INTERNATIONAL WORKSHOP

Forest and Climate Change: adaptation initiatives and new management practices

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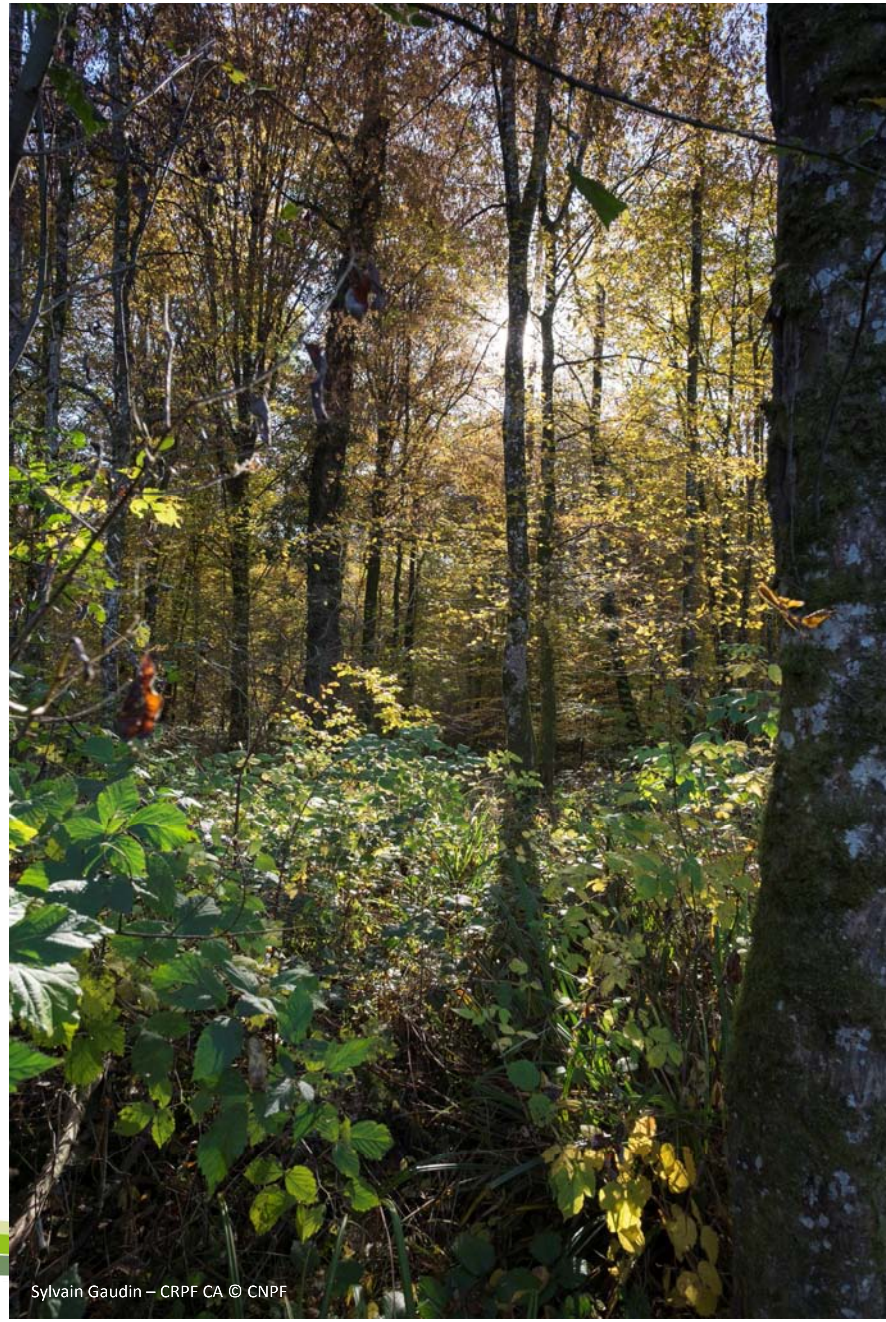
Book of abstracts

AFORCE
RMT Adaptation des forêts au changement climatique

Institut des Sciences de la Forêt tempérée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Summary

Supporting forests adaptation to climate change: a comparative review of approaches taken in France and Quebec

Olivier PICARD[1], Myriam LEGAY[2], Frédéric DOYON[3] et Céline PERRIER[1], in collaboration with Clément CHION[3] (France & Canada)

RMT AFORCE[1] and ISFORT (Institut des Sciences de la forêt tempérée) at the University of Quebec in Outaouais officialised their respective commitments on the question of support for foresters on forest adaptation to climate change, at the First International Workshop organised by RMT AFORCE in 2014. Very quickly, the idea of engaging a more in-depth collaborative effort between France and Quebec, to compare the methods and tools used by each, took shape. In 2015, AFORCE and ISFORT thus embarked on a cooperation project linking France and Quebec (the CPCFQ call for projects). The objective of this project was to structure experience- and expertise-sharing about developing new innovative transfer and decision-making assistance tools, in a shared approach to adapt forest planning to global challenges.

The project served as the opportunity to compare organisational structures and how they contribute to knowledge-sharing about forest adaptation to climate change. The meetings enabled a clearer understanding of the perception of change by foresters and their determination to take action in response to this new climate-related challenge. Assessment was carried out on the methods and tools developed by both countries (Perrier *& al.*, 2016). A cross-comparison of the approaches also made it possible to identify the coordination methods used to better understand the factors determining decision-making, in a context of uncertainty. The initiative showed in particular a significant need to set up new adaptation initiatives in a management context, which can be used for demonstration purposes, both to raise the awareness of practitioners and to support training. It also brought to light all the value, for teams from different countries, in being able to engage in exchange on the adaptation initiatives and tools used to support foresters.

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[1] A network of French foresters dedicated to support for foresters in preparing forests for climate change. It brings together 15 partners in forestry and is aimed to speeding up knowledge sharing, informing, sparking discussion, providing decision-making assistance tools, and providing a framework for adaptation initiatives (http://www.reseau-aforce.fr/).

A line made by walking: adaptation to climate change in forestry across Europe

Rita SOUSA-SILVA[1,], in collaboration with Bruno VERBIST[1], Quentin PONETTE[2], Kris VERHEYEN[3] et Bart MUYS[1,4,*] (Belgium)*

The challenge of adapting to climate change is now recognized to be one of the most important and difficult ever posed to the forest sector. Increased temperatures and levels of atmospheric CO_2 as well as changes in precipitation and in the frequency and severity of extreme weather events will have a substantially impact on the condition of Europe's forests, and impair their ability to deliver critical goods and ecosystem services. Rising to this challenge will require adjustments to forest strategies and changes to forest management plans and practices, but it is unclear to what extent this is already happening.

Using survey data from 885 forest owners and managers, the survey carried out in this research assesses how forest stakeholders perceive the role of their forest management in the context of climate change. The survey covers six European countries – Belgium, Estonia, France, the Netherlands, Portugal and Slovakia –, chosen so as to include practitioners operating in different economic, social, political and cultural structures in Europe. The survey record their observations of climate change impacts, the degree to which climate change is a part of their operational and planning activities and their ability to address related needs.

Overall, the results suggest that European foresters are convinced that climate is changing, that they have personally experienced its consequences and that it may foster further changes in their forests, with more than 30% expressing great concern about the impacts of climate change on their forests. However, although more than 70% of forest owners and managers are convinced that climate change will impact their forest, less than 40% reported modifying their management practices motivated by climate change. In France this figure increases to 50%, in contrast with Portugal where it does not exceed 15%. Interestingly, public managers were more likely to support adaptation actions than forest owners or private managers.

Among the constraints limiting their responses to climate change, lack of knowledge and information emerged as major barriers towards forest adaptation. When asked what assistance they would require to address climate change, a majority of respondents (49%) indicated that policy and financial incentives would make them more likely to undertake adaptation actions, with demands for more information and technical assistance coming third and fourth respectively. When it comes to advice about climate adaptation, foresters said that they largely rely on advice from forest associations (61%). The expert opinion of other forest managers is also highly valued when planning their management decisions.

In general, therefore, it seems that, although progress has been made developing and synthesizing climate change impacts and adaptation knowledge, the implementation of on the ground adaptation actions has not yet occurred to a substantial extent. Furthermore, it is only relatively recently that national adaptation strategies have begun to develop measures by which forestry can adapt to climate change (Keenan 2015).

In this respect, we should bear in mind two considerations. First, that climate hazards have local and regional impacts, and that no recommendations can be made that are applicable to an entire domain (Innes et al. 2009). Indeed, the differences in national forest management systems across Europe are significant. These differences, both among countries and between regions, may partly be explained by the varied forest ownership structures (private vs. public), the need to perform specific tasks, and different political cultures and forest governance traditions (market-based vs. state-centered regulations). Second, that despite these differences, international, national and regional cooperation can facilitate adaptation to climate change impacts through integrated planning and management (Keskitalo 2011). Thus, a common European framework for climate adaptation, accounting for the regional differences in adaptive capacities, is needed to ensure a consistent level of adaptation across Europe while maximizing the effectiveness of action at local and regional levels. In addition, as numerous countries have already developed adaptation strategies and action plans that can be used as learning examples, it is essential to facilitate knowledge sharing on successful climate solutions and best practices.

Further work needs also to be done in strengthening the relationship between scientific research and forest management to ensure that new information is disseminated and understood and that the results of research on forests and climate change are more fully taken into account in forest management decisions.

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Actual and expected climate change: today's forest challenge

Jean-Luc PEYRON, GIP ECOFOR (France)

While the reality of climate change has been established by science, much remains to be done in the field of forestry before its implications are actually taken into account. In particular, there needs to be an understanding of what the said reality encompasses, what consequences it has and how it should be addressed.

Yet climate change leaves us before a gaping uncertainty, with which it is difficult to come to grips, whether from the scientific standpoint or in practice. The Intergovernmental Panel on Climate Change (IPCC) has issued four representative concentration pathways (RCP scenarios[2] 2.6, 4.5, 6.0 and 8.5) reflecting that same uncertainty about the phenomenon's magnitude in the long term. Each scenario, however, leads to a body of future changes in temperature and precipitation depending on the model, first at the planetary level, then at the local level.

This uncertainty also obviously has ramifications on the consequences of climate change for forests. These can be seen first in the forests, their productivity, the risks that threaten them, and the composition and structure of their plant and animal communities. They impact all the ecosystem services and related anthropic services. Forest management needs to be defined with this in mind from as early as today, as the impacts could start to be felt in some areas already, and because it is important to preclude future impacts to the greatest extent possible.

Adaptation to climate change is a necessity for ecosystems, but above all for socio-systems, as is resilience, a concept that neighbours closely on it. While it occurs spontaneously in ecosystems, because of the importance of anticipating future developments, it is most frequently the result of voluntary and planned action for socio-systems. It aims to address multiple challenges, which are not always clearly stated: maintaining timber growth and production capacity, preventing risk, developing a strong capacity to mitigate climate change and, more generally speaking, achieving the continuity that comes with sustainable management. Adjustments in forestry can be made through population composition, structure and density, authorised tree harvesting ages, replacement modes (natural regeneration, planting, assisted migration), continuing and sanitary tracking methods, etc. Adaptation is of import for the scientific communities involved as well (from climatology to the economic, human and social sciences), R&D players, owners and managers, the general public and its representatives. The methods and tools used in adaptation play a crucial part with respect to all these communities, illustrating the challenges at large and solutions possible, as well as facilitating dialogue, interaction and communication.

The Paris Agreement is an important pre-requisite to mitigating climate change. It thus also purportedly facilitates forest adaptation. However, the latter cannot be limited to the scope of the international goals covered by the Agreement (roughly equivalent to the RCP 2.6 Scenario), insofar as the sum of the contributions determined by the States do not yet make it possible to reach the target (they are closer to the RCP 4.5 scenario) and are only intentions. It should thus not make us oblivious to the uncertainties that hang over the future and which need to be measured using all available tools before engaging the future of the forests in the second half of the 21st century and beyond.

[2] RCP: Representative Concentration Pathway

Session 1
What tools to explore the various futures ?

Moderator : Mériem FOURNIER, AgroParisTech

Interactive atlas: Impacts of climate change on tree species distribution in Quebec (Canada)

Catherine PERIE, Ministry of Forests, Wildlife and Parks/Direction of Forest research (Canada)

During the presentation, I will present some results of a study that we began in 2009 to evaluate the impacts of climate change on tree species distribution in Quebec (Canada) and to anticipate how forest stand composition could be vulnerable to climate change in the medium to long term.

Many of the world's forests are likely to face multiple stresses under a rapidly changing climate. Ecological processes as well as plant communities have already been affected. Because of their northern situation, Québec's forest ecosystem could be among those most affected by global warming. New species are expected to find refuge in the province, but some of those now present could become disadvantaged locally by the new climatic conditions, especially in the southernmost part of their current range of distribution. This study uses species distribution modelling to anticipate the effects of climate change on the future potential distribution of tree species located in and around the province of Québec. Results show that overall, the habitat suitability models adequately reproduce the species distributions observed at the end of the 20th century (reference period: 1961‑1990), with a 13% mean error for occurrence for the 120 species included in the study. Future projections (around the year 2100) indicate that 14 of the 49 species present in Quebec at the end of the 20th century could become mis adapted to the new climatic conditions on more than 50% of their range. Some of these, such as jack pine (*Pinus banksiana* Lamb.), white spruce (*Picea glauca* [Moench] Voss), tamarack (Larix *laricina* [Du Roi] K. Koch) and balsam fir (*Abies balsamea* [L.] Mill), are even at risk of a severe decline on more than 20% of their range (i.e., future climatic conditions could become sufficiently adverse to jeopardize their presence on these territories). In most cases, however, given the broad intraspecific genetic diversity of trees, certain individuals are likely to survive, even in territories where future conditions become adverse to their presence. By contrast, other species should be less directly affected by climatic change, since projections indicate that the end‑of‑21st century climate will be at least as favorable to their presence as the end‑of‑20th century climate, on the whole territory they occupied during the reference period. With the exception of Table Mountain pine (*Pinus pungens* Lamb.), these 14 species are all hardwoods which are not currently widespread in Québec, apart from red maple (*Acer rubrum* L.), which is more common. Furthermore, by the end of the 21st century, 41 new species could find environmental conditions in Québec which are favorable to their presence. If all of them were able to become established and to grow in these new territories, the number of tree species in the province could almost double over the next century. However, this number is probably overestimated, since it is unlikely that all these tree species will be able to travel as rapidly as does their favorable climate envelope.

These results should help guide forest managers in the choice of tree species to promote or plant in Québec forests, so as to account for the effects of climate change while implementing ecosystem based forest management.

Evaluating adaptation options to cope with drought episodes under future climate: Contributions from the on line water balance calculation tool Biljou©

Nathalie BRÉDA[1], in collaboration with André GRANIER[1], Vincent BADEAU[1], Damien MAURICE[1] (France)

Seasonal water balance controls interannual variations in radial growth as observed in dendrochronology, since the positive or negative pointer years are in general explained by the relative soil water content. Extreme drought events are pointed out to explain the most of the forest declines recorded in the past. In the context of climate change, climate scenarios for France converge to project anomalies in the seasonal distribution of rainfall and an increase in potential evapotranspiration.

These two pieces of information are not sufficient to assess the risk of a worsening of the drought hazard that forests will have to cope with. Indeed, knowledge of the frequency and intensity of drought episodes is a prerequisite before imagining the options for silvicultural adaptation or choice of species: to what intensity or frequency of drought events a given stand will have to cope with?

Based on a case study in a region that has recently experienced Douglas-fir dieback attributed to severe water deficit episodes, we will illustrate how to use Biljou©, an on-line forest water balance calculation tool, to:

1/ calculate retrospectively the frequency, the precocity and the intensity of the water deficits experienced by a given stand,

2/ evaluate how this water balance would be affected under a future climate,

3/ test whether an incremental adaptation of silviculture through leaf area index adjustment would be sufficient to avoid drought induced Douglas-fir dieback,

4/ test whether hard adaptation options like transformation by species substitution or Douglas-fir relocation on soils with higher extractable water would be an option to reduce the risk of dieback, maintain production and economic return to forest owner.

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Simulation-based decision support for forest management under climate change. An example from Austrian mountain forests.

Manfred J. LEXER, University of Natural Resources and Life Sciences – Institute of silviculture (Austria)

Projecting future forest development and the related provisioning of forest ecosystem services under changing climatic conditions is a prerequisite for informed decision making about forest management. The demand from forest landowners and managers is for specific, place-based decision support. To meet this demands forest managers can run a suitable simulation model on their own or hire a consultant. The former is usually beyond the capabilities of managers due to knowledge and time constraints. But also the consultant option is facing a gap between available tools in the science labs and the application of these tools in practice.

In this contribution we showcase an example from the Austrian Alps where a state-of-the-art forest ecosystem model is used to explore the likely consequences of management alternatives and climate change scenarios for a forest management unit. This contribution specifically focus on (i) a brief introduction of the PICUS ecosystem simulation model and its input requirements and output options, (ii) how simulation runs are initialized with inventory data and information from readily available remote sensing sources, (iii) the co-operative definition of management scenarios together with forest managers, (iv) the 3D landscape visualization of simulated forest development pathways and (iv) the quantitative comparison of management alternatives. Given the large number of available model output attributes crucial issues are the selection, aggregation and communication of simulation results, and deriving sound and practically relevant conclusions. Benefits and limitations of the approach are discussed and conclusions on possible improvements are drawn.

Session 2
How are adaptive tests implemented at the level of management systems?

Moderators : Thierry CAQUET, INRA
& Olivier PICARD, CNPF

Testing tree species adapted to future climates: a test case for adaptive management

Peter BRANG[1], in collaboration with Kathrin STREIT[1] (Switzerland)

The temperature increase predicted by regional climate models is likely to lead to an upslope shift of the vegetation belts by 500-700 m till the end of the 21st century in Switzerland. On a given site, the expected warming is probably coupled with increased summer drought. Forest site associations and tree species composition will be profoundly impacted by those climatic changes. On many sites, tree species which currently grow well may become mal-adapted within about 100 years. They will eventually be replaced by species which are not yet present or which are now performing badly.

Forest managers are accustomed to the business of altering tree species composition. The use of silvicultural tools working towards this goal such as regeneration cuts, enrichment planting and young-growth tending is well established. However, the magnitude of the required tree species shift poses new challenges. A large-scale species replacement is unfeasible in a country where foresters largely rely on natural regeneration. Moreover, planting requires browsing protection and is therefore costly, in particular on steep mountain slopes. Managers therefore try to integrate the species shift in regular silvicultural interventions.

In Switzerland, site-specific species recommendations are based on a vegetation- and soil-based assessment of site factors. We are now in the process of adapting those recommendations to future climates, using statistical modelling of two distinct future climates at the end of the 21st century. This work will be completed at the end of 2017.

What remains unclear is, whether 'future' tree species (those adapted to future climates) can already be introduced, and which factors limit their survival, growth and mortality. Many foresters facing such unanswered questions have started to experiment with 'future' tree species and established small trials, but without sufficient guidance. Therefore, we are starting a research and forest management initiative to establish test plantations of tree species in regions and altitudinal belts where they are currently absent, but likely to become suitable in the future. Two series of trials are envisaged: 1) The first will use a strict experimental design with statistical replication, using local altitudinal gradients. It focuses on 5-10 tree species and a fixed suite of provenances for each species. Surveys of these trials (mortality, growth, diseases) will be conducted using standardized methods. 2) The second series will use less requirements and consist of singular trials with a usually small number of species/provenances out of all species/provenances of potential interest to forest managers. Those trials will be less intensely surveyed and have limited potential of statistical inference, but they will provide trial and error evidence for planting success of a broad range of species/provenances at different sites, and still be suitable for local learning and training. The trials will also include non-native species, e.g. from the Mediterranean area, which may become suitable in Lowland sites. In total, the trials are envisaged to constitute ca. 100 plantations located in all altitudinal belts (colline to subalpine) and covering the most important forest sites and all climatic regions of Switzerland.

The test plantation project has a planned duration of 30 years. In the pilot phase (1,5 years) trials will be designed and decisions regarding species/provenances, replication, test regions and survey parameters will be made. Moreover, test sites will be identified with cantonal forest services. The whole project is planned as a test case for active adaptive forest management in a changing climate (Gregory et al. 2006 Ecol. Applic. 16: 2411-2425), i.e. a management approach which applies different treatments (here: species/provenances), monitors their effects and thus continuously generates new knowledge, reduces uncertainty and contributes to better management decisions.

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Testing new genetic resources for forest adaptation: from pioneer realisations to the building of a national cooperative project

Myriam LEGAY[1] & Cyril VITU[2], in collaboration with Brigitte MUSCH[1] (France)

Due to France's biogeographic position, many of the major essences native to French forests appear under threat from climate change across much of their area. Consequently, in France even more than elsewhere, when considering the topic of adaptation, foresters have dedicated a great deal of attention to identifying new genetic forest resources, whether to migrate origins or species already found across the territory or to bring in new ones.

They face many challenges, however: knowledge about essence response to the climate is far from comprehensive and moreover heterogeneous; in addition, many of foresters' previous attempts have ended in failure. As to assisted migration of origins, while it is often discussed from the theoretical standpoint, the actual implementation conditions remain very infrequently addressed.

We will first present two (of many) precursor projects that have brought thinking on this topic forward, the said thinking now being mature enough to spur the development of a partnership project at the national level.

The first of the projects was developed in the Lorraine Region, through a partnership between *Centre Régional de la Propriété Forestière Grand Est*, and *Office National des Forêts*, with funding from decentralised State agencies. It offered the chance to analyse the vulnerability of forest populations and bring to light two forestry contexts of significance at the regional level, in which the vulnerability of the primary essence and difficulty in identifying potential substitution essences warranted a specific search effort and testing of new resources:

- Hydromorphic oak stands
- Beech stands on limestone plateaus

Once the search for species potentially suited to the pedological conditions and a warmer climate was completed, efforts toward setting up the first experimental site began. We will briefly discuss the outcomes from this undertaking that carried many important lessons.

The second project was initiated by the ONF's Research, Development and Innovation Department. It was inspired by and draws upon the network for forest genetic resource conservation dedicated to major French essences, made up of on-site conservation units spread across national soil with the aim of sampling species' diversity as comprehensively as possible. It includes conservation units located at the edge of distribution range boundaries, potentially home to original and promising resources to adapt the species, but also particularly exposed to climate change. The principle underlying the GIONO project was thus to preserve resources by implanting a copy of the populations at the heart of the distribution range and, at the same time, take advantage of the process to study how new resources perform at the heart of a range compared to local resources, and study their behaviour in the face of climate change.

Thanks to these and other pioneering approaches not described here, French foresters were able to move forward in their thinking on new genetic resources, and can now put forward a broader, shared and consistent project testing new resources to adapt mainland forests to climate change. Involving a wide range of partners (forest managers, research institutes) and stakeholders (private forest growers, forest cooperatives, forest communes, the Forest Health Department, etc.), the approach is coordinated by combined technology network AFORCE. It is divided into three sections.

The first is dedicated to laying down the long-term foundations, building formal structures and equipping the partnership, in particular by negotiating data or metadata sharing agreements, and by setting up IT information-sharing tools.

The second is aimed at maximising the value of the existing heritage, by gaining a greater understanding of the partners' previous experimental heritage, a well as by studying past introduction efforts as part of forest management projects, likely to enable observations on the behaviour of species in various climate conditions. A similar approach had been initiated under the Lorraine project, with surprising results.

The third and final section is focused on designing and setting up a consistent network for new experimentation. The network will be structured with respect to the production systems, over which major adaptation challenges hangs. It will delineate various types of trials.

The international workshop is the opportunity for us to introduce this project to you, gather opinions and avenues for collaboration.

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Assisted Migration in Canada and Tools to help

Dan Mc KENNEY[1], in collaboration with John PEDLAR[1] & Isabelle AUBIN[1] (Canada)

Assisted migration (AM) refers to the human-assisted movement of species to climatically suitable locations outside traditional range limits. Though originally conceived as an approach to conserve biodiversity under climate change – primarily through poleward and upslope translocations of threatened species – the concept has expanded to include a variety of intended outcomes and focal biological units. In this presentation, we outline some of the unique features of AM in the context of commercial forestry operations in Canada, where the focus is on moving populations *within* species range limits in order to establish well-adapted and productive plantations. We briefly describe the evolving approaches to seed transfer policies across the country that are taking place in response to past and projected changes in climate.

We also report on a number of tools that have been developed to support forestry-related AM efforts. For example, Seedwhere is a web application that allows users to visualize the similarity between the climate at a location of interest and the climate across a user-defined study area – thus allowing users to identify climatically compatible seed sources and planting sites. In recent years, a number of extensions have been added to this basic Seedwhere functionality. Provenance data for several commercial tree species have been used to generate universal response functions (URFs), which can, in principle, predict the growth of any seed source at any planting site. These functions have been incorporated into Seedwhere to allow for more refined estimates of seed source growth. Economic parameters have also been added, allowing users to assess the monetary implications of planting decisions under climate change.

Finally, we present new findings from provenance trial data that suggest that cool-origin populations have significant potential for improved growth under climate change while warm-origin populations are likely to exhibit growth declines. We examine how these spatial patterns can be used in regeneration and restoration programs to promote populations that are both local to the planting site and resilient to climate change. Taken together these tools can assist decision-makers consider their options as they address some of the practical challenges associated with Assisted Migration.

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Adapting management of federal lands in the western United States to climate change

Jessica HALOFSKY, University of Washington - School of Environmental and Forest Sciences, (USA), in collaboration with David L. PETERSON

Federal land management agencies in the United States are beginning to incorporate climate change into their management planning and operations. Agency directives have spurred a flurry of climate change-related activity in federal land management agencies over the last few years. From that activity, science-management partnerships have emerged as effective catalysts for development of vulnerability assessments and land management adaptation plans at both the strategic and tactical level.

The U.S. Forest Service administers 78 million ha of land in 155 national forests and 20 national grasslands. Forest Service scientists and land managers are tasked with reducing the effects of climate change on ecosystem function and services. We initiated a series of science-management partnerships to support climate change vulnerability assessments and adaptation on Forest Service and National Park Service lands in mountainous regions of the western United States. A pioneering effort was conducted on Olympic National Forest and Olympic National Park, followed by a larger subregional and regional-scale efforts in the North Cascade Mountains of Washington, the southern Cascades of Oregon, the northern Rocky Mountains, and the Intermountain region, encompassing southern Idaho, Utah and Nevada. Partnership locations spanned a climatic gradient from the maritime climate of coastal Washington State, to the transitional climate of the North Cascade Mountains, to the continental climate of the Intermountain Region. Collectively, these projects included 38 national forests and 29 national parks.

Goals of the adaptation partnerships were to: (1) synthesize published information and data to assess the vulnerability of key resource areas, including water uses, infrastructure, fisheries, wildlife, vegetation, and ecosystem services; and (2) develop science-based adaptation strategies and tactics that will help to mitigate the negative effects of climate change and assist the transition of biological systems to a warmer climate. Scientists from the Forest Service, other federal agencies, and universities provided state-of-science summaries on the effects of climate change on various resources, including hydrology, vegetation, wildlife, fish, recreation, cultural resources, and ecosystem services. Scientists and managers worked together to identify the most important impacts for the region of interest. Then, based on initial vulnerability assessments, adaptation strategies and tactics were developed in a series of hands-on, two-day scientist-manager workshops. Results of both the vulnerability assessments and adaptation workshops were incorporated into peer-reviewed technical reports.

Adaptation strategies to increase ecosystem resilience to climate change were ubiquitous across regions, as were concerns about high-elevation flora and fauna. However, the focus on fire and insects as agents of change with warming climate increased in regions with more continental climate, specifically regions that are in the rain shadow of the Cascade and Rocky Mountains. For those regions, adaptation strategies and tactics were mostly focused on decreasing forest density to increase drought resilience and decrease the severity of fire and insect attacks.

Potential changes in hydrology with warming climate were also of major concern to resource managers. Snowpack is declining in the western U.S. and will continue to do so, leading to higher peak streamflows, flooding, and erosion in winter. Decreased snowpack will also result in lower streamflows and higher stream temperatures in summer. Higher stream temperatures will increase stress for salmonid species that require cold-water habitats, and thermally-sensitive fish species will likely be extirpated from lower elevation streams. Removing barriers to fish passage and restoring/protecting riparian vegetation to provide shade to streams were common adaptation strategies.

Overall, these efforts illustrated the utility of science-management partnerships in facilitating adaption to climate change. The partnerships have persisted through time, even beyond the end of the original projects, because of the effort that went into establishing relationships and providing information that can be directly applied to management. Resource managers and leadership in national forests and other lands where projects were conducted consistently cite the value of the projects in providing a new context for resource management and in enhancing "climate-smart" thinking. However, implementation of information derived from climate change vulnerability assessments in national forest and national park resource assessments and monitoring is just beginning. More time may be needed for the climate change context of resource management to be incorporated as a standard component of agency operations. We anticipate that evaluating climate change risks concurrently with other risks to resources will become standard practice over time.

Forest Water Balance: a practical guide

Sophie BERTIN[1] et Philippe BALANDIER[2], in collaboration with Céline PERRIER[3] (France)

Since the seventies, many forest stands have suffered from severe water stress coming from recurrent droughts under accentuated hot extremes. For standing stands, the question arises whether silvicultural practices could help to reduce the constraints endured by standing trees. In particular could the practitioners improve the stand water balance by adequate management? A group coordinated by the RMT AFORCE and consisting of practitioners and researchers addressed this issue.

First, the questions arising from practitioners and related to water management in standing stands have been inventoried. Second, a state-of-the-art has been made by researchers on that particular topic: what is known, unknow, or still in debate? Third, potential implications for forest management have been made based on existing scientific knowledge and were related to the inventoried questions.

The process was iterative with numerous exchanges between practitioners and researchers until a consensus was found. Fourth, a practical guide for forest practitioners has been edited, which gathers the scientific knowledge in 10 chapters, and potential implications for management in 10 other chapters.

This book is definitely not a compilation of ready-to-use silvicultural guidelines. Indeed recommendations are too much site- and stand-dependent to allow generating general silvicultural prescriptions. Instead, the reader is encouraged to cross different types of questions and related scientific knowledge to build up its own forest management strategy that will be adapted and applied to its local forest situations.

This approach is key to adapt to a potential water shortage in the near future. However, this book only addresses water issues and the reader’s final management strategy should be a compromise between different constraints and objectives. As a complement to this paper guide, an interactive website will be available soon on AFORCE website: http://www.reseau-aforce.fr/.

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Does uneven-aged silviculture better prepare forests to global change than even-aged silviculture?

Philippe NOLET, University of Québec in Outaouais UQO-ISFORT (Canada), in collaboration with Dan KNEESHAW, Christian MESSIER, Martin BELAND

With the increasing demand for wood products and with the various threats related to global change, forests are undoubtedly under pressure. Forest managers must therefore ensure that their practices fulfill this ever-growing demand while preparing forests to these threats. Worldwide, forests are managed by one of two broad approaches – even- and uneven-aged silviculture.

Despite the lack of a thorough literature comparison of the ecological effects of these two approaches, there is a general belief that uneven-aged silviculture better maintains biodiversity and key ecological processes and hence, would better prepare forests to face global change.

We reviewed more than 70 papers worldwide to compare the two approaches regarding their effects on species/structural diversity and processes. Although both silvicultural approaches affect these elements differently, we found that uneven-aged silviculture shows no clear advantage over even-aged silviculture in terms of maintaining biological diversity and processes. We call for taking advantage of the contrasting conditions triggered by even- and uneven-aged silviculture – through active adaptive management - to increase our knowledge of forest ecosystems and of the most appropriate strategies to face the forthcoming global change challenges.

Transferring climate change research into forest management – examples from Southwest Germany

Axel ALBRECHT, Forest Research Institute Baden-Wurttemberg (Germany)

In a first section, the scientific approach to climate change research for the forests of Southwestern Germany will be briefly presented. The approach mainly consists of making two ecologically important criteria of a tree species' suitability dynamic in terms of climate change: 1) The stability criterion of a tree species comprises altered levels of disturbance-based mortality, including storm risk, drought, and different biotic agents as well as changing probabilities of occurrence expressed by species distribution modeling. 2) The productive potential of a tree species as expressed by natural (i.e. site index, Nothdurft et al. 2012; Yue et al. 2016) and economic productivity (Hanewinkel et al. 2012) is modeled in a dynamic way as a function of climate change.

A first outcome of these modeling efforts are **suitability maps** (Hanewinkel et al. 2010; Hanewinkel et al. 2014): In combination with other, more static suitability criteria, a tree species' multi-criterial suitability is mapped and used as a basis for long-term forest planning, especially concerning the choice of tree species.

A second outcome of the different modeling tasks are **vulnerability maps**: expressing mostly the climate-change-sensitive risk aspects of today's existing stands, the short- and mid-term forest planning perspectives are addressed by identifying the most vulnerable stands existing today which have to be adapted and converted with a high priority.

Secondly, based on these scientific findings, the most relevant forest adaptation measures which are currently already being implemented will be presented. These forestry-specific measures are part of a trans-sectoral adaptation strategy of the state of Baden-Wurttemberg (Ministerium für Umwelt Klima und Energiewirtschaft Baden-Württemberg 2015) and include measures for both practical silviculture and research. Examples of such measures are promoting diversified forests, developing site- and climate-sensitive growth models, reducing target dimensions of stands, soil-stabilizing measures, efforts to take into account biome shift for conservation planning and important tasks concerning the transfer of the knowledge and education about climate change and adaptation potential.

The bundle of **silvicultural adaptation measures** begins with the regeneration phase of forest stands: a strong priority should be given to naturally regenerating forests due to the advantages of in situ germination for stability of young plants. However, where seed-trees of climate-adapted species are not present, introduction of adapted species by plantation will be inevitable. During the tending and precommercial thinning phases early interventions should ensure an appropriate species diversity of adapted species. Besides potentially positive effects of growth complementarity in species mixtures (Forrester et al. 2013; Forrester and Albrecht 2014; Forrester et al. 2014), diverse species sets allow diverting those mortality risks which may be mono-specific. During the thinning phase, improved mechanical individual tree stability should be improved by releasing those trees which are most likely to remain in the stands for the longest time. This measure improves rooting and water supply as well as storm resistance. Enhancing structural diversity is an effective measure to increase the vitality and increment under certain environmental conditions (Dănescu et al. 2016), and will improve the forests resilience in general by allowing advance regeneration. Improving the structural diversity within stands may thus have several advantageous effects for the adaptation to climate change. Last, reducing the target dimensions of tree species especially vulnerable under climate change is an overproportionally effective means of reducing potential damage. Specifically, this measure relates to species with high storm risk (Norway spruce, Silver fir, Douglas fir) and high risk of bark beetle damage (Norway spruce) and can be achieved by lowering target diameters or rotation ages of those species on especially vulnerable sites (Albrecht et al. 2015). This measure also enables the forest manager to convert forests more quickly to more climate-adapted species compositions and structures.

Lastly, an outlook will be presented discussing uncertainties of future projections, no-regret strategies and possible future focus of research activities, such as evaluating the suitability of new candidate tree species and provenances.

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Project LIFE11 ENV / IT / 000215 ResilForMed: defining monitoring protocols and silvicultural management models to improve the resilience of sicilian forests to climate change

Marcello MIOZZO, DREAM Italia (Italy)

The European Commission funded a project in 2012, still under implementation, in the region of Sicily, Italy, with the objective to improve the regional forest policies with the best management models to increase the resilience of forests to the effects of climate change.

Sicily Region has a forest area index significantly lower than the rest of Italy and its geographical location makes it extremely sensitive and prone to desertification.

ResilForMed project is co-funded by the LIFE+ Initiative (2007-2014) and started June 1st 2012 with an expected conclusion on June 30th 2017. The project consortium involves: Sicily Region, specifically the Department of Environment, Agriculture and Forestry, The University of Palermo, with the Department of Forestry and Agronomy and DEAM Italia.

The key results of the project are:

- the vulnerability map of Sicilian forests to desertification: the map was obtained overlaying the desertification map (regularly updated by the Forest Information System of the Region) and the regional forest map. The final vulnerability map points out 7 vulnerability classes with 3 critical thresholds and has a scale of 1:10,000
- the analysis of forest parameters to identify those thresholds corresponding to the minimum areas to be treated by silvicultural interventions: starting from the zoning of regional forests we identified 6 sample areas of more than 4,000 hectares each. The selected forests are located in the geographical areas of Sicani Mountains, Madonie Mountians, Nebrodi Mountains, Etna, Mont Calatino and finally Big Mountain in the island of Pantelleria. A diachronic analysis for photo-interpretation between 1955 and 2013 was carried out for the whole areas. The forests that were invariant for that period were analyzed using 200 sample plots on the ground, using 10 forest categories common in the Region. The analysis brought us to define the minimum thresholds of dendrometric parameters in order to ensure, in case of silvicultural intervention, a stable ecosystem condition
- the development of ornithological indicators for the evaluation of forest ecosystem quality: this is a protocol for extensive monitoring of forest landscape systems that is based on ornithological indicators, individual species or groups of species or specific diversity indices (37 indicators defined). After two series of ornithological sampling, one from vulnerable forests and the other from stable forests, 21 meaningful indicators were chosen to evaluate the positive or negative evolution of ecosystem quality versus the risk of desertification
- definition of 5 good management practices with 16 different types of practical interventions: the 5 best practices are developed into guidelines that are currently being published in Italian and English
- the realization of 16 types of intervention on 100 hectares of sample forests as a 'showcase'
- the development of 6 Pilot Forest Plans with participatory approach for the actual implementation of a resilience based forest management: a total of 2,500 hectares of public forest lands have been managed with methodologies developed by ResilForMed project
- training of the regional forest service personnel, seminars and info days for key regional stakeholders, with the involvement of a total of 700 people

- the transfer of project results into the new Regional Forest Plan is the most important and straightforward action currently under implementation. The monitoring protocols and approaches, the guidelines and planning methods defined by the project will became part of the Regional Forest Plan.

REINFFORCE: An Atlantic demonstration site network for research on forest adaptation to climate change.

Rebeca CORDERO, EFIATLANTIC (France)

Climate change does not only mean increase in temperature and in GHG concentration, but also change in water regimes, in wind regimes and increase of extreme events such as droughts, storms and temperature extremes.

Consequences for trees can be extremely damaging, they can induce mortality, growth loss and wood quality deterioration. Pests and diseases can take advantage of the new climate by extending their areas and making the most of the weakened stressed trees. They can also change their life cycle due to more favourable weather conditions and in some cases; they can even switch from an endemic status to an epidemic one. Foresters cannot only focus on what was working in the past to know what will work in the future. The forester needs to obtain an accurate knowledge of the tree's capacity to cope with future climate characteristics, and anticipate the best management for future changes related to climate change.

Scientists address climate change adaptation and impact on forests using existing trials and knowledge; they use different approaches such as the analysis of historical series, the analysis in climatic chambers, and the climatic envelopes and actual repartition. So even if the methods listed are of high interest for climate change analysis, it seemed essential to design a research infrastructure dedicated to climate change and tackling these criticisms.

The forest managers have access to literature and scientific results from simulation scenarios and modelling. They are aware of the potential climate change impacts on forests, and they are expecting help from science to manage their forests. Thus, certain questions need to be answered. Firstly, will current forest stands be able to adapt to the increase in temperature; secondly, will the precipitation patterns change as predicted by the climate models; thirdly, will there be an increase in extreme weather events; finally, how do we anticipate and manage the consequences of changes in insect population or fire frequency within the forest?

REINFFORCE will make an important contribution towards answering these questions through the Demonstration site network; its main aim is to test and demonstrate the efficiency of different adaptive management techniques.

In order to choose the type of risks and the alternative management techniques tested, a scientific literature review allowed to draw the main threats that can affect the forest under changing climates; finally the best alternative management techniques were proposed. These techniques were installed in forty-one sites especially designed for the network (e.g. climatic exposed areas); using also weather control to link the observed differences to the climate suffered by the stands (beside each site there is business as usual trial for comparing results).

The adaptive management options implemented in this REINFFORCE network are several:

-site preparation (e.g. different types of ploughing to see the impact on the rooting; it will contribute mainly to improve stability),

-density management strategy to reduce the competition between trees, and to see if when water becomes scarce this can can avoid dieback or growth loss (this strategy assumes that the under-storey is controlled, and is similar to the under-storey management strategies),

-edges management which plays a role in avoiding insect spray, making a reserve of predators and chemical masking; they can also play a role in increasing the resilience to some abiotic risks such as wind and fire,

-stand structure and the stand composition; the assumption is that all species of a mixture or all trees of different sizes/ages will not be affected in the same way in case of adverse conditions due to climate change,

-drought, soil water capacity improvement is tested, (e.g. by spreading charcoal).

For all Demonstration Sites, the axes of work and the management options were defined jointly, based on regional studies on the expected effects of climate change, and their possible consequences on the main production species. However, each site shows individual characteristics and they are managed differently with its own unique local-regional issues and opportunities.

All data collected from these trials can be upload into the FORESTRIALS harmonised database, coordinated by EFIATLANTIC and share between the network partners.

Some of the demonstration trials are decision support oriented. They offer opportunities to see in practice, on-site, how to apply some of the theories on adaptive management. As the effect of some of these measures are highly uncertain, only the long-term monitoring or the data collection after extreme events will provide relevant information to make recommendations. Nevertheless, the innovation brought by REINFFORCE also lies in this European-wide network architecture, which provides a solid basis for a more integrated approach to forest risk management.

In search of robustness: modelling a portefolio of forest stand responses to different silvicultural treatments under global change threats.

Frédérik DOYON, Université du Québec en Outaouais UQO-ISFORT (Canada), in collaboration with Ph. NOLET, P. DONOSO, Ch. MESSIER

Forests are faced with increasing social, economic and environmental pressure from a growing human population. As significant transformations of ecosystems are to be expected, many goods and services that humans derive from forests may no longer be maintained.

With this presentation, we demonstrate that silviculture can be a positive and efficient tool to reduce the vulnerability of forests to global change if adaptation goals are explicitly integrated with other production and protection objectives. We propose a silvicultural approach based on the identification of a portfolio of silvicultural options in order to increase the adaptability of forest ecosystems to global change factors. This portfolio is made up of alternatives seeking to improve the resistance and resilience of the forest or to facilitate the transition toward a more adapted state in regards of different potential threats.

An example from real stands in Quebec (Canada) threatened by climate change, the increase of drought intensity and frequency, the beech bark disease, the beech understory invasion and windthrow disturbances is presented. Monte-Carlo simulations from stand-level modeling is used to assess treatment alternatives from the point of view of their robustness in continuing to provide the expected ecosystem services under such pulse and push disturbances (sensu Millar & Stephenson 2015). These examples force us to revisit certain foundations of silviculture from a new angle and question ways silviculture has been done traditionally.

Session 3

How to encourage changes in practices and to ensure their monitoring?

Moderators : Guy LANDMANN, GIP ECOFOR
& Céline PERRIER, CNPF

Bringing Science into Practice - experiences from guidance on integrated forest management applied to carrying climate change intelligence into practice

Marcus LINDNER, EFI international (Finland)

Our understanding of forest ecosystem responses to climate change is improving, but considerable uncertainties remain. Even if the magnitude of climate warming can be limited, it is likely that climate variability and extreme events, as well as natural disturbances (e.g. storms, forest fires and insect outbreaks) will affect forest resilience in unprecedented ways. All this necessitates changes in traditional forest management practices. Adaptive forest management will therefore become a key requirement for sustainable forest management. How to adapt forest management to the changes in climate, extreme events, and disturbance regimes? How to communicate often complex scientific knowledge to practice? There is clearly a need for improved evidence-based decision support for climate change adaptation in forests. Various options how forest management could support adaptation to climate change have been identified. The implementation of climate change adaptation, however, still lacks sufficient ‘climate intelligence’ in forest management decision making processes (Keenan, 2015, Annals of Forest Science 72(2)).

What can we learn from recent experiences in the INTEGRATE+ project on bringing scientific understanding on integrated forest management to practice in the forest? This presentation will illustrate how scientific information related to management effects on biodiversity values and economic values was carried into the forest to guide practical forest management decision making. We will then draw some lessons from this experience and outline planned work in the new Resilience Programme of the European Forest Institute to develop improved climate intelligence for adaptive forest management that relies on (i) knowledge on past and future climate conditions including climate variability, extreme events and changing disturbance risks, (ii) understanding changing species suitability and susceptibility to disturbance risks, (iii) assessing forest resilience and understanding how it can be supported, and (iv) knowledge on adaptation strategies tailored to the local forest conditions. An important element in this work will be to share and exchange experiences across regions in Europe. All this will contribute to improved evidence-based decision support on resilience and climate change adaptation in European forests, to build more bridges from science to policy and practice.

Real-World Forest Adaptation: tools, examples, and lessons from the Northeastern United States

Christopher SWANSTON, USDA Forest Service - Northern Research Station (USA)

The creation of climate information and tools for natural resource managers has sharply increased in recent years with the intention of better enabling climate change adaptation. This investment is useful, but can become even more effective with greater sensitivity to and interaction with stakeholder values and goals. The Climate Change Response Framework (CCRF; www.forestadaptation.org) spans the upper Midwest and Northeast of the United States, and was launched in 2009 to help people meet their land stewardship goals while minimizing climate risk. The emphasis of the CCRF on stewardship goals represents a subtile but important shift in focus to people and their values, as opposed to climate change and its effects.

Prior to the creation of the CCRF, we spent a year engaging in climate change education, scoping activities, and discussion with resource managers, who identified four key challenges to intentionally pursuing climate adaptation: 1. Climate change is too big and complex; 2. Climate research is not relevant enough; 3. One-size-fits-all answers are insufficient; and, 4. There are not enough real-world examples. The CCRF community set about addressing these challenges by increasing capacity through effective *partnerships*, creating collaborative *vulnerability assessments* for resource managers, creating flexible *forest adaptation resources*, and supporting *adaptation demonstrations*.

The Climate Change Response Framework now is being actively pursued in 19 states in the upper Midwest and Northeast. It has involved thousands of people and over 125 organizations, and published six ecoregional vulnerability assessments with more than 130 authors. The CCRF developed a climate planning tool, the Adaptation Workbook (www.adaptationworkbook.org), for use along with ecosystem vulnerability assessments and a diverse "menu" of adaptation strategies to generate site-specific adaptation actions that meet the explicit conservation objectives of the landowner or resource manager. These tools have been integrated into an Adaptation Planning and Practices workshop that leads organizations through this structured process of designing adaptation tactics for their projects and plans. This approach has generated more than 200 intentional adaptation demonstrations in real-world land management projects on federal, state, tribal, county, conservancy, and private lands. In each case, landowners and resource managers pursued adaptation actions that reflected their own values, needs, constraints, and opportunities.

This presentation will consider lessons learned in moving from information to implementation with diverse stakeholders across a diverse landscape.

Climate change and forests - strategies for the adequacy of communications

Kristina BLENNOW, Université suédoise des Sciences agricoles, Alnarp (Sweden)

Land owners´ use of the land and how they respond to climate change is crucially important for the climate as well as for the supply of goods and other ecosystem services, the benefits of which people often assign value to. Approximately 50% of Europe's forest land is privately owned (Pulla et al. 2013). Hence the joint climate change response depends on the decisions by a large number of individuals (e.g. Blennow et al. 2014a). Because the success of their decisions depends on the information on which they are based, effective communication is critically important.

Although preferences and perceptions in relation to land-use differ between groups of people, the public is seldom allowed to influence land-use planning. The opinion of the public is, however, important to consider for reasons of democracy and sustainability (Pappila and Pölönen 2012). Arguably, the sustainability of a democratic society depends on its ability to create these conditions. In this respect, "Landscape approaches" have provided substantial progress in overcoming insufficient sectoral approaches to addressing social, environmental and political challenges (e.g. Sayer et al. 2013). To communicate effectively, rather than relying too much on collective means such as focus groups, even more attention on the individual decision-making agent is needed (e.g. Merton 1987).

Communication works in two ways. Hence, evidence in terms of expert knowledge as well as information on the needs of the other communication participant needs to be taken into account for communications to be effective. The gap between “what decision-making agents know” and “what they need to know”, sensu Fischhoff (2013), needs to be identified for effective communication to occur. This refers to any decision-maker; forest-owner, resident, advisor or policy-maker alike.

Management decisions critically depend on the decision-making agents’ perceptions of risk (e.g. Slovic 1999; Blennow et al. 2014b). Perceptions of climate change risk differ across Europe. For instance, it is less strong among Swedish private forest owners than among other members of the Swedish public (Blennow and Persson 2009), and much weaker than among private forest owners in Germany (Blennow et al. 2012). How come? Explanations based in cultural cognition thinking have gained popularity in recent years (Kahan et al. 2012). It proposes that individuals with the highest degrees of science literacy and technical reasoning capacity do not necessarily have the highest adaptive capacity because of value-driven polarization (Kahan et al. 2012). A recent study on forest owners' response to climate change, however, shows that the explanatory power of university education by far trumps value profile and that cultural cognition thinking has limited explanatory power (Blennow et al. 2016). Also other factors than education play a role. Individual decision-making agents may use various decision strategies in their decision making. For example, the availability effect implies that what easily comes to mind, such as a recent experience, may strongly influence a decision (e.g. Tversky and Kahneman 1973; Blennow et al. 2012).

How can this help us communicate, plan and formulate effective policies on climate change and forests more effectively? Blennow et al. (2014b) proposed a framework of what is needed: information on the beliefs and desires of all parties, knowledge of decision strategies, situations characterized by openness to promote learning, avoid taking knowledge risk, and consider the distribution of risk and benefit.

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How can multi-agent models provide lessons on the processes of change of practices: example in Sweden

Dr Victor BLANCO, University of Edinburgh (UK), in collaboration with C. BROWN, S. HOLZHAUER, F.LAGREGREN, G. VULTURIUS, M. LINDESKOG & M. ROUNSEVELL

The effects that climatic change and changing demands for ecosystem services will have on the distribution of forests and their levels of service provision are somewhat uncertain. Despite this uncertainty, adaptation is necessary to cope with or take advantage of the effects of climate change on the forestry sector. Relatively little is known about how successful adaptive decisions are likely to be in meeting demands for ecosystem services in an uncertain future.

We explore adaptation to climate and global change in the forestry sector using CRAFTY-Sweden; an agent-based model (ABM) that represents large-scale land-use dynamics, based on the demand and supply of ecosystem services. Services are supplied on the basis of land owner objectives, management preferences and other behavioural traits, as they compete for land under changing environmental conditions. The Swedish forestry sector was chosen as a case study because of its socio-economic importance and its sensitivity to climatic and global change. Future impacts and adaptation within this sector were simulated for scenarios of socio-economic change (Shared Socio-economic Pathways) and climatic change (Representative Concentration Pathways, for three climate models), between 2010 and 2100.

This talk will present the model and simulation results to reveal how ABMs can inform a process of change of practice. Furthermore, some differences and complementarities between such models and more traditional social sciences approaches will be discussed.

Canada's Forest Change program and tools to support for adaptation

Dan Mc KENNEY[1], in collaboration with J. PEDLAR[1] & I. AUBIN[1] (Canada)

The Canadian Forest Service (CFS, Natural Resources Canada) has been building a national framework to integrate existing and new scientific information in order to enable more integrated assessments of the implications of climate change for Canada's forest sector. The Forest Change initiative[1] includes developing a set of indicators of climate change impacts on forests and the forest sector, implementing a system to track and report on them and developing a toolkit of relevant, useful and actionable information and tools to inform operational, strategic and policy decisions.

In this talk, we will provide a brief description of some of the tools now available and aspirations for the next phase of the program. Examples include spatial climate models that cover all of North America, representing long-term averages, historical monthly and daily models as well as interpolations of future climate scenarios. Approximately 600,000 layers of variables relevant to climate impact and adaptation studies are available and have been used in a wide variety of studies[2].

Another important tool is Canada's Plant Hardiness web site, which includes climate habitat models (including future projections) for ~3000 species[3]. A similar effort is well underway on forest insects and diseases, with models available for some 1500 species. In addition, species-specific sensitivity and adaptive capacity were characterized using a trait-based approach and used to inform forest management strategies. This knowledge was also integrated with biophysical predictions to generate maps to communicate specific risks due to a changing climate (e.g. vulnerability to drought).

[1] http://www.nrcan.gc.ca/forests/climate-change/forest-change/17768
[2] http://cfs.nrcan.gc.ca/projects/3
[3] http://planthardiness.gc.ca

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Networking for risk and crisis management on regional an international level

Yvonne CHTIOUI, Forest Research Institute Baden-Wurttemberg (Germany)

KoNeKKTiW[3] is a government-financed project of the "forest climate fund". It is a cooperative of private, communal and public forest owner organizations in Germany and Austria that aims to support the forestry sector to adapt forest ecosystems and enterprises to changing climate conditions.

The network as a regional initiative is also part and role model of a so called "European Forest Risk Facility", a project carried out by EFICENT. KoNeKKTiW performs capacity building, social learning and proactive risk management to reclaim existing knowledge and make it suitable for implementation into practice. Its structure and function will be presented to enhance the establishment of a European cooperation.

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[3] KoNeKKTiW: Competence Network Climate Change, Risk Management and Transformation in Forest Ecosystems

Co-organizers and funders