Impacts of summer extreme events on soil respiration in grassland in a context of future climate change

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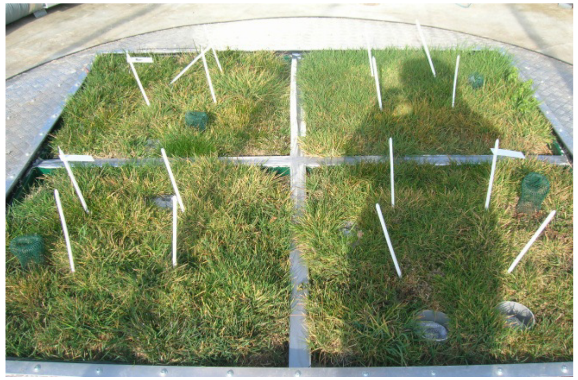

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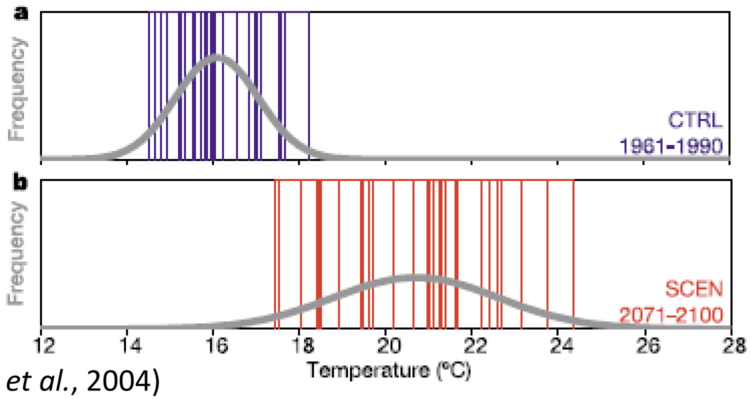
Future occurrence of extreme events



(Schär *et al.*, 2004)

Climate models, not only predict gradual warming and drying, but also more frequent and intense summer extreme events such as **heat waves** and **droughts** (Meehl *et al*., 2000; Schär *et al*., 2004; Fischer & Schär, 2010).

Climate change effects on above-and below-ground processes

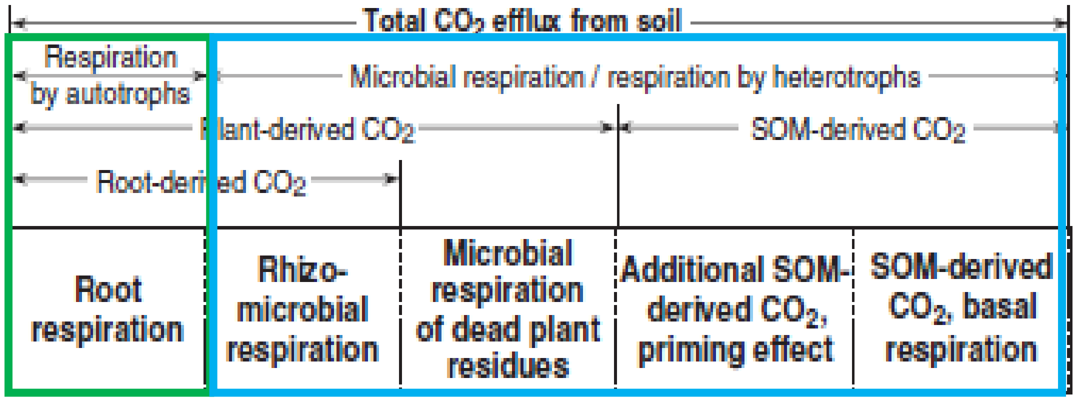
	Photosynthesis	Soil Respiration
Atmospheric CO_2 increase	⇧/⇩	⇧
Drought	⇩	⇩
Temperature increase	⇧/⇩	⇧/⇩

In grassland ecosystem **soil respiration** responses to **climate change** lack of results about:

- combined effects of climate drivers, except some cases (Wan et al, 2007).
- extreme events effects.

Soil respiration

- Soil respiration (**R**$_{tot}$) results from **root respiration** (**autotrophic respiration**) and from plant litter and soil organic matter **decomposition** (**heterotrophic respiration**)

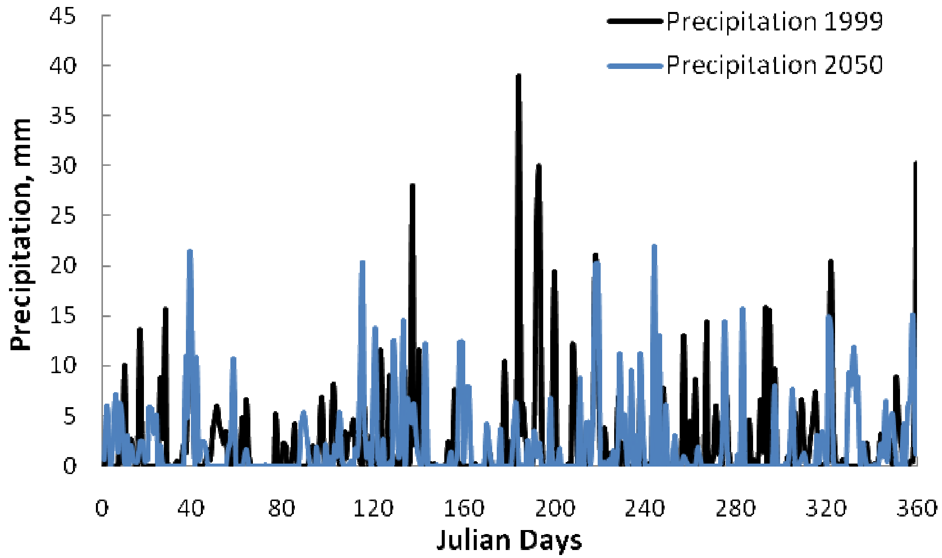


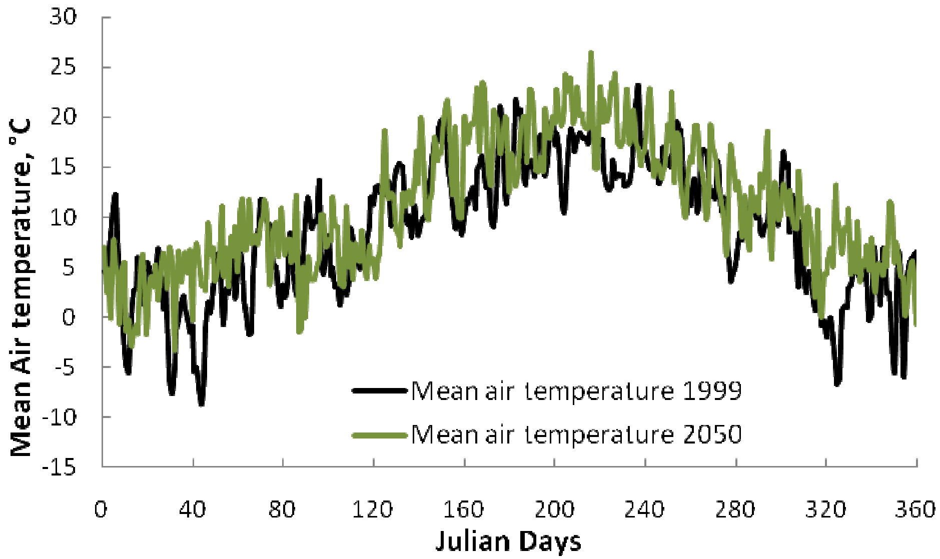
Aim of the study

In the context of future climate change our study aims to estimate in grassland ecosystem:

- The effect of **increasing CO_2** concentration on soil respiration and its components
- Effects of summer **extreme events** on soil respiration and its components
- A possible **mitigation of increasing CO_2** on the negative effect of **drought** and **heat wave** on soil respiration

Future climate scenario





Since **May 2010 ALL** grassland monoliths, coming from a mid-mountain site, were exposed, at the Montpellier **ECOTRON**, to a **warmer and dryer scenario** reproducing the forecasted climate for origin site for 2050

	Annual Precipitation	Annual Mean Air Temperature
1999	856 mm	8,6 °C
2050	770 mm	10,9 °C
Difference 2050/1999	10%	21 %

CO_2 treatment

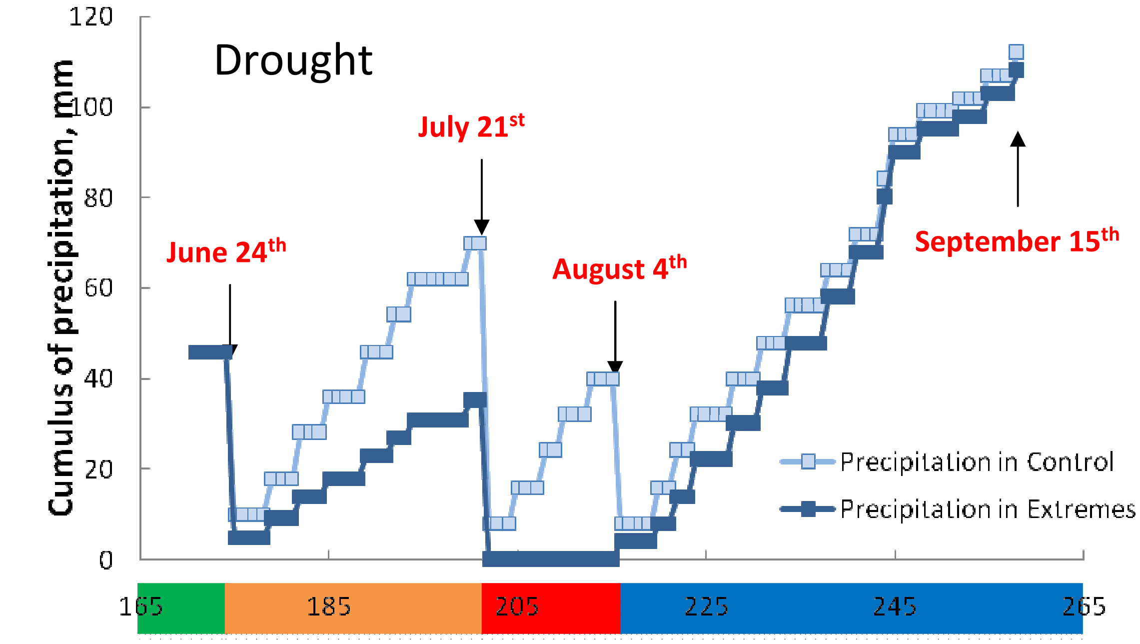
Since **March 2011** half of the monoliths were exposed to

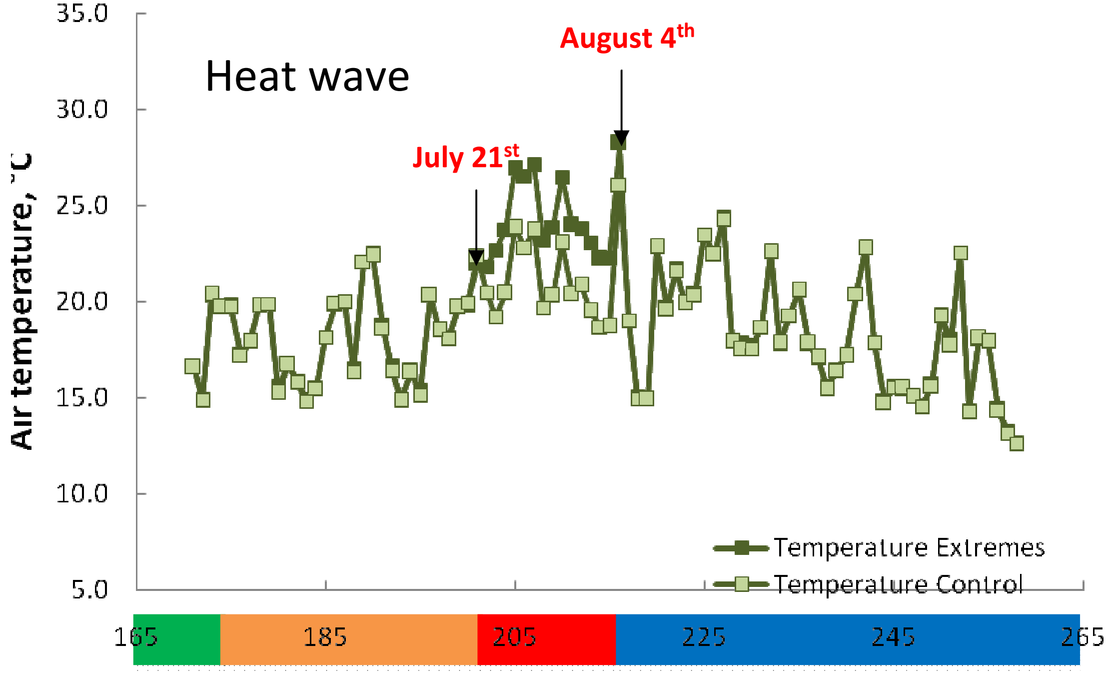
520 ppm CO_2,

while the other half was kept at

380 ppm CO_2.

Drought and heat wave treatments



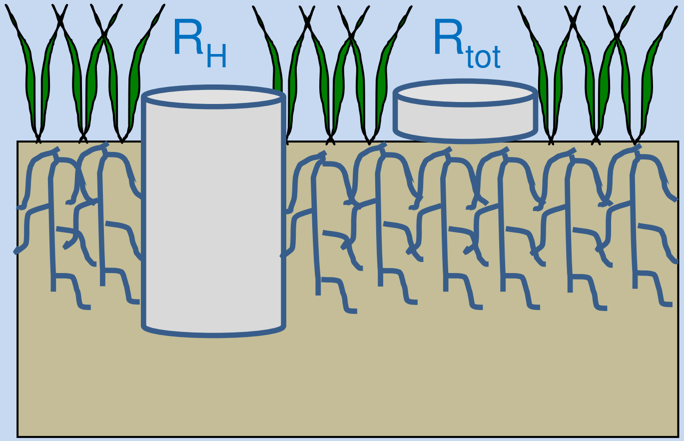


Extreme event treatment were applied during summer 2011 starting at the end of June

	Precipitation	Air Temperature
Control	2050	2050
Pre-treatment	50% of 2050	2050
Extreme Event	0	2050 + 3,5°C
Recovery	Gradually reaching 2050	2050

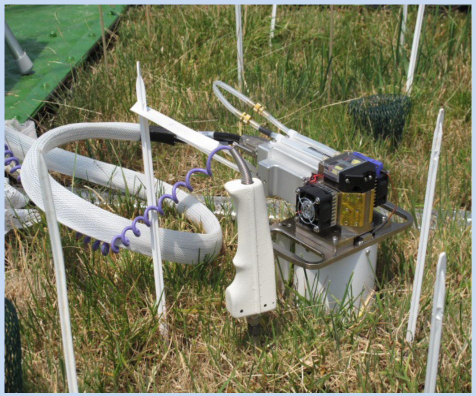
Below-ground processes analysis

Soil respiration measurements



Analysis of R_H and R_{TOT} was done by using **deep and surface collars** approach, by excluding or not root, respectively

Soil respiration was measured with a Licor 6400 provided with soil chamber

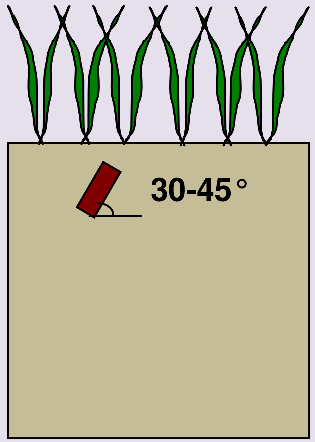


Root growth & respiration analysis

Analysis of root growth rate was done by using the **InGrowth core** approach, IGC were harvested on average each 5-6 weeks

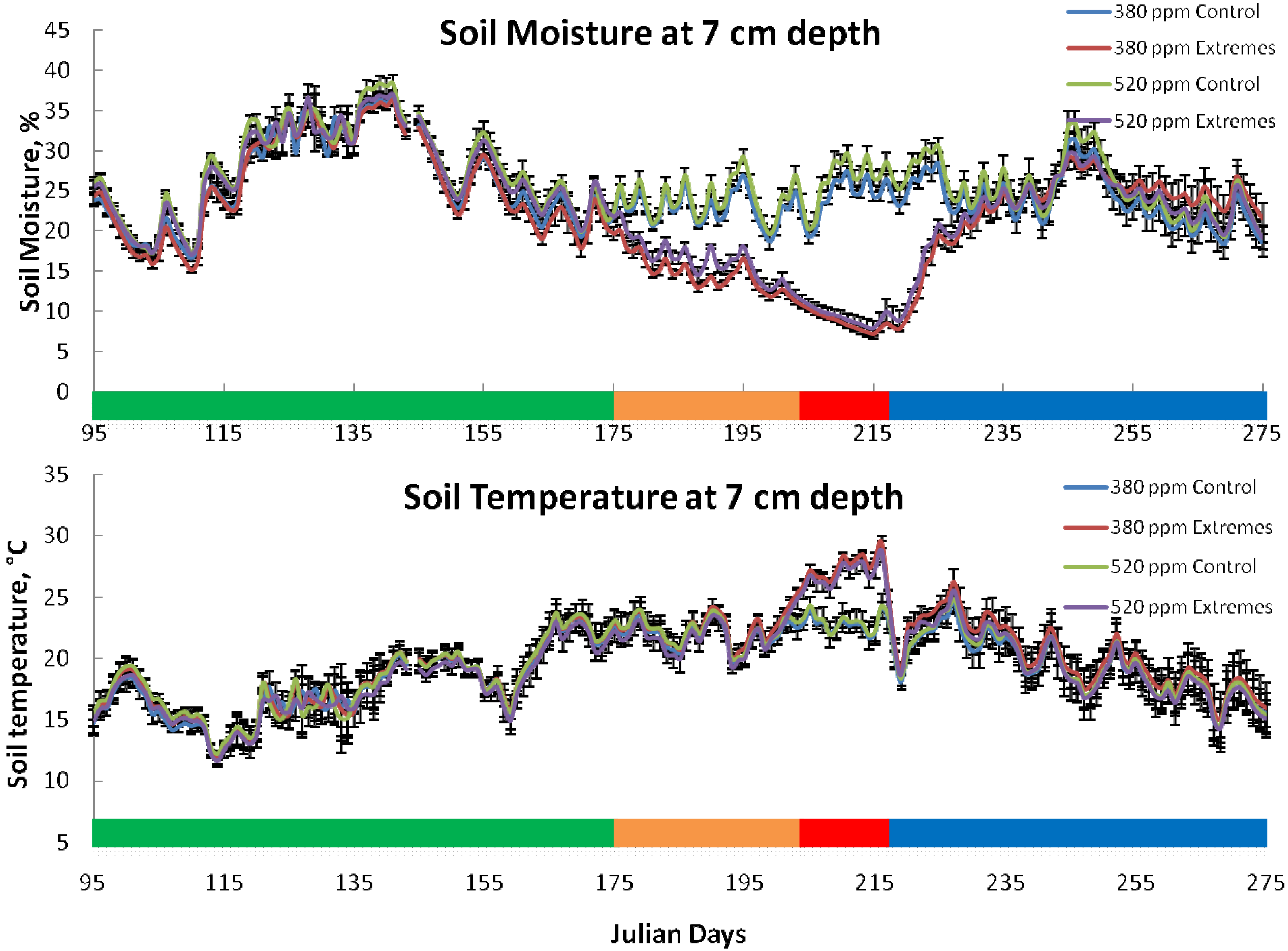
Newly grown roots were used for root respiration analysis

Root decomposition



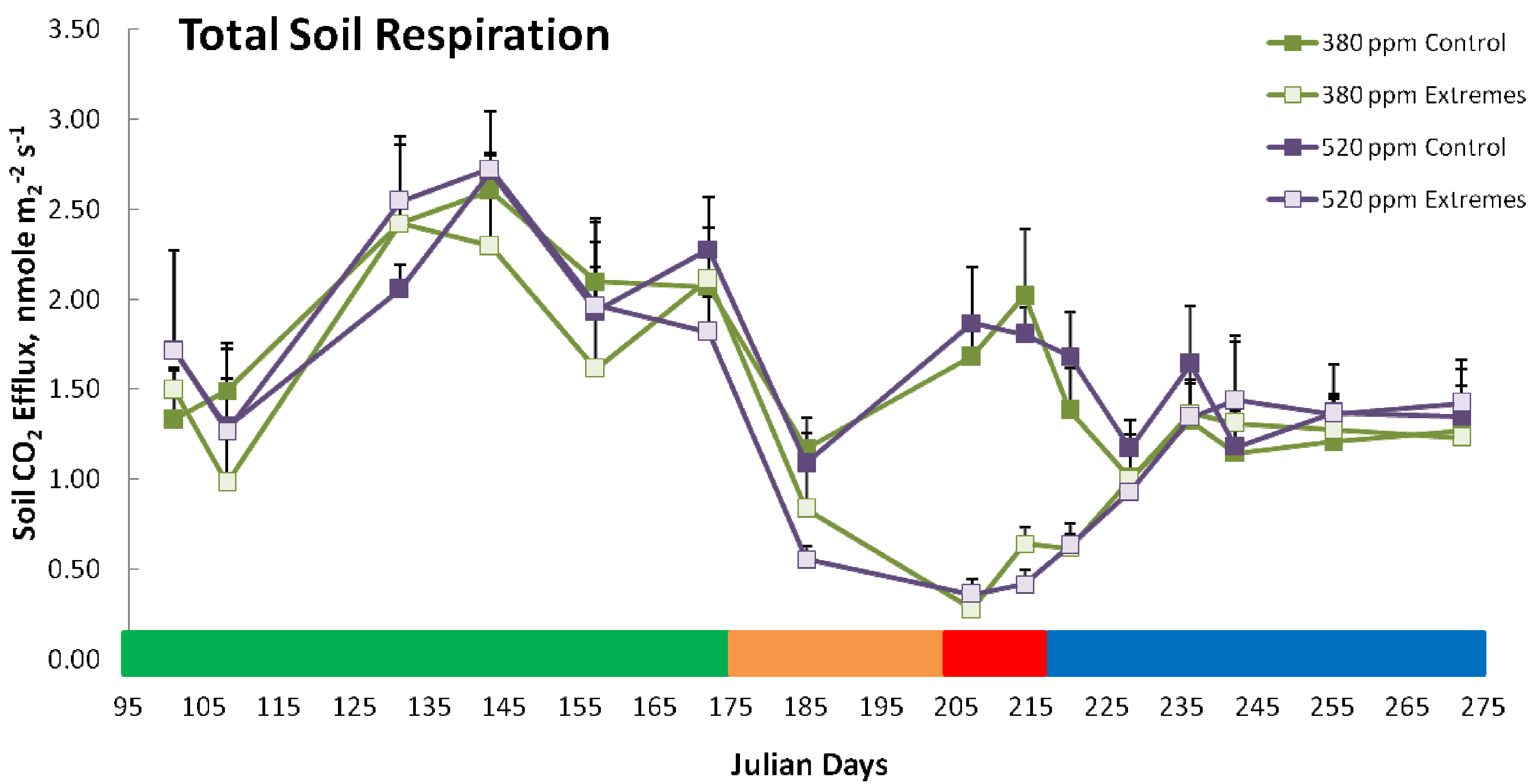
Litter bags containing root material were allocated at about 10cm depth in each monolith. Root decomposition was evaluated by measuring loss of root material

Soil Moisture and Soil Temperature under summer extreme events



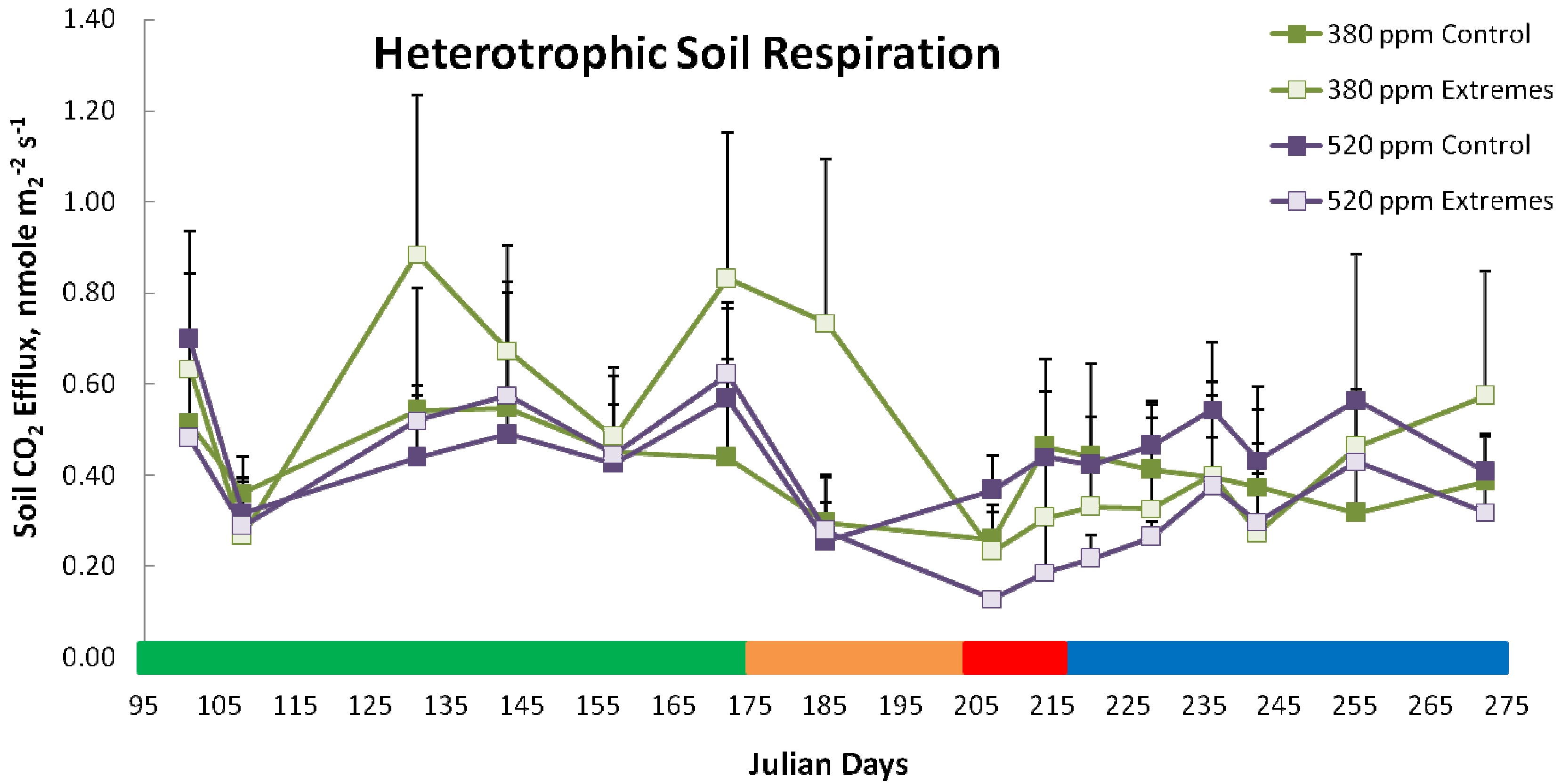
Heat wave and drought caused a 43% decrease in soil moisture and a 13.5% increase in soil temperature

Total soil responses to elevated CO_2 and to summer extreme events



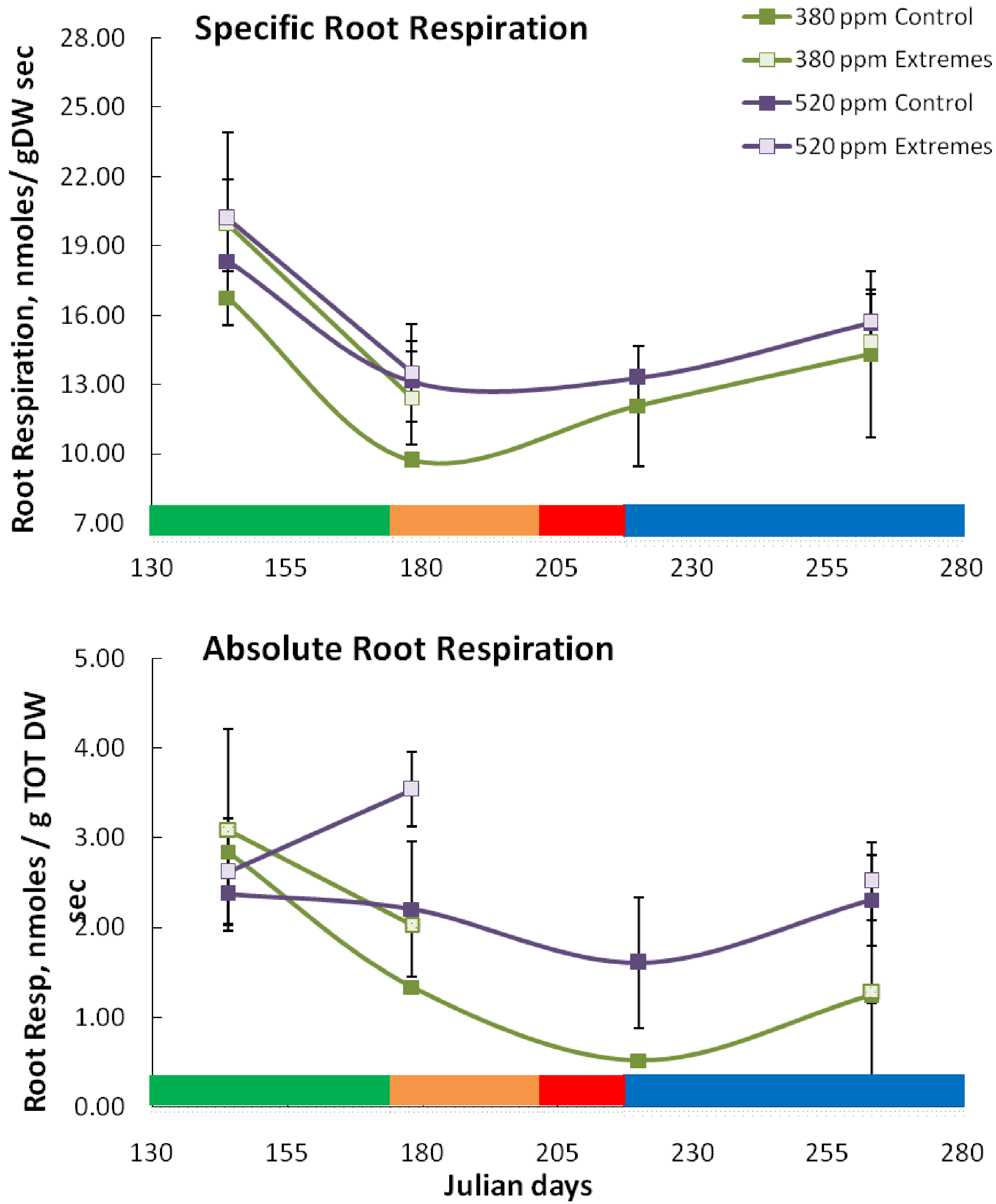
- Totol soil respiration (R_{TOT}) does not show any difference due to elevated CO_2
- **R_{TOTt}** responded to extremes treatments by decreasing about 60% both at ambient and at elevated CO_2
- Decrease in **R_{TOT}** follows the decrease in soil moisture, a positive relationship between R_{TOT} and soil moisture is recorded (data not shown)

Heterotrophic soil responses to elevated CO_2 and to summer extreme events



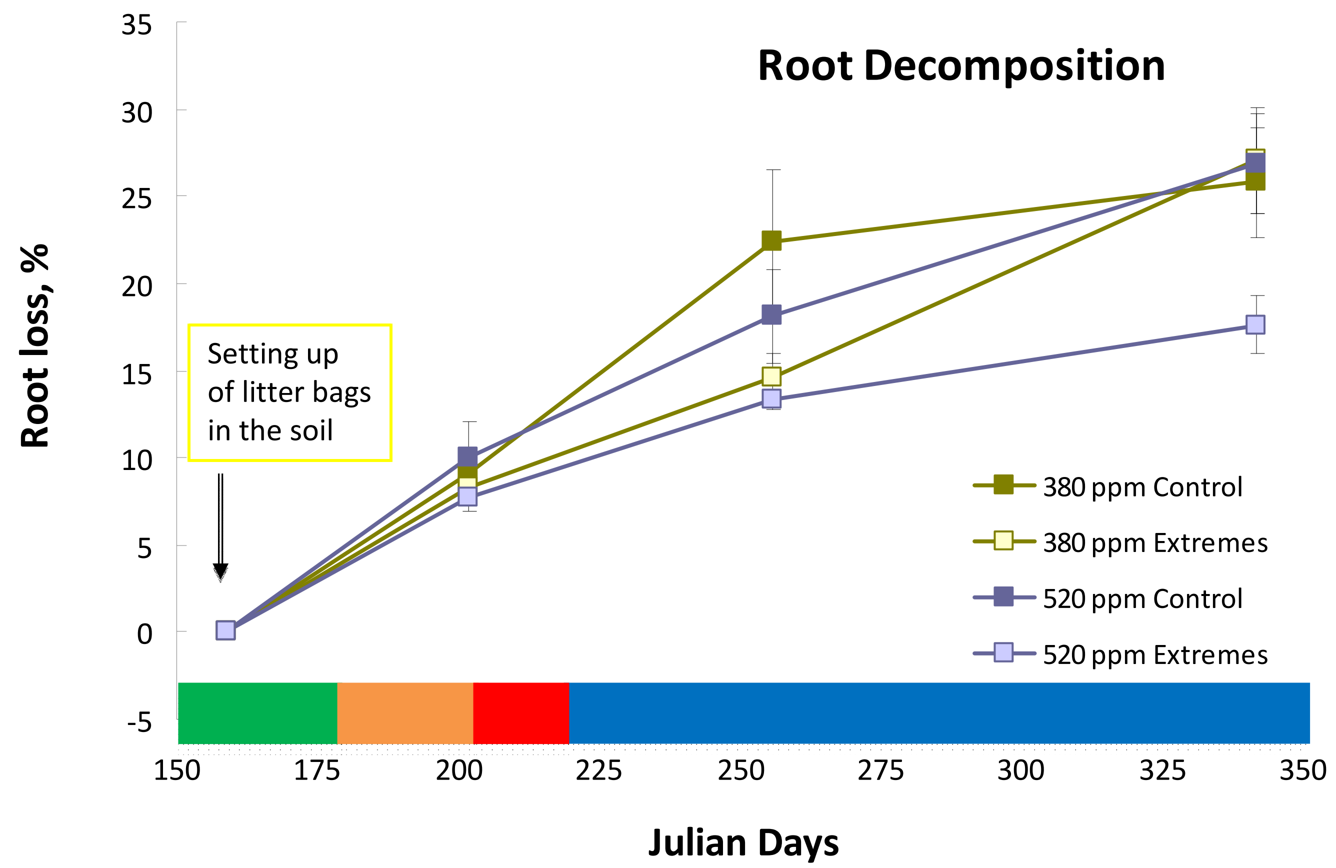
- On average on the whole season, $\mathbf{R_H}$ is about 28% less than total soil respiration
- $\mathbf{R_H}$ shows a slight increase under elevated CO_2 up to 20% during August and September
- $\mathbf{R_H}$ during extreme events decreases, but it does more slowly compared to R_{TOT}

Root respiration responses to elevated CO_2 and to extreme events



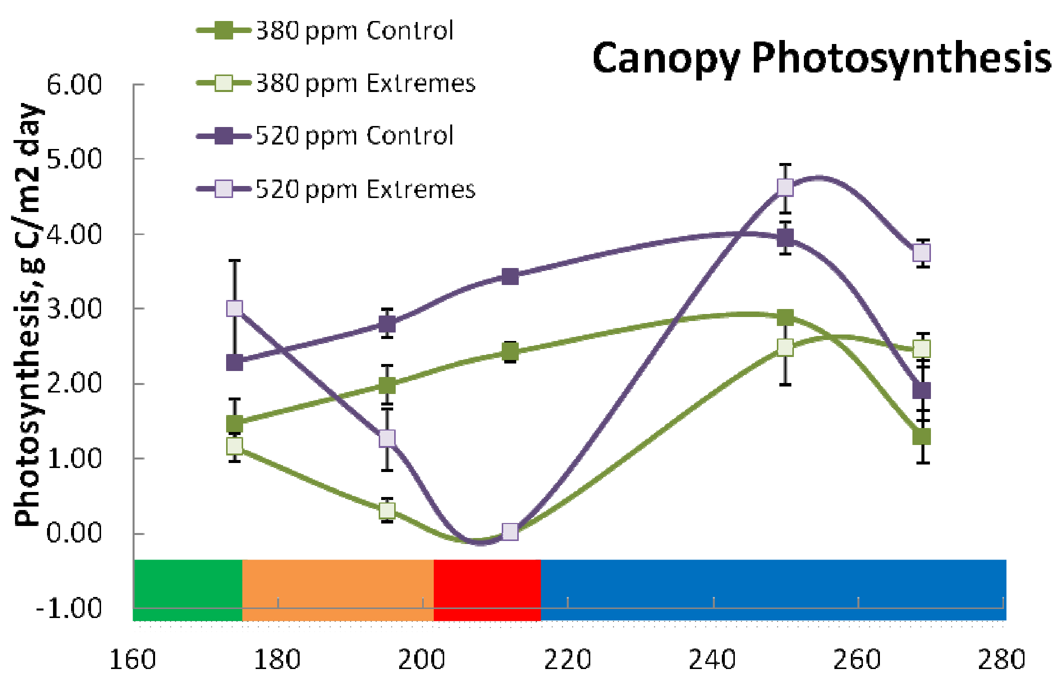
- Respiration from newly formed roots (**RR**), shows a decrease during summer both in control and extremes treatment
- **Specific RR** is not affected by elevated CO_2, but it is the case for absolute RR due to the higher root production (data not shown)
- During extreme treatments it was not possible to measure **RR**, due to very low root production
- During recovery **RR** reached control values after 40 days from re-watering.

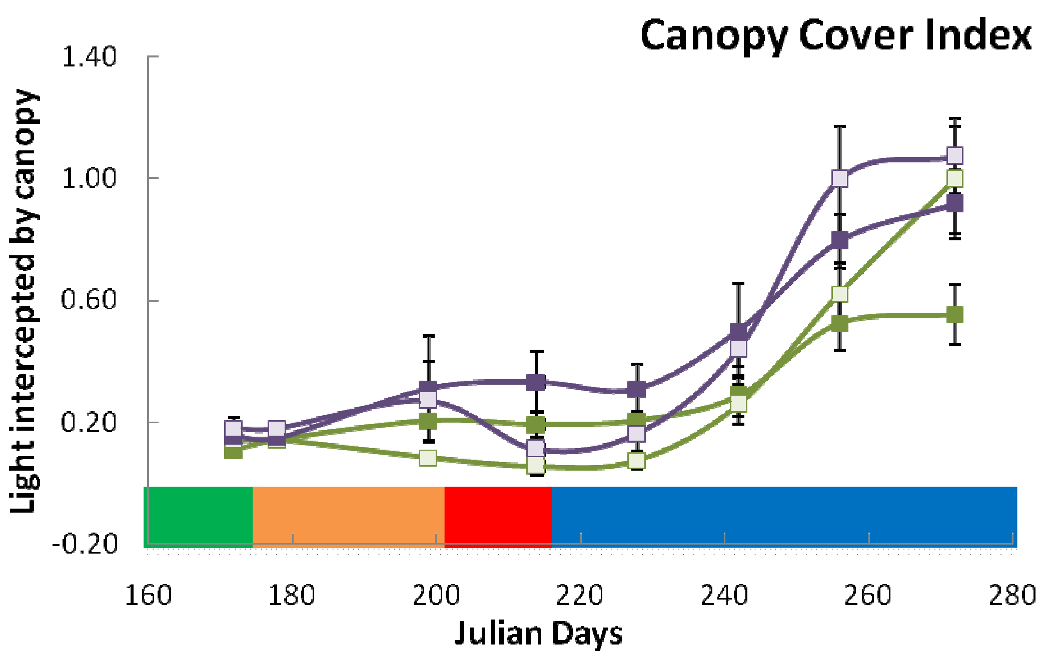
Root decomposition under elevated CO_2 and summer extreme events



- Root decomposition does not clearly respond to elevated CO_2
- Extreme treatments cause a decrease in decomposition compared to control
- At the end of the season, while decomposition at 380 ppm recovered to control values, decomposition at 520 ppm it is still lower than control

Photosynthesis and above-ground biomass production





- Photosynthesis at 520 ppm shows an increase of 30% compared to 380 ppm
- Canopy photosynthesis drop to zero during extreme events
- 40 days after re-watering photosynthesis recovers to control values.
- At 520 ppm the recovery is faster than at 380 ppm.
- Variations in canopy cover follow variation in photosynthesis

Conclusions

- Elevated CO_2 concentration clearly increased canopy photosynthesis
- It increased only slightly soil heterotrophic respiration, root growth rate, absolute root respiration
- No clear effect of elevated CO_2 was evident on total soil respiration and root decomposition

- **Summer drought and heat wave stress** caused a decrease in soil respiration even if the kinetics differ between total and heterotrophic components.
- They cause a sustained decrease in canopy photosynthesis and in root growth

- Grassland ecosystem recovers better from summer extreme events under elevated CO_2 for what concern photosynthesis and root growth rate, but this is not observed for total soil respiration

- The lower root decomposition under elevated CO_2 (during recovery under extreme) may indicate a reduction in rhizosphere activity (is there more C to plants than to microbes?)
- Need to calculate ecosystem C balance to understand the fate of C under elevated CO_2 during the recovery

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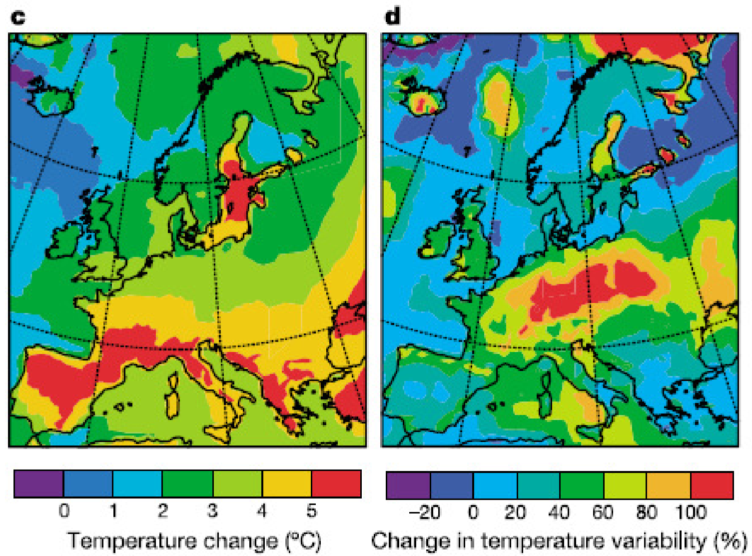
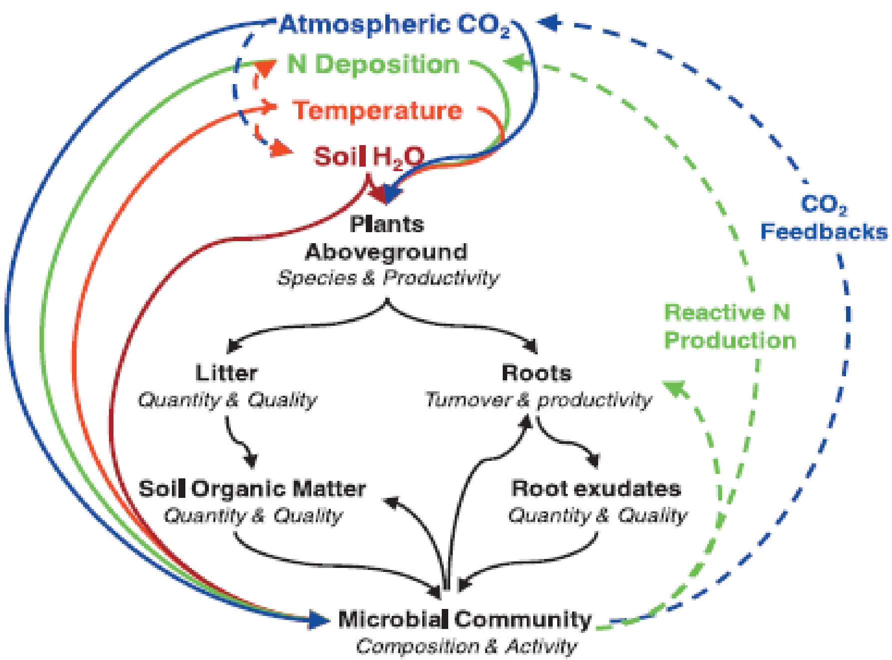
VALIDATE

ExpeER Ecosystem Research

Slides not used

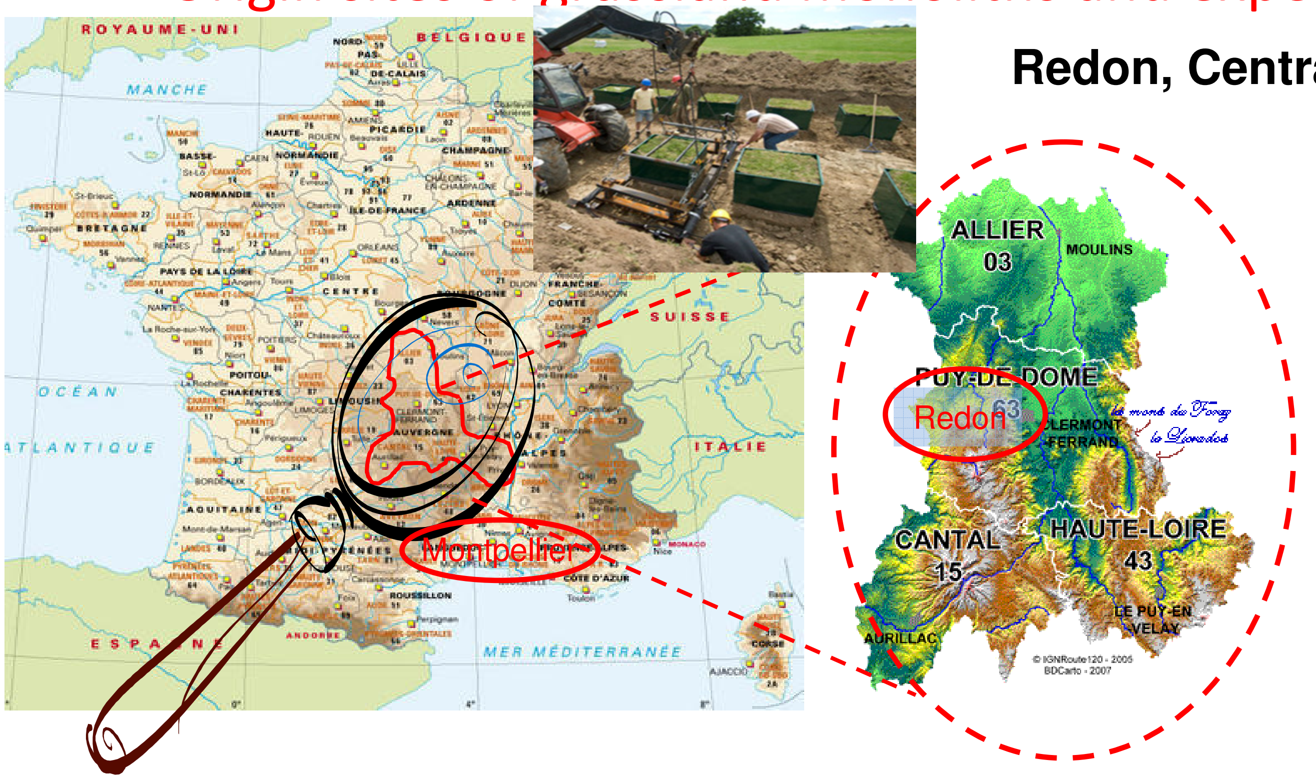


- Higher increase in air temperature in Southern Europe.
- Higher variability of air temperature in Central Europe.
- Higher frequency (1 out of 2 summer) of heat wave associated to summer drought as it has been in 2003.



- Climate drivers affect above- and below-ground processes
- Plants and microbial community act as feedback on climate, by affecting carbon and nutrient cycles
- In particular, below-ground processes act as feedback on atmospheric CO_2 concentration

Origin sites of grassland monoliths and experimental site



Redon, Central Massif, France

- Altitude: **850 m asl**
- **Forty-eight** monoliths (0,6 m^3) were allocated in 12 macrocosms at the **Ecotron of Montpellier**

- **Temperature, precipitation** and **atmospheric CO_2** were highly regulated

- **Carbon flux**, water lost for **evapotranspiration** and **soil moisture** and **temperature** were measured in continuous

- 4 weeks **Pre-treatment drought stress**, 50% of precipitation compared to precipitation rate forecasted for 2045

- 2 weeks **Drought stress**, 0% of precipitation compared to 2045 and

Air Temperature corresponding to **3.5 °C** higher than air temperature 2045

- 6 weeks **Recovery**, precipitation gradually reached the control.

Botanical composition

CV%VOL	nb monoli thes	% vol
Trifolium repens	55	**28.5**
Lolium perenne	54	**15.5**
Holcus lanatus	54	**13.6**
Agrostis capillaris	53	**5.9**
Alopecurus pratensis	49	**6.7**
Poa trivalis	42	3.8
Poa pratensis	35	2.2
Dactylis glomerata	32	3.8
Trisetum flavescens	26	5.0
Ranunculus acris	24	3.3
Rumex acetosa	16	3.4
Lathyrus pratense	14	6.0
Trifolium pratense	11	2.3

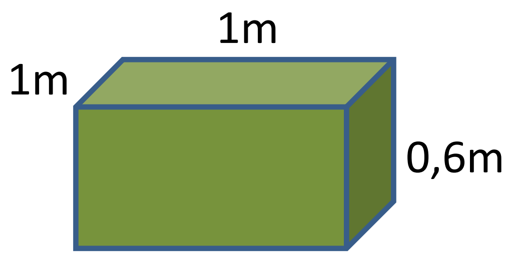
Botanical group	Grasses	Legume species	Non Fixing Dicot
A	**65**	**29**	**6**
B	**50**	**49**	**1**
C	**67**	**29**	**4**
D	**62**	**31**	**7**
Total	**61**	**35**	**5**

All 48 monoliths were screened for their botanical composition and separated in 4 botanical groups where the percentage in grasses, legumes species and non fixing dicotyledons were slightly different

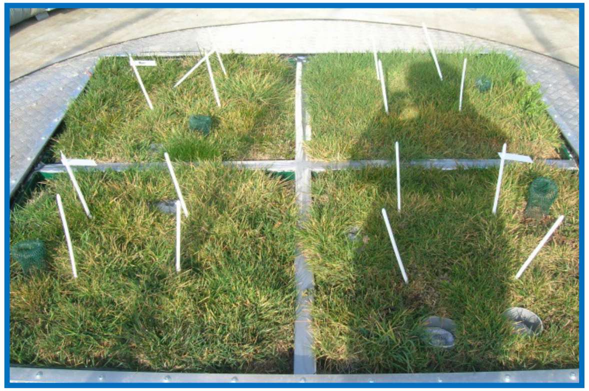
Materials and Methods: Plant material

Monolith area = 1 m^2

Monolith volume = 0,6 m^3



Materials and Methods: Ecotron of Montpellier



- The Ecotron consists of 12 units, called “macrocosms” of ??? m3.
- Each macrocosm is a gas tight unit where climate and atmospheric conditions can be regulated in continuous
- Ecophysiological parameters are measured in continuous

Parameters regulated at the Ecotron

- Air temperature
- Precipitation
- *Air Humidity*
- CO_2 concentration

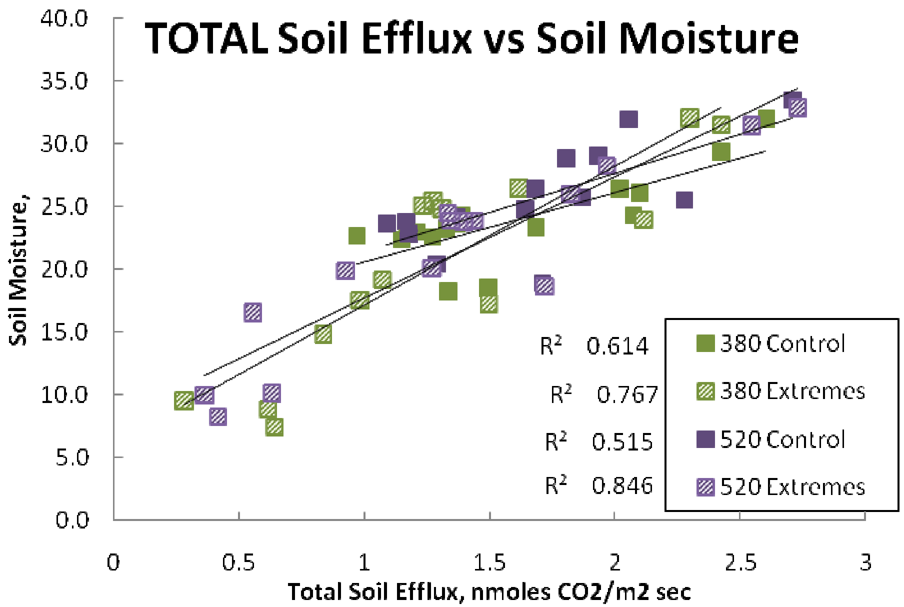
Parameters measured at the Ecotron

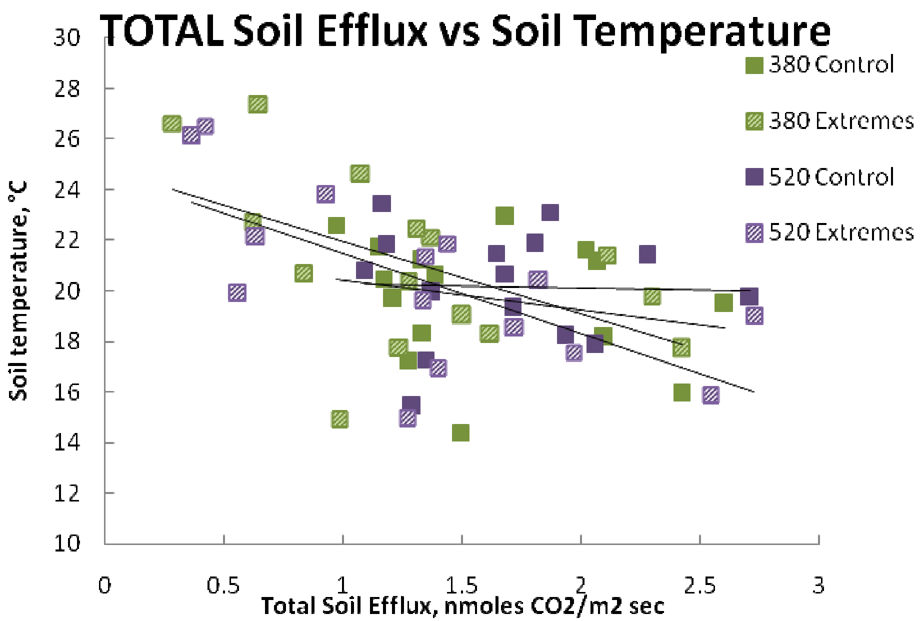
- Carbon uptake
- Water lost for evapotranspiration
- Soil Moisture and Temperature

In each macrocosms, 4 monoliths were allocated, one for each botanical group distinguished, for a total surface of $4m^2$.

Results: Total CO2 efflux and soil temperature and moisture at 7cm

- Positive relationship between soil humidity and total soil respiration.
- Relationships are stronger in extreme events than in control.

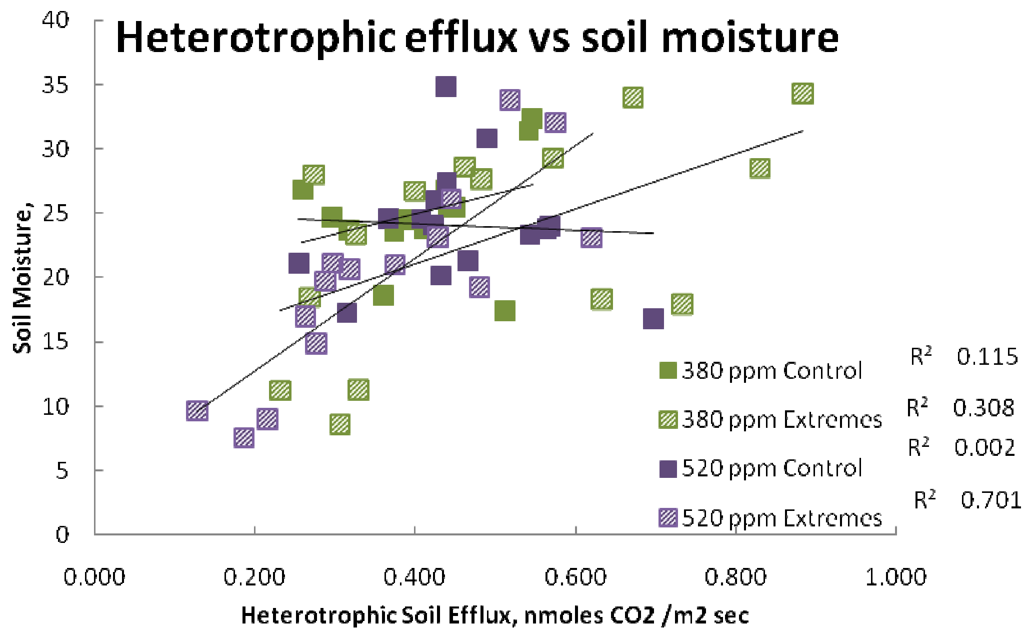


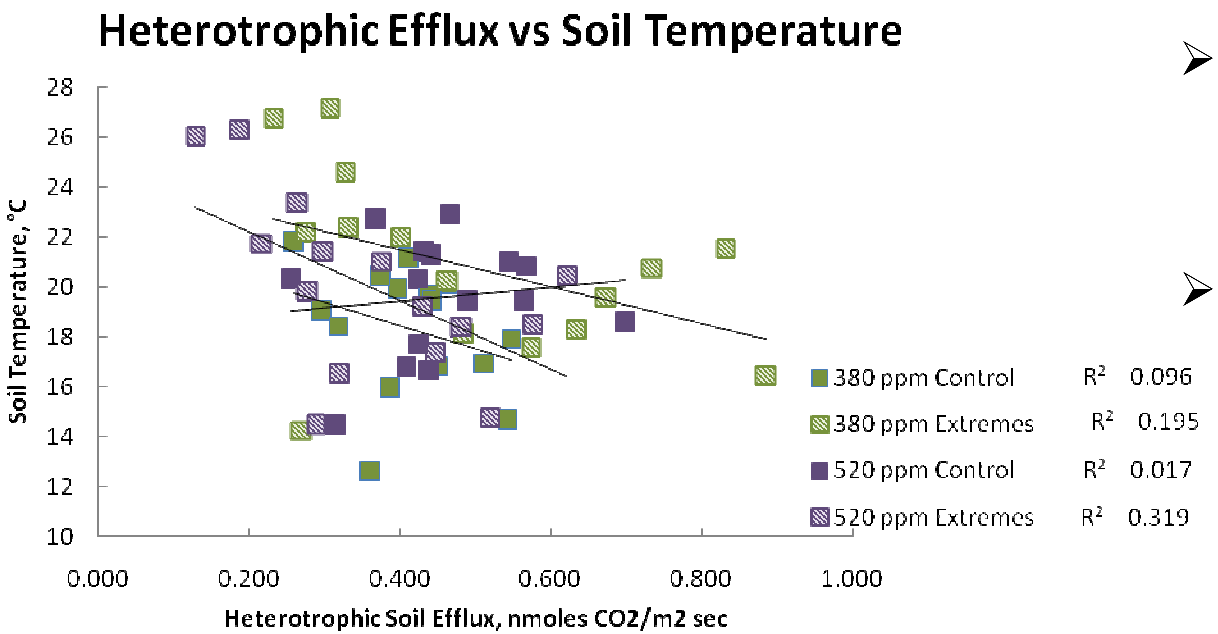


- Weak and negative relationship between temperature humidity and total soil respiration.
- Again relationships are stronger in extreme events than in control.

Results: Heterotrophic CO2 efflux and soil temperature and moisture at 7 cm (**eliminer**)

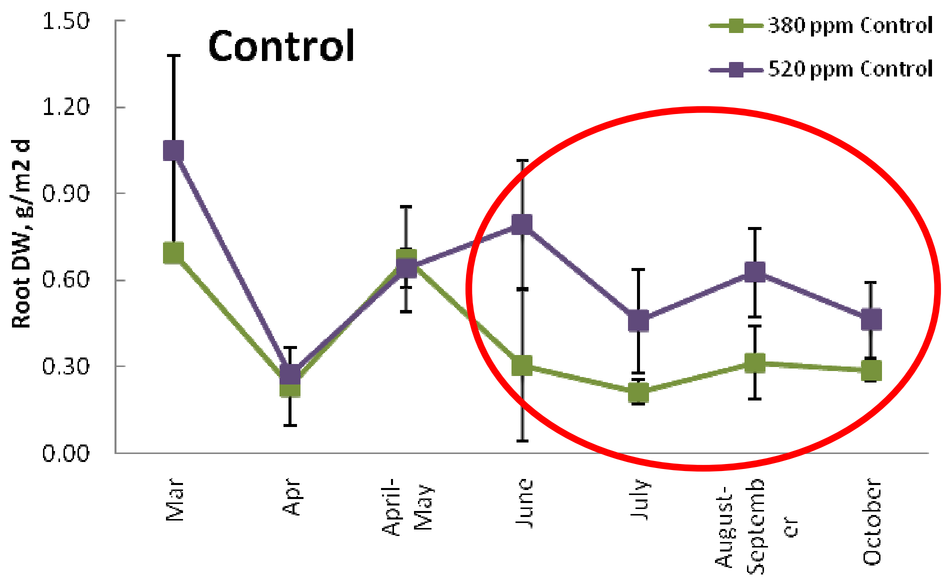
- Relationshisp between soil humidity and heterotrophic soil respiration have tendency to be positive.
- Relationships, as for total efflux, are stronger in extreme events than in control.





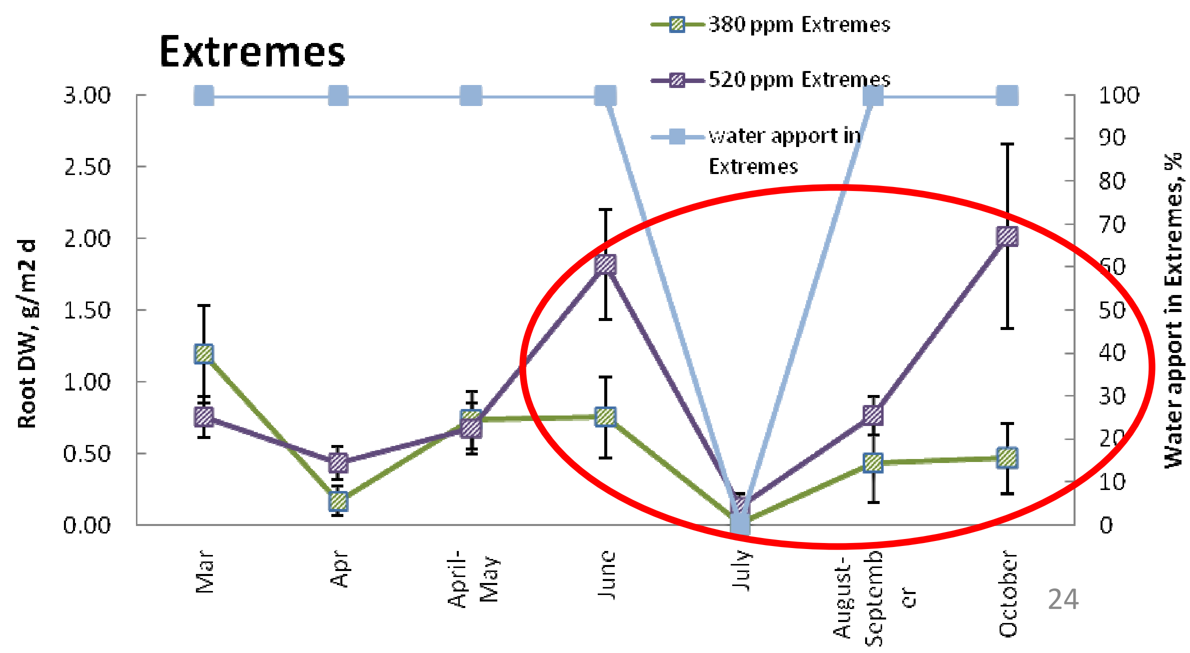
- Relationship between soil temperature and heterotrophic soil respiration have a negative tendency.
- Relationships, as for total efflux, are stronger in extreme events than in control, but still lower compared to the ones with soil moisture.

Root Growth Rate

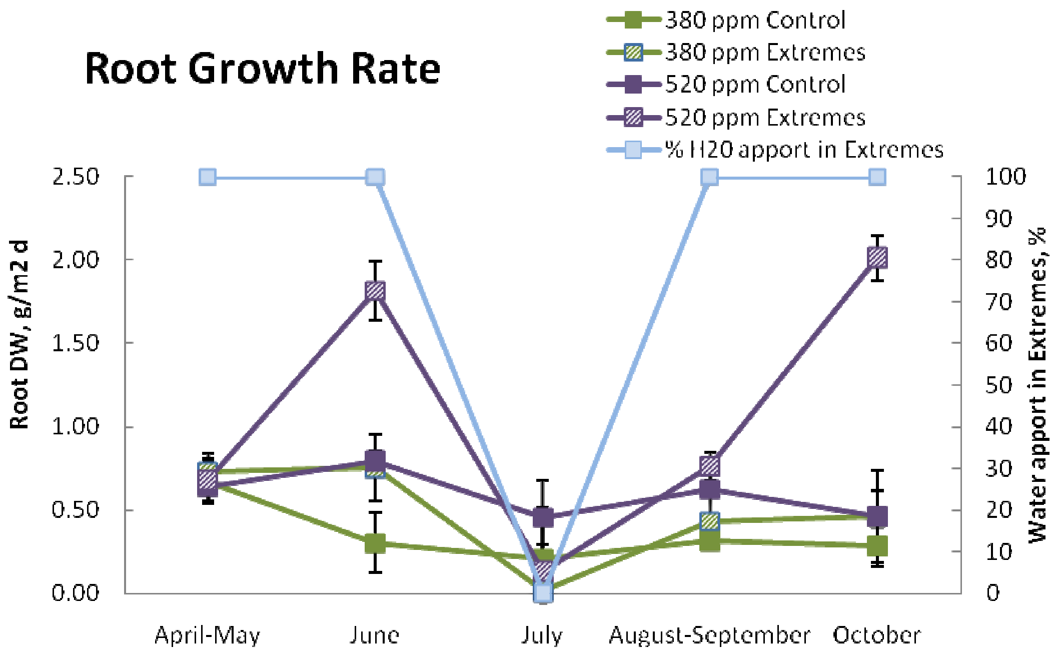


Root growth rate since 4 months beginning of CO_2 fumigation shows an increase in elevated CO_2 compared to ambient CO_2 both in control and extremes treatments.

During recovery from extreme events, root growth rate shows a significant increase in elevated CO_2 compared to ambient CO_2 (*consequent to higher above-ground biomass production*)

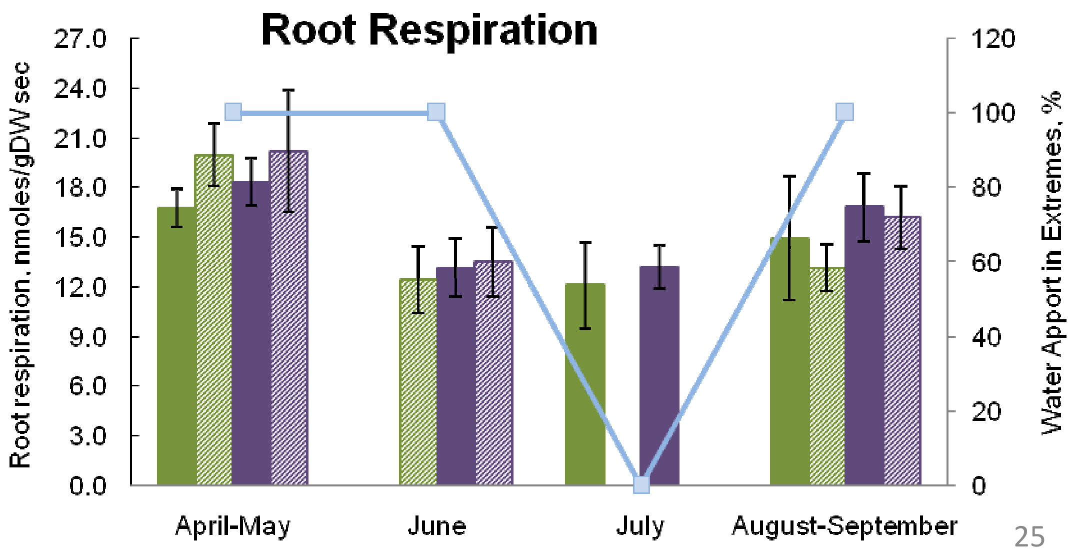


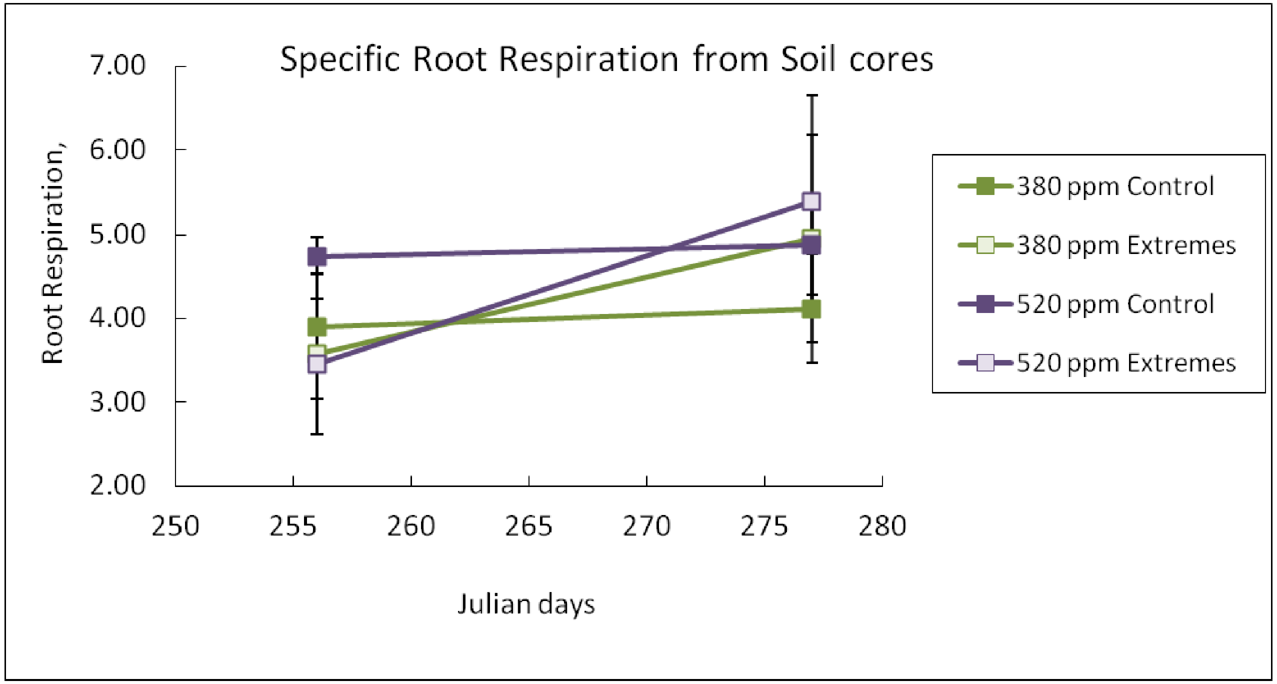
Root Respiration and Root Growth Rate

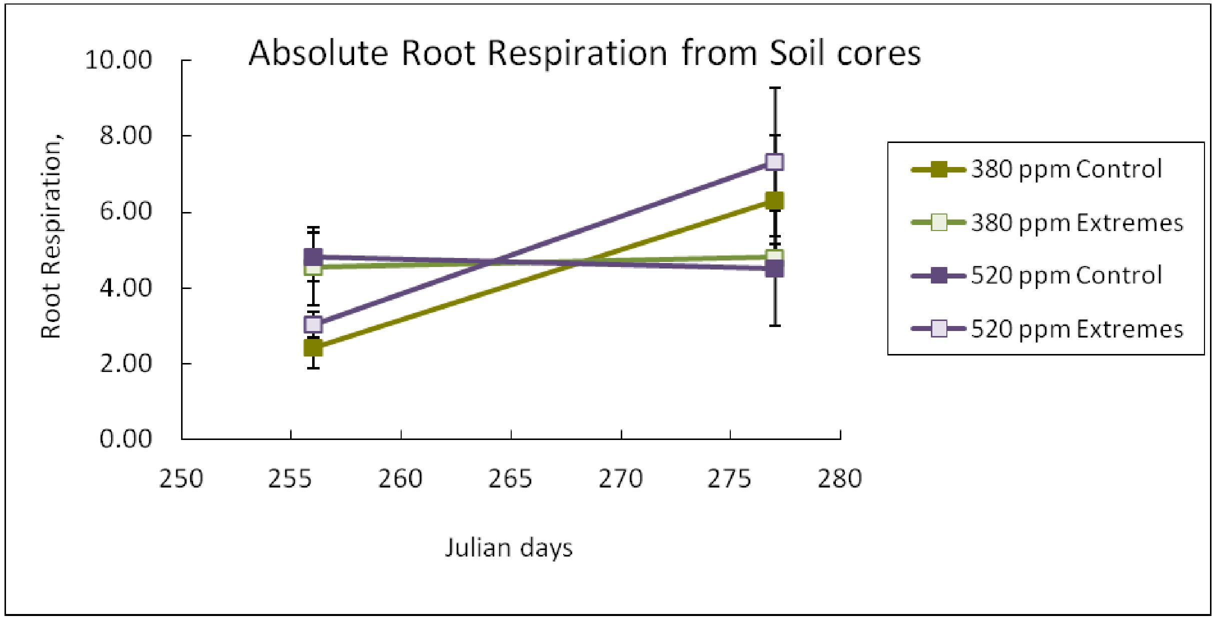


- During recovery from extreme events, root growth rate shows a significant increase in elevated CO2 compared to ambient CO2 (*consequent to higher above-ground biomass production*)

- It was not possible to measure root respiration during extreme treatments, due to the very low amount of root material.
- Anyway, during recovery, root respiration rate were comparable in extreme and control treatments.




Specific Root Respiration from Soil cores
Root Respiration,
7.00
6.00
5.00
4.00
3.00
2.00
250
255
260
265
270
275
280
Julian days
380 ppm Control
380 ppm Extremes
520 ppm Control
520 ppm Extremes


Absolute Root Respiration from Soil cores
Root Respiration,
10.00
8.00
6.00
4.00
2.00
0.00
250
255
260
265
270
275
280
Julian days
380 ppm Control
380 ppm Extremes
520 ppm Control
520 ppm Extremes