



## Resource Use Efficiency, Disturbance, and the Structure-Function Relationship

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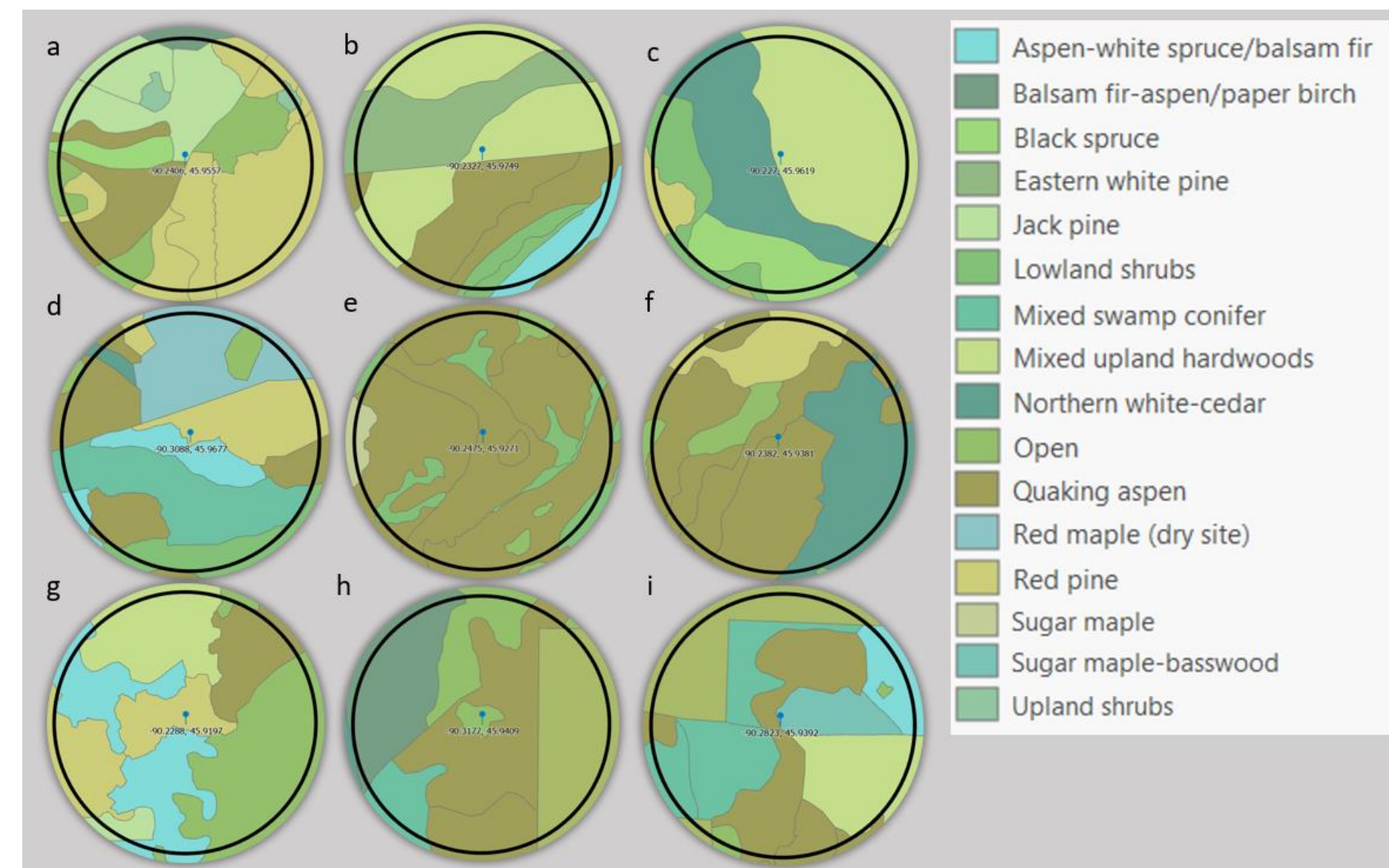
### Motivation

**Mapping mechanistic links between forest structure and function is fundamental to scaling measurements from the leaf → stand → landscape level**

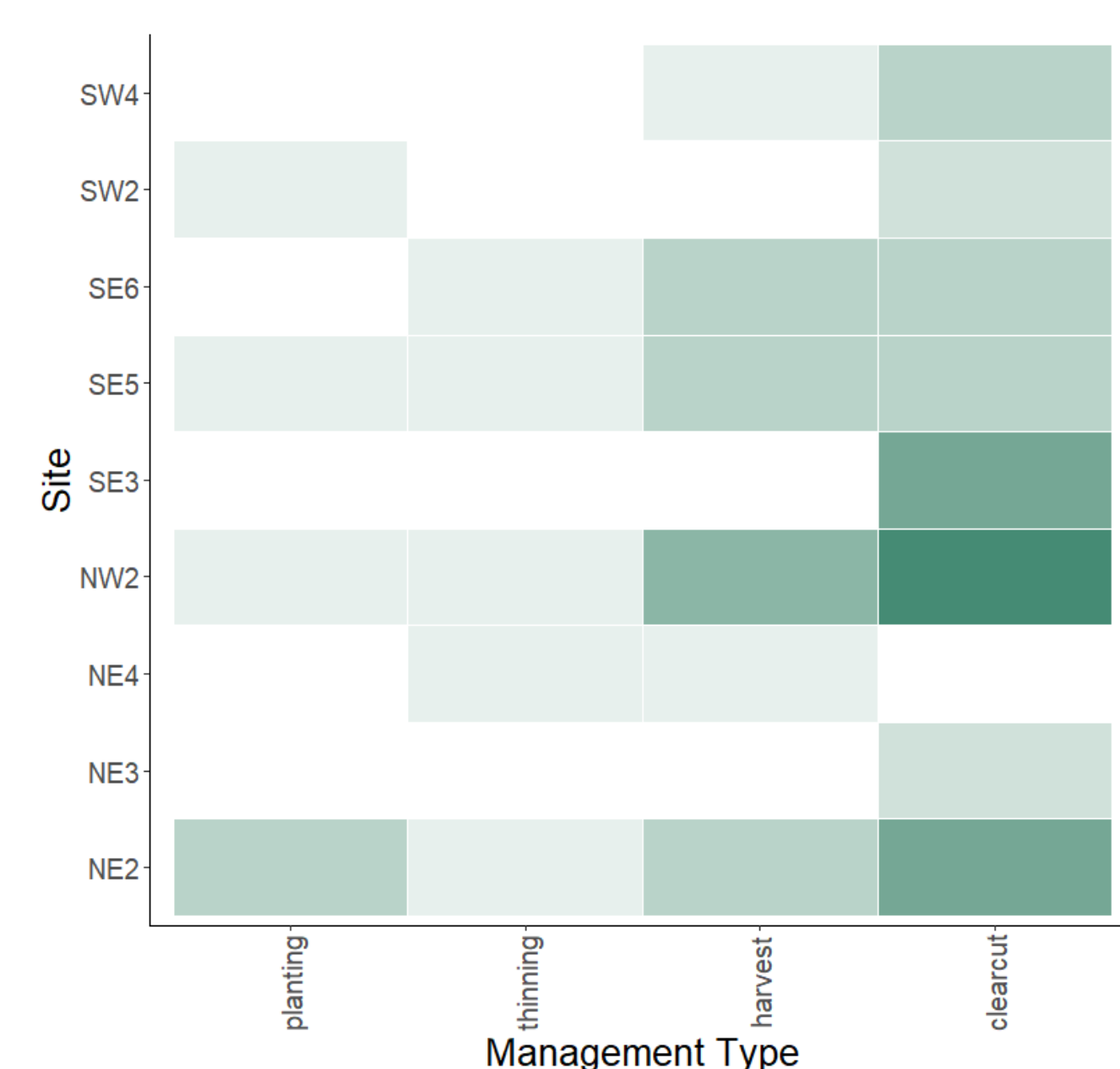
- Structural complexity (SC) characterizes the 3D arrangement of vegetation, & constrains the forest's ability to assimilate available resources for photosynthesis
- Synthesis of information from SC metrics across spatial scales can serve as a powerful indicator of ecosystem-scale functions such as gross primary productivity (GPP)
- Identifying which SC variables are the strongest drivers of GPP & what potential controls of the structure-function relationship exist is a vital aspect of this effort

### Research Questions

- Which SC metrics are the strongest drivers of GPP in mixed temperate forests with a high degree of heterogeneity and management?
- How do management legacies impact SC metrics and stand productivity?
- Is the mechanistic relationship between forest structure and function direct, or is it mediated by resource use efficiency (RUE)?
- Is the mechanistic relationship between forest structure and function dependent upon the scale of structural metric calculation?



**Figure 1.** Vegetation coverage at each of the nine forested sites: **a)** NE2 **b)** NE3 **c)** NE4 **d)** NW2 **e)** SE3 **f)** SE5 **g)** SE6 **h)** SW2 and **i)** SW4. Coverage is segmented by both vegetation type and stand age.

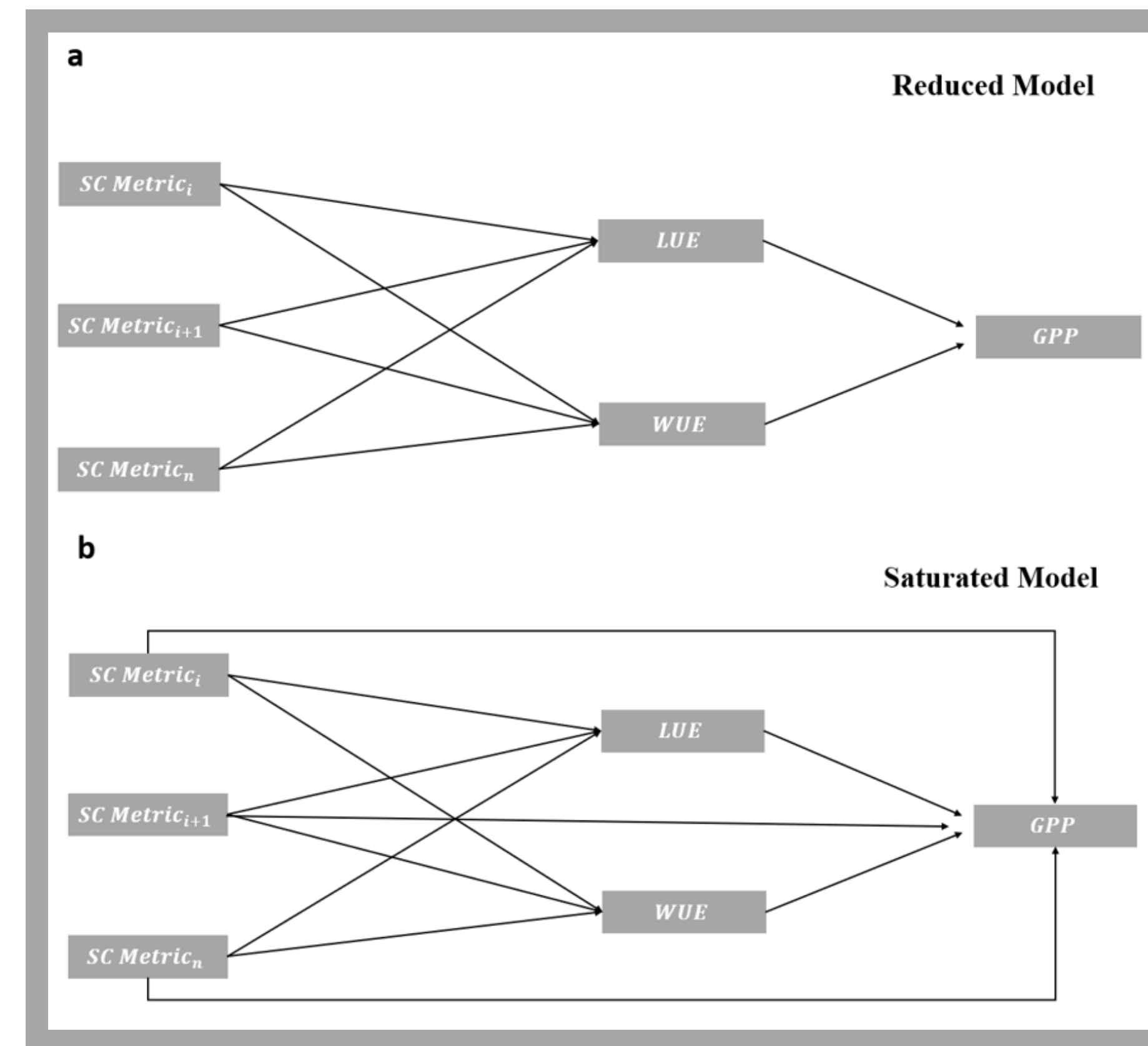


**Figure 2.** Management practices and frequency of occurrence

### The Solution

- 9 EC flux towers deployed in forested sites within the 10 x 10 km CHEESEHEAD19 field campaign domain in Northern Wisconsin, USA
- EC surface-atmosphere carbon and water fluxes paired with LiDAR-derived forest SC metrics to connect forest structure and function
- Structural Equation Modeling (SEM) to explore mechanistic relationships between SC metrics and GPP, and test mediation effects

SC metrics affect GPP both directly & indirectly through LUE & WUE

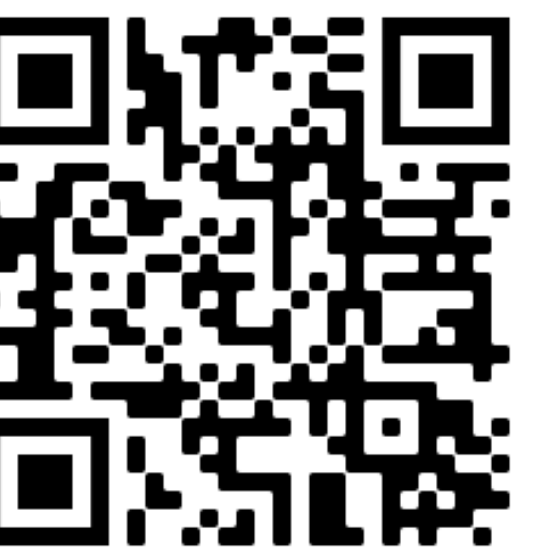
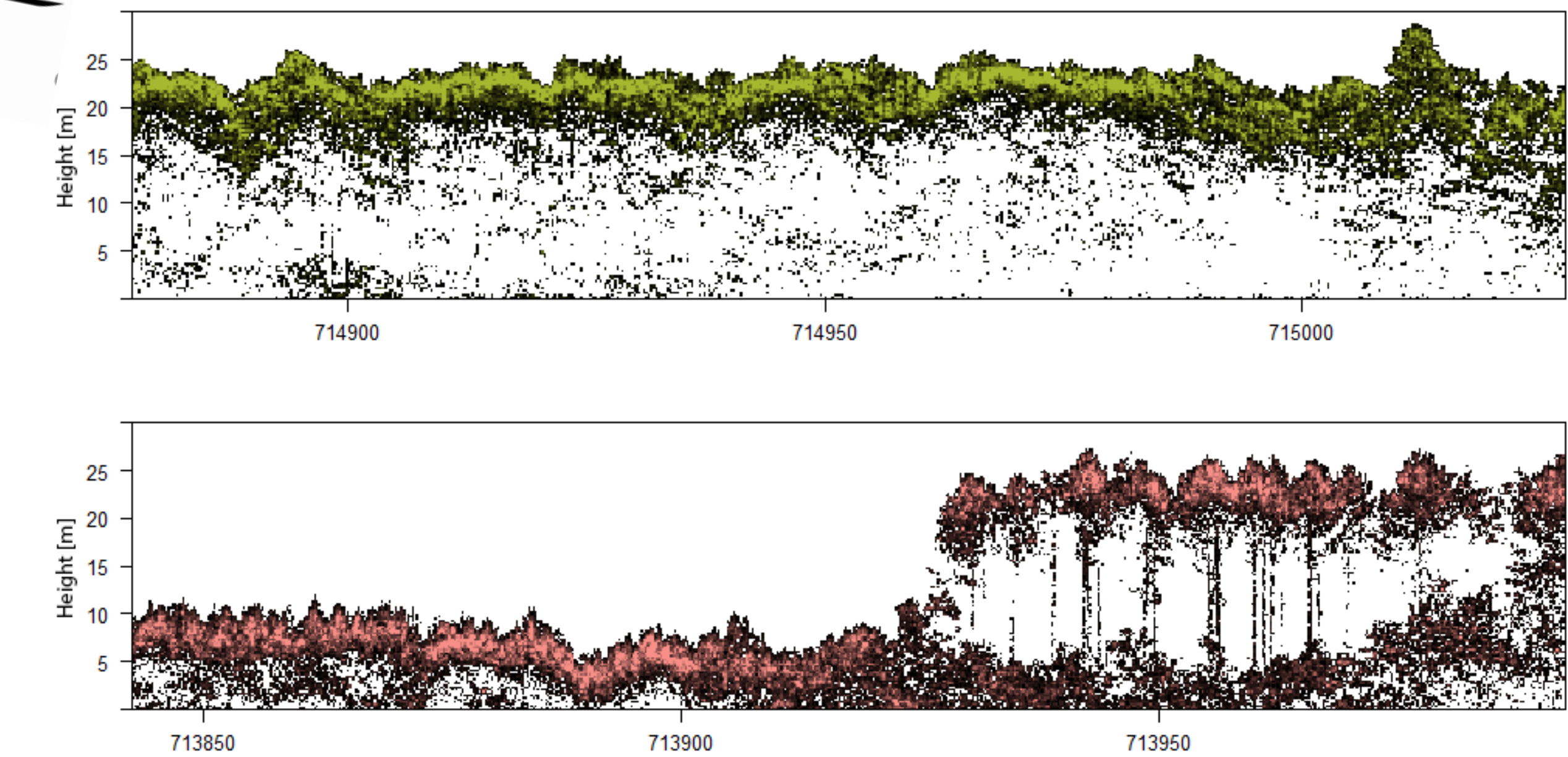
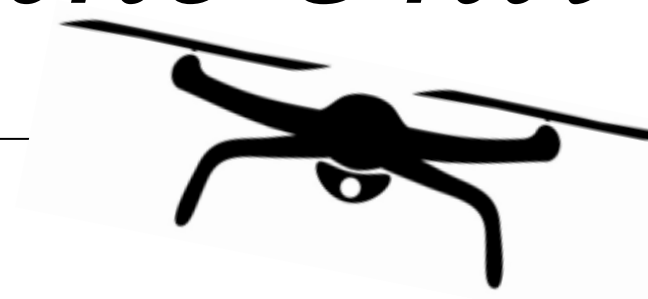
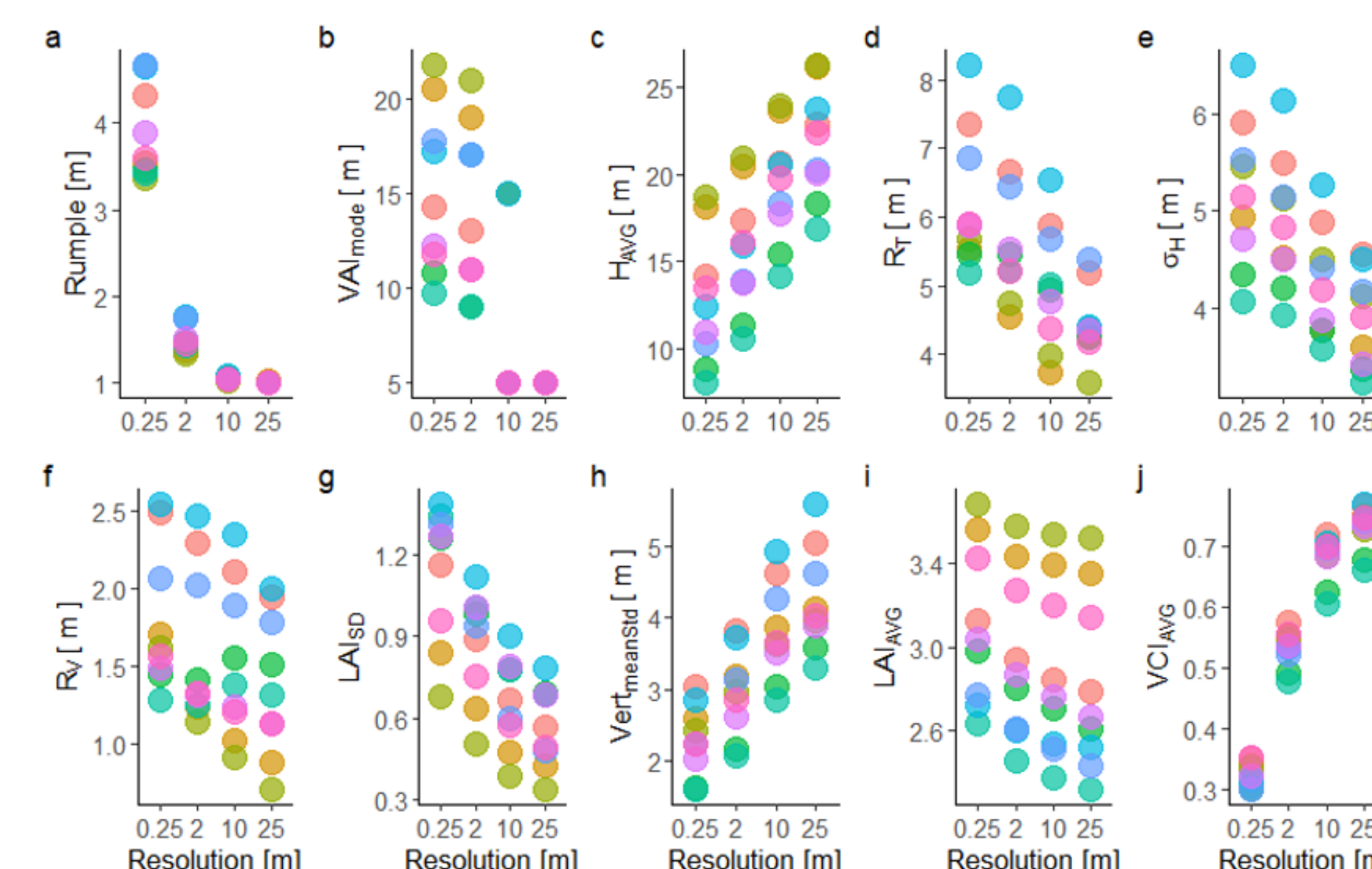


Restricts SC metrics to influencing GPP indirectly through LUE & WUE

### Structural Complexity

**Scale of metric calculation significantly impacts metric values, as well as which metrics are included in the best fit model**

**Figure 3.** SC metric values at each of the four calculation resolutions: 0.25 m, 2 m, 10 m, and 25 m



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### Structure-Function Relationship

- Positive mechanistic relationship exists between SC and productivity in mixed temperate forests, BUT relationship is impacted by additional factors such as species diversity and management history
- Relationship is mediated by the effective acquisition and assimilation of both light and water resources, and RUE generally is enhanced by increasing SC
- Water use efficiency (WUE) is a stronger driver of GPP (330% ) as well as mediator of the relationship between SC and GPP than light use efficiency (LUE)

### Disturbance Impacts

- Sites with intensive disturbance had lower levels of RUE and productivity, sites with moderate management had high levels of complexity and productivity
- Even with shared climatic and environmental conditions, differences in management, disturbance, and species diversity result in variability in exchanges of CO<sub>2</sub>.

### Key Takeaways

- Vertical heterogeneity metrics (specifically  $VCI_{AVG}$ ) are the most influential productivity drivers for temperate forests with a high degree of heterogeneity
- The structure-function relationship is mediated by RUE, with water use efficiency both the stronger mediator and driver of productivity
- The mechanistic forest structure-function relationship differs depending upon SC metric calculation resolutions

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