



Interrelation of Forest Structure and Variability of Ecosystem Functional Properties

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Introduction

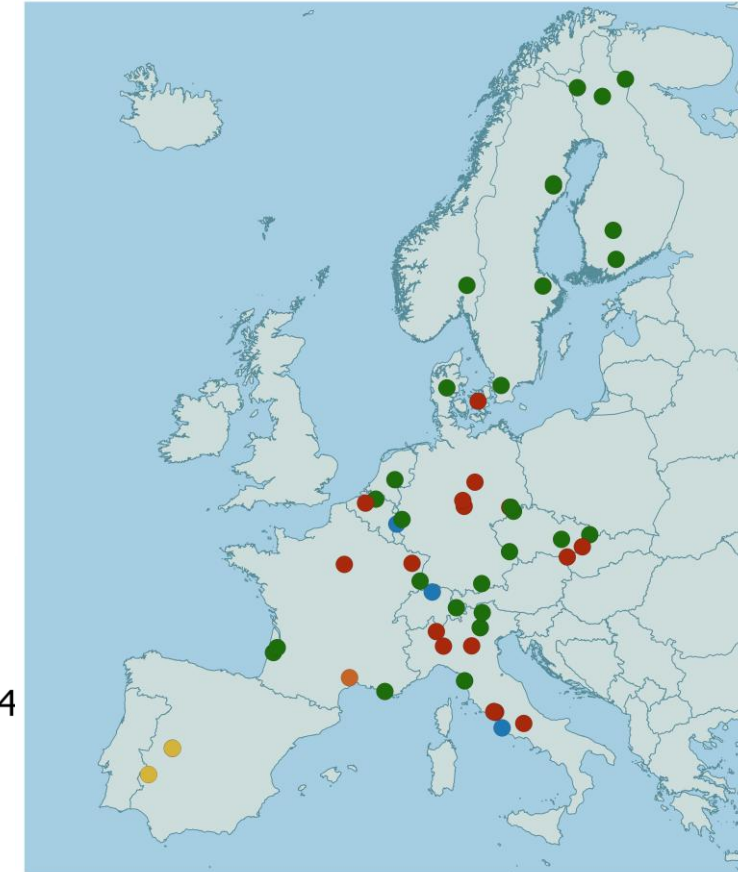
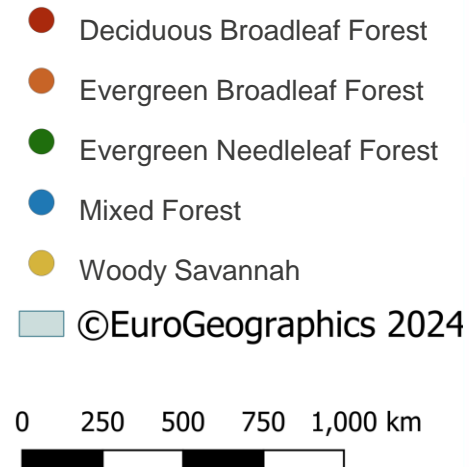
- Forests' capacity to maintain their function under **drought stress** becomes increasingly important
- Variability of **Ecosystem functional properties (EFP)** can represent that capacity
 - Lower variability indicates higher resistance¹
- EFP variability is influenced by meteorology, soil conditions and **forest structure**
- Specific role of forest structure is important information for forest management to enhance **forest drought resistance**

¹: Musavi et al., 2017 doi: 10.1038/s41559-016-0048

²: Musavi et al., 2016 doi: 10.1002/ece3.2479

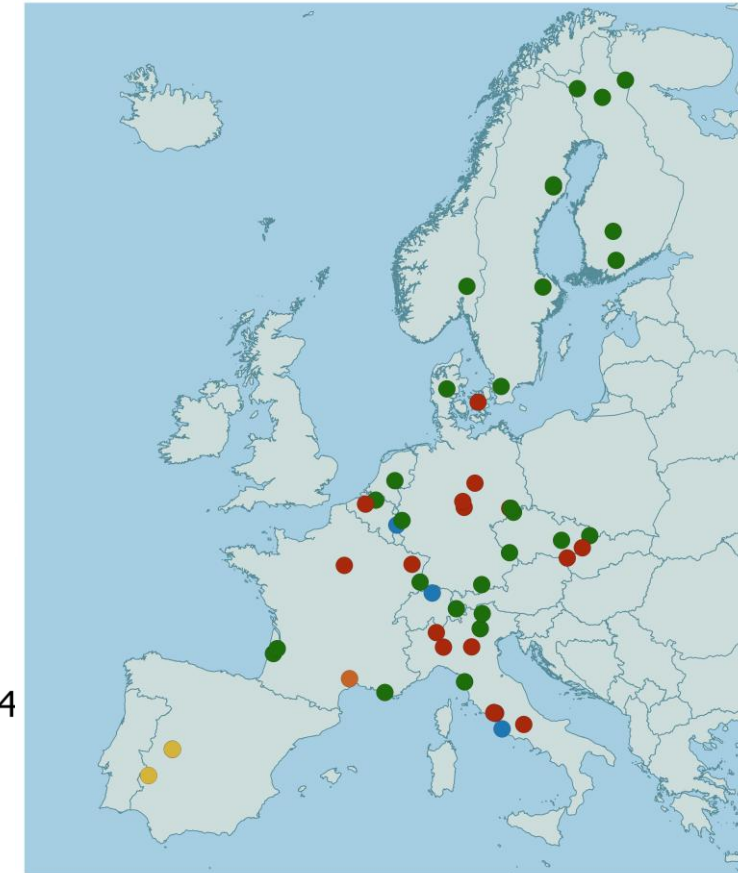
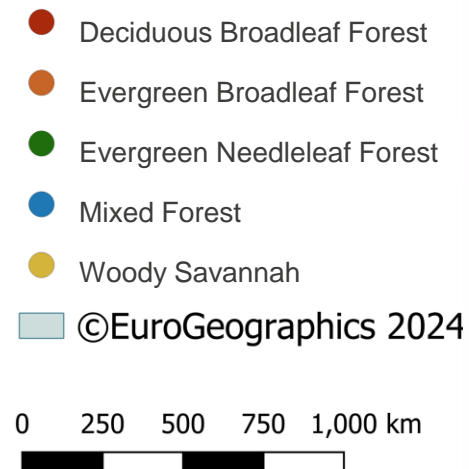
Objectives

- Obtain a comprehensive picture of forest response to drought stress by examining multiple EFPs at 60 forest sites



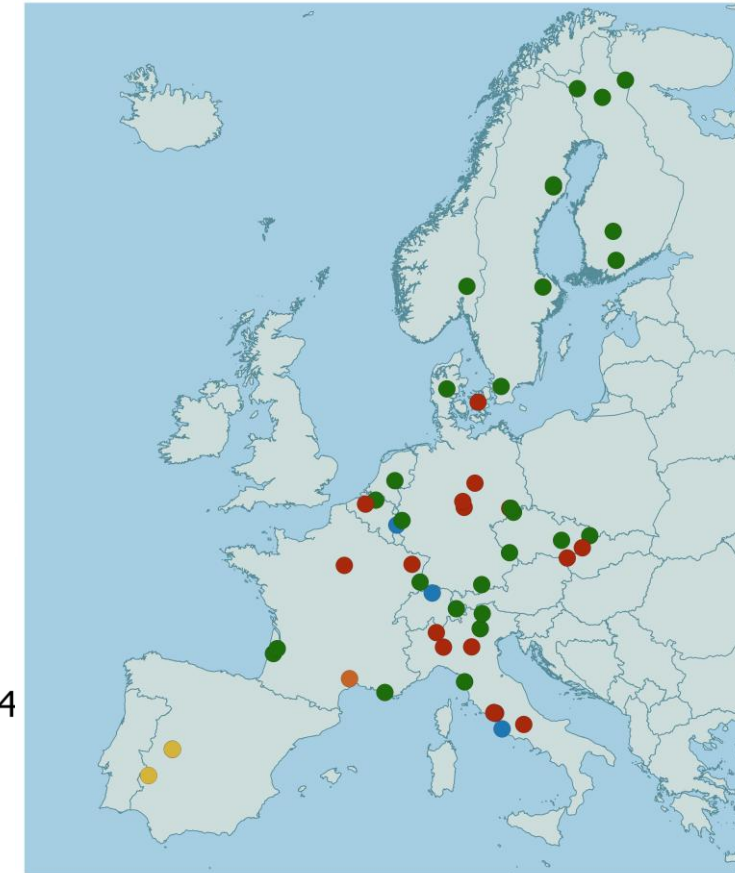
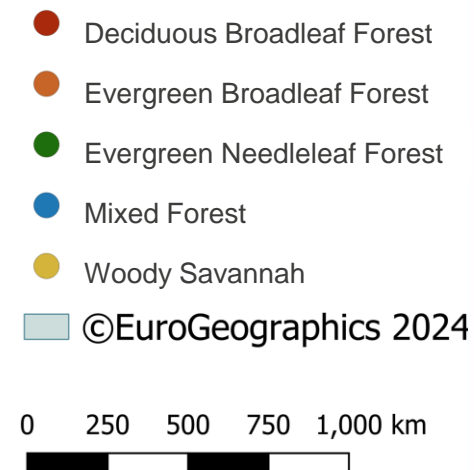
Objectives

- Obtain a comprehensive picture of the response to drought stress by examining multiple EFPs at 60 forest sites
- Assess influence of forest structure on EFP and their interannual variability

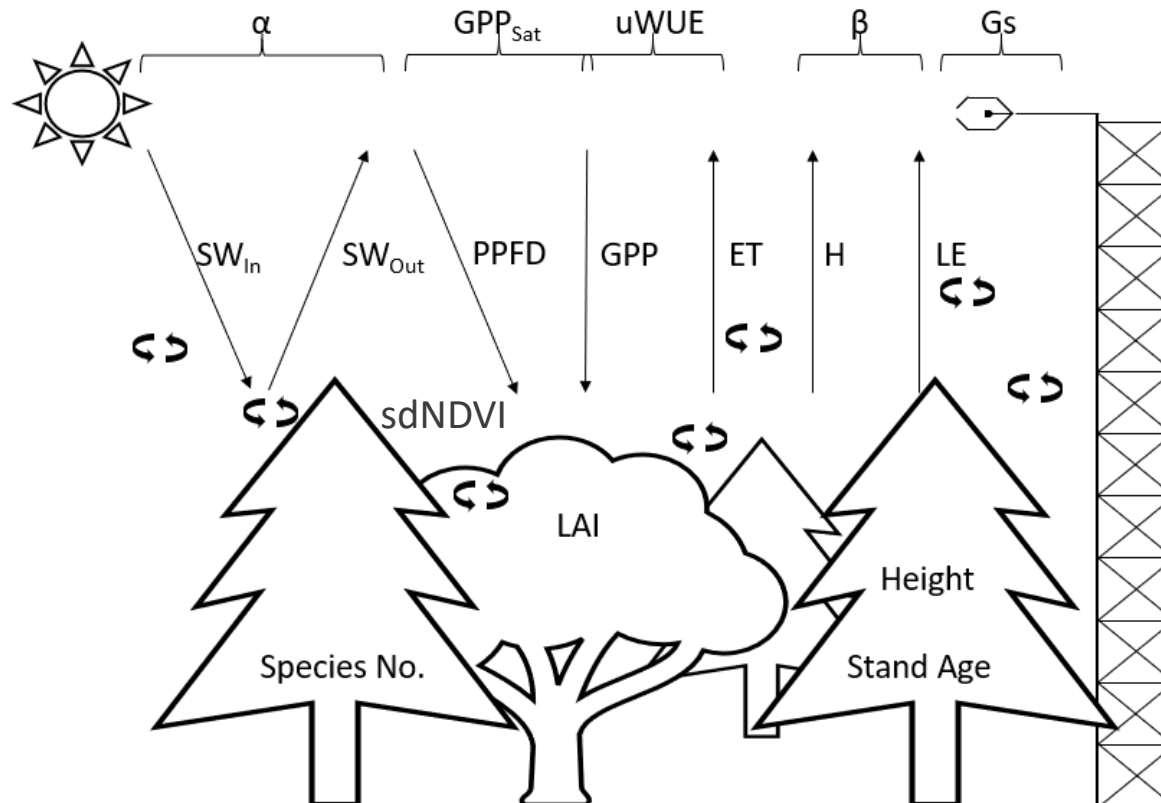


Objectives

- Obtain a comprehensive picture of the response to drought stress by examining multiple EFPs at 60 forest sites
- Assess influence of forest structure on EFP and their interannual variability
- Assess the influence of forest structure on EFP response to drought and determine the hierarchical importance of different structure variables

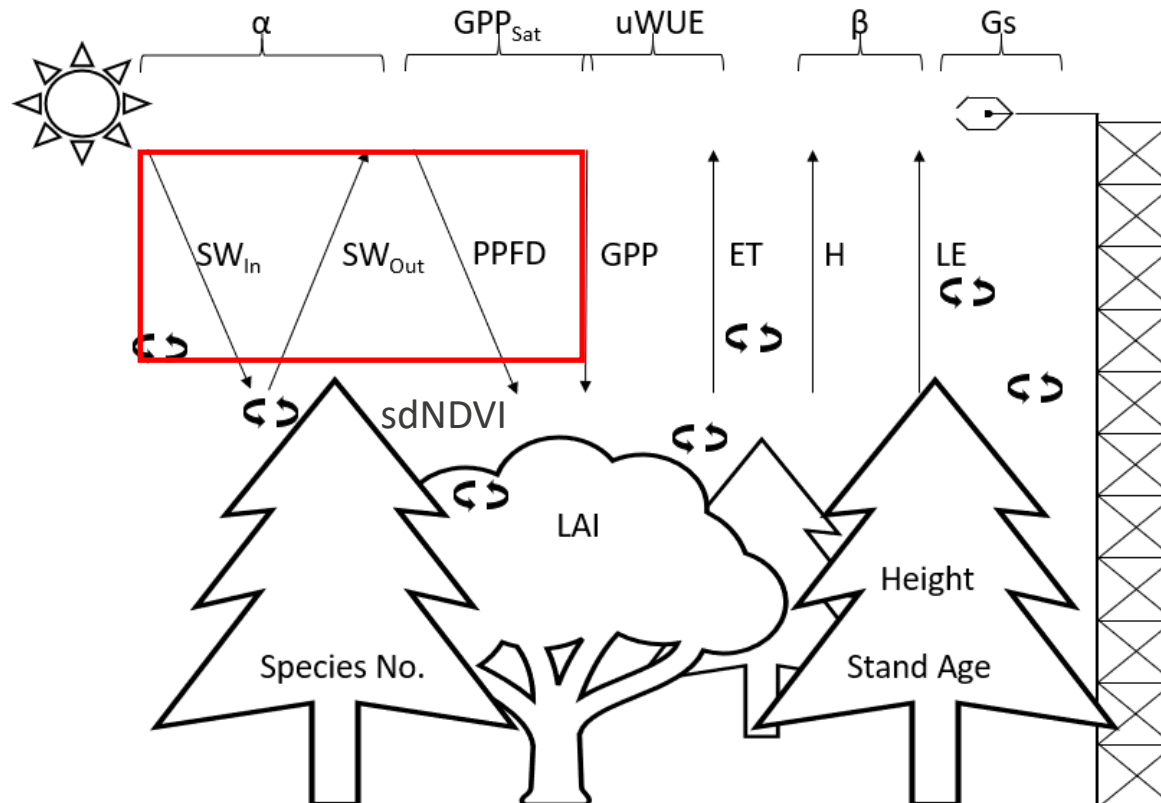


Ecosystem Functional Properties (EFP)



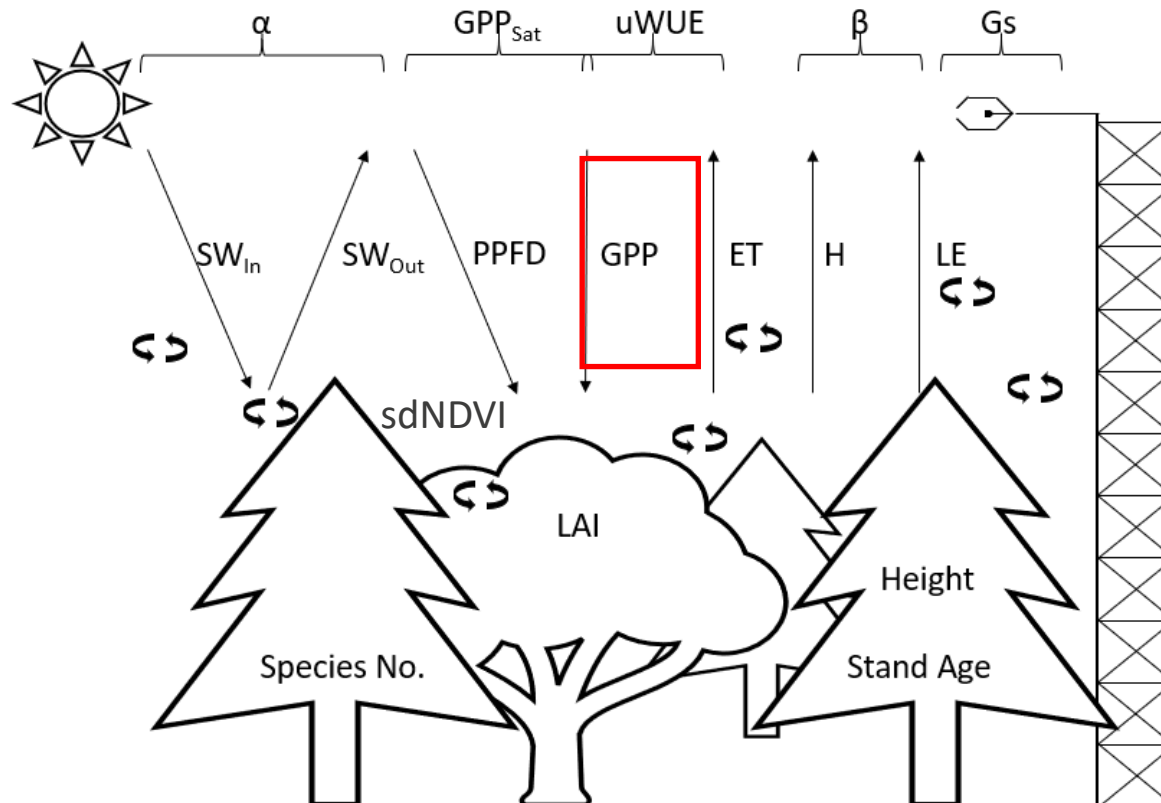
- Measured by Eddy-Covariance technique
- Ecosystem scale
- Half-hour resolution

Ecosystem Functional Properties (EFP)



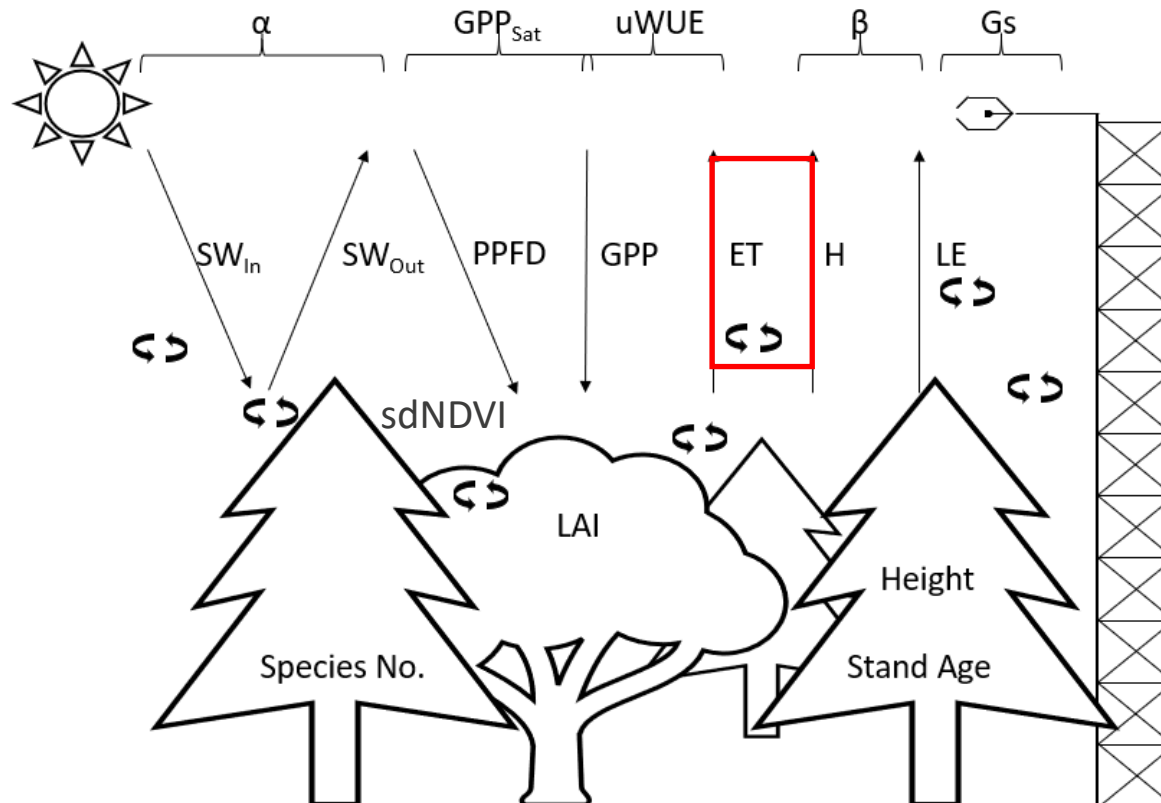
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Ecosystem Functional Properties (EFP)



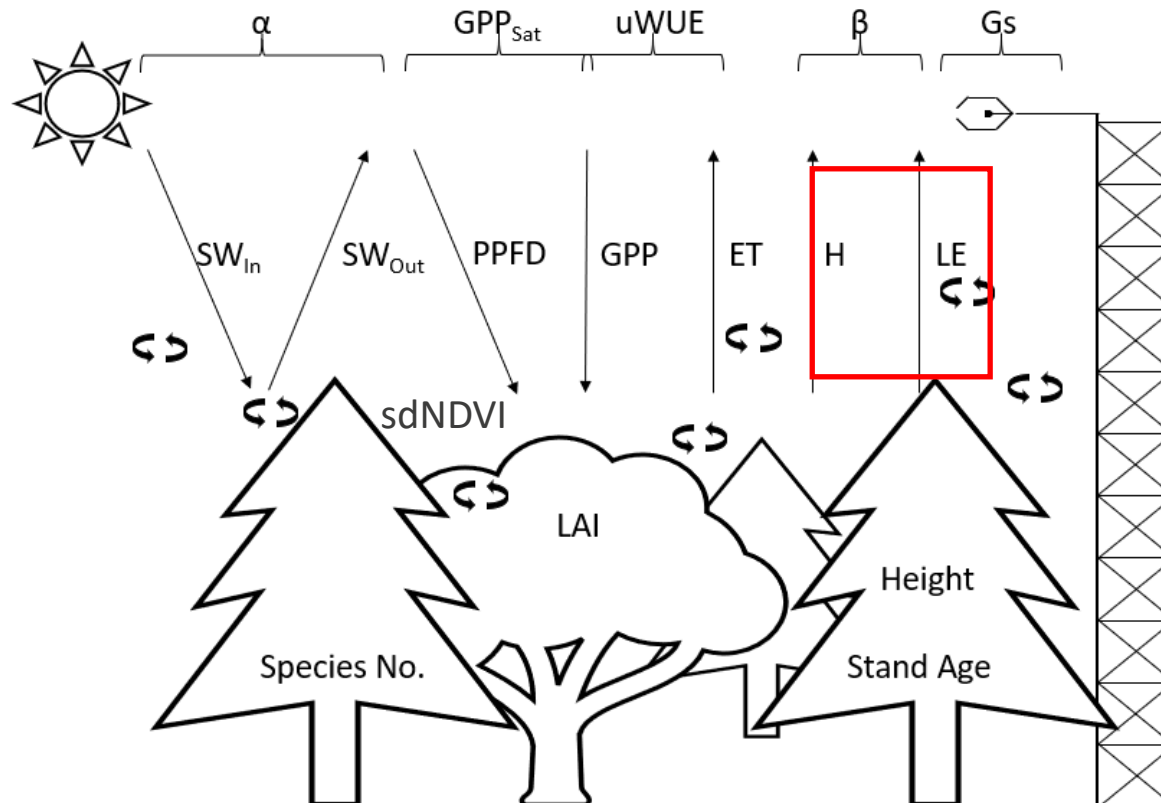
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Ecosystem Functional Properties (EFP)



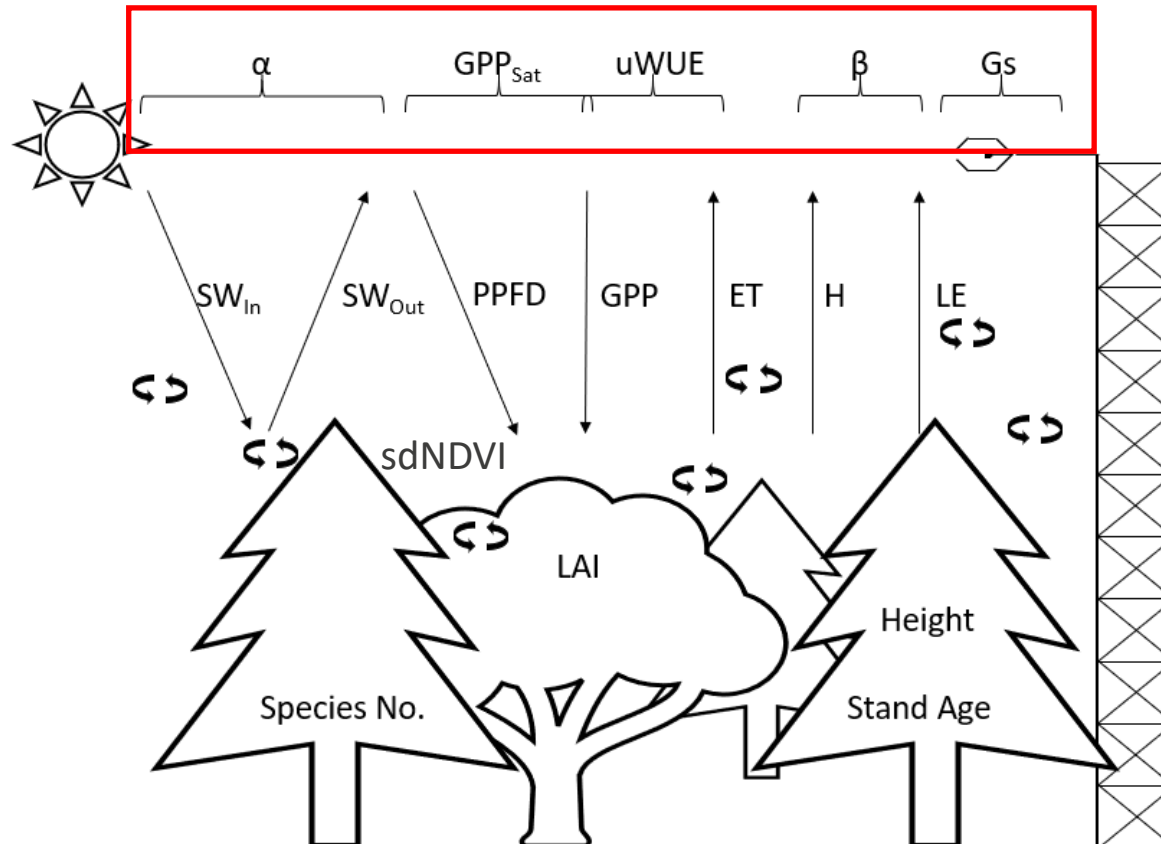
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Ecosystem Functional Properties (EFP)



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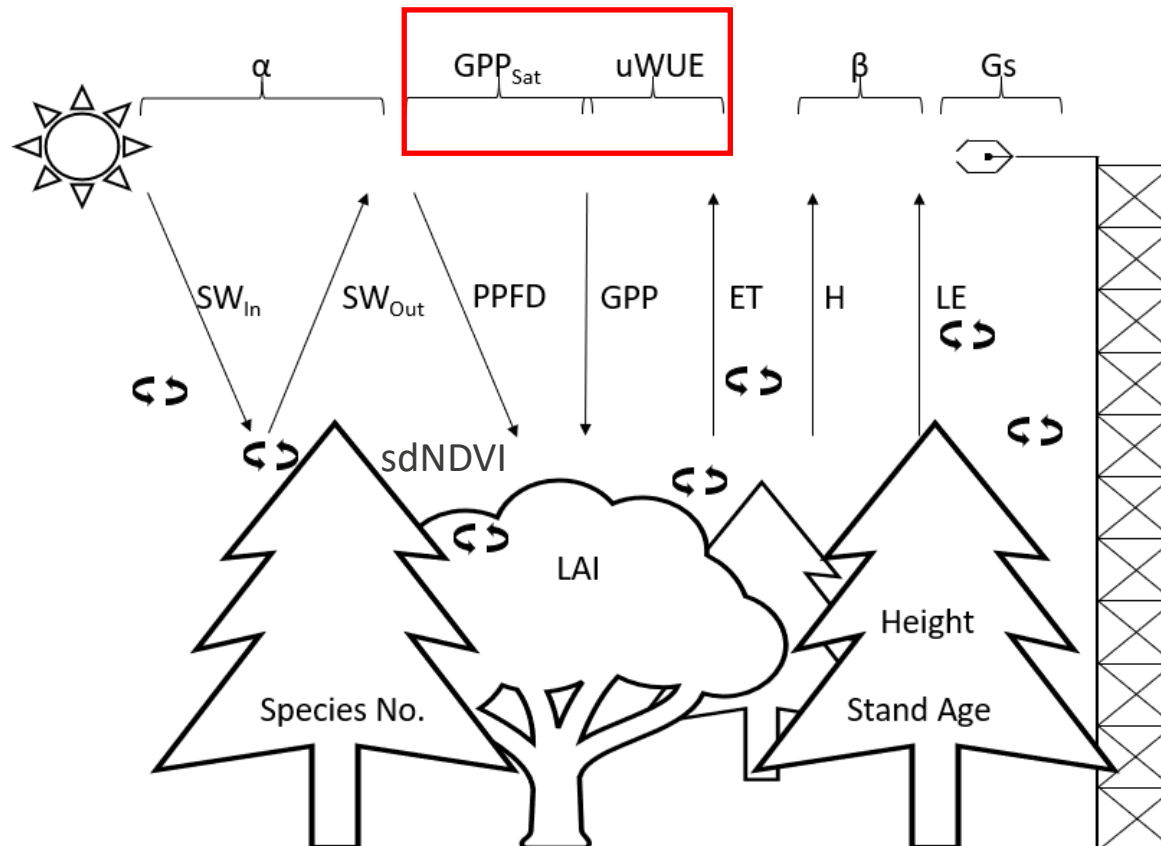
Ecosystem Functional Properties (EFP)



EFP:

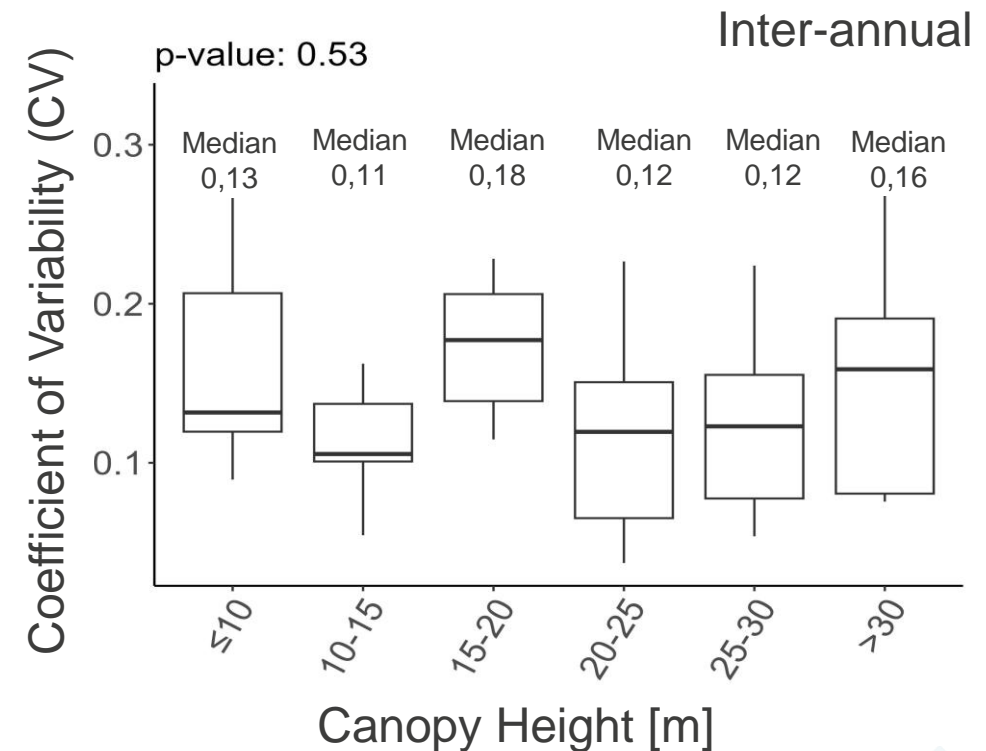
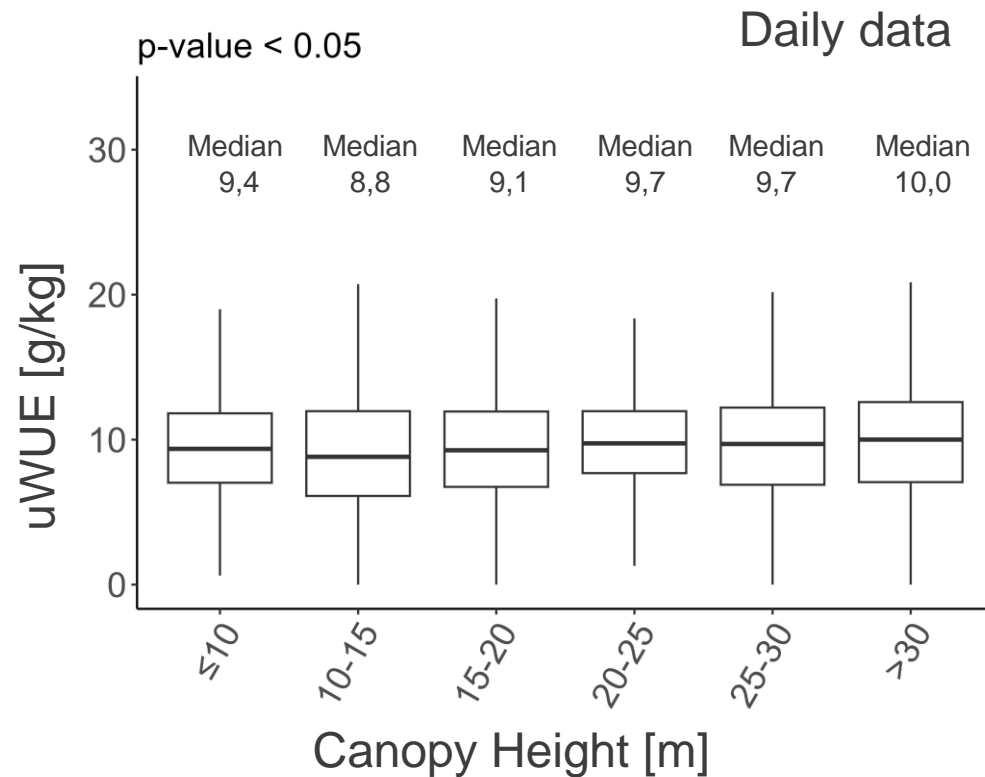
- Albedo (α)
- Photosynthetic capacity (GPP_{sat})
- Underlying water use efficiency ($uWUE$)
- Bowen Ratio (β)
- Canopy conductance (G_s)

Ecosystem Functional Properties (EFP)



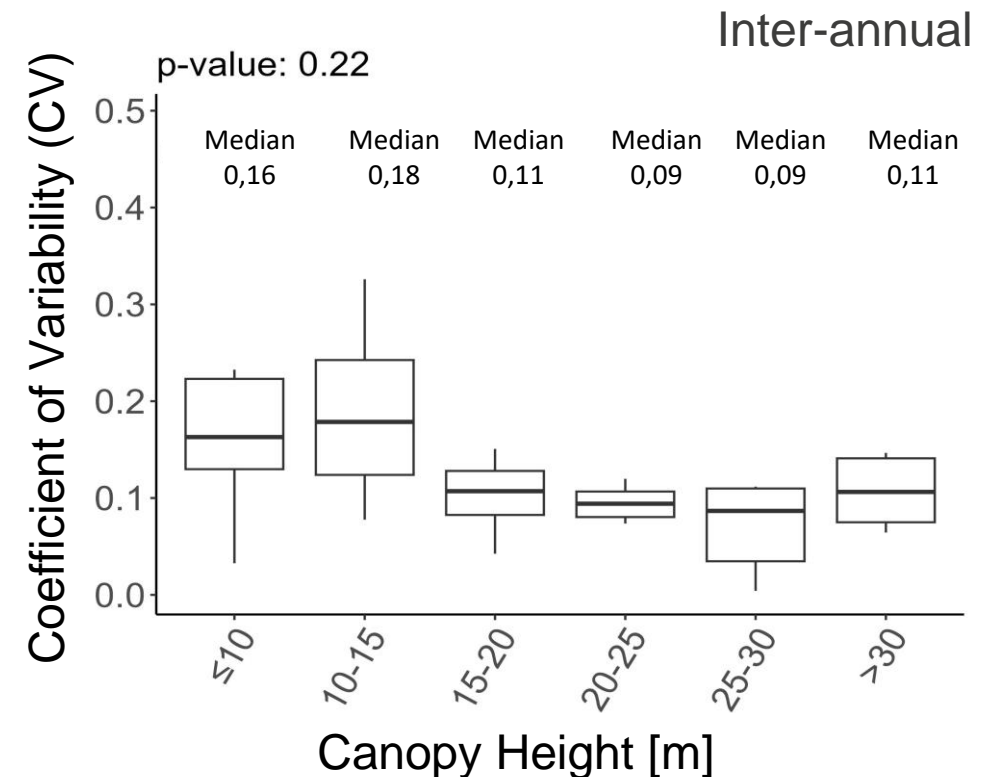
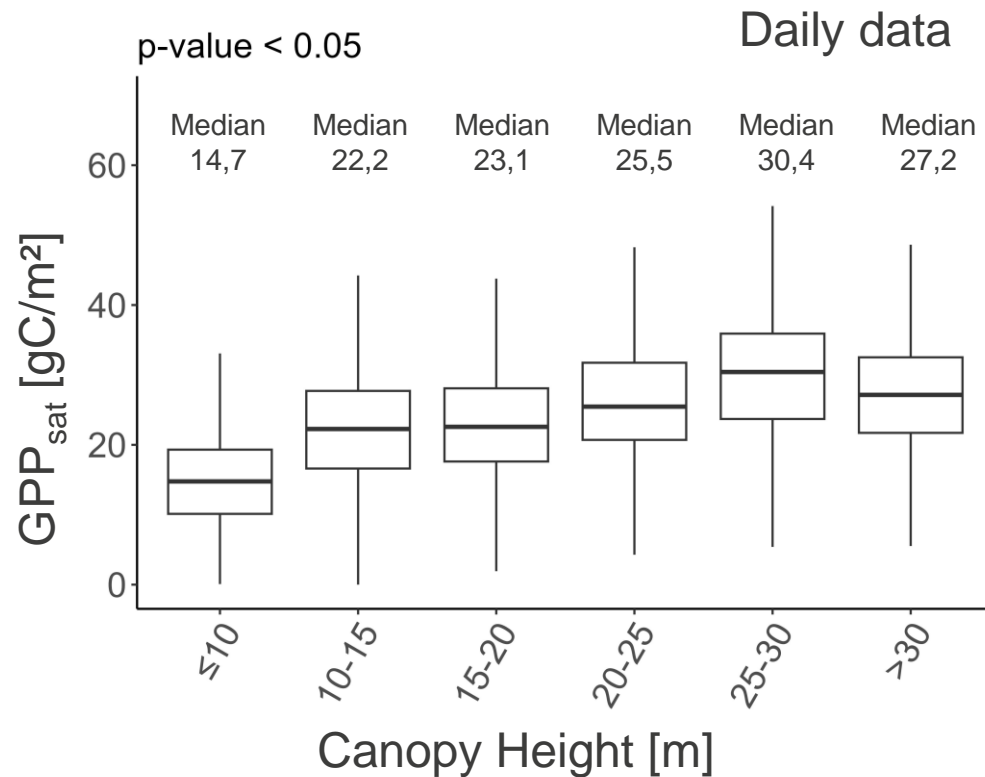
- Vegetation period
- Rain events excluded
- Daytime data
- Daily/ monthly/ annual resolution
- Quality control and despiking

Distribution of uWUE



→ Little difference in distribution and variability of uWUE across canopy height groups

Distribution of GPP_{sat}



→ Slight increase and lower variability of GPP_{sat} with increasing height

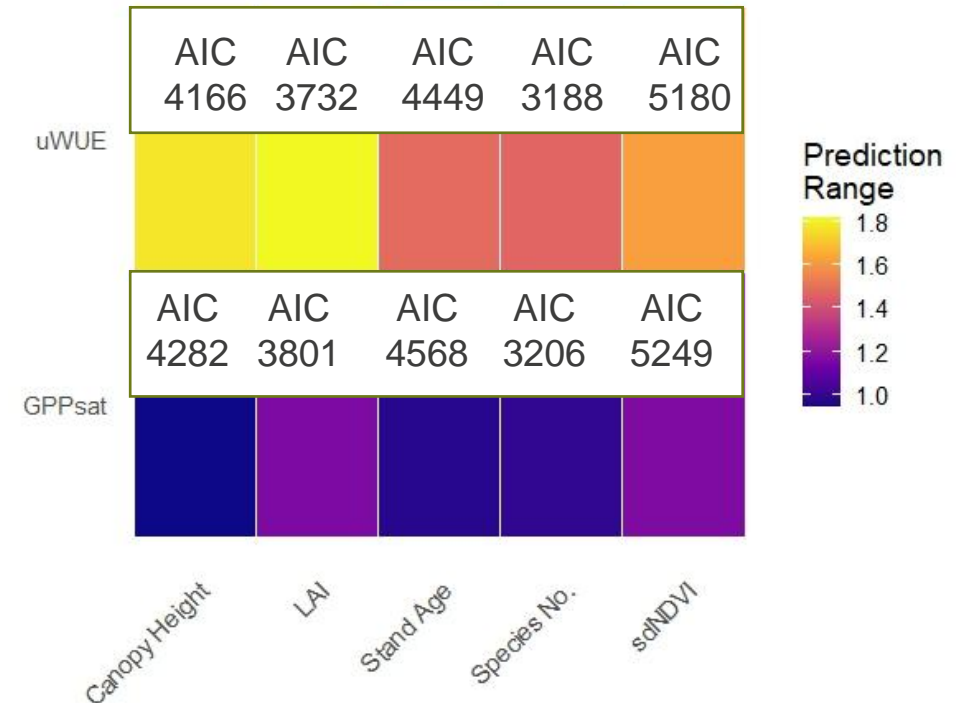
Drought Response

- Normalization of EFP using deseasonalized z-scores
- Generalized Additive Models (GAM) including climate zone and soil moisture to account for environmental effects
- Based on monthly data

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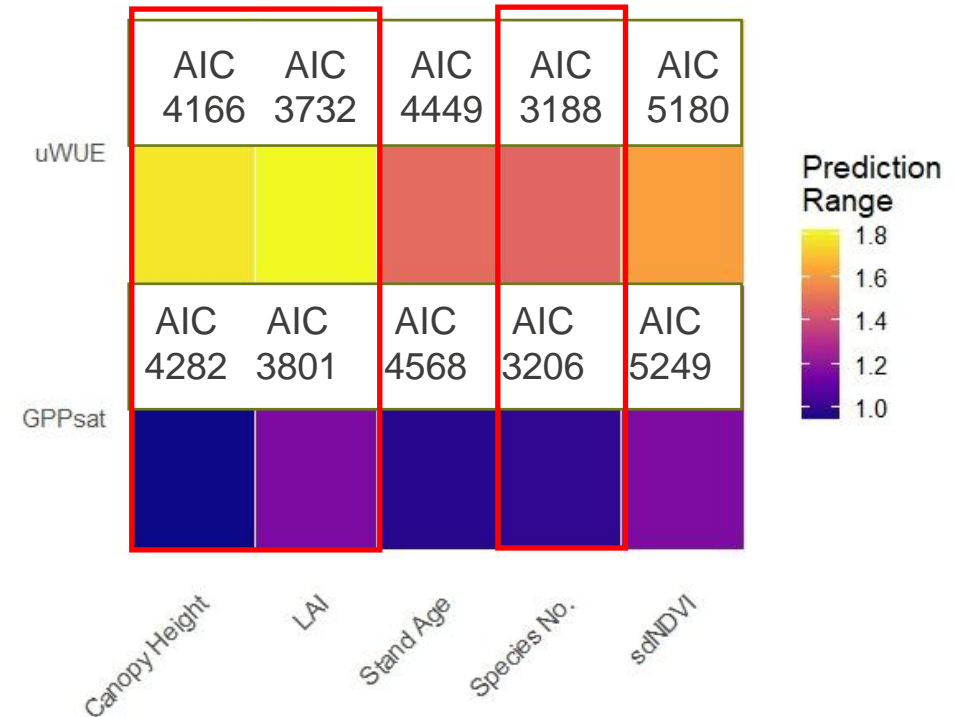
Influence of forest structure on EFP sensitivity to drought



Drought Response

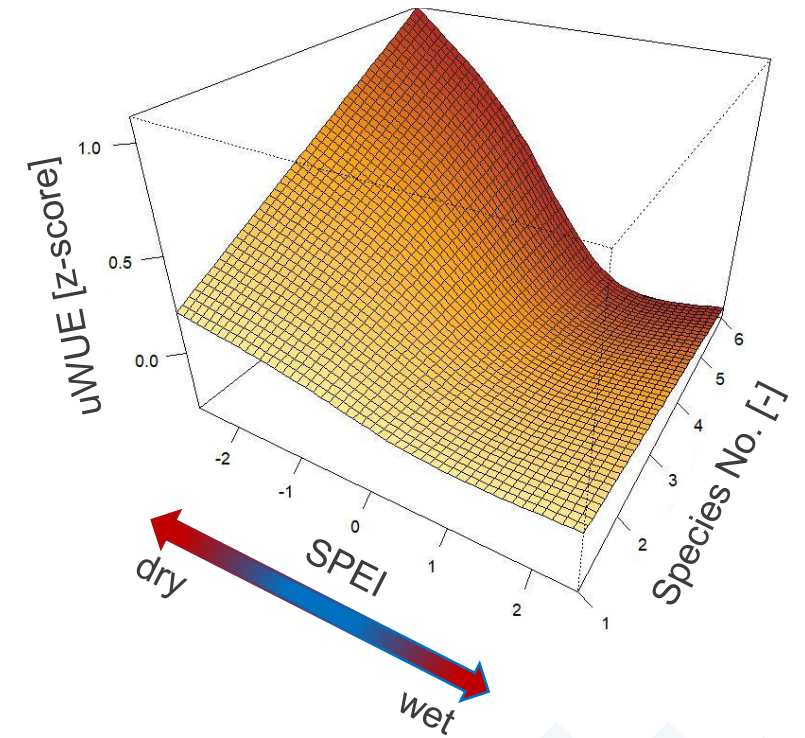
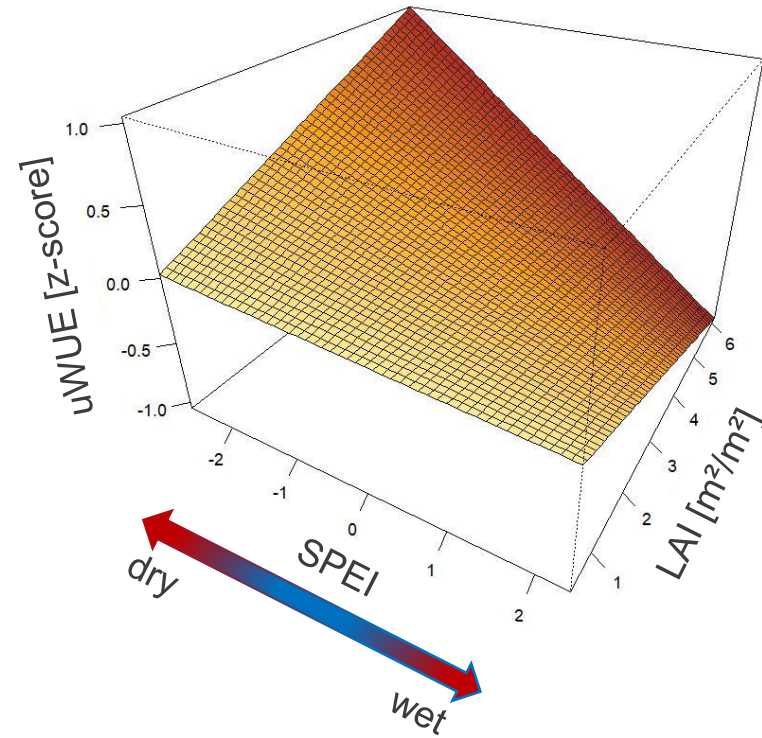
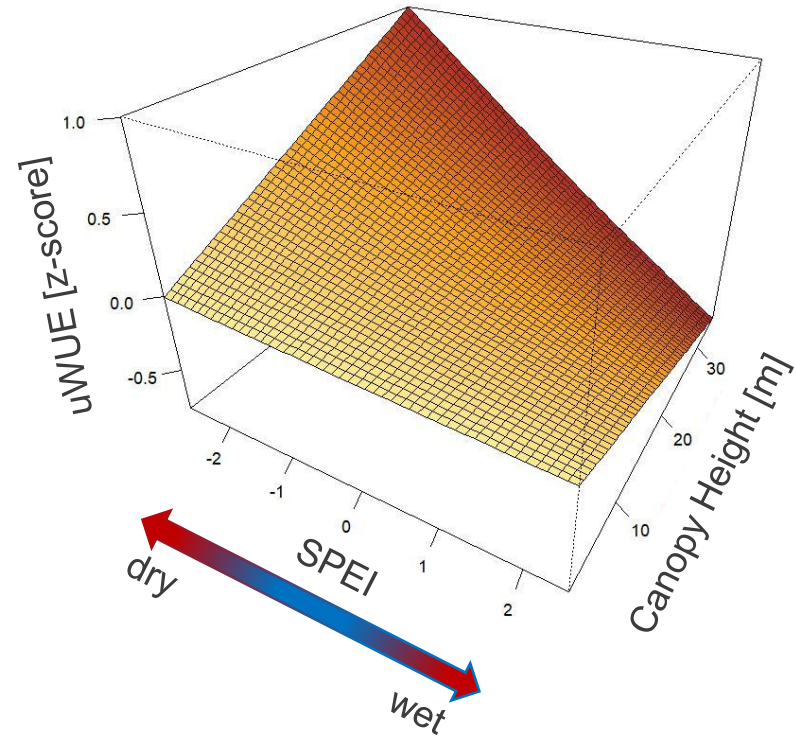
- Species No., LAI and canopy height are most important predictors of drought response of $uWUE$ and GPP_{sat}
- Based on AIC and prediction range

Influence of forest structure on EFP sensitivity to drought



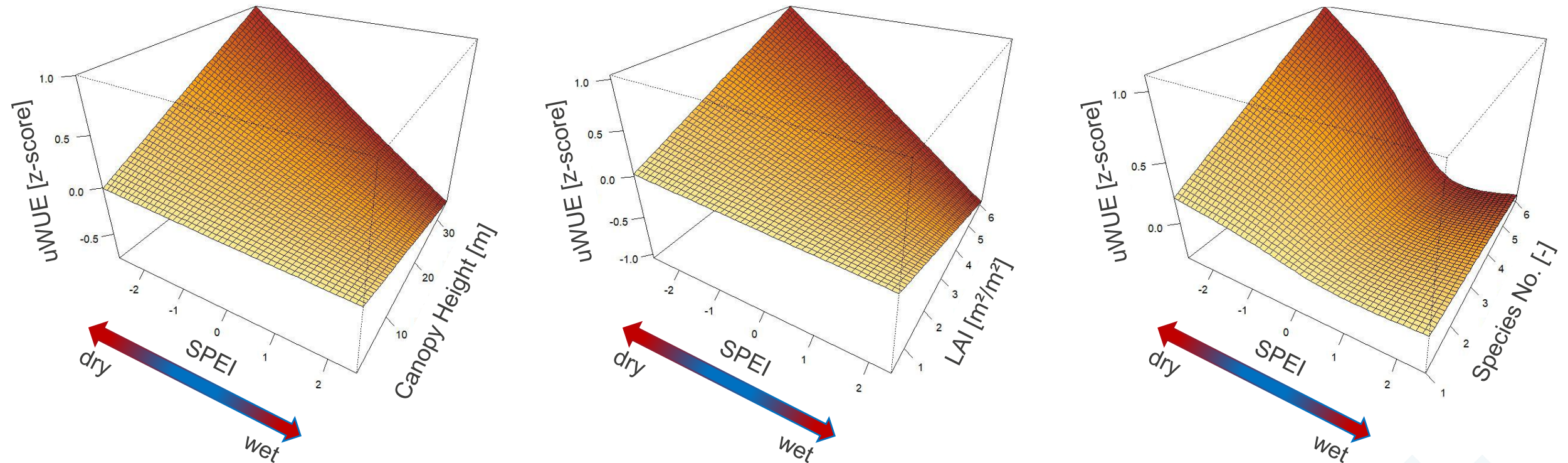
Drought Response - uWUE

Monthly data



Drought Response - uWUE

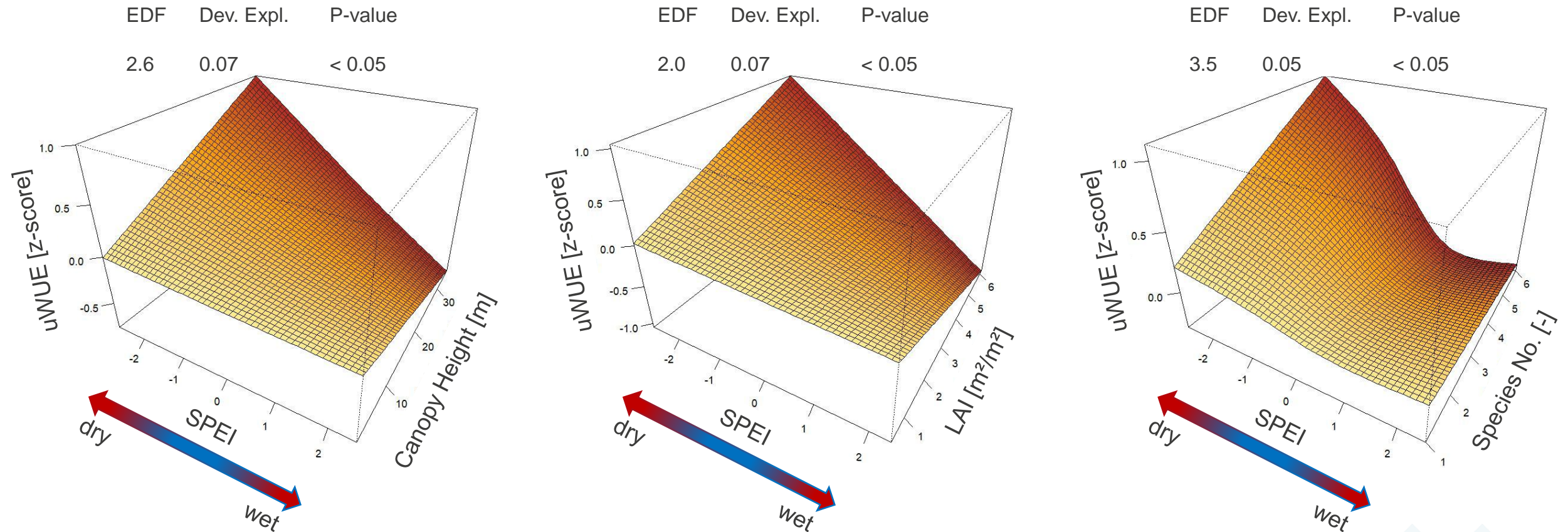
Monthly data



→ uWUE increases with drought stress

→ Increasing canopy height, LAI and species number enhances this response

Drought Response - uWUE

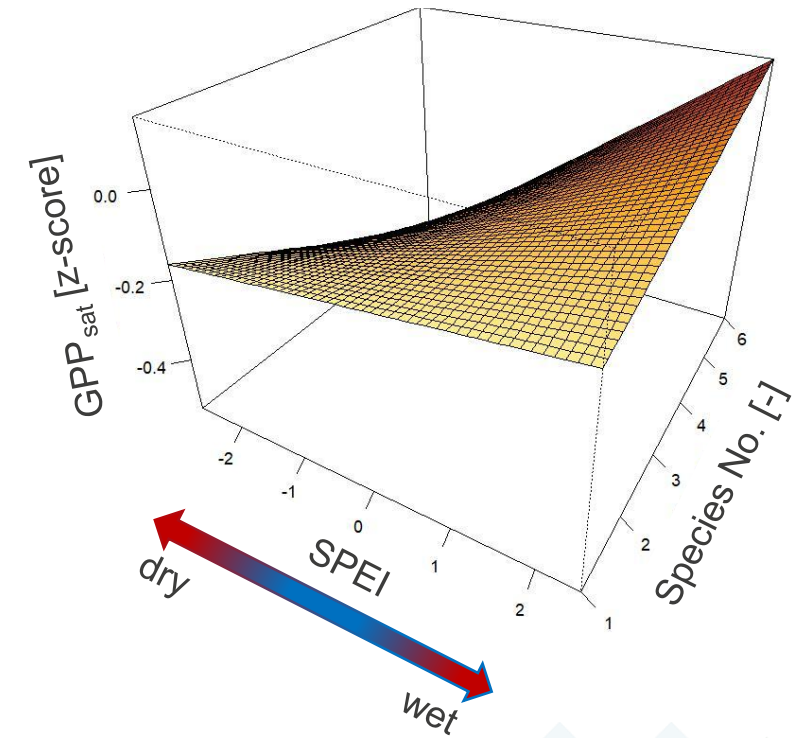
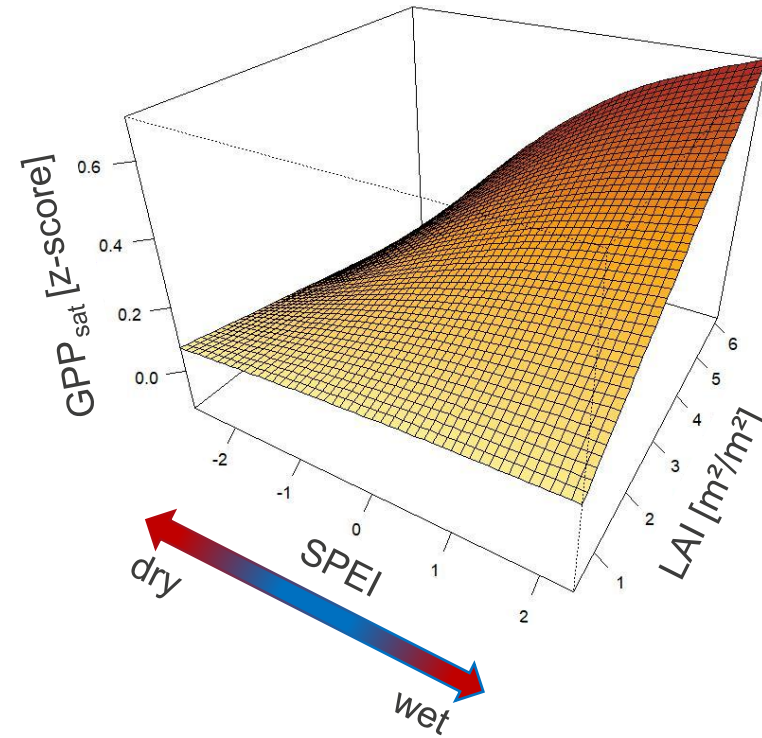
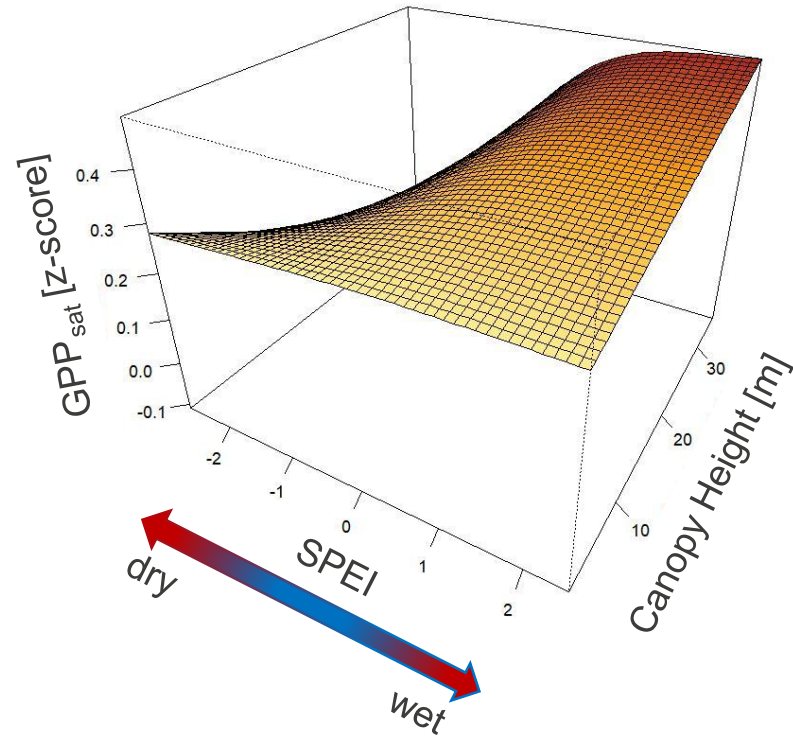


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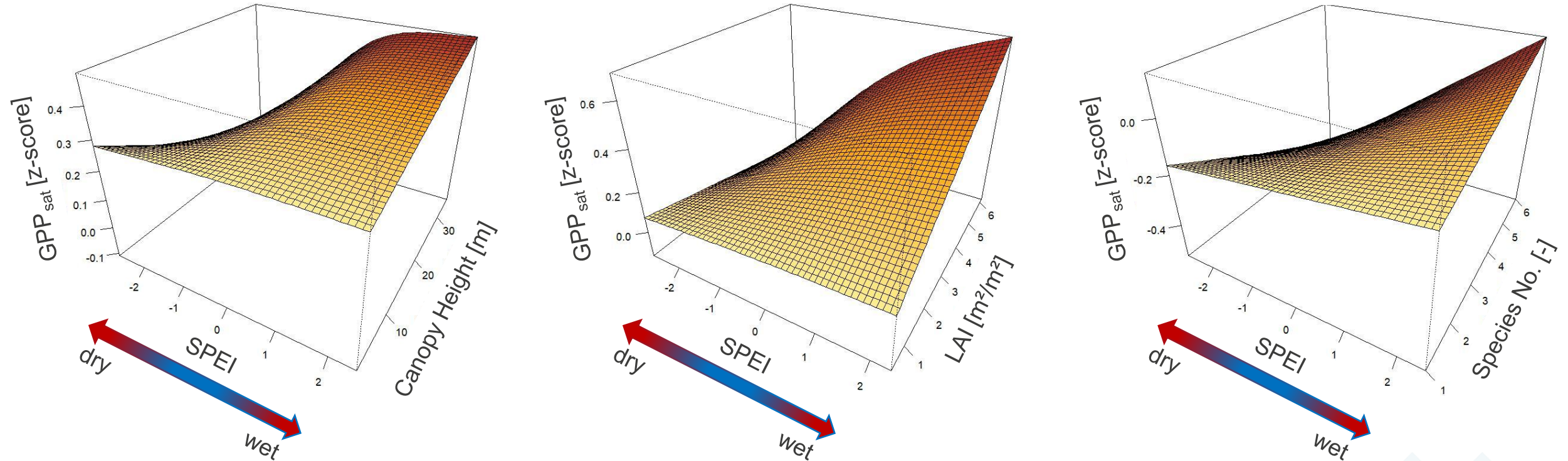
Drought Response - GPP_{sat}

Monthly data



Drought Response - GPP_{sat}

Monthly data



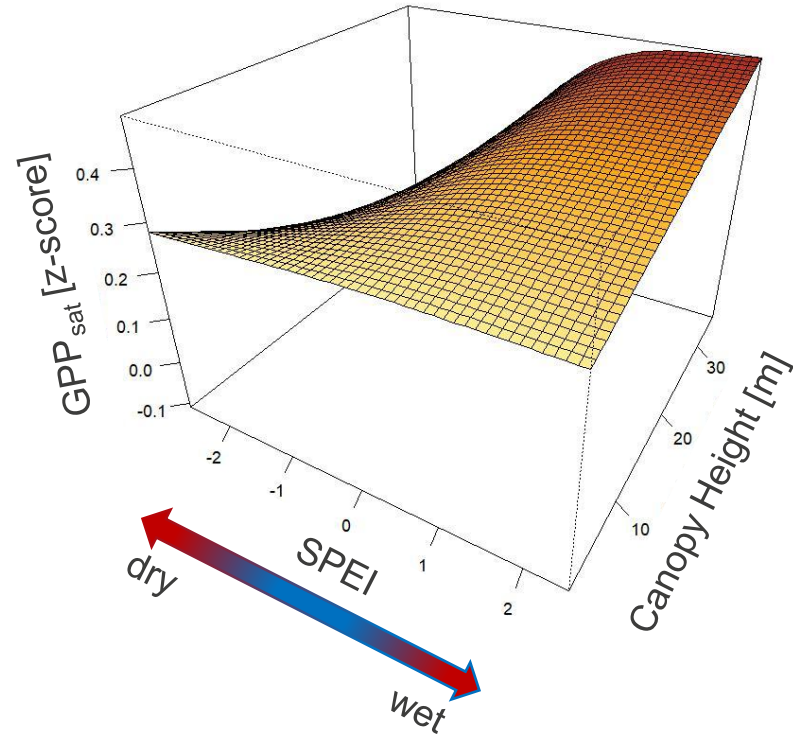
→ GPP_{sat} decreases with drought stress

→ Higher canopy height, LAI and species number leads to stronger decrease

Drought Response - GPP_{sat}

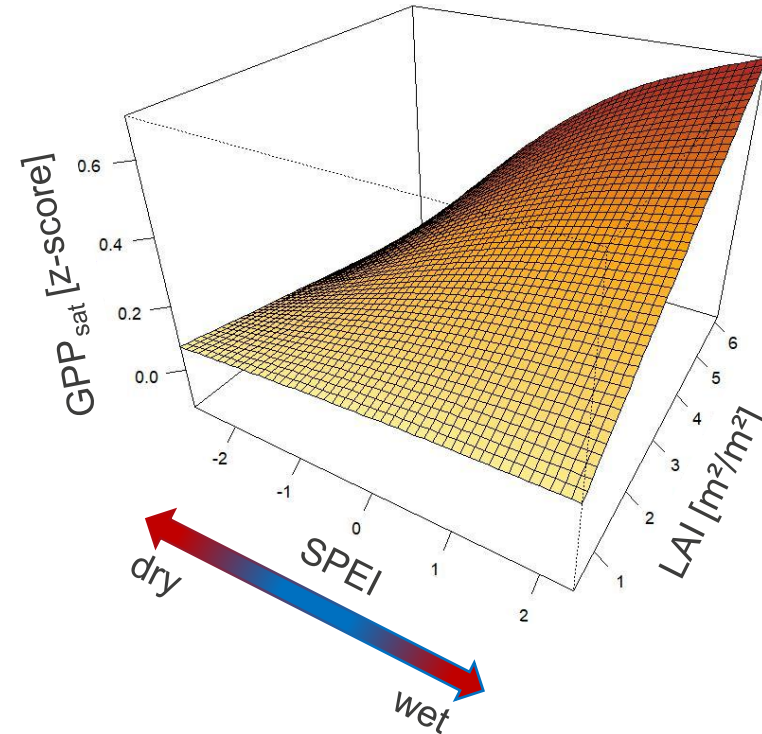
EDF Dev. Expl. P-value

2.7 0.03 < 0.05



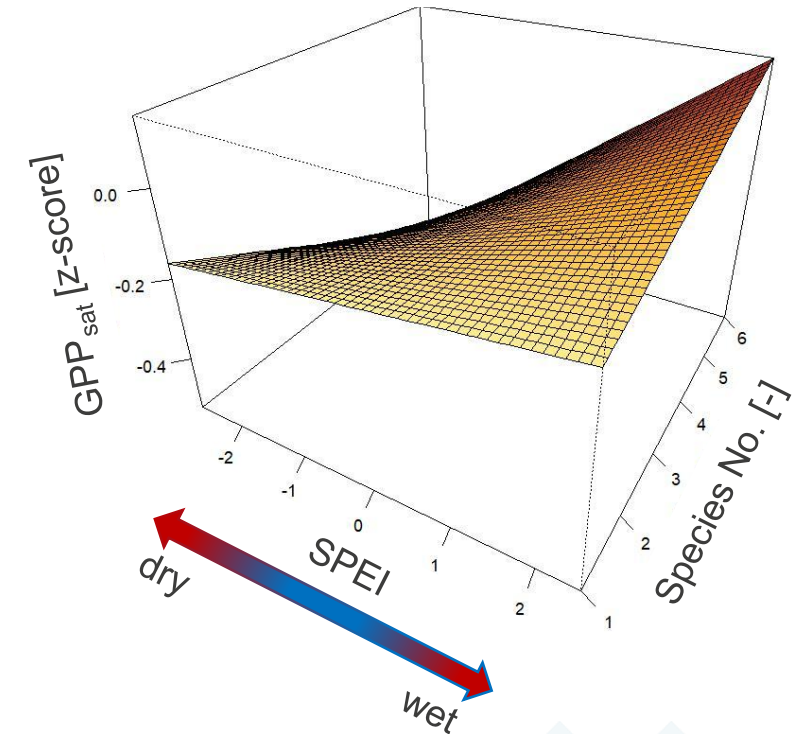
EDF Dev. Expl. P-value

2.5 0.03 < 0.05



EDF Dev. Expl. P-value

2.0 0.04 < 0.05



→ GPP_{sat} decreases with drought stress

→ Higher canopy height, LAI and species number leads to stronger decrease

Conclusions

- Forest structure did not influence the distribution or variability of EFP across European forests
- Forest structure variables had a weak but significant influence on forests' drought response
- Increasing canopy height, LAI and species number can enhance drought response of $uWUE$ and GPP_{sat}
 - Stronger increase of $uWUE$
 - Stronger decrease of GPP_{sat}

Outlook

- Include proper remote sensing product as standardized structure proxy
- Get more information on structural heterogeneity instead of structure averages
- Application of other statistical analysis

Poster by Julia Kelly this
afternoon: Hall X1 | X1.55



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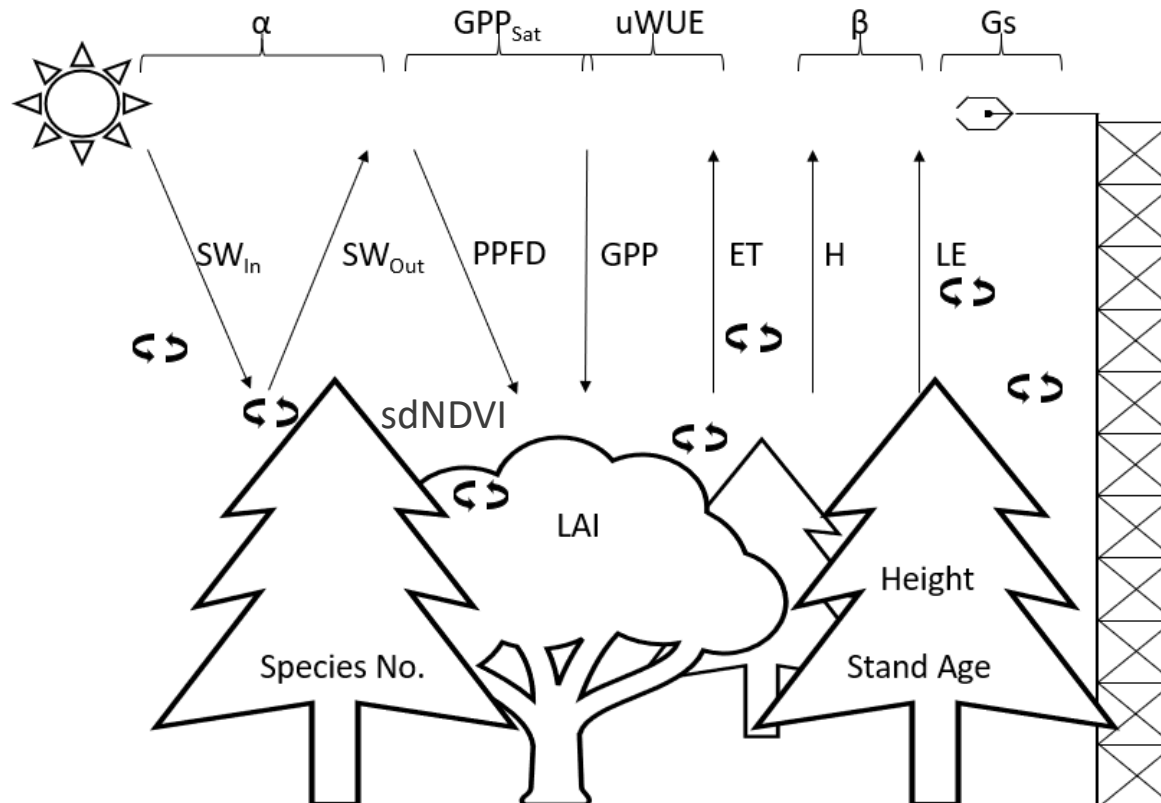
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Special thanks to all ICOS and Fluxnet employees for providing high quality data!



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Ecosystem Functional Properties (EFP)



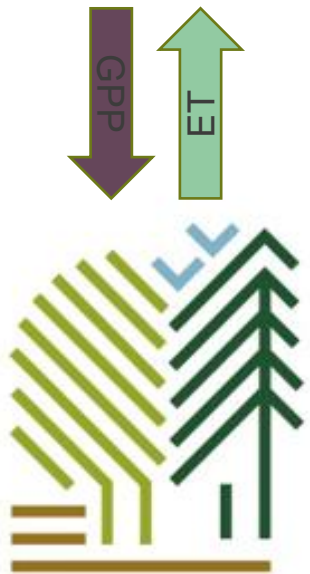
EFP:

- Albedo (α)
- Photosynthetic capacity (GPP_{sat})
- Underlying water use efficiency ($uWUE$)
- Bowen Ratio (β)
- Canopy conductance (G_s)

Fluxes:

- In- and outgoing shortwave radiation (SW_{in} and SW_{out})
- Photosynthetic active photon flux density (PPFD)
- Gross primary production (GPP)
- Evapotranspiration (ET)
- Sensible and latent heat (H and LE)

Underlying Water use Efficiency (uWUE)



- Ratio of Gross Primary Production (GPP) and Evapotranspiration (ET)
- Zhou et al (2014) proposed the **underlying Water Use Efficiency** (uWUE) → includes effect of the weighted mean vapor pressure deficit (VPDe)

$$uWUE = \frac{GPP * \sqrt{VPDe}}{ET}$$

Photosynthetic Capacity (GPP_{sat})

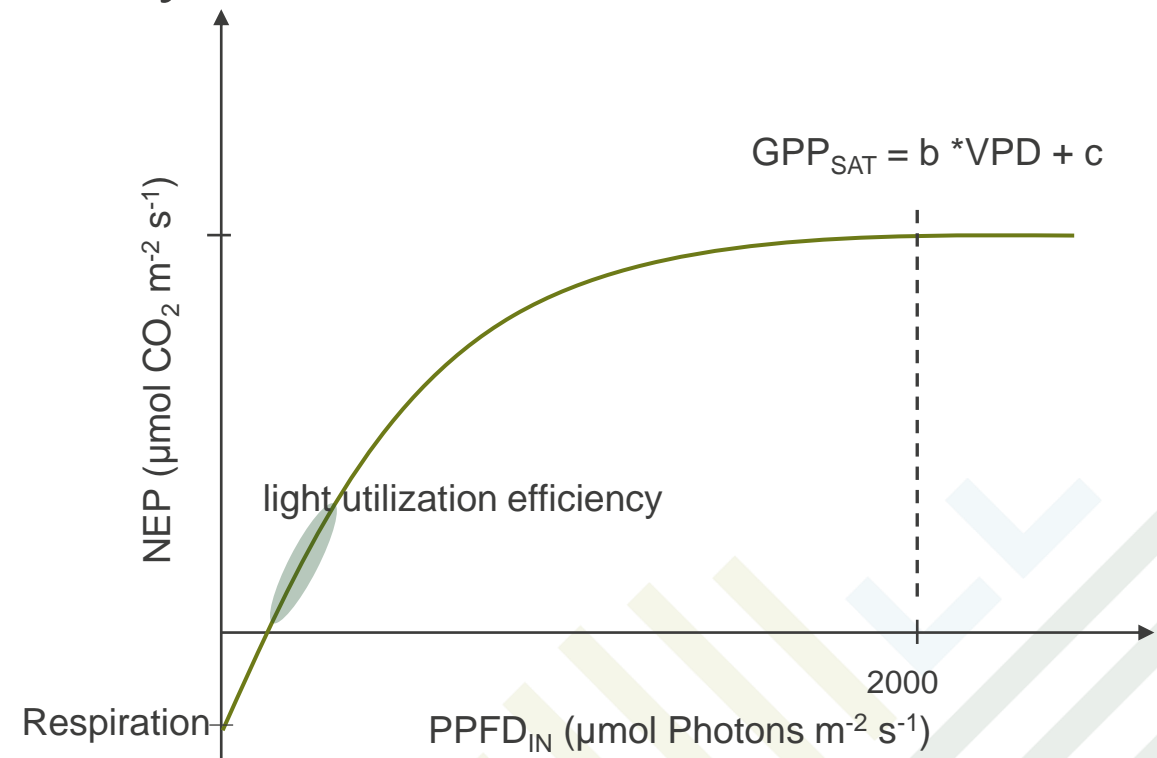
- **G**ross **P**rimary **P**roduction under light saturation (GPP_{SAT})
- Fitting of light response curve for 5 day window
 - After Falge et al., 2001
- GPP_{SAT} normalized with site VPD

$$GPP_{SAT} = b * VPD_{Mean} + c$$

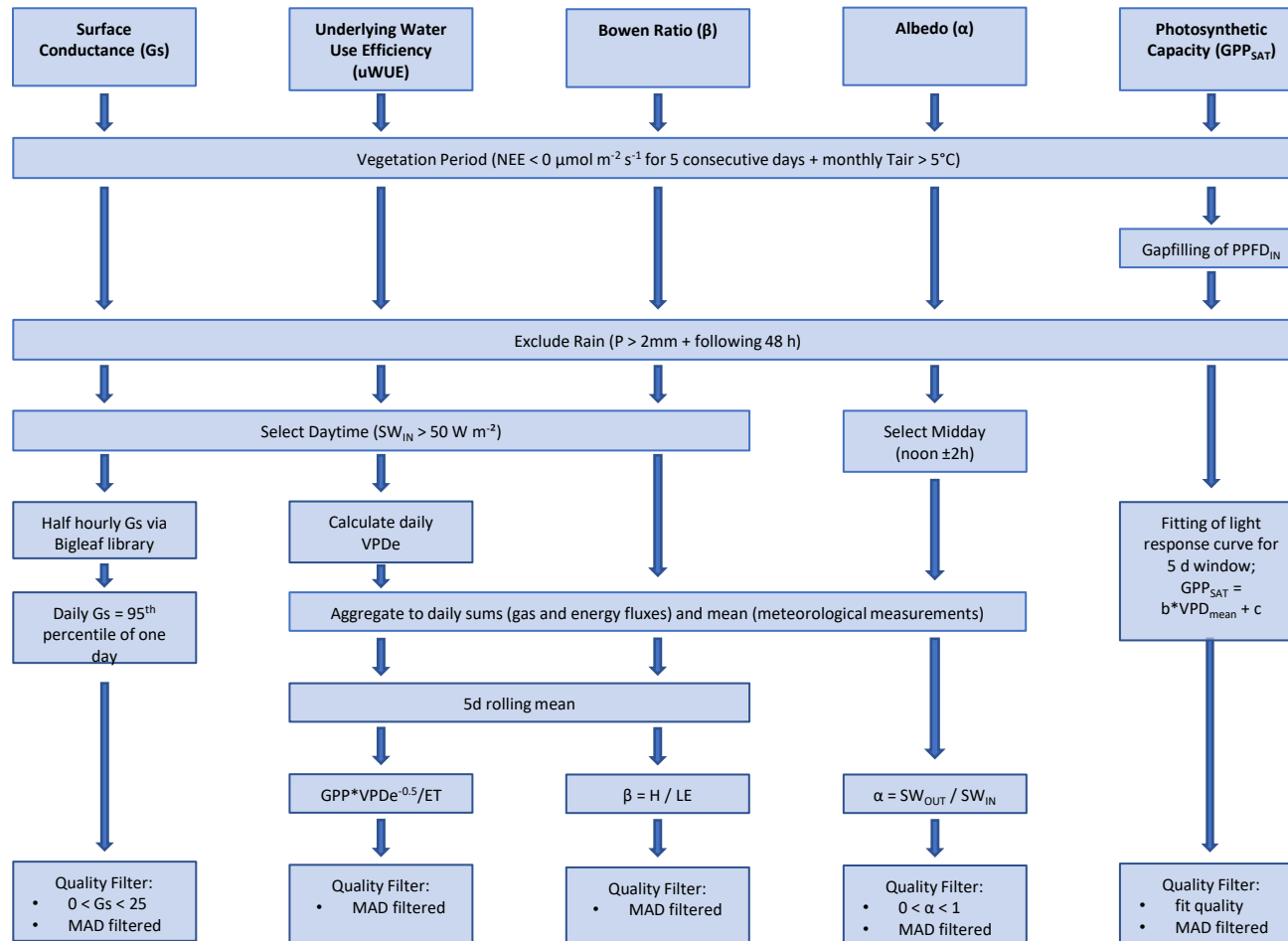
PPFD_{IN}: Incoming photosynthetic photon flux density

NEP: Net ecosystem productivity

VPD: Vapor pressure deficit



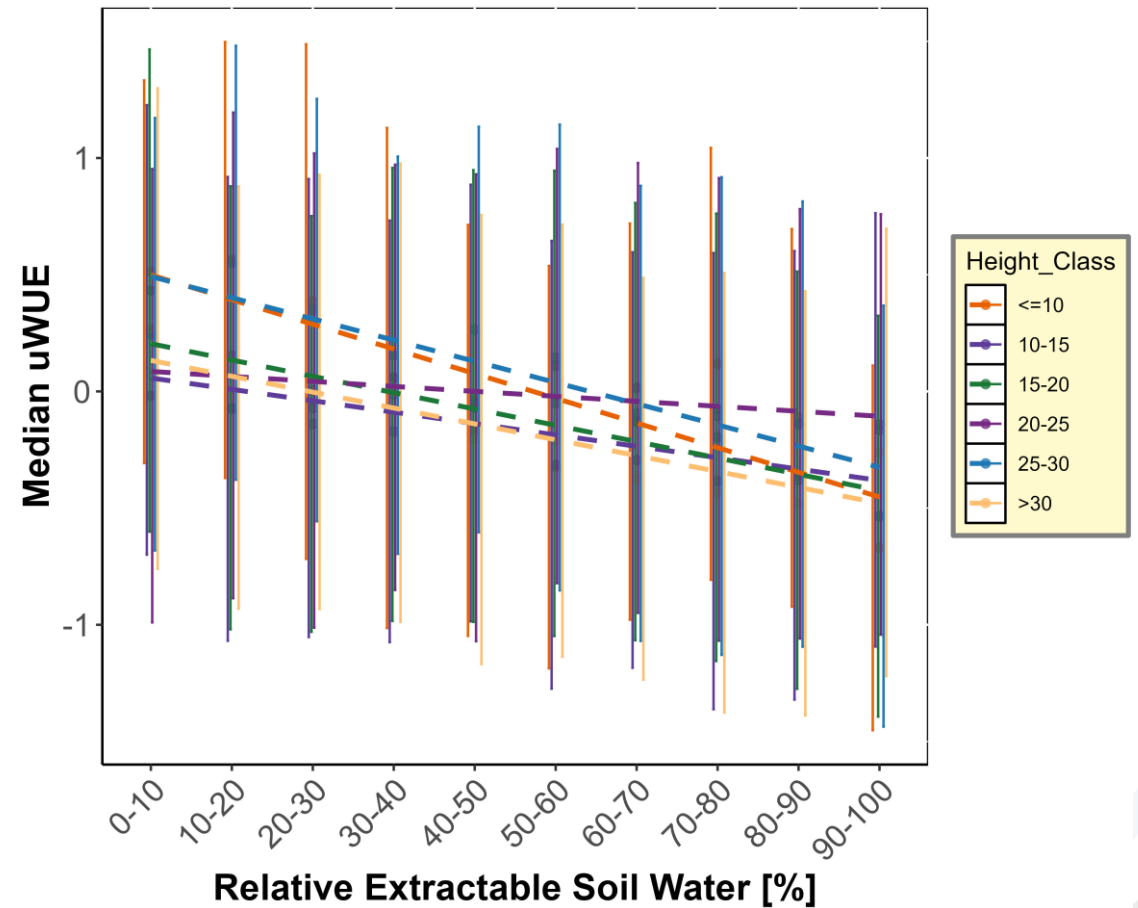
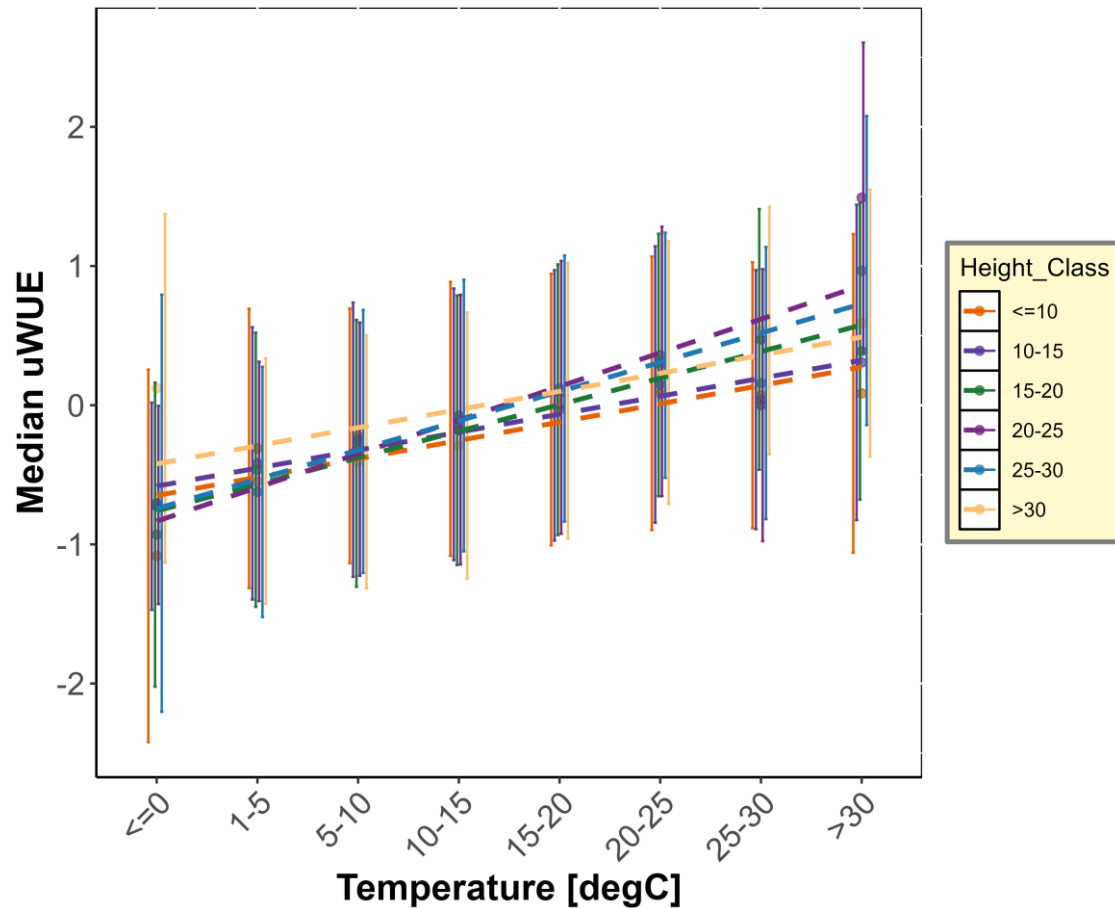
Workflow



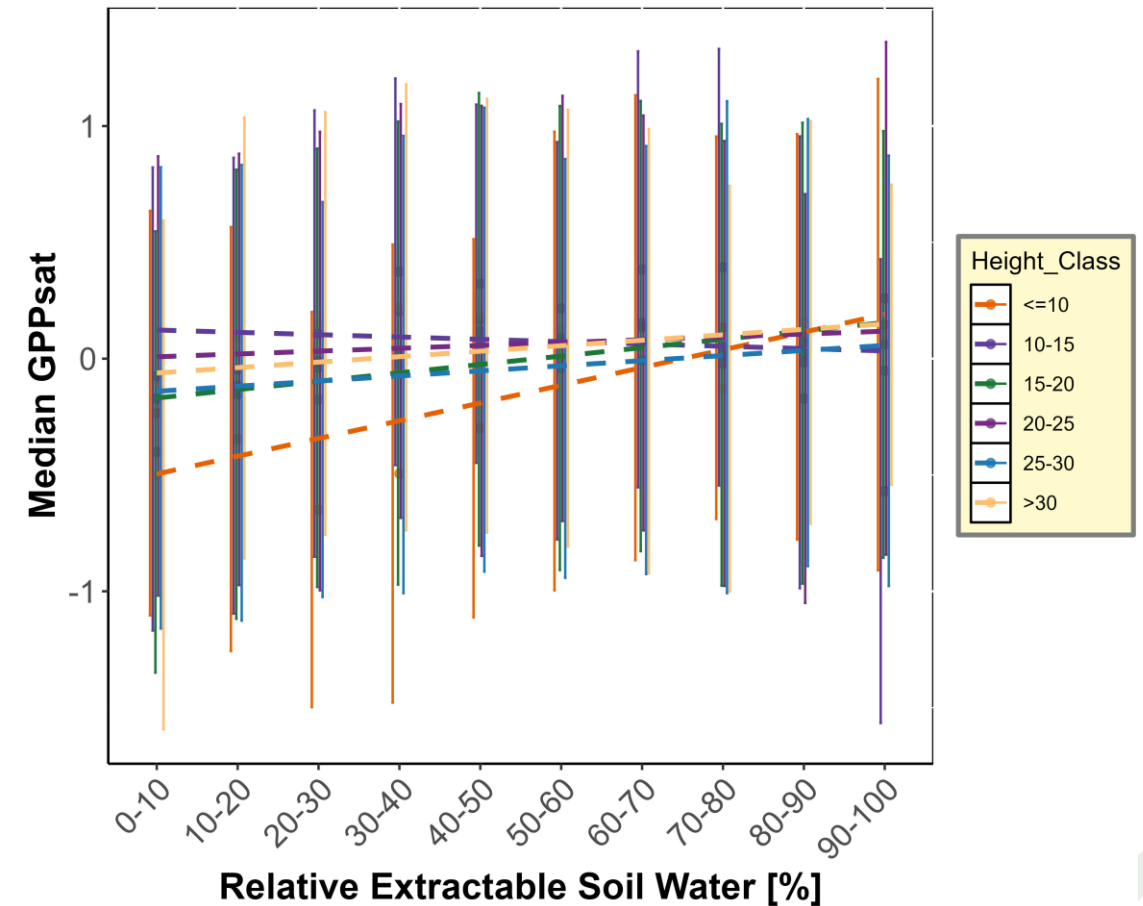
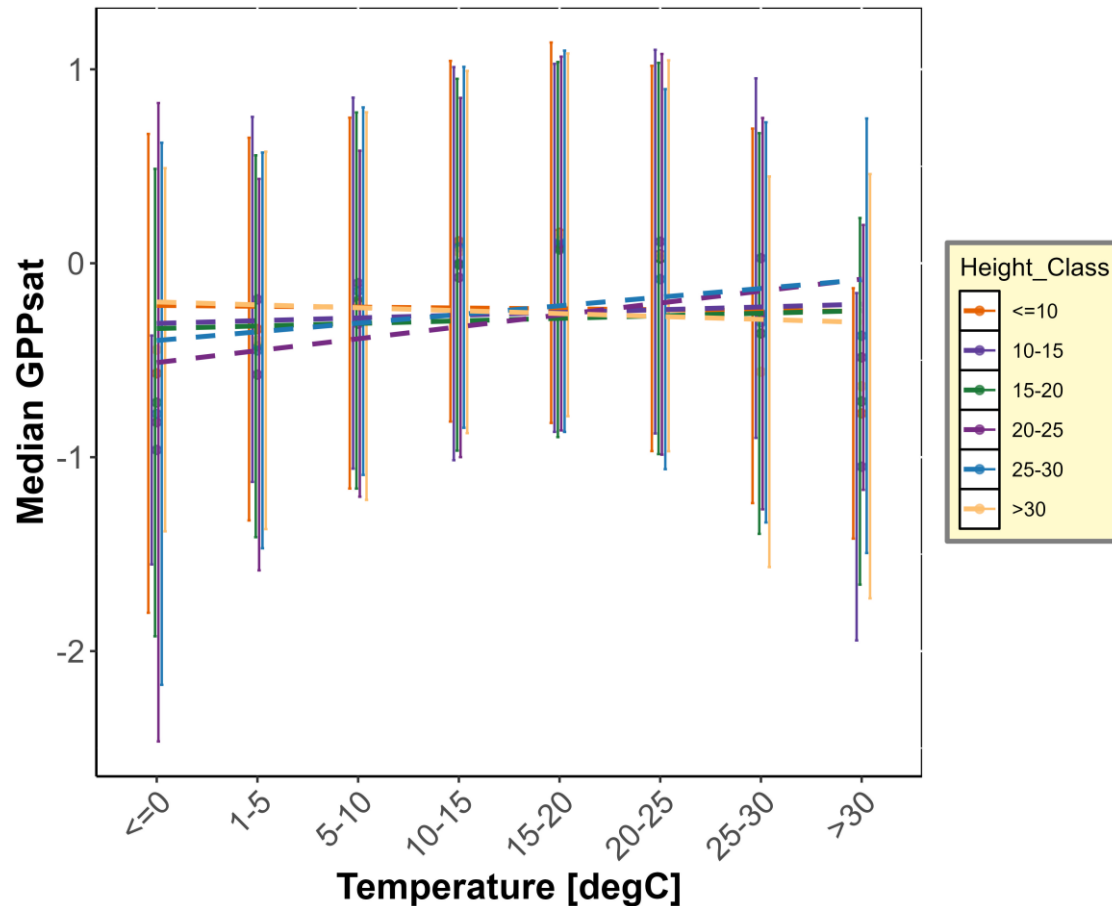
Key Steps:

- Vegetation period
- Exclusion of rain events
- Daytime / midday data
- Daily resolution
- Moving window for smoothing
- Quality control and despiking

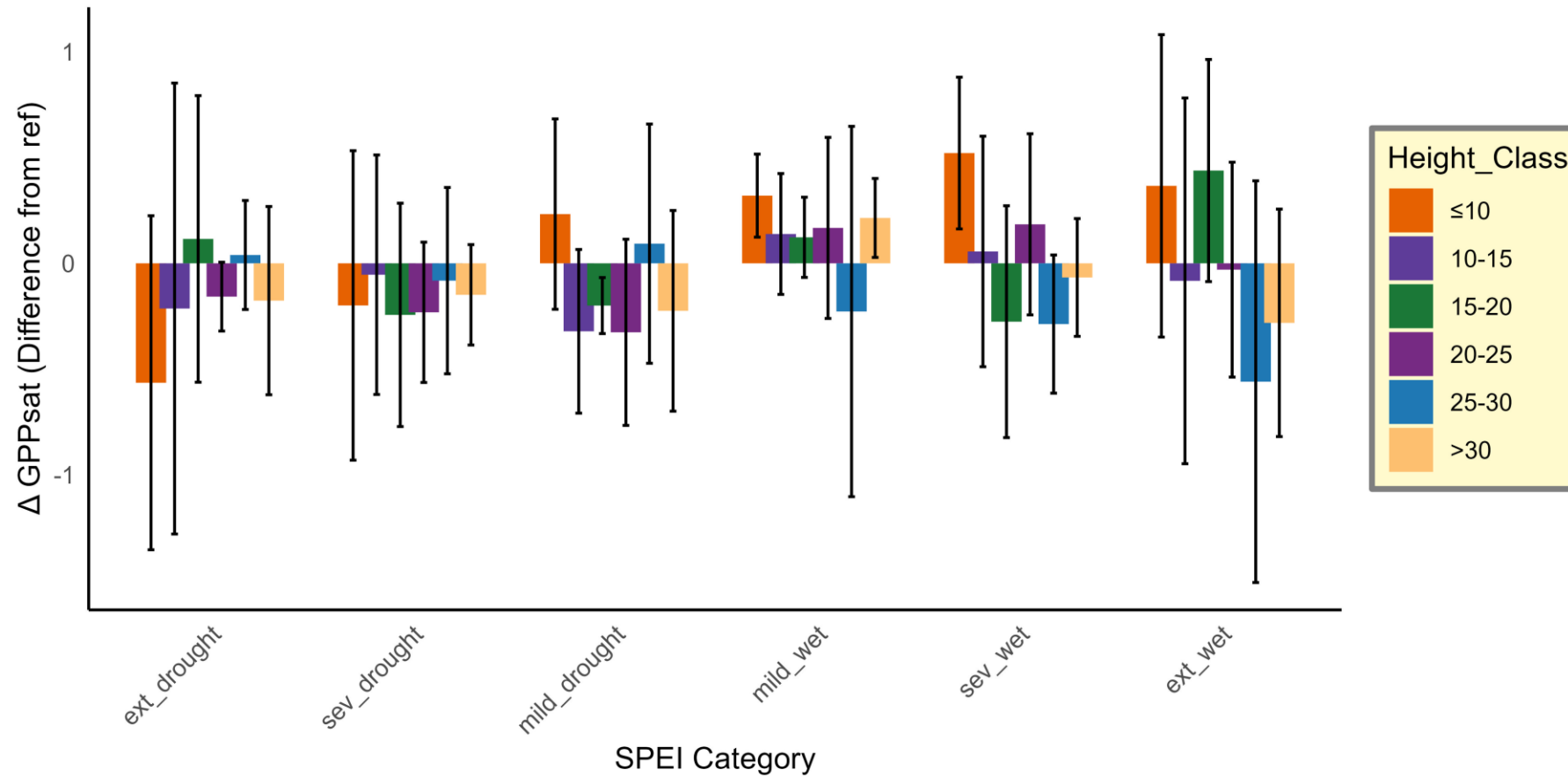
uWUE vs Temperature and soil water by canopy height class



Change of z-scored uWUE under wet and dry conditions compared to reference period



Change of z-scored GPP_{sat} under wet and dry conditions compared to reference period



Difference of z-scored uWUE between drought

