Mistra-SWECIA

Mistra-SWECIA is a multidisciplinary programme that develops research-based knowledge which is used to support decisions about adaptation to climate change.

The researchers involved in the programme study how the climate is changing, the effects of climate change and potential strategies for adaptation to climate change.

Mistra-SWECIA builds on expertise from several research areas, including climatology, ecosystem science, economics, sociology and political science, as well as close collaboration between decision-makers and others who are involved in the process of adaptation to climate change.

Climate change is a reality and it is important to analyse the effects these changes will have on the environment and on society, and investigate how we will be required to adapt our activities to the altered conditions. Mistra-SWECIA’s research focuses on land use and on the ways in which Swedish forests and forestry are affected by climate change and, more generally, how the effects of climate change are relevant to those involved in forestry, agriculture and nature conservation.

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SWECIA stands for Swedish Research Programme on Climate, Impacts and Adaptation. The programme involves SMHI (The Swedish Meteorological and Hydrological Institute), SEI (Stockholm Environment Institute), Lund University and Stockholm University. It started in 2008 and finished in 2015. SMHI is the programme host.
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A WORD FROM THE PROGRAMME DIRECTOR:

Information converted to ownership of knowledge

Little did I know in 2007 what the next eight years would bring. Back then we were writing the application to Mistra for what was to become Mistra-SWECIA. We were a handful of people with different scientific backgrounds who were familiar with different research methods. Some of us had collaborated before, some had not. In effect, we were an experiment in our own right. But, we saw the potential of engaging in new research, unlocking new collaborations and hopefully also making a difference to how well Sweden was equipped to face the challenge of adaptation to climate change. In our part of the world, this means a number of things, not least dealing with climate impacts on water resources and forests. In 2007, more research had been done on water than on forests. This motivated us to start with both of these at the beginning of the programme and, after developing new research work methods, to focus on the forest case.

The world has evolved over eight years. Awareness of climate change has tangibly increased alongside both the changes around us and our responses to them. For better and for worse, the door is now far more open to recognising the pertinence of adaptation to climate change. Municipalities, cities, forestry industries and forest owners are acting with increasing support from research, expert authorities, regional governments, the national government, and many others.

Science-based information, tailored for and targeting users, is fundamental. But not enough. Information needs to be converted to ownership of knowledge in order to be effective. We have explored these dimensions, and they are described in the articles in this eighth, and last, Annual Report from Mistra-SWECIA.

It has been a good eight years. My sincere thanks not only to all those who made the programme happen, researchers and users alike, but also to those who will make use of it during the years to come.

MARKKU RUMMUKAINEN
PROGRAMME DIRECTOR Mistra-SWECIA
A WORD FROM THE CHAIR OF THE PROGRAMME BOARD:

Multidisciplinary collaboration is essential

Thank you! I have had the privilege of being the Chair of the Mistra-SWECIA Programme Board for the eight years the programme has been running.

In the first phase, we studied various models for examining how the climate would change and for investigating which strategies were necessary for climate adaptation. Climate adaptation is a complicated process that impacts on many different fields of research. Therefore, an interdisciplinary approach was needed with a bank of experts from separate research fields. However, the different fields of research have their own methodologies and work processes, which can complicate any collaboration. Once these differences had been overcome, the multidisciplinary collaboration drove the research forward.

In the Programme’s second phase, the Swedish forestry industry was selected not only as a case study for the climate adaptation work, but also to test multidisciplinary collaboration work methods in practice. This involved close cooperation between researchers, forest owners, and other stakeholders in the forestry industry. The studies on how knowledge is disseminated between forest owners provides invaluable information on how knowledge and education can be powerful tools for promoting adaptation to climate changes.

In summary, there are a few learning points that I would like to highlight in particular.

Firstly, the importance of multidisciplinary collaboration cannot be over-emphasized. This is absolutely essential if we are to find solutions to complex problems.

Secondly, the importance of continuous collaboration between researchers and users. This is extremely important for the work with climate adaptation processes.

Many people, researchers, communicators and all types of users have been involved over the past years and have contributed to making Mistra-SWECIA a successful programme. I would like to thank you all for the work you have done and the results you have achieved.

Last but not least, I would like to thank Mistra for an excellent collaboration.

BENGT HOLGERSSON
CHAIRMAN OF THE BOARD,
Mistra-SWECIA
Eight years is a long time, and yet only a passing moment in long-term knowledge development, be it about science, societal development or a collaborative effort between these two fields. It is significant that these processes are dynamic, and developments in one area will have ripples that affect developments elsewhere.

A tale of one programme

A scientific finding can lead to societal attention. A public or policy development can highlight new knowledge needs. And so on.

We have experienced both steady development and deepening of knowledge fields during the eight years of the Mistra-SWECIA programme. When we started out, climate adaptation was still basically absent from the agendas in Sweden, and the more specific scientific support for adaptation to climate change was on many counts not available. However, the government’s Commission on Climate and Vulnerability had just handed in its report in which a number of challenges, possibilities and knowledge needs were outlined, together with suggestions for various actions. This was our backdrop.

It was clear from the onset that there was a need to advance research for adaptation to climate change as well as research on adaptation to climate change. In our plans, the former meant research on climate models and scenarios, climate impacts and economic aspects of climate change. These are linked, and we foresaw the possibility to explore these linkages in addition to deepening the knowledge on each area. Research on adaptation meant looking into societal actors and their processes for dealing with information, other actors and decisions. Also here we sensed an exciting opportunity to build on several research disciplines, combining social sciences, climate modelling and climate impact studies.

The early years of the programme were, to some extent, a learning period. Mistra-SWECIA brought together new teams from different backgrounds. For everyone, this meant exposure to new research traditions and methods, terms and vocabulary, and so on. Over time, two attractors of interdisciplinary research developed.

**Climate, impacts and adaptation**

Climate adaptation concerns a number of actors. Science can inform on climate change, its impacts and available response options, as well as pertinent uncertainties that can also play a part when decisions are taken. Research results are of course not necessarily in themselves enough to trigger action, and neither are they always available nor easy for users to take on board. During the first phase of the programme, a research effort was developed to bring together climate modellers, climate impact researchers and social scientists, in joint interaction with forest owners (see page 21 in this Annual Report). This method was further fine-tuned and implemented during the second phase of the programme.

The collaboration was instrumental in a series of focus group meetings in which scientists presented both climate change outlooks for the specific region where the meeting was held, and research on relevant climate change impacts. This was followed by discussions and exchanges facilitated by social scientists studying the forest owners’ processes and interaction. Knowledge travelled in both directions. The forest owners’ experience, other knowledge and voiced needs of information were proven to be useful when considering model development and analysis. The focus
groups were supplemented by workshops, and some of the findings were put into further perspective by questionnaires, development of tools and other spinoffs inspired by the users’ views.

During these exercises, mutual understanding of each other's disciplines could be seen to increase among the participating researchers with a growing shared vocabulary and the emergence of joint writing activities. At the end of the programme, as Mistra-SWECIA as a programme was starting to wind down, the researchers thus involved had also laid plans for continued interdisciplinary research, and were building further on the work laid down since the start of Mistra-SWECIA.

**Climate, carbon and economy**

The second area of new collaboration that developed strongly during the programme was climate-economy modelling. This involved modelling developed by economists and scientists together. In a sense this was an adventure; internationally, macroeconomics and climate science had barely developed models together. Having a macroeconomics perspective as a starting point meant that the work could bring a new take on modelling climate-economy compared to the Integrated Assessment Models (IAM) that existed at the beginning of Mistra-SWECIA. The ultimate goal was seen as an interactive model system that would fill some of the gaps in the state-of-the-art modelling approaches. Whereas the latter often provide the socio-economic change and emission scenarios, the climate change response, and the economic and cultural responses of human beings to climate change as separate steps, the new model would enable better highlighting of their connections. For example, an expectation of a certain climate impact can prompt an early response, which subsequently affects the unfolding of the future.

So-called dynamic stochastic general equilibrium (DSGE) models are familiar to macroeconomists. A unique characteristic compared with the other types of models included in the programme is that they take into account the forward-looking behaviour of economic agents, expectations about the future influencing today's consumption, investment, and energy use. For example, growing expectations of future climate impacts could lead to the introduction of measures to curb emissions, such as taxes. Expectation of taxes to be introduced can affect investors' behaviour. Climate models are used to compute future trajectories based on alternative fixed assumptions of greenhouse gas emission and land use change pathways. This makes the modelling approaches quite different. The economic models can only contain a handful of dynamic vari-
ables; their climate representation can be made nowhere near as complex as is the case for full climate models.

Mistra-SWECIA’s climate-economy modelling evolved along two connected pathways; a one-region global model, and a multi-region global model (see page 30). The latter has the attractive potential of accounting for regional differences in climate impacts, societal responses and economic development. The contribution from the natural sciences was both a better description of the climate, and of the dynamic terrestrial and marine carbon cycle components for both pathways. The second pathway proved more difficult to navigate than we had hoped, but the goal was reached by the end of the programme, with the uniquely high-resolution climate-economy model starting to crunch numbers. The vision of a high-resolution global integrated climate-economy-carbon-cycle-land use model is now well on this side of the horizon.

**Interdisciplinarity?**

Was interdisciplinarity a realistic goal for us? What is meant by interdisciplinarity varies. For us it meant cooperation, dialogue and hands-on working together among researchers who use different (disciplinary) methods to approach the same major questions about our changing world, and our responses to it. Each discipline’s methods require many years of university studies to master, and the challenge is equally tangible when coming together, learning from and teaching each other, and together creating new knowledge. The essential basis for this consisted of strong disciplinary expertise and willingness for exploration beyond the comfort zone of one’s own area of expertise. In Mistra-SWECIA, both senior scientists and PhD students engaged in the two attractors described in brief above. And the results were the better for it.

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**FURTHER READING**


The traditional model of research communication tends to be heavily reliant on one-directional processes from researchers to practitioners. Analyses have shown that this is often not very successful. Mistra-SWECIA therefore focused on improved communication and exchange of knowledge with stakeholders.

**Bridging the gap: problem-driven science-stakeholder dialogue**

Development of knowledge for the “real world” is a complicated process and one that is rarely given sufficient attention in research projects and programmes. Stakeholders are consulted when a research project is planned, and they may attend the final event after the research is concluded. In between these two milestones, research communication tends to be heavily reliant on one-directional processes from researchers to practitioners, through for example publications of popularised versions of research results. This fails to make use of stakeholders’ knowledge and tends not to be very effective.

Realising the shortcomings of the “traditional” approach, in phase II of Mistra-SWECIA, communication and cooperation between researchers and stakeholders was strengthened by continuous collaboration throughout the actual research process. Substantial resources were dedicated to this approach.

Basically, the idea was to link research on adaptation with knowledge for adaptation. It was deemed best to use a flexible approach with a work plan that was developed gradually, and jointly, by researchers and stakeholders as the time passed.

**Shared value resulting from continuous interaction**

In order to facilitate continuous cooperation between researchers and stakeholders, a working group was set up with Mistra-SWECIA researchers on the one hand, and practitioners within forestry and/or adaptation on the other. The latter represented industry, forest owner organisations and authorities at the national and regional level.

Within this framework, researchers and practitioners met repeatedly and discussed issues related to implementation of adaptation research based on Mistra-SWECIA’s findings. This facilitated a smoother flow of information than is generally the case. The interaction also involved identifying joint interests, which were followed up with events in the form of a workshop, a round table talk, and two forest excursions for more in-depth participatory discussions among a larger set of stakeholders and researchers from outside the working group.

Topics in focus included the need for science-based decision support systems for adaptation practitioners; how to manage natural reserves and support biodi-
versity in a changing climate; and how to develop risk management strategies for forest owners in the light of the new set of uncertainties brought about by climate change. In addition to these events, a synthesis study was also carried out in which Mistra-SWECIA research on climate change adaptation strategies was applied to the forest management guidelines of Holmen Skog, a large industrial forest owner in Sweden.

**Flexibility and responsiveness**

Flexibility was a key factor in facilitating this type of problem-driven work. It made it possible to respond to on-going events and to adjust the agenda as needed. For example, the final event carried out within this framework was a two-day forest excursion in 2015 to an area devastated by the large forest fire of 2014. This event was obviously not on any set agenda before the fire actually happened and, in fact, the risk of forest fires had rarely been up for discussion in the working group despite the fact that climate change is expected to increase fire risk. The fire made it very clear that there was a relevant topic that had been somewhat neglected beforehand and demanded increased attention.

The excursion, against the very real and touching backdrop of forest fires, considered risks pertaining to climate change in general.

**A novel approach, a pioneering approach?**

This form of engaging both researchers and stakeholders was novel to adaptation research in Sweden and as such also somewhat experimental in nature. But it proved quite fruitful and contributed both to the researchers’ and stakeholders’ insights and efforts. The continuous contact enabled not only the utilisation of researcher expertise in dealing with practical issues; there was also unexpected added value in the form of new research ideas that came up as a result of the discussions. In several cases, actual events also facilitated chance meetings between programme researchers and stakeholders in addition to those represented in the working group, which led to partnerships that greatly benefited the programme’s research.

During 2016, a thorough evaluation of the researcher-stakeholder work in Mistra-SWECIA will be made. We expect the results to be important in the further development of methods to bridge the gaps between the high halls of science and the boots in the forest. □
“With so many diverse actors gathered together, the Swedish Forestry Association saw an invaluable opportunity for constructive discussion of the very important issue of climate adaptation. Of course, there are differences of opinion, but one of the goals was to start discussions and to get the participants to take these questions back for further discussion within their organisations.”

Gunilla Lidén, the Swedish Forestry Association. In 2015, the autumn excursion was organised by the Swedish Forestry Association in collaboration with Mistra-SWECIA. For 113 years, the Association has organised autumn excursions, the purpose of which has been to gather together actors in the forestry sector for debate and discussion around current forestry issues.

“Evaluation of the guidelines has given me an insight into how far advanced our forestry is with regard to climate adaptation. The review has also contributed to us taking a stance at Holmen; we show what we think and are far from without answers to climate issues. The review was a useful exercise in how we should react, and the topic has been developed in our new publication Konsten att odla skog [The Art of Growing Forests]”

Erik Normark, Head of Research and Development, Holmen Skog
Adaption measures are needed together with mitigation. When it comes to climate adaptation in forestry, it is important to find robust strategies that will work for a range of future scenarios and which will generate opportunities to achieve multiple goals.

Forest management and adaptation in a changing climate

Measures to mitigate the ongoing climate change include both reduced emissions of carbon dioxide and other greenhouse gases, and increased carbon sequestration. While most sectors can contribute by reduced emissions only, forestry can do both. Tree photosynthesis and growth are intimately linked to uptake of carbon dioxide, and a substitution effect can be achieved by using forestry products instead of fossil-based products. However, global emissions have so far continued to increase and emissions that have already occurred will continue to influence the climate during the coming decades and beyond. This has led to an increased recognition that also adaptation measures, that reduce the negative impacts of climate change and take advantage of potential positive effects, are needed.

A warmer climate can lead to a longer growing season and thereby increased forest production in Scandinavia. However, climate change will also influence the frequency and magnitude of temperature and precipitation extremes. These are closely linked to the risk of drought stress, forest fires and attacks by pests and pathogens. The risk of storm damage could increase, even though the number of storm events in Scandinavia may not. This is because the tree root anchorage capacity becomes lower at higher soil water content and unfrozen soil conditions. The major risk factors vary from region to region. The forests of northern and central Europe are relatively sensitive to storm damage and subsequent spruce bark beetle attacks, whereas southern Europe is more prone to drought stress and forest fires. A further example is from North America which has recently experienced major outbreaks of the mountain pine beetle, an insect that is recognized to be more aggressive than the European spruce bark beetle. In general, experiences of climate-related damage serve as alarm bells. In Sweden, the discussions on how to reduce the future risk of forest damage were intensified after the two storm events in 2005 and 2007, which caused damage to 75 and 12 million cubic metres of forest, respectively, and the large forest fire in 2014 which spread over an area of 14 000 ha.

Quantitative assessments of climate change impacts can support climate adaptation. A few years ago, most assessments were based on annual or monthly averages. In Mistra-SWECIA, we have worked with ecosystem modelling combined with climate model data at a daily resolution to quantify the potential
effect of climate change on tree growth; the risk of spring frost events caused by cold spells after a period with mild climate; and the risk of storm damage and subsequent attacks by spruce bark beetles. Forest management and risk assessment modules were developed in the ecosystem model LPJ-GUESS, and model runs representing different management strategies were carried out to assess the adaptation potential. Forest management strategies influence landscape properties in terms of tree species and age distribution, which in turn influences the ecosystem services and biodiversity, as well as the predisposition to storm damage and bark beetle attacks. Spruce bark beetle attacks on living trees usually start after years with ample availability of storm-felled Norway spruce trees. A warmer climate in Sweden could lead to an increased number of years with two generations of spruce bark beetles, which will create a faster population build-up and thereby an increased risk of tree killing. Salvage and sanitary cutting, reducing the availability of brood trees and insects, respectively, are important countermeasures.

Forestry has traditionally been associated with wood production, although the focus has shifted in recent decades towards multi-use forestry. The concept of sustainable forest management, a foundation for international forestry certification programmes, emphasises that forest management should promote environmental, economic and social sustainability. However, taking more factors and longer-term perspectives into account adds to the complexity of decision-making, in particular as the information on future climate-change covers a range of scenarios. As one of our stakeholders expressed it: “Without clear and straightforward answers from scientists it is easy to neglect problems or to rationalize them by saying that, from a global perspective, the problems are very small”. One aspect of this is that the wide range of future scenarios and climate model datasets also makes the assessments of climate change impacts a complex task. Most studies have so far used only a limited number
Figure 1. Climate adaptation checklist. The upper row includes aspects that influence the forest stand and ecosystem in a longer (decadal) time perspective. The lower row lists forest management actions that are influenced by weather conditions before, during and after the management operation on the short-term time scale (days to weeks). Climate change will influence the probability of specific weather situations, which in turn will influence the risk of attacks by pests and pathogens as well as weather-related abiotic damage.
of scenarios and datasets, and the representativeness of the results is often not clear. It can therefore be difficult to compare results from different studies. To address this issue, a statistical tool for selecting climate model data for impact studies was developed in Mistra-SWECIA. The tool helps to explore the overall variation in ensembles of climate model data, and to find representative sub-sets of data when analysing study-specific questions (see also page 19).

Ultimately, climate adaptation boils down to finding robust strategies that will work over a range of future scenarios and provide the opportunity to achieve multiple goals. We therefore developed an adaptation checklist (Figure 1), together with a framework for discussing risks and opportunities in terms of combined active, reactive and proactive management strategies. Discussions on adaptation commonly focus on the long-term decisions, for example tree species selection at regeneration which will influence the forest for at least one rotation period (60-120 years). In terms of biodiversity and ecosystem services, the effect may be even longer. We also have “short-term” decisions on the checklist, to highlight the importance of considering when and how a management operation can be carried out. The weather conditions just before, during, or after a forest management operation can influence the outcome, for example drought stress to newly planted seedlings; driving damage to the forest soil caused by heavy machines; and the risk of forest fires that are started by management operations such as harvesting and soil scarification. The timings for planting and harvesting vary between years, regions and local conditions. Climate change may induce long-term trends, for instance towards earlier planting in spring or later planting in autumn.

The forest management and risk assessment modules developed in Mistra-SWECIA can be applied to provide process-based understanding of the forest landscape development over time, for example to address sector specific questions on what kind of incentives, information and decision support that is needed to promote climate change adaptation. Ongoing research focuses on multi-use forestry including economic aspects, biodiversity, and long term effects of changes in climate and land use. This includes analysis of economic consequences of risk-taking, for example that storm damage is less common in a young forest but the economic consequences are proportionally higher than in a mature forest. Weather forecasts are commonly used for planning purposes within the forestry sector. Seasonal forecasts, currently under development and evaluation, may in the future provide an additional tool for operational planning and prioritising for forest stands.

PLANTVAL:
Plantval is a tool developed by Skogforsk [The Forestry Research Institute of Sweden] to optimise forest regeneration material. It is widely used among forest actors in Sweden when choosing which seedlings to plant in their forest. It was originally based on current climate information. In a collaboration between Mistra-SWECIA and Skogforsk, the tool has been supplemented with climate scenario data based on state-of-the-art regional climate scenarios. This will contribute to more robust decisions on forests planted today and in the future to meet new climate conditions. (See [in Swedish]: www.skogforsk.se).

FURTHER READING:
Jönsson A M, Lagergren F and Smith b, 2015, Forest management facing climate change – an ecosystem model analysis of adaptation strategies, Mitigation and Adaptation Strategies for Global Change, 20, 201-220
A number of related articles in preparation can be found under Publications, Forthcoming.
The autumn excursion in Västmanland 2015 was an important activity in the dialogue between Mistra-SWECIA researchers, other experts and actors in the forestry sector.

Meeting in the forest on forestry in a changing climate

In the middle of September, Mistra-SWECIA organised an excursion ”Forestry in a changing climate” together with the Swedish Forestry Association. The focus was the vulnerability of forests and society. Around 130 people gathered around a great number of issues during intensive presentations, question and answer sessions, and spontaneous meetings. Field hosts were Sveaskog and Mellanskog, a forest owners association.

The first day was spent just west of Västerfärnebo, on the periphery of the area that was devastated by the major forest fire in Västmanland about a year earlier.

"The forest fire itself was a shocking event, but it was also a reminder to the forestry sector and society in general that we are vulnerable to climate change. This is about conditions for the future and subsequent changes in the risks associated with weather-related extreme events”, commented Markku Rummukainen, Mistra-SWECIA.

He showed how the climate will change in the future. The most positive scenario is a global increase that stops at 2 degrees, rather than warming that is significantly higher and continuously increasing.

Changes in society and various visions of the Swedish forests were also looked at in detail, together with in-depth presentations relating to the actual fire. One forest owner related his own experiences from the fire, and Karin Perers, Mellanskog, praised all the associations and organisations who assumed responsibility for people during the fire.

Gregor Vulturius, Mistra-SWECIA, described the results of a survey among forest owners which revealed that many forest owners are quite sceptical to climate change. He emphasised the importance of having objective dialogues on climate change and adaptation.

"I would encourage all forest owners and advisors to talk to each other. It helps.”

Insurance issues were also discussed, including the insurance process for the individual in a natural catastrophe, and how the insurance companies view climate change.

In the politician’s debate, at which the majority of the national parties were represented, the roles and responsibilities of the state and land owners in future catastrophes were discussed from various perspectives.

On the second day, the excursion went to Färna Ekopark. The topic was to what extent there are risks and opportunities that we are still underestimating. A tornado passed through this area eight years ago, and in its wake the spruce bark beetle has increased dramatically killing hundreds of trees. Åke Lindelöw from the Swedish University of Agricultural Sciences (SLU) reviewed several possible scenarios and concluded that insect damage to forests will probably not increase in Sweden.
Several risks associated with climate change and how we can capitalise on the value of the forests’ various ecosystem services were also discussed, as well as how owners can approach climate-related risks in forestry. Fredrik Lagergren, Mistra-SWECIA, took as an example that there are now more species of woodpeckers after the tornado and the spruce bark beetle attack in the Ecopark.

"The risk to one goal is an opportunity for another goal in forestry", he stated.

The audience also considered the risks posed by, and concrete tools for dealing with, driving damage, and for creating a robust forest ecosystem when the climate changes. One land owner saw falling lumber prices as a threat. Another participant drew attention to people’s natural lack of ability to predict the future.

"Our imagination is so limited. We know the risks but find it difficult to imagine the scenarios in front of us. Often something needs to happen before we start planning for that specific danger."

Ten challenges for the future
The excursion, including the concluding panel debate, crystallised the challenges and opportunities that affect forestry at the local and more overarching level; risk management for the individual and society; as well as the role of the forest in the future of society:

- Spread the risk by using a variety of methodologies.
- Raise your vision from the stand to the landscape to meet risks and to take advantage of opportunities.
- Harmonise the goals; create goal visions on common ground.
- Prevent risks and prepare for a variety of events that could still occur.
- Invest in the green gold through a price on carbon dioxide emissions which will make biobased products more profitable.
- The role of the forest in the future climate is an opportunity; the forest is a key to a biobased economy.
- Knowledge on climate change, the effects and the strategies for meeting these must be effectively disseminated in the forestry sector.
- A knowledgeable and mature forestry industry will be resistant in many ways. At the same time, increased collaboration is needed to manage various situations.
- The economic responsibility must be more clearly defined. Where is the boundary between the responsibility of the state and that of the individual?
- Planning for the unknown.

(Compiled by Mistra-SWECIA)
To meet the demand for information on climate extremes in the future, researchers are working to develop climate model systems with increasingly finer detail. A few projects in this area both benefit from, and contribute to, model development. This has been the case in Mistra-SWECIA.

**Regional climate modelling at increasingly high resolution**

Knowledge on future climate extremes is increasingly important for understanding climate impacts and for meeting these by adaptation to climate change. To meet this demand for information, the climate modelling community is working towards more fine detail in climate modelling systems, related to both time (minutes) and space (1-3 km resolution). This is highly computer-resource demanding and also requires advanced model development and evaluation efforts. Currently, only a limited number of institutes can invest serious research efforts in this area, among them the Rossby Centre at SMHI. This work has been a part of Mistra-SWECIA, specifically the development of the high-resolution RCM (Regional Climate Model) called HARMONIE-Climate (HCLIM). The development of HCLIM has been undertaken in close collaboration with the European NWP (Numerical Weather Prediction) community on which HARMONIE is based.

Climate model development is a long-term commitment. The RCM development by Rossby Centre was initiated in 1997 and resulted in the RCM named RCA (the Rossby Centre Regional Climate Model). Prior to 2011, five versions of RCA were released and applied in downscaling of regional climate change scenarios. At the start of Mistra-SWECIA, the European RCM community was approaching the end of a project in which for the first time RCM-based climate scenarios featured continuous simulations covering a time span of 150 years, and thus described climate pathways with time spans appropriate to forestry. Now, eight years later, the most recent version of RCA (RCA4) has been used to produce well over 100 scenarios, all spanning 150 years. The large number of scenarios is important, because this is the only well-established way to quantify the climate scenario uncertainty arising from different climate models and different greenhouse gas emission scenarios.

The general recommendation to users of climate scenarios is that as many scenarios as possible should be utilised in order to obtain a useful representation of the uncertainty. However, the use of all available scenarios is seldom possible. The question of how to optimally select a subset of scenarios for these studies is a challenge for the community. This question has been resolved in Mistra-SWECIA by both climate and impact modellers, and has resulted in the so-called “ensemble reduction method”. This allows an optimal subset of scenarios to be objectively selected, taking into account the requirements of the specific study in question.

Early on, the Mistra-SWECIA programme identified a need by the climate adaptation community for better information on how extreme events could change in frequency and intensity, as the global climate warms up. Society is vulnerable to a range of extreme events, not least to heavy precipitation. The ability to simulate extreme events is strongly related to the horizontal resolution of climate models. In 2011, Mistra-SWECIA supported the initiative to develop
and apply HCLIM, which has a high enough resolution to address these extreme events. Now, four years later, the first official version of HCLIM has been released within the HARMONIE network, combining lessons from both NWP and climate models. Figure 1 illustrates the ability of HCLIM to simulate precipitation over Switzerland as a function of the horizontal resolution applied. Switzerland was chosen because it offers a demanding terrain for the model together with the ready availability of dense and high-quality precipitation observations. It is clear that simulated precipitation corresponds better with observations as resolution is increased.

The main difference between NWP, which addresses time scales of some days, and pure climate applications, is that certain physical processes with long time scales, such as the ocean, need to be considered in the latter while they can be omitted in NWP applications. Although extremes can be short events, they still depend on the slow climate processes. Such processes are for example deep soil conditions, lake processes and snow conditions. Thus, most of the research in the development of HCLIM has been devoted to these processes, as well as to technical issues to process the large amounts of data generated in high-resolution models. HCLIM now consists of a multi-layer soil scheme with respect to thermal energy, water and ice. A multi-layer snow scheme is applied and a physical lake model is activated. Overall, HARMONIE constitutes a complex and flexible system that includes model options for different scales of resolution and processes.

Climate model development is a long-term activity. The models are gradually improved, and updated information on future scenarios is continuously generated, which is evident from looking back over the past eight years and more. Other research projects are running in parallel which interact with these modelling activities. However, only a few projects both benefit from and contribute to model development, as has been the case in Mistra-SWECIA. We have utilized output from climate models that were developed and applied before the start of the project while at the same time developing models that will produce climate change information for future projects. We regard this as a responsible research approach.

**FURTHER READING:**


Lind P, Lindstedt D, Kjellström E and Jones C, Spatial and temporal characteristics of summer precipitation over Central Europe in a suite of high-resolution climate models. Submitted to *Journal of climate*

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*Figure 1. HCLIM simulated precipitation intensity (mm/hour) over Switzerland for three different horizontal model resolutions, 15 km (blue), 6 km (red) and 2 km (green). Observed precipitation intensity is represented by the RdisaggH dataset (black). The graph on the left shows how precipitation intensity varies with altitude over Switzerland while the graph on the right shows how it varies with latitude. Available data from the period 1998-2010 has been used (Figure from Lind et al. 2015).*
Value-determined factors, such as trust in climate science and personal objectives, are of great importance for shaping opinions and behavioral intentions to respond to climate change. Beliefs in self-efficacy are also found to increase engagement of forest owners in adaptation. These are some of the findings of Mistra-SWECIA, that have emerged through the development and application of a methodology for participatory research on climate change adaptation.

Adaptation processes in Swedish forestry

Risk perceptions, drivers and communication

In 2008, when the Mistra-SWECIA programme was established, research on climate change adaptation in Sweden had just begun to receive increasing attention from researchers, policy-makers and practitioners. This was in part due to two major storms, Gudrun (January 2005) and Per (January 2007) which hit Swedish forests hard, particularly in the southern parts of the country. The Swedish Government’s Commission on Climate and Vulnerability had just delivered its final report and recommendations in 2007, and adaptation had started to become a factor in both policy-making and research. However, at that time the recognition of adaptation and what it entailed was generally limited, and was often confused with the efforts to reduce greenhouse gas emissions to combat climate change.

The aim of the social science-based research within Mistra-SWECIA was initially to improve the understanding of social factors that determine the success of adaptation, and to investigate what stakeholders can do to overcome barriers to maximising adaptation. This featured taking a broader perspective on climate risks, vulnerability and adaptation in the real-world context of urban planning in the Stockholm region, as well as Swedish forestry. The programme participants designed and applied an interdisciplinary, participatory research approach combining climate science, climate impacts and social science theories and methods. The focus was on the respective responsibilities of various stakeholders involved in adaptation; their perceptions of risk and uncertainty; the current and potential use of climate information; as well as opportunities and motivations for stakeholders to engage in a learning process on adaptation.

In the early focus groups with local government officials in Stockholm County, it became clear that climate change adaptation had generally not been prioritized to any noticeable extent at the political level. The demand for knowledge, support and guidance was high for raising awareness and for pushing climate change-related risks higher up on the policy agenda. The results also showed that many of the adaptation challenges were clearly linked to rapid urban growth, such as deteriorating air quality, demand for housing, transportation and water resources, where climate change was expected to put increasing pressure on infrastructure and use of land. Barriers to implementing adaptation that were highlighted included integration of climate risks in planning processes; collaboration within and across municipalities and other actors; prioritization; differing time perspectives (e.g. short-term immediate issues
versus long-term); uncertainty; and lack of scientific knowledge. This illustrates the importance of viewing climate change as an integrated issue, in close interaction with other societal development issues.

In the second programme phase (2012-2015), research on adaptation processes was widened to cover a broader geographical scope, and use was also made of a large statistical survey. The participatory research methodology was expanded, fine-tuned, and widely applied across four counties of Sweden (Skåne, Västerbotten, Gävleborg, Jämtland), and targeted private forest owners in particular. Use was made of science-based stakeholder dialogues that more directly address forest owners’ questions and needs, as well as enabling knowledge sharing and collaborative learning among forest owners and researchers. Another focus was the role of social networks for sharing of different types of knowledge and information between actors that all underpin opportunities for, and barriers to, adaptation. In 2015, we finalized the survey of about 3,000 forest owners and 840 forestry experts. The results provide insights into who forest owners communicate with regarding forest management, the frequency of these contacts, and whether and how the features of social networks affect forest owners’ perceptions of climate risks and adaptive capacity.

Overall, our research results highlight the importance of value-determined factors, such as trust in climate science and personal objectives, in shaping opinions and behavioural intentions to respond to climate change. Furthermore, beliefs in self-efficacy were found to increase engagement of forest owners in adaptation. In contrast, social and economic factors such as income, age and gender appear to play an insignificant or ambiguous role. Our findings also indicate that common goals and shared responsi-
RISK PERCEPTIONS, DRIVERS AND COMMUNICATION

Bilities for adaptive forest management in response to climate change should be negotiated among stakeholders in a planning process that is external to the research process. Moreover, to foster adaptation by forest owners, climate information should be shared by actors who are in a position to communicate effectively, such as the Swedish Forest Agency and forest owner associations. At the same time, opportunities for stakeholder meetings where peers can meet and share their knowledge and experiences need to be created, for example through workshops.

Over the course of eight years of research by Mistra-SWECIA, we have seen how the knowledge on and commitment to climate change adaptation has gradually increased, although of course there is variation across individuals and organisations. For example, from the discussions with forest owners we note a growing insight into how climate change will/may impact the forestry sector and into the various options for adaptive forest management. Moreover, we have observed how the debate has shifted from being a question of “what” and “why”, to “how”. It is in this new era and new adaptation landscape that ongoing political and practical actions are geared towards challenges of governance and financing of adaptation at subnational levels.

Mistra-SWECIA has a wealth of findings to share with other communities of science, practice and policy-making engaged in current or forthcoming adaptation initiatives. The rather unique, multidisciplinary methodology for participatory research on adaptation will provide important lessons for future, demand-driven approaches to climate services and climate adaptation services in Europe and elsewhere. Experiences from Mistra-SWECIA, and our collaboration with the Swedish forestry and agricultural sectors, have shown that there is a great demand for such services in Sweden. The participatory research approach developed in Mistra-SWECIA offers methodological insights into the production, tailoring, translation and delivery of climate information, aimed at ensuring that the best available decision-relevant science is effectively communicated and easily accessed by stakeholders. We also hope our overall findings will help to develop policies, and to evaluate mitigation and adaptation strategies; and that it will help build the necessary skills and capacities of different user groups in applying this information to reduce climate-related losses and enhance benefits.

FURTHER READING:
Vulturis G and Gerger Swartling Å, 2015, Overcoming social barriers to learning and engagement with climate change adaptation: experiences with Swedish forestry stakeholders, Scandinavian Journal of Forest Research, 1–9

Mistra-SWECIA Annual Report 2015
Climate change means that forest owners face a number of new decisions concerning their forests. During the ECCA 2015 Conference, Mistra-SWECIA hosted two sessions on forest owners, climate change and the power to make decisions.

Drivers for decisions and the power to make them

Research is one important driving force to influence decisions, but we need to know more about how forest owners and other actors respond to this information. Where does their knowledge come from? These were the opening words of the moderator, Bill Slee from the James Hutton Institute, Scotland.

Uncertainty about climate change and the risks it brings with it is a major problem, not least as there are still knowledge gaps. Social networks play a part in how knowledge on climate adaptation spreads, and there is much to suggest that forest owners’ commitment to climate adaptation is growing stronger with larger, more changeable networks, according to Karin André, Mistra-SWECIA.

Understanding the individual’s commitment is also important if we are to facilitate work for adaptation in the future, according to Gregor Vulturius, Mistra-SWECIA. Forest owners and forestry advisors in Sweden are somewhat non-committal on the question of whether climate change will affect forestry. For example, when they do not see any great risk of extreme weather events, it inhibits the tendency to act. There is also disagreement on a number of points with regard to which measures forest owners and advisors prefer.

Victor Blanco, Mistra-SWECIA, explained how knowledge about Swedish forest owners is used in an “agent-based model”. This model contributes towards understanding institutional decision-making and how institutions can act and adapt to environmental change.

Further presentations showed that habits, culture, risk and altruism are some of the driving forces that guide forest owners. Anna Maria Jönsson, Mistra-SWECIA, has developed a tool for Swedish forest owners’ decision-making strategies. A book, “The Art of Growing Forests”, that was recently published by the forest industry group Holmen, takes that model as a starting point.

A discussion followed on how researchers can retain the confidence of forest owners. Kristina Blennow, Mistra-SWECIA, mentioned components that need to be investigated: Two-way communication; learning more about the knowledge and goals of the various actors involved; creating environments for mutual learning. And a good education system so that everyone can better understand why carbon dioxide emissions affect us.

ECCA 2015

ECCA (The European Climate Change Adaptation Conference) 2015 was held in Copenhagen. Researchers from Mistra-SWECIA and invited speakers presented their work in two sessions on decision-making related to climate change in forestry: “Perception and drivers” and “Evolving drivers”. Mistra-SWECIA also contributed to presentations in other events and workshops.
Whilst direct impacts of climate change on Swedish society are rather well researched, Sweden is also at risk of indirect impacts resulting from climate change that takes place elsewhere in the world. Such indirect impacts can pose internal policy challenges to Swedish decision-makers in both the public and business sectors.

Indirect impacts of climate change – the case of Sweden and the Swedish forestry industry

Current research does not cover a wide spectrum of interconnections through which Sweden is affected by impacts occurring elsewhere. To address this gap in existing research, during 2015 Mistra-SWECIA researchers have been developing a framework for analysis of indirect impacts of climate change, as well as a global index for measuring exposure to indirect impacts. Based on this framework, two case studies have been conducted on impacts on the Swedish manufacturing industry, one qualitative and one quantitative, the latter with particular focus on forest industries.

The starting point for the conceptual framework for analysing indirect impacts of climate change is that direct effects that occur in one country or region may be transferred to another country or region by flows related to biophysical factors, trade, finance or people. In addition to these four pathways, the framework also takes into account a country’s degree of globalisation, for example the extent to which the country is connected to other countries via membership in international organisations, restrictions on trade, the number of internet users, etc.

Preliminary analyses show that Sweden’s exposure to indirect impacts of climate change is primarily the result of trade, people and financial flows. Sweden has a small and open economy; the value of Swedish exports is close to 50 percent of the GDP. Swedish trade flows can be impacted in several ways. To begin with, many Swedish export companies are high up in the value chain. This means that they are dependent on supply chains. These supply chains are often international and, consequently, Swedish export is impossible without Swedish import. In addition, there is demand: important export markets can be negatively affected by (direct) impacts of climate change, which can influence the demand for Swedish products and services. Another important aspect is that the import of food to Sweden increased very rapidly over the last decade, with the implicit increased exposure to climate risks abroad.

With regard to financial flow, an effect of a changing climate globally could shape future investment decisions by Swedish investors, both public (e.g. pension funds) and private. It could also have an effect on investment decisions taken outside Sweden, for example if foreign
investors include future impacts of a changing climate in Sweden in their analyses.

The people flow represents a particularly complex process. This flow includes both forced migration as well as tourism. Migration is highly complex and it is impossible to attribute it to any one driver in isolation, including climate change. The UN Climate Panel, IPCC, states that climate change will bear significant consequences for migration flows at particular times and places. Given Sweden’s history over the last decades of allowing entry of a relatively high number of refugees, this factor could be of increased importance in the future.

As for the Swedish forest industry, preliminary results indicate that it is one of the least vulnerable sectors with regards to indirect impacts of climate change. The primary reason is that it sources most of its input materials – i.e. wood – from within Sweden. With large shares of sales outside Sweden, however, climate change impacts on export destinations could disturb markets, especially as larger volumes are directed at emerging markets, many of which are more climate-vulnerable than the industry’s traditional key markets in Western Europe. □

Publication of the global index, the research framework and the two case studies is scheduled for 2016.
A problem generates an opportunity for a solution

Where there are risks and problems there are also opportunities for solutions. This was the essence of Mistra-SWECIA’s seminar directed at issues concerning the industry. Henrik Carlsen, Mistra-SWECIA, presented supply chain risk management and indirect climate impacts. The climate is changing which will lead to effects not only in Sweden but also abroad; the effects abroad will also have an impact on us here in Sweden.

Overviews generally show that parts of the world that are already most vulnerable, for example due to poverty, are also hardest hit by climate changes. Globalisation has also increased rapidly since the 1970s, and is an important factor in this context.

"Studies are generally based on the assumption that countries are independent units. But as the world appears today, a network perspective is more applicable. Countries are interconnected and this influences how the climate-related risks spread”, commented Henrik Carlsen.

He stated that international flow must be looked at more closely, for example with regard to trade, when assessing vulnerability within climate changes and resultant adaptation initiatives.

Linda Flink from the Confederation of Swedish
Enterprise reported that companies often only have a vague concept of what climate adaptation is, and that it has different importance for the different industries. Increased business opportunities and new markets are part of the opportunities, but the supply chains and changed conditions are also associated with risks. One example is the pea farmers for whom the cultivation belt is moving northwards, impacting on the opportunity to grow today's crops and to start growing new ones. The growing season has been extended, but these changes are also associated with risks of more unpredictable growing conditions. Companies need more knowledge on climate adaptation, including how the climate is going to change. Linda Flink believes that the companies should themselves decide on initiatives appropriate for them. Cost analyses are needed, rather than force through legislation.

The seminar on driving forces and instruments focussed on the question of working with climate adaptation internationally, nationally and locally. Karin André, Mistra-SWECIA presented the forest owners’ views on climate changes. They are compiling knowledge from many different sources, and other forest owners are also playing a major role. Forestry advisors, etc. are also important. Knowledge on climate changes will nonetheless often come from magazines, the radio and the media.

"For example, advisors must take the opportunity to introduce information on climate adaptation when they talk with forest owners", stated Karin André.

Using advisory services and climate adaptation initiatives, the National Board of Forestry has reached almost 20,000 forest owners. Most of the forest owners who have received individual advice or attended a course believe that it has influenced their choice of which measures to use in their forest, and what they think about climate adaptation and risk spreading. Many of the conclusions on instruments and knowledge transfer obtained from studies on forestry can be translated to other sectors. Thus, the extensive studies that have been conducted solely on the forestry sector can also benefit other sectors.

The overarching topic for the conference was “Who pays, who implements, and how do we explain why?” Representatives from the government, county boards, municipalities, industries and the university were brought together to discuss the issue of climate adaptation. Mistra-SWECIA’s two seminars dealt with “Driving forces and instruments – what can make us change our behaviour?” and “Climate-related risks and opportunities for industry and commerce.”
What are the effects of climate change on the economy and human welfare? How will the future emissions of green-house gases develop under the influence of economic development and the limited amount of fossil fuel available? How should an optimal mitigation policy such as taxation be devised? To answer such questions, IAMs (Integrated Assessment Models) have been constructed.

The climate and the economy – building better models

Climate-economy research in Mistra-SWECIA has focused on building a new generation of IAMs. The models need to describe the economy, the climate and the carbon cycle, as well as the mutual interaction between them. Around the start of the Mistra-SWECIA programme eight years ago, a number of elements were still lacking in the leading IAMs, primarily involving their macroeconomic modules. In the existing literature, most settings failed on one or more of the following dimensions: (i) very low regional resolution, (ii) no explicit economic dynamics (along the lines of standard optimal growth models) with forward-looking agents, (iii) a focus on “centralized planning solutions” instead of a market description making it difficult or impossible to predict the effects of taxes and other policies, and (iv) no explicit description of uncertainty. The main aim of our IAM construction has been to build a new generation of models with improvements to the type of problems listed above.

We now have such a model. The new IAM model has about 20,000 regions and addresses all of the issues above. The closest relative in terms of modelling, thus satisfying at least some of the four requirements just stated, is Nordhaus’s RICE, which has 13 regions. Currently, the new IAM is primarily a platform for examining a large number of extensions and applications. The work on the model has proceeded in several directions. In particular, we have conducted a number of “pilot studies” in order to examine parts of the core of the high-resolution model. For example, one of these studies derives an optimal carbon-tax formula for a “one-region” world economy. The very simple and analytically tractable model, even in the presence of several energy sources, provides a quite reasonable approximation compared to far more complicated models, including the most well-known one, Nordhaus’s DICE. An increasing number of researchers around the world are building on the core of our model in a number of different applications. This was also an explicit goal of our efforts: to make the climate-economy field accessible for the mainstream macroeconomist community with traditional training, but who are not experts at numerical models. The results of the study reveal, in particular, that the optimal carbon tax depends crucially on only three factors: the pure rate of time preference, how much carbon dioxide remains in the atmosphere over time, and what
we label the “damage elasticity”, i.e. the flow damage in percent of world GDP from a one-unit increase in atmospheric carbon concentration. Other factors – technology, population, mitigation costs, etc. – are of second-order importance.

Two other related pilot projects have been conducted on the energy sector and energy-saving. One of these looks into how energy and fossil fuel enter the “aggregate production function” that, from a birds-eye perspective, describes how GDP is produced from capital, labour and other production factors. Based on the answer, the analysis provides an economy-wide measure of energy-saving technical change with interesting properties. In particular, energy saving responds clearly to energy prices, which indicates a powerful mechanism in the form of “directed technical change”. However, it also found that faster energy-saving technical change comes at the expense of lower capital- and labour-saving technical change. A model based on this finding then explores the long-term features of energy dependence; the energy share, and overall output growth.

The focus in another pilot study is on the competition between food and biofuels. The study analyses how increased use of land for the production of biofuels can be expected to affect food prices in the long term under various types of policies. With free movement of production factors across sectors, the increase in food prices is limited. From the climate perspective, restrictions on using biomass for fuel may slow down the extraction of fossil oil and could hence be beneficial. The reason is that the value of saving fossil oil for later use is increased if biofuels are used less.

While moving towards the high-resolution model, we showed how to build a multi-region version of the earlier mentioned one-region model for optimal carbon tax. The same analytical framework is used, which allows closed-form solutions. We assume that capital does not flow across regions, but that regions interact through the energy market and climate externality. In ongoing research, we are examining international technology spillovers in the same framework.

The high-resolution model incorporates all the features that were examined in the pilot studies, and it allows for a number of other features as well. The consideration of climate is based on a simple global energy balance model that gives the global mean surface temperature. The regional temperature distribution is then obtained from the global mean using pattern scaling,
a type of statistical model which is calibrated with the results of highly complex climate models. It essentially estimates how much each of the regional temperatures change when the global mean temperature rises by one degree Celsius. Several formulations of regional damage have also been examined, leading to the adoption of a single damage function of local temperature. This formulation posits that damages in a given region (i) are proportional to “total-factor productivity” (TFP), as in Nordhaus’s work, and (ii) depend only on local temperature, with the same functional form for all regions. The parameters of this function were estimated by assuming that the aggregate damages in the high-resolution model match the damages estimated by Nordhaus. This matching is performed for three different warming scenarios: a one degree Celsius increase in global temperature compared to the pre-industrial level, a 2.5 degree increase, and a 5 degree increase. These three restrictions suffice for pinning down the parameters of the damage function. The resulting local damage function has its minimum at 11.1 degrees (daily mean temperature), with a rapid increase in damages on both sides of this “ideal temperature”. In other words, productivity is at its highest at 11.1 degrees Celsius. The economic model used (the base for the damage calibration) matches the world distribution of output across all regions. Two different versions of the model were constructed: one with unrestricted capital mobility across regions and one with no capital mobility.

The main results emerging from the high-resolution model so far can be summarized as follows:

- The local consequences of global warming are massive compared to the global average consequences, with many regions losing hugely but others gaining by similar magnitudes. A rather slim majority of regions are in favour of (even mild) taxation.
- There are significant additional human migration pressures arising from climate change.
- Capital mobility, which means “leakage” away from regions with above-average damage to other regions. This influences the welfare of all regions positively but has almost no effect at all on global climate change.

The Mistra-SWECIA research on climate economy will continue well beyond 2015. A large number of applications and extensions to the models are already in the pipeline.

**FURTHER READING:**
Climate, atmospheric composition, ecosystem function, land use and socio-economic development are inseparably intertwined; changes in one inducing responses in the others. Models and scenarios that attempt to describe the joint evolution of these human and natural factors in response to changing driving forces require a holistic approach.

Modelling global land use

Biophysical and socio-economic dimensions of climate change are connected via the provision and trading of ecosystem services provided by managed land, such as food, fodder, fibre, forest products and biomass energy. A changing climate will affect the availability and seasonal distribution of resources such as light, water and soil nutrients used by agricultural and timber crops. Atmospheric carbon dioxide (CO₂) is an additional resource used in photosynthesis; its availability is increasing as a result of emissions caused by humans. Other effects include losses, and risks of damage in conjunction with pest and pathogen outbreaks, the frequency and severity of which may be influenced by climate and land use change. Damages due to events such as storms, floods or droughts also influence ecosystem services and the costs of obtaining value from nature. Such factors affecting yields, risks and management costs may elicit responses from land managers as well as regulators, ranging from changing practices – for example choices of crop species and varieties, or management interventions such as irrigation and fertilisation – to the conversion of land from one land use type to another. In extreme cases, abandonment may withdraw land from active management. Prices for land-based commodities determined through market responses to changing supply, demand and trade are another important driver for land-use related decisions and transitions.

One line of research in Mistra-SWECIA has aimed to deepen understanding of such coupling of socio-economic and biophysical factors as they relate to global land use patterns and the supply of ecosystem services. One important goal has been to assess the degree to which future changes in land use and ecosystem services can be predicted against the backdrop of uncertainty in climatic and socio-economic drivers, and in the responding societal and ecological processes.

Another goal has been to inform discussions and reasoning about climate change adaptation by enriching generalised narratives of the future world – the often-used Shared Socioeconomic Pathways (SSP) – with coherent, quantitative trajectories of specific factors, such as world prices for agricultural and forest-based commodities, that may be expected to influence decision-making and adaptation at the regional scale. A specific case study has focused on the Swedish forest sector, which through its dependence on world prices and markets for forest products and other land-based commodities is indirectly affected by the many ways in which changing climate and socio-economic factors influence prices and markets.

A general framework for global application was developed building on “in house” models representing key components of the climate-biosphere-land use system (Figure 1). An ecosystem model (LPJ-GUESS)
simulates responses of ecosystem functions, such as biomass growth, ecosystem-atmosphere carbon balance and hydrological cycling, to variation in climate, atmospheric CO$_2$ concentration and other drivers such as nitrogen deposition. To serve the research goals of Mistra-SWECIA, the model has been enhanced to represent the dynamics of managed ecosystems, such as arable lands and managed forests, yield prediction of major classes of crops, timber production, carbon sequestration and related quantities linking ecosystem functions to societal interests and needs. Yields predicted by LPJ-GUESS feed into the land-use model PLUM, which describes changes in the allocation of land to different uses, such as cereal and livestock production, for each of the world’s countries. PLUM builds on relationships reflected in statistics from the UN Food and Agriculture Organisation (FAO). It relates land use and agricultural output to drivers such as technological advance, trade, population growth and its effects on calorific demand, economic output, and dietary preferences.

World economic output is an important driver of land use, affecting access to yield-enhancing technologies, per capita demand for food, and preferences for meat-based versus vegetarian diets. Climate mitigation policy that targets substitution of fossil fuels by renewable energy sources may profoundly impact the relative allocation of land to biofuel production. In this framework, a climate-economy model translates the impacts of imposing fossil energy taxes as an instrument of emissions reduction on economic output and green energy prices, in turn affecting the land use patterns predicted by PLUM.

The framework is being used to elucidate the complex links between the biophysical and socio-economic dimensions of global change in constraining possible pathways of future world development. The approach advances on existing practice for developing narratives of the future world, which are largely based on expert opinion and consensus, and are of their nature descriptive rather than quantitative. The framework can generate quantitative projections, attribute outcomes to underlying drivers and assumptions, and can also account for some key dimensions of uncertainty.

An example is shown in Figure 2, which depicts projections of the future evolution of world cropland area and crop yields under alternative SSP scenarios. The projections take into account the relative likelihood
Figure 1. Coherent framework for assessing impacts of global climate and socio-economic change on land use and ecosystem services.

Figure 2. Time course of cropland area and average yield under alternative pathways of socio-economic and climate change (SSP1-5 = sustainable future; current trends continue; regional fragmentation; inequality; fossil-fuelled development). The SSPs are associated, on a relative probability basis, with regional concentration pathways (RCPs) describing future emission trends. The RCPs are associated with multiple climate projections which in turn affect crop yields calculated in the model LPJ-GUESS.
of alternative future developments, accounting for uncertainty in driving climatic and socio-economic forces. Within the 95 percent confidence interval shown, much overlap is apparent between scenarios. For example, outcomes of SSP 1 (“sustainable future”) and SSP 2 (“current trends continue”) can scarcely be distinguished in terms of their effects on crop yields on a land area basis, but sustainability leads to lower cropland area as food demand declines as the result of a stabilising world population and reduced demand for meat and milk. This is just one example of the type of analysis that may be performed using the new framework.

Outcomes like this are also being used as a basis for reasoning about ecosystem and land use responses to the potential development of the global climate, and mitigation policy in response to climate change, under alternative SSP scenarios. Trajectories of world supply and demand for key ecosystem services will be used to outline broad characteristics of the future world as input to an agent-based model customised to represent land use decision-making within the Swedish forestry sector. The study will be one of the first to explore the impacts of global drivers on regional responses in an explicit, coherent framework of the natural and human dimensions of global change. □

**FURTHER READING**


New knowledge, new tools and deepened insights into the significance of climate change adaptation are examples of the contributions of Mistra-SWECIA to forest owners, industries, government agencies and county administrative boards.

What’s in it for society?

Mistra-SWECIA’s contributions to society are the most important in the wider forestry sector, but also other benefits are evident. While some effects are immediately visible, the full impact of the programme will of course unfold over time. This will take place in line with application of the developed knowledge and other insights in decision-making and other relevant developments. Benefits build both on the research and on the collaboration with stakeholders. The development of interdisciplinary research opens new avenues for novel scientific knowledge generation.

The interaction of researchers, forest owners and professionals during the programme has advanced the development of communication and knowledge exchange on climate adaptation challenges and possibilities. This contributes to the long-term resilience and robustness of the Swedish forestry sector. Special efforts have been made to make the research results easily available for the forestry sector through short research summaries and a final, comprehensive synthesis report in Swedish.

Deeper insights and new tools

The understanding of how managed forests will be affected by a changing climate has been in focus in Mistra-SWECIA. For example, research has addressed how different management strategies affect management goals concerning economy, biomass production, biodiversity, and carbon sequestration in the forests. The results can support the provision of improved recommendations for forest management with both economical and societal benefits, as well as highlight how different practical forest management options affect risks related to climate change impacts.

The insights from the evaluation of the Forest Agency’s education programmes on climate change adaptation, knowledge about from whom forest owners gain their information, and the experiences of the focus groups, can help to improve the effectiveness of climate change communication and consequently increase the knowledge and adaptive capacity of Swedish private forest owners, who collectively own 50 percent of the Swedish forests.

Cooperation with the forest industry group Holmen has resulted in climate change issues, relating to both mitigation and adaptation, being further incorporated in the company’s forestry manual. Because Holmen is a major actor in the forestry sector in Sweden, its choices can also influence other actors to look further into relevant issues related to the changing climate.

The cooperation within the dedicated science-policy interface group resulted not only in concrete activities engaging a range of stakeholders, but also built up knowledge for the researchers as well as the stakeholders. Much of the programme’s communication was channelled into already established arenas in the forestry sector. This was complemented by articles about the research, as well as Mistra-SWECIA’s other contributions to society.
activities, in specialised papers and magazines read by forest owners and other professionals.

One example of a specific activity is the excursion to the forest in Västmanland that was ravaged by fire in 2014. The excursion was organised in collaboration with The Swedish Forestry Association, which has a widespread network that includes forest owners, forest industries and politicians.

Additional initiatives
The programme’s work with Krinova Science Park on supply chain risk management and companies’ preparedness for a changing climate was the first of its kind in Sweden. It brought climate change into the companies’ strategic business development plan. The focus was on companies with a stake in the land use sector in southern Sweden. The method that was developed can, however, be applied to many sectors. Companies that are well-prepared for the new risks and opportunities in a changing climate will be better positioned in the future.

The new insights from the research on indirect effects demonstrate that climate impacts in other world regions also have tangible effects in Sweden due partly to the importance of world markets to Sweden and the Swedish economy.

The climate-economy research within Mistra-SWECIA has highlighted the effects and challenges of taxation of fossil fuels. How a global price on carbon could affect Swedish economy has been examined in relation to the fact that Sweden already has a domestic carbon tax.

The programme’s activities, results, insights and participants reached yet additional actors and processes. None of these processes by the actors were too small to be of importance; moreover, two of them were quite major: The climate-economists discussed desirable climate change policy for China in a private meeting with the Chinese Premier, and a second meeting is to follow. Mistra-SWECIA participants became authors of the fifth assessment report of the Intergovernmental Panel on Climate Change. Furthermore, one of Mistra-SWECIA partners, SEI, is represented on the programme council for Sweden’s recently established National Forest Programme, mainly as a result of their work within Mistra-SWECIA.

Last but not least, of particular value is the fact that people from different parts of the country geographically, from different organisations, and with different interests and drivers, have come into contact and exchanged experiences and learnt about the issues from each other. This will facilitate improved decision-making. We hope and anticipate, based on the experiences so far, that this will carry lasting value. If so, it certainly is one of the most significant outcomes of the programme.

SYNTHESIS REPORT – PRODUCED TO BE READ
The Mistra-SWECIA synthesis report “Climate adapted forestry: Drivers, risks and possibilities” from 2015 is aimed at civil servants, forest owners and other actors within the forest sector. It describes part of the programme’s research, with focus on forest-related issues in Sweden. The report is written in a popular style, in Swedish, and has mainly been distributed to the programme stakeholders. The report can be found on www.mistra-swecia.se

FURTHER READING:
Lagergren F, 2014, Klimateffekter och anpassningsstrategier i svenskt skogsbruk - exempel Holmen Skog, Mistra-SWECIA rapport nr 6
Synthesis report, 2015, Klimatanpassat skogsbruk: Drivkrafter, risiker och möjligheter, Mistra-SWECIA
“Mistra-SWECIA has been extremely helpful in guiding me in climate adaptation work. For example, I want to look at planned field use in forestry in the county, and have had my eyes opened to landscape planning in forestry. I have also realised the importance of understanding the actors and the variation in drivers: Some are driven by pure idealism and passion, others by sentimentality, a third group by profit, a fourth is totally indifferent, and so on. When these characteristics are combined they give differing owner competences. I had not fully appreciated the depth and width of this range previously.”

Måns Enander, Climate Adaptation Coordinator for the County Board in Västmanland

“The knowledge generated by Mistra-SWECIA’s research provides us in the Ministry with a better footing when we are arguing for general and cost-effective steering tools for daily work, and when we produce documentation for political management and for other commissions. The carbon dioxide issue is complex and involves factors such as indirect effects and different emission systems. The work done by the researchers in climate economy is highly pedagogic and lucid.”

Åsa Knudsen Sterte, Ministry Secretary for the Ministry of Finance
Researchers, forest owners and other stakeholders gathered at the Mistra-SWECIA Final Conference to summarise the work done during the eight years of the programme. Research developments and results, collaboration initiatives and reflections about the future were shared.

Eight years on:
More understanding, more knowledge and more connections

“Over the last few years, Mistra-SWECIA has focused on how to transfer knowledge on climate, impact and adaptation to forest owners”, commented Bengt Holgersson, Chair of the Programme Board, in the opening statements, and he continued:

“Forest owners are a very interesting group. They have become increasingly aware of climate change, and Mistra-SWECIA wanted to find a good model to work with adaptation issues. On several occasions, I have worked with both researchers and stakeholders and experienced that the two groups do not talk the same language. Mistra-SWECIA has made a significant contribution to better understanding between the researchers and stakeholders.”

Participants for the day included researchers, forest owners, journalists, representatives from relevant governmental agencies and other organisations, the programme host SMHI and the funder Mistra. Programme Director Markku Rummukainen made a personal reflection about being nine years older today than when he first started thinking about the programme:

“But Mistra-SWECIA has kept me young. The number of interesting and exciting people that we have met, one way or another, is in the thousands. People meeting one another is most definitely an important outcome”, he said.

Highlights of the Mistra-SWECIA research were presented during the conference. The research concerned adaptation to climate change in forest management; global drivers; and climate economy. A number of Mistra-SWECIA PhD students also presented their work in a “science slam” session. Tim Carter, the Finnish Environment Institute, SYKE, added to the bigger picture by guiding the participants through the European Adaptation Landscape while discussing Mistra-SWECIA’s place in it.

The researchers commented that Mistra-SWECIA’s interdisciplinary and collaborative approaches have made a strong impression. To understand and exchange ideas with researchers from other disciplines is important, and something that cannot be taken for granted. Contact with stakeholders has proven fruitful for the researcher’s understanding of research needs, and has added to broader dissemination of the results.

“It is important to take a step away from the models and talk about concrete strategies, and to be
open to alternative strategies, other than those that emerge from the researchers offices”, said Anna Maria Jönsson, Mistra-SWECIA, reflecting on the contact with forest owners.

Åsa Gerger Swartling, Mistra-SWECIA, referred to an increased awareness of climate and adaptation compared to that at the programme launch in 2008. Use of a problem-driven approach rather than a research-driven approach is important in the dialogue with different stakeholders, and it was stated repeatedly that it takes time to get people and different organisations to talk to each other. Per Krusell, Mistra-SWECIA, made the case that their research on climate economy is “on the map” today, and is now read by economists who might have been sceptics before.

In his closing words, Åke Iverfeldt, Mistra, stressed the importance of contact with as many people as possible. Sometimes the real impact of a programme can be seen four or five years after it has closed – it takes time for its benefit to manifest itself in society. Different strategies for the future are invaluable:

“Over the past eight years, you have created new research teams – try to continue with the teams and constellations you now have.”

Budget

PROGRAMME PHASE II (PERIOD 2012-2015)

PROGRAMME FUNDING (SEK ‘000)

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<tr>
<th>Source</th>
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<td>From SMHI</td>
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<td>From Stockholm University</td>
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PROGRAMME COSTS (SEK ‘000)

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<th>2016</th>
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<td>Adaptation processes</td>
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<td>Regional climate modelling: High resolution climate projections, impact modelling and risk assessment</td>
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<td>Land use narratives</td>
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<td>Component III: Partner-driven studies and synthesis</td>
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<td>14,090</td>
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Strategic reserve: 1,470

Total: 56,880

Note 1. Each amount is rounded to the nearest SEK 10,000.
Note 2. Programme management includes the Programme Director, the Secretariat and the Programme Board.
Note 3. Communication includes the Communicator, communication activities, website, meetings and events, as well as synthesis and collaborative studies.
Organisation

PROGRAMME BOARD
Bengt Holgersson, chair
Bodil Aarhus Andrae, SMHI
Tim Carter, the Finnish Environment Institute (SYKE)
Hillevi Eriksson, Swedish Forest Agency
Tom Hedlund, Swedish Environmental Protection Agency
Thomas Nilsson, Mistra (adj.)
Gunilla Saltin, Södra
Joakim Sonnegård, the Swedish Fiscal Policy Council

PROGRAMME DIRECTOR
Markku Rummukainen

SECRETARIAT
Susanna Bruzell, Programme Coordinator
Hanna Holm/ Kristina Rörström, Research Communicator

MANAGEMENT GROUP
Markku Rummukainen
Susanna Bruzell
John Hassler
Hanna Holm/Kristina Rörström
Jonas Nycander
Olle Olsson
Patrick Samuelsson
Ben Smith
Åsa Gerger Swartling

SCIENTIFIC REFERENCE GROUP
Martin Clausen, Max Planck Institute for Meteorology, Hamburg, Germany
Martin König, Umweltbundesamt, Austria
Rik Leemans, Wageningen University, the Netherlands
Sir Nicholas Stern, LSE, the UK
Roger Street, UKCIP-OUCE, the UK

ALL PARTICIPANTS
Anders Ahlström, Department of Physical Geography and Ecosystem Science at Lund University
Anna Fitch, Rossby Centre, SMHI
Anna Maria Jönsson, Department of Physical Geography and Ecosystem Science at Lund University
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Gustav Engström, the Beijer Institute of Ecological Economics
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Henrik Carlsen, Stockholm Environment Institute, SEI
Johan Gars, the Beijer Institute of Ecological Economics
Johanna Hedlund, Stockholm Environment Institute, SEI
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Kristina Rörström, Centre for Environmental and Climate Research at Lund University
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Laurent Marquer, Department of Physical Geography and Ecosystem Science at Lund University
Magnus Benzie, Stockholm Environment Institute, SEI
Mark Kupiainen, Rossby Centre, SMHI
Mark Rousevell, School of GeoSciences at the University of Edinburgh, UK
Markku Rummukainen, SMHI and Lund University
Masayuki Kudamatsu, Institute for International Economic Studies at Stockholm University
Mats Lindeskog, Department of Physical Geography and Ecosystem Science at Lund University
SCIENTIFIC ARTICLES


Andersson M, Kellomäki S, Gardiner B and Blennow K, 2015, Life-style services and yield from south-Swedish forests adaptively managed against the risk of wind damage – a simulation study, Regional Environmental Change, 15(8), 1489-1500

André K and Jonsson A C, 2015, Science-practice interactions regarding climate adaptation in two contexts: Municipal planning and forestry in Sweden, Journal of Environmental Planning and Management, 58:2, 297-314


Blanco V, Brown C and Rouncevell M, 2015, Characterising forest owners through their objectives, attributes and management strategies, European Journal of Forest Research, 134(6), 1027–1041


Jönsson A M, Lagergren F and Smith B, 2015, Forest management facing climate change – an ecosystem model analysis of adaptation strategies, Mitigation and Adaptation Strategies for Global Change, 20, 201-220

Krusell P and Smith T, 2015, Environmental Macroeconomics, to appear in Handbook of Macroeconomics, North-Holland

Lindstedt D, Lind P, Jones C and Kjellström E, 2015, A new regional climate model operating at the meso-gamma scale; performance over Europe, Tellus A, 67, 24138

May W, Meier A, Rummukainen M, Berg A, Chéruy F and Hagemann S, 2015, Contributions of soil moisture interactions to climate change in the tropics in the GLACE-CMIP5 experiment, Climate Dynamics, 45 (11-12), 3275-3297


Vulturius G and Gerger Swartling Å, 2015, Overcoming social barriers to learning and engagement with climate change adaptation, Scandinavian Journal of Forest Research, 30:3, 217-225


**PRESENTATIONS**

150121 Rummukainen M “Climate change – not about 100 years”, Agriculture and climate – course for advisors, Greppa Näringer, Uppsala, Sweden

150127 Smith B “Predicting climate change impacts on ecosystems. Ecosystems in 2075”, Final Conference of Villum Foundation Centre of Excellence – Climate, Copenhagen, Denmark

150128 Rummukainen M “The scientific basis of climate change” Miljömålsberedningen, Stockholm, Sweden


150408 Smith B “Modelling C-N interactions using LPJ-GUESS”, Royal Netherlands Academy of Arts and Sciences Colloquium, Climate models revisited: the biogeochemical consequences of mycorrhizal dynamics, Amsterdam, The Netherlands


150413 Wilcke R A I and Bärring L “Selecting regional climate scenario for impact modelling studies”, EGU General Assembly, Vienna, Austria

150416 Wilcke R A I and Chandler, R E “Analysis of inter-variable relations in regional climate model output”, EGU General Assembly, Vienna, Austria

150424 Rummukainen M “Climate change – a challenge with solutions” Kraftringen, Lund, Sweden

150506, Smith B, Zhang W and Miller P A “Ecological dimensions of 21st century land-atmosphere interactions in the Arctic”, AGU-GAC-MAC-CGU Joint Assembly, Montreal, Canada


150508 Rummukainen M “Climate scenarios for decisions and policies” Nordic eInfrastructure, Helsingfors, Finland

150511 Rounsevell M D A “Integrating land use change models with DGVMs “Dynamic global vegetation modelling: towards a third generation, Landskrona, Sweden

150511 Rummukainen M “Climate-proofed Scania”, County Administrative Board, Malmö, Sweden


150512 Ahlström A “Relative importance of vegetation dynamics for future C-uptake uncertainties”, Dynamic global vegetation modelling: towards a third generation, Landskrona, Sweden

150513 Blanco V, Holzhauer S, Brown C and Rounsevell M, “The role of institutions in forest land-use decision making – Modelling institutional adaptation to climate change”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark
150512-14 André K, Baird J, Gerger Swartling Å, Vulturius G and Plummer R “Communicating knowledge on climate adaptation in Swedish forestry: the role of social networks”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark

150512-14 Blennow K, Persson E, Lindner M, Faias S P and Hanewinkel M “Adapting to indirect effects of climate change – motivations and attitudes among European forest owners”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark

150512-14 Carlsen H, Hedlund J and Benzie M “Introducing a pathway (or network, or system)-based conceptual framework to identify indirect impacts of climate change”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark

150512-14 Gerger Swartling Å, André K, Vulturius G, Jönsson AM, Samuelsson P and Lagergren F “Communicating climate change in stakeholder dialogues - lessons learnt from the Swedish forestry sector”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark

150512-14 Gerger Swartling Å, André K, Vulturius G, Jönsson A M, Wallgren O, Olsson O and Lagergren F “Interdisciplinary methodology on science-stakeholder based adaptation research: The experience of Mistra-SWECIA and reflections for future research”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark

150512-14 Hedlund J, Carlsen H and Benzie M “A global index of exposure to the indirect impacts of climate change and examples from Sweden”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark

150512-14 Jönsson A M and Gerger Swartling Å “Science-Stakeholder Interactions in Climate Change Adaptation Research – a case study of the Swedish Forestry sector”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark

150512-14 Jönsson A M, André K, Gerger Swartling Å, Vulturius G and Lagergren F “Tool development for analysing forest owners’ strategies to manage risks and adapt to climate change”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark

150512-14 Olofsson J, Jönsson A M, Linderson M-L and Nilsson C “Educating the next generation decision makers – the multi-disciplinary classroom as a platform for developing communication skills needed for future progress of adaptation measures”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark

150512-14 Vulturius G, André K, Gerger Swartling Å, Blanco V, Rounsevell M and Lundgren L “Assessing and explaining individual engagement with climate change adaptation and preferences for adaptation measures”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark

150512-14 Vulturius G, André K, Gerger Swartling Å, Brown C and Rounsevell, M “Can Climate Change Communication effectively promote adaptation?”, 2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark

150527-28 André K, Gerger Swartling Å and Vulturius G “Experiences of science-based stakeholder dialogues on climate adaptation in the Swedish forestry sector: reflections on methodological challenges of conducting transdisciplinary research”, Environmental governance in an increasingly complex world, Stockholm, Sweden


150528 Rummukainen M “Climate change – a challenge with solutions”, Kraftringen, Helsingborg, Sweden

150624 Rummukainen M “Uncertainties in climate change projections”, NOSCCA (North Sea Region Climate Change Assessment), Hamburg, Germany

150701 Rummukainen M “Green transformation” Öresund dialogues, Almedalen, Sweden

150701 Rummukainen M “How should we build”, Business Arena, Almedalen, Sweden


150813 Hassler J “Economics of Climate Change – risks and Challenges”, University of the Chinese Academy of Sciences, Beijing, China
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<th>Date</th>
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<td>150820</td>
<td>Krusell P <em>Climate Change Around the World</em>, Walras-Bowley key-note lecture, 2015 World Congress Econometric Society, Montreal, Canada</td>
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<td>150825</td>
<td>Rummukainen M &quot;Climate change, today’s shadow on tomorrow&quot;, County Administrative Board, Malmö, Sweden</td>
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<td>150916-17</td>
<td>Lagergren F “Hur förhålla sig till klimatrelaterade risker i skogsbruket?”&quot;, Föreningen Skogens Höstekursion 2015, Västmanland, Sweden</td>
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<td>Vulturius G and André K “Skogsägares syn på klimatrisker. Skogsbruk i ett förändrat klimat”, Föreningen Skogens Höstekursion 2015, Västmanland, Sweden</td>
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<td>Carlsen H “Supply Chain Risk Management och indirekta klimateffekter”, Klimatanpassning Sverige 2015, Stockholm, Sweden</td>
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<td>André K “Skogsägares drivkrafter för klimatanpassning”, Klimatanpassning Sverige 2015, Stockholm, Sweden</td>
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<td>Smith B &quot;Modelling the ecosystem” JPI Climate workshop on European long-term observation networks, Paris, France</td>
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<td>151215</td>
<td>Wilcke R A I and Chandler R E “Inter-variable relations in regional climate model output”, AGU Fall meeting San Francisco, USA</td>
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**EVENTS**

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<td>150512-15</td>
<td>2nd European Climate Change Adaptation Conference (ECCA), Copenhagen, Denmark, “Decision making related to climate change in forestry”, two sessions: “Perception and drivers” and “Evolving drivers”</td>
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<td>150916-17</td>
<td>Föreningen Skogens Höstekursion 2015, Västmanland, Sweden</td>
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<td>150923</td>
<td>Klimatanpassning Sverige 2015, programme board and two seminars: “Driving forces and instruments – what can make us change our behaviour?” and “Climate-related risks and opportunities for industry and commerce”</td>
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**OTHERS**


André K, Gerger Swartling Å, Vulturius G, Olsson O, Carlsten H and Davis M, 2015, Climate change adaptation in Swedish forestry: Driving forces, risks and opportunities, Stockholm Environment Institute, SEI Research Synthesis Brief


Hassler J, Krusell P and Nycander J, 2015, Climate policy, Policy paper for The 62nd Economic Policy Panel Meeting, Luxembourg City, Luxembourg

Rummukainen M, 2015, Lång väg att gå även efter Paris (column), Fastighetsnytt 05/2015, s 101


FORTHCOMING


Lagergren F and Jönsson A M, How to consider the diverse aspects of ecosystem services and biodiversity in forest management. In preparation

Lind P, Lindstedt D, Kjellström E and Jones C, Spatial and temporal characteristics of summer precipitation over Central Europe in a suite of high-resolution climate models. Submitted to Journal of climate


Marquer L et al. Millennia changes in tree niches of the most common taxa in northern Europe. To be submitted to Journal of Quaternary Science

Pontarp M, Horgan K and Jönsson A M, How to maintain biodiversity in production forests in a changing environment – linking ecological theory and forest management. In preparation


Wilcke R A I and Bärring L, Selecting regional climate scenarios for impact modelling studies. Submitted to Environmental Modelling and Software


Van Vliet J, Brown C, Dendoncker N, Holzhauer S, Moseley D, Robinson D T, Vulturius G and Rounsevell M, Advancing land-use modeling requires new data to understand and represent human decision making. In review Land Use Policy
There are big challenges facing the world, connected to our environment and how we humans use natural resources and influence our surroundings. Mistra is a foundation which plays an active role in meeting these challenges by investing in strategic environmental research which contributes to sustainable social development. This is done by investing in various efforts in which researchers in collaboration with users contribute to solving important environmental problems. Read more at: www.mistra.org