



## MAESTRO

### **Dynamic sampling and inference for a smart forest monitoring with applications to the French National Forest Inventory**

Principle investigator:: Olivier Bouriaud, Laboratoire d'Inventaire Forestier, IGN, Nancy

Partner : IECL (Elie Cartan)

With the collaboration of Dr Guillaume Chauvet (HDR), ENSAI, UMR IRMAR, Rennes

*Action thématique concernée :* WP2

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#### **Context —**

The effects of global change and the loss of biodiversity are issues that entered the public and political spheres, and the awareness of the imprint of human actions increases expectations towards forests. These new expectations highlight the need to quantify and monitor not only the condition of forests but also their ability to support the provision of these ecosystem services. However, large-scale inventory methods have been developed for resource monitoring and at a multi-annual timescale. New expectations, as well as more intense and frequent disruptions, require a review of these methods, to make them evolve towards greater responsiveness.

The sampling and estimation methods of the French national forest inventory were redesigned in 2004 with the aim of allowing annual coverage of the territory and adaptability of the sampling effort. The data collected over the past 15 years constitute an unequaled empirical basis, which should make it possible to assess the effectiveness and limits of current methods.

Moreover, the skills needed to analyze survey and estimation methods are extremely rare, particularly in the forestry sector. The premature disappearance of the pairs (Jean-Christophe Hervé, Adrian Lanz) leaves a deep lack in a very small community. The role of the project is to contribute to the renewal of these skills and to develop new sampling and inference strategies, by bringing together within the framework of the project people who can each contribute a specific and complementary experience.

#### **Objectives —**

The goal of the project is to develop survey methods, ranging from sampling to estimation, to respond to rapid modulation constraints of the sampling intensity, while maintaining high levels of precision. Although developed in the context of the national forest inventory, the general nature of these methods will be maintained and strengthened to allow them to be used in ecosystem surveys.

A first objective is to describe and evaluate current post-stratified statistical estimators, and to compare them with existing estimators in critical contexts. A second objective is to evaluate and optimize forest stratification/post-stratification schemes with perspectives on variance-bias trade-off and small strata issues. A third objective is to redesign the sampling strategy of this inventory and increase its flexibility and independence.

#### **Approaches —**

The approach has two very complementary aspects: axiomization and quantitative analysis. The axiomization constitutes a formalization of the sampling and estimation methods of the national forest inventory. This formalization represents an effort to anchor inventory methods in the survey theory, and therefore represents an essentially theoretical activity. This activity aims to provide the work with statistical foundations specific to the discipline as well as a base of bibliographical references. The formalization also ensures the development of the limit properties and the validity hypotheses of the statistical estimators.

The quantitative analysis is based on the development of the exceptional database of the national forest inventory, and first, to carry out a critical quantitative analysis. The hypotheses and theoretical limit values will be compared with the ranges and variance of the empirical values collected during the fifteen years of operation of the inventory method.

**Key results** — (presented as separated bullet points)

- The thesis started in December 2021, with the arrival in Nancy of the doctoral student previously trained in survey theory as part of the Franco-Vietnamese Master's degree at the University of Rennes.
- The formation of the individual monitoring committee offered the opportunity to bring together specialists on the subject: Antoine Lejay (Elie Cartan-INRIA), Alina Matei (University of Neuchatel, Switzerland).

**Perspectives** —

The formalization of sampling methods for the national forest inventory will provide the theoretical framework and the statistical basis that the inventory has long lacked.

**Leveraging effect of the project**—

By providing a budget and a working framework, the project allows players from different institutes to collaborate on the same subject, around the work of the doctoral student.

The project allows an international influence.