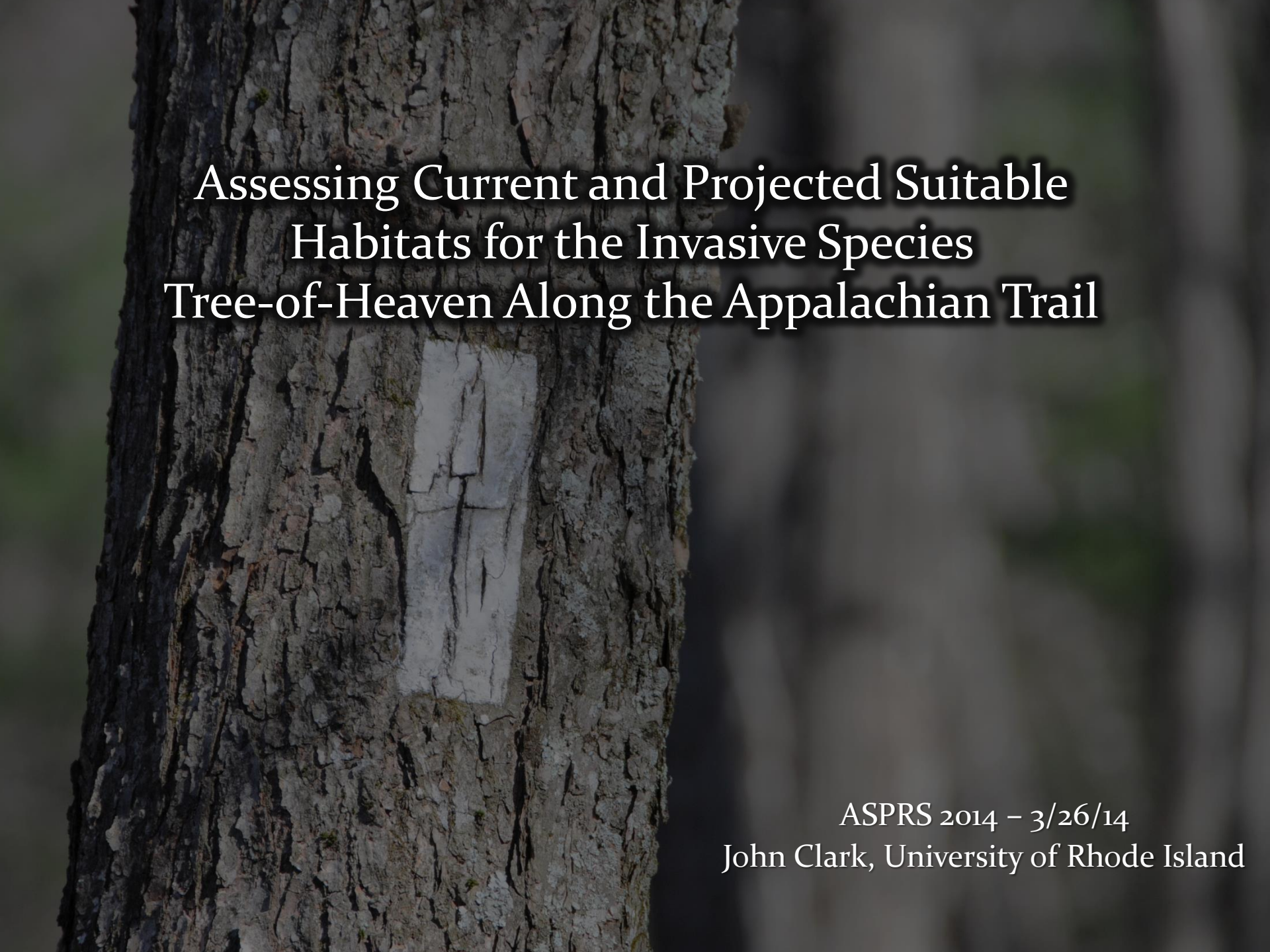
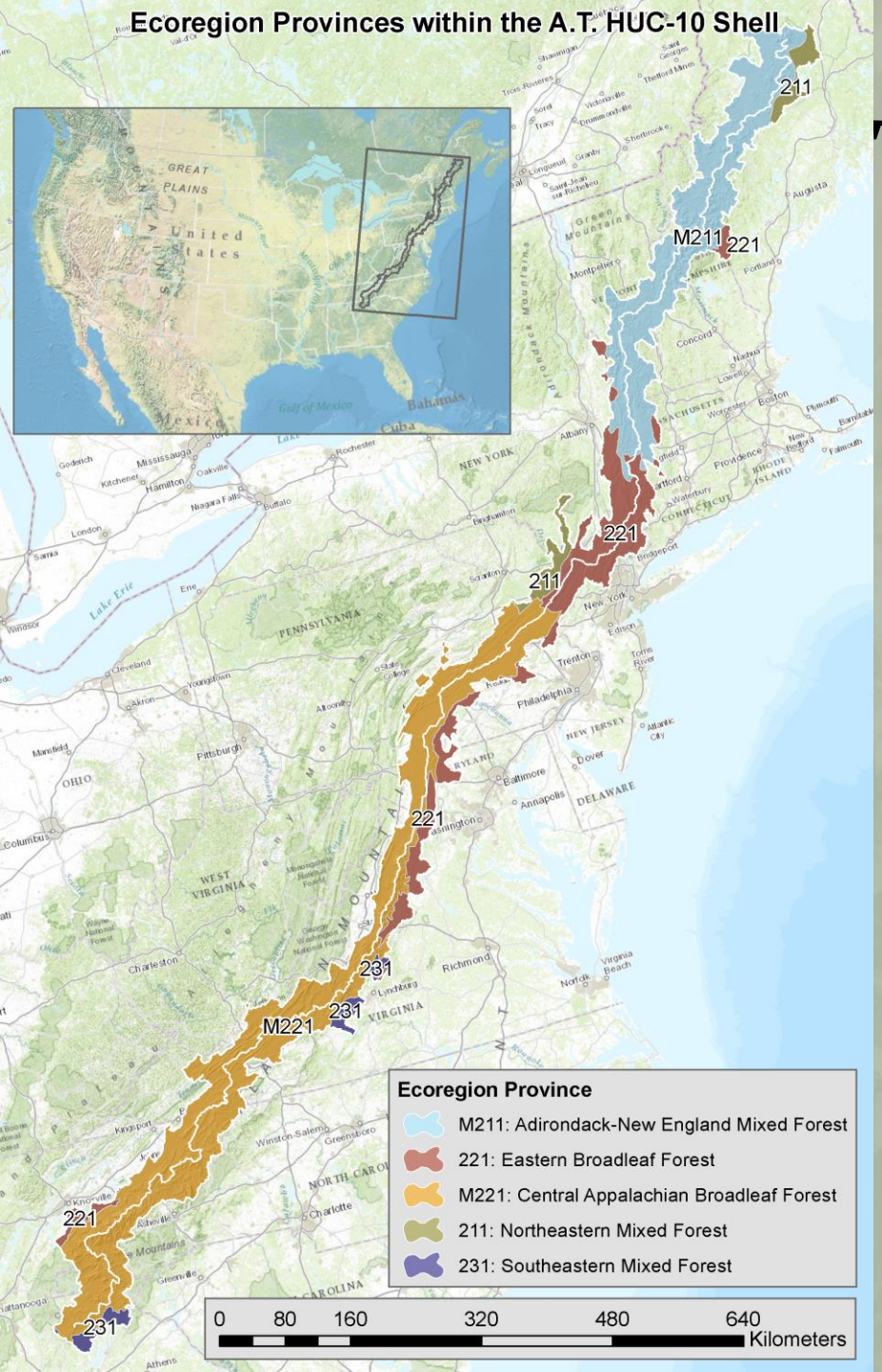


Assessing Current and Projected Suitable Habitats for the Invasive Species Tree-of-Heaven Along the Appalachian Trail

ASPRS 2014 – 3/26/14

John Clark, University of Rhode Island



The Appalachian Trail

- Foot path spanning over 2,175 miles from Springer Mountain, GA to Mount Katahdin, ME
- Diverse ecosystems, rare species, and important services
- Latitudinal and altitudinal gradient of conditions

Objectives

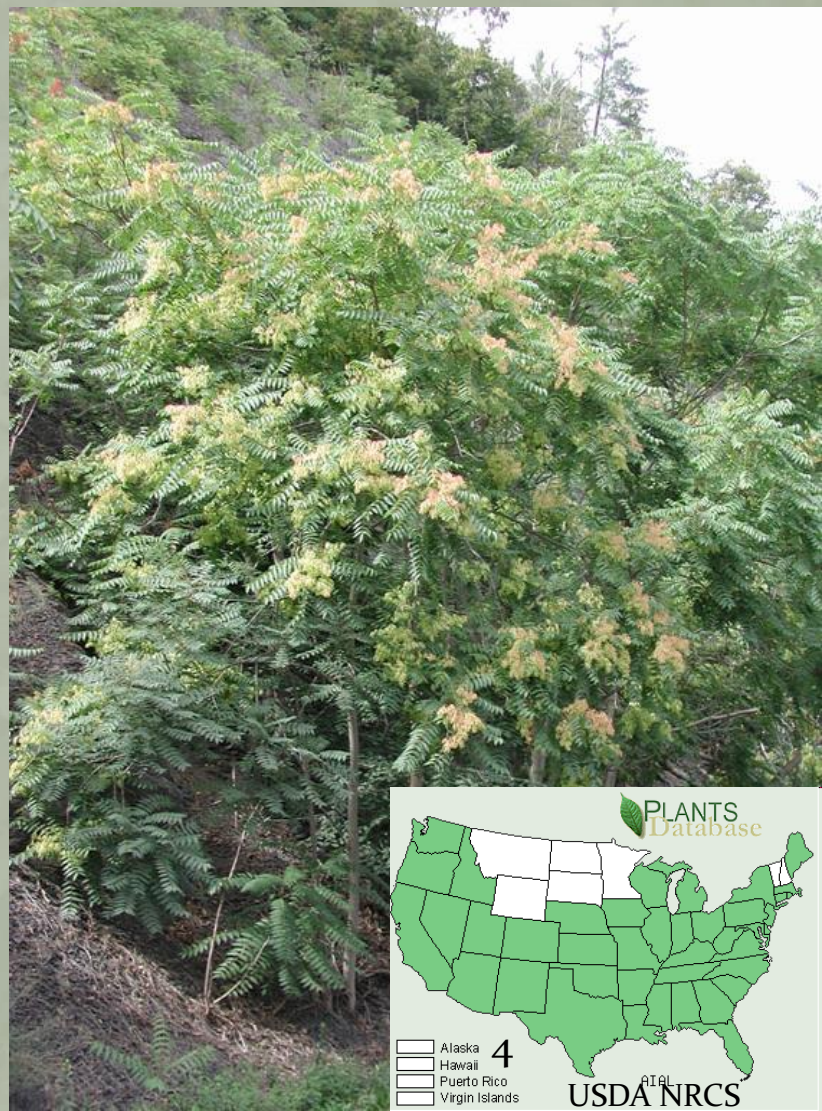
Developing a prototype application for the DSS

1. Relate field-based observations of the distribution of *Ailanthus* to a set of ecogeographical variables.
2. Map the current distribution of suitable habitats and identify high-risk regions along the A.T.
3. Integrate projected precipitation and temperature data to simulate potential shifts in the distribution of *Ailanthus* habitats.

Invasive Species: *Ailanthus altissima*

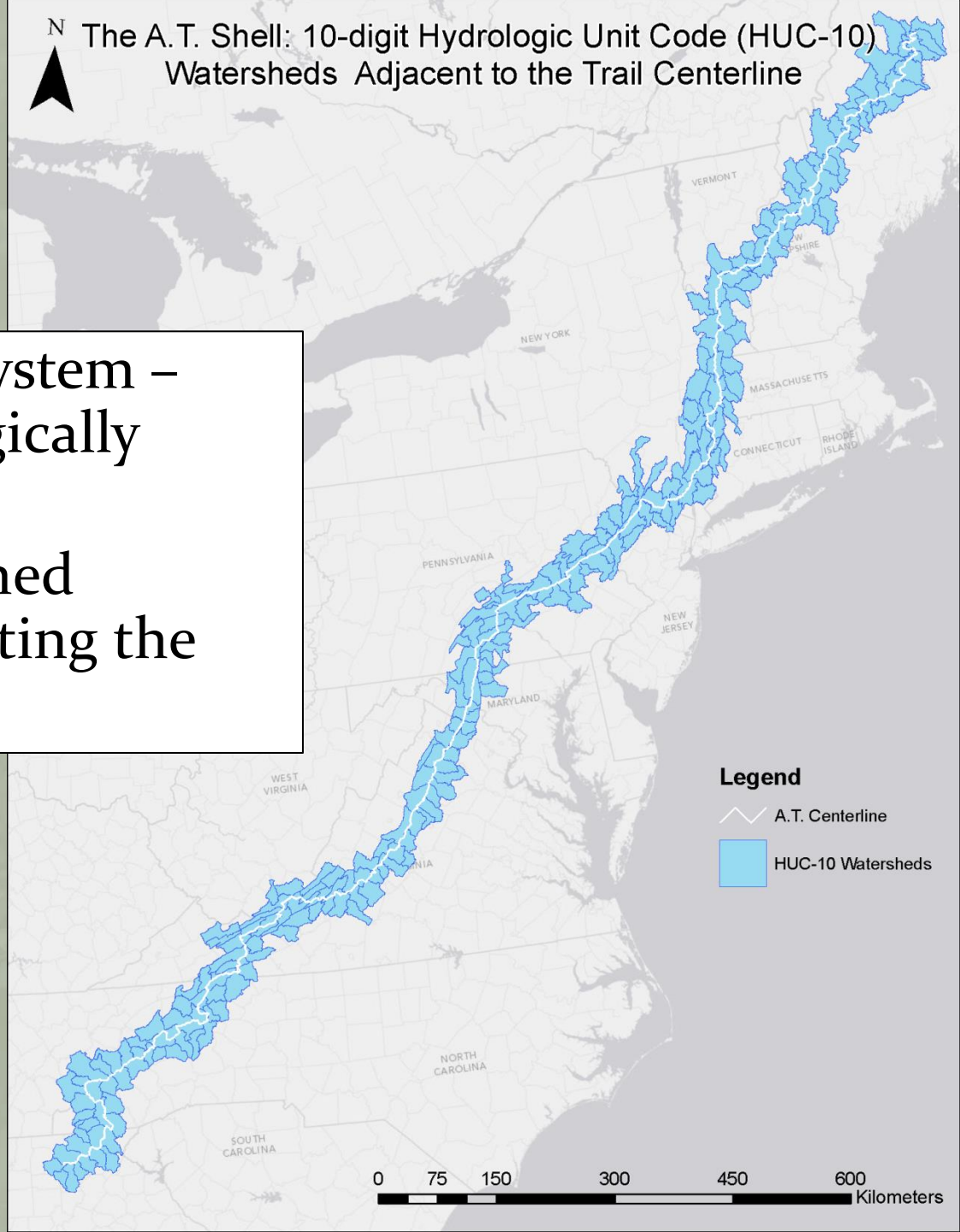
Tree of Heaven, Chinese Sumac

- Native to China
  - Introduced to urban areas
  - Tolerates stress
  - Wide range of conditions
- Problematic invasive in N. America
  - Large # airborne seeds
  - Rapid growth
  - Allelopathic
  - Root and stump shoot regeneration
  - Disrupts native communities



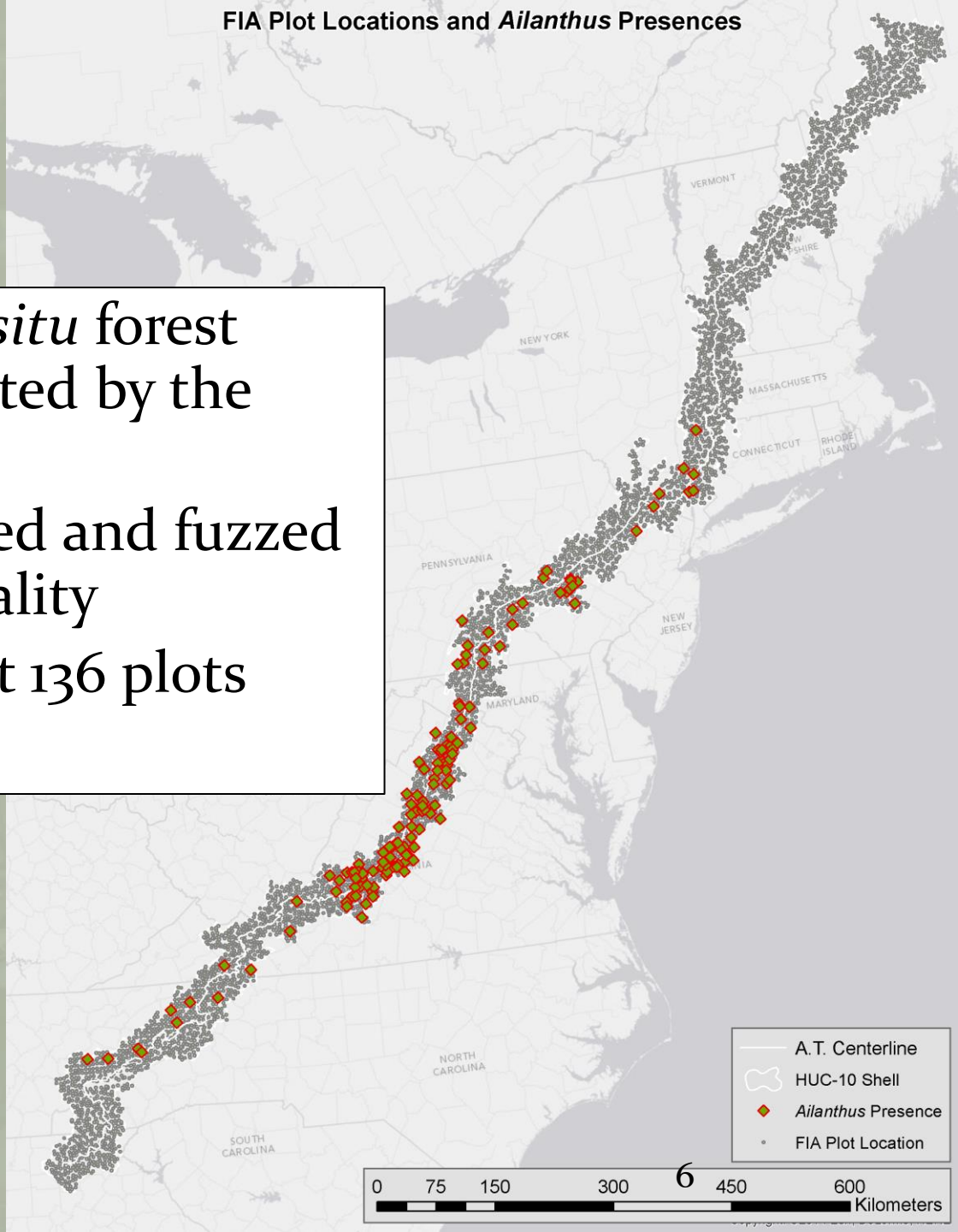
The A.T. Shell

- Open and complex system – need to define ecologically relevant extent
- HUC-10 level watershed delineations intersecting the A.T. centerline



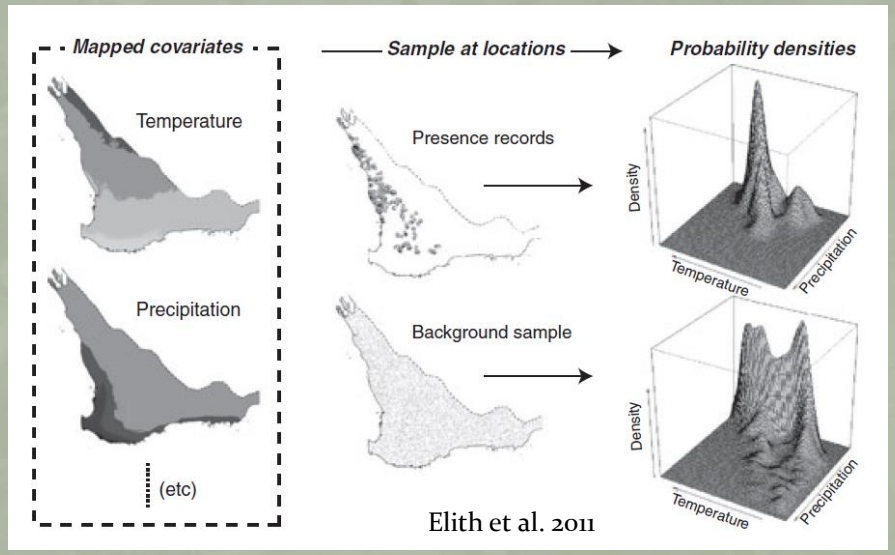
FIA Data

- Large database of *in situ* forest measurements collected by the Forest Service
- Plot locations swapped and fuzzed to protect confidentiality
- *Ailanthus* observed at 136 plots within the A.T. Shell



Maximum Entropy Modeling (Maxent)

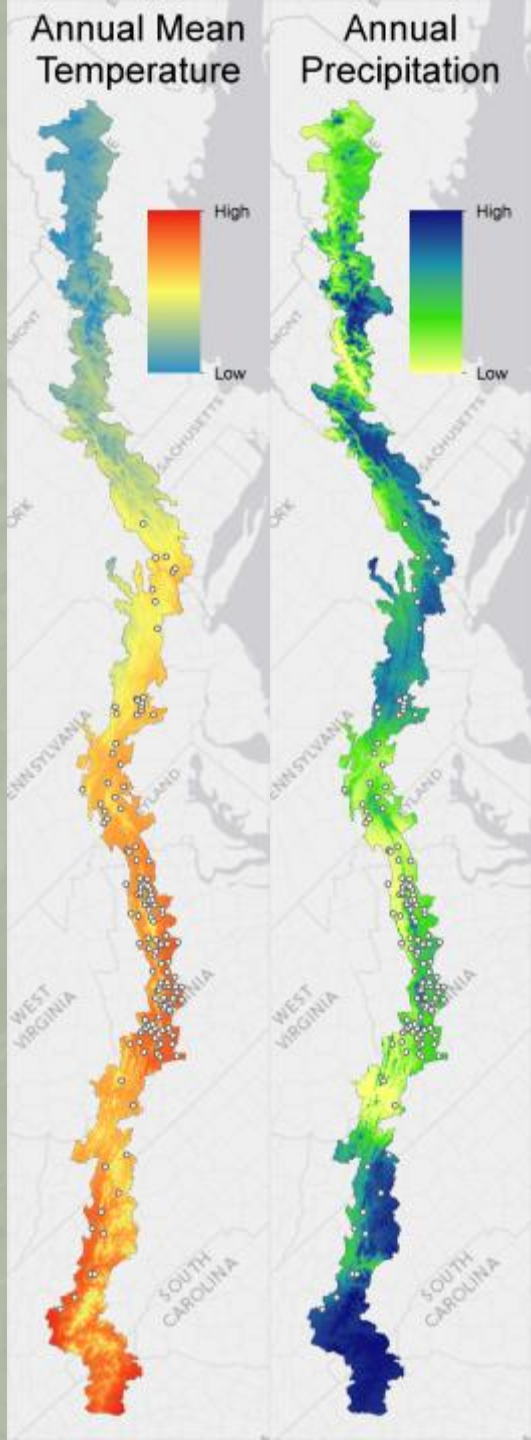
- Presence-only modeling
  - Invasive population out of equilibrium within landscape, absences do not indicate poor conditions
- Machine learning method
  - Maximum entropy distribution = least constrained
  - Generates 'features' based on distribution of environmental variables across presence points
  - Many iterations, balancing gain against regularization to prevent overfitting
- Widely used
  - Ranked high in comparative studies
  - Large body of literature
  - Applied to diverse species and regions
  - Stable package and active user group



Elith et al. 2011

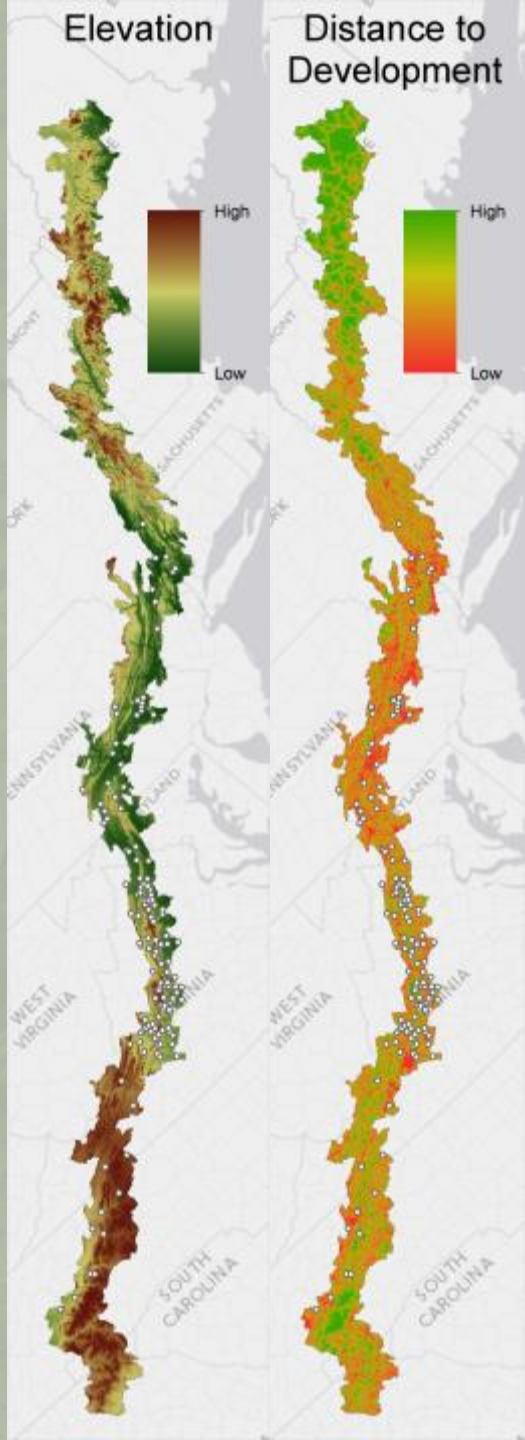
Climate Data

- From NASA's Terrestrial Observation and Prediction System (TOPS)
  - AR5 CMIP5 RCP6.0
- Generate bioclimatic variables
  - Used R package 'dismo'
  - Suite of 19 biologically meaningful climate variables
  - Annual trends
  - Seasonality
  - Extreme or limiting environmental factors
- Baseline (1950-2005) and projected (2090-2095) data



Ancillary Data

- Topographic (NED)
  - Elevation, slope, aspect…
- Landcover (NLCD06)
  - Developed areas, agriculture, canopy cover…
- Soil Moisture (STATSGO)



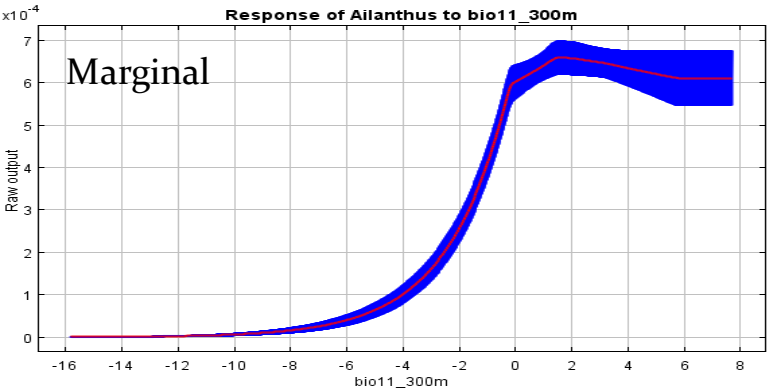
Model Evaluation

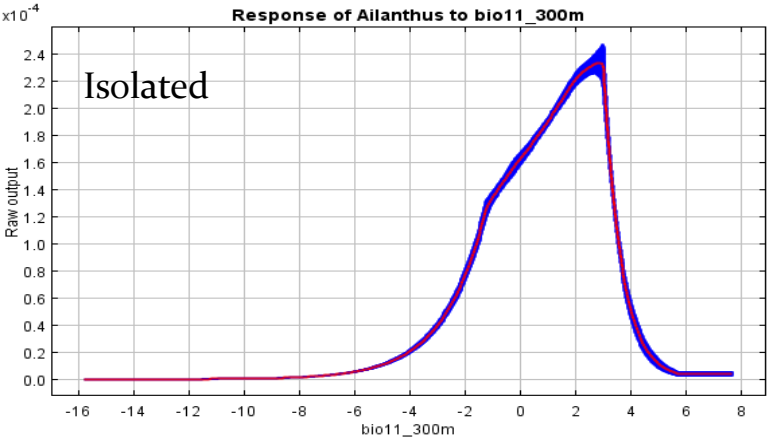
- Performance: 10-fold cross validation on test area under curve of receiver operating characteristics
- Complexity: sample size adjusted Akaike information criteria (AIC_c)
  - Simplicity especially desirable when transferring (projecting) to new conditions
- Consistency: ecologically significant variables selected and resulting distribution in agreement with existing knowledge

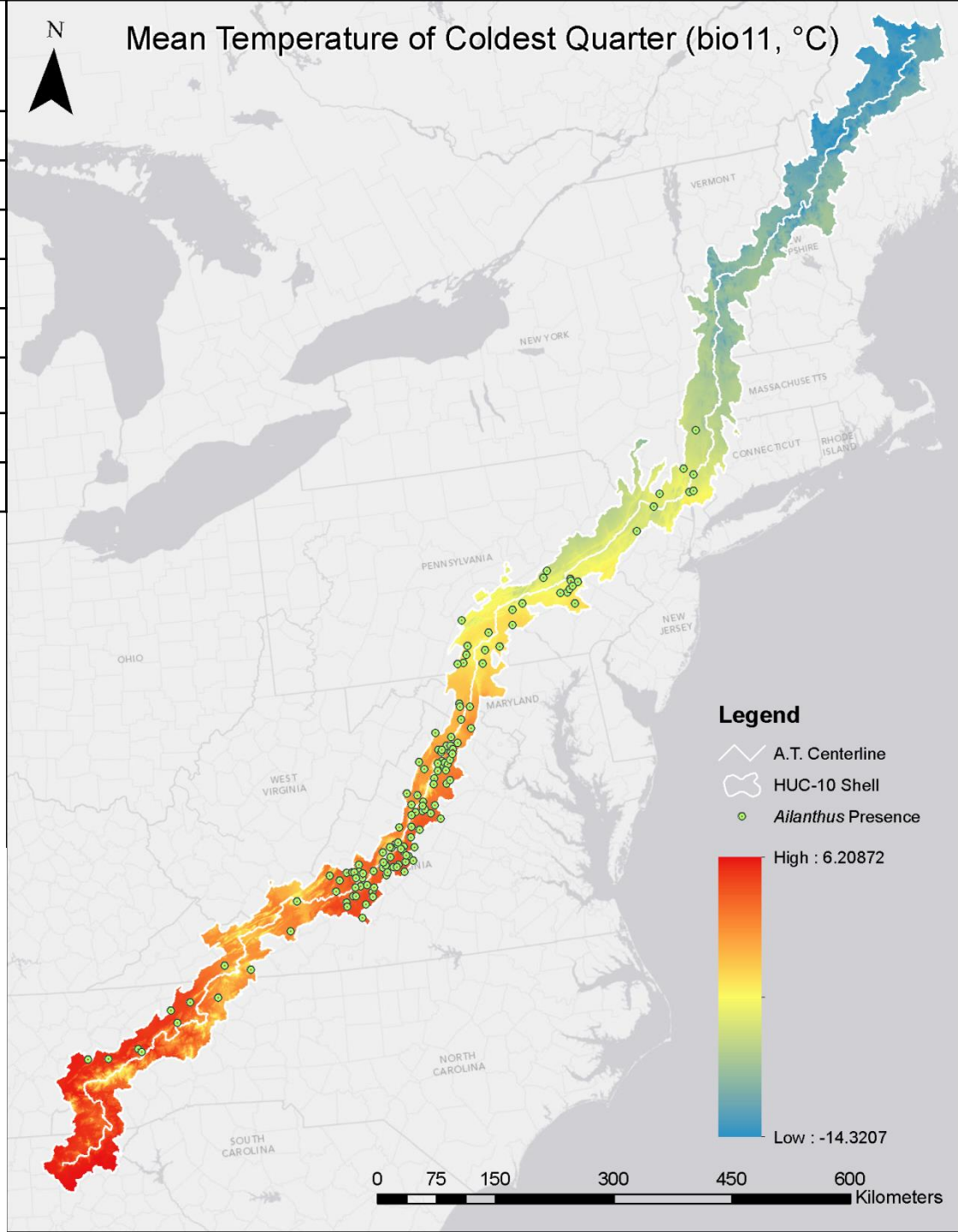
Model Evaluation Metrics

model	climate variables	topographic variables	landcover variables	log-likelihood	parameters	AICc score	mean test AUC	AUC SD
4bio_4topo	*4*	*4*	*0*	*−1751.24*	*56.8*	*3707.533*	*0.85*	*0.034*
2bio_1topo	2	1	0	−1796.72	40.9	3713.173	0.812	0.035
4bioalt_4topo_2lc	4	4	2	−1749.24	61.8	3733.685	0.847	0.034
5bioalt_5topo	5	5	0	−1747.56	68.2	3777.135	0.848	0.045
10bioalt_6topo	10	6	0	−1735.15	72.2	3788.426	0.855	0.047
5bioalt_4topo	5	4	0	−1747.74	69.8	3794.235	0.849	0.044
4bioalt_3topo	4	3	0	−1752.98	67.8	3796.161	0.85	0.041
5bioalt2_3topo	5	3	0	−1750.84	69.4	3804.34	0.852	0.04
6bioalt_6topo	6	6	0	−1743.5	73.1	3817.243	0.848	0.046
allbio_alltopo	19	10	0	−1732.14	76.2	3821.316	0.847	0.039
5bio_5topo	5	5	0	−1751.37	74.4	3862.39	0.848	0.045
10bio_5topo	10	5	0	−1739.94	79.4	3886.28	0.851	0.048
4bio_5topo	4	5	0	−1752.8	76.9	3886.495	0.842	0.046
10bio_5topo_4lc	10	5	4	−1734.39	88.3	3997.353	0.844	0.046
allbio_alltopo_alllc	19	10	7	−1722.52	92.5	4079.972	0.844	0.049

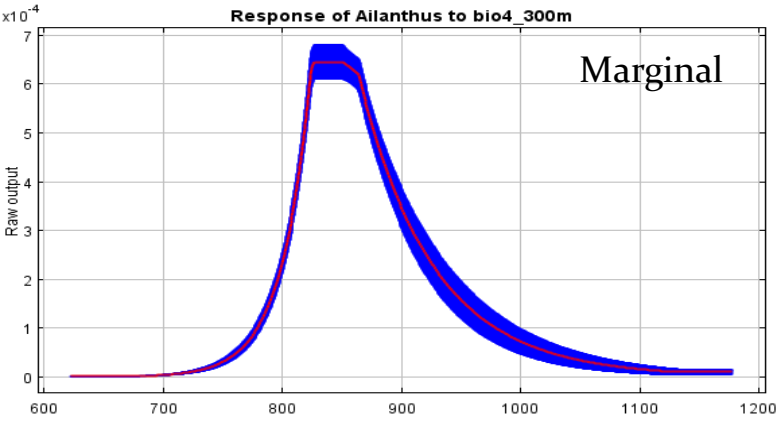
Variable	Percent contribution	Permutation importance
bio11	***40.1***	***34.7***
bio4	27.1	43.9
bio8	22.7	6
slope	4.6	5.1
trasp	3.1	2
nlcd_wet	0.9	0.7
bio19	0.8	2.4
dem	0.6	5.3

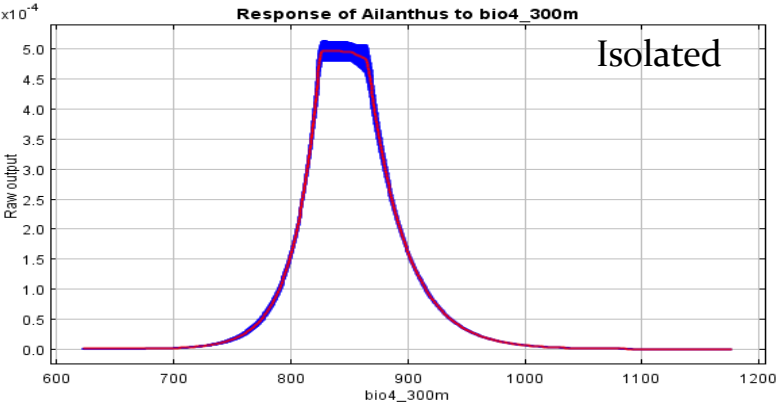


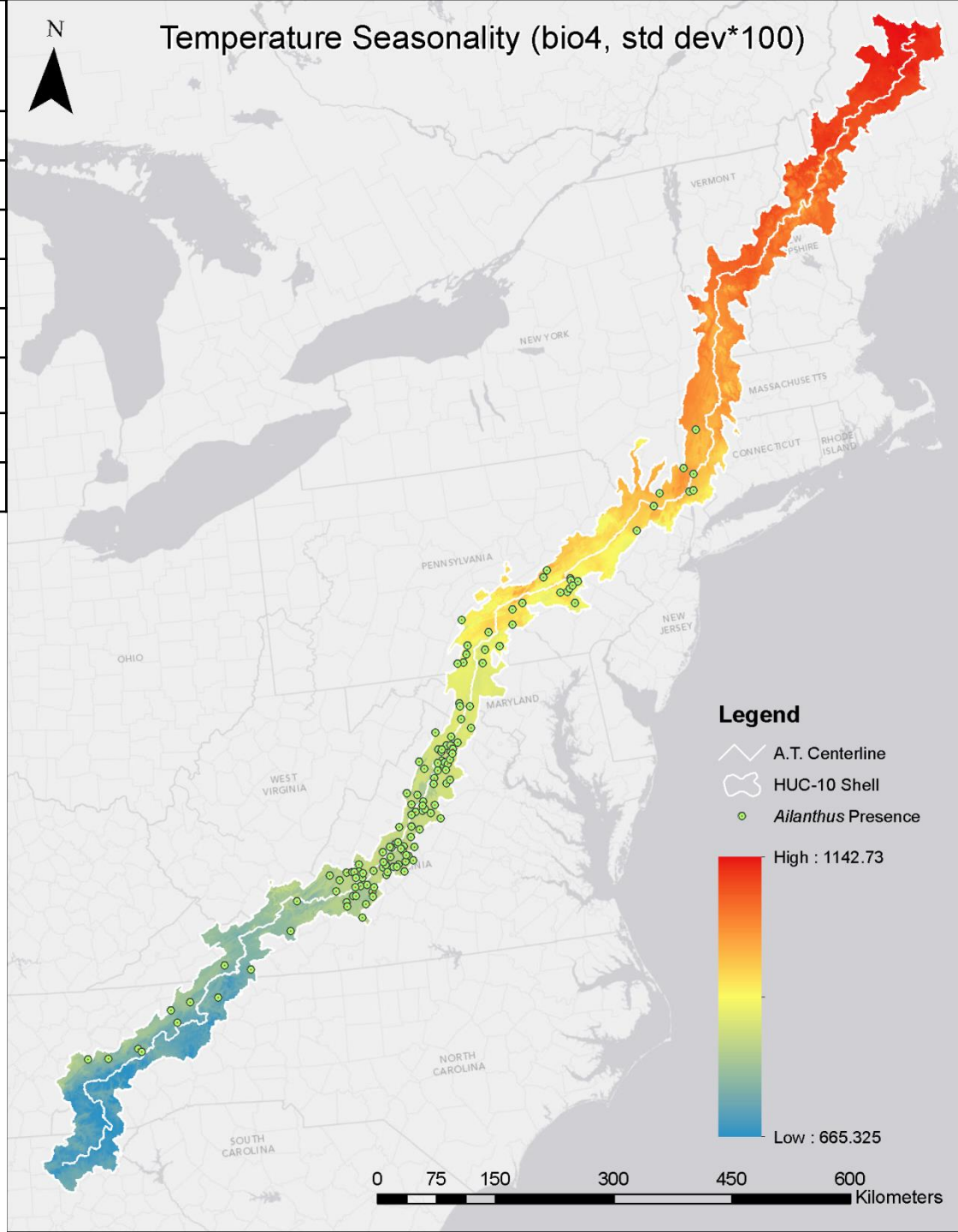




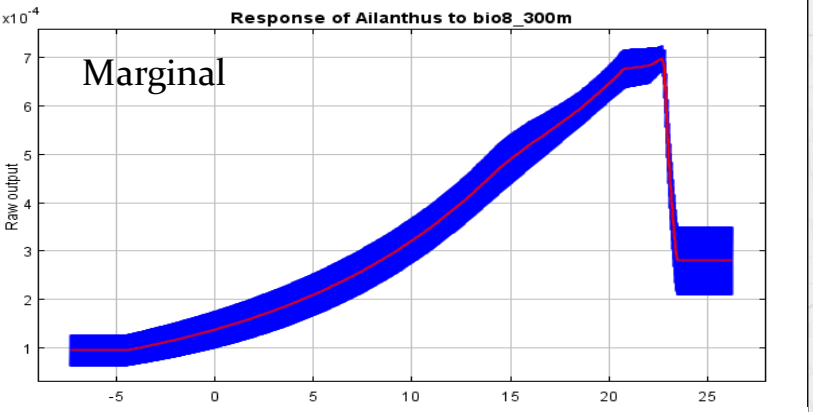
Variable	Percent contribution	Permutation importance
bio11	40.1	34.7
bio4	***27.1***	***43.9***
bio8	22.7	6
slope	4.6	5.1
trasp	3.1	2
nlcd_wet	0.9	0.7
bio19	0.8	2.4
dem	0.6	5.3

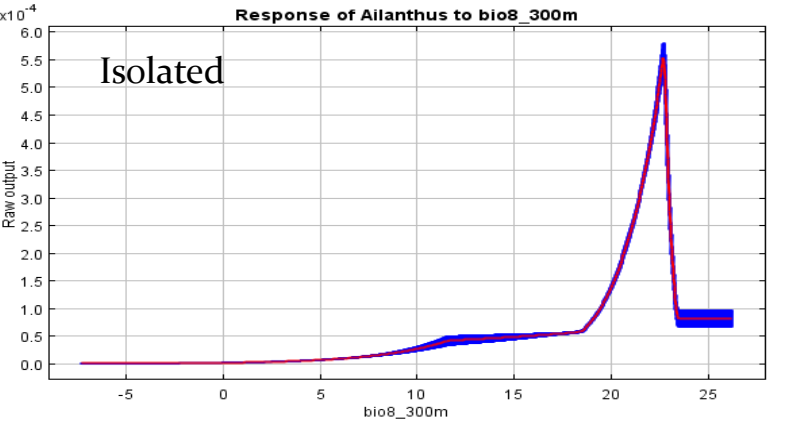


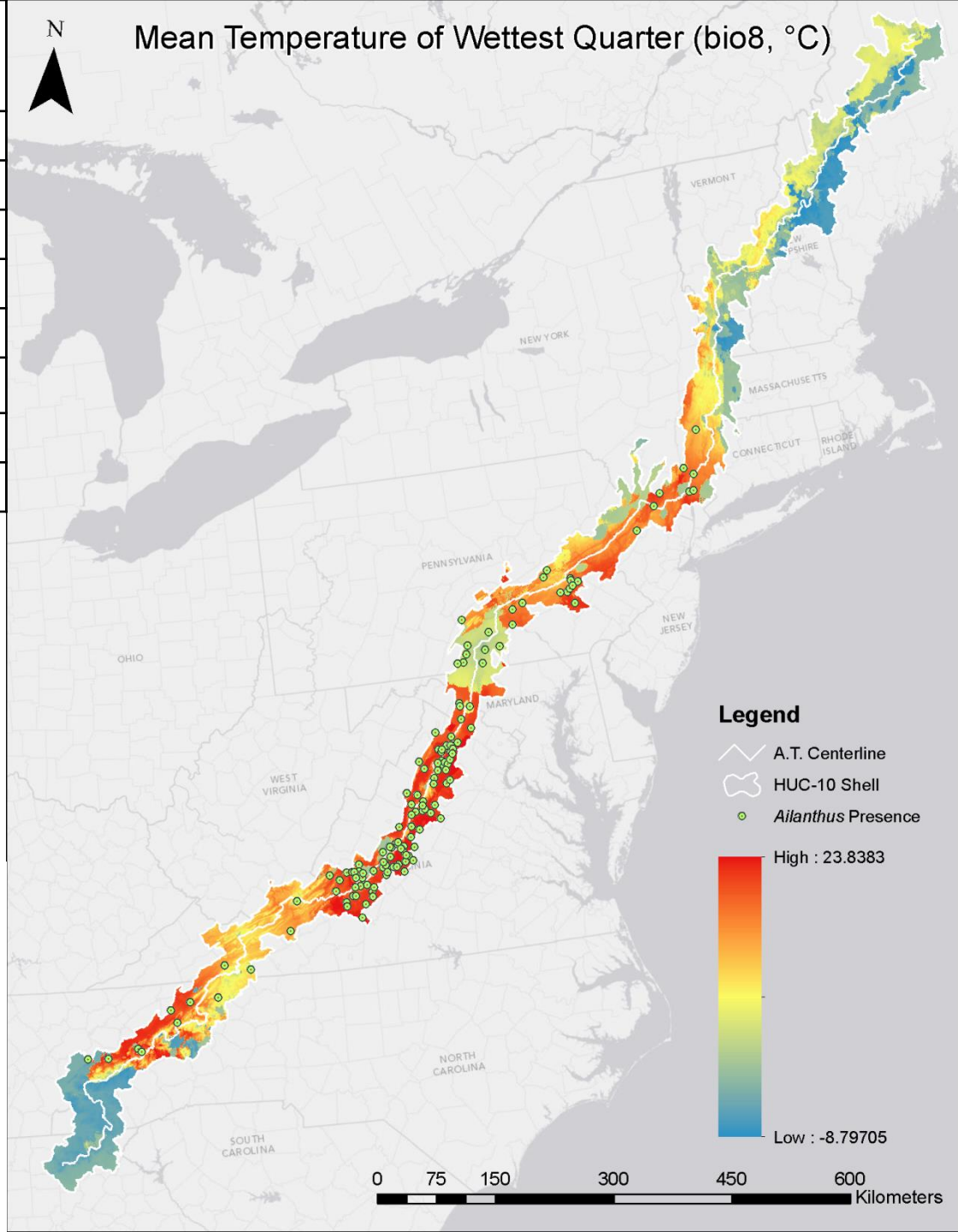




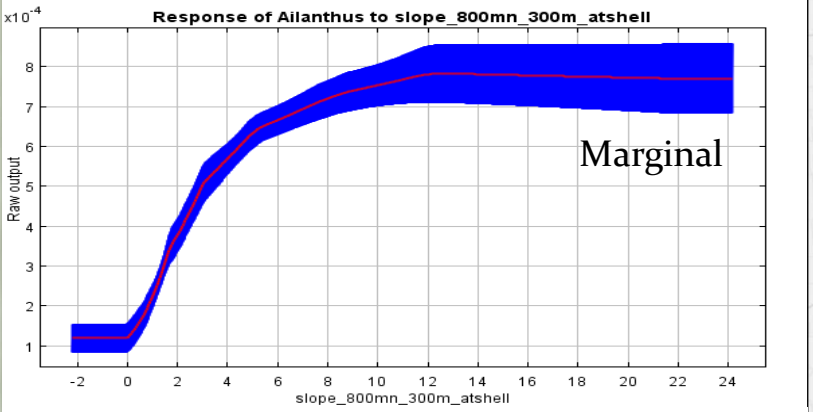
Variable	Percent contribution	Permutation importance
bio11	40.1	34.7
bio4	27.1	43.9
bio8	***22.7***	***6***
slope	4.6	5.1
trasp	3.1	2
nlcd_wet	0.9	0.7
bio19	0.8	2.4
dem	0.6	5.3

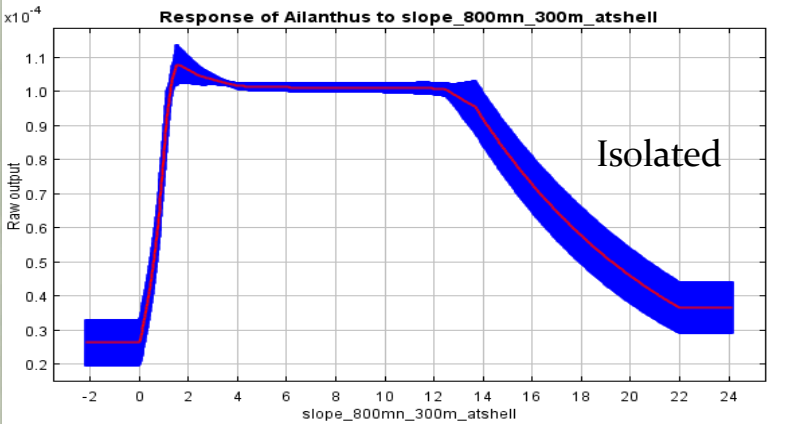


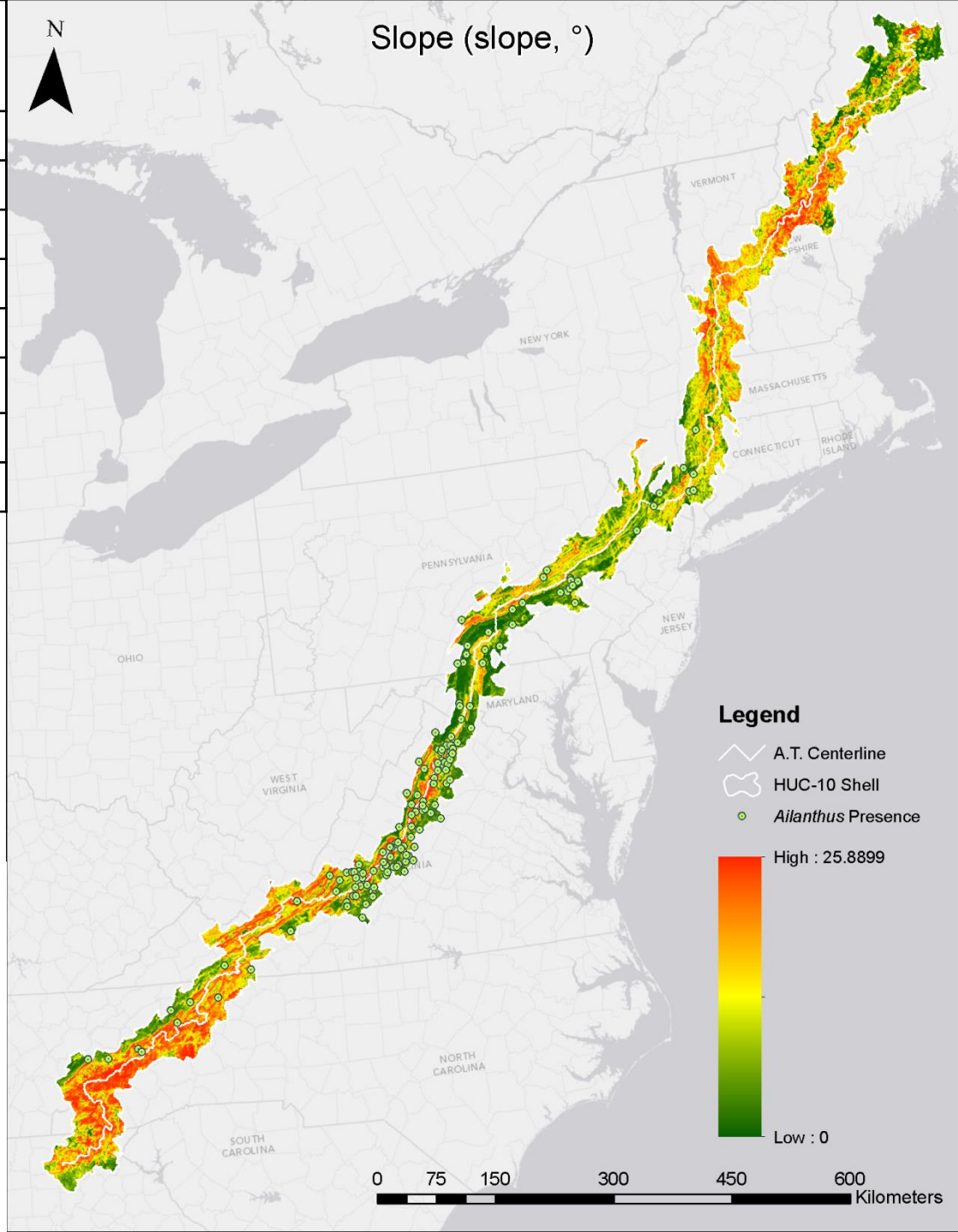




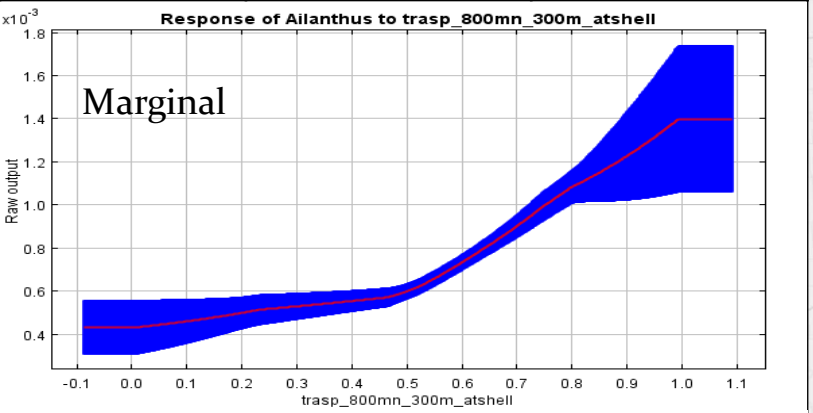
Variable	Percent contribution	Permutation importance
bio11	40.1	34.7
bio4	27.1	43.9
bio8	22.7	6
slope	***4.6***	***5.1***
trasp	3.1	2
nlcd_wet	0.9	0.7
bio19	0.8	2.4
dem	0.6	5.3

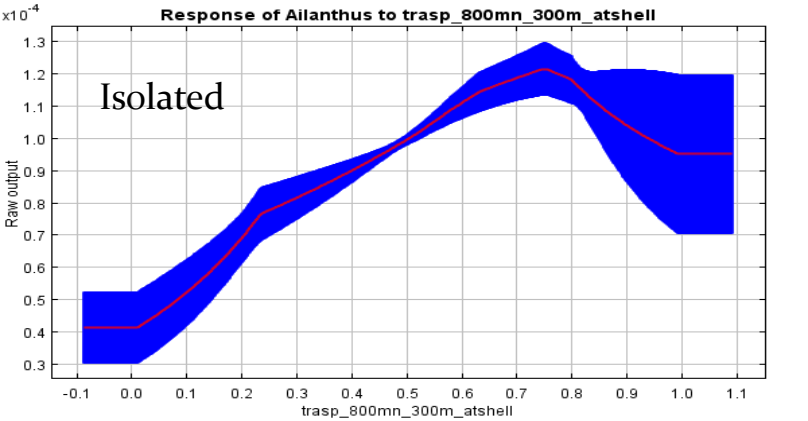


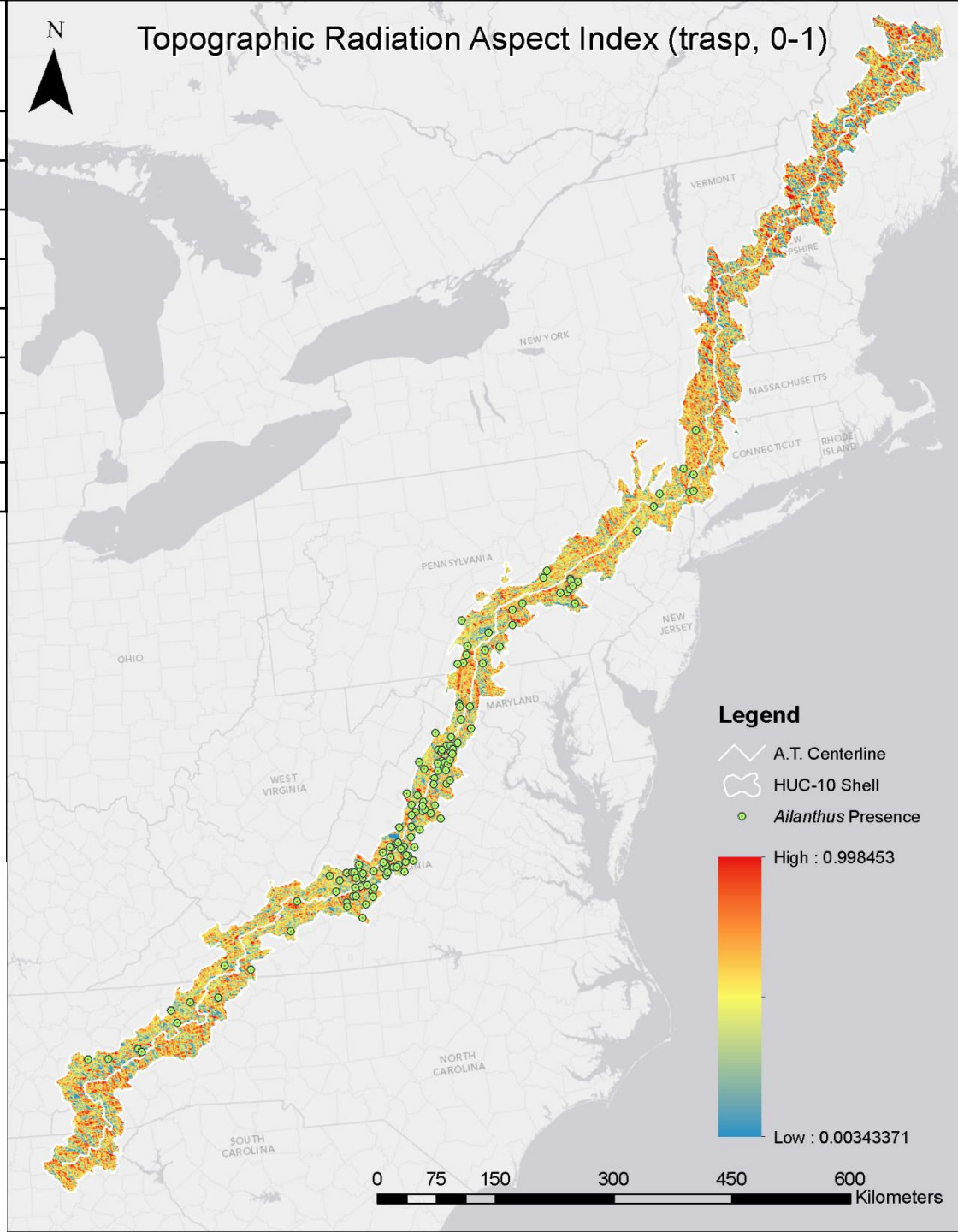




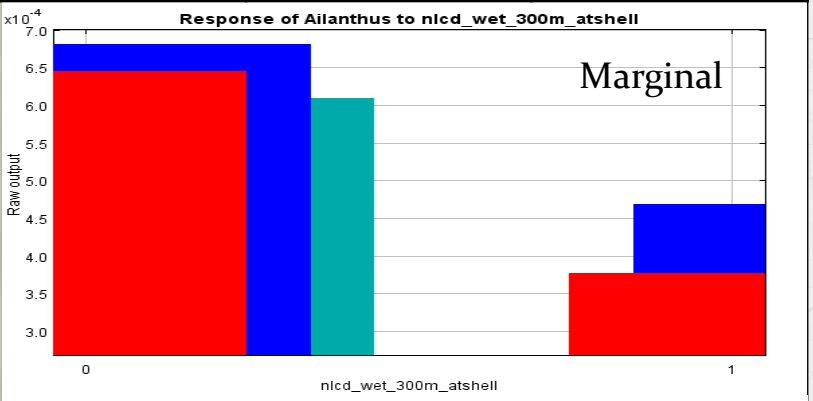
Variable	Percent contribution	Permutation importance
bio11	40.1	34.7
bio4	27.1	43.9
bio8	22.7	6
slope	4.6	5.1
trasp	***3.1***	***2***
nlcd_wet	0.9	0.7
bio19	0.8	2.4
dem	0.6	5.3

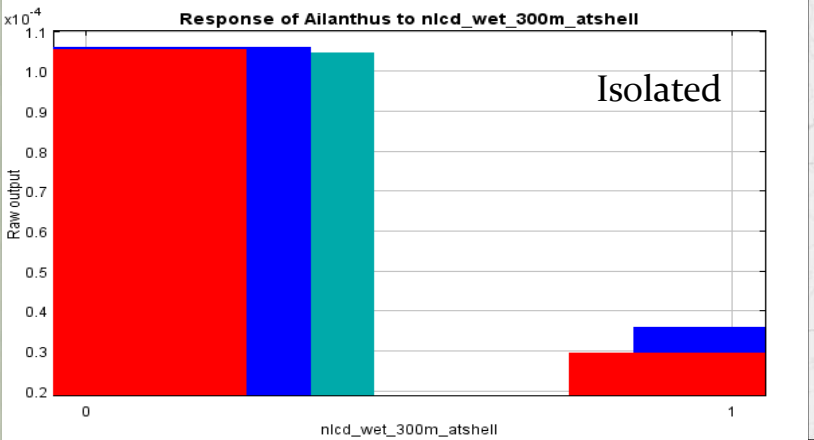


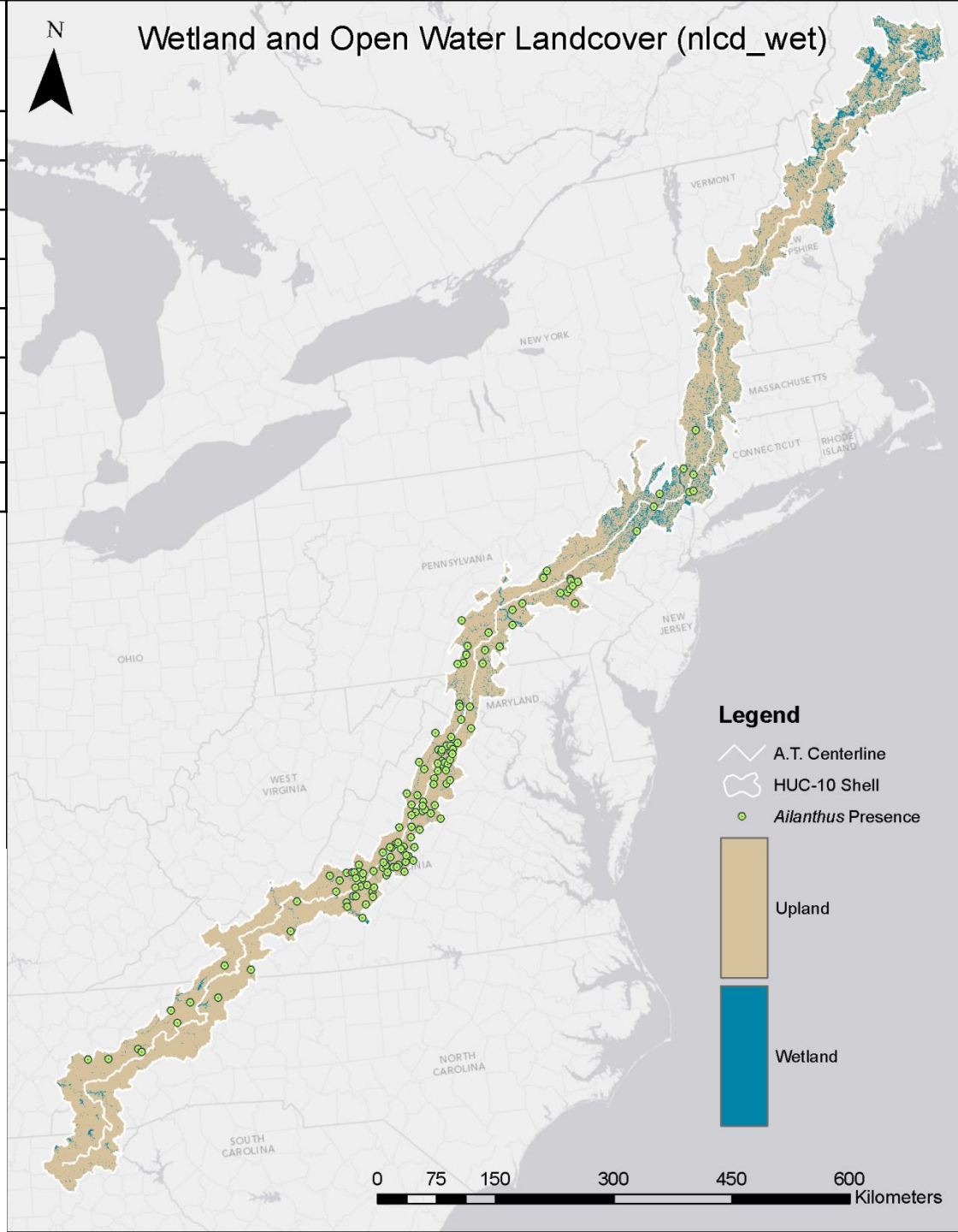




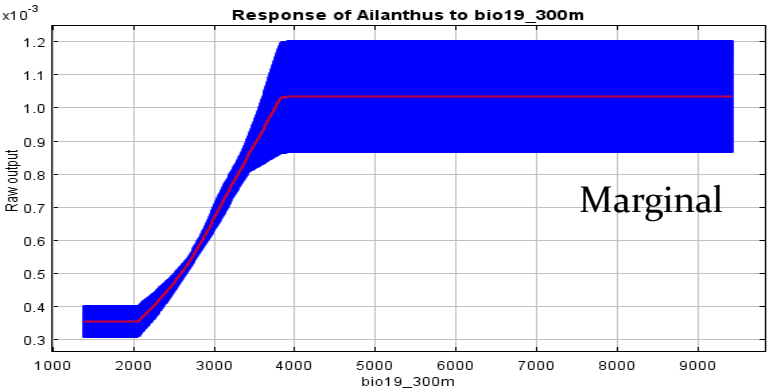
Variable	Percent contribution	Permutation importance
bio11	40.1	34.7
bio4	27.1	43.9
bio8	22.7	6
slope	4.6	5.1
trasp	3.1	2
nlcd_wet	***0.9***	***0.7***
bio19	0.8	2.4
dem	0.6	5.3

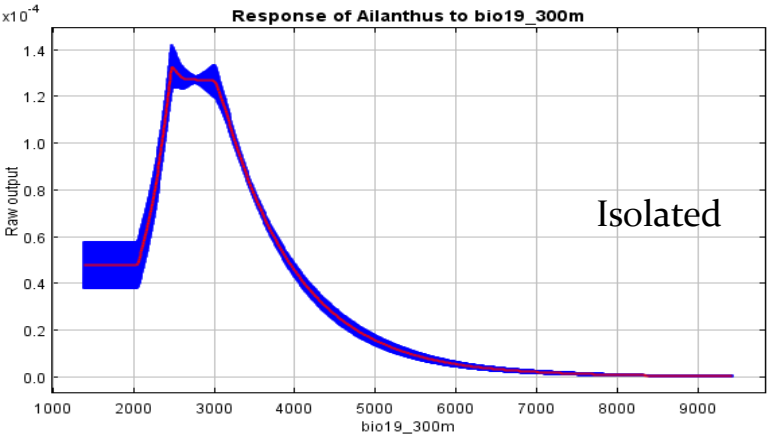


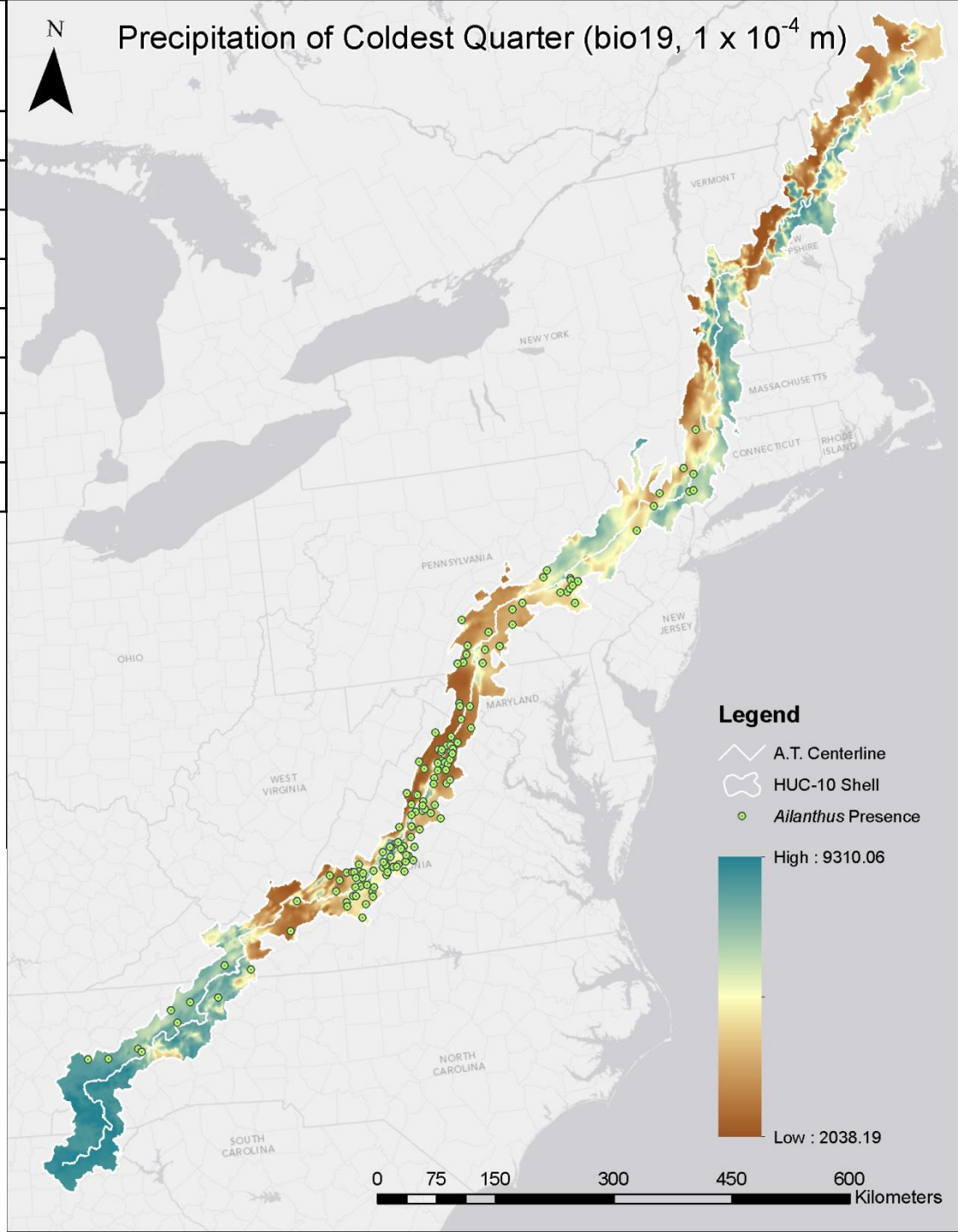




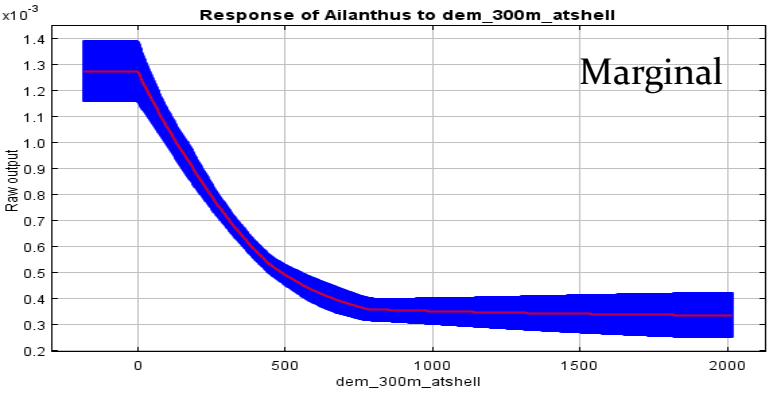
Variable	Percent contribution	Permutation importance
bio11	40.1	34.7
bio4	27.1	43.9
bio8	22.7	6
slope	4.6	5.1
trasp	3.1	2
nlcd_wet	0.9	0.7
bio19	***0.8***	***2.4***
dem	0.6	5.3

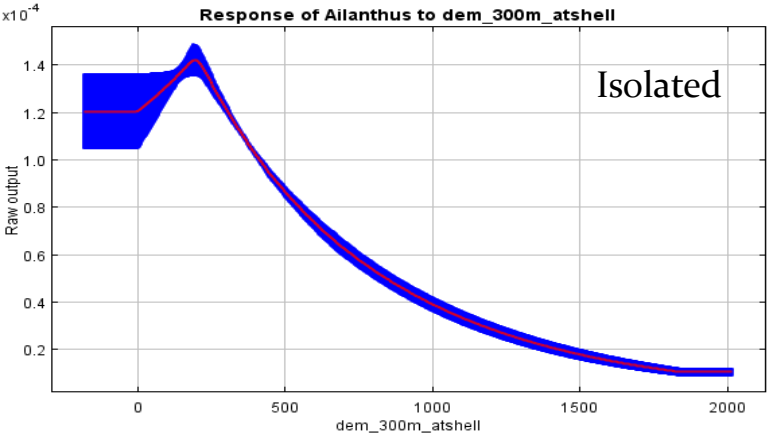


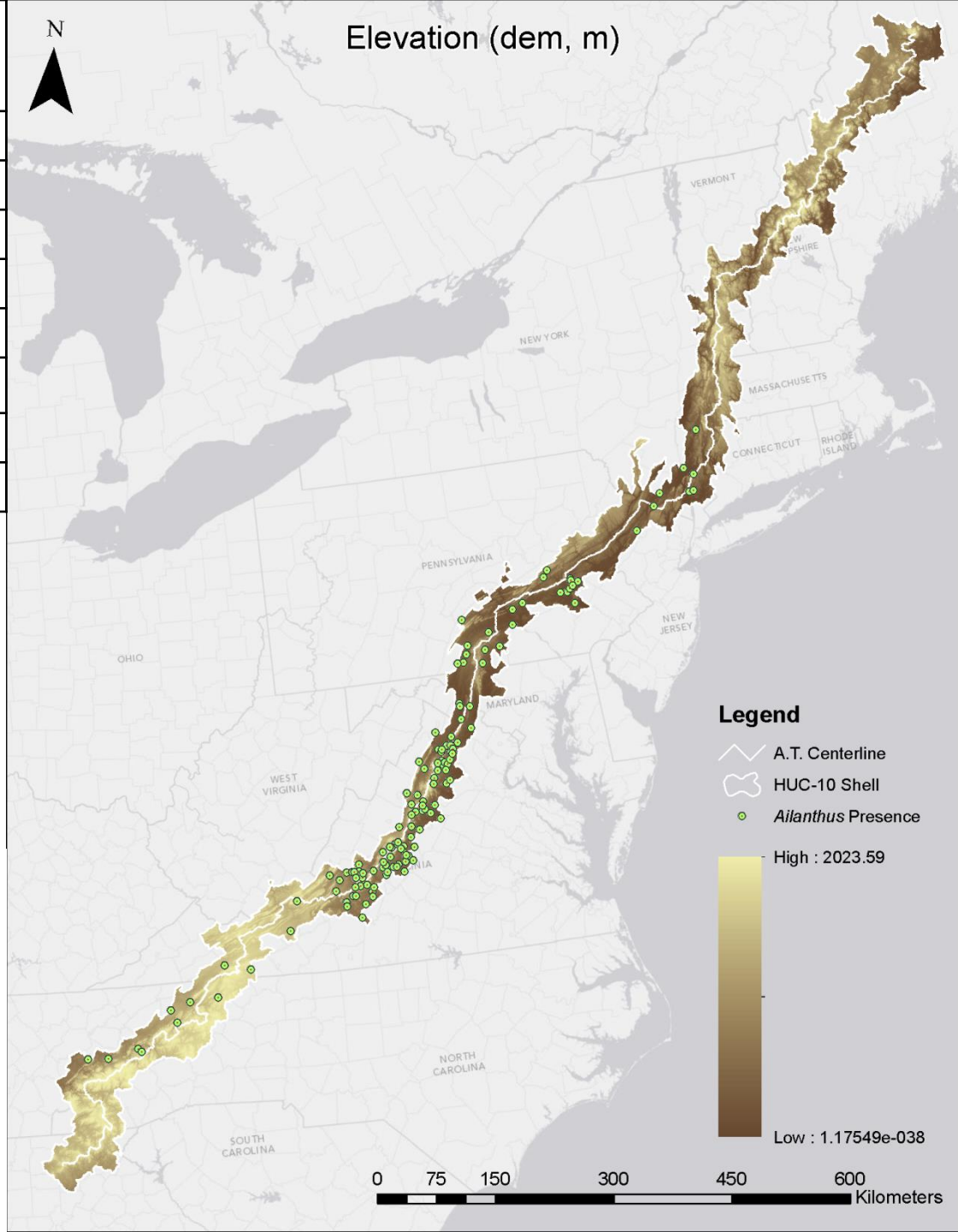


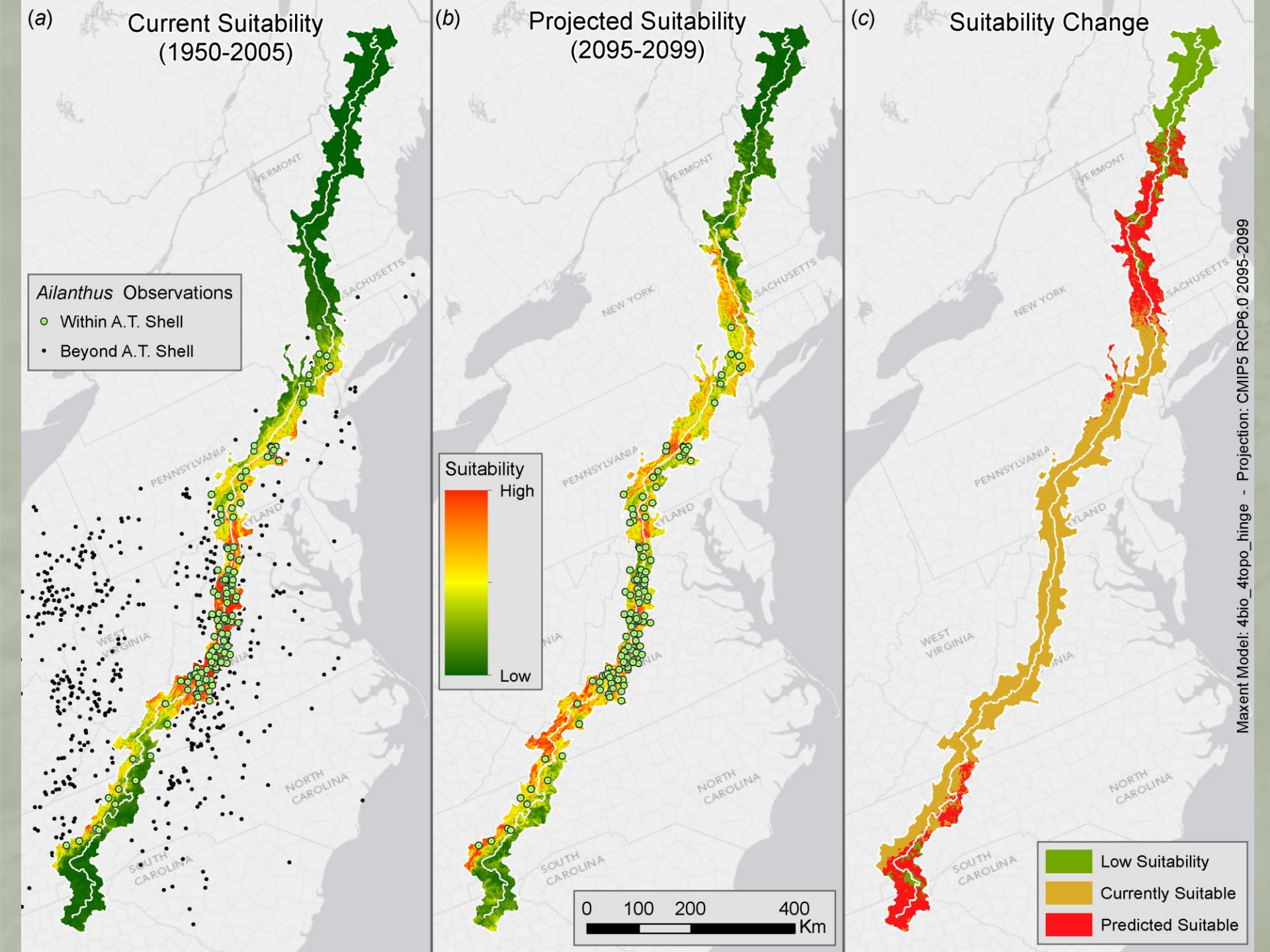


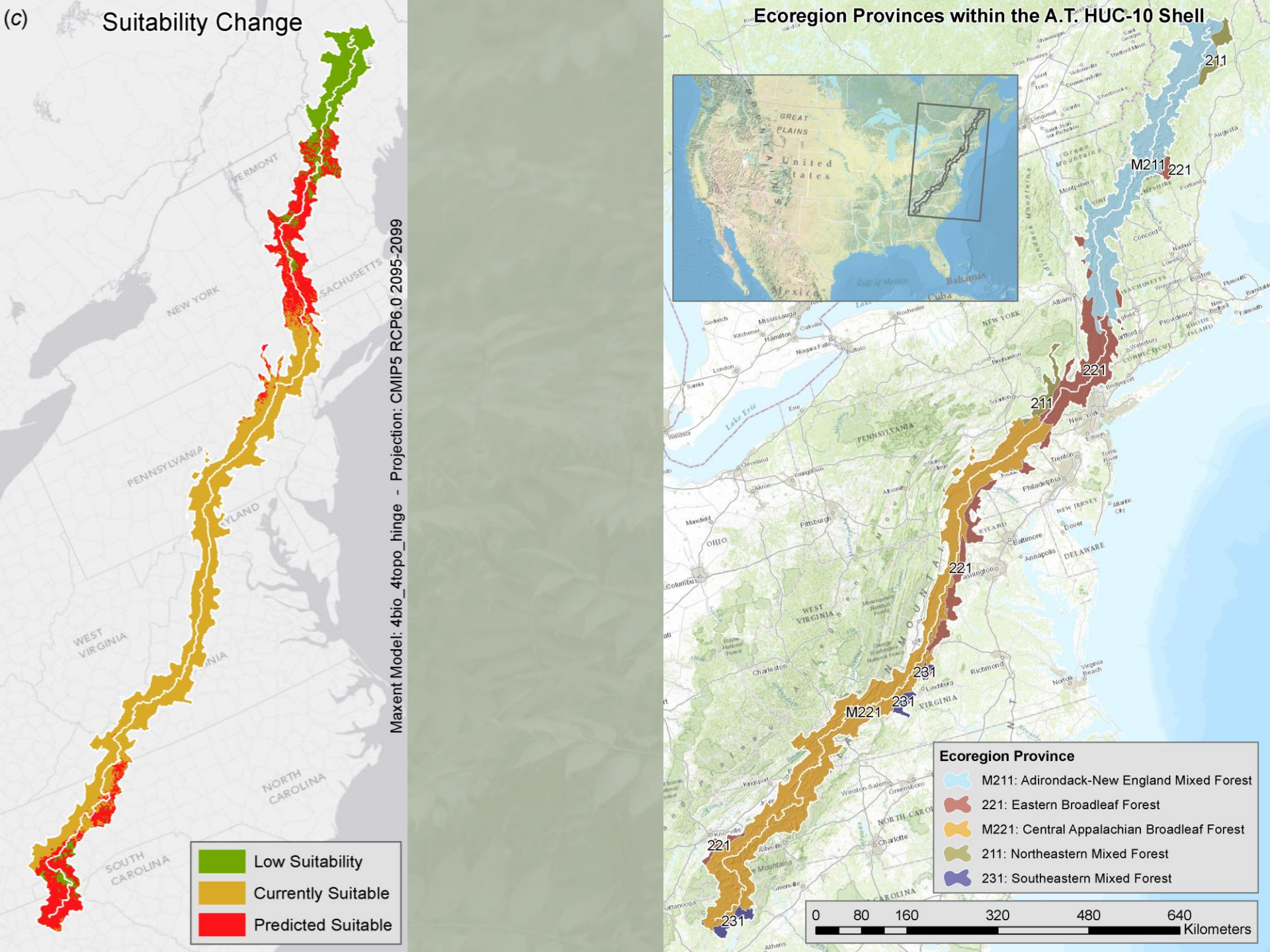
Variable	Percent contribution	Permutation importance
bio11	40.1	34.7
bio4	27.1	43.9
bio8	22.7	6
slope	4.6	5.1
trasp	3.1	2
nlcd_wet	0.9	0.7
bio19	0.8	2.4
dem	***0.6***	***5.3***



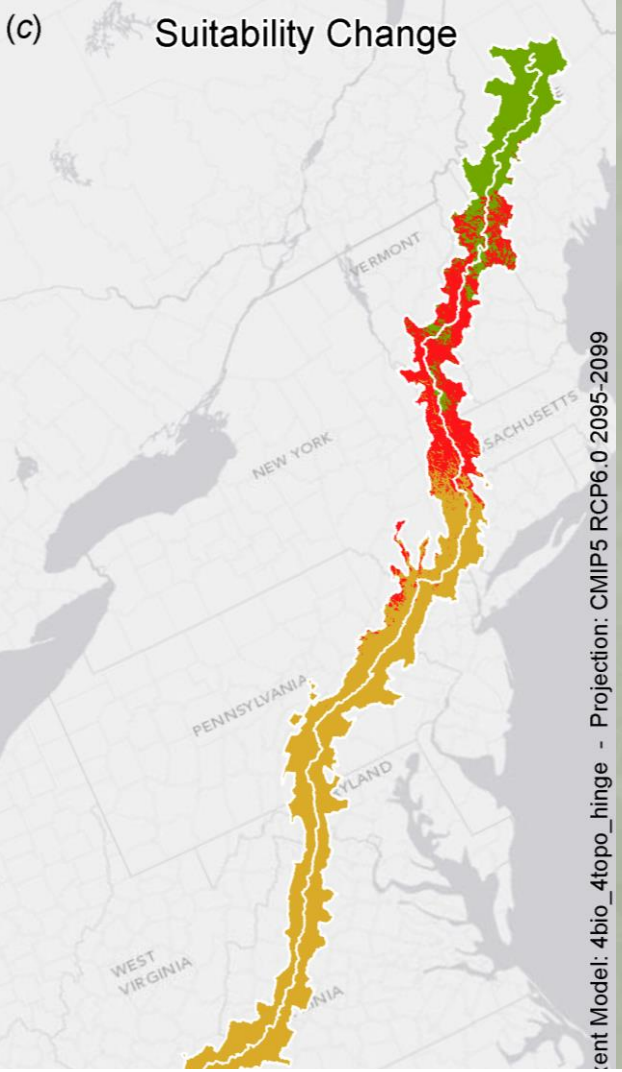





(a)
Current Suitability
(1950-2005)
Ailanthus Observations
Within A.T. Shell
Beyond A.T. Shell
(b)
Projected Suitability
(2095-2099)
Suitability
High
Low
0 100 200 400
Km
(c)
Suitability Change
Low Suitability
Currently Suitable
Predicted Suitable
Maxent Model: 4bio_4topo_hinge - Projection: CMIP5 RCP6.0 2095-2099
VERMONT
NEW YORK
PENNSYLVANIA
WEST VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA

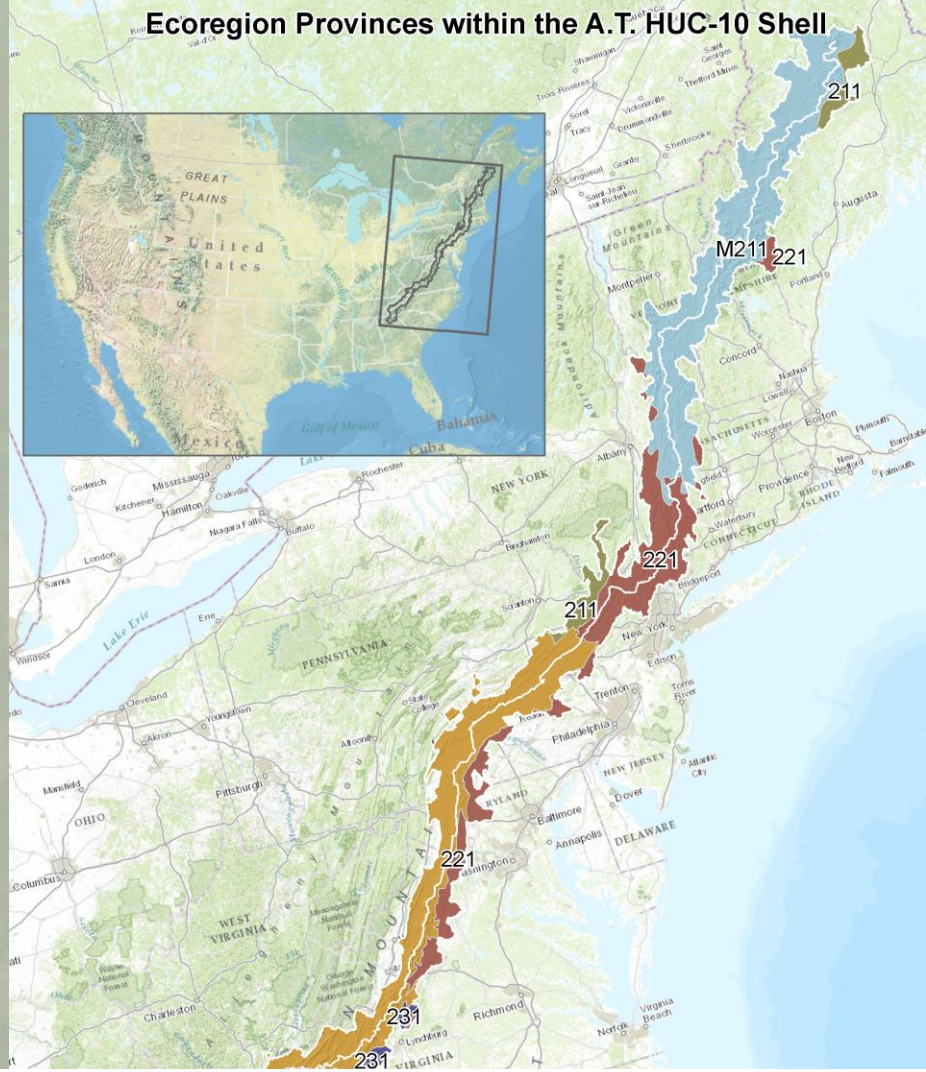

(c)
Suitability Change
Maxent Model: 4bio_4topo_hinge - Projection: CMIP5 RCP6.0 2095-2099
Low Suitability
Currently Suitable
Predicted Suitable
Ecoregion Provinces within the A.T. HUC-10 Shell
211
M211
221
231
M221
Ecoregion Province
M211: Adirondack-New England Mixed Forest
221: Eastern Broadleaf Forest
M221: Central Appalachian Broadleaf Forest
211: Northeastern Mixed Forest
231: Southeastern Mixed Forest
0 80 160 320 480 640
Kilometers

(c) Suitability Change



Current Model: 4bio_4topo_hinge - Projection: CMIP5 RCP6.0 2095-2099

Ecoregion Provinces within the A.T. HUC-10 Shell



province	suitable area (km²) total area	current	%	projected	%	change	%	mean elevation (m) current	projected	change	%	mean latitude current	projected	change (km)
211	*4478*	*1283*	*28.7*	*2372*	*53.0*	*1089*	*84.8*	*289*	*414*	*125*	*43.3*	*41.26*	*41.41*	*17*
221	20 013	17 211	86.0	19 802	98.9	2591	15.1	195	201	6	3.0	40.31	40.63	36
231	*2831*	*1577*	*55.7*	*2824*	*99.7*	*1247*	*79.1*	*267*	*348*	*81*	*30.1*	*37.17*	*36.02*	*−128*
M211	29 746	624	2.1	14 969	50.3	14 345	2298.3	340	436	96	28.2	42.49	43.46	108
M221	51 004	39 348	77.1	49 098	96.3	9750	24.8	491	561	70	14.2	38.23	37.68	−61
A.T. Shell	10 8072	60 044	55.6	89 066	82.4	29 022	48.3	391	449	59	15.1	38.91	39.35	49

Discussion

- Simple models with clear ecological interpretation performed strongest
- Projecting to future conditions precludes use of landcover/veg variables
  - performed poorly at broad scale of model regardless
- FIA plot location fuzzing limits examination of fine-scale site characteristics
- Independent test data needed to further evaluate performance

Conclusions

- Combining *Ailanthus* presences from FIA and Maxent modeling techniques successfully estimated current and projected suitable habitats
- Strong indication potential extent of *Ailanthus* habitats likely to increase as climate changes
- Introductions will increase invasive pressure on sensitive high elevation and northern ecosystems

Thank You!

Major Professor – Dr. Y.Q. Wang
Thesis Committee – Drs. Keith Killingbeck, Pete August, and Charlie Roman.
URI A.T. DSS Team – Roland Duhaime, Chris Damon, Jianjun Zhao, Fu Luo, Chuck Labash, and Peter Paton

The Environmental Data Center, Laboratory for Terrestrial Remote Sensing, and the NRS community

A.T. DSS Project Team: Rama Nemani[2], Fred Dieffenbach[3], Ken Stolte[4], Glenn Holcomb[5], Matt Robinson[6], Marcia McNiff[5], Paul Mitchell[7], Casey Reese[6], Forrest Melton[2], Hirofumi Hashimoto[2], Sam Haitt[2], Brian Mitchell[3], Geri Tierney[8]
2. NASA/Ames Research Center, 3. National Park Service/Northeast Temperate Network, 4. U.S. Forest Service, 5. U.S. Geological Survey, 6. National Park Service/Appalachian National Scenic Trail, 7. Appalachian Trail Conservancy, 8. SUNY