From Canopy to Rain Chemistry: Vegetation Phenology as a Driver of Organic Matter Wet Deposition

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Introduction

- Wet deposition is a key pathway for transferring carbon (C) and nitrogen (N) from the atmosphere to the biosphere.
- While inorganic N deposition has been widely studied, dissolved organic matter (DOM – composed of organic C and N) deposition remains understudied.
- Natural and anthropogenic emissions contribute to DOM wet deposition. Natural volatile organic compounds (BVOCs) emitted by plants are major precursors of organic molecules that can be scavenged by rain to form DOM (Fig 1). BVOC emissions co-occur with photosynthesis and transpiration during the growing season.
- The role of terrestrial phenology (i.e., vegetation growth, growing season) in driving spatiotemporal patterns of DOM wet deposition is poorly understood.

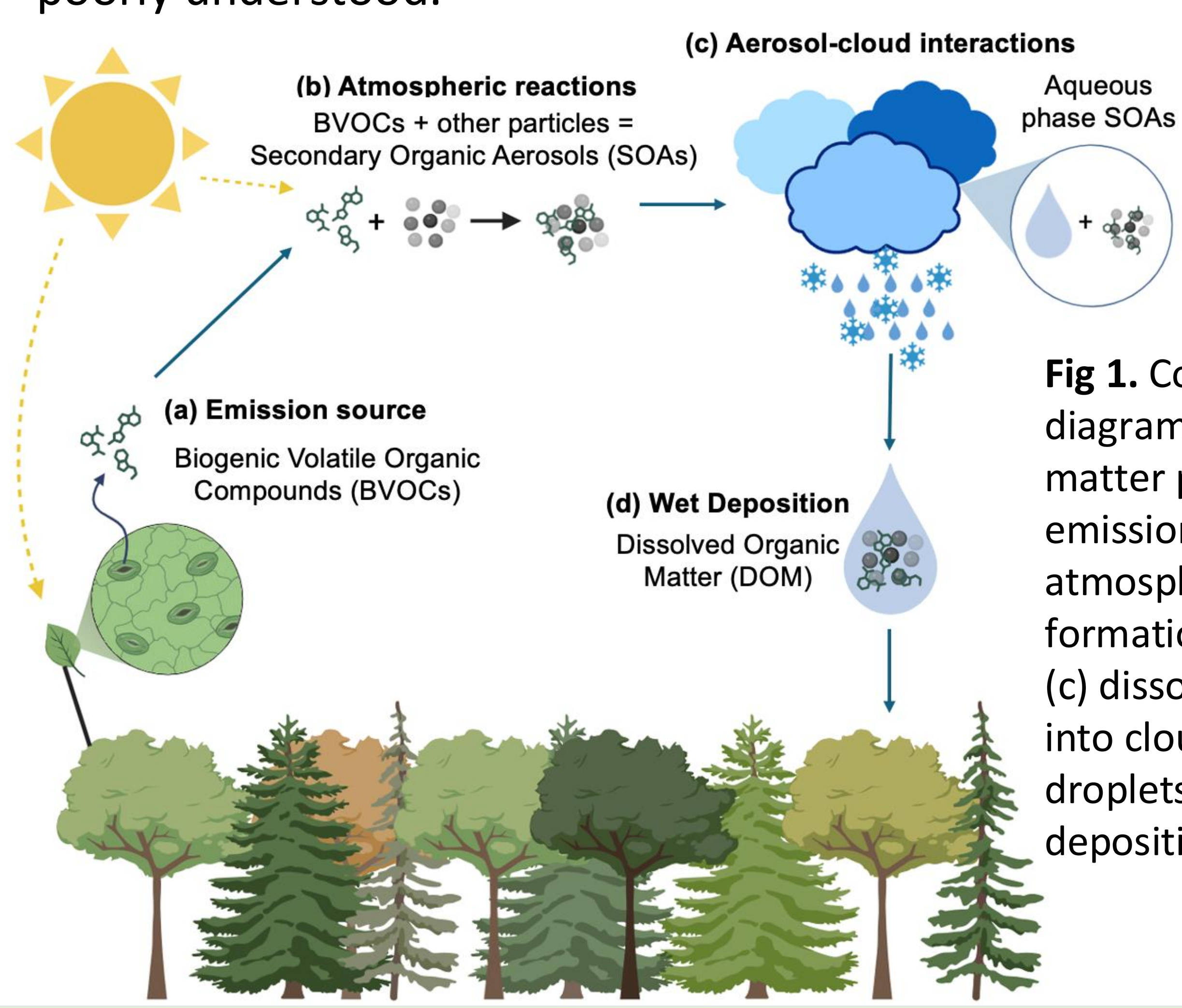

Fig 1. Conceptual diagram of (a) organic matter precursor emissions to the atmosphere, (b) SOA formation from BVOCs, (c) dissolution of SOAs into cloud and rain droplets, and (d) wet deposition of DOM.

Research Question & Hypothesis

How do spatial and seasonal differences in vegetation phenology across eastern forests co-vary with DOM wet deposition?

H: Higher concentrations of DOM wet deposition are associated with greater terrestrial productivity metrics measured as leaf area index (LAI), normalized difference vegetation index (NDVI), and transpiration (E_t) due to increased BVOC emissions from plants.

Methods

- Analyzed 1,058 archived 2018 NADP wet deposition samples from 27 sites, selected based on EPA Level II ecoregions (Fig 2).
- Validated stability of dissolved inorganic N (NH_4^+, NO_3^-) before measuring TDN and DOC (Fig 3); DON was estimated by subtraction.
- NASA Moderate Resolution Imaging Spectroradiometer LAI (MOD15AH), NDVI (MCD43A4), and Global Land Evaporation Amsterdam Model E_t data products were used to characterize phenology within a 100km area around each site.

Results: Seasonality and Drivers of DOM Deposition

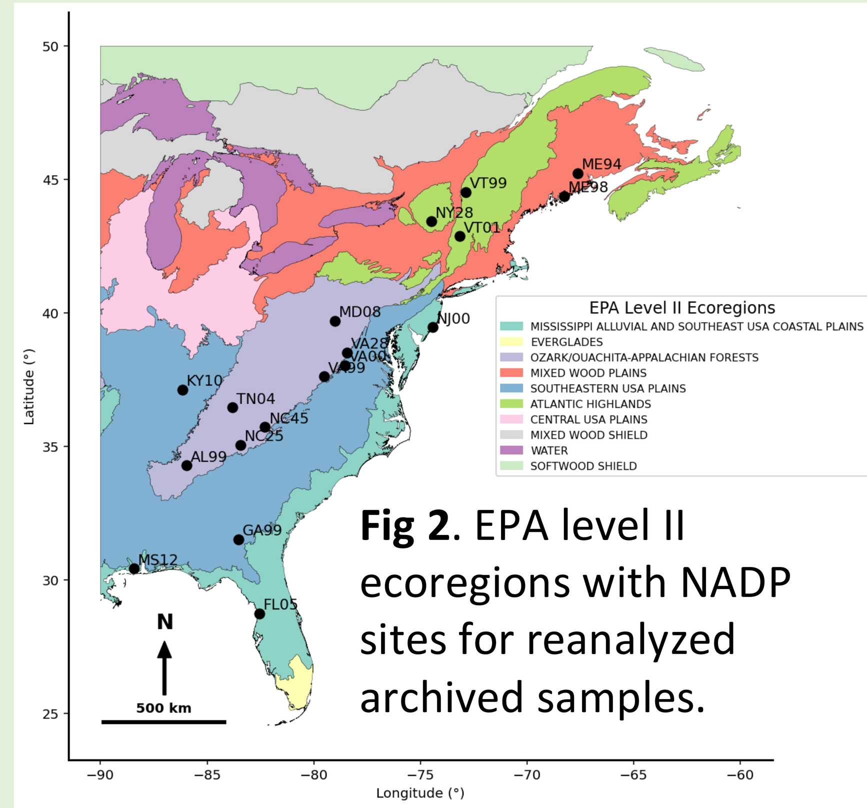

Fig 2. EPA level II ecoregions with NADP sites for reanalyzed archived samples.

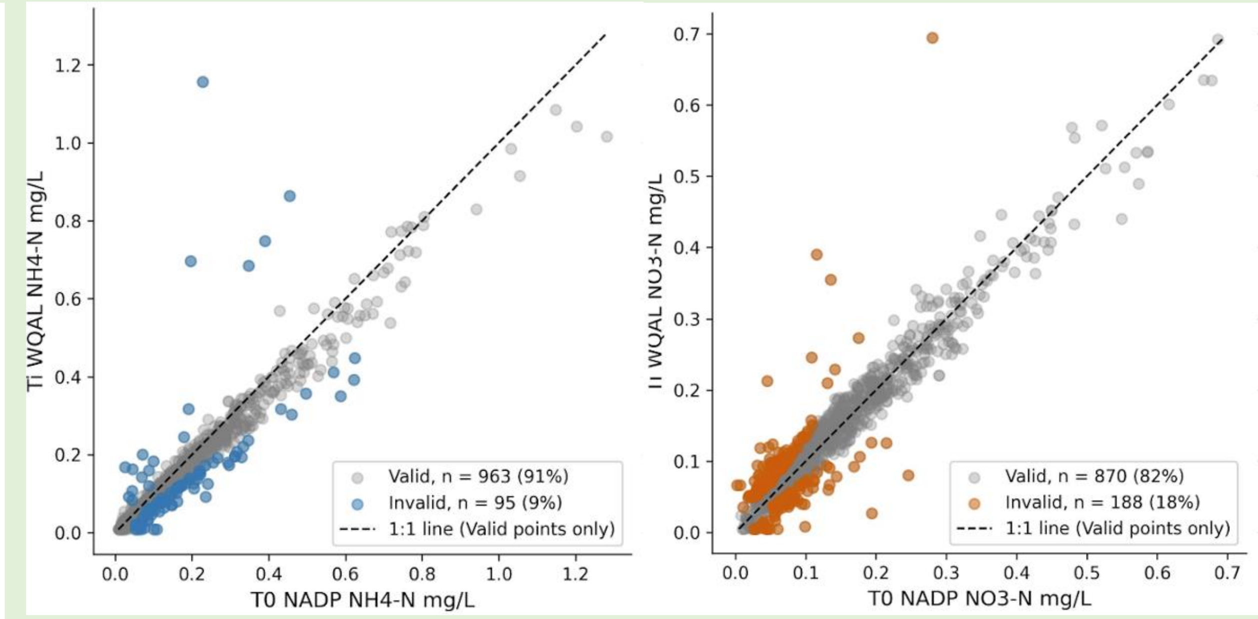

Fig 3. Validation plots of DIN concentrations analyzed by UNH Water Quality Analysis Lab (WQAL) and NADP for all sites. 75% of samples (*n=793*) were viable in 2025.

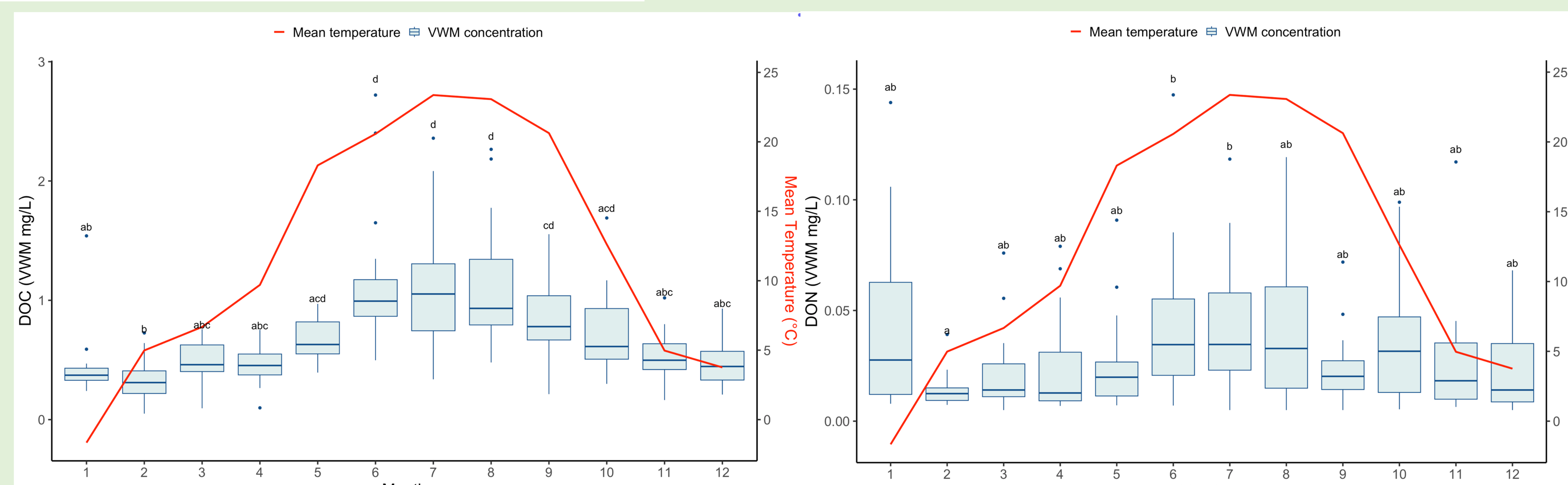

Fig 4. Monthly boxplots of DOC and DON volume-weighted mean (VWM) concentrations showing seasonal variation. Letters indicate statistically significant differences between months from Kruskal-Wallis test.

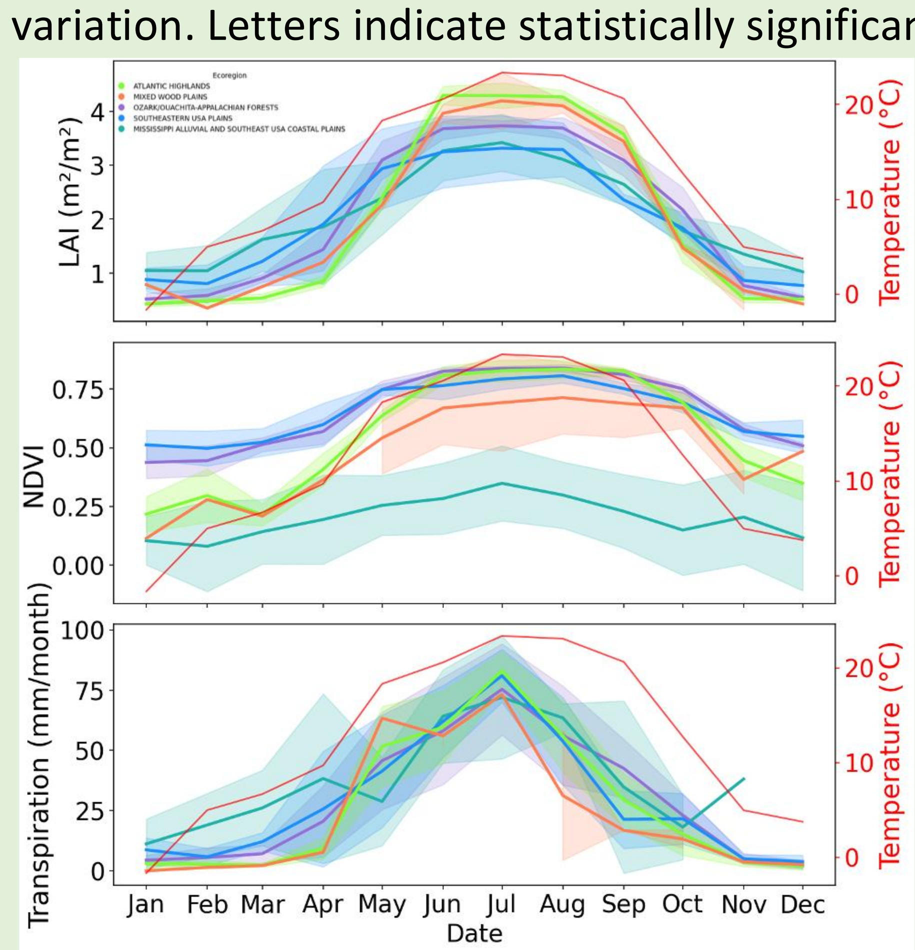

Fig 5. Monthly mean LAI, NDVI, and total E_t for each region. Lines colored by ecoregion and shading denotes ±1 SD.

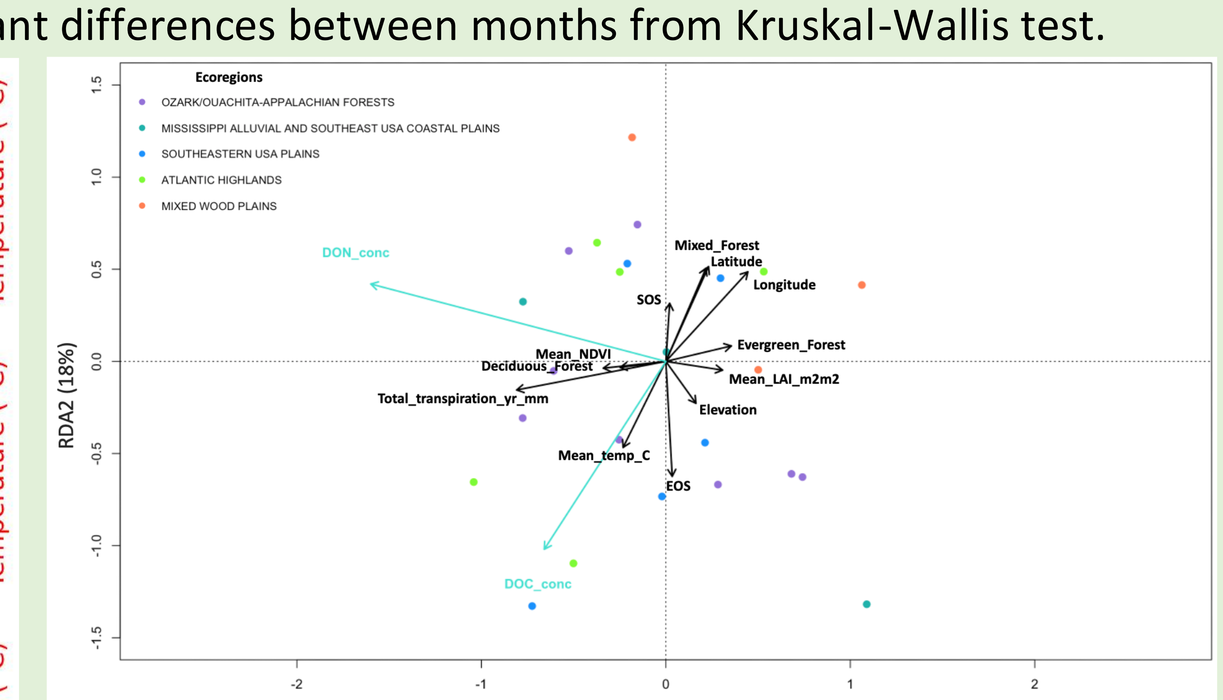

Fig 6. Redundancy analysis of annual mean DOC and DON wet deposition concentrations, LAI, NDVI, Et, temperature, start of season (SOS), end of season (EOS), and % forest cover. Points colored by ecoregion.

Key Results

- DOM concentrations show seasonal variation, increasing as vegetation develops during the growing season (Figs 4 & 5).
- DOC deposition concentrations are positively correlated with vegetation metrics. DON wet deposition had significant correlations with vegetation metrics at mid-latitudes (Figs 6 & 7).
- The strength of this increasing trend varies by region, with certain regions showing stronger correlations between DOC concentrations and vegetation metrics (Fig 7).

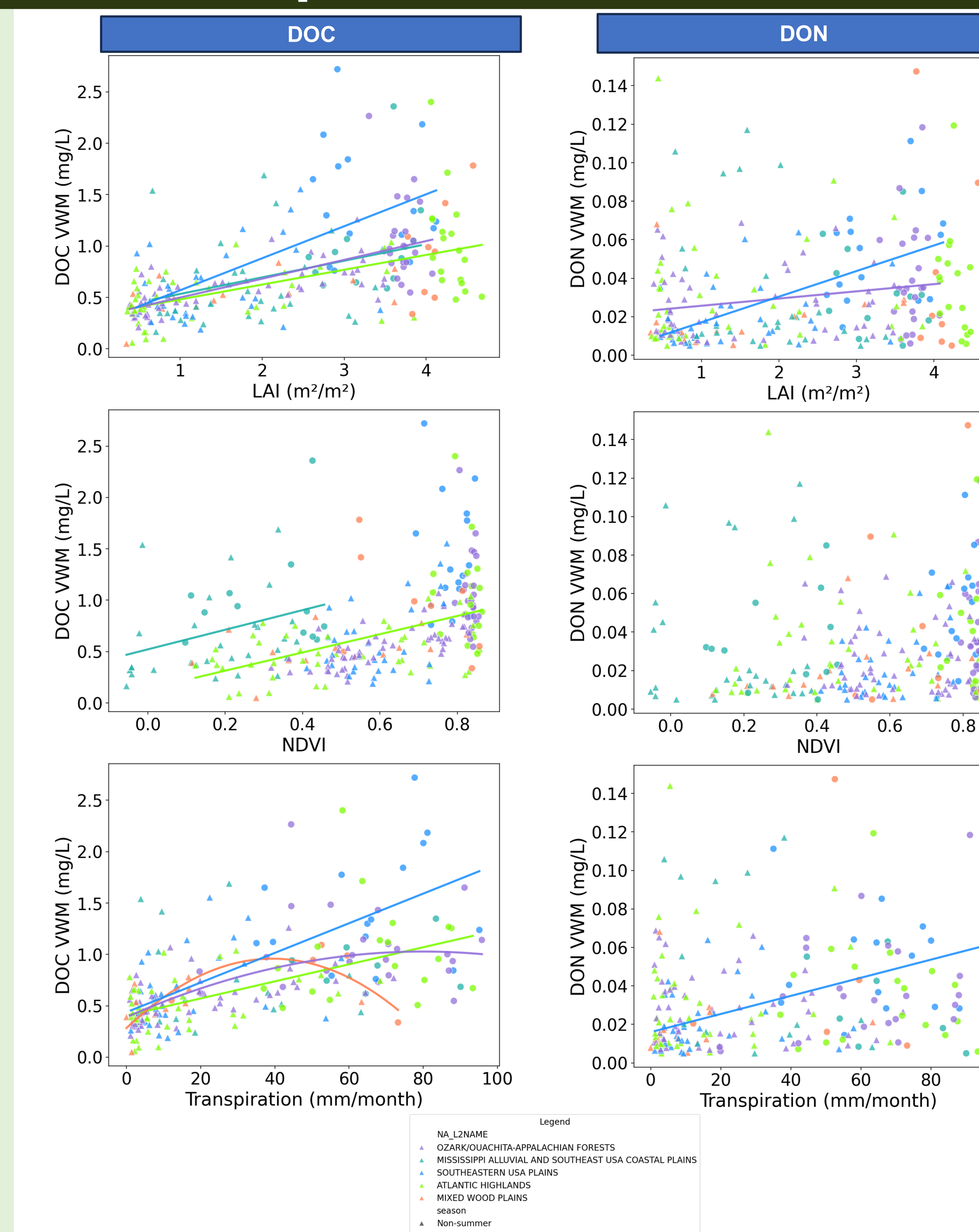

Fig 7. Relationships between monthly averages of vegetation metrics and VWM DOC (left) and DON (right) concentrations. Lines show significant trends.

Conclusions

- DOM deposition concentrations increase with vegetation metrics during warmer months, showing a link between vegetation activity, temperature, and DOM deposition.
- Higher growing season DOM inputs likely reflect increased biogenic emissions from developing vegetation with regional differences in vegetation type, phenology, and emissions leading to variability in DOM wet deposition.
- Higher DOM inputs during warmer months may increase primary productivity, microbial activity, N availability, and the risk of downstream eutrophication.

Acknowledgements

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