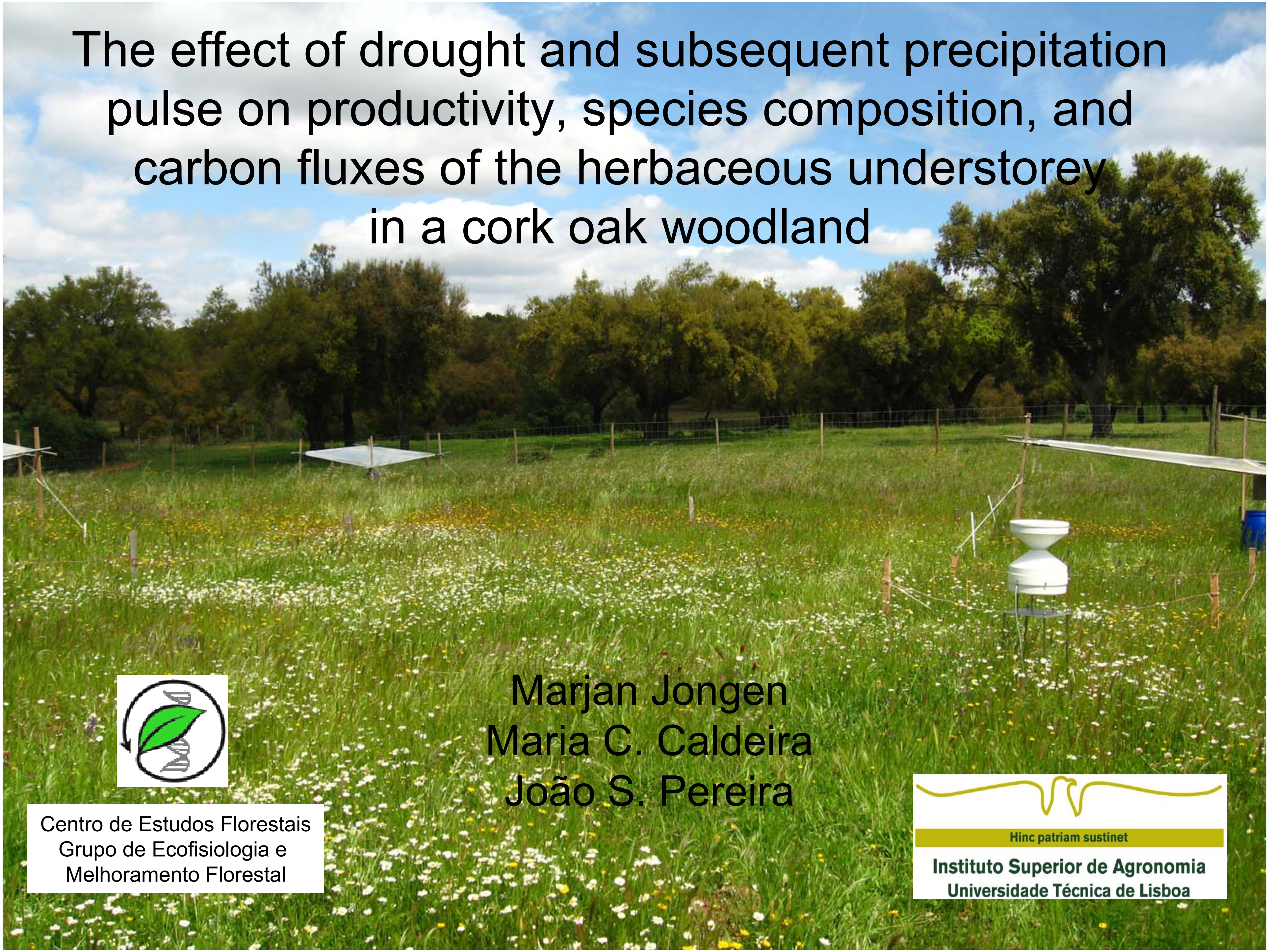
The effect of drought and subsequent precipitation pulse on productivity, species composition, and carbon fluxes of the herbaceous understorey in a cork oak woodland



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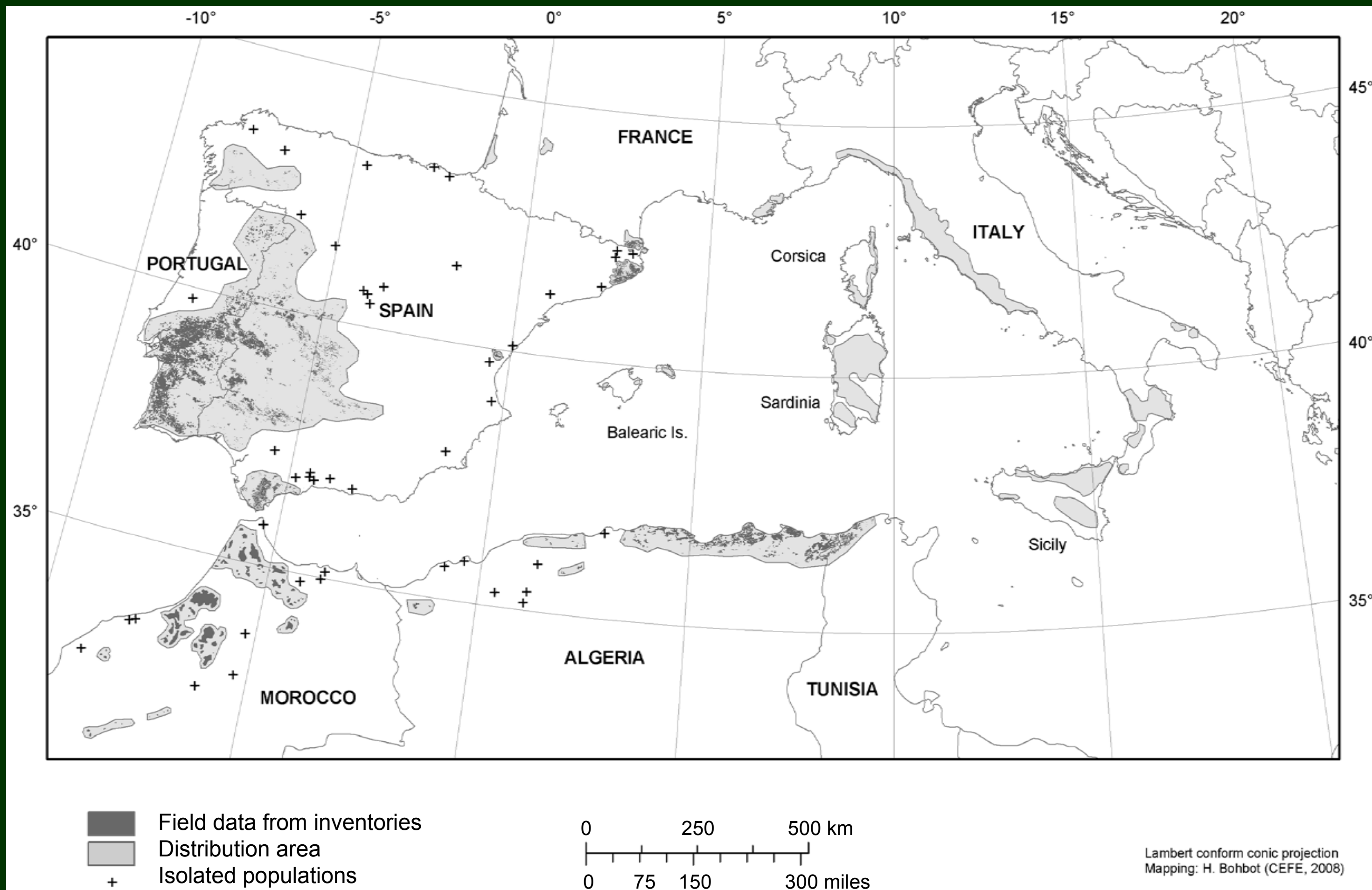
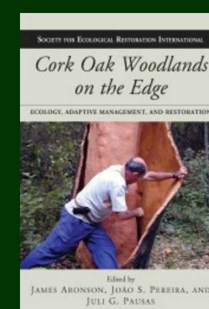
Montados
Distribution of *Quercus suber* (cork oak)



- In Mediterranean: 2.3 million hectares
- In Portugal: 750.000 hectares



Source: Aronson J, Pereira JS, Pausas JG (eds) (2009)

Info slide:

- The work presented here was carried out in a montado in Portugal. Montados are savanna-type ecosystems where *Quercus suber*, the cork oak, is the predominant species. These ecosystems cover nearly 2.3 million hectares in the western Mediterranean region. One can find them in Portugal and Spain, but also in Morocco, northern Algeria and Tunisia, the south of France, and Corsica and Sardinia.
- In Portugal, montados cover approx. 750,000 hectares, representing 23% of the Portuguese forests.
- Montados play an important ecological role in carbon sequestration, water retention and soil conservation, the latter being important for combating desertification.

Montados
high biodiversity

Iberian imperial eagle (*Aquila adalbert*)

Iberian lynx (*Lynx pardinus*)


Photo courtesy markdowe.files.wordpress.com


Photo courtesy www.animalesextincion.es

Black stork (*Cicconia nigra*)


Photo courtesy www.mlahanas.de

plant biodiversity


Photo courtesy www.azenhadoramalho.com

Info slide:

- Biodiversity in montado ecosystems is high, in both flora and fauna. Montados are habitats for several endangered species such as the Iberian lynx (*Lynx pardinus*), the Iberian Imperial Eagle (*Aquila adalberti*) and the Black stork (*Cicconia nigra).*
- Plant diversity can reach over 100 species in plots of 0.1 ha, many with aromatic, culinary or medicinal value, although plant diversity depends, among others, on agricultural practices.

Montados
multifunctional ecosystems

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(1) forestry

(2) pastures for grazing

(3) agricultural cultivation

Info slide:

- Montados form an agro-silvo-pastoral system; they are multifunctional ecosystems. Their main function is forestry, with the production of cork as the main objective. As well, the pastures provide grazing for sheep or cattle, or for both. They may also be used for agricultural cultivation, for example of wheat, barley or oats.
- Thus, this ecosystem is comprised of two distinct ecological niches; one located beneath the tree canopy, composed of the oak tree and its associated herbaceous stratum, and a second one located outside the tree canopy, composed of herbaceous plants alone.
- This herbaceous layer plays an important role in ecosystem functioning. For example, legumes are an important source of nitrogen for the ecosystem. Since soils are generally poor in nitrogen. It has also been shown that the herbaceous layer plays an important role in the carbon sequestration capacity of this ecosystem, as a result of its large leaf area index during the spring growth.
- Therefore our research interest is to study the impact of future climate change scenarios on the herbaceous understory.

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Climate change

Climate change scenarios suggest:

- rise in temperature between 2°C to 4.5°C
- reduced precipitation in spring → longer dry season
- higher frequency of extreme events

Info slide:

- What do climate change scenarios say for the Mediterranean region? First of all, the impact of climate change is expected to be high. Scenarios predict a rise in temperature, between 2 and 4.5˚C, and a decrease in spring precipitation. This will result in a longer dry season, which will affect the plant photosynthetic capacity, leading to reduced primary production. Also, senescence of annual plants, which constitute the majority of the herbaceous layer, could occur earlier.
- In addition, the frequency of extreme events is expected to increase, including drought events, heat waves and floods.

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Objectives

- Effect of induced drought during the growing period on productivity and C and N dynamics
- Effect of extreme event (precipitation pulse) on soil respiration and microbial activity

Info slide:

- The objectives of our study were twofold. First, we wanted to gather data on the effects of an induced drought during the growing period on productivity and on carbon and nitrogen dynamics
- The induced drought was followed by an extreme event, a precipitation pulse. Our second objective was to study the effect of this precipitation pulse on soil respiration and microbial activity.

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Experimental set-up

- Improved pasture in montado
- Fenced area, excluding grazing since November 2006
- Mean annual temperature: 15.5˚C
- Mean annual precipitation: 700 mm

Info slide:

- The experiment was conducted in a montado ecosystem in Montemor, which is about 100 km east of Lisbon. The site is an improved montado, which means that a few years prior to the experiment the field was rotavated and reseeded with a legume-rich mixture. Subsequently, the montado was grazed by cattle and sheep. However, one year prior to the experiment, the site was fenced, to exclude grazing.
- The climate at the study site is Mediterranean, with hot summers and mild winters. Mean annual temperature is 15.5˚C, and average precipitation is approx. 700 mm, with most of the precipitation being confined to the period between October and May. The beginning of the growing season depends on the timing of the first precipitation in autumn, which is followed by rapid growth. The understorey vegetation is thus active in winter and early spring, with senescence starting generally in May.

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Experimental set-up

- 5 control plots
- 5 plots with rain exclusion
- size rainout shelter:
  2.5 m x 2.5 m
- polyethyleen cover:
  approx. 12% reduction of PAR

Info slide:

- The experimental set-up consists of 5 control plots and 5 exclusion plots with a rainout shelter. The shelters were 2.5 by 2.5 m, and provide a means of controlling the input of water. They were fabricated using polyethylene material. The effect of the shelter on temperature was negligible. However, the shelters decreased PAR levels by approx. 12%.

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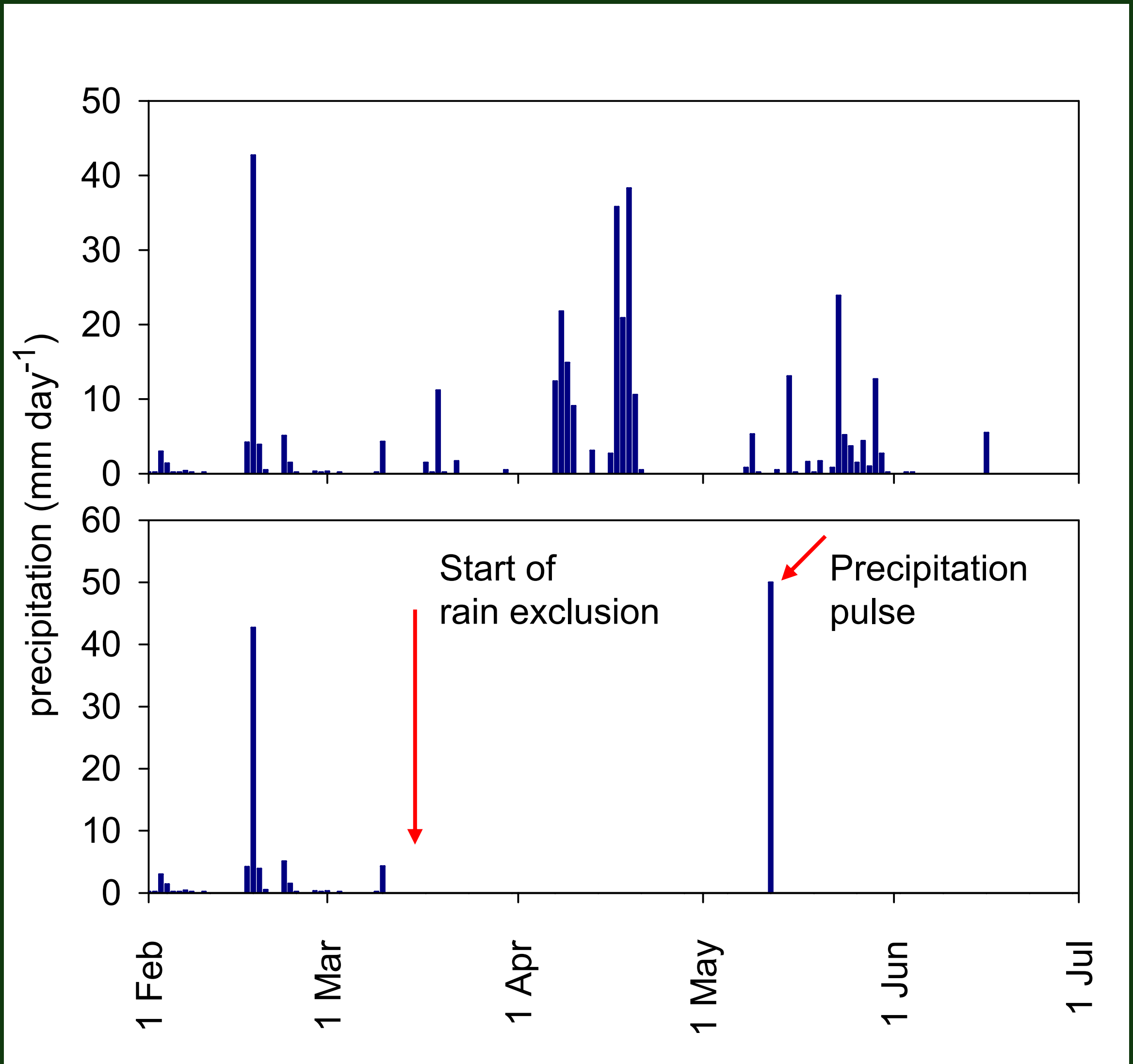
Experimental set-up



Control plots

Rain exclusion plots

- precipitation excluded from 17 March – 28 June: 273 mm
- precipitation pulse on 12 May: 50 mm

Info slide:

- In the upper graph you see the pattern of natural precipitation over the course of the study, this being the water received by the control plots. Up till the start of the rain exclusion, both control and exclusion plots received a total of 330 mm since the autumn of the previous year, which marks the beginning of the growth of this vegetation. Rain exclusion started on the 17th of March, and control plots received a total of 273 mm of precipitation until the end of June. Exclusion plots only received a precipitation pulse of 50 mm on the 12th of May.
- The rainout shelters were in place from the 17th of March until the 28th of June. During this period, natural precipitation was excluded from these plots, with the exception of the 12th of May, when these plots received a precipitation pulse of 50 mm.

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Measurements

- Soil water content

- Biomass

- Species composition

- Soil respiration

- Microbial activity (0-10 cm)

- Soil nitrogen content (0-10 cm)

Info slide:

What measurements did we take?

- Soil water content was measured at weekly intervals at several depths using a PR1 system.
- Biomass was measured within quadrats of 40 by 40 cm, taken at the beginning and at the end of the experiment. All aboveground biomass was harvested and separated into species, and green and senescent material. Belowground biomass was measured in May using a root corer.
- Point-quadrat measurements were taken for estimation of species composition.
- Soil respiration was measured at weekly intervals using PP systems equipment.
- Microbial activity was measured at several times. Soil was incubated for approx. 6 weeks at 25˚C, and microbial activity was calculated from the amount of CO2 taken up by a cylinder of NaOH, at weekly intervals.
- Soil nitrogen content was calculated using an extraction method in KCl.

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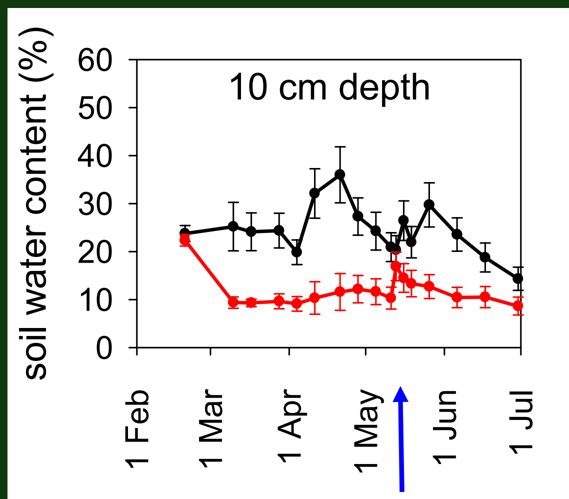
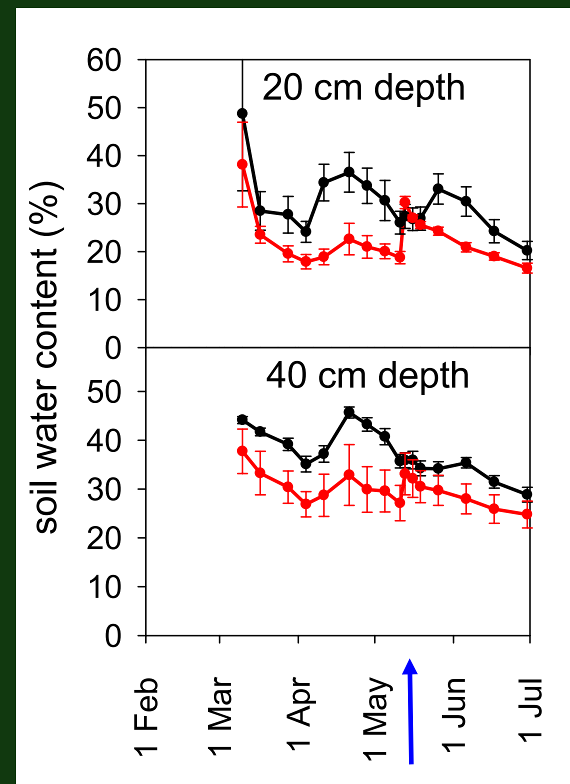
Results

Soil water content



Precipitation
pulse



Precipitation
pulse

control
exclusion

Info slide:

- Soil water content in the control plots reflects natural precipitation patterns. In the middle of April and during the second half of May there is substantial rainfall, and soil water content rises to approx. 30-35% at 10 cm depth.
- In the rain exclusion plots soil water content decreases rapidly to approx. 10%. The precipitation pulse given in the middle of May increases soil water content to 16%, but three weeks later it is back to 10%.
- The precipitation pulse can still be detected at a depth of 40 cm, although again the effect of the pulse lasts only about 3 weeks.

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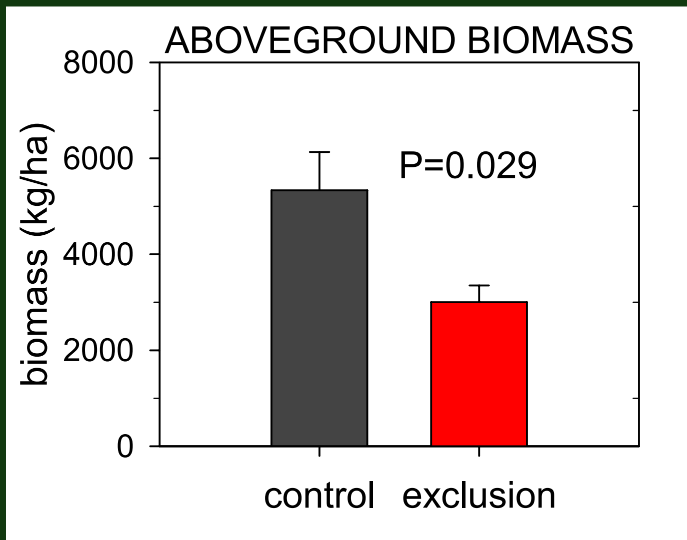
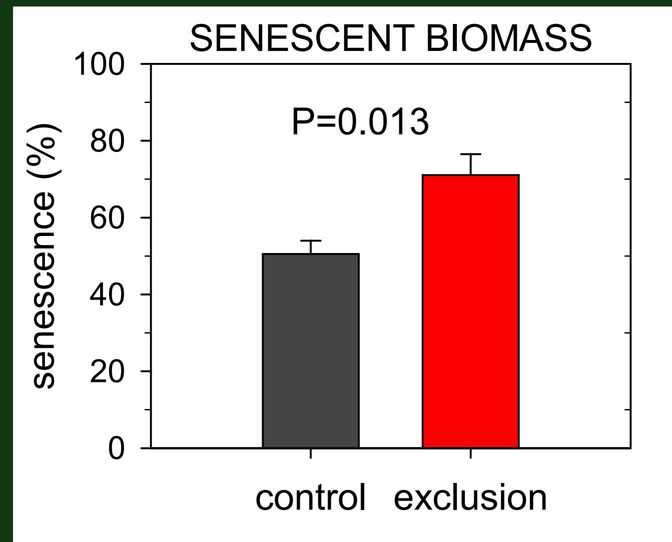
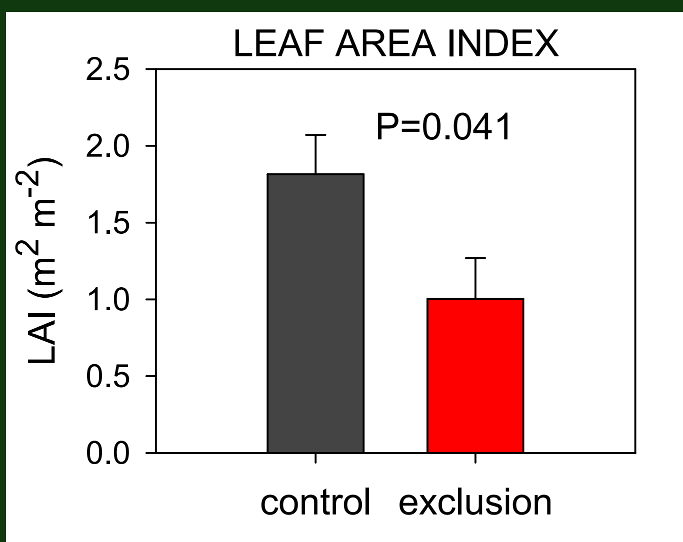
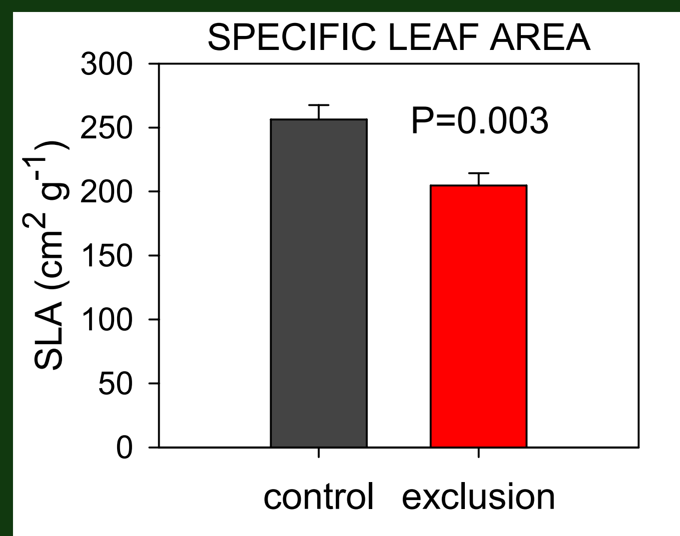
Biomass









Info slide:

- As this montado is an improved montado, productivity is expected to be high. At the beginning of the experiment, in the middle of March, biomass was approx. 1250 kg/ha, increasing in the control plots to 5300 kg/ha in June. For a montado ecosystem, this is indeed a high productivity, reflecting the favorable soil properties. In the exclusion plots, aboveground biomass was significantly lower, with 3000 kg/ha in June. Senescence on the other hand was significantly higher in the exclusion plots, increasing from 51 to 71%.
- Leaf area index at the time of the precipitation pulse was significantly higher in the control plots, with values of 1.8 m^2 m^{-2} as compared to the 1 m^2 m^{-2} in the exclusion plots.
- However, specific leaf area, an indicator of leaf thickness, was lower in the plots exposed to drought. This decrease of SLA under drought conditions is a common finding, and is assumed to be a way to improve water use efficiency. Thicker leaves usually have a higher density of chlorophyll and, hence, have a greater photosynthetic capacity than thinner leaves.

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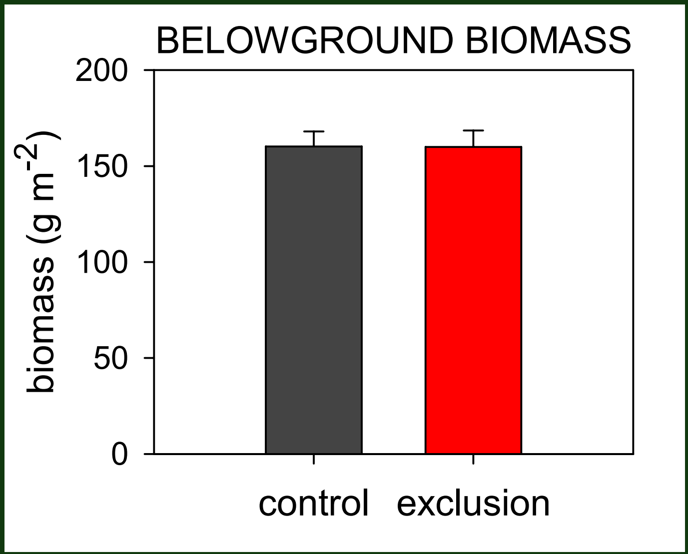
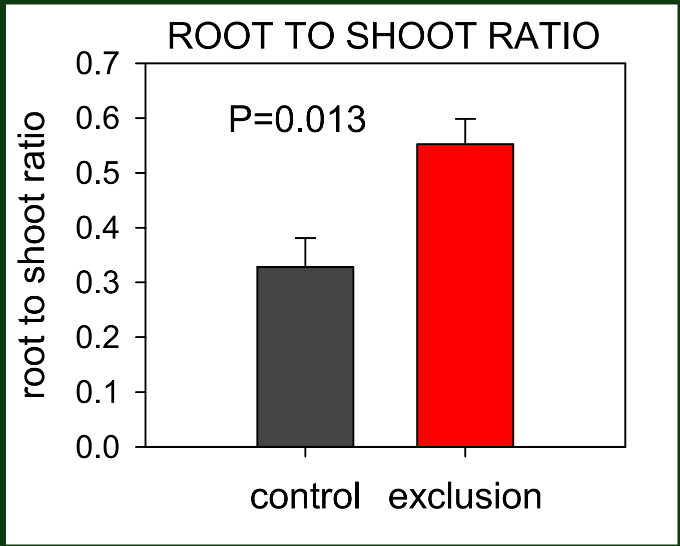
Biomass





Info slide:

- Belowground biomass was not affected by the drought treatment. However, root to shoot ratio was significantly higher in the exclusion plots. This change in the allocation pattern - increasing root to shoot ratio under water limiting conditions - has been frequently observed and is involved in the adaptation of plants to drought stress.

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Species diversity

Shannon (H´) diversity index

	February	May
control	1.27 ± 0.07	1.28 ± 0.04
exclusion	1.16 ± 0.07	1.06 ± 0.05
	P=0.125	P=0.045

Similarity index – coefficient of Czekanowski

	February	May
C-E	87.62	81.62

P=0.055

Info slide:

- Species composition was assessed in February and May. In February, the Shannon diversity index showed no significant difference between the control and the exclusion plots. However, in May diversity in the exclusion plots was significantly lower as compared to the control plots.
- The Czekanowski similarity index, which calculates similarity according to the abundance of species, was calculated in February and May. The results show that the control and exclusion plots are more similar to each other in February than they are in May. Thus, in May, there was a bigger difference between the vegetation in the control and exclusion plots, as a result of the induced drought.

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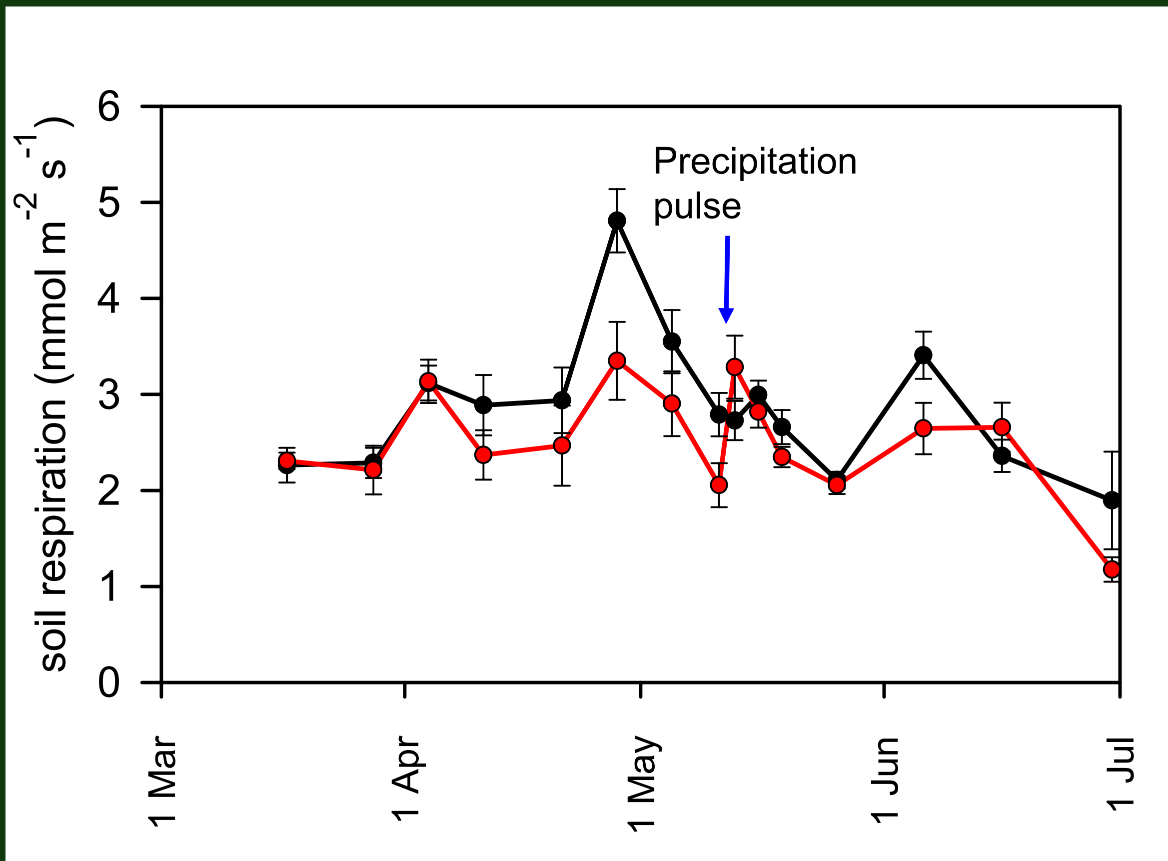
Soil respiration



control
exclusion

Info slide:

- This graph shows soil respiration over the course of the study. Overall, soil respiration followed the course of available soil water and it was higher in the control plots as compared to the exclusion plots. During the first month, soil respiration increased in all plots as a result of increasing temperatures, as soil water was not limiting. However, in April, soil respiration in the exclusion plots was lower, as water was limiting. After the rain pulse in May, soil respiration in the exclusion plots increased and was higher than respiration in the control plots, although only for a few days. Towards the end of the study, soil respiration in all plots decreased as water became a limiting factor, also in the control plots.

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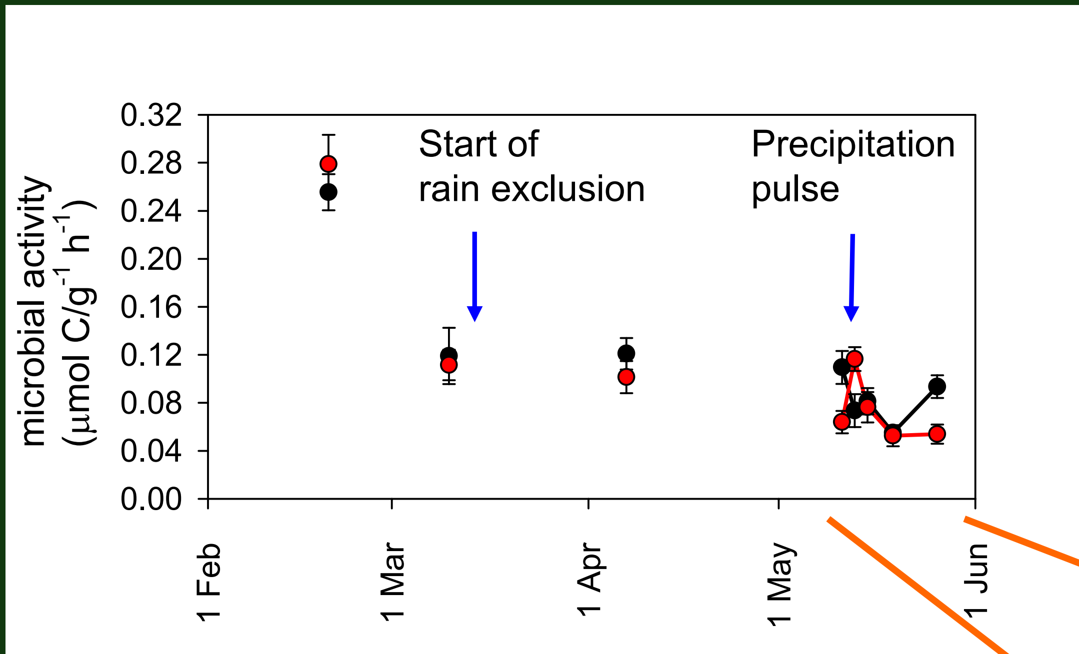
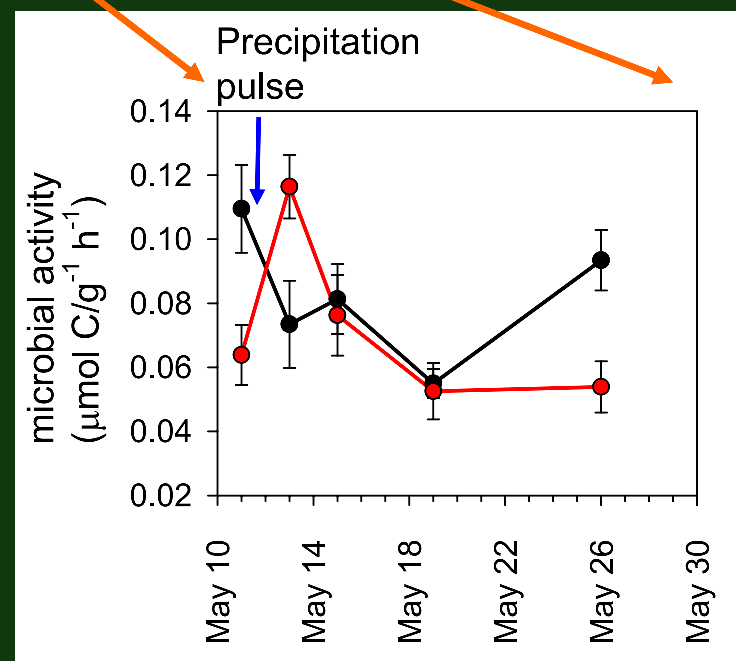
Microbial activity



control
exclusion



Info slide:

- Microbial activity over the course of the study decreased, as microbial activity depends on soil water content, which decreases. Just before the precipitation pulse, microbial activity in the exclusion plots lower, and shows a sharp increase after the rain pulse on the 12th of May. However, this enhanced activity is only maintained for about one week, and microbial activity around 19th of May is back at pre-pulse levels. The increase in the control plots at the end of May is the result of a lot of rain at that time.

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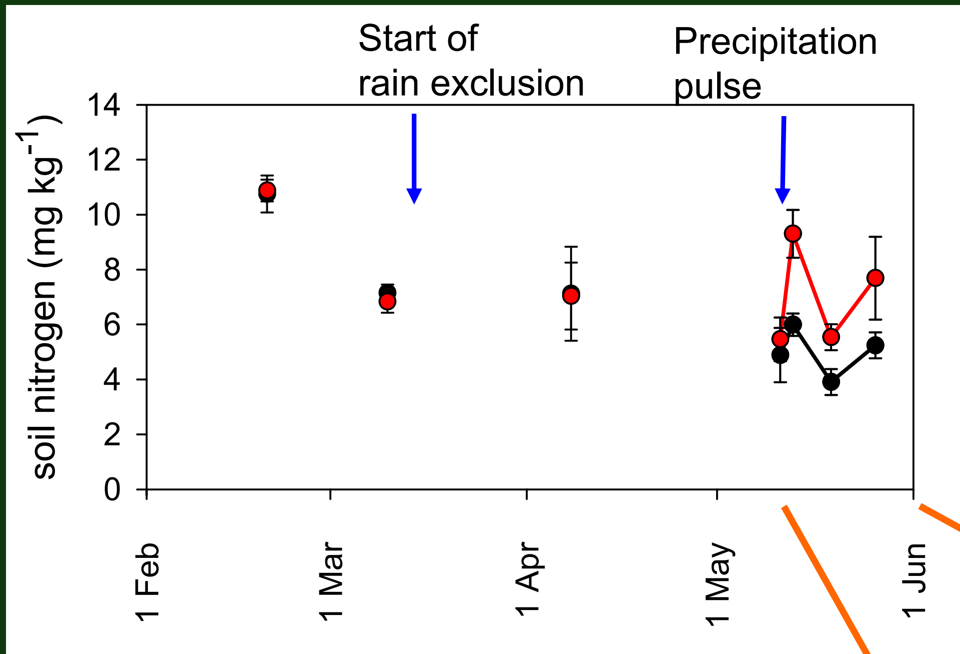
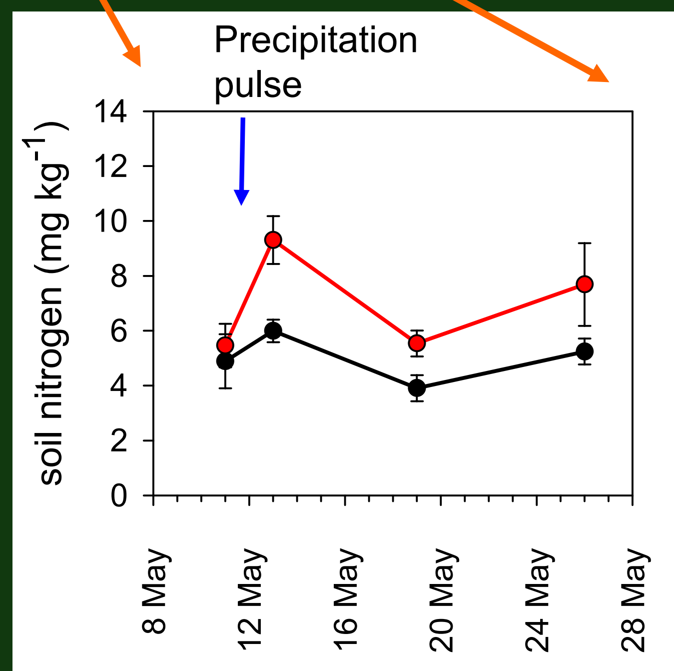
Soil nitrogen





Info slide:

- During the induced drought period, soil nitrogen in the control and exclusion plots was not significantly different. Immediately after the rain pulse, soil nitrogen in the exclusion plots increases sharply. As with microbial activity, soil nitrogen is back at pre-pulse levels after a week.

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Conclusions

induced drought

↓

soil water availability ↓

↓

N mobililization and availability ↓

→ biomass ↓

Info slide:

- From this experiment we can conclude that an induced drought reduces soil water content, which in turn directly affects aboveground productivity, with a decrease in biomass. In addition, the reduced soil water content affects nitrogen mobilization and availability, thereby indirectly, and negatively affecting biomass

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Conclusions

precipitation pulse

↓

pulse of N mobilization and availability

↓

phenology too advanced for plants to take advantage of increased N

Info slide:

- The precipitation pulse increased soil respiration, microbial activity and soil nitrogen. There was a pulse of N mobilization and availability, often referred to as the Birch-effect. However, the plants could not take full advantage of the enhanced nitrogen availability, since phenology was at an advanced stage, with 38% of the biomass senescent at the time of the precipitation pulse.

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February 2004

February 2005

Info slide:

- I want to finish off, with showing you these satellite images of Portugal, taken in February of 2004 and February 2005, which clearly show the effect of the extreme drought that affected Europe in 2005. In 2004, the green of Portugal's forests and fields can be clearly seen, but this is missing from an image in 2005, and the livestock and agricultural losses were pretty devastating. Our results show that unfortunately, we might be able to see more images like this with future climate change.

Acknowledgements

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