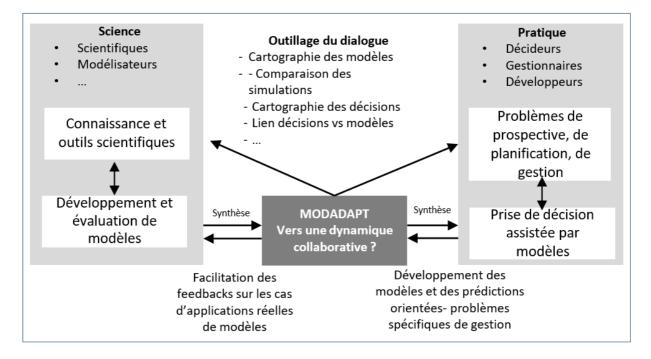# MODADAPT



## What models to provide guidance for the adaptation of forests to climate change ?

Principle investigator: Myriam LEGAY, UMR SILVA/AgroParisTech – équipe EcoSilva

LabEx partners: Julien SAINTE MARIE, UMR SILVA/AgroParisTech ; Christian PIEDALLU, UMR SILVA/AgroParisTech ; Vincent BADEAU UMR SILVA/INRAE ; Nikola BESIC, LIF/IGN ;  Alexandre PIBOULE, ONF; Céline PERRIER and Hedi KEBLI, RMT Aforce-CNPF

Thematic actions concerned:  WP2 et WP4

### *Context*

The expected impacts of climate change on the forest are a challenge for forest management. The forest and wood sector are already affected by crises related to climate change, which are expected to intensify in the near future. The adaptation of forests has become a major issue, included in public policies (Roadmap for the adaptation of forests to climate change, recovery plan ...). In this context of transition and uncertainty, forest managers express the need for tools to assist silvicultural decisions, and in particular the choice of species.

### *Objectives*

- Definition of an analytical framework for a comparative evaluation of model predictions;
- Mapping and description of the diversity of climate-sensitive forest models;
- Mapping and description of the diversity of forestry decisions at different scales;
- Case study of comparative evaluation of predictions of different models;
- Recommendations for the development of decision support based on climate-sensitive forest models.

*Approaches*

The proposed novel framework is based on the reduction of the model output to the relatively simplistic information about the presence of the tree species suitable for the forest management, making it comparable with the largely available observations. The framework comes along with a new metric, based on the joint use of the Principal Component Analysis and the Co-inertia Analysis, which evaluates the model vis-à-vis the corresponding observations with the focus on its phase space dynamics i.e. its dependence on external environmental variables, rather than its spatial precision. Both the framework and the metric are elaborated and described by conjointly using real and synthetic data, whereas the pertinence of the proposed multi-scale approach is demonstrated on the example of the comparison of two tree species distribution models.

The description and mapping of the climate-sensitive forest models was done based on a literature review and interviews with modelers. The proposed description methodology is applicable to any climate sensitive forest model, and describes its characteristics that are required to appreciate its decision support potential. The article is completed by a data base providing the attributes selected by this approach for the set of models described in the article. and the description and mapping of the climate-sensitive forest decisions was done based on the literature and a workshop with forest experts with different views and scales.

*Key results*

- The new framework developed contains a new metric for the comparative analysis of forest models integrating the impact of external climatic variables and addresses the most general case of disjointed phase spaces between models, reducing the comparison to the evaluation of the predicted vs. observed presences in the space of external variables of each of the models.
- Almost all climate-sensitive forest models developed in France are post-2000, whereas the development of forest dynamics models in France is much earlier, indicating that we are currently still in a phase of radiative exploration of the possibilities offered by climate-sensitive forest modelling.
- The choice of a model can be the determining factor in making predictions to support forest decisions.
- There is a diversity of sensitive forest decisions at different scales related to different decision-making contexts.
- For each forest issue at each scale, several models are available. For decision-makers, the challenge is to know the diversity of models in order to choose models adapted to the question at hand and ideally to compare the diversity of projections in order to fully appreciate the uncertainty.

*Main conclusions including key points of discussion*

This developed metric provides a measure of the pertinence of the dynamics of a model as opposed to the one of observations projected to the space of variables of the former. The added value of the approach is illustrated using a simulated dataset, but also using a multi-scale evaluation of one tree species distribution model as well as the multi-scale comparison of two such models.

There are some gaps to fill in terms of forest model's development and in their use in informing forest decisions. Regeneration and mortality processes are considered in a limited way in process-based models. There is a lack of forest fire and biotic models that represent the forest cover. Communication and collaboration between forest modelers and decision-makers need to be supported by dedicated means to facilitate the development of models that are more oriented towards issues of forest management and adaptation to climate change.

For each forest management question at each scale, several models are available. The Gordian knot to be decided is finally how to choose the appropriate model, adapted to the question, to the data that can

be mobilized and to the level of technicality that can be mobilized. However, from a decision-support perspective, the model must remain a support to clarify choices and objectify the discussion, but it must not replace the decision-maker, who alone is capable of integrating a much broader set of factors.

*Perspectives*

The most obvious perspective of the developed framework would be the analytical exercise of comparing the multitude of forest models sensitive to climatic parameters, both statistical and process-based ones. The most ambitious perspective would be to build upon the presented analytical approach a consensus method which would combine information coming from different models at multiple scales, assuring that forest adaptation measures are based on the best of our knowledge to predict natural processes. The presented framework and metric could be also adapted and exploited by modelers during the model development process, e.g. to check the relevance of the variables considered, or to compare different sets of environmental variables (e.g. climate variables issuing from different climate models).
Another perspective is to develop a decision-making framework that will provide decision-makers, at the scale of France, with a set of decision criteria based on expert knowledge and forest models, which will provide guidance for the choice of forest species as target for adaptive forest management under climate change. These decisions can be informed for the main French forest species using forest productivity, derived from process-based models, forest risk regime, derived from risks assessment models, and the probability of presence of the species based on species distribution models, as performance criteria.

**Valorization** — (scientific: publications, book chapter, presentation at conferences,); economic: Soleau envelope, patent, license, distribution: press release, interview, ...)

*Project-related oral presentations:*

- 15/6/2021: Presentation at FOREM seminar
- 14/10/2021: Presentation at the Deepsurf International Symposium
- 7/12/2021: Presentation at the annual scientific animation day of the SILVA laboratory
- 22-23/03/2022: Presentation at the FOREM seminar
- 11/10/2022: Presentation at the Labex ARBRE PhD and postdoctoral students' day
- 20/01/2023 : Presentation to the practitioners mobilised for the workshop on climate sensitive forest decisions

*Articles being published in the framework of the project:*

- Modeling the impact of climate change on the forest: a novel framework and a new metric for the comparative analysis - The Journal of Agricultural, Biological and Environmental Statistics (JABES). *Submitted, revisions* in progress
- Using climate-sensitive forest models to provide guidance for adaptive forest management under climate change - Annals of Forest Science. *Submitted*
- Une diversité de modèles pour éclairer les décisions forestières face au changement climatique - Revue forestière française. *In progress*
- Panorama des décisions forestières sensibles au climat à différentes échelles de décision - Revue forestière française. *In progress*

## Leveraging effect of the project

The funding of the labex has made it possible to aggregate funding from the Grand Est Region (23 k€), on the one hand, and from the RMT Aforce (23 k€) on the other hand, so that the funding of the Labex has been tripled.