Ameriflux PI Meeting 2018

Linking variation in intrinsic water-use efficiency to isohydricity

: a comparison at multiple spatiotemporal scales

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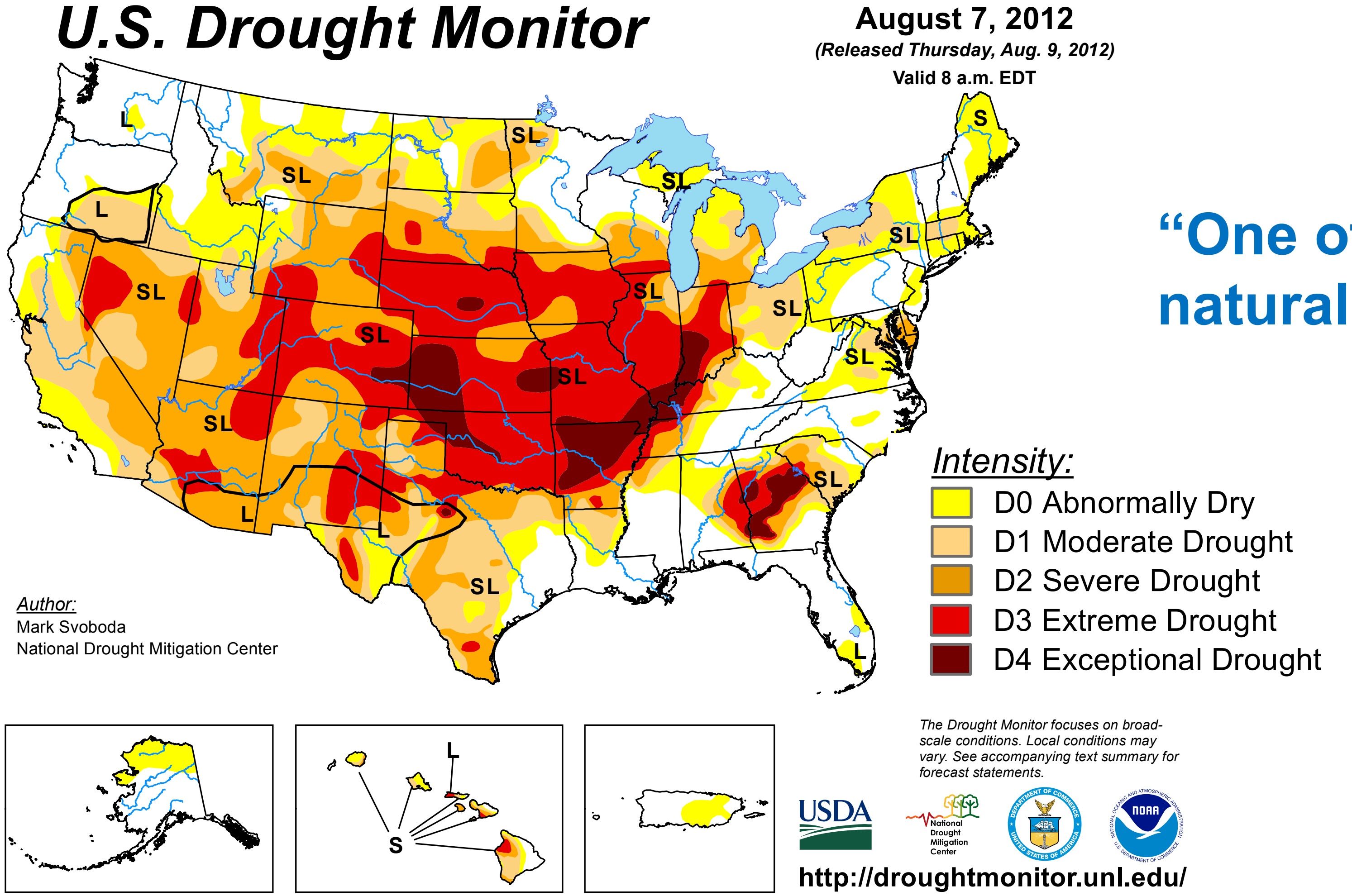
Nationwide severe drought in 2012

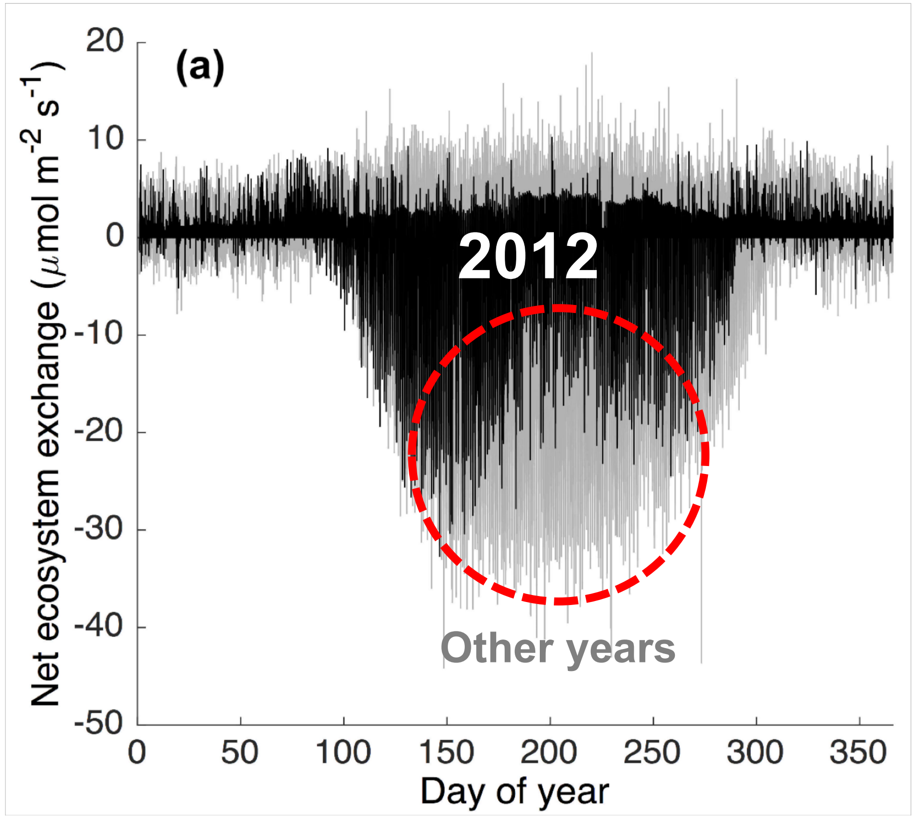


"One of the costliest and widespread natural disaster since 1980"

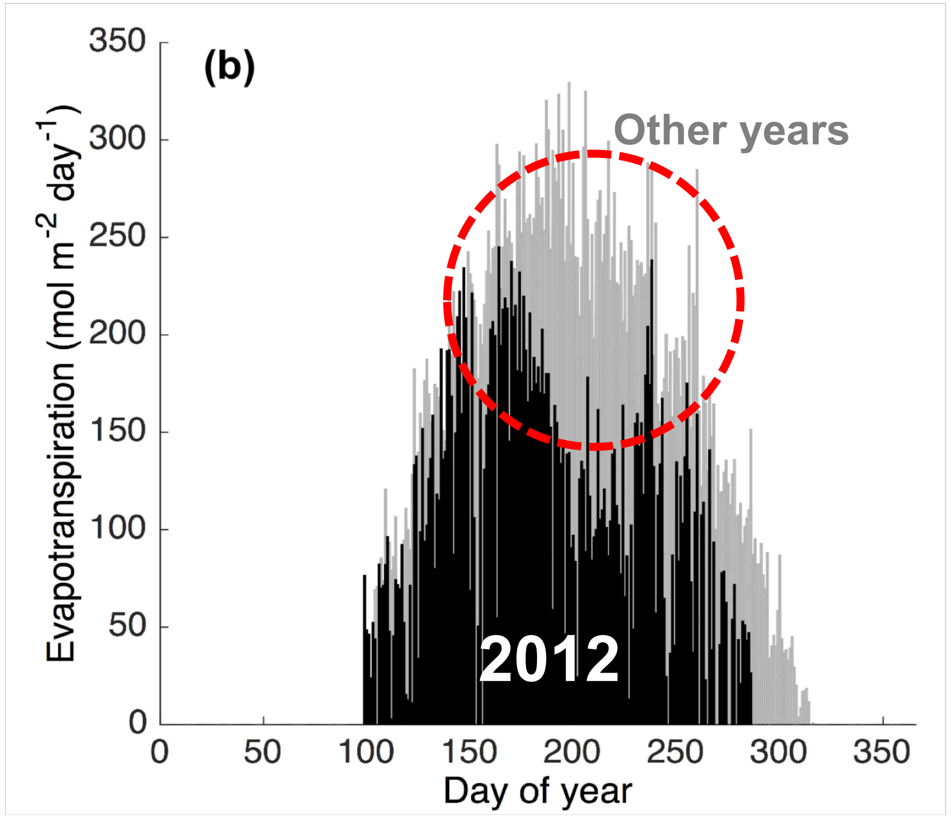
National Center for Environmental Information
Rippey 2015

Carbon & Water exchanges at MMSF (2012)

Carbon exchange (NEE)



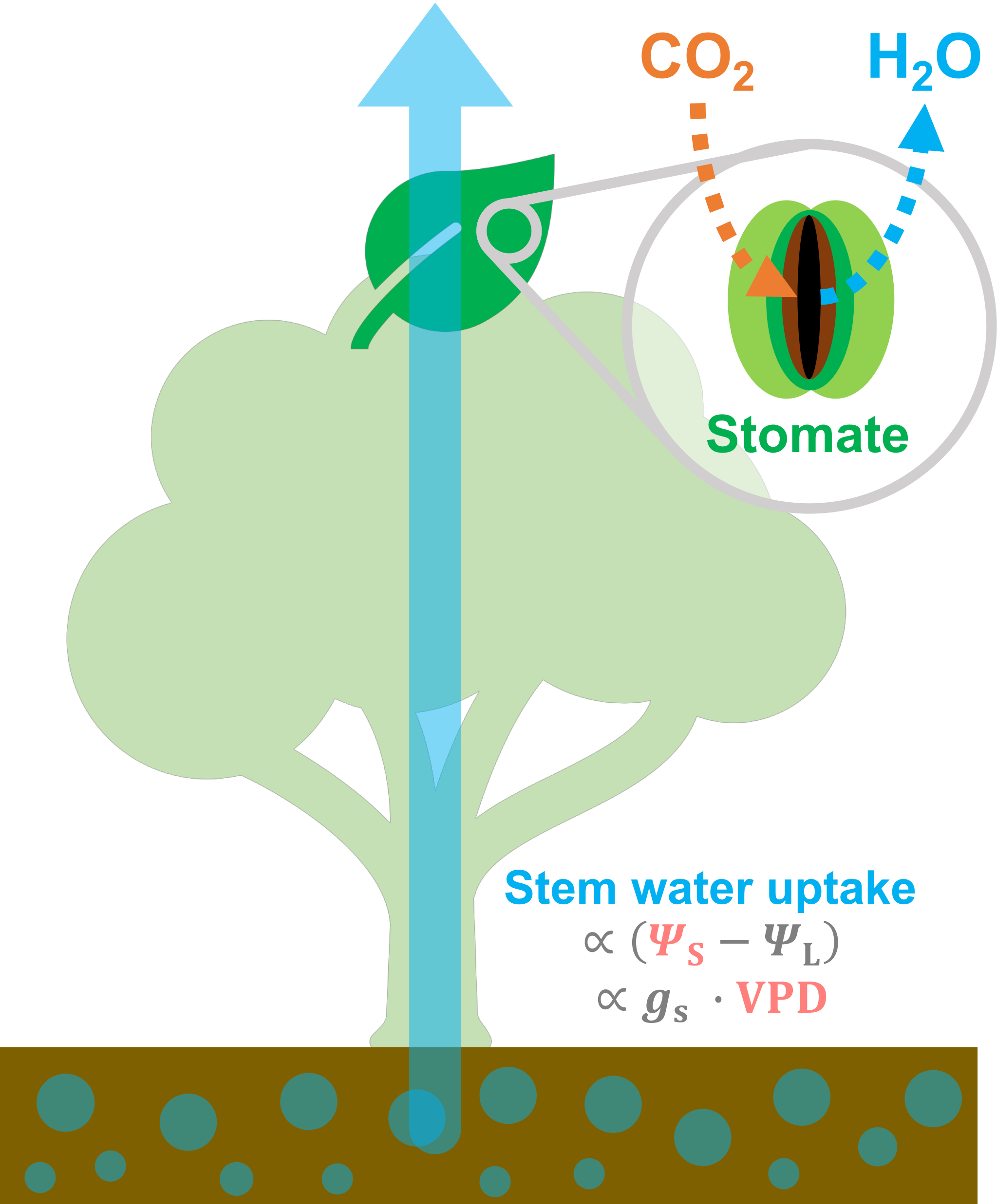
Water exchange (ET)



~50% reductions during late growing season

Why this happened?: Stomatal closure

Carbon–Water balance regulated by Stomates



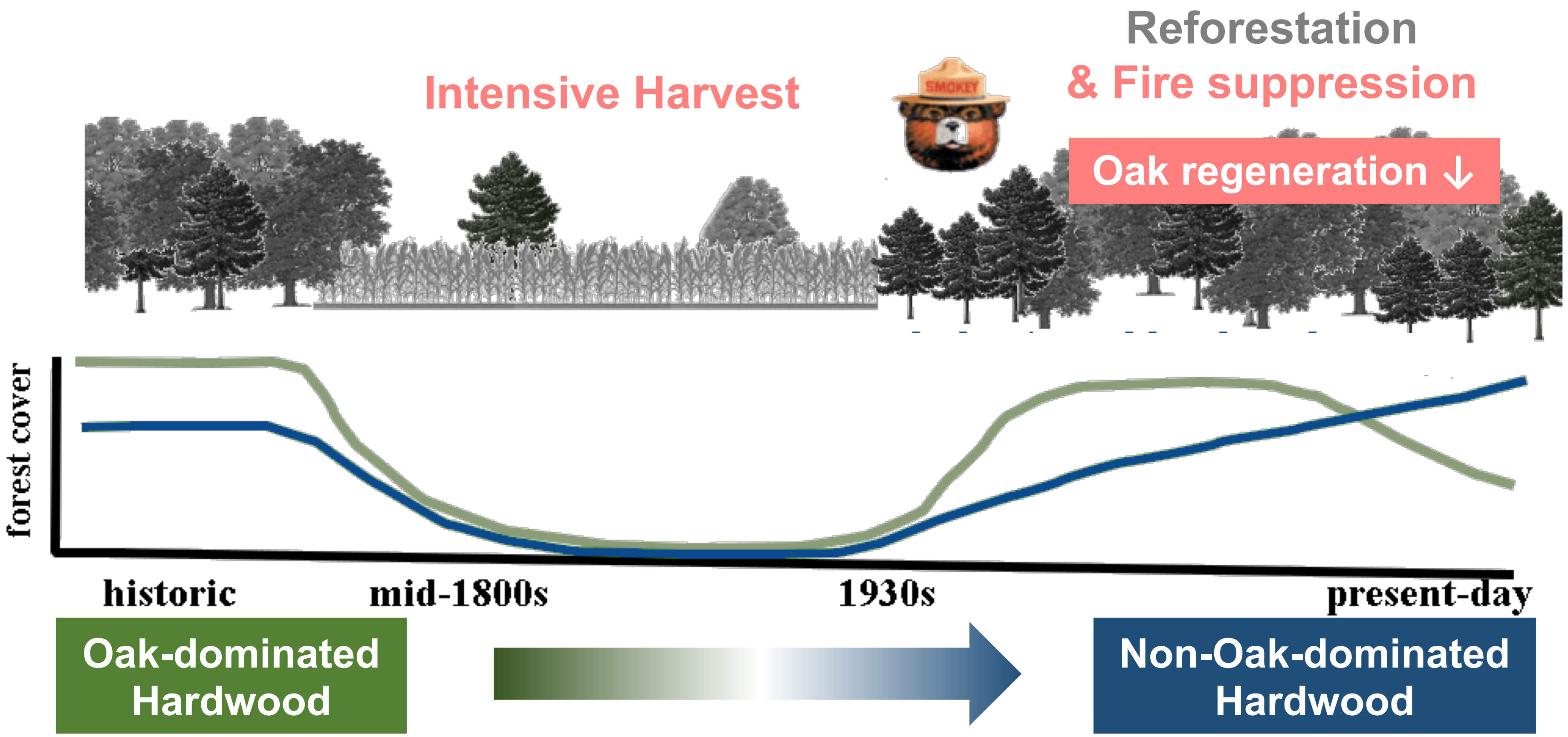
- C uptake & H_2O loss occur simultaneously through the same pathway: Stomates
- Plants regulate stomates to reduce water loss during drought.
- Stomatal response to drought influences the balance between C uptake & H_2O loss of plants (e.g. intrinsic water-use efficiency)

$$\mathrm{iWUE} = A \,/\, g_s$$

A: C assimilation rate
g_s: stomatal conductance
*Different versions exist for different observational scales.

- Water uptake (and thus iWUE) is regulated by both soil dryness (SWC) & air dryness (VPD); However, impact of VPD is often neglected when discussing drought.

Historical change in species composition in eastern U.S.



Highly dynamic species composition in eastern U.S. emphasizes **importance of understanding species-specific responses.**

Research goals

Evaluation of the impacts of drought on iWUE
Soil dryness (SWC) vs. Air dryness (VPD)

Comparison of species-specific response
Isohydric – anisohydric framework

Comparison across observational scales
Leaf, tree, and stand-levels

Evaluation of the impacts of drought on C gain / tree growth
C assimilation rate, basal area increment, GPP

Measurements at MMSF

Leaf gas exchange

Eddy covariance

Leaf & stem water potential

Sap flux

Tree-ring study (+ stable C isotope)

Measurements for different observational scales

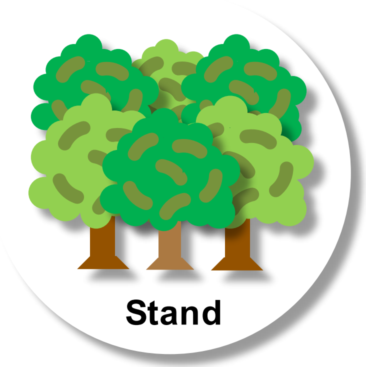
- $\mathbf{iWUE_L = A / g_s}$
- **C assimilation rate (*A*)**

A = carbon assimilation rate
g_s = stomatal conductance

+

- $\mathbf{iWUE_T = (c_a - c_i) / 1.6}$
- $\Delta = a + \frac{(b-a)c_i}{c_a}$
- $\Delta = (\delta^{13}C_{air} - \delta^{13}C_{plant})/(1 + (\delta^{13}C_{plant})/1000)$
- **Basal area increment**

c_a = ambient CO_2 conc.
c_i = intercellular CO_2 conc.

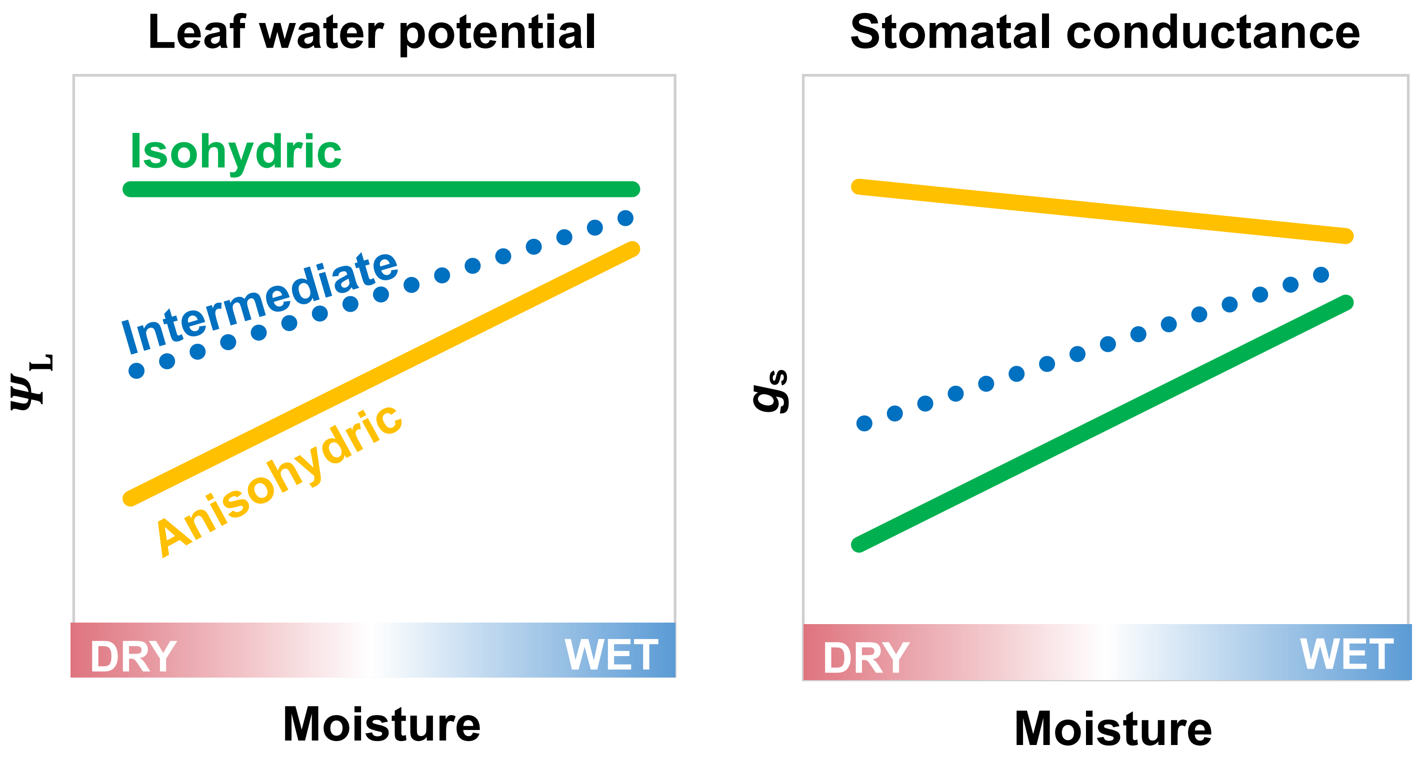


- $\mathbf{iWUE^* = GPP \times VPD / ET}$
- **GPP**

GPP = gross primary productivity
D = vapor pressure deficit
ET = evapotranspiration rate

Species-specific water use strategy

Isohydric – anisohydric framework



Isohydric species:

- Ideal to avoid hydraulic failure
- Reduced C uptake

Anisohydric species:

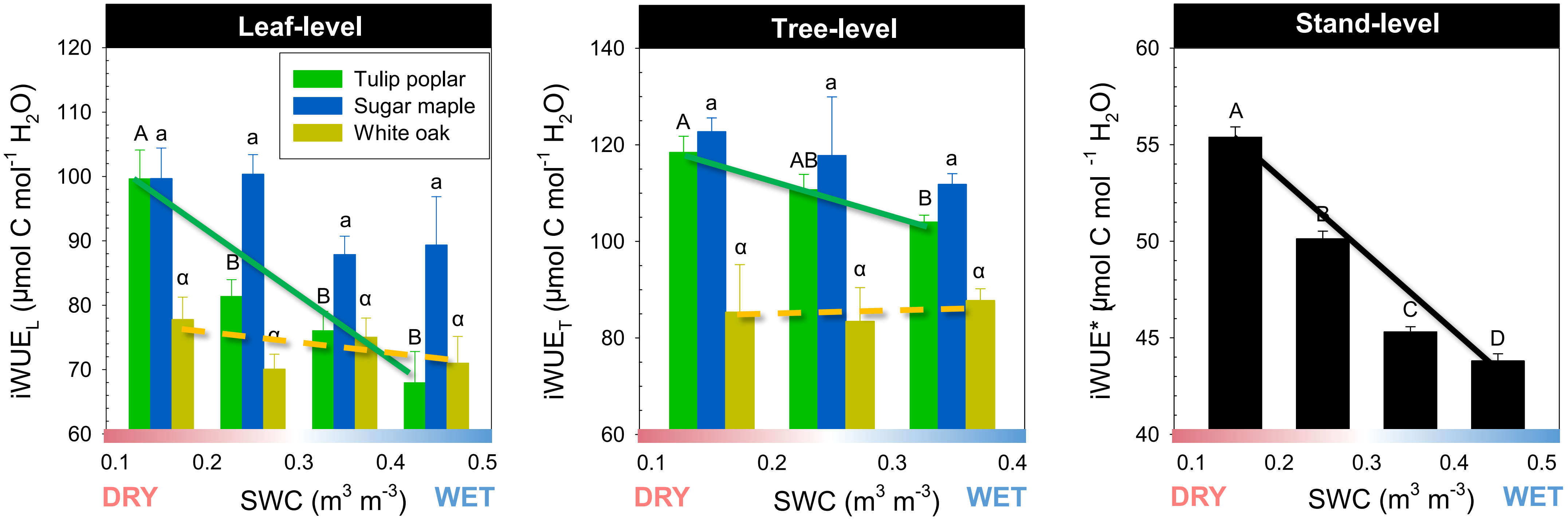
- Ideal to maintain C uptake
- Higher risk of hydraulic failure

Canopy dominant trees at MMSF

- Tulip poplar: Most Isohydric
- White oak: Most Anisohydric
- Sugar maple: Intermediate

(Roman et al. 2015)

Response of iWUE to drought



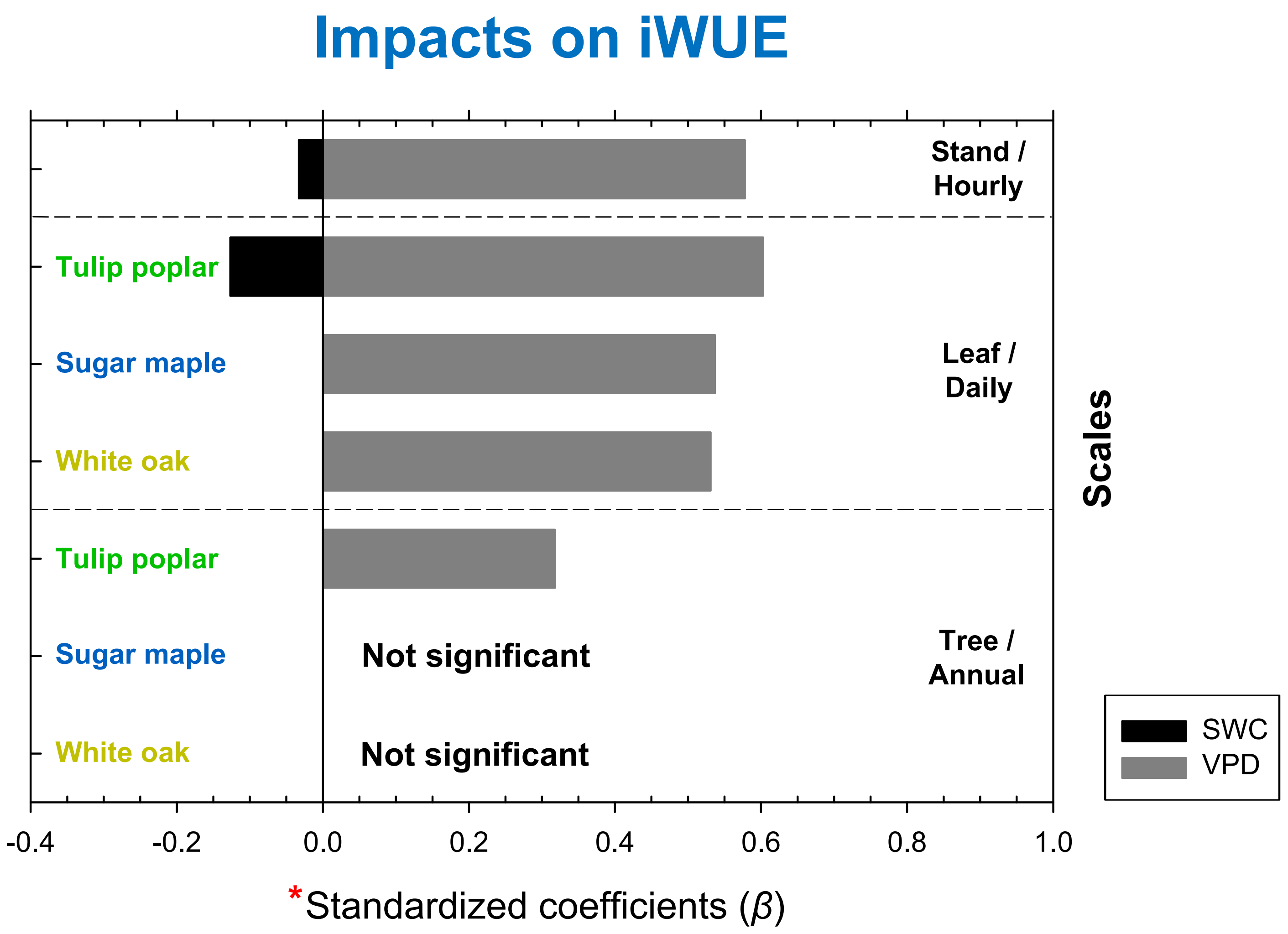
Sensitivity: Isohydric > Anisohydric
(∵ rapid & earlier stomatal closure for isohydric species)

Isohydric: iWUE↑ under drier condition
Anisohydric: constant iWUE

Stand-level response ≈ isohydric species
(∵ species composition: isohydric > anisohydric)

(Same conclusion for iWUE-VPD)

Relative impacts of SWC & VPD on iWUE



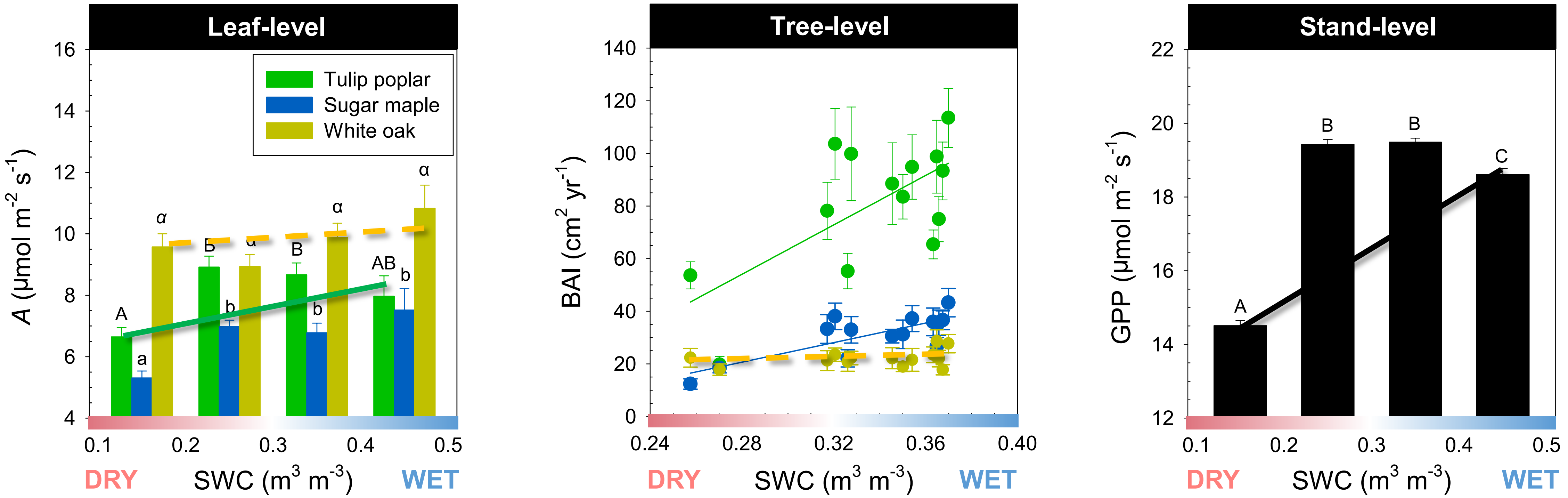
- **Sensitivity:**
  Isohydric > Anisohydric

- **Relative impact:**
  VPD > SWC
  across ALL scale & species

$$^{*}Z_{iWUE} = \beta_1 \cdot Z_{SWC} + \beta_2 \cdot Z_{VPD} + \epsilon$$

($Z_{variable}$: z-score for a variable)

Response of C gain to drought



Sensitivity: Isohydric > Anisohydric

(∵ rapid & earlier stomatal closure for isohydric species)

Isohydric: C gain ↓ under drier condition
Anisohydric: constant C gain

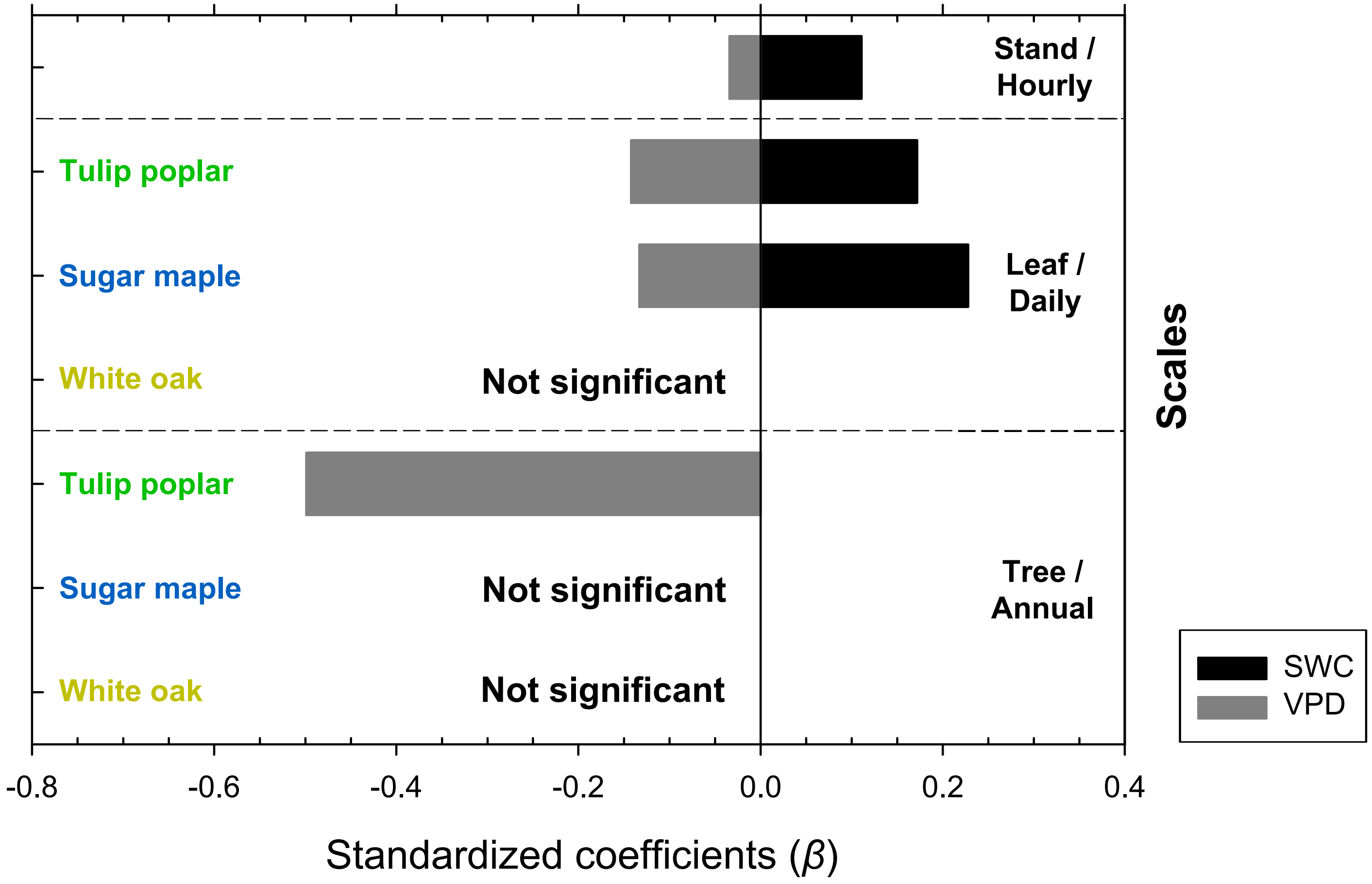
Stand-level response ≈ isohydric species

(∵ species composition: isohydric > anisohydric)

(Same conclusion for C gain-VPD)

Relative impacts of SWC & VPD on C gain

Impacts on C gain



- **Sensitivity:**
  Isohydric > Anisohydric

- **Relative impact:**
  SWC > VPD
  at the **shorter timescale** (i.e., hour/daily)

  VPD > SWC
  at the **longer timescale** (i.e., annual)

Conclusion

- Species-specific response to drought → Isohydric: iWUE↑, C gain↓
  Anisohydric: constant iWUE & C gain
- High impact of VPD (often > SWC)
- Similar trend across observational scale. → However, impact of drought may vary.
- Stand-level response represented the response of dominant species. → ∴ Shifting species composition would cause significant change in C & water exchange at stand-level.

For instance,
Oak-dominated → Non-oak-dominated hardwood
: C reduction↑↑

Thanks!

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