

Mid-term Internal Review

Biodiversity and Ecosystem Services in a Changing Climate (BECC)

January 2010- June 2013



BECC is a collaboration between Lund University and University of Gothenburg. It is a strategic research area that strives for a better understanding of the impacts of climate change and land use decisions on terrestrial ecosystems and biodiversity, addressing the consequences of ecosystem changes for human beings and socio-economic systems.

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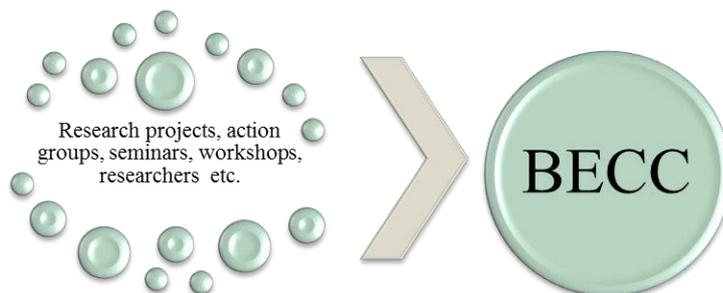
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1. Overview of BECC as a Strategic Research Area

BECC is a strategic research area (SRA) uniting research on climate-ecosystem-biodiversity relationships at Lund University and University of Gothenburg. The vision of BECC is to pursue world-leading interdisciplinary research, bringing together ecological modelling with empirical studies and linking this with policy and governance for the sustainable management of ecosystems and biodiversity in a rapidly changing world. In particular, BECC aims to:

- assess climate change impacts on biodiversity and ecosystem services in Sweden, with a particular focus on forest, agricultural and subarctic ecosystems, but also including aquatic systems that are affected by runoff from forest and farmland.
- support regional, national and global policymakers through the scientific evaluation of policy options combining adaptation and mitigation strategies to climate change with conservation of biodiversity and ecosystem resilience.
- create synergies and added value to the climate impacts research at Lund University and University of Gothenburg by bringing together modelling, empirical ecology, economics and social science analysis, and by integrating stakeholder experience in the research process.

To achieve these aims, BECC uses its financial and human resources to support existing successful research groups and to stimulate interactions among them, thus create a research environment that is more than the sum of its individual parts, see figure below.



Such support includes contributions to the funding of both basic and applied research as well as interactions between researchers within and beyond BECC, and between researchers and societal stakeholders such as national and regional agencies and authorities, industry and NGOs. BECC has a high ambition not only to produce research of highest international standard, but also to actively communicate research and interact with important stakeholders in the areas it encompasses.

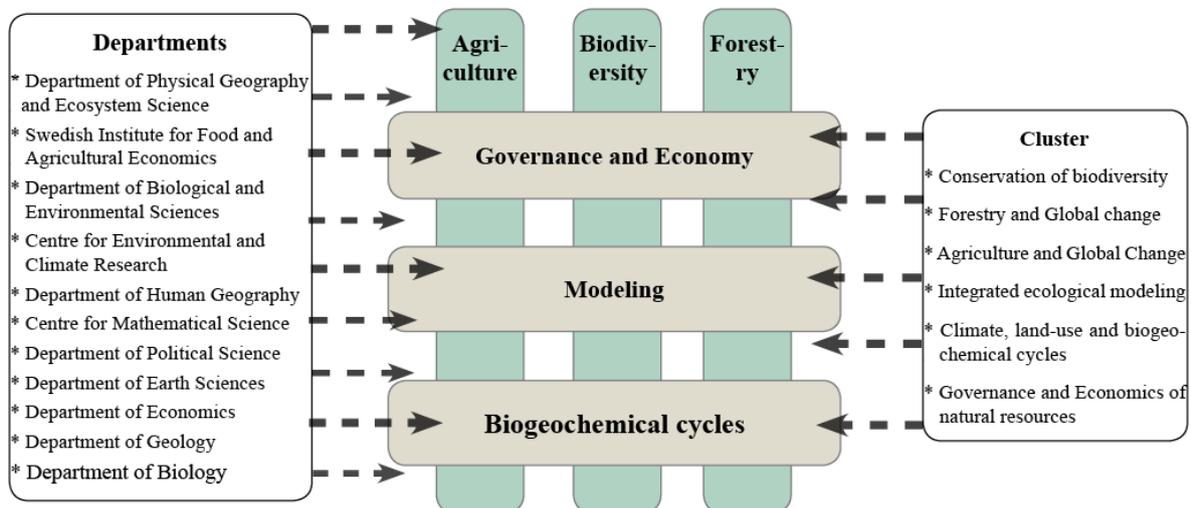
Examples of activities initiated or facilitated by BECC include:

- salary and other support to researchers at involved departments
- identification and support of new research positions and projects at and between departments.
- organisation of internal and external seminars, workshops and other gatherings of researchers across and beyond BECC
- stakeholder reference group containing senior representatives for key stakeholder organisations

- guest researcher programme
- Action Groups focusing on a specific topic or question for a limited time.
- the postgraduate research school ClimBEco focused on cross-disciplinary research on climate, biodiversity and ecosystem relationships

Organisation

BECC encompasses more than 140 senior researchers and 80 PhD-students from about 12 departments at Lund University and University of Gothenburg. To create some thematic and organisational structure in such a large environment, while promoting cross-cutting activities and synergies, clusters unite BECC-affiliated research within each of six thematic areas (see figure below). Individual projects often include aspects of relevance to more than one cluster, so that individual researchers may be active in more than one cluster.



Financing

BECC receives 100 million SEK in direct funding for the years 2010-2014 from the Swedish Government, 78% of this going to Lund University and 22% to University of Gothenburg. Total funding for BECC-affiliated activities, including external funding and co-funding by the universities, amounted to 390 million SEK for the years 2010-2012. While BECC is thus underpinned an appreciable level of direct funding, it is a research environment defined by the participating researchers and their often externally funded projects, which explains why the direct funding only constitutes c. 20 % of total funding. By supporting and stimulating existing successful research groups and interactions between them, BECC has evolved to become a substantial, cross-cutting environment for fundamental and applied research that—hopefully—is much more than the sum of its individual parts.

BECC along with all other SRAs initiated across the research landscape of Sweden in 2010, will be externally evaluated in 2014. The outcome of that evaluation is expected to determine whether and at what level funding will continue beyond 2015.

2. The internal review and aims of the report

During May-November 2013 the board of BECC board, in dialogue with the BECC community and PI's, undertook an internal review of the scientific progress and development of BECC. The goal of the review is to prepare for the upcoming external evaluation through the research councils, planned for 2014-15, as well as to begin planning for the future of BECC, beyond the current funding phase. The goal is *not* to compare the relative success of individual scientists or research groups. The review encompasses an inventory of current activities and achievements, a review of the previously defined objectives, and a consideration of relevant developments in the research community and society since BECC began. The review has led to the identification of a number of gaps and possible measures to fill them, as well as some adjustment of priorities based on the resulting insights. This report provides a baseline to guide a discussion and strategic process with the aim of best realising the potential of BECC in terms of research excellence and societal relevance, for the coming years and a longer term future.

The internal review is based on the yearly reports to which BECC researchers have contributed, discussions in the clusters and at the 2013 annual meeting, interviews with research group leaders, and feedback and critique received from the wider BECC community. Activities up until June 2013 have been considered.

The report begins with an overview of the research carried out in the six clusters of BECC (Section 3) and continues with an overview framed by the 5- year goals from the original application (Section 4). Overall conclusions are presented in Section 5.

BECC has also created a number of Action Groups (AG) focused on specific problems, which have been formally associated with the clusters. AGs exist for a limited time during which they act to utilise the expertise, resources and networks within BECC. This involves links between existing research projects or individuals, arranging seminars and workshops, writing synthesis papers, reports or policy briefs and preparing funding applications. Short information about the AGs can be found in appendix ii.

An important aim of BECC is dissemination of research both to BECC researchers and to society and stakeholders. BECC seminars and workshops from January 2010- June 2013 are listed in appendix iii.

We greatly appreciate and acknowledge all researchers that have contributed to the internal review during this process.

November 13 2013

The BECC board: Henrik Smith, Håkan Pleijel, Ben Smith, Katarina Hedlund, Anders Tunlid, Annica Kronsell and Lina Herbertsson (board members); Jessica Coria and Fariborz Zelli (co-opted).

3. Cluster reports

BECC strives for stimulation and support of transdisciplinary collaboration and interaction between research areas, within faculties as well as between natural and social sciences. BECC has therefore organised research activities in six Research Clusters, each lead by members of the board. The intention of the clusters, including scientific focus and aims, was formulated in an operational plan in line with the research proposal and decided by the board in 2010. Every cluster report ends with a section identifying gaps and potential actions for the future

The clusters have represented a useful structure for reaching BECC's aims. However, many research activities are crossing over cluster boundaries, why researchers often are active within more than one cluster.

This section outlines progress and gaps in relation to the aims stated in the operational plan for the clusters.

Cluster 1. Synergies and Trade-offs between Conservation of Biodiversity and Maintenance of Ecosystem Services in a Changing Climate

Coordinator: Henrik Smith Deputy coordinator: Ben Smith

This cluster will synthesize current knowledge and identify research needs to determine the relative merits of different strategies to integrate biodiversity conservation in Swedish agriculture and forestry with production of multiple ecosystem services under climate change.

Cluster aim 1. *Determine the ability of species to track climate shifts or adapt to novel environmental circumstances, in particular the interacting effects of climate change and habitat deterioration.*

BECC capitalizes on a fundament of high quality basic research on biodiversity at LU and UGOT to understand phenological change, range shifts and evolutionary responses to climate change. There has been significant progress in these areas, with both increased collaboration between research groups and development of new high quality research as a result of cluster activities. Two very active action groups have been established, and a number of postdocs and research projects funded. In addition, BECC has supported national and international workshops/conferences contributing to increased scientific networking and promoting new research constellations.

Phenological research at Biology, LU, has resulted in the development of a novel game-theoretical approach. Research at Physical Geography and Ecosystem Science, LU, has improved methods to use satellite imagery to trace changes in vegetation phenology over large areas and targets the incorporation of more process-based representations of tree phenology in models of management and climate impacts on forests. The newly started project “Phenobird” connects research at Biology and Physical Geography and Ecosystem Science to understand cross-continental consequences of changes in phenology. Mesocosm studies have shed new light into plankton phenology in ponds and lakes. BECC researchers have been involved in high-profile international synthesis work. In general phenological research is an internationally competitive research area in BECC under strong development.

Range-shift research includes statistical modelling of existing data as well as theoretical work. BECC has significantly contributed to an increased use of the Swedish bird monitoring data managed by LU to understand range-shifts in relation to climate change, habitat and bird traits. Dynamic vegetation modelling has contributed to understanding historical range-shifts in both tree species and animals. The stated goal of joining empirical research and vegetation modelling is still in its infancy, most progress having been made in informing dynamic vegetation modelling and climate modelling with data resulting from the reconstruction of past landscapes based on pollen records. BECC has supported development of novel theoretical approaches on consequences of species-interactions for range-shifts and community change in response to climate change, including the recent establishment of the cross-disciplinary project “Species response in a changing climate, an approach across study systems”. Combined modelling, monitoring and mesocosm experiments contribute to understanding of changes in species composition of aquatic communities.

Research on evolutionary responses has explored evolutionary dynamics at range margins. BECC has specifically sought to support evolutionary research related to climate change by funding a postdoc on adaptation to new environments in mobile insects. Recently initiated work on landscape genetics is a

promising avenue, capitalizing on the strength of the molecular research. Research in the Molecular ecology and evolution lab at Biology, LU, is of high quality and highly relevant to understand animal-disease interactions in a changing climate, but interactions with other parts of BECC are underutilized.

Impacts of climate change on *arctic biodiversity* is a focus area of BECC, encompassing both empirical and modelling approaches. A newly started action group has explicitly worked on increasing interaction among researchers from different departments with a common interest in arctic environments and is currently working on a synthesis based on existing BECC research. The interactive impact of reindeer grazing and climate warming is covered by research at UGOT. Researchers at UGOT combine evaluation of historical records with field-experimental approaches, resulting in frequent involvement in high profile international syntheses. BECC has contributed to the infrastructure of this research by supporting Latnjajaure research station in the Swedish subarctic, an important node for studies explicitly addressing the three-way linkages between climate, biodiversity and ecosystem functional change. This has contributed to extension of time series of observations on high mountain landscape, vegetation and biodiversity.

Cluster aim 2 and 3. *Identify links between biodiversity and ecosystem services and determine impacts of agricultural and silvicultural management in a changing climate & determine the scale at which the synergies and trade-offs between biodiversity conservation and other ecosystem services occur.*

Links between biodiversity and ecosystem services have been explored by both empirical and modelling research focussing on how landscape patterns filter ecological communities and the resulting consequences for ecosystem services at multiple spatial scales (see also cluster 3). BECC has contributed through cluster activities, funding of research, a guest-researcher and initiating a new permanent lecturer position. Research at Biology and CEC at LU has contributed to understanding of ecosystem services related to agriculture; pollination research has investigated the relative contribution of wild and managed pollinators and research on biological control estimate consequences of community composition of natural enemies. The interactions between ecosystem services as generated by different taxa have been studied using a novel experimental approach. Studies at Physical Geography and Ecosystem Science based on large-scale mapping of vegetation structure and habitats using dynamic vegetation modelling approaches also address biodiversity-function relationships in forests.

There is considerable research investigating the *links between agricultural/silvicultural management, conservation and ecosystem services* which BECC has supported through funding of a post-doc, research projects and a new lecture position. Research at Biology and CEC at LU focuses on conservation of biodiversity in relation to agricultural intensification, a possible indirect consequence of climate change, using both empirical and modelling approaches. This research has contributed to the understanding of how ecological traits such as dispersal propensity and mobility contribute to the effect of anthropogenic landscape change on communities. Using modelling and empirical work, links to land-use and policy are established in a cross-disciplinary effort involving researchers at CEC and Biology at LU, Economics at UGOT and a guest researcher Frank Wätzold. This work is supported by an action group on land-sharing vs. land-sparing. Research specifically targeting biodiversity issues in forest is planned within the Mistra-SWECIA project; a postdoctoral position at Physical Geography and Ecosystem Science is under recruitment. Researchers at Physical Geography and Ecosystem Science have been involved in risk assessment for biodiversity.

Cluster aim 4. *Interact with stakeholders regarding formulation and evaluation of policies to preserve biodiversity in a changing climate.*

The aim concerns both biodiversity conservation in a changing climate and promotion of ecosystem services through conservation measures. Hence, there is an overlap with the Forestry and Global change and Agriculture and Global Change clusters.

Since BECC researchers at LU are responsible for national monitoring programs for birds and butterflies, there are repeated interactions with authorities regarding the trends for biodiversity in Sweden and what are causing them. In addition, BECC researchers have interacted systematically with the Board of Agriculture regarding biodiversity in farmland and measures to restore it. BECC researchers are involved in a systematic work with Regional County of Scania including conservation of biodiversity in general farmland to benefit ecosystem services. BECC researchers have contributed to a synthetic review on the consequences of agri-environment schemes to protect biodiversity and ecosystem services and to a massive compilation of evidence of the effect of interventions in farmland to preserve biodiversity in collaboration with 'Conservation Evidence' in Cambridge, which was later used for evaluating the CAP reform. BECC modelling informs about the consequences of a changing climate for forest management, with considerable outreach, but is not directly related to biodiversity conservation *per se*.

Gaps and proposed future aims and strategies

- Research on phenology and range-shifts has demonstrated considerable progress, resulting in developments of empirical research using monitoring data, field-experimental approaches and novel theoretical approaches. Part of the success is due to increased interactions between researchers e.g. at Biology, Physical Geography and Ecosystem Science and CEC at LU, catalysed by postdocs working across research groups. There is now a need to consolidate this development, for example by focussing on assisting young researchers by *creating medium to long-term funded positions in this area*.
- Within BECC there are successful developments of both the fields of landscape and evolutionary ecology, but little interactions between research groups. By developing joint approaches, e.g. methodological developments in landscape analyses, BECC would make a significant step forward. This would also be an opportunity to focus on the interactive effects of climate and land-use change on biodiversity and range-shifts, which would contribute to increased policy relevance. However, for this there is a need to demonstrate the utility of such collaboration, e.g. by demonstrating how the field of landscape analysis can connect evolutionary and population oriented biodiversity research. This could be the issue of a *novel action group* in evolutionary landscape ecology.
- Within BECC there is substantial research on the link between land-use and functional biodiversity, but there is an opportunity to increasingly use a response – effect trait framework to predict ecosystem services under combined land-use and climate change. Similarly, there is considerable research on biodiversity conservation, but research on how large-scale policy changes interact with climate change to affect conservation of rare species needs to be strengthened. There are considerable skills among postdocs and young researchers in the BECC community to develop these areas, but BECC need to *assist in creating medium to long-term funded positions*.

- The fundamentally strong research in BECC could increasingly be used in integrated modelling of the effects of alternative conservation and management policies on land-use, biodiversity and ecosystem services in a changing climate. Current developments, e.g. the use of agent-based modelling of agricultural and silvicultural systems, are promising. BECC should *secure and strengthen the integrated modelling* in this area. A way to increase cross-disciplinary interaction may be to promote links between ecological research at LU and economic research at LU as well as political science at LU and ecology at UGOT, by e.g. issuing *internal “guest researcher”* positions for LU/ UGOT researchers such that a researcher from one discipline (economy, political science, natural science) can spend significant amounts of time at the other university, with the aim to produce a specific collaborative synthesis. BECC also has well developed stakeholder contacts e.g. with the Board of Agriculture, Forestry Service or Region Skåne which could be used to *develop trans-disciplinary research* evaluating the consequences of policies on functional biodiversity and rare species as mutually funded projects.
- Interactions between climate, ecosystem structure (e.g. tundra community dynamics, treeline dynamics) and ecosystem functioning in high-latitude environments are the subject of substantial research activity both at LU and UGOT, are generally linked to internationally prominent research programmes and networks, and are relevant to a core research objective of BECC. However, the engagement and visibility as well as the direct funding by BECC of LU and UGOT researchers working in this area has been limited to date. The new action group on arctic biodiversity is a step in achieving greater integration, but more effort is necessary to encompass and encourage linkages to researchers working on experimental alpine ecology (UGOT), vegetation history reconstruction using e.g. dendrochronology (UGOT) and sedimentary records (LU), as well as linkages to palaeoecological studies of Holocene landscape change and ecosystem modelling. A greater visibility and awareness of BECC in the context of major networks and programmes targeting arctic climate change, such as NCoE DEFROST and INTERACT (both coordinated from LU), should also be encouraged, e.g. through organisation of joint workshops etc.

Cluster 2: Forestry and Global Change

Coordinator: Håkan Pleijel Deputy coordinator: Anders Tunlid

A key focus is the study of recent and potential future changes in forest structure and function under multiple drivers. Better understanding of key processes is needed as a basis for their representation in models targeting the stand-, landscape and regional/global scale. A close dialogue with stakeholders is needed to define and formulate suitable adaptation and mitigation measures within and beyond the forest sector. Scenario studies accounting for management, multiple drivers and multiple sources of uncertainty will provide a basis for the assessment of impacts and risks.

Cluster aim 1. *Further develop models of forest ecosystem responses to global change (e.g. rising temperatures and CO₂ concentrations) and regional pollution (effects of ozone and deposition of nitrogen and sulphur), accounting for potentially important processes and interactions missing or poorly represented in current models such as nutrient dynamics, trophic interactions, disturbances and the influence of management practices (e.g. choice of tree species, intensity of biomass production, fertilization, harvesting methods, and protection of areas with high biodiversity) on forest production and damages.*

Most of the aspects covered by the Cluster aim 1 have been well covered in a cooperation between the Forestry and Global Change cluster and two other BECC clusters – Integrated Ecosystem modelling and Climate, Land use and Biogeochemical Cycles. Three ecosystem models with somewhat different focus have been used, LPJ-GUESS, COUP and ForSAFE. Improvement would be possible for the biodiversity aspect, which has been covered to a relatively limited extent. We are working with implementation of the scientific findings in different models in essentially all areas where the cluster is active.

Sustainable forestry in a changing climate from a nutrient perspective. BECC has enabled the establishment of the Biogeochemistry modelling group, focusing on model development and application of the dynamic forest ecosystem model ForSAFE. The group is based at CEC and the department of Physical Geography and Ecosystem Science LU, and has close collaboration with experimental scientists within BECC, mainly in the field of microbiology. The group has strong links to three clusters: Forestry and Global Change, Integrated Ecosystem Modelling and Climate and Land use and Biogeochemical Cycles. The focus of the group is effects of climate change, forest management and atmospheric deposition on nutrient cycling (N, P, Ca, Mg, K) in forest soils and transport to surface waters. Model development so far is focused on lateral transport of water and including phosphorous in the model. Since BECC started, the group has become part of three strong research environments (ForWater about effects of climate and forest management on surface water, QWARTS about weathering rates linked to sustainable forestry and Multistressors about multiple stressors on the Baltic Sea), which contribute to model development, financially and through collaboration with researchers from other universities, mainly SLU. The model group also cooperates with researchers abroad, mainly regarding development of a ground vegetation module and calculating critical loads, e.g. critical loads of nitrogen based on vegetation change.

Bringing models together. Cooperation between ForSAFE modellers and LPJ-GUESS modelling team has started, e.g. regarding nitrogen. A post doc with a background in the LPJ-GUESS modelling team

has been recruited to the ForSAFE group, which increases the potential for intensified cooperation. A workshop was held in April 2011, “Carbon and Nitrogen Interactions in Forest Soils: A Workshop Bringing Together Modelers and Ecologists”, co-organized by BECC and Nordic Forest Soil Carbon Network (financed by NordForsk). In this workshop COUP and ForSAFE modellers met ecologists to discuss process understanding and potential model improvements. Within the QWARTS program, BECC modelers explored ways to integrate lateral water flows and chemical transport from forest soils to surface waters.

Management scenarios. BECC has been central in initiating cooperation about forest management scenarios in dynamic modelling. In December 2011 a workshop was organized at IVL in Stockholm, through collaboration between several forest related research programmes. In 2013 this was followed up, by BECC and the research programmes, Mistra-SWECIA and CLEO, through a working report on forest management scenarios in dynamic ecosystem modelling. One further result of the co-operation is a seminar in October 2013 at the Royal Swedish Academy of Agriculture and Forestry (KSLA) in Stockholm over the topic: ‘Skogsbruk i ett förändrat klimat – Hur påverkas mångfald och miljö?’ (‘Forest management in a changing climate – How will it affect biodiversity and the environment?’), organized by BECC, Mistra-SWECIA and CLEO.

Effects of tropospheric ozone and CO₂ on forests. Ecosystem modellers at LU (Physical Geography and Ecosystem Science) and experimentalists at UGOT (Biology and Environmental Science) have worked closely together to improve process-based ozone impact assessment on forest productivity. An ozone module of the LPJ-Guess model has been implemented and applied to estimate global forest productivity and biogenic volatile organic compound (VOC) emissions in a changing climate. Leading European ozone impact researchers have met twice to discuss knowledge-gaps and ways forward in model-based large-scale ozone impact assessment. One of these meetings was hosted by the BECC action group *Effects of ozone, carbon dioxide and temperature on crops and forests in global change perspective*. Global meta-analyses of how elevated CO₂ and ozone affect trees and forest ecosystems have been conducted by the BECC-funded researchers. Key results in these meta-analyses will have large influence on how to predict the impact of climate change on forest productivity. The CO₂ meta-analysis shows that the CO₂-induced productivity stimulation does not diminish over time due to progressive nitrogen limitation, and the ozone meta-analysis reveals that leaf morphology is a strong determinant of plant ozone sensitivity. National scale modelling with ForSAFE has investigated the interactive effects of elevated CO₂, temperatures and predicted precipitation regimes on forest growth in Sweden, indicating that summer droughts may be so severe as to cancel out the expected positive effects of the latter even before nutrient limitations arise. The results were communicated to the Swedish EPA (Environmental Protection Agency) and are being used for the in-depth evaluation of the environmental goals.

Effects of temperature on forest vegetation. Collaboration has been initiated in which plant thermal acclimation to warming is to be implemented into the ecosystem model LPJ-Guess. Currently, plant responses to temperature are represented by static response functions, while in reality plants acclimate by adjusting their physiology to a change in growth temperature. A first meta-analysis will serve to quantify the degree of such thermal acclimation in different groups of plants. Thereafter, an LJP-Guess modelling experiment will explore the implications. The ForSAFE-Veg model has been used within the UN Convention on Long Range Transboundary Air Pollution showing that the expected effects on understory vegetation of increased temperatures may overshadow those from eutrophication.

Norway spruce pests and pathogens in a changing climate. The aim is to develop basic knowledge on the life cycle and ecosystem interactions of a new forest pest, the Hungarian spruce scale,

Physokermes inopinatus. The objective is to provide forestry stakeholders with support on how to assess the risks associated with this invasive forest pest. For analysis, three related species have been selected: *Physokermes inopinatus*, *P. piceae*, and *P. hemicryphus* (Department of Biology and Physical Geography and Ecosystem Science, LU). A project on spruce bark beetle impacts on spruce forest productivity under climate change has been initiated. In this project, ecosystem models developed at Lund University have been refined and parameterized based on by experimental findings by researchers at the University of Gothenburg.

Impacts of growing season changes on tree growth in Sweden – combining dendrochronological and phenological data. In this project led by GULD (Gothenburg University Laboratory for Dendrochronology, Department of Earth Sciences) in collaboration with Physical Geography and Ecosystem Science, LU, the aim of the project is to analyze high-resolution dendrochronological data to determine the onset and duration of the growing season, as well as the temporal importance of various weather variables associated with growing season changes, by means of statistical calibration with daily meteorological data over the twentieth century.

Cluster aim 2. *Analyze how the combined effects of land use (e.g. landscape patterns, silvicultural management, conservation measures), climate change and other global change drivers such as pollutant levels may affect biodiversity and ecosystem services in Swedish forest ecosystems.*

The aim of one of the Action Groups “Sustainable forestry in a changing climate” linked to the cluster, which suggests a workshop and a conference in this field is important. They fit very well with this aim. The analysis of the combined effects of land use, climate change and other global change drivers should be developed further, e.g. by support to analysis of the complex interaction between climate change, request for bioenergy from the forest ecosystems and regulation/legislation. As for Cluster aim 1, biodiversity may be considered to an area where there is potential for improvement.

The Biogeochemistry modelling group is involved in the CLEO project about Climate change and the *Swedish national environmental objectives*, financed by the Swedish EPA. The ForSAFE model is applied for different climate, management and deposition scenarios. Through this program we reach stakeholders working with the national environmental objectives. BECC researchers contribute yearly to the follow-up of the Swedish national environmental objectives Natural acidification only and Zero eutrophication. Models, experimental and monitoring data are used together. Climate change and intensified forest management are important to consider in the evaluation. Furthermore we contribute to the synthesis work at the Energy Agency about sustainable harvesting of forest fuels.

Impacts of climate change, including rising atmospheric CO₂, ground-level ozone, temperature and nitrogen deposition, on tree and forest productivity have been experimentally studied in several ongoing or recently published studies. Several of these studies have been used to parameterize ecosystem models, which in turn are being used to assess forest productivity in a changing climate (see examples under Cluster aim 1). Long-term forest hydrology and water runoff have been investigated for Swedish spruce forests as well as in collaboration with US scientists in order to separate the influences of different climatic and atmospheric factors on the important ecosystem service stream flow.

The main objective of the BECC project “Forests and forest management in a changing climate” was to develop and refine climate impact assessments of relevance to the Swedish forestry sector, by

exploring functional relationships using the process-based ecosystem model LPJ-Guess. The project is currently on-going via the FORMAS project "Climate change impact on tree defence capacity."

Cluster aim 3. *In cooperation with the Agriculture, Biodiversity and Biogeochemical clusters of BECC, assess the links between management/policy/land use choices in forestry and other sectors under global change and highlight the potential for integrated (i.e. cross-sectorial) management to achieve adaptation and mitigation goals. The results will support policy makers and stakeholders for making recommendations and decisions on future forestry in Sweden.*

To substantially fulfil this aim further action is needed. Interaction is quite strong with the Biogeochemistry cluster, but integrated cross-sectorial analyses remain to be developed within the BECC programme. Impacts of climate change on crop productivity are assessed in a project involving both the Forestry and Global Change and the Agriculture and Global Change clusters. This project involves experimental plant ecophysiology and ecosystem modelling as well as economic impact assessment. BECC researchers are currently working on a cross-sectorial manuscript/opinion paper: In recent years, climate impact assessments of relevance to the agricultural and forestry sectors have received considerable attention. Assessments of ecosystem performance do however rarely include impacts of climate extremes or attacks by pests and pathogens, which can considerably reduce the crop yields and increase the risk of severe forest dieback. In the paper we give a brief overview of different impact modelling methods, discuss the importance of stakeholder communication of ecological and management aspects, and highlight the importance of communicating model.

Gaps and proposed future aims and strategies

- A strength and opportunity of the activity in the Forestry and Global Change Cluster is its stimulation of collaboration among research groups. This is explicitly stated by several researchers at LU and UGOT to be a strength and added value by BECC, both funding and facilitation of contacts leading to new research approaches. There is strong potential for *further model development where empirical information from different research groups is implemented*, including pest and parasite interaction, effects of air pollutants (sulphur, nitrogen, ozone) and carbon dioxide on forest ecosystems as well as temperature and nitrogen deposition effects. The BECC programme should continue to actively support these activities and consider by what means they can be further promoted.
- BECC researchers are active in *evaluating effects of increased bioenergy harvesting* to meet the demand of renewable energy, with a main focus on effects on nutrient and carbon balances. An opportunity for future BECC research is to further analyse the consequences of different types of demands on forest resources in a changing climate, from an environmental effect perspective. This would involve several research groups, including other clusters (e.g. Agriculture) and would be highly relevant to stakeholders, society and BECC overall aims. BECC should organise a workshop involving all relevant research areas aiming at an action plan how to efficiently make use of the combined skills within the research environment with respect to scenarios for future bioenergy request and their consequences for land use and ecosystems.

- A major strength of the Forestry and Global Change Cluster, which is currently being further developed, is the *strong interaction with stakeholders*. Several activities involving stakeholders are planned, e.g. the seminar in Stockholm 16 October 2013 mentioned above; Skogsbruk i ett förändrat klimat – Hur påverkas mångfald och miljö? (Forest management in a changing climate – How will it affect biodiversity and the environment?). The BECC programme should also organise a larger stakeholder-oriented conference related to forest ecosystems/forestry, climate change and other environmental pressures.
- Although some activity exists, it may be considered a gap that *forest biodiversity* issues are not sufficiently well represented in the Forestry and Global Change Cluster, e.g. compared to the activity in other parts of BECC related to the agricultural landscape and alpine/arctic ecosystems and in relation the overall BECC aims. Further, information on forest biodiversity in a global change/land use perspective has been explicitly requested by stakeholders in the process of establishing the stakeholder group, in particular by the Swedish Forest Agency. This BECC programme should take an initiative for a research based investigation of the potential effects of climate change on forest biodiversity in Sweden with consideration of land use change and other environmental drivers. This has to be a combined effort of several of the BECC clusters.
- There has so far been limited interaction between clusters for important *meta-level questions concerning land use* as stated in Cluster aim 3, which can be considered a gap. However, considering the wide competence of the combined BECC research team and the emerging interaction between different BECC components we believe that there is a strong opportunity for important results in this field over the next two years. Agent Based Modelling (ABM) might become an important tool in the future effects of BECC researchers within this field. It is suggested that a new Action Group on meta-level questions concerning land use is initiated to lead this work.

Cluster 3. Agriculture and Global Change

Coordinator: Katarina Hedlund Deputy coordinator: Henrik Smith

This cluster will synthesize knowledge and identify research needs to assess how the combined effects of land use and climate change affect biodiversity and production of ecosystem services in agricultural landscapes, in particular consequences of adaptation- and mitigation-oriented management.

Cluster aim 1. *Determine trade-offs and synergies between provisioning and regulating ecosystem services in conjunction with the intensification of agricultural management.*

Agent based models for evaluating trade-offs between agricultural production and land use change/habitat conservation. We have developed a new agent-based model in a collaboration between economists and ecologists within BECC for exploring whether cooperation among farmers to manage habitat in the whole landscape will increase profits and under what conditions, compared to farmers managing habitat independently. In an extension of this work we now aim to study the optimal level of governance of agricultural landscapes, and how different assumptions about farmer behaviour (e.g. TIT-FOR-TAT) might affect the evolution of cooperative habitat management. Further, we will analyse the robustness of cooperative solutions under different climate scenarios (see above).

Trade-offs among ecosystem services A framework for this have been developed within BECC when regarding regulating services in agriculture such as nutrient retention, climate mitigation, pollination and biotic resistance, and their trade-offs towards provisioning services. We have developed novel approaches to model production of ecosystem services, through development of production functions of above and below ground in landscape based ecosystems. This has been within the research projects SAPES, the EU projects SOILSERVICE and ECOFINDER and also enabled through collaboration with SLU as holder of data from long term agricultural experiments. Also through collaboration with the Basque centre of climate change, we developed a framework for working with trade-offs among ecosystem services in agriculture. A number of recent publications in highly ranked journals have been produced by cluster members that show the impact of intensification of agriculture on regulating and provisioning ecosystem services. One action group has been allocated within the agricultural cluster "Multifunctional agriculture" that covers several research projects within the cluster but aims at cross cutting over these projects.

Cluster aim 2. *Develop methods and models to quantify and value ecosystem services to predict agricultural land use across temporal and spatial scales.*

Valuation of ecosystem services- The economic modelling knowledge promoted in BECC has given a good strong research environment where we have had opportunities to develop our research in economic-ecologic modelling and thus here especially in agriculture which is a new research area at LU and that has been greatly enhanced by this. The support of economic modelling in research concerning biodiversity and ecosystem services has in a very efficient way promoted a research environment that has been used not only in the projects listed above but also by PhD students enrolled in the different PhD programs of eg Biology and Environmental sciences together with post docs from

the externally funded projects. A dynamic portfolio model has been developed as a tool for farmers/society to evaluate the risk reducing capacity (insurance value) of conserving soil organic carbon in the face of uncertainty about the future (i.e. climate change and market prices). The model can be used to determine how farmers might optimally manage their land to mitigate risk. The portfolio model is currently being applied to analyze the effectiveness of conserving soil organic carbon in arable soils as an adaptation measure for farmers. To develop this further with climate projections for the future is done in a new collaboration with Physical Geography.

Cluster aim 3. *With modelling activities evaluate the consequences for biodiversity and ecosystem services of different management and policy options.*

We have extended an agent based model for testing agricultural policy, the Agricultural Policy Simulator- AgriPoliS model for modelling not only farmers economy in response to current and future policy interventions but also incorporated the additional effects of production of ecosystem services on crop yields and land use decisions by farmers. This is done in collaboration between the SOILSERVICE project, SAPES and BECC and have given a very efficient model to test how ecosystem services can influence farmers economy and their decisions on management practices. This model is now capable of analysing individual farmers' responses to policy and determining effects on ecosystem services at the region/landscape scale. Currently we are working on integration of above-ground ecosystem services (pollination and biocontrol) into the models.

Improvements of models on crop phenology and allocation of carbohydrates in the crop in response to climate change has been develop in a new version of LPJ-GUESS, together with Physical geography at LU. Site-level simulations of crop (mainly wheat) production for selected sites in Sweden and Europe is ongoing. Collaboration between UGOT and LU regarding comparison of empirical studies (manipulation experiments) and modelling studies has been started.

Cluster aim 4. *Determine how mitigation and adaptation activities within agricultural land use will feed back to the socio-economic and governance systems.*

The link between agriculture and climate changes activities has mainly focused on land use intensification as on effect of mitigation activities and a review has been produced where a framework was presented that will increase the scientific knowledge on the impacts of agro-bioenergy on ES. A farmers postal survey comprising 1200 farmers in Scania conclude farmers attitudes towards decisions on land use and soil management. We have a visiting researcher Erik Nelson who is an economist and will start to develop models for valuation of ecosystem services under adaptation strategies to mitigate climate change, during his time in Lund. The LU- UGOT collaboration is developing, for the large scale modelling work on ecosystem services and agriculture, and economic modelling and regarding comparison of empirical studies (manipulation experiments) and modelling studies. Initiating contacts and gaining understanding for each other's methods has taken time, but the groups are well equipped now to address common research questions. Workshops and conferences have given a good added value to integrate the different research areas, like the scaling issues and modelling, that were presented in May 2013.

Cluster aim 5. *Engage stakeholders in order to develop ways to demonstrate how agriculture supports ecosystem services and provide a common channel for the dissemination of research findings to relevant stakeholders and society at large.*

We have a number of activities promoting stakeholder interactions on different levels of decision making, these have been reported in the BECC reports and are also listed in the appendix. We are active on the regional, national and international policy arena where we are pushing results from research into the research policy interface. The main focus have been on promoting ecosystem services in agriculture into frameworks such as CAP on national (with the Swedish Agricultural Board) and EU level, or the Intergovernmental platform for biodiversity and ecosystem services. On regional level there is also work in collaboration with stakeholders, as the Regional County of Scania, where a synthesis on ecosystem services is on the way and with Rural Economy and Agricultural Society of Malmöhus where we will build a web based user decision tool for farmers. Through several of the research projects we have started close collaboration with farmers organisations that now are part of research proposals and projects.

Gaps and proposed future aims and strategies

- The economic modelling knowledge has develop very well in BECC which has given unique opportunities to the good strong research environment where we have had opportunities to develop applications and activities cross over to almost all other clusters. Valuation of ecosystem services is and will be a very efficient way of promoting sustainable use of natural resources and also to achieve important stakeholder and policy impact. Thus we need to promote this area of research and to market the results we get in order to strengthen the impact of our research activities. The links /conceptual models between valuation of ecosystem services and decision on different levels and especially those in connection to climate change are yet to be developed. Though some collaboration between Lund and Gothenburg is now starting between the agricultural research projects research on policy at Gothenburg. We need to increase the production of synthesis and cross disciplinary of our research so that we can bridge among our different research topics. *To keep and further develop these competences within BECC in the future we need to make them long term and commit resources to this also the future.*
- We have in the cluster plenty of research activities on agriculture and the production of ecosystem services, at LU and UGOT, though still lack studies on predicting ecosystem services with adaptations for mitigating climate change. Here we have identified a need for addressing production of bioenergy crops and conflicts on land use as one key area of future research. We have started a small working group to propose how this can be turned into action. *There is a need for joint activities within BECC, as e.g. a synthesis of the current knowledge in this area that will cross over several clusters and especially the policy cluster as well as to promote a large research proposal on bioenergy for the future and to carry out conferences, workshops or seminar series to market ourselves both within BECC and outside.*
- Within the modelling framework of this cluster, we have two parallel modelling activities. One is modelling on a large global scale and long-time scales to predict future agricultural production during climate change (eg LPJ Guess). The other is more based on local adaptations or management and models on much shorter time scales and on regional scales, as e.g. the economic ecological modelling can work with around 20 years in the dynamic models. Within the cluster these two research areas are working in parallel and have difficulties in

merging some of the work that was intended in BECC. *The benefits from getting a more integrated view on these two types of modelling deserve more attention, such as work on a more conceptual way of bridging between them and land use –climate change questions.*

- We have not yet a focused strategy on how to do the science policy interface process within this area, and stakeholders meetings are good for making contacts but seldom result in actions for synthesis. *Here we need to get new initiatives for actions groups to be more targeted in their outcomes than what has been done so far.*

Cluster 4: Integrated Ecological Modelling

Coordinator: Ben Smith Deputy coordinator: Henrik Smith

While models will be applied in all clusters of BECC, the Integrated Modelling cluster will provide a forum for communication among the modelling groups (including mathematical statisticians) and, where appropriate, between modellers and empirical scientists, with the following aims:

Cluster aim 1. *Identify synergies between models, research teams and disciplinary expertise to facilitate the application of modelling approaches as envisaged in the proposal, and in current and planned future research of BECC.*

BECC has encouraged and brought together a number of research teams that were previously not interacting, or interacting at a lower level, around development and application of modelling approaches within research on biodiversity-climate-ecosystem interactions. Key examples:

- reconstruction of past land cover in coastal areas of the Baltic Sea to attribute past changes in coastal eutrophication and biogeochemistry to climate and human land use (Physical Geography and Ecosystem Science /Geology).
- statistical modelling of bird species climatic niches and ongoing work towards development of more mechanistic modelling of bird distributional changes accounting explicitly for climate and land use-related changes in habitats and landscape structure. (Physical Geography and Ecosystem Science /Biology).
- physiological process representations in large-scale models, e.g. plant ozone impacts, resistance mechanisms, carbohydrate storage and acclimation to temperature change, bringing together ecophysiological and process modelling expertise at Department of Earth Sciences with DGVM modelling at Physical Geography and Ecosystem Science.
- joint influence of ecosystem impacts and socio-economic drivers on land use decision making, the representation of such decision making in agent-based models, and the use of such models for the evaluation of adaptation alternatives in agriculture and forestry (CEC agricultural economics groups, Physical Geography and Ecosystem Science and external collaborators).

Cluster aim 2. *Develop e.g. statistical tools and methodologies for combining models with different properties and strengths for improved accuracy, coverage and the explicit treatment of uncertainty.*

Activities targeting this aim within BECC have been slow to get underway. To encourage the establishment of research in this area an action group on the topic of data assimilation and multi-model integration has been established. This AG focuses on providing tools and advice on approaches for *uncertainty/risk analysis* based on appropriate state-of-the-art statistical methods for projects throughout BECC; providing a test-bed for *synthesis* of scientific results; and identifying areas where policy recommendations are difficult to make due to knowledge gaps, high uncertainties etc.

Recent and ongoing activities initiated by the AG and relevant to this area include:

- Workshop on integrative modelling—data synthesis and emulation 21-22 May 2013, covering basics of Bayesian methods; emulation for analysis of computer models, expert elicitation and bayesian meta-analysis. The workshop attracted 26 participants including 12 ClimBEco-affiliated PhD students.
- Case study on altered risks due to climate-induced changes in bird phenology
- Collaboration with AG on on multifunctional landscapes bringing in risk analysis methods to analysis of trade-offs between ecosystem services in farmland accounting for resilience of land use alternatives.
- Development of an emulator-approach to parameter estimation and uncertainty analysis of a global agricultural production model.

Cluster aim 3. *Define scenarios and other external assumptions (policy, socio-economic drivers, management, land use etc) for impact studies throughout BECC.*

To encourage the use of common scenarios for “future climate” studies, thereby facilitating intercomparison and synthesis across different strands of BECC research, an action group was initiated on the topic of scenarios and climate data. In addition to organising a seminar on the generation and application of future projections of climate and land use, involving international speakers and attracting some 70 participants, the AG has initiated development of a web-based tool “DataGURU” designed to facilitate downloading, reformatting and interpolating of climate, land use and potentially other types of input and boundary condition data for impacts studies, as well dissemination of output data and results, e.g. for use as input data to other models/studies. The web tool will be accompanied by a manual including guidelines and advice for the choice of scenario data. The development of these tools has been guided by dialogue with the BECC community including a questionnaire.

With regard to “scenario” data for past climate, land use and vegetation, BECC researchers from Physical Geography and Ecosystem Science and Geology are active in LandClim (a now finished Nordic researcher network) and related follow-up activities that compile pollen-based landscape reconstruction and associated climate, land use and other data of relevance for the assessment of past interactions between climate, human land use and ecosystem structure and function, as an analogue of the future. This area, among others, is covered by the recently initiated AG on land-sea interactions.

Cluster aim 4. *Monitor and promote the integration of modelling within the various activities of BECC.*

This is the task of the cluster leader and role of the cluster meetings and other formal and informal interactions amongst the modelling cluster.

Modelling of soil biogeochemistry and soil biota-function links using the Coupe and ForSAFE models is pursued mainly under the umbrella of the Cluster 5 on climate, land use and biogeochemical cycles. This area could potentially benefit from synergies with other modelling groups via the modelling cluster.

Cluster aim 5. *Interact with stakeholders in pursuit of more relevant models, assumptions and applications and dissemination of findings.*

Stakeholder interactions directly initiated through the modelling cluster have so far not taken place. However, the use of models as a platform for concretising dialogue and information exchange between stakeholders and researchers remains an important goal. BECC researchers are active in a number of other projects with participatory activities involving stakeholders as part of the core methodology. In particular:

- Mistra-SWECIA is pursuing a study of global change adaptation in Swedish forestry from an interdisciplinary and cross-scalar perspective, accounting for multiple levels of governance as well as impacts on drivers from individual estate to landscape, national, regional and global scale. Participatory elements involving stakeholder dialogue in “focus groups” as well as interviews and questionnaires confront stakeholders such as forest owners (individuals and companies), advisers and policy makers with scenarios and impact assessments as well as evaluating the conditions and drivers of adaptation as a social process. This work directly involves BECC researchers from Environmental Economics (UGOT), Physical Geography and Ecosystem Science and CEC/Agricultural economics and also links to an EU-FP7 project CONNECT. BECC is supporting the development of agent-based modelling as a platform for stakeholder dialogue through a postdoctoral position on ABM.
- There is interest inter alia at LU/Biology in the use of risk analysis to support conservation and natural resource management, with some ongoing activities in collaboration with sectoral authorities.

To help encourage activities in this area the modelling cluster is cosponsoring a seminar on structured decision making in Autumn 2013.

Gaps and proposed future aims and strategies

- Work on the development and communication of knowledge about tools for model-data fusion, multi-model integration and risk analysis is just beginning. To promote a wide adoption of such tools and approaches, it will be important to complement the ongoing case-studies via the AG with guidelines, access to specific software e.g. for Bayesian analysis, worked examples etc. Creation of PhD course within ClimbECO on relevant topics should also be considered.
- There is a risk that the “added value” of the integrated ecological modelling cluster is only sparsely reflected in publications, as tools, data, concepts etc provided are part of the methodology not an outcome of science. Effort needs to be invested in finding ways to publish the development and framing of tools and methods as such. AGs are tasked to think about this. A few “fast track” papers to be published in time to include in the upcoming external evaluation would be desirable.
- There is still an unrealised potential to learn from past changes as a basis for understanding possible developments in the future, by more closely integrating the various strains of palaeoenvironmental research in BECC with the development of impact modelling as well as scenarios. While a new AG on land-sea interactions encompasses some relevant groups at

LU/Geology as well as Physical Geography and Ecosystem Science, this focus limits the representation of e.g. palaeoclimate researchers based on reconstruction using pollen, other proxies and tree rings at LU and UGOT.

- Land use is a common theme in several of the action groups and in other externally-funded projects in which BECC researchers are active. It is also relevant to a cluster of projects addressing direct versus indirect climate effects in Cluster 1 (mainly LU/Biology and UGOT /Environmental economics). Land use transitions (e.g. forest to agricultural land) are hardly discussed within current Swedish research, but are happening at a surprising rate, as revealed e.g. by work at the Department of Human geography, Land use transitions could represent a “niche” for BECC to develop analysis on. Generally in the area of land use change there are opportunities for synthesis as well as synergy, bringing together different modelling approaches (e.g. agent-based modelling, cost-benefit approach) as well as empirical studies with regard to present and potential future as well as past land use and land cover and relevant work on governance issues, e.g. institutional fragmentation. Potential downstream applications of resultant “products” such as maps and time series of potential future land use change include mechanistic studies of species distribution shifts and effects of land use and management on trace gas emissions.
- Accounting for anthropogenic processes (macroeconomics, trade, land use, management) in coupled Earth system models (regional and global scale). This is a “grand vision” in climate science and aligns with the breadth of research within BECC as well as in MERGE and related initiatives targeting the development and evaluation of ESMs. This area *may be relevant as a core objective in a future second phase of BECC.*

Cluster 5: Climate, land use and biogeochemical cycles

Coordinator: Anders Tunlid Deputy coordinator: Håkan Pleijel

The cluster focus on biogeochemical processes that are critical to the functioning of ecosystems and their services to society such as carbon (C) sequestration, greenhouse gas production and mobilization of nutrients (N, P and S).

Cluster aim 1. *Provide a platform for the interaction between ecologists analyzing the diversity of microbial communities, geoscientists who measure the release of greenhouse gases, C sequestration, and nutrient cycling, and theoreticians who develop and evaluate models of climate impacts change on ecosystem processes.*

While there are extensive researchers on biogeochemical processes on ecosystem levels, little is known about the molecular processes that control the transformation of C and nutrients, and this limits our ability to predict how ecosystems services like C sequestration and mobilization of nutrients will respond to environmental changes. However, *molecular geochemistry* is under rapid development due to the applications of novel methods. To become an active part of this development, the BECC environment has recruited a new professor, Per Persson. The recruitment was initiated by the BECC guest research program and become possible by additional funds from the Crafoord Foundation and LU. A major part of Per Perssons research has been devoted to surface chemistry of metal oxides/sulfides, desorption/adsorption reactions of P and the molecular structure of organic matter in soils and waters. He is an expert in spectroscopy and is involved in the development of the MAX IV synchrotron facility, which is a national research infrastructure hosted by LU. To promote research using this technology, an international workshop was organized in May 2013.

Increasing N deposition from human activities has altered the biogeochemical cycles in many regions throughout the US and of Europe and led to a range of environmental problems ranging from diversity losses and N leaching. Soil N availability will also affect C sequestration. BECC has supported the establishment of a research team of ecosystem modelers (at CEC and Physical Geography and Ecosystem Sciences, LU) and microbial ecologist (Biology, Lund) that examines the *interactions between nutrient and C cycling in forest ecosystems*. In 2011, the team organized an international workshop on “Carbon and nitrogen interactions in forest carbon storage”. The research team works in close contact with various stakeholders and has formed an action group. The team participates in several large projects and networks, e.g. the FORMAS Strong Research Environment Quantifying WeAthering RaTes for Sustainable Forestry (QWARTS) and a Nordic Network on Forest Soil Carbon-sinks.

Research on the *microbial control of the terrestrial C cycle* is very active in BECC. The group at Biology, LU examines the complex interactions between soil organic matter (SOM), environmental conditions, and the activity of soil microorganisms, that controls the stability of SOM. Research is conducted at different spatial scales including studies in model systems and experiments in mesocosms and ecosystems. The team has a close collaboration with the newly established group in molecular geochemistry. An important part of the research is to develop novel methods to assess the microbial activity and stability of SOM. The team has established an action group that has organized a number of international workshops and synthesis papers. Several of the researchers are active in LUCCI - Lund University Centre for Studies of Carbon Cycle and Climate Interactions, which is a VR

funded research centre at LU. The project that involves groups at Quaternary Sciences, Physical Geography and Ecosystem Sciences, and Biology examines the interaction between the C cycle and climate at different time periods ranging from the present time, through the "historical" period and the Quaternary, all the way back to the Cretaceous-Tertiary boundary 70 million years ago.

Aquatic biogeochemistry research in BECC focuses on the transport and transformations of dissolved organic carbon (DOC) and nutrients from terrestrial environment to freshwater, brackish water including the Baltic Sea. Recently initiated work at Biology, LU, on the interaction between DOC and reactive iron, and its impact on the stability/mobility of organic matter and brownification of surface water is a promising avenue that is stimulated by interaction with the group in molecular geochemistry. Another area that will take advantage of synchrotron-based spectroscopy is the research at Quaternary Sciences, LU, on the biogeochemical silica cycle. The researchers in aquatic biogeochemistry are active in the FORMAS Strong Research Environment Managing Multiple Stressors in the Baltic Sea, MULTISTRESSORS. The projects combine paleo-based approaches, ecological approaches, terrestrial and aquatic biogeochemistry, and modeling to address problems from the past, the present and the future.

Another strong research area at Physical Geography and Ecosystem Sciences, LU, is the *biogeochemistry and permafrost dynamics of northern ecosystems*. Particular emphasis is on permafrost dynamics and how melting permafrost throughout the Arctic are affecting ecosystem functioning in the form of greenhouse gas exchanges. The groups are working extensively in the field in Scandinavia, Svalbard and Greenland but also in controlled environment facilities in the laboratory. BECC has contributed to the funding of a project examining the interactions between plant, soil and herbivores and their feedbacks to the C cycle. Field studies are done on an arctic wetland located in the Zackenberg research facility on Greenland. The research group is coordinating DEFROST, which is a Nordic Centre of Excellence focused on cryosphere-mediated interactions between climate and ecosystems.

BECC has participated in creating two major national infrastructures that will significantly promote research within the area of Climate, land use and biogeochemical cycles. The first infrastructure is *ICOS-Sweden* (the Swedish part of Integrated Carbon Observation System - a European research infrastructure to quantify and understand the greenhouse gas balance of the European continent and of adjacent regions) is coordinated by researchers at Physical Geography and Ecosystem Sciences, LU. The program has created six ecosystem stations that allows for studying the underlying mechanisms for Greenhouse Gas (GHG) emissions in a transect from North to the South of Sweden. The second national infrastructure is the *Skogaryd Research Catchment (SRC)* station. This facility has been established by researchers at Earth Sciences, UGOT, with funds from BECC and the strategic FORMAS project LAGGE (Landscape Scale Investigation of Greenhouse Gas Exchange) and support from UGOT. SRC was recently selected by VR to be one of the key terrestrial and limnic stations in the Swedish InfraStructure for Ecosystem Science (SITES).

Cluster aim 2. *Improve existing ecosystem models at various levels of complexity and scales for predicting the emission of greenhouse gases, terrestrial C sinks, and nutrient retention, utilizing best available data and theoretical understanding. Relevant data sources may include eddy flux, chamber and other measurements and high-throughput molecular analyses of the diversity and activities of microbial communities.*

Cluster aim 3. *In cooperation with the Integrated Modeling cluster of BECC, develop conceptual frameworks and tools (like data-assimilation techniques) for connecting data and models at scales*

from genomes to ecosystems over which the diversity of microbial communities could influence ecosystem services like release of greenhouse gases, nutrient leakage and C storage.

The dynamic integrated ecosystem model *ForSAFE-Veg* was initially developed by researchers at LU. BECC funding to the team working with the interactions between nutrient and C cycling has developed a “Phosphorous cycle module” that will be integrated into *ForSAFE-Veg*. The team is also working on a module describing nutrient feedbacks on C allocation pathways in forest ecosystems. There are also several ongoing studies validating the *ForSAFE-Veg* model using data from long term monitoring and experimental forest sites in Sweden.

Researchers at Earth Sciences, UGOT use the Coupled heat and mass transfer model for soil-plant-atmosphere system (*CoupModel*) that was developed at KTH (Royal Institute of Technology) in Stockholm. The BECC funded group at Earth science department further developed the greenhouse gas and leaching module in *Coup* and it has been used for modeling the effects of management and N-deposition in Swedish forest ecosystem. The group has also implemented the MYCOFON model to the *CoupModel*. The MYCOFON model contains a description of fungal C and N pools and all major C and N exchange processes and simulates the contribution of ectomycorrhizal fungi to forest C- and N- cycling. Furthermore, the *CoupModel* has been calibrated for drained afforested organic soils describing nitrous oxide (N₂O) emission from soils, conducted using data from the SRC station. This work couples to a Swedish Energy Agency funded project on development of tools for estimating N₂O emission due to energy production. Furthermore, tools to predict GHG emission size (CO₂, N₂O and CH₄), like modeling and emission factors, are under development by the UGOT team, for use in prediction of emission size due to land use management and production of biomass as well as upscaling emission over full landscapes.

No major achievements have been done in the development of *data assimilation techniques* aiming at connecting high-dimensional molecular data generated by sequencing or spectroscopy to rates of biogeochemical processes.

Cluster aim 4. *Develop novel high through-put methods for assessing the functional diversity of microbial communities in soils.*

BECC has supported a project aiming at Biology, LU, developing *new molecular methods for assessing the functional diversity* of microorganisms involved in the terrestrial C cycle. A web-based tool for analyzing the diversity of genes and transcripts encoding enzymes involved in the hydrolysis and oxidation of C substrates has been developed. The method is validated by analyzing the functional diversity of the carbon-degrading microbial community in agricultural soils subjected to various management intensities. The projects benefits from the infrastructure developed at the large-scale DNA sequencing infrastructure at the Biology department of LU. BECC funding has contributed to the bioinformatic support provided by this unit. BECC has also supported the development of a facility at LU for *Isotope Ratio Mass Spectrometry* (IRMS). Funds from LU have been obtained for setting up a new FTIR/Raman spectroscopy laboratory for analyzing the chemical structure of organic matter and its interaction with microorganisms and mineral surfaces. The value of having these infrastructure facilities close to the researchers cannot be overemphasized; novel protocols and methods can be developed and the steps needed for applying such advanced technologies for inexperienced users becomes relatively small. Furthermore, the facilities are important platforms for organizing workshops, training courses and for developing novel projects and interactions.

Cluster aim 5. Assess how the combined effects of land use/management and climate change affect the biodiversity and ecosystem services provided by microbial communities.

This is the focus in many of the research groups affiliated with the Cluster. Examples of projects are: (1) The effects of increased N loads on N leaching from forest ecosystems; (2) The effects of land use/management on the decomposition and transport of organic material from terrestrial to aquatic ecosystems; (3) The effects of increasing temperature and drought/rewetting on fungal and bacterial communities (including activities in collaborations with the FORHOT, the INCREASE and the Rubicon projects, and The Harvard Forest Long Term Ecological Research (LTER) program); (4) Soil salinization effects on the microbial functioning and soil fertility in agricultural ecosystems; (5) The role of soil microbial communities in mitigating shifts in nutrient availability resulting from either fertilization, increased harvesting, or natural gradients in mineralogy; (6) Combined climate change effects (elevated CO₂, warming, drought) on nitrogen cycling in soils; (7) The importance of plant-herbivore interactions for trace gas exchange and nutrient cycling in a warming arctic climate; (8) Impact of draining and land management on GHG emission, a work connected to Global Research Alliance and the FAO community for climate change mitigation in agriculture.

Cluster aim 6. *In cooperation with the Forestry, Agriculture and Integrated Modeling clusters, improve the assessment of risks of increased carbon release, greenhouse gas emissions and nutrient leakage from forest and agricultural soils due to global change. The result should be put in a policy perspective by modeling different scenarios of climate changes, land use management and atmospheric deposition, to provide decision support to stakeholders.*

Knowledge produced within the BECC research area of soil management and climate change impact on ecosystem nutrient cycling and losses to the environment has been valuable for stakeholder policy and decision support. This is continuously requested from both Swedish and international stakeholders. Examples of well-established interactions with Swedish stakeholders are: the Swedish Environmental Protection Agency, the County Administrative Board of Skåne, the Swedish Energy Agency, The Swedish Forest Agency, the Swedish Board of Agriculture and the Federation of Swedish Farmers (LRF). Internationally BECC researchers are co-operating with a large number of organizations like the Environment Directorate- General and the Joint Research Centre of the European Commission, the UN Food and Agricultural Organization (FAO), the Global Research Alliance on agricultural greenhouse gases, the IPCC Emission Factor Database and many others. Further information on some of these activities is reported in Cluster 2 (Forestry and Global Change) and Cluster 3 (Agriculture and Global Change).

Gaps and proposed future aims and strategies

- High priority should be made to develop the frameworks and tools needed for connecting high dimensional biodiversity and molecular data to the rate of biogeochemical processes (i.e. Cluster aim 3). The approach is needed for extrapolating measurements of biodiversity and processes from small to large spatial scales and for integrating and understanding of mechanisms at molecular levels to processes operating at ecosystem levels. BECC should consider launching a post-doctoral position in this area. There are many international efforts in this direction and BECC scientists should be stimulated to participate in these networks.
- The spatial arrangement of habitats in the landscape channelizes and constraints the flow of nutrients and carbon among landscape elements. There is a need for more knowledge about these processes and *BECC should stimulate the developments of projects examining the cross-*

boundary flow of materials and organisms between various habitats. The SRC infrastructure provides a large opportunity for such projects.

- In BECC several models are developed and used in parallel; the ForSAFE-Veg ecosystem model, LPJ-GUESS and the CoupModel. These models have all been developed for many years, however having different premises and possibilities. Co-operation and integration of modeling projects have the possibility to compare performance of predictability of e.g. the emission of greenhouse gases, nutrient retention and C sequestration. *BECC should stimulate activities promoting the interactions between the various communities of modelers, as well as an increased cross-fertilisation between modelling activities and empirical research, building for example on model-data fusion and multi-model integration techniques developed in the Integrated Ecological Modelling cluster.*
- *There is a need to develop an infrastructure for mesocosm experiments* that could reveal the mechanisms underlying the response of microbial driven biogeochemical processes to climate change. Such experiments provide a platform for coupling genomic-based, mechanistic biology and soil science to environmental and climate variables to explore the linkages between biogeochemical processes and ecosystem functions. BECC should assist in funding such an infrastructure.
- Biogenic volatile organic compounds (BVOC) emitted from terrestrial ecosystems influence the global climate. However, BVOC is not only emitted from the vegetation, but also from soil microorganisms participating in biogeochemical cycles. *BECC should promote interactions - e.g. by organizing a workshop - between the geoscientists studying BVOC emissions from terrestrial plants and the microbial ecologists examining the turnover of soil organic matter.*

Cluster 6: Governance and Economics of Natural Resources

Coordinator: Fariborz Zelli/Jessica Coria/Annica Kronsell Deputy co-ordinator: Katarina Hedlund

This cluster will critically evaluate synergies and trade-offs between policies addressing climate change, biodiversity protection and ecosystem resilience as well as formulate policies and strategies that lead to an integrated policy management of these areas. This includes both analysis *for* policy and analysis *of* policy. In the following we discuss how the cluster has progressed in addressing these aims.

Cluster aim 1. *Critically evaluate synergies and conflicts between policy instruments and institutions that address climate change, biodiversity protection and ecosystem resilience as well as formulate policies and strategies that lead to an integrated policy management.*

The action group on ‘Monitoring forests and the effects of forest governance in a changing climate’ was set up to develop options for integrated policy management. It combines the widest spread of disciplines that BECC has to offer, from physical geography to economics and political science and their work will lead to inter-disciplinary publications on synergies and conflicts between political and social aspects of remote sensing, inventory and modeling approaches.

A range of specific projects also focus on this aim and evaluate synergies and conflicts between policy instruments in more detail. The project ‘Conserve or convert? Pan-tropical modeling of REDD–bioenergy competition’ analyses land competition between tropical bioenergy plantations and forest using spatially explicit data on biofuel feedstock (oil palm and sugar cane) suitability and forest biomass carbon stocks. The results show that REDD+ may play an important role in stemming biodiversity loss but presents a risk in relying on a system that values forests solely for their carbon retention capacities which needs to be taken into account when designing policies. The project ‘Interaction between the Pillars of The Common Agricultural Policy (CAP)’ analyses the effects of the interactions of the two pillars of the CAP on farmers’ participation in organic farming in Sweden. The results indicate the existence of trade-offs between the pillars. The project ‘Land Development Restrictions and Preemptive Action: on the Benefits of Compromise and Differentiated Regulation under Endangered Species Act’ addresses the problem of preemptive land development to avoid future regulation.

Another set of projects analyze the relation between institutions and policy: The project on institutional fragmentation and complexity maps synergies and conflicts between institutions and policy approaches in the fields of climate change, biodiversity, forestry and renewable energies. Another project identifies and compares different rationalities and techniques of government in the history of Swedish Forest Politics and yet another takes a multi-level perspective to address conflicts between norms that inform different policy instruments and institutions on carbon accounting in forestry governance.

Several publications outline the ‘analytics of carbon accounting’. Contemporary climate governance hinges on the ability to account for stocks and flows of carbon and to turn those into stable objects that become governable. Different policy instruments rely on a similar governmental rationality (the counting of carbon). It raises questions whether it is useful to base different policies on the

measurement of carbon and what the implications of this are for different ecosystems (e.g. tropical rainforests).

Cluster aim 2. *Analyse the coherence between existing institutions and potential policies and policy instruments in the face of ecosystem and biodiversity changes, for instance in terms of regulations of new management practices, and the capacity for dealing with goal conflicts within different institutional frameworks.*

A number of projects on land and on forestry are addressing this aim. For example, the ‘Land Conservation Programs, Spatial Contiguity, and Crowding-out or Crowding-in Conservation Effort’ analyses the effects of the interactions of land conservation programs sponsored by government agencies, quasi-governmental agencies, and private conservation organizations. Research on the forestry sector looks at how REDD as a new policy instrument creates difficulties as it overlaps between new institutions and existing forestry governance institutions. On the other hand, it is also evident that REDD related norms can drive policy innovation and institution-building in forest governance. Another research group models changes of decision-making in the forest sector in the course of the sector’s adaption to climate change.

Cluster aim 3. *Analyse the costs and benefits of ecosystem service and biodiversity losses under alternative adaptation and mitigation strategies, with a particular focus on the role of ethics, discounting and uncertainty in long-term assessments.*

Two projects quantified the benefits of ecosystem services. ‘Amenity Values of Proximity to National Wildlife Refuges—an Analysis of Urban Residential Property Value’ quantifies the property value benefits of the National Wildlife Refuge system in United States. The project CONNECT uses choice experiments to gain a better understanding of the societal demand for ecosystem services and biodiversity. It includes monetary valuation of biodiversity variables and other ecosystem services in the Swedish forest landscape. Other research makes such evaluations in more general terms, such as in the project on bioenergy governance that has looked at indirect land-use changes in relation to EU biofuel policy by scrutinizing the implications of decision-making under uncertainty in this emerging field of governance. Another project analyzes the impacts of soil management on soil fertility and yields, based on policy analysis (CAP) at the regional level.

Cluster aim 4. *Develop and critically evaluate policy and management scenarios targeting adaptation, mitigation and conservation goals for Sweden and Europe, integrated with global narratives and their assumptions in terms of global, regional and national development in socio-economic and biophysical drivers (climate change, emissions) of biodiversity and ecosystem change.*

Several projects take on this task: ‘Does biodiversity promote uptake of organic farming? A micro land plot level study in Skåne (Sweden)’ provides an in-depth evaluation of the policy effectiveness for agro environmental schemes by testing whether land with a higher biodiversity level are more likely to be enrolled in the organic farming. The project ‘Changing the land use of drained organic soils, implications for GHG emissions, biodiversity and policy instruments’ analyses different land management options for drained organic soils on the change of GHG emissions, biodiversity and leaching. It compares the cost-efficiency of different mitigation strategies based on drained organic soils and evaluates the use of bundling of ecosystem services as a policy alternative that brings both reduced GHGs and increased biodiversity together.

Cluster aim 5. *Evaluate the consequences for biodiversity and ecosystem services of different management and policy options, and to critically analyse the changing conditions for policy development.*

Two projects address this aim: ‘Natural Resource Management: Challenges and Policy Options’ questions the role of current rare species strategies in biodiversity management. Using interdisciplinary synthesis it asks what are the consequences of different management and policy options for biodiversity and ecosystem services. The MULTAGRI project evaluates how the governance of agricultural landscapes can promote rural development.

Cluster aim 6. *Engage in dialogue with societal actors as well as integrate perspectives of stakeholders in the research process on the evaluation of sectoral policies.*

We have actively engaged in dialogue with stakeholders through dissemination of research results at conferences of several academic associations, research institutes and related networks. We have interacted with public agencies and in particular the Swedish Environmental Protection Agency, United Nations Convention on Biological Diversity, United Framework Convention on Climate Change and the United Nations Forum on Forests. Furthermore, we have also built a close relationship with the Swedish Forest Agency. The project ‘Changing the land use of drained organic soils, implications for GHG emissions, biodiversity and policy instruments’ has established a pattern of regular meetings with stakeholders and the Länstyrelsen in Jönköping is particularly important.

Cluster aim 7. *Provide policy support and recommendations to the policy community for a more integrated policy management of biodiversity, climate and agricultural policies.*

There are several examples on how this aim has been reached: The project ‘Optimal Regulation of Multiple Pollutants’ provides specific policy recommendations for a more integrated policy management. Another project ‘Optimal pricing of variable environmental load – the case of congestion fees’ offers policy recommendations regarding the design of environmental policies to deal with the presence of environmental thresholds and variable pollution loads. The MULTIAGRI project will provide policy recommendations on the governance of agricultural landscapes. Agent-based modeling provides insights on how cooperation evolves among farmers. This can optimize existing policy instruments.

The cluster has also made recommendations directed to international policy-makers on how to navigate and orchestrate the different institutions in the climate change sector in a meaningful way. More specifically, overviews were given to policymakers in the Global Forest Expert Panel on Biodiversity, Forest Management and REDD+ about the overlaps and conflicts between policy instruments and the implications of these conflicts on stakeholder participation.

Gaps and proposed future aims and strategies

- While core research areas for BECC like land, agriculture and forestry have been addressed in the cluster, one key research area that would have benefitted from stronger support is the area of bioenergy governance. Some research efforts addressed this timely policy topic in an interdisciplinary manner – thereby serving the goal of analyzing costs and benefits of mitigation strategies – but these first approaches have not been further pursued in the cluster.

The new initiative on a BECC action group on bioenergy may be a way to intensify this strand of research.

- It is clear that the different research groups and projects included in the cluster have so far contributed novel research results that relate to all cluster goals. However, the listing of contributions shows its patchy character: depending on the mix of researchers, the availability of methods, some activities are stronger on some goals than on others. For instance, the goal of evaluating policy and management scenarios can only be served by projects with respective skills. This patchiness may not necessarily be a weakness in terms of a lack of integration; it may be due to certain choices of the involved people in terms of research goals. However, for future research, it is desirable to further extend the research across disciplinary boundaries of natural and social science in this cluster.
- The experiences of collaboration in the cluster indicate that building interdisciplinary understanding between diverse scholarly cultures and personalities is not easy and may take more time than anticipated. But once this common understanding and confidence has been created, this investment pays off and yields increasing benefits over time. Thus, it is important not to think of the research and action groups and / or synthesis work only as short term projects. After the first phase of research that has been fairly effective, an extension could multiply results and ultimately contribute to the core of BECC's objectives and its high interdisciplinary ambition.
- It may be worth putting more effort in some overarching themes to which all different activities could contribute more coherently. In the cluster we will explore options for joint work on the paradigm of 'green economy'. Many researchers within and beyond the cluster already work on this issue from different angles: market-liberal norms in environmental governance, economic rationality in governance, climate transitions, market-based environmental mechanisms, the Rio+20 process and its failure, bioenergy and biobased economy. Bringing the different angles together in an inter-disciplinary discussion of different understandings, options for and limits to a transition to a green economy could provide a major synthesis outcome for BECC. Having this as the topic of our annual meeting can provide one starting point for a cross-cutting debate.

4. Development of BECC as a strategic research environment

Here, we synthesise the main conclusions arising from the clusterwise analyses of gaps and priority areas for development within BECC in a medium and longer term. The analysis and conclusions drawn are relative to the long-term vision, defined in the original proposal:

“The vision of BECC is to create a world-leading inter-disciplinary research programme on climate-ecosystem-biodiversity relationships at multiple scales, bringing together ecological modelling with empirical studies and linking this with policy and governance for the sustainable management of ecosystems and biodiversity in a rapidly changing world”.

For the medium-term, encompassing above all the remaining 1-2 years for which the central funding of BECC is secured, the specific aims and objectives laid out in the original proposal constitute a primary consideration for the identification of gaps and the definition and prioritisation of activities to fill the gaps. This is seen as critical for a successful external evaluation, and as a basis for the further development in a prospective future phase. Current aims and objectives form a backdrop also for reasoning as to the long-term strategic development of BECC, beyond the current period of funding, but we have also taken into consideration ongoing and prospective developments within the diversity of fields encompassed by our research, as well as the realised evolution of BECC in terms of organisation, focus, scope and expertise.

BECC is not a research project, but an environment that builds upon and supports the development of already existing research project as well as stimulating the development of relevant new research projects and studies. Thus BECC strives to identify efficient ways to support and develop research, to promote an intellectually stimulating and creative research environment, to assist researchers in developing their careers, to strengthen international scientific interactions and, not least, to stimulate interactions with society in a mutual learning process. In this section we identify the progress and the gaps in this area in relation to seven goals for the 5 first years of BECC, formulated in the original application.

- ***Goal 1: A research platform recognized as a world-leading research environments on the interactions between climate, biodiversity and ecosystem functioning***

BECC is well on its way in several areas, in particular benefitting from the high quality research and visibility of several strong and emerging research groups. BECC researchers are also active in the leadership of many international research projects. During its first years, BECC has significantly promoted the development of research in the area it encompasses by strengthening the interactions between existing research groups. International workshops organized have increased our international visibility.

However, although research carried out in various parts of BECC has a high international and national visibility, as a research environment we is less well known outside of Lund and Gothenburg Universities. Increasing the visibility of BECC as a research platform may benefit the generation of grants, top-level recruitments and guest researchers, as well as enhancing the level of interest in our findings and activities by stakeholders such as national authorities. Thus, it is important that all of the many research groups encompassed by BECC perceive benefit from our activities and infrastructure,

thereby motivating researchers to expose and highlight their affiliation not only when presenting directly BECC-funded research but at all opportunities. The high number of cluster, action-group and seminar activities has undoubtedly contributed to building a common identity and team atmosphere among the BECC community.

Gaps and proposed future aims and strategies

- BECC should systematically support researchers in applying for and coordinating large international research projects, including various instruments under Horizon 2020 (the new framework programme of the EU), for example by direct administrative *support during writing of applications*.
- BECC should aim for *organizing symposia/sessions* at large international conferences to promote visibility. This could be done by allocating some resources to support researchers taking on such responsibility with a significant BECC contribution.
- BECC should continue with the organizational and/or financial *support for international workshops* at LU/UGOT, but also increasingly expose the results of these workshops internally and externally.
- BECC should systematically *document and expose the role of BECC-affiliated researchers in the international research community*, for example as invited speakers, symposia organizers, project coordinators etc. Such information should be showcased inter alia through the BECC website.
- To promote visibility, BECC should develop a systematic way to support young researchers in the publication of regular papers, opinion pieces or synthesis *papers in highly ranked journals*. To this end BECC could arrange high-quality training courses and support and/or create a supporting peer-system.
- Develop a systematic *branding strategy*, including e.g. presentation templates, brochures, acknowledgement formulations etc.
- ***Goal 2: Significantly increased our ability to predict consequences of climate change on sustainable production, biodiversity and ecosystem services, by the integration of new knowledge on ecological processes in mechanistic modelling frameworks.***

BECC has significantly contributed to increased interactions between modellers and empirical scientists. However, there is still scope for working more systematically to utilize details in ecological process understanding to develop predictive models, for example in the biogeochemistry area. By analogy, there are also opportunities to build on extensive expertise in land use, land management, policy-making and economics in the environmental area as a basis for accounting for such processes in models such as agent-based models (ABMs), integrated assessment models (IAMs) and a future generation of Earth system models (ESMs). Important progress has been made in adapting modern statistical approaches to the analysis and integration of models as well as ecological data in pursuit of improved ways of accounting for uncertainties and as a basis for a risk perspective on impacts. We have also made significant progress in terms of linking economic and ecological modelling. We have

developed tools to facilitate to provision scenarios and boundary conditions for ecosystem impact studies and to facilitate synthesis across BECC.

Gaps and proposed future aims and strategies

- Models relating productivity and ecosystem services to land-use and climate are developed in several research groups and benefit from empirical research in additional groups. However, these models differ in scale and objective. There is an opportunity to link these models to be able to capture the combined effects of climate and land-use change. Agent-based modelling and related approaches keep promise for bringing together socio-economic and biophysical dynamics of land use.
- BECC research findings on ecosystem and biodiversity impacts and their relationships to biophysical drivers as well as habitats and landscape patterns are relevant for linking to global and, particularly, regional Earth system modelling, as developed and evaluated in MERGE and related efforts. For example ecosystem impact modelling may be used to address the ecological consequences of ESM-generated projections and scenarios. In addition, BECC research on land use decision making/management can inform the development of “human dimensions” components for a future generation of ESMs.
- There is potential for increased interactions and synergies across research groups working with paleo-landscape reconstruction, analysis of land-use trends, landscape modelling and impact studies on land-use related effects. The new action group “Land-Sea Interactions in a long time perspective” provides one platform for such linkages. Some of this work hinges on researchers with time-limited contracts. Thus, it is important that BECC *contribute to the long-term development* of this area.
- An important goal of BECC is to bring together models focusing on different components and processes of ecosystems and on different scales, along with data and process knowledge emerging from empirical studies, using modern statistical methods such as data assimilation techniques, emulators and bayesian statistics, for increased predictability, analytical power and the explicit consideration of uncertainty and risk. *BECC should stimulate activities promoting the interactions among the modelling communities within BECC, as well as an increased cross-fertilisation between empirical and model-based research.*

- ***Goal 3: Established a common research school***

BECC has, together with MERGE and other partners developed a research school *ClimBEco* with a yearly admittance of 30 PhD-students. The development has been highly satisfactory, the first cohort of students now having completed the two-year syllabus. Activities encompass two general meetings annually, a large number of courses in different disciplines as well as a mentorship programme. Students from all departments involved in BECC and MERGE, as well as external applicants, have been enrolled in the school. Courses are both trans-disciplinary and in-depth and are mainly organized by researchers in BECC and MERGE, contributing to development of the research and promoting an increased cross-disciplinary knowledge and interest in a future generation of researchers. The mentorship programme supports the PhD students in areas such as career planning, building and strengthening networks, personal development - improving self-knowledge and communication. By

increasing communication among PhD students, as well as between students and senior researchers, ClimBEco is an important and highly relevant part of BECC today, and this will continue in the future.

Gaps and proposed future aims and strategies

- ClimBEco is jointly funded by BECC, MERGE and the Faculty of Science at LU. It is important to already now pay attention to future funding to *secure the long-term development* of the school. This has to be done in close collaboration with involved departments and faculties.
- BECC should work for the creation of a ClimBEco summer-school for PhD-students on climate-biodiversity-ecosystem service relationships as a way to increase international visibility and create networks for young researchers.
- ClimBEco is well integrated with BECC, but an even better integration could be achieved by more systematic cross-communication between ClimBEco and BECC regarding e.g. courses offered, key areas of research, other related activities such as seminars, workshops and stakeholder interactions, and opportunities for engagement in BECC.
- ***Goal 4: Recruited internationally leading researchers on climate change in a way that contributes to gender equality***

BECC has made or jointly supported a number of external recruitments that have added new competence to BECC, including lecturer positions, several postdocs and a professorship. BECC has also hosted a number of international guest researchers in different fields. While significantly stimulating research development, the recruitments have not contributed to increasing the gender equality in BECC. BECC has also supported young researchers in the BECC community in their ambition to obtain permanent positions, including highly skilled female researcher, thereby promoting increased gender equality in the longer perspective.

Gaps and proposed future aims and strategies

- Recruitment of well-recognized international researchers is currently being encouraged at both national and university levels, external funding opportunities exist. In close collaboration with collaborating departments and strong research environments, BECC should aim for *top-level recruitments*, which may both benefit research development and increase visibility. Here BECC should pay particular attention to contributing to gender equality.
- BECC should, in close collaboration with involved departments, focus on supporting highly qualified mid-career researchers in obtaining permanent positions. Depending on circumstances, this may, for example, include generation of external resources or creation of lecturer positions.
- Systematically utilize the opportunity to *invite guest researchers*, to develop prioritized areas of BECC research.
- BECC should facilitate sabbaticals by informing about suitable funding sources and potentially contribute funding, to increase collaboration with and visibility at important research centres.

- ***Goal 5: Significantly contributed to development of national and European policy concerning sustainable agriculture and forestry***

BECC has become established as a major knowledge hub for important Swedish stakeholders, e.g. the Board of Agriculture, the Forestry Service, and the Nature Conservancy Agency. BECC has been active in promoting outreach activities such as seminars with stakeholders, syntheses, opinion articles, etc. We are contributing to European policy development through involvement of European research projects (e.g. SoilService) and participation in think-tanks and networks (e.g. IUFRO – The World's Network of Forest Science) with some activities by BECC, for example in relation to the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). In addition BECC researchers have been very active in expert groups linked to the (mostly European) Convention on Long-Range Transboundary Air Pollution with respect to effects of air pollutants on forest and agricultural ecosystems. While a number of BECC-affiliated researchers are active in the international policy arena, an increasing mobilisation of relevant expertise from within the BECC community could be encouraged.

Gaps and proposed future aims and strategies

- BECC should significantly increase its activities vis-à-vis international initiatives such as IPBES, Future Earth and the Ecosystem Assessment in Europe, and the European biodiversity strategy, by monitoring their activities and brief the BECC community, as well as when possible aiming for direct involvement in these processes both at international and national level. To this end, BECC should find resources to create a web-based platform about ecosystem services under climate change to promote the science policy interface within this area.
 - BECC should develop a form for synthesis work for policy relevant questions. This work may be coordinated by the synthesis work recently initiated at CEC and the Centre for Environment and Sustainability efforts in Gothenburg. As a part of this BECC should also initiate a policy brief series and allocate resources to produce these briefs.
 - BECC should increasingly be present at international policy conferences, e.g. by arranging side events. This could be achieved by economically supporting research groups that organize such events.
-
- ***Goal 6: Established a long-term stakeholder network that enables the continuous presence of stakeholders throughout the research process.***

Stakeholder interactions are progressively changing from traditional outreach to two-way interactions, evidenced by systematic stakeholder interactions in many projects, in particular concerning forestry and agriculture. BECC has also contributed to increased opportunities to receive support during the grant application process in identifying and interacting with stakeholders. BECC has, together with MERGE, established a stakeholder reference groups. The group has developed a systematic process to identify research questions and areas in need of synthesis, which is currently finding its forms. This has resulted in a first inventory which will soon result in concrete actions. Stakeholder interactions are

progressively changing from traditional outreach to two-way interactions, evidenced by systematic stakeholder interactions in many projects, in particular concerning forestry and agriculture. BECC has also contributed to increased opportunities to receive support during the grant application process in identifying and interacting with stakeholders.

Gaps and proposed future aims and strategies

- The process on-going in the stakeholder reference group holds promise for additional developments of research and syntheses. It has resulted in a first inventory that will result in concrete actions to elaborate the proposals developed there.
- Interactions with stakeholders may make research questions more relevant, increase researchers' knowledge of the policy process, increase the use of research results etc, but may also affect research integrity and may take time and resources from other activities both for researchers and stakeholders. To discuss these issues BECC could arrange a workshop were good examples, are presented as well as potential problems discussed, to increase the awareness of BECC researchers of the benefits and risks of systematic stakeholder interactions.
- BECC's stakeholder interaction needs to be firmly placed within its science policy. In the coming years BECC will strive to evaluate stakeholder activities in a systematic way that is thoroughly informed by academic knowledge about the science and policy interface. BECC will consider if it may be relevant to put resources into studying how the process of stakeholder interaction evolves and through this contribute to general knowledge about stakeholder interaction.
- BECC should strive to increase the breadth of researcher participating in policy work at different levels, by encouraging young researchers to participate in policy-related conferences and inform about research in the public debate. This may give young researchers their own networks that they can use when producing applications or carrying out research.
- ***Goal 7: Made significant contributions to the method of synthesis and further developed interdisciplinary competence within the research groups.***

BECC has identified synthesis as an area where we need to make significant progress. To this end BECC has created a number of action groups, one goal of which is to promote the creation of specific synthesis products. By promoting meetings across disciplinary borders e.g. in the clusters, BECC has also encouraged cross-disciplinary synthesis. CEC with support from BECC is increasingly a meeting point for researchers from different disciplines, including new recruitments to use integrated assessment as a tool for synthesis. BECC is also contributing to the development of methods to integrate information from different sources, such as handling of uncertainty in multi model integration and combining quantitative and qualitative information when predicting. ClimBEco has spread interdisciplinary knowledge and interest among PhD-students. Interdisciplinarity has been a criterion for funding research projects in BECC.

Gaps and proposed future aims and strategies

- Although many interdisciplinary activities are going on within BECC, they are often not visible to the whole BECC community. Thus, there is an opportunity to use on-going efforts to stimulate additional development. Hence, BECC should *increase the visibility of interdisciplinary activities* in BECC, internally through our newsletter and externally through our home-page. Half-day workshops/seminars focusing on important societal issues that BECC are addressing from different disciplines may both expose and foster new cross-disciplinary research.
- Although several of the participating research groups have strong publication records within their respective fields, it can be viewed as a gap that the new positions or collaborations specifically initiated within BECC have so far resulted in relatively few publications. This modest production is partly the cost of establishing new research projects and interactions, in some cases starting up new PhD students/post docs, which may in the long run lead to important and pioneering science. There is a strong opportunity to promote scientific publication from the projects involving new constellations of partly multidisciplinary research initiated by BECC. Such publications should be made visible in newsletters etc.
- BECC has strived to promote cross-disciplinary research by (co)funding postdocs and research projects as well as by supporting Action Groups bridging disciplinary borders. It is important that BECC continues to support such initiatives, including defining new Action Groups that target emerging issues requiring a cross-disciplinary research agenda.

5. Conclusions

BECC received funding to carry out research that will contribute to advancing the international research front in the area of global change impacts on ecosystems and biodiversity, building further on an already strong baseline of internationally competitive research, and to benefit Swedish society by better informing management and policy choices in the face of environmental and socio-economic change.

This internal review, based on the yearly reports, discussions in the clusters and extensive consultation with the BECC community, confirms that BECC has been successful in creating a strong research environment by bringing together and facilitating links among research in a range of relevant fields and disciplines at Lund and Gothenburg universities. Existing strong research have benefitted from new investments in infrastructure, financial support to research, new recruitments, PhD-students, workshops etc. Furthermore, targeted efforts have resulted in new collaborations, an increased flow of ideas and methodologies, new synergies between disciplines and research teams, and many new projects. Even though BECC remains young as a research environment and relatively little effort has yet been invested in promoting BECC as a “brand”, BECC is, both internally and externally, increasingly known as a stimulating and competitive research environment.

An important goal of BECC is to increase cross-disciplinary interactions among its research groups to be able to tackle major research questions. Cross-cutting activities have begun to emerge in several areas, but since cross-disciplinary research takes time to establish this has so far not resulted in a significant increase in publications (relative to the number of involved researchers), particularly with regard to the challenging aim of cross-disciplinary *synthesis*. It will be important for BECC to secure the long-term development of the cross-disciplinary research that has been initiated and to continue to promote new initiatives of a cross-cutting nature. BECC should also increase its effort to make its findings visible to the research community and to stakeholders.

The clusters of BECC have been instrumental in developing the research, by functioning as an arena for discussions both about how to develop specific areas of research, and as a context in for different research groups to meet and develop collaboration. However, there is a need to further develop efforts targeting the assessment of management/policy/land use choices and their consequences in different sectors under global change, and studies of the potential for integrated (i.e. cross-sectorial) management to achieve adaptation and mitigation goals.

BECC has recruited early-career researchers in several fields, who have been pivotal in creating links between research groups from the involved universities, departments and disciplines. It will be important to secure a return on the investment in this new generation of researchers to secure BECC’s long-term development, supporting them in their ambition to secure continued funding and by the establishment of new faculty positions in interaction with collaborating departments.

BECC is very active at the policy arena both internationally and nationally, through the collective efforts of engaged researchers. By making BECC as a research environment more visible in this context, we may attract more attention to the relevant work by BECC researchers, in particular in times when ecosystem services in a changing climate are increasingly in focus in the policy arena. Where possible and relevant, BECC should therefore take initiative to engage in the public debate, exposing the importance of our research for the future development of Swedish economy and welfare to stakeholders, decision-makers and the public at large.

i. Abbreviations

ABM: Agent Based Modelling

AG: Action Groups

BECC: Biodiversity and Ecosystem Services in a Changing Climate

BVOC: Biogenic volatile organic compounds

CAP: The Common Agricultural Policy

CEC: Centre for Environmental and Climate research

COUP: Coupled heat and mass transfer model for soil-plant-atmosphere system

DGVM: A Dynamic Global Vegetation Model

DOC: Dissolved Organic Carbon

ESM: Earth System Models

FORMAS: The Swedish Research Council Formas

ForSAFE: An integrated dynamic forest ecosystem model

GHG: Green House Gas

LPJ-GUESS: an ecosystem modelling framework

LU: Lund University

REDD: Reducing Emissions from Deforestation and Forest Degradation

SLU: Swedish University of Agricultural Sciences

SOM: Soil Organic Matter

SRC: Skogaryd Research Catchment

UGOT: University of Gothenburg

VOC: Volatile Organic Compounds

VR: The Swedish Research Council

ii. Short description of AGs

Land-sharing vs. land-sparing in a changing climate: consequences for ecosystem services and biodiversity *Coordinator: Johan Ekroos.*

This action group asks whether we can find synergies between the conservation of rare and/or endangered species in a changing climate and the promotion of ecosystem services in agri- and silviculture by land-sparing, as conservation areas may promote regulating ecosystem services in production landscapes (e.g. through organism spill-over), or land-sharing, because actions benefitting ecosystem providers in production landscapes also benefit rare species (e.g. by promoting habitat connectivity).

The action group has been working with several synthesis papers combining economists, ecologists and social scientists. These efforts have so far resulted in one (submitted) paper, dealing with how to move forward in the debate on land-sparing versus land-sharing, and another (to be submitted in September 2013) on a conceptual model on the spatial allocation of agri-environment schemes specifically targeting rare species or ecosystem service providers.

In addition, an inclusive review including multiple BECC researchers is on the planning stage, and a workshop is also on the agenda. The review paper deals with fundamental problems relating to definitions of land-sparing and sharing in production landscapes, what evidence we actually have for 1) sparing to benefit regulating ecosystem services and 2) sharing to benefit rare species, and finally how to achieve efficient sparing/sharing in production landscapes through agglomeration/collaboration between multiple farmers/forest owners.

Consequences of phenological shifts for wild and managed ecosystems in Sweden *Coordinator: Jacob Johansson.*

This group will move beyond the simple statistical relationships between phenology and climate, and determine the role of species interactions in a changing climate on phenology and what consequences this has for conservation policies. It will:

- determine how shifting phenologies affect species interactions, demography of populations and important ecosystem services in a changing climate
- use this knowledge to inform forestry, agriculture and conservation policies

The action group has been very active and successful in creating a network between researchers from different research groups and departments, and attaching Lund to the national Swedish phenology network. A symposium with large attendance from researchers from all parts of Sweden was arranged in connection to the Oikos conference. Drafts for two review articles have been prepared. Work on a special issue on "Phenological shifts and ecological interactions" for the Oikos journal has been initiated and has attracted internationally leading scientists. Activities in the action group resulted in the Phenobird project, which got funded by BECC and is now running. Six local seminars have been held.

Sustainable forestry in a changing climate *Coordinator: Cecilia Akselsson.*

This action group closely relates to the overarching goal to assess how the combined effects of land use and climate change affect biodiversity and ecosystem services in forests, in particular consequences of adaptation- and mitigation-oriented management alternatives. Thus, the action group builds on a combination of policy research and science. The group will:

- create a common platform for forest related research in BECC and other programs where BECC researchers are involved (e.g. MISTRA-Swecia and CLEO), in order to be able to give a more holistic view on climate change effects and resulting adaptations on sustainability.
- identify areas where we need to improve in the forest research and come up with strategies on how to solve it.
- coordinate stakeholder interactions.
- facilitate communication between social and natural scientists in the forestry field.
- perform synthesis work and mappings in related research fields.

The action group has together with Mistra-SWECIA and CLEO written a working report about forest management scenarios in dynamic modelling; *Skogsskötsel i dynamisk ekosystemmodellering – Vilka val måste göras och vad bör dom grundas på?* Furthermore, the group has been responsible for the planning of a seminar arranged in a cooperation with Mistra-SWEICA, CLEO and KSLA, with stakeholders as an important target group. The seminar *Skogsbruk i ett förändrat klimat – Hur påverkas mångfald och miljö*, will take place in Stockholm October 2013. The action group has organized an internal BECC seminar in 2012 discussing the multiple requests of ecosystem services from forests. The group is also involved in synthesis work on C sequestration in forest soils, in collaboration with the Nordic Forest Soil Carbon Network (Nordforsk).

Climate data and scenarios: *Coordinator: Veiko Lehsten*

We realized that the available climate and scenario data is underutilized in current research activities within BECC. One reason is that the available climate data often comes in a format, unit, resolution or extend which does require data manipulation to allow the researchers to use it in their research. We also realized that many projects generate large amounts of data in the form of times series of maps which are not directly publishable but nevertheless very interesting for later projects or projects of other groups. Here again, the format that the data has been stored might not be known to the format that the other research groups work with. This has been realized by the funding agencies and VR as well as FORMAS require a data dissemination strategy for each project to be funded. Within BECC no central data dissemination strategy has been developed before.

The main aims of the action group are to promote the use of climate and scenario data and to provide a technical solution for long time data dissemination.

We started to develop a server application which will allow via a simple interface to browse, re-grid, trim and download climate and scenario data. This web-based service (DataGURU) is currently in a starting phase, it contains already several climate reanalysis data sets with a number of variables. It is fully functional in a way that the user can already browse and re-format the data and will be provided with a download link once the operations are finished. Next steps will be to build up a database in which all project generated data can be stored for a long time.

We also organized a seminar with the title ‘Generation and application of future projections for policies, land use and climate’ to which we invited internationally renowned speakers to present the available data as well as presenting typical uses of this kind of data within BECC.

MICROGLOBE Microbial control of global biogeochemical cycles *Coordinator: Johannes Rousk.*

Soils represent the largest and most stable reservoir of carbon (C) in terrestrial ecosystems and contain more than three times as much carbon as the atmosphere. It remains largely unknown why some of the soil organic matter (SOM) persists for millennia whereas other decomposes readily –and this limits the ability to predict how this carbon stock will respond to climate change. The action group will:

- provide a platform for the interaction between microbial ecologists analyzing the diversity and activity of soil microbial communities, biogeochemists who measure the turnover of SOM and nutrients, and modelers who develop and evaluate climate impact change on carbon cycle and biosequestration.
- support a forum to develop the ideas of aim 1 through organisation of workshops, seminar series, and synthetic publications.
- develop a toolbox to determine how the microbial community partitions its C-use, and to connect microbial activities at the micro-scale to ecosystem-scale C fluxes

The action group has been very active in organizing workshops and symposia. “Microbial regulation of global biogeochemical cycles” attracted 10 international keynote speakers and 40 participants, and the contributions will be published as a Research Topic (Special issue) in *Frontiers in Microbiology*. To stimulate interactions between ecologists, geoscientists and spectroscopists, the international symposium “Synchrotron radiation in environmental and soil science” was jointly organized by BECC and the MAX IV synchrotron group at Lund University. The group has also organized a mini symposium on “The biogeochemistry and microbial ecology of soil desiccation and re-wetting”.

Constraints on range-shifts: consequences for conservation strategies *Coordinator: Paul Caplat.*

A major challenge for ecology is to predict and manage global change impacts on species and ecosystems. Species’ movement (or stasis), through a shift, expansion, or contraction of their ranges, is a key focus of that research. The aim of this action group is to identify the potential for species range-shifts in Sweden, and to assess their consequences on biodiversity. We will study different taxa, with an emphasis on birds, for which we have long term data. We aim at:

- Identify species that have already shifted their range (*are range-shifts a reality?*)
- Project species distributions (*where will species go?*)
- Assess if changes in species distributions will impact biodiversity and productivity (*How do species range shifts affect ecosystem services?*)

The action group has been very active and successful in creating a network between researchers from different research groups and departments, in particular by joining empirical ecologists and modellers. It has created a trait database of value for further research; developed a set of metrics to assess the amplitude of species’ range-shifts; collected data to analyse long-term changes in alpine plant communities; contributed to the development of an integrated bird migration model within the

Phenobird project. Much of the effort is directed towards developing research in interaction between researchers and this seems very successful.

Multifunctional landscapes: trade-offs between ecosystem services in farmland *Coordinator: Klaus Birkhofer*

This action group closely relates to the overarching goal of BECC to determine the temporal and spatial scales, from local to global, over which important ecosystem service providers influence ecosystem services like pollination or pest control, and feed these findings into frameworks and models of ecosystem services to predict effects across scales. In particular, this action group develops such approaches for farmland and uses them to develop interactions with stakeholders. We will:

- establish a research platform for developing a production function approach for ecosystem services that accounts for the spatial scale services are generated, enabling policy evaluation in farmland.
- produce policy-evaluation based on either agent-based modelling or down-scales available scenarios, including an evaluation of CAP 2013 (The Common Agricultural Policy of EC)
- perform synthesis on the management of ecosystem services in farmland for the production of multiple ecosystem services.
- organize a workshop on consequences of bioenergy strategies for the delivery of ecosystem services in farmland

The action group has initiated the work on evaluating CAP 2013. A meta-analysis on effects of organic farming on taxonomic distinctness has been produced (manuscript) as well as a report section on biological control in Scania to Region Skåne. A workshop on the role of ecological research in ecosystem service science has been organized in Germany (July 2013) and at Lund University (August 2013).

Effects of ozone, carbon dioxide and temperature on crops and forests in a global change perspective *Coordinator: Johan Uddling*

This Action Group is meant to facilitate the synthesis of ecophysiological and experimental expertise at University of Gothenburg with ecosystem modeling expertise at Lund University in order to improve predictions of the impacts of climate change on agricultural and forest ecosystem processes and services. We aim at:

- Predict the impact of climate change and tropospheric ozone on crop and forest productivity and forest BVOC emissions.
- Evaluate the impact of elevated CO₂ and temperature on crops and forests

Ecosystem modellers at Lund University and experimentalists at the University of Gothenburg have worked closely together to improve process-based ozone impact assessment on forest productivity. An ozone module of the LPJ-Guess model has been implemented and applied. Leading European ozone impact researchers have met twice to discuss knowledge-gaps and ways forward in model-based large-scale ozone impact assessment. Global meta-analyses of how elevated CO₂ and ozone affect trees and forest ecosystems have been conducted. Key results in these meta-analyses will have large influence

on how to predict the impact of climate change on forest productivity. Collaboration has been initiated with the aim to implement plant thermal acclimation (i.e. dynamic temperature responses) into the ecosystem model LPJ-Guess. A project on spruce bark beetle impacts on spruce forest productivity under climate change has been initiated. Long-term forest hydrology and water runoff have been investigated for Swedish spruce forests as well as US forests in order to separate the influences of different climatic and atmospheric factors on streamflow.

Monitoring Forests and the Effects of Forest Governance in a Changing Climate *Coordinators: Fariborz Zelli and Fredrik Lagergren.*

There are ongoing debates within and across disciplines as well as in political practice about appropriate toolkits to measure not only the natural effects of forest protection policies (for carbon stocks and biodiversity), but also their social and economic impacts, e.g. with regard to questions of justice (who is involved in monitoring? who benefits?) and cost-effectiveness. These conflicts are reflected in a large diversity of approaches that affects each major methodical camp (remote sensing, inventories, cost-benefit analysis, community-based monitoring, social safeguards). We aim at:

- Mapping the diversity of natural and social monitoring approaches to forest carbon stocks and forest governance
- Analyzing natural and social Implications of these approaches and their choices
- Formulating Policy Recommendations on ‘navigating’ this diversity

The action group organized an international Expert Workshop on 7 May 2013 in Lund: ‘NAVIGATING THE JUNGLE: Assessing the Diversity of Monitoring Approaches to Forest Carbon Stocks and Good Forest Governance. Researchers within the action group has mapped the complexity of institutions and approaches of forest governance in general and REDD governance in particular, identified major interests and perspectives that compete across this institutional patchwork, found significant differences across the results of the various monitoring approaches used in these institutions, e.g. in their assessment of Swedish forests between 2000 – 2009, and identified economic incentives for choosing certain REDD approaches over others. A journal article and Polyci brief product will be produced and there is an ongoing dissemination of results via the network we created, e.g. through the workshop (Oxford, FOCALI, SLU, ESG, ICOS, etc.) and through presentations at UN meetings and major academic conferences.

The influence of climate change and forest management on nutrient cycling and N leaching - an integrated empirical and modeling approach *Coordinator: Nicholas Rosenstock.*

This action group attempts to shed light on processes governing the response of forest ecosystems to changes in climate, fertilization and intensified harvesting. Through a close collaboration between experimental manipulations and mechanistic modelling, the group aims to get a better mechanistic understanding of the interactions between N, P and microbes in relation to forest productivity and nitrogen leaching. Today’s ecosystem models do not describe many of the responses to shifts in forest nutrient regime, including shifts in carbon storage, productivity, and nitrogen leaching. The data obtained from forest fertilization experiments, natural fertility gradients, and laboratory mesocosms will be used to improve ecosystems models. The potential of Swedish forests to retain nitrogen,

sustain tree production, recover from acidification and sequester carbon will be examined. The group will:

- Evaluate the risk of N leaching from forest soils and possible implications for eutrophication and critical loads,
- Evaluate the risk for and implications of a shift from nitrogen limitation to limitations by other nutrients, especially phosphorus.
- Examine the role of mycorrhizal communities in nutrient cycling and C sequestration.
- Use mesocosm experiments to improve parameterization of ecosystem models.

Achievements directly attributable to the formation of this action group include an international meeting and workshop that brought together over 50 Modelers and Ecologists entitled: "Carbon and Nitrogen Interactions in Forest Soils", integration of phosphorus in the ecosystem model ForSAFE, a field study on the effects of geologically caused variation in nutrient status on ecosystem functioning, microbial communities and carbon storage, a field study on the role of forest fertilization on forest productivity patterns, and the establishment of a mesocosm experiment (to run for 1 year) examining ecosystem responses to forest fertilization and nitrogen pollution. A review article is under way entitled "Effects of global changes in resource stoichiometry on soil organic matter" that arose from the BECC sponsored workshop mentioned above.

Integration of information linking data to decision/ Data assimilation and multi-model integration *Coordinator: Johan Lindström*

This BECC action group was defined to focus on data assimilation and multi-model integration. Data assimilation, the process by which observations (or information) from multiple sources is combined and incorporated into a system model, can potentially occur at two different levels in BECC. Firstly it takes place when combining observations, data, and expert opinions into a single modelling scheme; an example would be the combination of station and satellite measurements with output from climate/ecosystem models to provide combined results for temperature, vegetation cover, etc. Secondly an assimilation step takes place when synthesising the result from several models, or BECC subgroups, into policy recommendations. Although the two cases might seem different there are similarities in the underlying statistical methods and thought processes used; a possible common methodology is the use of Bayesian hierarchical modelling to try and account for different uncertainties in the different data sources.

For the policy side the data assimilation could be used to investigate how individual BECC modelling results combine to influence policy and strategic goals within BECC. The results could also be used to indicate areas within BECC where additional scientific effort is most likely to add significant value by increasing the quality of policy recommendations and statements; e.g. by determining which knowledge gaps that contribute the largest uncertainties for the model synthesis.

Plan:

We aim to, during October 2012, identify a few (2-3) of the policy recommendations that BECC has promised to provide, along with the research aimed at each of these goals. We will then investigate what recommendations that can be made based on a synthesis of the scientific results. The goal is to provide a test bed both for synthesising scientific results from different sources and for identifying

areas where lack of knowledge contributes to large uncertainties in the resulting policy recommendations.

We propose to:

- Organise a workshops/short course covering emulators/ensemble methods.
- Organise a workshops/short course covering Bayesian hierarchical modelling (BHM) for environmental data.
- Investigate, with the aid of a PhD/PostDoc level researcher, the possible uses of emulators and BHM in combining data from several BECC groups to answer policy questions. The focus would be on the chains that are planned to be identified during October 2012.

The two proposed workshops should include invited top-researchers in the relevant fields and should be offered in a format allowing them to be given as PhD-courses.

Arctic treeline dynamics: drivers, consequences and challenges *Coordinators: Anna Ekberg and Robert Björk.*

Climate warming is more pronounced in the arctic and sub-arctic than in other parts of the world and has consequences for ecosystem structure and functioning, biodiversity, and ecosystem services. World-leading arctic researchers are active within the BECC consortium, but interaction between research groups from different disciplines can be improved. One of the central aims of this AG is therefore to create common meeting grounds and bring together researchers with an interest in the Arctic and Sub-arctic. Our main activities include:

- Synthesis work resulting in review paper
- Stakeholder/researcher workshop
- Applications for project funding

A first draft of the synthesis paper (Changing treeline ecosystems and ecosystem services in the Scandes mountains) is at hand and is progressing. R. Björk participated in the conference ‘Storslagen Fjällmiljö’ (13-16 March 2013) hosted by the Swedish EPA, involving scientists and stakeholders with interests in the Swedish mountains. He has also been nominated by the government to coordinate the Swedish efforts within COST Action ES1203 ‘Enhancing the resilience capacity of SENSitive mountain FORest ecosystems under environmental change’ (SENSFOR). In BECC Lund’s call for research funding proposals 2013-14, one application from our group got funded: ‘BVOC emission response to herbivory in treeline ecosystems in the Scandes mountains’ (Ekberg, Lund University and Björk, Gothenburg University). Fieldwork was carried out during summer 2013.

Land-Sea Interactions in a long time perspective *Coordinators: Anneli Poska and Anne Birgitte Nielsen*

The action group is intended to increase the visibility and availability of palaeo-environmental data in BECC and related projects, to coordinate the development of the methodology for determining and quantifying the impact of long term land-use on terrestrial and aquatic ecosystems and for data-model comparison. We are now at the stage where it is possible to couple terrestrial and marine records in a

new and unique way, in order to improve our understanding of the links between climate, land use and aquatic systems. The aims of the AG are:

- To provide a catchment wide perspective on land use change and its consequences on land and on the coastal zone and beyond.
- To unite researches with interest in long term changes in terrestrial and aquatic environments and coordinate collaboration within BECC and related programs (e.g. MERGE, LUCCI, Multistressors etc.)
- To disseminate and assist possible implementation of long-term studies of environmental change to topics addressed in BECC.
- To facilitate interdisciplinary communication and establish relations with relevant stakeholders.

The action group organized a Startup meeting Feb. 26th 2013 with participants from INES, Geology and SLU. The meeting consisted of a presentation of the AG, an introduction round to identify research areas and possible collaborations and a discussion of future actions. The group co-organised a seminar day with Multistressors June 12th 2013, with three invited speakers. The action group has proposed, and will be convening, a session at the Nordic Geological Winter Meeting, January 8-10 2014 in Lund on the action group themes.

iii. Workshops and seminars arranged 2010- June 2013

2010

- BECC seminar: *Ecological modeling*, 18 June 2010 in Lund.
- BECC seminar: *Environmental Economics*, 15 September 2010 in Göteborg.

2011

- Seminar series: *Animal Movement in Conservation Ecology*, in 2011 at the Biology Department in Lund organised by BECC and CAnMove.
- BECC seminar: *Policy and Governance*, 26 January 2011 in Lund.
- BECC seminar: *Effects of CO₂ and ozone on vegetation*, 29 March 2011 in Göteborg.
- International Workshop: *Carbon and Nitrogen Interactions in Forest Soils: A Workshop Bringing Together Modelers and Ecologists*, 4-5 April 2011 in Höör organized by BECC and Nordic Forest Soil Carbon Network (financed by NordForsk).
- International workshop: *Statistical approaches to down- and up scaling in climate models*, 27-29 April 2011 in Lund organised by Sarma.
- BECC seminar: *Brownification of inland and coastal waters*, 31 May 2011 in Lund organised by BECC and Multistressor.
- International Conference: *Governing Climate Change: Rationality, Practice and Power*, 19-21 June 2011 in Lund.
- International workshop: *Beyond the Climate Envelope*, 10-11 October 2011 in Lund organised by BECC and CAnMove.
- BECC seminar: *Palaeoperspective on climate, terrester and aquatic ecosystem*, 25 October 2011 in Lund organised by BECC, MERGE, LANDCLIM, Multistressor.
- BECC seminar: *Microbial biodiversity and ecosystem processes - examples from decomposition and nutrient cycling in forests*, 29 November 2011 in Lund.

2012

- BECC seminar *Agriculture Cluster workshop* 12 January 2012 in Lund.
- Seminar: *Measuring dispersal through space and time with landscape genetics* 19 April 2012 in Lund organised by BECC and CAnMove.
- International workshop: *Functional traits and Ecosystem services* 25-26 April 2012 in Höör organised by BECC and SAPES.
- BECC Seminar: *Multiple use of forests in a changing climate – Synergies and conflict regarding policies and environmental effects*, 27 April 2012 in Lund.
- BECC seminar: *Pollen research - biology and environmental science*, 29 May 2012 in Göteborg.
- BECC international workshop: *Microbial Control of Biogeochemical Cycles*, 18-19 August 2012 in Lund.
- Internal workshop: *Effects of ozone, carbon dioxide and temperature on crops and forests in global change perspective*, 5-6 November 2012 in Halmstad organized by the Action Group Effects of ozone, carbon dioxide and temperature on crops and forests in a global change perspective.

2013-11-13

- Workshop: *Applications of Stable Isotopes in Environmental Research*, 12 November 2012 in Lund.
- BECC-seminar: *Multi-decadal records show reduced winter snowpack and increasing streamflow at a site in the northern Rocky Mountains*, 15 Nov 2012 in Gothenburg.
- Conference: *Scaling down and scaling up: climate scenarios and ecological interactions*, 26 November 2012 in Stockholm organised by BECC and Swedish Phenology Network.
- BECC seminar: *Human impact & climate change as inferred from palaeo-records of aquatic ecosystems*, 5 December 2012 in Lund organised by BECC and Multistressor.
- BECC symposium; *The microbial ecology and biogeochemistry of soil desiccation and rewetting*, 10 December 2012 in Lund.

2013

- International symposium: *Causes & Consequences of Organism dispersal*, 31 Jan – 1 Feb 2013 organised by BECC and CAnMove in Lund.
- International workshop: *Ozone impact meeting*, 31 Jan – 1 Feb 2013 in Tylösand, Sweden.
- Symposium: *What are the ecological consequences of climate-driven phenological shifts?* 6 February 2013 in Linköping organised by BECC and Swedish Phenology Network.
- BECC seminar: *The 11th hour for biodiversity - the pressing need for agriculture reform*, 12 February 2013 in Lund.
- BECC International Expert Workshop: *NAVIGATING THE JUNGLE: Assessing the Diversity of Monitoring Approaches to Forest Carbon Stocks and Good Forest Governance*, 7 May 2013 in Lund.
- BECC workshop: *The Scale Problem in Earth System Science*, 13-15 May 2013 in Lund organised by BECC and ClimBEco.
- BECC workshop PhD course: *Integrative modelling—data synthesis and emulation*, 21-22 May 2013 organised by BECC AG Data assimilation and SARMA.
- BECC seminar: *Generation and application of future projections for policies, land use and climate*, 30 May 2013.
- International workshop: *Workshop on Synchrotron Radiation in Environmental and Soil Science*, 30-31 May 2013 in Lund organized by BECC and MAX IV.
- Inspiration days: *Nancy Rabalais* 12-13 June 2013 in Lund organised by BECC Action Group Land-Sea interaction and Multistressor.