ESF Short Visit Grant – Scientific Report

CLIMMANI - Exchange Grant - 2849

Applicant: Wouter Dieleman, Research Group of Plant- and Vegetation Ecology, University of Antwerp, Belgium

Host: Claus Beier, Risø National Laboratory for Sustainable Energy, Roskilde, Denmark

1. Purpose of the visit

The ongoing changes in the global climate expose the world's ecosystems to increasing CO_2 concentrations and temperatures, but also to altered precipitation regimes. Current climate models generally indicate a tendency towards an intensification of the hydrological cycle, with wetter conditions in the tropics and at high latitude and further drying in subtropical regions. As water is one of the main abiotic variables influencing plant growth and biological processes, changes in soil water availability can interfere with plant productivity, soil structure, decomposition processes, and ultimately C balance of terrestrial ecosystems.

Several research projects have investigated the effects of changing amount and timing of rainfall, and length and intensity of drought. Their findings mainly indicated that rainfall variability is more important than the total amount of annual precipitation, and that interactions with other climate change drivers are not straightforward.

Earlier efforts to bring results of water manipulation experiments together were performed at the EPRECOT workshop (http://www.climaite.dk/eprecot/eprecot.html). The resulting database is available in Denmark. Another database containing results of climate manipulation experiments is available at the University of Antwerp. Both databases contain experimental results on plant growth and C cycling components.

The purpose of this exchange is to synchronize both databases, and to synthesize effects of water manipulations on plant growth, soil C cycling, and C balance of terrestrial ecosystems. Particular interest will be given to the length and intensity of drought events, and to the interaction of water manipulation with other climate change drivers in multifactor experiments.

2. Description of the work carried out

Data were partly provided by the NitroEurope database, and partly by a literature database on manipulation experiments.

The first week of the exchange visit was largely dedicated to exploration of the datasets. We chose to analyze water manipulation effects on soil respiration. A number of sites performed applied a drought, or irrigated their sites during experiments. Site info is listed in table 1.

Initially, three questions were raised, and preliminary analyses were performed to estimate whether these questions where feasible to answer with this dataset.

1. Is it possible to observe overall treatment effects based on annual data?
2. Can we find variables that determine the response of terrestrial ecosystems to changes in water availability?
3. Does the treatment have a similar effect during the entire duration of experiments? Is there an increasing/decreasing trend in the soil respiration response throughout several years of treatment?

Table 1: Description of the sites used in the analyses. MAP = Mean Annual Precipitation, MAT = Mean Annual Temperature.

Site Name	**Treatments**	**Experimental species**	**Country**	**MAP (mm)**	**MAT (°C)**
Bordeaux	FertilizationxWater	Pinus pinaster	France	983	13.2
Jasper Ridge FACE	CO2xFertilizationxWarmingxWater	California annual grassland	USA	677	19.3
Kessler Farm Field Laboratory	WarmingxWater	tallgrass prairie	USA	967	16.3
Palmer Station	WarmingxWater	tundra	Antarctica	750	-1.7
Savannah River	FertilizationxWater	Mixed tree stand	USA	1214	17.9
Brandjberg	CO2xWarmingxDrought	temperate heath	Denmark	600	8
Capo Caccia	Drought	Mediterranean shrubland	Italy	640	16.8
Clocaenog	Drought	Shrubland	UK	1675	9.2
Garraf	Drought	Mediterranean shrubland	Spain	455	15.1
Oldebroek	Drought	Atlantic heathland	The Netherlands	1042	10.1
SETRES	FertilizationxWater	Pinus taeda	USA	1210	17
Mols	Drought	Atlantic heathland	Denmark	758	9.4
Duolun	WarmingxWater	Temperate steppe	China	386	2.1
Heinola	FertilizationxWater	Picea abies	Finland		
Sahalahti	FertilizationxWater	Picea abies	Finland		
Kiskunsag	Drought	Atlantic heathland	Hungary	550	10.5
Santa Rosa	FertilizationxWater	Populus deltoides, Platanus occidentalis, Pinus taeda, Quercus falcata	USA	1700	19
Oak Ridge	CO2xWarmingxWater	Model grassland	USA	1322	14.3

3. Description of the main results

Question 1: Overall effects on annual basis.

Since water is essential for biological activity, it is not surprising that reducing water availability generally decreases soil respiration, and irrigation has a beneficial effect (Fig. 1). However, overall we could not observe an effect of water manipulations, because individual responses are too variable (Fig. 1).

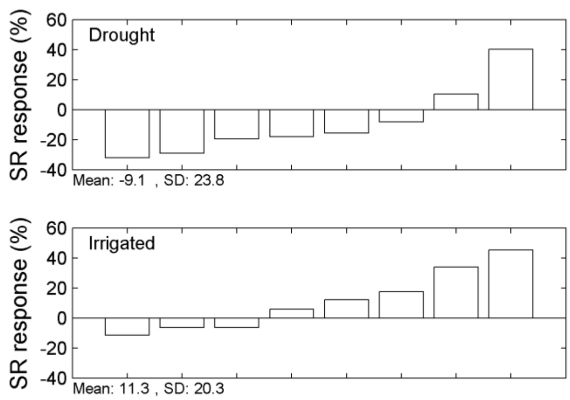

Fig. 1: All individual soil respiration responses included in the analysis. Data are separated by drought and irrigation experiments. Overall means and deviations are given below each figure.

Question 2: Can we find the variables that determine the response of terrestrial ecosystems to changes in water availability?

The large variability probably arises from site-specific differences depending on their location, e.g. initial water content, annual precipitation, capacity of the soil to hold water, soil temperature, organic content and inputs in the soil. As we had mean annual precipitation (MAP) data and some soil data available, the next step in our analysis was to plot the soil respiration responses against SWC response, MAP, and some indication for soil water holding capacity (i.e. % sand, clay, organic content).

The droughted sites demonstrated a significant relationship with the response of SWC (P=0.02, data not shown), indicating that larger differences in SWC elicit stronger soil respiration responses. However, more general, the same trends as in Fig. 1 can be observed in Fig. 2. Most of the droughted sites demonstrate negative soil respiration responses, while the irrigated ones demonstrate positive responses. Sites that deviate from this pattern likely would have distinct site-specific differences compared to the other sites. One of them could be the annual precipitation.

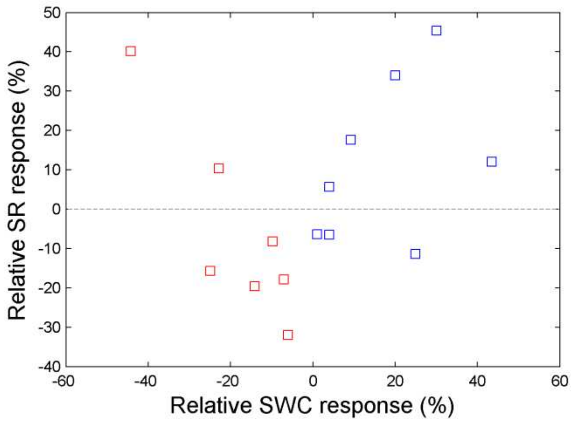

Fig. 2: The relative soil respiration response (treatment/ambient) plotted against the relative SWC response (treatment/ambient) at the respective sites. Red squares are drought manipulation sites, blue squares are irrigated sites.

However, no relationship was found between the soil respiration responses and MAP (Fig. 3). Drier sites seem to be more susceptible for water manipulation effects. At drier sites, water is limiting soil respiration, so adding water increases the soil respiration, while further decreasing available water in the soil depresses soil respiration. The wetter the site, the more soil respiration is limited by lack of oxygen for aerobe decomposition processes.

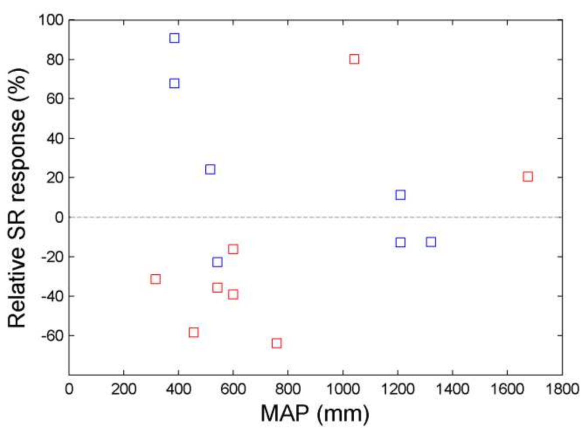

Fig. 3: The relative soil respiration response (treatment/ambient) plotted against the mean annual precipitation (MAP) at the respective sites. Red squares are drought manipulation sites, blue squares are irrigated sites.

A third factor is soil water holding capacity. Currently, we made a classification, more or less based on % sand (when available), and an estimation organic content. At sandy sites, drought treatment clearly reduced soil respiration and soil water content, while in the irrigated sites, water content was increased and soil respiration was not affected (Fig. 4). At the sites with higher soil water holding capacity, soil water content clearly decreased in droughted experiments, and soil respiration concomitantly increased. The irrigated experiments demonstrated a positive trend in both soil water content as soil respiration, but it was less conclusive than the response on droughted sites.

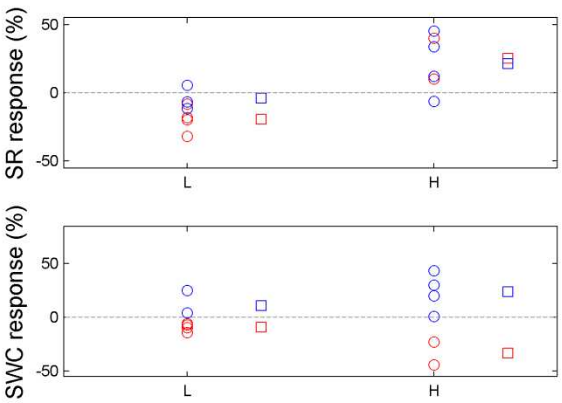

Fig. 4: The relative soil respiration response (treatment/ambient) at sandy sites (Low water holding capacity, L) and at sites with higher clay or organic C content (High water holding capacity, H) at the respective sites. Red circles are drought manipulation sites, blue circles are irrigated sites. Squares use the same color code, and represent mean values for droughted or irrigated sites.

None of the variables we investigated demonstrated a convincing relationship with the soil respiration responses to water manipulations. A combination of soil structure and MAP, however, did reveal a relationship (Fig. 5).

We can see that the most extreme responses are to be expected in low precipitation sites, both at low and high soil water holding capacity. At wetter sites, responses are far less pronounced, and soil respiration responses are similar in different soil types. This means that at dry and sandy sites, soil respiration will strongly be depressed by drought, while irrigation might have only a minor effect, since water washes out very rapidly. In contrast, at sites with organic or clayey soils, adding water would increase soil water for a longer period, allowing to be stimulated. In this case, soil respiration depends less on initial water content.

In conclusion, dry sites are most vulnerable to droughts, while soil structure is an important determinant in preserving longer-term water availability. The dataset should be expanded to test whether these patterns are to be generalized.

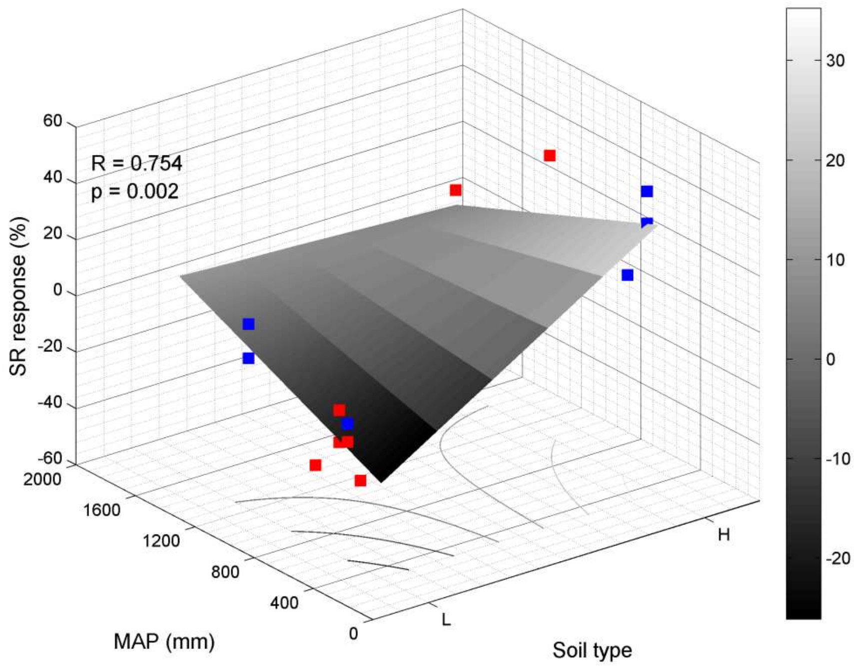

Fig. 5: The relative soil respiration response (treatment/ambient) at sandy sites (Low water holding capacity, L) and at sites with higher clay or organic C content (High water holding capacity, H), along an annual precipitation gradient at the respective sites. Red squares are drought manipulation sites, blue squares are irrigated sites. The mesh regression is a linear fit for the total dataset.

<u>Question 3: Duration effects</u>

While the previous analyses were based on means, calculated over multiple years of results (where available), we attempt to find out whether there are trends related to the length of the treatments. However, due to lack of data, we have to limit ourselves to the interpretation of data from 1 site only (Clocaenog (green symbols)).

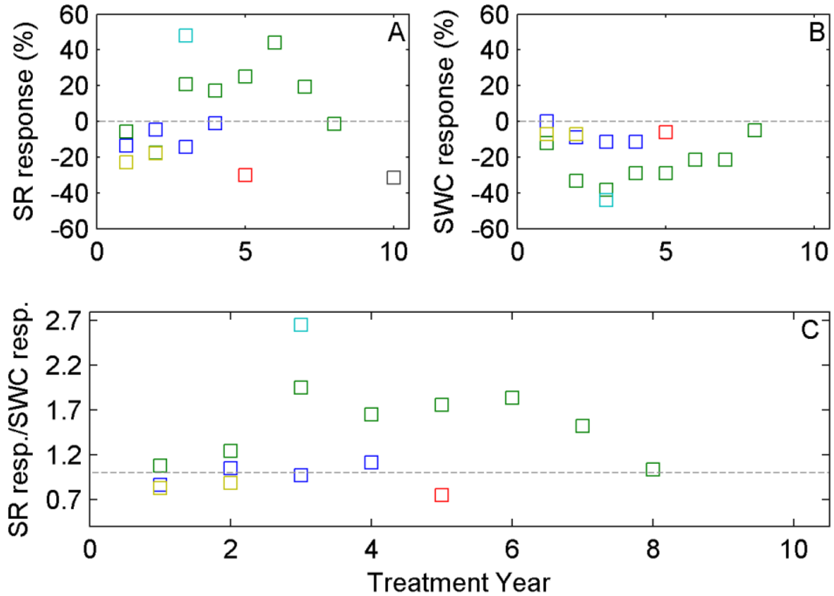

Fig. 6: Annual values for the soil respiration response (A), SWC response (B) and their ratio (C). Different symbols represent different sites. Data represent droughted sites only.

We can see that the larger part of the soil respiration response is explained by the SWC response (Fig. 6A-B). However, we still see a strong response in the early years of treatment, and an acclimation after 4 years of treatment (Fig. 6C). Since the Clocaenog site is a peaty site in a wet region, we might have expected a strong positive response as a consequence of drought, as aerobic decomposition processes might be stimulated by drying of an otherwise very wet soil. Therefore, once the soil is drying, there is enough substrate to be decomposed. Hence the strong soil respiration effect, unrelated to the change in SWC. The strong decrease in the last year of measurement is almost completely explained by the lack of change in SWC.

Overall too little data are available to make general conclusions on long-term drought effects.

4. Future collaboration

Future collaborations lie in the expansion of the dataset.

Data on organic C content, soil temperature and more precise data on soil structure will be gathered to further analyze what the driving factors in the soil respiration response to water manipulation are.

5. Projected publications/articles resulting from the grant

If the patterns found in these preliminary analyses are valid after expansion of the dataset.