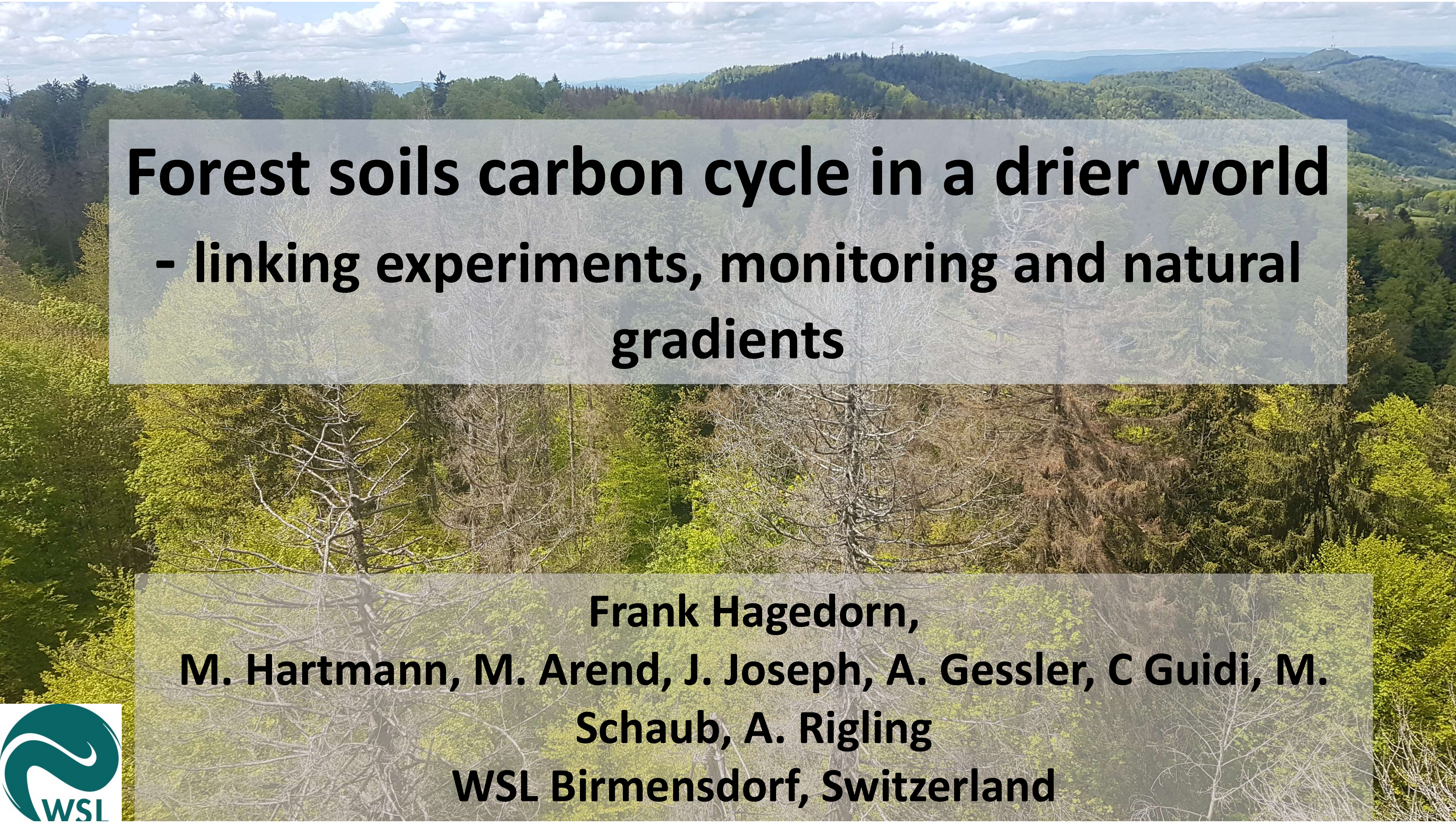

Forest soils carbon cycle in a drier world - linking experiments, monitoring and natural gradients

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nature geoscience

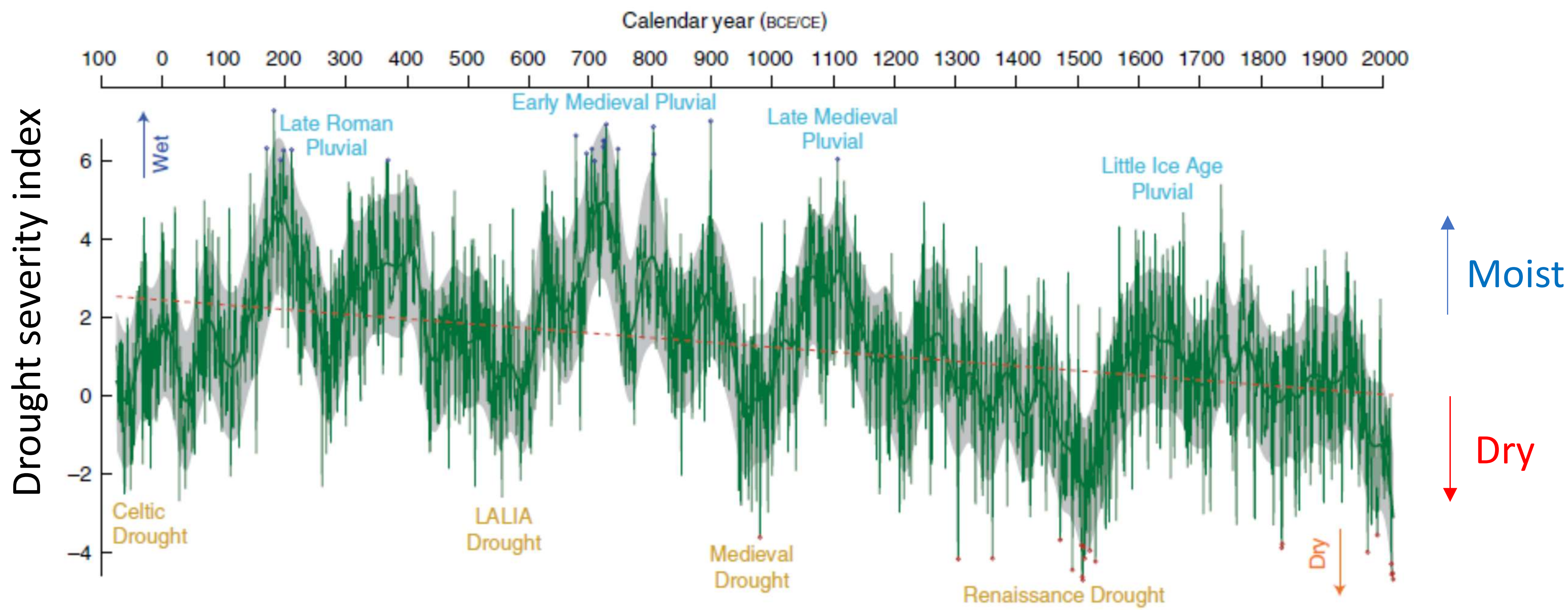
ARTICLES

https://doi.org/10.1038/s41561-021-00698-0

Check for updates

Recent European drought extremes beyond Common Era background variability

Ulf Büntgen[1,2,3,4], Otmar Urban[2], Paul J. Krusic[1,5], Michal Rybníček[2,6], Tomáš Kolář[2,6],

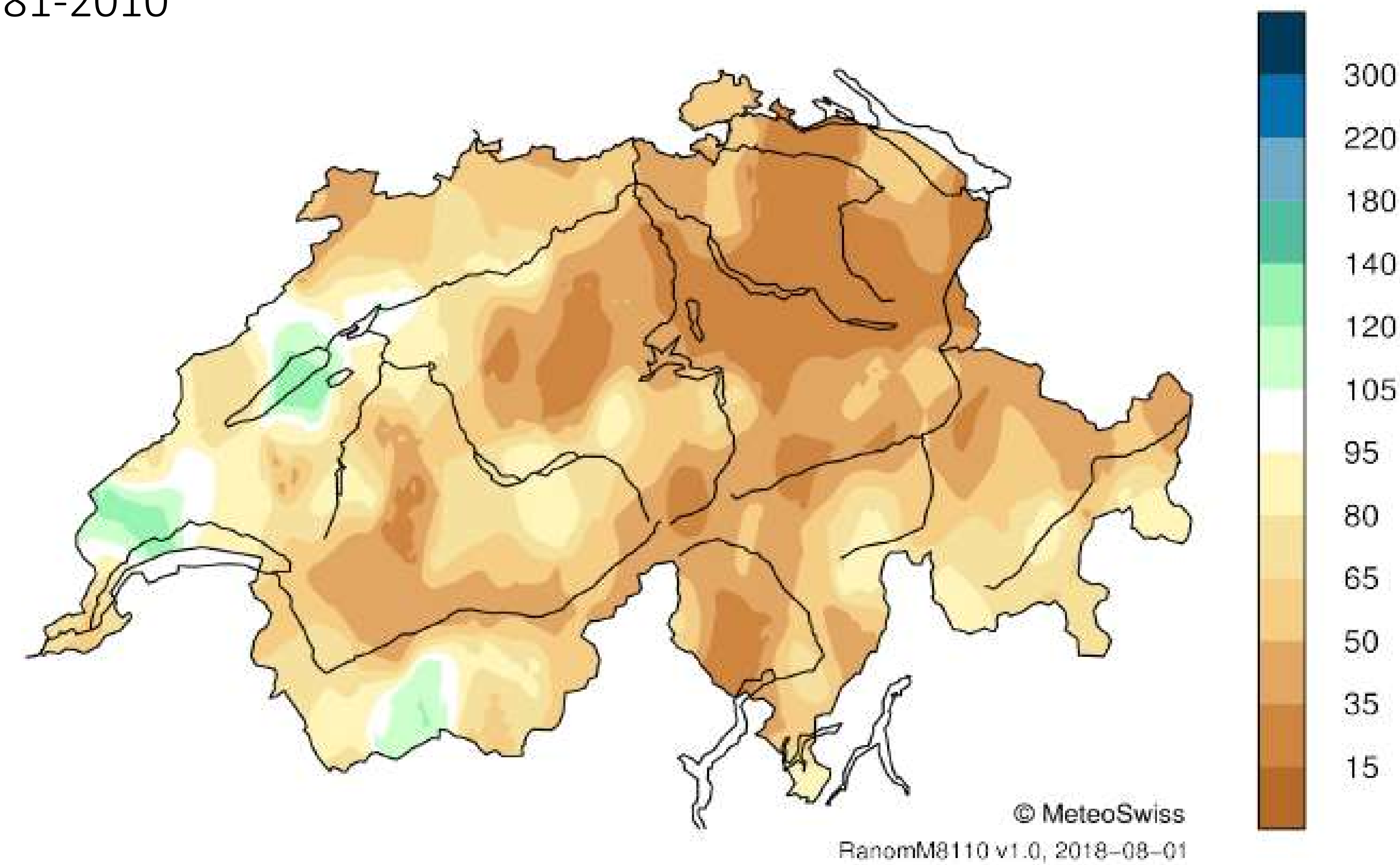


-------------------- 2000 years -----------------------

Büntgen et al., 2021 Nature Geosciences

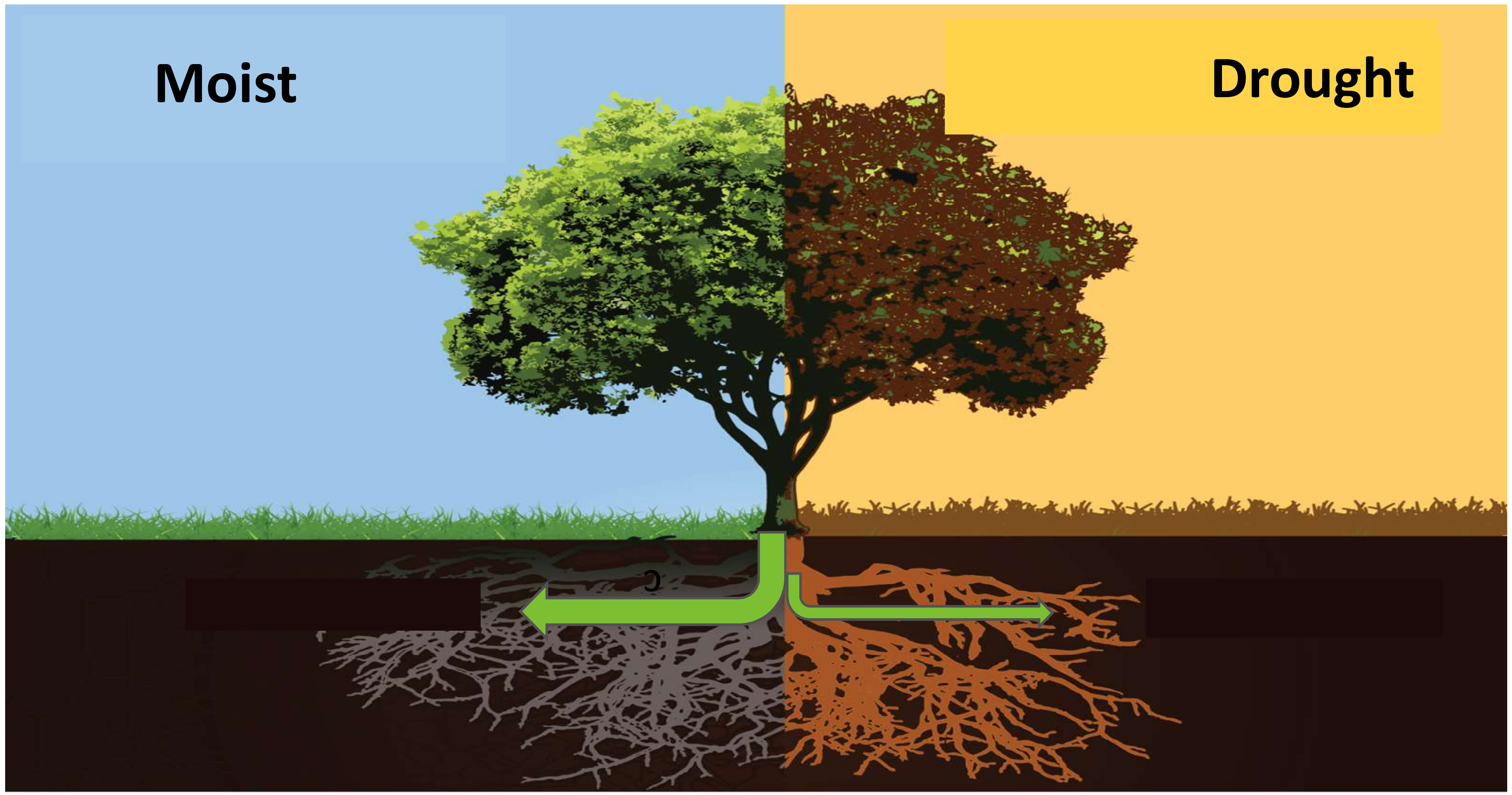
Record breaking summer 2018

Monthly Precipitation Anomaly (%) in July as compared to 1981-2010

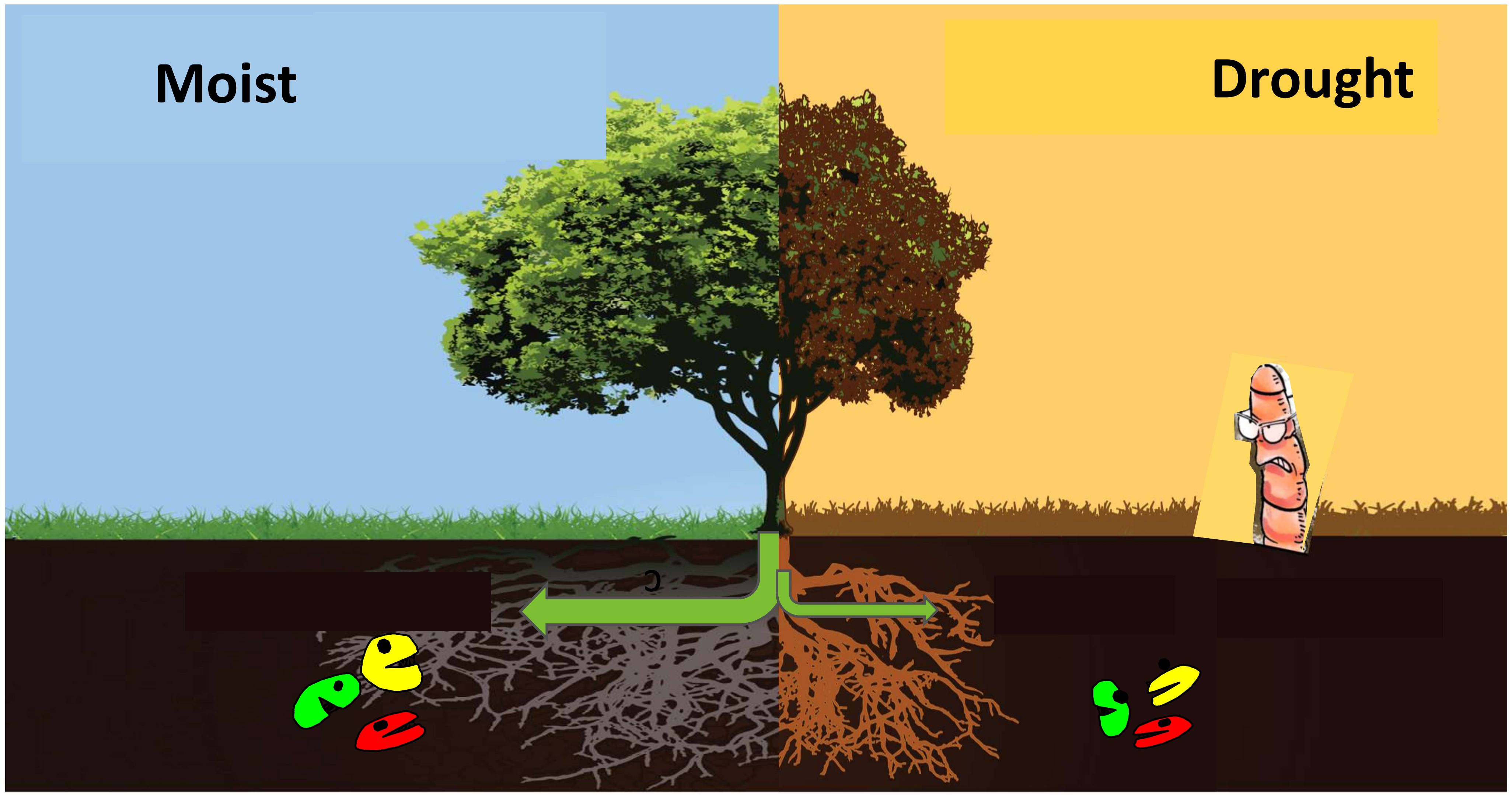


www.meteoSwiss

Drought effects on forest (soil) carbon cycle

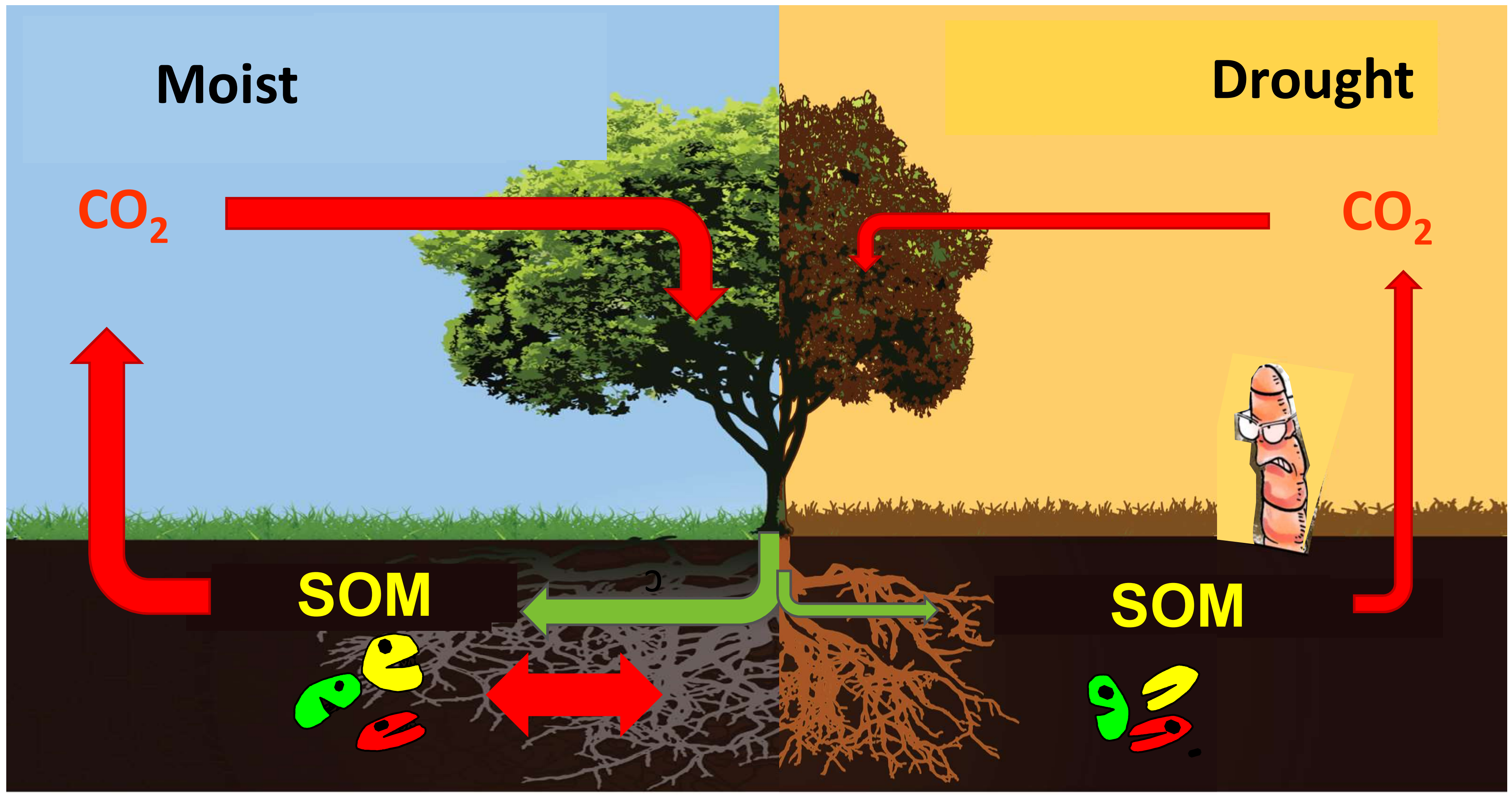


Drought effects on forest (soil) carbon cycle



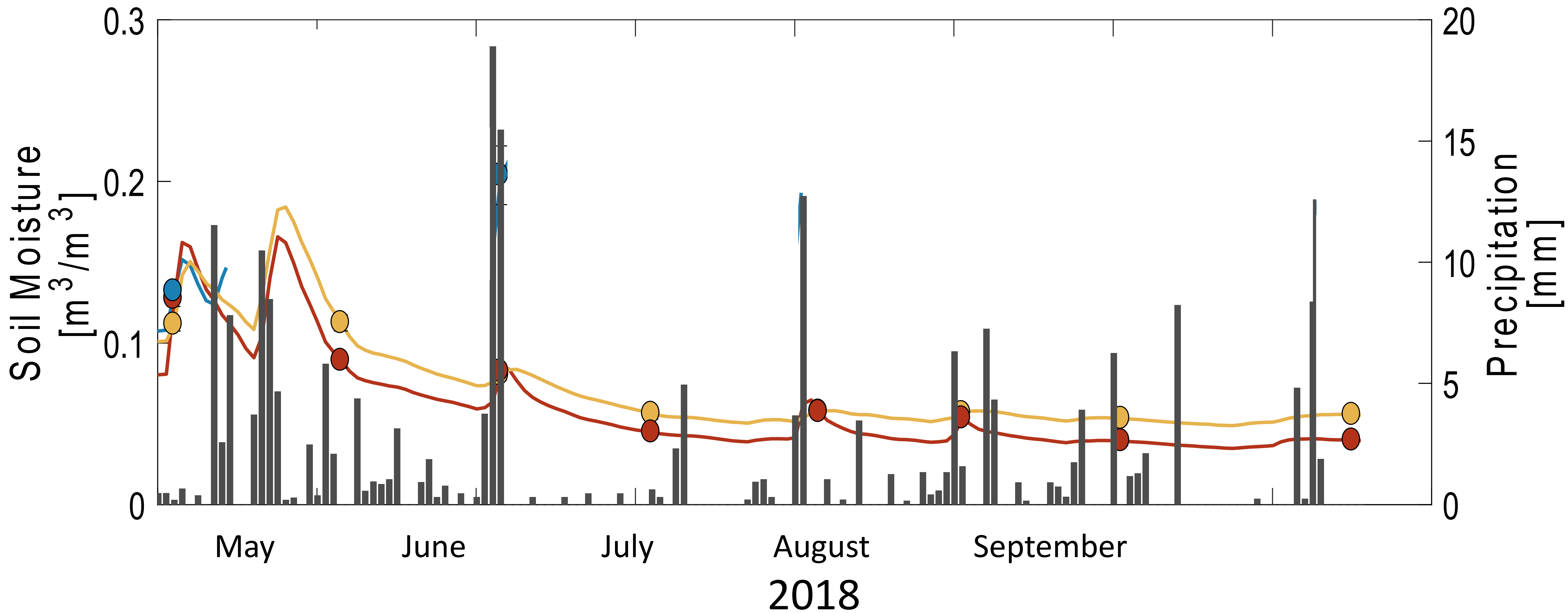
→ Above and belowground activity are reduced

Drought effects on forest (soil) carbon cycle



→ Above and belowground activity are reduced by drought
→ Above and belowground is closely coupled
→ Drought effects will feed back between above and belowground

Drought ≠ Drought



→ Duration & intensity of drought crucial for above- and belowground C cycle

Outline: Forest soil carbon cycling under drought

1. **How does drought and rewetting impact above- and belowground C cycle?**

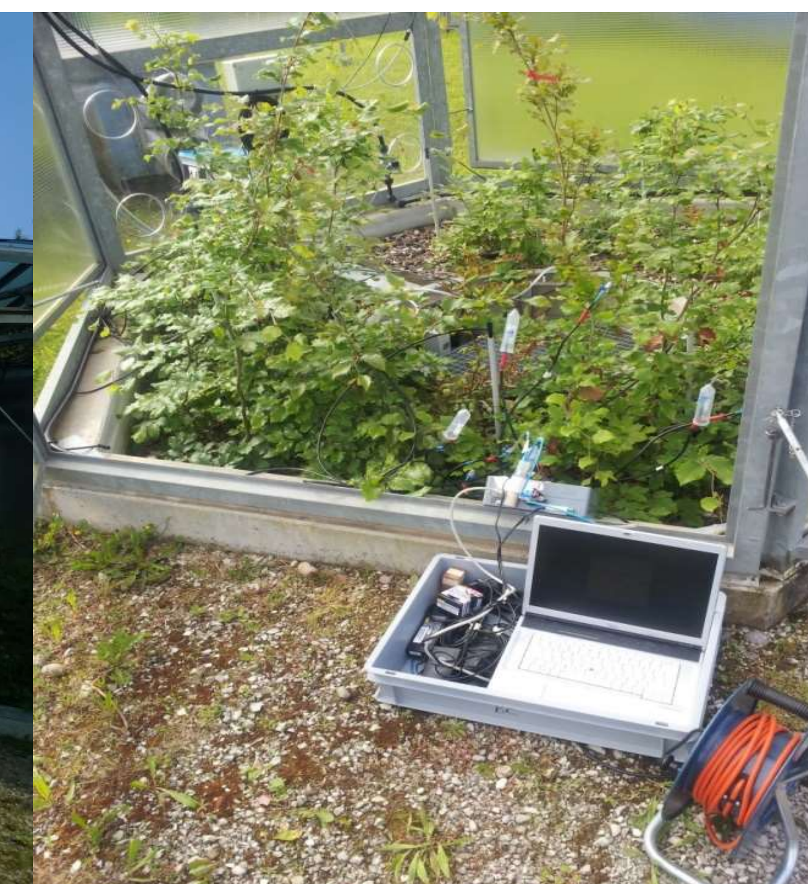
2. **What are the short and longer term effects of drought in the belowground?**

Drought (recovery) experiment

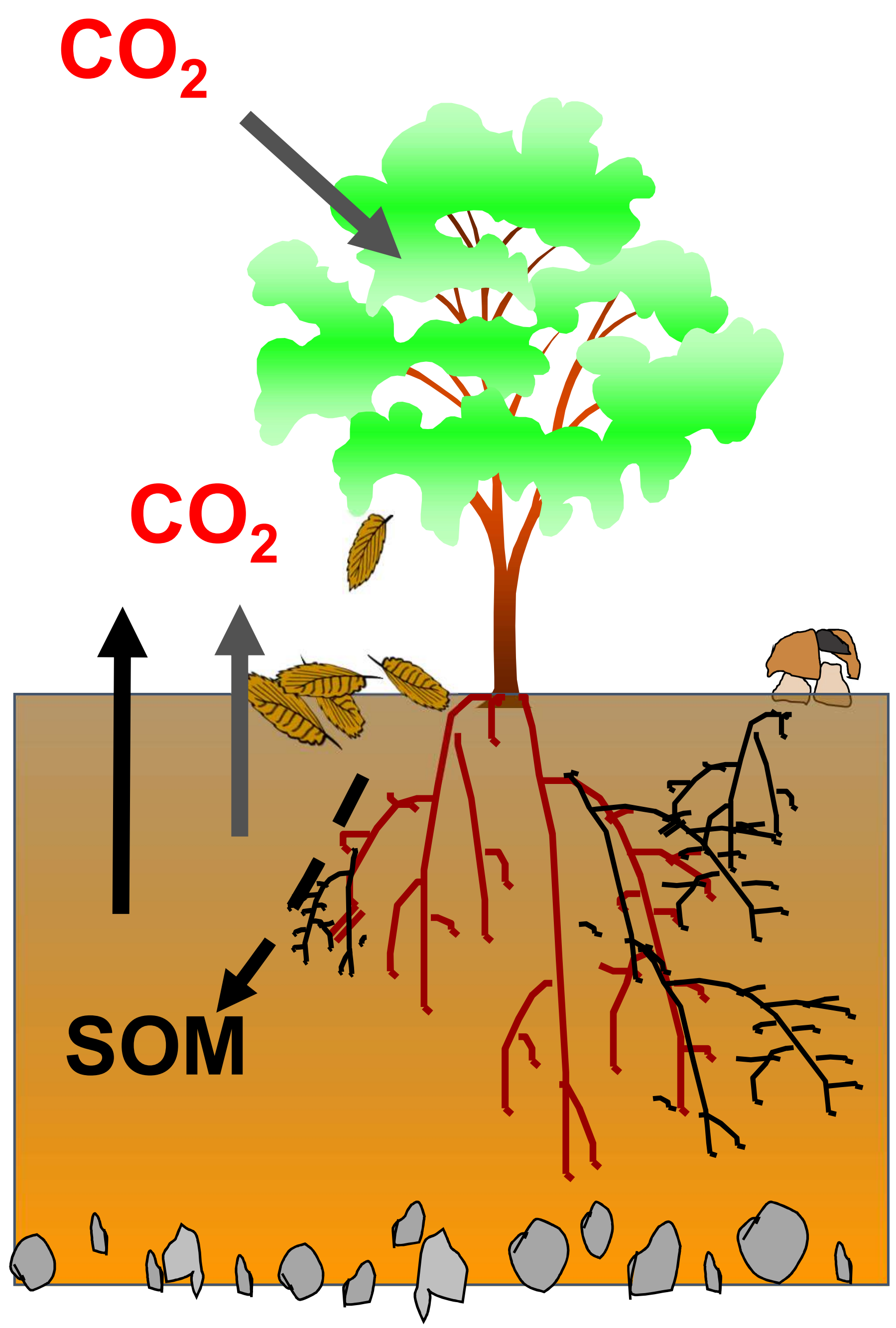
16 open-top chambers,
each with 2 lysimeters

4 year old beech trees

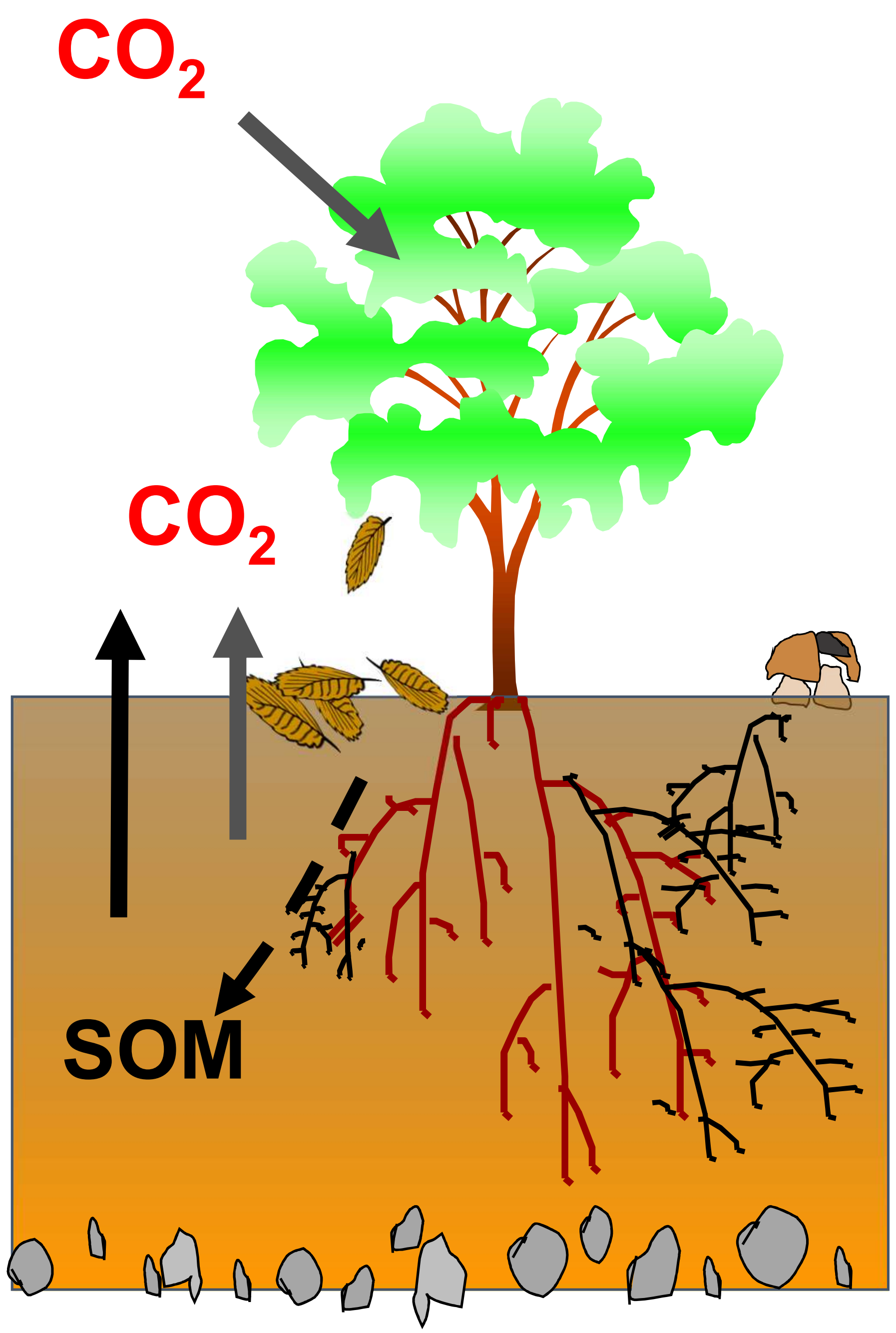
→ 2 months drought exposure then rewatering

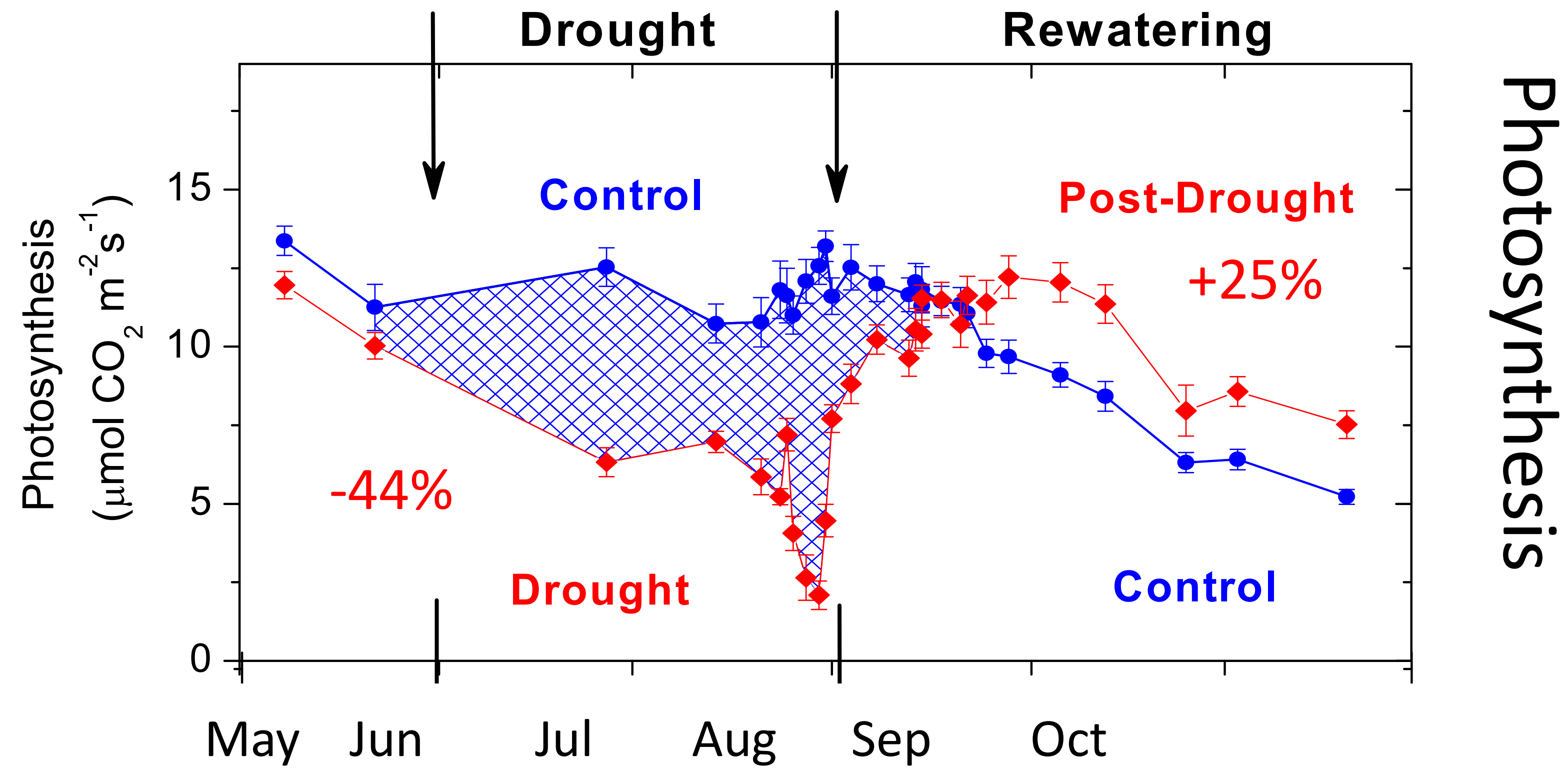


Drought (recovery) experiment: C fluxes



Drought (recovery) experiment: C fluxes



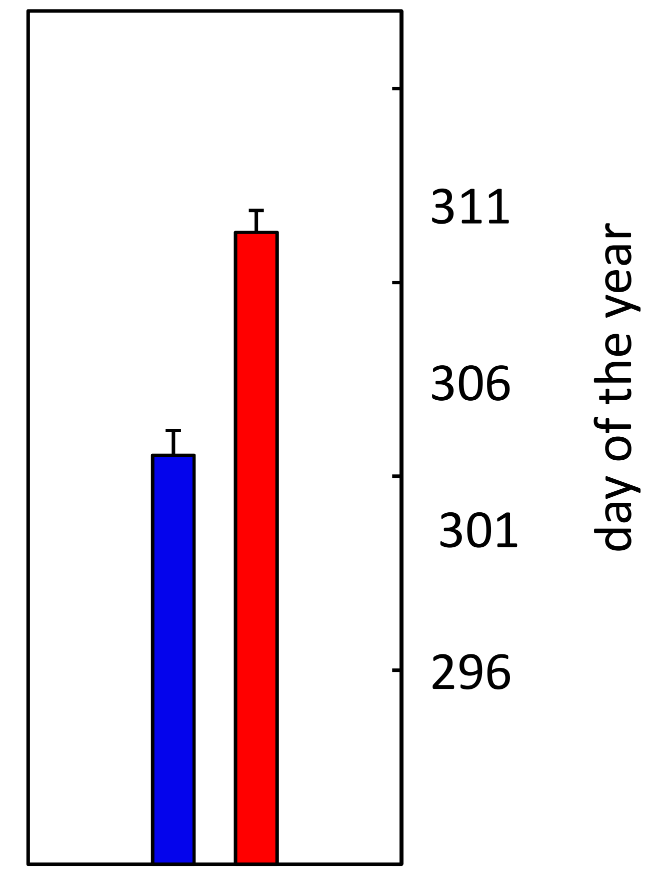


Hagedorn et al. (2016): *Nature Plants*

Drought (recovery) experiment: C fluxes

Control

Post-drought



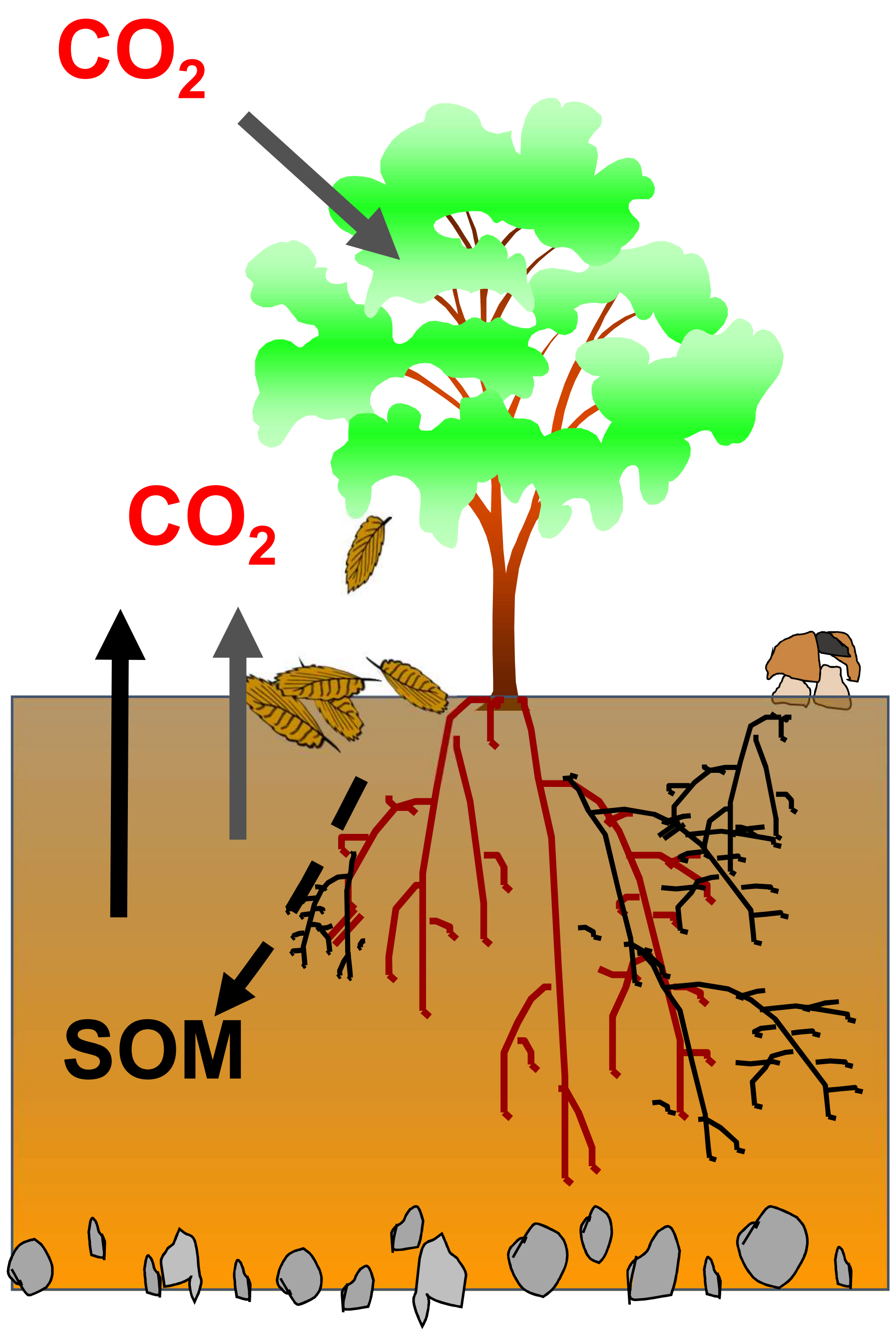
50% chlorophyll loss

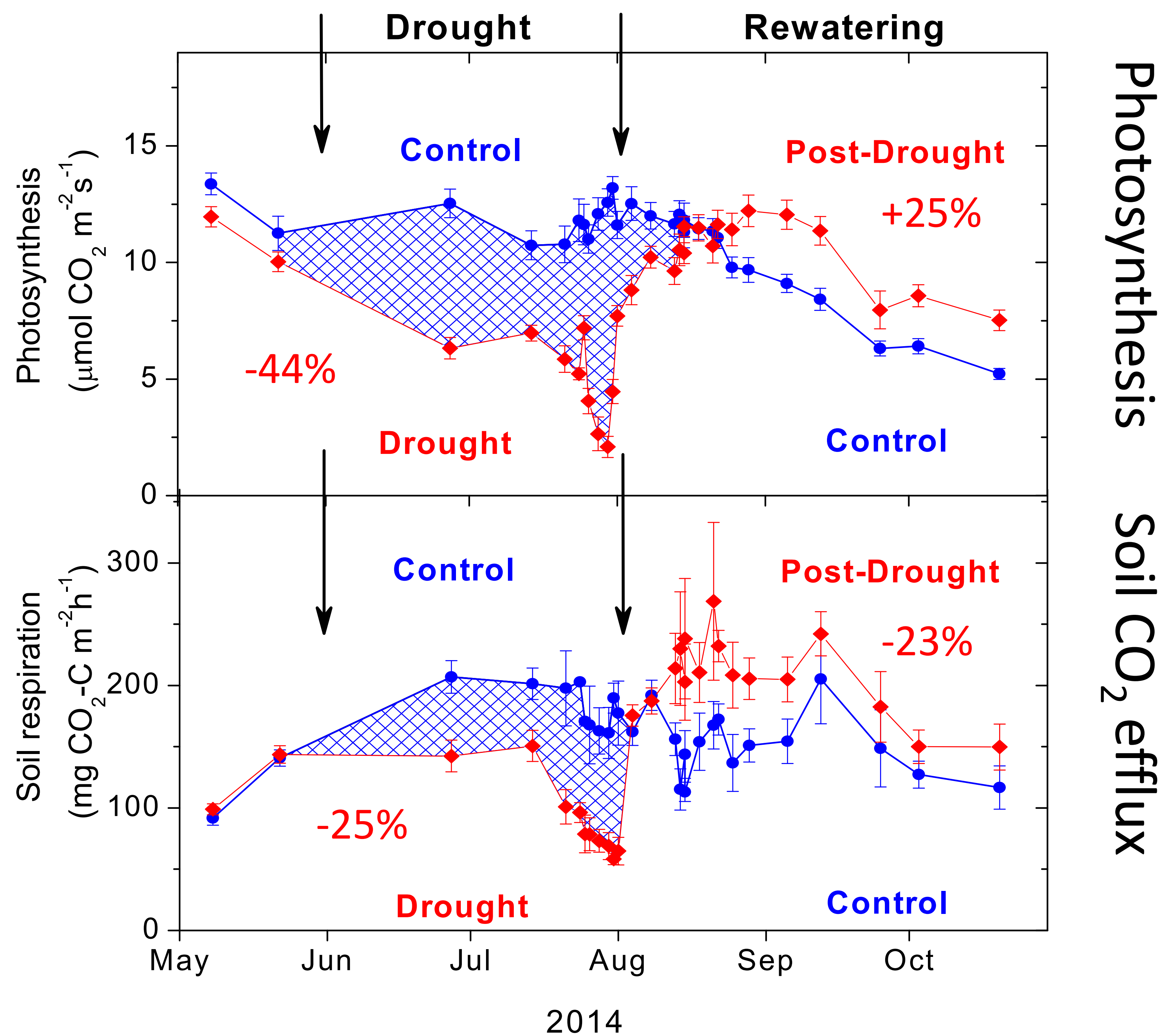
control
post-drought

Delay of autumnal leaf senescence after a severe summer drought

Arend et al. 2016. Agricultural and Forest Meteorology

Drought (recovery) experiment: C fluxes



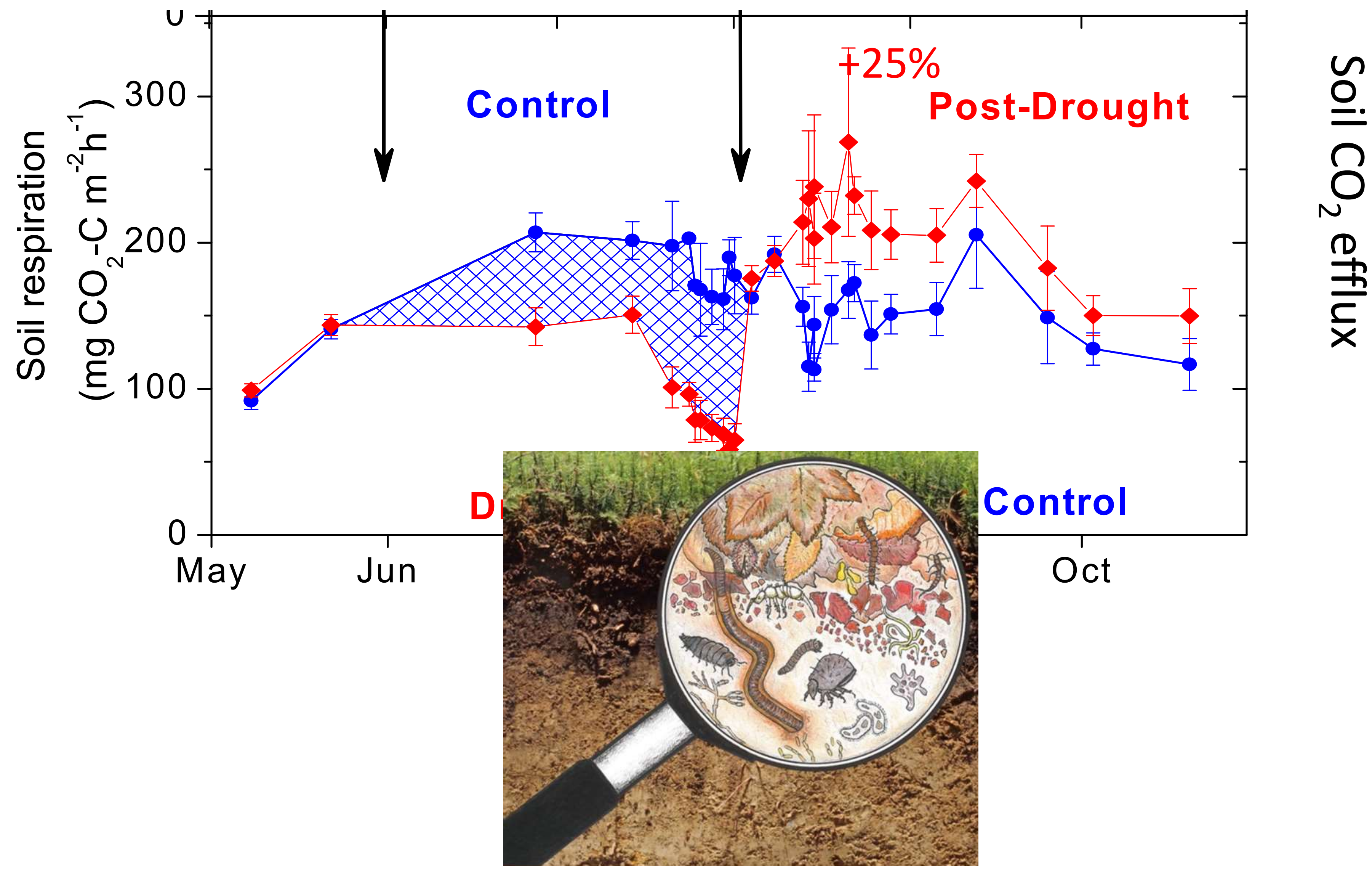


Hagedorn et al. (2016): *Nature Plants*

Drought (recovery) experiment: C fluxes

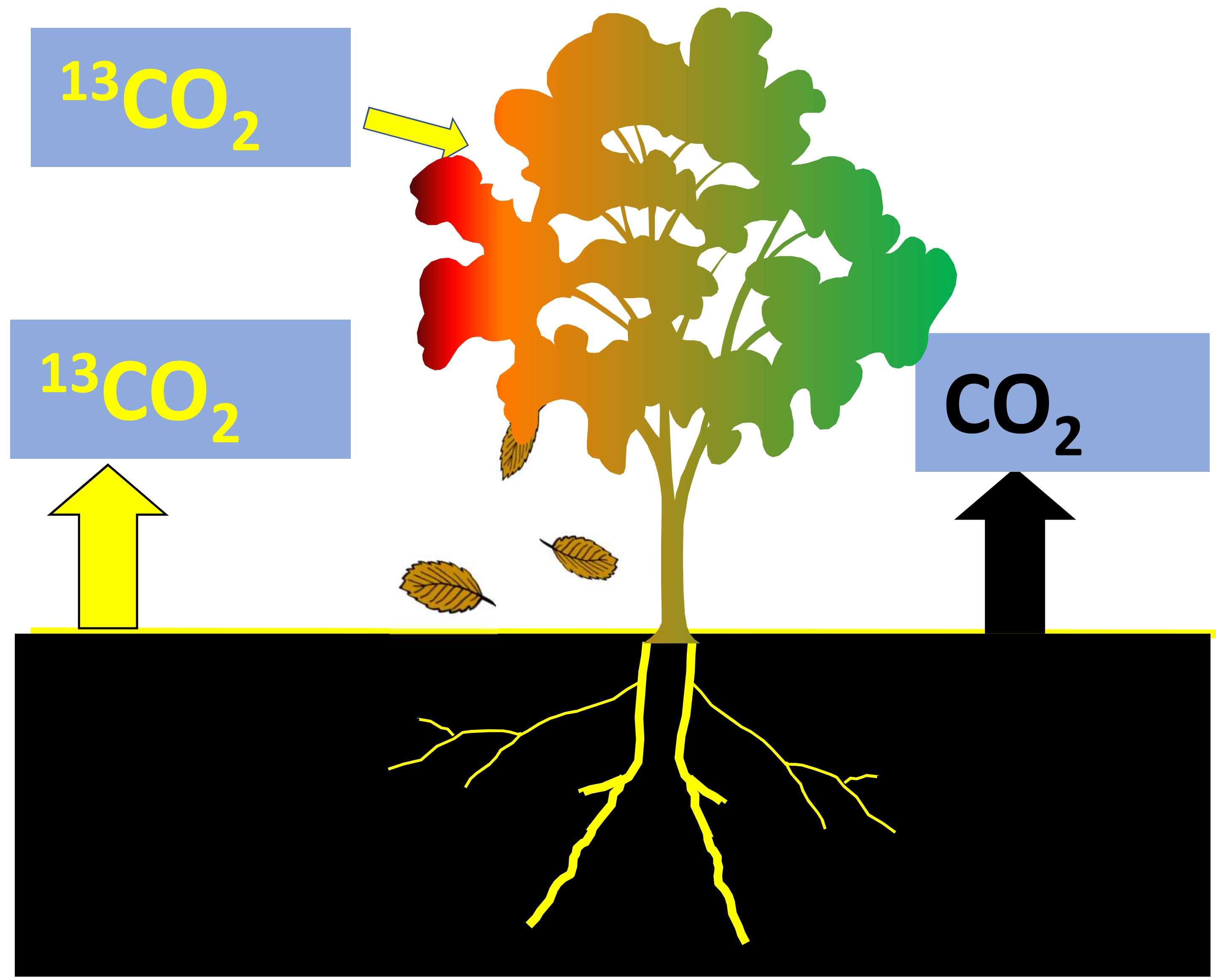
CO_2 flush at rewetting

1. **Burst of microbial cells by osmotic shock**



Hagedorn et al. (2016): *Nature Plants*

From Leaf to Soil: Tracking ^{13}C



How fast and how much assimilates are allocated to the soil under drought and rewetting?

^{13}C-pulse labelling in model ecosystems

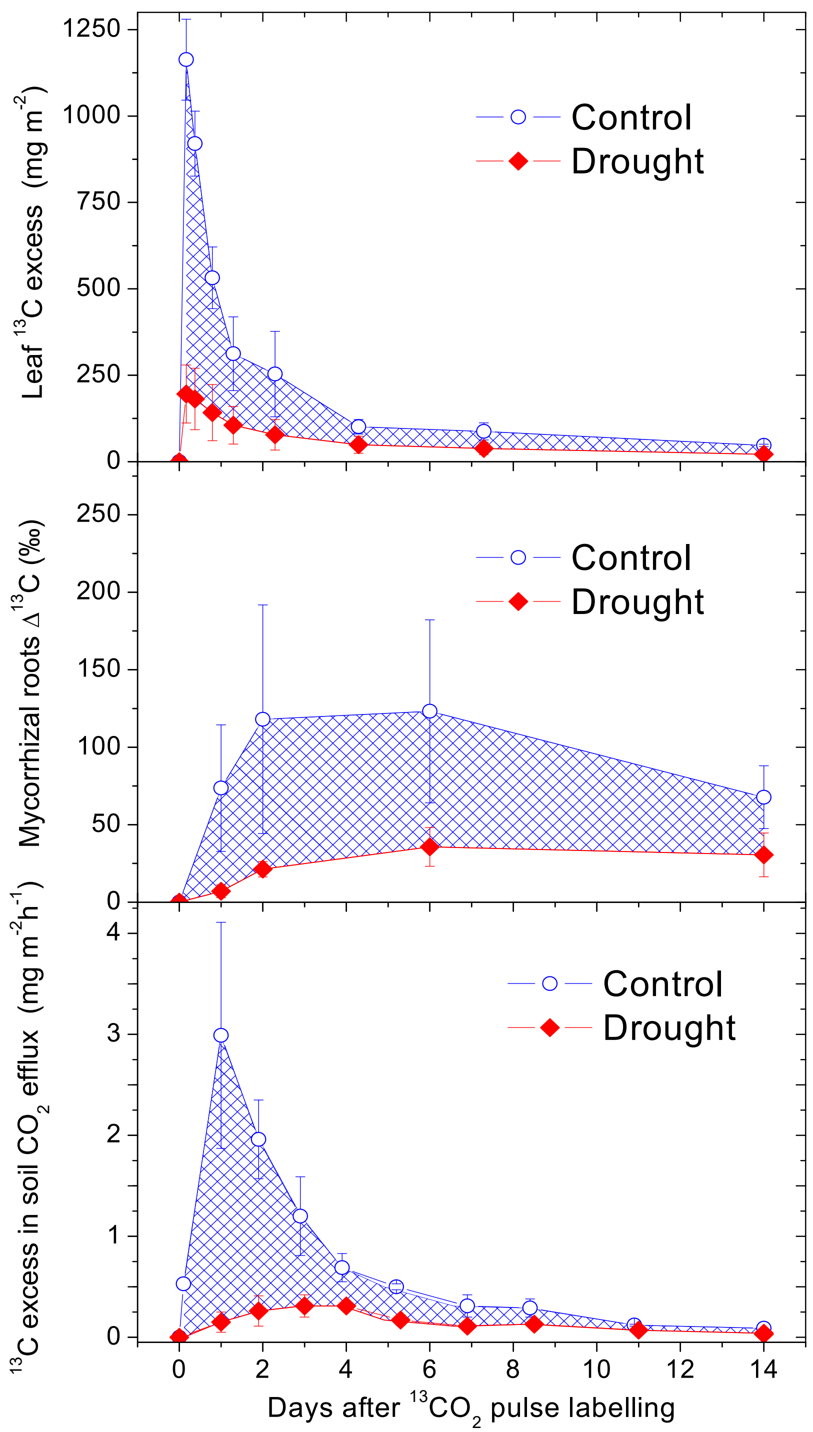
→ Addition of $^{13}CO_2$ (50% atom) for 4 hours, total n=14 model ecosystems

Collaboration with
M. Arend, J. Joseph, P. Bleuler, A. Zürcher, R. Siegwolf, J. Luster, M. Peters, A. Gessler

Hagedorn et al. (2016): *Nature Plants*

^{13}C tracking of assimilates

Drought



Leaf

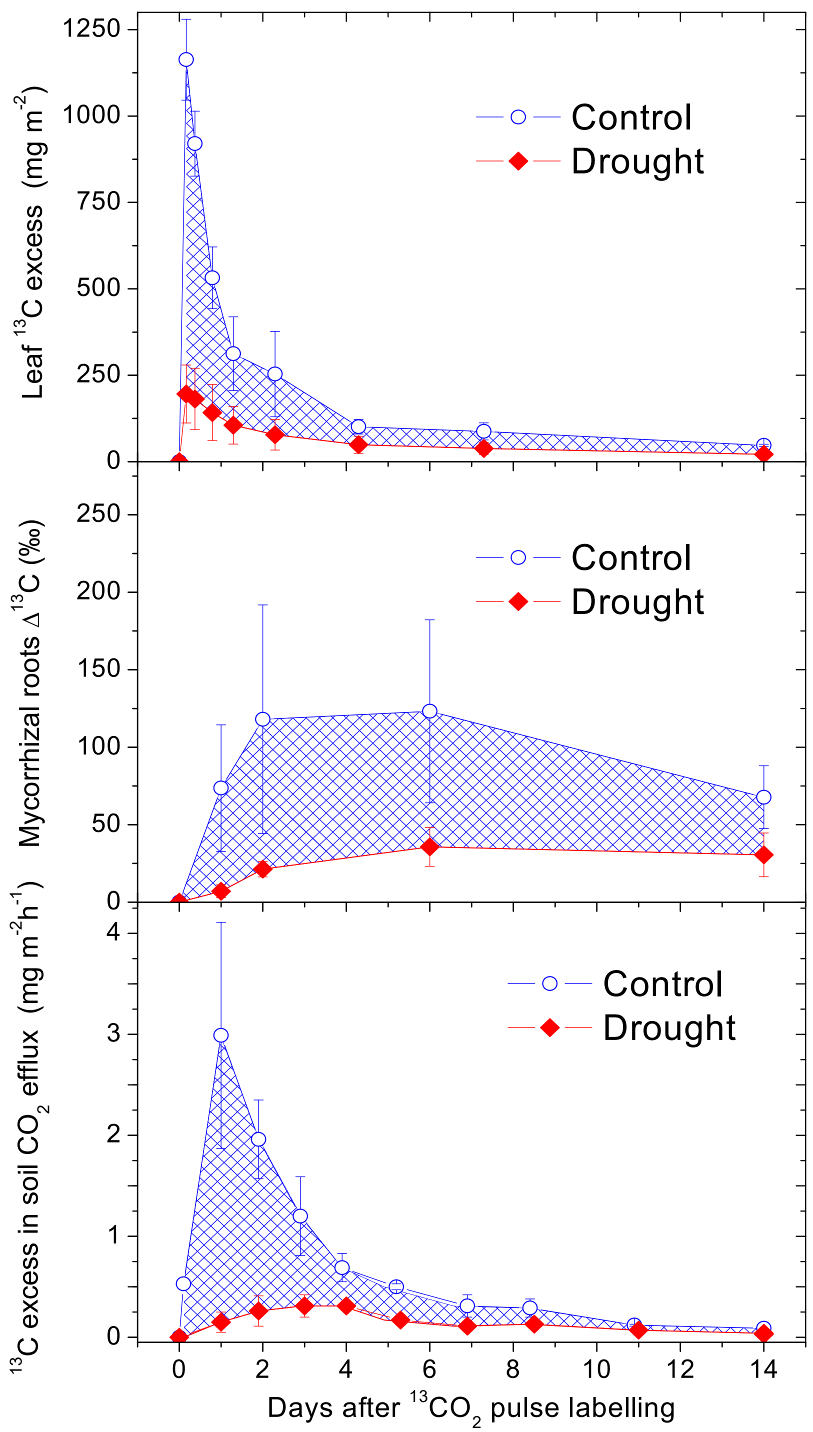
Mycorrhizal roots

Soil respiration, ^{13}C peak: 1 day moist, 4 days drought

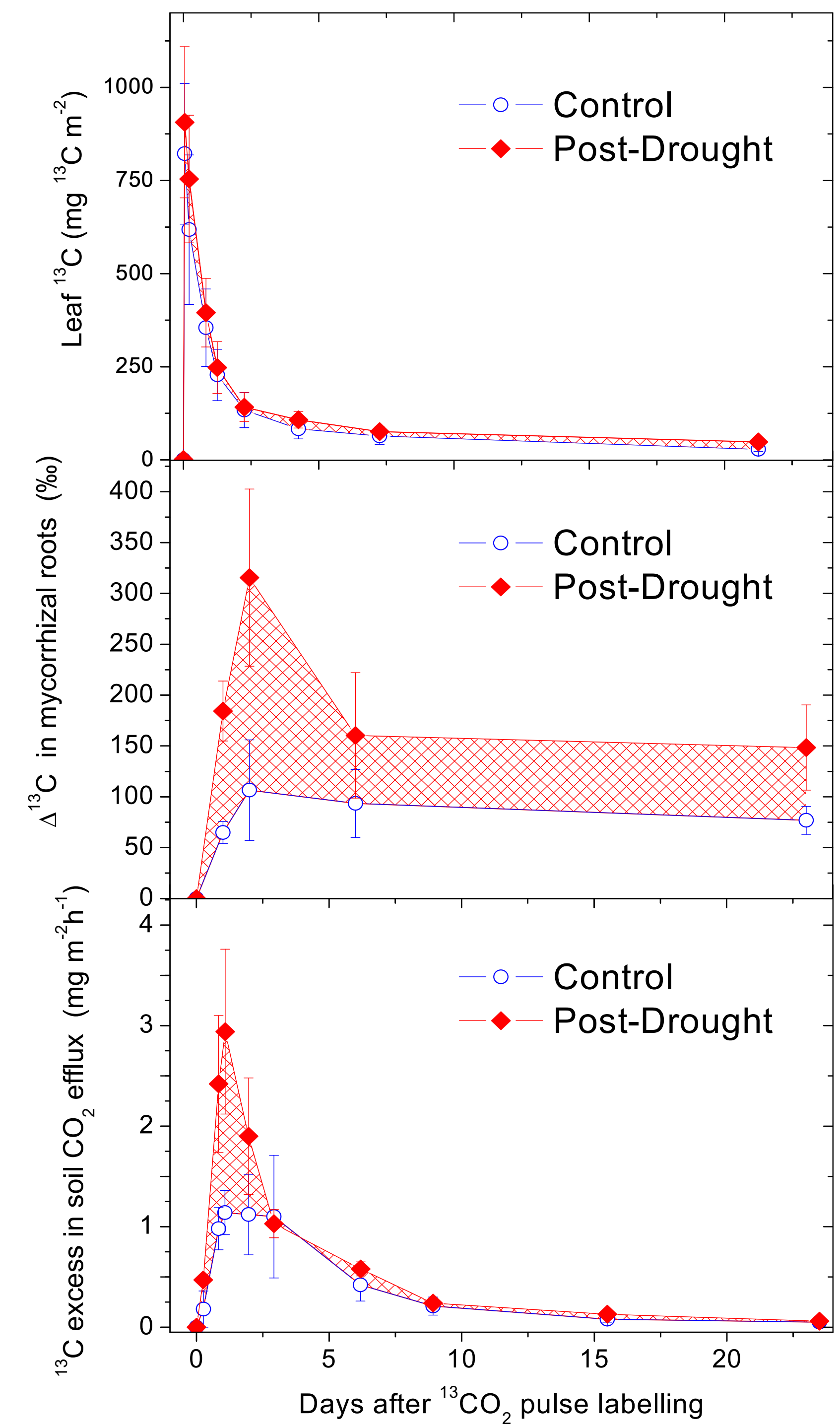
Hagedorn et al. (2016): *Nature Plants*

^{13}C tracking of assimilates

Drought



10 days after rewatering



Leaf

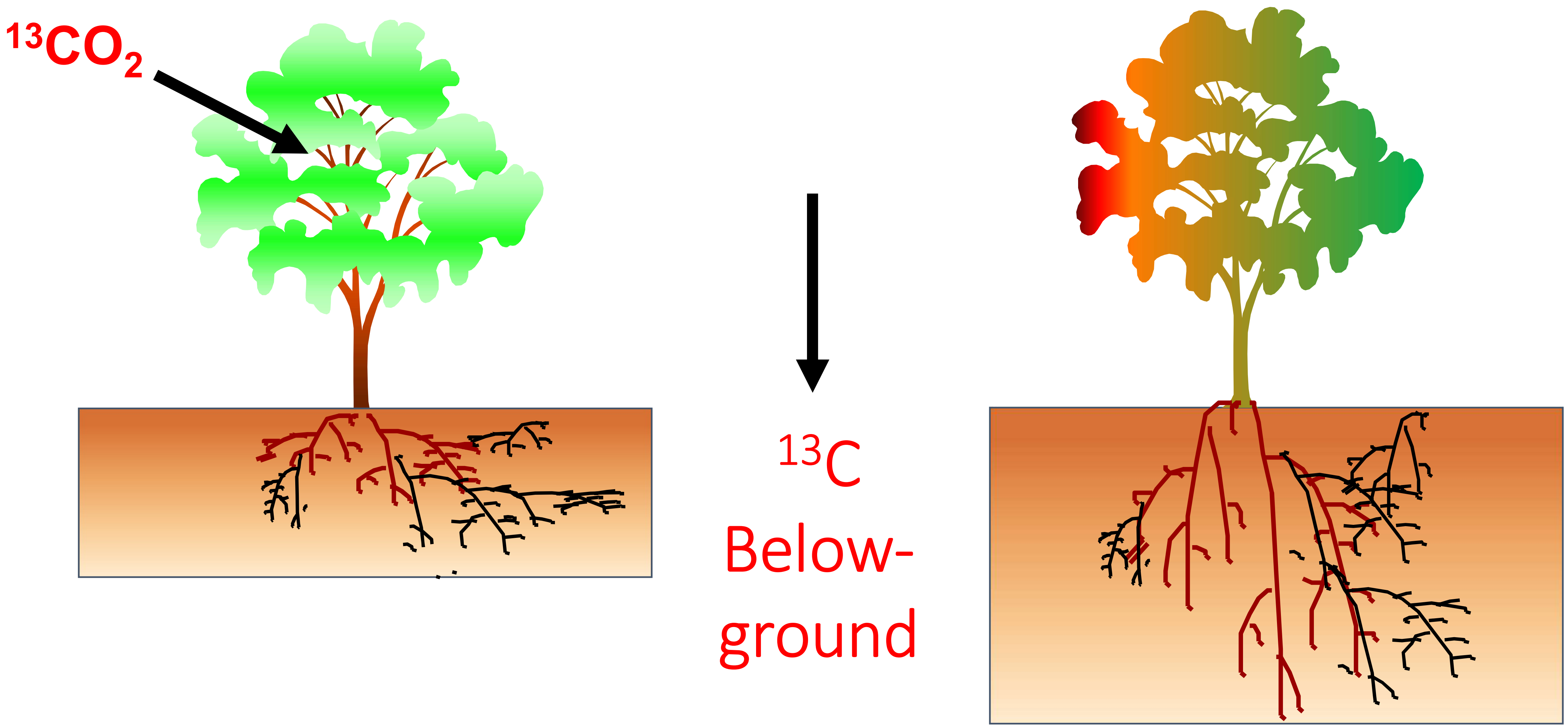
Mycorrhizal roots

Soil respiration

Hagedorn et al. (2016): *Nature Plants*

Belowground investment of assimilates

Permanently moist | **Previous drought-stressed**



→ Root repair

20±5 %

38±10%

Hagedorn et al. (2016): *Nature Plants*

Recovery of trees from drought

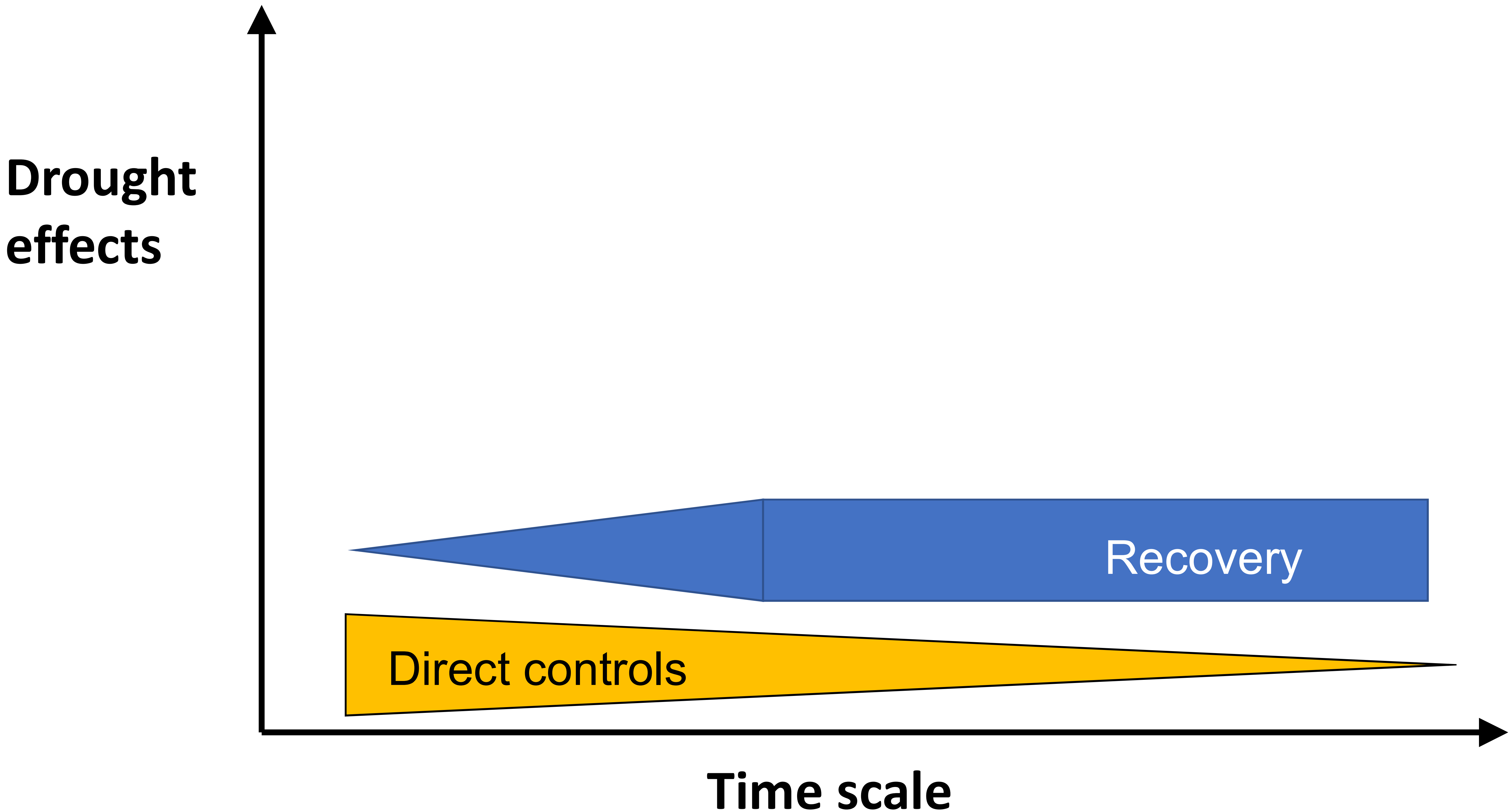
→ **Recovery partly compensates for losses during drought**

→ **Rapid transfer of assimilates to belowground**

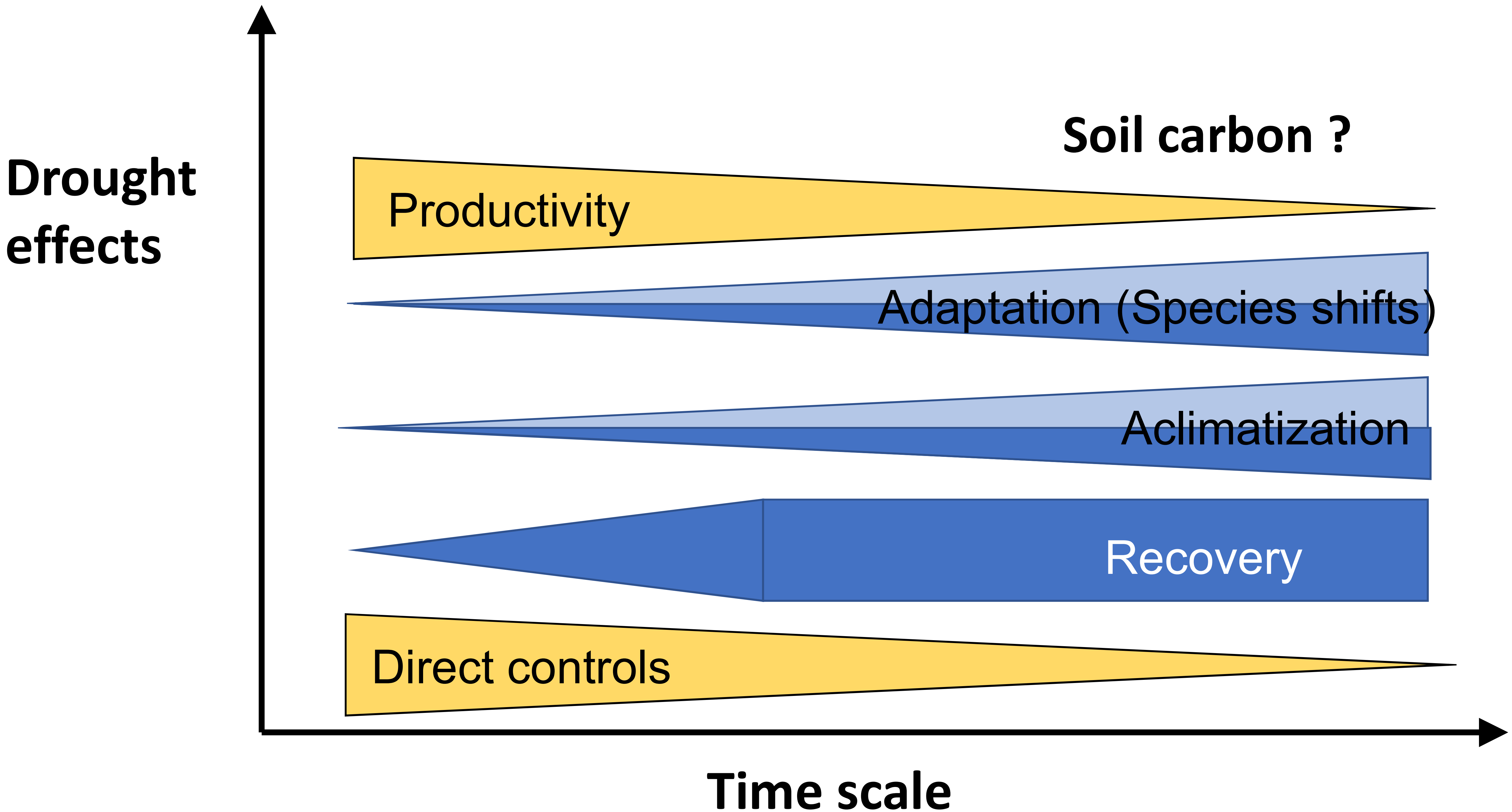
→ **Tree prioritize in repairing their roots**

→ **Impact C inputs into soils and thus soil C cycling**

Forest responses to drought – short term



Forest responses to drought – **longer term**




Pfynwald

Long-term irrigation experiment since 2003

Irrigation:+5 mm per night
+610 – 790 mm in summer

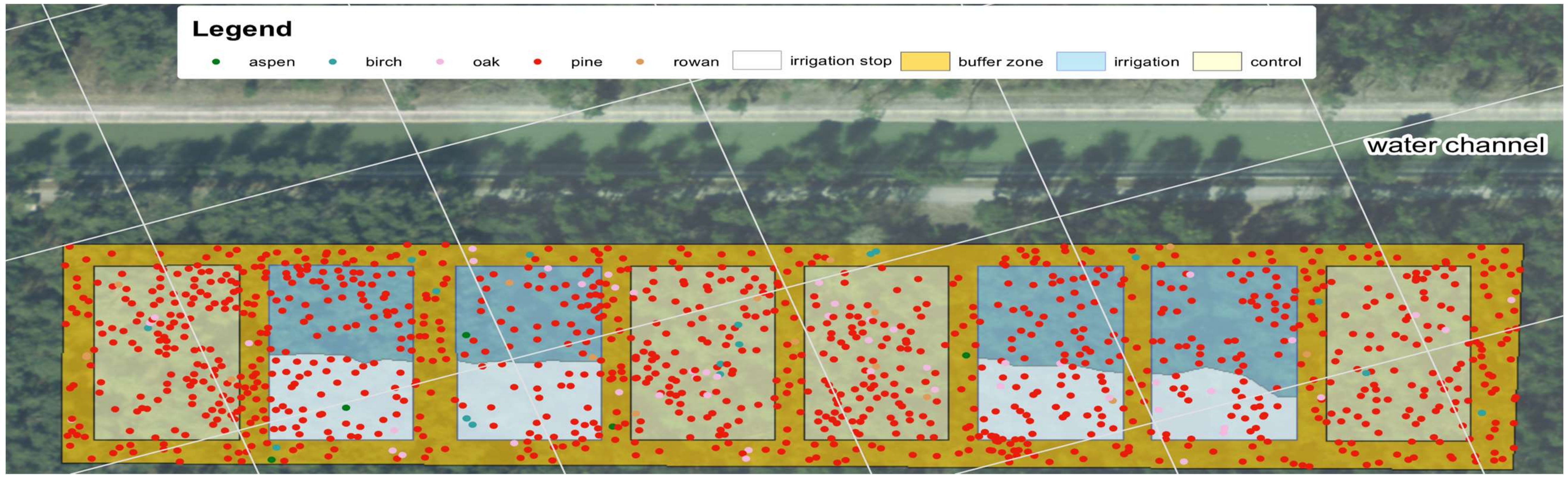
→ Removal of water limitation

Dobbertin *et al. 2010: Tree Physiology*

Rigling *et al. 2013: Global Change Biology*

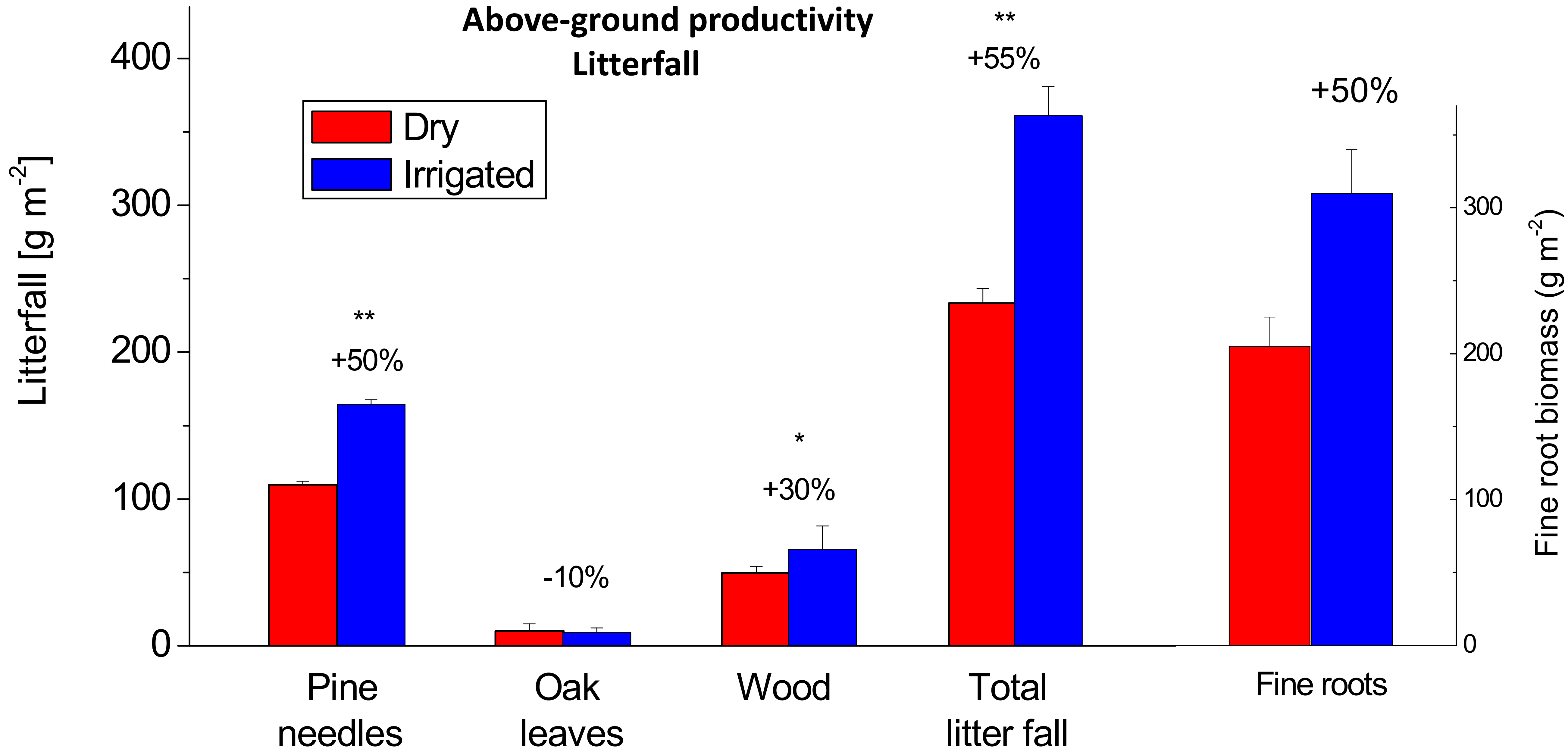
Hartmann *et al. 2017: Molecular Ecology*

Long-term irrigation experiment since 2003



Litterfall: species-specific responses

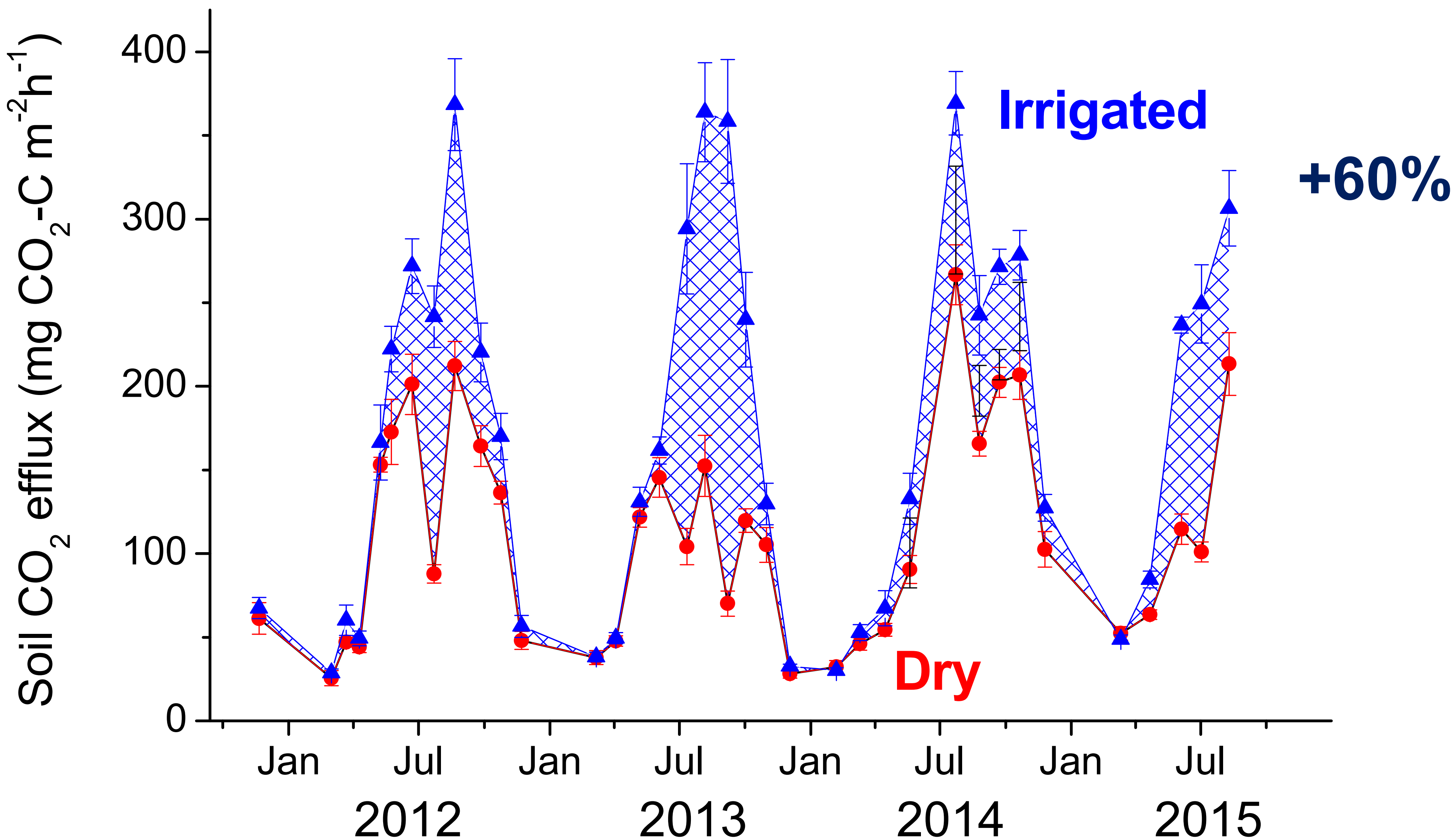
Fine roots



After 11 years; n=4 plots each with 6 traps

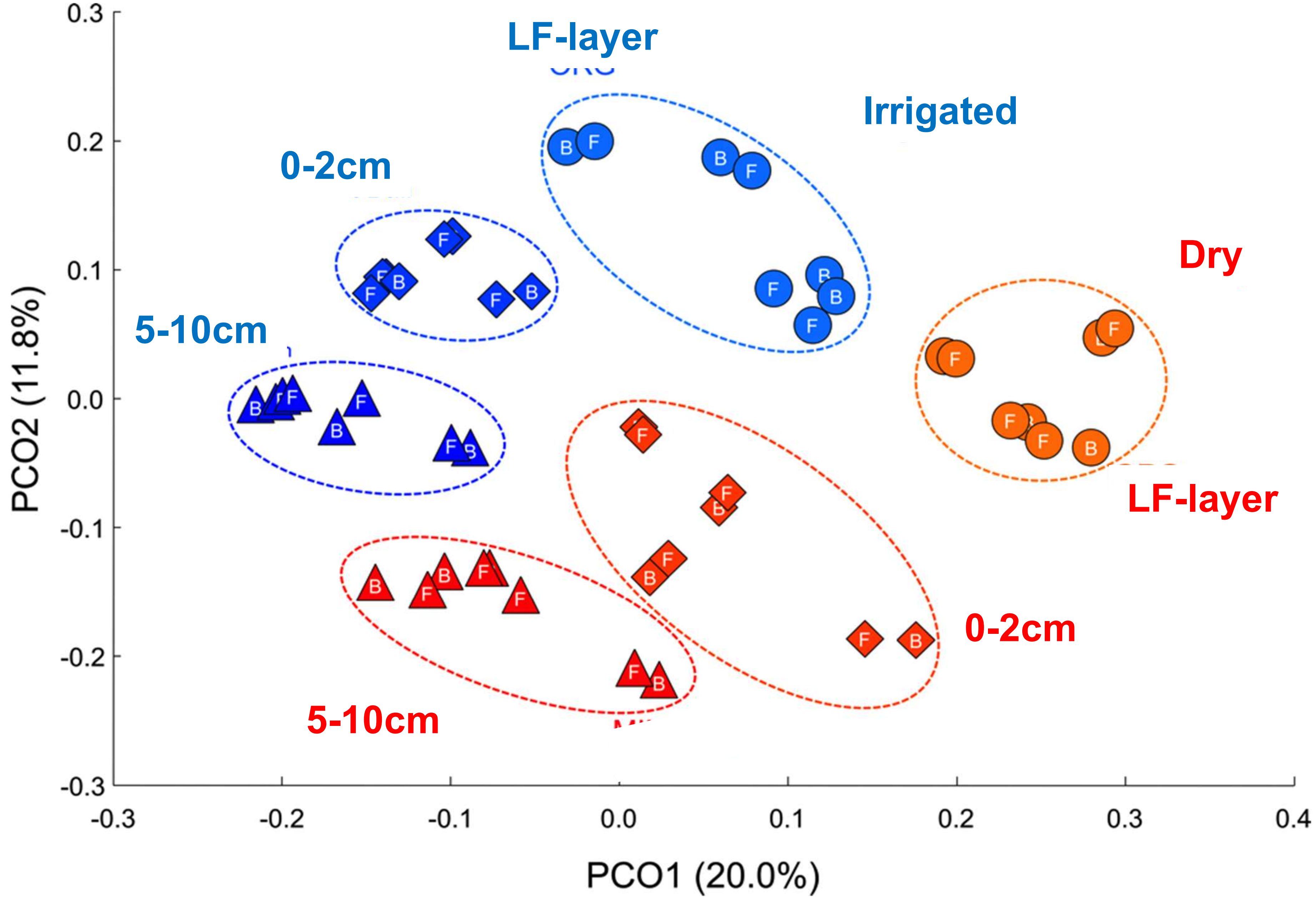
Herzog et al. (2014): *PLOSOne*

Soil CO_2 efflux



After 10-13 years, n=4 plots per treatment; 4 collars per plot

Water regime alters bacterial and fungal β-diversity



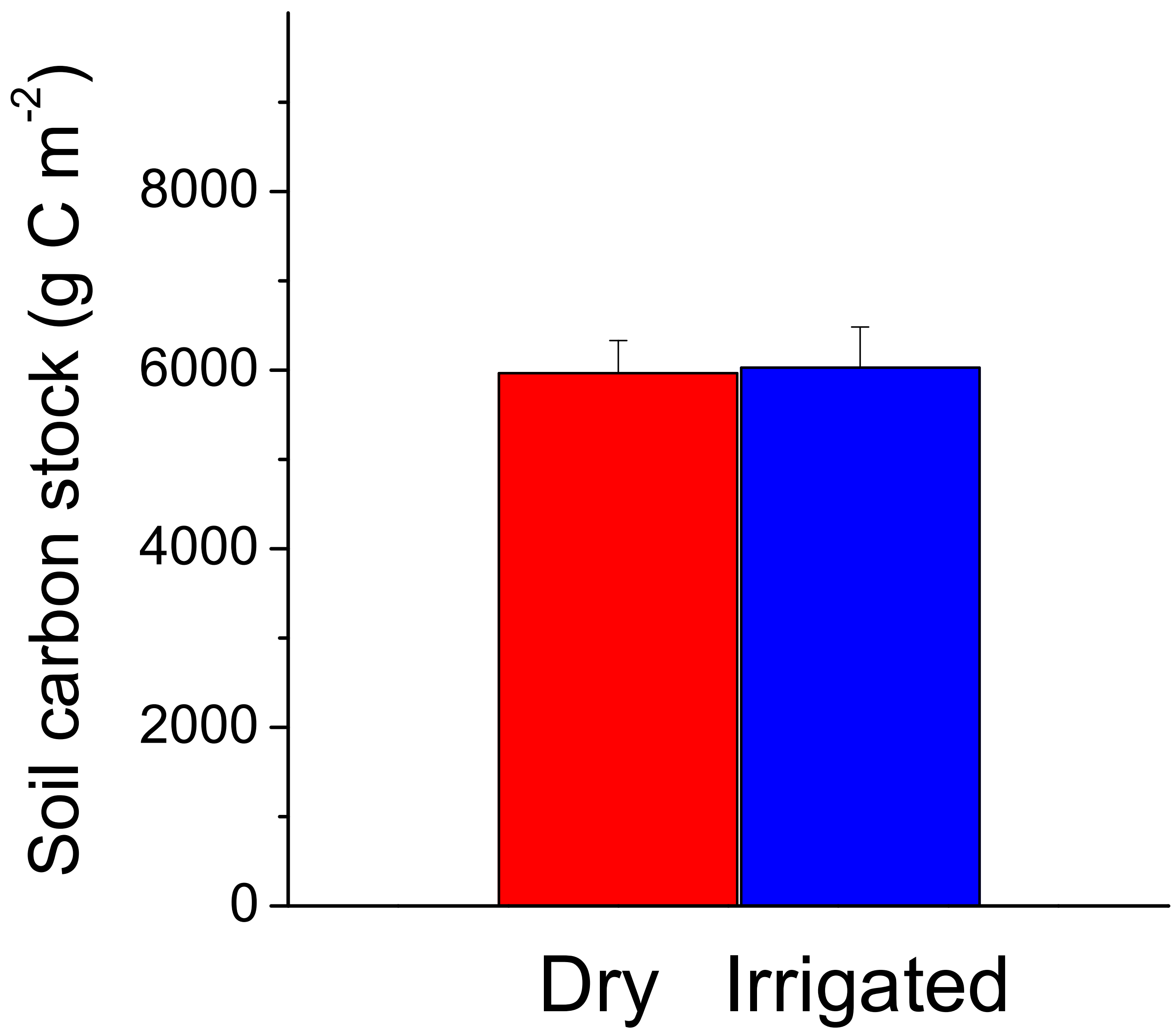
PERMANOVA	Bacteria F(P)	Fungi F(P)
Irrigation	**3.40 (<0.001)**	**3.85 (<0.001)**
Soil horizon	**2.88 (<0.001)**	**2.83 (<0.001)**
Irrigation × soil horizon	1.06 (0.305)	1.10 (0.265)

→ More bacteria with a oligotrophic life strategy under drought

454 pyrosequencing

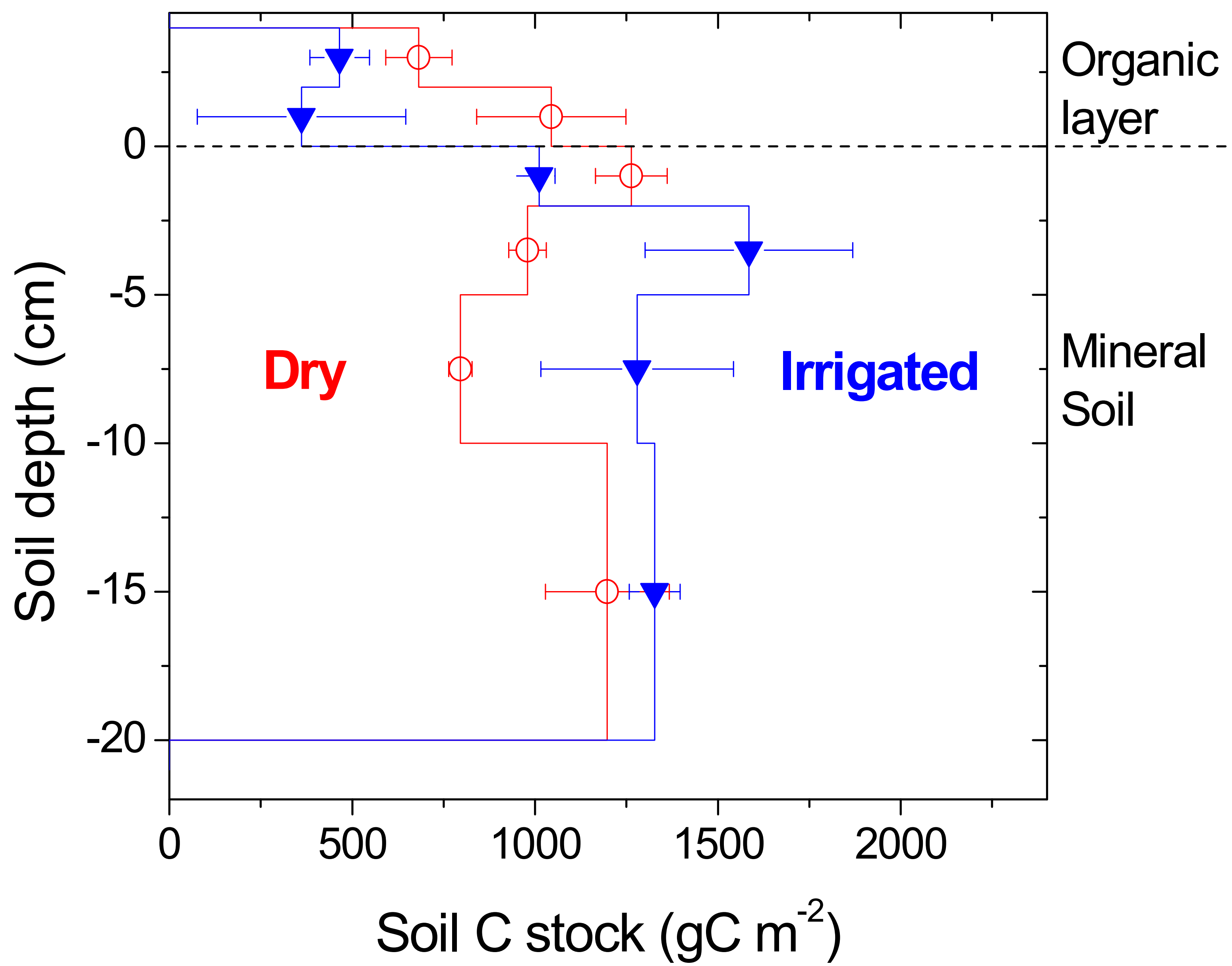
Hartmann et al. (2017) *Molecular Ecology*

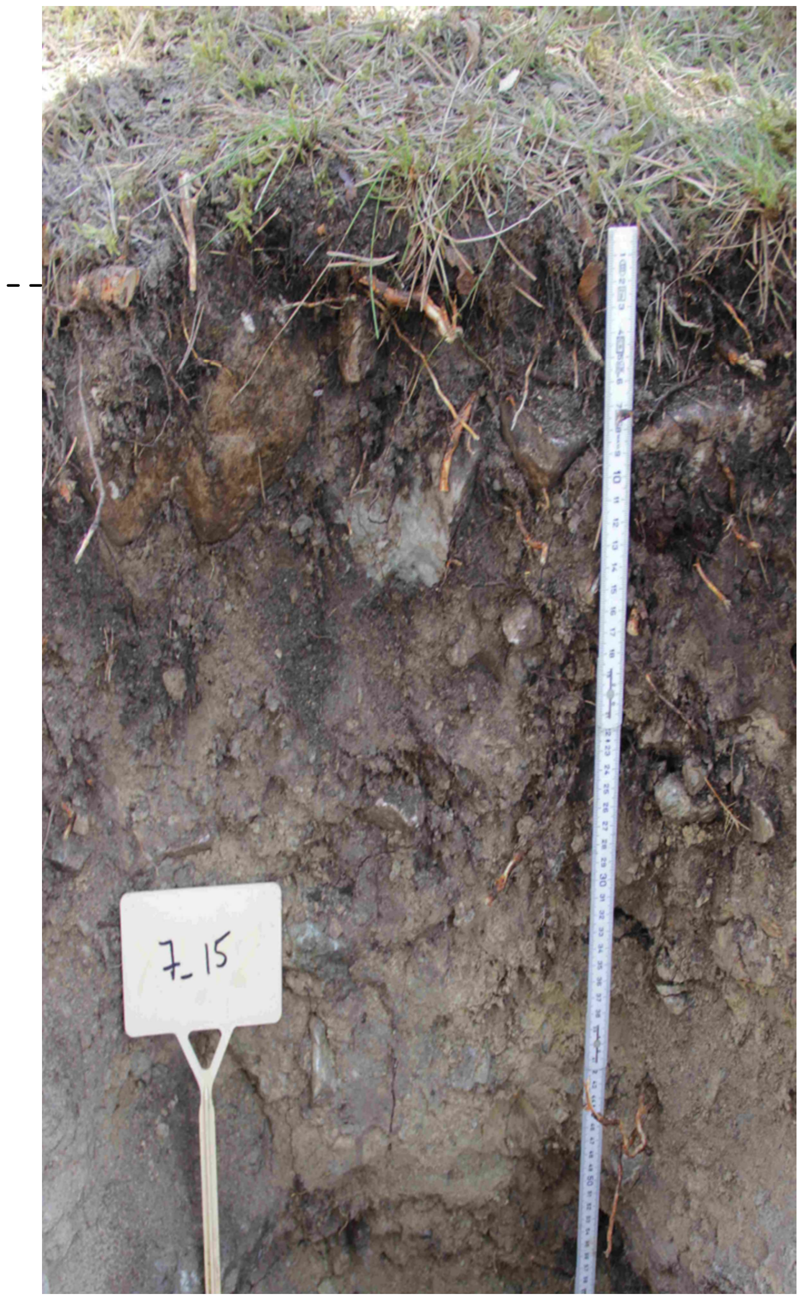
Soil organic carbon stocks



0-20 cm; $P_{Drought}$<n.s.; n=4 plots per treatment, 4 profiles per plot, total n= 32 profiles

Soil organic carbon stocks





$P_{Drought\ X\ Depth}<0.02$; n=4 plots per treatment, 4 profiles per plot, total n= 32 profiles

Soil organic carbon distribution

C-losses in organic layer, C-gains in mineral soil under irrigation

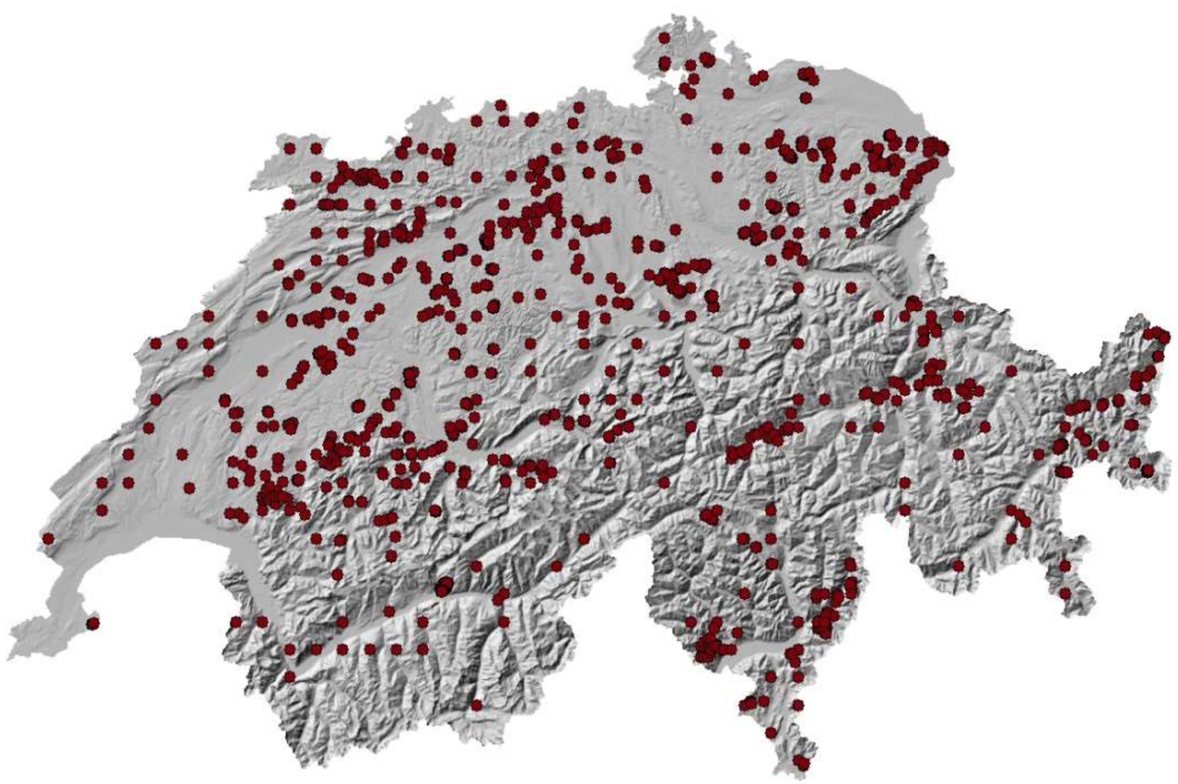
1. Increased litter decomposition + rhizodeposition

2. Enhanced DOC leaching

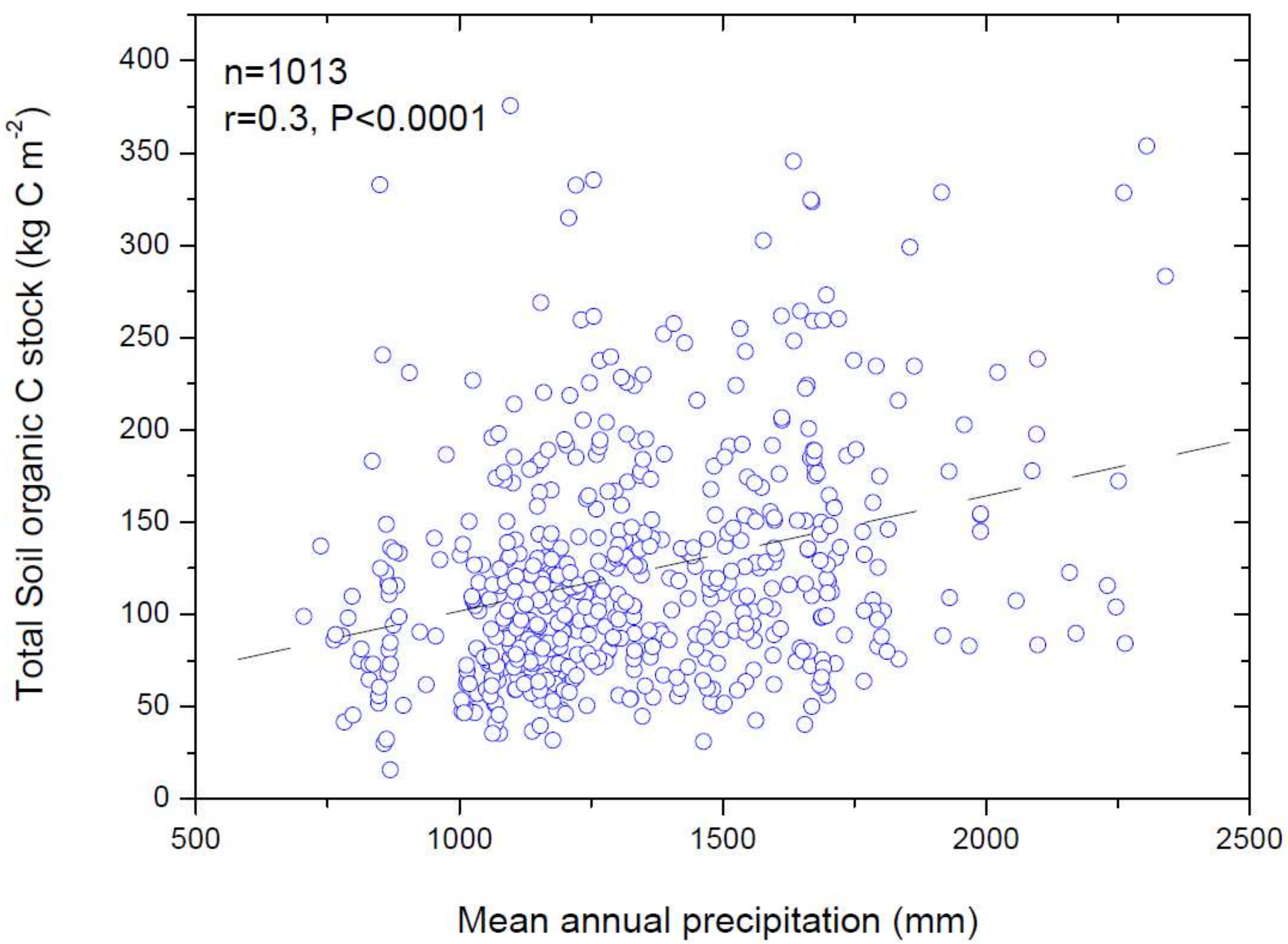
3. Stronger incorporation of litter into minerals soil by macrofauna (e.g. earthworms)

Evaluating climate impact from natural gradients

Swiss forest soils
MAT: 0.6 – 12°C
MAP: 700 – 2400 mm



Soil C stocks decline with decreasing MAP



ANOVA for SOC-stocks (n=1012), Explained variance

	pH, clay, Ca, Al, Fe	MAT	MAP	Forest Type
Forest floor	**18*** **	**8*** **	**0.1^{ns}**	**8*** **
Mineral soil	**21*** **	**0.1^{ns}**	**11*** **	**1***

Gosheva et al. (2017) *Ecosystems*

Summary

1. Drought alters C cycling at various time scales
2. Trees can recover from drought, prioritize in repairing their roots

3. Repeated summer drought reduces C fluxes and impacts biodiversity
4. In the long-term: reduction of carbon stock

Photo:
Agroscope, 2013

Thanks to
teams
Biogeochemistry
Pfynwald

Soil as a Resource
National Research Programme NRP 68

SWISS FOREST LAB

From canopy to soil: ^{13}C tracing in a mature forest

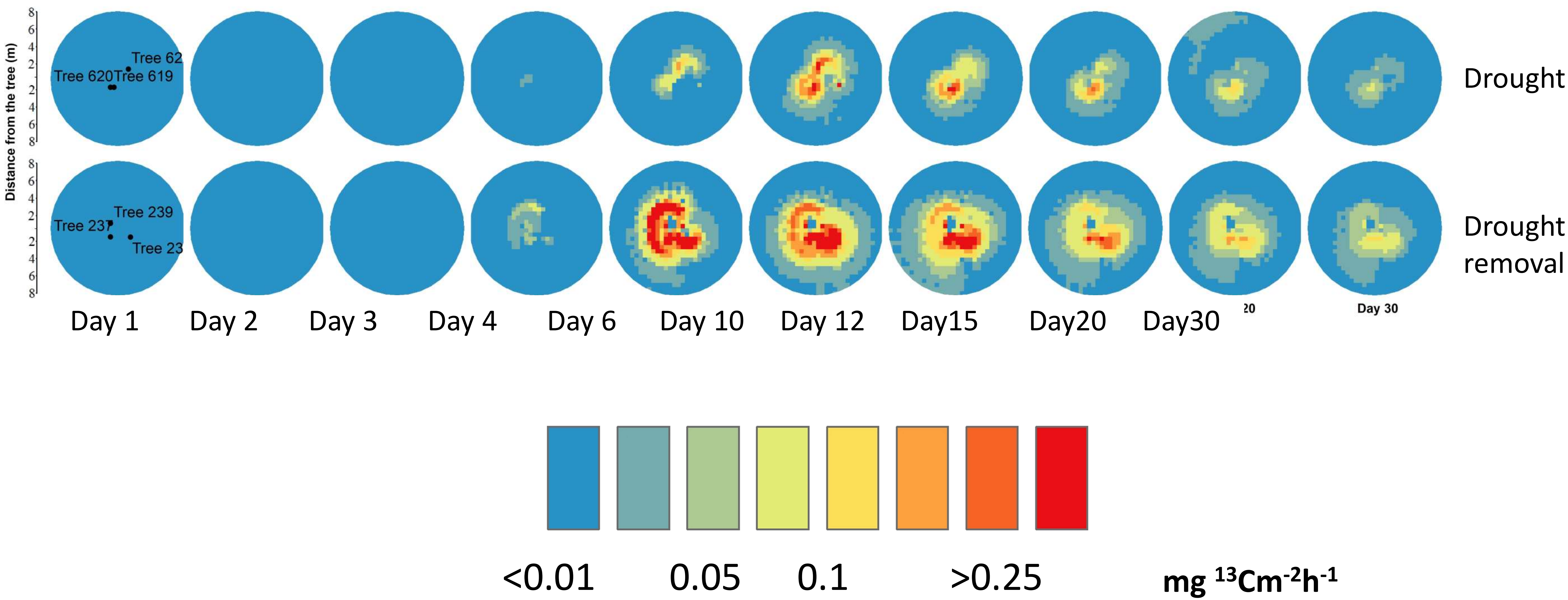
Collaboration wth
Decai Gao, R. Werner, A. Zürcher, A. Gessler, J. Jobin, J. Luster, G. Gleixner, M. Saurer, H. Hartmann, C. Poll
....

<u>3h ^{13}C-labelling in blocks</u>

5 trees under moderate drought

5 trees irrigated

Spatio-temporal ^{13}C tracing to soil respiration



^{13}C belowground allocation – threshold pattern