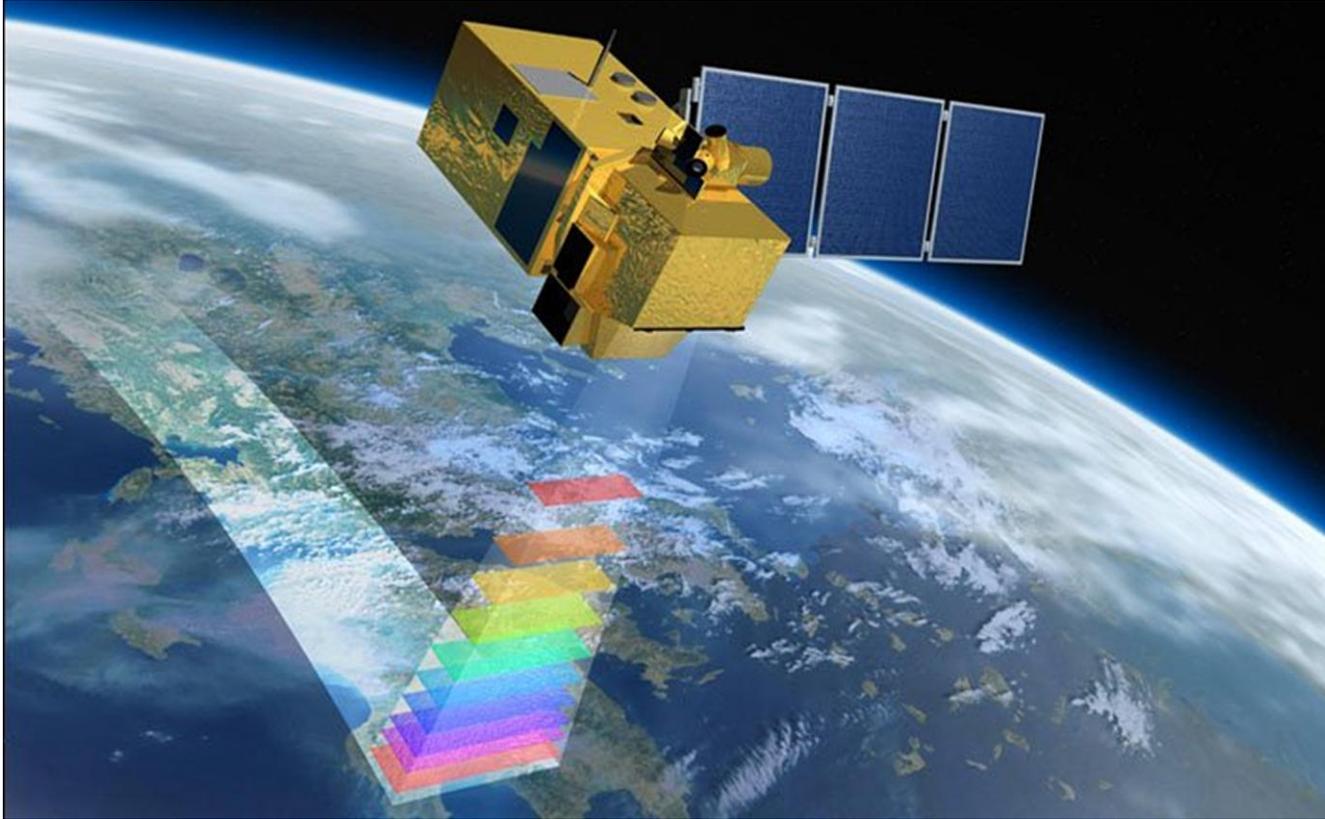


A New Method for Mapping Beech Tree Distribution and Decline



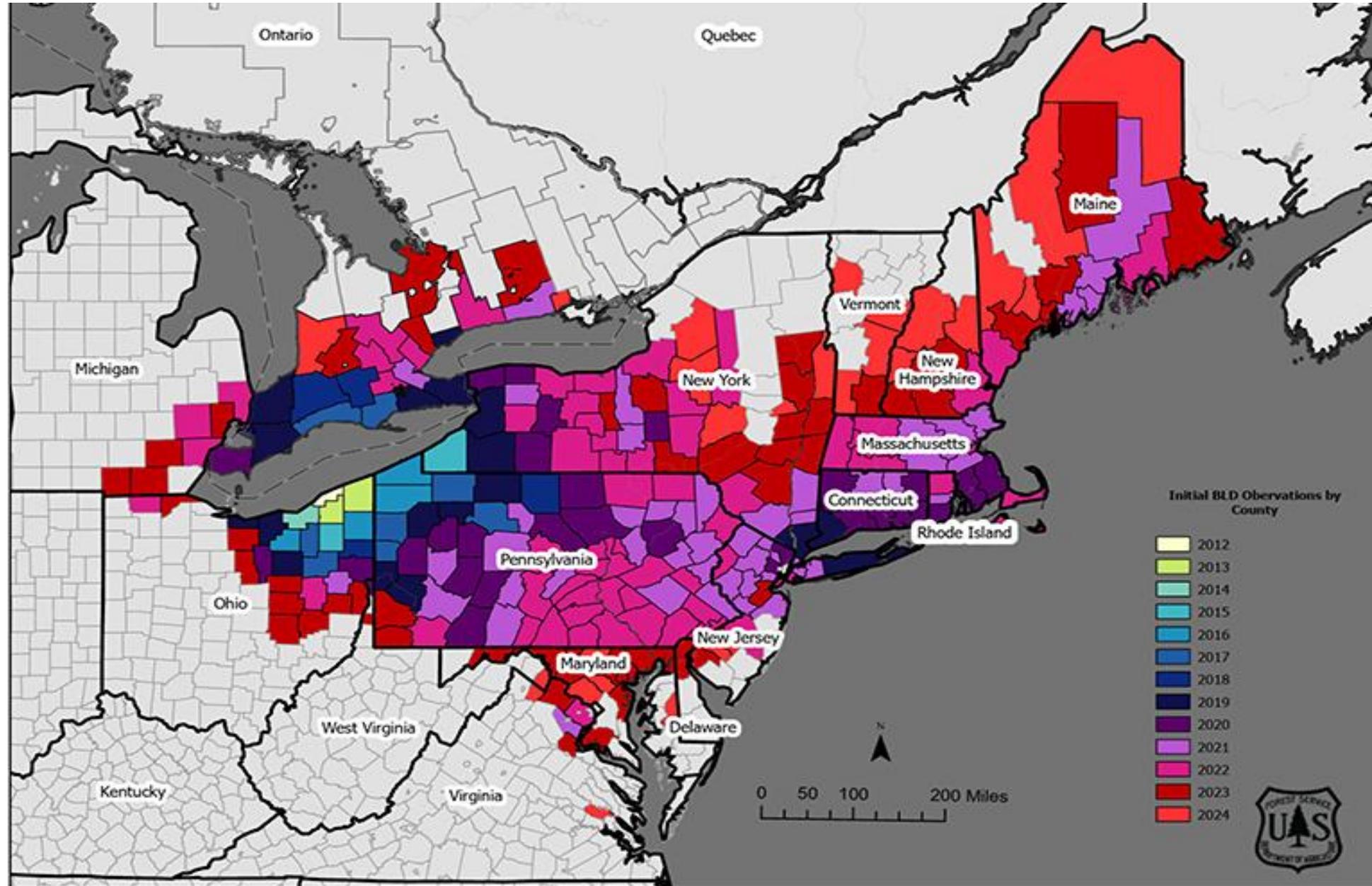
Rosemary McGuinness¹, Justin Bowers¹, and **Andy Reinmann**^{1,2}

¹CUNY Advanced Science Research Center;

²Dept. Of Geography and Environmental Science, Hunter College



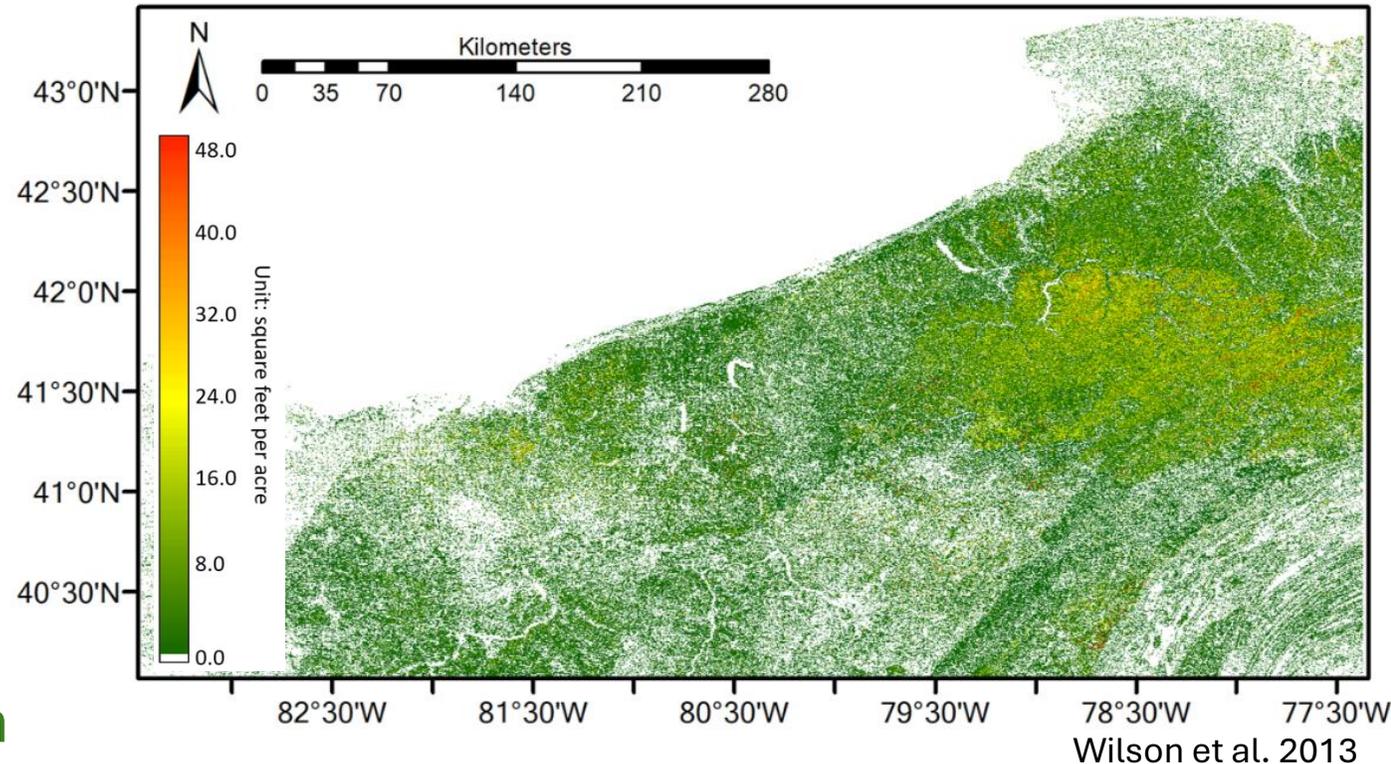
Beech Leaf Disease is Spreading Rapidly



Tracking Decline is Key for Targeting Management

- There are some options for treating individual trees
 - Impractical at stand/silvicultural scales (and concerns about toxicity)
- Management is focused on mitigating adverse ecological impacts
 - Invasive plant control
 - Adaptive silviculture

- **Knowledge of beech spatial distribution is essential for tracking decline and efficient management**
 - Mostly reliant on field surveys
 - Some predictive models (e.g., Zhao et al. 2023)
 - Based on abiotic conditions, not empirical evidence of beech

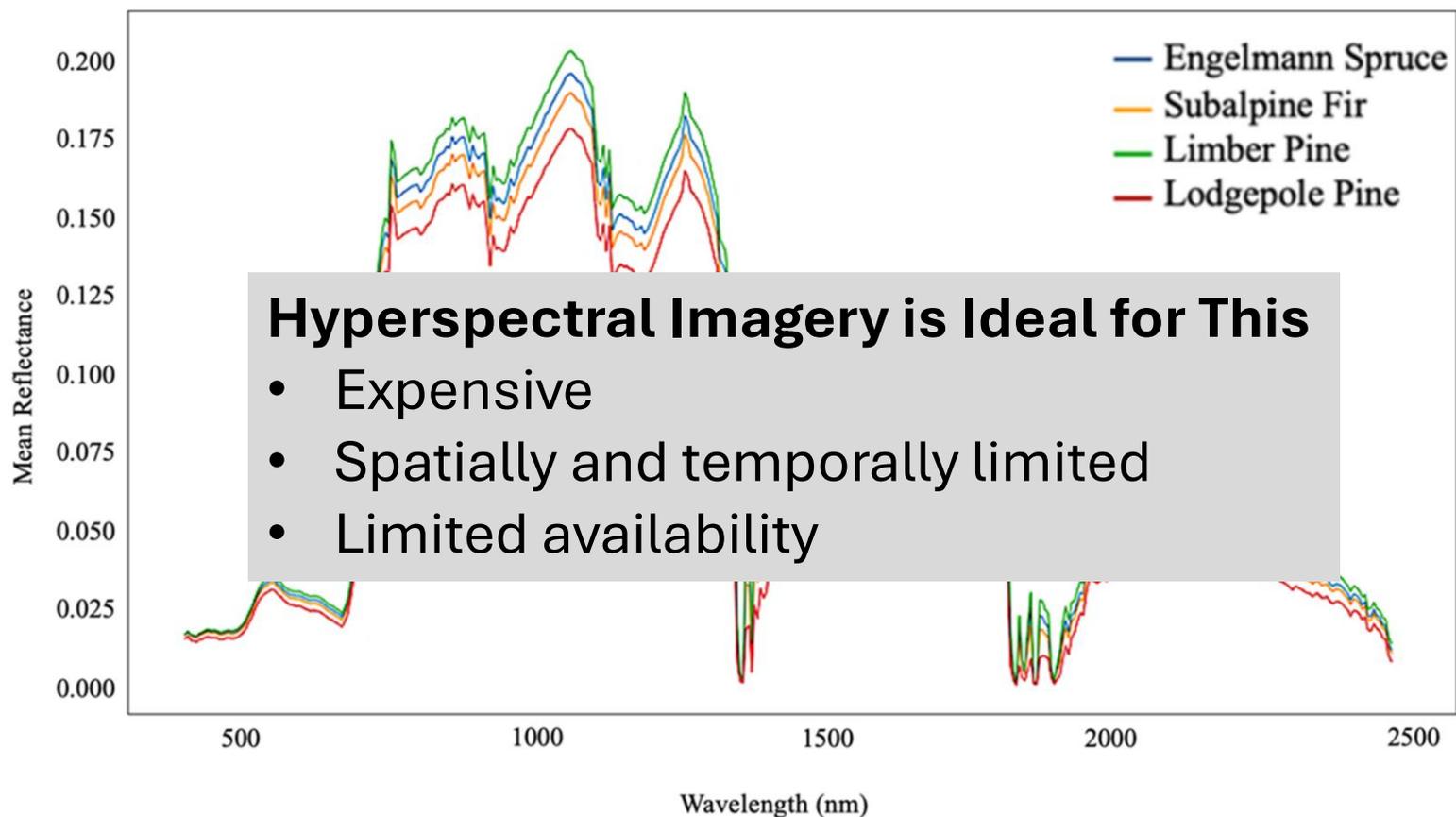


Building Tree Species Distribution Models with Remote Sensing

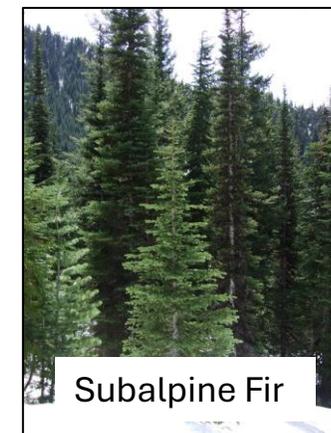


Building Tree Species Distribution Models with Remote Sensing

- The electromagnetic spectrum is divided into hundreds of very narrow ‘bands’
- Captures distinct spectral signatures for different vegetation types



Engelmann Spruce



Subalpine Fir

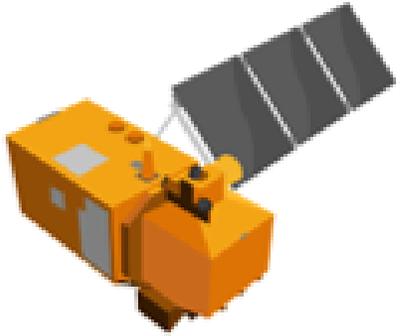


Limber Pine

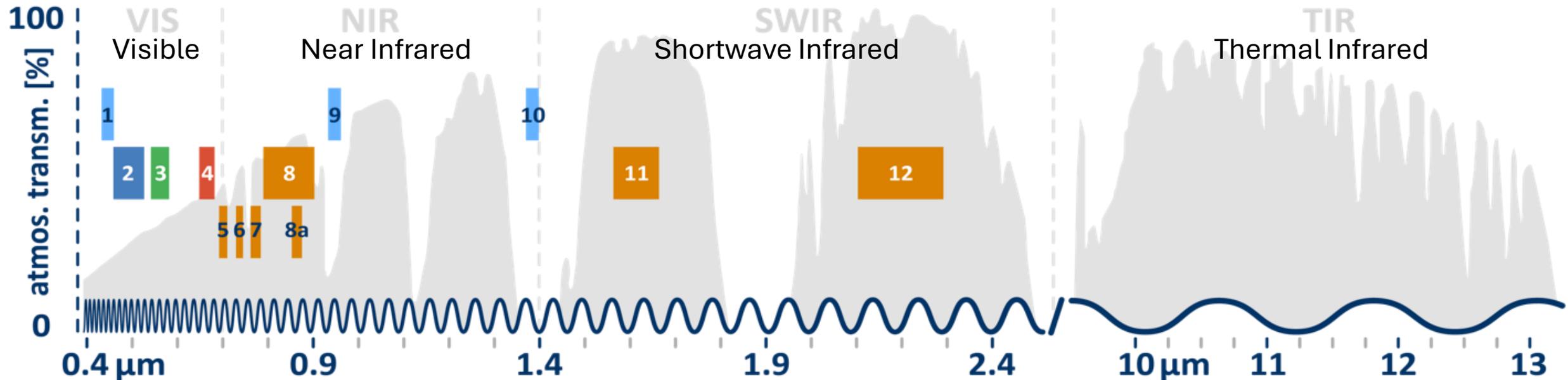


Lodgepole Pine

Building Tree Species Distribution Models with Remote Sensing Multispectral Imagery

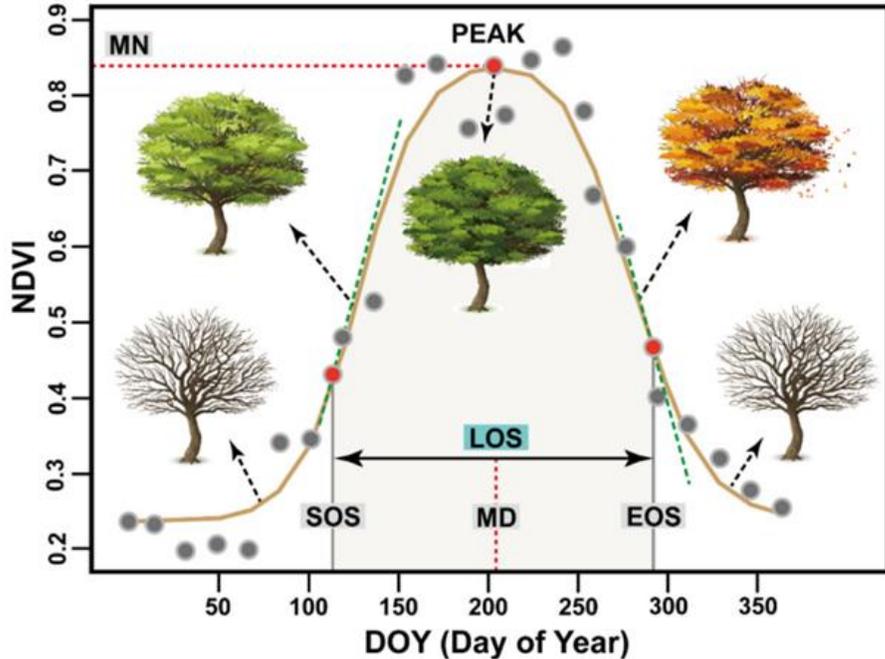


- **Sentinel-2 satellite** constellation captures 12 bands at 10m resolution
- Collecting imagery at regular intervals throughout the year since 2015
- Multi-temporal imagery allows us to capture differences in phenology



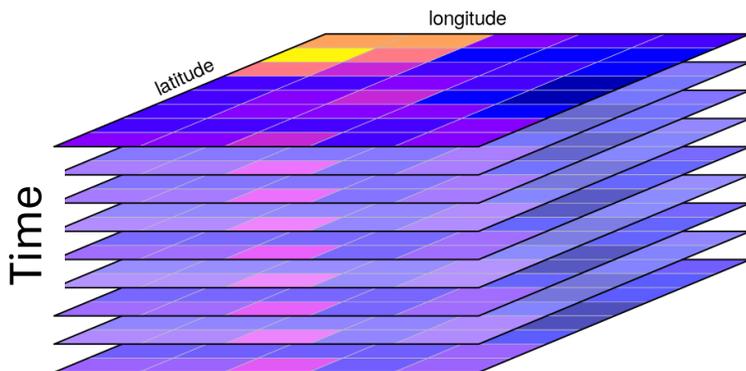
Sentinel-2 Remote Sensing Model Development:

1. Data Pre-Processing



- Acquire imagery from 3 time points in the growing season (spring, summer & fall)

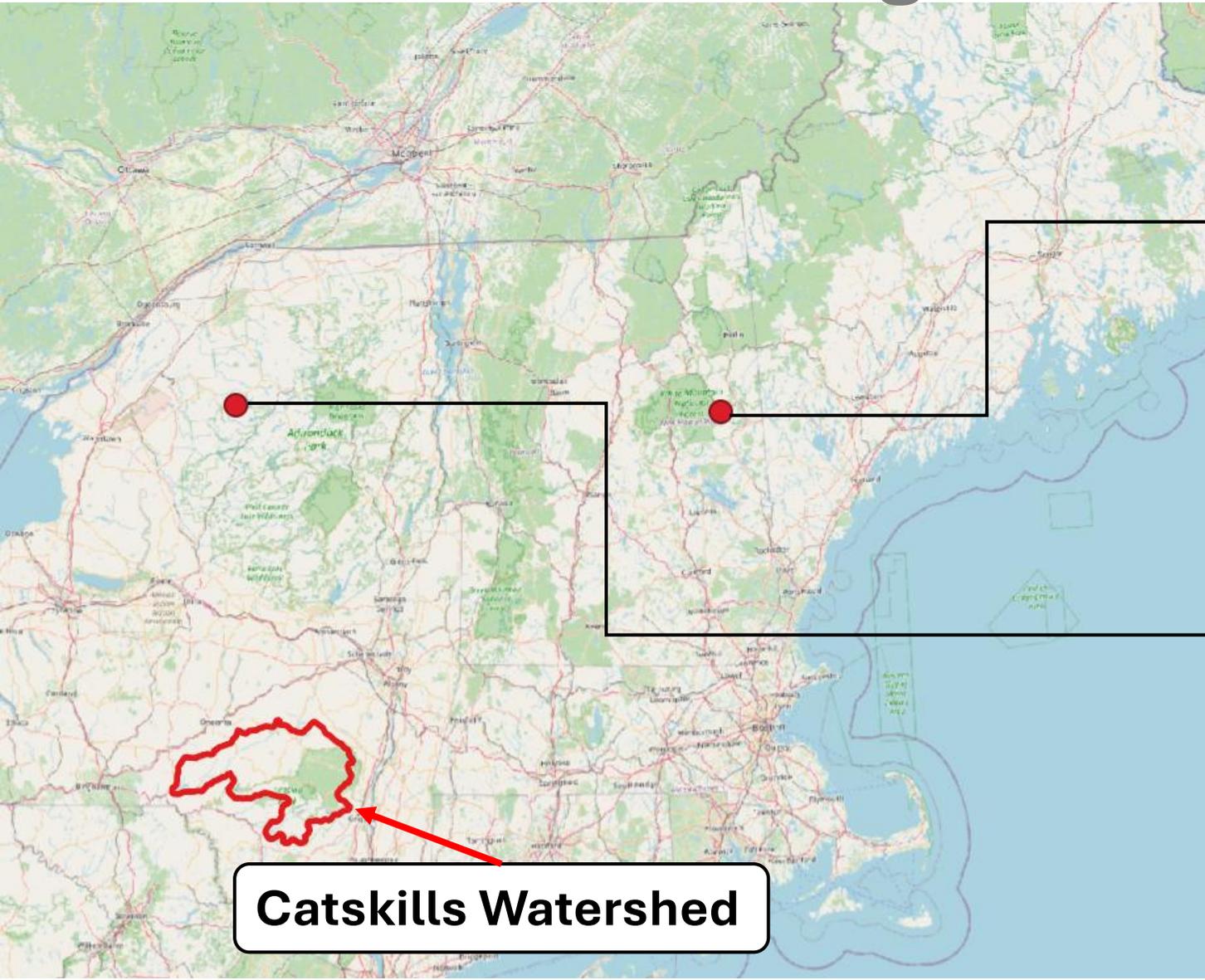
- Derive a set of vegetation indices:
 - Enhanced Vegetation Index (EVI)
 - Specific Leaf Area Vegetation Index (SLAVI)
 - Land Surface Water Index (LSWI)
 - Plant Senescence Reflectance Index (PSRI)



- Stack the bands & indices from all time points together to create a 'pseudo-hyperspectral' dataset

Sentinel-2 Remote Sensing Model Development:

2. Model Training with Ground Truth Data



Bartlett Experimental Forest

- National Ecological Observation Network (NEON) site

James F. Dubuar Memorial Forest (SUNY)

- SUNY College of Environmental Science and Forestry, Wanakena Campus

Catskills Watershed

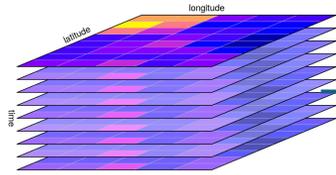
Sentinel-2 Remote Sensing Model Development:

3. Data Processing

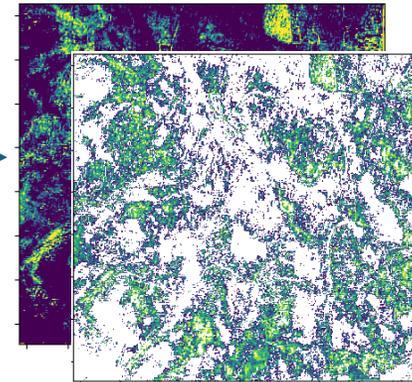
Spectral Unmixing

- The multitemporal data stack is input into a Mixture-Tuned Matched Filtering algorithm
 - Extract the signal from pixels known to contain beech
 - The algorithm quantifies how similar each pixel is to these reference pixels

Sentinel-2 data stack



Spectral
Unmixing



Output:
Two new raster layers
quantifying similarity
to beech signal

Reference beech signal

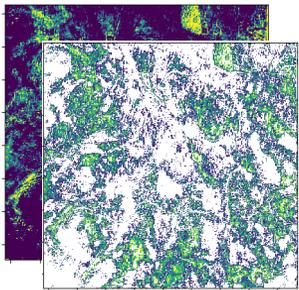
Sentinel-2 Remote Sensing Model Development:

4. Data Translation and Analysis

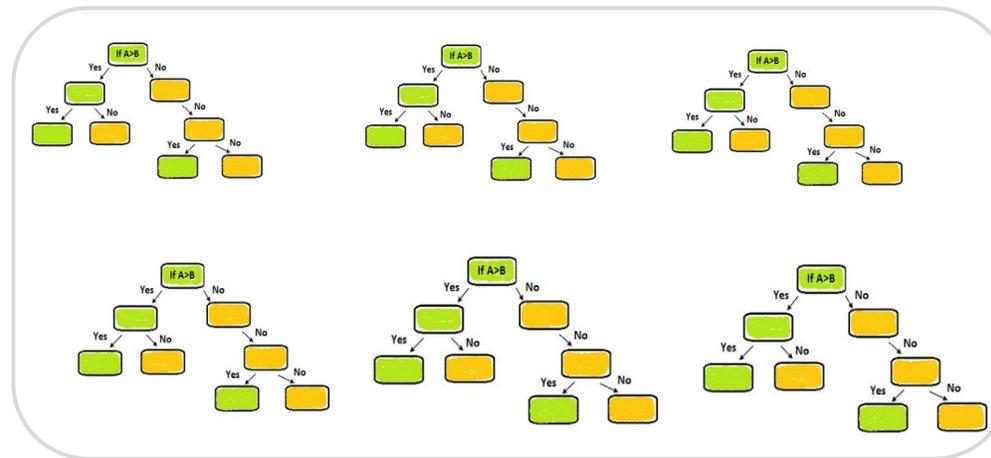
Machine-learning Model

- The results of spectral unmixing are mathematically meaningful, but not readily human-interpretable.

Spectral Unmixing Output



Random Forest Model



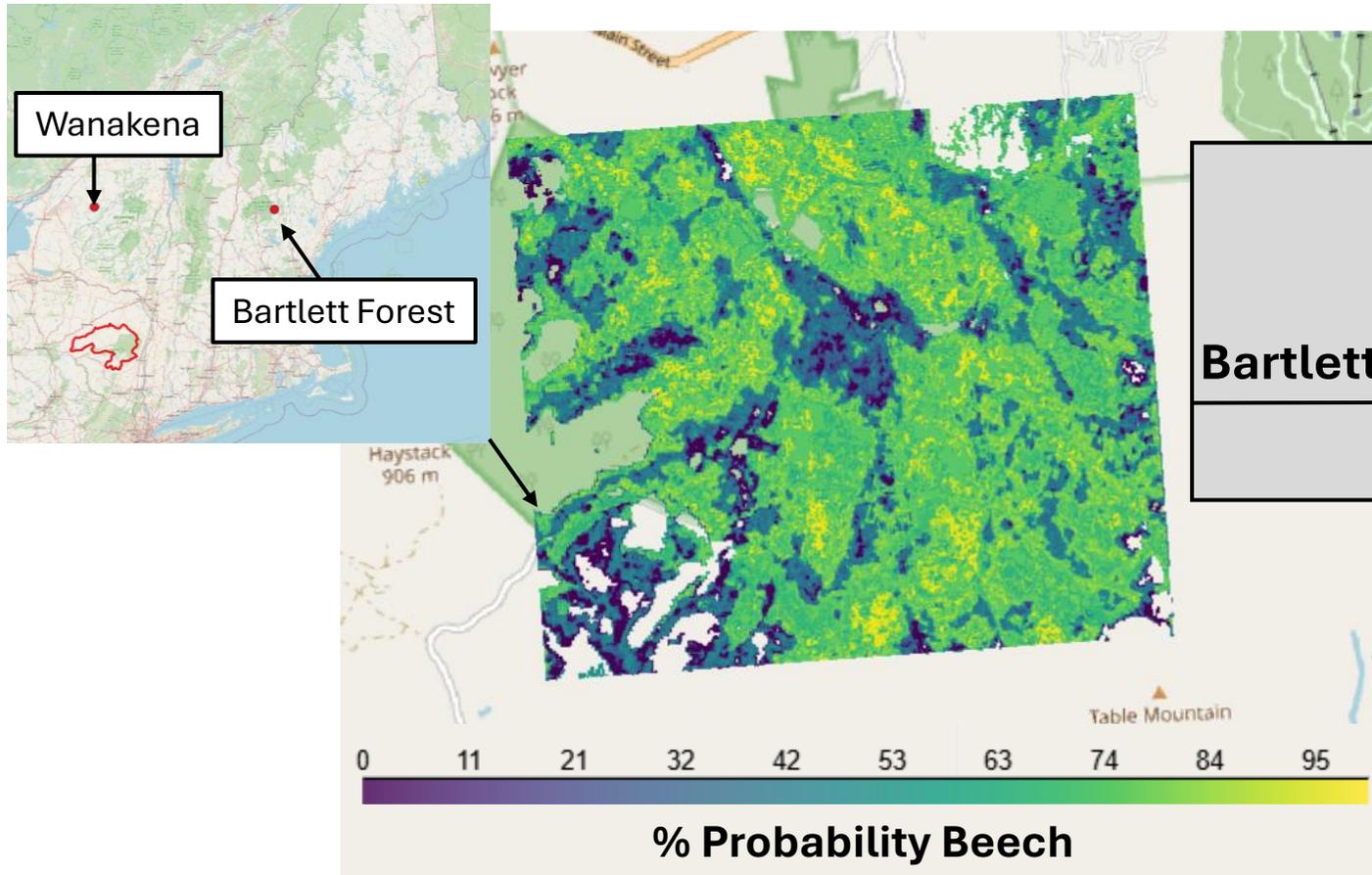
Final output:

**Map of probability
that each pixel
contains beech**

Sentinel-2 Remote Sensing Model Development:

5. Model Assessment

- 70% of Ground truth points at Bartlett were used for model training, remaining 30% were used for validation
 - Good performance at Bartlett



	% of known beech pixels found	Of pixels labeled beech, % that are actually beech
Bartlett:	83%	78%

- The results suggest that the model can be successfully transferred to a new site

Does Our Model Work in the Catskills?

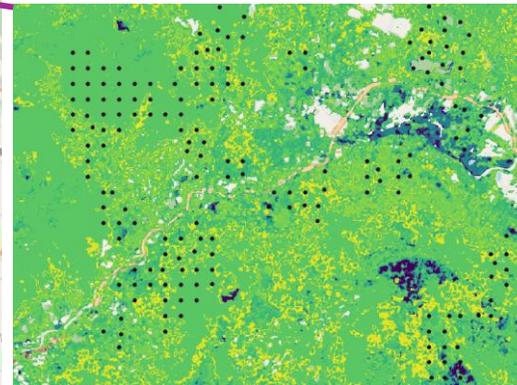
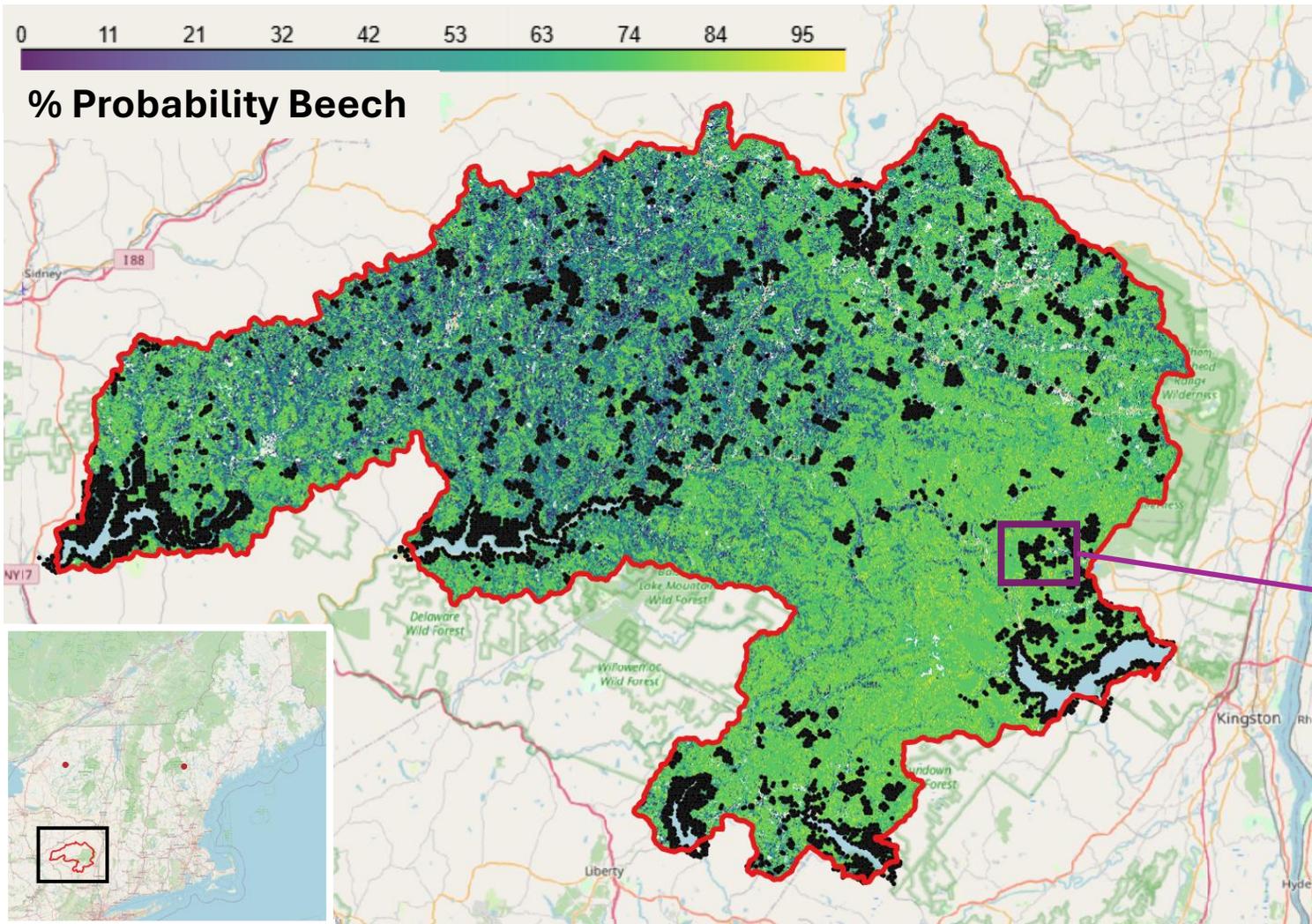
Validation Dataset:

DEP Forest Inventory

- 8,879 total variable radius plots
 - 1,545 plots contain beech
 - 7,334 plots contain no beech

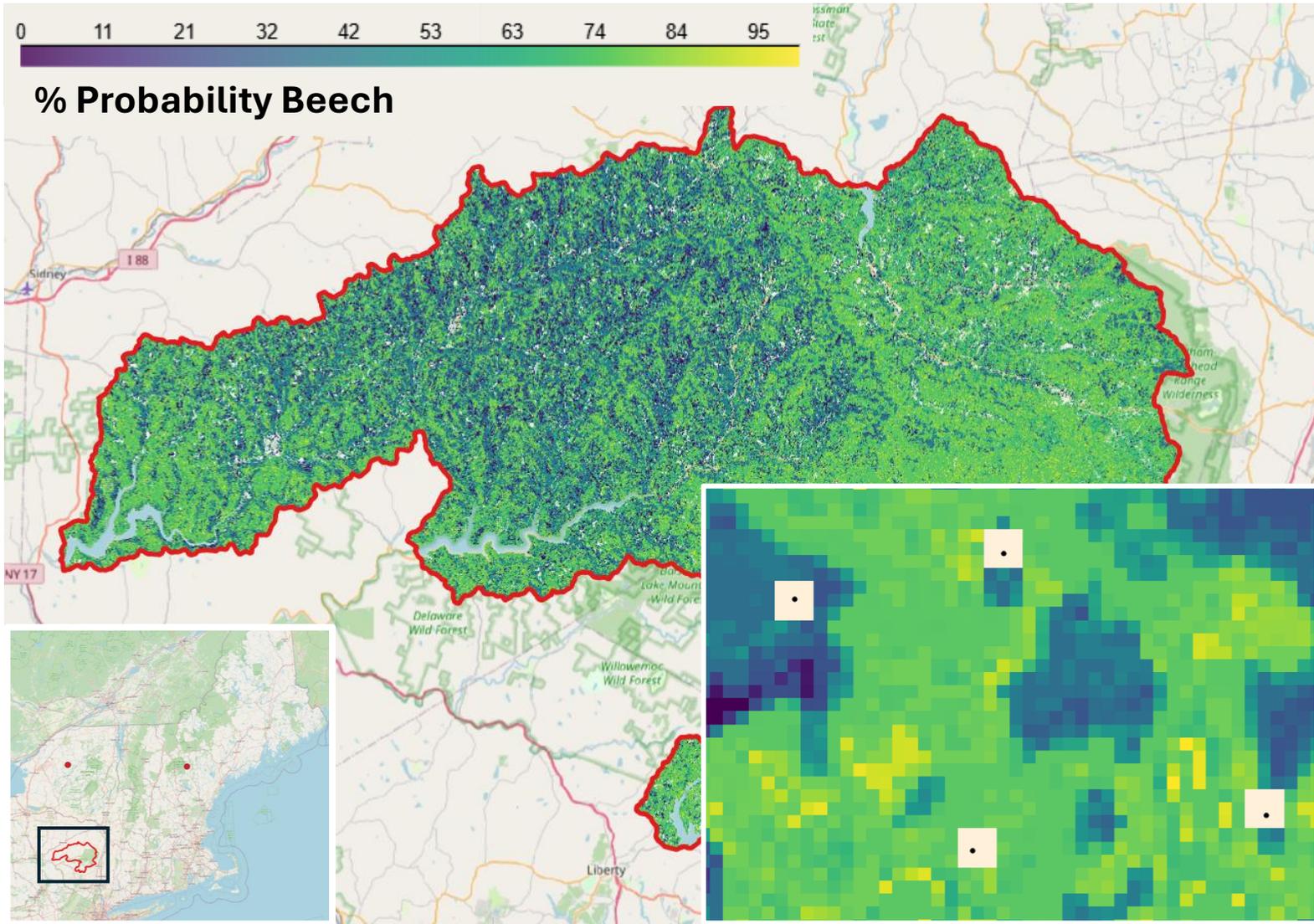
Limitation

- The actual location within ~20m of the plot center and canopy position of beech is unknown



Does Our Model Work in the Catskills?

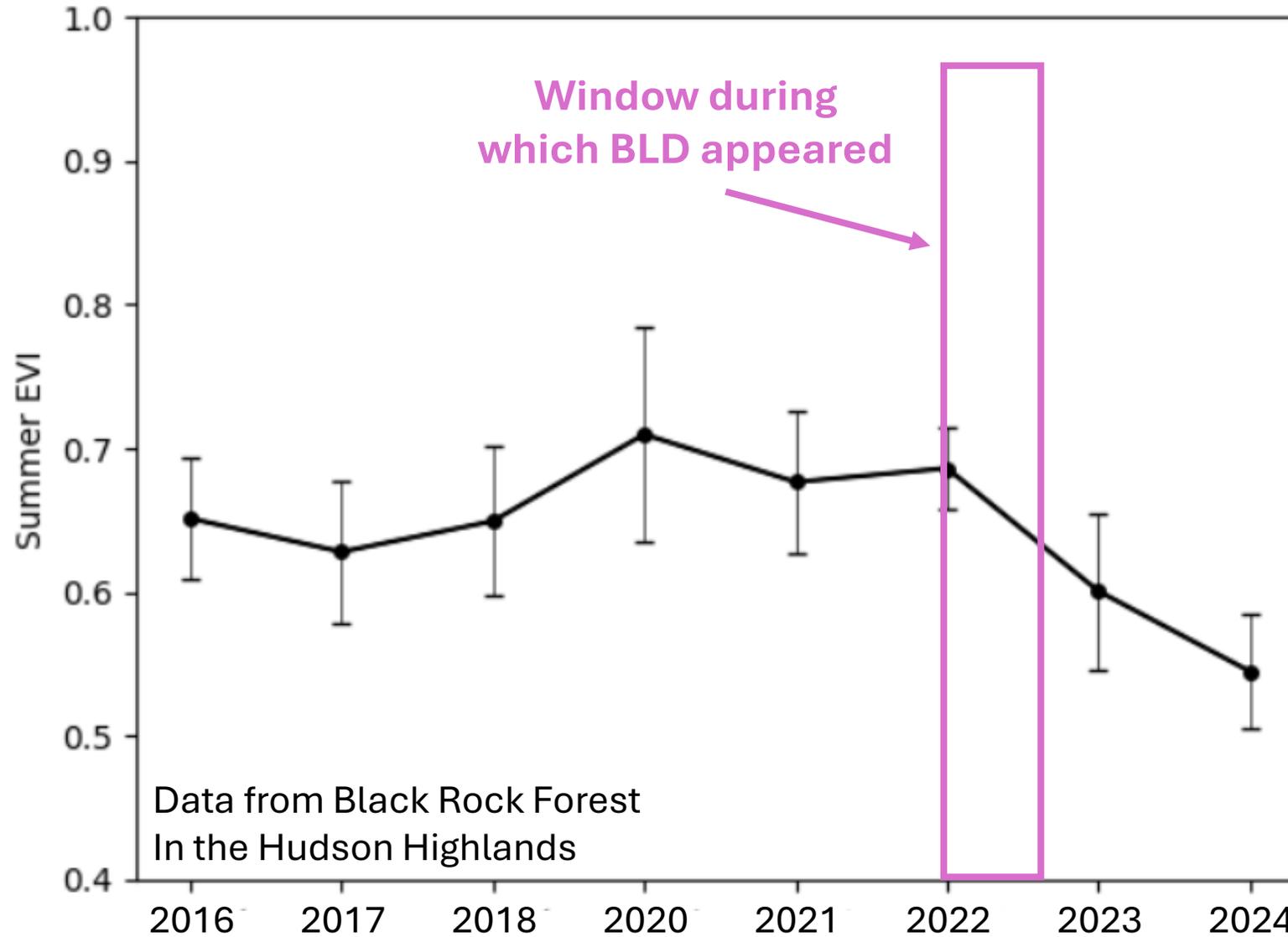
Cautious Optimism!



Validation approach

- If a DEP variable radius plot has beech, does our model predict $>70\%$ likelihood of beech in any of the pixels adjacent to the plot center?
- The model correctly found 89% of the plots that contained beech
- We can improve model assessment and training with more data of georeferenced canopy beech trees

If we Know Where Beech Are, We Track Declines in Health



Take-Home

Our results demonstrate the promise of using opensource multi-spectral, multi-temporal satellite remote sensing imagery for mapping the distribution and health of beech trees across large geographic areas

- Large field-based datasets are critical for model training and validation

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