

Claus Beier: *Vulnerability of European Shrublands to Climate Change*

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Shrublands are important ecosystems as they are vulnerable to climate change. Their key ecosystem services include drinking water, climate feedback, soil fertility and biodiversity. Many studies focus on biogeochemistry and there is a lack of biodiversity research.

Climate change affects key biological processes, ecosystem functioning and services, however it is difficult to study as there are three main interacting factors (CO₂, temperature and precipitation). There are also difficulties simulating how systems will react in the future. This may be overcome by “substituting time for space” i.e. by using a gradient of study sites which have conditions that we believe will be similar to those we expect in the future.

CLIMEX: This was a greenhouse experiment built in an arboreal forest in Norway in which the temperature was increased by 3-5°C. The ecosystem was found to switch from a nitrogen sink to a nitrogen source. This demonstrated that climate change has the potential to affect the nitrogen cycle and have impacts on drinking water quality.

VULCAN: A climate change experiment conducted along an environmental gradient across several European countries (E-W-gradient = rainfall gradient; N-S-gradient = temperature gradient). Experimental plots were created using a series of retractable covers.

N deposition was found to be related to N leaching, warming increased leaching in “N-polluted sites” (Netherlands), i.e. climate change has the potential to affect drinking water, but the effects depend on the background N levels. The response to climate change vulnerability is also dependent on nutrient availability i.e. Progressive Nutrient Limitation (PNL).

Warming experiments showed differences in biodiversity (site specific) and composition changes, whereas the differences are seasonal as well as annual. Furthermore, a loss of species in Spain occurred, but there is potential to recruit new species. Climate change has also the potential to affect phenology – plants that can take advantage of an early spring may become dominant. Herbivory responds to warming (goes up with temperature), possibly because of an increase in N in plants. This is an important secondary effect of climate change and highly species specific.

Carbon Balance: The carbon balance of an ecosystem is determined by the interaction of soil respiration and biomass uptake. Which factor is affected most strongly will determine whether the ecosystem will become a source or a sink.

Soil respiration was found to be sensitive to warming, and to be more sensitive at the colder sites (at northern sites = increased C loss, at southern sites = decreased C loss), the response was not equally strong at all sites.

It was expected that soil respiration would be the most sensitive factor, however it was found that biomass was more sensitive. Warming increased biomass and drought decreased biomass (except Spain). However we still don't know which process is the strongest (i.e. will shrublands move towards being a source or a sink?)

In the Welsh and Dutch sites investigated, the drought conditions caused a long term change in the capacity of the soil to hold water (even in Wales which has more than 2m rain per year), the experiments revealed that drought has the capacity to alter soil structure. Fire risk as well as erosion risk are also increased under drought conditions.

Ecosystem Disturbances: Disturbances such as beetle attacks or the interaction of summer drought and grazing of sheep affect and may change i.e. nitrogen mineralization, soil

structure, water holding capacity, canopy structure. Interactions need to be taken into account, either by studies or by modelling.

Climate change is not a single factor problem. To study the effects of climate change, multifactor experiments like **CLIMATE**, a field scale manipulation of CO₂ (using the CO₂ dosing FACE technique), of temperature and of water in shrubland ecosystems, or **NEU** (NitroEurope), a study on the interactions between C and N and the implications for greenhouse gas emissions in manipulated terrestrial ecosystems, started in recent years.

Conclusions: Experiments showed that shrublands are vulnerable to climate change, however, short time effects may differ from long term effects. The key uncertainty is the possible change in species composition which consequently leads to a change in the processes determining the ecosystem. Possible interactions – which can be quite strong – need to be taken into account.

There was a long and detailed discussion of which the main points are summarised below:

Experimental design

Drought effects: In an experiment where temperature is increased but drought is not simulated, additional water is not added. Any drought imposed by the warming is considered part of the warming process and soil water is traced to determine how much is lost. In experiments where CO₂ levels are elevated in addition to temperature, plants may not suffer drought as stomata can be closed for longer periods. This will lead to less water loss from the plants and soil water will increase.

Understanding the interactions between factors: It can be difficult and costly to undertake experiments examining interactions between factors. For instance, warming and water effects may be additive but their relationship in combination with CO₂ may be more complex. However CO₂ is the most expensive element in climate change experiments so it is often studied in isolation.

Timescale: It may be possible to examine aspects of ecosystem acclimatisation to climate change, even in a five-year experiment. It depends on whether the acclimatisation is genetic or morphological (for instance, short term responses such as CO₂ uptake by plants). However it may not be possible to study evolutionary processes, although annual plants may respond more quickly. For this reason it is important that experiments include both short- and long-lived species.

Other vegetation types: Some experimental data from shrublands such as CO₂ uptake and nutrient cycling processes may be applicable to other systems, but biodiversity driven processes, such as competition, probably cannot be applied elsewhere without the use of models.

Standardisation: Within a project, such as VULCAN it is important to have a standardised protocol, but this is not always necessary to be able to compare results between projects.

Modelling

Use of models: We need data to confirm that we understand the processes involved in shrubland response to climate change before undertaking modelling. However, with factors

where we have a lack of knowledge, such as precipitation, modelling and scenario development may provide a starting point from which hypotheses may be posed.

Developing integrated models: Most models focus on specific parts of the ecosystem and not the whole environment. Some models have attempted to include more factors but some responses e.g. heather beetle attacks can be difficult to include, as we don't yet understand the processes involved. The use of plant functional traits may be useful in integrated models. We need more data, so the first step is determine whether we can replicate results across Europe and the U.S.A. and then to try to develop integrated models.

Ecosystem services provided by shrublands

Drinking water: In Denmark this ESS may currently be of little importance but on a European scale it is of major importance.

Carbon storage: Shrublands, especially in the wetter northern areas where they occur on deep peat, may be important carbon sinks. This is an important reason for understanding the response of these systems to climate change.