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Drought effects on ecosystem functioning and interactions with CO2 and warming – results from CLIMAITE

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Current predictions indicate that, unless greenhouse gas emissions are significantly curtailed, atmospheric CO2 concentrations will double during the present century inducing an additional 1.4 to 5.8oC increase in mean global temperature, alterations in global and regional precipitation patterns, and increase the frequency and magnitude of severe weather events (e.g. droughts and floods). Such changes will have strong effects on the terrestrial ecosystems as CO2, temperature and water are main drivers in ecosystem processes.

There is growing concern that climate driven changes in precipitation patterns and water availability will have significant effects on ecosystem processes and functioning, and in some regions may be the most influential climate change factor. Yet, it has received much less attention in recent climate change research relative to elevated CO2 and temperature. Furthermore, most precipitation experiments have focussed on water alone despite the fact that at least CO2 and temperature will change simultaneously and both of these factors will have direct or indirect effects on water status and use in the ecosystem.
In the CLIMAITE project a Danish heathland has been exposed since 2005 to elevated CO2, temperature and extended drought in a full factorial experiment (Mikkelsen et al., 2008). The CO2 concentration in the canopy level is elevated by 50% by the Free Air Carbon Enrichment (FACE) technique, temperature is elevated by 1-2 °C by the passive night time warming technique and summer drought is extended for 4-6 weeks by rain out shelters. The full factor combination mimics recent climate projections for Denmark 2075. Following the experiments, responses of major ecosystem processes and functioning is recorded.
Drought generally leads to hypothesised reductions in most ecosystem processes during and shortly after the drought but on the short term, many of these processes also show a strong potential to recover during rewetting. Drought reduces both processes responsible for inputs and outputs of carbon with an overall effect of drought reducing the carbon gain in the ecosystem. Long term changes in rewetting capability observed in other drought studies (Sowerby et al., 2009) are not visible in the CLIMAITE experiment yet.
Elevated CO2 improves the water use efficiency and thereby reduces the water use and water stress in the ecosystem during droughts. Consequently, a higher plant growth and carbon gain can be maintained during dry periods. Higher water status during dry periods might also stimulate carbon turnover by microbes, but this effect is, at least on the short term less prominent than the effect on plant growth and CO2 in combination with drought seemed to stimulate ecosystem carbon gain. Increased temperature may amplify reduced water availability by stimulating evapotranspiration, and the responses in CLIMAITE generally support this with reduced plant growth and carbon uptake in plants when temperature and drought was combined. Furthermore, it might be expected that elevated temperature stimulates soil carbon mineralisation leading to an overall reduction in ecosystem carbon gain when the ecosystem is exposed to both warming and drought. However, the short term results from CLIMAITE are inconclusive on this point with generally small and varied responses to warming.
The full factorial experiment shows clear interactions among factors and simple precipitation change experiments may not provide a valid picture of the responses to the combined climate change scenario, even at the short term. On the longer term more complex interactions may occur and make prediction even more uncertain. In relation to water this may in particular be linked to long term changes in soil structure and microbial biomass as well as

changes in plant species composition leading to dominating plants with better opportunities to deal with either limited or fluctuating water availability. The CLIMAITE studies support emerging ideas that increased complexity seems to reduce effects size.