Tree Crown-scale Greendown Rates from Harmonized Landsat and Sentinel-2 Phenology Data at eight NEON Sites in the Broadleaf Deciduous Forests of North America

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ABSTRACT

Landsat data has highlighted the impacts of global change on ecosystem phenology, including less-studied phenomena like greendown, a decline in greenness between full leaf expansion and senescence in broadleaf deciduous forests. By combining and Harmonized Landsat and Sentinel-2 (HLS) observations of the near Infrared of Vegetation Index (NIR_v) with a field-delineated dataset of over 300 tree crowns from the National Ecological Observatory Network (NEON), we measured greendown from the phenology of individual trees of varying species and across wide environmental gradients.

1. INTRODUCTION

- Greendown, the decline in NIR reflectance through growing season (**Fig. 1**), affects estimates of productivity, and potentially signals tree and ecosystem responses to environmental changes.
- Influenced by abiotic (e.g., sun angle), but also biotic (e.g., crown architecture) drivers, greendown may be part of a tree's ecological strategy (McNeil et al. 2023).
- We quantified tree crown-scale greendown across diverse species and wide environmental gradients using HLS and NEON data to address an unanswered question: what drives greendown?

2. DATA & OBJECTIVES

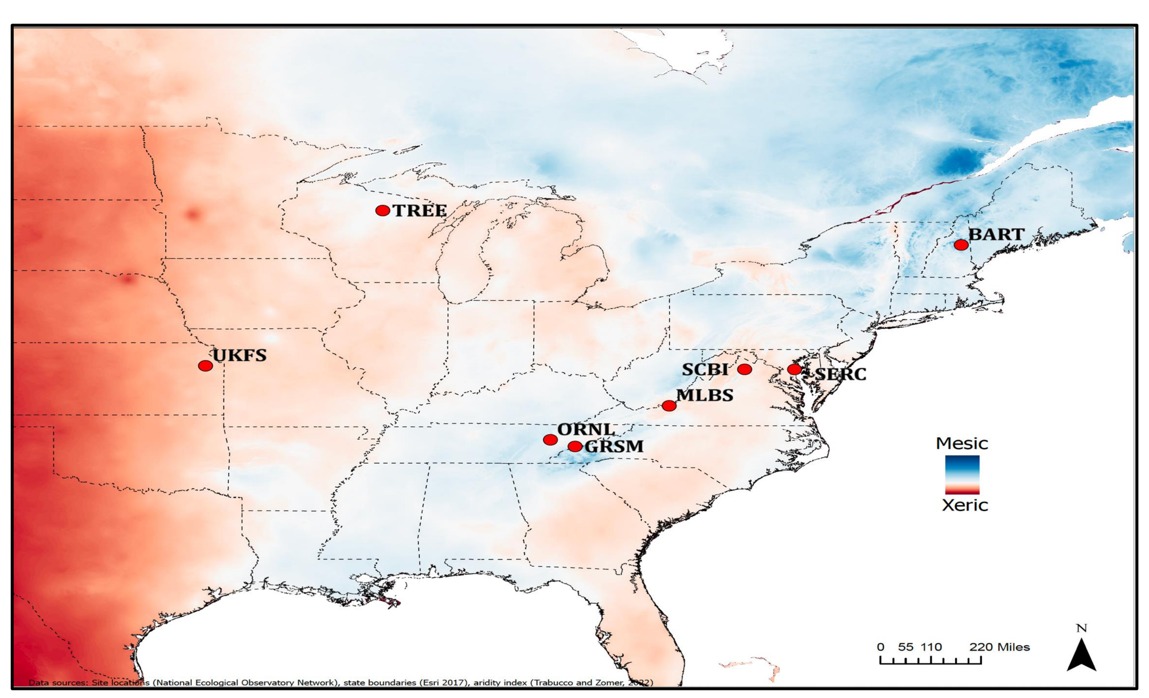

Fig. 2 *Locations of* 8 NEON broadleaf deciduous forest sites across a strong climate gradient in eastern North America

We use HLS- derived (v2.0) (30m) NIR_v measurements from 2013 through 2024 from 8 of NEON's broadleaf deciduous-dominated forest sites to quantify key phenological parameters, including tree crown-scale greendown across a wide moisture gradient (**Fig. 2**). Specifically, we:

1) Assessed the degree to which species and sites differed in greendown, MAXVEG and season length
2) Evaluated the intra-specific variability in these metrics across sites
3) Explored sub-continental scale drivers of greendown

3.1 METHODS

- We fitted a NIR_v phenology curve using a dual logistic model (**Fig. 1**, Elmore et al., 2012). NIR_v = NIR × NDVI, where NDVI = (NIR - RED) / (NIR + RED) (Badgley et al., 2017).
- We derived the 7 key parameters (Elmore et al., 2012) and other phenological traits (e.g., season length)
- **Quality Control:** we filtered bad-fit crowns based on season length (<100 or >300), greendown length (<60), model fit (misfit>95), and DoY of MAXVEG (>200) (**Fig. 1**), resulting in a robust phenology data for 310 high-quality tree crowns.

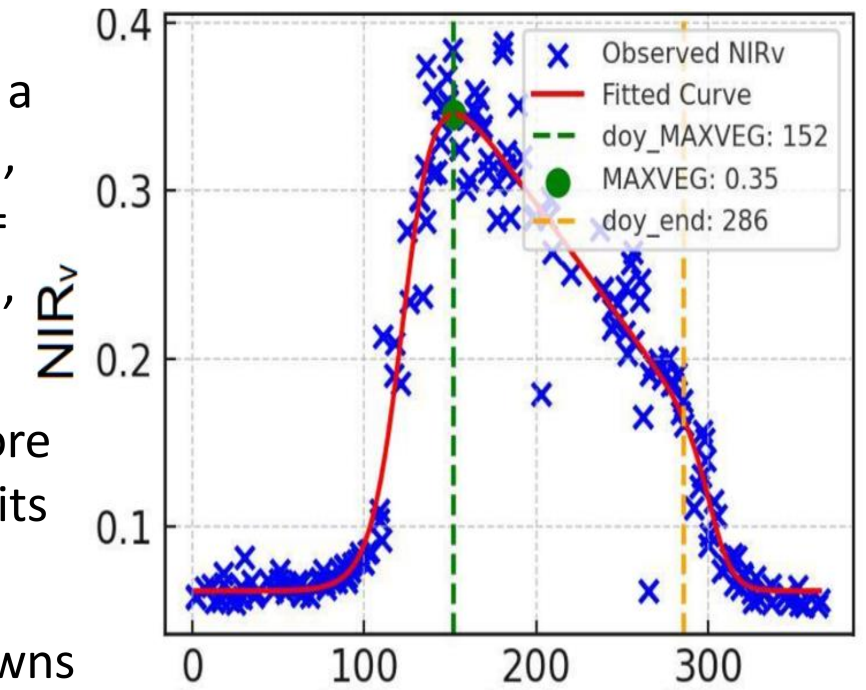

Fig. 1 *An example of greendown phenology fitted using a dual logistic model (Elmore et al., 2012) to HLS-derived NIR of vegetation (NIRv) for a tulip tree at the GRSM NEON site.*

4. RESULTS & DISCUSSION

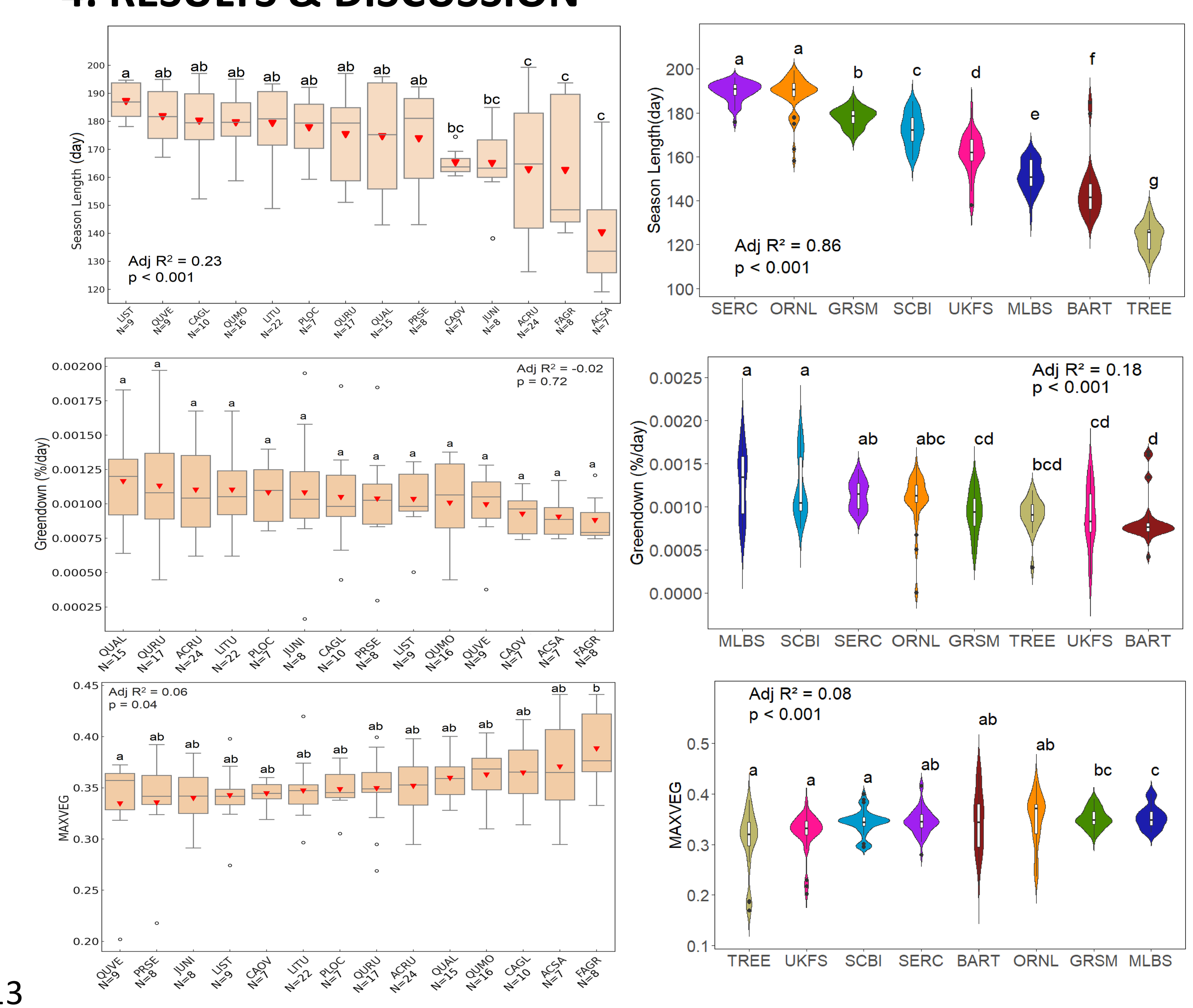

Fig. 3 *Distributions of species (left) and site (right) differences in season length, greendown, and MAXVEG, with effects shown as ANOVA adj R2. Letters denote sites whose means are significant*

- **Species differences (Fig. 3):** Species did not significantly differ in greendown, but species with more northern distributions, like sugar maple (ACSA) & American beech (FAGR), had shorter season lengths, and higher MAXVEG.
  - The higher MaxVeg may be linked to species differences in crown architecture, such as more horizontal leaf angles in ACSA and FAGR

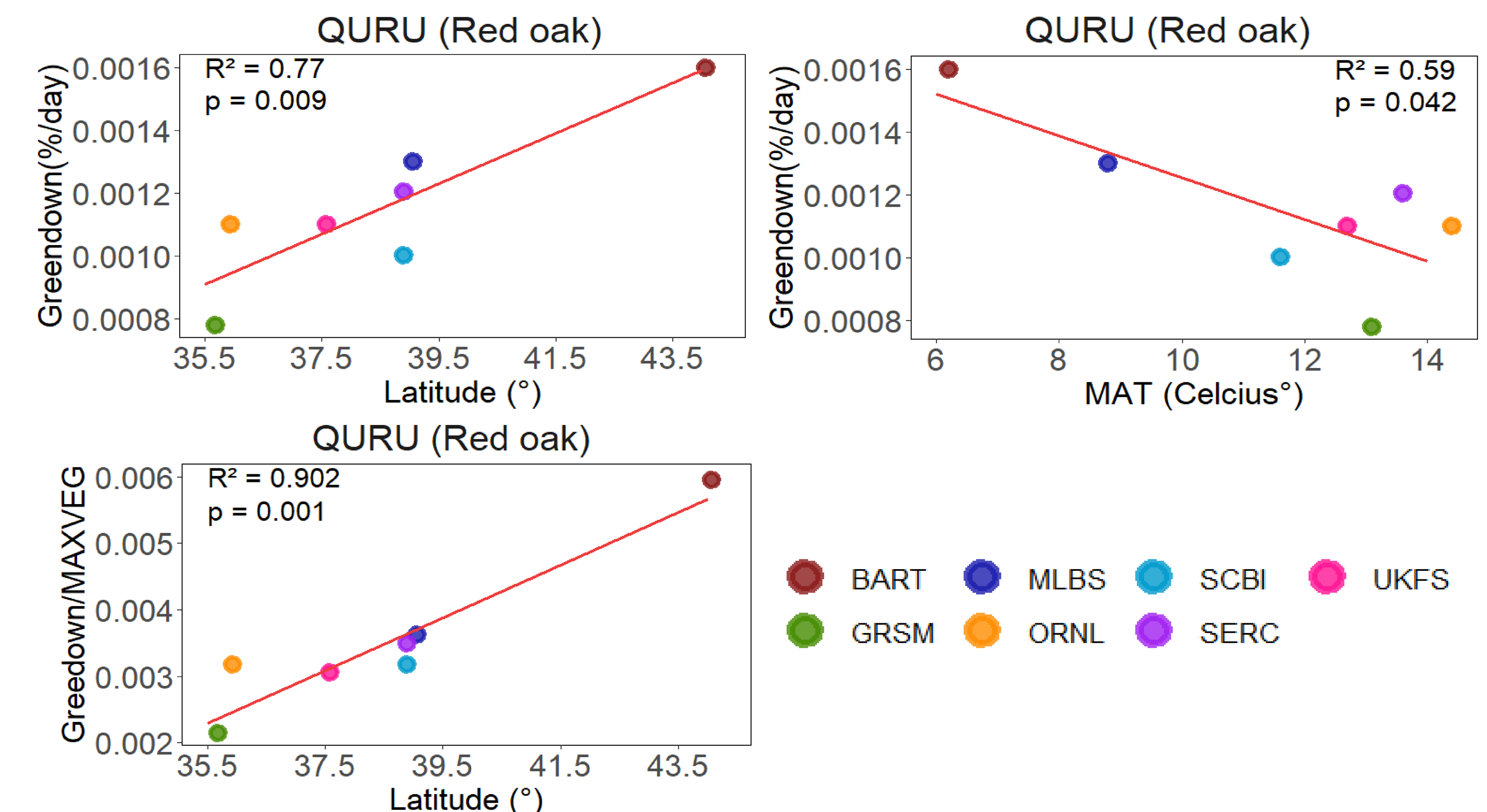

Fig. 4 *Intra-specific variability of red oak, a wide-spread northeastern species, in greendown along gradients of latitude and mean annual temperature (MAT).*

- **Site Differences (Fig. 3)**: Even though latitude had a strong effect on season length across the 8 sites, the amplitude (MaxVeg) and rate of change in greenness (greendown) often had as much variability within a site as across sites. This reflects NEON's crown delineations of diverse species at each site.
- **Variability within a species (Fig. 3 & 4)** : In the more northerly sites containing the widespread species of red oak, we observed stronger rates of greendown, which may be linked to ecotypic and dynamic variability in crown architecture and/or leaf chemistry & structure.

5. CONCLUSIONS

- Like other aspects of phenology, greendown is shaped by complex, multi-scale interactions among abiotic & biotic factors (Melaas et al., 2018).
- High greendown may be an ecological strategy that prioritizes productivity in early summer at the expense of maintaining productivity through the late summer (Elmore et al. 2016).
- Future work could productively explore the genetic basis, as well as the leaf and crown economic mechanisms of greendown (McNeil et al. 2023).

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