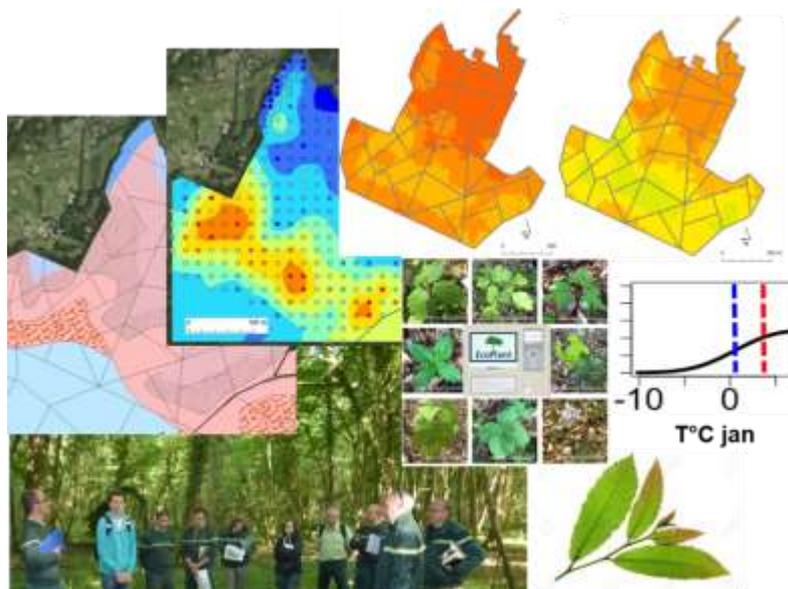


# FORMANCLIM



## New tools for site classification and choice of tree species: Application to Forest Management in Climatic change context.

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**Context** — the choice of tree species to be favored in the context of forest management is based on a successfully matching between environment characteristics and the ecology of tree species. For this choice, forest managers have traditional decision-making tools (i.e. station catalogs and guides for the choice of species) which do not enable them to take into account climate change into the decision-making process. Formalized methods linking the distribution of tree species to climate parameters have been developed since the 2000s. Coupled with climate change models, they are likely to allow the choice of species adapted to both the current and future climate. In parallel with these works, spatialized models for the quantitative evaluation of acidity, nitrogen availability and soil waterlogging using optimized methods of bioindication with forest flora have been developed. Climate and edaphic models have been successfully integrated to produce environmental models for predicting the variability of species distribution and growth at national scale as a function of current and future soil and climate conditions. These models have not yet been evaluated at the forest and stand scales. The lack of knowledge on their accuracy at this scale makes it difficult to recommend these new tools for operational forest management.

**Objectives** — to apply at the local scale the new tools for characterization of site conditions and tree species distribution in order to integrate the impact of climatic changes when managers face with tree species choice. Specific objectives: (i) evaluate the efficiency of soil acidity mapping when using the new protocol of soil properties assessment based on plants bioindication (ii) evaluate the efficiency of distribution models calibrated at national scale using climatic and soil predictors to assess tree species suitable areas at the scale of forest management.



**Approaches** — Using EcoPlant indicator values and partial floristic inventories, soil acidity, nitrogen and mineral nutrition were estimated on 274, 210 and 293 plots carried out on a systematic sampling grid of 50 x 50 to 250 m x 250 m in three lowland forest of Central and North-Est France (Marly-le-Roi, Cierges-sous-Montfaucon and Neuville-en-Argonne, respectively). The pH estimations at the plot level were mapped at the forest level using interpolation methods. A complementary data set with 37, 20, and 55 plots distributed randomly in Marly-le-Roi, Cierges-sous-Montfaucon, and Neuville with floristic inventories and soil pH measures, allowed to evaluate the quality of both bioindication approach and pH maps. The performance of the spatialized predictions was evaluated by the square of the linear correlation coefficient ( $R^2$ ) and the root mean square error (RMSE) between measured and mapped pH. Distribution models calibrated at the scale of France for nine broadleaves and coniferous species of high economic importance were applied to the 777 plots of the 3 studied forests and on 168 plots of Rupt-Sur-Moselle forest, a mountain forest of northern France. Distribution models efficiency was evaluated by the AUC and TSS indexes computed from predicted and observed species occurrences at local scale.

#### **Key results** —

- Our results have shown that optimizing bioindication methods allow managers to describe the intra-forest spatial variation of acidity, nitrogen availability and mineral nutrition (pH, C/N, S/T, respectively). We also confirmed the consistency of the new protocol to characterize ecologically forest sites in the context of forest management.
- Acidity maps based on bioindication methods allow to distinguish between oligotrophic and eutrophic situations at the forest scale with a precision close to 0.5 point of pH (RMSE of 0.47, 0.45 and 0.61 in Cierges, Neuville and Marly-le-Roi, respectively).
- Species distribution models (SDM) including climate, soil acidity and nitrogen availability can significantly explain the distribution of the 9 studied species at the local scale with a prediction success reaching 85%. The local performance of SDM, evaluated by the area under the curve (AUC) calculated at the forest scale, revealed good to excellent levels (from 0.70 to 0.91) with a lower performance (AUC of 0.52) for *Pinus sylvestris*, a pioneer species. Spatial variation of tree species distribution is better predicted for species having a niche highly controlled by soil conditions (e.g. nutrient-demanding species as *Fraxinus excelsior* or acidophilous species as *Castanea sativa* with AUC of 0.85 and 0.91, respectively). The maximum model performance was reached in mountain context where both climatic and soil conditions are highly variable (mean AUC in lowland and mountain forests were 0.70 and 0.78, respectively).

#### **Main conclusions including key points of discussion** —

- Our results allowed to confirm that the time-optimized vegetation survey protocol, defined in the Labex Project OBUP, is a method useful and precise enough for soil properties mapping at stand level in the context of forest management.
- Our results highlight that within a favourable climatic envelope, studied niche models allowed to identify fine-scale environmental variations of probability of presence of species, useful when the goal is to map tree species suitable or unsuitable areas at the forest scale. This approach, taking into account both soil and climate conditions, allow to integrate future environmental changes in forest management decision-making tools.

**Perspectives** — Mediterranean ecosystems have not been included in our research despite their vulnerability in a climatic change context. The time-optimized vegetation survey protocol could be a method useful for soil characteristics mapping at stand level in Mediterranean forests. Coupled to niche and growth models this approach of site description might produce useful information for forest managers.

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

#### **Scientific**

##### *Publications*

Paulina Pinto, Dupouey J-L., Gégout J-C., Hervé J.Ch, Legay M., Montpied P., Piedallu Ch., Pousse N., Wurpillot S. (2019) "Faut-il des relevés de flore exhaustifs pour caractériser et cartographier l'acidité et les propriétés nutritionnelles des sols ? Rendez-Vous Techniques, 61-62: 71-84.

##### *Presentation at international conferences*

Pinto P.E, Dietz L., Rizzetto S., Piedallu C., Gégout J-C. (2018). Soil factors allow the use of species distribution models as support tools for forest management in the context of global change. *103<sup>rd</sup> Ecological Society of America (ESA) annual meeting*. New Orleans, Louisiana, 5/08/2018 – 10/08/2018. Oral communication and summary.

#### *Conferences*

Pinto, P. New support tools for forest management decisions in a context of climatic change: « seminar USDA Forest Service » 01/08/2016. USDA Forest Service, Delaware, OH, USA. 2016. (Visit supported by the Labex ARBRE).

#### *Talks to professionals* (“Restitution projet FormanClim”)

- Dietz, L. « Validation de nouveaux outils de caractérisation stationnelle et de choix des essences en contexte de changement climatique Application à la forêt de Marly ». Oral presentation 29/09/17, Maison forestière de l’Hippodrome, 4 Cité de la Croix Saint-Simon, 78260 Achères, France.
- Dietz, L. Atelier portant sur les nouveaux outils pour la caractérisation stationnelle et le choix des essences en contexte de changement climatique. Application aux forêts en Argonne. Oral presentation 06/07/2017, ONF-UT, Clermont-en-Argonne, France.

#### *Supervision of students*

Dietz L., 2017. Validation de nouveaux outils de caractérisation stationnelle et de choix des essences en contexte de changement climatique. Application à des forêts d’Argonne et d’Ile de France. Rapport de fin d’étude AgroSup Dijon. Spécialité Agronomie – Dominante Agronomie et Environnement. 45p + Annexes et Livret de cartes. (Supervisor: Pinto, P.)

#### **Leveraging effect of the project**

As part of the evaluation of site conditions, the Formanclim project is making bio-indication methods more accessible to managers to assess site quality using plant species. The use of the time-optimized vegetation study protocol, used in this project for the selection of tree species, has recently been successfully extended for site classification in the Habitat typology of the European directive Natura 2000 (Thesis Lise Maciejewski 2021). The simplification of flora protocols also opens the way protocols citizen sciences for broader ecosystems monitoring. In a changing environmental context, the local applicability of quantitative bioindication methods, which make it possible to relate, at fine scale, site quality to species distribution and productivity models, provides new information for forest managers taking into account the expected effects of climate change on the species in place. Finally, the FormanClim Project contributes, through its results and new data sets, to the improvement of large-scale mapping of soil variables and their testing for the choice of a relevant resolution (MSc. Eloise Pederosi, 2019; RESCAL Project, in progress. led by Christian Piedallu).