

Impacts of Root Distribution and Root Water Uptake on Maize Water Use in Shallow Groundwater Agroecosystems

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Background

- Plant roots connect the soil to the atmosphere through helping transport water and nutrients residing in the soil to the tissues of plants.
- Root depth and the vertical profile determines the distribution and amount of water uptake



Plant drought adaptation strategies

Shorter Time
Scale
(~Weekly)

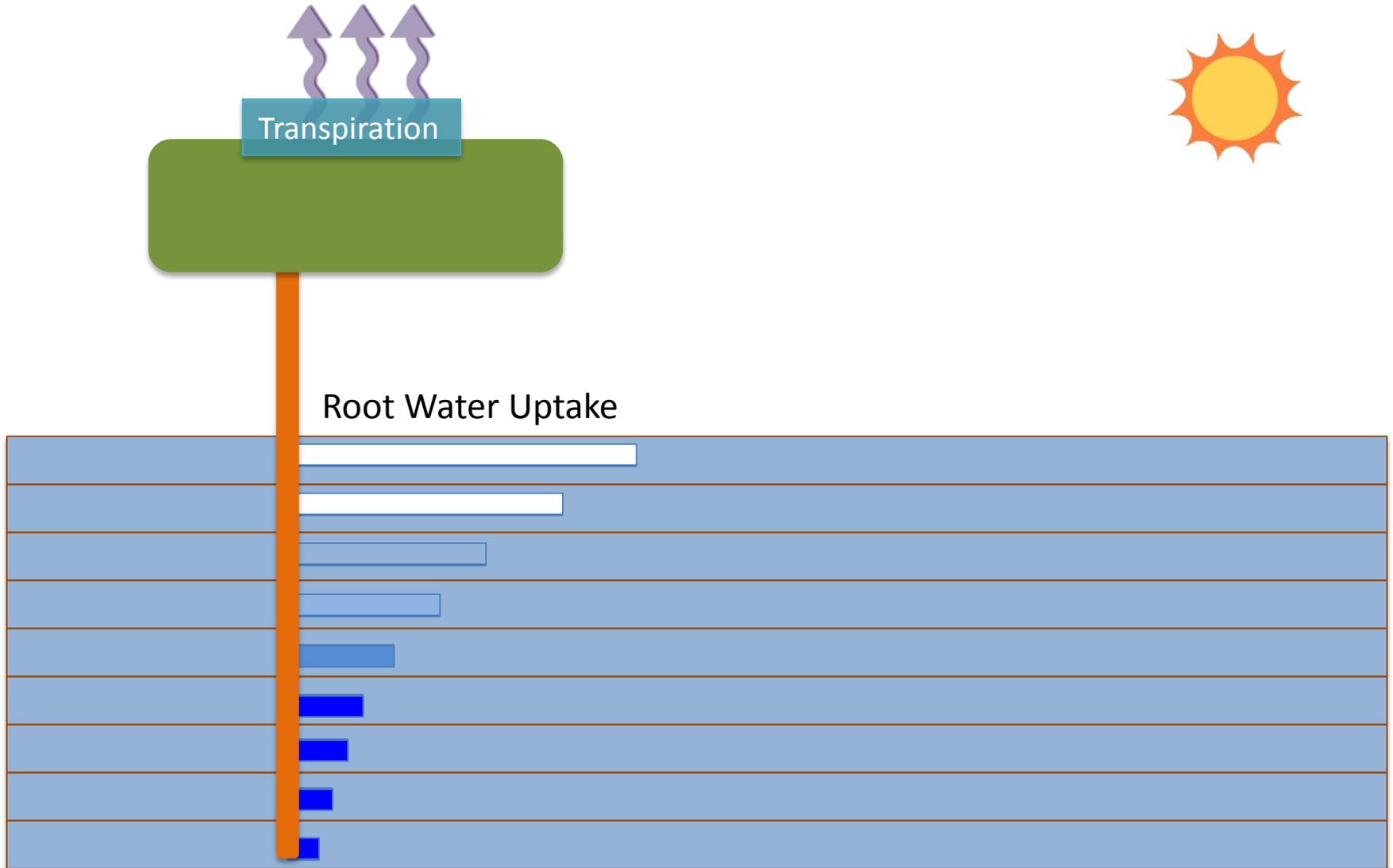
- Root water uptake (RWU) **compensation**
- Hydraulic redistribution

Seasonal Time
Scale

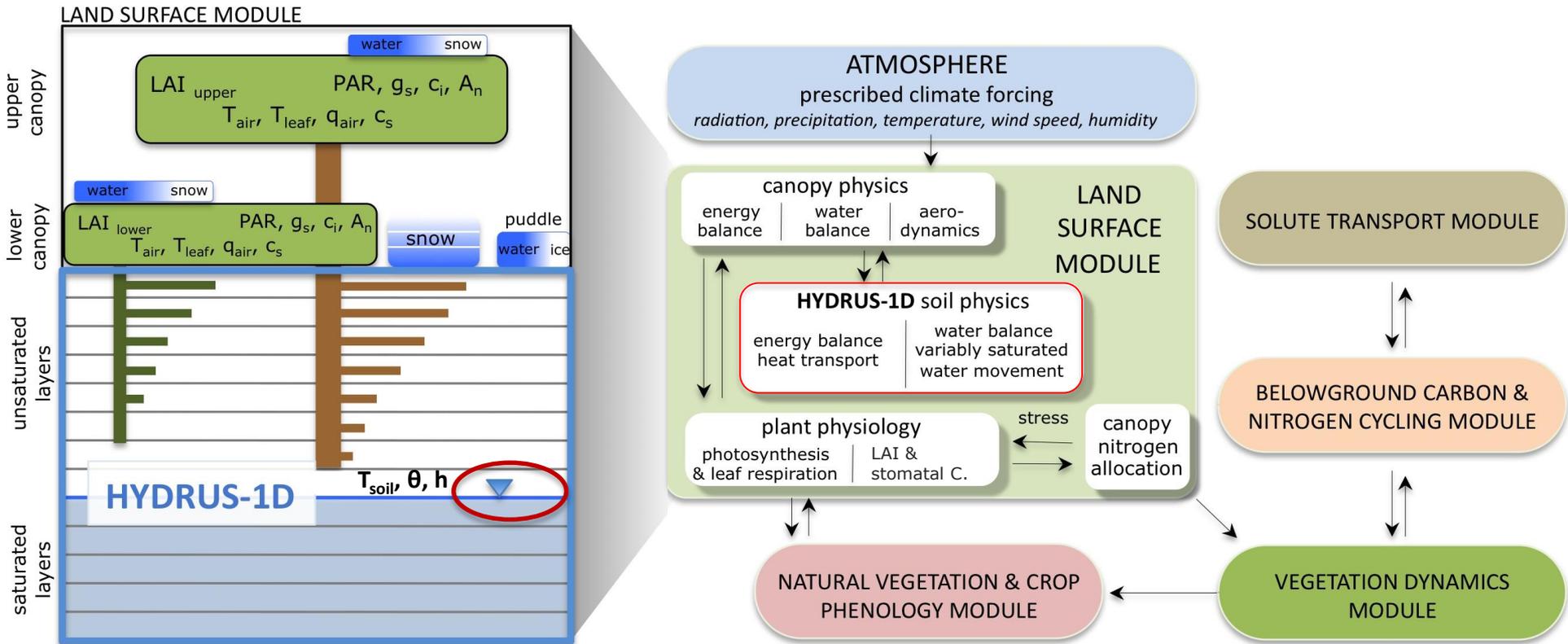
- Developing fine roots based on the moisture availability (adapting their **Root Length Density – RLD**)

RLD = the total length of root per unit volume of soil

Root Water Uptake Compensation

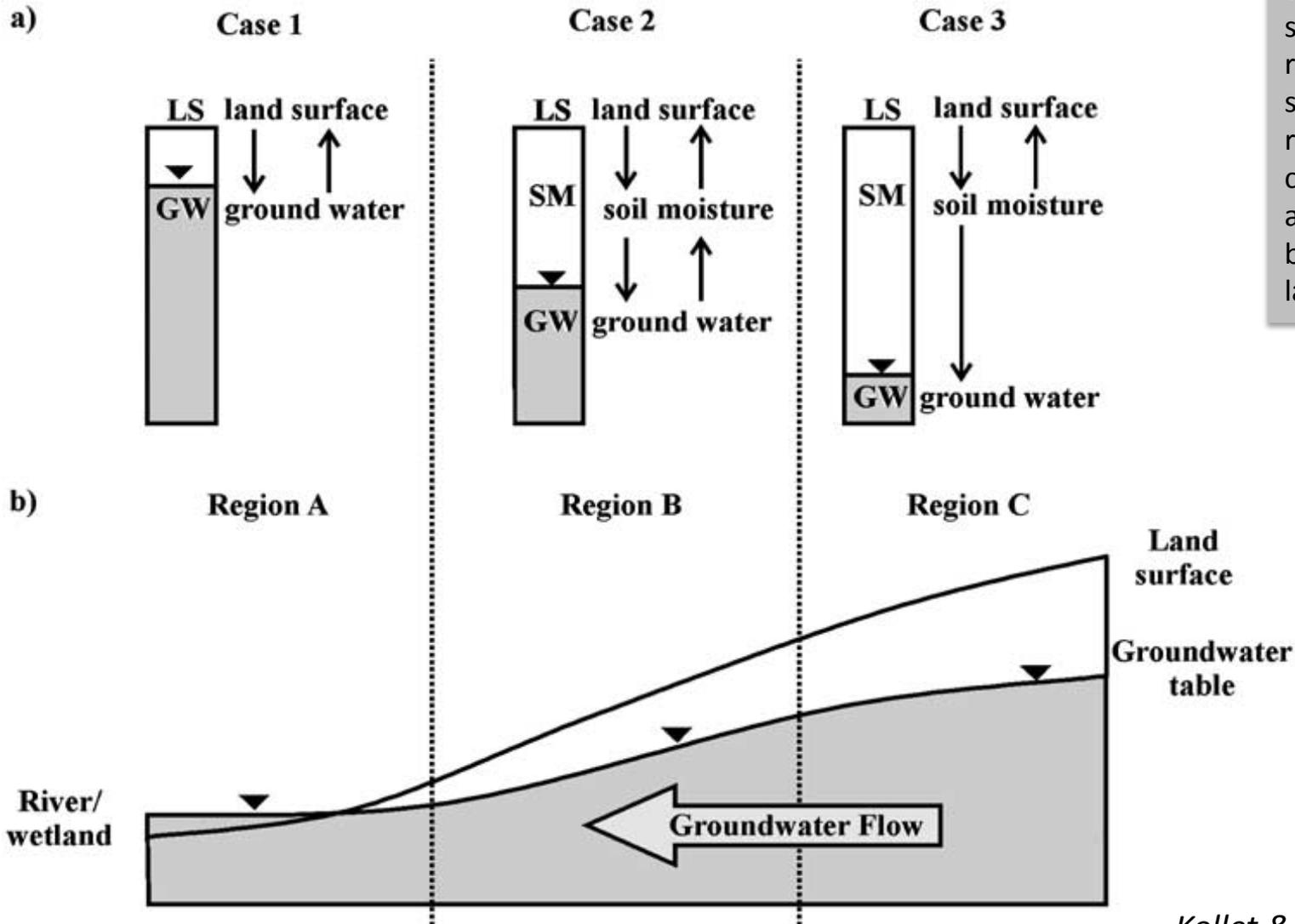


Model Description – AgrolIBIS-VSF

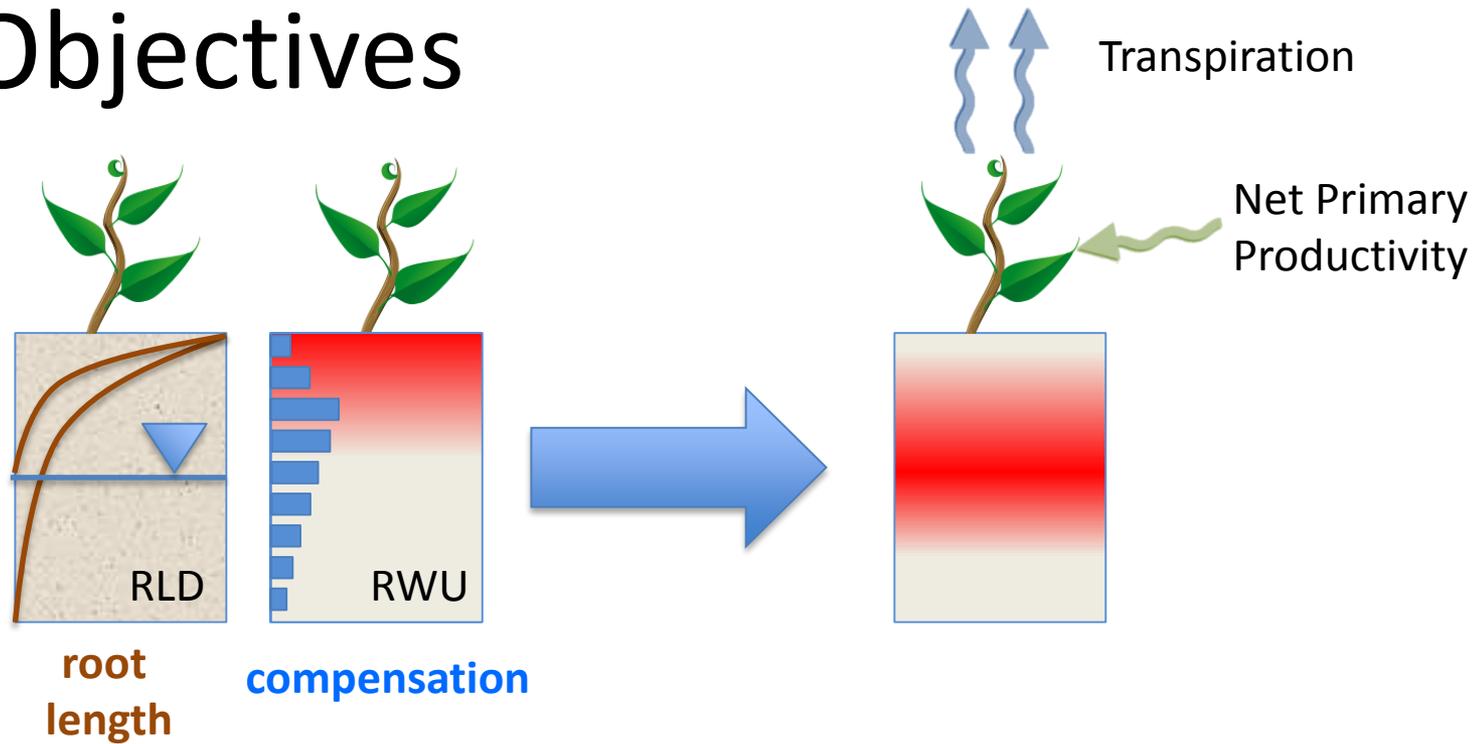


The influence of groundwater on land-atmosphere interactions

In Case 2, water table is at “critical depth”, where small changes in groundwater depth cause significant vertical redistribution of soil moisture resulting in changes of water and energy balance at the land surface



Objectives



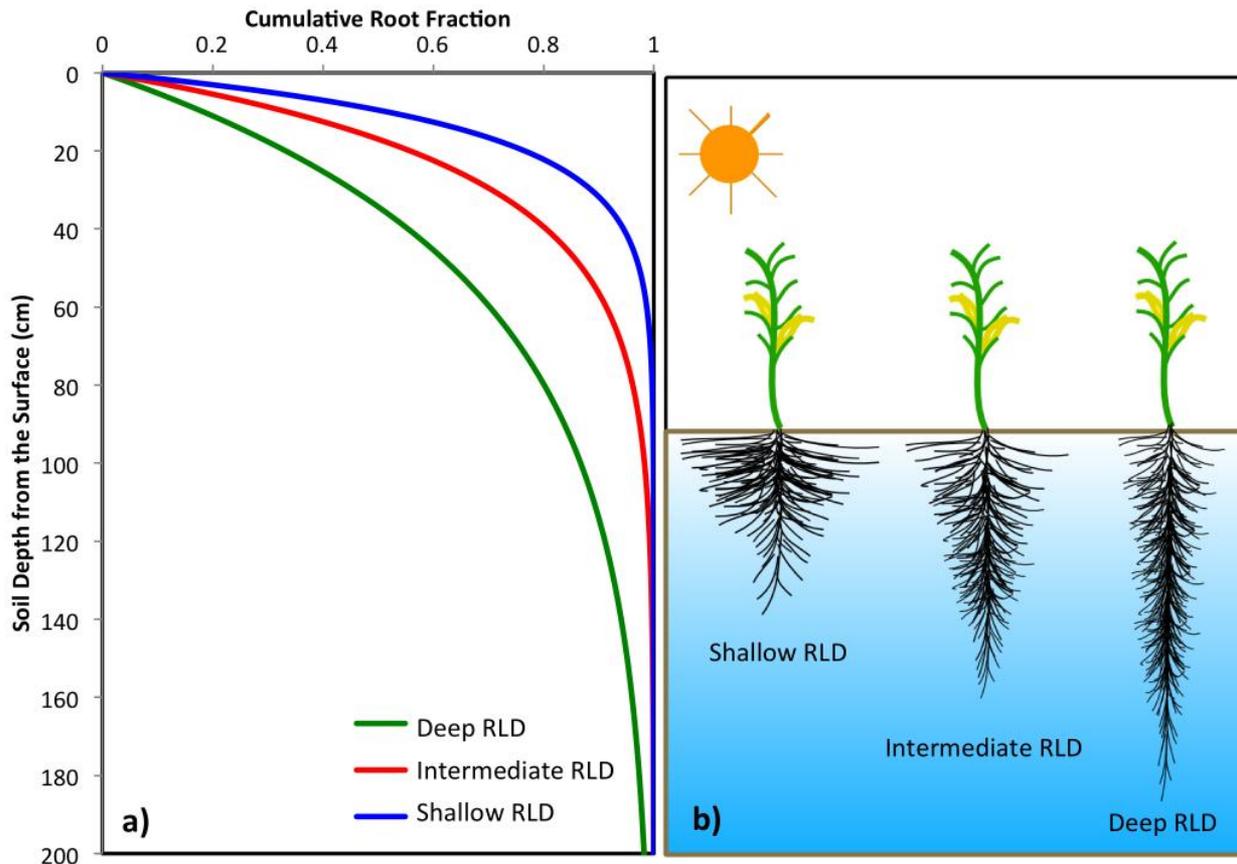
How are **seasonal scale (root length)** and **short-term (compensation)** plant adaptive strategies able to mitigate the adverse effects of plant water stress during dry years?

How does maize utilize groundwater given varying water table depths and how is the groundwater contribution influenced by the RLD distribution and RWU compensation mechanism?

Simulation Design

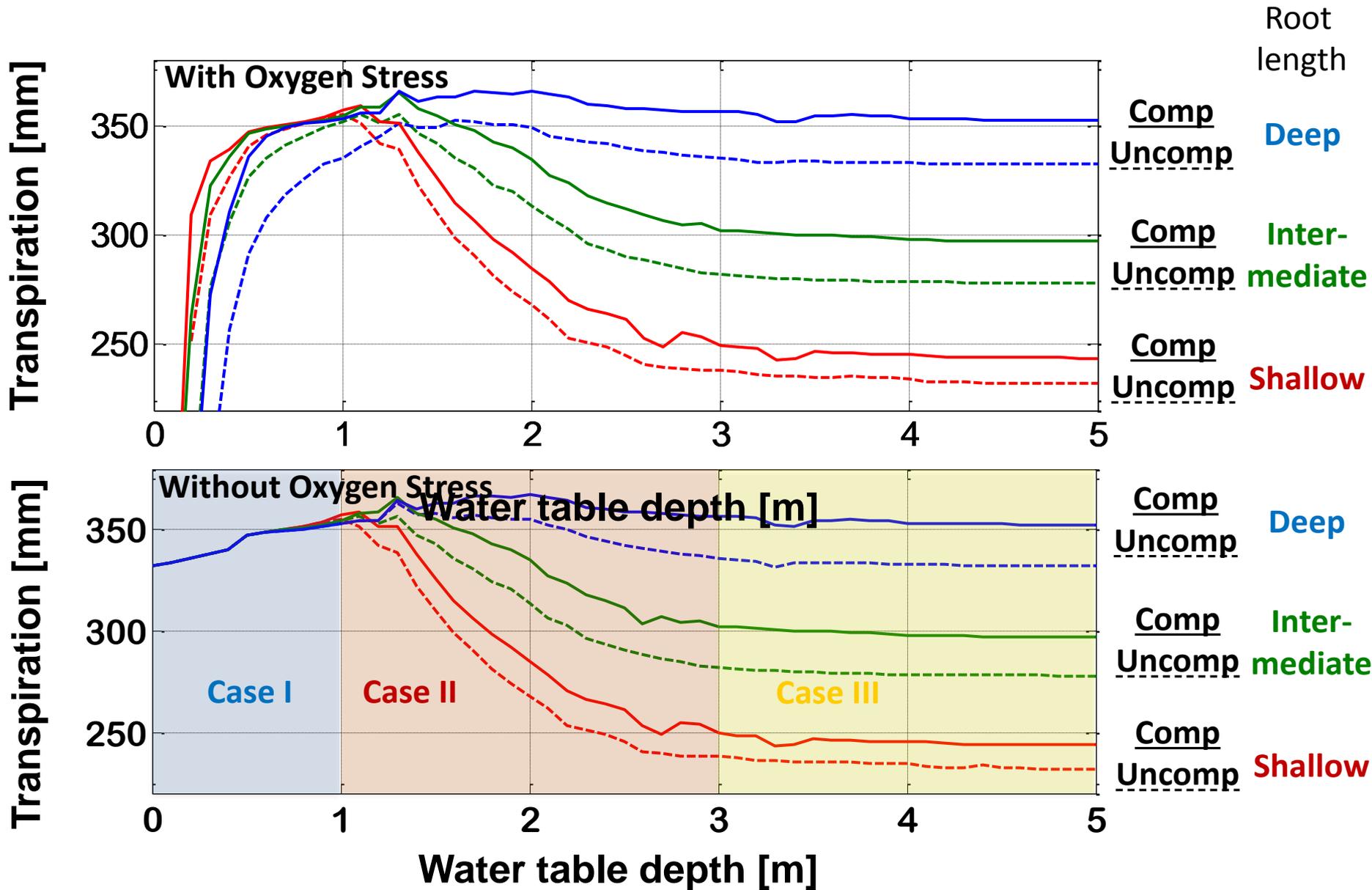


Photo courtesy of Arlington Agricultural Research Station

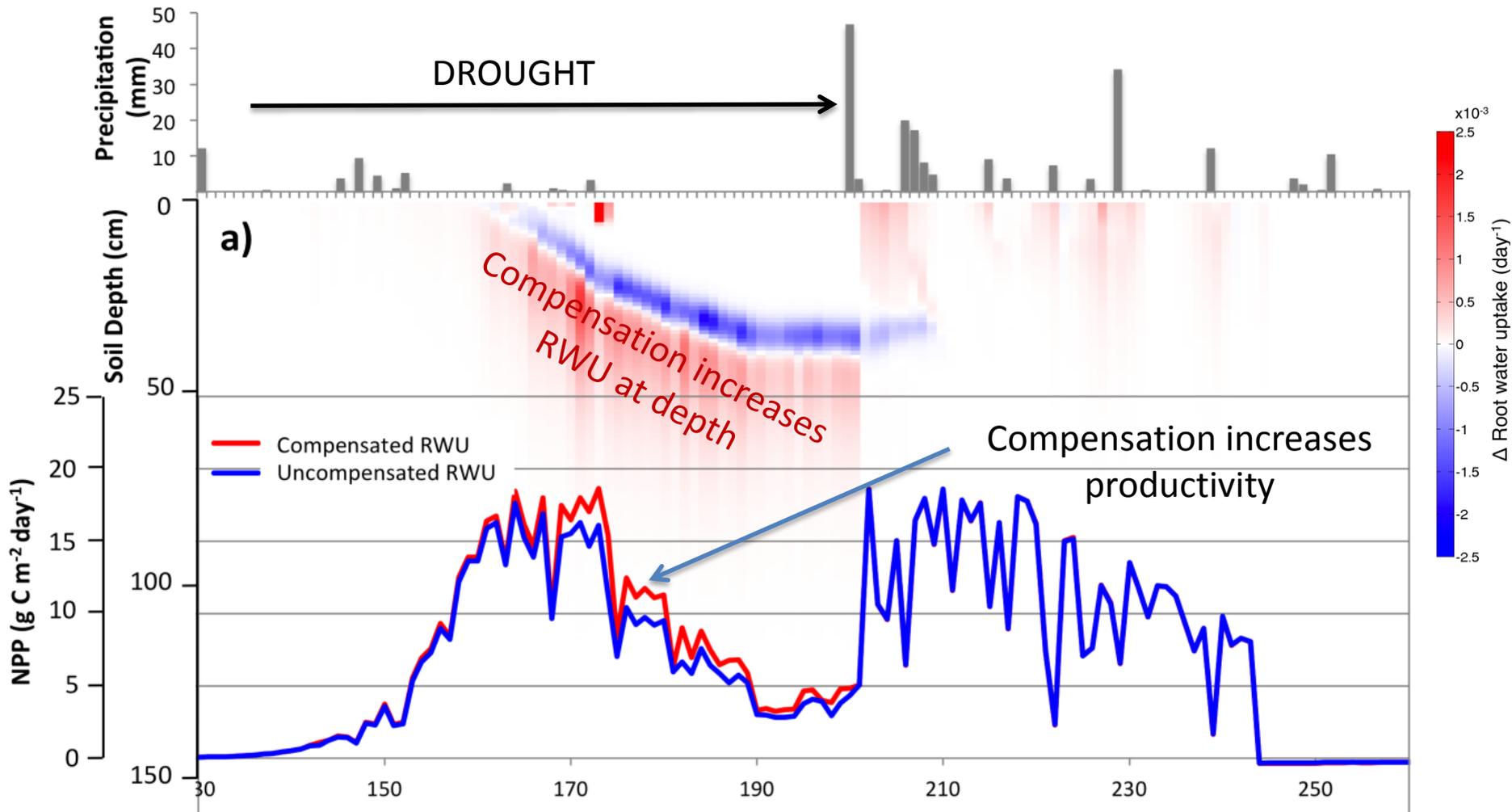


1. Corn with 3 root distribution for a continuum of water table depths
2. Hourly meteorological observations between 1986-2012 from the Arlington Agricultural Research Station
3. Compensated and uncompensated RWU approaches were applied separately
4. Separate simulations by applying and removing the effect of oxygen stress

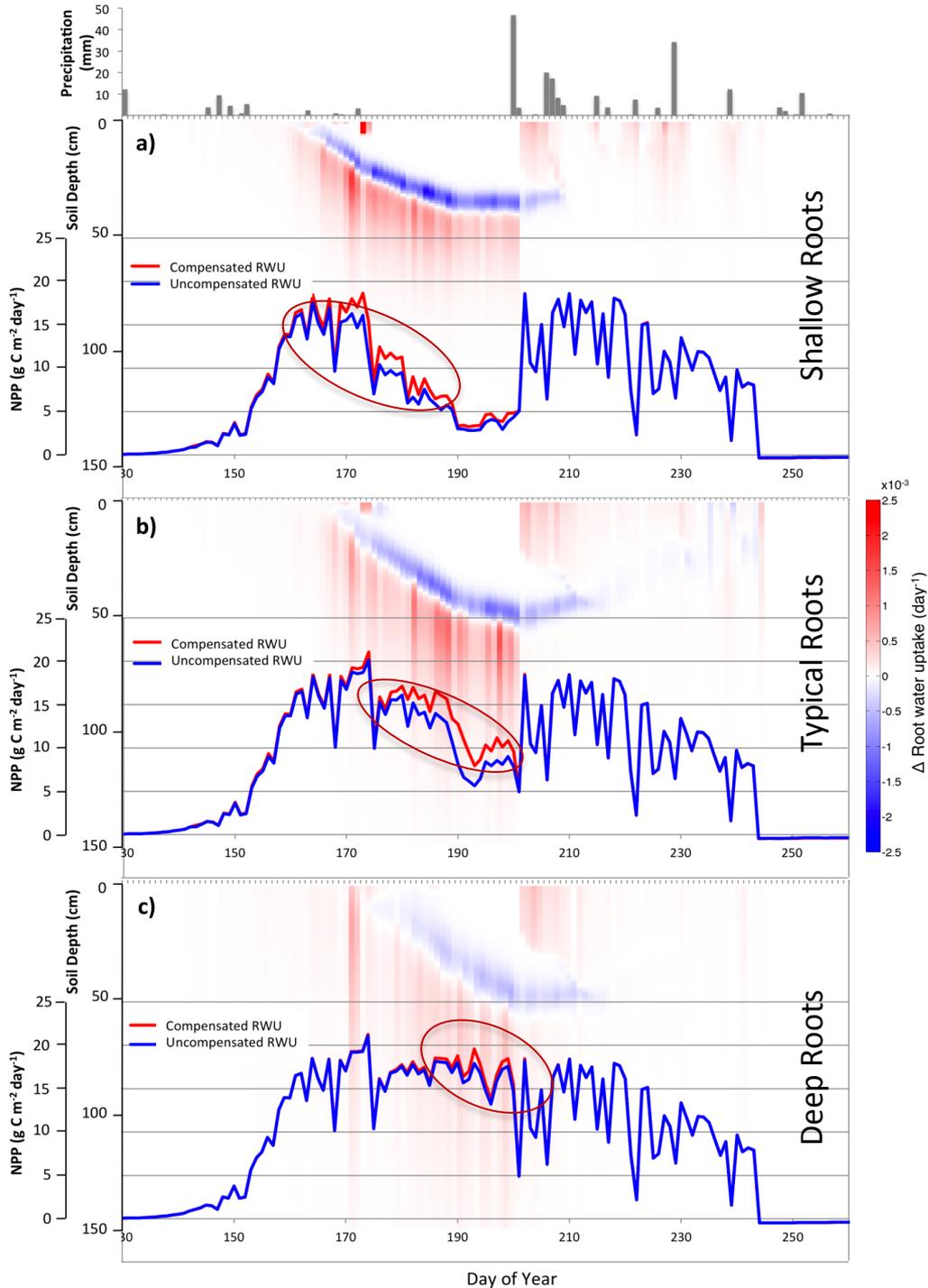
Water Table Depth and Plant Water Use



Daily net primary productivity time series for an extreme dry year (2012)

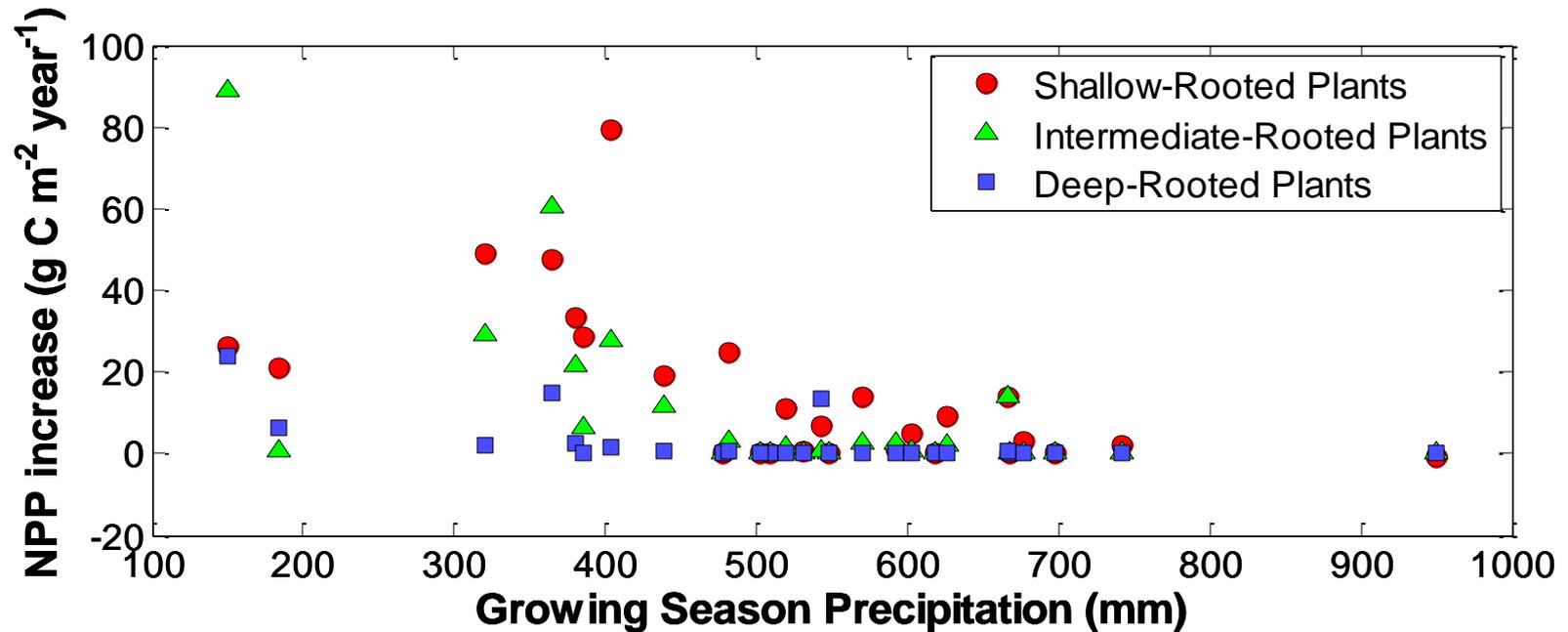


Daily net primary productivity time series for an extreme dry year

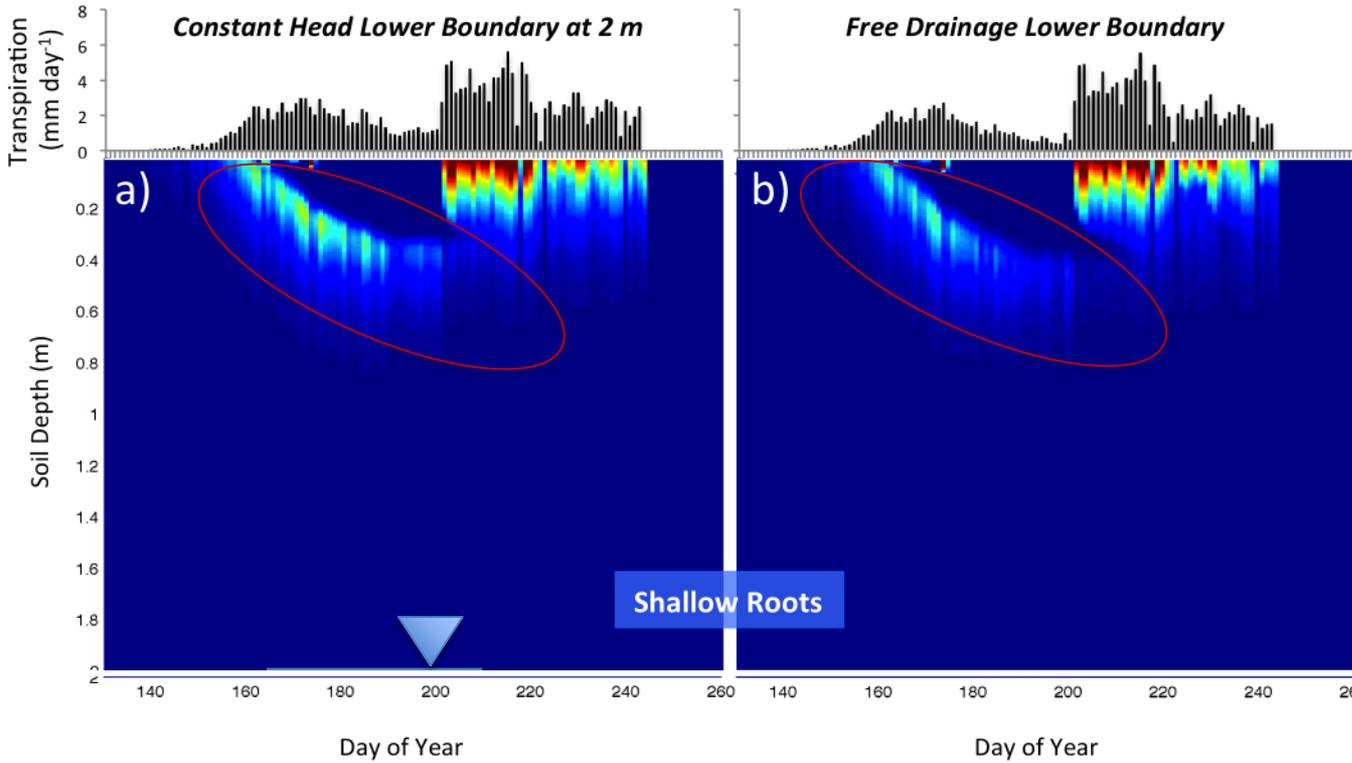


- DTWT is kept constant at 2m
- As the roots become deeper effects of compensation are delayed and reduced

NPP contribution from compensated RWU



$$\text{NPP}_{\text{compensatory RWU}} - \text{NPP}_{\text{uncompensatory RWU}}$$

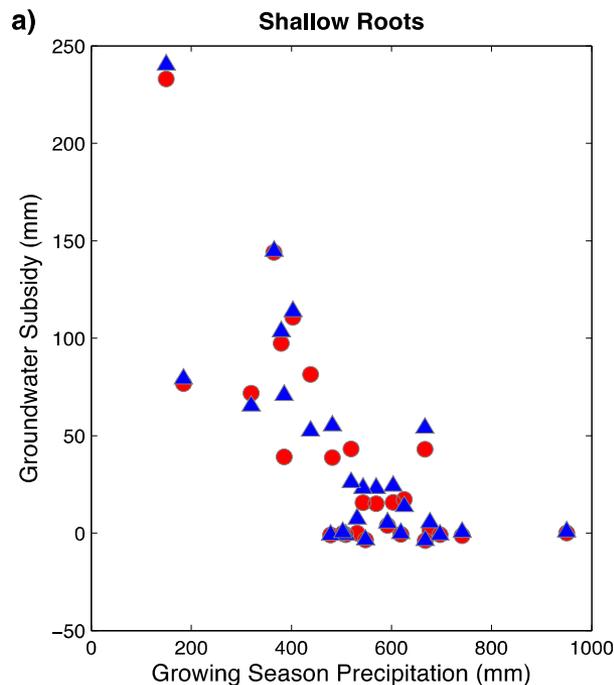


Spatial and Temporal Distributions of RWU

- Groundwater at 2m has subtle effects on root water uptake in the top 50 cm
- RWU is better distributed across the domain when roots are deep and is less sensitive to drought

Influence of Root Depth and Compensation on Groundwater Subsidy to Transpiration

Groundwater subsidy is additional water available for transpiration from shallow groundwater (Lowry and Loheide, 2010)



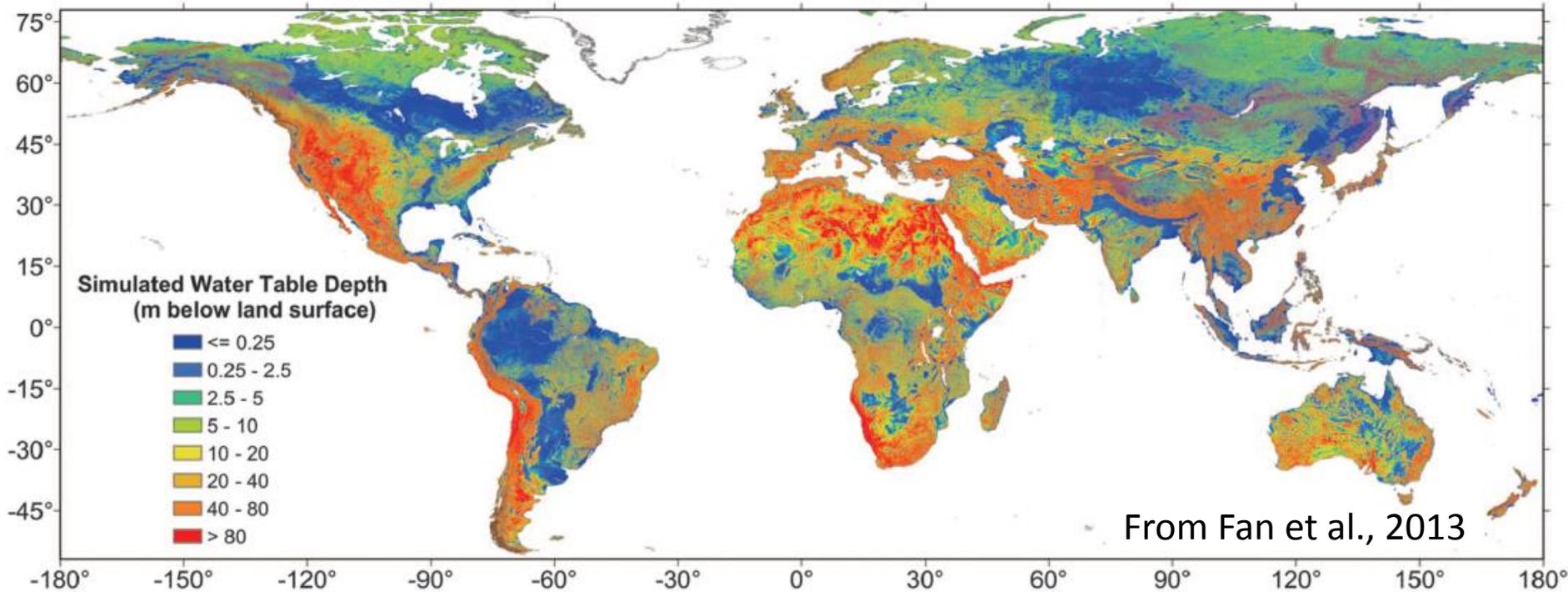
The groundwater subsidy decreases as roots become deeper because the deep rooted plants have access to more sufficient soil water even in the absence of shallow groundwater

Summary & Conclusions

- Strength of the relationship between groundwater depth and plant water usage in the critical water table depth range is controlled by plant root structure and RWU strategies.
- The negative impact of drought on plants lessens as RLD becomes deeper
- Shallow rooted plants are more vulnerable to dry periods and their benefit is greater when GW is shallow
- The mean additional net carbon amounts that are fixed due to the compensated RWU approach were 5.1%, 5.5%, and 1.2% for the plants with shallow, typical and deep RLD, respectively.

Implications:

- Shallow groundwater exists globally
- Shallow groundwater is neglected in GCMs used to predict climate change although it alters the land surface energy balance



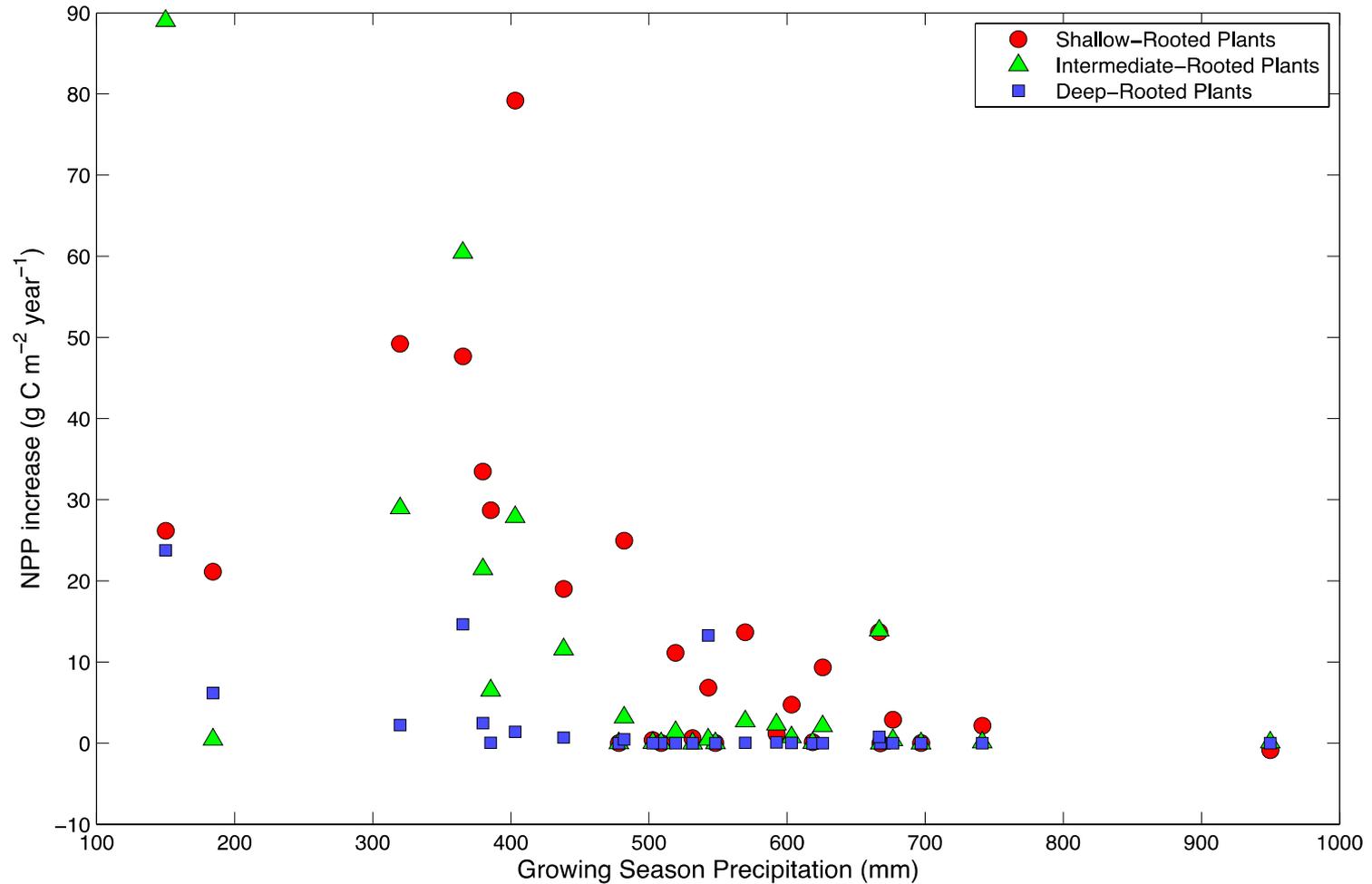
Acknowledgements

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Photo courtesy of Sam Zipper

NPP contribution for compensated RWU



$$\text{NPP}_{\text{compensatory RWU}} - \text{NPP}_{\text{uncompensatory RWU}}$$