**Working Title:** Subcanopy plant functional trait response to varying disturbance severity and implications for ecosystem net primary production resilience

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1. Introduction:

2. Materials and Methods:

*2.1 Experimental design and site description*

This study took place within the Forest Resilience Threshold Experiment (FoRTE), an ecosystem-scale disturbance manipulation at the University of Michigan Biological Station in northern lower peninsula Michigan (UMBS, 45.56°N, 84.67°W). [[forest description, soils, MAT/MAP]] The roughly century-old regrown forest of UMBS is currently undergoing successional transition (Wolter & White REF), with dominant tree species shifting from early successional aspen (*Populus grandidentata* and *P. tremuloides*) and birch (*Betula papyrifera*) to later successional species including northern red oak (*Quercus rubra*), red maple (*Acer rubrum*), American beech (*Fagus grandifolia*), white pine (*Pinus strobus*).

Baseline data collection, including tree inventory, assessment of forest structure, and above- and belowground carbon flux measurements, began in summer 2018 prior to experimental disturbance initiation. Before leaf out the following spring (May 2019), we stem girdled ~3700 trees across 8 ha. of forest. Stem girdling involves cutting and removal of a ring of bark and phloem tissue from the tree stem at approximately 1 m above the ground, achieved via chain saw and pry bar. This treatment results in carbon starvation to the roots and typically kills a tree in 1 – 3 years following girdling (Gough et al., 2013).

*2.2 Subcanopy leaf functional traits*

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*2.3 Vegetation canopy structure*

Canopy structure, or the quantity and arrangement of vegetation cover in the forest canopy, was assessed via annual measurements at full leaf-out across FoRTE subplots using portable canopy LiDAR (PCL). PCL entails the use of a user-mounted, upward facing near-infrared pulsed laser operating at 2000 Hz (Riegl USA, Inc., Orlando, Florida, USA) collecting returns as the user walks two transects of 40 m length through experimental subplots (full methods described in (Hardiman et al., 2011). Data are then analyzed using the *forestr* R package to compute a suite of canopy structural metrics (Atkins et al., 2018), including vegetation area index (VAI). VAI is a unitless measure of total canopy surface area (leaves plus the woody components of the canopy) per unit ground area and has been found to correlate with ecosystem functions of interest, including net primary production (REF). VAI was computed from the means of two 40 m transects in each subplot in each year. Due to a technical issues, 2 subplots were omitted from measurement in 2018 and 1 in 2019.

*2.4 Aboveground wood net primary production*

Aboveground wood net primary production (ANPPw) was computed from

mapping of all stems ≤ 8 cm diameter at breast height (DBH)

*2.5 Statistical analysis*

To test relationships between subplot mean leaf functional traits and disturbance severity, type, and time, we used split-split plot mixed effects ANOVA with experimental replicate as a blocking factor. In these models, disturbance severity was the fully randomized whole-plot factor while treatment type (bottom-up or top-down) was the restrictively randomized split-plot factor. In addition to treatment, time (as year) could not be fully randomized within blocks and was treated as the split-split plot factor in the models. Pair-wise post-hoc comparisons using Fisher’s LSD were tested at alpha = 0.05 where significant effects were found. While three of four leaf functional traits satisfied the assumptions of normality and homogeneous variance required for ANOVA, leaf mass per area (LMA) followed a right-skewed distribution typical for this variable in mixed hardwood-conifer forests (REF) and was transformed via 1/x transformation before running the analysis.

The second stage of our three-part analysis entailed the use of linear mixed effects models to assess the relationships between canopy structure (as VAI), disturbance severity, time, and leaf functional traits. All models were generated using R package *lme4* (REF) and the best candidate models were selected using the Akaike information criterion (AIC; REF). In these models, VAI, year, and their interaction were treated as fixed effects with regression coefficients of interest, while replicate was included as a random effect. Because there is no assumption of a Gaussian distribution for outcome variables in linear mixed effects models, we did not transform LMA for this analysis.

3. Results