

# The New York Forest Carbon Assessment

## Outputs, Applications & Insights for Adirondack Research & Stewardship

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Adirondack Park Agency  
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# Overview

## Background

- Objective
- Approach

## Functions & Outputs

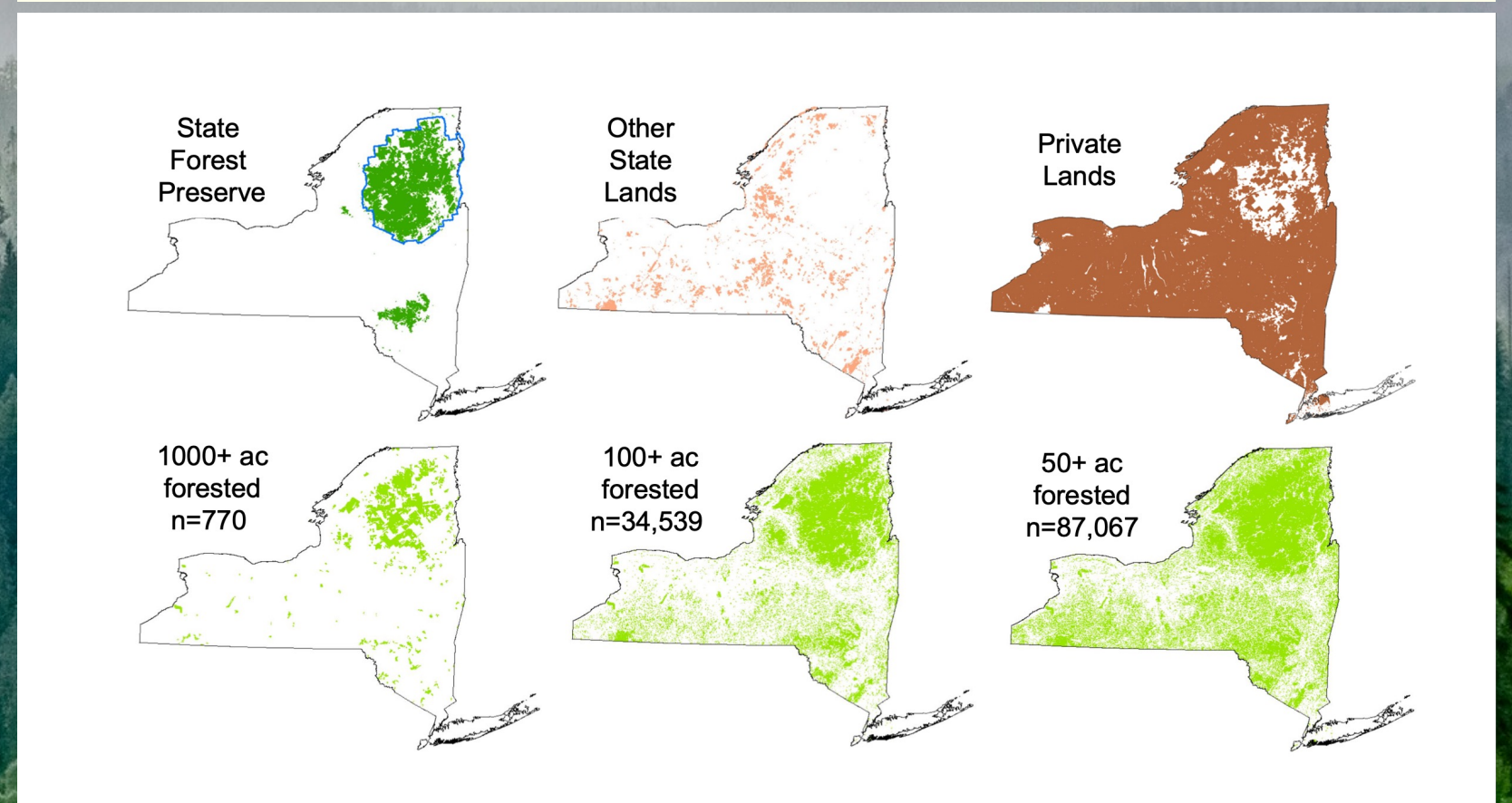
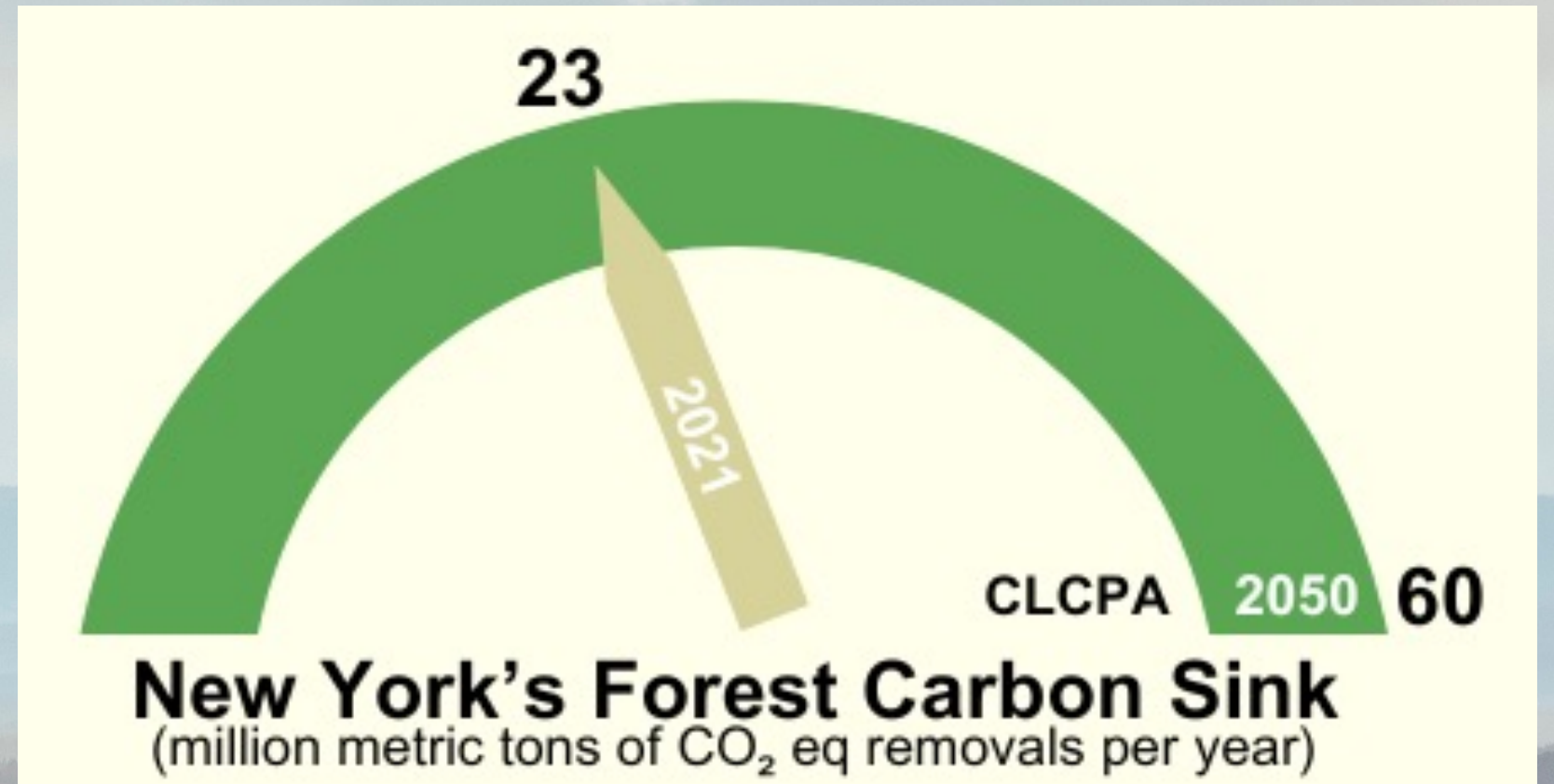
- AGB & C Mapping
- Stock-Change
- Monitoring
- Change Detection
- Uncertainty

## Applications

- Parcel-level analysis
- Solar facility siting
- Statewide MRV
- GHG Inventory

## Insights

- Disturbance trends
- C benefits on public vs private ADK lands





# New York

Table 349: Net CO<sub>2</sub> Flux from Forest Pools in *Forest Land Remaining Forest Land* (MMT CO<sub>2</sub> Eq.), New York

Carbon Pools	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
<b>Forest Ecosystems</b>	(27.9)	(27.6)	(27.7)	(27.4)	(27.4)	(27.2)	(27.2)	(27.1)	(26.9)	(26.8)	(26.7)	(26.4)	(26.4)	(26.3)	(26.2)	(26.1)	(26.0)	(25.9)	(25.9)	(25.8)	(25.7)	(25.5)	(25.4)	(25.2)	(25.1)	(24.9)	(24.7)	(24.3)	(24.2)	(23.9)
Aboveground Biomass	(20.2)	(20.2)	(20.2)	(20.0)	(19.9)	(19.8)	(19.7)	(19.4)	(19.3)	(19.0)	(18.2)	(18.1)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(17.9)	(17.3)	(17.1)
Belowground Biomass	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.7)	(3.7)	(3.7)	(3.7)	(3.7)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)	(3.8)
Dead Wood	(2.7)	(2.7)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)	(2.6)
Litter	(0.7)	(0.7)	(0.7)	(0.7)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)
Soil (Mineral)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
Soil (Organic)	(0.1)	(0.1)	(0.1)	(0.1)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Drained Organic Soil <sup>b</sup>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

+ Absolute value does not exceed 0.05 MMT CO<sub>2</sub> Eq.  
 - No observations of drained organic soil available.  
<sup>a</sup> These estimates include C stock changes from drained organic soils from both *Forest Land Remaining Forest Land* and *Land Converted to Forest Land*.  
 Notes: The forest ecosystem C stock changes do not include trees on non-forest land (e.g., agroforestry systems and settlement areas). Parentheses indicate net C uptake (i.e., a net removal of C from the atmosphere). Total net flux is an estimate of the actual net flux between the total forest C pool and the atmosphere. Totals may not sum due to independent rounding.

Table 350: Net C Flux from Forest Pools in *Forest Land Remaining Forest Land* (MMT C), New York

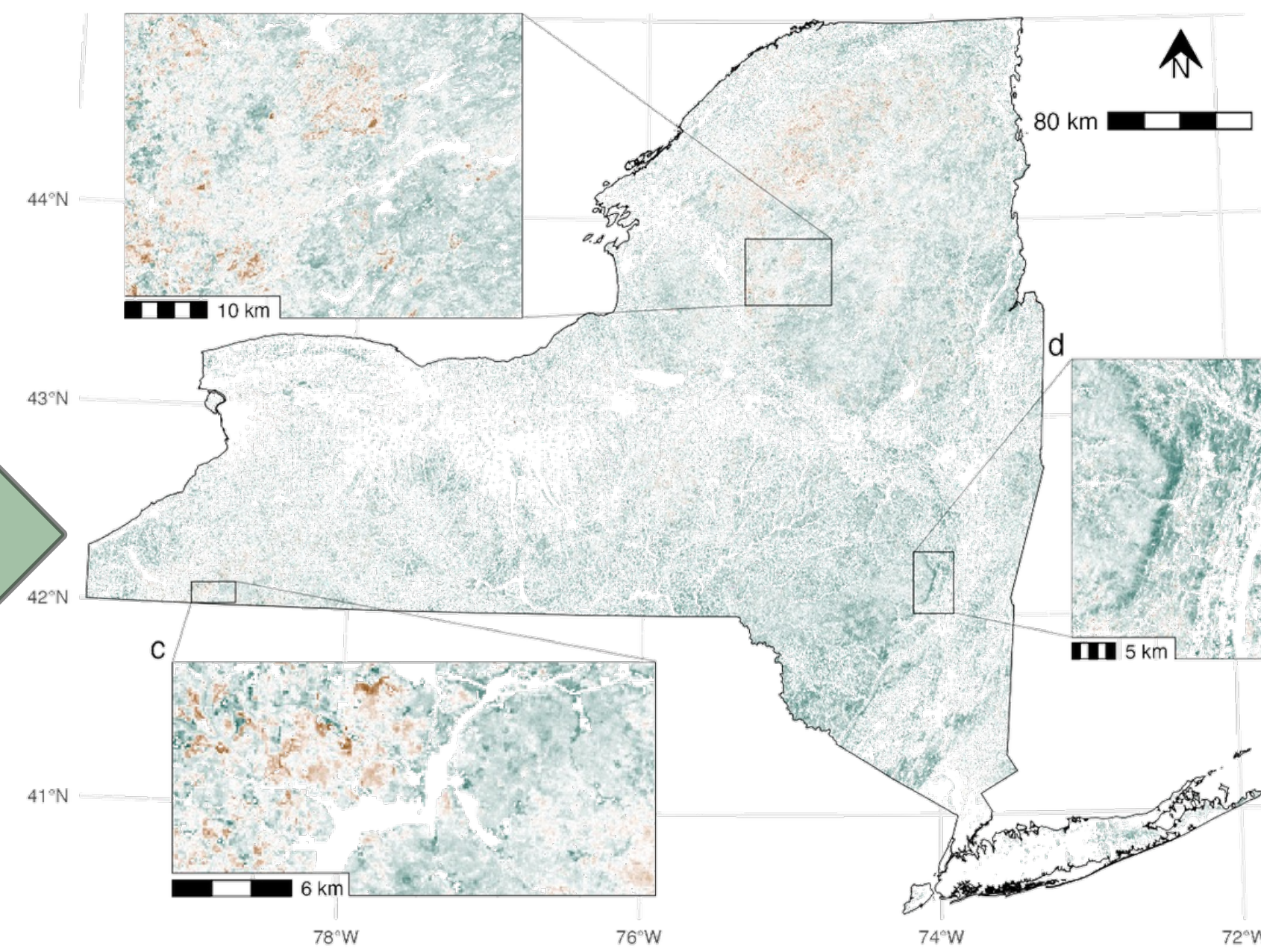
Carbon Pools	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
<b>Forest Ecosystems</b>	(7.6)	(7.6)	(7.6)	(7.5)	(7.5)	(7.5)	(7.4)	(7.4)	(7.3)	(7.3)	(7.3)	(7.2)	(7.2)	(7.2)	(7.1)	(7.1)	(7.1)	(7.1)	(7.1)	(7.0)	(7.0)	(7.0)	(6.9)	(6.9)	(6.8)	(6.8)	(6.7)	(6.7)	(6.4)	(6.3)
Aboveground Biomass	(5.5)	(5.5)	(5.5)	(5.5)	(5.4)	(5.4)	(5.4)	(5.3)	(5.3)	(5.2)	(5.2)	(5.2)	(5.2)	(5.2)	(5.1)	(5.1)	(5.1)	(5.1)	(5.1)	(5.0)	(5.0)	(5.0)	(4.9)	(4.9)	(4.9)	(4.9)	(4.8)	(4.8)	(4.7)	(4.7)
Belowground Biomass	(1.1)	(1.1)	(1.1)	(1.1)	(1.1)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)	(1.0)
Dead Wood	(0.7)	(0.7)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)
Litter	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
Soil (Mineral)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
Soil (Organic)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Drained Organic Soil <sup>b</sup>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

+ Absolute value does not exceed 0.05 MMT C.  
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 Notes: The forest ecosystem C stock changes do not include trees on non-forest land (e.g., agroforestry systems and settlement areas). Parentheses indicate net C uptake (i.e., a net removal of C from the atmosphere). Total net flux is an estimate of the actual net flux between the total forest C pool and the atmosphere. Totals may not sum due to independent rounding.

Table 351: C Stocks in *Forest Land Remaining Forest Land* (MMT C), New York

Carbon Pools	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>Forest Ecosystems</b>	1,698	1,706	1,712	1,721	1,728	1,736	1,743	1,751	1,758	1,766	1,772	1,780	1,787	1,795	1,802	1,809	1,816	1,823	1,830	1,837	1,844	1,851	1,858	1,865	1,872	1,879	1,886	1,892	1,899	1,906	1,912
Aboveground Biomass	424	429	435	440	446	451	457	462	467	473	476	483	489	494	499	504	508	514	519	524	529	534	539	544	548	554	558	564	569	574	578
Belowground Biomass	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	111
Dead Wood	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
Litter	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106
Soil (Mineral)	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043	1,043
Soil (Organic)	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11

Notes: The forest ecosystem C stocks do not include trees on non-forest land (e.g., agroforestry systems and settlement areas). Totals may not sum due to independent rounding. Population estimates compiled using FIA data are assumed to represent stocks as of January 1 of the inventory year. Flux is the net annual change in stock. Thus, an estimate of flux for 2019 requires estimates of C stocks for 2019 and 2020.



## Objective

To build a map-based forest carbon accounting system for NYS that replicates USFS/EPA methods for GHG inventory and supports scale-relevant public and private-sector decision-making for climate solutions



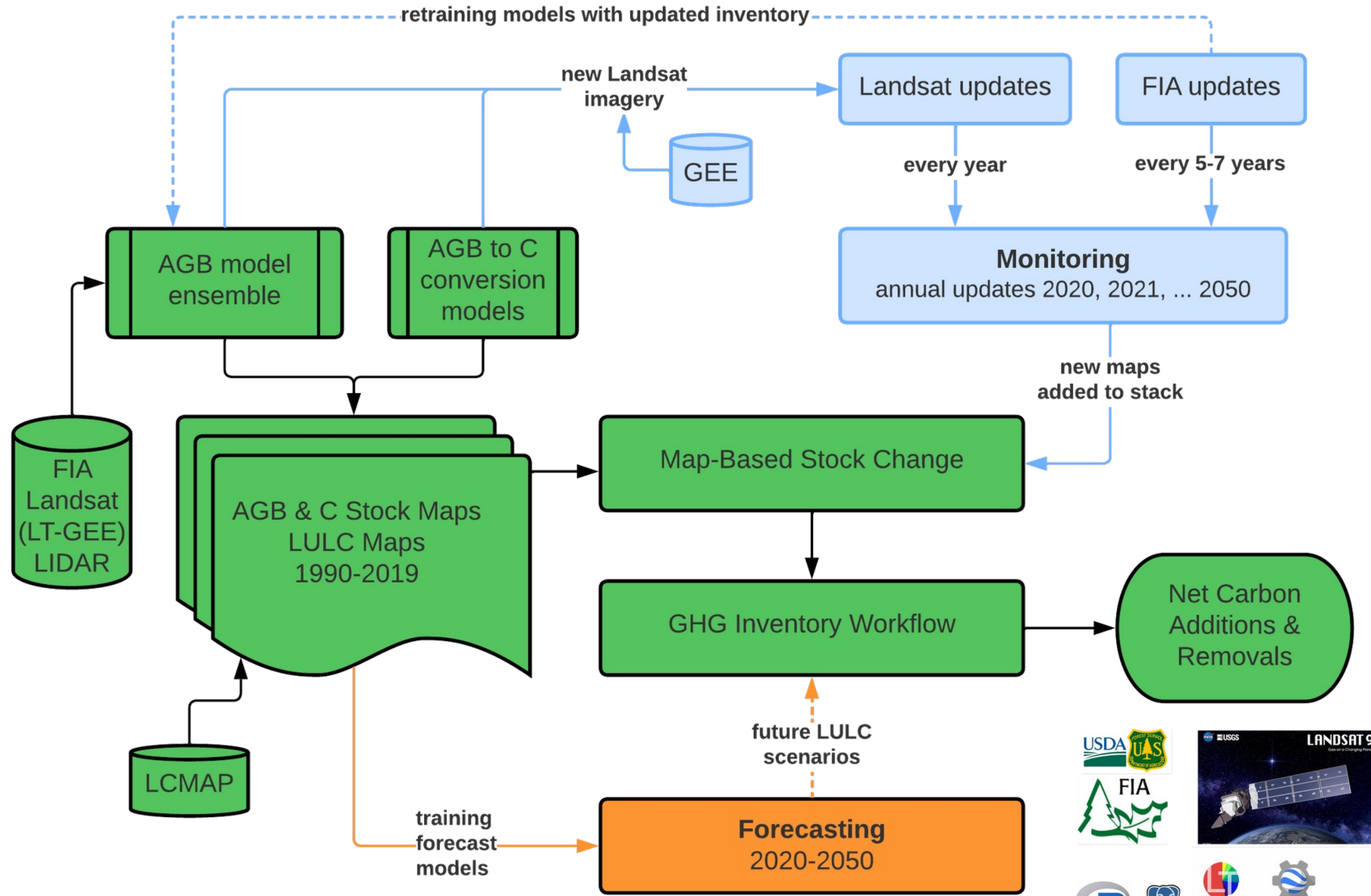
Integrated basis for

- **AGB & C Mapping**
- **Stock Change**
- **GHG Inventory**
- **Monitoring**
- **Forecasting**

Built on freely available data\* and open-source computational tools



# Approach



\*excludes FIA plot coordinates!





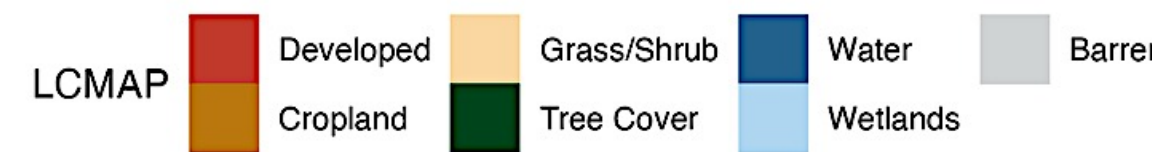
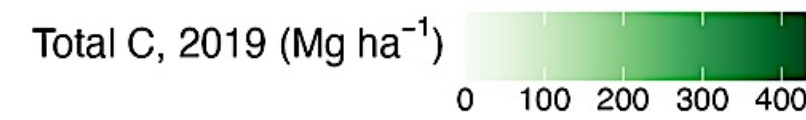
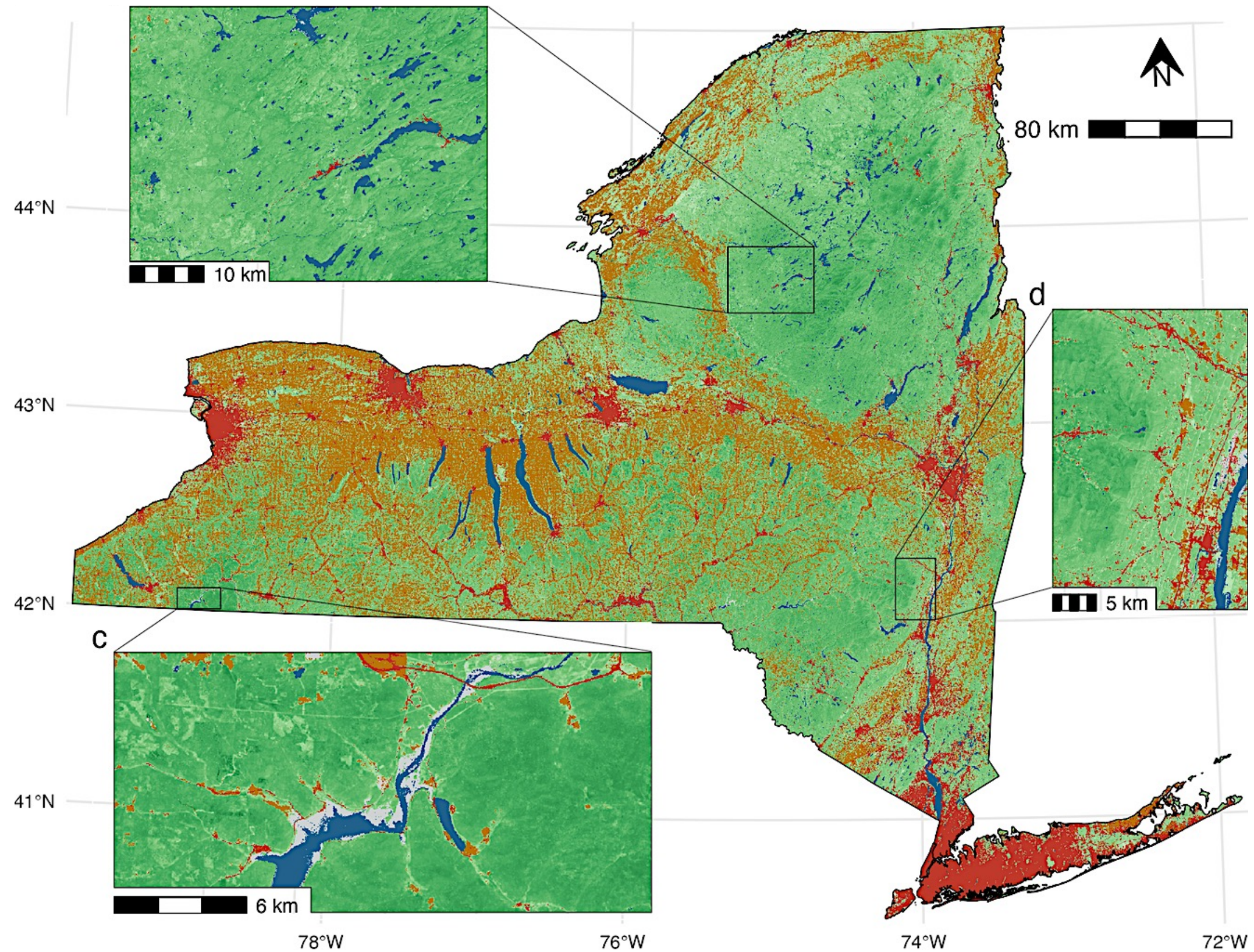
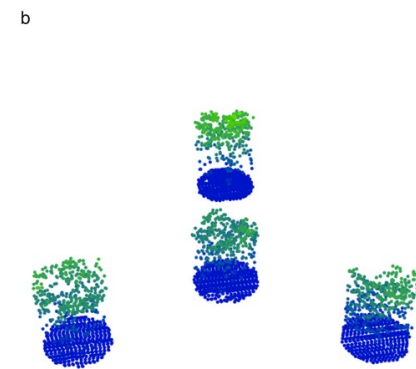
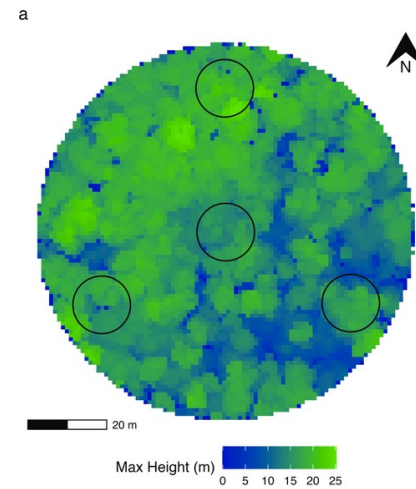
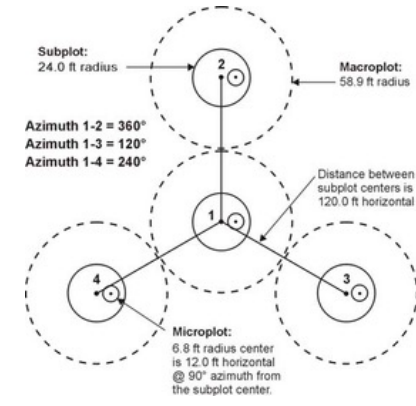
Ensemble machine-learning models, trained on FIA plots and EO data (LIDAR/ALS, Landsat C2, LT-GEE)

Created 30m annual AGB maps 1990 to 2019 statewide

AGB maps converted to 'live C' maps using FIA allometrics

Soil, litter, deadwood C pools mapped with models trained on FIA Phase 3 and EO data

Annual 30m C pools mapped only for forested pixels



# AGB & C Mapping

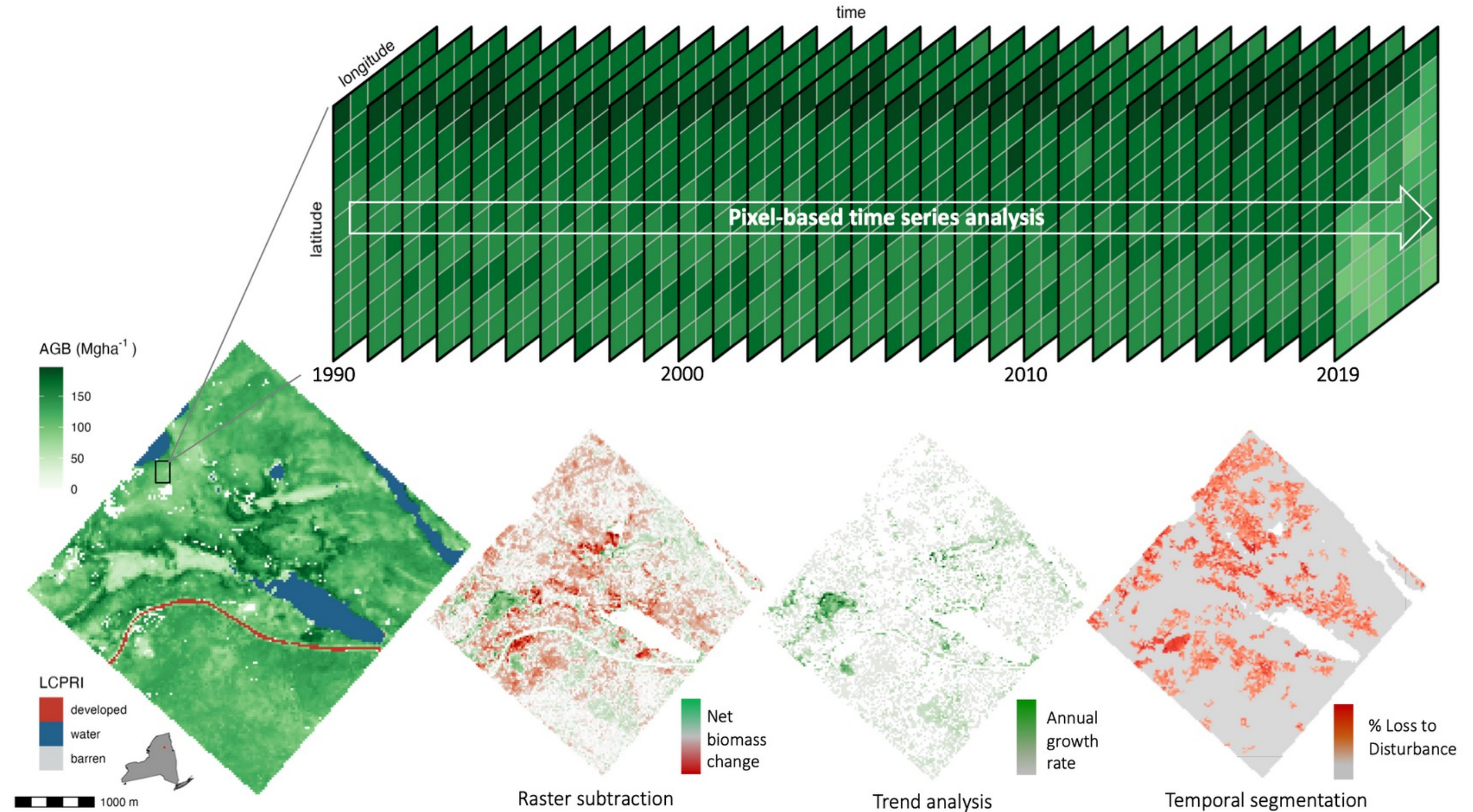


Compiled raster stacks of 30m annual AGB/C maps

Flexible basis for stock-change analysis using raster operations:

- simple differencing
- trend analysis
- temporal segmentation

Next step: spatiotemporal segmentation for object-based (i.e., stand-level) analysis and forecasting



**Stock-Change**

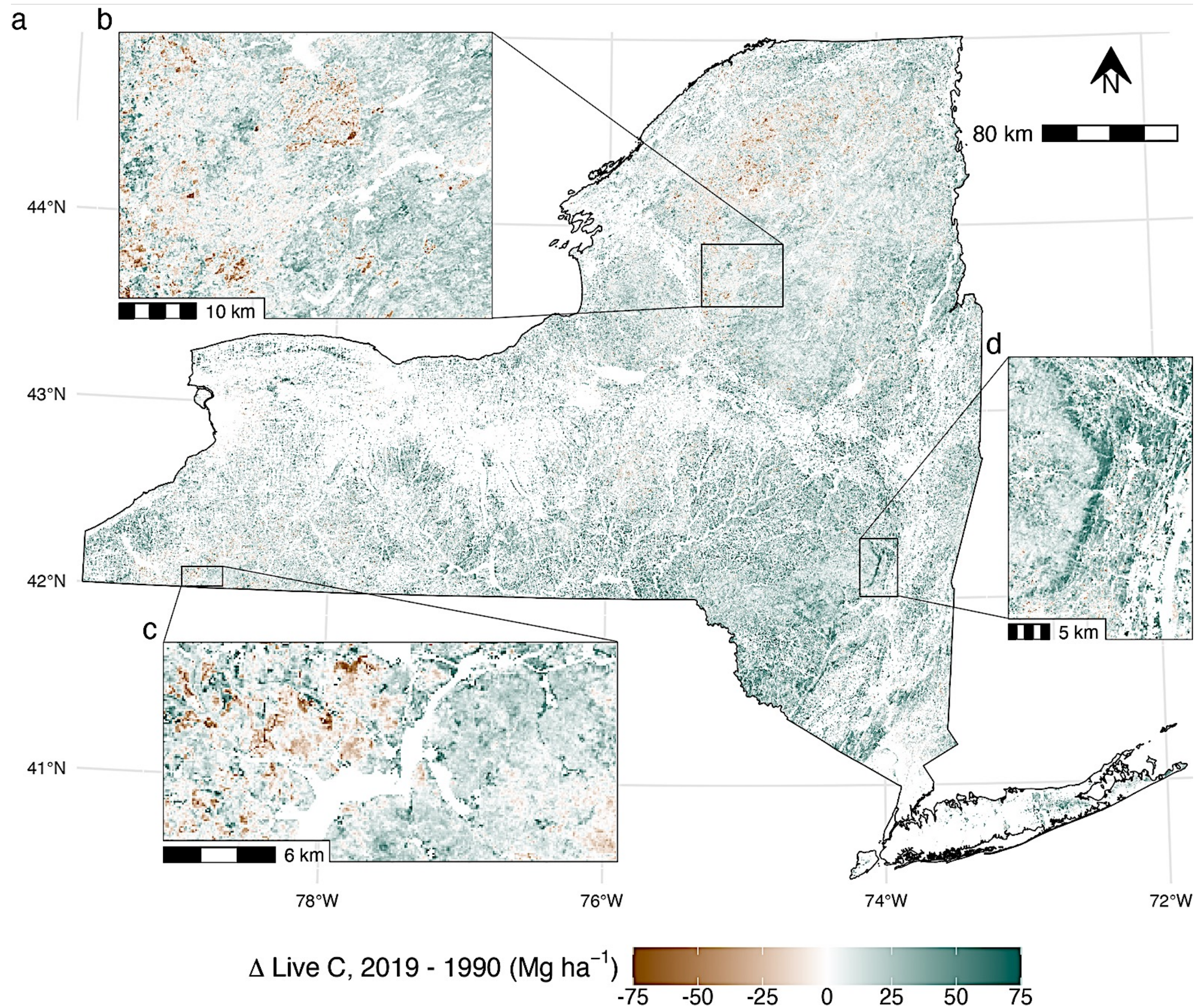


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**Stock-Change**

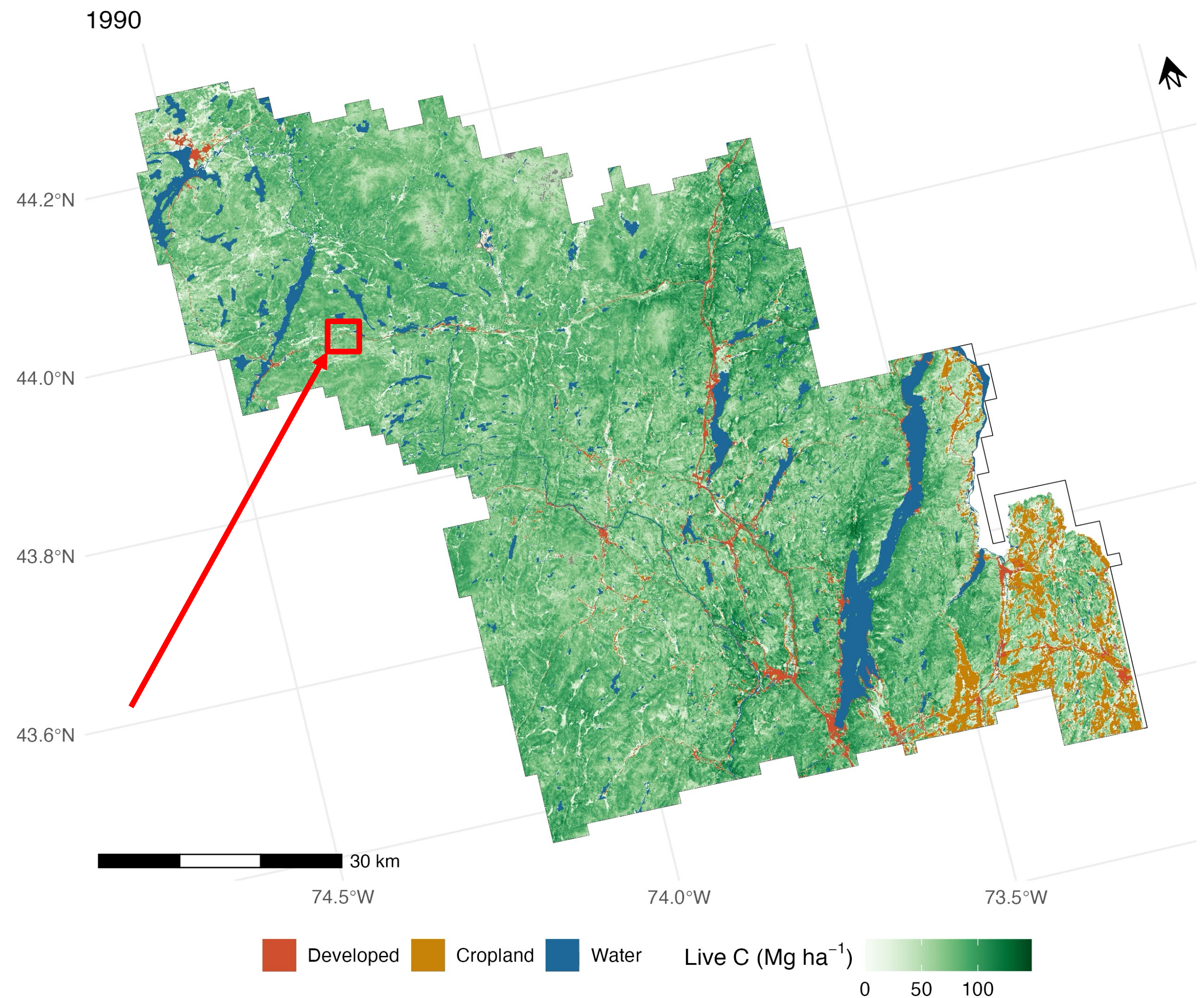


Compiled raster stacks of  
30m annual AGB/C maps

Flexible basis for stock-  
change analysis using raster  
operations:

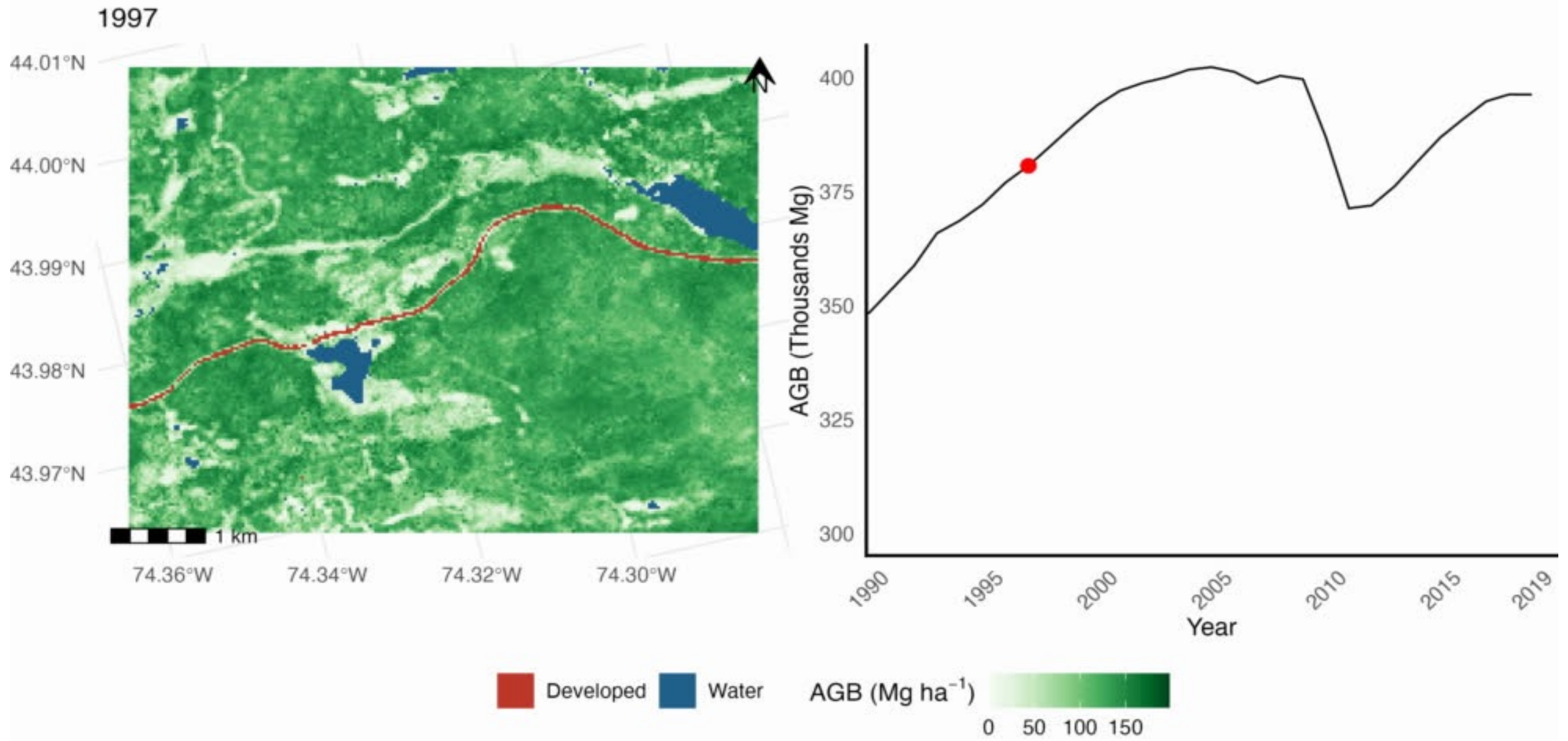
- simple differencing
- trend analysis
- temporal segmentation

Next step: spatiotemporal  
segmentation for object-  
based (i.e., stand-level)  
analysis and forecasting



**Stock-Change**

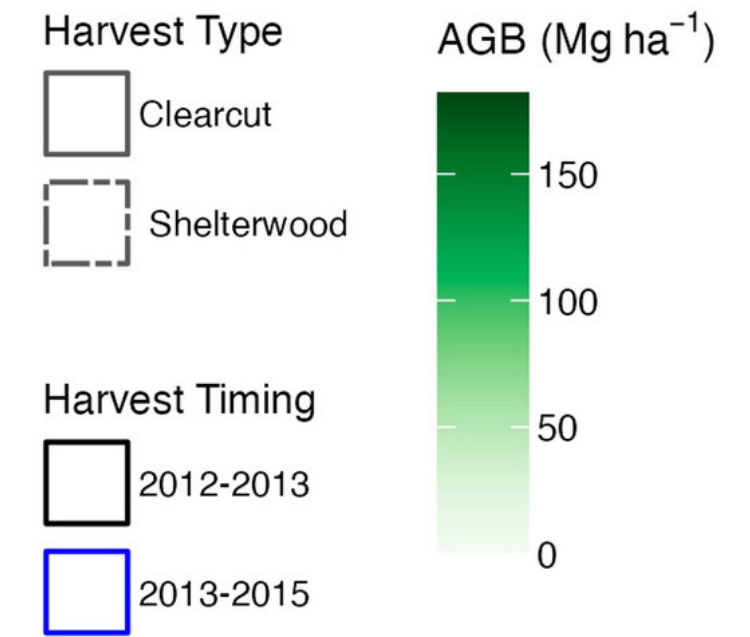
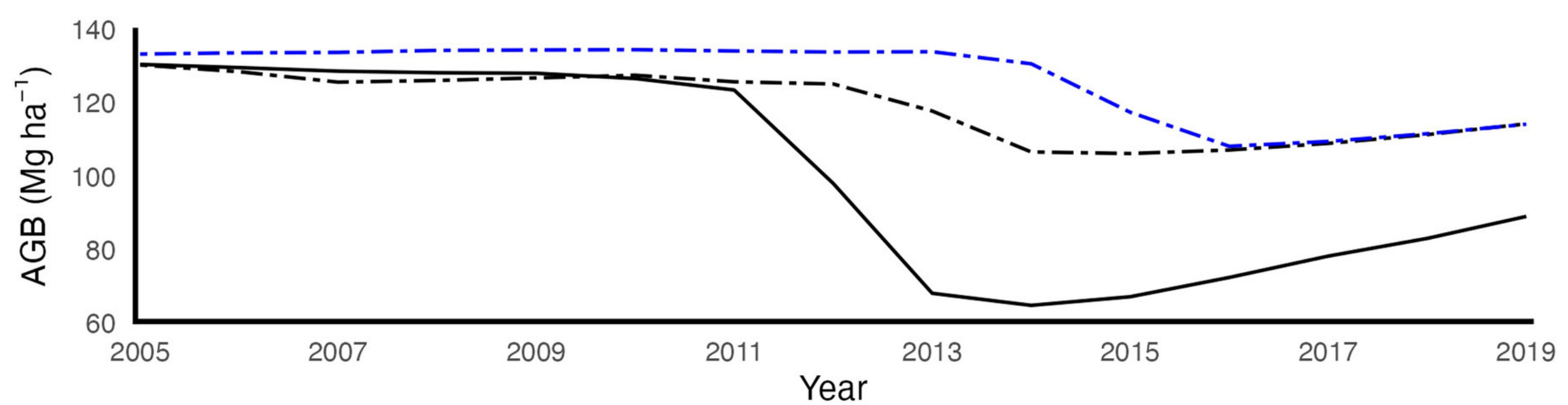
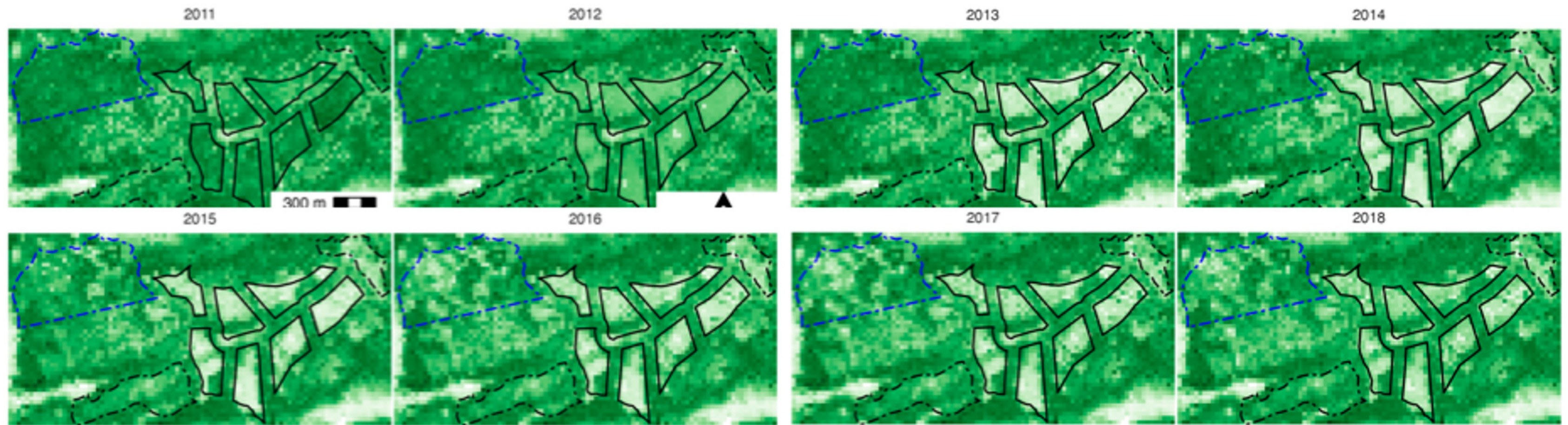




# Monitoring

As new Landsat imagery is released, we use the same ensemble models to produce annual 'update' maps of AGB and C stocks. The update maps are added to our raster stacks and stock-change metrics are recalculated. Core models will be re-trained and ensembles updated based on the FIA panel schedule (i.e., every 7 years in NYS).





## Monitoring

Time-series maps accurately capture harvest and regeneration dynamics, based on ground-referencing with management records provided by industrial landowners

Models likely underpredict biomass removals and overpredict early regeneration rates

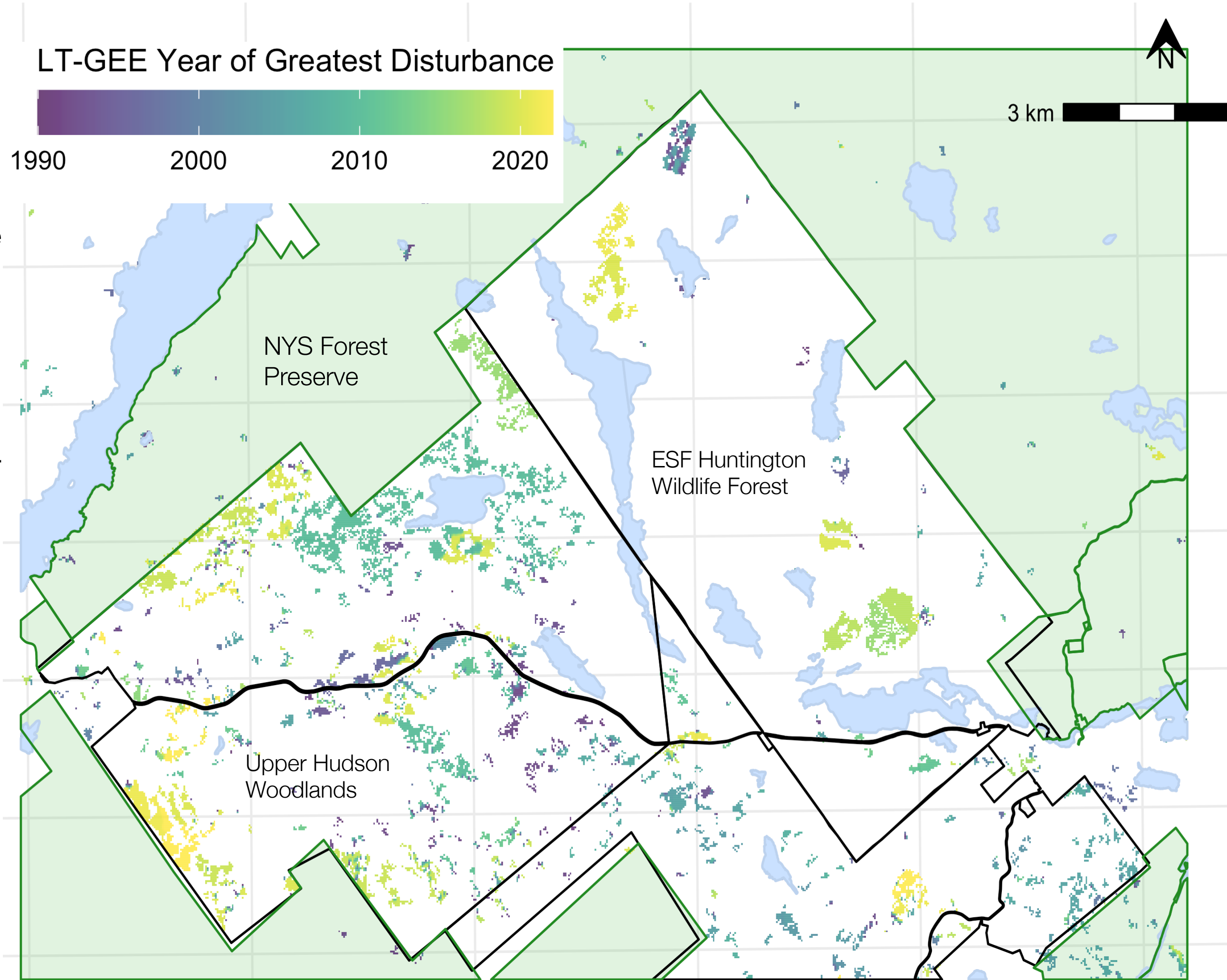


Ground-truthed change detection tools based on Landsat time-series imagery and harvest maps

Landtrendr on Google Earth Engine (LT-GEE) was 'tuned' on ~400K ac of ADK harvest maps/records provided by industrial landowners

Trained a change attribution model based on spatial and temporal attributes of harvests vs. natural disturbances (on Forest Preserve)

Can classify harvest/non-harvest with ~95% accuracy, but cannot classify among 'natural' causes



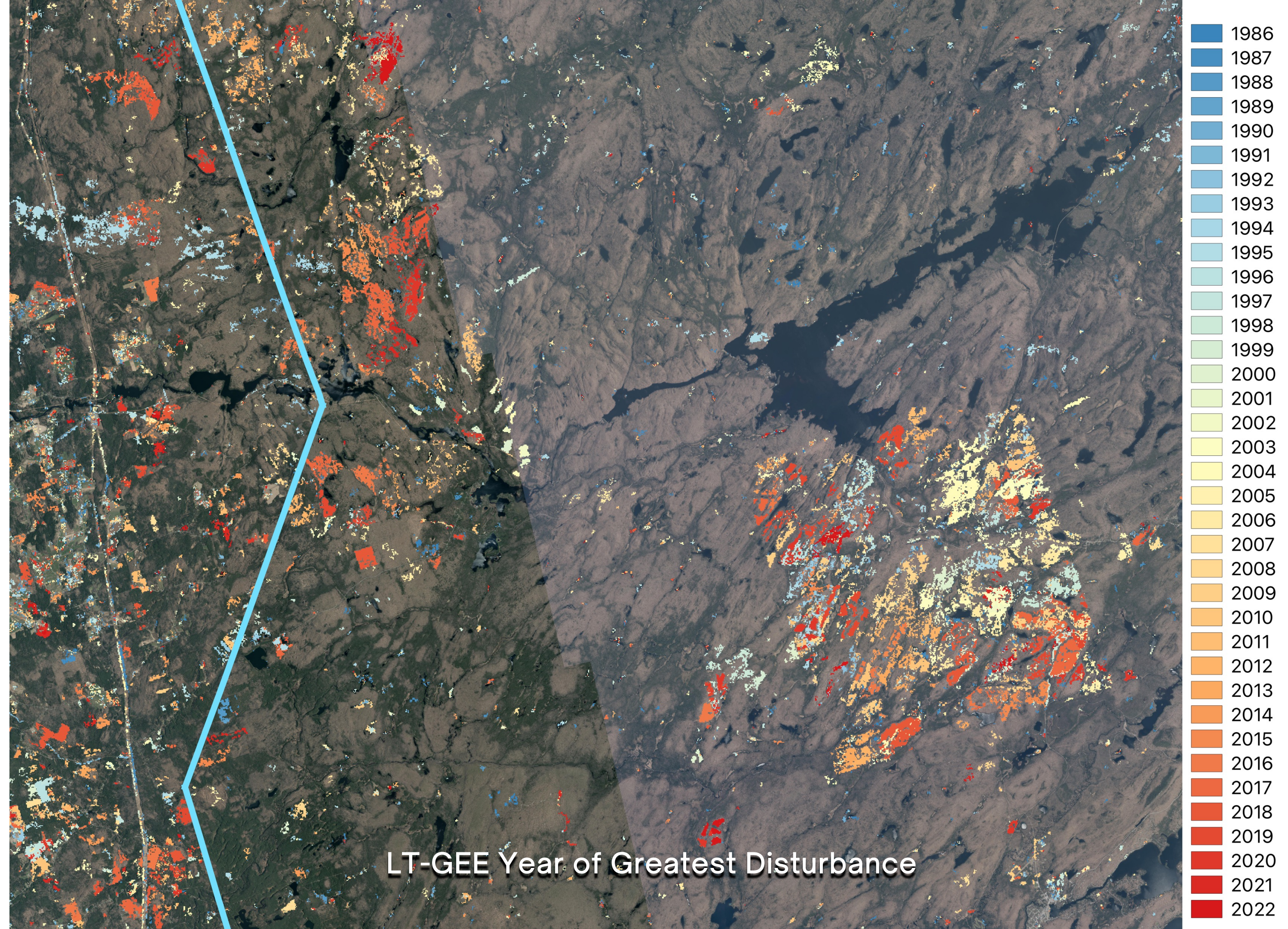
## Change Detection



Change detection and attribution tools allow mapping of historical land use and disturbance (back to 1990)

Reconstruct recent patterns of forest management, including areas with multiple entries

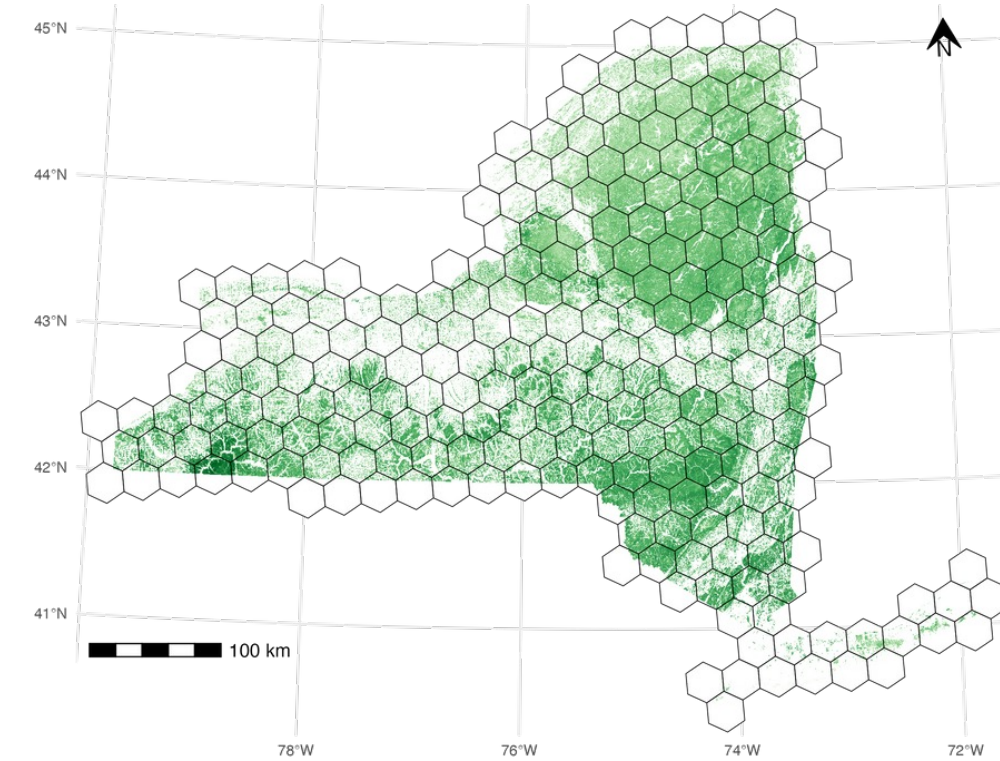
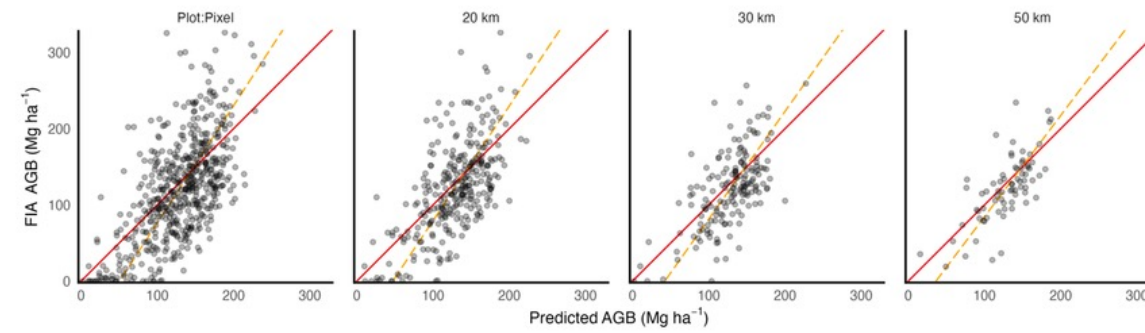
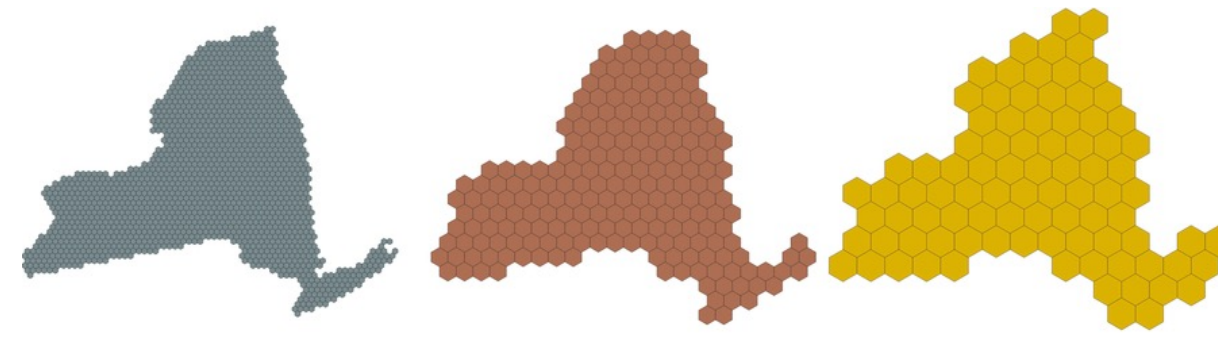
Next step: training models to estimate harvest yields by species & grade, for use in spatial life-cycle assessment of the GHG balance of NYS harvested wood products (HWP)





# Model

Prediction accuracy on 70/30 training holdout plots; k-fold cross-validation, hyperparameter tuning; ensembling

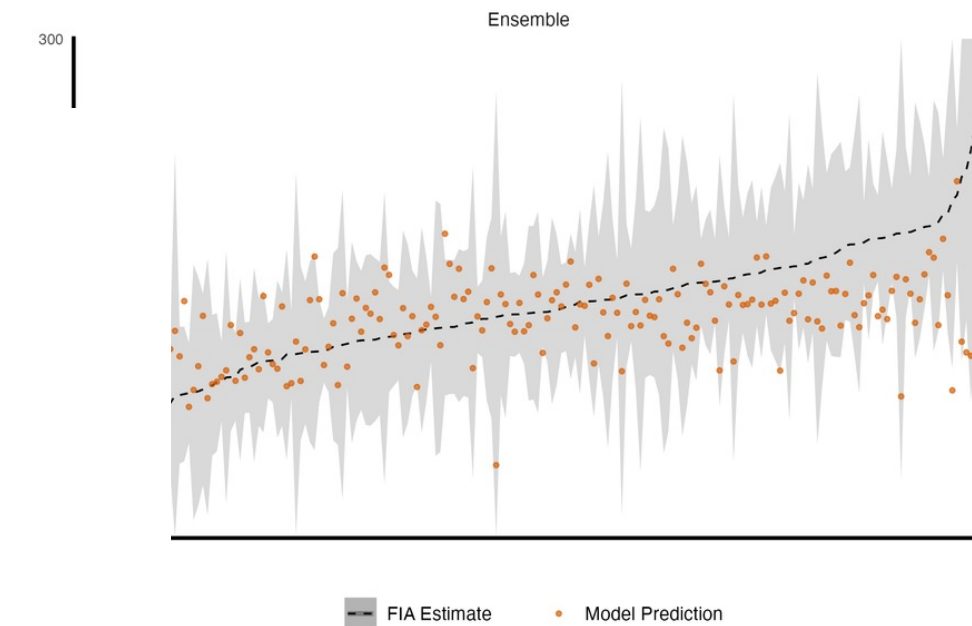
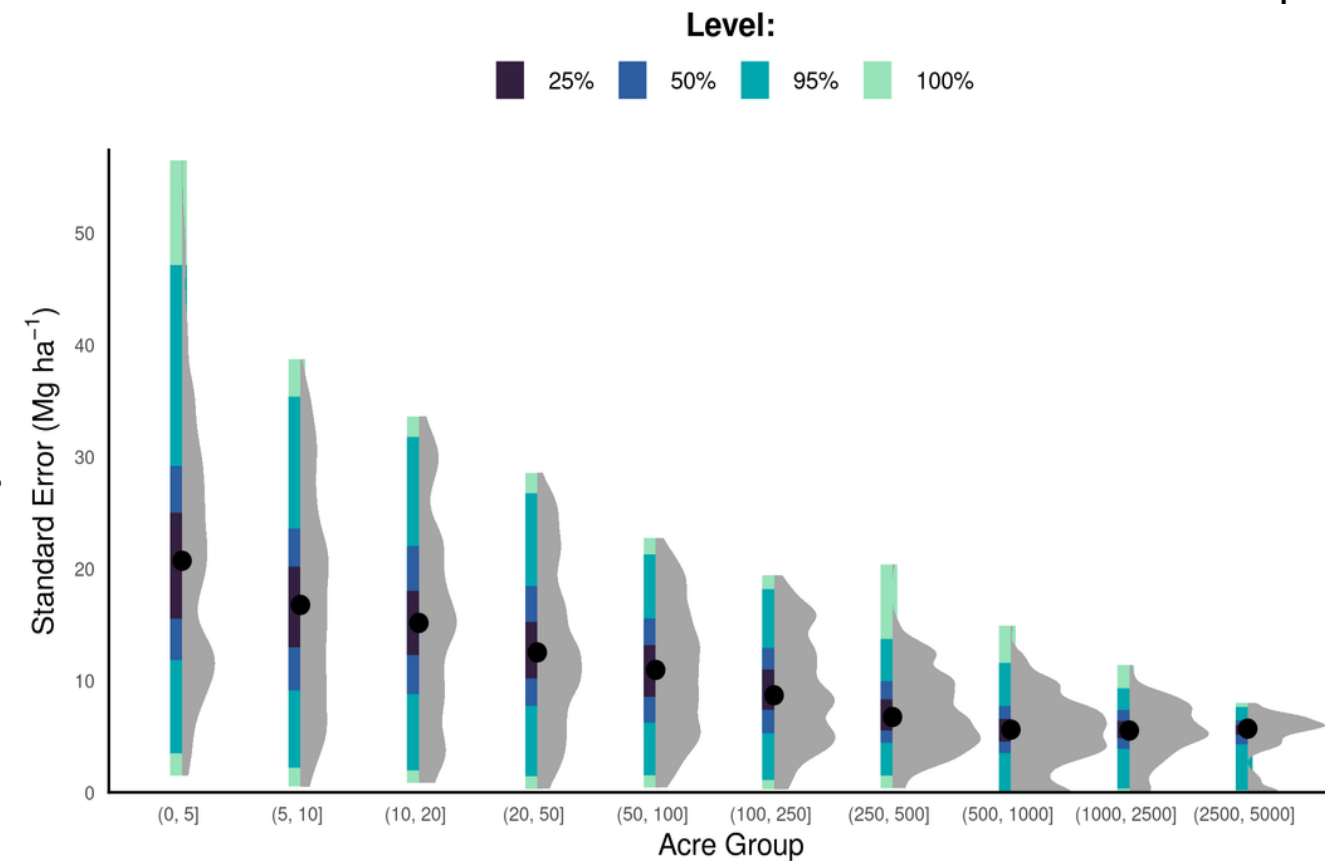


# Map

Plot-to-pixel comparisons aggregated to variable scales and LULC-corrected validation against FIA small-area map estimates (60,000 ha hexagons)

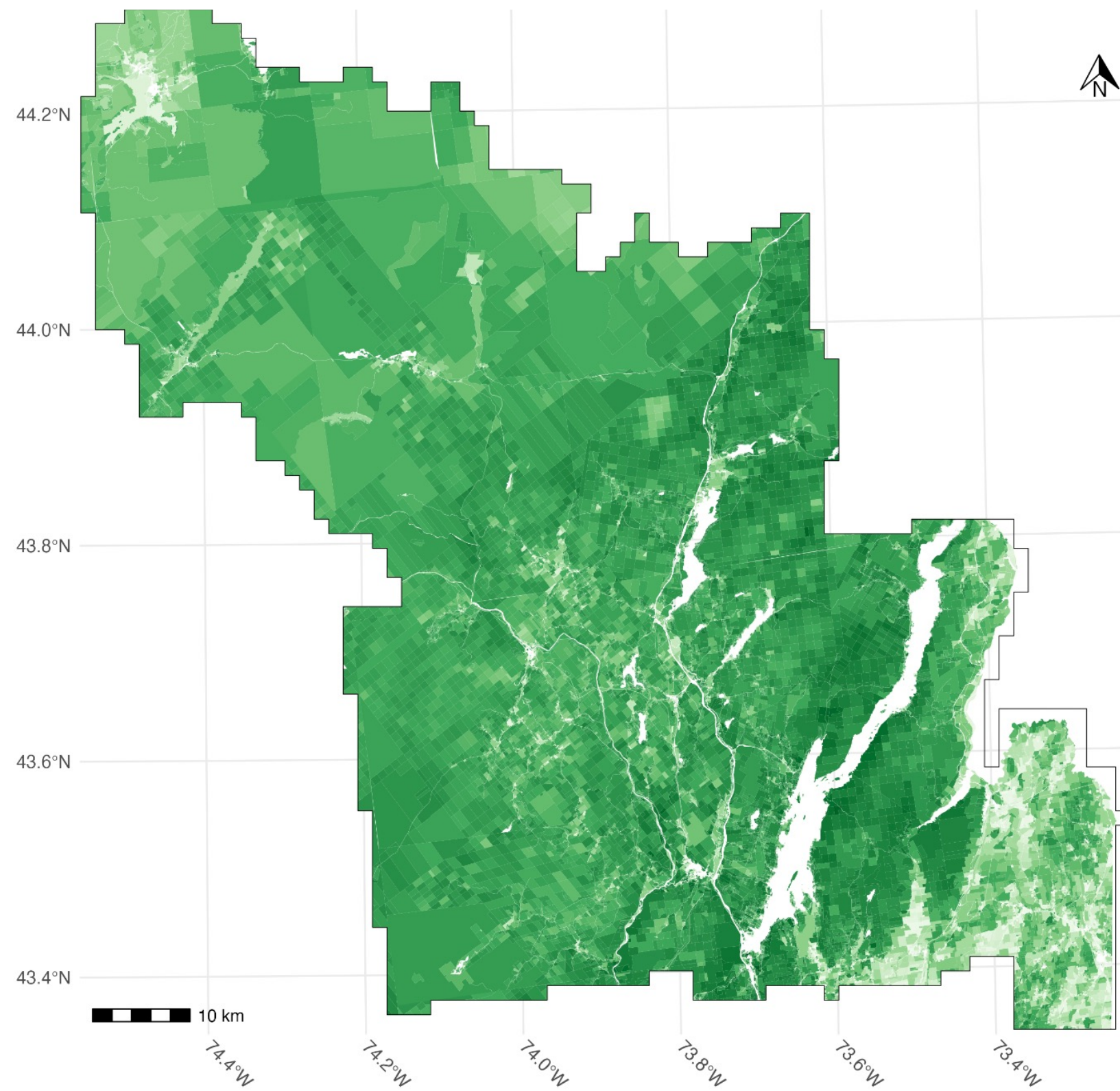
# Scale

Bootstrapped cumulative uncertainty from reference plots, allometrics, model residuals, spatial autocorrelation, etc;



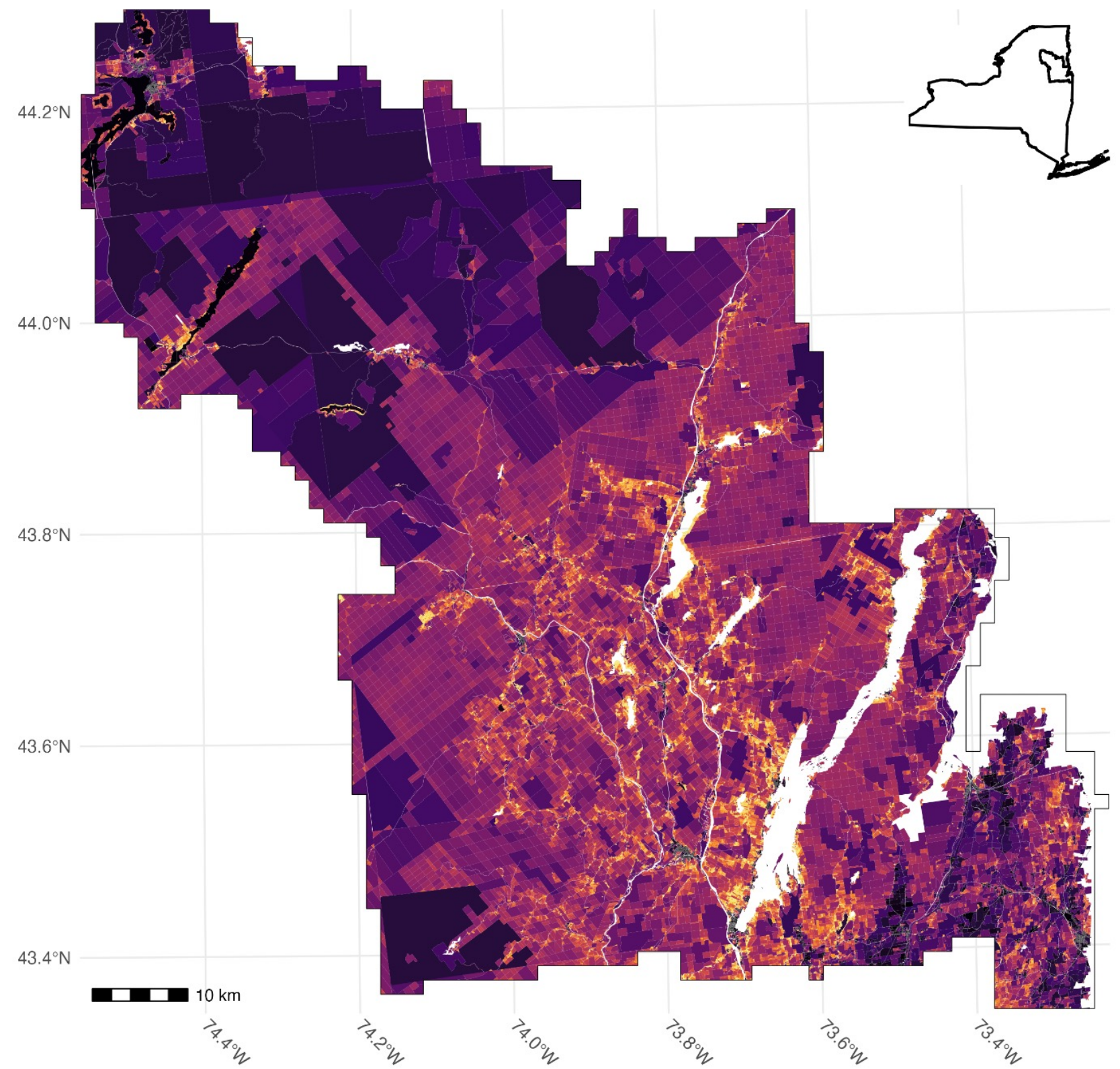
# Uncertainty





AGB, 2019 ( $\text{Mg ha}^{-1}$ )

0 50 100 150 200



Standard Error ( $\text{Mg ha}^{-1}$ )

0 10 20 30 40+

## Uncertainty

We can rapidly estimate the standard error (SE) of our map predictions of biomass and carbon stocks for individual parcels (and any other arbitrary areas within NYS)

Provides easy to understand 'error bars' for decision-support applications



## Parcels

Screening/prioritizing forest parcels for enrollment in voluntary programs, tax incentives, conservation easements, land acquisitions, offsets, etc.

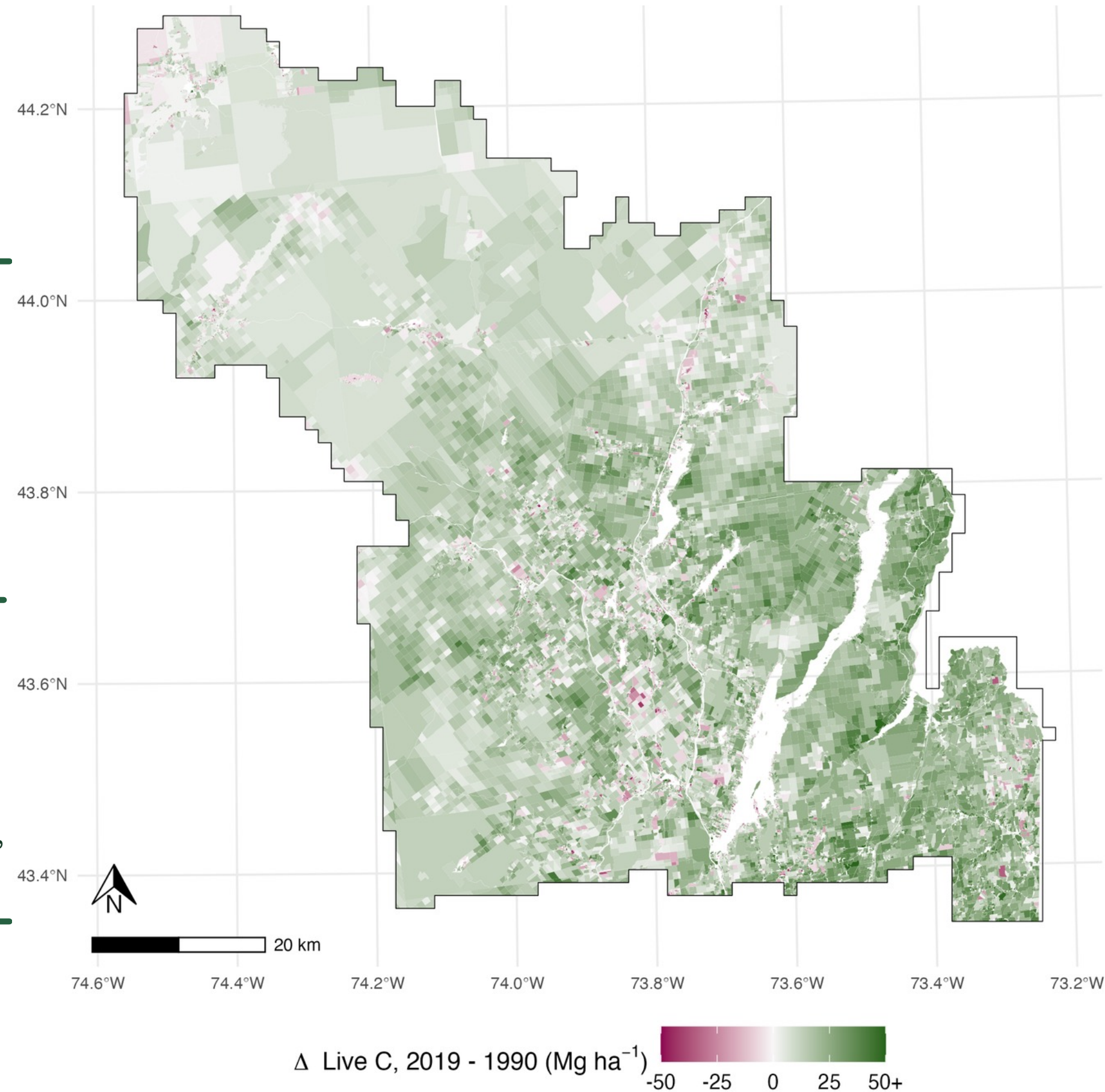
## MMRV

NY Connects: USDA Climate Smart Commodities project will invest \$13M into forestry practices via DEC's RegenerateNY program over next 5 years

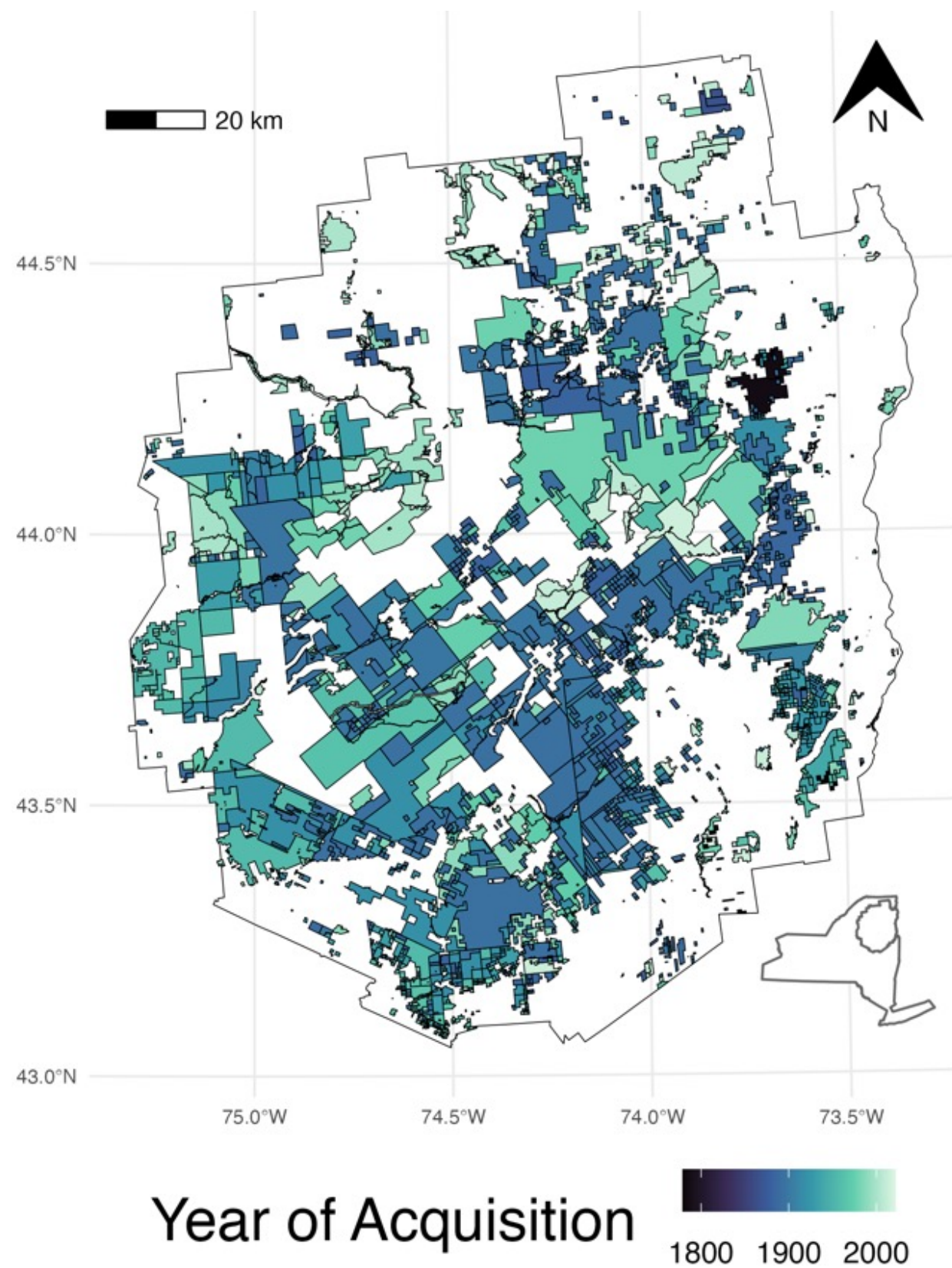
## Solar

Rapid assessment of proposed solar facilities for NYSERDA's Solar Scorecard, to minimize forest loss, C emissions due to land clearing for solar farms

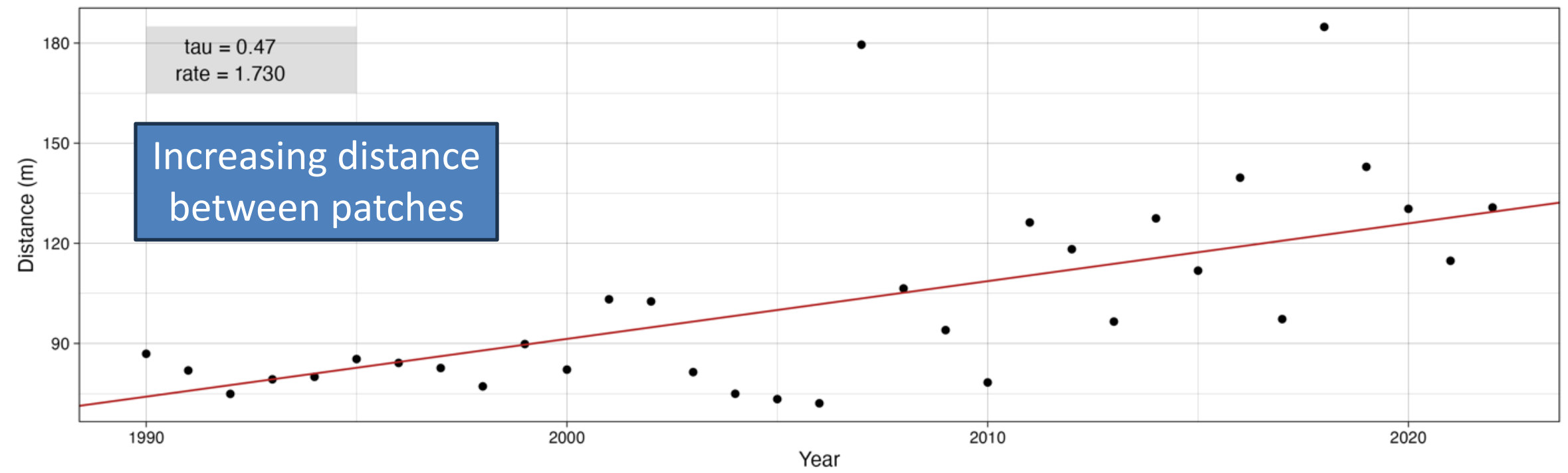
# Applications



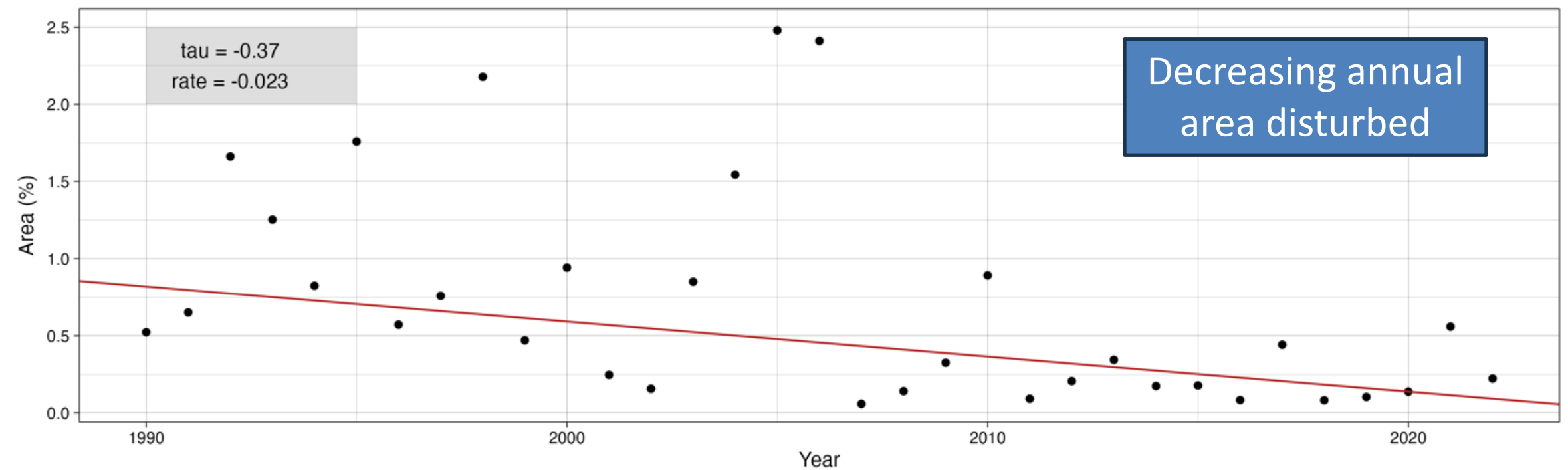




A. Mean Euclidean Nearest Neighbor Distance (ENN)



B. Percentage of Forest Preserve Land Disturbed Annually

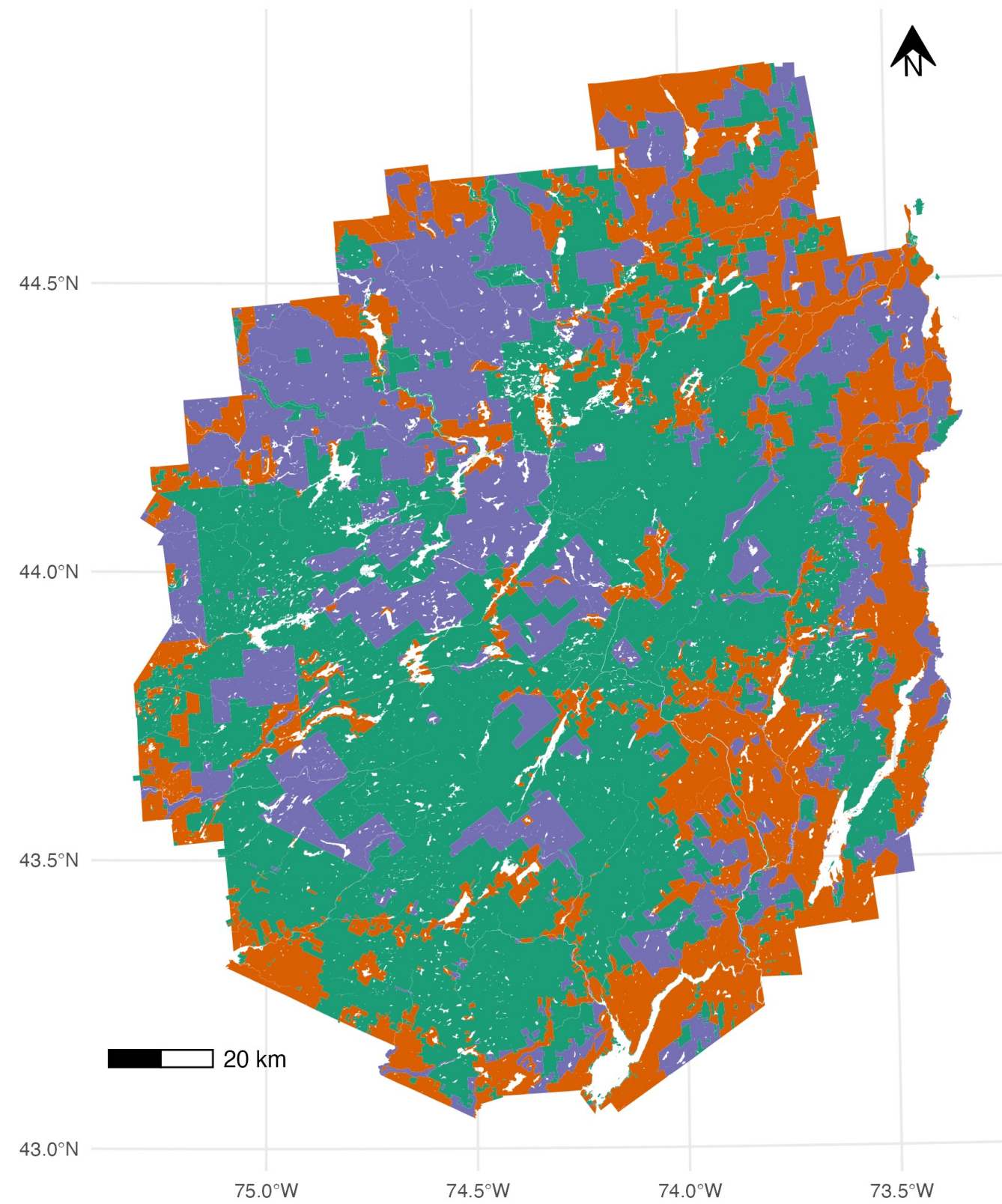


## Insights

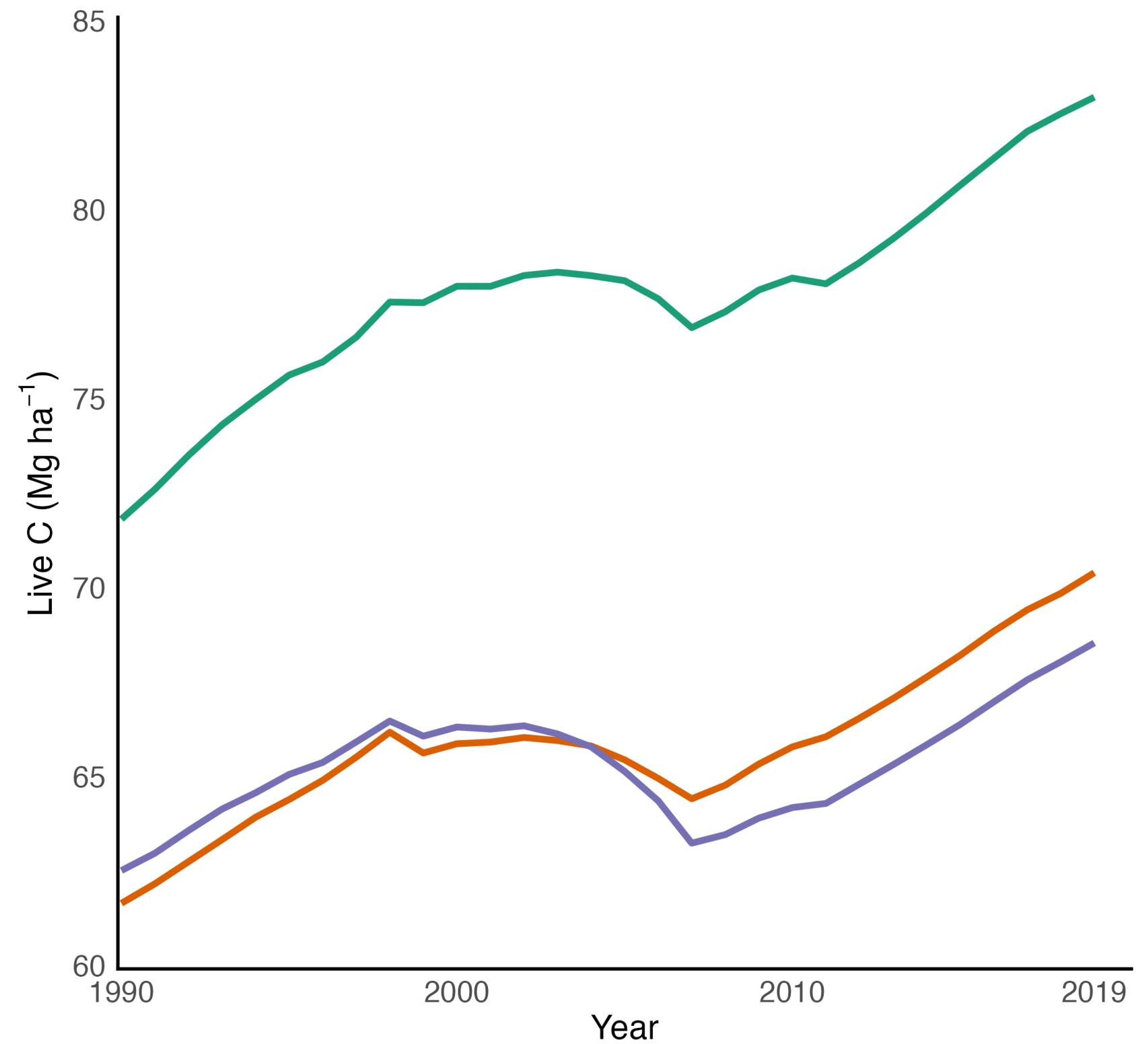
We reconstructed forest disturbance history and assessed trends across the Forest Preserve.

Contrary to expectations, we found no evidence of an intensifying disturbance regime, but observed decreasing frequency of canopy loss (based on annual % area disturbed) since 1990.





Parcel Category ■ Forest Preserve ■ Other Private ■ Resource Mgt.



Parcel Category — Forest Preserve — Other Private — Resource Mgt.

## Insights

On average, Forest Preserve lands have greater live C stocks than privately-owned ADK lands

Based on stock-changes, working and reserve lands across the ADK Park have very similar average rates of C sequestration (net CO<sub>2</sub> eq removals) over the last 15 years



# Thanks. Questions?

## Contributors

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## Partners

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The image shows the cover of a report titled 'NEW YORK FOREST CARBON ASSESSMENT SUMMARY REPORT'. The cover features a green background with a white central panel. At the top, the title is written in large, bold, green letters. Below the title, there is a section labeled 'SUMMARY REPORT' in black. The central part of the cover is dominated by a large, vibrant photograph of a forest canopy with sunlight filtering through the leaves. Above and below this photograph are several smaller maps and diagrams. The top row of maps shows 'Historical Stock-Change', 'Current Stocks', and 'MMRV & Forecasting' for the years 1990, 2000, 2010, 2020, 2030, 2040, and 2050. The bottom row of maps shows '2000 Use C', '2000 Use C', and '2000 Use C' with various legends and scales. At the bottom of the cover, the text 'CLIMATE & APPLIED FOREST RESEARCH INSTITUTE JUNE 2023' is centered. Below this, there are three logos: ESF (State University of New York College of Environmental Science and Forestry), CAFRI (Climate & Applied Forest Research Institute), and the New York State Department of Environmental Conservation.