SIXTH FRAMEWORK PROGRAMME

TERACC

RISØ

Climate

eprecot

Effects of Precipitation Changes on Terrestrial Ecosystems

- intensified and more severe rain events
- longer and more frequent dry periods and droughts

These projections for the future were presented at the **eprecot** scientific workshop 2006.

How will such changes in precipitation affect terrestrial ecosystems?

Rainfall

Soil water

Nutrient uptake

Plant growth

CO_2-uptake

Litterfall

Soil organic matter

Soil structure

Microbial activity

Decomposition

Carbon emission

Phenology

Adaptation

Plant community

Biodiversity

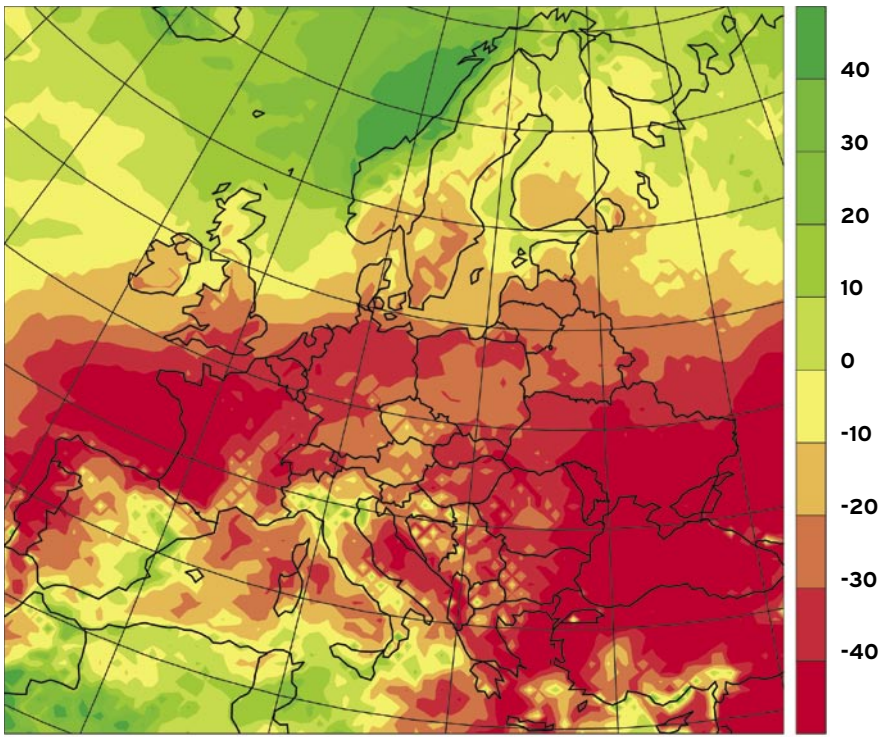
Ecosystem functioning

Future climate change

Human derived atmospheric emissions of carbon dioxide (CO_2) and other gases contribute to global warming. Scientists predict that this warming will result in increased evaporation and accumulation of water vapour in the atmosphere. As a consequence the amounts and patterns of precipitation (rain and snowfall) will change.

Climate model projections

- **More variable precipitation patterns in the future**
  Heavy rain storms as well as prolonged dry periods and droughts will become more frequent.
- **More global warming means stronger changes in precipitation**
  The changes in rainfall patterns will be dependent on the degree of global warming. Areas that are already warm and dry, such as the Mediteranean, will become even warmer and drier.
- **Summer drying will be less severe in colder areas**
  Northern latitudes will be relatively less affected than southern latitudes.



Changes in summer rainfall from present day (1960-1990) to the end of this century (2050-2080). Changes is indicated as percentage change per degree of warming.

Yellow: no difference;
light green/green: +10%/+20%;
orange/red: -10%/-20%
(Source: EU project PRUDENCE, prudence.dmi.dk.)

Water Regulates Biological Processes

Water is vital to the regulation of biological processes in plants and terrestrial ecosystems. Plants around the globe are adapted to the climatic conditions where they grow, including the availability of water. Different plant species have different strategies to cope with excess or lack of water, such as matching root distribution to water distribution or, reducing growth during drought.

If future precipitation patterns lead to a wetter climate in some regions and drier climate in other regions or to alterations in the rainfall patterns and intensity, changes in fundamental biological processes will occur. Shifts in biological processes can alter the structure and functioning of natural ecosystems. Recent observations provide evidence that ecosystem changes are already occurring.

Excess water can cause:

- Reduced below ground biological activity leading to slower decomposition of organic matter and consequent accumulation of carbon in soils.
- Anaerobic conditions.
- Greater flood frequency and duration along rivers and lakes.
- Increased soil erosion associated with greater rainfall intensity and higher runoff.

Lack of water can cause:

- Reduced below ground biological activity leading to slower decomposition of organic matter.
- Reduced plant water and nutrient uptake leading to decreased plant growth.
- Increased plant death and accumulation of plant debris in ecosystems leading to increased risk of wild fires.
- A shift in plant and animal communities to less productive, more stress tolerant assemblages.
- Increased soil aeration and changed soil structure.

Other factors regulate water

The water balance for individual plants and whole ecosystems is not only controlled by precipitation inputs but also by other factors such as:

- **Temperature**
  Higher temperature increase evaporation and consequently increases the loss of water from plants and soils.
- **Carbon dioxide (CO_2)**
  Elevated atmospheric CO_2 reduces the demand for water because plants can accumulate more carbom and grow more with the same amount of water.

Climate change is characterised by simultaneous changes in CO_2, temperature and precipitation. The effects of changes in precipitation patterns therefore have to be assessed together with the simultaneous impacts of CO_2 and temperature.

In the year 2000 a substantial fraction of low altitude pines died in Samos, including some 80-year-old trees. This year was exceptional with a 60% reduction in rainfall compared to the long term average combined with very low rainfalls in the years before. The combined effect of several consecutive dry years mark an extreme situation that seems to have pushed these trees very close to their survival limits.
Photo: C. Körner, University of Basel.

Effects of Precipitation Change

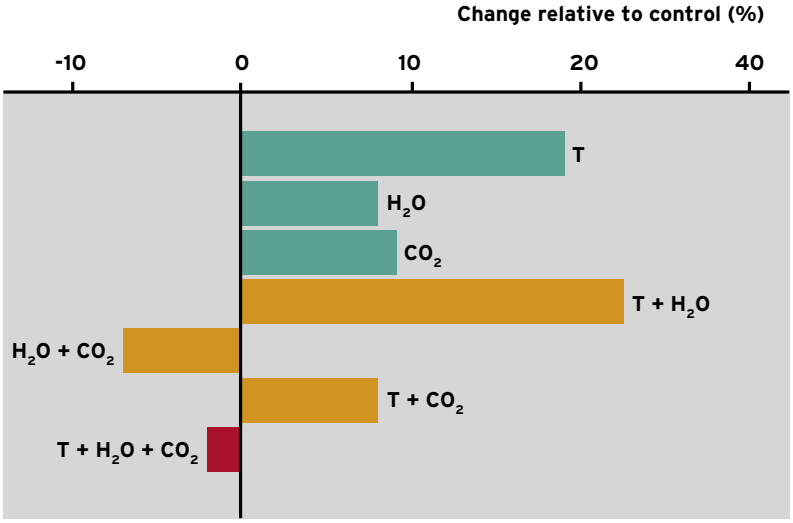
Irrigation at the multifacotorial "Jasper Ridge global change experiment" in US, where the combined effects of altered rainfall and elevated CO_2, temperature and nitrogen on ecosystem functioning are studied.
Photo: N. Chiariello, Stanford University.

Results from experimental studies and observations have provided evidence that changes in precipitation will potentially influence key ecosystem properties and processes such as:

- **The carbon balance**
  Drought will reduce plant growth and soil carbon losses in dry and semi-dry ecosystems and increase plant growth and soil carbon losses in very wet ecosystems (such as mires, wet meadows, moorlands). Increased rainfall will increase plant growth in dry ecosystems.

- **Soil structure**
  Drought can induce long term changes in soil structure through loss of carbon.

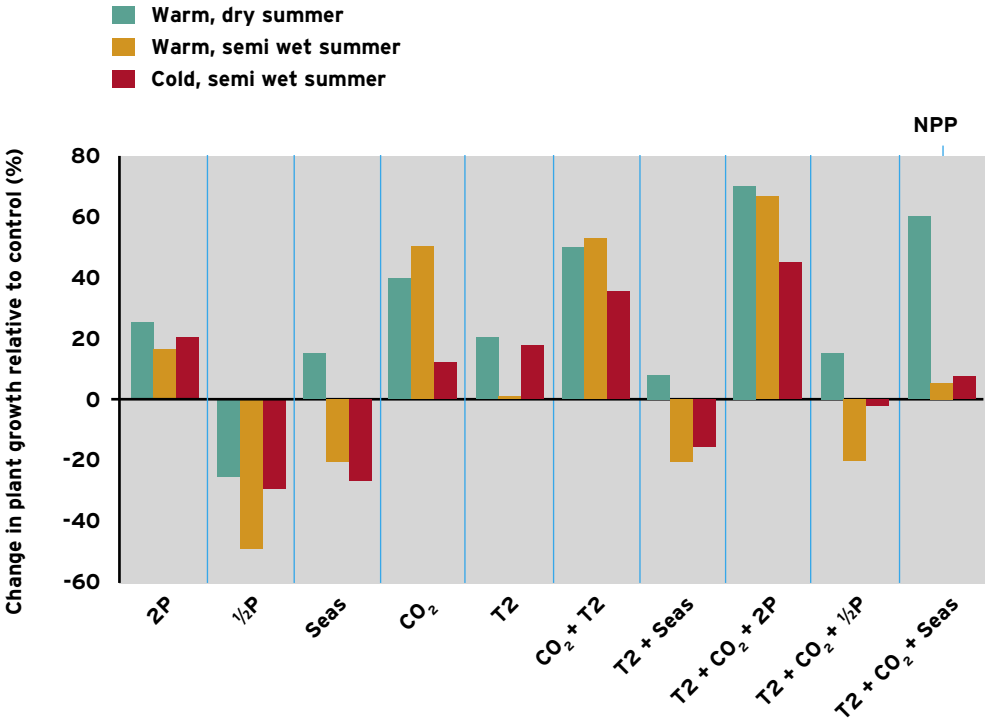
- **Biodiversity**
  Alterations in water (more and less water) will induce changes in growth conditions beneficial to some plants at the expense of others with long term consequences for biodiversity.



Effects of experimental manipulation of temperature, water and CO_2 on plant growth at Jasper Ridge in US.
The results show that the effects of combined factors cannot be predicted simply from the effects of the individual factors.
The effects are shown as percentage change relative to the untreated plots.
(Source: Science (2002), vol. 298, p 1987-1990).

Model projections show that:

- In some ecosystems the changes in precipitation have a greater impact than changes in CO_2 and temperature.
- Very wet and very dry ecosystems are most vulnerable to the adverse effects of changes in precipitation.
- The effects of increased or decreased precipitation may be vastly different if the changes occur simultaneously with changes in CO_2 and temperature.
- Nitrogen deposition, land management, and grazing also interact with precipitation to affect ecosystems through altering the rates of plant growth and soil compaction.
- Interactions between water and other aspects of global change (such as CO_2, temperature, and nitrogen deposition) could be substantial but they are not well understood and are difficult to predict.



*Model predictions of the long term effects of climatic changes (water, CO_2 and temperature) on plant growth presented at the **epricot** workshop. The effects are shown relative to plant growth with unchanged climate. Factors are:*

2P: double precipitation
½P: half precipitation
T2: 2°C temperature increase
Seas: change in precipitation among seasons
CO_2: doubled CO_2 concentration.

Science and Networks

Many research projects have been conducted to investigate the effects of precipitation change on terrestrial ecosystems. These include field-scale experiments that manipulate:

- the amount and timing of rainfall
- the intensity and length of drought periods
- snow cover and snow melting

More research is needed to investigate the interaction of precipitation change and other climate related factors, such as CO_2 and temperature.

Research on the effects of climate change on terrestrial ecosystems is carried out by many groups all over the world. Networks involving these groups are essential in order to share ideas, experiences and data. Research groups focusing specifically on precipitation change have formed a collaborative network – PrecipNet. However, funding to run such global networks and support meetings and integrative work is almost none existent. Mechanisms to provide funding for global networks will be essential to maximize the results and outcome of ongoing and future individual research efforts.

Multifactor climate change experiment at the CLIMAITE site in Denmark where the combined effects of drought, elevated temperature and elevated CO_2 on biological processes and ecosystem functioning are studied. The white covers exclude rainfall in the summer to create drought and reflect radiation during night time to increase the temperature.
Photo: P. Sørensen, Risø National Laboratory.

Relevant networks and activities

PrecipNet – an international network of precipitation change projects
PrecipNet fosters collaboration and interaction among research groups studying the effects of precipitation change on ecosystems worldwide; and promotes enhanced research within this field by sharing ideas, data, and experiences as well as by organizing workshops, courses and conferences. PrecipNet provides an overview of the ongoing research activities within the field of precipitation research. PrecipNet is an unfunded initiative.

Interaction between precipitation and other climatic changes
PrecipNet is further organized within TERACC (Terrestrial Ecosystem Response to Atmospheric and Climatic Change), which is an international global change network sponsored by the US National Science Foundation. By working together, these two networks ensure that the knowledge gained through PrecipNet is integrated with research on CO_2, global warming, and nitrogen deposition.

Climate change research and risk projections
Field-scale studies investigating the interactions between water, CO_2 and temperature are conducted within the CLIMAITE project in Denmark www.climaite.dk and the Jasper Ridge Global Change Experiment in the United States www.globalecology.stanford.edu/DGE/Dukes/JRGCE/home.html.

The former EU project PRUDENCE www.prudence.dmi.dk and the current EU project ENSEMBLES www.ensembles-en.org provide predictions for future climatic conditions in Europe.

The current EU project ALARM www.alarmproject.net provides large scale risk assessment for biodiversity as well as terrestrial and freshwater ecosystems as a part of an environmental risk assessment, including risk assessment of multifactor problems.

Policy use
The research conducted within the EU projects and the PrecipNet and TERACC networks provides a useful knowledge base for policy and management decisions related to climate change (such as inclusion in reports of the International Panel on Climate Change, or IPCC).

Recommendations for future research

Based on the discussions at the **eprecot** workshop, five key areas for future research were identified.

1 Rainfall variability

Predictions for future climate change indicate that rainfall variability will increase (more heavy rain events and longer drought periods). Such changes are likely to have a major impact on ecosystem functioning, but research is needed to understand and predict these effects.

2 Long term effects on ecosystems

The long term effects of changes in rainfall and rainfall patterns may cause changes in plant species composition, which may dramatically alter ecosystem structure, function, and response to future climate change. Research is needed to better understand these processes.

3 Multifactor experiments including water

Many experimental studies have focused on the individual effects of elevated CO_2, warming and altered precipitation. However, future climatic changes will involve a combination of all three factors. The interactive effects of these are largely unknown and multifactor experiments involving all important factors driving ecosystem processes are needed.

Study of the impact of snow cover on photosynthesis in shrubland ecosystem in the Sierra Nevada of California. The snow cover near and away from the snow fence in the background is very different. This difference is used to investigate the effects of changes in the snow depth and melting time on ecosystem processes.
Photo: M.E. Loik, University of California, SC.

4 Extreme environments and events

Increased precipitation has stronger effects in dry ecosystems than wet ecosystems, and long dry periods can have strong effects in wetter ecosystems. The majority of experimental projects have so far been in regions with mesic conditions. Therefore there is a need for more studies and more focus on the "extreme" conditions, i.e. wet/dry ecosystems and long term droughts/flooding.

5 Model development

Mathematical models are one of the key tools to predict and test different potential future scenarios. The direct and indirect effects of precipitation change on ecosystems and the interactions with other global changes need to be better incorporated into ecosystem, regional, and global scale models and more data model comparisons need to be done to validate these results. Biodiversity changes related to rainfall amounts and patterns are currently not included in models and there is a need to develop models which also include this aspect.

Other fotos: Polfoto / Layout: Ann Scales

About **eprecot**

- **eprecot**, "Effects of Precipitation Change on Terrestrial Ecosystems" was an international workshop held in Denmark 22-25th May 2006.
- **eprecot** was funded by EU (FP6), the US network TERACC (Terrestrial Ecosystem Research in Atmospheric and Climate Change) and the CLIMAITE project.
- **eprecot** involved 70 key scientists from all over the world with expertise in climate predictions, historical climate records, biological processes, ecosystem functioning and mathematical modelling of effects of precipitation change.

Further information and contacts

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This brochure is one of the outputs of the Specific Support Action **eprecot**, supported under the 6th Framework programme, Global Change and Ecosystems priority and through a grant from the US National Science Foundation. (Grant No. 0090238).