EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

RESEARCH NETWORKING PROGRAMME

CLIMATIC CHANGE – MANIPULATION EXPERIMENTS IN TERRESTRIAL ECOSYSTEMS (CLIMMANI)

Standing Committee for Life, Earth and Environmental Sciences (LESC)

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Cover Figure:
The Swiss Treeline FACE project in Stillberg, Switzerland.
Photo: Christian Körner.

Introduction

The Earth's climate is changing as a consequence of increased emission of greenhouse gasses, in particular CO_2, derived from human activities. Future atmospheric and climatic conditions have therefore been projected to include elevated atmospheric CO_2, temperature, and altered amounts and patterns of precipitation. These three climatic-driven changes will, alone and in combination with changes in N deposition, have great effects on terrestrial ecosystem functioning and will therefore affect the goods and services provided by these ecosystems (biodiversity, forest, range, agricultural productivity, ground water provision, ground water quality, fire protection, recreation, etc.).

Considerable progress has been made in understanding the response of terrestrial ecosystems to these atmospheric changes, using field observations, manipulation experiments and dynamic ecosystem modelling. However, our present knowledge of the effects and consequences is generally derived from individual projects with different foci, and a coherent view and understanding does not exist. Consequently, there is a significant need to review our present understanding of climatic-driven changes in ecosystem functioning and to synthesise our knowledge across drivers, ecosystems and ecosystem processes.

Atmospheric change is a truly transnational problem and research into understanding the effects of these changes has a clear international and interdisciplinary potential. The value of individual projects will become many times higher if conducted and viewed in a broader context, bringing the multitude of knowledge, results and activities together in a common integrated network.

CLIMMANI is just such an integrated network and provides a strong supplement to ongoing European research activities. CLIMMANI will build on an integrated approach and provide a framework for networking past and current terrestrial ecosystem research. CLIMMANI will in particular:

- bring together key researchers within the field
- build coherent interdisciplinary databases
- coordinate research activities globally

CLIMMANI will hereby improve our capacity for understanding, detecting and predicting global atmospheric change, formulating future research needs and developing strategies for prevention, mitigation and adaptation.

The running period of the ESF CLIMMANI Research Networking Programme is five years from June 2008 to June 2013.

Overview of the Danish CLIMAITE project situated on heathland at Brandbjerg.

Background

Atmospheric and climatic change – why and how?

The global climate is changing. Atmospheric CO_2 concentrations have increased by ~33% in the last 100 years, and are continuing to increase by ~0.4% per year which together with increased concentrations of other greenhouse gases have the potential to raise mean global temperatures. Mean global surface temperature has already increased by ~0.6 °C over the last century, with the most rapid changes occurring over the last two decades. Furthermore, the timing and extent of precipitation might change. Both the magnitude and the scope of these changes are likely to continue and increase in the future, leading to an increase in the frequency and degree of severe weather events (e.g. droughts and floods).

Major changes in ecosystem functioning, biological diversity and ecological complexity are occurring on a global scale simultaneously with changes in climate. Specifically, elevated temperatures and extended droughts are predicted to significantly affect the functioning of natural and semi-natural terrestrial ecosystems both directly and through interactions with land management and pollutant loading. Thus, climatic changes may have particular strong effects on vulnerable ecosystems, which are already subjected to other impacts such as elevated N deposition and land use. However, the responses of terrestrial ecosystems to current and future changes in atmospheric CO_2 concentrations, temperature and altered precipitation and the interactions with other drivers of global change are highly complex and poorly understood. For example, on the one hand net ecosystem productivity and hence C storage in plant biomass and soil organic matter may be stimulated and increase due to elevated CO_2, warmer temperatures, and/or elevated atmospheric N deposition, while on the other hand net ecosystem productivity might be reduced by warmer temperatures combined with less precipitation and excess N resulting in decreased C storage and accelerated CO_2 concentration in the atmosphere. Consequently, understanding the interactive effects of these combined vectors of global change on terrestrial ecosystems and how they affect the global C cycle will be critical for predicting future global environments and developing effective strategies to minimise the effects of global change. Given that any change in environmental conditions will create winners and losers among species, changes of species assemblages are inevitable, arguing for a need for studies on successional processes and biodiversity.

The Swiss Canopy Crane CO_2-enrichment facility in a mature deciduous forest near Basel in Switzerland.

Manipulation experiments – current research

Considerable progress has been made to better understand the response of terrestrial ecosystems to the global change factors using both field manipulation experiments, observations along gradients and modelling. Many EU projects have worked on different angles of ecosystem responses often concentrating on changes in atmospheric CO_2 concentrations, increased temperatures, changes in precipitation and manipulations in N input. For each specific driver, experimental technologies are well developed, and research often focuses on responses in ecosystem processes at various trophic levels such as species response (photosynthesis, water use, growth, microbial activity, soil fauna), community response (plant and microbial species composition and competition, reproductive success, plant phenology) and ecosystem functioning (biomass accumulation, litter decomposition, soil respiration and C exchange, CH_4 and N_2O exchange, N mineralisation, water use, C and N interactions and allocation, soil solution chemistry and leaching).

Thus, a significant number of experiments, knowledge and data are generated on climate change within the European research community, but much of this is fragmented and has been generated in individual projects with little or no coordination with other similar projects.

CLIMMANI – Scientific Aims and Objectives

The knowledge and results from these past and ongoing projects and studies provide a significant potential for generating new knowledge through syntheses, integration and modelling and thereby help to improve our understanding and ability to better act to solve climate change problems. Therefore,

CLIMMANI aims to provide an umbrella for coordinated activities bringing together researchers, data and knowledge from past and ongoing European research projects in order to synthesise the knowledge and improve ecosystem models.

The specific objectives of the programme are to:

- establish a comprehensive network of global change scientists in order to promote better communication and integration between researchers to assure and improve research activities for the benefit of society within global environmental parameters;
- organise a series of workshops and working groups to present and discuss key ecosystem processes and the impact and interaction of climate change factors and other important drivers and to supply better grounds for integrated work between experimentalists and modellers;
- generate a database on data from ecosystem manipulation studies for better comparisons, syntheses and modelling efforts;
- synthesise and assess the impact of climate change factors on key ecosystem processes and the interactions between the different climate change factors and with other drivers;
- provide opportunities for ecosystem researchers and modellers to work together in order to improve our mutual understanding of ecosystem processes and the impacts of climate change drivers, to improve ecosystem models and to publish synthesis and review papers;
- facilitate European networking and coordination of research activities among Europe and US researchers, and
- identify important gaps in knowledge, research priorities and future research needs related to whole-ecosystem responses to key global change factors.

Topics and key research questions

CLIMMANI will focus on the different climatic drivers and their interactions as key topics in the work. Furthermore, CLIMMANI will improve the foundation for overall ecosystem modelling as a tool to better understand the complex mechanisms of responses to changes in the ecological drivers in atmospheric change. For each of these topic areas, specific key research questions are asked.

Elevated atmospheric CO_2 concentrations

The responses of plants to elevated CO_2 concentrations have been extensively studied over the last decade by a variety of techniques including open-top chambers, controlled environment chambers, free-air CO_2 enrichment technologies and by using natural CO_2 springs. Results have unambiguously shown that increasing atmospheric CO_2 concentrations will stimulate photosynthesis and in most cases plant biomass accumulation and interact with plant water relationships. Despite these advances in understanding the effects of elevated CO_2 on plants and ecosystems, considerable uncertainties remain.
Key research questions:

- How does ecosystem C storage respond to elevated CO_2 concentrations?
- How do leaf-level physiological responses scale (spatially and temporally) to whole canopies?
- Does assimilation of CO_2 drive growth or vice versa?
- What will the responses be to CO_2 across life stages of long-lived perennial plants?
- What is the sensitivity of different plant species and functional types and can we explain it?
- Which signals are photosynthesis (C) driven and which are stomata (water) driven?

Increased temperatures

The responses of ecosystems to warming have been studied during the past two decades in a number of heating/warming experiments around the world by greenhouse experiments, controlled environment chambers, open-top chambers, heating cables, overhead infra red lamps and passive night-time warming. Results from these studies have shown that increased temperature can increase rates of photosynthesis, litter decomposition, soil respiration, CH_4 oxidation, N mineralisation and N leaching, and alter plant phenology, species composition, and microbial activity and biomass. Also, plant productivity including reproductive success, growth and stress might be influenced when temperature is raised. The understanding of the direct responses to warming has increased but it still is incomplete.

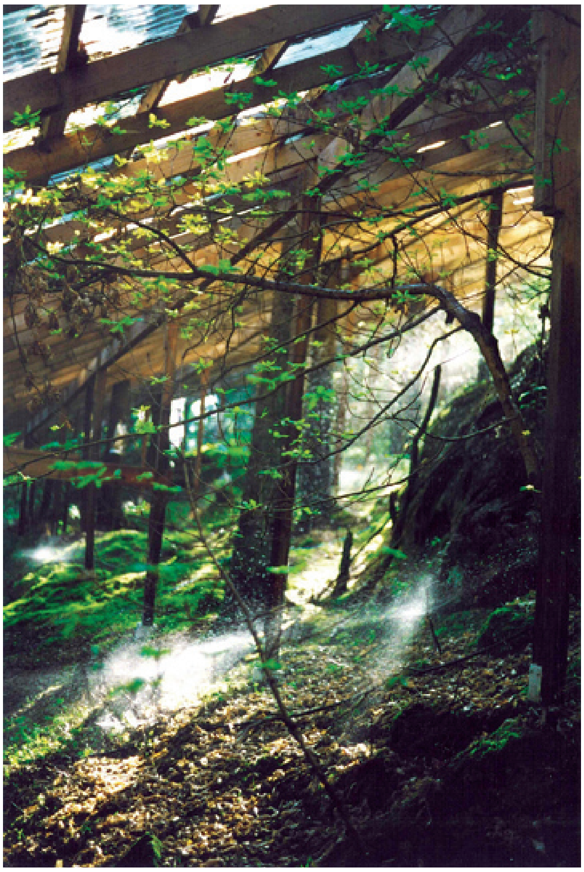
Key research questions:
- How can site data be scaled spatially and temporally?
- What are the long-term consequences of elevated temperatures for ecosystem C storage?
- What is the sensitivity of different life stages and functional groups to warming?
- What will be the long-term effects of community changes?
- How can we separate true temperature effects from confounding moisture effects?

Change in precipitation

Water is one of the fundamental drivers of all chemical and biological processes, and together with temperature, it plays a central role in determining the structure and function of terrestrial ecosystems. Shifts in precipitation regimes may have a profound impact on ecosystem dynamics. Changes in seasonality and variability of precipitation are likely to affect the distribution of soil moisture in space and time with ramifications for the performance of species (plant water use strategies and biomass production) and their interactions with other organisms. In contrast to the growing amount of elevated CO_2 and ecosystem warming manipulation experiments, relatively few precipitation manipulation experiments have been undertaken. Greenhouse and growth chamber studies have provided considerable insight into the response of seedlings and saplings to moisture manipulations and field-scale manipulations of water inputs to terrestrial ecosystems have provided important knowledge on drought stress in mature plants and ecosystems.
Key research questions:
- How do whole ecosystems respond to periodic, short-term changes in moisture (droughts, floods)?
- How do alterations in the seasonality and magnitude of precipitation affect soil and plant processes?
- How do we extrapolate results from chamber studies on seedlings to mature plants and whole ecosystems?
- Who is winning, who is losing and why (biodiversity)?

Change in snow cover

Extended periods of freezing/thawing are natural phenomena in many regions of the Earth; however, increased winter temperatures are likely to result in reduced snow accumulation with implications for soil temperature regime, freeze/thaw cycles, hydrological flow and growth season onset. This may impact on transformations, transport and pools of C and N, greenhouse gas emissions, root function and phenology. In recent years, a number of projects have addressed these issues in field and laboratory studies and gained insight into the importance of freeze/thaw cycles on soil respiration and greenhouse gas emission rates. However, our knowledge about the driving mechanisms and the relevance of such events on longer time scales is still limited.
Key research questions:
- How do the intensity of frost and drought influence rates and thresholds of key processes and organisms?
- How do changes in freeze/thaw frequencies affect the functioning of microbial communities?
- How do changes in snow cover affect the water and nutrient transport pathways and the run off of snow melt and what are the impacts on down slope ecosystems?



Manipulation of precipitation and N deposition at the roof project at Gårdsjön in Sweden.

Increased N deposition

Although not a direct consequence of climatic changes, changes in N deposition is an additional driver which strongly interacts with and potentially modifies the responses of terrestrial ecosystems to current and future changes in atmospheric CO_2 concentrations, temperature and changes in the quantity and distribution of precipitation. A rather large range of manipulation experiments exists on ecosystem effects of increased or reduced N deposition performed as N addition/removal experiments, fertiliser experiments and tracer experiments (^{15}N). These projects have provided strong insight into ecosystem responses at all trophic levels and above and below ground (e.g. growth, nutrient cycling and limitations, C and N interactions in plant growth and microbial processes, N leaching).
Key research questions:
- How does N addition/removal interact with climate change drivers?
- How does N addition/removal affect greenhouse gas emissions?
- Is there a critical load at species or ecosystem level?
- How does N availability interact with other key nutrients such as P?

Interactions between drivers

Most climate change studies have focused on single driver studies. However, future climatic changes will involve multifactor changes. From the few multifactor experiments existing we know that the interactions may at times be strong and this makes predictions based on single-factor knowledge erroneous. It is therefore important that existing knowledge from different single and multifactor experiments can be combined and multifactor interactions be investigated by combinations of experiments with year-to-year variability.
Key research questions:
- How will interaction of different global change drivers affect species and how will this change ecosystem processes?
- What is the relative importance of the different climate change-related drivers?
- Are changes in water relations the overarching (co-) driver of all the above global change effects?

Pinpoint assessments at a small drought experiment in the Danish CLIMAITE project.

Ecosystem modelling

Many of the questions of long-term response, scaling from ecosystem levels to regional and global scales, and interactions with other factors are beyond the scope of manipulation experiments. Therefore, ecosystem modelling techniques play an important role in generalising and upscaling the results from the individual manipulation projects. Ecosystem models based on ecosystem manipulation experiments will be used in CLIMMANI as a strong tool for deriving a better understanding of the complex mechanisms of response to changes in the ecological drivers in atmospheric change. Based on this understanding, the results may then be scaled up in time and space to better predict whole ecosystem and regional-scale response to potential longer-term shifts in global change factors.
Key research questions:
- Can long-term effects of climate change be predicted from short term studies?
- Can we model changes in ecosystem structure and composition (species presence/absence) as a prerequisite for predicting biogeochemical changes?
- Do we have sufficient knowledge and data to model responses of ecosystems and biological processes across the range of climatic conditions in Europe?
- Can we account for element stoichiometry, changes in species abundance and changes in water regime?

Programme Activities

CLIMMANI will particularly focus on the following activities:

- **Workshop and conference organisation** – bringing together researchers and working groups from different disciplines with experimental as well as modelling backgrounds to assess results from manipulation experiments, evaluate existing literature and databases and identify and discuss progress and developments within climate change research. Workshops and working groups will be formed, including collaborative meetings with the US networks TERACC and PrecipNet;
- Shorter **exchange visits** of 2-6 months with the aims of analysing and synthesising data and results, writing syntheses and/or organising and gap-filling measurements for use in databases, modelling as well as synthesis writing;
- Establishment of a comprehensive integrated **database** that contains data on all manipulation experiments and from both ongoing and past EU research projects as well as from existing national databases. This will be conducted in close collaboration with major climate change-related projects and provide links to other databases;
- **International networking** of CLIMMANI activities with existing US networks on climate change (Terrestrial Ecosystem Responses to Atmospheric and Climatic Change (TERACC) and Precipitation and Ecosystem Change Network (PrecipNet). Activities will as far as possible be planned in joint cooperation.

CLIMMANI has an official website (www.esf.org/climmani) as well as a local website (www.climmani.org) with easily available information that will act as a communication platform for partners and a dissemination platform for end-users.

Links to other programme activities

The work of CLIMMANI will be linked to many already existing initiatives relating to networking and building databases. These are:

- The NitroEurope Integrated Project
- The CarboEurope Integrated Project
- The NinE ESF project
- The TERACC network in the US
- The PrecipNet network in the US
- Many European and national projects

CO_2 enrichment experiment in an alpine heathland (Furka pass, 2500 m) at the Swiss Central Alps.

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  United Kingdom

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Manipulation of snow cover at Storgama in Norway.

CLIMMANI Steering Committee

Dr. Claus Beier (Chair)
Risø National Laboratory for Sustainable Energy
Technical University of Denmark
Frederiksborgvej 399
PO Box 49
4000 Roskilde
Denmark
Tel: +45 4677 4161
Fax: +45 4677 4160
Email: claus.beier@risoe.dk

Professor Rien Aerts
Department of Systems Ecology
Faculty of Earth and Life Sciences
Vrije Universiteit
De Boelelaan 1085
1081 HV Amsterdam
Netherlands
Tel: +31 20 598 72 11
Fax: +31 20 598 71 23
Email: rien.aerts@ecology.falw.vu.nl

Dr. Ana Alebic-Juretic
Air Pollution Division
Teaching Institute of Public Health
Kresimirova 52a
51000 Rijeka
Croatia
Tel: +385 51 358 742
Fax: +358 51 358 753
Email: ana.alebic@zzjzpgz.hr
alebic@riteh.hr

Dr. Ovidiu Badea
Biometrics and Forest Inventory Department
Forest Research and Management Institute
Sos. Stefanesti, 128, Voluntari, Ilfov
077190 Bucharest
Romania
Tel: +40 21 350 32 42
Fax: +40 21 350 32 45
Email: obadea@icas.ro
biometrie@icas.ro

Dr. Heleen De Wit
Norwegian Institute for Water Research (NIVA)
Gaustadalléen 21
0349 Oslo
Norway
Tel: +47 22 18 51 00
Fax: +47 22 18 52 00
Email: heleen.de.wit@niva.no

Dr. Bridget Emmett
Biogeochemistry Programme
Centre for Ecology and Hydrology
Environment Centre Wales
Deiniol Rd
Bangor
Gwynedd LL57 2UW
United Kingdom
Tel: +44 1248 374500
Fax: +44 1248 362133
Email: bae@ceh.ac.uk

Dr. Petr Holub
Department of Ecology
Institute of Botany
Academy of Sciences of the Czech Republic
Porici 3b
60300 Brno
Czech Republic
Tel: +420 543 211 562
Fax: +420 543 211 562
Email: hugo@brno.cas.cz

Dr. Krassimira Ilieva-Makulec
Centre for Ecological Research
Polish Academy of Sciences
ul. M. Konopnickiej 1
Dziekanów Lesny
05-092 Lomianki
Poland
Tel: +48 22 751 30 46
Email: krassi.makulec@cbe-pan.pl

Professor Ivan Janssens
Department of Biology
University of Antwerp
Campus Drie Eiken, D.C16, Universiteitsplein 1
2610 Wilrijk
Belgium
Tel: +32 3 820 22 55
Fax: +32 3 820 22 71
Email: ivan.janssens@ua.ac.be

Professor Seppo Kellomäki
Faculty of Forestry
University of Joensuu
PO Box 111
80101 Joensuu
Finland
Tel: +358 13 2513630
Fax: +358 13 2514444
Email: seppo.kellomaki@forest.joensuu.fi

Professor Christian Körner
Institute of Botany
University of Basel
Schönbeinstrasse 6
4056 Basel
Switzerland
Tel: +41 61 267 35 10
Fax: +41 61 267 3504
Email: Ch.Koerner@unibas.ch
ch.koerner@intergga.ch

Professor Sune Linder
Southern Swedish Forest Research Centre
Swedish University of Agricultural Sciences
PO BOX 49
23053 Alnarp
Sweden
Tel: +46 40 415 162
Fax: +46 40 462 325
Email: sune.linder@ess.slu.se

Dr. Franco Miglietta
Head of Research
Institute of Biometeorology (IBIMET)
National Research Council (CNR)
Via Caproni 8
50144 Firenze
Italy
Tel: +39 055 3033711
Fax: +39 055 308910
Email: f.miglietta@ibimet.cnr.it

Professor Josep Penuelas
Unitat Ecofisiologia i Canvi Global CSIC-CEAB-CREAF
CREAF, Center for Ecological Research and Forestry Applications
Edifici C – Campus Universitat Autònoma de Barcelona
08193 Bellaterra
Spain
Tel: +34 93 581 2199
Fax: +34 93 581 4151
Email: josep.penuelas@uab.cat

Dr. Sophie Zechmeister-Boltenstern
Federal Research and Training Centre for Forests
Natural Hazards and Landscape (BFW)
Seckendorff-Gudent-Weg 8
1131 Vienna
Austria
Tel: +43 1 878 381 304
Fax: +43 1 878 381 250
Email: sophie.zechmeister@bfw.gv.at

Programme coordinator

Dr. Karin Hansen
Forest & Landscape Denmark
Department of Forest and Landscape Ecology
University of Copenhagen
Hørsholm Kongevej 11
2970 Hørsholm
Denmark
Tel: +46 8 767 8580
+45 35 33 16 82
Fax: +45 35 33 15 17
Email: kiha@life.ku.dk

ESF Liaison

Dr. Inge Jonckheere
Science

Ms. Cindy Hury
Administration

Life, Earth and Environmental Sciences Unit (LESC)
European Science Foundation
1 quai Lezay-Marnésia
BP 90015
67080 Strasbourg cedex
France
Tel: +33 (0)3 88 76 21 62
Fax: +33 (0)3 88 37 05 32
Email: chury@esf.org

For the latest information on this Research Networking Programme consult the CLIMMANI websites:
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www.climmani.org

EUROPEAN SCIENCE FOUNDATION
SETTING SCIENCE AGENDAS FOR EUROPE

1 quai Lezay-Marnésia | BP 90015
67080 Strasbourg cedex | France
Tel: +33 (0)3 88 76 71 00 | Fax: +33 (0)3 88 37 05 32
www.esf.org

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