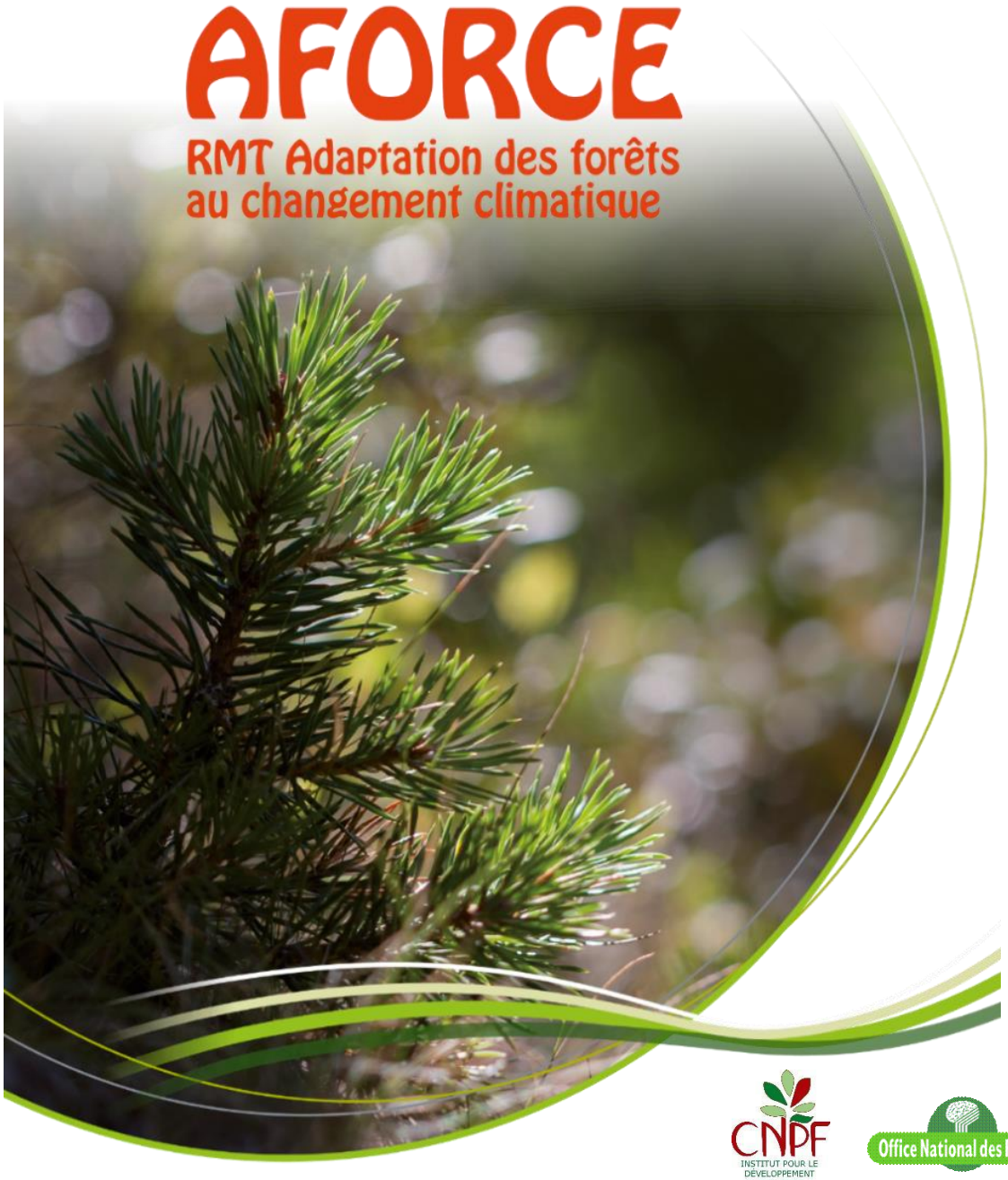

AFORCE Symposium 2019

Forests and climate change:

Providing support to the adaptation decision

April 2-3, 2019 in Montpellier (France)

Book of abstracts

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Climate change: what can be expected for forests in the future?

Jérôme DUVERNOY (ONERC)

The conclusion of the IPCC special report on the "impacts of a global warming of 1.5°C" is unequivocal. It confirms that the global climate has already warmed by approximately 1°C on average compared to the pre-industrial era and describes in detail the consequences of a global warming of 1.5°C: recrudescence and intensification of extreme climatic events, rising sea levels, melting ice, dwindling water resources, reduced agricultural production, increased threats to terrestrial and marine biodiversity, health damage, economic losses, increased poverty.

The IPCC considers, however, that it is still possible to limit this rise in temperature to 1.5°C and to limit the damage to man and his environment, subject to determined public policies and properly oriented investments. The report stresses that all options for not exceeding an increase of 1.5°C require major transformations, in all sectors of society and worldwide, and that it is essential to implement them rapidly.

In line with the long-term objectives of the Paris Agreement and with the relevant objectives of the other international conventions, France will have to adapt to the share of climate change that past greenhouse gas emissions accumulated in the world now make inevitable. The hypothesis adopted is an increase in the average global temperature of 2°C compared to the pre-industrial era even if France acts on the national and international level to limit this increase to 1.5°C. The national adaptation policy is therefore the essential counterpart to our climate change mitigation policy aimed at achieving carbon neutrality. It also aims to avoid the contradictions of the various adaptation actions between them and with the actions of environmental protection. It recognizes the value of biodiversity and ecosystem services for adaptation and seeks, wherever possible, synergies by focusing on nature-based solutions. It is also part of the principle of ecological and solidarity transition.

The general objective of the National Plan for Adaptation to Climate Change 2018-2022 (PNACC-2) is to implement the necessary actions to adapt, by 2050, the territories of metropolitan France and overseas to the anticipated regional climate changes.

In the forest sector, these actions should ensure coherence between the mitigation and adaptation potential of forest management or conservation policies and that of recovery and recycling of wood and biomass. One of the objectives is, for example, to contribute to reducing the risk of fires and increasing resilience to this risk, so as to maintain the potential for mitigation. Forest resilience, in the face of climate change, is an environmental, social and economic challenge that seeks to preserve ecosystems, atmospheric carbon sequestration, wood production and recreational uses of the forest.

The impacts of climate change in the Pyrenean forests: the Pyrenean Observatory of Climate Change (CANOPEE)

Sébastien CHAUVIN (FORESPIR)

The forest occupies more than half of the surface of the Pyrenees and provides many goods and services, both locally and regionally.Climate change can hinder this multifunctionality by causing decline in production or protection of forests, destruction of species or remarkable habitats, deterioration of the forest landscape etc.

Consequently, it is becoming increasingly clear that forest managers in the Pyrenees need to anticipate these changes by developing common tools to improve knowledge and decision-making in the implementation of adaptation actions within the territory.

Against this background, FORESPIR, the National Center for Forest Property, the National Forest Office, the HAZI Fundazioa Foundation, the Center for Forest Sciences and Technologies of Catalonia, the Forest Property Center of Catalonia, the Pyrenean Ecology Institute, the Government of Aragon, the Environmental Management of Navarre public company and the Institute of Andorran Studies launched the "Climate Change and Adaptation of the Pyrenees Forests" CANOPEE project within the framework of the Pyrenees Climate Change Observatory (https://opcc-ctp.org/fr).

This cross-border cooperation project financed by the European Union (FEDER- INTERREG POCTEFA https://www.poctefa.eu/fr/), the French State and the "Pyrénées-Méditerranée" Occitan region aims to:

Strengthen the monitoring of climate change impact indicators on the main species of the Pyrenees.

Dependent exclusively on weather conditions, phenology is a true reflection of the annual climate. As a short-term indicator, it allows for annual comparisons of differences in the biological life cycles of species development. Regular monitoring of bud burst makes it possible to judge the real impact of climatic conditions on trees. Thus, 53 plots in the Pyrénées-Atlantiques, Haute-Garonne, Ariège, Pyrénées-Orientales, Catalonia, Aragon, Navarre, Basque Country and Andorra are monitored each year.

Develop a tool to characterize the vitality of the trees in the forest massif and their vulnerability to decline.

It is the ARCHI method (which aims to diagnose the resilience dynamics of trees by basing its analysis of decline on the integration of the notion of reversibility of a state of stress) which has been deployed in a cooperation framework between France, Spain and Andorra. Four new ARCHI keys (Fagus sylvatica, Pinus sylvestris, Pinus uncinata, Pinus nigra) and a smartphone-tablet application were created. Several training courses for Pyrenean foresters complete this technical aspect.

Map the areas of vigilance (current and future) of the main forest species in the Pyrenees according to different scenarios of climate change.

The studies carried out in France and Spain on the possible effect of climate change on the potential future distribution of species or on their vulnerability generally concern national or regional scales; in this context the Pyrenees are in marginal situation for which the validity of the models is probably less reliable and the results less relevant and difficult to use. Current Climatic Vigilance maps have thus been produced by statistical modeling (link between the current distribution of stands where the species is dominant and climatic averages for 1981-2010, according to the available information). Each Current Climate Watch (VCA) map offers a closer look at where the species is in a warmer or drier climate than in the whole of its Pyrenean range. Future vigilance maps will also be produced based on the data generated by the CLIMPY project https://opcc-ctp.org/fr/climpy (regionalized scenarios).

Develop and implement adaptive management actions to minimize the anticipated impacts.

A series of pilot plots representative of the diversity of the forests of the Pyrenean massif (potentially vulnerable to the effects of climate change and/or showing signs of active decline) were selected. Different types of adaptive forest management actions are currently being implemented to reduce the vulnerability of these stands to climate change. The consequences of these operations on the water resource are modeled and a monitoring protocol is developed in order to evaluate the impact of the treatments on the development of the treated stands in the medium term. Finally, a manual of good forestry practices to reduce the vulnerability of the forests of the Pyrenean massif to climate change will be produced.

Further information: https://opcc-ctp.org/fr/canopee

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How adaptative measures implemented to face climate change are taken into account by foresters (MACCLIF)

Annabelle AMM (GIP ECOFOR), Éric SEVRIN (CNPF-IDF) and Brigitte PILARD-LANDEAU (ONF)

The MACCLIF project (2016-2019), led by the GIP Ecofor, seeks to assess the perception and consideration of climate change by foresters. The distinctive feature of the project was to focus on both public and private forests throughout France, to carry out quantitative and qualitative surveys of foresters and to explore the consideration of climate change in forest guidance and management documents.

Perception of climate change by foresters:

A quantitative survey (web-questionnaire) for professionals was conducted at the national level. 922 web-questionnaires were completed. It was supplemented by 74 semi-structured interviews with professionals in the Auvergne Rhône-Alpes and Center-Val de Loire regions. A telephone survey was conducted by CREDOC with 960 owners.

Quantitative surveys of professionals or forest owners converge towards a high level of awareness of climate change. 93% of professionals and 74% of forest owners believe that the climate is changing. Among them, 90% of the professionals and 85% of the owners think that this change is due to human activity.

Semi-structured interviews confirm that professionals are extremely concerned about climate change. Nevertheless, they made it possible to highlight the uncertainties that professionals perceive regarding the intensity and speed of warming or the management measures to be put in place to adapt the forests.

Of the professionals who believe in climate change, 85% say they are changing their silvicultural practices, while only 25% of forestry owners have changed or are considering modifying them. The main motivation of the professionals is the observation of the effects of climate change in the forest. The uncertainty around climate change is often mentioned by professionals as a reason not to adapt or slow down when implementing adaptation actions. The owners believe that they still have time to adapt.

Consideration of climate change in forest guidance and management documents

Guidance documents for public and private forests have been in existence for more than 10 years. Their analysis shows that the consideration of climate change is varied at the national level. The vocabulary associated with climate change in these documents reveals that it was perceived, when they were written, as essentially a threat (examples of associated vocabulary: decline, pathogen attack, water stress). About 5% of public forest developments clearly mention climate change. Simple private forest management plans do not explicitly mention climate change although some measures such as shorter rotations may be adopted to counter the impacts of climate change.

Overwiew of the regional mobilization on forest adaptation to climate change : conclusion of an expert mission supported by the EIP-AGRI and the National Rural Network

Benjamin CHAPELET (CNPF) and Jean CROISEL (Regional Council Bourgogne Franche-Comté)

The AFORCE network was commissioned (May 2017 to December 2018) by the MAA *via* the CNPF to undertake a thematic appraisal on "forest, climate change and innovation". This mission, carried out as part of the animation of the European Partnership for Innovation (PEI-AGRI) which is led by the French National Rural Network, is the result of several initiatives undertaken at different levels:

- The implementation of the PEI-AGRI by the Rural Network as part of the Europe Strategy 2014-2020.
- The mobilization in 2015 of a collective of 11 national forest stakeholders, initiated by the CNPF and the MAA, for a better integration of forestry issues in the PEI-AGRI.
- The creation of a Focus group n°24 of the PEI-AGRI on the same theme "Forest and climate change".

To this end, a **first working group** has been set up with the main national forest stakeholders, most of whom are also members of the AFORCE network, in order to frame the organization of regional exchange workshops. Each workshop was thus organized in collaboration with the Regional Councils, the DRAAF and the AFORCE network correspondents, which made it possible to refine the list of local forest actors to associate. **A second working group** made up of European forest stakeholders aimed to put this thematic expertise into perspective with similar approaches and work on a European scale.

Thus **6 exchange workshops were organized in the regions** around the theme. They brought together 127 participants from more than 400 identified regional stakeholders and made it possible to:

- Identify existing projects and initiatives, as well as other events dealing with the theme;
- Promote the sharing of information and synergies on the theme between a wide range of stakeholders and decision makers at regional, national and European level;
- Identify the innovation needs of local stakeholders on this theme and the capacities of research actors to respond to them;
- Help regional authorities and project leaders to have a global, coherent and structured vision of possible actions;
- Give impetus to new projects notably *via* the PEI-AGRI Operational Groups;
- Promote the AFORCE network as a national network able to federate all the approaches on this theme.

Extremely valuable exchanges within these workshops made it possible to identify various **forest themes considered as priorities** by the mobilized stakeholders**:**

- Risk management
- The forestry/hunting balance as a prerequisite for any forest action
- Adaptation to climate change
    - Organization of observation of developments and impacts (vigilance)
    - Experimentation of new species and new silviculture
    - Strengthening station and silvicultural diagnosis
    - Accompaniment for forest renewal and exploitation
- Promoting the role of forests in mitigating climate change
- Training, technical and higher education
- Communication

From these 6 interregional workshops, it has emerged that forest stakeholders are waiting for more exchanges and sharing around issues that affect them within their own particular regions but also with neighboring regions. At the end of these workshops, the AFORCE network proposed to make available pages dedicated to each region on its website to promote local actions. However, publicizing is not enough. The establishment of a regional thematic event, coherent with the national action could, in addition, give impetus to new multi-partner and interregional projects around the adaptation of forests to climate change, focusing on priorities and consistent with national and

regional issues. These workshops laid the groundwork for the first steps. The AFORCE network must now build on these conclusions to build its 2020-2025 program accordingly.

Learn more:
- The thematic appraisal >>> https://www.reseau-aforce.fr/n/reseau-rural-francais/n:3389
- The regional exchange workshops >>> https://www.reseau-aforce.fr/n/ateliers-d-echange-en-region/n:3243
- The regional initiatives >>> https://www.reseau-aforce.fr/n/aforce-en-region/n:3427
- The forest PEI-AGRI >>> https://www.reseau-aforce.fr/n/partenariat-europeen-pour-l-innovation/n:3390

Presentation of European initiatives on climate change adaptation and risk mitigation by EFI and input of the EIP-AGRI via focus group

Christophe ORAZIO (EFIPLANT), Olivier PICARD (CNPF, RMT AFORCE Coordinator) and Pacôme ELOUNA-EYENGA (EIP-AGRI Service Point)

This intervention aims to present current initiatives at European level related to the consequences of climate change on forests. Firstly, the role of the AGRI point service and the first conclusions of the focus group on forest adaptation to climate change, which brought together 20 experts to structure and produce recommendations for the creation of operational groups, as well as research topics that appear useful to develop. This roadmap will be the basis for calls for projects in the next framework program for European research.

In the second phase, European projects directly related to climate change adaptation and induced risk management will be introduced. An overview of the project in preparation for a pre-ACT thematic network aimed at facilitating exchanges of experts and good practices will be discussed, as well as the PLURIFOR project for the creation and improvement of cross-border forest risk management plans. This project has made it possible, particularly in France, to develop storm risk vulnerability mapping tools, to adjust pine nematode risk management strategies, and to set up a plan for emerging biotic risks. A quick demonstration of the SYLVALERT smartphone application for reporting risks in the forest will be made. An overview of the multi-criteria analyses as conceived within the framework of the FORRISK project will be an opportunity to discuss the different components of the notion of risk.

Finally, the first results obtained on the 6-year-old trees of the REINFFORCE arboretum network arranged along a climatic gradient from northern England to Portugal will be presented. An overview of the models obtained using this gradient to categorize species according to their behavior in the face of drought or temperature increase will be presented and the application of these models to estimate the risk induced in the future climates of the ocean area will be explained.

A multipartner national network to evaluate genetic forestry resources for the future (ESPERENSE)

Hedi Kebli (CNPF-IDF)

The various climatic scenarios produced by the IPCC raise fears of a decline in the productivity of French forestry. The climatic trajectory taken in recent years, the extent of the impacts and the duration of rotation of the species require a rapid and appropriate response by forest managers. Our know-how and silvicultural methods will not be enough to maintain productive stands. It has therefore become essential to anticipate by proposing reasoned and innovative adaptation options based on existing knowledge as of now.

The latest advances in research have highlighted the vulnerability of the main French forest species to global climate change. Managers are particularly aware of these issues and the importance of selecting species to plant or promote. Nevertheless, they feel particularly unequipped to make such decisions alone, with far-reaching consequences for the future of the forestry industry. They are waiting for recommendations for the management and renewal of their forest stands. It is becoming increasingly urgent to be able to offer them options.

The establishment of multidisciplinary networks of actors is an effective solution to respond to such challenges of adapting the forest to the expected climate changes. In addition, the pooling of resources from both research and public and private R&D organizations and managers is an effective option for addressing complex national issues. The ESPERENSE project relies on comparable pooling to initiate a network of multi-partner experiments to evaluate new forest genetic resources for the future. It receives financial support from the Ministry of Agriculture as part of the national call for projects 2016-2017 “Innovation and investments for upstream forestry” financed by the Forest and Wood Strategic Fund (FSFB). It is led by the RMT AFORCE and includes 6 partners (CNPF, EFIPLANT, FCBA, INRA, IRSTEA and ONF). Also invited are CETEF, DSF, FNCOFOR, FRANSYLVA, GIE Semences forestières, IGN, private nurseries, the SFCDC and UCFF. The purpose of this project is to set up a network of plots, the monitoring of which will ultimately improve knowledge concerning the behavior of new species and provenances in different forest station contexts. This prerequisite is essential in order to identify potential species of substitution for vulnerable species in the territory. At the end of the project, a diagram of this network accompanied by methodological elements (species list, installation protocol, etc.) will be provided to allow its progressive implementation on the territory. A greenhouse analysis is also conducted as part of the project to study the effects of water stress in young age. Indeed, to understand the resilience of species to climate change, growth and mortality measures in *in situ* tests alone are not sufficient. The physiological function under stress must also be taken into account.

The project's stakeholders wish to participate in a lasting partnership around the experimentation of new species and provenances, as well as for the sharing of experiences beyond the period of this project. For that, a reflection is carried out 1 / regarding the creation of a consortium of partner actors of the French experimentation of new essences, and 2 / regarding the installation of an interoperable national infrastructure of data bases. The federation of forces and means will allow the establishment of a solid and sustainable experimentation network. It will be consistent with the already existing experimental assets and can be integrated into the list of networks interacting with IN-SYLVA France. This collaborative approach involving researchers and managers will make it possible to integrate the initiatives as the project progresses and to ensure faster and more efficient feedback from forest experimenters.

Supplying foresters with quality seeds in order to test new species (TREC)

Patrice BRAHIC (ONF) and Catherine DUCATILLION (INRA)

By modifying the growth conditions of our native species, climate change is likely to put the current species of production in difficulty. One possibility for adapting forests to these changes is to enrich the range of tree species. To test species that are potentially adapted to future climatic conditions, one of the first steps is to obtain quality forest seeds. Obstacles remain to be removed, including:

The supply of seed in quantity and quality, of known and certified origin, for species from non-member countries,

- Regulatory constraints and phytosanitary rules applying to their trade,
- The methods of storage and germination of species whose cultivation is not or little known.

The project is built around these issues. Deliverables that will be made available to experimenters and nurserymen:

- A list of reliable dealers offering quality seeds whose supply has been tested, selected on the basis of an evaluation criteria grid,
- Summary of information on the regulations that apply to their trade,
- Pretreatment and germination protocols.

To best explore all aspects of the issue, twenty species were chosen, approaching the softwood/hardwood parity, taking into account i) their undeniable forest interest, ii) the diversity of geographical areas of origin: North America (US), South America (Chile), Asia (China) and Europe (Hungary and Balkan countries), iii) their supply which can be assumed: easy, moderately easy, difficult, very difficult. The selected species have the advantage of testing and / or identifying suppliers among these four geographical areas with a relatively restricted list of species. The 20 chosen species are the following: *Abies cephalonica, Abies lowiana, Abies pinsapo, Calocedrus decurrens, Cunninghamia lanceolata, Nothofagus obliqua, Picea engelmannii, Picea omorika, Picea pungens, Pinus brutia, Pinus peuce, Pinus rigida, Alnus cordata, Fagus orientalis, Liquidambar orientalis, Populus yunnanensis, Quercus cerris, Quercus frainetto, Quercus vulcanica, Tilia cordata,*

Of these, the thirteen species below have been subject to actual sourcing tests:

Abies cephalonica, Abies lowiana, Calocedrus decurrens, Cunninghamia lanceolata, Picea omorika, Pinus peuce, Pinus rigida, Fagus orientalis, Liquidambar orientalis, Nothofagus obliqua, Quercus canariensis, Quercus cerris and Quercus frainetto

A list of reliable suppliers offering a high quality resource has been established. For that, various criteria were analyzed: accessibility of the catalog; responsiveness; sending time; duration of transport; documents provided, quality and precision of the indications mentioned; phytosanitary certificate; quality of the packaging; condition of the batch upon unpacking; apparent health status; comparison of the indicated and actual weight; purity ... The stability of the supplier's offer was also taken into account.

The species whose supply was successful have been the subject of various tests of dormancy and pregermination in order to propose the most suitable protocol. Three to four protocols were tested per species.

The Alpine and Mediterranean forests confronted with climate change in the Provence-Alpes-Côte d'Azur region (SYLFORCLIM)

Pauline MARTY (CNPF-CRPF PACA) and Michel VENNETIER (IRSTEA)

Météo-France's study of climate change over the last 50 years reveals that Provence-Alpes-Côte d'Azur is the region of France most affected by these changes (Gibelin A., Météo France, 2015). The Scots pine is the most important species in the region in terms of area (250,000 ha). It was heavily impacted by the repeated droughts of the 2000s (A. Thabeet, 2008 Lelou D., 2010, Thauvin G. 2011). The stakes for the timber industry are therefore high, without counting the effects on biodiversity, multifunctionality and increased fire risk.

The objectives that have been achieved in the Sylforclim project are:

1. Mapping the sensitivity to climate change for the Scots pine with the BIOCLIMSOL tool
2. Estimating the factors of compensation or aggravation of the climate (soil, topography ...)
3. Better understanding the impact of climate and its evolution on the radial growth of Scots pine from a dendroecological study
4. Proposing silvicultural recommendations to limit the risk of decline

The project, funded by RMT Aforce and DRAAF PACA, was piloted by CRPF PACA and conducted in partnership with IRSTEA and IDF. Technical Committee meetings involved the DSF, the ONF, the RMT, INRA, DRAAF, DREAL, the PACA Region, the Mediterranean Forests Association and the forest managers.

Field surveys were carried out on 90 plots. The results highlight the high rate of defoliation of Scots pine (48% on average). This rate is higher on hot slopes, at low altitude and at the top of slopes. But it is above 40% even in the most favorable conditions.

The two dominant variables in the explanatory model of decline are biotic variables: mistletoe and the processionary caterpillar with relative weights of 56% and 33% respectively. The topoedaphic index (which synthesizes the characteristics of the station) represents 23%.

In addition, it has been shown that the rate of mistletoe is determined by climatic variables. Where the Scots pine is subject to a high water deficit (edaphic and/or climatic) and high temperatures, the probability of encountering tree trunks with mistletoe is much higher.

Ring analysis has shown that caterpillar attacks are recurrent at some sites. This has a strong, repeated and lasting effect on the productivity of the stands concerned. The more frequent climatic accidents become, the greater the probability of combining the two phenomena (climatic stress and caterpillar infestation). Thus the risk of decline becomes higher.

The tools produced as part of the Sylforclim project are:

- a climate watch map that defines the risk of Scots pine decline;
- an index including the climate and at the station (ground climate index);
- a decision support key with management recommendations.

Dendroecology study on Quercus petraea using long-term forest monitoring (ADAREEX)

François LEBOURGEOIS1 in collaboration with Anna SCHMITT[1], Raphaël TROUVE[2], Claudine RICHTER[3] and Ingrid SEYNAVE[1]

Controlling stand density is widely advocated as a strategy that foresters have at their disposal to modulate the response of trees to climate (particularly to drought events) and to cope with predicted climate changes. As response to drought also depends on the site water availability and the tree social position within the stand, we analyzed the joined joint effects of stand density, social status, and water balance on tree growth mean response to climate (1997-2012) and resistance (Rt), resilience (Rs), and recovery (Rc) following the severe drought of 2003. We used retrospective growth data in young stands (mean of 34 years in 2012) of sessile oak (Quercus petraea) collected in French permanent silvicultural plots (269 trees). The network experienced three climatic conditions (mean summer water balance: -182, -126 and -96 mm; dry, mesic and wet) and three stand densities (Relative density index: 0.20, 0.53 and 1.04; low, medium and high). Bootstrapped correlation coefficients showed that mean response to climate differed with water availability. Tree growth highly depended on spring and summer droughts on dry and mesic sites and not at all under wet conditions sites. Neither stand density nor social status modulated mean response to climate. Decreasing stand density increased resistance, resilience, and recovery, particularly on dry sites and the effect was independent of tree social position within the stand. Thus, despite experiencing higher soil water deficits, trees growing in drier sites exhibited remarkably faster growth recovery than those in moister sites. These results highlight the role of acclimation in tree community responses to present and future climates.

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Effect of the reduction of leaf area on the sensitivity of trees to drought (REDSURF)

François COURBET (INRA-URFM), Nicolas MARTIN-St PAUL (INRA-URFM) and Jean LADIER (ONF) in collaboration with Guillaume SIMIONI (INRA-URFM) and Claude DOUSSAN (INRA-EMMAH)

The aim of the REDSURF project was to advance knowledge on the effect of silvicultural interventions on the adaptation of forest stands to climate change.

Methods:

Two species have been studied: the silver fir (Aude), and the Atlas cedar (Gard).

Two experimental systems, one per species, were used to detect the effects of silvicultural interventions on drought tolerance through health status, diameter growth, and ecophysiological behavior characteristics. The environment (soil + subsoil by electrical conductivity measurements, climate) and the development of vegetation (undergrowth and stand) were characterized.

At the same time, water balance and functioning models (BILJOU© and Sureau) were used to evaluate the stress sensitivity of trees and stands according to the intensity of thinning. Uncertainties regarding the leaf area and useful soil reserve, at which models are sensitive, remain strong.

Results:

The electrical resistivity measurements of the substratum show that cedars take water well beyond the soil layer, up to 5 m.

In the fir the thinning did not have a positive effect on the evolution of the foliar deficit. The cambial necrosis noted on cedars appeared preferentially in years with a more favorable water balance and on the most conducive zones.

A mixed effects model was used to model the effect of different variables, including the interaction between density and climate (or annual component) on annual measured basal area increments of cedars. For 5 years after thinning, there is a positive effect of thinning on the growth-climate relationship, which is significant between extreme densities (10 and 40 m²/ha). This effect subsequently fades.

Leaf water potential measurements (an index of water stress) in 2017 show that cedars in thinned plots undergo less water stress 25 years after thinning, despite undergrowth development. We also found a modest acclimatization of cedar drought resistance in the high-density plot (1,200 trees/ha), compared to high-thinned patches (400 trees/ha).

Simulations carried out over the period 1995-2015 showed that thinning reduces water stress and the risk of hydraulic failure (which can lead to decline), particularly in the cedar system.

In 2017, Sureau reproduced the difference in water potential between treatments after thinning 1,200 and 400 cedars/ha.

In addition, the simulations (1960-2100) suggest that under climate change, in the absence of thinning, the trees could experience cavitation rates that are all the greater as the change is more severe. Thinning would greatly reduce the risk of cavitation.

The drafting of an educational reference base, presenting the main ecophysiological indicators and operating models currently in use, is currently under way.

Adapting Haut-Languedoc forests to climate change: the LIFE FORECCAsT project

Juliane CASQUET[1], Raphaël BEC[2] and Constance PROUTIERE[1] in collaboration with Baptiste ALGAYER[1], Michèle LAGACHERIE[3], Jean LEMAIRE[4], Xavier BEAUSSART[1]

Located at the confluence of three climate types (Mediterranean, Atlantic, mountain), the Haut-Languedoc Regional Natural Park (Pnr HL) is particularly sensitive to climate change. The forest covering two thirds of the territory is a major economic, environmental and social asset. In view of the risks associated with these changes, the Pnr HL associated with the National Center for Forest Property (CNPF) and the Alliance Forêts Bois forestry cooperative are implementing actions aimed at adapting forests. The LIFE FORECCAsT project will ultimately provide forest owners, forest managers and local elected officials with tools to adapt their silviculture to climate change, and will educate professionals and the general public on these topics.

One of the project's flagship tools consists of a reference network for different methods of adapting forestry to climate change, consisting of 24 experimental sites. Half of the sites concern forest stands in place, of varying species and age, in which protocols are tested to limit water demand, mitigate health risks, promote natural regeneration, or preserve natural habitats of community interest. Nine sites are mixed plantations of species more or less well known in the territory, installed in various ways (lines, bands, mosaics). Combining several species reduces risks in an uncertain future climate context, can spread the use of water resources in stands, encourages their biodiversity and improves their resilience. Finally, three sites representative of the three types of climate of the Pnr HL, include arboretums of about twenty species. They will make it possible to evaluate the potential of certain species, *a priori* better adapted to the future climate and never tested on the territory.

Long-term silvicultural testing is monitored by a tripartite agreement between the Pnr HL, the CNPF and the site owners. Test plots now constitute information, extension and demonstration media for adaptation practices in forest management.

Among the tools developed by FORECCAsT is also a mobile application called "FORECCAsT by BioClimSol". Based on field data entered by the user, georeferenced climatic and topographic data, and mathematical algorithms based on the BioClimSol method (developed by the CNPF), it allows a diagnosis of climate vigilance to be carried out everywhere in France. the current context and future climate, for existing forest stands or reforestation projects and link them to silvicultural management approaches adapted to climate change.

In parallel with these tools, FORECCAsT implements numerous awareness-raising and information actions aimed at professionals, elected representatives and the general public.

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Evaluation and limitation of multiple risks in planted forests (MULTIRISKS)

Céline MEREDIEU[1] (INRA) in collaboration with Thierry LABBE[1], Marielle BRUNETTE[2], Sylvain CAURLA[2], Hervé JACTEL[3]

The question of interactions between forest hazards modified by climate change is the subject of growing concern on the part of forest owners. Indeed, it is expected that the impacts of these hazards are greater than their simple addition due to synergistic effects. For example, storm-caused windthrow can be more abundant in stands weakened by root rot, which in turn leads to outbreaks of insects.

The aim of the MULTIRISKS project is to analyze the bioeconomic impacts of interactions between hazards on the forest resource and to identify silvicultural routes that can attenuate them simultaneously. For this, the project focused on the maritime pine sector in Aquitaine. Simulations will be carried out using the Pinuspinaster model developed on the Capsis platform to evaluate the impacts of two interacting hazards: fomes attack (Heterobasidion annosum s.s.), and pine processionary caterpillar infestations. The results of the simulations with a calculation of the impact of the processionary caterpillar infestations indicate that the relative production losses (compared to the same stand free from pine processionary caterpillar attacks) in the basal area vary by 0.2% (median defoliation of 9%) at 11% (for the 5% of the most defoliated stands, at 52% defoliation).

A key simulation adjustment variable is density management via thinning. Indeed, simulations integrating fertility levels and variable thinning regimes show particular interactions between the management option and the level of impact of the hazard.

The production losses resulting from the realization of the hazard affect the growing stock which is the input variable of the forest-timber sector model developed at BETA (French Forest Sector Model). It is thus possible to analyze the impact of these hazards on the maritime pine industry in Aquitaine via various variables such as changes in volumes, prices, surpluses and carbon footprint. The impact on other regions can also be studied.

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Feasibility of forest health status diagnosis using remote sensing: example of chestnut in Dordogne (CASTELDIAG)

Michel CHARTIER[1] and Véronique CHERET[2] in collaboration avec Michel GOULARD[2]

Forest declines are of concern to professionals in the industry and are crucial to the diagnosis of the health status of trees. The chestnut is a good example.

This essence is both sick (identified and reproducible cause) and declining (multiple and complex causes, not known in their entirety) without being able to quantify the impacted surfaces.

The Casteldiag project aims to determine the health status of a stand by remote sensing in addition to the field diagnosis using a method adapted to chestnut coppice. The Dordogne department was chosen as a study area.

To evaluate the stage of decline, the CNPF has developed a diagnostic tool called ARCHI that works on many species (oaks, pines, etc.) but which has required adaptation for chestnut. The work carried out makes it possible to take into consideration different situations: coppice, mature forest as well as fruit orchards. In the end, the ARCHI key makes it possible to carry out a double diagnosis, that of the stage of development and that of the physiological state. The final result is considered fully operational and can be disseminated to managers through training.

At the same time, the aim was to explore the potential of remote sensing for mapping the health status of the chestnut forest by distinguishing healthy stands from declining stands. The work focused on the processing of Sentinel-2A satellite imagery. We therefore sought to analyze, for one year of data (2016), the spatial variability of the state of the chestnut coppice surfaces. The objective was to develop a statistical model, integrating three types of variables: *i)* the 10 spectral bands at 10 and 20 m (visible, Red Edge, PIR and MIR), *ii)* 36 vegetation indices calculated from these 10 spectral bands and chosen for their potential to translate plant activity, productivity, water content or the content of leaf pigments, and finally *iii)* 5 biophysical parameters (Blcv, Glcv, fApar, GLAI and Wat) estimated by applying models simulating radiative transfer in vegetation with Overland software (Airbus DS).

Several predictive models of decline were constructed from these 51 variables. Their calibration was carried out thanks to field observations of the health status of the stands made according to two approaches, by application of the ARCHI diagnosis and expert rating (CRPF). A first level of analysis allowed to select the most significant variables for the construction of the models and to show the importance of their contribution to the prediction. A validation step could be carried out from a second field campaign. The best Kappa (0.64) is obtained from the ARCHI references and with the July image. A final selection is proposed with the 8 models presenting the best predictions. Maps have been established for these different models.

The conclusions of this study are that the results from the Sentinel-2 data processing are promising and several observations can serve as a basis for further work on this topic.

The use of this type of information, even if it is still too early, could be considered to define action priorities depending on the stages of decline.

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EIP regional mobilization - Precision forestry in Nouvelle Aquitaine

Roland DE LARY (CNPF-CRPF Nouvelle Aquitaine) and Céline MEREDIEU (INRA)

The project aims to carry out actions around the two species (chestnut and maritime pine) and at two levels of scales:

- Macro level: forest ownership, forest massif,
- Local level: plot/tree

The project is taking place in Nouvelle–Aquitaine in the Dordogne and Landes de Gascogne departments. The project is supported by the CNPF and is associated with the research laboratories of the INRA, FCBA, the Purpan School as well as the ONF, Alliance Foret Bois, the IGN and certain local authorities.
It has been approved as a European Innovation Program and will be 80% financed by Europe and the Region.

Specific objectives for the maritime pine:

- Creation and development of a decision-making smartphone tool for triggering thinning of maritime pine forests according to specific silviculture standards
- Development of a "participatory silviculture" database (BDP) powered by the smartphone application (foresters using the application will be able, if they wish, to transmit their data and thus participate in the continuous improvement of the model of growth used in the application)

Phase 1 of the project involves the completion of a feasibility study of the smartphone application integrating the writing of specifications in connection with the partnership organization necessary to choose the most appropriate technical solutions. It also provides for the establishment of basic structures for the operation of the software, including the data architecture necessary for its functioning.

Specific objectives for chestnut:
Providing forest managers and territories with diagnostic tools, but also silviculture simulations (marteloscopes) and carbon impact (climafor) to boost silviculture, and attract carbon projects able to contribute to financing the renovation of the chestnut stands.

It is thus planned:

- To provide a cartographic method enabling the response of the chestnut coppices to biotic and abiotic hazards to be monitored annually from satellite images;
- To provide the manager with field diagnostic tools: ARCHI, BIOCLIMSOL;
- To deploy a smartphone application for citizen epidemiological surveillance of chestnut ink disease;
- To produce ink diagnostic tools;
- To make the Climafor tool available for chestnut stands;
- To popularize and train.

Project actions:
In total 8 actions have been defined
Local level:

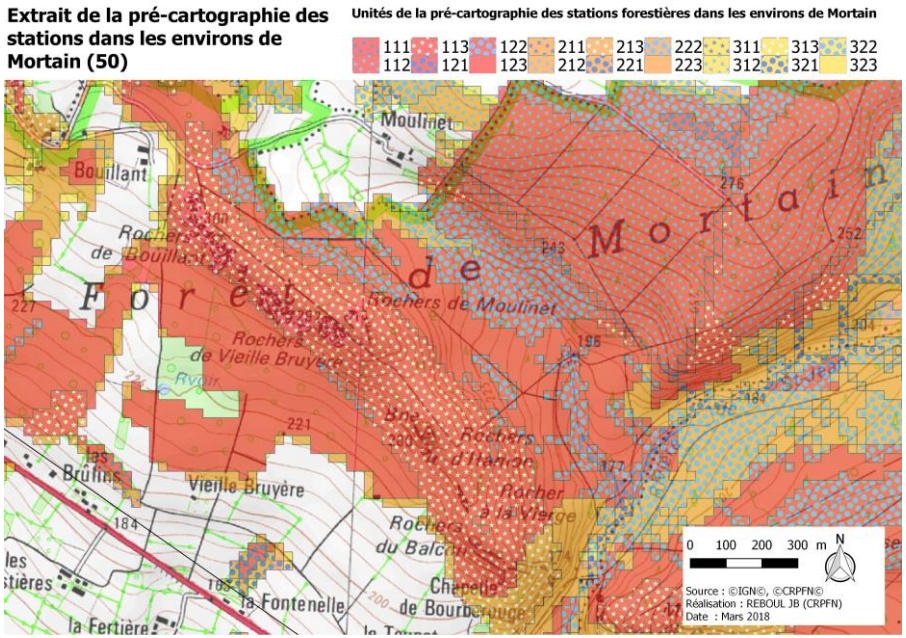
1. Developing a mobile application for decision-making at the plot level for triggering thinning in maritime pine stands
2. Setting up a group and testing the Bioclimsol application
3. Training in the ARCHI Chestnut method and dissemination of the tool
4. Establishing a "schools" site: reference plots and marteloscopes

Macro level:

5. Creating a "Participatory silviculture" database to feed action 1
6. Study on the relevance of the remote sensing model (established in Dordogne) on the whole of the Nouvelle-Aquitaine region
7. Development and training in the use of Vigil'encre and diagnosis of chestnut diseases
8. Bibliographic research and integration of chestnut stand data (production table and technical itineraries) in the Climafor tool

Spatial predictions of forest sites in the North West of France (PRESTATION-NO)

Jean-Baptiste REBOUL (CNPF-CRPF Normandie) and Christian PIEDALLU (AgroParisTech)



Context

The study area (Hauts de France, Normandy, Ile de France, Center Val de Loire regions) is almost entirely covered by catalogs/station guides, without these latter being valorized in the form of maps of forest stations, integrated into sustainable management documents in private forests. This is often due to the fact that the production of a map of forest stations is a heavy and technical operation for the forest managers/owners, who systematically carry out at least one point per hectare. Nevertheless, a methodology was developed by the LERFOB in the Vosges region (PIEDALLU C., et al., 2006), for the realization of a predictive map of the forest stations, without the managers/owners having taken in hand this new tool. It seemed interesting to test whether this methodology was reproducible in the study area and whether the resulting pre-mapping could be a basis for simplifying the final mapping of forest stations.

Another limitation of the catalogs/guides of the study area is that they integrate little or no climate variations in space, but also the potential impact of climate change.

Objectives

- Improve the methodology for setting up pre-mapping of forest stations. Identify the key stages in establishing a pre-mapping of the stations and evaluate its reproducibility in other regions.
- Test the reliability of the pre-mapping and identify its different possible boundaries and possible links with existing species selection guides. Write instructions for using these new tools…
- Undertake a climate zoning of the study area based on a methodology similar to that of Joly (Joly et al., 2010) and see its evolution with climate change according to the models and different carbon emission scenarios and with different time steps.

Approach

- Establishment of a large database of phytoecological records and establishment of a cartographic database.
- Modelling of three pedological variables: bioindicated pH (ECOPLANT) of the A horizon; Wösten maximum useful water reserve 90 cm; depth of appearance of a marked hydromorphy.
- Reclassification of these pedological variables at the level of the administrative regions and crossing to produce pre-mapping of the forest stations (36 units = 6 trophic level classes* 2 classes of maximum useful water reserve* 3 classes of level of hydromorphy).
- Validation of these models and pre-mapping: study zone/administrative region/department/SER/forest region /pilot forests = forest massifs ranging from 20 to 500 ha with a map of the stations.
- ACP/CAH/AFD on the DIGITALIS climate data (1981-2010) DRIAS for present and future climate zoning.

Key results — (presented as separate chips)

- Database of significant phytoecological readings = 11 suppliers for 43 different studies = 41,200 readings including 26,338 readings at the precise location.
- A network of pilot forests covering the diversity of forest regions (21 in Normandy totaling 2,705 ha, 26 in Haut de France totaling 1,458 ha, 10 in Ile de France and Centre Val de Loire totaling 515 ha).
- Pre-mapping of forest stations specific to each administrative region.
- Pre-mapping distributed to managers in Normandy, with instructions on how to use it to simplify the mapping procedure.

Main conclusions including key points of discussion

- Develop and strengthen tools for centralizing phytoecological readings (ECOPLANT and DONESOL…) in the forest, as many readings are still dispersed and not centralized…
- Significant contribution of forest lifespan maps in improving the trophic level model, as well as 1/50,000 pedological maps on all models. These are two essential areas for future improvement of the pre-mapping of forest stations…
- Important questioning on the improvement of the models notably on the risk of saturation with more precise DEMs of the order of 5 m (LIDAR). How to handle this voluminous data; will local indices be more relevant than indices calculated on larger scales?
- A great variability in the evolution of climatic zonings according to the climate model tested, which raises the question of how to manage their multiplicity?

Prospects

The creation of a tool for centralizing station data in order to continuously improve models on pedological variables is one possibility. Crossing station maps with the map of pilot forest stands to reflect on management choices in relation to climate change is another possibility.

Promotion (scientific: publications, book chapter, presentation at conferences…report possible prizes); economic: Soleau budget, patent, license…; broadcasting: press release, interview, public presentations…):

- Madrolles F., Reboul J.-B. (2016). Le projet ECOGEODYN en Normandie : des cartes prédictives aux utilisations pratiques dans les forêts normandes. Forêt-entreprise, 228, p. 44-48.
- Madrolles F., Reboul J-B (2018). Guide de choix des essences de Normandie. CRPFN. 212 p.

Provision of pre-mapping of forest stations for Normandy on the website: https://normandie.cnpf.fr/n/cartographie-des-stations-forestieres/n:3305

Leveraging effect of the project

The Normandy region is currently financing the establishment of forest station maps with the help of pre-mapping, with the obligation for the managers/owners to return the localized surveys to the CRPFN. Ultimately, this new data will improve the models. The Hauts-de-France region, which is already funding the establishment of forest station maps, will also oblige the stakeholders to return the survey sheets to the CRPFN.

Author's detail:

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With the collaboration of: IGN, BRGM

LUBERON2, a simulation tool for the evaluation of genetic impacts of silviculture practices (IGS)

Claire Godineau (INRA, ISEM) and Sabine Girard (CNPF)

LUBERON2 is a model of the CAPSIS platform consisting of three components: a model of demographic dynamics of the Atlas cedar (growth, self-thinning mortality, reproduction), a model of inter-individual genetic variation of demographic performances, a model of random disturbances regime. It is a tool for population simulation and graphical visualization of its demographic and genetic characteristics over time, allowing the effects of various different silvicultural routes in different disturbance contexts to be compared. This simulator works on spatially individualized trees, at the scale of a stand, over a few regeneration cycles.

A first distinctive feature of LUBERON2 is that genetic diversity is taken into account in both directions, it is a coupled demo-genetic model: genetic diversity has an effect on stand dynamics and the response to silviculture and, conversely, dynamics and silviculture influence the evolution of genetic diversity. A second original feature is that it takes into account a random disturbance regime that can be set.

This workshop will present a method of using LUBERON2 for educational purposes, to generally illustrate the potential genetic impacts in the short and medium term of a choice of silvicultural route, and to better understand the mechanisms of these impacts. The goal of the simulations presented is to open a new perspective regarding silvicultural practices: what is the impact of silviculture on the management of genetic resources?

LUBERON2 can also be used in a sharper and more detailed manner in management, in order to compare different silvicultural options specifically in the Atlas cedar, for example in the framework of adaptation strategy. It is also a research tool for analyzing the interaction mechanisms between silvicultural practices and disturbance regimes. The challenges of validating the quantitative predictions of simulations are complex: if each of the three components of the model results from empirical calibration or theoretical validation, we do not have readily available empirical data to compare the predictions of the coupled model, in particular in terms of genetics. A sensitivity study of the model coupled with the different demographic and genetic parameters remains to be realized. LUBERON2 continues to develop, and the approach initiated with LUBERON2 on the Atlas cedar case will soon be extended to other species, or even other types of forest stands.

LUBERON2 was developed at INRA by **Claire Godineau, Nicolas Beudez, François de Coligny, Sylvie Muratorio, Leopoldo Sanchez, François Courbet, Christine Deleuze** (ONF), **Christian Pichot and François Lefèvre**, with the help of the project partners Evaluation of genetic impacts of silvicultural practices for adaptation, co-funded by RMT AFORCE and GC84.

A tool for the selection of tree species (CARAVANE & IKSMAPS)

Sophie BERTIN (EKOLOG), Myriam LEGAY (ONF) and Alexandre PIBOULE (ONF)

The forester commits himself to long-term directions with each management decision. The challenge around these decisions is today exacerbated by the context of climate change and by the uncertainty weighing on the different scenarios of possible climate change. The choice of a tree species to favor among the species in place or to be implanted during a renewal or an enrichment constitutes a central element in his decision. To guide this choice, the forester must have information on the potential of these species, their requirements, their flexibility and their vulnerability to the impacts of climate change both in the short and long term. A tree species must, in fact, both withstand the current climate and be adapted to an imperfectly known future climate.

The online help tool for the choice of forest species allows the improvement of the knowledge of species, their requirements and their specific behavior in the face of possible changes in the climate. The tool is in the form of a website. It is composed of a set of organized and up-to-date technical and knowledge elements, to help forest decision-makers in the choice of species to favor, plant

or experiment in the context of climate change. Each element of information is associated with a degree of reliability or a representation of the uncertainties. Knowledge gaps are also highlighted. The site thus makes it possible to limit errors in introduction and planting as much as possible. It also allows the manager to have elements available to make a decision with full knowledge of the facts at a given moment.

This tool combines a documentary approach on the autoecological and climatic requirements of 140 species present or not on French soil, with a modeling approach that projects the evolution of climate compatibility areas of species at different time scales and for different CPR trajectories. For the documentary approach, the site relies on the work carried out by the NOMADES and CARAVANES projects where the species sheets are grouped into an interactive catalog and broken down into 37 criteria (including silviculture, autecology, services, biotic and abiotic risks). For the modeling approach, the site builds on the results of the IKSMAPS project which consisted of developing the components of a sylvoclimatic service to project the evolution of the climatic compatibility zone of the species according to scenarios of climate change. It is based on the IKS model.

Three major user experiences/trajectories are identified on the site. They correspond to practical questions of entry and reflect the types of possible uses of the site:

- Improving my knowledge of forest species
- Assessing climate evolution
- Putting the right species in the right place