Plant-soil-water interactions in the tropics: Using isotopes to explore environmental change implications for agriculture

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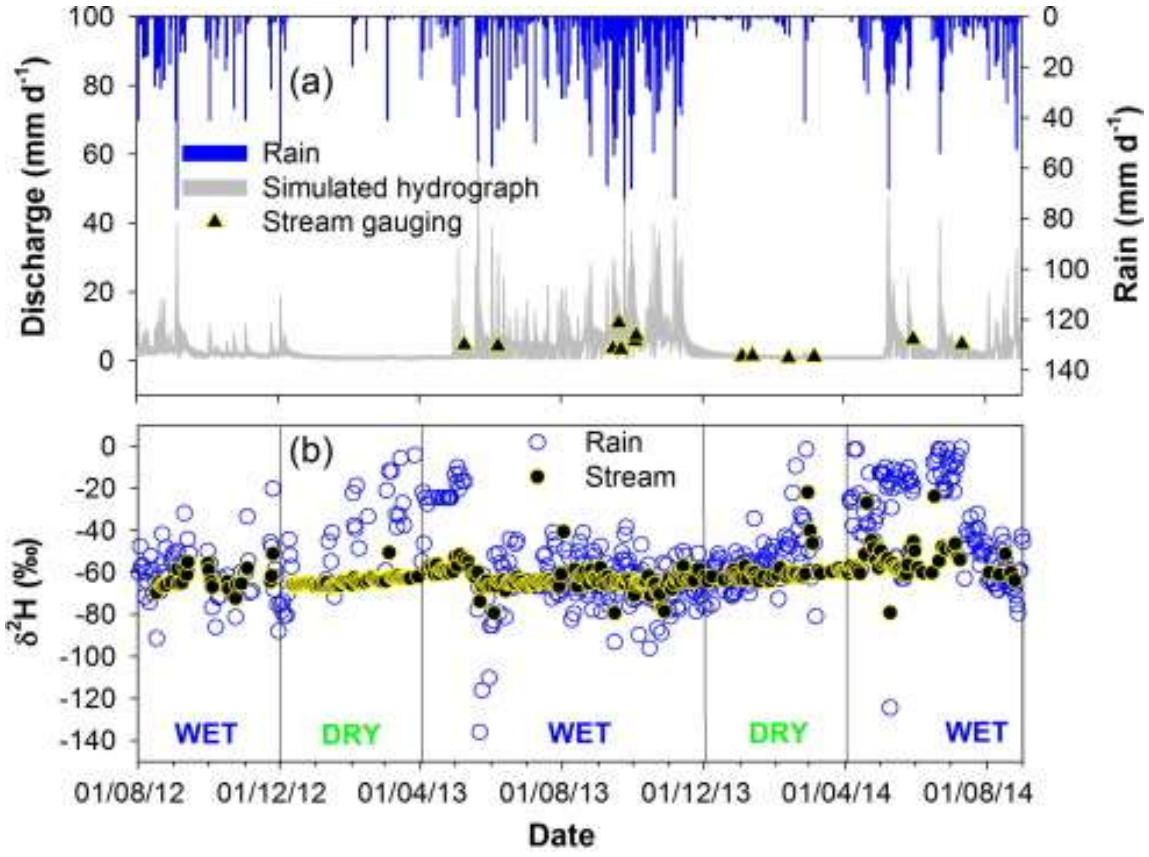
Hydrological response in tropics

- Typically characterized by distinct wet and dry seasons
- As a result, **there is much temporal variability in plant available water**
- Understanding plant water uptake under these conditions is crucial for developing effective and sustainable water use strategies, especially for agriculture



Birkel *et al.*, 2016

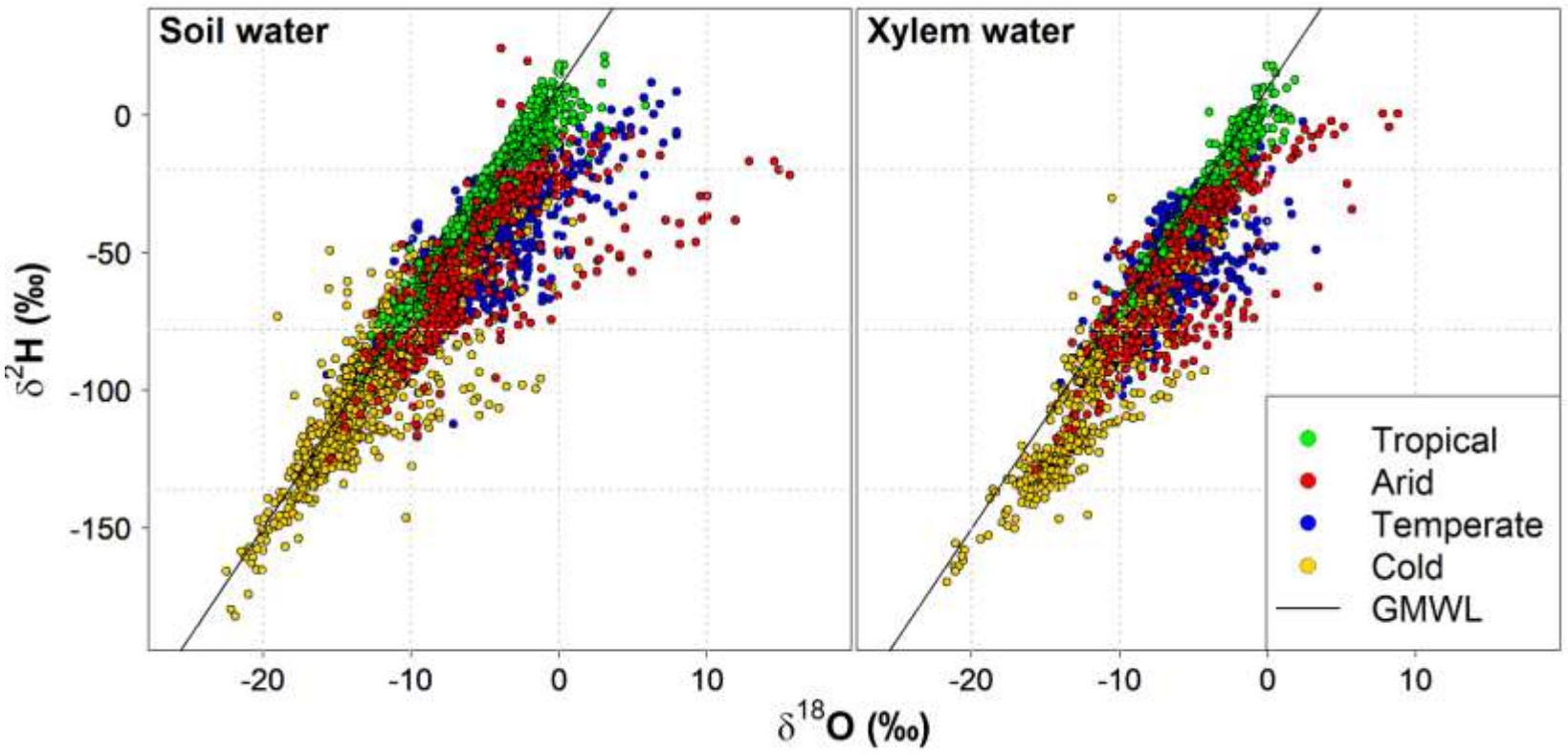
Objectives:

- Explore plant-soil-water interactions (plant water uptake patterns) in the tropics as opposed to other climates using soil and xylem water isotopes

- Propose wider use of stable water isotopes in tropics, especially in agricultural settings

- Discuss some future directions where stable water isotopes can help to explore environmental change implications for agriculture

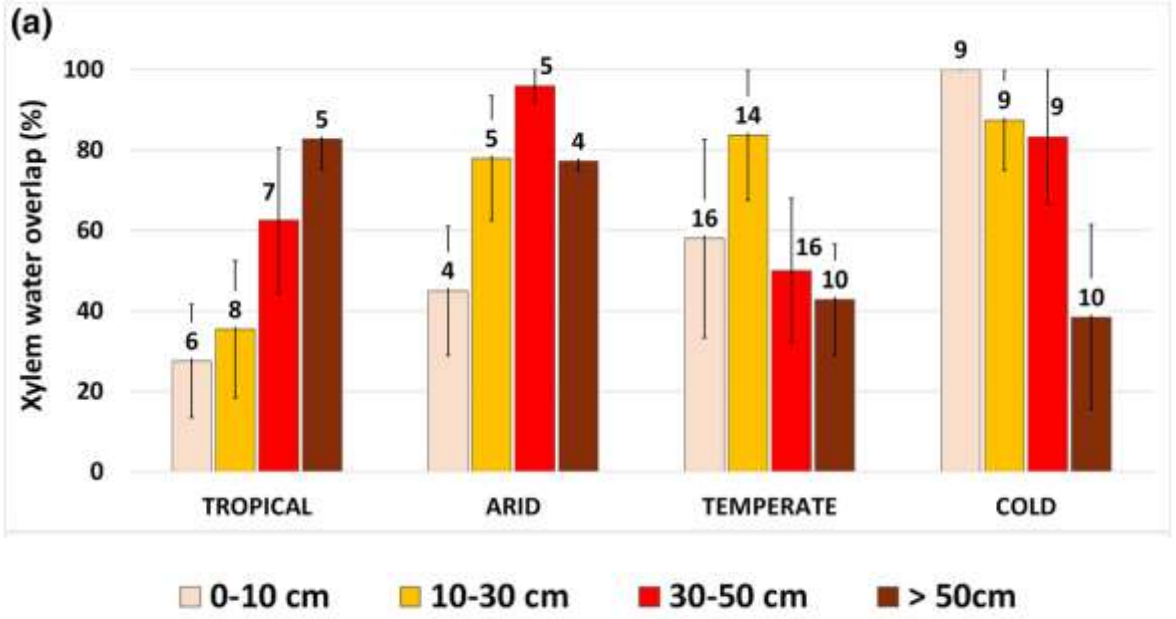
Compared to other climate zones, soil and xylem water isotopes in the tropics are:



Amin *et al.*, 2020

- **Most enriched** in heavy isotopes (as is precipitation)
- Show **least effects of evaporative fractionation** (d-excess close to 10, even in shallow soils), which may be linked to high humidity and typically dense vegetation cover

Compared to other climate zones, xylem and soil water isotopes in the tropics revealed that:



Median overlap (percentage) of xylem water with soil water at different depths (0–10, 10–30, 30–50, and >50 cm) in different climate zones. The number reported above each bar indicates the number of study sites. Error bars represent median absolute deviations. Based on meta-analyses (up until end of 2017) involving 8, 12, 31 and 15 papers in total for the four climate regions, respectively.

Amin *et al.*, 2020

- There is least overlap of xylem water with shallow (0-10 cm) soil water
- **Plants appear to exploit more water from deep (especially >50 cm) soil layers**, probably facilitated by relatively deep root systems, for water uptake in dry periods

Future Work / Discussion Points:

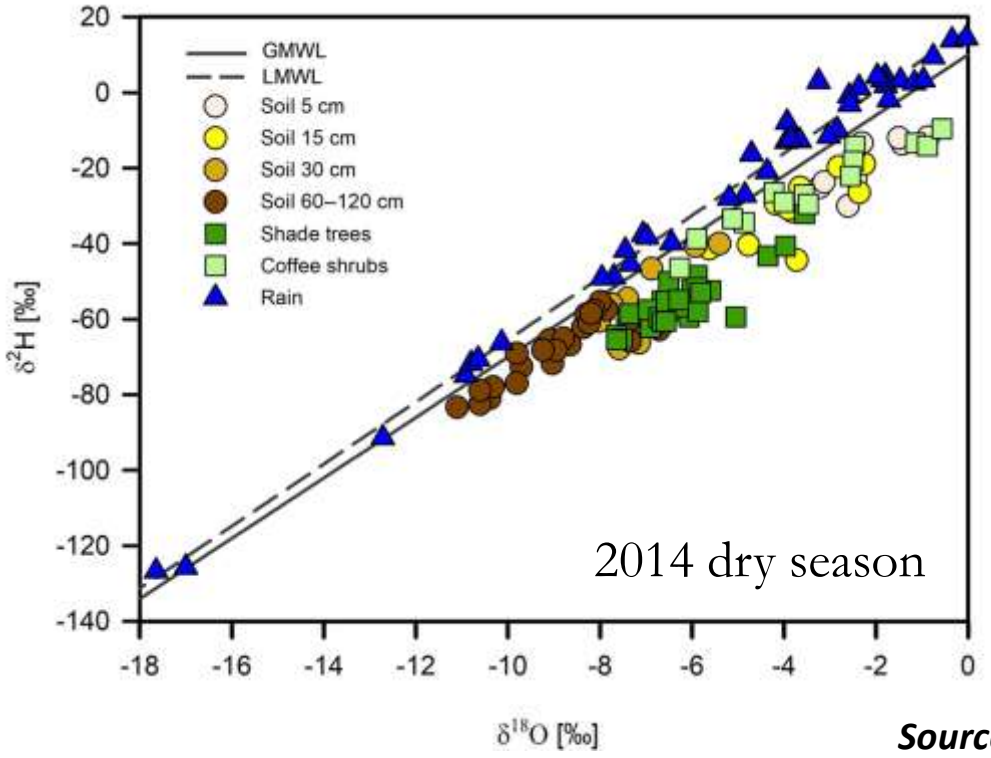
- Consider temporal variability (likely high in tropics because seasonal variability)
- Limited number of studies in the tropics & mainly in natural (forest) environments

In agricultural areas, water isotopes can help to evaluate management strategies in:

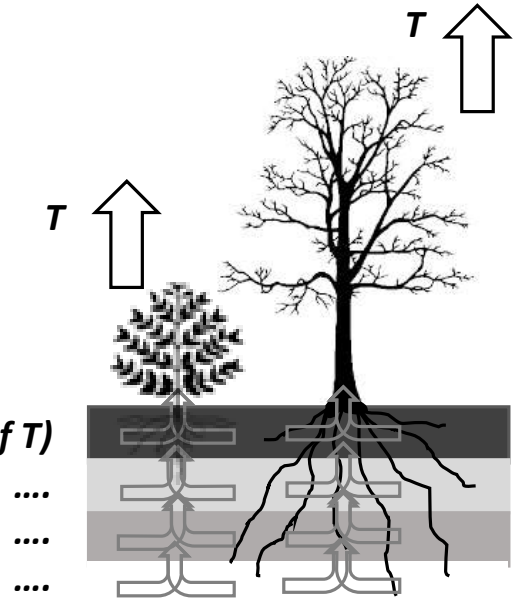
- Choice in species for co-cropping (e.g. Mexico)
- Need for and timing of irrigation (e.g. China)
- Better understand water quality dynamics (e.g. Botswana)

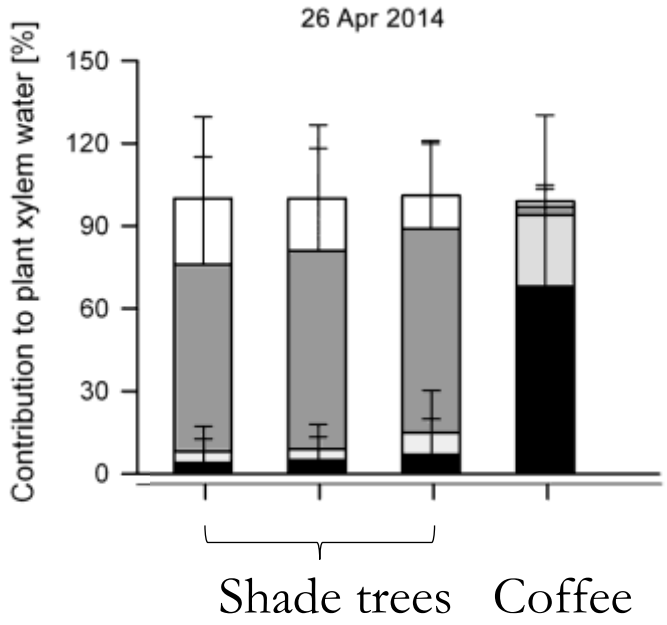
See also Penna *et al.*, 2020

Coffee and shade trees showed complementary use of soil water



- i.e. their **water uptake is predominantly from different depths** in a traditional agroforestry tropical ecosystem

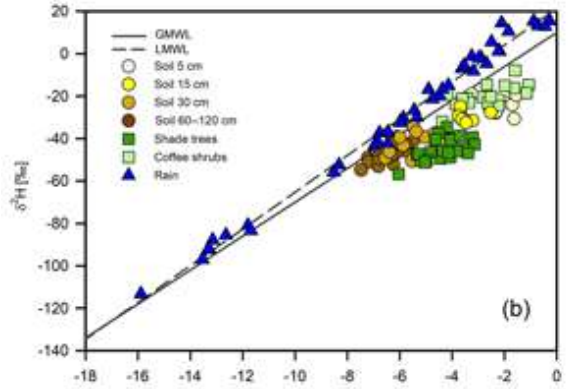


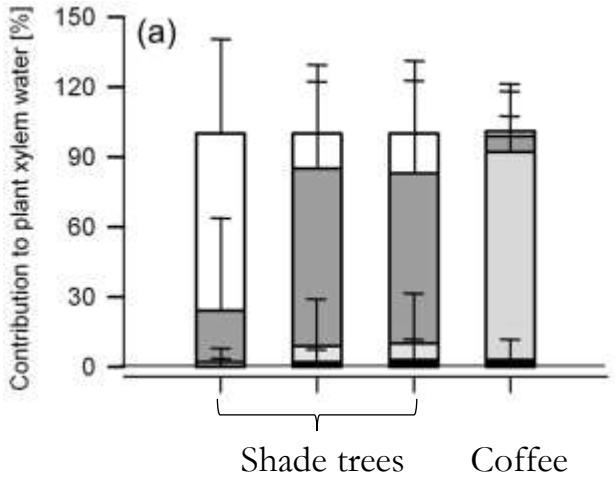


Muñoz-Villers *et al.*, 2020

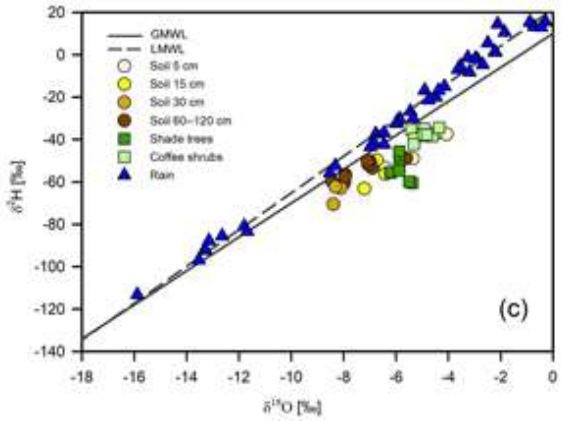
Complementarity in water uptake prevailed throughout dry and wet seasons

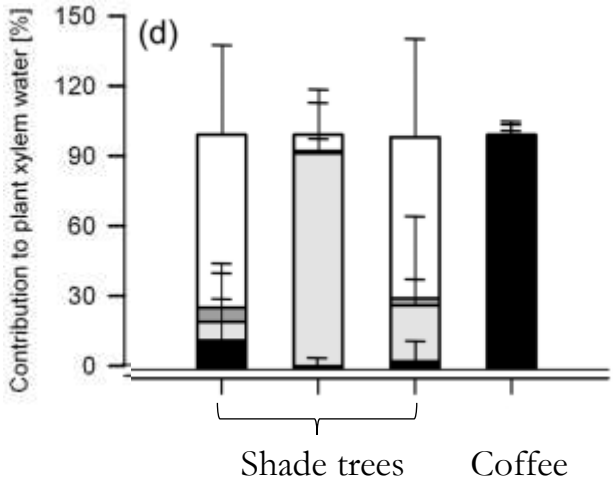
2017 Dry Season:





2017 Wet Season:





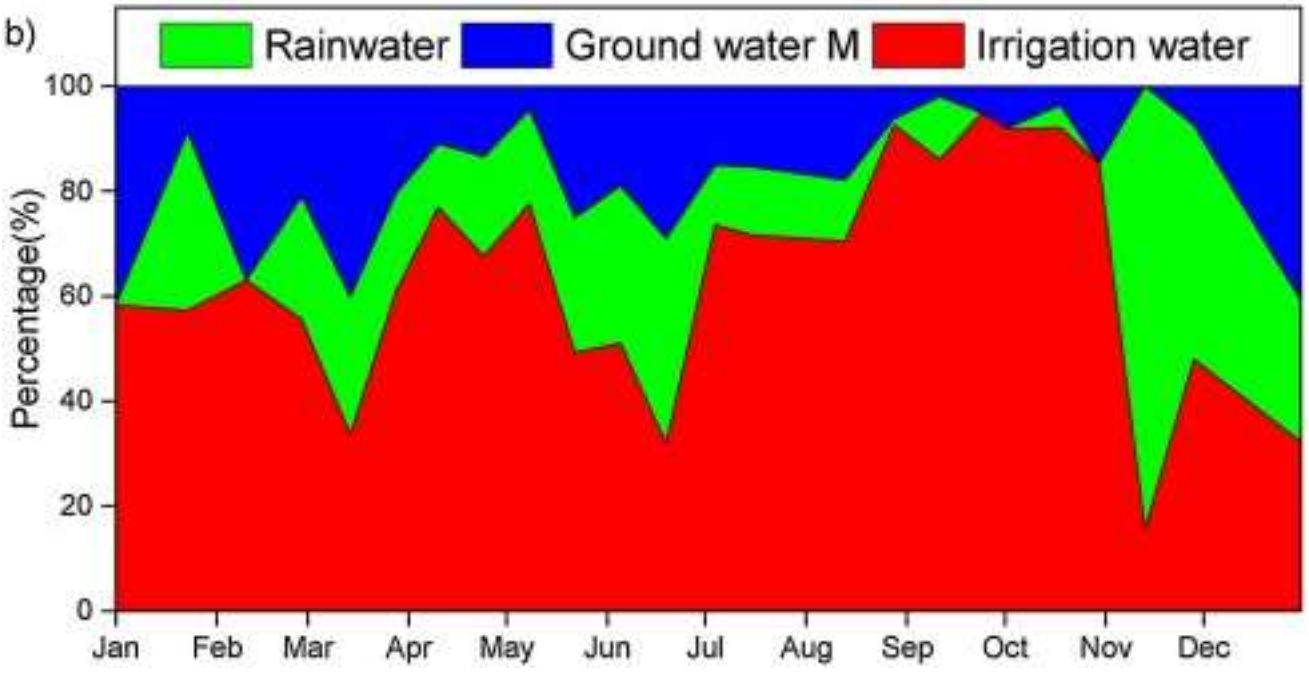
Muñoz-Villers *et al.*, 2020

- However, somewhat smaller segregation in source water, i.e. **relatively more competition, during dry periods**

Future Work / Discussion Points:

- Would competition increase if different coffee varieties (e.g. with deeper root systems) were used?
- Would competition increase with climate change?
- Wider role of shade trees in total water use?

Timing and amount of irrigation:



Contribution of three endmembers to streamflow using five-tracer (including stable water isotopes) EMMA (%)

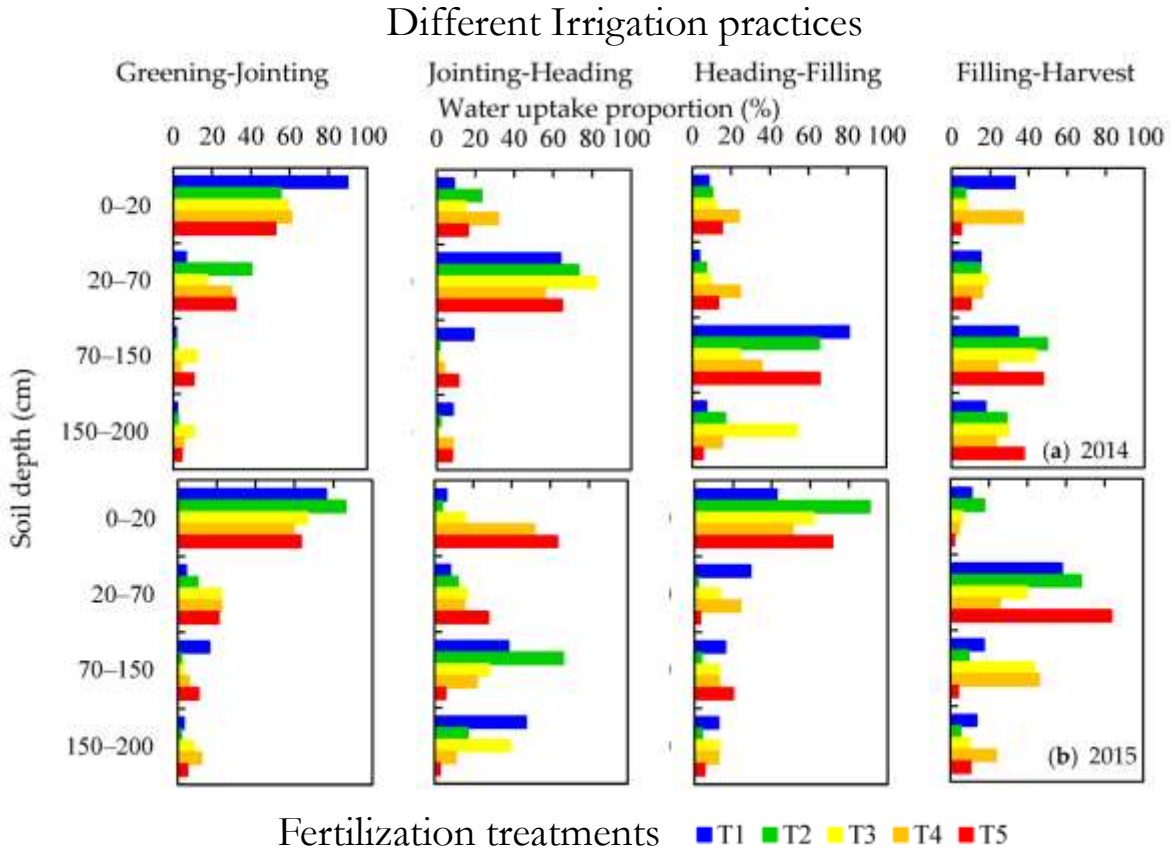
Lv *et al.*, 2018

- At agricultural sites in China, isotopes revealed large **temporal variability in losses of irrigation water** to streamflow

Future Work / Discussion Point:

- Understanding the sources of plant water uptake (including proportion of irrigation water) can help to design efficient irrigation management

Example of water uptake under different irrigation and fertilization practices



Ma and Song, 2018

Using stable water isotopes and mixing models, this example from a sub-humid climate shows **contrasting wheat water uptake patterns, depending on irrigation and fertilization strategy**

Future Work/Discussion Points:

- Combined with nutrient uptake experiments, insights could help improve resource use efficiency
- Irrigation and extreme rainfall accelerates recharge and pollution leaching (Geris *et al.*)

Some key points:

- Root water uptake patterns in tropical environments might be characterized based on the strong seasonality in precipitation
- However, with more pronounced seasonality, adaptation strategies for agriculture are likely required
- More isotope studies on water uptake in the tropics would be desirable, especially for agricultural sites in general, these can be useful for a wide range of management applications

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UCR Universidad de Costa Rica

BIUST Botswana International University of Science & Technology

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