Warming and Disturbances Threaten Arctic-Boreal Vegetation Resilience

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1 Background & Objectives

- Rapid warming and increasing disturbances cause large uncertainties in future vegetation changes and carbon sink strength of Arctic-boreal ecosystems.
- Related predictions require understanding when and where vegetation becomes vulnerable to climate fluctuations and disturbances and how fast it recovers from deviated states, i.e., vegetation resilience.
- Based on nonlinear dynamical theory (*Sheffer et al., 2015*), we measured vegetation resilience using lag-1 autocorrelation of Enhanced Vegetation Index (EVI) from MODIS across the NASA Arctic-Boreal Vulnerability Experiment (ABoVE) core domain to evaluate:

① Pattern of resilience change over the recent decades;
② Climate & environmental factors driving the change;
③ Temporal trajectory of resilience before and after land cover changes and fire disturbance.

2 Data & Methods

- EVI: MODIS, 250 m, 16-day, 2000 to 2019
- Land cover change, 30 m (*Wang, J.A. et al. 2019*)
- Disturbances, 30 m (*Zhang et al., 2022*)
- Climate: ClimateNA, 4 km (*Wang, T. et al., 2016*)
- Topography, permafrost, soil nitrogen, soil moisture

EVI & Climate time series

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Bayesian dynamic linear model (*Liu et al., 2019*):

$$EVI_t = F_t^T \theta_t + v_t, \theta_t = G\theta_{t-1} + w_t$$

$$\theta_t = (\theta_{Trend,t}, \theta_{Seasonality,t}, \theta_{Climate,t}, \theta_{AC,t})^T$$

$\theta_{AC,t}$: time-varying lag-1 AC of EVI measuring resilience

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① •AC+ (reduced resilience) •AC- (enhanced resilience) ⇐ ② Random forest ⇐ Climate & environmental factors

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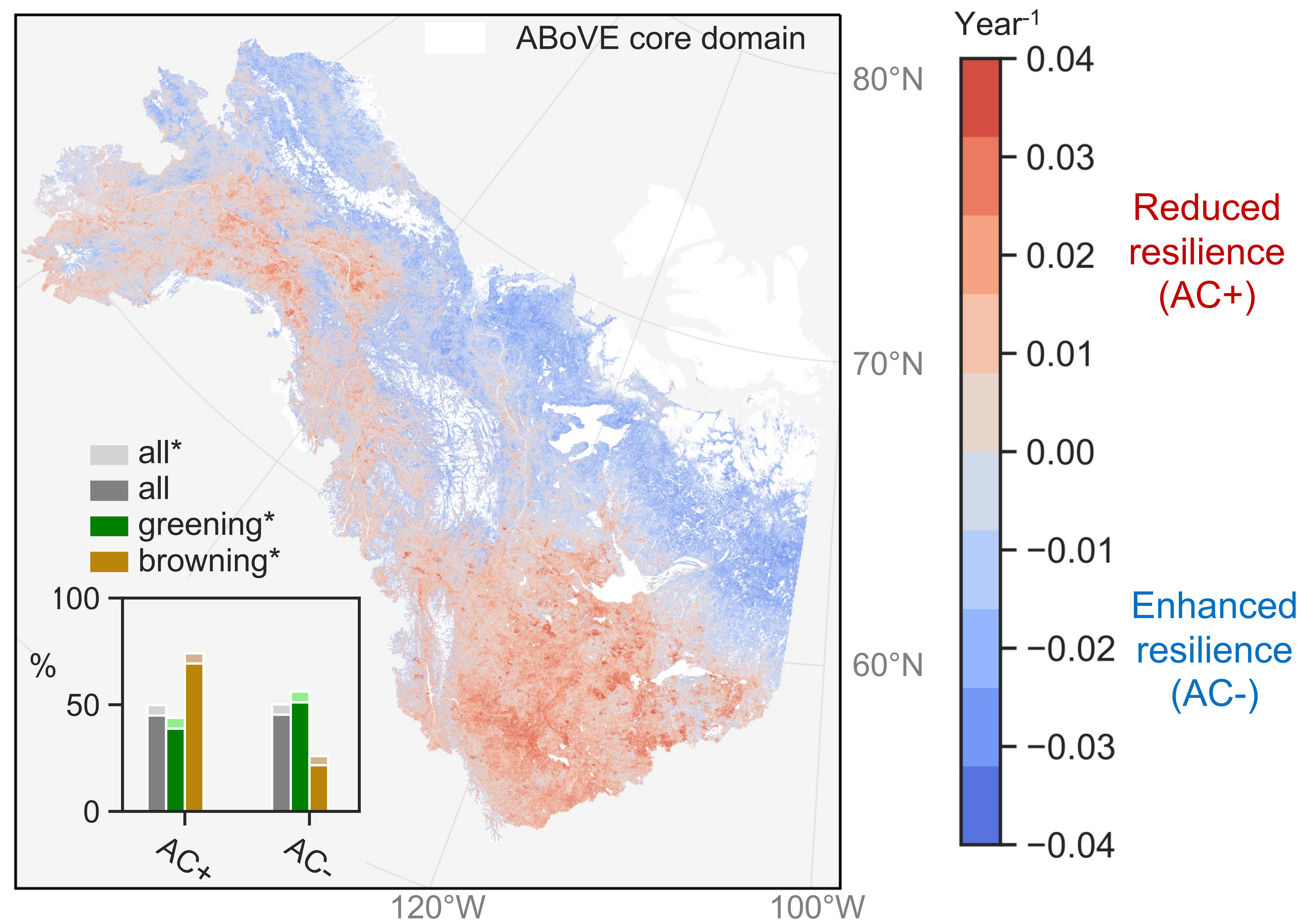
Disturbance & land cover change maps ⇒ ③ Resilience trajectory before & after

The Ohio State University

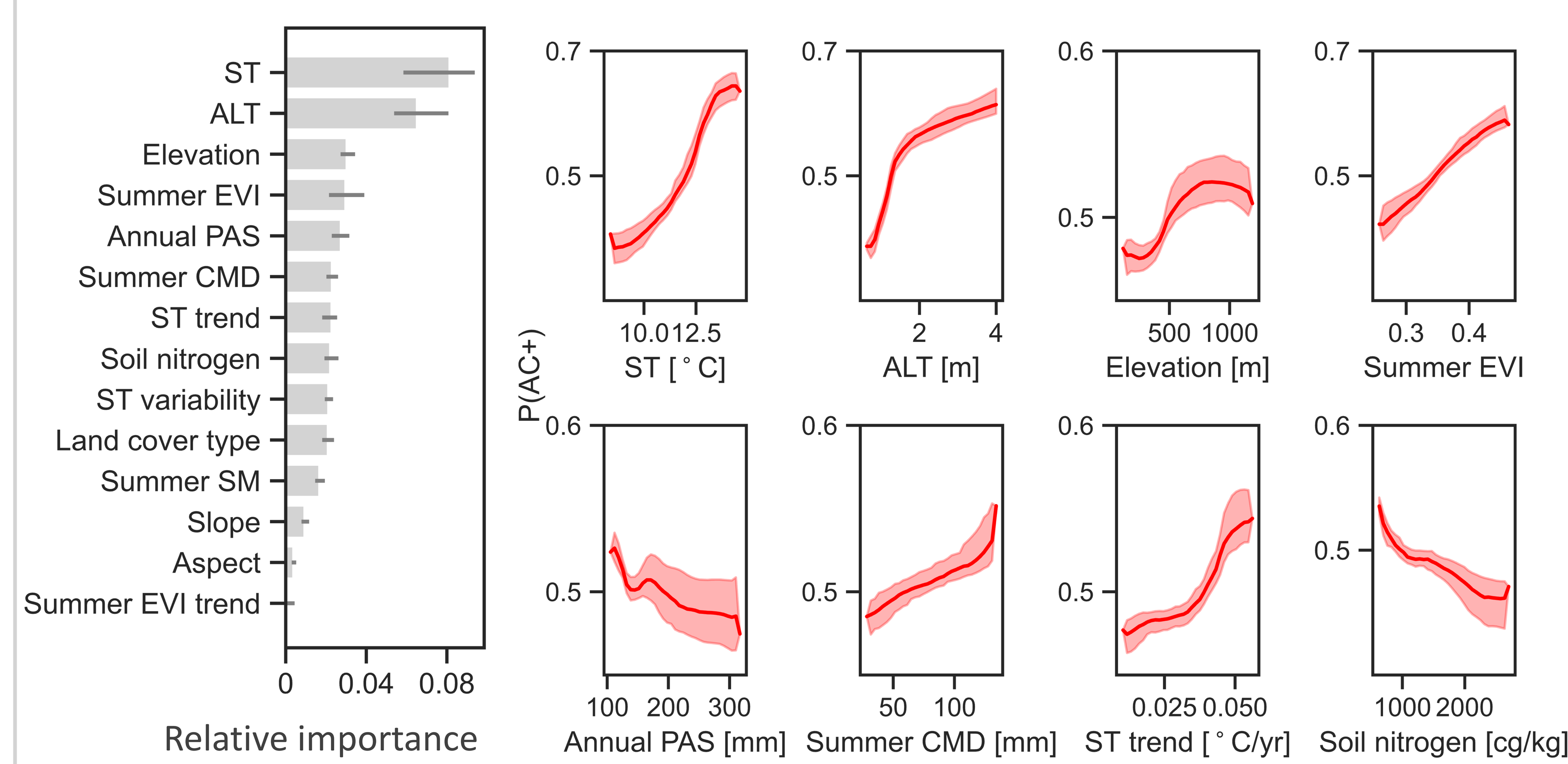
3 Results

3.1 Spatial pattern of resilience trend during 2000-2019



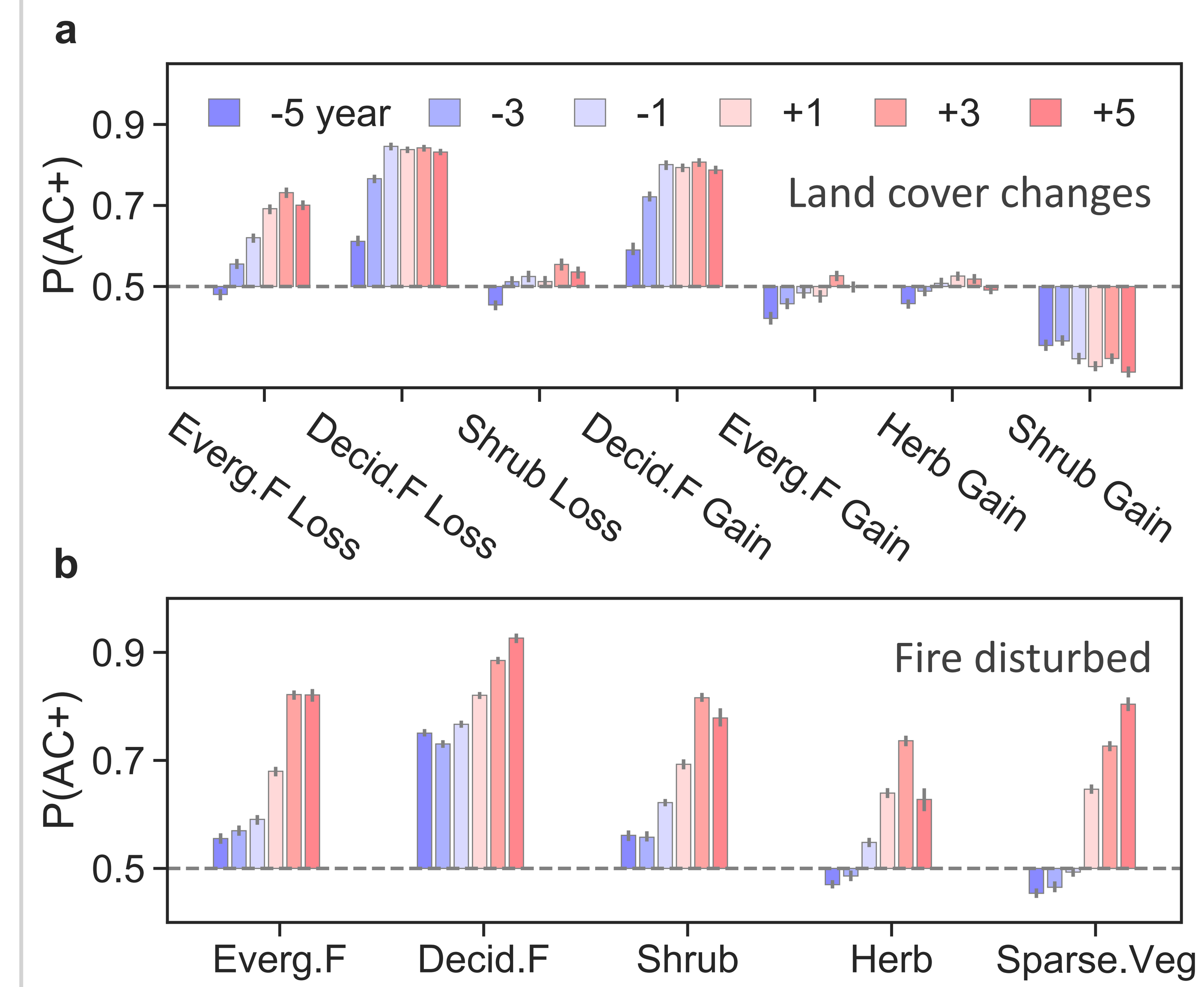
- Vegetation resilience pervasively declined in boreal forests while increased in Arctic tundra.
- Browning areas more frequently exhibited reduced resilience.
- Yet 40% of greening areas still experienced reduced resilience.

3.2 Critical controls explaining resilience change pattern



- Resilience was more likely to reduce (high P(AC+)) in areas with higher summer temperature, greater active layer thickness, higher elevation, larger EVI, lower precipitation as snow, higher climate moisture deficit, faster warming, and lower soil nitrogen content.

3.3 Resilience trajectory before/after land cover changes and fire disturbance



- Land cover changes and fires were frequently accompanied by low resilience before and after.
- Reduced resilience proceeded forest losses.
- Resilience frequently remained low 5 years after, especially in fire disturbed woody ecosystems.

4. Take-aways

- Vegetation resilience pervasively increased in Arctic tundra but declined in boreal forests under warming.
- Greening did not always enhance resilience.
- Warm, dry, and high elevation areas were hotspots of resilience decline.
- Land cover changes and fires further diminished resilience.
- Impaired ecosystem stability could potentially dampen the expected increase of boreal forest carbon sink strength under future climate.

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ARCTIC – BOREAL VULNERABILITY EXPERIMENT