

## ***Carbon Cycle and Climate Change*** **Strategic plan 2017–2020, BECC challenge theme**

We have entered the Anthropocene, the age in Earth history in which human activities dominate over natural processes in forming the Earth System. Climate is changing fast and the biogeochemical cycles of key elements for life are highly disturbed as a result of human activity.

Climate change is both a symptom and cause of a disturbed carbon cycle. The carbon cycle dynamically couples the biosphere, oceans and atmosphere, and links societal and biophysical dimensions of the Earth system. The disturbances in it can be assessed at different scales, from molecular to global, and by their effects on the atmosphere and ultimately on natural systems including the development of human societies. The carbon cycle is also tightly coupled to biogeochemical cycles of other elements such as P and N, and direct and indirect feedback mechanisms may enhance or dampen climate change.

### **The *Climate* Theme within BECC**

This strategic plan aims to identify the scope of the BECC research theme *Carbon Cycle and Climate Change* – hereafter abbreviated to *Climate* – for the second BECC period 2017-2020.

The BECC *Climate* theme is a hub for interdisciplinary research and connections to stakeholders interested in questions of climate change. It provides a platform to initiate and support novel research activities within our scope. It especially supports interdisciplinary projects during their establishment phase, which will likely result in synergies and insights that could not have been achieved without the collaboration.

The BECC *Climate* theme welcomes and encourages all BECC researchers to join the theme or selected *Climate* theme meetings. It has a mailing list of its own that is updated regularly. Information on meetings, workshops or other activity is always announced first to the entire BECC community.

### **Climate Theme Vision for 2017-2020 and beyond**

The *Climate* theme aims to improve understanding of the carbon cycle to better predict and mitigate climate change. The theme aims to foster carbon cycle and climate change-related research, especially interdisciplinary collaborations, such as empirical research to modeling activities, or to connect natural sciences, social sciences and humanities. It also especially encourages interactions between the Universities of Lund and Gothenburg.

BECC *Climate* has a strong research profile in biogeochemistry, soil carbon dynamics, microbial ecology, ecological modeling, global climate projections, mitigation scenarios, social implications of climate change, as well as climate policy and environmental regulation. Successful interdisciplinary projects have already been established e.g. within microbial biogeochemistry, microbial process modeling, coupled ecological and economical assessments, mapping research needs globally, interactions between animals and terrestrial systems. However, important challenges remains to be tackled.

Our most important *grand challenge* is to reduce wide uncertainty in the components of the

carbon cycle, its responses to anthropogenic and biophysical drivers, and the legacy effects of slow-responding processes of vegetation and soils. To address this challenge, it is necessary to combine empirical ecology and modeling, informed by studies of the past, and accounting for links across scales from the local to the global. Accurately quantifying and projecting changes in the carbon balance, regionally and globally, across compartments and sectors, and accounting for links to other biogeochemical cycles (e.g. N and P), is central to understanding and predicting climate change and its impacts on ecosystems and biodiversity. This in turn provides a sound basis for the design of effective mitigation strategies to sequester greenhouse gases from the atmosphere through land use and management interventions.

## Identified knowledge gaps and opportunities

Despite important achieved accomplishments, BECC *Climate* identified core knowledge gaps in the science frontiers that can be tackled by bringing together different competences within the BECC PI team. It further identified competences gaps in BECC *Climate*'s present composition of PIs.

The most important, but not limited to, are the following:

- *How correct are soil carbon stock estimates, and where is the highest need for improvement of monitoring?* Soil C stock estimates, and projected changes in those, are a crucial base for earth ecosystem models and policy arguments. However, these estimates are often crude, and sometimes manifold wrong. Especially in the Arctic and boreal regions, where we predict largest changes in C stocks, and impact on global climate, current estimates are very uncertain. Permafrost soils and their fate and feedback loops to climate change are of special importance. BECC *Climate* actively works towards a strategy to improve assessment, monitoring and dissemination of soil C estimates in those regions.
- *Uncertainty in chemical process rates within degradation of recalcitrant soil organic matter.* Plants and soil organisms are the main sources for input of organic matter into soils. The gross of the material will be recycled back to CO<sub>2</sub> within short time periods, but parts will remain in the soils for years to decades or millennia. We do not well understand what drives increased or decreased recalcitrance of organic matter, and how to upscale this. BECC already has ongoing collaborations addressing empirical estimates in combination with modeling on molecular processes in organic matter degradation, including priming effects, and BECC *Climate* will support and encourage to expand those.
- *How spatial soil structures and dynamics at micro- to molecular scale influence microbial driving of the C cycle, and how soil treatment techniques can alter these.* An important but rudimentary understood way of soil C stabilization is by physical protection, i.e. spatially disrupting decomposers from access to organic matter substrates. We have BECC PI competence in researching soil structure effects on microbial processes at bulk scale, investigating into mechanisms at microscale (amongst others via synchrotron analyses), experimentally manipulating soil structure at microscale, and microbial modeling for upscaling of empirically confirmed processes. BECC *Climate* will actively work to foster ongoing and initial new collaborations within the topic.
- *Constraining long-term (decadal to centennial-scale) variations in soil and biosphere carbon storage.* Earth system models lack a confident data base to model the so-far uncertain and

slow response rates; thus, a correct assessment and projections of these are of high importance for recommendations to policy-makers.

Archives in tree rings and isotope signatures in geological deposits could help to provide such constraints to tune models. Among BECC researchers we have experts in tree ring analysis and other proxy data, which could together with the ecosystem modelers design experiments to constrain the slow carbon processes in the models. BECC Climate aims to bring together the involved scientists and encourage them to tackle this question.

- *Linkages and feedbacks between nutrient and carbon cycles.*

We expect complex feedback interactions between nutrient- and carbon cycle especially through the biosphere. However, mechanisms are not sufficiently understood and predictions are therefore uncertain. Too little is known on e.g. the effect of CO<sub>2</sub> fertilization in combination with nutrient deposition, and how decomposition rates may be affected by shifts in mineral nutrient limitations. BECC *Climate* aims to work on the basis of the Global Carbon Project on these questions, and to initiate a joint experimental climate manipulation facility (see below).

- *C cycle and climate change in Sweden embedded in global processes*

Sweden and its policies are not uncoupled from the rest of the world, and all recommendations and incentives regarding climate change mitigation needs to be seen in a global context. Further, we can learn from other ecosystems around the globe, or policies in other countries and use their experiences to improve Swedish society. BECC *Climate* actively encourages studies of topics outside of the Nordic countries when they can be used as a model for future Swedish problems.

- *How to make climate scenarios realistic and relevant for society?*

Climate scenarios are an important tool for influencing societal development via policy making. The choice and combination of scenarios may be crucial for what politicians will consider as realistic. BECC has an expert team on researching into narratives of climate scenarios and their impact on notion and perception in society. BECC Climate will actively bring together them with modelers to improve model scenario choices.

## **Mainstreaming [consideration of] ecosystem services into land use decision-making under global change**

### **Strategic plan 2017-2020 for the Challenge theme**

#### **Grand challenge and vision**

Climate change, land-use changes and other environmental changes may profoundly affect ecosystem processes and as a result have both negative and positive effect on the ability of ecosystems to deliver services to humans. In order for decision makers to be able to make sound decisions, robust decision support on the effects on ecosystem services, based on multiple approaches, is required. One of the grand challenges identified within BECC is:

*to integrate the private and public value of ecosystem services into management and policy while accounting for the projected impacts of climate, land-use and other drivers of change.*

To meet the grand challenge, an active role of scientists and policy makers in the science-policy interface is required. A central task is the analysis of the effects of different policy strategies on ecosystem services, using modelling, empirical research and metaanalysis. Here, issues of relevant scales for drivers, processes and consequences associated with ecosystem services, and how they relate to the scales for decision making, are of particular importance. The role of biodiversity for ecosystem services merits further investigation, in terms of the roles of functional and taxonomic diversity, and the relationship with conservation-relevant aspects.

A deeper understanding has to be reached of the motivations, behaviour and interactions of stakeholders and institutions facing different adaptation choices, and having different, sometimes conflicting, goals. Drivers of land-use changes have to be analysed and methods for cost-effective policies have to be developed. Tools are needed that can describe key aspects of change, and consequences of proposed adaptation measures, in terms of metrics of interest to decision-makers ranging from farmers and forest owners to regulators, policy makers, government agencies dependent industries, while accounting for governance factors that may help or hinder the realisation of adaptation goals.

The vision of the BECC Ecosystem Services theme is: *to be an internationally visible hub generating innovative interdisciplinary science studying and supporting the generation and use of ecosystem services and providing insights for decision making in a society facing global change.*

#### **Long-term strategy: 2017-2021**

The strategy of the Ecosystem Services theme for the coming five years, in order to meet the grand challenge and reach the vision, is to:

- assist researchers and research groups in taking the step towards working interdisciplinary with ecosystem services, and to make all BECC researchers, in all departments, all types of environments, and with all available methods, become aware of how their work relates to ecosystem services, including, but not limited to, the risks and opportunities offered in this context by the increasing importance of ecosystem-based climate adaptation and the bioeconomy. This will be done by organising thematic workshops and seminars and multi-disciplinary syntheses where main research challenges are identified.

- increase the added value of the BECC stakeholder contacts, by encouraging and supporting projects and action groups where stakeholders are involved throughout the process.
- build capacity (i) among the next generation of researchers and practitioners to pursue excellent and innovative research on ecosystem services, and (ii) among business and administration to enhance the sound application of ecosystem service approaches. This will be achieved by proposing new theme-related courses (and striving to maintain existing ones) in the PhD Graduate school ClimBEco, increasing the transmission of theme-related knowledge and methodologies in undergraduate curricula, and arranging meetings and workshops for identifying and responding to training needs for actors in business and administration.
- maintain and further develop and strengthen the already strong interdisciplinary group in BECC working on ecosystem services in agriculture by identifying upcoming hot topics, research gaps and policy windows, and the best ways to address them.
- tie together the already strong but decoupled smaller groups working on ecosystem services in forests, with the long-term aim to be able to lead or participate in research programs on the topic, and to identify and fill-in competence gaps, e.g related to forest biodiversity and law. To achieve this, a workshop will be arranged as a starting point, and the theme will encourage proposals of action groups and research projects in this topic. The work on ecosystem services in agriculture will be used as a role model.
- explore and develop research about ecosystem services in arctic environments, based on the strong empirical and model based research performed in BECC on processes in arctic environments.
- facilitate governance perspectives in the work on ecosystem services, through working actively to incorporate awareness and knowledge about such perspectives in research. This can be achieved both through interdisciplinarity and through involving stakeholders from the governance sphere more actively in seminars and workshops as well as in research projects.
- facilitate landscape-perspectives in the work on ecosystem services, by supporting exchange between researchers using spatio-temporal data from contrasting land use types and supporting the operationalization of cutting-edge spatio-temporal data sources. To achieve this, a workshop will be arranged as a starting point, and the theme will encourage proposals of action groups and research projects in this topic.
- strengthen the research on the ecosystem services coupled to connections between agriculture, forestry and aquatic systems, as well as governance, in order to put BECC in the forefront in the area of ecosystem based climate adaptation. The theme will encourage proposals of action groups and research projects in this topic.
- further bridge the gap between different approaches such as dynamic modelling, agent-based modelling and empirical research, in order to be able to fully use the potential of the combined approaches in analyses of ecosystem services. This will be done by encouraging and supporting projects, action groups and seminars including multiple methods.
- develop the theme homepage, both an internal and an external version, in order to provide BECC researchers with background information on ecosystem services, examples of

successful projects and information on on-going projects, action groups and forthcoming seminars and workshop, and to provide policy makers and the research community with links to relevant project homepages, external seminars and reports.

### **How will the work within the theme be organized?**

There will be one theme meeting every spring, which will serve as a basis for the planning of the coming year, and thus focus on new ideas from the participants about research projects, action groups, seminars, courses, etc. On the yearly meeting in the autumn there will be opportunities to follow up on the theme activities decided on the spring meeting.

The main activities in the theme will, however, be performed in seminars, workshops, action groups and in projects. The contact between the theme members and the theme leader and assistant theme leaders will be continuous, and the theme leader will represent the theme in the board.

In the theme homepage, information about on-going and previous projects and action groups will be collected, and previous and future activities will be listed and documented, in order to make it easy for the BECC community, especially new employees, to get an overview of the theme activities.

### **Coordination with other themes**

There are strong overlaps and opportunities for cooperation between the themes. There will be continuous contact between the theme leaders when questions that relate to more than one theme come up. The theme leaders will also meet at BECC board meetings.

### **How will the theme contribute to education?**

On the spring meetings, one session will be open for ideas about PhD courses and courses on a basic level about ecosystem services, stakeholder interactions and topics related to that. The ClimBEco courses “Biodiversity and ecosystem functioning in agriculture and forestry” will be revised, to get more of an ecosystem service focus.

## **”Effective strategies for biodiversity conservation under the combined pressures from climate change and land use change” Strategic plan 2017–2020, BECC challenge theme**

### **Background and vision**

Although habitat loss and degradation are the main drivers of current biodiversity loss, climate change is a growing threat to biodiversity. A changing climate may affect species both *directly* because species respond to changes in temperature and precipitation, and *indirectly* because climate change induces changes in land-use as part of climate change adaptation and mitigation strategies. Importantly, direct and indirect effects may together amplify the threats to biodiversity, for example because induced land-use changes may constrain species’ abilities to adapt to a changing climate. Well-functioning ecosystems are also a necessity for mitigation and adaptation to climate change. Within biodiversity research and landscape ecology there is a need to focus on both climate change and land-use change effects, but hitherto research in these fields have almost exclusively considered land-use change and climate change in isolation.

Furthermore, biodiversity research has largely neglected to consider additional factors that may modify the impact of climate change, such as the impact of invasive species and pathogens, or adaptation measures. In addition, many biodiversity models – such as forecasts of species distributions – are overly simplistic, as they are based on just few biologically relevant parameters, and do not take into account e.g. biotic interactions, species-specific abilities to disperse or adapt evolutionary. *A grand challenge is therefore to develop a scientific basis for effective and biologically meaningful conservation strategies under on-going and future global changes.* Such strategies need to integrate the need to protect and maintain high-quality habitat for in situ biodiversity, e.g. using traditional conservation interventions, and enhancing the ability of species to adapt to, or escape from, climate change, as well as for mitigation and adaptation strategies at large.

A key challenge within evidence-based conservation is to find effective ways to integrate evidence into decision support systems, and especially to integrate evidence based in the natural and social sciences. This integration of evidence into decision support systems is dependent on a better understanding of the context in which local, national and international decisions and strategies for biodiversity conservation are made and implemented. These decisions and strategies cannot be seen as separate from other environmental decisions or wider societal priorities. As an example, green infrastructure has rapidly become one of the main policy tools for biodiversity conservation, but green infrastructure is in addition targeting a broader set of ecosystem services and ecosystem-based adaptation strategies, with possibly conflicting outcomes on biodiversity conservation. Finding effective biodiversity conservation strategies demands identifying whether synergies or trade-offs between conservation goals and other societal needs emerge, and if so, under which conditions. Considering cost-effectiveness and uncertainty related to competing conservation strategies is equally important.

### **Strategy**

The long-term strategy of the biodiversity theme links to the challenges and opportunities identified below (adopted with slight modifications from the [strategic plan](#) of BECC):

An increasing demand for food, fibre, bioenergy, wood and other products leading to intensified agriculture and forest production may be expected to negatively impact other ecosystem services and biodiversity. A key challenge will be to identify solutions for a green economy that balance and exploit potential synergies between biodiversity and various classes of ecosystem services, including agricultural and forest yields. However, current models are weak in their ability to predict the impacts of climate and landscape changes on biodiversity, while empirical evidence for hypothesised systematic effects of biodiversity changes on ecosystem functioning remains sparse and contradictory. More generally, there is a need to highlight synergies and conflicts between different ecosystem services, and among alternative policies, for example green production, climate adaptation, cultural values and conservation of rare species. [...] The development of landscape ecology and landscape genetics research opens for a unique potential to develop studies striving to identify synergies between conservation and provision of ecosystem services.

The ambition of the biodiversity theme is to address these challenges and opportunities by pursuing the strategies listed below.

- To identify opportunities and possibilities to strengthen our competence and allocate resources to reach the [grand challenges](#) underpinning the theme
- To inspire researchers in the BECC community to pursue novel interdisciplinary research on biodiversity both within natural sciences and between natural and social sciences
- Strengthen research on joint effects of climate change and land-use change on biodiversity, in synergy with other variables, e.g. by increasing collaborative efforts with the strategic research area MERGE
- Strengthen collaborative biodiversity research between LU and UGOT
- Develop a collaboration between the BECC network and the Gothenburg Global Biodiversity Centre (GGBC)
- Strengthen the already strong research on trade-offs and synergies between biodiversity conservation and enhancing ecosystem services by joint research efforts together with the two other BECC themes
- Increase links between biodiversity research and training at BSc, MSc and PhD levels via (i) organising, or facilitating and encouraging the establishment of, new courses, (ii) contributing to already existing courses and workshops in the research school ClimBEco, and (iii) organising possibilities for master students and PhD students affiliated with BECC to participate in student-driven systematic review papers