AFORCE
RMT Adaptation des forêts au changement climatique

Institut des Sciences de la Forêt tempérée

# AFORCE INTERNATIONAL WORKSHOP 2017

## The forest and climate change: adaptation initiatives and new management practices

## Workshop Proceedings

*Source: Mr. DRIEU and Mr. IMMER, students of the school of Mirecourt*

*8 and 9 March 2017, at the École Nationale Supérieure d'architecture of Nancy (France)*

Foresters have become fully aware of the need to respond quickly and in a concerted manner to climate change. Initially interested in better understanding the processes at work, foresters began by studying the impacts of climate change: those already perceptible and those to be considered according to different scenarios of climate change and society. Initial findings highlighted the need to improve knowledge of how trees and settlements function, to set up observation sites and to develop diagnostic tools to characterise their current status and potential vulnerability. Some of these tools were presented at a first international workshop organised in 2014 by the RMT AFORCE. It was devoted to global adaptation strategies and action plans put in place in different countries to deal with climate change.

The RMT AFORCE and the Institute of Sciences of the Temperate Forest (ISFORT) of the University of Quebec in Outaouais wished in 2017 to focus on the new practices and concrete measures of adaptation, from their elaboration until their implementation. To this end, it organised on 8 and 9 March 2017, in collaboration with AgroParisTech, the CNPF, EFIATLANTIC, INRA, the GIP ECOFOR, the ONF, the OURANOS consortium and the Canadian Forest Service a new international workshop on the topic "The forest and climate change: adaptation initiatives and new management practices".

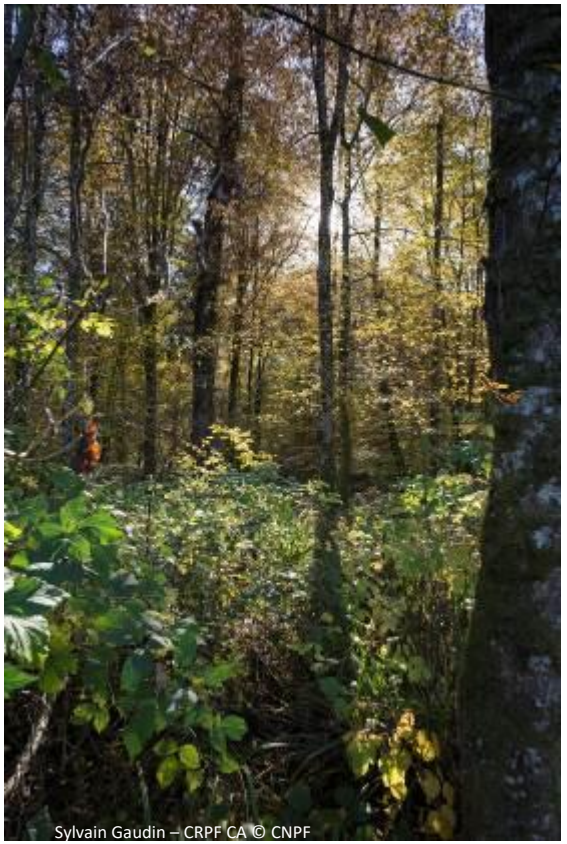
The **main objectives** of the workshop were:

• **to share experiences of support with the changes**: how is the advice elaborated, the recommendations of action? What projection tools does it use to explore the future evolution of the forest? How to best support their dissemination? Where are we applying them? What is the incentive to change practices? How to evaluate the success of the support measures implemented?

• **to present existing initiatives of new practices put in place by managers** of forests that are vulnerable or likely to become so: how are these adaptation actions implemented at the level of management systems? Do the actions taken respond to the issue? Do they join a network or are they isolated? Are they based on a diagnosis? Has monitoring been put in place?

The event brought together a diverse audience of researchers in applied research, development officers, forestry consultants, teachers, trainers and policy makers who are involved in forest issues.

The exchanges from these days were recorded in summary form in this document with the help of the students of the EPLEFPA of Mirecourt (France), under the direction of Jean-Michel ESCURAT, and students of AgroParisTech (France), under the direction of Mériem FOURNIER. We thank them for their active participation in this event.


Sylvain Gaudin – CRPF CA © CNPF

# Workshop programme

## *DAY 1 - Wednesday 8 March 2017*

**1pm** — **Coffee reception**

**1:30pm** — **Introduction**
*Olivier PICARD, CNPF-IDF and coordinator of the RMT AFORCE (France)*
*Frédérik DOYON, University of Quebec in Outaouais UQO-ISFORT (Canada)*

**Supporting the adaptation of forests to climate change: a cross-check of French and Quebec approaches.**
*Olivier PICARD, CNPF-IDF and coordinator of RMT AFORCE (France), Myriam LEGAY, ONF (France), Frédérik DOYON, University of Quebec in Outaouais UQO-ISFORT (Canada) and Céline PERRIER, CNPF and facilitator of RMT AFORCE (France) , in collaboration with Clément CHION*

**"A line made by walking": adaptation to climate change in forest silviculture across Europe**
*Rita SOUSA-SILVA, University of Louvain (Belgium), in collaboration with Bruno VERBIST, Quentin PONETTE, Kris VERHEYEN, Bart MUYS*

**Predicted and expected climate change: today's forestry challenge**
*Jean-Luc PEYRON, GIP ECOFOR (France)*

**2:45pm** — **SESSION 1 - Which instruments for exploring possible futures?**
Moderators: Mériem FOURNIER, AgroParisTech

**▶Interactive Atlas: Impacts of Climate Change on the Distribution of Tree Species in Quebec (Canada)**
*Catherine PERIE, Ministry of Forests, Wildlife and Parks/ Forest Research Management (Canada)*

**▶Evaluate adaptation options for drought in a future climate:**
**contributions of the online water balance calculation tool Biljou©**
*Nathalie BRÉDA INRA (France), in collaboration with André GRANIER, Vincent BADEAU, Damien MAURICE*

**▶Applying simulations to guide forest management decisions in the context of climate change: an example from Austria's mountain forests.**
*Manfred J. LEXER, University of Natural Sciences and Life Sciences (Austria)*

**4:30pm** — **Close DAY 1**

**6pm** — **Cocktails**

## *DAY 2 - Thursday 9 March 2017*

**8pm** — **Coffee reception**

**8:30pm** — **SESSION 2 - How is the implementation of adaptation tests carried out at management system level?**
Moderators: Thierry CAQUET, INRA & Olivier PICARD, CNPF

**Choosing the species to plant**

**▶Evaluating species adapted to future climates: a case study for adaptive management**
*Peter BRANG, Federal Institute for Forest, Snow and Landscape Research WSL (Switzerland), in collaboration with Kathrin STREIT*

**▶Evaluation of new forest genetic resources for adaptation: From precursor projects to setting up a national organisation**

*Myriam LEGAY, ONF and Cyril VITU, CRPF Grand Est (France), in collaboration with Brigitte MUSCH*

**►Assisted Migration in Canada and Tools to Help Implement it**

*Dan Mc KENNEY, Natural Resources Canada, Canadian Forestry Service (Canada), in collaboration with J. PEDLAR and I. AUBIN*

## Towards new silviculture

**►Adaptation of Federal Land Management to Climate Change in the Western United States**

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

**►Water balance of forests: a practical guide**

*Sophie BERTIN, EKOLOG & Philippe BALANDIER, IRSTEA (France)*

**►Does irregular silviculture better prepare forests for global change than regular silviculture?**

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

**10:40pm** **Break**

**►Transfer of Climate Change Research Results to Forest Management - Examples in Southwest Germany**

*Axel ALBRECHT, Forest Research Institute of Baden-Württemberg (Germany)*

**►ResilForMed project: defining protocols for monitoring and silvicultural management models to improve the resilience of Sicilian forests to climate change**

*Marcello MIOZZO, DREAM Italia (Italy)*

**►REINFFORCE: a network of pilot sites on the Atlantic Arc dedicated to research on the adaptation of forests to climate change**

*Rebeca CORDERO, EFIATLANTIC (France)*

**►In search of robustness: modelling a portfolio of forest settlement responses in different silvicultural scenarios, in the context of threats of global change.**

*Frédérik DOYON, University of Quebec in Outaouais UQO-ISFORT (Canada), in collaboration with Ph. NOLET, P. DONOSO, Ch. MESSIER*

**12:30pm** **MEAL**

## SESSION 3 - How to encourage and monitor changes in practice?

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

**►Moving from Science to Practice: Transposing Experiences from Integrated Forest Management Guidelines into Practical Knowledge of Climate Change in Management**

*Marcus LINDNER, EFI international (Finland)*

**► Adapting Forests in the current context: tools, examples and lessons from the North East of the United States**

*Christopher SWANSTON, USDA Forest Service - Northern Research Station (United States)*

**► Climate change and forests: strategies for ensuring appropriate communication**

*Kristina BLENNOW, Swedish University of Agricultural Sciences, Alnarp (Sweden)*

**► What lessons can multi-agent models bring to change in practice processes? Example in Sweden**

*Dr. Victor BLANCO, University of Edinburgh (United Kingdom), in collaboration with Calum BROWN, Sascha HOLZHAUER, Fredrik LAGREGREN, Gregor VULTURIUS, Mats LINDESKOG, Mark ROUNSEVELL*

► **The Canadian Forest Change Programme and tools to support adaptation**
*Dan Mc KENNEY, Natural Resources Canada, Canadian Forestry Service (Canada), in collaboration with J. PEDLAR and I. AUBIN*

► **Networking for regional and international risk and crisis management**
*Yvonne CHTIOUI, Forest Research Institute of Baden-Württemberg (Germany)*

►**What management decisions to be made for the mountain pine forest in the face of climate change?**
*Aurélien BARTHELEMY, Forest Experts of France (France), in collaboration with Ph. GOURMAIN*

**Training by the students of AgroParisTech and the EPLEFPA of Mirecourt**
*Under the supervision of Mériem FOURNIER, AgroParisTech and Jean-Michel ESCURAT, EPLEFPA of Mirecourt (France)*

**Conclusion**
*Eric BATAILLE, Ministry of Agriculture, Agro-food and Forestry (France)*

**5pm** **Close DAY 2**

# INTRODUCTION

Moderator: Mériem FOURNIER, AgroParisTech

## ►Supporting the adaptation of forests to climate change: a cross-check of French and Quebec approaches.

*Olivier PICARD, CNPF-IDF and coordinator of RMT AFORCE (France), Myriam LEGAY, ONF (France), Frédérik DOYON, University of Quebec in Outaouais UQO-ISFORT (Canada) and Céline PERRIER, CNPF-IDF and facilitator of RMT AFORCE ( France), in collaboration with Clément CHION, University of Quebec in Outaouais UQO-ISFORT (Canada)*

Frédérik DOYON presents the ISFORT (Institute of Temperate Forest Science) located in the Outaouais, in Quebec. Focusing on the issues surrounding the forest ecosystem and the communities that depend on it, with the central issue of adaptation to climate change. The institute is composed of a dozen research professors and about thirty students.

Céline PERRIER presents the RMT AFORCE, a mixed technology network dedicated to the adaptation of forests to climate change. It is a French national network that brings together 15 research partners, management bodies, educational institutions, and other partners who make their services available, such as Météo-France. The aim is to support foresters in their choices to cope with climate change and to accelerate the transfer of knowledge. The network therefore organises many events such as this workshop and funds projects whose objective is to provide knowledge and decision support for developers and, where possible (advanced knowledge), decision support tools for managers.

**How did this idea of collaboration between France and Quebec emerge?**

Frédérik's motivations for working with AFORCE came after observing at AFORCE's 2014 international workshop how different technologies were in different countries on this issue of adapting forests to climate change. He was surprised to note the progress in France in the field of adaptation silvicultural experimentation and assisted migration experience. He also appreciated French innovation at its different levels. As for AFORCE, the choice to work with ISFORT is explained by the presentation made by Frédérik during the same event, which involved owners and managers to work together on the issue. of climate change. All network partners thought there could be a lot to learn from ISFORT about this.

**What was the purpose of the cooperation project?**

The France-Québec cooperation project that initiated this workshop approach is funded by the Permanent Commission for France-Quebec Cooperation of the France Division of the Quebec Ministry of International Relations and Francophonie and the Consulate General of France in Quebec. The idea is to try to compare knowledge transfer methods to guide forest adaptation through climate change. The two protagonists wanted to compare the way in which management is supported in decision making, to identify the various decision tools available, and finally, to assess how the stakeholders involved in adaptation issues and transfer of knowledge, to face this challenge. There were two tours, one in Quebec in March 2016 and the other in France in June of the same year.

**What did you do during your tours?**

The purpose of the tours was to allow the invited guests to appreciate the organisation of the sector as a whole, and on the issue of climate change. To this end, the tours were organised in such a way as to allow the meeting of the different key players invested in the transfer of knowledge and in order to discover some particularly structuring and innovative projects in this field.

- *Reception of the French delegation in Quebec*

ISFORT led the French delegation to a regional agency for the development of private forests and to a forestry consultant to see with them how they include the issue of climate change in the advise and the work, and what questions they raise with regard to the management to be

implemented. Namely, in Canada, the issue of forest management is managed at the provincial level. The second stop was the Canadian Forest Service (governmental), which developed a programme called "Forest Changes" at the national level, which provides information on climate change, but above all a whole series of tools (presented at this workshop). The delegation then went to Montreal to meet the research consortium OURANOS, an organisation structuring adaptation in Quebec, in all sectors, including the forestry sector. The French delegation was able to appreciate the advantage of having in the same organisation specialists in climate science, climate scenario production services and adaptation coordinators. OURANOS's support for partners and the synergy effect that its coordination of research generates make it a very efficient organisation. Along the way, a stop was made in a cooperative and its subsidiary "Horizon multi-resources". The next step led the delegation to Quebec City, initially to the Canadian Forest Service to meet researchers who are developing very advanced decision support tools for forest adaptation. It then went to the Forest Research Directorate of the Ministry of Forests, Wildlife and Parks, which welcomed the group in the Montmorency forest, north of Quebec City, to visit ecosystem monitoring experiments. allowing them to understand how climate change affects how settlements function. Finally, the tour ended in Montreal with an interview with the Quebec Federation of Forest Producers, which provided an overview of forest owners' profiles and how adaptation issues could be considered.

- *Reception of the Quebec delegation in France*

The course began with a discovery with the team of the National Forest Office of the forest of Fontainebleau. It is considered to be a "Forest of Exception". This forest also hosts a permanent monitoring plot of ecosystems (RENECOFOR). Then the delegation went to Toulouse, to meet some representatives of Météo-France, including scientists working on the provision of climate scenarios to professionals and the general public through the DRIAS platform. In Mazamet, the delegation met with a group of forest owners who were meeting on the EVAFORA project led by INRA, to discuss the interest and feasibility of different modelled technical paths. These models have the particularity of including a carbon footprint. The next step led the group to the INRA centre in Pierroton, near Bordeaux, both to meet geneticists and to appreciate their work on the topic, and also to be introduced to a device for the forest on risk prevention related to pests through the use of biodiversity. This day ended with a meeting with the forestry cooperative, ALLIANCE Forêt Bois, which showed how they, as managers, are facing up to global change. Following this, the delegation went back to Niort to exchange information with the Regional Centre of the Forest Ownership on the advised actions carried out locally and to visit an arboretum of the European entity REINFFORCE, a network installed on the Atlantic facade to test the introduction of species and sources, but also some innovative adaptation silvicultural tests. The tour ended in Orleans with a multi-partner meeting, to discuss issues of genetic improvement and silviculture, then with a visit to a forest owner to see what he was doing to include the tools at his disposal and put in place new silviculture.

**What did you remember from the forests you visited?**

*Distinctive features of Quebec forests*

In Quebec, forests cover 76 million hectares. Three quarters of this is boreal forest and one quarter is temperate forest. Productivity is weak and growth is low. There is a possibility of levying 43 million cubic metres for an actual felling level of 26 million cubic metres. The forest is 90% public and targets sawing, pulp and paper, peeling, veneering, cogeneration and energy. There is a significant presence of aboriginals, a major problem in Canada, that must be taken into account for management. Private forest accounts for only 10% of the area, but it accounts for 20% of the province's wood production. It is distributed in a fragmented way in the province, as it is in France. There are 34 000 simple management plans for 134 000 owners. Of the uses, maple products make up 31% of uses and sawing and pulp make up 54%.

*Distinctive features of French forests*

French forests are 75% private. They are mostly composed of hardwood, dominated by oak. They have a wide variety of climates, with the exception of the boreal climate. These climates are accompanied by differences in the forest level, for example in the stock of standing timber.

**What are the impacts of climate change already perceptible in these two countries?**

In Quebec, there is a higher frequency of heat extremity, which increases the risk of fires. New diseases and new pests appear. Beech cortical disease develops due to warming. Insects such as gypsy moth or wool hemlock aphid arrive from the United States. Freeze / thaw issues are crucial for the production of maple syrup: the increase in climate extremes has a strong impact on production.

In France, it has a change in vegetation and a change in productivity. There is an increase in the frequency and duration of drought periods as with the example of 2003 causing significant mortality, increased fire risk, and a high risk of storms/ pests.

**How do professionals mobilise to deal with this?**

In Quebec, OURANOS coordinates the different sectors, and offers various tools to the different stakeholders according to their specific needs. There is also a programme led by the Canadian Forest Service "Forest Change" which is managed at the federal level. A government action plan aims to coordinate what is happening in different ministries with development of transferal in training. In France, at the research level, INRA has implemented the ACCAF meta-programme (Adaptation of Agriculture and Forestry to climate change). It organises collaboration between departments to address climate change as a whole and manages project funding on this issue. The GIP ECOFOR (Public Interest Group) is involved in the training and coordination for research programmes on the subject and undertakes a census of projects. At the level of development and management, the CNPF and the ONF have set up internal approaches for support consultants, planners and managers. All are involved in the RMT AFORCE which works to accelerate the transfer of knowledge and their recording for use as practical tools.

**How is climate change perceived by forest owners today?**

In Quebec, for a number of years now, there has been a sociological transformation amongst owners. This is manifested by a transfer to the city of woodlot owners with fewer farmers and more white-collar and blue-collar workers. Their preoccupation is not primarily the production of wood, but rather recreation. These owners still seem vigilant about the state of their forest, having experienced windfall, pests and diseases. And they undertake reactive adaptation rather than preventive adaptation to use Frédérik's words.

In France, what interests owners is preserving their family heritage. The forest is perceived as a place of relaxation, the economic aspect as secondary. An awareness amongst owners as a result of the drought of 2003 was felt. Today, they are more vigilant to the appearance of insects, fungi, etc.

**Which projects have most impressed you during your two tours?**

For Quebec, the first project presented is a modelling and support approach through "serious games". Socio-ecological modelling is carried out on a region with several uses. The technique used is a French technique by Michel Etienne which involves the organisation of an ARDI workshop for stakeholders from the same region with cross-interests. This technique makes it possible to characterise the local dynamics, to better understand the stakes and by which means or mechanisms, there can be obstacles to the implementation of adaptation measures. The serious games platform is built on this system in which several stakeholders will interact together with management scenarios and will have to develop decision making mechanisms to adapt to sudden or gradual changes. The goal is to see if the stakeholders are take the right or the wrong decision. The second project presented is called "Forest Adapt". It aims to develop adaptive silviculture, and wants to assess the adaptive capacity of species to be able to develop a silviculture that combines resilience, resistance and facilitation to transition. According to the information of the diagnosis on the capacity of adaptation they want to develop a silviculture which will be tested and put in place to evaluate the socio-economic aspect.

For France, the project presented is the EVAFORA project. It consists, based on simulations made with population growth models on maritime pine and Douglas-fir, of comparing different technical paths in terms of productivity, water balance, $CO_2$ balance etc. The objective is to assess the impact of climate change on these paths. They are confronted with groups of forest owners to see their reaction and test their feasibility. The resulting discussions provide an appreciation of what they would be willing to alter to mitigate these changes.

**How to support foresters in the face of climate change?**

In private forests in Quebec, development agencies are responsible for coordinating development activities. They can vary greatly from one agency to another. Tools to help the decision are available but support for their use is still insufficient. In addition, the challenge of forest management is intimidating, especially because of the scale of work: in public forests, forest management units (UAF) are between 100 000 and 1 000 000 ha... Even if a resulting job has been engaged to characterise vulnerability, a real sense of helplessness is felt in the face of the magnitude of the task.

In France, there is a gradual adaptation to two levels, at the national level general recommendations and tools are produced in the context of the RMT AFORCE. An effort is made to try to understand the needs, to analyse them, and to use the research work as the basis from which to answer them. Then, at the local level, networks of correspondents are set up with a connection that is made with the national level to appropriate tools and adapt them to local issues. The stakeholders and local councillors in charge of the decision also transmit their findings and needs.

Several ideas for collaboration were born as a product of this exchange. This workshop is one of them! The design of a network of demonstration plots of adaptation silviculture experiments, the development of participatory simulation approaches to other typical cases and the renewal of such inter-country comparison were discussed.

In conclusion, several paths for development have been evoked. For Quebec, pooled approaches such as AFORCE involving research, private forests and public forests are considered to be of great interest. It would be interesting to develop comparable approaches, allowing dialogue between research and management. The combination of adaptation and mitigation issues is mentioned for both countries as a major issue. For France, vulnerability modelling is becoming a priority. The implementation of a research organisation comparable to OURANOS for climate issues would be of great help. Finally, approaches to co-constructing adaptation solutions with practitioners are still too few. The serious gaming approach is an inspiring example.

## ►"A line made by walking": adaptation to climate change in forest silviculture across Europe

*Rita SOUSA-SILVA, University of Louvain (Belgium), in collaboration with Bruno VERBIST, Quentin PONETTE, Kris VERHEYEN, Bart MUYS*

The presentation consists of reporting the results of a survey of forest owners and managers from 7 European countries: France, Slovakia, Belgium, Estonia, Portugal, the Netherlands and Romania. The purpose of this survey was to study how these stakeholders each perceive in their country, the effects of climate change and the role of forest management in the face of climate change.

Respondents were selected from public and private forest stakeholders. here were more than 1 100 responses to the survey questionnaire. Belgium, Romania and France are the 3 countries with the highest number of responses.

**Perception of climate change in Europe and experience of changes**

The results of the survey indicate that 91% of respondents believe in climate change and among them 74% believe that human activities are the cause. Of those who believe in climate change, 55% have experienced the consequences in one way or another, 71% expect to experience the consequences soon and 36% are doing their best to adapt.

Among those who have experienced it, it is for:

- *33% storms and droughts;*
- *24% heat waves;*
- *18% extreme precipitation;*
- *5% early and/ or late frost;*
- *3% snowstorms and cold snaps.*

**Awareness of the impacts linked to climate change**

For those interviewed, the impacts to be expected on forests are:

- *69% extreme weather occurrences;*
- *60% insects and diseases;*
- *55% change in species composition of forests;*
- *12% change in soil fertility and tree growth.*

**Differences in awareness of the necessities of adaptation**

On average, 54% of respondents are aware of the need to adapt. Only 36% actually implemented adaptation measures. In France, this percentage increases to 50%.

Among the adaptation measures that can be implemented, the respondents give priority to species selection (planting better adapted species and promoting natural regeneration). They cite in second position: "promoting mixed settlements, setting up monitoring of the damages, and to change the durations of revolution and the felling techniques".

The elements that prevent respondents from anticipating climate change are primarily a need for more technical knowledge (19%).

Of all the possible assistance, the respondents would need a financial incentive (49%) to take action and more awareness (41%), more information (39%) and technical assistance (33%). Only 1% consider that tackling climate change is not essential.

In conclusion, the forest sphere is mainly informed about possible future impacts of climate change but it needs to be advised and supported to deal with it. It is therefore necessary to provide support to professionals, whether in terms of information, locally adapted technical advice or incentives. The transfer of knowledge must be supported so that new knowledge fosters reflections in the field and gradually guide managers in their choice.

## ►Verified and expected climate change: a forestry challenge for today

*Jean-Luc PEYRON, GIP ECOFOR (France)*

**Which climate change?**

Climate change is now recognised as a reality and is accepted by most. We therefore know that forest management needs to be reviewed in this new context. The challenge is that there is a lot of uncertainty about the extent of climate change and the speed of climate change. Scientists at GIEC[1] proposed for the 5th report (AR5), on the basis of the recommendations of the scientific community, four possible reference scenarios of the evolution of radiative forcing during the period 2006-2300 of which:

- ***RCP[2] 2.6*** *(the most favourable), which can be considered a utopia because the warming will not stop now.*
- ***RCP 4.5*** *(relative stabilisation in 2050) which represents the maximum possible evolution without too much damage.*
- ***RCP 8.5****, the most pessimistic, which leads to a rise in average annual temperatures of +12°C in 2100.*

**What types of consequences for forests?**

There may be several consequences due to global changes for forests. There will, of course, be variations in production because several opposite effects will occur. For example, the fact that there is a higher concentration of $CO_2$ in the atmosphere will boost photosynthesis and, consequently, wood production. However, because of this increase in concentration, the temperature will increase causing invasions of insect pests and pathogens, and drying of the soil, which will cause a loss of production. Even in the best of cases, the proportion of certain species will tend to decrease under the effect of these evolutions.

**Which adaptation(s)?**

Silviculture will have to be partly redesigned in the light of these developments. It is essential to act quickly by trying to anticipate the changes as best as possible in order to prevent potential negative impacts. All this must be done without targeting a single treatment, thinking that we have the solution: there are too many uncertainties to take the risk of getting locked into a single idea. Diversifying your reactions is the solution. Part of the action will be on the basis of voluntarism: we must not wait to have certainties to act. Foresters are working together today to identify possible management options to provide owners with a range of choices that can be adjusted to their specific objectives.

In any case, it will be necessary for both foresters and the general public to adapt to these changes. How to limit risks while remaining in a logic of sustainable management, preservation of the wooded state and maintenance of wood production? Research and development stakeholders, researchers, consultants, but also policy makers all have an important role to play in helping to better adapt. We will have to use the tools at our disposal, understand, measure, communicate, demonstrate, debate, have dialogues with the owners and managers to convince them to act and to be able to follow the changes.

**What scenarios for the future after the Paris agreement?**

The international targets of the Paris Agreement correspond roughly to the RCP 2.6 scenario. If we consider the real means currently envisaged to implement the individual Member States (INDC[3]), they do not achieve this scenario, but rather RCP 4.5. It is therefore still very likely that we are engaging with pessimistic climate change evolutionary curves for which we need to be prepared. As foresters we have a responsibility for the future of forests and must know all the ins and outs so as not to ignore any hypothesis.

[1] Intergovernmental Panel of experts on Climate Change
[2] Representative Concentration Pathway
[3] Intented Nationally Determined Contributions

## SESSION 1 - Which instruments for exploring possible futures?

Moderator: Mériem FOURNIER, AgroParisTech

### ►Interactive Atlas: Impacts of Climate Change on the Distribution of Tree Species in Quebec (Canada)

*Catherine PERIE, Ministry of Forests, Wildlife and Parks/ Forest Research Management (Canada)*

This presentation aims to reproduce a part of a study carried out in 2009 whose purpose was to model the evolution of the distribution of forest species under the effect of climate change in Quebec (Canada) and to understand the effect on settlement composition in their vulnerability to these changes. The ultimate goal is to be able to guide the selection of species to renew, conserve or promote. Climate change in Quebec may be more pronounced than in Europe according to estimates of average temperature and precipitation trends for 2071-2100 compared to the 1971-2000 reference. Thus, the average annual temperature increase is estimated at +3.7°C. It will be +3.2°C in summer and +4.9°C in winter. Precipitation will be higher than the reference of +14% on average, with the following distribution: +23% during the winter and -1.5% during the summer.

As a reminder, the forests of Quebec are of three types: from south to north, a broadleaf then mixed softwood-leafy forest and finally, mainly coniferous to the north. By the end of the 21$^{st}$ century, climate change could lead to a shift in average climatic conditions of 230 km towards the north.

The study area covers 2 567 million km². The 6 418 plots described in this area were divided into two sets: the first was used to calibrate the model and the second to validate it. Modelling of habitat evolution and species changes within habitats are based on several climate scenarios. The observation of their possible evolution makes it possible to define zones at risk and areas where climate change becomes an opportunity for the species or for certain mixtures.

Three scenarios are possible:

- LOSS OF HABITAT: either the species is no longer adapted to the geographical area in question and it is necessary to propose an alternative for renewal,
- MAINTAIN: either it is still adapted and can be preserved,
- GAIN: or it is better adapted and must be favoured. However, it is necessary to be careful because many things condition the setup.

An interactive atlas including the results of this modelling is being finalised. Some screenshots are presented.
The simulations indicate that in this territory, currently, 43 species are present in the Quebec forests but, with climate change, it is estimated that there are more than 90 species that could be stationed in Quebec by 2100 (the double).

In conclusion, assisted migration is, depending on sources, rather relevant, as is the need to adapt silviculture to climate change and to try to preserve the genetic diversity of settlements.

## ▶Evaluating adaptation options for drought in a future climate: contributions from the online water balance calculation tool Biljou©

*Nathalie BRÉDA INRA (France), in collaboration with André GRANIER, Vincent BADEAU, Damien MAURICE*

Biljou© is a computerised tool created by INRA. It aims to help understand the effects of past climatic disturbances (from 1951 to the present) on forests (water cycle, productivity, health, etc.). It also allows to observe their possible evolution in the near future (2025-2050) but also in the distant future (2075-2100) according to different climatic scenarios. It allows the characterisation of settlement-level drought and a daily time step (water balance, drought index, etc.).

In several countries of the world as well as in France, climatic services have been created and Biljou© is an example. Over time, researchers have realised that many forest practitioners do not have the tools to assess drought. It was therefore of interest to create a tool to measure with relative accuracy the effects of climatic disturbances on soils and settlements, comparing droughts from one year to the next. It is thus possible to reconstruct a detailed report over several years on various forests according to their soil properties and species composition. This tool was created in 1999 and was intended for research. It was not until the year 2010 that, thanks to the RMT AFORCE, its access was made public via a website. This has allowed a large number of practitioners to be able to perform calculations for their own forests.

**Demonstration of utilisation of the tool**

This tool calculates climate data for a particular forest. The required input data is as follows:

- GPS coordinates and altitude in order to have the greatest possible accuracy on the location of the study site;
- soil characteristics (depth of each soil layer, water supply, root proportion, moisture content and bulk density) to distinguish soil horizons and depth;
- the foliar index of the forest, as the settlement in place plays a major role in the interception of rainwater and evapotranspiration;
- meteorological data.

Once these elements are entered in the database, the tool provides different graphs representing:

- the soil moisture deficit index and the number of days/ year of water stress;
- a classified representation of drought years according to three indicators: water deficit, duration of deficit, earliness of deficit;
- potential evapotranspiration (ETP) and actual evapotranspiration (ETR);
- the daily log of the water deficit (or by month or by year),
- the highest annual water stress indices (since the first meteorological data input in a selected year);
- interception and daily drainage (or by month or year) and the number of days of water stress experienced by the settlement each year.

The reasoning process for using the tool is as follows:

◦ *What is the climactic situation for the past years?*

It is recommended at first to observe in more detail how water flows have evolved at the settlement and soil level. The simulation must be conducted over a minimum of ten years. We can then refer to the evolutionary curves of the relative extractable water reserve (REW) over years of past droughts, such as that of 2003, where we saw a strong decline just after the heat wave episode in all of France.

◦ *What can the settlement be faced with in the future?*

To answer this question, a dedicated meteorological data file must be used for several climatic scenarios. The simulations created will make it possible to propose a range of possibilities, facilitating the representation of what the settlement might undergo in the future.

Depending on the results obtained and assuming that it is very highly probable that between 2030 and 2100, all years will be above the current

normal drought (equivalent to the summer of 2003), we come to to ask ourselves the following questions:

- *Can we keep the same species in this settlement in the future?*

If the settlement is really in its optimal state with regard to the water deficit, the species in place can be kept. But then you have to use other decision filters like the range of insect pests, for example.

- *If there is a risk that the current species are no longer adapted to the settlement in 50 or 100 years, which species or silviculture can I put in place to overcome the disappearance of my forest?*

If a risk exists, it is possible to intervene on the leaf area index as well as on the nature of the species (softwood or hardwood) according to their water requirement and their leaf area index. The tool thus makes it possible to identify by playing on these factors what types of settlements will be for this site, the best adapted to climate change.

The possible solutions when one clearly identifies that the species will no longer be adapted by 2100 are:

- to substitute conifers (excluding Larch), which have a strong annual interception, with hardwoods;
- conduct dynamic silviculture to promote the arrival of water on the ground by lowering the leaf area index. But beware! A good balance needs to be struck because if silviculture is too dynamic, there may be competition concerns for water between the settlement and the lower layer;
- favour species whose roots have a larger and deeper prospected volume;
- favour species that mineralise the humus of the soils (mountain ash, hazel, etc.) quickly to increase the soil's useful reserve.

Thus, this tool is very useful on a daily basis for practitioners and researchers. There is also a plan to design maps of possible future settlements based on soil and drought.

URL of the tool: https://appgeodb.nancy.inra.fr/biljou/

## ▶Applying simulations to guide forest management decisions in the context of climate change: an example from Austria's mountain forests.

*Manfred J. LEXER, University of Natural Resources and Life Sciences (Austria)*

The future evolution of forests in a context of climate change is a difficult thing to grasp given the difficulty of predicting what the future climate will be. Different climate change scenarios are proposed by scientists. These projections are used to study the evolution of the forest on the Austrian Alps. Owners and managers need decision support that takes into account the different environmental factors and possible hazards associated with climate change. In this sector, forest managers have the choice between using a suitable simulation model or calling on a forestry expert. The 2nd choice is preferred for lack of time and lack of technical knowledge in the use of the software and the parameters it takes into account. But, to call on a specialist often shows a discrepancy between this vision and the recommendations of the scientists.

The PICUS software is presented, as well as its implementation in the Austrian Alps. It was created by the University of Natural Resources and Life Sciences in Austria. It allows a virtual demonstration of the evolution of forests in the face of climate change. Given the technical progress of the last few years, more data is available on forests and this helps to refine the results. PICUS is a sylviculture simulator, simulating the evolution of forest ecosystems according to possible management alternatives and climate change scenarios on the same management unit. The data and information necessary for the software to perform simulations are presented: topographical, geographical, climatic and game factors. Aerial photographs are also used.

The software provides 3D simulations of forest development with a quantitative and qualitative comparison of different management alternatives. It allows an approach by groups of trees or by ranges of several hectares. It can simulate up to 25 ha over a year and up to 100 years into the future.

This tool provides operational advice to foresters and optimises management plans. The software can also be used to design regional guidelines.

The use of such a tool including many parameters to include entails support. It allows for the consideration of uncertainty and a better interpretation of the results.

The benefits and limitations of this approach are currently being discussed to identify areas for improvement.

## SESSION 2 - How is the implementation of adaptation tests carried out at management system level?

Moderators : Thierry CAQUET, INRA & Olivier PICARD, CNPF

### Choosing the species to plant

#### ►Evaluating species adapted to future climates: a case study for adaptive management

*Peter BRANG, Swiss Federal Research Institute WSL (Switzerland), in collaboration with Kathrin STREIT*

Climate change projected according to IPCC scenarios[4] project a rise in temperatures and increased summer drought. Studies conducted in Switzerland ("The Forest and Climate Change" programme) by researchers have led to progress on distribution range modelling. Some first migrations and very localised diebacks have already been observed. In mountain areas, in moderate scenarios, a rise in vegetation from 500 to 700m should occur.

The adaptation of forests to this phenomenon could also be done by a substitution of species. The modelling of the temperatures according to the altitude will thus make it possible to find the most favourable composition for the threatened settlements of the mountain floor. For this, it is important to start as soon as possible to support the change of species for the concerned settlements because natural migration takes time. This can be done by replacing the species in place with more tolerant species or even with species of Mediterranean climate. However, this choice must be carefully considered because its locations will be long term.

Managers aware of the impact of climate on our forests therefore want solutions to adapt and be able to respond to owners who seek to act with care. The advent of model based silviculture tools makes it possible to virtually simulate the impacts of forest management on forests. The problem is that the impacted areas are too large and the establishment of new species on rugged terrain remains expensive and difficult through artificial regeneration. Game browsing is a significant constraint to be taken into account, which must be addressed by means of protection and fencing that are also very expensive.

Swiss researchers are working on a project aimed at producing recommendations on species to favour for forest management. For this, they study the various stationary factors in correlation with climatic evolutions. The work will be completed at the end of 2017 and will propose a group of species adapted to the environment and its possible evolution.

There are many uncertainties about the species, their requirements and behaviour, and their introduction: what are the limiting factors? What is their survival capacity if they are introduced today? The project presented is based on an experimental network of plantations near Geneva. To simulate possible future adaptations, tree planting tests are conducted. They are set up on plains and slopes where they are not present naturally but where they could adapt in the long term. The parameters measured are: the failure or success of plantations from different sources and the flexibility of the introduced species.

Two types of tests will be carried out:

- experimental plantations that will concern 5 to 10 species of trees with different sources for each species. They will be introduced on an altitudinal gradient. The parameters that will be measured during this test are the mortality rate, growth and health status.
- a much smaller test network which will focus on studying a few species from different sources, but this time taking into account the economic aspect for the wood industry and likely to interest

[4] Intergovernmental Panel of experts on Climate Change

forestry experts. The trials will not stop with only the indigenous species of the region but will go so far as to test more exotic species that are potentially capable of adapting. For the statistical results to be interpretable a hundred plantations will be planted at elevation gradients covering the different stages (slopes up to sub-alpine) on the most important Swiss forests that are representative of different climatic regions.

The project is planned over 30 years. A first phase over a year and a half will define in consultation with protocol practitioners, sources and species to be tested and the criteria to be observed. The project will be punctuated with phases of visits and demonstrations to dialogue with the practitioners. The implication and the serious follow-up of this project will thus be a real help for all the foresters to better know the sensitivity of certain species or sources and to guide the managers to engage adaptation to climate change.

## ▶Evaluation of new forest genetic resources for adaptation: From precursor projects to setting up a national organisation

*Myriam LEGAY, ONF and Cyril VITU, CRPF Grand Est (France), in collaboration with Brigitte MUSCH*

Due to the evolution of the bioclimatic context of France, many main species of the French forest seem vulnerable to climate change. Due to the relative paucity of European flora, there have been a number of exotic species introductions in the past, some of which have failed. It seems that some of these introductions may, along with assisted migration, constitute one of the solutions for adaptation to the challenge facing foresters today.

In France, several projects have been set up to search for new forest genetic resources. They are at the origin of a national multi-partner project: ESPERENSE.

**A pioneering project in Lorraine**

One of these projects was carried out in Lorraine thanks to a partnership between the National Forest Office and the National Centre for Forest Ownership. Lorraine is a very forested area with a semi-continental climate (and its main species are beech on the plains and oaks and in the mountains, fir and spruce). The project consisted of the identification and analysis of two systems that are vulnerable to climate change: mixed oak forests on hydromorphic soil and limestone plateau beech forests. Once these systems have been characterised, alternative species have been researched (inventory of atypical species in particular) and tests to experiment with solutions have been put in place. The results of the NOMADES project (RMT AFORCE) were used at this stage, as well as simulations of the IKS model to approach the future climate.

The models predict for Lorraine a warming of +1.25° to +1.85°C by 2050 and of +2° to +4°C by 2100, with major uncertainties in rainfall. In this context, they foresee, for example, a very high risk of vulnerability for beech with high uncertainty. For oak, it is high risk with high uncertainty. For Scots pine and spruce, this is a significant risk with moderate uncertainty. The behaviour tests put in place will be monitored long term. They have the following characteristics: tests without repetition, 4 measuring plots of 35x35m (12.25 ares), isolation strip of 10m, spacing of plants 3*3m, worked stumps, plants in buckets, fence.

**The GIONO project**

Initiated by the Research, Development and Innovation Department of the National Office of Forrests, it aims to initiate an assisted migration of beech, oak and fir tree genetic resources from the south to the north. For example, to be able to follow the anticipated future evolution of the climatic conditions favourable to its growth, the beech should migrate 30m/ year,... It is therefore urgent to act. The objective of this assisted migration is to obtain, by mixing with sources from the south, a greater genetic diversity in the heart of the area, and to compare the performance of these southern resources with those already in place. Harvested seeds may also allow conservation of endangered genetic resources. To date, two planting campaigns have already been conducted for the implementation of source comparison tests. A site for each species is planned, with 4 repetitions per site.

**The ESPERENSE national multi-partner project**

The two projects are part of pioneering approaches that have allowed the setting up of a large-scale multi-partner project aimed at setting up a multi-partner network of experimental plots for the testing of new species and sources throughout the territory. The goal is to identify the genetic resources of tomorrow. A first consultation process (EXPRESS) organised by the RMT AFORCE laid the foundations for this project.

The project is structured around three main components:

- setting up a sustainable consortium and defining the conditions for sharing data,
- enhancement of existing experimental heritage and introduction initiatives in the context of management,
- setting up a network of experimentation of new species.

This project will build a long-term partnership that will make it possible to better know and value the experiments with new species and sources. Successes and failures can be valued. Supply circuits will be set up. Site monitoring and data processing protocols will be harmonised. Thus, it will be easier to identify resources to implement in order to adapt settlements in the most vulnerable areas.

## ▶Assisted Migration in Canada and Tools to Help Implement it

*Dan Mc KENNEY, Natural Resources Canada, Canadian Forestry Service (Canada), in collaboration with J. PEDLAR and I. AUBIN*

Climate change makes it necessary to question the forestry models on which foresters rely. In Canada, they will have several impacts on forests, such as an increase in the length of the growing season and an increase in the annual average temperature. Over the last 50 years there has been a 60km northward shift of habitat. This shift could be greater than 700km by 2100 in the least optimistic scenario (RCP 8.5). As a result, many of the species are threatened, and many of these are highly economically valuable (at least 18 of Canada's major species are threatened).

Based on this observation, a state of the art concerning assisted migration (AM) in Canada has been completed. It has been shown that this concept was originally used for the conservation of biodiversity (movement of endangered species). It is now an adaptation solution that consists of intervening to move species to areas that are or could become more favourable to their growth. To date, 1.5 million hectares are reforested annually in North America (USA and Canada) of the 5 million hectares used for felling or burned annually (left in natural regeneration). This could be an opportunity to develop AM more quickly.

A review of the status of AM has been completed in the provinces of Canada. British Columbia, Alberta, Quebec and Ontario are the most advanced. Some of their actions include: production of a methodological guide for the transfer of seeds, development of transfer functions for certain species, adaptation of the regulations to allow the use of sources taken further south, setting up cartographic tools to identify risks of maladaptation in the case of seed transfer, implementation of source comparison tests, etc. The other provinces have initiated dialogue on this concept and are starting to collect source data, their requirements and their growth potential.

In order to help foresters in their decision making, a web application has been developed: Seedwhere. It makes it possible to visualise on a map climate analogies, between a seed harvesting area for example, and a planting area, and their evolution over time. This software, which takes into account the different scenarios, makes it possible to define the best plant source for a given region and makes it possible to make estimates of the potential increase. The tool is regularly updated with new data and additional modules:

- theoretical projection, according to the climate, of the growth of any source at a given site (URF);
- cost evaluation based on seed sources used.

Source data from 120 commercial species were used to generate the URFs (Universal Response Functions). They highlight that seeds used for assisted migration should be particularly monitored for their source and quality. Indeed, local sources are not necessarily the best for reforestation. Populations in northern Canada appear to be relatively well adapted to possible climate warming, in contrast to southern populations.

In conclusion, there is a strong interest in assisted migration in Canada. Local species are favoured over exotic species. Therefore we are promoting the movement of distribution ranges. However, this remains a solution with its limits, which can not be used everywhere. To make progress, it is useful to ensure the sharing of methods and protocols, to set up appropriate training, and to initiate national/ international cooperation to exchange feedback.

## Towards new silviculture

### ▶Adaptation of Federal Land Management to Climate Change in the Western United States

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

The US Forest Service manages 78 million hectares of land, including 155 national forests, managed primarily for timber production, or for recreation. Scientists at the US Forest Service have put in place a National Roadmap for Responding to Climate Change that sets out actions to be implemented at the national level to improve system resilience and mitigate the risks of climate change:

- assessing risks, vulnerabilities, knowledge gaps and effectiveness of policies and management;
- working together to find solutions to the problems of climate change;
- managing resilience in ecosystems and communities.

Then, at the national forest level, implementation was followed by the establishment of a Performance Scorecard, which evolves according to how forests respond to climate change. Thus, each national forest must report on its progress in terms of organisational capacity, vulnerability and development of adaptation options. This process led to the creation of a reference point for US foresters. The goal is to reduce the negative effects of climate change, and to implement a transition of the ecosystem and of natural resources. After having thought for a long time that the situation could not improve, they propose a plan for each forest for a period of 10 years where climate change is now included.

To design these plans, partnerships with scientists, universities, the research branch of the US Forest Service, or managers have been set up. The aim was to synthesise knowledge, heighten awareness, assess resources and their vulnerability, and develop adaptation strategies that could eventually be incorporated into a management plan. The partnership projects put in place involved 29 national parks and 38 national forests. As a first step, a knowledge synthesis was implemented to qualify the effects of climate change and assess vulnerabilities. Then, managers and scientists worked in workshops to identify local adaptation strategies to be implemented according to the impacts already noted in their sector. Finally, these strategies have been included into existing management plans.

Each strategy is defined based on an expected vulnerability or impact. It is accompanied by tactics of implementation and the highlighting of the associated potential obstacles. For example, to cope with the growing risk of more natural fires due to droughts, the recommended strategy is to increase the resilience of ecosystems to more frequent fires. For this same risk, the tactic is to reduce settlement density, increase species diversity and implement controlled burning. The results of these studies are available online: Climate Change Adaptation Library (*http://adaptationpartners.org/index.php*). In conclusion, the interest of this whole process is to allow a better awareness of climate change and its effects.

Sustainable partnerships have been established and will enable better responsiveness and long-term monitoring with feedback. The sites worked on will be able to constitute reference points to inform similar approaches or to collect data. Finally, the various projects will have highlighted the knowledge gaps that will need to be filled in order to refine the strategies.

## Water balance of forests: a practical guide

*Sophie BERTIN, EKOLOG & Philippe BALANDIER, IRSTEA (France)*

More and more forestry practitioners are giving thought to the silviculture that needs to be put in place in order to respond as effectively as possible to climate change.

In an attempt to answer this question, a group of researchers and practitioners led by Nathalie BREDA (INRA) and Jacques BECQUEY (CNPF) was formed by the RMT AFORCE. The work of this group resulted in the design of a guide: "*The water balance of forest settlements; The state of scientific and technical knowledge and implication for management*", published in 2016 and presented here.

The work consisted initially in identifying the questions asked by the managers, faced on the ground with dieback and anxious for solutions. Then, a complete as possible inventory of the past and current knowledge acquired by the forestry world was drawn up. This was the work of Sophie BERTIN in particular, who mediated between practitioners and scientists. Based on this assessment, it was possible to identify the questions that the group was able to answer and those for which the research could not yet provide solutions.

This work on questions/ answers was the lengthiest and most laborious. It soon became apparent that behind every general managerial question lay a multitude of scientific questions. It was therefore necessary to begin with each question one by one. A consultation between scientists and managers to reformulate the questions and for the answers given to foresters to be expressed simply and with the least possible loss of information (with proofreading by scientists) was therefore set up. Managers also had knowledge gaps and sometimes some misconceptions that had to be discussed. For their part, the researchers have been able to measure the content and scope of the questions on the ground and the difficulty that sometimes may be involved in translating their results into concrete recommendations. It is a complete exercise of co-construction of both questions and answers that has come into place. The work was spread over 2 years to allow these necessary back and forth exchanges.

Another difficulty in this exercise that was not anticipated was the choice of words. The two parties did not use the same vocabulary to describe the same object or the same definitions. This is why a glossary was created.

This guide is very easy to use. Indeed, it is broken down into three main parts:

- synthesis of scientific and technical knowledge;
- implications for management;
- glossary.

The first two parts are subdivided into 10 chapters. For the first part, the chapters deal with (from A to J) the different factors that influence the water balance. It highlights the knowledge acquired by the scientific world but also the questions that remain unanswered. For the second part, the management implications are numbered from 1 to 10.

In the first part, at each beginning of a chapter, the knowledge that can be brought and the prerequisites that are advisable to have to better understand the reasoning are summarised. A reference is systematically made at the end of the chapter to the chapters that are correlated for both parts. Part II works on this basis: a question is asked on a very specific theme and then a structured and illustrated answer is provided. There is also a great diversity of illustrations: diagrams, photos and graphics explained.

The aesthetic aspect (involving the practical aspect) has also been highly elaborated for this guide; Each chapter and part has been cut like inter leaves. In addition, a colour code based on the content (researchers' question/ answer and potential silvicultural implications) has been developed

On the other hand, this guide only deals with the water balance, so it can not be taken as a guide to forestry. But it can be used in conjunction with

the Biljou© tool developed by INRA (*https://appgeodb.nancy.inra.fr/biljou/*). An interactive digital version of this guide will be posted on the RMT AFORCE website in 2017.

It is important to keep in mind that this work is a long-term collaborative project, which was complicated to set up, but which was particularly rewarding for all the stakeholders involved. A finding can be made and is well-founded: knowledge of the water balance for monospecific regular high forests is acquired for the most, but is still too vague for silviculture in irregular forests and mixed settlements.

This guide was created with the purpose of providing recommendations on silviculture to put in place so that settlements are as resilient as possible depending on local climatic and soil conditions. It serves practitioners in the development of their management methods, making it a very useful guide for the forest world. Attention, it is not a book that gives silvicultural guidelines, but simply advice to find the appropriate solutions for individual cases. The water balance depends mainly on the local climate and the water storage varies depending on the rooting (and therefore of the settlement) and the soil, the guide can not be precise on the silviculture to be applied. In addition, the issue of vulnerability to climate change is not addressed directly in the texts, but is implicit.

## ►Does irregular silviculture better prepare forests for global change than regular silviculture?

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

In literature, according to very strong beliefs, irregular silviculture would allow the settlement to be more resilient, more biologically resistant but also to climate change (storms). Philippe Nolet gives two possible reasons for this: the majority of studies deal with temperate forests in North America where the diversity of species allows for greater resistance and where there is a certain maintenance of the ecological process. These beliefs are supported by the general public, some foresters (including members of the Pro Silva network) and researchers. However, these beliefs are unfounded, no evidence has ever been adduced to support these claims. It is this basis that the study is presented.

Its objective was to determine, thanks to a documentary basis, if the irregular treatment is more adapted to answer a global change than the regular treatment. For this, a review of the world literature (English language scientific publications exclusively) comparing regular/ irregular treatments on all points (processes studied, measurements made, biodiversity) was carried out beforehand. Only seventy studies were found. Researchers identified the processes studied, which parameters were measured, on what spatial and temporal scales they were based and finally the biomes studied in order to synthesise the studies. They respected the interpretation (pro/ anti irregular) of the authors of the publications Of the 79 studies compared, only 18 suggested that irregular treatment would be preferable to regular treatment.

These (surprising) results are questionable. Indeed, the 79 studies considered came almost exclusively from North America and were English-speaking, which excludes many French, Swiss and German studies (cradle of irregular silviculture). The restricted number of studies and their over-specialised sources raise questions on the reliability of the study.

The vocabulary used during the process also leaves the freedom to make several interpretations. In fact, irregular silviculture in Quebec is not necessarily the same as its French counterpart. This caused some misunderstandings and it distorts the study. Moreover, the comparisons were complex because the spatial and temporal scales were not taken into account (need to compare the regular/ irregular treatments on the entirety of a revolution). Many subsystems and different management intensities in these two treatments also complicate comparisons of the study.

This study does not, therefore, show the superiority of irregular treatment over regular treatment, but raises many questions about how to conduct such a study to obtain valid and representative results.

Philippe Nolet concluded by stating that regular silviculture must be an integral part of adaptation solutions because the key to success will be the diversity of treatments put in place. An answer to this question will not be built in a few studies, but by working in partnership between research and practitioners to conduct studies. Forest management must be a pretext for implementing scientific studies.

## ►Transfer of Climate Change Research Results to Forest Management - Examples in Southwest Germany

*Axel ALBRECHT, Forest Research Institute of Baden-Württemberg (Germany)*

The adaptation of species to climate change involves the management of competition, suitability/ compatibility with the environment, resistance to biotic and abiotic risks (stability of the species depending on the stability of the climate) and productivity. These different criteria are integrated into expert models to assess the adaptability of settlements in a context of climate change. This approach is the one favoured by scientists, particularly in the context of the study of climate change and its impacts on the forests of south-west Germany. The study focused on two fundamental criteria for the ecology of a species and its adaptation to climate change. The first mentioned is that of the stability of a tree species faced with likely disturbances. This can be risks of drought or frost, pest attacks or storms for example. Changing distribution ranges may also affect this stability. The second criterion is that of the productive potential coupled with the economic value of the species.

Based on the results of the study, modelling based on these criteria allowed the production of two types of maps to help practitioners visualise the changes and decide on the adaptation measures to be implemented:

- Suitability Maps to facilitate the visualisation of distribution range changes and to identify which species to prioritise based on geographic location and different climate scenarios;
- vulnerability maps that incorporate the probability of occurrence of the risk and its potential impact.

The results show that the 4 main species present in the study area (spruce, beech, fir and sessile oak) could suffer substantial losses. The distribution range of the beech could be reduced and move, but the species is not in question. On the other hand, this is the case for spruce, which seems not to be adapted to potential future climatic conditions, probably because of the decrease in water availability.

The study relies on these productions to identify suitable adaptation measures for each case. The reflection conducted in this framework was used to develop a strategic and tactical document for Baden-Württemberg. It concerns both practical applications to improve management but also addresses recommendations for research. Here are some examples of recommendations made:

- reduce the exploitability diameter by 10 to 20%, which is equivalent to lowering the duration of revolutions, in order to improve settlement resistance in the face of climate change;
- diversify species to diversify resistance to potential risks and thus avoid habitat loss as much as possible;
- diversify structures and avoid competition between species for the availability of water and minerals;
- stabilise soils
- take into account the movement of biomes to plan the conservation of forest settlements.

In parallel, it is recommended to intervene in important missions concerning the transmission of knowledge and training on climate change and adaptation potential. Some of these actions are already being implemented.

Overall, adaptation recommendations are structured to correspond to each phase of settlement development since renewal where a high priority is given to natural regeneration until felling. The interest that different silvicultural interventions may have during the life of the settlement (promoting specific and structural diversity, reducing competition, improving resistance, etc.) is also detailed.

In conclusion, the interest of a map representation of vulnerability and distribution range changes is discussed: the observation is that a map representation does not capture uncertainty well, but at the same time it remains the most powerful means of communication. Finally, some lines of research are presented.

## ►REINFFORCE: a network of pilot sites on the Atlantic Arc dedicated to research on the adaptation of forests to climate change

*Rebeca CORDERO, EFIATLANTIC (France)*

The REINFFORCE project was carried out at the European level from 2009 to 2013. It includes 38 arboretums on the Atlantic arc, from northern Scotland to Portugal. To this network of experimental sites is added a network of demonstration sites on which alternative techniques of climate change management are tested.

The aim of this approach was to create a tool that is up to the challenges of climate change, sufficiently comprehensive and effective to answer management questions. For this, the measurement protocols are common and the measurements and observations are stored in a shared database (TREEDATA). This device should in the end, allow us 1) to have a better knowledge of the behaviour of species and sources to determine which ones we could use in a future climate, and 2) to test the effectiveness of alternative techniques in forest management.

The presentation focuses on the network of demonstration sites. Their goal is to test and demonstrate the effectiveness of different alternative forest management techniques to face up to climate change. Classic tests are carried out to compare them with the usual techniques. The tests are monitored over the long term and are subject to climatological surveys with weather stations (precipitation, temperature, wind, etc.) and the damage caused by extreme occurrences is noted. The sites are selected from the most vulnerable to extreme occurrences. Indeed, there is no point in choosing a site without something at stake because the evaluation is about alternatives to be implemented when there is a risk for the population linked to the increase of the frequency of the hazards.

A total of 41 sites have been installed. They each have different levels and types of risk to test: wind, fire, drought (which is the important theme), biotic risks, species mismatch in the environment, etc. Alternatives to experiment are therefore also variable. For example, they deal with soil preparation, density management, fringe management, improvement of the useful reserve, and so on.

Several examples are detailed:

- Method of soil preparation (Landes, France): 6 different types of soil preparation are tested. This modality is quite expected following cyclone Klaus in 2009, compared to the stability of the trees. We are interested in the impact of different methods on settlement stability, but also on root development, access to water resources and sensitivity to drought. Density management (Eg.: tests on maritime pine, eucalyptus and oak): this is one of the most tested modalities. The aim is to characterise its impact on competitiveness, for access to water, for stability against wind, for difficulty of regeneration, etc.
- Management of the fringe: the goal is to contain the pests, but it can also have the function of reducing the progression of fires or reducing the risk of wind. The tests put in place in France were following cyclone Klaus which had generated a lot of questions on the subject (how to increase the biodiversity to avoid the risk of pests, increase the resilience of settlements and increase resistance to wind risk?).
- Settlement structure and composition: the question is between irregular or regular treatment, which is the most adapted to climate change. Will trees of different ages/ sizes or different species be affected in the same way? There are several essays on this issue, but these are long-term demonstrations so there are no immediate results. It is necessary to wait 10-15 years to have a perspective on the climate and to evaluate the effectiveness of the alternatives.
- Organic matter enrichment of soil: a first method (Basque Country, France) consists of soil enrichment via Biochar (charcoal powder or pieces to increase the water retention capacity of the soil. The other method is to add ash to improve the chemical richness of the soil and thereby increase the resistance of trees to drought. All the sites are registered in a metadata database managed by EFIATLANTIC where all types of tests (FORESTRIALS) are recorded.

In conclusion, it must be remembered that this network of sites is a coordinated action for the transfer and demonstration of alternative management. It is therefore an important tool that acts as a showcase for local communication and with students, foresters, landowners, etc. It is also a strategic tool for answering very practical questions about the adaptation of forests to climate change and to challenge conventional wisdom. This network brings together 11 partners who have signed a consortium agreement to sustain the monitoring over a minimum of 15 years. It thus allows the coordination of stakeholders, dialogue and the harmonisation of practices.

## ►In search of robustness: modelling a portfolio of forest settlement responses in different silvicultural scenarios, in the context of threats of global change.

*Frédérik DOYON, University of Quebec in Outaouais UQO-ISFORT (Canada), in collaboration with P. NOLET, P. DONOSO, C. MESSIER*

Climate change will, with a set of global changes, bring about the emergence of different stresses: drought, pollutants, game, insects, invasive species, etc. But how to maintain all the ecosystem services that the forest provides against all these threats? The silviculturist is undoubtedly the major stakeholder and must now think about a new silviculture that can include this multi-risk dimension.

To do this, Frédérik Doyon presents an options portfolio approach aimed at diversifying the possible responses to these threats. These options are based on three principles:

1) Resistance, which aims to keep the current ecosystem in place, to limit change;
2) Resilience, which aims to ensure that, even if the ecosystem changes after stress, it can eventually return to a stable state similar to that before the disturbance;
3) Transition facilitation, which aims to accelerate the transformation of the ecosystem to another stable state deemed more suitable for future conditions.

There is no longer a good specific treatment, as it is necessary to know how to diversify; there is no Swiss army knife but a toolbox. The important thing is no longer to maximize production but to find the range of silvicultural plans that offer the most robustness to maintain the expected levels of different ecosystem services.

The presentation then offers a real example in Quebec: it is a maple settlement that is colonised by a lower level of large-leaved beech. However, beech is affected by a disease (cortical beech disease) that affects almost all stems as soon as they reach market size. In addition, there are chronic episodes of drought and windfall. The case is illustrated using simulations obtained from a parameterised model based on local data on growth, mortality and the recruitment of species according to their size and the competition exercised by their congeners. From this model, future developments, under different stress and disturbance scenarios, are generated for settlements subject to different silvicultural plans (high selection, irregular selection through gradual irregular cutting regular gradual cutting, protected cutting from small traders and clear-cut) in order to detect the plans that appear to be the most promising from the point of view of robustness.

The results show that silvicultural systems do not all have the same capacity for resistance or resilience. Invasion by beech seems to be accelerating in the majority of cases. Thus, if inappropriate treatment is used by the silviculturist, this can lead to maladaptation and instead accelerate changes in an unwanted direction. It is therefore necessary to adapt silviculture, and it use different models to evaluate multiple silvicultural paths.

## SESSION 3 - How to encourage and monitor changes in practice?

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

### ►Moving from science to practice: transposing experiences from integrated forest management guidelines into practice of knowledge about climate change in management

*Marcus LINDNER, EFI international (Finland)*

Climate change is a big challenge for the European forest. While there are many uncertainties about climate change, we are sure that there will be natural disturbances of unprecedented magnitude such as storms, fires and pest attacks.

In order to face up to this, we need scientific knowledge and a transfer of this knowledge into practice. The establishment of an effective science/ practice interface is crucial. It is necessary that the different European countries dialogue on what has been done and share observations and experiences.

Adaptive management must be initiated as soon as possible to improve the resilience of the forest to climate change.

There is a need for sustainable forest management that combines protection of biodiversity and wood production for the economy in the same forest.

The EFI (European Forest Institute) is developing several projects, including the INTEGRATE+ project, whose objective is to identify the management measures to be put in place to better take into account biodiversity.

This programme consists of providing practitioners with a representation of the possible evolution of biodiversity according to different management scenarios. A marteloscope has been set up. The forester can consult directly in the field, according to their choice, maps and help with software on a tablet. Users have direct feedback on all silvicultural decisions they have implemented. They can also interact with participants. All this gives information to foresters for decision support.

This type of project can serve as a model to guide practitioners in adapting forests to climate change. EFI wants to build on this as part of the new "Resilience" programme that it is putting in place. The objective of this programme is to work on the connections between science, practices and public policies. It will focus on providing practitioners with concrete decisions for adaptive forest management.

## ►Adapting Forests in the current context: tools, examples and lessons from the North East of the United States

*Christopher SWANSTON, USDA Forest Service,*
*Northern Research Station (United States)*

It is important to keep in mind the distribution between private and public forests in the United States: the public forests are concentrated mainly in the West of the country while the private forests are in the East. They are extremely diverse, particularly in terms of the ecosystem services they provide (hunting, recreation, etc.).

A first survey was conducted in 2009 among public and private managers and owners. The aim was to heighten awareness about climate change while being attentive to their priorities, demands, challenges and goals in a context of climate change. The goal was also to see if they trusted scientists. The responses have been broadly diverse, but scientists have identified four challenges that must be overcome before forest adaptation actions can be put in place to address climate change:

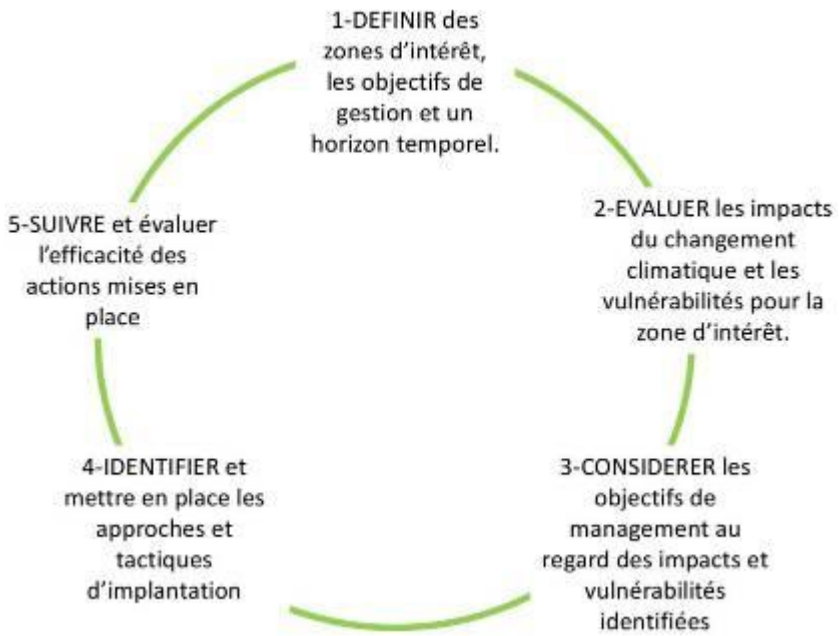
- climate change is too complex to understand;
- information about these changes is neither sufficient nor adapted;
- ready-made food recipes type solutions are insufficient;
- there are not enough real-concrete examples of solutions.

These issues of trust and confusion/ concern about climate change have prompted the creation of a programme by NIACS (Northern Institute of Applied Climate Science): Climate Change Response Framework or CCRF. It concerns the North Midwest and Northeastern United States. It is about creating tools that aim to provide a framework for forest owners and other forest stakeholders to respond to climate change and apply them in the field. Adaptation strategies are built with the goal of the owner in mind. This programme also allows better communication between researchers and landowners through the establishment of many partnerships. This project is the result of the desire to give practical answers to practitioners and to reduce their concerns.

The CCRF began by conducting vulnerability studies (6 published by 130 authors, 2 in the publication phase, 1 new one in preparation) in collaboration with the landowners on federal territory to define the current situation and its future possibilities. Knowing “where we’ve come from and where we are going” is the bedrock of adaptation. The next step was the writing of the “Forest Adaptation Resource”. A book that defines, according to the objectives of the owner, the different types of adaptations that they can implement. It consists of a menu in four phases:

1. Choice of **option**: resistance/ resilience/ transition;
2. Taking into account the specific conditions of the region for the definition of **strategies;**
3. Deciding on the **approach** in order to take into account the specificities related to the ecosystem or the type of forest);
4. Setting up a **tactic** (depending on local conditions and the wishes of the owners).

This work leads to a “Menu of possible strategies”. It is complemented by a “Workbook” that provides structured and flexible methods at the end of the process. It is the working support for the CCRF information and action on owners’ forests project. This Workbook provides context to better understand the overall situation. It is linked to the phases described above because it includes its results (strategies, approaches and tactics) in its phase 4 (see diagram below according to Swanston *et al.*, 2016). The process is circular, all the steps are important. The finding is that the owner often tends to start with tactics.




The two associated approaches connect the concepts to future interventions. Local contexts and data are included in this process. These tools are all interrelated to ensure flexibility of decisions. Thus, the multitude of factors that can play a role in the adaptation of forests for climate change can be taken into account and can then easily reorient the axes of decision taken. These tools simplify and structure the work of forest managers and can even be used by an owner independently.

Christopher Swanston insists that this tool will not guide owners towards preconceived management solutions, but presents them, according to their own data, a range of options deemed most consistent with their objectives and in the face of climate change. This tool is not intended to influence the owner, but to inform them in creating their own management solution adapted to their challenges.

This project covers 22 states. The CCRF has chosen to post on-line adaptation demonstrations (more than 200 demonstrations), to illustrate and give examples of the use of the tools and the implementation of the approach. This provides homeowners with evidence of the effectiveness of these tools, illustrates the different tactics and approaches, and facilitates understanding. Shared accounts from past owners is also online at forestadaptation.org. Planning and adaptation workshops and working groups were held with stakeholders. This has greatly facilitated the building of trust between owners and managers and the exchange of experiences. This step is essential because: “the decisions do not depend on the climate, they depend above all on men”. These workshops have also highlighted the differences in perception between stakeholders: what is perceived as a success for some can be felt as a failure for others.

The next step will be the implementation of the monitoring of these practices for a progressive and collective learning of successes and failures.

## ► Climate change and forests: strategies for ensuring appropriate communication

*Kristina BLENNOW, Swedish University of Agricultural Sciences, Alnarp (Sweden)*

Owners are the engines of adaptation. It is them who will be making the management adjustments to deal with climate change. Thus, informing them is crucial. The question of what is "appropriate communication" can then be asked. It must be both accessible and understandable. It also involves taking into account the target and its diversity. Knowing your counterpart and their needs is very important. This makes it possible to measure the path to take so that it is informed and to choose the modes and vectors of communication to be favoured.

Kristina Blennow describes a study set up in Europe. Landowners were asked if they took action against climate change. These questions were asked of forest owners in Portugal, Germany and Sweden. It appears that in Southern Europe, more people have taken action against climate change than in Sweden. However, this result must be qualified because there were fewer respondents (around 70) than in Sweden and in Germany (350 to 400 responses).

Two main questions were asked:

- How much do you believe in the effects of climate change on your forest?
- How much have you felt the effect of climate change?

In 2005, a big storm hit the forests of southern Sweden, some owners reacted but most of them did not.

It seems that believing in climate change does not prejudge awareness and therefore the certainty that action must be taken. Experiencing the effects of climate change can help raise awareness, but very often it has a limited duration. The study of the relationship between respondents' level of education and their response shows that education is not always a guarantee of the implementation of an adaptation measure. Indeed, not everyone feels concerned. It depends on the individual values of the person.

In conclusion, for appropriate and effective communication, it is necessary to:

- know your counterpart;
- that information about climate change is easy for owners to understand and that they understand what it is about; finding concrete examples that remind them of what they see in their forest or on the ground;
- talk to them about what interests them and is of interest for their forest.

Finally, in the context of climate change, a major part of the information work for owners must be to make them understand its reality and the need to adapt to limit the risks to come for their forest.

## ► What lessons can multi-agent models bring to change in practice processes? Example in Sweden

*Dr. Victor BLANCO, University of Edinburgh (United Kingdom), in collaboration with Calum BROWN, Sascha HOLZHAUER, Fredrik LAGREGREN, Gregor VULTURIUS, Mats LINDESKOG, Mark ROUNSEVELL*

Adaptation of forests to climate change requires knowledge of its impacts: How can global changes change land use and forest services? It is because there is an urgent need to answer these questions that modelling is important. The model presented here is the CRAFTY model, a Swedish multi-agent model that represents large-scale land-use dynamics, and which relies on supply and demand for ecosystem services.

In a forest, there are different contexts: different owners and types of properties, types of management, ecosystem services, etc. This is particularly true in the private forest sector.

Swedish owners often ask themselves this question: we have environmental services in place but are they competitive with those of the neighbour owner? There is thus competition between forest owners (in Sweden) to see what works best in terms of adaptation to climate change.

Regarding the services provided by the forest, several scenarios are taken into consideration: wood production, recreation, forestry and environmental protection, but also multifactorial services, to be compared with the abandonment of the plot.

The wood production service is the largest in Sweden. This is particularly due to the 1960s, when there were many plantations, which has an effect of "heritage" today leading to heavy felling. These are not always followed by replanting or regeneration of the settlement. This service is important enough to be influenced by different climate change scenarios. Indeed, this service fluctuates according to the socio-economic demand, which is not common for most other European countries. It can be seen that the socio-economic impact in Sweden is stronger than the possible impacts of climate change on forest management.

Forest management applied in the field is defined by various criteria: the objectives to be achieved, the behaviour of the owner and the manager and the strategy adopted to achieve the objectives. Based on these criteria and the expectations of the owner, the adaptive capacity of forests to climate change varies.

Finally, there are three main reasons for using multi-agent models. They can simulate:

- current processes;
- potential future trajectories;
- interactions in the general context in which an owner makes their decision.

Three management choices can result from the simulations:

- Keeping current processes;
- Preparing to use new trajectories;
- Making adaptation decisions now.

Today, it would be useful to see the evolution of adaptation strategy changes on ecosystem services. This is why the Swedish researchers have been able to define eight large archetypes of forest owners in order to represent different ways of seeing things. They achieved this synthesis through questionnaire surveys with a systematic verification of results) within the forestry world.

Past data is useful for seeing the evolution but is less relevant to the updated data in terms of the current mentality.

## ► The Canadian Forest Change Programme and tools to support adaptation

*Dan Mc KENNEY, Natural Resources Canada, Canadian Forestry Service (Canada), in collaboration with J. PEDLAR and I. AUBIN*

Climate change is already causing problems for North American forests, such as the proliferation of bark beetles, droughts, storms and damage from winter logging.

The Forestry Change programme was created by the Canadian Forest Service. It has been in existence for 5 years and has been renewed for another 5 years (2016-2021).

This programme has already allowed:

- the set up of a monitoring system for climate change indicators (impacts on the vulnerability of the forestry sector);
- to develop a toolbox for adapting practices (management in a changing climate);
- to ensure an integrated assessment of the implications of climate change for the forest-wood sector (to guide public policies and investments).

All of these tools are available online on the Canadian Forest Service website. There is a focus here on some of these tools.

**Spatialised climate data:** this tool provides spacial climate data that covers North America. This data comes in daily, monthly and yearly time steps. Nearly 80 variables are available for a period ranging from 1800 to the present day and for several future scenarios.

**Spatial climate model**: climate models are proposed at several spatial scales. They allow to see the evolution of the climate according to several future climate scenarios. Combined with other layers of information, they provide information on the impacts and development of insect pests and forest pathogens for over 1300 species with maps.

**Plant Hardiness and Species Modelling**: this tool is used to represent the evolution of climatic envelopes according to a particular index of hardiness (equation developed by Ouellet and Sherk). The use of this index and a species database that includes nearly 3 million occurrences and was used to model current and future climate envelopes. This work has been done for more than 3000 species.

**Forest pathogens**: availability of data and maps of presence of forest pathogens with a history of more than 60 years.

**Insect and disease risk mapping**: detection of 1500 species of pathogens and pests, areas potentially exposed in the current climate and for a future climate.

**Source tests catalogue**: it contains 488 projects, ie almost 1300 tests. The associated information (location, manager, years of implementation, factors monitored, etc.) are stored in a database in Excel format.

**Seedwhere**: This tool presented previously allows to identify the zones presenting a future climate similar to that of the current climate for a given place. It is thus possible to identify seed sources that would be compatible with the projected climates for a given site.

**The TOPIC Network**: a platform listing the main functional traits of plant species in Canada. The combination of more general information on climate, settlements, etc., with this database makes it possible, for example, to produce vulnerability maps for different hazards.

**Database of adaptation options**: it lists the adaptation options identified in the literature.

The availability of this toolkit is helpful in helping make the decision, but it is difficult for decision makers to make choices. They must include the context according to economic, ecological and social conditions and their possible evolution. Confidence in the advice given to them is decisive. Knowing who puts together the advice can be a plus. Measuring costs and benefits can also help trigger action. Finally, we must not forget that small changes can sometimes be enough to solve big problems.

## ► Networking for regional and international risk and crisis management

*Yvonne CHTIOUI, Forest Research Institute of Baden-Württemberg (Germany)*

KoNeKKTIW is a German skills network that focuses on climate change. It deals with forest ecosystem transformations and risk management for forest owners and associated businesses. It is a project of the "Fund for the Climate" financed by the German State. With a duration of 4 years (from 2014 to 2017), the network has benefited from an aid of €1 233 488 and has 30 partners: forest owners associations, the German forestry management council, the forestry service of the different Lander, several organisations from Austria and Spain, etc. As a result, the project covers all types of forest properties.

KoNeKKTIW started as with a regional initiative, which serves as a starting point to build a national network and continues its international development. It is also an important part of the project called "Risks for European Forests" (FRISK), led by the European Forestry Institute. It aims to help forest owners to adapt their forests to climate change, but also to advise forest companies, because climate change will change the range of species, which can be problematic because these companies are often used to/ specialised in certain species and certain types of associated products.

The goal of KoNeKKTIW is to form a representative network of all public and private infrastructures that manage, use, and study the forest environment. It seeks to heighten awareness of the various stakeholders of climate change, to help them acquire skills, but also to centralise the knowledge of different countries and different organisations, to confront them and sometimes to find common ground.

Due to the diversity of activities and members of the network, practitioners with different values to forest companies with sometimes diverging interests, it is difficult to address everyone with one voice. We must adapt the language and try to address each group of stakeholders in a targeted way.

The network consists of a hard core of supervisors and many members who participate and use their information. The team that runs the KoNeKKTIW project is made up of 4.8 full-time equivalents who have forestry degrees and specialisations in training to ensure knowledge transfer and dissemination. This represents a lot of staff - who are nevertheless overwhelmed - and who work in a socio-efficient network: that is to say, communication with target groups and the dissemination of information through coherent means of communication (newspapers, online videos, articles, etc.). Each article posted online is reviewed and verified by each member of the network beforehand.

A report deals with climate change adaptation measures, obstacles that can slow down the implementation of these measures. Why are these measures not as numerous and as concrete as the practitioners would like them to be? The main obstacles are the different policies, the different economic and psychosocial contexts in different countries. Publications that record the current state of knowledge are not easily accessible and difficult for managers and other stakeholders to understand. There is a gap between current scientific knowledge of climate change and its potential to be directly applicable.

The long-term goal of this network is to have a European organisation that can oversee and coordinate local actions in different countries to strengthen the capacity for large-scale crisis management and to have a European database so as not to repeat the same experiences.

## ▶What management decisions to be made for the mountain pine forest in the face of climate change?

*Aurélien BARTHELEMY, Forest Experts of France (France), in collaboration with Ph. GOURMAIN*

It is important to keep in mind the role of forestry experts in France. There are 165 of them and they work on nearly 1 000 000 ha. Settlement management is entrusted to them and they must deal with the constraints and uncertainties, be they economic or climatic. To illustrate this, they took the example of the spruce-fir in a private forest in the Ariège Pyrenees. The property spreads over 800 ha, at an altitude ranging from 700 to 1600m. It is managed as an irregular forest. The main species of this forest is the pectin tree. For lack of sampling, it is today dominated by large woods and very large woods.

In this fir forest, there is massive dieback on the rocky southern slopes. This phenomenon is due to the successive droughts since 2003 and to which the species is sensitive. The diebacks are brutal, unlike the Vosges range, and this leaves little time to use the woods. On the exposed slopes, up to 4 sanitation cuts were made in 6-7 years and every year for some slopes. In some cases the most critical decisions were to not wait for an improbable regeneration, as the senescent subjects have poor fruiting, so it was necessary to proceed to small clear cuts (between 0.5 and 3 ha).

In addition, in the context of climate change, the pectin tree is no longer in place on the southern slopes and rocky domes, so plantations were made with Atlas cedars. So in this case the strategy was to make an anticipation by changing species, however not all owners follow.

Some areas where there were very steep slopes and too high a concentration of rocks have not been reforested because the conditions are too difficult and the costs too high.

In somewhat more favourable contexts, where diebacks are significant but more diffuse, it was decided to accelerate regeneration by taking a large stock of large wood and very large wood. So the strategy here was to reduce the risk by decreasing the stock and the amount of the wood susceptible to dieback. The opening of the settlements has been accompanied by regeneration maintenance work. The areas are mainly limestone, so we made a specific cut of hazelnut and boxwood. On the other hand very few plantations and enrichments of the gaps were made at this stage. Considering that the fir was still in its place in these contexts, we decided on natural regeneration.

Finally, at very good stations, on North slopes and valley bases, diebacks are less numerous and the future of the population is not questioned. Nevertheless, heavy felling of very large timber for commercial reasons and to allow a slow regeneration is practiced. The rare hardwoods are kept (beech and linden) to increase biodiversity and to improve the fir's regenerative capacity. At these stations, managers have relied on the capacity of existing settlements to overcome periods of climatic stress.

Thus, depending on the soil's climatic context and depending on the settlement diagnosis (including health status), the strategy to be implemented within the same range can vary greatly. In the first case (south and rocky slopes), the strategy is to anticipate climate change by focusing on a new species. In the second (other slopes and ridges), the preferred strategy is to limit the risk. In the third (north slopes and valley base), the emphasis is on the resilience of the settlements.

What is to be remembered is that we must observe to understand and imagine scenarios. Thus, the inability to accurately predict settlement evolutions should not paralyse managers. Means of action exist. In some cases we must decide and dare to act, with determination, measure, consistency and pragmatism, at the risk of failure. It is also wise to diversify strategies. It is necessary to evolve according to the experiences and the environment, indeed climatic change begins with a period of transition which will require regular adjustments in the management. Finally, it is necessary to share information between foresters and between managers and researchers. This will allow an improvement of knowledge, as well as the production of practical guides and therefore a proposal of a variety of solutions.

In conclusion, we can say that we must all tame uncertainty.

# CONCLUSION

Moderators: Mériem FOURNIER, AgroParisTech

## ► Conclusion by the students of AgroParisTech

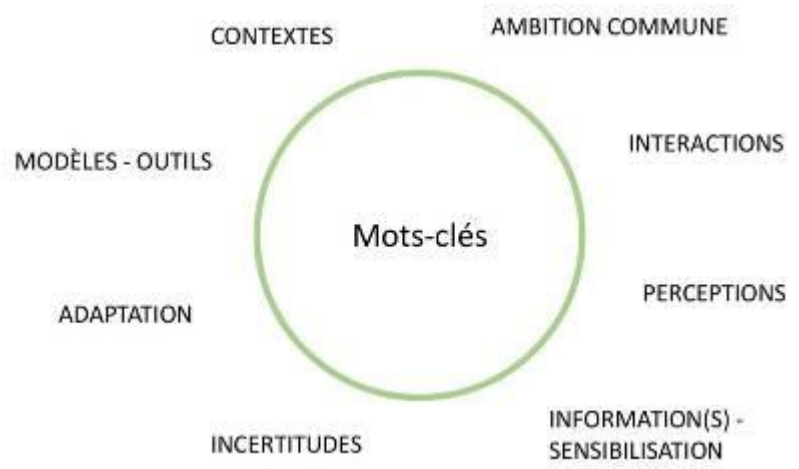
*ARNOULD Maxence and BONIN Frédéric - Masters FAGE Wood, Forest and Sustainable Development, under the supervision of Mériem FOURNIER, AgroParisTech (France)*

The presentations made during these two days mainly focused on the observation of climate change and on future perspectives: evolution of practices according to this new context and new organisations necessary for their implementation.

They also provided an overview of the instruments i.e. tools made available to influence changes in practice and their level of ownership. Various means to implement to support their use have been proposed. Finally, the wealth of knowledge available today, the knowledge to be acquired, the knowledge that reaches the decision-maker and what they perceive from it, was also discussed.

It appears that climate change is an international challenge that affects all professions in the forest. Many wonder about the means to implement to include industrialists in the reflections: how to anticipate the supply and the future demand? Should we move to exotic species if we have no certainty of an outlet?

At the end of these days, a certain number of keywords which return regularly in the presentations come to mind:




The combination of these keywords reflects the richness of this workshop, the diversity of discussions and the contribution of each participant:

***"In spite of different CONTEXTS and PERCEPTIONS, thanks to a common AMBITION, INTERACTIONS and INFORMATION, MODELS are created and transformed into TOOLS which, by means of an adapted AWARENESS, will make it possible to face up to UNCERTAINTIES."***

It simply and effectively summarises the rapid international situational analysis that the organisers have tried to address during these days.

## ► Conclusive session by the students of the EPLEFPA of Mirecourt

*Under the supervision of Jean-Michel ESCURAT, EPLEFPA of Mirecourt (France)*

*Scenario of the session devised by the students of the EPLEFPA of Mirecourt*

**Contexte** :
2 students from the school of architecture were mistaken, they followed the symposium thinking it was one of their courses. They found climate change interesting and discuss it at the end.
1 "object" character, often plays the role of advertising and illustrates the discussion. They have a thermo-watch (a thermometer as a watch)

**Exordium**
("object" person looks at their thermo-watch, in a distraught manner)
The two students come down to the front of the room

**ALEXANDRE:** It's funny, since yesterday I do not feel like taking architecture classes!

**FLAVIAN:** Yeah, it's true that it does not look like it, finally for general knowledge it was rather not bad, I really found it interesting these discussions! Hey, usually there are not so many people coming to teach us! Can you imagine how privileged we are?

**ALEXANDRE:** Interesting, interesting, it's a little depressing this climate change business! And I'm not even sure I understood all the subtleties of their messages,....

**Intro**
**FLAVIAN:** What I understood is they want to forge ahead! Their goal is to move forward, but especially to move forward together!

**HANNAH***:* "As part of the France-Quebec cooperation, we went directly to Quebec and France to meet the forest producers of our regions and our meteorological service partners, among others. You see, there is a real human relationship between us and our associates,... friends! Join us!"
Excuse us for this short page of advertising.

**ALEXANDRE:** The problem is that there is no way to know 100% what will happen in the future, the uncertainties of predictions about the rate of precipitation for example, the amplitude of variation is 400mm! And if we respect the Paris agreement, and its predictions, and its averages, probably the probability of being lower must increase, and the probability of being higher must decrease! ...but .... we are not sure!

**Session 1**
**FLAVIAN:** Well that's why they have developed a lot of simulation systems to try to anticipate several scenarios. For example, many practitioners complain about not having enough tools and knowledge available, and the risk of drought is scary for everyone, so they would like to know how to measure and quantify droughts.
*(measurement of Flavian by Hannah with a measuring meter)*

**HANNAH:** "Nowadays, with our new simulation tool, save time in your measurements! Okay, we took over 120 hours for the calculation... but it's a quick tool, I assure you! Contact us now for any further information."

**ALEXANDRE:** Tell me, will [Hannah] she react to everything we say? She adapts like Quebec, rather reactive than preventive!

**HANNAH:** It's climate stress, sorry...

**FLAVIAN:** Well, it does not matter... I trust the science, if today it tells us that we must radically change our vision of things, I do not know where to go, but we'll go!

**ALEXANDRE:** Radically? It's a bit rich! Little by little it's already quite a lot, to be sure that it works, preach incremental adaptation!

**FLAVIAN:** Incremental?….Yep, ... that's not wrong!

**HANNAH:** "Do you have adaptation problems in your forests? Let nature play its role! With its adaptability and responsiveness, it adapts its climates to your species to give them a comfortable living environment and... *(looks at the thermo-watch)* warm! With nature, say goodbye to adverse climates."

**ALEXANDRE:** For heaven's sake! The contingency obligation has escaped us again! I think it even left us... peace to her soul!

**Session 2**

**FLAVIAN:** But all the better, remain open, it's already a step forward! Scientists have a time horizon to reach, do not lose people along the way! Researchers are not simply used to vulgarly throw out kilos of information in all possible languages, they have a role of help, of assistance to practitioners.

**ALEXANDRE:** We will have to give up the reaction of "I do not know so I do not act". Darnation, we are forced to react, I suddenly feel important, essential in the natural chain! I will not let the warming sweeten the maples!
*(to the "object" character)* How much time do we have left?

**HANNAH:** 2 degrees.. !
Projects have to take shape in different countries, and slower than that, please! The adaptation is not a sprint, it's a marathon! Come on, come on, lets get involved! Lets get things moving! To hell with order and discipline, I want resistance, resilience and answers in our forests!

**Session 3**

**FLAVIAN:** Yeah, I'm a little suspicious anyway, why should we believe all these people?

**HANNAH:** Excellent question, my dear! Here, our scientists know how to take things in hand. They show themselves, they listen to you, they are honest and transparent. What's more, they are accompanied by the greatest, most intelligent engineer in the world: the climate! What else?

**Conclusion**

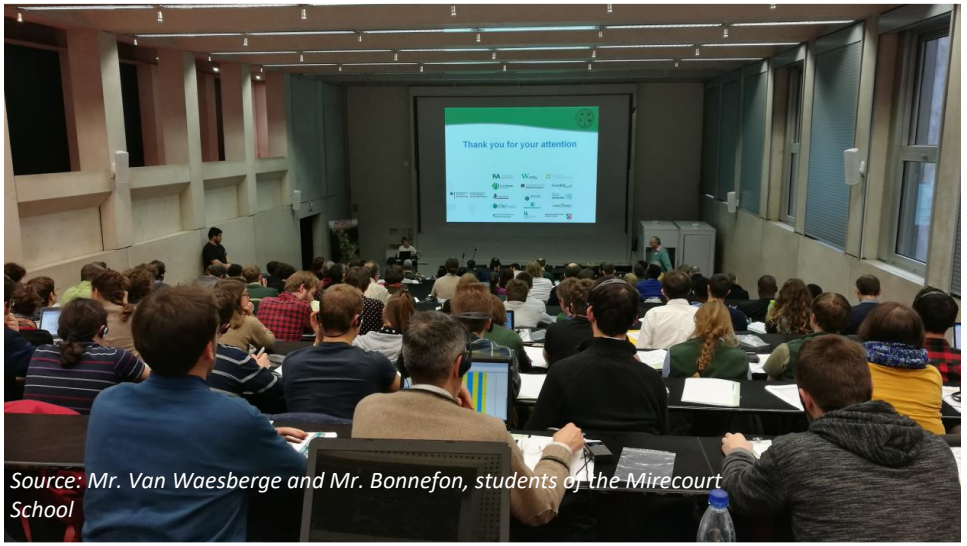
**FLAVIAN:** Finally, with our bioclimatic homes, timber, all that stuff, climate change, it will affect us too! It watches us, it roams all around us... it is everywhere! It hides behind almost every profession, ready to impose when you least expect it!

**ALEXANDRE:** Well, we've been warned! Finally we did a good job to get rooms mixed up, we will now be able to act and inform!

**HANNAH:** Oh and, for questions, you have not already had an answer for simple questions, we will not hide it: we will not answer you for the complicated ones either! And anyway... we do not have time anymore!

*(The 3 characters go back to their place at pace.)*

With the participation of:


*Source: Mr. Van Waesberge and Mr. Bonnefon, students of the Mirecourt School*