South Atlantic Landscape Conservation Cooperative (SALCC) Workshop

Indicators and Biomonitoring

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Energy Flow in Forest Ecosystems

Radiant Energy to Chemical Energy
(fixed C = energy + building material)

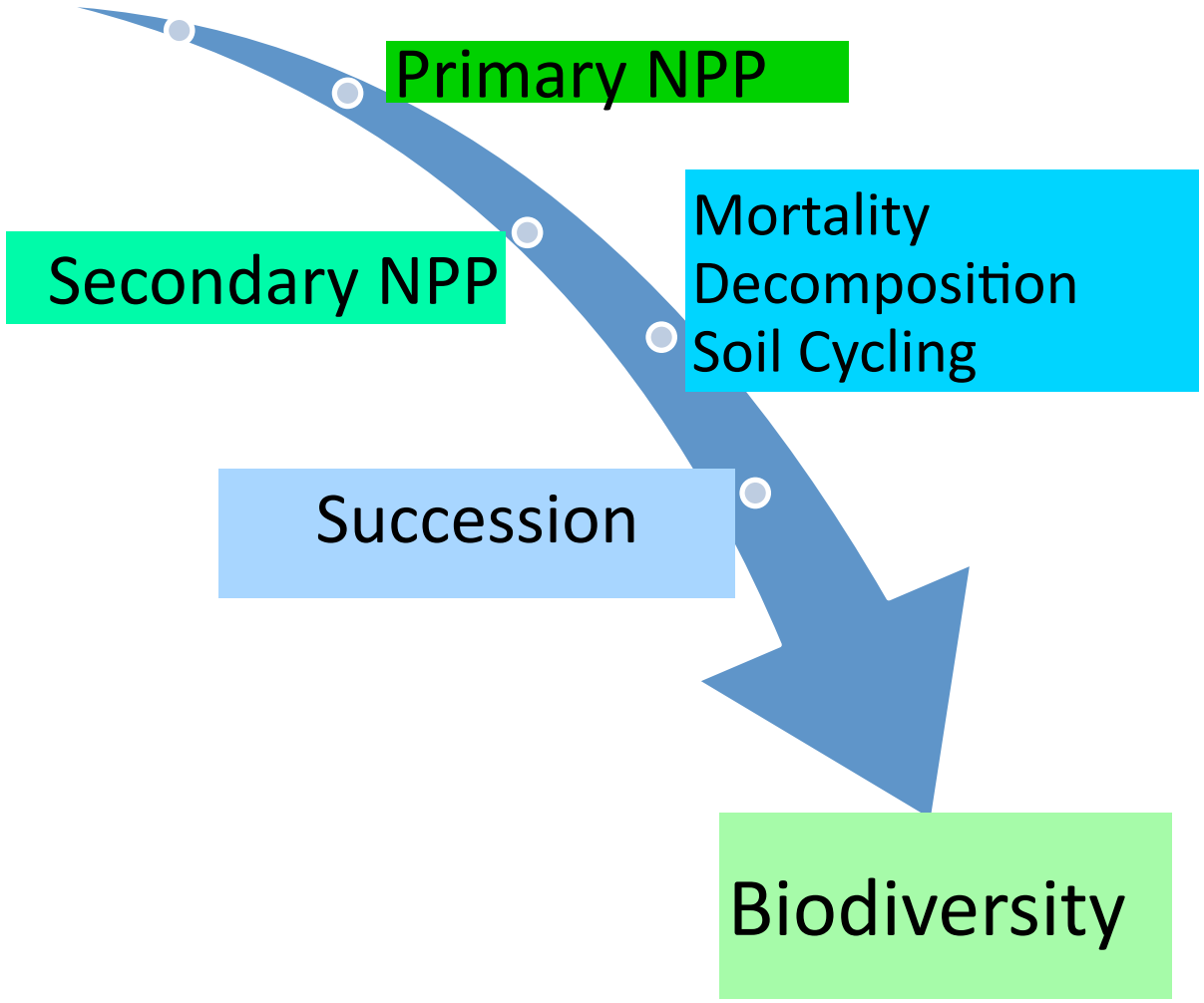


Table 3. Some of the anticipated effects of climate change induceddrought on various components of a forest ecosystem.

Climate change induced drought effects on ridge ecotones	**Strata**	**Type Change**	**Primary Effects**
Vascular Plants -trees -shrubs -herbs -vines -ferns & mosses	All	Increased mortality Decreased abundance Decreased species Decreased size Altered phenology	Biodiversity Productivity Fire regimes Habitat
Tree Growth	Seedling to overstory	Reduced photosynthesis	Productivity
Tree Mortality	Seedling to overstory	Increase volume & number	Habitat Fire risk
Tree Regeneration	Seedling & sapling	Decreased	Future structure and composition
Litter & Duff	Floor	Increase then decrease	Increased fire risk
DWD	3 classes	Increased DWD	Increased fire risk
Ozone Bioindicators	Seedling to overstory	Increase or decreased effects	Productivity
Native Insects & Pathogens	Native & Exotic	Increased activity & tree mortality	Biodiversity Productivity Fire risk
Exotic Invasive Plants	Increase	Replace native species	Biodiversity Fire risk

BASICS

- What data are needed and why??
- Focus on interpretability
- Population-based sample (unbiased sample)
- Indicators of nodal (key) processes
- Remove/reduce measurement error

Good Indicators

- Regional scale applicability
- Easily interpretable
- Logistically feasible
- High signal/noise ratio

GOOD INDICATOR of a BAD DISEASE…..
BLACK PLAGUE (*Yersinia pestis)*

Visible Symptoms on Victims:
Black Circles or Splotches

Black Splotches = *Yersinia pestis*

- Regional scale applicability: Most of Europe
- Easily interpretable: Symptoms = *Yersinia pestis*
- Logistically feasible: A quick glance by any citizen
- High signal/noise ratio: Symptoms were not other things

Why good indicator?
Black splotches caused by (directly linked) to Yersinia pestis

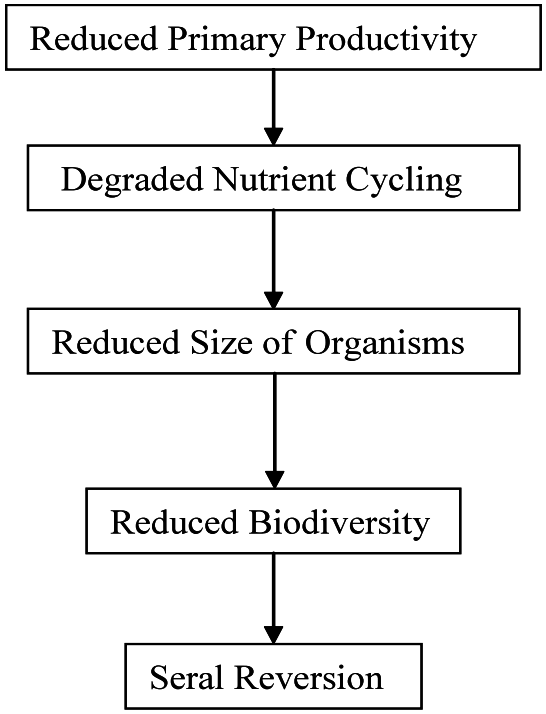
Effects on Ecosystems[1]	Key Ecological Processes[2]	Indicators of Processes[3]	Metrics[4]
Reduced Primary Productivity	Photosynthesis; Assimilation, Respiration	Crown Condition	Foliar Transparency & Dieback
Degraded Nutrient Cycling	Decomposition; Oxidation and Reduction; Mineralization	Soil pH; cations; SOM; DWD	pH; nutrient cations; CWD & FWD
Reduce Size of Organisms	Carbon Storage; Carbon Allocation; Mortality; Regeneration	Growth; Cover	Tree dbh & height ; understory veg. cover
Seral Reversion	Succession	Stand composition & structure; seedling & sapling composition & number	Tree & Understory diversity; vertical structure; seedling & sapling species & number
Reduced Species Diversity	Community survival; maintenance of processes; structural diversity	Species richness & Abundance	No. & abundance of tree, understory, and lichen species

[1] From Rapport, D. J., H. A. Regier, and T. C. Hutchinson. 1985. Ecosystem behavior under stress. American Naturalist. 125:617-640.

[2] Processes are hierarchal and therefore higher order effects also include processes at all lower levels

[3] Indicators currently implemented at national or multi-regional scales by FIA

[4] Specific measurements within Process Indicators



Hierarchical relationships of five common effects of any stressor on any ecosystem (Hutchinson and others)

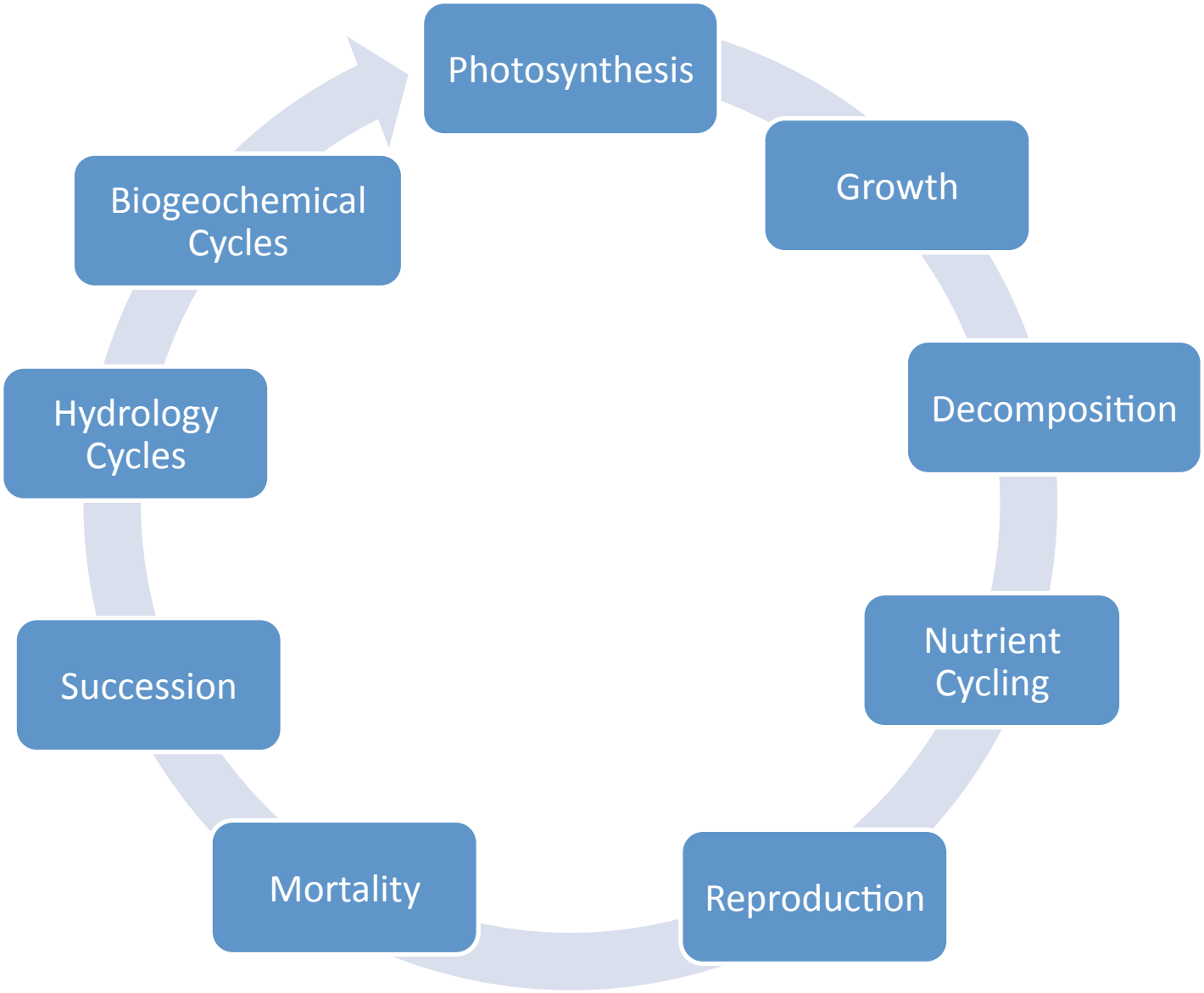
ECOLOGICAL PROCESS NODES

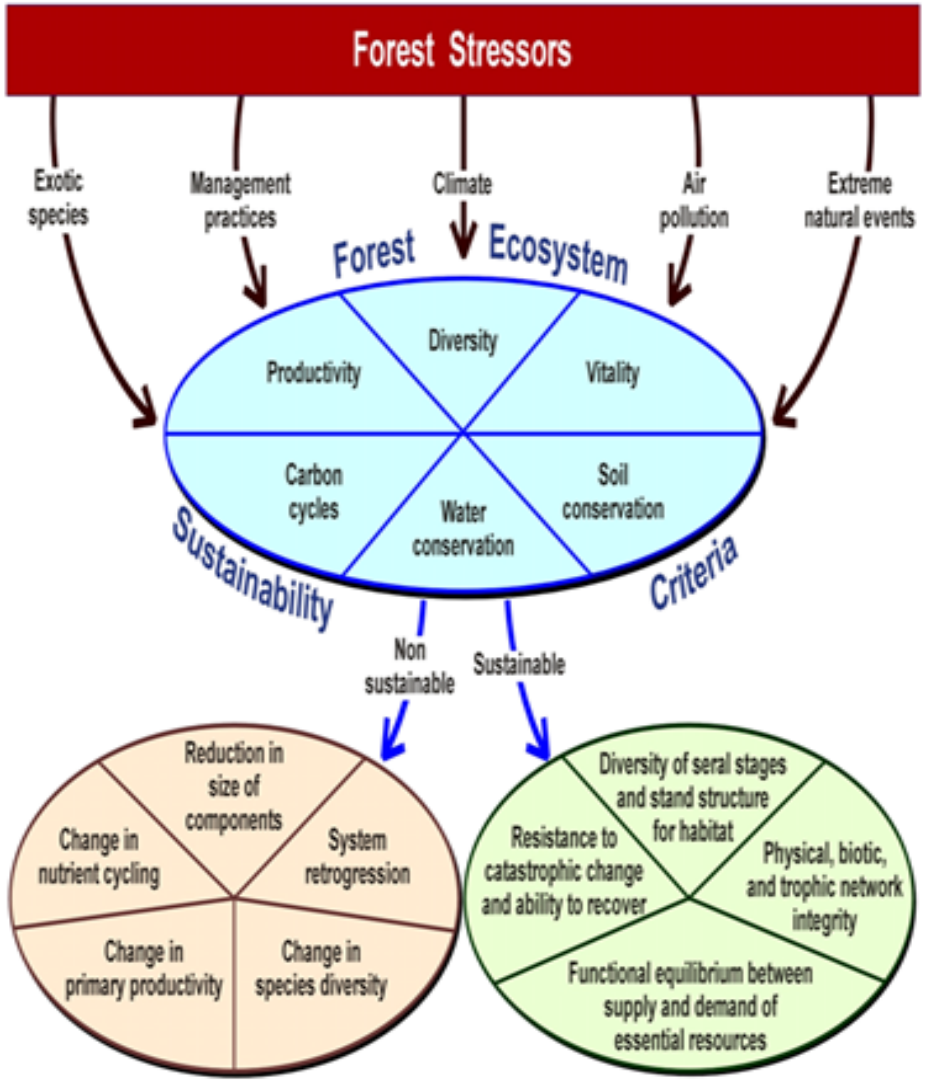
POINT OF MEASUREMENT OF UNDERLYING ECOLOGICAL PROCESSES

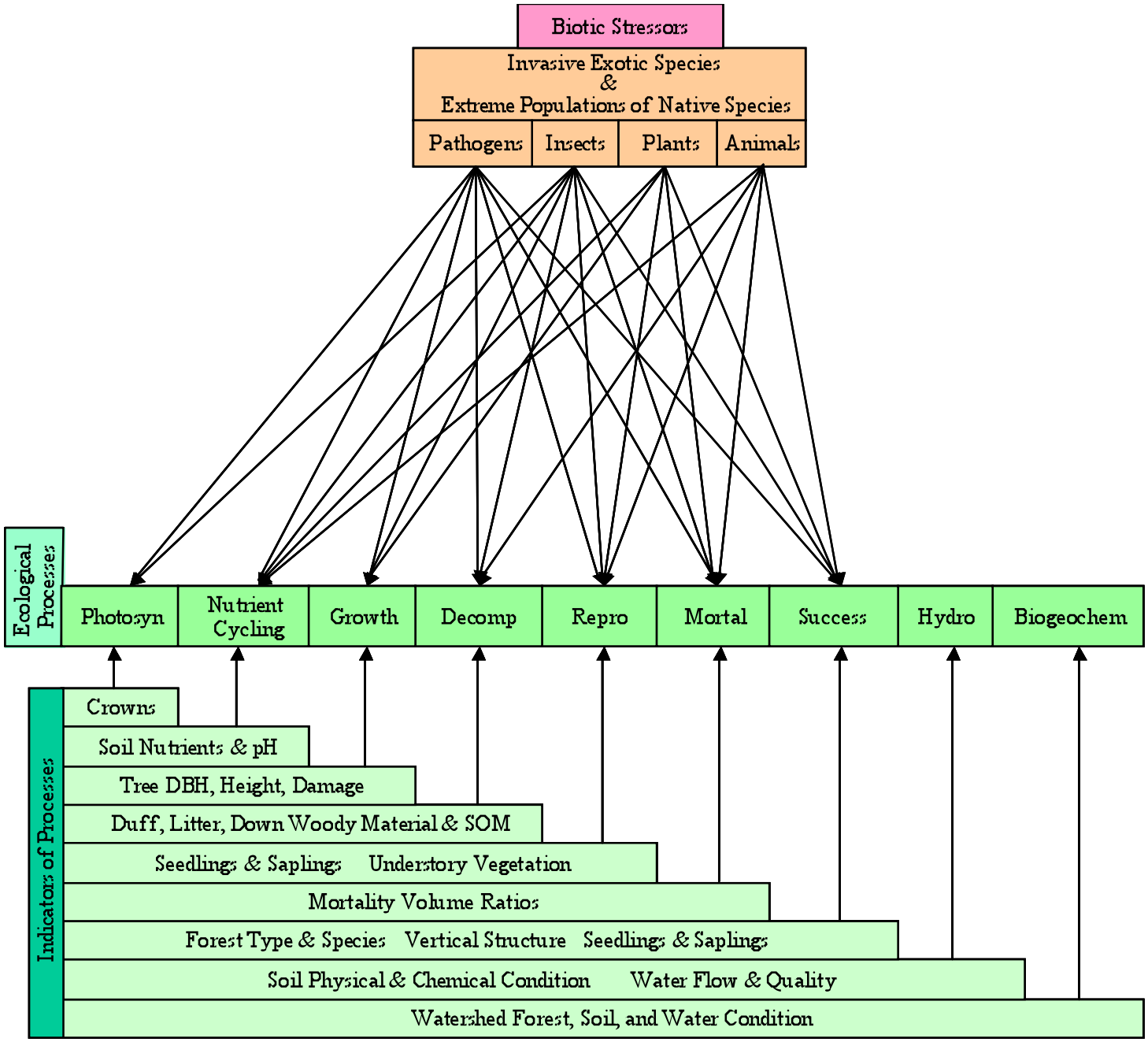
GROWTH = photosynthesis, transport, nutrient cycling, damage repair, etc.

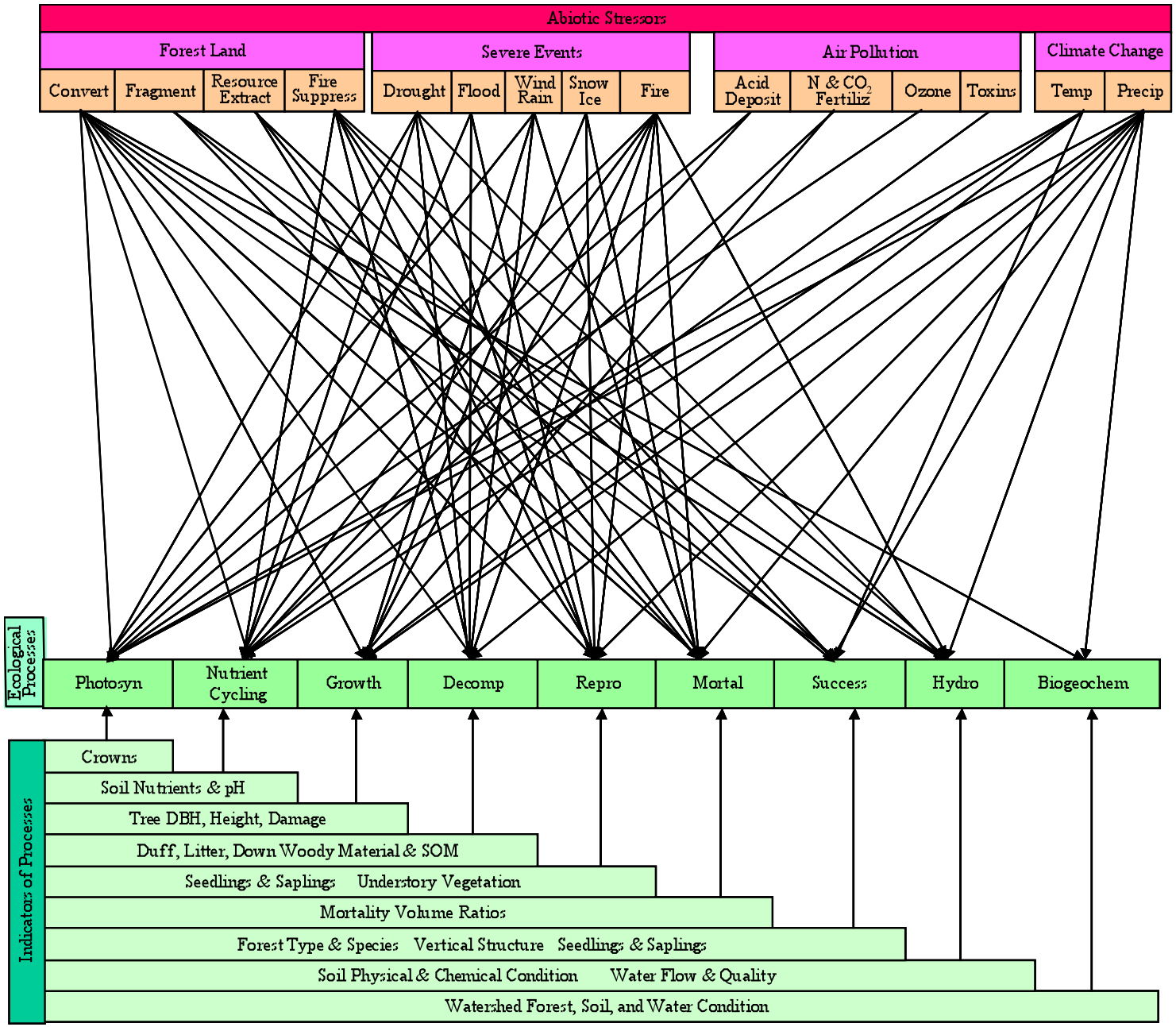
- Difficult to measure photosynthesis, transport, nutrient cycling, damage repair
- Tree growth measured as tree height and diameter (tree volume)

Nodal Ecological Processes




Forest Stressors
Exotic species
Management practices
Climate
Air pollution
Extreme natural events
Forest Ecosystem
Productivity
Diversity
Vitality
Carbon cycles
Water conservation
Soil conservation
Sustainability
Criteria
Non sustainable
Sustainable
Reduction in size of components
Change in nutrient cycling
System retrogression
Change in primary productivity
Change in species diversity
Diversity of seral stages and stand structure for habitat
Resistance to catastrophic change and ability to recover
Physical, biotic, and trophic network integrity
Functional equilibrium between supply and demand of essential resources


Biotic Stressors
Invasive Exotic Species
&
Extreme Populations of Native Species
Pathogens
Insects
Plants
Animals
Ecological Processes
Photosyn
Nutrient Cycling
Growth
Decomp
Repro
Mortal
Success
Hydro
Biogeochem
Indicators of Processes
Crowns
Soil Nutrients & pH
Tree DBH, Height, Damage
Duff, Litter, Down Woody Material & SOM
Seedlings & Saplings
Understory Vegetation
Mortality Volume Ratios
Forest Type & Species
Vertical Structure
Seedlings & Saplings
Soil Physical & Chemical Condition
Water Flow & Quality
Watershed Forest, Soil, and Water Condition


Abiotic Stressors
Forest Land
Convert
Fragment
Resource Extract
Fire Suppress
Severe Events
Drought
Flood
Wind Rain
Snow Ice
Fire
Air Pollution
Acid Deposit
N & CO_2 Fertiliz
Ozone
Toxins
Climate Change
Temp
Precip
Ecological Processes
Photosyn
Nutrient Cycling
Growth
Decomp
Repro
Mortal
Success
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Seedlings & Saplings Understory Vegetation
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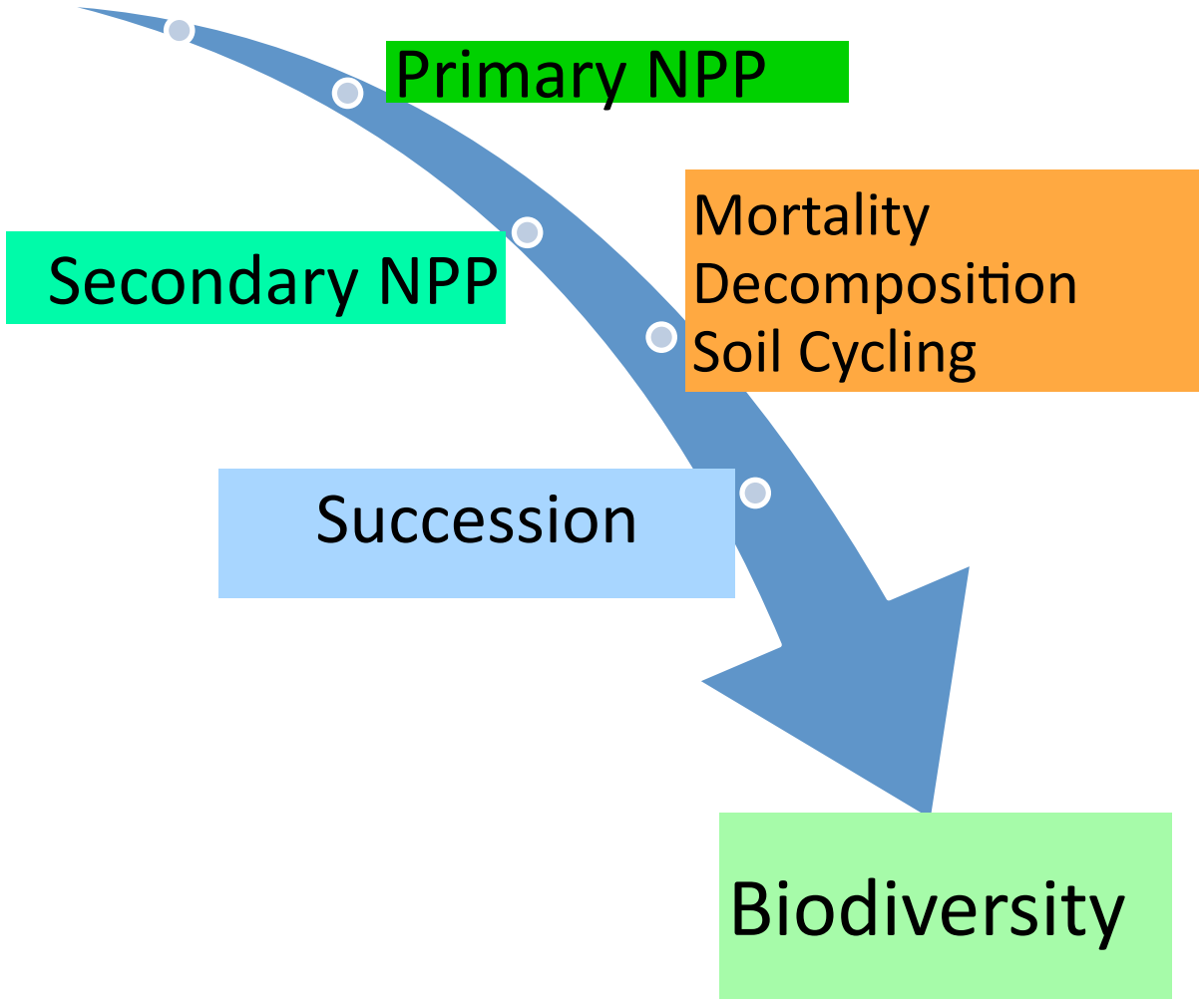
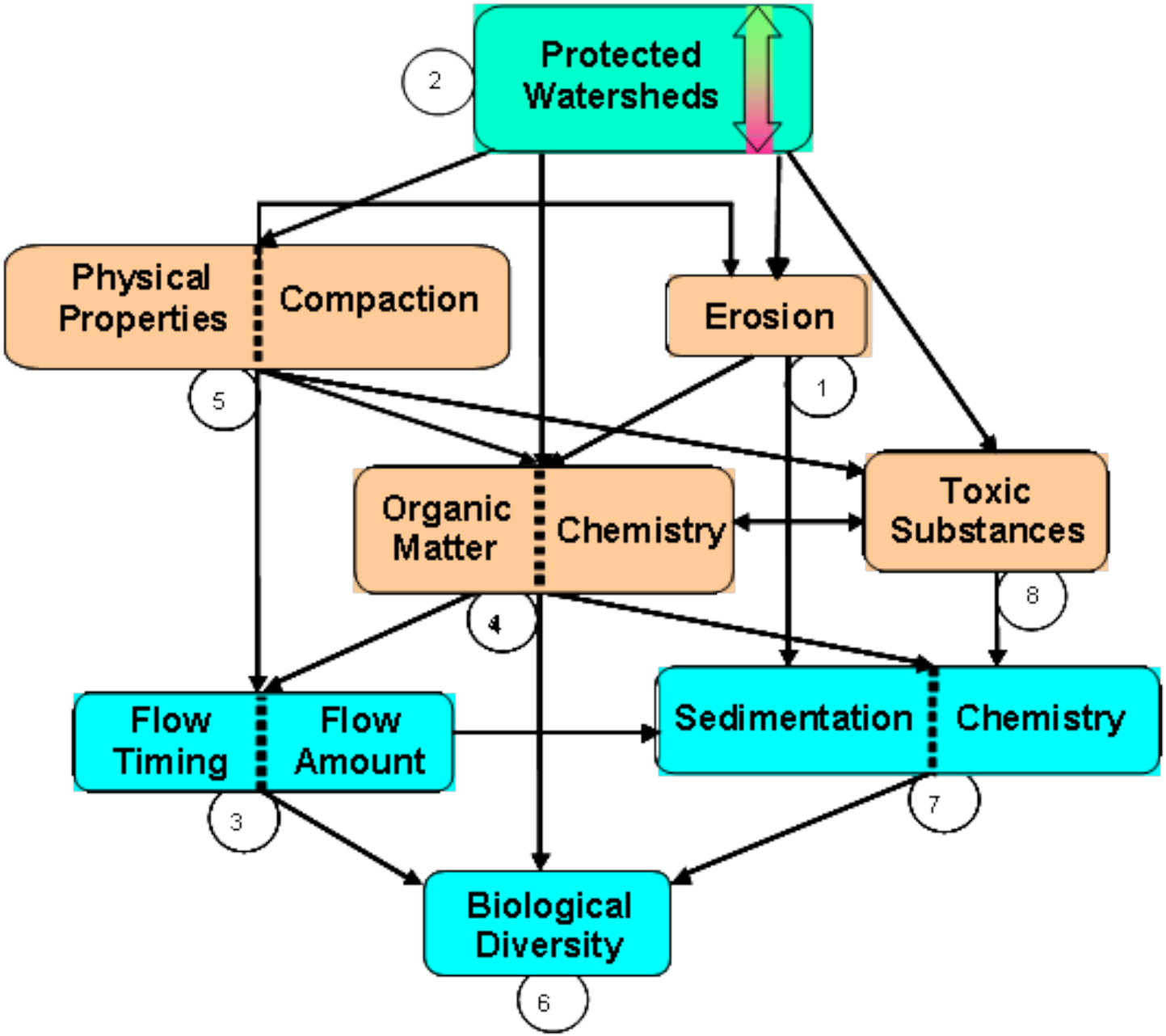
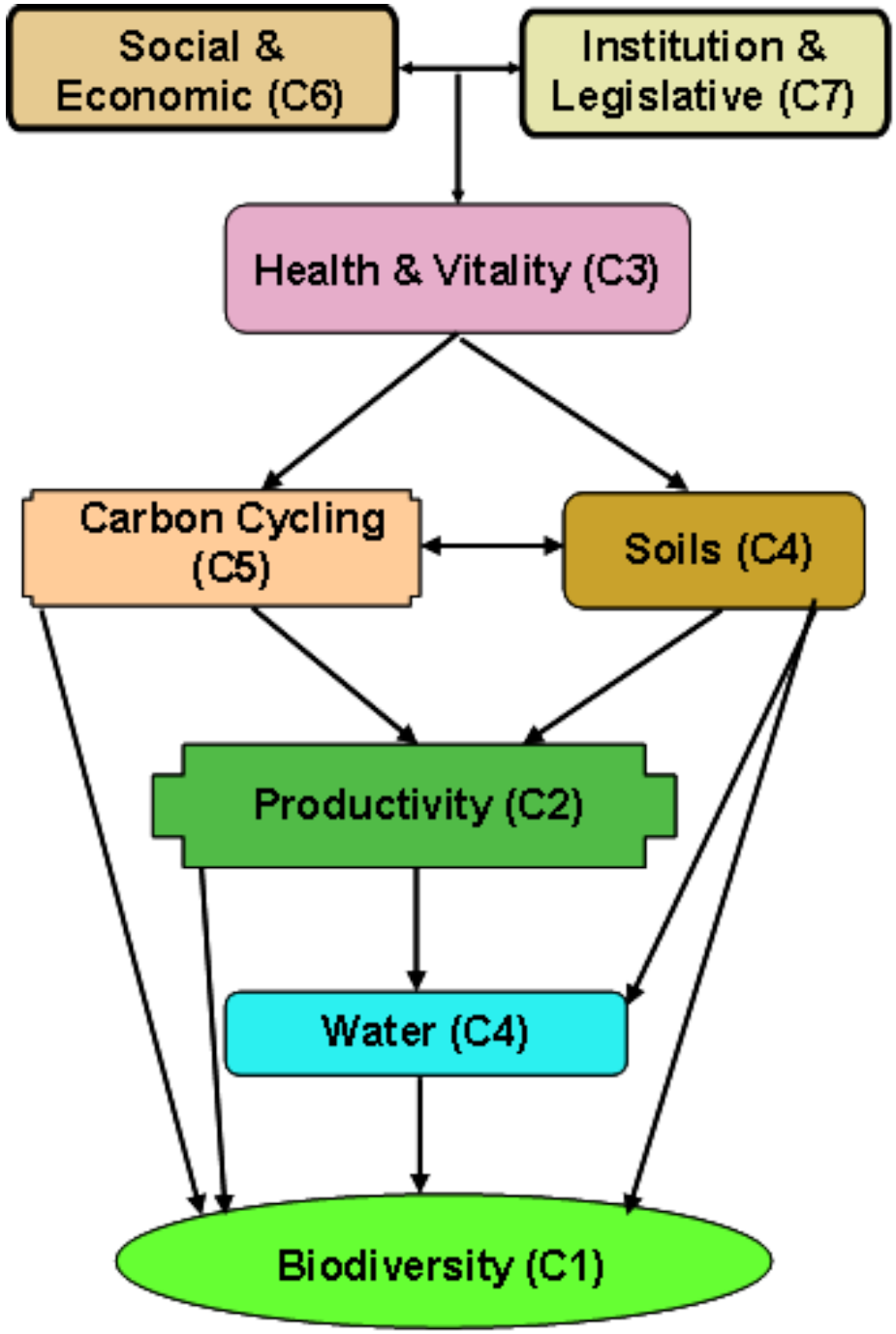
Forest Type & Species Vertical Structure Seedlings & Saplings
Soil Physical & Chemical Condition Water Flow & Quality
Watershed Forest, Soil, and Water Condition

Energy Flow in Forest Ecosystems

Radiant Energy to Chemical Energy
(fixed C = energy + building material)




Protected Watersheds
2
Physical Properties
Compaction
Erosion
5
1
Organic Matter
Chemistry
Toxic Substances
8
4
Flow Timing
Flow Amount
Sedimentation
Chemistry
3
7
Biological Diversity
6


Social & Economic (C6)
Institution & Legislative (C7)
Health & Vitality (C3)
Carbon Cycling (C5)
Soils (C4)
Productivity (C2)
Water (C4)
Biodiversity (C1)

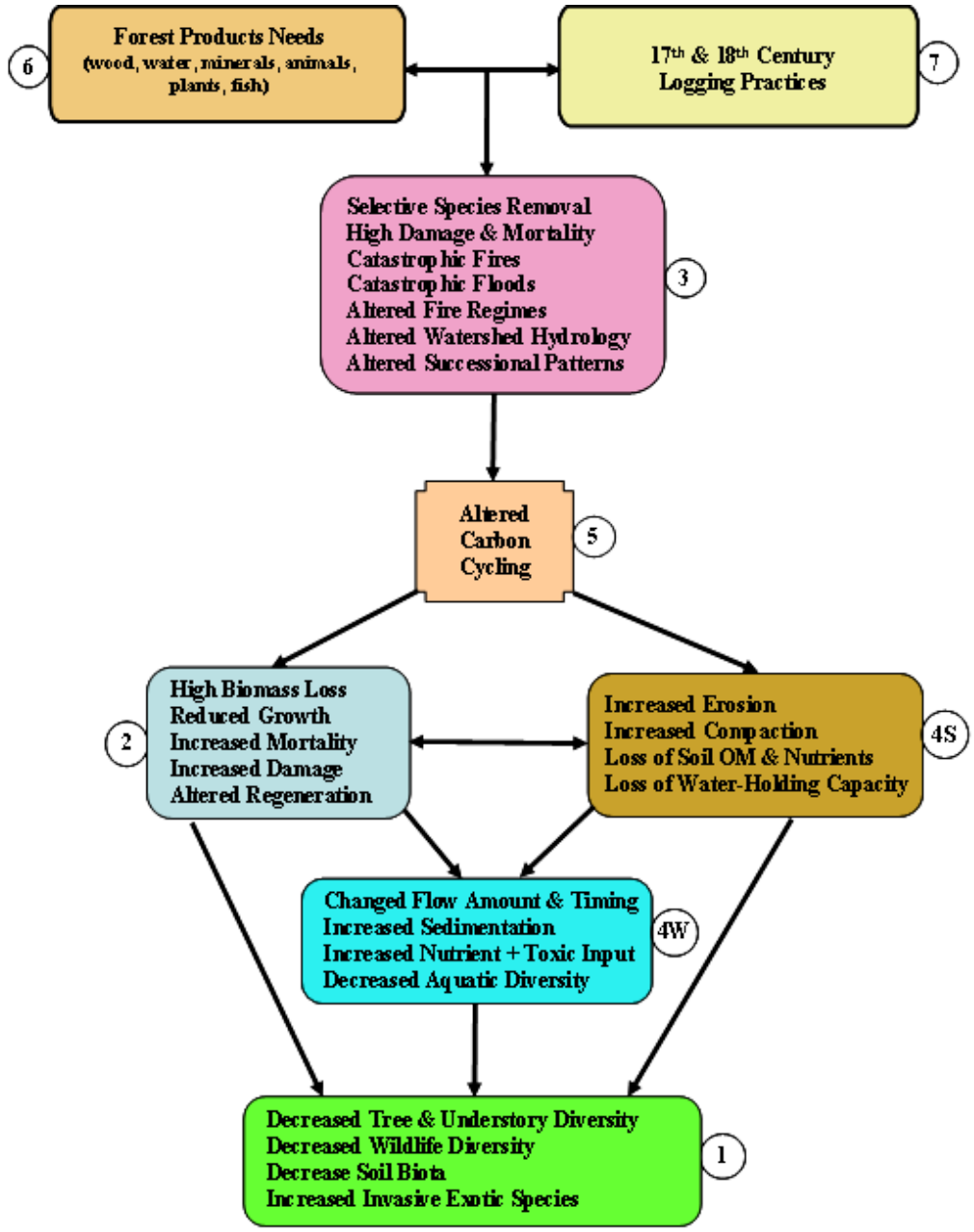
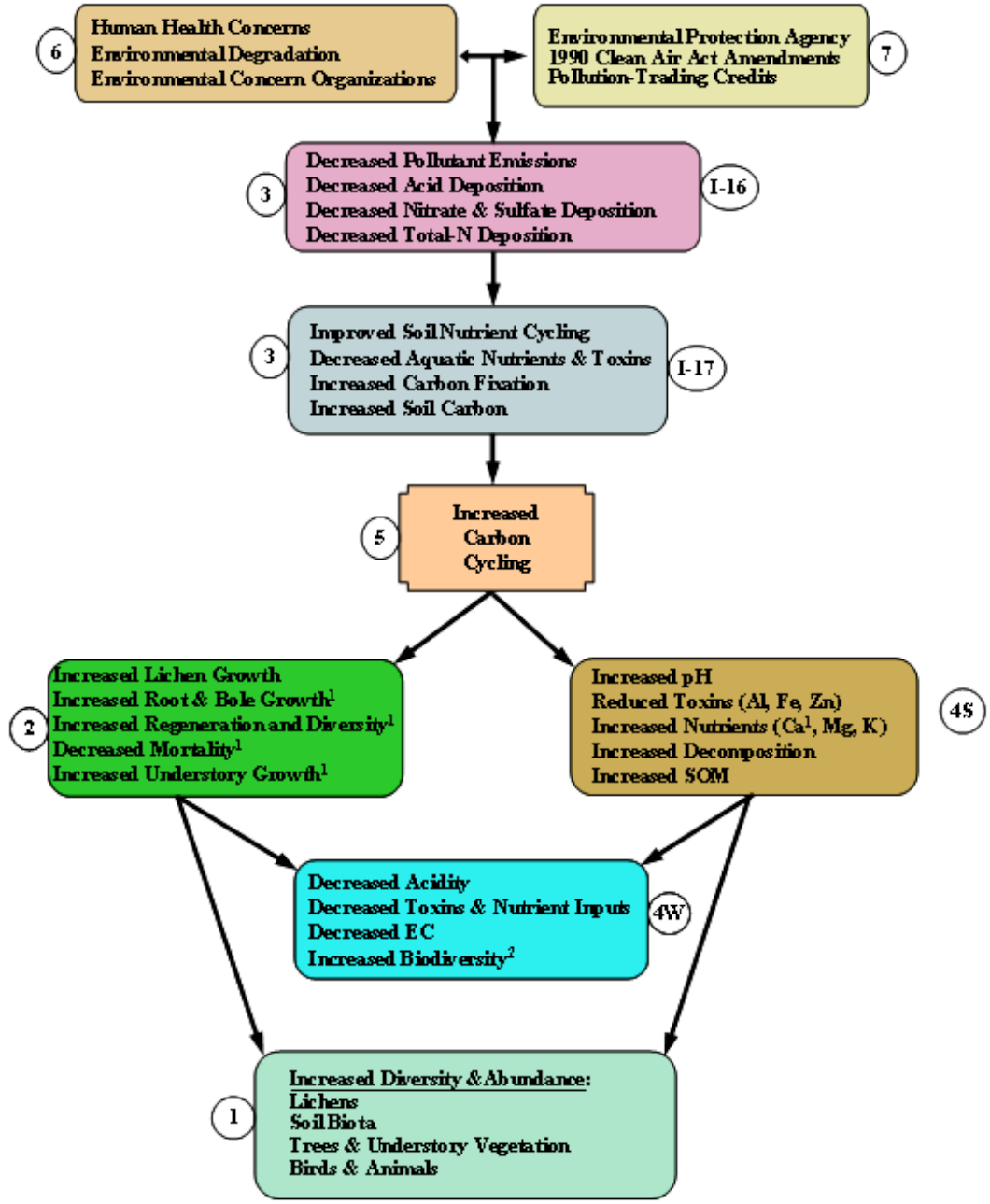


Figure 5. An example of the functioning of the MPCI conceptual models showing relationships between categories of biotic stressors that negatively affect forest ecosystems at large, landscape scales, primary, initial effects on forest ecosystem processes, and process-indicators that can be monitored at landscape-scales. There



[1]Expected improvements after mineralization-processes replaces soil calcium

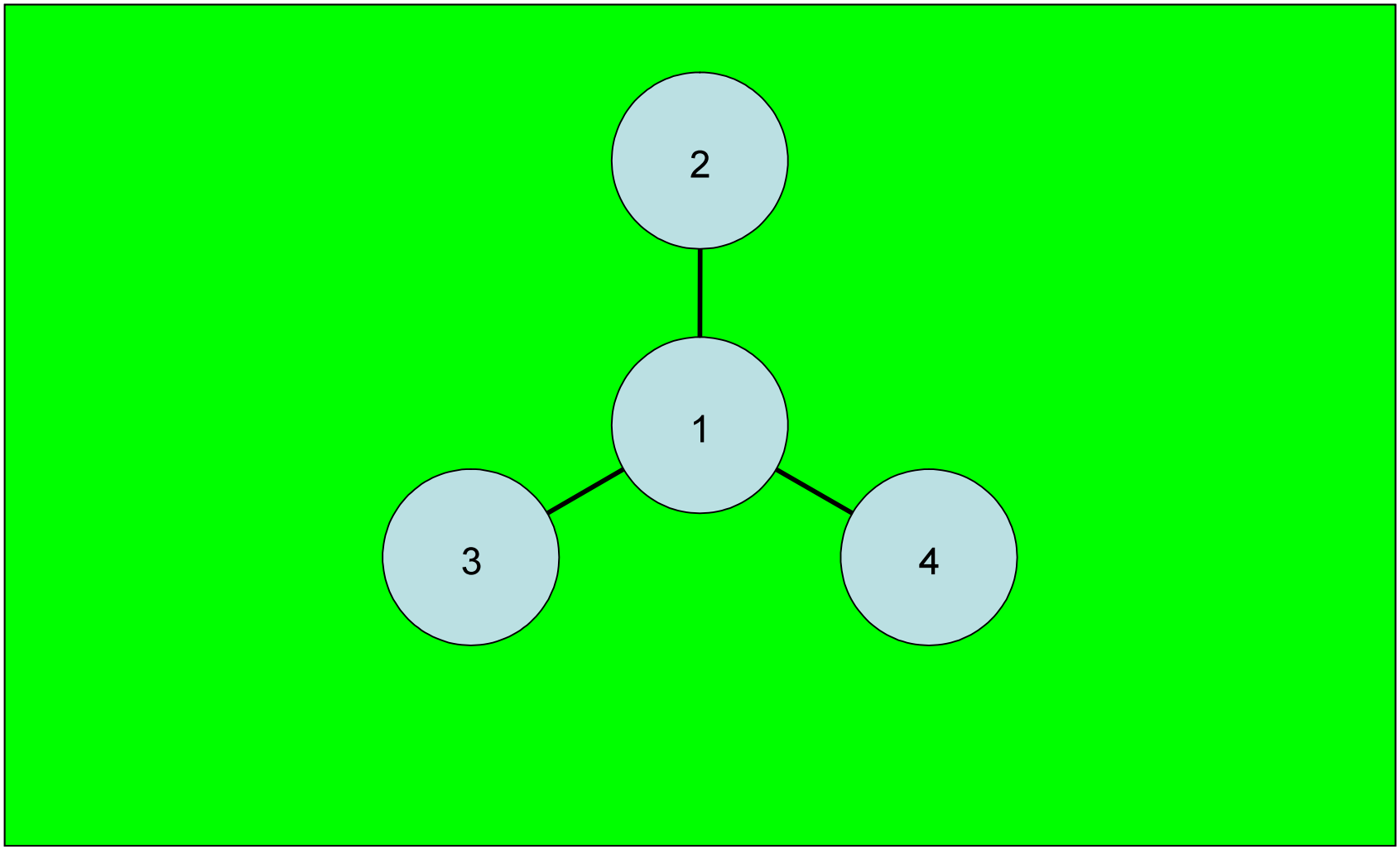
Figure 6. An example of the functioning of the MPCI conceptual model showing relationships between categories of abiotic stressors that negatively affect forest ecosystems at large, landscape scales, the primary, initial effects on forest ecosystem processes, and process indicators that can be monitored at landscape scales. There

FIA Plots and TOPS

- Links between clusters of FIA plots and TOPS data
- Analysis at multiple spatial scales
  - Ecoregion sections and subsections
  - HUC10 watersheds
  - County

- About 4000 forested plots in HUC10
- About 88,000 trees
- Broad suite of FIA data

The Forest Health Monitoring (FHM) and Forest Inventory & Analysis (FIA) 4-Point Fixed-Area Plot Design



Species: all species, all conifers, all hardwoods, all forest types; 10 most common sp; 10 highest values sp; 10 lowest values sp.; 10 special species (e.g., hemlock, butternut, dogwood, others)				
FIA Data	**Component**		**Attributes of Interest**	**MPCI**
Plot numbers & conditions	Plot tally		total plots	C1
			forested plots	C1
			non-forested plots	C1
			forested & partial forested	C1
			non-sampled plots	C1
			area covered	C1
	Physical environment		Slope	
			Elevation	
			Aspect	
			physical disturbances	C3
			site index	C2
	Biological environment		forest type	C1
			forest condition class	C1
			stand size	C1
			structural stage	C1
			biological disturbances	C3
	Management environment		Ownership, type of use, etc.	C6
			Reserved Status class	C7
			Ownership Group class	C6
			Plot Disturbance/No disturb	C3
Trees	Productivity		Live Basal Area (proportion unadjusted)	C2
			Growth Rate	C2
			Average net annual growth	C2
				C2
			Forest stand volume	C2
			Forest stand density	C2
			Forest stand age	C2
	Regeneration		Number seedlings: (is regen at plot sufficient to maintain species in stand?)	C1
	Mortality		Volume of trees dead; MRATIO=mortality vol/net growth vol; DDLD= live dbh/dead dbh; cause of mortality when known	C3
			Snags by Size Class–Number&percent between: 1. 5-30 cm and >30cm; 2. 1-5; 5-12; 12-15; > 15 in	C1
	Diversity		Number and abundance of tree species	C1
			Invasive Species –Non-native tree species type and number	C1
			Tree genera --number and area covered	C1
			Forest types--number and area covered	C1
			Structural diversity	C1
	Plot and subplot conditions; disturbances, etc.		Physical description; micro-habitat differences; land-use; history;	C3

			Snags by Size Class– Number&percent between: 1. 5-30 cm and >30cm; 2. 1-5; 5-12; 12-15; > 15 in	C1
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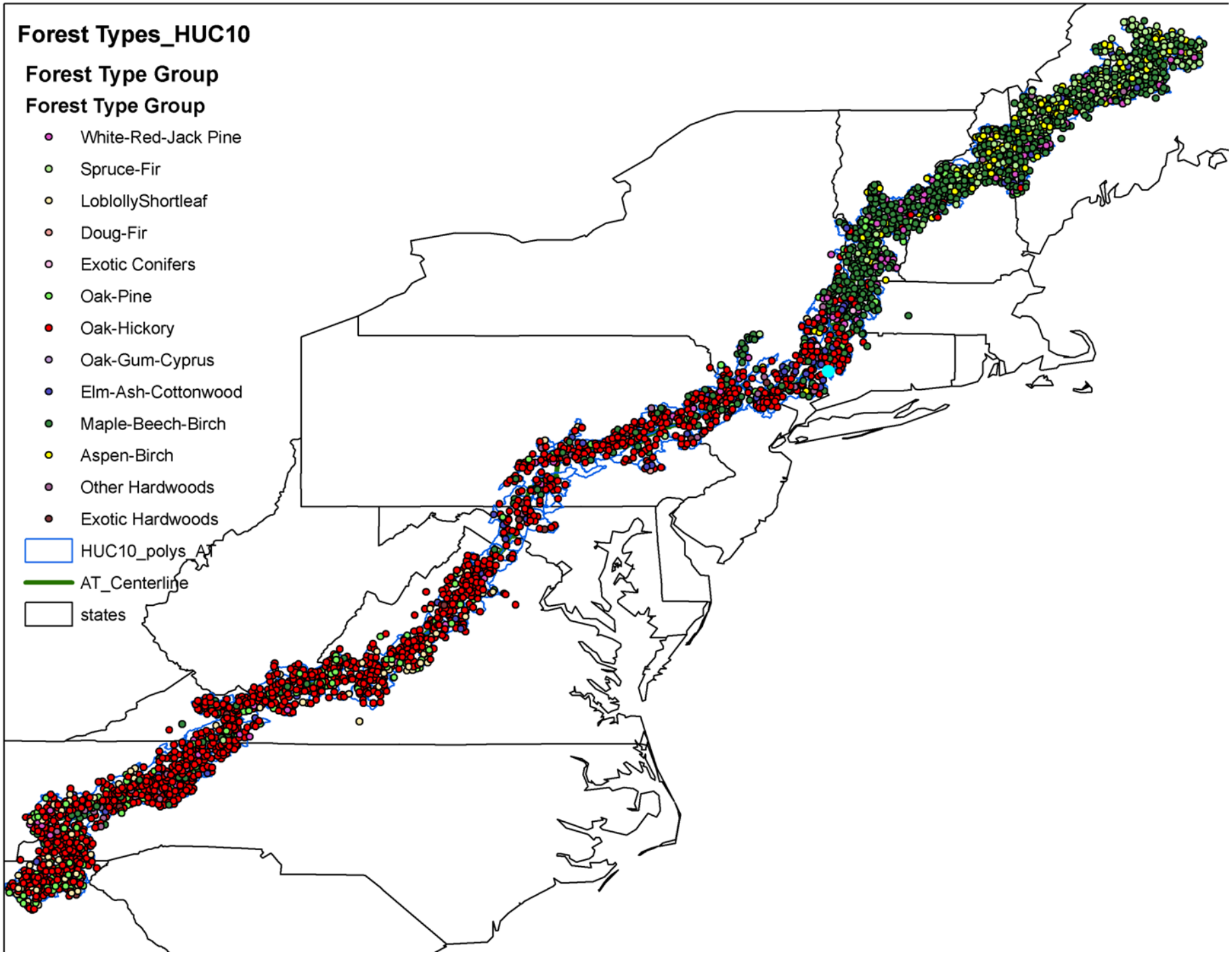
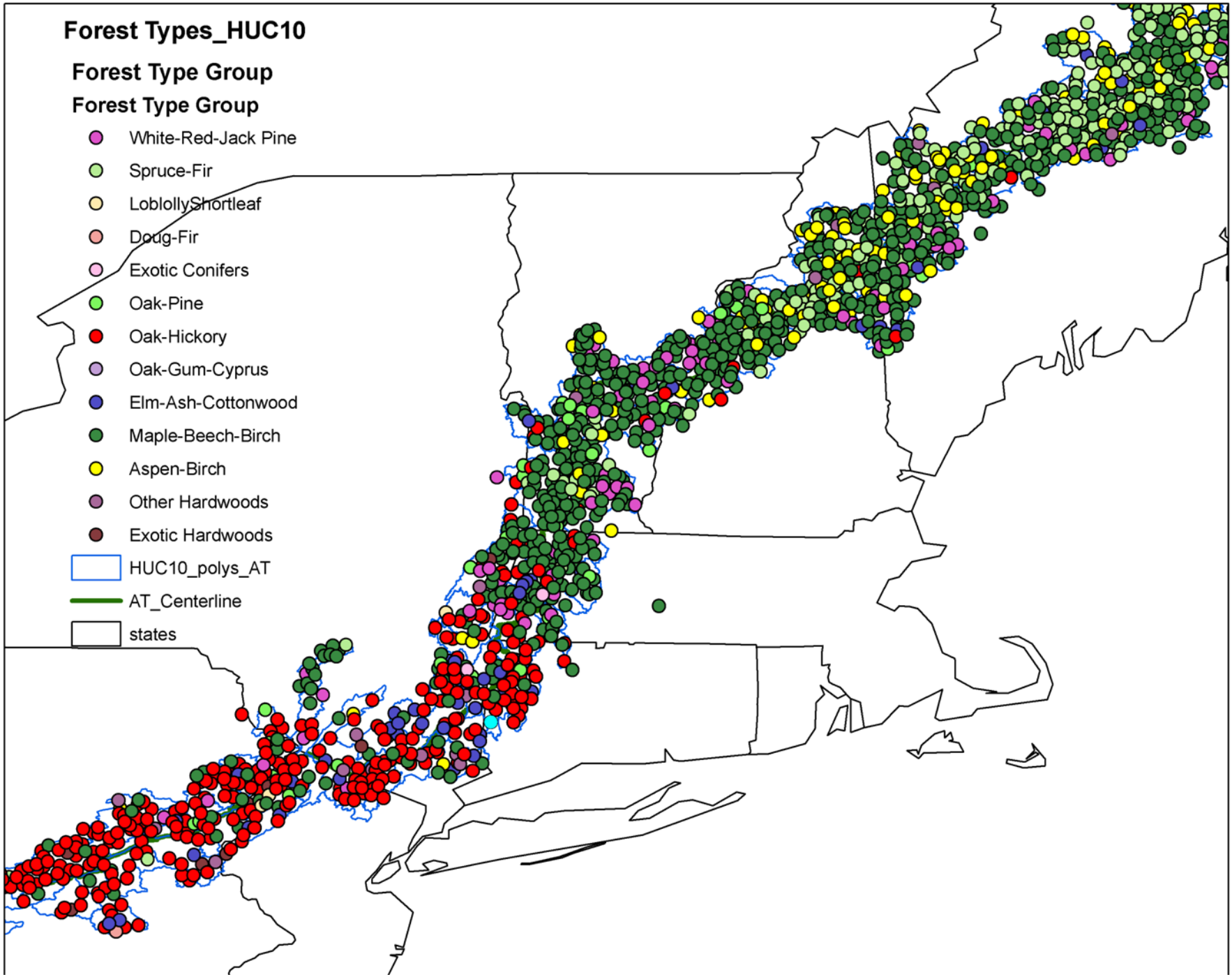
			Tree genera --number and area covered	C1
			Forest types--number and area covered	C1
			Structural diversity	C1
	Plot and subplot conditions; disturbances, etc.		Physical description; micro-habitat differences; land-use; history;	C3
	Significant tree damage(s) = damage type, location, and severity-- I will calculate Damage Index)		Damage to roots, bole, crown; (all species; conifers; hardwoods)	C3
			Tree Damage: species, number, and percent	C3
Crowns	Ratio		Crown ratio	C1,C2
	Density		Crown density	C1,C2
	Diameter		Measured or estimated	C1,C2
	Dieback		Indicator of stress--loss of vigor	C3
	Transparency		Indicator of stress--loss of photosyn. Base	C3
	Crown Indices		Volume, structure, others (KaDonna Randolph)	C1,C2
	Canopy Density		Percent sunlight trough all trees above subplot (crowns, boles, branches, seeds, etc)	C1,C2
Soils	Nutrients		Soil Chemistry C/N	C4
			Soil Chemistry Al/Ca	C4
	Acidity (pH)		Hydrogen ion concentration	C2,C3,C4
	Toxins		Toxins: Al, Fe, Pb, Zn, Cu, others	C2,C3,C4
	Organic Matter & physical properties		Amount SOM; type of soil (clay, loam, sand)	
	Erosion		Soil cover; Slope & Run; Rainfall; Soil factors; MUSLE	

	Toxins		Toxins: Al, Fe, Pb, Zn, Cu, others	C2,C3,C4
	Organic Matter & physical properties		Amount SOM; type of soil (clay, loam, sand)	
	Erosion		Soil cover; Slope & Run; Rainfall; Soil factors; MUSLE and WEPP models;	
	Compaction		Visual Symptoms (structure and trails, etc.); Penetrability; depth to hardpan	
Lichens	Diversity		Species richness and abundance	
	Air quality		Type and abundance of N and S sensitive lichen species; AQ score	
	Climate Change		Type and abundance of temperature and moisture sensitive lichen species; climate score	
O3 Bioindicator	Ozone impacts		Incidence and severity of foliar ozone injury on known O_3 susceptible species	
Understory Veg Diversity	Diversity, abundance, & structure of understory plants; phenological stage		Species richness and cover by vertical strata of understory plants; ground cover.	
			Invasive Species – Type and abundance of non-native tree species	
Down Woody Material	Type, condition and abundance of downed wood		CWD – Coarse woody debris	
			FWD - Fine woody debris	
Fuel Loading & Fire Risk	Amount, distribution, & condition		Mensuration, veg. structure, downed wood, height of liove and dead herbs, grasses, shrubs, slash,; PDSI; slope, etc.(Basic data to run fuel loading/fire risk models)	
Stressors	Air Pollution		Ozone, N-dep., dep. Ph (EPA; NADP)	
	Historic fire regimes		Change in historic fire regimes	
	Insects		Native (FHP)	
			Exotic (FHP)	
	Pathogens		Native (FHP)	
			Exotic (FHP)	
	Storms		Wind, snow, ice (TOPS, NOAA)	
	Climate Change		T, ppt (ecoregions and plot clusters)	
	Land use change		Urban, Ag (crops/pasture), forest, water (NRI)	


Forest Types_HUC10
Forest Type Group
Forest Type Group
White-Red-Jack Pine
Spruce-Fir
LoblollyShortleaf
Doug-Fir
Exotic Conifers
Oak-Pine
Oak-Hickory
Oak-Gum-Cyprus
Elm-Ash-Cottonwood
Maple-Beech-Birch
Aspen-Birch
Other Hardwoods
Exotic Hardwoods
HUC10_polys_AT
AT_Centerline
states


Forest Types_HUC10
Forest Type Group
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LoblollyShortleaf
Doug-Fir
Exotic Conifers
Oak-Pine
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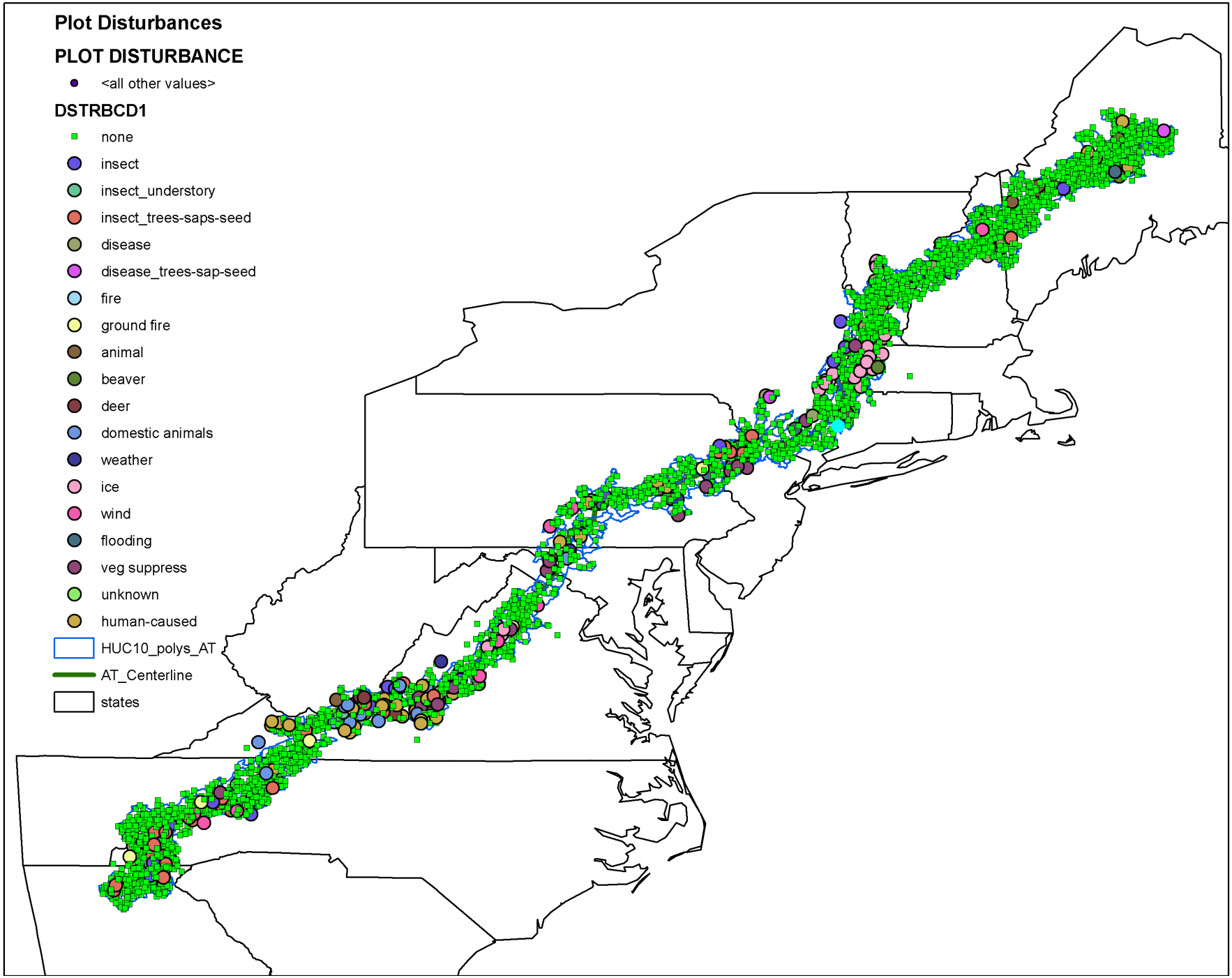
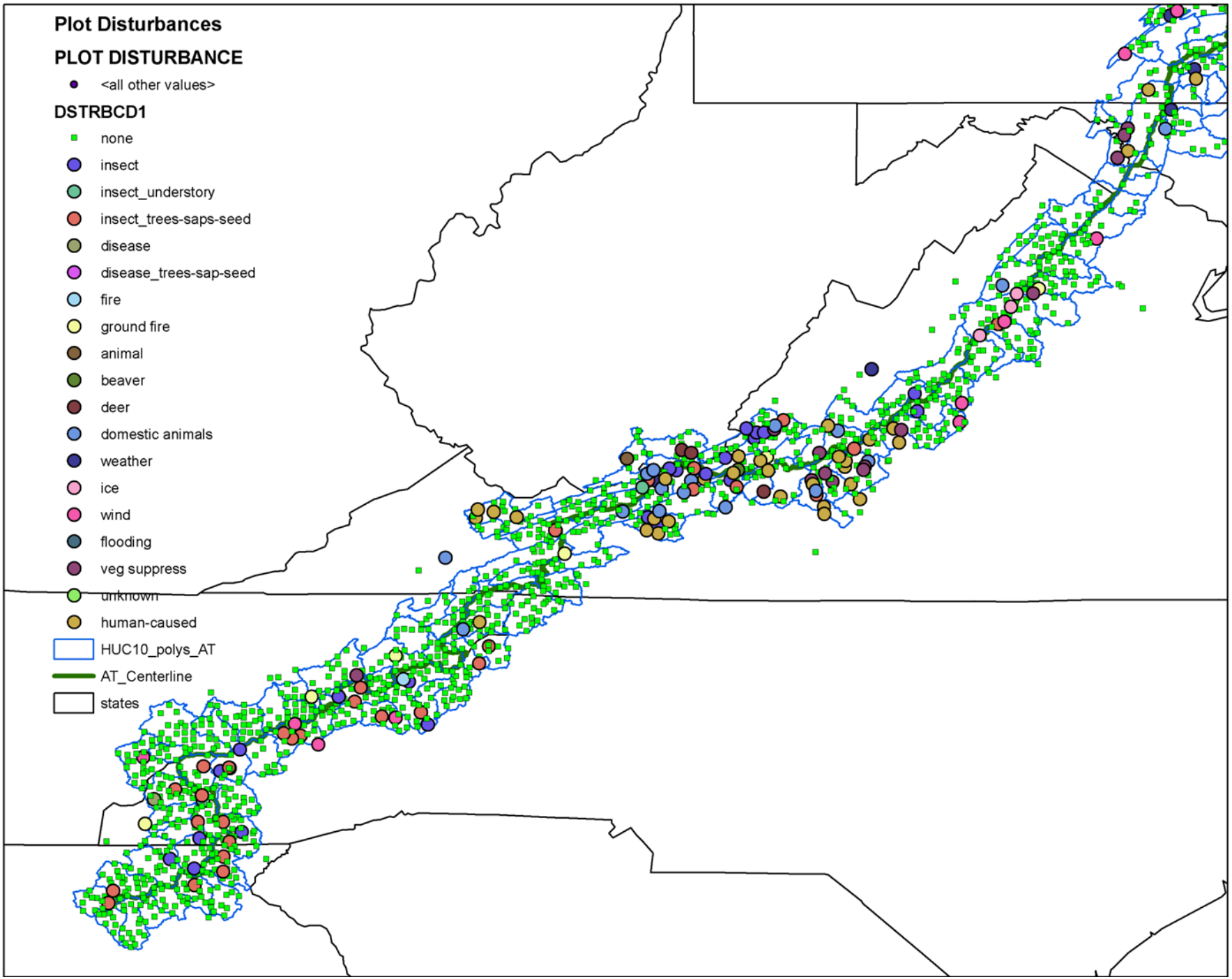
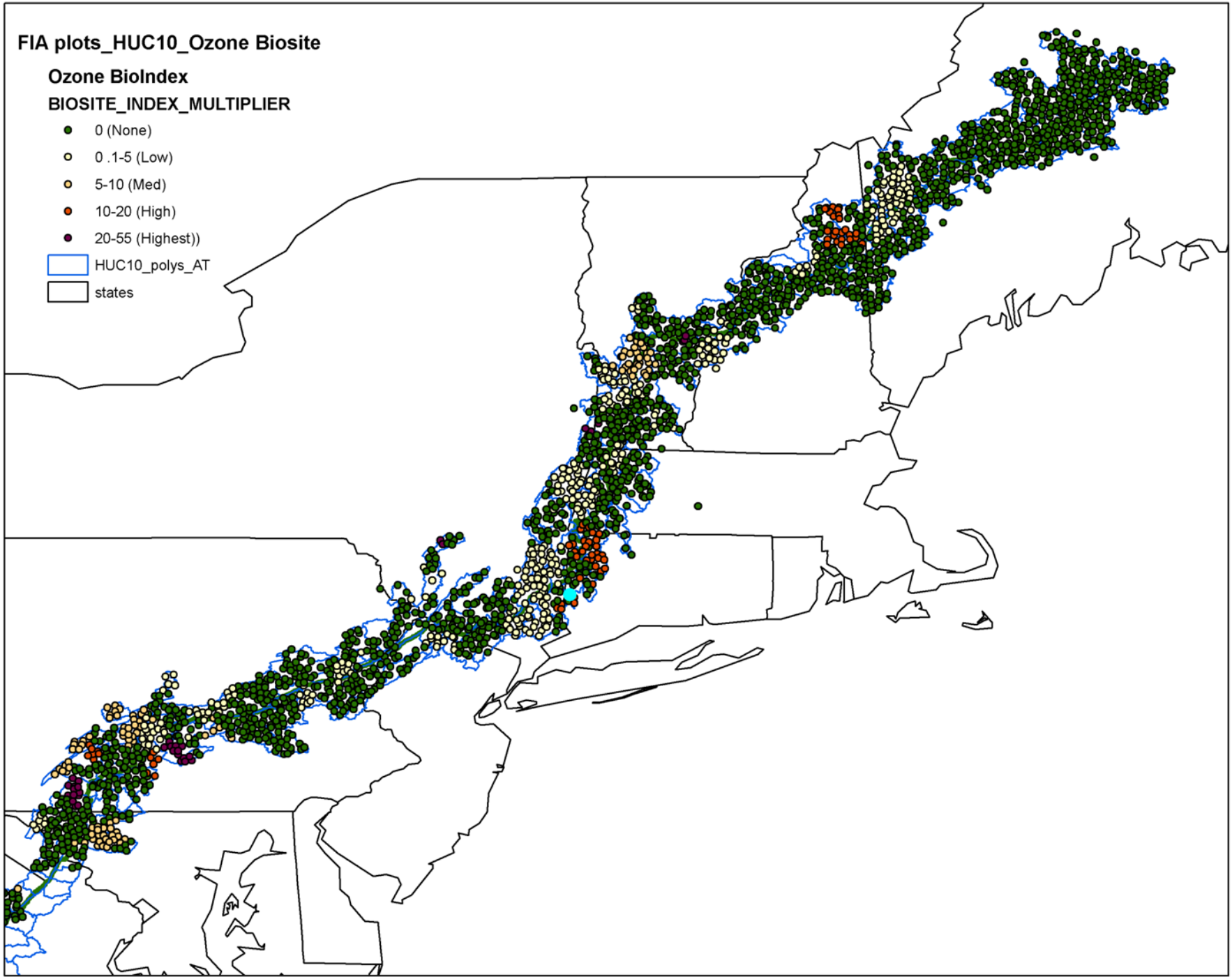
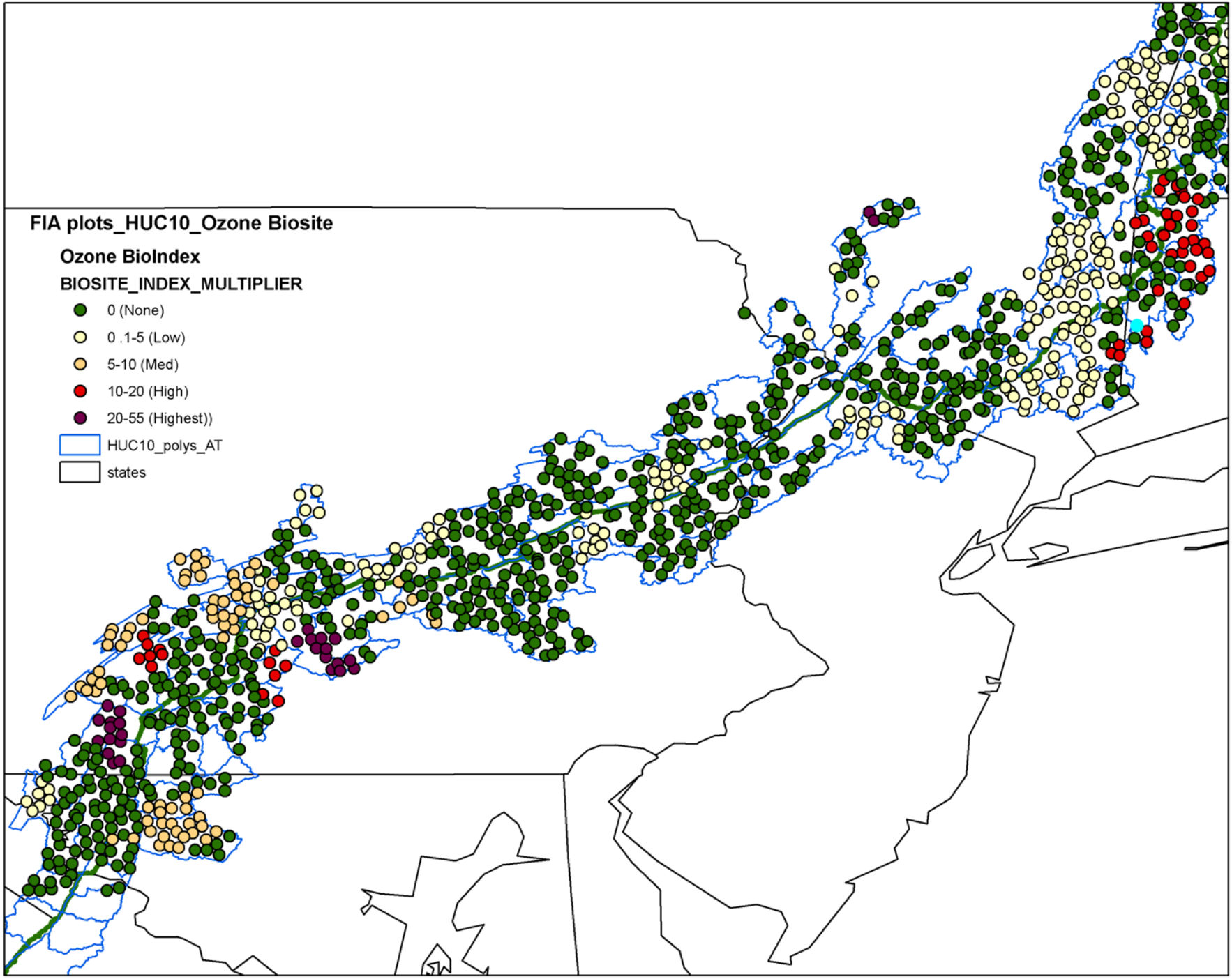
Exotic Hardwoods
HUC10_polys_AT
AT_Centerline
states


Plot Disturbances
PLOT DISTURBANCE
<all other values>
DSTRBCD1
none
insect
insect_understory
insect_trees-saps-seed
disease
disease_trees-sap-seed
fire
ground fire
animal
beaver
deer
domestic animals
weather
ice
wind
flooding
veg suppress
unknown
human-caused
HUC10_polys_AT
AT_Centerline
states


Plot Disturbances
PLOT DISTURBANCE
<all other values>
DSTRBCD1
none
insect
insect_understory
insect_trees-saps-seed
disease
disease_trees-sap-seed
fire
ground fire
animal
beaver
deer
domestic animals
weather
ice
wind
flooding
veg suppress
unknown
human-caused
HUC10_polys_AT
AT_Centerline
states


FIA plots_HUC10_Ozone Biosite
Ozone BioIndex
BIOSITE_INDEX_MULTIPLIER
0 (None)
0 .1-5 (Low)
5-10 (Med)
10-20 (High)
20-55 (Highest))
HUC10_polys_AT
states


FIA plots_HUC10_Ozone Biosite
Ozone BioIndex
BIOSITE_INDEX_MULTIPLIER
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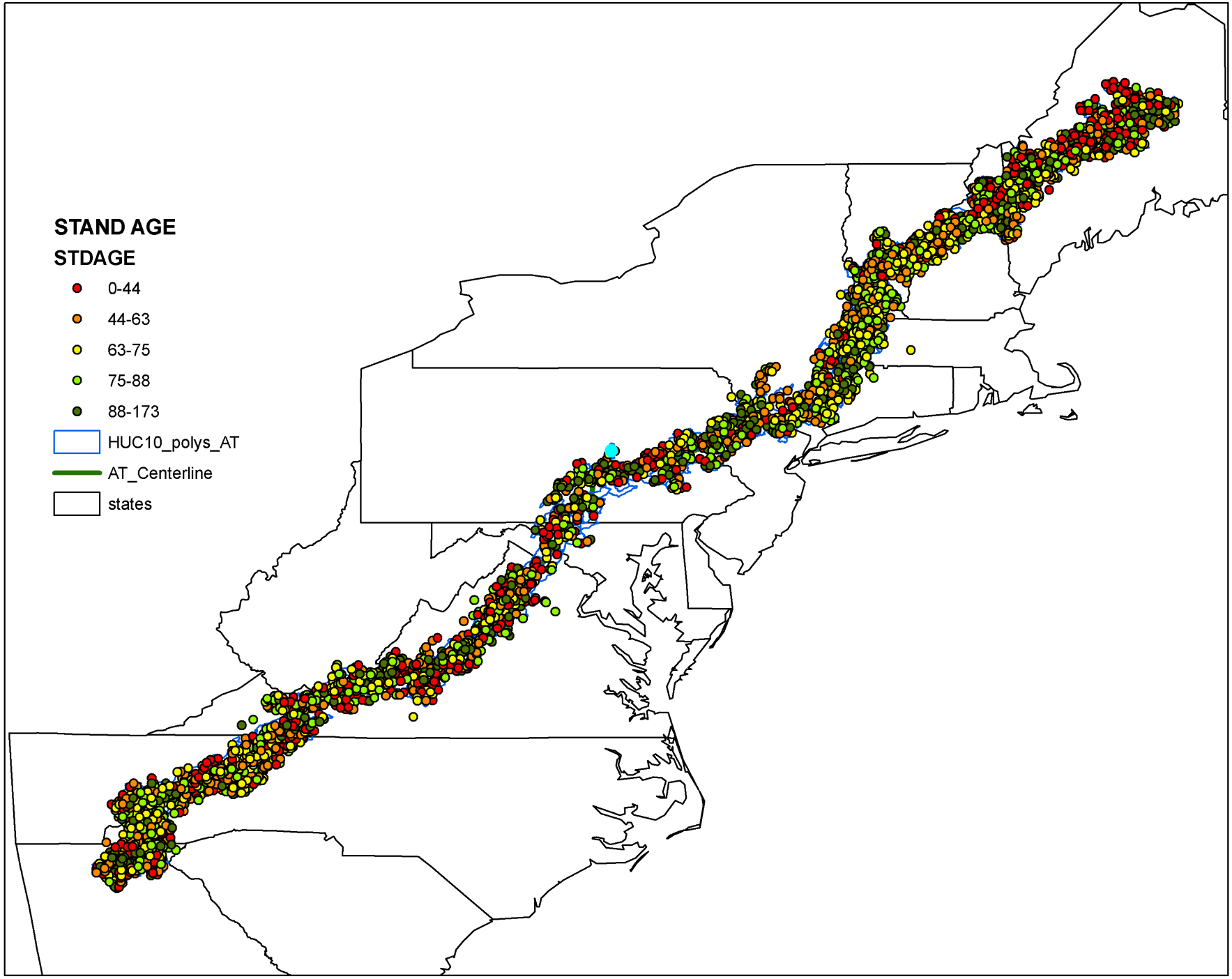
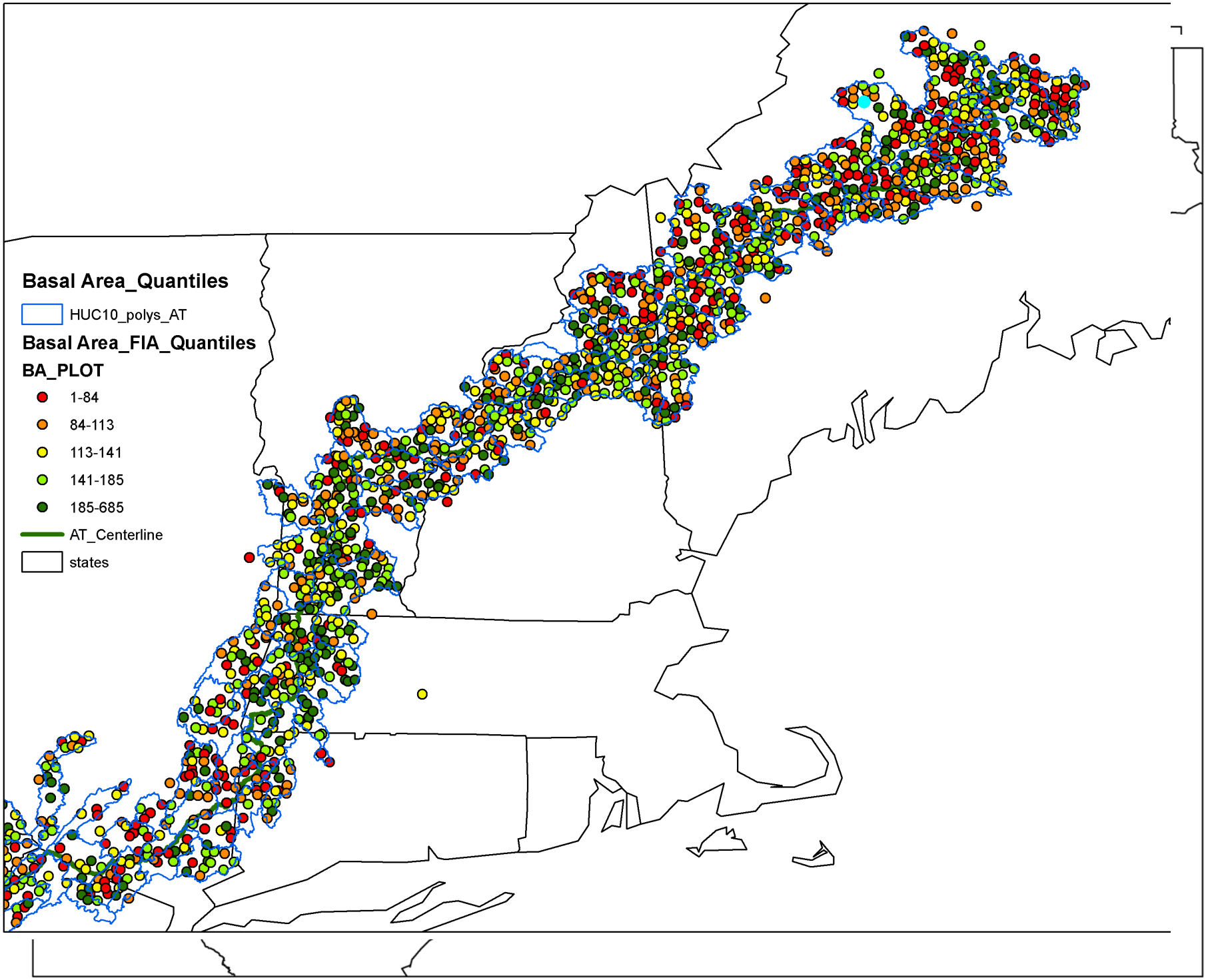
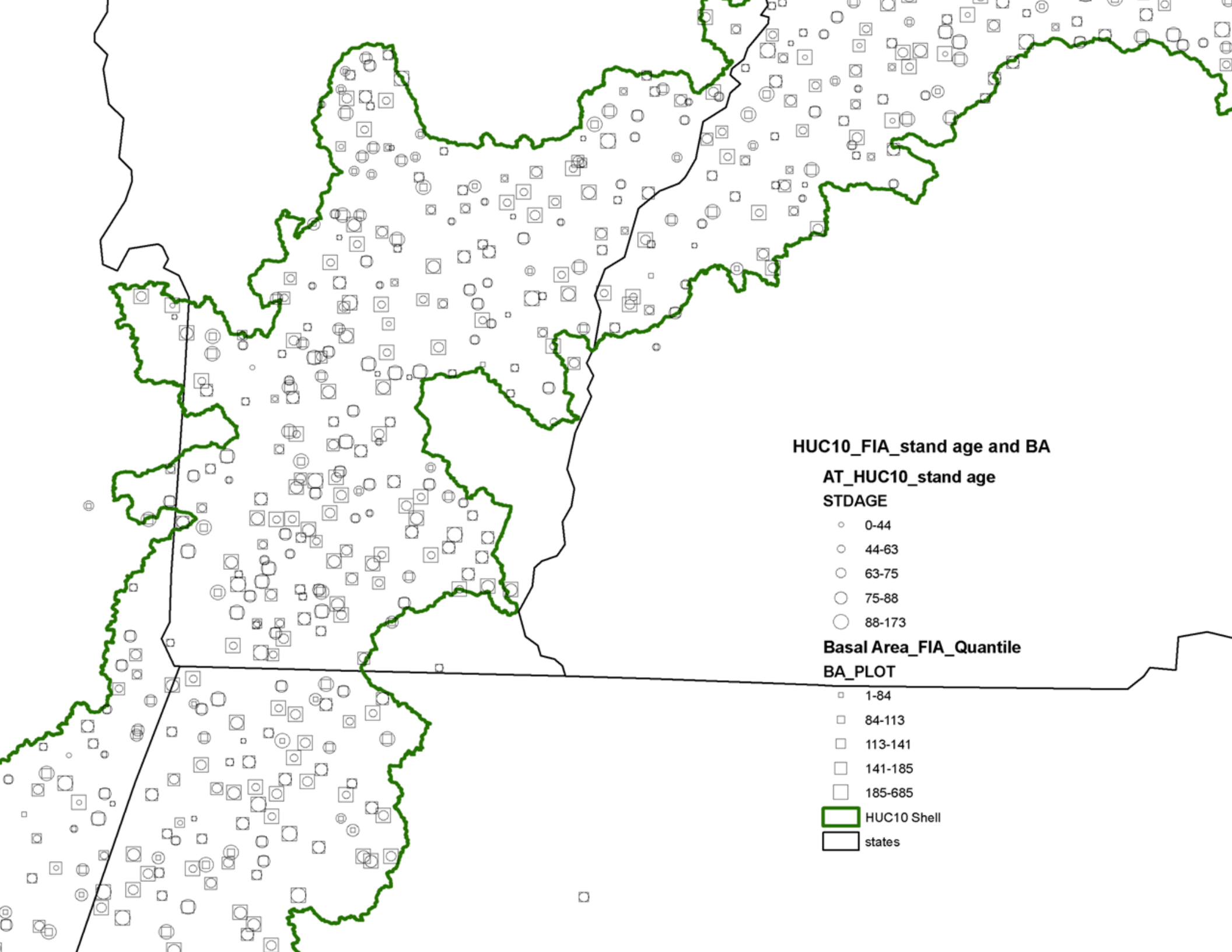
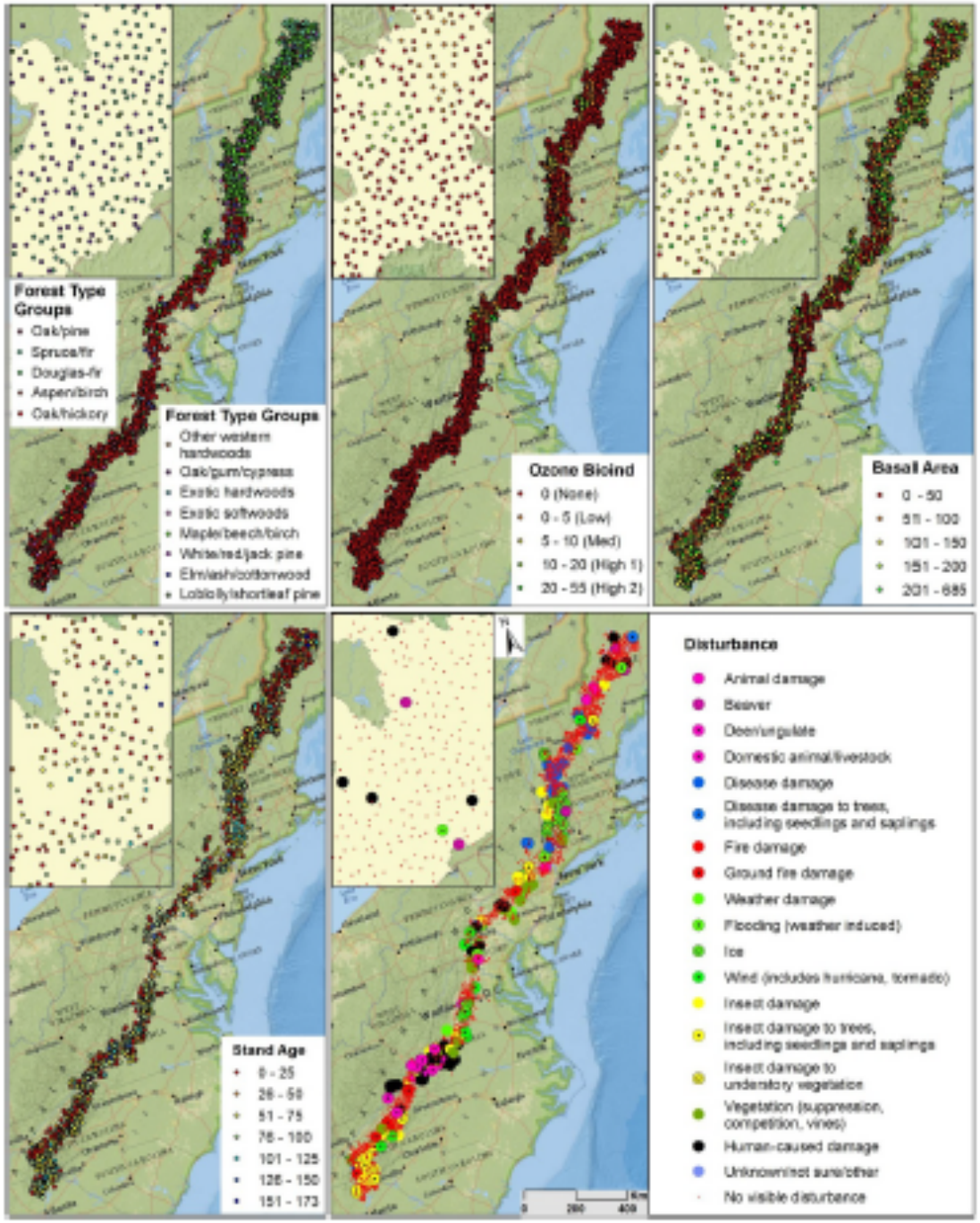
0 .1-5 (Low)
5-10 (Med)
10-20 (High)
20-55 (Highest))
HUC10_polys_AT
states


STAND AGE
STDAGE
0-44
44-63
63-75
75-88
88-173
HUC10_polys_AT
AT_Centerline
states


Basal Area_Quantiles
HUC10_polys_AT
Basal Area_FIA_Quantiles
BA_PLOT
1-84
84-113
113-141
141-185
185-685
AT_Centerline
states


HUC10_FIA_stand age and BA
AT_HUC10_stand age
STDAGE
0-44
44-63
63-75
75-88
88-173
Basal Area_FIA_Quantile
BA_PLOT
1-84
84-113
113-141
141-185
185-685
HUC10 Shell
states


Forest Type Groups
Oak/pine
Spruce/fir
Douglas-fir
Aspen/birch
Oak/hickory
Forest Type Groups
Other western hardwoods
Oak/gum/cypress
Exotic hardwoods
Exotic softwoods
Maple/beech/birch
White/red/jack pine
Elm/ash/cottonwood
Loblolly/shortleaf pine
Ozone Biomass
0 (None)
0 - 5 (Low)
5 - 10 (Med)
10 - 20 (High 1)
20 - 55 (High 2)
Basal Area
0 - 50
51 - 100
101 - 150
151 - 200
201 - 685
Stand Age
0 - 25
26 - 50
51 - 75
76 - 100
101 - 125
126 - 150
151 - 173
Disturbance
Animal damage
Beaver
Deer/ungulate
Domestic animal/livestock
Disease damage
Disease damage to trees, including seedlings and saplings
Fire damage
Ground fire damage
Weather damage
Flooding (weather induced)
Ice
Wind (includes hurricane, tornado)
Insect damage
Insect damage to trees, including seedlings and saplings
Insect damage to understory vegetation
Vegetation (suppression, competition, vines)
Human-caused damage
Unknown/not sure/other
No visible disturbance

FIA data

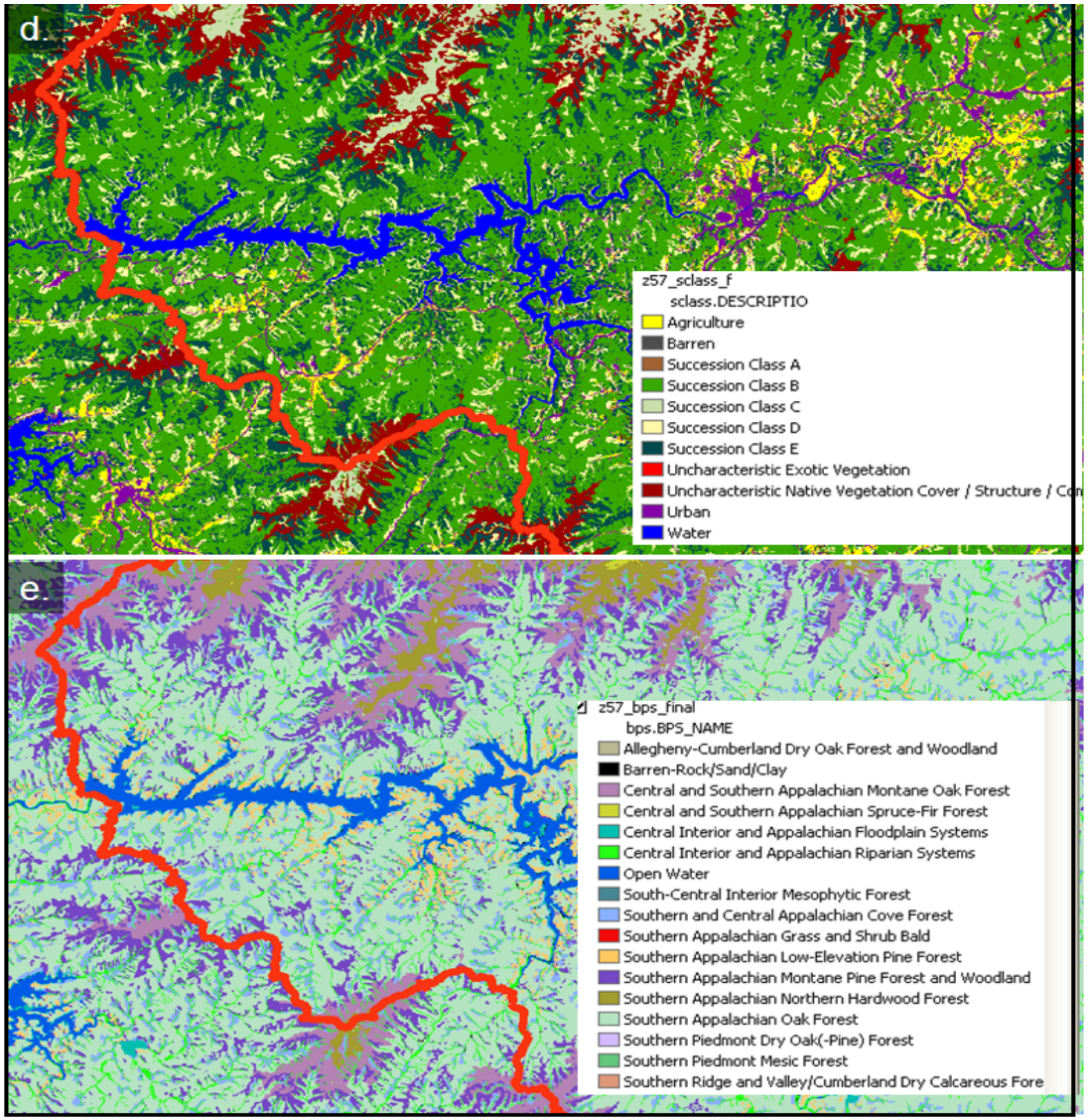
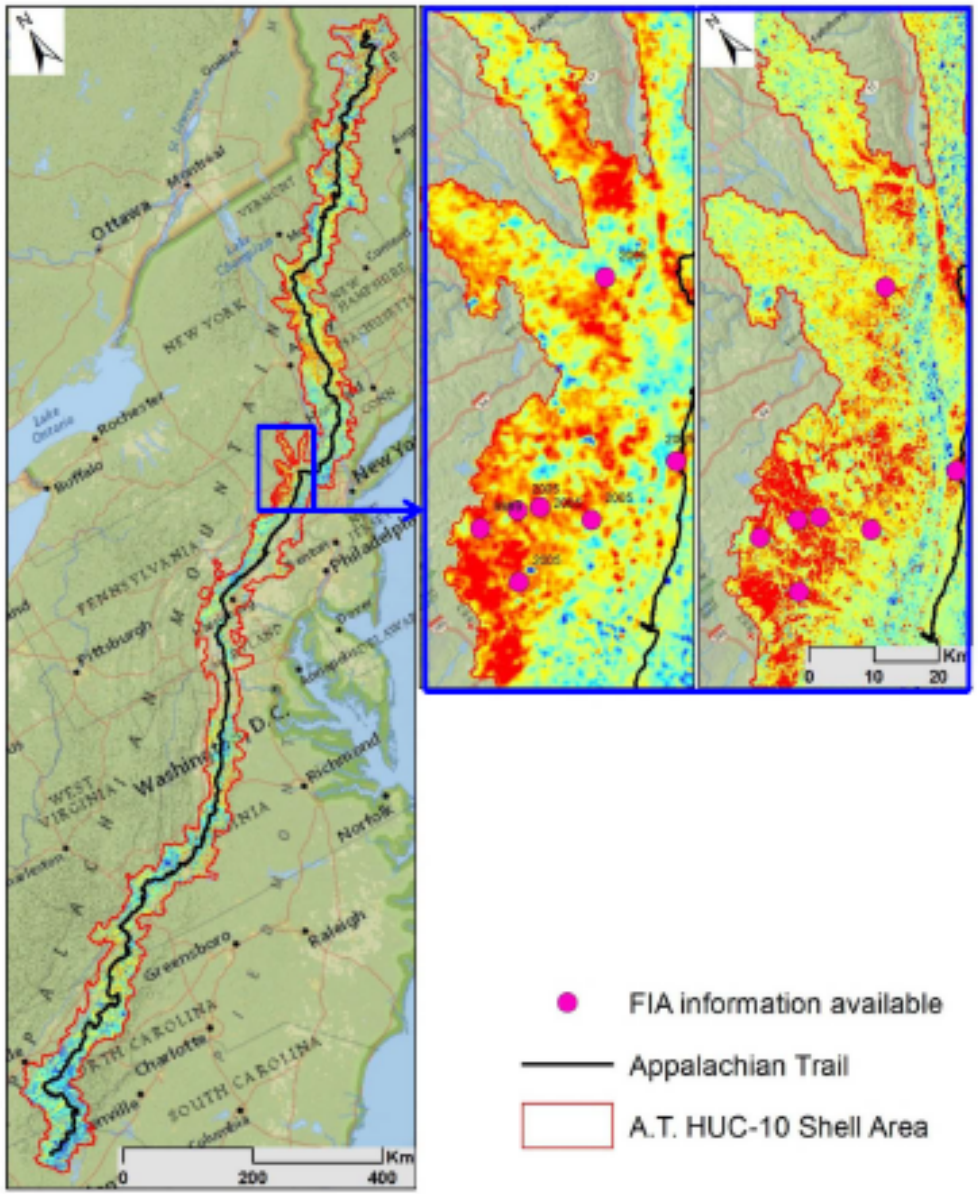
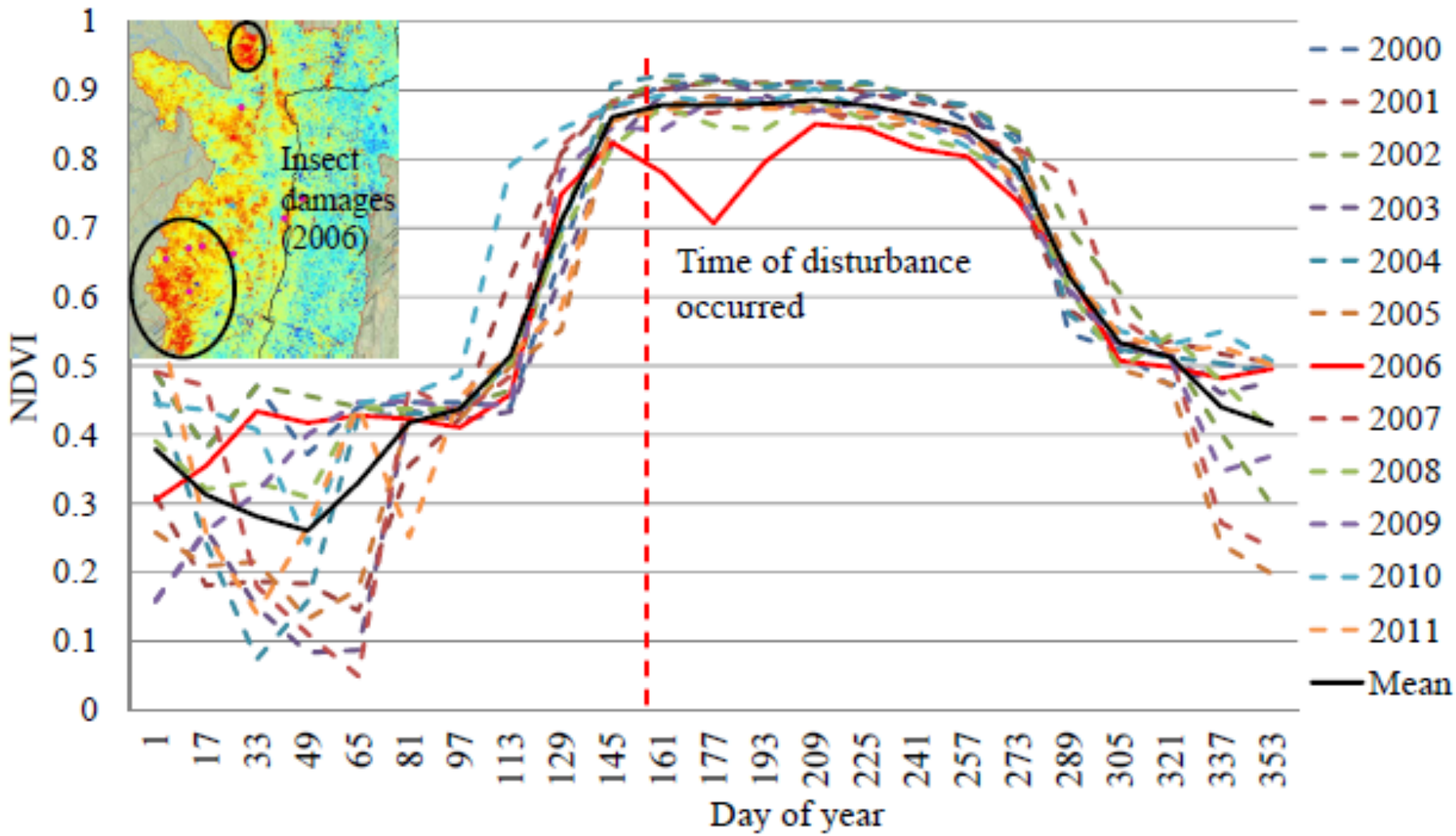


Figure 3. a-e. Example of outputs from TOPS information system. Landscape scale data from TOPS will be used to interpret information from ridge ecotone plots and other FIA plots in HUC10 shell.

Example: Areas with insect damages observed from MODIS (250-m) and Landsat TM (30-m) data.





MODIS (250-m) data illustrate the areas of insect damages from time series NDVI for selected test sites.