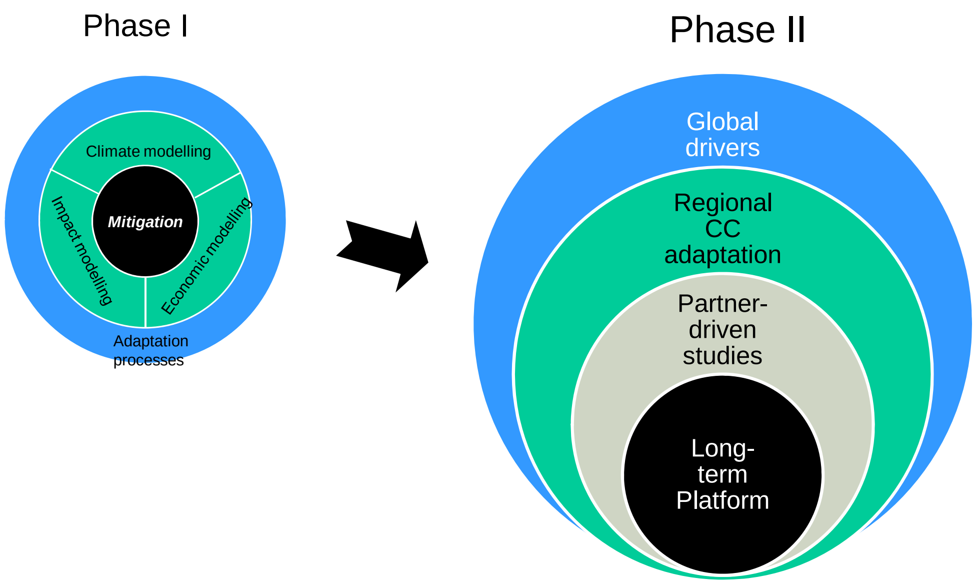
Mistra-SWECIA Phase II, 2012-2015

Programme Plan



MISTRA SWECIA
CLIMATE, IMPACTS & ADAPTATION

Norrköping, Stockholm and Lund, 15 November 2011

Basic facts of the Mistra-SWECIA programme

Programme name:

Mistra SWEdish research programme on Climate, Impacts and Adaptation (Mistra-SWECIA; SWECIA)

Programme participants:

Swedish Meteorological and Hydrological Institute, SMHI

Stockholm University, MISU

Stockholm University, IIES

Lund University, ENES

Stockholm Environment Institute, SEI

Programme Host:

Swedish Meteorological and Hydrological Institute, SMHI

Programme Board:

Chair: Bengt Holgersson

Members: Bodil Aarhus Andrae, Tim Carter, Tom Hedlund, Klas Eklund, Lena Sommestad, Mistra/Thomas Nilsson (adj)

In Phase II, a new member of the Board will be nominated, to represent interests in the land use-based sectors, or branches of government supporting or overseeing land use (e.g. County Administrative Boards).

Programme Director:

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Mistra-budget:

48 MSEK

Period:

1 January, 2012 – 31 December, 2015 (4 years)

Summary

Vision, mission, purpose

Mistra-SWECIA aims to provide high quality and salient scientific support for informing climate change adaptation. This aim is closely aligned with current scientific and societal agendas. The approach is to perform scientifically sound, scenario-based integrated climate, impact and economic analysis and research on the adaptation process.

Parallel to, and as one approach to achieving its science goals, the programme engages with stakeholders within and across different sectors and at a range of scales. By collaborating with the programme, stakeholders are expected to benefit from focused decision-support and an enhanced capacity to translate scientific information into practical knowledge of direct relevance for decision making. Researchers, in turn, are offered the promise of a long-term legacy of interdisciplinary research on climate change adaptation at the research front in the fields of climate science, economics, life sciences and social sciences. For researchers and stakeholders alike, Mistra-SWECIA presents an arena for science-policy dialogue and problem-based research that promotes relevance, synergy and scientific innovation.

The second phase of Mistra-SWECIA (2012-2015) will utilise and build further on accomplishments made in the first phase. The programme continues to be a collaborative effort between five main partners with wide-ranging but complementary expertise, which provides opportunities for cross-cutting integration and synthesis.

Outcomes – scientific value and value to stakeholders and society at large

By the end of the second programme phase, eight years of increasingly integrated and user-oriented research will have resulted in three main outcomes. First, a core group of interdisciplinary Swedish climate scientists with established collaboration and a demonstrated ability to produce top-class research will have been formed. Second, we will have contributed to the development of solid Swedish capacity for integrated model-based analysis of climate change, related impacts and economic assessments of such change, combined with deepened understanding of sector-related climate change adaptation processes, institutions and interactions. Finally, we will have developed and demonstrated the utility of a sustained interactive model for outreach, decision-support and communication on climate change and adaptation. More specifically, key results of the programme will be:

- a new strong and cross-disciplinary Swedish research arena, bringing together physical climate sciences, terrestrial ecosystem and carbon cycle science, economics, and social sciences at the international state-of-the-art level
- strengthened ability of Sweden to manage climate change by means of proactive adaptation on local, regional (sub-national) and national scales, which may also be used to support other countries – put forward as a model for “good practice”, and used for capacity building in the least developed and developing nations
- building-blocks of a strategy for long-term science-based and stakeholder-oriented operations of a national climate and adaptation dialogue platform

The second programme phase will primarily focus on sectors in which land use decisions and management are key activities. The starting point will be a continued (viz. Phase I Forestry case study) and more extensive analysis of climate change adaptation in Swedish forestry. This will include both production and environmental goals that are the objectives of Sweden’s forestry policy. These considerations will thereafter be related to other alternative or neighbouring land uses within the landscape, such as agriculture and nature protection, and

their implications for land use decisions, including the potential for transitions between land use types.

The research and stakeholder interaction will jointly contribute to the development of a framework for assessing climate change adaptation needs and solutions on a sector and multi-sector basis, at the local-to-regional level in Sweden. The framework will in the course of the programme be demonstrated for the sectors involved.

Programme structure and components

In Phase I, the programme has recorded notable successes and achievements relative to its original goals. In the second programme phase we will retain a core of top-class research activities, while increasing emphasis on stakeholder interaction and dissemination of results to users. Provision of advanced science that responds to the needs of society is in line with the vision for Mistra's programmes.

In the second Mistra-SWECIA phase, we will switch from an organisation along disciplinary lines to one that focuses our efforts in two thematic and interdisciplinary research components. These are i) the study of sectorial climate change impacts and adaptation processes in Sweden, and ii) assessments of global and indirect drivers that determine the needs for and context in which such adaptation has to take place.

The organisation in these two main thematic research areas builds on the first programme phase experiences of the research team, with the further aim of consolidating our work into areas in which there is great potential for interdisciplinary research to mature. Judging from the results of our stakeholder consultations, it is clear that the new organisation aligns not only with research logic but also with stakeholders' needs. In these themes, work will be organised in five Working Areas.

The two thematic research components are complemented with activities exclusively devoted to bridging science, policy and practice through partner-driven studies and synthesis (Component III). Overall, the programme is organised as follows:

I) Regional adaptation

1. Research on climate change adaptation processes
2. Research on regional climate modelling: high resolution climate projections, impact modelling and risk assessment

II) Global drivers

3. Climate-economy modelling
4. Global Climate Projections
5. Land use narratives

III) Partner-driven studies and synthesis

The third programme component (III) will act as a platform for collaboration between the researchers and stakeholders. It will draw on results from the research work in the other components, and offer a platform for joint interdisciplinary studies and syntheses. A core working group of both researchers and stakeholders will be formed. The collaboration will aim at bridging science and practice by mutual learning, identification of priority areas, formulation of research questions, exchange of experiences and partner-driven studies and syntheses, as well as shared communication with relevant users.

By the time of submission of the proposal, commitments to take part in the working group had been received from the Swedish Forest Agency, WWF Sweden, the Swedish Society for

Nature Conservation (SNF), and the County Administrative Boards in Uppsala, Gävleborg and Västmanland.

User value and communication

The second phase of Mistra-SWECIA builds on the conviction that science shows its clearest value to society once it is put to use in decision making and implementation. Parallel to the specific stakeholder contacts in the joint working group, there will be dissemination of research results of a more conventional nature. Beyond publications in peer-reviewed journals and the programme's working paper and report series, communication efforts will include, but not be limited to, a newsletter regularly distributed to a wide array of fellow Swedish and international researchers as well as stakeholders and users in Sweden, a website continuously updated with new results, news about seminars and other events, and popular science articles.

Budget

The proposed programme budget is 52 MSEK, distributed over the four years of 2012-2015. Of these funds, 48 MSEK are sought from Mistra. The total effort in terms of research and stakeholder interaction is 451 person-months over the four years. In addition, there are 45 person-months of dedicated communication effort, as well as approximately 60 person-months of programme management effort, which includes contributions to synthesis and communication efforts.

1. Vision and objectives

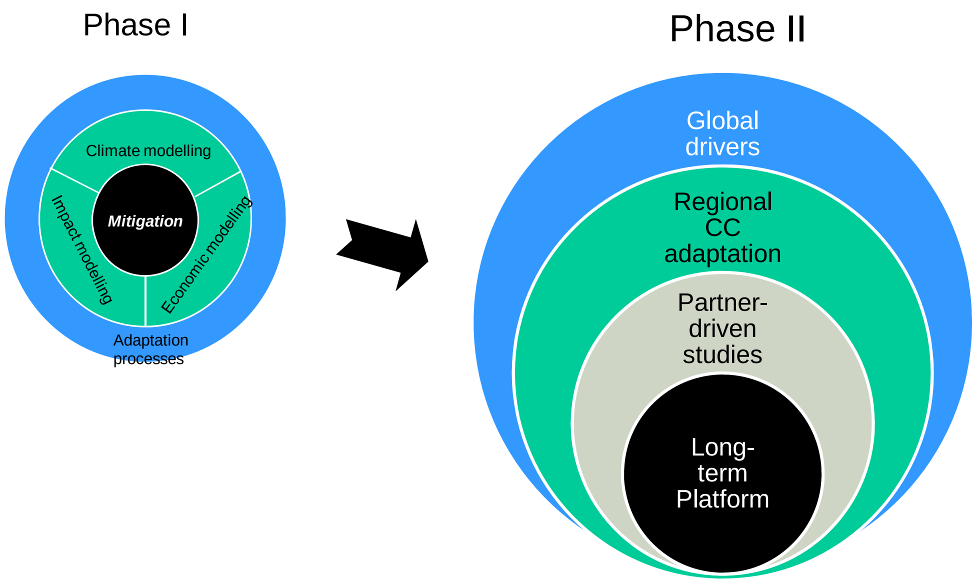
Mistra-SWECIA aims to provide high quality and salient scientific support for informing climate change adaptation, working with stakeholders within and across different sectors and at a range of scales. Stakeholders will benefit from focused decision-support and an enhanced capacity to translate scientific information into practical knowledge for underpinning decisions. Researchers are offered the promise of a long-term legacy of advanced interdisciplinary research on climate change adaptation across the fields of climate science, economics, life sciences and social sciences. For researchers and stakeholders alike, Mistra-SWECIA presents an ideal arena for science-policy dialogue and problem-based research.

The Mistra-SWECIA programme was launched in January 2008. It was planned as an 8-10 year effort. The current year of 2011 marks the end of the four-year first programme phase. This programme plan thus concerns the continuation of these efforts over the course of the second programme phase (Phase II).

The purpose of Mistra-SWECIA is closely aligned with current scientific and societal agendas. The programme's aim is to facilitate climate adaptation by means of scientifically sound, scenario-based integrated climate, impact and economic analysis and research on the adaptation process. The programme combines this with the ambition of providing scientific information to supplement and enrich existing stakeholder knowledge.

In Phase I, the programme has recorded notable successes and achievements relative to its original goals. (The Phase I developments and results are documented in a separate report.) However, there was greater emphasis on research aspects than on stakeholder interaction or user-oriented delivery of results. This balance will shift at the onset of Phase II (see below). Also, while the research so far has been organised along disciplinary lines (climate modelling, economic modelling, sectorial impact assessment and analysis of adaptation processes, respectively), for Phase II a different arrangement is proposed (see the Figure below). Based on extensive consultations, it is clear that the new organisation aligns with stakeholder needs. The new arrangement is based on the prior experiences of the research team, and it looks to consolidate the two research areas for which there is great potential for interdisciplinary research to mature in the programme. These areas concern the global drivers of regional climate change adaptation and the regional climate change adaptation process. Stakeholders are brought aboard in a partner-driven research component.

In Phase II, the programme will build on its earlier research in conjunction with societal stakeholders, combining: (i) research on climate change, global economics, sectorial impacts and autonomous and institutional adaptation, and (ii) knowledge of stakeholders' questions, decision-processes and networks. The research and participatory activities will lead into a framework for assessing climate adaptation needs and solutions on a sectorial and multi-sectorial basis, at a landscape level in Sweden, but also considering how this relates to the operations and climate adaptation activities of County Administrative Boards' (regional government authorities). In the course of the programme, the framework will be applied and demonstrated for sectors characterised by land use, especially forestry, agriculture and nature conservation. The final outcome may be a permanent platform for continuous interaction and exchange between the research community and Swedish decision makers and actors addressing climate change adaptation in the running of their organisations. By the end of the second programme phase, we aim to present a concrete proposal for how a Swedish programme equivalent should be organised and run, together with a network of researchers and practitioners willing to contribute to its launch.



The first programme phase (2008-2011) was organised in rather traditional disciplinary compartments. In Phase II, the development of interdisciplinarity in Mistra-SWECIA is reflected in the organisation into three major thematic areas.

1.1 Significance of the research in terms of solving important environmental problems

While the evidence on anthropogenic climate change and its impacts continues to mount, there are still obstacles to embracing the need for adaptation by stakeholders in the private and public sectors. In some cases, this has to do with lack of *scientific information*, or a perception of a lack of such information on climate change, impacts and the "best" adaptation measures, which equates to a lack of *knowledge* possessed by stakeholders. A further contributing factor is that appropriate institutional structures for adaptation remain to be established to provide leadership, national guidelines and support for policy formulation and implementation.

The programme, and its evolution, responds to the main societal determinants for climate change adaptation, and how they are developing. In the Swedish setting, perhaps the most fundamental cornerstone of the current climate adaptation policy development is the 2007 report by the government Commission of Climate and Vulnerability (SOU 2007:60). Following the recommendations of the commission, the County Administrative Boards were in 2009 given the responsibility of coordinating adaptation at the regional level (Prop. 2008/09:162). In addition, National Platform[1] (2010) notes that out of a total of 59 recommendations by the Commission on climate adaptation related activities, different actors had been tasked with 28 (there are also activities being pursued that do not trace back to the Commission). The governmental authorities who are behind the National Platform's report call for more dialogue on: (i) how best to manage climate adaptation that concerns different actors (public and private) and different scales (local, regional, national), (ii) how best to collect and provide information on on-going climate adaptation activities and, (iii) definition

[1] National Platform for Natural Disasters, on which 18 Swedish authorities and organizations co-operate with the purpose of to increase societal capabilities for preventing and dealing with the negative consequences of natural events, known in everyday speech as natural disasters. See http://www.msb.se/en/Civil-contingencies/Natural-Disaster-Risk-Reduction/National-platform/

of climate change adaptation and its scope. The report also emphasizes the need for contacts between governmental authorities, the County Administrative Boards and municipalities in work on climate change adaptation in different sectors of society, including forestry, agriculture and nature conservation.

The importance of climate adaptation has become more prominent internationally. The slow progress of climate negotiations reflects a persisting lack of momentum that would be needed to pursue the so called 2-degree target[2] in earnest, not to mention even more ambitious mitigation goals that are voiced by some international bodies, such as AOSIS (Alliance of Small Island States). This suggests that the adaptation challenge has evolved from an issue of coping with committed climate change due to past emissions alone, to an issue of unavoidable long-term climate change resulting also from continued (and uncertain levels of) future emissions. These issues are often difficult to bring to bear on actors' agendas. Yet, when weather and climate extremes strike, the vulnerability of modern society becomes only too apparent. Though single events cannot and should not be attributed to climate change, extreme precipitation, drought and various other extremes are projected to change as time goes by.

Indeed, at a global, regional and local scale, there are climate adaptation needs in more or less all sectors. Each of the sectors and scales is complex in itself, but also in terms of all the inter-relationships. Quite often, there *is* relevant scientific information (e.g. climate scenarios, climate impact studies) that can support adaptation decisions, but it often has a patchy character or is difficult to make use of. The latter can be due to incomplete knowledge or the methods used in making existing knowledge available. Lack of coherent, system-scale information is especially inconvenient for policy-makers and actors who are active in sectorial or landscape (see below) contexts. This in turn affects actors who are responsible for handling more specific or local issues.

Climate change adaptation is a part of the bigger picture that many stakeholders need to deal with. This is also the setting for Mistra-SWECIA's Phase II research and stakeholder contacts, looking at adaptation related to and implemented in conjunction with activities on land use and land use change. In sectorial terms, this means the forests and forestry, nature conservation, agriculture and other uses of the land. Our discussions with County Administrative Boards emphasise the urgent timeliness of this issue. While climate change adaptation is progressing on some fronts, there is a marked paucity of activity in the various sectors relevant for land use planning. These shortcomings are especially pertinent in the context of Swedish Environmental Objectives and the recent and on-going revision of the strategies and goals. It has been, for example, recognised that climate change and economic assessment of the Objectives and the measures taken is a new aspect that needs to be looked at (e.g., Jones-Walters 2008). The framing by the stakeholders involves the concepts of a "Landscape perspective" and "Ecosystem Approach[3]".

The Landscape Perspective gives a complementary perspective to dealing with mere spatial scales (local, regional, and national) or in terms of such administrative units as Counties. The difference is that Landscape refers to "an area as perceived by people, whose character is the

[2] The 2-degree target is a climate stabilization goal referring to keeping the long-term global mean temperature change below 2°C compared to the preindustrial period. The target was adopted by the EU some time ago and subsequently by the UNFCCC in the recent COP16 in 2010. Within the UNFCCC process, a revision of this ambition is foreseen, which *could* result in, e.g., a 1.5-degree target.

[3] The Ecosystem Approach is about a method, or a strategy for integrated management that promotes conservation and sustainable use of natural recourses in an equitable way. (Cf. Convention on Biological Diversity, COP 5 Decision V/6).

result of the action and interaction of natural and/or human factors"[4]. Consequently, "Landscape policy" refers to general principles, strategies and guidelines by competent public authorities that enable measures for protection, management and planning of landscapes. This may include Landscape "quality objectives", "protection", "management" and "planning". The sustainable development aim is evident in the European Landscape Convention that also Sweden is a signatory since 2001. Furthermore, the reference to managing changes brought about by "social, economic and environmental processes" reflects well on climate change adaption issues.

The Ecosystem Approach focuses on the inherent value of ecosystems and ecosystem services for humankind, the importance of science support for management of ecosystems and – importantly – the need for adaptive management in the face of ecosystem change. The Ecosystem Approach is not a new concept. It was adopted internationally by the CBD COP in 2000, and it has been noted in Sweden (e.g., SEPA 2007).

In the course of our contacts with stakeholders such as County Administrative Boards during the spring of 2011, various topical questions emerged. These will be on list of stakeholders' issues considered in the Mistra-SWECIA Phase II programme component III (see Section 6.4), e.g.:

- How does climate change affect the balancing of nature conservation and traditional forestry?
- How will fundamental ecosystem services be affected by climate change?
- How will specially threatened species be affected by climate change?

These concerns map both onto the two equally emphasised Swedish forest policy objectives of production and environmental goals, and onto the Swedish Environmental Objectives efforts on (re)defining near-, mid- and long-term goals, assessing actions already taken and assessing the need of additional measures. Climate change adaptation is still a new aspect to be brought on board in these efforts.

These kinds of questions translate well to scientific issues relating to ecosystem services (production, risk management, economic and other valuation) in a landscape perspective (biodiversity, environmental protection, forestry and other land use) under a changing climate, and also parallel other timely societal and environmental issues and relate to national and international structures, networks and arenas.

There are also more generic research and practical considerations that are of keen interest, such as decision-making under uncertainty, how to communicate complex issues and information, optimisation of communication efforts (e.g. identification of exemplar cases and actors that can help to mobilise the community).

Indeed, climate change adaptation is a significant societal challenge that is interwoven with other environmental issues. Hence, Mistra-SWECIA aims to build on its advances in Phase I to work with key stakeholders tackling some priority challenges for climate change adaptation in forestry, agriculture, nature conservation and environmental protection as they impinge upon land use and land management issues. Thus, the aim and ambition of the programme is to create and provide science-based knowledge support for stakeholders already dealing with these sectors, but now tasked with managing in addition climate change adaptation.

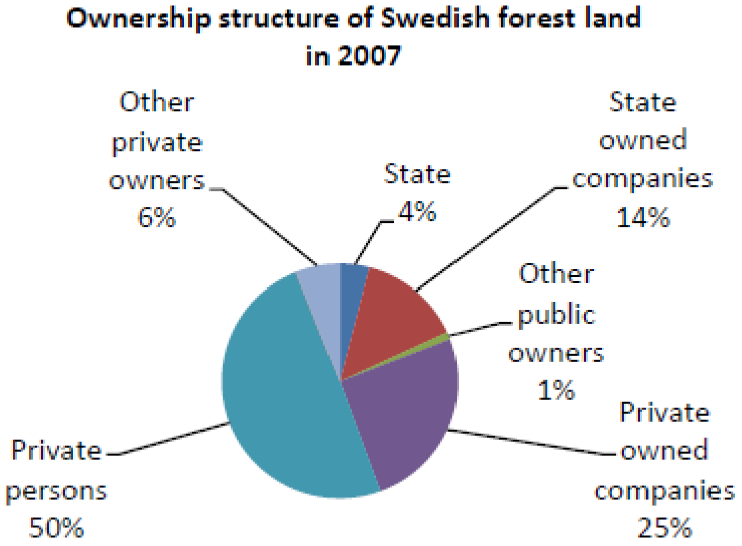
[4] The European Landscape convention, (Council of Europe 2000). http://conventions.coe.int/Treaty/en/Treaties/html/176.htm

1.2 Significance of the research in terms of promoting Sweden's competitiveness and of creating strong research environments

The proposed continued Mistra-SWECIA research recognises the societal challenges related to climate change adaptation in conjunction with sustainable ecosystem management, biodiversity and the Sweden's Environmental Objectives. Each of these aspects involves finding and managing a balance between production, preservation and other uses of land/land use related resources, in a continuously changing climate, environmental and societal setting. There are significant aspects for Sweden as such (e.g., the forestry industry), but also a bearing on Sweden's role in engaging in international negotiations and other arenas on which these issues are dealt with.

Swedish land use and competitiveness

The Swedish model for forestry policy has two key characteristics: (i) the weight given to production and environmental goals, and (ii) the shared responsibility of the state and forest owners to aim for and achieve these goals. Furthermore, there are laws that lay down the principles, but there is flexibility on exactly how the goals are met by the actors, which can be expressed as "frihet under ansvar" (freedom in the context of responsibility). Today, there are diverging views on how well this joint responsibility works when it comes to preservation of biodiversity. The forest companies' perspective (Skogsindustrierna 2011) and the national policy actors' perspective (i.e., the Swedish Forest Agency) differ in the way they measure progress, on the full nature of the ultimate goals and how these goals should be pursued. Those owning the Swedish forest land are furthermore many and they make up a varied community, as exemplified with the Figure below.



The largest forest owner categories in Sweden in 2007 (The Swedish Forest Agency 2008).

The value for the overall forest produce is considerable, which means that the value of any measure taken is significant, for instance refraining from production in favour of biodiversity, on some specific forest area. For example, the Forest company SCA reserves 5% of its land holdings for meeting biodiversity goals. The corresponding production value is estimated as 200 MSEK. Indeed, there are economic issues for forest owners and the forestry industry. These issues are challenging in themselves. For example, today there does not exist full shared understanding between the forest industries and the Swedish Forest Agency on how to pursue the preservation goal in the forest policy in terms of specific goals and indicators of progress.

Nevertheless, climate change certainly is a voiced concern of the different actors. Some key public aspects of this were already discussed above (Section 1.1). For the forest owners and industries, for example, one may note on the need to optimise the choice of which kind of forest to plant and how to best manage it, taking into account changing risks as well as opportunities due to climate change in Sweden. This necessarily involves various indirect effects that come to bear on the Swedish arena via the global nature of markets (demand and provision of food, fibre and carbon storage). Risk management is conditioned by climate impacts elsewhere in the world via insurance and reinsurance mechanisms. Decisions on how to best use land in Sweden, e.g. for growing timber, carbon storage, nature conservation food production or perhaps biofuels, in turn depend not only on markets on national, regional and global scale, but also international policy and progress on CBD and UNFCCC negotiations.

In more specific terms, climate change and Sweden's long term competitiveness on sectors and markets related to land use is about risks, but also opportunities. This concerns small and large private actors, exports, employment on forestry and other sectors, but also Sweden as a player in the international policy arena. Many of these decisions are becoming urgent. After all, the present state of the forests in themselves and the sector is a result of decisions and actions in the past, while the future will unfold in new ways. Furthermore, some of the relevant time scales are long. An investment cycle in forestry ranges from 50 years (Norway spruce in the south) to 120 years (beech forest). The final return will depend on how well the forest grew, the quality of the produce, the world demand for the particular kind of timber etc.

Sweden's agricultural sector is less export-oriented than the forestry sector. Potential climate change impacts are probably a mixture of increasing production potential as well as changing risks. However, forward-looking/anticipatory adaptation may give a competitive edge for the actors. This is especially true if climate change impacts elsewhere would lead to increasing demand of Swedish produce.

In nature conservation, on the other hand, decisions on which areas to protect are long-term in their character, but of course have economic consequences on all time scales (e.g. untapped production) as mentioned above. Should climate change negatively affect the valued nature aspect, the cumulative loss of production potential may have been in vain. Herein, Sweden also is affected by its engagement in international conventions, not least those on Biodiversity (CBD) and climate (UNFCCC).

Overall, the societal, practitioner, research and economic perspectives on land use have for some time now been much about using productive land in the best possible way with a proper balance between economic and biodiversity values. This is challenging by itself, but it is increasingly urgent to factor in climate adaptation as an additional term. This should be based on science-based knowledge. Focused research is a key in enabling action, and warrants keen consideration of stakeholders' needs and their evolving agendas. The results themselves are, at the same time, only one needed outcome. They need to be combined with dialogue on how research is made, for transparency and, consequently, credibility.

Some specific examples of questions relating to Swedish competitiveness viz. climate adaptation and land use include:

- How do risks and expectation of returns in forest insurance and reinsurance develop, with climate change impact prospects; what is the impact on replanting and management (supply of timber)?
- How to best handle potential management conflicts in forestry, e.g. if a climate change induced increase in production potential implies a shortening of rotation periods (in order

to optimise the production of fibre and wood while at the same time reducing the risk for damage), which in turn amplifies climate change induced threats to biodiversity?

- How does climate adaptation affect existing conflicts between the State and forest owners in interpreting forest and environmental policy goals?
- What are the possible economic and broader socioeconomic consequences of revisions of forest policy, strategies and measures in order to account for climate adaptation needs?
- What are the possible economic and broader socioeconomic consequences of climate adaptation action on related sectors in Sweden and internationally?

Strong research environments

At the onset of Phase I, we stated that:

The challenge and promise of Mistra-SWECIA is to forge together a new line of research, combining the expertise and approaches of different disciplines (physical climate system science, biology, economics and social sciences) into a coherent whole. The research will be conducted in dialogue with users and include a more generic outreach. User dialogue and outreach will serve to promote insights on the relevant questions and available answers, as well as to focus the Programme efforts.

These aims have been pursued in the first phase of the programme (cf. the Phase I Progress Report) and they remain valid for Phase II. The nature of the programme has developed both in a multi-disciplinary sense, but also edged further towards interdisciplinarity. The two attractors are the natural and social sciences collaboration on sectorial climate adaptation processes and the collaboration between climate, impact and economy research, aiming at more and better-founded integrated coupled models. More recently, Mistra-SWECIA has started to acquire some transdisciplinary flavour via consideration of how to involve stakeholders in the research and communication process.

In the course of the continued programme efforts over Phase II the following will have been achieved over the eight-year total programme period: (i) a core group of interdisciplinary Swedish climate scientists, (ii) an enhanced Swedish capacity of integrated model-based earth system, impacts and economic assessment of climate change with global, regional and local focus, and (iii) a key to a sustained interactive effort of outreach, decision-support and communication on climate change and adaptation. More specifically, this means:

- a new strong and cross-disciplinary Swedish research arena, bringing together physical climate sciences, biology/ecology, economics, and social sciences that contribute to state-of-the-art international research
- strengthened ability of Sweden to manage climate change, and to contribute to international climate politics, for example the international climate treaties beyond 2012, capacity building in developing nations, and the definition of the mitigation and proactive adaptation targets
- a concrete proposal for how a Swedish programme for climate change adaptation knowledge provision and support could be organised and run, prepared together with a network of researchers and practitioners willing to contribute to its launch

With the Phase I achievements as a stepping stone, Phase II will focus on land-use aspects of climate adaptation in Sweden. The starting perspective will be that of forestry, but it will widen to encompass such related sectors as agriculture and nature conservation. Stakeholders dealing with these issues, while primarily concerned on local and regional scale land use in forestry, are also affected by the wider regional and global scale developments.

2. Scientific value

2.1 Synthesis of existing knowledge and how the proposed work relates to current international research

In this section, we provide a brief overview of the current status of international research as it concerns the proposed Phase II topics. As in Phase II, Mistra-SWECIA's science will be collected and combined based on two overall research areas (see Section 6.1), the same division is used below, to provide a brief synthesis of the state-of-the-art.

2.1.2 Regional adaptation

Adaptation processes

The science of climate change adaptation is still young. Much attention has been paid to vulnerability analyses and assessments of adaptive capacity notably in developing country contexts and among indigenous people. Climate adaptation is, however, an expanding field of science, spurred by the increasing sense of urgency, and commitment to adaptation action at all levels. The recent Cancun Adaptation Framework, developed under the UNFCCC at COP16 in 2010, established the goal of enhancing action on adaptation, including through international cooperation and coherent consideration of matters relating to adaptation under the Convention. An Adaptation Committee will be set up to ensure adaptation measures are taken in a coherent manner under the Convention.

At the European level, the EU White Paper on *Adapting to Climate Change* (European Commission 2009), together with National Adaptation Strategies, provide key steps towards European frameworks for adaptation measures and policies to increase resilience to climate change in Europe. The intended approach includes top-down policy strategies for mainstreaming adaptation into EU sectorial policies, and bottom-up activities building adaptive capacity and implementing actions across member states (EEA 2010). An EU Clearinghouse on climate change impacts, vulnerability and adaptation is proposed in the White Paper to be put in place by 2011.

Nordic research on the impacts of climate change has so far focused on the biophysical impacts, with less attention to socio-economic factors involved in adaptation processes. Apart from isolated earlier studies (e.g. O'Brien et al., 2004, Storbjörk 2007), it is only in recent years that concerted efforts have been made towards coordinated research on the social dimension of adaptation to climate change, notably through the Norwegian PLAN project, the Finnish ISTO, and the Mistra-SWECIA. Despite recent research efforts, more research is needed to understand of the process of adaptation in the society. In Phase II of Mistra-SWECIA, we will build on research undertaken in Phase I, as well as draw on other studies and novel approaches in the field. This commitment involves identifying and analysing the institutional landscape involved in adaptation in a sectorial context (forestry), including the characteristics of and enabling processes for adaptation, as well as the interdependencies across actors and governance levels. Insights will be provided at a wider (e.g. multi-sectorial or regional) scale and contributions will be made to the design of an multidisciplinary methodology on adaptation analysis combining state of the art risk assessment and participatory research methods in a sectorial context.

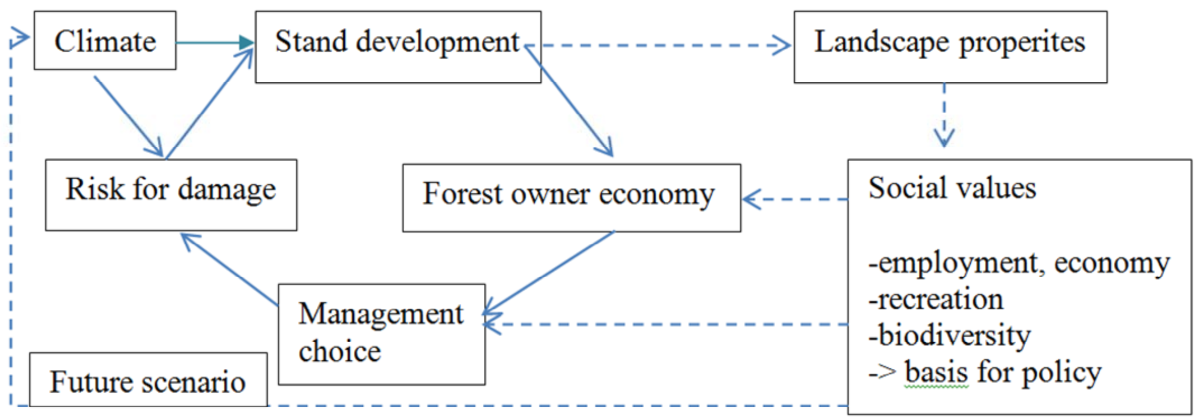
Regional climate modelling and risk analysis

It is now well established that reliable information on potential future regional climate change requires an ensemble approach (Christensen et al. 2007). Such an approach must sample the main factors leading to uncertainty in future climate change over a given region, while also retaining sufficient simulation quality and spatial resolution to deliver results that are both realistic and useable (Déqué et al. 2007). The primary factors contributing to uncertainty in regional climate variability on shorter timescales (e.g. ~1-40 years into the future) are; (i) an inability to accurately predict the time evolution of natural variability in the climate system (referred to as internal variability) and (ii) limitations of global and regional climate models to accurately represent important climate processes (referred to as model limitations) (Hawkins and Sutton 2009). On longer timescales (e.g. more than ~40 years into the future) model limitations and uncertainties in future greenhouse gas emissions and land use are the dominant uncertainties (the latter referred to as scenario uncertainty, Hawkins and Sutton [2009]).

Within the first programme phase, as well as through wider European collaborations, we developed a large ensemble of regional climate change scenarios for Europe which sampled a significant part of the aforementioned uncertainty space (Kjellström et al. 2011, Nikulin et al. 2011). In Phase II we plan to continue utilising this ensemble to quantify climate change risks over Sweden, particularly with respect to potential changes in extreme climate events. We also plan to increase the size and utility of this ensemble by; (i) Generating a new set of regional climate change projections, made with an updated and higher resolution version of the Rossby Centre Regional Climate Model, driven by a new set of Global Climate Projections, developed within the 5th Coupled Model Intercomparison Project (CMIP5, Meehl et al. 2007); (ii) To make a limited set of very high resolution (2-3km) projections for specified regions of Scandinavia tied to the sectorial/impact needs of Mistra-SWECIA phase II stakeholders, and (iii) Use the full set of regional climate projections to drive a very high resolution (1-2km scale) surface-ecosystem impact assessment model. Results from these latter simulations will be communicated to the programme's stakeholders and through a sustained dialogue tailored to provide climate information of use in their planning and adaptation activities.

Policy in the fields of climate change and ecosystem services is rapidly developing, and the requirement of scientific input for continuously updated decision supports emphasizes the importance of a close and continuous collaboration between scientists and stakeholders (Freer-Smith 2007, Hickey 2008). An important aspect is to evaluate potential consequences of climate change and management strategies on the different, sometimes conflicting, demands on biomass production and ecosystem services (e.g. soil carbon sequestration and biodiversity) (Geijer et al. 2011). This also includes the broader landscape and regional perspective, focusing on sustainable production capacity, and ecosystem services (Gough et al. 2008, Tasser et al. 2008). Important topics for forestry are the choice of tree species, intensity of biomass harvesting, risk of forest damage, carbon sequestration and protection of areas of high biodiversity values (Chapin et al. 2007).

In Phase II, the proposed work on risk analysis involves state-of-the-art ecosystem modelling, the results of which will serve as a basis for evaluation of management strategies, state-of-the-art economy model calculations for including "non-market values", and also make use of agent based modelling and/or fuzzy logic for understanding the landscape level, and to simulate how external forces (climate change, policy decisions) can influence the statistical distribution of management choices. The aims include understanding of how the values of different ecosystem products and ecosystem services (both from a forest owner and a societal point of view) influence the forest landscape. Finally, the ecosystem model is used to study how the availability and quality of information can influence the development, (proactive management and adaptation to climate change, vs. wait with adaptation, claiming that a better basis for policy development is needed. These links are represented in the diagram below.



Components of the forest management system that will be analysed. The outer loop (dashed line) indicates the future global-scale scenarios of emissions, land use, economy, technological development, etc., that will influence climate change, and thereby ecosystem performances and landscape properties. Future projections (i.e. results from climate and ecosystem model simulations) provide input to the societal considerations and policy options. The inner loop (solid line) indicates considerations affected by climate change that are more directly tangible for forest owners and suchlike. This includes forest production and risk scenarios, and links to the outer loop via economic and societal considerations that influence forest management decisions.

Adaptation to indirect effects of climate change

It is likely that many significant climate change impacts on Sweden, Swedish economic sectors, Swedish policy making and Sweden's international engagements will not manifest primarily as direct changes in Swedish climate and weather events, but as indirect (or secondary) social, economic or political effects from (more severe) impacts elsewhere in the world. These impacts will together with global policy measures and changes in the global economy create changes in flows of goods, capital and people. This implies adaptation needs in Sweden to ensure that opportunities are harnessed and negative impacts reduced.

Indirect effects of climate change have received relatively little attention in the academic literature. There have been some research efforts on the international/ human security dimensions of indirect effects of climate change with a special focus on geopolitical and national security aspects (Barnett 2003, Brown et al. 2007, Mobjörk et al. 2010). A large amount of economic modelling at various scales has also been carried out, primarily aimed at assessing the economic effects of various mitigation regimes, as well as some combined effects on ecosystems and the economy. Studies have also been carried out addressing the health effects of climate change (Costello et al. 2010), and the impacts of climate change on food security (Schmidhuber and Tubiello 2007). However, more generic analytical frameworks capturing the whole range of potential secondary effects (both positive and negative, and including effects that do not lend themselves to quantification) are to our knowledge missing.

2.1.3 Global drivers

Climate-economy modelling

Current international climate modelling research involves a host of models, from rather simple ones to very advanced models. In these the economy is viewed as exogenous. The most advanced model that presently incorporates both the economy and the climate – Nordhaus's RICE – has only 8 regions, it does not handle uncertainty, and it is not a general-equilibrium setting. The latter makes policy evaluation in principle impossible. However, the

RICE model is pioneering and also our approach can be viewed as a modern version of RICE. Still, the Mistra-SWECIA effort represents a major step forward, as it allows a full study of how poor countries and poor regions are influenced by climate change, and of how adaptation mechanisms and policies on both a global and local scale affect these outcomes. It will offer a new scientific way of illustrating the distributional impacts of climate policy (and the absence thereof), thus shedding light on climate change adaptation needs and opportunities.

The Phase II Mistra-SWECIA efforts on this area aim at a full-scale climate-economy model that brings major renewal and improvements to the research area, e.g. having many regions and being a modern dynamic stochastic general equilibrium model with full and explicit economy-climate feedbacks. A central feature is that it can be simulated and used in communication with stakeholders to facilitate an understanding of global drivers of climate change and the way local regions are affected (boundary conditions). The one-region model that was set up in Phase I is used as a pilot study for various important aspects, such as global drivers such as energy markets, technical change in response to policy and market conditions. The resulting insights will be incorporated into the full-scale model about midway through Phase II for means for provision of stakeholder-value.

Overall, although there are some global estimates on the economics of adaptation (e.g., UNFCCC 2007, 2008), the financial aspects are still rather incompletely known. In particular, there is a need to address the distributional aspects, e.g. on country and sectorial scales (*ibid,* Parry et al. 2009, Fankhauser 2010), in order to reduce the uncertainty on the resources required for climate change adaptation on both global and regional scale.

Global Climate modelling

In Phase II, global climate model scenarios will be provided to Mistra-SWECIA in kind by the Rossby Centre at SMHI, based on on-going contributions to the CMIP5 intercomparison. The Rossby Centre in particular provides several model runs with the EC-Earth global model, as a part of the European Earth System Modelling collaborations. The overall CMIP5 archive, as well as the Representative Concentration Pathway (RCP, Moss et al. 2010) scenarios will also be available to Mistra-SWECIA.

Related to the RCPs, researchers internationally are currently discussing a framework and process for also developing a coherent set of new socioeconomic scenarios to be used by the different scientific communities working on climate change impacts, adaptation and mitigation. It is intended that these scenarios should complement the RCPs that are the new standard used in climate modelling. As well as describing plausible world developments (e.g. of population, economy, technology and land use) that might result in the atmospheric concentrations of radiatively important gases described by the RCPs, the new scenarios will also explore other plausible futures, provide regional quantification of key variables and offer descriptive narratives of the future (storylines). In addition, the scenarios should offer a basis for ensuring consistency across studies assessed by the IPCC, as was discussed at an Expert Workshop in Berlin in November 2010.

Land use

Models have played a major role in land system science in undertaking structured analysis of complex interactions within the land system. Where real-life experiments are not possible, models provide artificial experiments to explore system behaviour, i.e. as a computational laboratory (Matthews et al. 2007). In addition, models enable *ex-ante* assessments of policies and provide input to the planning process (Bennett et al. 2003, Nilsson 2009, Rounsevell et al. 2006, van Ittersum et al. 2008).

At the global scale, models that seek to treat land systems in a fully coupled way are based on the principles of Integrated Assessment Models (IAMs) or macro-economic models. These models employ simple equations or optimisation based approaches (e.g. van Meijl et al. 2006, Fischer et al. 2005), but lack representation of the diversity of human behavioural and decisional processes (Rounsevell and Arneth, in press).

At the local (landscape) scale level, there has been considerable effort in modelling the land system using complex systems principles (Matthews et al. 2007, Bousquet and Le Page 2004). Agent-based modelling (ABM) is an application of multi-agent systems, a concept that has recently gained popularity in the social sciences. Recently, a number of authors have used ABM to link human and natural systems at different spatial and temporal scales to understand changes in land cover and management (e.g. Parker et al. 2003, Murray-Rust et al. in press).These models seek to represent human behavioural and decisional processes within a common, dynamic modelling framework. The ABM approach attempts to identify the individual, institutional, sectorial etc. decision makers and their cognitive strategies and interactions that facilitate or hinder adaptative land use changes as driving conditions (demand, commodity prices, risks of damages, subsidies, etc.) change (Acosta-Michlik and Rounsevell 2005). Social survey data (e.g. Janssen and Ostrom 2006, Valbuena et al. 2010) are used to identify the goals, motivations and behaviours that underpin the decision making strategies of real world, human actors and this insight is translated into computer-based representations of agents in social simulation models (Murray-Rust et al. in press; Parker et al. 2003). Agents have an individual decision making strategy that is influenced by interactions with their environment and with one another through social networks. They can respond to changes in their circumstances or in their environment by changing behaviour through a process of adaptive learning (An et al. 2005). This capacity to deal explicitly with the process of adaptation (Macy and Willer 2002) marks ABM out from the traditional reductionism of IAMs, and is an attribute of value therefore to this project.

In research on human-biophysical relationships such as land use, the traditional focus on either top-down, (multi-)sectorial approaches or bottom-up, agent-based approaches does not sufficiently capture the complexity of human-environment interactions across different scales. There is a need for the further development of models for integrated analysis and to better address causal relationships, combining data with different spatial scales and from widely different sources (e.g. Crawford et al. 2005, Gaube et al. 2009, Turner et al. 2009, Walsh and Crews-Meyer 2002). We propose to develop a new Agent-Based Modelling (ABM) approach for Sweden, to be used to up-scale the representation of human behaviour and decision making processes to large geographic areas, taking account of adaptive learning. This research will be informed by stakeholder interactions both within Mistra-SWECIA and via links to other research projects such as EU-FP7 MOTIVE. The ABM will be a tool for mutual learning on adaptation issues and will support a dialogue with both policy stakeholders and forest practitioners.

The ABM requires boundary conditions, which will be obtained with a multi-scale approach to land system modelling that brings together global scale macro-economic approaches with global scale land system models that are able to represent the probability space of land use futures. The ABM work will thus make use (as drivers or input to the ABM) of the comprehensive suite of global models developed or adopted in Mistra-SWECIA to analyse the major global drivers of land use decisions and explore their possible changes under future climate and socio-economic development. These include production of land-based commodities such as food, forest products and biofuels (ecosystem modelling); fossil fuel emissions, economic growth, GDP distribution, consumer preferences and trade (climate-economy modelling), and climate scenarios as such (climate/Earth system modelling).

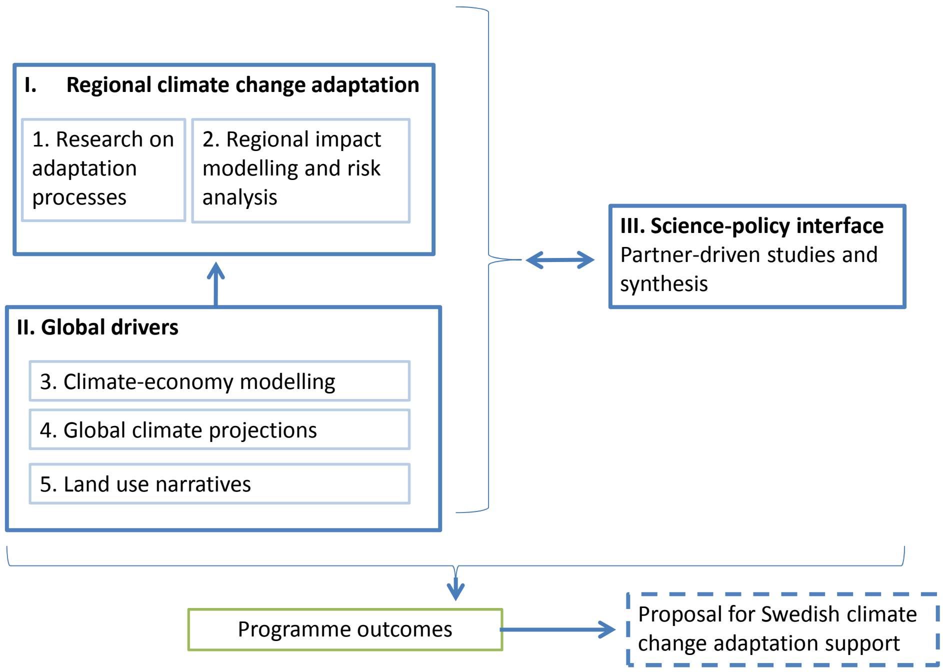
2.2 Theory, research design and methods common to the Programme

In the original programme plan from 2007, we stated that

Estimates of future climate change, its impacts and adaptation needs hinge crucially on future socio-economic developments. The comparability of estimates is often hampered because different assumptions about the socio-economic future, climate change, climate impacts and the type and level of adaptation measures are used. This is much due to a failure to integrate insights from climate, impact and adaptation research. SWECIA will close these gaps and provide integrated research, building on common assumptions.

As already taken as a starting point in Phase I, it is important to bring together research and communication into a common framework, so that stakeholders can gain a holistic view on what pertains to their decisions and how do their decision impact other stakeholders and processes. A common research design is also a prerequisite to underlie synthesis.

Mistra-SWECIA will continue to provide applied science, building on a foundation of basic research. In Phase II, however, the focus shifts increasingly from basic sciences flavours to applications, supported by a more vigorous stakeholder dialogue and outreach.



The Mistra-SWECIA Phase II programme elements and key flows of information.

In Phase I, we had to scale down the ambitions of developing a Common Scenario Framework, based on the coupled climate-economy-impact models of Mistra-SWECIA. The Phase I development of the multi-region global economy model is now becoming to a stage when it can be used in research applications. The advances made include also a better treatment of carbon cycle in climate-economy models. The Phase II common scenario framework will be pursued by developing coherent narratives that are relevant for land use aspects of regional climate adaptation, making use of climate change scenarios and economy scenarios generated within the Programme. Another way of collecting the programme's efforts is to better bring in sectorial stakeholders and to focus on their knowledge needs both on regional scale climate change adaptation and the global drivers that may either enable specific actions or force stakeholders' hand (see the figure above for an overall graphic of the programme's elements). A more detailed description of these programme elements is provided in Section 6.

The Phase II flow

The flow of Phase II has four key stages. They run partially in parallel, but the list below indicates their overall chronological order.

1. Focus on the forests and the Forestry sector: Understanding the institutional landscape and adaptation processes:

   (i) Analyse the existing institutional landscape and its characteristics, and enabling processes for, adaptation action and policymaking

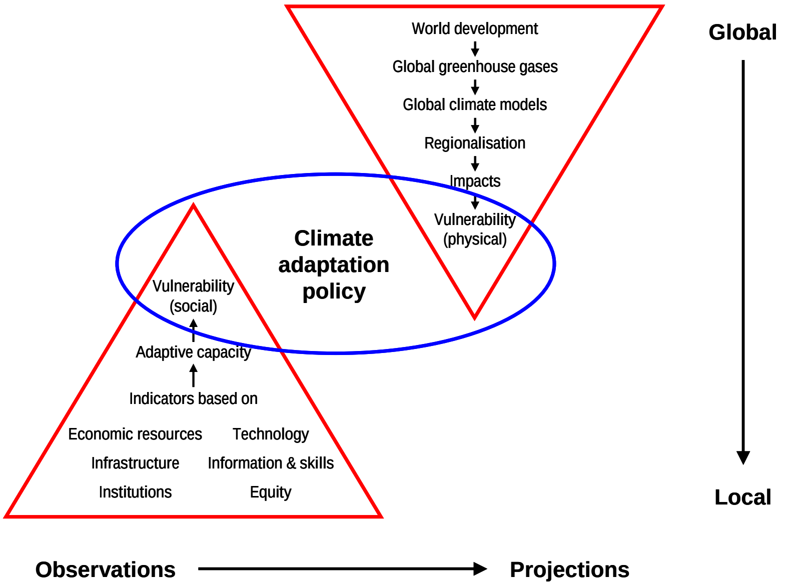
   (ii) Map out and provide regional climate scenario information at high resolution and analysed for stakeholders

   (iii) Risk analysis for climate impacts and adaptation decisions

   This phase also features further development of the programme's models, in particular the multi-region climate-economy model
2. Consideration of a wider, multi-sectorial and regional, context: foundation for providing insights on adaptation processes building on the findings from stage (1). The sectors considered all feature land use, such as Agriculture and landscape-level Environmental Protection
3. Study of stakeholder motivations, preferences and decision-making, both through direct dialogue with sectorial actors and simulation studies with an agent-based model (ABM)
4. A methodology for adaptation analysis combining state of the art risk assessment and participatory research methods in a sectorial context as well as a coherent qualitative and quantitative approach to global boundary conditions for adaptation in Sweden, accounting for coupled changes in climate, economy and their impacts on supply and demand of land-based commodities

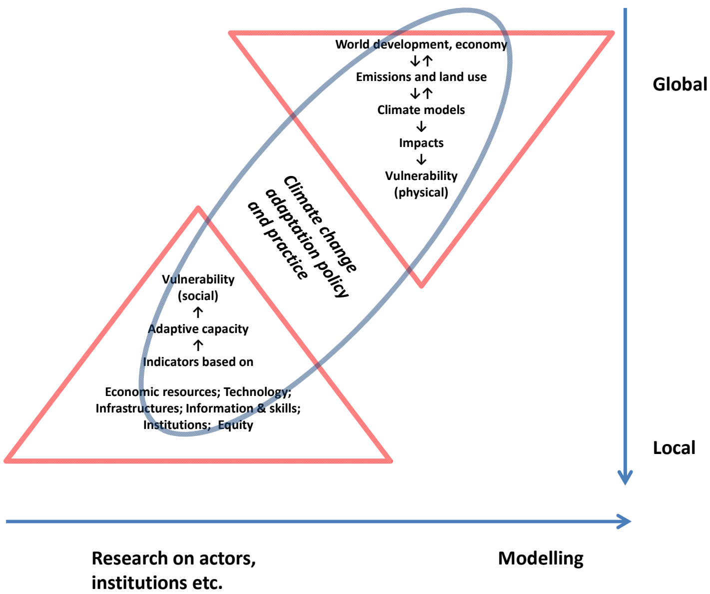
Narrowing the gap between the top-down and the bottom-up approaches

We continue to bridge the duality in adaptation research that has been typical between *top-down* and *bottom-up* studies of the adaptive capacity of relevant physical and natural systems, including institutional and other actor or sector-specific driving forces (see the Figure below). While both of these approaches address climate adaptation policy, the goal of providing knowledge for climate adaptation policy resides in the gap between the approaches.



The top-down and bottom-up research approaches contributing to climate adaptation policy (after Dessai and Hulme 2003).

Progress towards closing this gap was made in the Mistra-SWECIA's Phase I. For example, the programme adopted both of these two approaches and made use of modelling in the stakeholder-studies (e.g., focus groups) and the stakeholder-interactions provided some first guidance on model development needs. Mistra-SWECIA has today a different structure, which can be exemplified with the Figure below.



The top-down and bottom-up research approaches contributing to climate adaptation policy (modified from Dessai and Hulme 2003).

We also continue to emphasise that climate adaptation needs depend on both climate and non-climate factors. While some impacts are dealt with without planned adaptation, planned adaptation can greatly reduce risks and avoid costs. The latter continues to be the topical in Mistra-SWECIA. The programme conducts climate change adaptation research that contributes to adaptation policy by identifying which adaptation policies are needed, and how they can best be developed, applied, and funded. Here, however, we shall not recommend specific decisions to stakeholders. Rather, we shall support them in exploring alternatives and via co-development of needed knowledge, including specific findings, insights on relevant research methods, dialogue on problem formulation, etc.

Our models

Our global, regional and local scale assessments will build on a climate/economy/impact modelling core that has as a common basis the description of relationships between driving factors and response variables based on observational data and constrained by assumptions about the underlying processes. Data and insights (assessment of key uncertainties and model development needs) will flow between these biogeophysical models, physical climate system models and the global-to-regional economy models. As far as is feasible, we strive for the use of common assumptions about exogenous factors – so-called narratives – such as the influence of environmental concerns on policy. The ambition will be, especially, to learn to better decipher the responses of environmental and societal systems to climate change, especially at regional-to-local scales or their global driving processes' level.

The models in Mistra-SWECIA are (described in more detail in Section 6):

- Global climate models: EC-Earth, but results will also be used from the CMIP5 host of models
- Global and multi-regional climate-economy models from the Phase I of Mistra-SWECIA
- Dynamic vegetation model: LPJ-GUESS
- Land-use modelling: the parsimonious land-use model PLUM
- Regional climate model: RCA3, RCA4, HARMONIE. Results will also be used from the Euro-CORDEX models, as well as those models that have contributed to such earlier projects as ENSEMBLES
- A high-resolution land-soil-hydrology-ecosystem-lake model LSHEL, for climate and impact modelling, based on SURFEX (land-soil-lake-boundary layer model), as well as LPJ-GUESS (ecosystem model at Lund University) and HYPE (surface hydrology model at SMHI)
- Agent-based model(ling) (ABM), developed in Mistra-SWECIA Phase II

The scales considered

Above, we refer to global, regional and local scales. The definition of not least "regional" is of course context-specific. In regional climate modelling, it means an area that may encompass a continent, or at least a sub-continent. In a stakeholder context, it more often implies "sub-national". Furthermore, the stakeholders' and research questions can be even more varied viz. the scale. Thus, even though we realise that it can lead to some ambiguity, we often refer to "regional" in this plan, although we mean, as appropriate, "local", "local-to-regional", "county" and "landscape" (see Section 1.1) aspects.

2.3 Planned scientific deliverables at the programme level

These deliverables are also listed in Section 7.1 (Part B of this programme plan).

- A new framework for problem-oriented assessment of climate change adaptation, including research assignments, sectorial landscape-level, as well as in a multi-sectorial context (further information: Sections 6.2-6.4)
- Assessment of the needs, possibilities, process and progress of climate change adaptation, with a focus on land use and land use change (e.g. agriculture, forestry, nature

conservation, etc.), built on advanced climate, climate-economy, ecosystem and land use modelling and stakeholder-focused investigations (Sections 6.2-6.4)

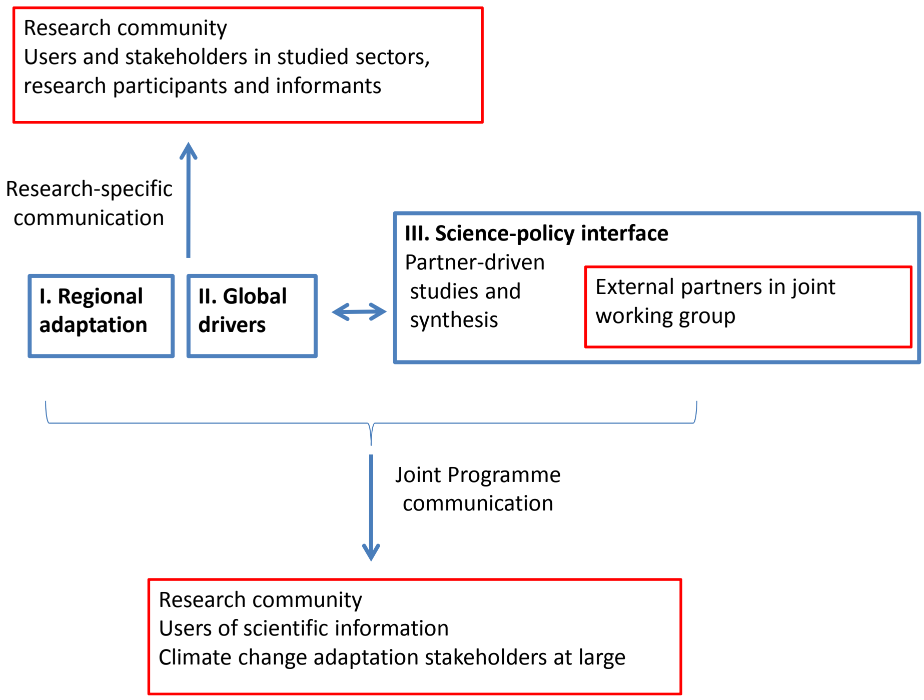
- Agent-based model for Swedish land-use including key agents (Section 6.2.1)
- High-resolution regional climate model scenarios and tailored analysis (Section 6.2.2)
- A regionally disaggregated climate-economy-impacts model (Section 6.3.1)
- International conference on climate economics, 2012 (Section 8)
- International conference on climate change adaptation – vulnerability, costing and adaptive management (co-organised NORDCLAD-Net event, 2012) (Section 8)
- A new generation of cross-disciplinary Swedish climate, impact and adaptation scientists.

3. Value to stakeholders

3.1 Our stakeholders

Phase I of the programme was much about research on modelling, processes and actors, with the aim of building a better base for interdisciplinary research effort on climate adaptation. While research-specific communication continues, in Phase II, the focus will shift to the stakeholders' perspectives (see the Figure below). Already in Phase I it was evident that many forest owners and decision-makers in the forestry sector are primarily concerned with climate change impacts rather than climate change as such. While a substantial part of Phase I was devoted to this (e.g. the close links between Projects 1 and 3) it was soon experienced that research groups outside the programme can draw on Mistra-SWECIA research, and address yet additional aspects of the forestry sector's wide-ranging need for information on climate change *impacts*. As a part of the scientific outreach activities of the Phase I forestry case study several pilot external research collaborations were initiated.

In Phase II, there is a specific programme component that has stakeholders at the centre stage. The stakeholders, including external scientific collaborators and the Mistra-SWECIA researchers work together on the identification and joint formulation of relevant and scientifically tractable research questions that are pertinent on the stakeholders' agendas, as well as in addressing them. This implies applied research, but also feeds back to the rest of the Phase II research, in which stakeholders' views and needs are considered in efforts on model development, analysis and applications. There will also be a dialogue on how scientific information can best be conveyed.



An illustration of how the Mistra-SWECIA Phase II programme elements link to the programme's communication and stakeholder interactions.

In the course of the planning of the second programme phase, efforts have been made on identifying relevant stakeholders as the potential stakeholders are very many, while the possibilities for active collaboration are of course limited. The Phase I forestry case study findings have also been made use of in the process of identifying stakeholders.

As is further detailed below, we consider *the Swedish Forest Agency, the Forestry Research Institute of Sweden*, *County Administrative Boards, forest owners' associations* and the *forest industry companies* as key stakeholder for our work. Furthermore, we consider *non-governmental organisations* (NGO) as an important type of stakeholders that complements the governmental authorities' and industry's perspective. The industry is of course a relevant stakeholder community, together with forest owners in general, and the relevant insurance industry. We look forward to involving also these types of stakeholders over the course of the second programme phase. Finally, other researchers and professional advisers involved in various forms of forestry support are also considered stakeholders, as their work is (and will increasingly be) informed by modelling results concerning the impacts of climate change.

3.2 Stakeholder groups involved in the programme

As mentioned above, the relevant main stakeholder communities are many and include, *inter alia*, owners of forests and agricultural land, industries, the state/governmental authorities/policy and NGOs. At the same time, there are limitations on how many specific stakeholders the programme can effectively interact with and also on how much time and effort stakeholders can invest in a dialogue. In Phase II, there will be two tiers of stakeholder involvement. One of these engages stakeholders who can actively engage in the effort and invest time and resources in joint work. We believe this collaboration will involve 5-10 parties. It is described in more detail in section 6.4. The other level of stakeholder involvement will add leverage to the joint efforts by involving a broader reference group of users. The stakeholders will have the option of moving between the two groups, and the groups' membership will be open throughout the programme time span.

The stakeholders provide their time in kind. As appropriate, Mistra-SWECIA will explore additional joint projects with external funding, to create additional leverage on pursuing questions that emerge in the course of the dialogue.

Value to stakeholders is foreseen to arise, in addition to the customary scientific results, through:

- Joint formulation of climate adaptation issues, research needs and creating "good practices"
- Shared communication activities (e.g., joint events targeting key audiences)
- Generation of insights on the research methods, which eases the use of generated information by advanced models and social sciences methodologies
- Vision and realisation of the final outcome of Mistra-SWECIA in either a new working process on problem-oriented climate adaptation, combining scientific and stakeholders' knowledge and knowledge production
- Scenario development

The stakeholder interaction will be formalised with specified expectations, roles and working modalities. We foresee regular meetings held at stakeholders' home turf, at the Mistra-SWECIA programme partners' sites or in external locations, depending on the nature of the meeting and minding practicalities. In general, the stakeholders will be interacted with as a group, but also smaller meetings will be held.

The leader of the Component III of Mistra-SWECIA will be the main moderator of the stakeholder interaction, coordinating these efforts with the programme communicator.

Tier 1: The core working group

The dialogues with the tier 1 stakeholders will be on a regular basis, with meetings, seminars or workshops occurring at least every 3-4 months.

Mistra-SWECIA has held discussions with the following stakeholders, who subsequently have provided support letters indicating their willingness to actively collaborate with the programme in its Phase II (see Appendix II):

- County administration of Västmanland
- County administration of Gävleborg
- County administration of Uppsala
- Swedish Forest Agency
- World Wide Fund for Nature (WWF-Sweden)
- The Swedish Society for Nature Conservation (SNF)

In addition, The Swedish insurance company "Länsförsäkringar" (forest and agriculture insurance) has expressed its interest in collaborating, as has Södra, en economic association of 51,000 forest owners in southern Sweden.

Contacts with the Swedish Energy Agency (e.g., biofuels) have also turned out well and the agency emphasises its interest in collaborating with Mistra-SWECIA. However, as the agency is also acting as a research funding body it is prevented from producing a support letter or suchlike

To date, none of these partners have made any commitments to support the programme financially. The second half of 2011 will be used to further specify the scope and content of work. The key features of the 2012 work plan should be available at the time of the evaluation hearing in September 2011.

Up until and beyond the launch of the second phase of the programme, efforts will be made to bring representatives of forest owners' associations and forest industry companies into the realm of tier 1 stakeholders (see section 6.4)

Tier 2: The reference group

The tier 2 stakeholders will be representatives of largely the same stakeholder communities as is the case with the tier 1 group, but will reach out also to trade organisations and others that are identified in the discussions with the tier 1 stakeholder group. However, the meetings will be less frequent and the main focus will be on sharing views, information and scientific results.

3.3 Planned user deliverables at the programme level

These deliverables are also listed in Section 7.1 (Part B of this programme plan).

- A new framework for problem-oriented and stakeholder-driven climate change adaptation assessment, building on, sector and landscape-level analysis, and explicitly taking a multi-sector contexts into account (further information: Section 6.4)

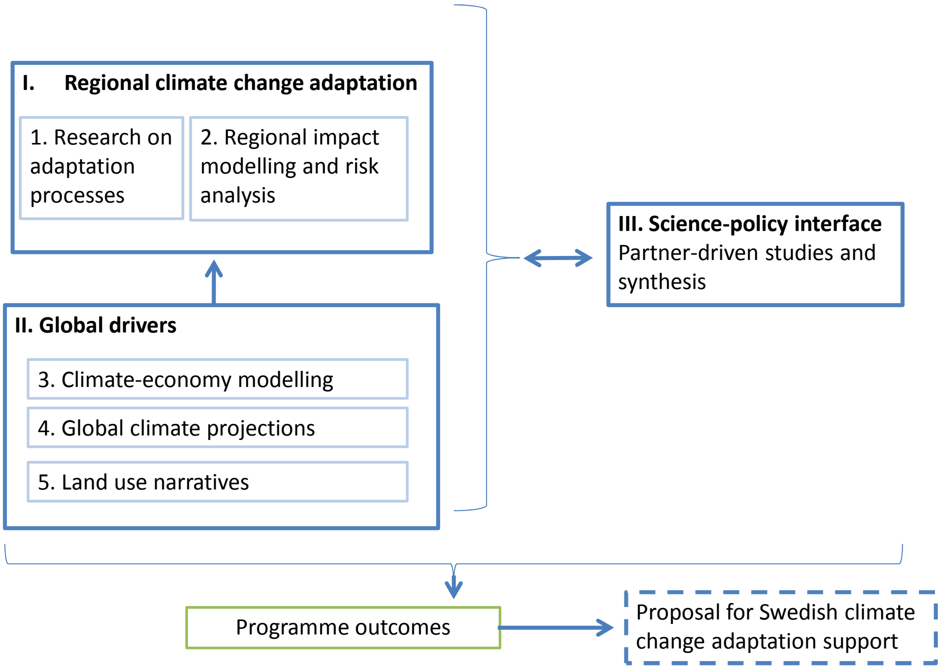
- Demonstration of the new framework, providing a comprehensive assessment of climate adaptation needs, decision-support, opportunities, networks and linkages with related sectors (Sections 6.2-6.4)
- Permanent stakeholder cooperation platform for model development and research feedback: identification of knowledge gaps and important questions to focus on, priority-setting for which aspects to include in climate change related modelling efforts (Section 6.4)
- Land use and land use change narratives consistent with global assumptions on climate, economy and impacts (Section 6.3.3)
- A stakeholder-friendly global climate-economy-impacts' model for basic policy investigations of different climate policy options (Section 6.3.1)
- Stakeholder-oriented information via a home page in Swedish, a popular Newsletter and popular science briefs (Section 8)
- International NORDCLAD-Net conference (co-organisation, 2012) (See Section 8)
- Dialogue with external partners, collaborative studies and synthesis, joint learning activities (seminars, courses, staff exchanges) (Sections 6.4 and 8)
- A strategy and a concrete proposal for how a Swedish programme for climate change adaptation knowledge provision and support could be organised and run, prepared together with a network of researchers and practitioners willing to contribute to its launch (see Component III).

4. Programme structure

4.1 Programme structure

While a scientific discipline-oriented programme structure was motivated for the first programme phase, given the partially untested partnerships. Especially the economists had not been very extensively engaged in climate change research. However, already at the beginning, we aimed at an increasingly interdisciplinary effort. This also came about in practice, both viz. coupled modelling (climate, economy, carbon cycle) and stakeholder-oriented studies (social sciences, impact studies and climate scenario analysis). This development is benefited from on Phase II and leads to a renewed organisation of the programme.

The Programme structure for the second programme phase involves three main components (I, II, III) and under these, five Working Areas (1-5). The structure which was already depicted in Section 2.2 is reproduced below, for reference.



The Mistra-SWECIA Phase II programme elements and key flows of information.

The first two components (I, II) have much of a research character, some being basic and some applied. They contain some of the research directions already present in Phase I of Mistra-SWECIA: global and regional climate and climate-economy models, as well as adaptation processes. Risk assessment aspects of climate impacts emerged in Phase I and are now more explicitly included. Analysis of indirect climate effects is a new area, as are narratives viz. land use.

Components I and II also involve stakeholder contacts. This implies discussion on the research methods, need for specific analyses and best means for the provision of results. It can be noted that these two research-oriented components have different timelines, the research in Component I being more mature in the sense of involving regional stakeholders than the research in Component II. The latter component is also more oriented towards stakeholders dealing with national, rather than region, policy and measures.

Component III focuses directly on stakeholders' questions and knowledge needs. Stakeholders are foreseen to participate actively in problem formulation, knowledge production and promotion of findings. The involved stakeholders will be relatively few.

These three components are linked both with each other and internally. Further information on the components is provided in Section 6 of this plan.

4.2 Arrangements for collaboration, integration and synthesis

The Programme will be a consolidated undertaking. As is already evident, the development of new climate-economy models clearly benefits from active collaboration between economists, climate modellers and carbon cycle scientists. The development of regional and global Earth System Modelling involves collaboration between ecosystem and climate modelling scientists. The sectorially-focused climate adaptation efforts involve climate, impact and social sciences expertise. These collaborations were developed over the first Programme Phase and will continue to evolve in Phase II.

In Phase I, special efforts were made to facilitate the development of the interdisciplinary collaborations. In science seminars and workshops, researchers came together to discuss different common themes, highlighting the role of respective discipline. The Phase I case studies and of these especially the second one that concerned forestry became a breakthrough process in terms of interdisciplinary research. This is also the model on which we build on in Phase II, which is built in into the programme's structure of thematic rather than disciplinary areas.

As in Phase I, we shall also maintain operational supporting collaboration processes, such as:

- At the management level, the Programme Director and the Project Leaders will meet regularly in person to review the progress. The venue will rotate between the home institutes
- The programme components will largely be collaborative ventures, involving both natural and social sciences expertise whenever relevant
- Scientific and social integration will be facilitated by means of seminars (several per year), annual all-programme meetings and selected workshops (1-2 per year)
- Common Programme home page, logotype, graphical profile and newsletters
- Common PhD-targeted activities (information on education and study opportunities, a once-a-year special gathering of involved students, scholarship opportunities
- Each Programme participant is expected to have at least one scientist active in the Programme on a 70-100% basis, as well as another one on a 25-50% basis, so that there is a core group of staff with primary affiliation to the Programme. Additional scientists and sub-contractors can be less extensively involved, even down to 0% provided that they collaborate on other funding.

4.3 Management structure of Programme

The Programme management has the following elements:

The Programme Board…

… is the decision-making body of the Programme, but can delegate responsibility to the Programme Director. The Board operates under the stipulations by Mistra.

Chair: Bengt Holgersson

Members: Bodil Aarhus Andrae, Tim Carter, Tom Hedlund, Klas Eklund, Lena Sommestad, Johan Edman/Mistra (adj).

In Phase II, an additional member of the Board will be nominated. He or she is foreseen to “represent” interests in the land use -based sectors, or branches of government supporting or overseeing land use (e.g. County Administrative Boards”).

The Programme Director (PD, 0.2 Full Time Equivalents [FTE])…

… has the overall responsibility of the activities, interacts with the Programme Board, leads the preparation of annual plan revisions, progress and economic reporting. The Programme Director is affiliated to the Programme Host.

The Programme Director will be Markku Rummukainen, SMHI.

A Programme Manager (PM, 0.8 FTE)…

… will assist the Programme Director and the Programme component Leaders (see below) in the operational management of research coordination and integration, as well as in key administrative duties.

The Programme Manager will be recruited at the start of Phase II.

The Programme Host…

… has the overall contract with Mistra and administers the overall economy and similar matters.

The Phase II Programme Host will be SMHI.

The Programme component Leaders (PL)…

… manage respective part of the Programme on a day-to-day basis, as well as contribute to planning and reporting activities.

The foreseen PLs are:

Component I: Åsa Gerger Swartling, SEI and Stockholm Resilience Centre (SRC)

Working Area 1: Åsa Gerger Swartling, SEI and SRC

Working Area 2: Anna Maria Jönsson, Lund University

Component II: Ben Smith, Lund University

Working Area 3: John Hassler, IIES, Stockholm University

Working Area 4: Lars Bärring, Rossby Centre, SMHI

Working Area 5: Ben Smith, Lund University

Component III: Oskar Wallgren, SEI

The Management Group…

… consists of the PD, the PM and the PLs, joined by the programme’s communicator. The Management Group facilitates cross-Programme Component collaboration and also works on strategic development of research and communication.

In addition to the elements listed above, the management and joint efforts will be facilitated by a Communicator (1 FTE) and scientific secretary resources (0.5 FTE).

Overall, the management, coordination and communication efforts will be run with a net staff resource of 2.35 FTE, to which add efforts by the Board and the Programme component Leaders.

4.4 Scientific reference group

The Phase I Mistra-SWECIA scientific reference group consisted of the following distinguished scholars:

- Prof Annika Carlsson-Kanyama, Swedish Defence Research Agency (FOI), Sweden
- Prof Karen O'Brien, GECHS, University of Oslo, Norway
- Prof Martin Claussen, Max Planck Institute for Meteorology in Hamburg, Germany
- Dr Martin König, Umweltbundesamt, Austria
- Sir Nicholas Stern, LSE, the UK
- Prof Rik Leemans, Wageningen University, the Netherlands
- Dr Roger Street, UKCIP-OUCE, the UK

In Phase II, we foresee both a continuation of the Scientific reference group and a renewal. Specifically, some of the group’s present members will stay on, and some will be replaced. The changes are made in dialogue with the present members. This dialogue will be about i) how they have experienced their engagement in the programme both in terms of contributions and what they have gained and (ii) about their interest of staying on viz. the Phase II plans. In the solicitation of new members both the research and outreach aims of the programme will be minded.

The Phase II Management Group will also consider, based on the dialogue mentioned above, as well as the programme participants’ reflections, on how the utility of the Scientific reference group can be increased. In Phase I, most of the interaction was concentrated to the annual programme meetings, which was valuable in the strategic development of the programme as well as exchanging information. However, a more vigorous interaction may promote increased networking, staff exchanges and also benefit the development of outreach activities.

5. Skills and networks

5.1 Skills, knowledge and qualifications of the applicant group

See Appendix I for CVs, provided for the key staff marked with an "*" below.

The Rossby Centre, SMHI (RC) is the climate modelling research unit at the Research and Development department of the Swedish Meteorological and Hydrological Institute, SMHI, with 14 co-workers (advanced climate modelling, impact studies, supercomputing and communication). RC was the core of the Swedish regional climate modelling programme, SWECLIM (1997-2003). RC has since its establishment in 1997 contributed to many national, Nordic and international research networks on advanced regional climate modelling and scenario analyses (previously e.g. PRUDENCE, PRISM, CLIME, GLIMPSE, DAMOCLES, ENSEMBLES; presently: EC-Earth, CORDEX, IS-ENES, COMBINE, EUCLISE). The Rossby Centre contributes to the leadership in the EC-Earth collaboration, as well as the CORDEX effort on coordinated regional downscaling over the world. The key experts involved in Mistra-SWECIA are

* *Colin Jones* has a PhD from the Climatic Research Unit at the University of East Anglia, U.K. He is presently the Head of the Rossby Centre at the Swedish Meteorological and Hydrological Institute. In 2004-2005, he was Visiting Professor at University of Quebec at Montreal and in 2005-2008 the Canada Research Chair in Regional Climate Modelling and Professor at University of Quebec at Montreal, Dept of Earth and Atmospheric Sciences. He has experience from several projects funded from the EU framework research programmes (presently, EUCLISE, COMBINE, IS-ENES). He serves also in the international EC-Earth, Earth System Modelling Steering Group and is a Co-Chair of the WCRP CORDEX project.

Erik Kjellström has a Ph.D. in meteorology from Stockholm University. He has previously worked on chemical meteorology concerning the atmospheric part of the sulphur and carbon cycles (GLOMAC, SINDICATE within EUROTRAC and in EUROSIB), at the Stockholm University and the Massachusetts Institute of Technology. He has worked on regional climate modelling since 2003 at the Rossby Centre. He specialises in advanced evaluation of regional climate modelling experiments and engages in cooperative Swedish and European research projects.

Patrick Samuelsson, Ph.D., works with modelling of land-surface processes, lake processes and surface layer turbulent processes for climate modelling purposes and has been responsible for the land surface part of the Rossby Centre Regional climate model (RCA) since 2001.

Department of Meteorology, Stockholm University (MISU) is a leading Swedish university department in climate studies on physical atmospheric and oceanic research. The Department's main research directions are: Dynamic meteorology, atmospheric chemistry, atmospheric physics and physical oceanography. In climate research both modelling as well as process studies related to cloud formation and aerosols are central. Large scale circulation studies in the atmosphere and oceans are another core activity. In 2006, Stockholm University obtained a Linnaeus grant for a ten-year basic climate research effort. In 2009 it obtained a Strategic Research Area grant from the Swedish government to strengthen research in climate modelling. The key experts in Mistra-SWECIA are:

* *Jonas Nycander*, Professor in Geophysical fluid dynamics. He received his PhD in plasma physics from Uppsala University in 1989, and has then worked at Uppsala University, at the National Defence Research Establishment (FOI), and since 2001, at MISU. His main field is

physical oceanography, but in recent years he has also worked on vegetation modelling and the ocean carbon system.

Department of Earth and Ecosystem Sciences, Division of Physical Geography and Ecosystem Analysis (ENES), and **Centre for Environmental and Climate Research (CEC), Lund University** pursues climate and climate impacts research, including process-based modelling of ecosystems and the biosphere, and their application to assess impacts, mitigation potential and adaptation options. Much of this work has been in international (e.g. GCTE, VEMAP) and European (*e.g.* ETEMA, ATEAM, PRUDENCE, ALARM, ENSEMBLES) collaborations. Ecosystem models originating from ENES (FORSKA2, BIOME3, STASH, LPJ-DGVM, LPJ-GUESS) are widely used internationally. ENES has a long-standing co-operation with the Rossby Centre of SMHI on regional (RCA-GUESS) and global Earth System Modelling (EC-Earth) incorporating process-based vegetation dynamics and ecosystem biogeochemistry as well as secondary organic aerosol (SOA) from biospheric emissions. Other relevant strengths include the integration of modelling with remote sensing for upscaling of field measurements, studies of the impacts of climatic extremes on forest health and growth, and the biogeochemistry of tundra ecosystems under climate change. ENES and CEC area are also key institutes in the Linnaeus research environment LUCCI and the Strategic Research Area MERGE. The key experts in Mistra-SWECIA are:

* *Benjamin Smith,* Associate Professor, ENES, an ecologist and ecosystem modeller with broad experience of climate and impacts research. He developed GUESS, the first operational model of physiology-based ecosystem biogeochemistry and individual-based vegetation dynamics, and was co-author of LPJ-DGVM, a widely-used model in global ecosystem studies. Via participation in EU projects (*e.g.* ATEAM, PRUDENCE, ALARM) he has contributed to an emerging understanding of global change, ecosystems and society. He led a recent assessment of climate impacts on land ecosystems of the Baltic Sea region, and contributes to the Commission on climate and vulnerability. In collaboration with the Rossby Centre, he is developing a regional “Earth system” model to explore vegetation and land use change feedback on regional climate.

* *Anna Maria Jönsson,* Associate Professor, ENES, a plant ecologist specialised in developing impact models for assessing biological effects of climate change. She has been working with modelling of tree damage caused by extreme weather events and attacks by insect pests.

Fredrik Lagergren, Associate Professor, ENES, having expertise on modelling of forest management and storm damage.

* *Markku Rummukainen,* Professor, CEC. He is a climate scientist with a background on atmospheric chemistry and regional climate modelling. He has been a Programme Director of an earlier Mistra programme (Swedish regional climate modelling programme) as well as the Head of the Rossby Centre and contributed as a climate expert in different contexts. Today, he is Climate Advisor at SMHI and involved in the Swedish IPCC work and in the Swedish and EU climate negotiations’ delegation. He is also a WG I Lead Author in IPCC’s AR5, having earlier contributed in Expert Reviewer and Contributing Author roles. Currently, he also coordinated one of the recently-established Strategic Research Areas, namely MERGE that deals with the role of the vegetation and ecosystems in the regional and global Earth system.

Centre for Environmental Change and Sustainability, University of Edinburgh (CECS)
The University of Edinburgh is one of the largest and most successful universities in the UK, with an international reputation as a centre of academic excellence. Its international character is reflected in its truly international staff and in its joint research and other links with overseas universities, institutes, companies and governments. The main body of work on this project

will be carried out within CECS). CECS provides scientific evidence and analyses that support policies for sustainable development in the fields of climate, land and water use and international development. It is a hub for policy-related, interdisciplinary research and teaching within the School of Geosciences and the University of Edinburgh.

Mark Rounsevell, Professor of Rural Economy and Environmental Sustainability, is specialised in land use change modelling. His research focuses on the effects of environmental change on rural and urban landscapes with particular emphasis on models of land-use change and socio-ecological systems. Applications of these models are used to explore the effect of alternative futures of climate and other environmental change drivers on landscapes and ecosystem services and the response of individuals and society to these changes. He was a lead author to the 2nd, 3rd, 4th and 5th Assessment Reports of Working Group II of the Intergovernmental Panel on Climate Change (IPCC), leader of the society theme of the Scottish Alliance for Geosciences, Environment and Society (SAGES) and has also contributed to the expert group on scenarios for the National Ecosystem Assessment and to the DIUS Foresight land use futures project. He has contributed to a number of EU-funded research projects including IMPEL and ACCELERATES (as coordinator), ATEAM, ALARM, PLUREL, COCONUT, ECOCHANGE and FARO and CLIMSAVE. He has authored or co-authored over 100 international, peer-reviewed publications and is a member of the Editorial Board of the journal Global Environmental Change.

Verena Rieser, Post-Doctoral Research Fellow is a computer modeller with expertise in statistical learning and optimisation, as well as multimodal interfaces. She holds a PhD in Computer Sciences (Computational Linguistics) and is applying her technical expertise in land use modelling and uncertainty assessment in the multi-disciplinary EU-funded research projects PLUREL and ECOCHANGE. She was previously a WP leader in the EU-funded CLASSIC project (Computational Learning in Adaptive Systems for Spoken Conversation)**.**

Marc Metzger, Senior Research Fellow in Environmental Change Modelling, is specialised in multidisciplinary global change vulnerability assessment and scenario development. He was the leader of the vulnerability assessment methodology developed within the ATEAM project and has contributed to a number of further EU-funded research projects including BIOHAB, SEAMLESS-IP, FARO, COCONUT, EBONE, and CLIMSAVE.

The Institute for International Economic Studies, Stockholm University (IIES) started out as an independent research institute in 1962. It is now a separate research institute under the faculty of social sciences. The IIES is a leading European research centre with high-impact research in several subfields of economics. Current strengths are in macroeconomics, growth and development economics, public economics, and political economics. A common denominator is the analysis of the effects and determinants of economic policy making. Before Mistra-SWECIA, IIES had not specialized in research on the economics of climate change, but it has extensive experience in developing quantitative equilibrium models and in evaluating alternative economic policy strategies. IIES has very good international contacts, via research collaborations, and from the Institute's active programme to promote visits by top researchers from abroad. The key experts in Mistra-SWECIA are:

* *John Hassler* joined the IIES in 1994 after receiving a PhD in Economics from Massachusetts Institute of Technology and become a tenured professor in 2005. His research covers areas in dynamic macroeconomics and political economics and he collaborates with colleagues in Scandinavia, continental Europe, the UK, the US and Israel. He has been involved in policy advising, *e.g.,* in Economic Council of Sweden for several years. He is a member of the Editorial Board of the Review of Economic Studies and associate editor of

Scandinavian Journal of Economics. He is also a fellow of the international networks of academic economists CEPR (based in the U.K.) and IZA and CESIfo based in Germany.

* *Per Krusell*, Professor of Economics at IIES. His research interests are in macroeconomics broadly defined, technological change and economic growth, public economics, and political economics. He has done extensive research that involves solving and analysing quantitative dynamic stochastic macroeconomic models with heterogeneous agents. After his graduation from University of Minnesota in 1992, he worked at Northwestern University, University of Pennsylvania, University of Rochester, and Princeton University. Krusell is also a member of the two leading networks of academic economists: CEPR in Europe, and NBER in the US.

David Strömberg, Ph. D. in Economics at Princeton University, Senior Research Fellow at IIES. He has made theoretical and empirical contributions to political economics, not least on the role of the media in the economic policymaking process, and research on natural disasters.

Stockholm Environment Institute (SEI) is an independent, non-profit international research institute, established in 1989. The institute has established a reputation for rigorous and objective scientific analysis in the field of environment and development. SEI's goal is to bring about change for sustainable development by bridging science and policy. This is achieved by providing integrated analysis that supports decision makers. SEI is working primarily in Asia, Africa and Europe and has a proven track record on user-relevant climate research, including participatory processes, scenario development and analysis, sectorial studies and capacity building. The interdisciplinary work is carried out at local, national, regional and global policy levels and is gathered into four thematic teams that tackle overarching issues: Managing Environmental Systems, Reducing Climate Risk, Transforming Governance and Rethinking Development. Based on a list of 6,480 think tanks from 169 countries, SEI was in 2010 ranked tenth in the environmental think tank category in the global ranking conducted by the Think Tanks and Civil Societies Program at the University of Pennsylvania.

* *Åsa Gerger Swartling*, PhD in Sociology, is a Senior Research Fellow, and Theme Leader at SEI as well as co-leader at the Stockholm Resilience Centre. She specialises in participatory approaches to environmental policy and management. Since she joined SEI in 1994, she has been involved in and managed numerous research projects dealing with stakeholder engagement, learning, sustainability assessment, project evaluation and policy integration, particularly in the areas of climate change, energy and urban environment. Swartling's research interests and experience include both developing and developed countries.

* *Oskar Wallgren* is a Research Fellow at SEI, which he joined 2002. He leads one of the Stockholm centre's four research groups and in part of the centre management team. He is involved in multidisciplinary and problem-oriented research projects on climate change adaptation, environmental management and sustainability planning. In the first phase of Mistra-SWECIA he was responsible for program-wide case study coordination, and he was part of the programme management group.

Dr *Richard J. T. Klein* is a geographer with more than fifteen years of research experience on human vulnerability and adaptation to climate variability and change. He is an internationally leading expert on adaptation science and climate policy and has been involved in the Intergovernmental Panel on Climate Change since 1994, most recently as coordinating lead author in the Fourth Assessment Report. He also contributed to the Millennium Ecosystem Assessment and to the Stern Review on the Economics of Climate Change. Richard coordinates climate policy research across all SEI centres. He will act as act as scientific advisor in the work on adaptation to indirect effects of climate change.

Dr *Måns Nilsson* is Deputy Director at SEI. He specialises in policy analysis, institutional development, public sector management, and strategic assessment, with emphasis on climate and energy policy and development policy. He will act as scientific advisor in the work on indirect effects and adaptation processes, with particular emphasis on policy and governance dimensions.

5.2 Networks of researchers and users linked to the Programme

5.2.1 Networks of researchers

- *EC-EARTH*[5] is a new European consortium developing an advanced Earth System Model based on the European Centre for Medium-range Weather Forecasts (ECMWF) global forecast model. In Sweden, the Rossby Centre at SMHI, Department of Meteorology at Stockholm University (MISU) and Lund University (ENES, CEC) all contribute to EC-Earth. EC-Earth is also the name of the model system that the consortium develops. The baseline EC-Earth model is further developed into an Earth System model by the efforts of the consortium's members, today including 22 academic institutions and meteorological services from 10 countries in Europe. EC-Earth is currently running a range of the international CMIP5-simulations.
- *SURFEX*[6] network in Europe. Development of the high-resolution LSHEL model is based on SURFEX (land-soil-lake-boundary layer model), as well as LPJ-GUESS (ecosystem model at Lund University, LU) and HYPE (surface hydrology model at SMHI), is a wider European effort to develop a high-resolution coupled regional climate system model. While the development of the LSHEL offline model will mainly be a collaboration between SMHI and LU, collaboration with the SURFEX development team at Météo-France will also be necessary.
- *Harmonie*[7] *NWP* groups (SMHI and Harmonie consortium) plus the Harmonie climate network with several European weather services: SMHI (SE), KNMI (NL), DMI (DK), AEMET (ES), Météo-France (FR)
- *The Stockholm Resilience Centre*[8] is an international cross-disciplinary research centre at Stockholm University that focuses on the governance of social-ecological systems. It combines the expertise of the SEI, the Stockholm University and the Beijer Institute. The Centre is funded by Mistra. Mistra-SWECIA will continue and benefit from and contribute to the research being developed in the Centre particularly through the SEI.
- *The Bert Bolin Centre* is a collaboration between four departments at Stockholm University: Meteorology, Physical Geography and Quaternary Geology, Geological Sciences, and Applied Environmental Science. It comprises around 70 researchers and PhD-students. The research concerns natural climate evolution and variability, as well as man's impact through emission of greenhouse gases and aerosols, and changes in land-use and hydrology. Climate modelling is a core activity. The centre is funded by VR (the Swedish Research Council) for a 10-year period under their Linneaus program.
- *Models for Adaptive Forest Management (MOTIVE)*[9] is an EU-FP7 project that evaluates the consequences of the intensified competition for forest resources given climate and

[5] http://ecearth.knmi.nl/
[6] http://www.cnrm.meteo.fr/surfex/
[7] http://hirlam.org/index.php?option=com_content&view=article&id=65&Itemid=102
[8] http://www.stockholmresilience.su.se/
[9] http://www.motive-project.net/

land use change. The project focuses on a wide range of European forest types, including Swedish forest, under different intensities of forest management, seeking to develop and evaluate strategies that can adapt forest management practices to balance multiple objectives under changing environmental conditions. Participatory methods are used to study decision-making under uncertainty, science-stakeholder communication and other issues relevant to forest sector adaptation to direct and indirect drivers of change. SLU Alnarp researchers involved in MOTIVE will contribute the development and analysis, in Mistra-SWECIA Phase II, of an agent based model (ABM) for land use decision making in the Swedish forest sector, taking on board findings and insights from stakeholder engagement activities in MOTIVE.

- *NORD-STAR*[10] (Nordic Strategic Adaptation Research) is a new Centre of Excellence initiative and is a collaboration between organisations from all five Nordic countries. From Sweden it involves SEI, Linköping University and Chalmers University. It will advance the science and knowledge base for two types of adaptation: adaptation to climate change, and adaptation to climate policy. The Centre will operate on the interface of science, practice and policy. It will explore new types of dialogue between research and society, focusing initially on land-use change and energy transitions.
- *NORDCLAD-Net*[11] (Nordic climate change adaptation research network) is a concerted effort to bring out the best from Nordic research on adaptation to climate change. Based on funding from the Nordic Top-level Research Initiative (Effect Studies and Adaptation to Climate Change), the network will organize two major conferences and offer training to young researchers. The first conference was held in Stockholm on 8-10 November 2010 on the theme Climate adaptation in the Nordic countries – science, practice, policy. The second conference, planned for 2012 in Finland, will address the interface between research and decision-making including a focus on economics of climate change. Mistra-SWECIA will contribute to the conference, and aims at dissemination of results to other researchers and stakeholders.
- *BECC*[12] (Biodiversity and Ecosystem Services in a Changing Climate) is a strategic research area at Lund and Gothenburg Universities engaged in interdisciplinary research on biodiversity-ecosystem service coupling with a particular focus on the Scandinavian landscapes and environment. Synergies with Mistra-SWECIA exist particular with regard to the development of coherent scenarios and analysis of land use decision making under climate and policy change, and in the development of a mechanistic approach – robust to future conditions – for modelling and assessing tree resistance and forest damage risk to disturbance and stress.
- *Collaborative climate adaptation and impacts research.* During Phase I, Mistra-SWECIA established collaboration involving researchers from Brock University, and Environment Canada (EC), Canada, and SEI/LiU. The collaborative research covers in the area of climate adaptation and impacts, with particular emphasis on the learning dimension of community based adaptation.
- *Future Forests*[13] is another Mistra-programme, hosted by the Swedish University of Agricultural Sciences (SLU) and also involving Umeå University and the Forestry Research Institute of Sweden. Its backdrop the climate change, globalization, and increased consumption of materials and energy, which lead to a higher pressure on forest

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[10] http://www.nord-star.info
[11] http://www.sei-international.org/nordclad
[12] http://www.cec.lu.se/o.o.i.s/24960
[13] www.futureforests.se

resources, and consequently to questions on intensifying forestry to produce more timber, paper, and energy, while at the same time ensuring ecosystem services, such as biodiversity and recreation. Future Forests has a long-term perspective and considers climate, as well as global and market development as major factors likely to have a strong influence on forest management and forests in the future. Uncertainties, vulnerability, and the adaptive capacity of social-ecological systems is focal targets for research. The programme combines empirical research with modelling, scenario analysis, and synthesis work, and involves both forest researchers and stakeholders.

Mistra-SWECIA and Future Forests will have an annual programme management-level meeting for dialogue.

6. Programme components

6.1 Overview

The three programme components and the different work areas are discussed below.

6.2 Component I: Regional climate change adaptation

The research in this component focuses on adaptation processes at the land use -based sectors, taking account of a wide range of factors influencing the decision-making process in these sectors. Initially, the forest sector in Sweden will be used as a case study. Research on adaptation processes (Working Area 1) is integrated with model-based studies of impacts of climate change and global drivers on forest resources and environmental values studies (Working Area 2).

Three common methodologies/approaches will contribute to integration between the two Working Areas. Firstly, we will continue to make use of *focus group* methods. Powell and Single (1996:499) define a focus group as: "a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research." There are many variations of the basic method, but generally, a focus group is a method for collecting qualitative research data through carefully planned group discussions with the purpose of obtaining perceptions of participants in a permissive and non-threatening environment (Morgan 1988). In Phase II we will build on and fine-tune the focus group method used in Phase I, to make it fit for purpose across various regions and contexts of the forestry sector. The focus groups will be complemented with larger stakeholder workshops gathering all involved stakeholders for follow up discussions and to receive feedback from participants.

Second, to provide a complementary perspective, and as a key innovation, we will develop an agent-based model of decision making processes of forest sector actors, spanning governance levels (stand to policy/local to national). The model will be developed as a tool to explore and visualise the interactions among actors under alternative pathways of change in multiple drivers such as forest production, damage risks, prices and trade in forest products.

Thirdly, cross affiliation of researchers performing model-based impact analysis (Lund University, University of Edinburgh, SLU) in this Component's two Working Areas will promote the exchange of results and insights from both the social science and ecological/ biogeophysical aspects of the research and their integration in the data analysis and modelling.

6.2.1 Working Area 1: Research on adaptation processes

This Working Area encompasses the empirical research on the decision making and motivations of key actors of the Swedish forestry sector. Both existing and emerging/potential adaptation processes will be studied. A central aspect of the approach will be the communication of results from model-based analysis of the impacts of climate and other drivers on forest resources and other factors influencing decision making, as one basis for discussion and dialogue among stakeholders and researchers. A parallel and closely linked line of work within the Working Area will be the analysis of adaptation decision making in response to indirect effects of climate change, i.e. political, social and economic effects experienced in Sweden as a result of climate change impacts in other locations.

Building on the findings from the above approach, and providing a complementary perspective on the adaptation process, an agent-based model (ABM) representing and informed by possible interpretations of the decision-making processes of key actors in response to hypothesised changes in the drivers will be developed and used as one tool to explore, visualise and discuss the possible implications of decision-making under climate- and global socio-economic change with stakeholders. ABM is an application of multi-agent systems, an area that is emerging as an important approach in the social sciences. A key innovation with the ABM work in Mistra-SWECIA will be to incorporate the synergies and conflicts among actors at different governance levels, e.g. land owners versus policymakers, and their possible implications for management and adaptation in Swedish forestry.

Central research questions

1. What factors promote or hinder adaptation to climate change and how?
2. Who are concerned with facilitation and implementation of adaptation to climate risks in the selected thematic areas and regions?
3. What are the concerned stakeholders' respective roles, interests and actual efforts in the local/regional adaptation process?
4. What characterizes the links (e.g. collaborations, leadership, knowledge transfer, resource allocations) across the institutional landscape?
5. Which (scientific, practical/experiential) knowledge is required by stakeholders, how is such knowledge best communicated and how is it used?
6. How is scientific knowledge interpreted and how does it influence stakeholders' perspectives and adaptation preferences?
7. What is the role of learning in climate change adaptation processes?
8. What are the opportunities and motivations for stakeholders to engage in a process of social learning on climate adaptation issues?
9. In what way do indirect effects of climate change pose new or altered threats and opportunities in a years-to-decades time perspective to which government and private sector decision making has to adapt?
10. What approaches/tools/methods can be used to describe, quantify and analyse such effects?
11. How can government and private sector decision making (better) accommodate indirect effects of climate change, to the benefit of Sweden, Swedish society and the Swedish economy?

Foreseen results and other outcomes

In terms of outcomes, the research within this Working Area will:

- Map out the existing institutional landscape in the thematic area or sector under study
- Explore the involved characteristics of, and enabling processes for, adaptation action in the thematic area or sector under study
- Provide insights on adaptation processes at a wider (e.g. multi-sectorial or regional) context, based on findings at the sectorial or thematic level

- Provide insights and contribute to the development of a methodology on adaptation analysis combining state of the art risk assessment and participatory research methods in a sectorial context.
- Develop the use of agent-based modelling as a tool for analysing synergies and conflicts between adaptation decisions across organisations and institutions, and for conveying these to stakeholders in a participatory research context.

In relation to indirect effects of climate change, the research will furthermore provide

- Empirical understanding of government and private sector needs and capacities in terms of addressing indirect effects of climate change today. This understanding will be gained through a mapping of the decision support tools/methods currently employed in such decision making (e.g. projections, scenarios, analytical tools, deliberative processes).
- Practical experience from applying conceptual frameworks and/or analytical tools for systematically analysing the indirect effects of climate change qualitatively and quantitatively, illustrating their utility in both short-term and long-term decision making.
- An improved understanding of how climate change impacts outside Sweden will affect Swedish society and the Swedish economy. This understanding will be gained through an assessment of the most important indirect effects for Sweden in a years-to-decades time perspective and an outline of possible adaptation strategies in relation to these effects
- Information for Sweden's efforts at the international political arena, e.g. in climate negotiations and development assistance

Rationale

Over the past decades it has become clear that the impact of past greenhouse gas emissions will influence our climate for decades. Thus, alongside mitigation efforts we need to prepare for the climate change that we cannot avoid. The Central European floods of 2002 and the European heat-wave of 2003 showed that successful preparation and adaptation cannot be taken for granted, even in the most developed societies. In Sweden, there is still much uncertainty about how to respond to the effects of climate change. The aftermath of the windstorms Gudrun (2005) and Per (2007) in southern Sweden illustrates that the ability to deal with extreme weather events is lacking. Preparing for climate change is important to ensure a continued high quality of life, profitability of economic sectors and security from floods, storms and other climate risks.

The science of climate adaptation is still young and has tended to focus on understanding the concept of adaptation, with most evidence coming from developing country contexts. In recent years, communities of science, policy and practice have begun to recognize the need to understand the process of adaptation itself, including factors determining the success of adaptation, and what stakeholders can do to overcome barriers to achieve effective adaptation. As is evident from real-world experiences across the world, adaptation is a complex process which is determined by multiple, non-linear and sometimes counteractive factors and forces. These include among others cultural norms and values, different modes of learning, access to tools, knowledge and financial resources, and adaptation leadership. Moreover, the policy environment, cross-scale dynamics and power structures set the context in which adaptation takes place. Only with an enabling environment will partnership and collaborations form, co-sharing of knowledge and learning take place, and trust and capacity be built.

As a contribution to advancing the adaptation science domain, Mistra-SWECIA will in its Phase II build on and extend the research on the adaptation process undertaken in Phase I. Moreover, we will strengthen the emerging partnerships and build synergies with existing research collaborations on climate adaptation in developed contexts, where SEI is engaged, such as the recently established Centre of Excellence NORDSTAR[14] and the five-year agreement between SEI and Brock University in Canada on climate risks and community-based climate adaptation. By being relevant to stakeholders, and by developing knowledge and providing science support, this programme Component will facilitate adaptation and contribute to the overall Mistra-SWECIA vision.

The ways in which individuals and institutions adapt to changing environments is underpinned by their values, behaviour and decision making processes. ABM is unique amongst land use modelling strategies in being able to represent these types of processes for real-world actors through agent simulation. Moreover, being explicit about adaptive learning across spatial scales in the linked land use modelling approach will allow us to combine scientific and local, practical knowledge and perspectives in an interactive and conducive setting which has appeared a promising approach to adaptation assessments in Phase I. This is central to the creation of appropriate and relevant platforms for science-stakeholder dialogue. Since the agent simulations of adaptation processes relate closely to the actions of individuals and stakeholders, the science-stakeholder dialogue will also be embedded within a common epistemology.

Indirect effects of climate change (i.e. effects in location “A” resulting from climate change impacts in location “B”) will likely be significant for the Swedish economic sectors, policy making and international engagements of Sweden. Together with global policy measures and changes in the global economy, one may expect changes in flows of goods, capital and people. Also these changes will require adaptation to ensure that opportunities are harnessed and negative impacts mitigated.

Methodology

In Phase II of Mistra-SWECIA we will capitalise on on-going research carried out in Phase I, as well as draw on other studies and novel approaches in the field.

The Swedish forestry sector will serve as a case study over the full programme phase. The empirical focus on a single sector will enable deeper insights into the complexity and realities of existing and emerging adaptation processes. On the part of involved stakeholders, there will be greater opportunities for meaningful interactions and a more conducive environment for sharing of knowledge and perspectives, reflection, and co-learning.

The research approach is partly bottom-up, driven by stakeholder framings, perspectives, needs and interests and the local conditions through research observations and participatory research methods in some selected settings. The participatory nature of our work will also allow us to involve stakeholders from society and the private sector in the entire research cycle. Apart from desk study based research, there will be a series of participatory exercises, notably focus groups in some carefully selected localities to allow for exchange between participants and opportunities to reflect and share knowledge and perspectives with each other as well with climate and impact scientists. A number of focus groups will be organised jointly with notably climate impact scientists in the programme, to investigate how state of the art scientific knowledge is interpreted; how it influences stakeholders’ perspectives and adaptation preferences; as well as the desirable modes and forms of science-stakeholder interactions and communication.

The localities/regions for the empirical study will be chosen based on selection criteria which will be determined in consultation with the entire programme.

[14] http://www.nord-star.info

The policy environment, cross-scale dynamics and various power structures set the context in which adaptation takes place. To understand some of the critical factors involved in policymaking, the participatory approach in the focus group activities will also include an exploration of the policy dimension of adaptation processes in involved organisations.

To enable wider applicability of the research undertaken in Working Area 1, we will provide analysis from both a case study specific viewpoint, as well as from a multi-sectorial or regional perspective. This will provide a basis for the Working Area's contribution to the methodology on adaptation analysis combining state of the art risk assessment and participatory research methods in a sectorial context.

In the research on adaptation to indirect effects, we will employ a dual case study research design, as we target *understanding the use of knowledge and assumptions about the future in decision making processes* (see e.g. Nilsson *et al* 2008, Nilsson and Dalkman 2001) rather than producing quantitative predictions of indirect climate change effects. Case study research (Gomm et al. 2000, Mitchell 1983, Stake 1995) and is well suited to research in which context is influential (Yin 1993). Two different cases will be examined. One will be the Swedish forestry sector with a particular focus on trade in timber, wood and fuels. The national perspective will complement previous work on climate change adaptation at local level (e.g. Keskitalo 2008). A parallel case will be identified during 2012. For both cases, resource constraints will limit empirical data collection to Sweden and the Swedish actors. The document analysis will, however, cover also relevant European policy and legislation. A combination of qualitative (interview) and quantitative (survey) methods will be employed.

The efforts will also include use of climate-economy modelling results (WA3) and development of land-use narratives (WA5), as well as from external integrated assessment modelling partners. We will use also focus groups of professional stakeholders who can reflect on different approaches. The focus group material collected will be analysed using an evaluation protocol covering factors such as the perceived accessibility, flexibility/ease-of-use, data needs and costs of different approaches.

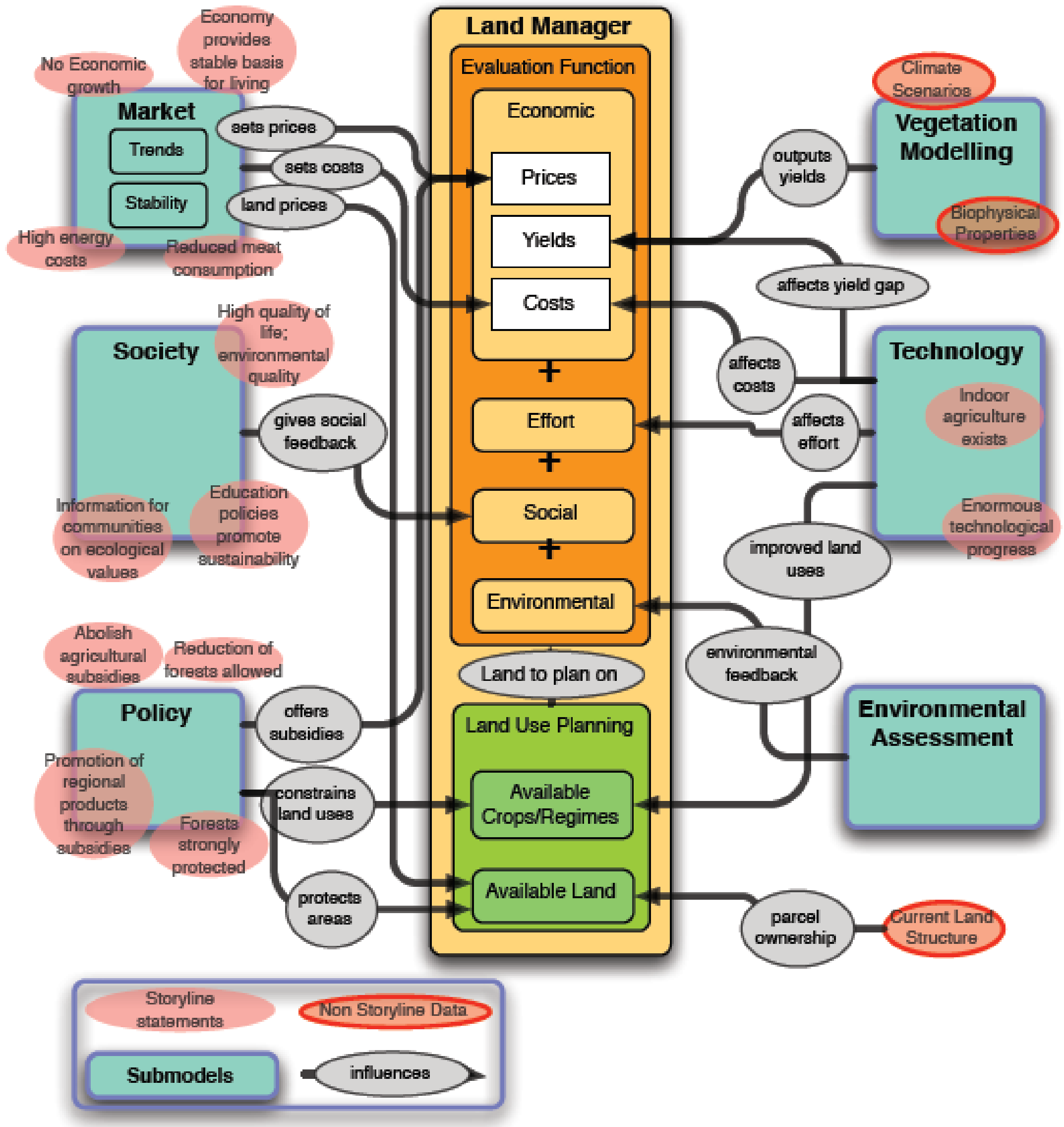
Research data will be collected using several methods, including a survey (Marsden and Wright 2010) in order to get a broader picture of the way in which climate change is addressed in the case study sectors. Business representatives, trade association and consultancies, as well as government officials and policy makers will be targeted, aiming for 100+ individual responses per case. Semi-structured, in-depth interviews (Chirban 1996, McCracken 1988) will be conducted with some 10-15 informants in each case. The group of respondents will cover the key categories of actors and stakeholders in the sectors, based on a simplified stakeholder and institutional mapping approach (Aligica 2006). The aim will be to collect qualitative data on how industry and government actors are thinking strategically about international opportunities and threats in a larger context of global change on these issues. Third, quantitative and qualitative content analysis (see Silverman 2001) of key documentation will be made. The content analysis will be focused principally on political documents (e.g. government bills), market analyses, scenarios, annual reports and other similar reports published by or for the key actors in the sector(s). For both interviews and document analysis, the general analytical framework of Miles and Huberman (1994) will be employed in the analysis of qualitative data. Quantitative data will be analysed statistically.

An agent-based model (ABM) will be developed as a tool for analysing and visualising the potential consequences of forest sector decision-making on land use and sector development. The ABM will be informed by the stakeholder engagement activities (Working Area 1), impact modelling (Working Area 2) and descriptions of global drivers, both modelling and exogenous assumptions (narratives) (Working Areas 3, 4, 5). A key challenge and innovation will be to incorporate actors from the local (land owner, forest manager) to regional (county councils) and national (government authorities) levels as interacting agents within a common dynamic framework. This will allow synergies and conflicts between adaptation decisions across organisations and institutions to be analysed and discussed with stakeholders in a participatory research context. Apart from offering an opportunity to explore forest stakeholders' perspectives on adaptation needs and options in a sectorial context, the ABM simulations, when presented in focus group settings, will enable stakeholder feedback on model improvements.

The technical platform for the ABM remains to be decided. The principles for the construction of the ABM will be similar to those of the existing ABM platform designed to simulate land use change in a number of regional case studies throughout Europe within the EU projects ECOCHANGE and VOLANTE (Murray-Rust et al., in press, Rounsevell et al., in review) and related national projects (Rounsevell and Arneth, in press). The latter uses an approach based on behaviour decision theory, but also analysis of the qualitative/quantitative empirical data that derives from stakeholder analysis/survey in each regional case study. Compared to this platform, the ABM developed in the present study would be modified. to incorporate institutional as well as individual agents, is depicted in the Figure below, which demonstrates the key state variables to be *potentially* modelled by the ABM, as well as the exogenous variables that will be provided by other modelling strategies or as assumptions adopted from external scenarios/narratives.

The representation of the land manager is core to the ABM, and this will be informed by the stakeholder focus groups and other empirical work undertaken in WA1 supporting the implementation of agent behaviour-decision theories within the model (see Rounsevell et al., in review). The stakeholder analysis will also provide input to the 'society' box in terms of alternative representations of societal expectations, norms and values. We will investigate the motivations and behaviour of different real-world actors including individuals (e.g., land owners), and organisations (for example the Swedish Forest Agency, County Administrative Boards, the Ministry for Rural Affairs, the Swedish EPA), and use as the basis of the development of the ABM framework. This work will be integrated within the focus group discussions and other engagements with these stakeholders, including the opportunity to present and discuss results from the ABM simulations. Links to other relevant projects on forest sector adaptation, such as EU-FP7 MOTIVE and the strategic research area BECC at Lund and Gothenburg Universities (see below), will provide further input.

External drivers or boundary conditions to the ABM include impact model-generated scenarios of changing forest or agriculture production, damage risks and non-economic values (e.g. biodiversity-related values) from stand to regional scales, as well as indirect drivers of land use decision making, such as global demand and world prices for land-based commodities. The climate-economy models (Working Area 3) and global climate, ecosystem and land use models (Working Areas 4-5) are thus important in providing the national-scale, boundary conditions for the ABM. This includes the provision of variables for the 'market' box (such as GDP, prices and costs for different socio-economic sectors) and the 'vegetation modelling' box. Finally, the narratives defined in Working Area 5 will provide exogenous assumptions in relation to socio-economic factors (e.g. human demography, globalisation, environmental policy) assumed but not modelled explicitly by any of the global models.



Illustrative structure of the ABM showing the simulated variables and external assumptions potentially influencing land use decision making in Swedish forestry. The actual model developed might adopt a simplified structure, treating some components implicitly or as constant assumptions based on external scenarios etc.

The ABM development work will be coordinated and interact with a research project on multi-level decision making in Swedish forestry within the strategic research area BECC at Lund and Gothenburg Universities. The BECC project complements Mistra-SWECIA with senior expertise in agent-based modelling, policy analysis and characterising of policy/institutional actors, multi-level governance, environmental economics and empirical understanding of the mechanisms of historical land use change in Sweden. In exchange for involvement in relevant participatory activities in WA1 and analysis of the resulting data, the BECC project will contribute to the development of the ABM tool, including the definition of agents represented in the model and the 'rules' defining their decision making and interactions. The resulting ABM will be used in the BECC project as a tool to explore policy alternatives for Swedish forestry under global change, such as 'land sparing' (setting aside reserves for biodiversity conservation, using remaining land for intensive production) versus 'land sharing' (landscape management integrating production and environmental goals).

Dependencies / links (incl. external)

In order to undertake the above research, this Working Area will draw on, and deliver inputs to, the following other research activities of Mistra-SWECIA Phase II:

Working Area 2

Climate and impact scientists will be involved in focus groups and larger stakeholder workshops to provide scientific input and enable more informed assessments of adaptation needs and options. Feedback will be provided to climate and impacts scientists to guide future research, including model development. Findings from stakeholder engagement, e.g. focus groups, will inform the development of the ABM of land use decision making.

Modelling of impacts and risks from stand to regional scales will provide input to focus groups and other elements of the participatory research on adaptation. They are also needed as input to the ABM which will provide one platform for exploring the consequences of alternative adaptation choices in conjunction with stakeholders.

Working Areas 3-5

Results from the global drivers -analysis will be used to frame stakeholder dialogues, possibly through the use of global scenarios or narratives in focus group settings, providing one basis for participatory exploration of adaptation issues among stakeholders and researchers. Climate-economy modelling (WA3) will provide relevant drivers (e.g. global and regional economic growth, GDP distribution, trade patterns) under the common external assumptions and narratives adopted.

Component III

The indirect effects study will feed into the stakeholder discussions to stimulate exploration and enhanced understanding of multi scale dimension of climate change, as well as explore the implications this knowledge has on perceptions of risk, adaptation needs, and on learning.

Results from the analysis of the adaptation process will provide important insights into the extent to which indirect effects presently are identified, interpreted and (potentially) addressed in the studied sector(s).

Information on the institutional landscape and adaptation research analysis will give crucial input to discussions with stakeholders and the formulation of joint partner-driven studies.

Resources and key personnel

Estimate of person months linked to each specific activity and indication of the distribution of work across these deliverables over the period 2012-2015

Person-months linked to the Working Area 1:

	2012	2013	2014	2015	Total
SEI	24	37	26	7	95
LU	16	16	11	7	50

Key personnel

SEI: Åsa Swartling, Oskar Wallgren, Måns Nilsson, Postdoc Karin André, junior researcher/PhD student NN.

Lund University: Anna Maria Jönsson, Fredrik Lagergren, PhD student NN (subcontractor Edinburgh), Dave Murray-Rust (Edinburgh), Kristina Blennow (subcontractor SLU).

6.2.2 Working Area 2: Research on Regional Climate Modelling: High Resolution climate projections, impact modelling and risk assessment

This Working Area focuses on the analysis and compilation of scenarios of the impacts of climate and other drivers on factors important for decision making in the forest sector, accounting for changes in forest production and their economic outcomes, but also non-economic drivers including environmental and biodiversity values of forests, and the opportunity costs of alternative land uses, such as agriculture and nature conservation. The risk analysis framework, developed during Phase I, will be refined to account for the influence of global drivers, e.g. world markets and trade in forest commodities, and to represent non-production aspects of change, such as biodiversity values, that cannot be directly modelled based on indicators or proxies (that can be modelled), defined in discussion with stakeholders.

The model-based analysis of impacts and risks will feed into the empirical research on decision making and adaptation of forest sector actors, in Working Area 1. Outcomes from impact modelling will also feed into the development and application of the agent-based model for the Swedish forest sector, providing the drivers of decision processes of the agents represented in the model.

Central research questions

1. Is ranking of management options influenced by the risk-behaviour of the forest owner, and will climate change influence the ranking of management options by influence on risk, rather than by influence on production? How does inclusion of non-market values (carbon storage, biodiversity, recreation) influence ranking of the management options, compared to ranking based solely on economic considerations?
2. Can the land use and management decisions of forest owners and other actors across organisations and institutional landscape in response to changing markets, values and risks be characterised in an ABM and what outcomes in terms of landscape patterns, policy and economy may this lead to under alternative future scenarios of relevant drivers?
3. How can probabilistic climate change projections best be provided to user groups? On what (i) spatial scales can this information be reliably provided, (ii) time averaging periods in the future should such information be delivered and (iii) how can one best communicate the level of certainty/reliability in the developed probabilities?
4. Can the spatial detail and accuracy of climate projections for the Nordic region be improved by utilizing a very high resolution (~1-2km) offline land-ecosystem-hydrology-lake model driven by climate fields derived from lower resolution (~10-20km) Regional Climate Model projections? If so how do these improvements compare to direct regional climate model projections run explicitly at the ~2km scale?

Foreseen results and other outcomes

- A large matrix of regional climate simulations will be collected and analysed to generate a set of probabilistic climate change projections for Northern Europe. These will provide estimates of changes in the present-climate Probability Distribution Function (PDF) of key variables, expressed for overlapping 30 year periods in the future, at the highest feasible spatial resolution. The estimates will be accompanied by information detailing the *probability of occurrence* of the respective climate change signals.
- A high-resolution land-soil-hydrology-ecosystem-lake (LSHEL) impact assessment model will be developed for Sweden. The LSHEL model will be driven with output from the matrix of regional climate change projections to provide high spatial resolution

information (~1-2km) of key aspects of climate change linked to forestry, water resources and ecosystem stability over Sweden.

- A limited number of very-high resolution (~2-3km) regional climate change projections will be made for SWECIA users case studies. These will utilize a multi-nesting technique to downscale GCM projections first to the European scale at ~10km resolution, these simulations will then drive a number of time slice projections using a 2-3km RCM, configured over the case study regions of SWECIA, in order to provide highly detailed climate information for use in the case studies.
- High-resolution studies of climate change impacts on a range of forestry-relevant processes/parameters will be developed and provided/explored with Swedish forest stakeholders.
- A risk analysis framework for Swedish forestry including: characterisation of relevant risks at landscape level, integration of non-economic values such as environmental services and biodiversity with economic valuation of production, damage and management costs, influence of world markets and trade on economic returns from forestry, opportunity costs of alternative land uses such as agriculture, biofuel production, or environmental services.
- Relating the land use and management decisions of forest owners and other actors across organisational hierarchies and institutional landscape to global and regional drivers that affect markets for commodities, non-economic values such as biodiversity, damage risks and management costs to project outcomes in terms of landscape patterns, environmental or land management policy and forest sector growth/share of GDP by agent based modelling.
- An analysis of how risks and benefits (economic but also intangibles, identified as important by stakeholders) may be affected by regional and global climate and socio-economic change and how management and adaptation policy choices may affect these risks and benefits. The analysis is expected to be of direct value as a basis for decision-making by the user groups involved in the study. It will also serve as a demonstration of how the overall Phase II developed framework may be applied as part of a comprehensive study of adaptation opportunities and needs at a regional and sectorial level.

Rationale

Regional climate and impact scenarios are an important part of the decision-support information available to stakeholders. Such information needs to sample all relevant (uncertain) factors that contribute to spread in future climates at the local to regional scale. Ideally, a sufficient number of climate realizations will be available to describe the observed present-climate PDF for key variables and subsequent changes in these PDFs as a function of time into the future. Furthermore, the large number of future climate realizations should allow robust *probabilities of occurrence* to be assigned to each climate change estimate. Such an approach provides to the stakeholder both estimates of changes to the full range of present-day regional to local climate variability, as well as estimates of the likelihood of each projected change occurring. Such an approach is the only reliable methodology to assess climate change impacts at the regional to local scale.

In turn, stakeholders (as well as scientists), are challenged by the nature of such information (e.g., uncertainty, scale, parameters) thereby requiring a close and continuous dialogue between those generating climate information and the stakeholders and decision-makers that must use this information in their planning activities. Improved climate projections (resolution, transparency, robustness, key uncertainties described and explained) and impact assessments (ibid, risk analysis) can facilitate the use of projections either as framing information or as concrete basis for specific decisions.

Specifically, viz. forestry, according to the Swedish forestry act, the production goal and the environmental goal are equal (sustainable forestry, preserved production capacity). Recent storm events have raised questions about the need for adaptation of forest management in order to reduce the risk for windthrow and attacks by spruce bark beetles. A shortening of the rotation period can be implemented to reduce the risk for damage, although this may have a negative impact on the biodiversity at landscape level. Increased production of broadleaved trees is another option. Decision support is partly lacking, as the forest stand economic calculations generally focus on wood production, and do not include the risk for damage or any other aspects that influence the choice of management such as biodiversity, recreation and carbon sequestration (Ekvall and Bosted 2009).

Methods

<u>Regional Climate Modelling</u>

A large set of Regional Climate projections for Europe, developed through extensive European collaboration over the past ~5-10 years, will be combined with a new set of projections taking form under the CORDEX (Coordinated Regional Climate Downscaling Experiment) activity. Specifically for Europe, Euro-CORDEX will produce a matrix of ~10km regional climate projections covering the period 1950-2100, based on a suite of European RCMs, each driven by a range of GCM projections from the CMIP5 experiment. Through this collaborative effort Euro-CORDEX will generate a matrix of high-resolution climate projections for Europe that sample a large number of GCMs, RCMs and CMIP5 Reference Concentrations Pathways (RCPs). SMHI contributes to this activity and thereby has free access to all simulations made in Euro-CORDEX, results from this effort will be available during the approximate period 2011-2015. This data will be combined with, and compared to, earlier projections for Europe, with the aim of generating a large ensemble of information from which estimates of climate change can be made for variables of high user interest.

These estimates will target potential changes to portions of the present-climate Probability Distribution Function (PDF) for each variable under study, such as changes to the median and a number of percentile bands (e.g. 0-25th, 75th-100th percentile, etc.) spanning the full PDF. The projected change in a given variable and percentile band, for example the 0-25th percentile of the present-climate winter-mean surface temperature distribution, will also be estimated in terms of a probability distribution. In this case the assigned probability represents the likelihood of occurrence of a climate change of a given magnitude, here to the 0-25th percentile band of winter-mean surface temperature, relative to all possible changes to this variable/band in the matrix of simulations. Variables to be analysed will be decided in discussion with Mistra-SWECIA user groups, but will likely be a combination of standard climate variables; e.g. PDFs of seasonal or daily mean surface temperature, wind speed and precipitation, as well as more derived quantities such as changes in drought length/frequency or number of spring days with temperatures below 0°C.

The final aim is a set of probabilities that describe the full range of possible changes in pre-defined sections of the present-climate PDF, for all important user-defined variables. The probabilities of change will be generated for Scandinavia at the highest spatial resolution at which such information can be reliably provided and will be presented as mean changes for overlapping 30 year periods into the future.

The development and use of a very-high resolution impact assessment model for Sweden

While regional climate change information at ~10-25km scale is highly useful in many sectors, there remains an urgent need to downscale this data to even higher spatial resolution for use in a range of localized impact assessment studies and to provide actionable climate change information to decision-makers. To generate such high-resolution information, that also samples the full range of uncertainty in regional climate change estimates, is a daunting task presently beyond the capabilities of any single country. In phase II we propose to develop an offline surface model that is able to both sample the full range of uncertainty in regional climate change estimates, while still allowing change estimates to be translated to the high spatial resolutions required for local climate change impact assessment and adaptation planning.

We will develop a very-high resolution (~1-2km) offline land surface-soil-hydrology-ecosystem-lake (LSHEL) model for spatially-detailed impact assessment studies over Scandinavia/Sweden. This model will be based on a number of advanced modelling components, already used and part-developed by us.

The core of the LSHEL system will be the SURFEX land surface-soil model. SURFEX is the land-surface/soil scheme run interactively as part of the HARMONIE regional climate model presently under development at SMHI. SURFEX can also be configured to run in stand-alone mode, forced either by observed, reanalysed or model simulated atmospheric variables. In particular, in Mistra-SWECIA, we will couple the LPJ-GUESS interactive vegetation model to SURFEX, along with the HYPE (a new surface hydrology model at SMHI) and Flake (a dynamic-thermodynamic lake model). Such a model can then be run for the recent observed past using; (i) observed and analysed atmospheric fields, (ii) reanalysis driven RCM output and (iii) GCM historical simulations downscaled by a range of RCMs. Such analysis will be used both to develop and evaluate the LSHEL system and with respect to (iii) as a method to evaluate the simulated control climates of the various GCM-RCM combinations.

The LSHEL system will then be driven with output from the future projection periods to develop high-resolution climate change impact assessments for Sweden that extensively sample the uncertainty space of future climate conditions. The basic driving data for the LSHEL model will be the Euro-CORDEX simulations made at ~10km resolution. LSHEL will be configured at a resolution of ~1-2km for all of Sweden, allowing high spatial detail in surface topography and land cover type to contribute to the land surface, vegetation, hydrology and lake responses to the driving atmospheric fields. As a result of only integrating the land-surface part of the climate system at high resolution, it will still be feasible to sample a large range of regional climate projections enabling probabilities of occurrence estimates to be assigned to each future climate response.

Very-High resolution local climate projections

As well as utilizing the LSHEL approach for making spatially detailed land-surface impact assessment studies, we also plan to make a number of multi-nested RCM integrations whereby the innermost nest of the GCM-RCM chain will simulate regional climate processes over Scandinavia at ~2-3km resolution. It is expected that such simulations will greatly increase the local fidelity of simulated climate and climate change, as well as contributing to an improved representation of key climate extremes, such as intense precipitation and wind events. Output from these simulations will also be used to drive the LSHEL model. Simulation results for the observed past will allow an evaluation of the benefits of using 2-3km simulated climate data instead of ~10km data for driving impact-assessment models. Output for future projection periods will be used to generate very high resolution impact assessments within the Phase II sectorial studies.

In the first stage of this effort, continuing the Phase I work, the HARMONIE RCM will be configured for Southern Sweden at a resolution of ~2.5km and integrated over the recent past (1979-2010) forced by (i) a single step downscaling directly using ERA-interim reanalysis and (ii) a double-nesting step, whereby ERA-interim drives a Europe-scale 10km RCM, the output of which is then used to drive the high resolution HARMONIE model. Evaluation of the simulated climate statistics and comparison of these runs to equivalent period, ERA-interim driven runs for Europe at ~10km resolution, will indicate the added-value of significantly increased spatial resolution local to the region of interest. Subsequent to this assessment a number of time slice future projections will be made using the double-nesting approach, sampling a suitable range of CMIP5 GCM boundary data. Output from these simulations will be used to develop very-high resolution climate change estimates for Southern Sweden, for comparison to the lower resolution results. This projection data will also be used to drive the LSHEL model. These LSHEL simulations feature management/economics embedded within the LPJ-GUESS and consequently will provide an analysis of sectorial climate impacts.

Impact modelling

By having close co-operation with representatives from stakeholders (Component III) we will extend our current development of predictive models and risk analysis to aid the development of climate change adaptation recommendations. We will use novel approaches for evaluating consequences of alternative management and policies, combining climate and ecosystem model data with agent-based modelling and integrated impact assessments.

The impact of climate change on forestry will be assessed in relation to multiple management goals and options, as defined by the stakeholders. This will include goals such as sustainable timber production, bioenergy, food (for opportunity costs), carbon sequestration as well as non-tangibles like environmental services and biodiversity. The goals and options will be related policy documents such as the environmental objectives (societal goals on nature conservation and ecosystem services), and the current international standards of forest certification (FSC and PEFC, agreed upon/signed by many forest companies and forest owners in Sweden).

Forest stand development, risk for damage, and key-factors affecting biodiversity will be simulated in an ecosystem model using climate model data as input. We will refine and adapt the risk analysis framework, developed in Phase I, for application to Swedish forestry in a wider spatial and sectorial context. Developments relative to method used in the Phase I forestry case study includes integrate non-economic values such as environmental services and biodiversity with economic valuation of production, damage and management costs. This will link to the development of ABM (Working Area 1) in terms of biogeophysical (ecosystem services, biodiversity indicators, damage risks) and economic (management costs, net margin) drivers, technical platform, etc.

A risk assessment framework will be applied to evaluate the development of categories of risks identified as important under coherent scenarios of change in climate, greenhouse gases, and socio-economics (including global land use, economics and world commodity prices), highlighting consequences of adaptation choices from local (land owner/forest manager) to national (environmental, resource management and energy policy) levels, factoring in the influence of uncertainty, e.g. propagating from differences among GCMs, on risks.

Plans for dissemination include possible workshop-style interactions between impact modellers and users were model simulations on the effects of management choices on risks and returns from forestry are discussed. The outcome of the project will link to interdisciplinary analysis of ecosystem services, socio-economic interactions and policy for sustainable forest management.

Dependencies

Working Area 1

Interaction with users at least partly integrated with adaptation studies in Working Area 1. Development of ABM method for mutual learning will require external collaboration and/or integration with other projects, e.g. EU-FP7 ECOCHANGE and Lund University's BECC.

The high-resolution regional climate model simulations provide input to the ABM development.

Working Areas 3-5

Global scenarios from these Working Areas (GCM scenarios, global prices/demand for timber, food, biofuels, ecosystem impact projections) will be input to the regional climate change and impact assessment.

Component III

Information from the stakeholder interaction, e.g. better specification of their research needs, knowledge questions and the need for climate input as decision support will be used to guide the analysis of climate scenario simulations.

The climate scenario data and tailored analyses will be provided to the stakeholder interaction process, including high-resolution scenarios, probabilistic estimates of future changes for variables of stakeholder interest and specific impact assessment.

External

Within the International CORDEX project, nine Regional Climate Modelling groups in Europe, including SMHI, will coordinate downscaling of CMIP5 GCM simulations to thoroughly sample different RCPs, GCM boundary data and RCM formulation to generate a large matrix of ~10km climate projections for Europe. Results will be centrally archived in a standardized format and be freely available. Access to the full matrix of results (beyond those from SMHI) therefore depends on coordination with other groups in CORDEX.

The number of 10km projections made by SMHI and the resolution and overall number of simulations depends on access to suitable computing resources.

Development will require preliminary GCM, RCM and ecosystem model projections, global and regional land use scenarios and economic valuation of forest products and management costs. Most of these are available 'off the shelf' from Phase I.

Resources and key personnel

Estimate of person months linked to each specific activity and indication of the distribution of work across these deliverables over the period 2012-2015

The mentioned Euro-CORDEX simulations with RCA4, as well as provision of Euro-CORDEX data will be in kind (funded external to Mistra-SWECIA).

Person-months linked to the Working Area 2

	2012	2013	2014	2015	Total
SMHI	18	24	18	15	75
LU	7	12	16	20	55

Key Personnel

SMHI: Grigory Nikulin, Erik Kjellström, Christer Jansson, Patrick Samuelsson, David Lindstedt, Marco Kuipianen.

Lund University: Fredrik Lagergren, Anna Maria Jönsson, Ben Smith, PhD student NN (sub-contractor Edinburgh).

6.3. Component II: Global drivers

6.3.1 Working Area 3: Climate-economy modelling

Central research questions

1. What are the global – aggregate as well as distributional, across regions – effects on the climate and the economy, with the welfare of different groups as a central outcome variable, of different policy paths, and how does this relate to climate change adaptation needs and opportunities on regional scale?
2. How do alternative global-scale adaptation mechanisms, such as a variety of markets and migration, influence the answer to the above question?
3. What is the importance of the global drivers of climate and economy outcomes for local/regional decision making viz. climate change adaptation?

Foreseen outcomes and other results

This research continues from the Phase I basic research based state-of-the art climate-economy model research and will reach out to the international academic community. There will also be substantial user value for Swedish stakeholders.

Specifically, we will;

- Produce consistent scenarios of economic and climate variables, including the regional distribution of GDP. These will be used as inputs in other parts of the project, for example in studies of land use. The fact that our models are based on explicit modelling of a decentralized economy also allows a “reverse engineering” analyses of which developments of GDP and other economic variables are consistent with a representative concentration pathway (RCP) or a specified path of CO_2 emissions.
- Have a continuous dialogue with policy makers. Co-operation with the Ministry of Finance in Sweden has already begun, and we expect intensification as well as a broadening of this cooperation over the project period. The output from the project will be important for forecasting as well as for policy analysis, e.g., for use in international negotiations on climate policy coordination.
- Produce “boundary conditions” for analysis of Swedish adaptation needs used in the dialogue with stakeholders in other parts of the project. Arguably, the largest impacts of climate change on Swedish stakeholders will come from secondary effects driven by how global warming affects the countries around us and the world economy as a whole. Global warming, as well as global policy measures and global technical change, will affect prices and flows of goods, capital, and people. To understand these effects and to prepare for adaptation, local stakeholders must gain a solid understanding of the underlying phenomena, both on a global, regional, and local scale.

Rationale

The purpose of the research is to finalize the construction of a new generation of integrated climate-economy models. The foundations for this were undertaken in Phase I. The new models will be built on state-of-the-art modelling in both climate and economic sciences. By adapting existing and developing new economic models we aim at a significant improvement over existing integrated assessment models by allowing very high regional resolution and an explicit treatment of uncertainty and technical change. Our leverage comes from the use of modern macroeconomic theory and recent advances in computational methods regarding how to solve economic models with a high degree of heterogeneity.

The new generation of models will be used to generate climate predictions and for the evaluation of policy as well as various adaptation channels. These predictions and evaluations will be made both on a global level and for specific regions. They will thus be used to give policymakers, domestically and on the international arena, as well as other stakeholders both a broad and, depending on the target, detailed understanding of the global and regional mechanisms that lie behind the changes in the climate.

During Phase II, more effort will be devoted to linking up with established international networks on climate and climate-economy modelling. Our point of departure in Phase II has been to use modern macroeconomic tools to build prototype global integrated assesment models. We strongly believe that this approach can provide an important complement to existing models of the climate-economy interaction. Our networking has so far been extensive with respect to the international macroeconomic community. Needed natural science input to the economic models have been drawn from project-internal sources. As our work progresses into Phase II, in particular when it comes to calibration of our disaggregated models, it becomes natural to broaden our outreach and build links to networks outside macroeconomics, like the Energy Modelling Forum (EMF), and the new Integrated Assessment Modeling Consortium (IAMC[15]). Our linkage to the international macroeconomic community will also strengthen. A cornerstone will be the international symposium on climate and economics in Stockholm September 2012.

Methods

Global single-region model

The purpose of this work project is to finish the construction of a global coupled model of the economy, the carbon system and the climate. The model will consist of one or only a few regions. A main reason for developing a model at this low degree of resolution is that it will be transparent and easily lend itself to use by policymakers and other stakeholders. The economic part contrasts in important ways to existing models, like Nordhaus's DICE and RICE models. First, it builds on explicit modelling of markets, rather than solving a central planning problem. This allows the analysis of the consequences of various assumptions on, e.g., policy and market structure, for the development of global GDP, CO_2 concentration and global temperature. Second, we build on recent developments in growth theory that allows an explicit treatment of uncertainty and directed technical change, e.g., in energy saving technology.

The carbon system includes a description of carbon in the terrestrial biosphere and the carbonate system in the ocean. In contrast to other coupled economy-climate models, we will capture non-linearities in the ocean carbon cycle system. The climate system will be based on a global few-variable system. A key issue is to draw on recent advances in the understanding

[15] http://iamconsortium.org/

of the climate sensitivity and the impact of aerosols on climate change and describe this in a simple system that can be coupled with the economy module.

Multi-region model

The overarching objective of this work project is to finalize a coupled model of the economy, the carbon system and the climate. As the single-region model, it builds on an explicit modelling of markets and forward looking agents. However, the economic model is quite different from any other global economic model in the sense that it consists of very large number of regions. It builds on methodologies originally developed by the project participants Per Krusell and Tony Smith for handling a large number of heterogeneous agents.

The carbon system and the global climate model will be the same as in the single-region model. To reach the same degree of resolution as the economic module, statistical methods (e.g., pattern scaling) will be used to create a regional distribution of climate outcomes.

Model development

The first task during Phase II is to improve the calibration of the models, in particular regarding climate damages and energy markets. Regarding damages, we have so far relied on the work by Nordhaus. The fact that we in Phase I have shown how to explicitly include uncertainty about damages and the climate sensitivity allows a more realistic calibration than what has been done previously.

The calibration of damages will draw on work in both natural and social sciences. Statistical analysis of high resolution global circulation models will be used to find a statistical representation of the relation between global state variables, in particular the global mean temperature, and key characteristics of the regional climate. When characterizing the mapping from regional climate to regional damages, we intend to use both a bottom up approach and a more reduced form macroeconomic approach. In the former, microeconomic impact studies undertaken both within and outside the project are aggregated. In the latter, we draw on studies relating regional macroeconomic developments, in particular economic growth, to historic variations in climate.

The second task is to integrate our previous work on technical change into the models. In phase I we worked two fronts. The first aimed at describing how energy efficiency in the aggregate responds to economic incentives. To quantify this relation is of key importance for providing policy advice. We constructed a measure of aggregate energy efficiency and demonstrated how it has responded strongly to economic incentives in the post-war period: the trend in aggregate energy efficiency is strongly affected by energy prices. We also show that when the growth rate of aggregate energy efficiency increases this comes at the cost of reductions in the growth rate of technical change saving on other production factors. Our results allow a quantitative assessment of this trade-off, which is entirely new to the literature.

The second technology front is pursed in a series of papers in Phase I, looking more in detail at the nature of technical change. Here, we have spelled out exactly under what conditions on technology and other model aspects the analysis will feature a "Green Paradox": that the more successful is the development of alternative, clean technology, the faster will the fossil fuel stocks be depleted, which in turn speeds up climate change. We have also examined how different kinds of policies must interact to produce a good outcome: to the extent policies inducing the development of clean technologies are adopted, taxation of (or quantity restriction on) fossil fuel becomes all the more urgent and higher taxes will be needed.

Dependencies

Working Area 1

The macroeconomic implications of climate change for forestry is a focal issue that offers an integrating theme. We aim to use our global modelling to provide input to the regional case studies within Sweden.

The idea is to model indirect effects of climate change related to world market prices, trade, migration and so forth. As our global modelling matures, we also hope to be able to include in the analysis variables more specifically related to Swedish forestry.

Working Area 3 provides input to the global framing of climate adaptation in Sweden.

Working Area 5

Input is provided to Working Area 5 in the form of socio-economic boundary conditions: land use drivers (e.g. global populations and demographics, global and regional climate, energy and agricultural policy, trade barriers) from climate-economy modelling (e.g. global and regional economic growth and GDP distribution at the resolution of the multi-region model).

Component III

Working Area 3 provides a global economic development framing for the interactive climate change adaptation considerations together with the stakeholders.

Resources and key personnel

Person-months linked to the Working Area 3:

	2012	2013	2014	2015	Total
IIES	16	16	16	16	64
MISU	25	16	10	2	53
LU	4				4

Key personnel

IIES: John Hassler, Per Krusell, Conny Olovsson, David Strömberg.

MISU: Jonas Nycander, PhD students: Anna Lewinschal, Jonas Claesson and Jenny Hedvall.

Lund University: PhD student Anders Ahlström.

6.3.2 Working Area 4: Global Climate Projections

This Working Area involves in-kind contributions to Mistra-SWECIA. It involves state-of-the-art global climate model projections that are produced in the international CMIP5 collaboration. The Mistra-SWECIA partners SMHI (Rossby Centre), MISU and Lund University are all contributors to the development and use of the EC-Earth global climate model now being used for CMIP5 integrations. Mistra-SWECIA, in its Phase I, contributed to the underlying scientific effort and networking on the EC-Earth development that has now resulted in a new global climate model and contributions to international science efforts.

In addition to specific EC-Earth global projections following the CMIP5 protocol, in CMIP5's decadal prediction and centennial simulation streams, SMHI facilitates access to the overall CMIP5 archive, thus providing state-of-the-art global climate scenarios for use in Mistra-SWECIA Components I and II (and thus subsequently III), as boundary conditions for regional climate scenarios and climate scenario information for the climate-economy modelling. The CMIP5 runs meet the criteria for credibility, transparency and comprehended usefulness of climate scenarios by means of their timely and well-documented nature, the scientific community driven set-up and the expected usefulness for scientific results that will underlie the IPCC's AR5. Related to these runs is of course the new set of climate forcing scenarios known as Representative Concentration Pathways (RCP, Moss et al. 2010).

Researchers internationally are currently discussing a framework and process for also developing a coherent set of new socioeconomic scenarios ("Shared Socioeconomic Pathways", SSP) to be used by the different scientific communities working on climate change impacts, adaptation and mitigation. It is intended that these scenarios should complement the RCPs that are the new standard used in climate modelling. As well as describing plausible world developments (e.g. of population, economy, technology and land use) that might result in the atmospheric concentrations of radiatively important gases described by the RCPs, the new scenarios will also explore other plausible futures, provide regional quantification of key variables and offer descriptive narratives of the future (storylines). In addition, the scenarios should offer a basis for ensuring consistency across studies assessed by the IPCC, as was discussed at an Expert Workshop in Berlin, November 2010.

Foreseen outcomes and other results

- Global climate projections that sample future socio-economic and land-use scenarios mentioned above.

Methods

The now on-going EC-Earth simulations extended over 1860-2100 using three standard RCPs (Representative Concentration Pathways) at a resolution of ~1° (~100 km). In addition to the "standard" centennial global climate projections, there will also be a large set of decadal prediction experiment simulations and, perhaps, also Earth System Model version of EC-Earth runs.

These runs are expected to be available for Mistra-SWECIA use starting from mid-2011.

For a number of time slice periods, also a high resolution atmosphere-only version of EC-Earth (~0.3° resolution) will be run with SSTs from the above-mentioned EC-Earth runs. These integrations aim at a more realistic representation of mid-latitude weather systems and associated extreme wind conditions, particularly the extreme tail of the wind-speed distribution over Northern Europe. Possible changes in extreme wind frequencies/intensities will be an important input to forest planning and risk assessment. These runs will likely go at T511 (atmosphere) and 0.5° (ocean). The main set (i) will concentrate on 30 year periods centred on the global mean temperature reaching 2°C above pre-industrial from a range of GCM/RCP combinations (so different time-horizons into the future when 2C is exceeded). A second set (ii) may concentrate on the 30 year period 2030-2050 or 2060, to coincide with the CMIP5 timeslice decade 2030-2040.

These runs are likely to be made in 2013-2014.

Dependencies

<u>Working Areas 1-2</u>

Provision of boundary conditions for regional climate model downscaling over Northern Europe. High-resolution global climate model runs for analysis of extreme winds and other stakeholder-identified key climate aspects, to compare and contrast with regional climate model results.

Working Area 3

Global climate data (present-day and future scenarios) for use in the calibration of and simulations with the climate-economy models.

Component III

Global climate change scenario framing for the interactive climate change adaptation considerations together with the stakeholders.

Resources and key personnel

Provided in kind by the SMHI/Rossby Centre.

6.3.3 Working Area 5: Land use narratives

Central research questions

1. How may interactions and feedbacks between climate, ecosystem services and economic activity be affected by alternative future trajectories of exogenous socio-economic factors such as population growth and demography, environmental and economic policy, trade flows and barriers and technological development?
2. What global and regional patterns in land use may emerge from these interactions, feedbacks and responses to drivers and do they constitute autonomous climate change adaptation?
3. How may alternative developments of land use and ecosystem services such as food production, forest productivity, water supply and biofuel production affect global commodity prices and markets, and how does this relate to climate change adaptation needs and opportunities?

Foreseen outcomes and other results

- Probabilistic or ensemble-based future scenarios of land use, ecosystem services, commodity prices, demand and trade flows. These factors constitute potentially important considerations for adaptation decision making in Sweden. They will provide a backdrop for the participatory methods for studying the adaptation process in Working Area 1 and provide input to the ABM that will provide one tool for exploring and visualising interactions among the individual and institutional actors involved in adaptation in the Swedish forestry sector.

Rationale

The biogeophysical and socio-economic components of the Earth system are linked via land use and ecosystem services for land; climate effects on ecosystem services such as food, timber and biofuel production affect the opportunity costs of alternative land uses and may lead to shifts between land use classes such as agriculture, forestry and energy plantations, as well as abandonment of marginal lands leading to regeneration of ‘natural’ ecosystems. Environmental policy decisions may also influence land use by setting aside land or imposing restrictions on management. The spatial configuration of land use and of the production of ecosystem services per unit land, globally and at a large regional (e.g. European) scale, has a fundamental influence on the supply side of global markets for land-based commodities (food, timber, pulp, energy crops), directly affecting world prices and trade.

A coherent description of biogeophysical and socio-economic world futures and their linkages via land use and ecosystem services is fundamental to defining the global drivers of decision-making and economic activity within a land-based sector such as forestry in an individual region or country, such as Sweden. There are two requirements to this: (1) description of exogenous factors that cannot be projected using available models; (2) modelling of system components responding to these factors. A coherent treatment of (1) and (2) will provide "narratives" describing potential future trajectories of a suite of global drivers of relevance to the regional and sectorial focus of Mistra-SWECIA Phase II.

Global or "large-region" socio-economic assumptions used as boundary conditions for global climate, carbon cycle and land use modelling are available from a number of sources. The best known of these are the four reference narratives of the Special Report on Emissions Scenarios (SRES) of the IPCC (Nakićenović et al. 2000). The A1B scenario, often regarded as a "balanced" or "mid-range" scenario that leads to an intermediate trajectory of future greenhouse gas emissions, was adopted as a baseline scenario in the Fourth Assessment Report (AR4) of the IPCC from 2007. A large ensemble of 21st century climate projections forced by A1B-based emissions is available from the CMIP3 intercomparison, the results of which were synthesised in IPCC-AR4.

A1B was designated the common scenario framework (CSF) of Mistra-SWECIA Phase I, and provided forcing/background assumptions/boundary conditions for RCM-downscaling scenarios, global and regional ecosystem model simulations and land use projections compiled in Phase I. These materials, which are readily available, will provide the basis for an initial set of narratives and scenarios in Phase II, allowing work on the regional adaptation and framing etc. to commence without delay.

Parallel to this initial work, a new set of narratives will be compiled. These will be

- more comprehensive (covering a wider range of plausible developments in exogenous drivers);
- compatible with the representative concentration pathways (RCPs) used to force GCM climate projections in the CMIP5 intercomparison that will form the basis for the next IPCC assessment report;
- more coherent (same assumptions used by different models);
- state-of-the-art, by making maximal use of the suite of models and assessment tools developed in SWECIA for the assessment of global climate-carbon cycle-economy interactions, ecosystem services and land use change.

The resultant narratives and the associated model projections will provide global drivers for regional adaptation and impact studies in Component I and should also be highly relevant for the user-driven research in Component III. The global climate projections used for this purpose will be mostly obtained from external sources (CMIP5) and will be forced by/compatible with the representative concentration pathways (RCPs, Moss et al. 2010) used for IPCC (see Section 6.3.2). The components of this new set of narratives will be:

- Global modelling of ecosystem services and carbon cycle.
- Global modelling of the coupled climate-carbon cycle-economy system.
- Global-scale scenarios of land use change in terms of the broad land use categories forest/natural, agriculture, biofuels.
- World prices and demand for land-based commodities such as food, forest products, woody and liquid biofuels consistent with land use scenarios, socio-economic narratives from and climate-economic modelling in Working Area 3.
- Parts of the work will form an integral part of the research in WA1 on adaptation to indirect effects of climate change. The results of the land use narratives work will help

answer the WA1 research questions regarding (1) the type and magnitude of possible indirect effects of climate change, and (2) the available approaches/methods/tools to understand and quantify such effects.

Methods

In the initial stages of the project, future projections of climate, ecosystem services and land use arising from the research in Phase I, or available from external sources (AR4, SRES), will be synthesised (report or dataset), providing an initial set of narratives for the regional adaptation and impact studies.

A refined set of narratives will employ the RCP-based narratives now being compiled[16] ahead of the Fifth Assessment Report of the IPCC with the aim to be uses in the regional adaptation and impact studies by the end of 2013.

Global projections of ecosystem services will be performed by the global version of the LPJ-GUESS ecosystem model, developed in Mistra-SWECIA Phase I. Forced by an ensemble of CMIP5 GCM-based climate projections and the associated RCP-based CO_2 concentration pathways, the model will simulate net primary production (NPP), crop yields, forest production and terrestrial ecosystem carbon balance (net ecosystem exchange, NEE). The resultant projections will provide as input to land use projections and climate-economy modelling.

Global projections of macro-economic factors such as GDP, its distribution among regions, and trade flows will be performed (Working Area 3) using the new multi-region integrated assessment model initiated in Mistra-SWECIA Phase I. This component will be contingent on the on-going development of this model, and will provide economic forcing of the global land use model projections.

Global land use patterns in response to developments in climate, ecosystem services and economic factors such as GDP growth and distribution will be generated by the parsimonious land-use model (PLUM) under a range of RCP-based narratives. The PLUM model is based on the established principles of land use change modelling described Ewert et al. (2005), Rounsevell et al. (2006) and Schroeter et al. (2005). The model takes account of changes in ecosystem services such as agricultural production, and these will be taken from the LPJ-GUESS model results based on the same narrative (see above). An ensemble approach, based on multiple GCMs and associated ecosystem model simulations, will encompass part of the uncertainty in future land use development. Additional uncertainty will be accommodated by performing multiple simulations with PLUM, resampling the parameter space of the model using a Monte Carlo approach (cf. Zaehle et al. 2005)

Dependencies

Working Area 1

Input to and provision of global narratives to research on the adaptation process as well as research on adaptation to indirect effects of climate change.

Working Area 3

Climate-economy modelling will provide quantification of the socio-economic narratives and global drivers of land use change (e.g. global populations and demographics, global and regional climate, energy and agricultural policy, trade barriers, global and regional economic

[16] http://www.iiasa.ac.at/web-apps/tnt/RcpDb/dsd?Action=htmlpage&page=welcome and http://www.iiasa.ac.at/Research/ENE/IAMC/rcp.html

growth, GDP distribution) consistent with common underlying assumptions, e.g. based on the RCP-based narratives of the IPCC.

Working Area 4

RCPs and socio-economic narratives from IPCC integrated assessment models; information from climate-economy modelling

Acquire GCM scenarios

Component III

Framing for the interactive climate change adaptation considerations together with the stakeholders.

Resources and key personnel

Person-months linked to the Working Area 6:

	2012	2013	2014	2015	Total
LU	11	15	15	9	50

Key personnel

Lund University: Ben Smith, Postdoc NN on global modelling and scenario analysis, Mark Rounsevell (University of Edinburgh, subcontractor to LU), Verena Rieser (Edinburgh), PhD student NN on agent-based modelling (Edinburgh).

6.4 Component III: Science-policy interface - partner-driven studies and synthesis

Component III introduces a somewhat new approach in Mistra-SWECIA. It is launched in Phase II in order to increase opportunities for reaching out to, and learning from, stakeholders. It will serve as one of the programme's most important interfaces between research activities and practitioners, policy makers and users of research results. It will draw on results from the work in the other two programme components, and offer a platform for interdisciplinary work.

Central challenge

One of the key insights from the user-oriented research in Phase I was that it is very difficult (and often impossible) to combine *research on* adaptation (i.e. the study of how adaptation takes place) with *support for* adaptation (i.e., sharing research results, providing knowledge support and engaging in dialogues). Roles tend to get mixed up and stakeholder expectations (on continued support and involvement in local processes) tend not to be fulfilled. One way to address this problem is to set specific programme resources aside that are not tied to a particular research agenda aiming at scientific publications, but that instead put the needs of the stakeholders up front, together with the need to create user value.

One of the best ways to provide such value to practitioners and decision-makers is by providing an enabling environment for engagement of policy communities as well as communities of practice (actors, sectors, organizations) in research. Such engagement and interactions between science, policy and practice offer a more demand driven, problem based and socially relevant approach than the one traditionally employed (cf. "dissemination of research results"). It stimulates interdisciplinary collaborations and cross fertilizations between various programme components, disciplines and stakeholders, and provides the ultimate venue for feedback to scientists.

Interdisciplinarity is a resource intensive endeavour, requiring investments beyond regular research budgets into coordination, logistics and interactions. However, if designed and run well, joint work at the science-practice-policy interface can solve specific questions that users and scientists identify together, and that would otherwise not sit comfortably in any of the other programme components. Such questions will, apart from providing scientific value, empower users and promote co-ordinated and well informed assessments and adaptation actions.

Foreseen outcomes

Tentatively, work in Component III will be organized around broader problems formulated by researcher and external partners in co-operation. The work carried out would be based on existing or new research results, with the prime aim of providing tangible value to the external partners (rather than publishing in intra-disciplinary scientific journals). It is envisioned that each problem will be illuminated by researchers from a variety of disciplines. Tangible outputs (like reports and seminars) will be paired with less tangible, but equally important, outcomes among the partners involved (increased capacity to respond to the adaptation challenge).

Towards the end of the second programme phase period, we envision the collaborative work developed within Component III to have matured to a point where it can form the basis for a transition to a more permanent platform for continuous interaction and exchange between the research community and Swedish decision makers and actors addressing climate change adaptation in the running of their organisations. Inspired by the success of the UK Climate

Impacts Programme (UKCIP), we define as a vision for work within Component III that we by the end of the second programme phase can present a concrete proposal for how a Swedish programme equivalent should be organised and run, together with a network of researchers and practitioners willing to contribute to its launch.

Setup

Initially, resources in Component III (part-time individuals at SEI, SMHI and Lund respectively) will be devoted to establishing a working group with external partners, building networks and exploring opportunities for mobilizing external resources. Once the working group is established it is envisioned that an increasing share of staff resources will be used to engaging in synthesis work.

Work in Component III will also draw on central programme resources, most notably the programme communicator, who we envision will spend a large part of his/her time directly involved in supporting and organising Component III activities.

Component III is in a sense a pilot study – an experiment in building lasting science-policy bridges that there are to our knowledge few examples of in Sweden to date . The Programme Board may make use of the strategic budget reserve to further develop this part of the programme as the work progresses and demonstrates success. An internal evaluation of the progress in Component III will be carried out half-way through the second programme phase.

An overall ambition of the work is that a substantive part of the work carried out in this component should be based on concrete partnerships and collaborations with partners outside the programme. In order to provide opportunities for larger partner-driven efforts (e.g. targeted applied research activities), the principle of cost and or effort (in kind) sharing between the interested stakeholders and the research programme will be explored.

The external partners that have so far agreed to take part in Component III are listed in Section 3. To date, none of these partners have made any commitments to support the programme financially. Lacking from the list of already committed partners are from forest owner associations and forestry industry companies. Efforts will be made to encourage their participation from the beginning of Phase II.

The commitment by external partners to participate in the working group will be secured by i) critically assessing and jointly agreeing on the Terms of Reference and workplan for the working group (thus ensuring that all partners see a direct value in participating), and by ii) asking partners to sign a simple MoU in which the partner agrees to allow the involved individual(s) to spend the required working time necessary to meaningfully participate in the work. The workplan will updated on a year-by-year basis and should clearly state the expected benefits for both participating scientists and stakeholder representatives, as well as the required contribution in (terms of staff time) required by the stakeholder representatives.

Potential areas of exploration during 2011 and beyond

The second half of 2011 will be used to further specify the scope and content of work. The key features of the 2012 work plan should be available at the time of the evaluation hearing in September 2011.

To date, initial discussions with stakeholders and other preparatory efforts have resulted in a gross list of problems that could be explored within Component III. For illustration purposes, a selection of these questions (as formulated by external stakeholders) is listed below. As we plan to carry over on-going work in the forestry sector from Phase I into the first years of the second programme phase, our stakeholders were asked to formulate questions related to forests. Over the course of the whole four-year second programme period we will expand the scope to cover also other land use (most importantly agriculture).

- “What is the future role of insurance solutions in farming and forestry under a changing climate? Does climate change present these sectors with new threats or opportunities that warrant new insurance approaches? How can these threats or opportunities be quantified, how are they perceived by the actors in the sector, and what constitute a relevant policy response?”
- “How to both enhance the forest production capacity and preserve biodiversity in a changing climate? Climate change may induce geographical changes in species distribution, affecting both rare species protected in conservation areas and common species highly important for the ecosystem services. It may thus become as urgent to preserve possibilities for species to disperse and evolve, as to conserve areas targeted for rare species.”
- “How will the relationship between protected areas and conventional forestry be affected by climate change? Present forest policy has parallel production and nature conservation ambitions. The biodiversity of forests is dependent on both the protected areas' size and nature conservation activities in the areas subject to conventional forestry. How will climate change affect these conditions? Today there is talk of a landscape approach to management. How robust is this approach if the climate changes? How to organize the dialogue between forestry and nature conservation?”
- “How are basic ecosystem services affected by climate change? It has been proposed that by 2013, all basic ecosystem services [in the forests] should be identified and threats to the ecosystems mapped. How is this ambition influenced by a changing climate?”
- “How are species requiring special management interventions affected by climate change? It has been proposed that by 2015, programs should be implemented to achieve favourable conservation conditions for endangered species and habitats that can not supported through conventional land and water use. There may be several species that depend on different agricultural landscape environments. How will the conditions for protecting and caring for these species change with a different climate? Who are the major players? How to organize the dialogue with them? What skills are needed?”

It should be emphasized that the list above is a mere collection of examples. The programme has to date made no commitments exactly as to which problems will be further explored in Component III. Such decisions will be made only once the working group with external partners has been firmly established.

Dependencies

All Working Areas 1-5 provide framing for the interactive climate change adaptation considerations viz. the stakeholders, the stakeholder communities and the sectors in focus (input in the form of climate, impact and economic scenarios, as well as risk assessment results).

All Working Areas 1-5 respond in terms of model and analysis development to the emerging information and decision support needs of the stakeholders. This will also be reflected in the programme’s synthesis efforts (Section 8).

Resources and key personnel

Person-months linked to the Working Area:

	2012	2013	2014	2015	Total
SEI	6	5	5	5	21
LU		6	6	6	18
SMHI	4	4	4	4	16

Key personnel

SEI: Benita Forsman, Oskar Wallgren, Åsa Gerger Swartling, Karin André.

Lund University: Ben Smith, Fredrik Lagergren, Anna Maria Jönsson, Postdoc NN.

SMHI: Lars Bärring, Anna Lilja

References

Acosta-Michlik, L. and Rounsevell, M. 2005, From generic indices to adaptive agents: Shifting foci in assessing vulnerability to the combined impacts of globalization and climate change. *IHDP Update 1/2005,* 14-16

Aligica, P. D. 2006. Institutional and Stakeholder Mapping: Frameworks for Policy Analysis and Institutional Change. *Public Organization Review 6:1,* 79-90

An, L., Linderman, M., Qi, J., Shortridge, A. and Liu, J., 2005. Exploring complexity in a human-environment system: an agent-based spatial model for multidisciplinary and multiscale integration. *Annals of the Association of American Geographers 95:1,* 54-79.

Barnett, J., 2003, Security and Climate Change. *Global Environmental Change 13,* 7-17.

Bennett, E. M., Carpenter, S. R., Zurek, M., Pingali, P., Peterson, G. D. and Cumming, G .C., 2003, Why global scenarios need ecology. *Frontiers in Ecology 1,* 322-329.

Bousquet, F. and Le Page, C., 2004, Multi-agent simulations and ecosystem management: a review. *Ecological Modelling 176,* 313-332.

Brown, O., Hammil, A. and McLeman, R., 2007, Climate change as the "new" security threat: implications for Africa. *International Affairs 83:6,* 1141-1154.

Burgess, P. J., Moffat, A. J. and Matthews, R. B., 2010, Assessing climate change causes, risks and opportunities in forestry. *Outlook on agriculture 39:4,* 263-268. Doi:10.5367/oa.2010.0012

Chapin, F. S., Danell, K., Elmqvist, T., Folke, C. and Fresco, N., 2007, Managing climate change impacts to enhance the resilience and sustainability of Fennoscandian forests. *Ambio 36,* 528-533.

Chirban, J. T. 1996. Interviewing in depth: the interactive-relational approach. Sage, Londo.n

Christensen, J. H., Carter, T. R., Rummukainen, M. and Amanatidis. G. 2007, Evaluating the performance and utility of regional climate models: the PRUDENCE project. *Climatic Change 81, Supplement 1,* 1-6, Doi:10.1007/s10584-006-9211-6

Costello, A. et al., 2009, Managing the health effects of climate change. *Lancet 373,* 1693-1733.

Crawford, T. W., Messina, J. P., Manson, S. M. and O'Sullivan, D., 2005, Complexity science, complex systems, and land-use research. *Environment and Planning B: Planning and Design 32,* 792-798.

Déqué, M., et al. ,2007, An intercomparison of regional climate simulations for Europe: assessing uncertainties in model projections. *Climatic Change 81, Supplement 1,* 53-70. Doi:10.1007/s10584-006-9228-x

Dessai, S. and Hulme, M., 2003, Does climate policy need probabilities. *Tyndall Centre Working Paper No. 34.* Tyndall Centre for Climate Change Research, UK, 42 pp.

EEA, 2010, *European Environment State and Outlook 2010 report. EEA,* Copenhagen, Denmark.

Ekvall, H. och Bostedt, G., 2009. Skogsskötselns ekonomi. *Skogsskötselserien nr 18,* Skogsstyrelsen (www.skogsstyrelsen.se/skogsskotselserien).

European Commission, 2009, *White Paper. Adapting to climate change: Towards a European framework for action,* Brussels, Belgium.

Ewert, F., Rounsevell, M., Reginster, I, Metzger, M. J. and Leemans, R., 2005, Future scenarios of European agricultural land use. I: Estimating changes in crop productivity. *Agriculture, Ecosystems and Environment 107:2-3,* 101-116.

Fankhauser, S., 2010, The costs of adaptation. *WIRE (Wiley Interdisciplinary Reviews: Climate Change)* Opinion 1, 1, 23-30.

Freer-Smith, P., 2007, Environmental change and the sustainability of European forests. *Journal of Sustainable Forestry 24,* 165-187.

Gaube, V., et al., 2009, Combining agent-based and stock-flow modeling approaches in a participative analysis of the integrated land system in Reichraming, Austria. *Landscape Ecol. 24,* 1149-1165.

Geijer, E., Bostedt, G. and Brännlund, R., 2011, Damned if you do, damned if you do not--Reduced Climate Impact vs. Sustainable Forests in Sweden. *Resource and Energy Economics 33,* 94-106.

Gomm, R., Hammersley, M. and Foster, P. 2000. In: Gomm R, Hammersley M and P Foster (eds.) Case study method: key issues, key texts. Sage, London. pp 98–115.

Gough, A. D., Innes, J. L. and Allen, S. D., 2008, Development of common indicators of sustainable forest management. *Ecological Indicators 8,* 425-430.

Hawkins, E. and Sutton, R., 2009, The potential to narrow uncertainty in regional climate predictions, *Bull Amer. Met. Soc. 90,* 1095. Doi: 10.1175/2009BAMS2607.1

Hickey, G. M., 2008, Evaluating sustainable forest management. *Ecological Indicators 8,* 109–114.

Janssen, M. A. and Ostrom, E., 2006, Empirically-Based, agent-based models. *Ecology and Society 11:2,* 37.

Jones-Walters, L., 2008, Biodiversity in multifunctional landscapes. *Journal for Nature Conservation 16,* 117-119.

Keskitalo, E. C. H. 2008. Vulnerability and adaptive capacity in forestry in northern Europe: a Swedish case study *Climatic Change 87,* 219–234.

Kjellström, E., Nikulin, G., Hansson, U., Strandberg, G. and Ullerstig, A., 2011, 21st century changes in the European climate: uncertainties derived from an ensemble of regional climate model simulations. *Tellus 63A:1,* 24-40. Doi:10.1111/j.1600-0870.2010.00475.x

Macy, M. W. and Willer, R., 2002, From factors to actors: computational sociology and agent-based modelling. *Annual Review of Sociology 28,* 143-66.

Marsden, P. V. and Wright, J. D. (eds) 2010. Handbook of survey research. Emerald Group Publishing, Bingley.

Matthews, R. B., Gilbert, N. G., Roach, A., Polhill, J. G. and Gotts, N. M., 2007, Agent-based land-use models: a review of applications. *Landscape Ecology 22:10,* 1447-1459.

McCracken, G. 1988. The long interview. Sage, London.

McKenzie Hedger, M., Connell, R. and Bramwell, P., 2006, Bridging the gap: empowering decision-making for adaptation through the UK Climate Impacts Programme. *Climate Policy* 6, 201-215.

Meehl, G. A. and Hibbard, K. A., 2007, A strategy for climate change stabilization experiments with AOGCMs and ESMs. *WCRP Informal Report No. 3/2007, ICPO Publication No. 112, IGBP Report No. 57,* World Climate Research Programme. Geneva, 35 pp.

Miles, M. B. and Huberman, A. M. 1994. Qualitative data analysis. Sage, London.

Mitchell, J. C. 1983. Case and situation analysis. *Sociological Review 31,* 187–211.

Mobjörk, M., Eriksson, M. and H. Carlsen, H., 2010, *On Connecting Climate Change with Security and Armed Conflict. Investigating knowledge from the scientific community.* Stockholm: FOI, Swedish Defence Research Agency.

Morgan, D.,1988, *Focus Groups as Qualitative Research.* Newbury Park, CA: Sage Publications.

Moss, R. H., Edmonds, J. A., Hibbard, K. A. et al., 2010, The next generation of scenarios for climate change research and assessment. *Nature 463,* 747-756.

Murray-Rust, D., et al.., in press. Conceptualising the analysis of socio-ecological systems through ecosystem services and agent based modelling. *Journal of Land Use Science 00,* 000-000

Nakićenović, N., et al., 2000, *Emission Scenarios.* A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, U. K., 599 pp.

Nationell plattform, 2010, Klimatanpassning i Sverige – en översikt. *MSB publikation nr 214.* 66 s.

Nikulin, G., Kjellström, E., Hansson, U., Strandberg, G. and Ullerstig, A., 2011, Evaluation and Future Projections of Temperature, Precipitation and Wind Extremes over Europe in an Ensemble of Regional Climate Simulations. *Tellus 63A:1,* Doi:10.1111/j.1600-0870.2010.00466.x

Nilsson, M. and Dalkman, H. 2001. Decision making and strategic environmental assessment. *Journal of Environmental Assessment Policy and Management 3:3,* 305–327.

Nilsson, M. et al. 2008 The use and non-use of policy appraisal tools in public policy making: An analysis of three European countries and the European Union. *Policy Sciences 41,* 335-355.

Nilsson, K. S. B., Nielsen, T. A. S. and Pauleit, S., 2009, Integrated European research on sustainable development and peri-urban land use relationships. *Urbanistica 138,* 106-110.

O'Brien, K., Sygna, L. and Haugen, J. E., 2004, Vulnerable or Resilient? A Multi-Scale Assessment of Climate Impacts and Vulnerability in Norway, *Climatic Change. 64:1-2,* 193-225.

Parker, D. C., Manson, S. M., Janssen, M. A., Hoffmann, M. J. and Deadman, P., 2003, Multi-Agent Systems for the Simulation of Land-Use and Land-Cover Change: A Review. *Annals of the Association of American Geographers 93:2,* 314-337.

Parry, M., et al. 2009, *The costs of adaptation to climate change. A critique of the UNFCCC and other global estimates.* Mimeo, Grantham Institute on Climate Change, Imperial College London, the U.K., 111 pp.

Powell, R. A. and Single, H. M., 1996, Focus Groups. *International Journal of Quality in Health Care 8:5,* 499-504.

Prop. 2008/09:162, En sammanhållen klimat- och energipolitik – klimat. Näringsdepartementet och Miljödepartementet. (Swedish Government Bill 2008/09:162). Stockholm, Sweden.

Rounsevell, M .D. A. and Arneth, A. (in press). Representing human behaviour and decisional processes in land system models as an integral component of the earth system. *Global Environmental Change*, 00-000-000

Rounsevell, M. D. A., et al., 2006, A coherent set of future land use change scenarios for Europe. *Agriculture, Ecosystems & Environment 114,* 57-68.

Rounsevell. M. D. A., Robinson, D. and Murray-Rust, D. (in review), From actors to agents in socio-ecological systems models. *Philo Trans Royal Soc B.*

Schmidhuber, J and Tubiello, F. N., 2007, Global food security under climate change. *Proceedings of the National Academy of Sciences 104:50,* 19,703-19,708. Doi:10.1073/pnas.0701976104

Schmidhuber, J. and Tubiello, F.N., 2007, Global food security under climate change. *Proc. Natl. Acad. Sci. 104*, 19703-19708. Doi:10.1073/pnas.0701976104

Schroter, D., et al., 2005, Ecosystem Service Supply and Human Vulnerability to Global Change in Europe. *Science 310*, 1333-1337.

SEPA (Swedish Environmental Protection Agency), 2007, Ekosystemansatsen – en väg mot bevarande och hållbart nyttjande av naturresurser. *Rapport 5782.*

Silverman D 2001. Interpreting qualitative data. Methods for analysing talk, text and interaction. Sage, London.

Skogsindustrierna, 2011, *Levande skogar – om Skogsindustriernas arbete för att bevara den biologiska mångfalden.* 60 s. [http://skogsindustrierna.org/web/Biologisk_mangfald.aspx]

SOU, 2007:60, *Sweden Facing Climate Change – threats and opportunities.* Final report from the Swedish Commission on Climate and Vulnerability. Swedish Government Official Reports 2007, Stockholm, Sweden.

Stake, R. E. 1995. The art of case study research. Sage, London.

Storbjörk, S., 2007, Governing Climate Adaptation in the Local Arena: Challenges of Risk Management and Planning in Sweden. *Local Environment 12:5*, 457-469.

Tasser, E., Sternbach, E. and Tappeiner, U., 2008, Biodiversity indicators for sustainability monitoring at municipality level: An example of implementation in an alpine region. *Ecological indicators 8,* 204-223.

The Swedish Forest Agency, 2008, *Statistical yearbook of forestry,* Skogsstyrelsen, Jönköping, Sweden.

Turner II, B. L., Lambin, E. F. and Reenberg, A., 2007, The emergence of land change science for global environmental change and sustainability. *Proceedings of the National Academy of Sciences 104:52,* 20,666-20,671.

UNFCCC, 2007, *Investment and financial flows to address climate change.* Bonn, Germany. UNFCCC Climate Change Secretariat, 272 pp.

UNFCCC, 2008, Investment and financial flows to address climate change: an update. *FCCC/TP/2008/7* (UNFCCC technical paper), 2008, 111 pp.

Valbuena, D., Verburg, P., Bregt, A. and Ligtenberg, A., 2009, An agent-based approach to model land-use change at a regional scale. *Landscape Ecology 25: 2,* 185-199. Doi:10.1007/s10980-009-9380-6

van Ittersum, M. K., et al., 2008, Integrated assessment of agricultural systems – A component-based framework for the European Union (SEAMLESS). *Agricultural Systems 96,* 150-165.

van Meijl, H., van Rheenen, T., Tabeau, A. and Eickhout, B., 2006, The impact of different policy environments on agricultural land use in Europe. *Agriculture, Ecosystems and Environment 114,* 21-38

Walsh, S. J. and Crews-Meyer, K.A., (eds.), 2002, *Linking People, Place, and Policy: A GIScience Approach.* Boston, MA, Kluwer Academic Publ.

Yin, R. K. 1993. Applications of case study research. Sage, London.