1 FORESTS IN NUMBERS

for more informations

INRAE

Globally

4.0
billion hectares

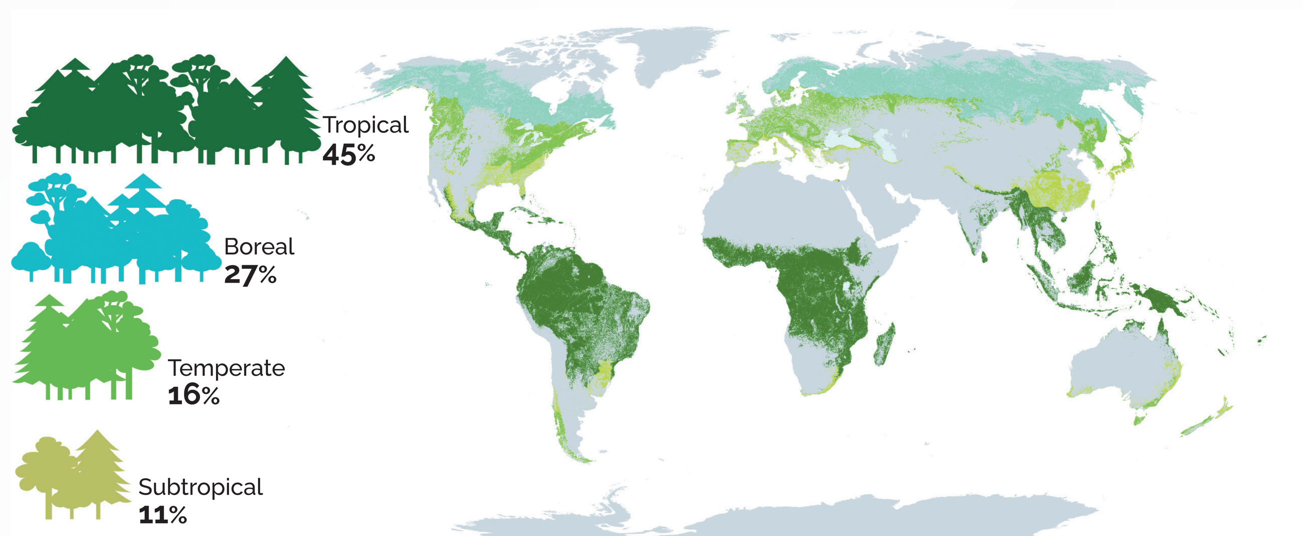
31 % of the terrestrial surface

75 000 species of trees

3 000 billion trees

422 trees/person

state of the world's forest



- 2nd largest carbon sink globally
- 20% of global CO_2 emissions captured and stored
- 1st reservoir of terrestrial biodiversity

36% primary forests

57% secondary forests

› Recent human activities
› Naturally regenerated

7% planted forests

Deforestation and degradation -10 million ha/year

Afforestation and reforestation +5 million ha/year

› Ecological processes intact
› No recent disturbance

› More often monospecific

France

17.3
million hectares in mainland France

25% public

75% private

Varied pedoclimatic conditions: a diverse forest

4th largest European forest in area

31% of land covered by forest

11,3 billion trees

55 million cubic metres of harvested wood/year (½ of annual increment) of which 40 million cubic metres is commercialised

13 % planted forests

450 000 employees

+

8.0
million hectares in French Guiana

1 712 tree species described

96% of land covered by forest

Forest area

Broadleaves	Mixed forest	Conifers
67 %	12 %	21 %

Nouvelle-Aquitaine

2.9
million hectares

90% private ← → 10% public

34% of land covered by forest

10 millions cubic metres of harvested wood/year

24% of the national production

59 000 employees

- Multiple forest types with high forest productivity
- Maritime pine : 9 million cubic metres of harvested wood/year
- Lumber, pulp and paper, wood-based panels and energy industries
- Dynamic Research, Development and Innovation sectors

2 FOREST MULTIFUNCTIONALITY

for more informations

INRAE

A place for individual and social well-being

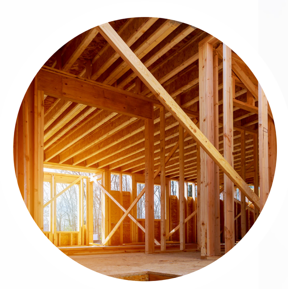
- Quality of the landscape
- Publically accessible
- Leisure activities
- Education in environmental protection

Reservoir of biodiversity

- Ethical issue: life on Earth
- Number of species in mainland France forests:
  136 trees, 73 mammals, 120 birds, 72% of flora, 30 000 fungi, 30 000 insects
- Link between biodiversity and ecosystem health:
  source of adaptation and nature based-solutions

Source of raw materials

- Wood production (lumber, pulp and paper, wood-based panels and energy)
- Carbon storage by wood products
- Substitution of concrete and steel
- Employment in rural areas
- Local land-use management



Carbon sink

- CO_2 sequestration (tree biomass and soil)
  7-10% of national emissions in 2024

Solar energy

Chlorophyll

Carbon dioxide (in the air)

Dioxygen

$$6\ CO_2 + 6H_2O \gg C_6H_{12}O_6 + 6O_2$$

Water (from the soil)

Sugar

- 2nd largest carbon sink globally
- Mitigation of global warming

Regulation and protection

- Climate regulation
  decrease of temperature: shade and evapotranspiration
- Water and air filtering
  - Natural purification of rain water as it runs through the ground
  - Improvement of air quality (filtration of dust and air pollution)
- Generation of rainfall

- Protection against natural disasters
  torrential floods, rock falls, avalanches, landslides
- Protection against erosion
  soil and coastal dunes

Contributions

- Material wealth
- Intangible value
- Regulatory contribution

3 CESTAS-PIERROTON

HISTORY OF A “TREE AND FOREST” RESEARCH CENTRE

for more informations

INRAE

1864
Construction of the Château by a Bordeaux merchant

1898
Acquisition of the estate by an agricultural company, followed by the establishment of the congregation of the Fathers of the Holy Spirit in the Château (sanatorium)

1930
Acquisition of the estate and purchase of the land by the French State (Freshwater and Forestry Administration)

1946
Creation of INRA

1949
Cestas “The fire of the century”:
52 000 ha burned and 82 victims

1950
Creation of an annex of the Nancy forest research station in Bordeaux, and of an experimental station in Pierroton

1950-1965
- Germination of maritime pine
- Tapping (resin production)
- Establishment of arboretums
- Fertilisation trials

1964
The Pierroton experimental station joins INRA

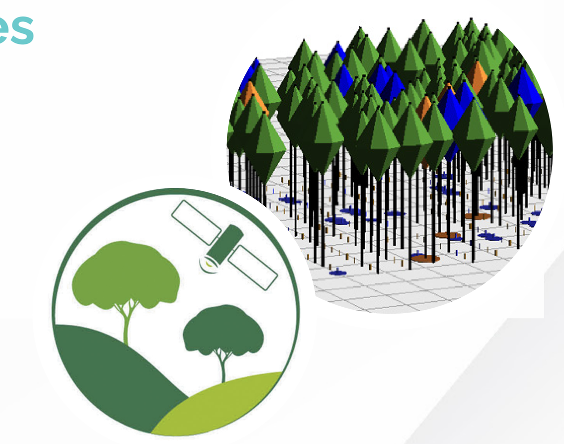
1990>Today
- Consortium for the genetic improvement and the creation of maritime pine varieties
- Molecular, physiological, genetic and environmental determinants of tree and forest functioning
- Monitoring of forest resources: forest health, biodiversity, wood biomass
- Dynamics and functional role of biodiversity
- Vulnerability of trees to biotic and abiotic stresses
- Adaptive forest management and maintenance of ecosystem services

Groupe Pin Maritime du Futur

1990>Today
Development of research infrastructures, association with the University of Bordeaux and international cooperation

Université de Bordeaux
EU

1975-1990
- Genetic improvement strategy: maritime pine, red oak, tulip tree, corsica pine
- Description of the genetic diversity of trees
- Study of forest pests and pathogens
- Modelling of stand growth
- Development of remote sensing and monitoring of forest dynamics



1967-1975
Acquisition of plots and creation of a nursery

1965-1970
- Maritime pine genetic improvement program: geographical variability and selection of elite trees in the Landes forest
- Silvicultural management methods
- Study of soils
- Forest entomology

1966
Development of research in Pierroton

2020
Creation of INRAE

Today > The INRAE research stations in numbers

400 hectares for experimentation

120 people

3 research laboratories

- UEFP: Pierroton Forest Experimental Unit
- BIOGECO: biodiversity genes and communities
- ISPA: soil-plant-atmosphere interactions

3 technological platforms

- PGTB: Genome analysis
- PHENOBOIS: Measurement of physico-chemical properties of wood and tree hydraulics
- XYLOSYLVE: Environmental assessment of fast growing plantations

Forestry centre in Nouvelle-Aquitaine

R&D: European Institute of Planted Forest

R&D: FCBA Industrial Technical Center

R&D: Department of Forest Health

Forestry Cooperative : Alliance Forêts-Bois

4 CESTAS-PIERROTON

75 YEARS OF RESEARCH

for more informations

INRAE

Agronomic approach to maritime pine forest management

Research for sustainable and multifunctional forest management

Evolution of the temperature of mainland France since 1945

Creating – Silviculture standards

Creating – Improved varieties

Protecting – Forest genetic resources

Understanding – Forest ecology

Deciphering – Tree genomes

Main silvicultural stages of planted maritime pine forest

- Regeneration by planting or sowing
- Clearing and cleaning of vegetation
- Thinnings according to the management objective
- Progressive selection of trees
- Felling of mature trees
- Diagnosis and forest renewal

Genetic improvement of maritime pine

Natural genetic diversity » Improved varieties

Selection cycle (20 years)

- Multi-criteria selection (adaptation, growth, wood quality)
- Cross-breeding between selected trees
- seeds
- Assessment of the progeny in the forest

The 3 pillars of sustainable management

5 HOW DO WE PRACTISE OUR RESEARCH?

for more informations

INRAE

3 major research themes

Effect of global changes on forest ecosystems and the provision of ecosystem services

Structure, function and evolution of biodiversity: from genes to communities of organisms

Major carbon and nutrient cycles in forest ecosystems: transfers between soil, trees and the atmosphere

Drivers of adaptive forest management, which is productive and favourable to biodiversity

Observe

- The flow of carbon and water between the forest and the atmosphere
- Components of biodiversity and environmental variables
- Growth and physiological functioning
- Mineral and carbon nutrition
- Forest health

...

Experiment

- Adaptive capacities of populations and tree species
- Response of trees to stress
- Forest management options

...

Analyse

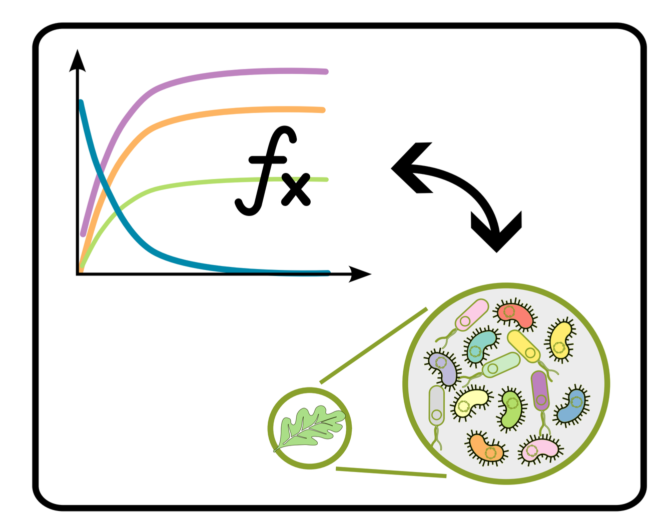
- Impact of climate change on biodiversity
- Genomes of trees and associated organisms
- Physico-chemical properties of soils
- Causes of forest decline
- Structure of forest stands
- Tree architecture

...

Model

- Carbon and nutrient cycles
- Species distribution ranges
- Biotic interactions
- Adaptive capacity
- Forest management

...



Manage and disseminate information

- Scientific publications
- Education and training
- Participatory research
- Press Releases

Data INRAE

6 MONITORING THE FORESTS
BY SATELLITES

for more informations

INRAE

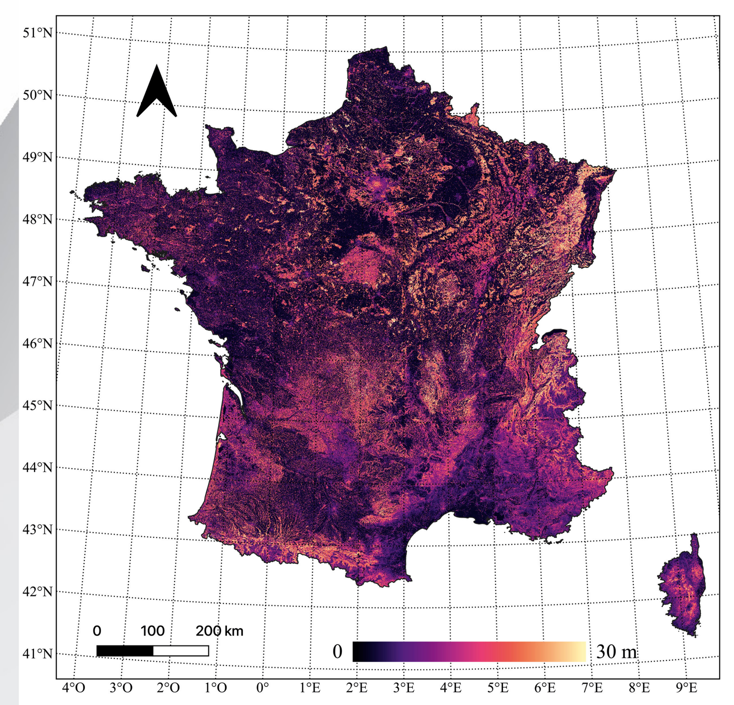
Global, temporal
(daily-annual)
and historic monitoring
(e.g. since 1972 for Landsat)

1 Biodiversity monitoring

- Forest typology
- Species identification

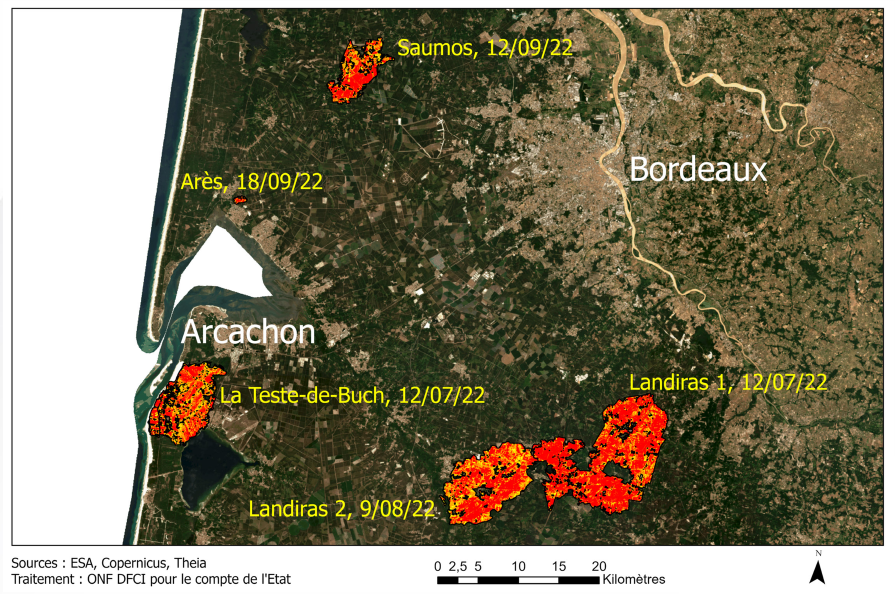
2 Annual survey of forest resources

- Height (e.g. France map at 10m resolution)
- Biomass (e.g. France map at 30m resolution)
- Volume, density, etc.



3 Monitoring of forest management and damages

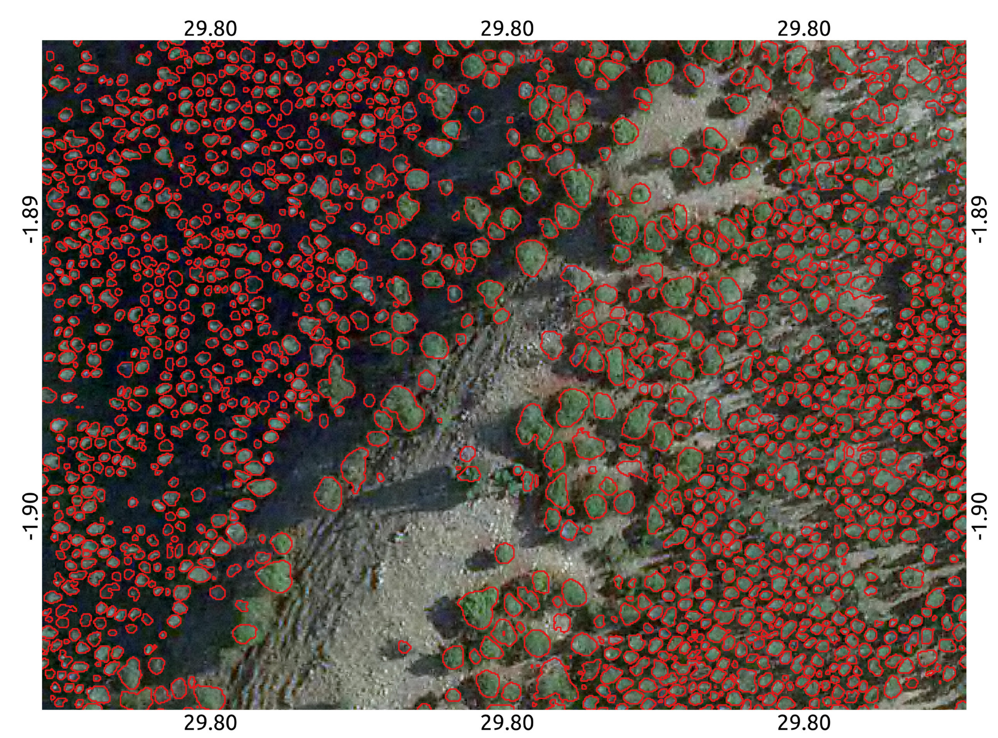
- Logging operations
- Deforestation
- Impacts of pests, storms, fires



Forest fires in Gironde (2022)

4 Monitoring of forest cover

Resolution: up to mapping individual tree crowns
(forest and urban areas)



These data are essential for:

- Sustainable forest management
- International regulations in terms of monitoring and protection of forests (monitoring deforestation, replanting, protected areas...)

7 BIOLOGICAL CONTROL:

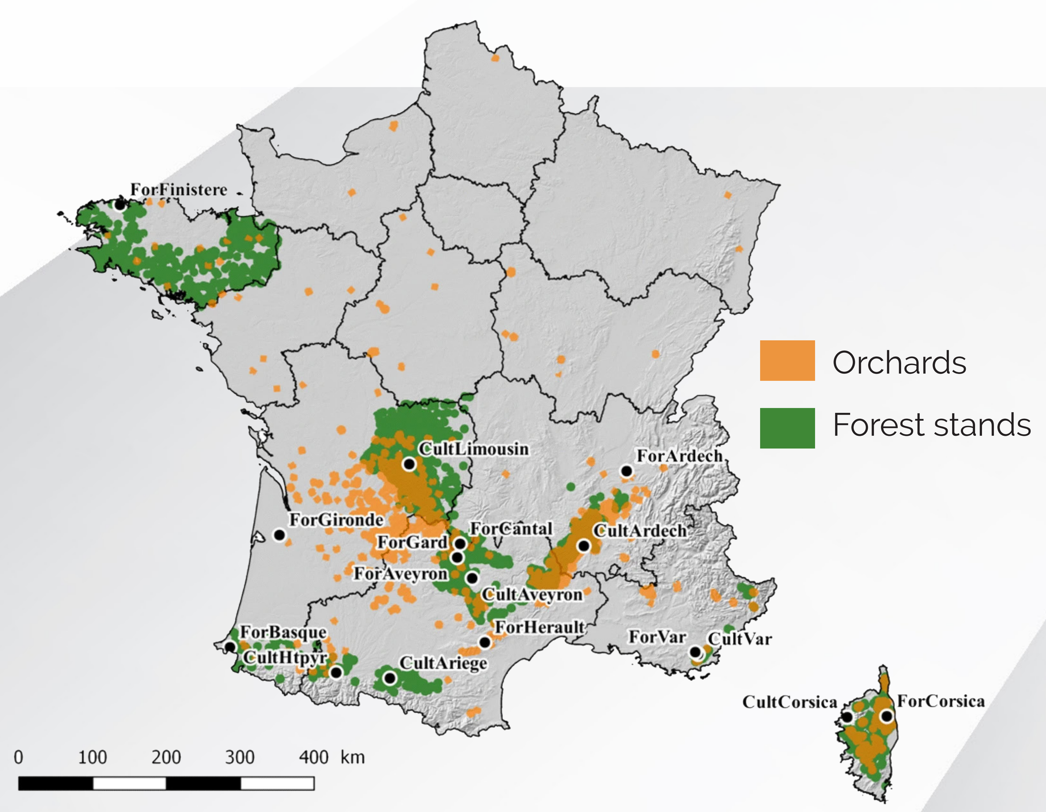
A PATHOGENIC FUNGAL VIRUS TO RESCUE CHESTNUT TREES

for more informations

INRAE

The chestnut tree in France

3rd broadleaf species with multiple uses: wood, chestnuts, honey, etc.



Chestnut forests (where the chestnut represents at least 75% of the cover, IGN data)

1

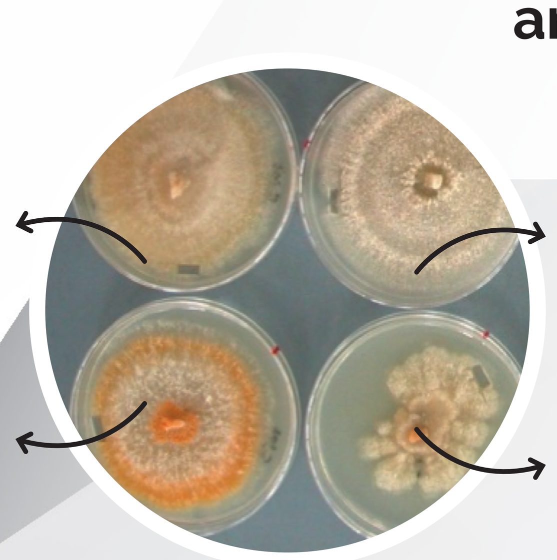
2

Chestnut blight

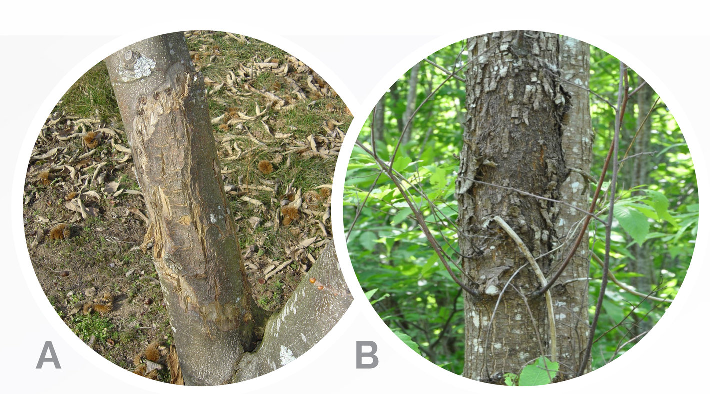
- From 1956, an epidemic of chestnut blight spread rapidly throughout France.
- This disease is caused by a fungus *(Cryphonectria parasitica)*, which infects trunks and branches, causing cankerous lesions and often leading to tree mortality.

But chestnut blight is not inevitable...

- Strains of *C. parasitica* infected by a virus *(Cryphonectria Hypovirus)* have low pathogenicity.
- These hypovirulent strains allow the tree to heal.
- The virus can be transmitted to a virulent strain and thus make it hypovirulent.



In the laboratory, the colour of cultures can be used to identify virus-infected strains



Healed cankers:
A > after treatment with hypovirulent strains
B > after natural transmission of the virus

3

4

A biological control method against chestnut blight

- Research carried out at INRAE made it possible to develop a biological control method against chestnut blight using hypovirulent strains.
- These strains are marketed under the INRAE licence (since 2021, under the name HYPOCRYPHO). Applying them to diseased trees avoids large losses in fruit production in orchards.
- The natural propagation of virus-infected strains significantly reduces the severity of the disease in forests.

Application of hypovirulent strains to a canker

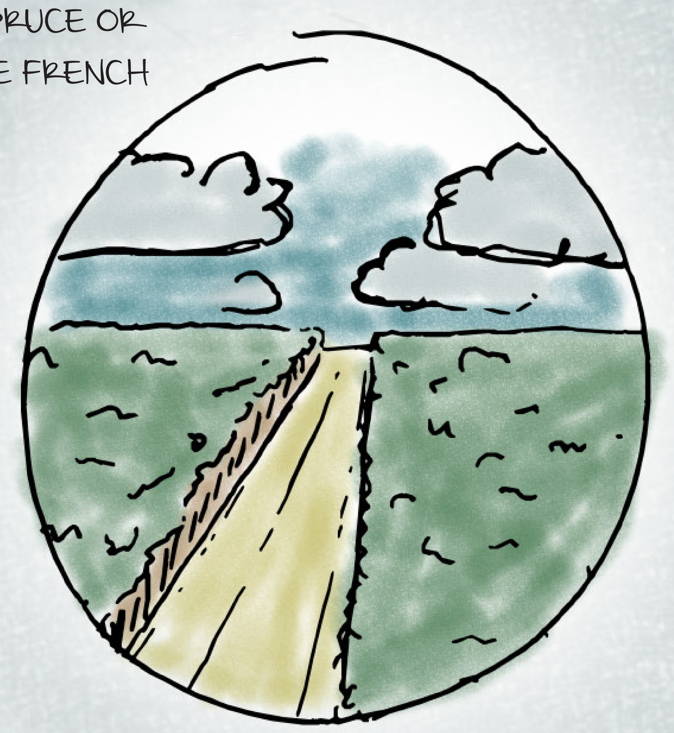
Chestnut orchard

Thanks to the *Cryphonectria Hypovirus* the European chestnut survived the canker epidemic and still occupies an important place in the French landscape for more informations

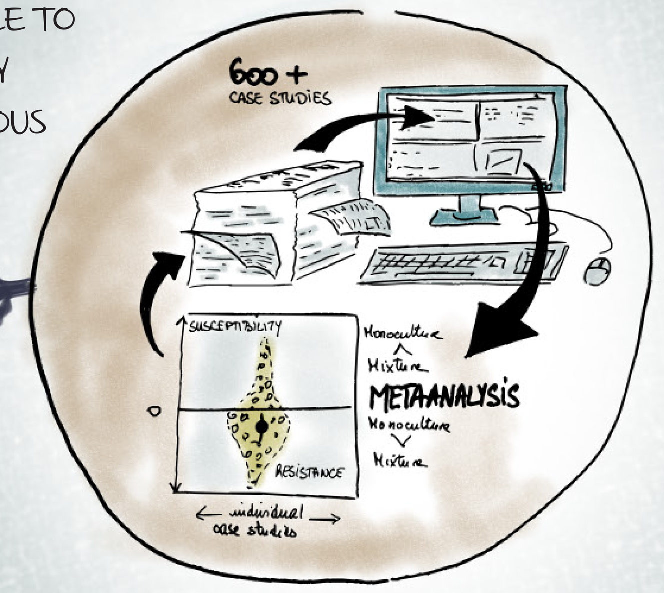
INRAE

DIVERSITY of trees & RESISTANCE to attacks BY HERBIVOROUS INSECTS

THE MAJORITY OF LARGE PLANTATION FORESTS ARE MANAGED IN MONOCULTURE. ALL THE TREES BELONG TO THE SAME SPECIES: MARITIME PINE, DOUGLAS FIR, SPRUCE OR POPLAR FOR THE FRENCH FORESTS.



THE SCIENTIFIC LITERATURE INDICATES THAT MONOCULTURES ARE GENERALLY MORE VULNERABLE TO ATTACKS BY HERBIVOROUS INSECTS.



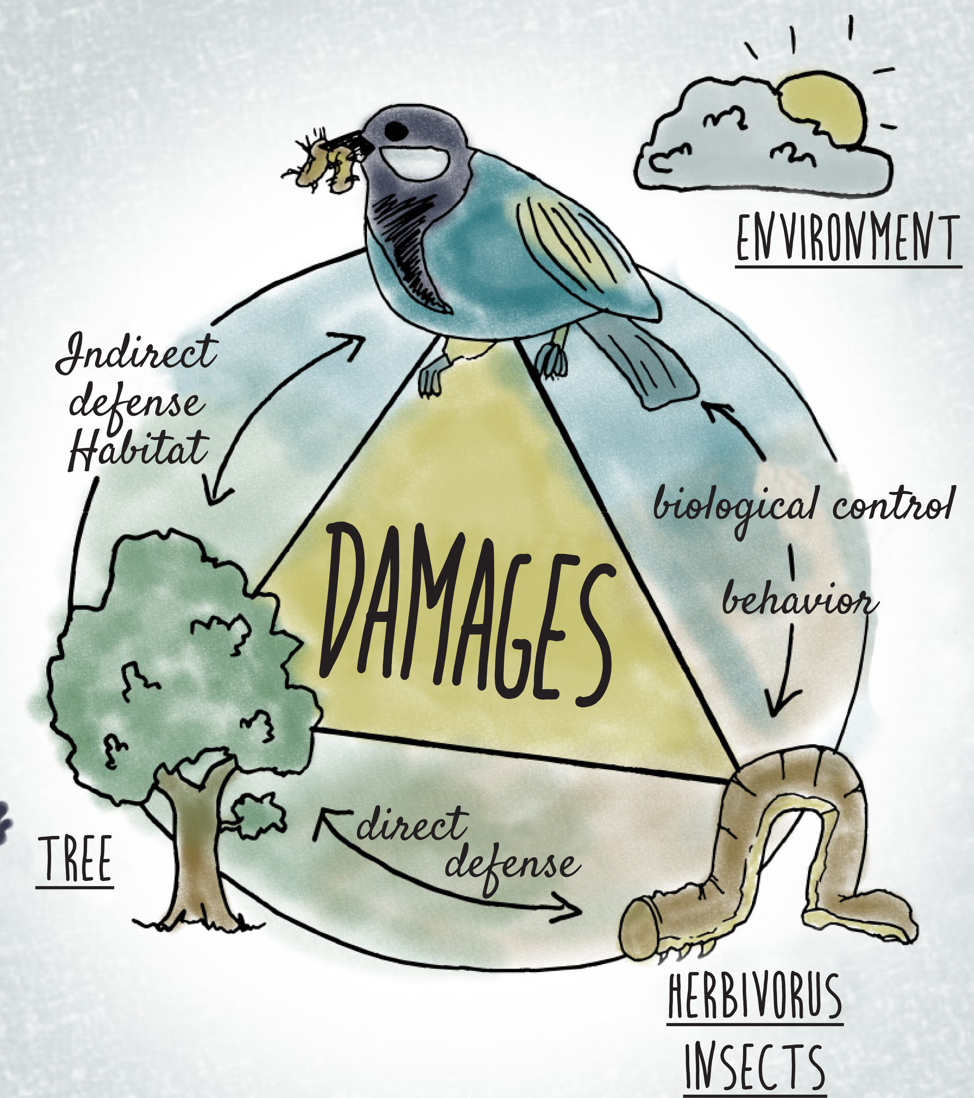
THIS IS EXPLAINED BY THE FACT THAT IN MIXED FORESTS, INSECTS HAVE MORE DIFFICULTY LOCATING AND COLONISING THEIR HOST TREES, ON WHICH THEY CAN FEED.

FURTHERMORE, PREDATORS OF HERBIVOROUS INSECTS ARE GENERALLY MORE ABUNDANT, MORE DIVERSIFIED AND MORE EFFECTIVE IN MIXED POPULATIONS WHERE THEY HAVE AN IMPROVED CONTRIBUTION TO THE REGULATION OF HERBIVORES.

FOREST SPECIES COMPOSITION AFFECTS THE DIVERSITY OF HERBIVORES, AS IT CAN MODIFY THE QUALITY OF THE LEAVES ON WHICH HERBIVOROUS INSECTS FEED...

... AND IT CAN EVEN INCREASE THE CAPACITY OF TREES TO PRODUCE THEIR OWN DEFENCES AGAINST HERBIVOROUS INSECTS.

THE EXPERIMENTS THAT WE CARRY OUT ARE REPEATED IN MANY OTHER COUNTRIES. THIS MAKES IT POSSIBLE TO COMPARE THE EFFECTS OF TREE DIVERSITY ON THE RESISTANCE OF FORESTS TO HERBIVOROUS INSECTS IN DIFFERENT CLIMATES.



IT IS BECAUSE WE STUDY TREES, HERBIVOROUS INSECTS AND THEIR PREDATORS AT THE SAME TIME, IN DIFFERENT CLIMATES AND USING DIFFERENT APPROACHES THAT WE ARE ABLE TO DISSECT THE MECHANISMS OF FOREST RESILIENCE TO HERBIVOROUS INSECTS.

9 THE GREAT HISTORY

OF OAK TREES TOLD THROUGH THE LITTLE STORY OF THEIR GENES

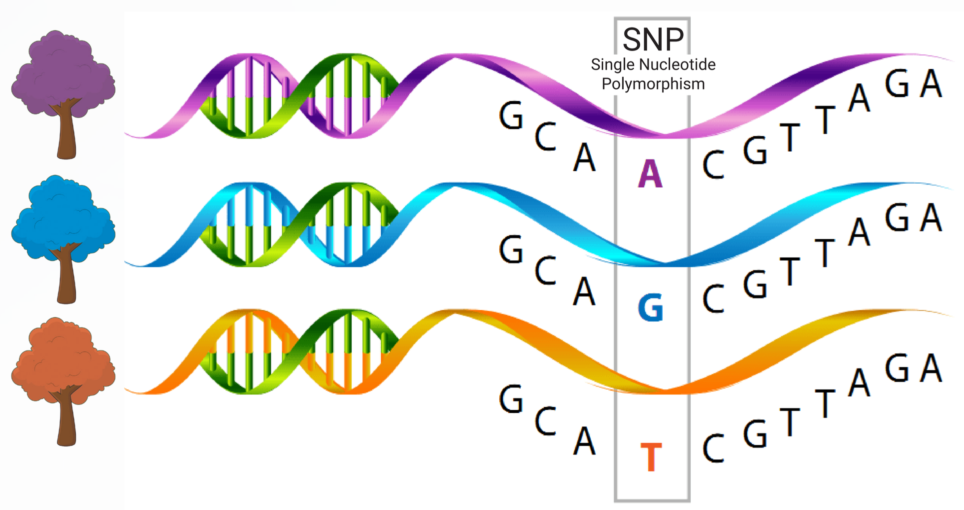
for more informations

INRAE

How to reconstruct the history of oak trees?

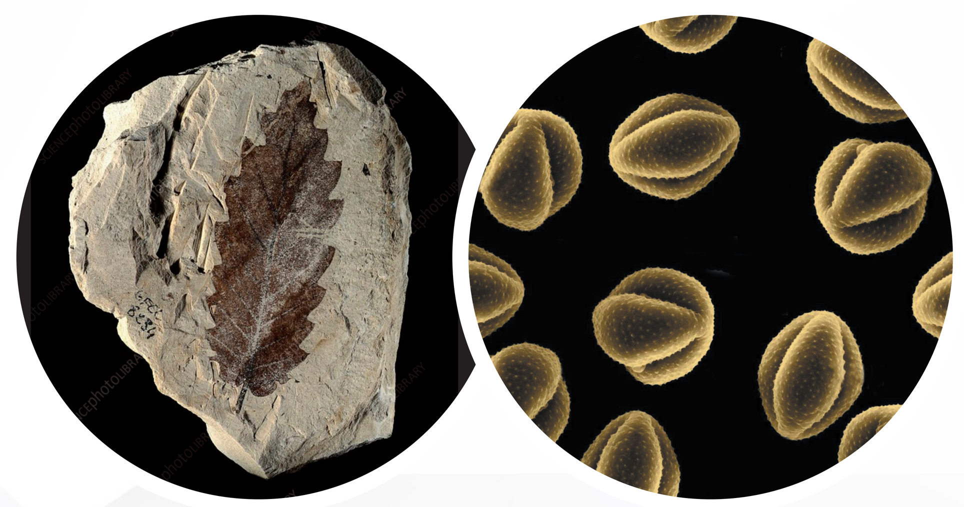
The genome: a history book

Variations in DNA sequences (mutations) bear witness to the formation of new species, their migration routes and their demographic changes. Numerous DNA variations in oaks allow the retrospective reconstruction of these events.



Fossil remains: the witnesses of history

Trees have left numerous fossils: pollen grains in sediments, macro-fossils in the form of wood or seeds, archaeological remains in human constructions. These fossils can be dated and allow the reconstruction of the evolutionary history of species over millions of years.



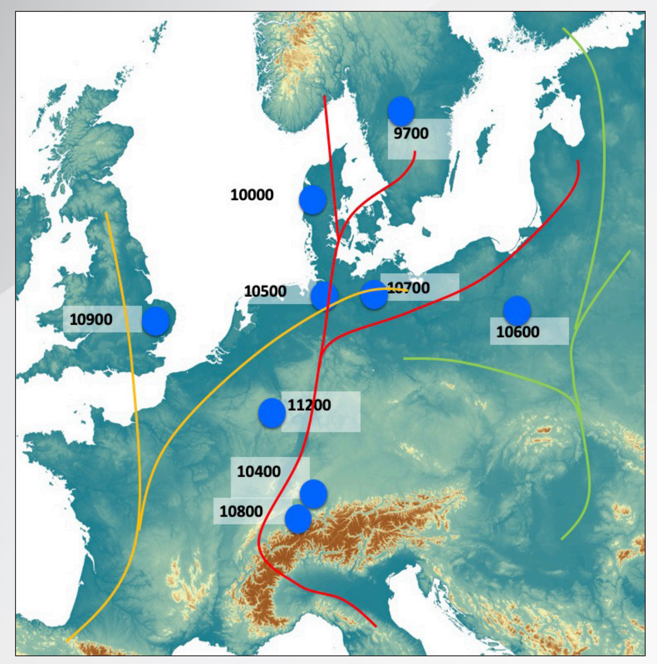
Ancient DNA: the historical narrative

It is currently possible to extract DNA from macro-fossils or archaeological remains dating back to the Bronze Age: below are remains of pile dwellings present at the bottom of the alpine lakes. By combining genetic and paleontological data, we can reconstruct the demographic and evolutionary histories of oaks.

What does this history teach us?

The Oaks, migrants from the plant world

The current distribution of oaks in temperate Europe results from colonisation during postglacial warming (beginning 15,000 years ago) from Southern Europe (Spain, Italy, Balkans).



Continuous genetic mixing

Current and past evolutionary events are marked by continuous and massive exchanges of genes between populations and species mainly through pollen flow. These exchanges have helped maintain high levels of genetic diversity, accelerated migration and contributed to the transfer of adaptations between populations and species.

Rapid evolution and adaptive capacity

Provenance tests established throughout Europe showed that oak populations have adapted to local conditions in just a few generations. They were able to keep pace with the changing climate and adapt thanks to their reservoir of genetic diversity.

Two populations of sessile oak from the common garden of Sillegny (57)

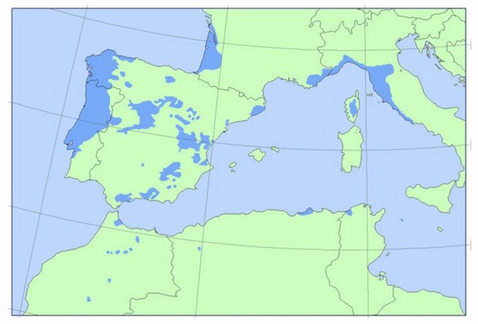
10 RESEARCH AND INNOVATION FOR THE SUSTAINABLE MANAGEMENT OF MARITIME PINE FORESTS

for more informations

The maritime pine, an endemic forest species, is well adapted to the soil and climatic conditions of the southwest of France. It is the 2nd most productive species in mainland France (carbon sink). It is used in planted forests for the production of wood (25% of wood harvested in France and processed locally) and provides numerous associated services (coastal management, leisure,...). New challenges to face: decline in productive areas, consequences of climate change, invasive pests, etc.

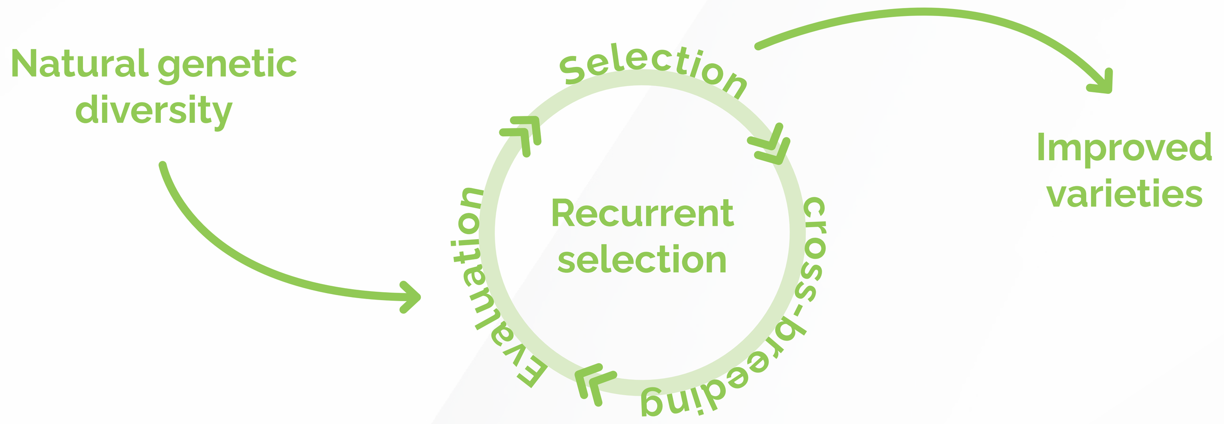
Genetic diversity: conservation and breeding

- Study of the genetic diversity
- In situ and ex situ conservation of maritime pine populations from the natural distribution range



Maritime pine distribution range (Euforgen)

- Genetic improvement strategy: preservation of the genetic diversity and of the genetic gain in the long term



- Valorisation of genetic diversity by the selection of improved varieties: productivity, wood quality, adaptation to stresses

Maritime pine seed orchard

Innovations in forest management:

- Experimental networks constantly renewed...

- Taking into account plant biodiversity: management of understory vegetation, mixtures of tree species, broadleaf hedgerows

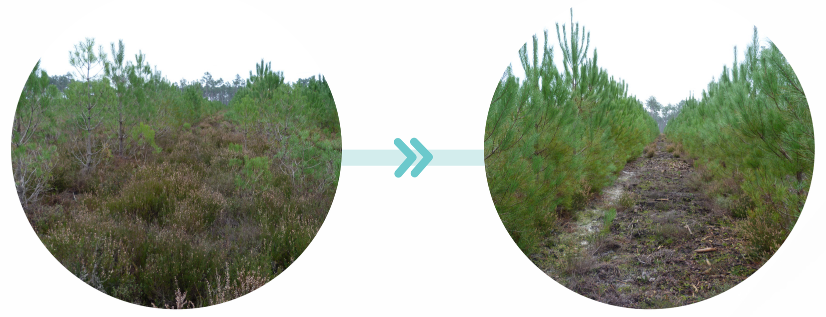
Broadleaf hedgerow around maritime pine stands

Mixed plantation of birch and pine

- Maintaining soil fertility: assess the harvests and compensate: experiment with legume crops in the understory

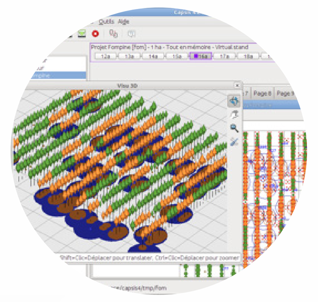
- Experimenting scenarios for forest renewal depending on the environment (e.g. dunes) or the context (e.g. after fire)

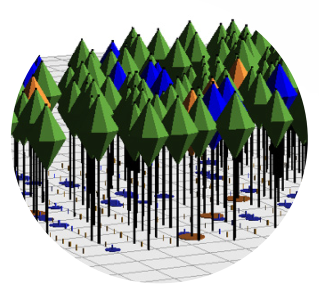
- Adaptation to summer drought stress: density of stands, management of understory, genetic variability of maritime pine



Experimental design for clearing vegetation

- ... to improve the development of management tools for decision-making in forest management: mathematical modelling of forest dynamics

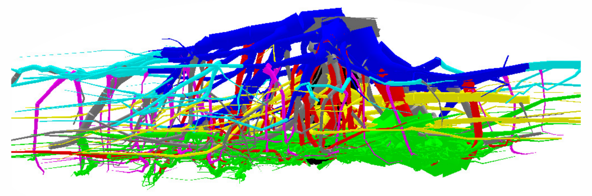




Capsis software (models PP3 and Pinuspinaster)

Risks: adaptation to global changes

- Understanding resistance to wind and root anchoring: simulation of the stressor, forest regeneration silvicultural practices, genetic variability and phenotypic plasticity



Architecture of the root system of a 50-year-old maritime pine on sandy soil with an indurated horizon. Roots are coloured by root types. We observe a strong acclimatation to the prevailing winds and the limitation of growth depth due to the soil.

- Anticipation of control methods for the pinewood nematode: evaluation of pine resistance in a confinement greenhouse, study of the insect vector, quantify forest landscape structure

Pinewood nematode inoculation

- Monitoring and control of pathogenic fungi: roadside inventory, high resolution remote sensing (drone), spraying an antagonistic fungus on freshly cut stumps

- Maintaining good productivity in seed orchards: monitoring of seed production and health protection

Leptoglossus occidentalis: invasive seed bug attacking pine cones and seeds