northern Research Station and Northern Institute of Applied Climate Science, Delaware, OH. https://www.nrs.fs.fed.us/atlas.

Tree Atlas habitat quality change maps for green ash

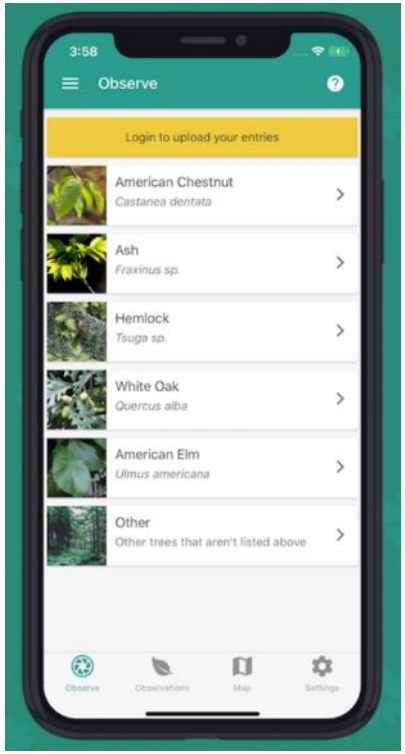


Peters, M.P., Prasad, A.M., Matthews, S.N., & Iverson, L.R. 2020. Climate change tree atlas, Version 4. U.S. Forest Service, Northern Research Station and Northern Institute of Applied Climate Science, Delaware, OH. https://www.nrs.fs.fed.us/atlas.

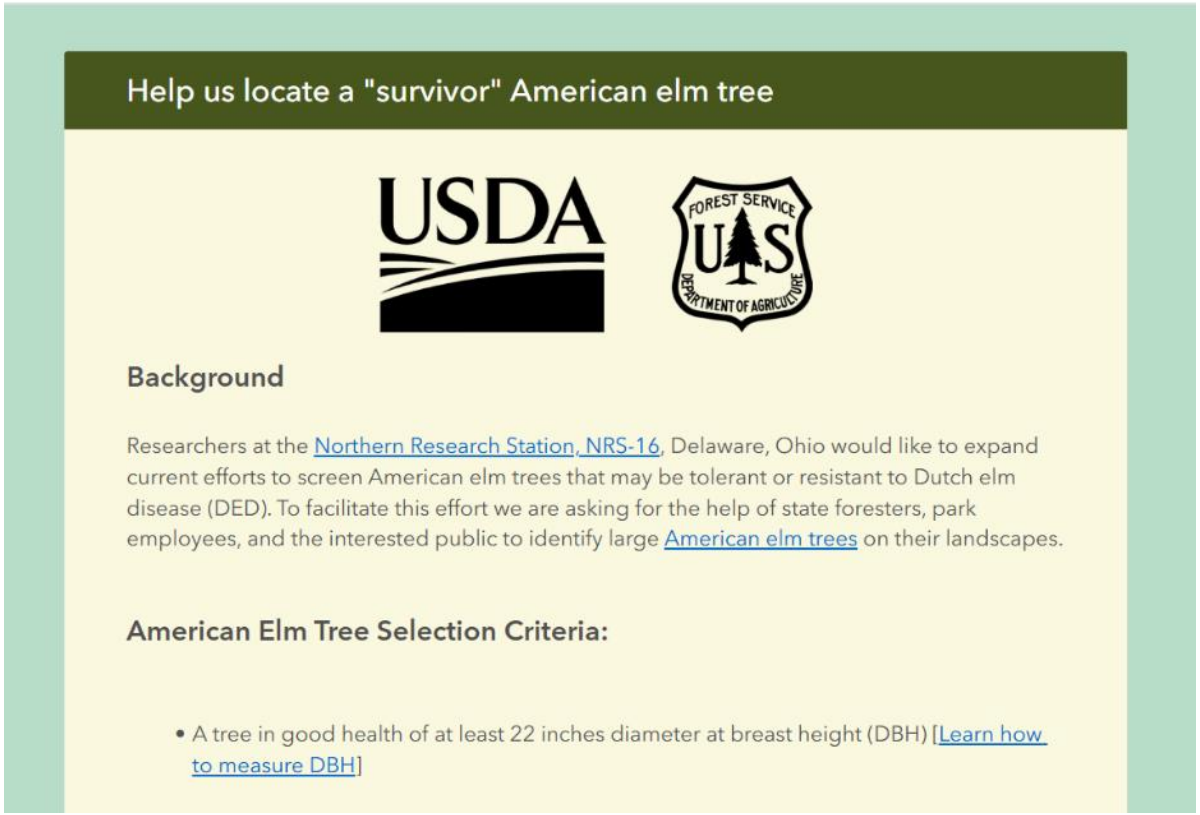
How you can help

How can you help?

- Watch for and preserve good trees!
- Submit them to a database
  - Treesnap https://treesnap.org/
  - Monitoring and Managing Ash (MaMA) http://www.monitoringash.org/
- Great Lakes Basin Forest Health Collaborative
  - https://holdenfg.org/great-lakes-basin-forest-health-collaborative/
  - Coordinator:Rachel Kappler rkappler@holdenfg.org
    - training
    - networking partners to establish breeding programs



How can you help?



https://survey123.arcgis.com/share/77e3ae96618c48afbf9f1f31b8ead0c3

Google “American elm survivor database”

Selection Criteria for “lingering” ash

- >95% mortality of mature ash trees has occurred at least 2 years ago (4 yrs after 50% mortality)
- Tree was large enough to be infested during the peak EAB infestation
  - In monitoring plots > 4” dbh
  - Current recommendation, >10” dbh
- Tree currently has a healthy canopy
  - Initially 1 or 2, currently recommend 1 only

Selection Criteria for survivor American elms

- American elms 24” dbh and greater
- Healthy canopy
- Even better if it is located close to elms showing disease symptoms

Contact

Mary Mason, NRS
Mary.Mason@usda.gov

Leila Wilson, NRS
Cornelia.Wilson@usda.gov