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## Forest reproductive material (FRM): shaping tomorrow's forests

June 2022

# *In this dossier*

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Producing high-quality forest seeds requires scientific knowledge in several fields, including selection, breeding, fructification and evaluation.

## Forest reproductive material (FRM): shaping tomorrow's forests

*Public policy efforts to reforest through planting has allowed France to increase its forest cover by 1.5 million hectares in the last 50 years. The adaptability of tree species used in reforestation, however, is an important issue: what characteristics will be important in the trees of tomorrow? What species should be planted, and where? What inter- and intra-species genetic diversity will be needed? Research at INRAE —on the varietal selection of forest species and the establishment and management of seed production in seed orchards and seed stands— contributes to the development of more resilient forests by guaranteeing the genetic origin and quality of forest seeds.*

France is home to a more diverse range of forest species than any other country in Europe. This diverse forest cover, central to ecological and energy transitions, must not only adapt to the impacts of climate change and supply the wood needed for construction and energy. It is now also tasked with mitigating those impacts. Forest ecosystems are also at the heart of a new bioeconomy. A natural, renewable economic resource that has been on the rise for decades, forests will play an increasingly large role as an alternative to energy consuming materials

and polluting plastic. Suitable tree species are therefore needed to meet the needs of reforestation as well as those of the wood industry. Forest species are continuously improved in an effort to develop the characteristics needed to accommodate and withstand the impacts of climate change. The French Ministry of Agriculture and Food mobilizes INRAE expertise in its management of the genetic resources needed for reforestation. INRAE intervenes across the forest seed production chain, sourcing the best genetic resources in France and

abroad, assisting in their regulation and inclusion on a national register, monitoring harvests and sales, and drafting recommendations on how to use different species for reforestation. Several teams from INRAE's Ecology and Biodiversity division (ECODIV) take part in selection and testing programs that evaluate and help shape the characteristics of tomorrow's trees. The Institute plays an important role in managing genetic diversity.

## ➤ Public policy to guide the reforestation of French forests

### THE IMPORTANCE OF REFORESTATION

French forests play an essential environmental, economic and social role, in addition to protecting against natural risks. Its role in the environment, in terms of carbon storage and as a reservoir of biodiversity, is especially important. Forests in mainland France are home to a wide range of species, including 73 types of mammals and 120 types of birds. Given that 20% of France's carbon emissions are offset by the forest-wood sector, they also play a vital role in achieving the country's net-zero emissions objective by 2050. In light of this, reforestation contributes to ecosystem renewal and the adaptation of tree stands to the effects of global warming. Reforestation, a component of forest planning, basic management plans and sustainable forest management plans, is carried out after the harvest of mature wood and to rebuild damaged stands. The seedlings used grow in nurseries for 1-3 years and seed origin and physical qualities are meticulously monitored.

Despite this, droughts in 2003, 2018 and 2019, along with bark beetle infestations in spruce tree forests in eastern France, drew attention to the vulnerability of forests. In the last five years, several public policies have been implemented to enhance the resilience of forests to climate change via reforestation.

### SCIENCE AND PUBLIC POLICY TO PRODUCE HIGH-QUALITY FOREST REPRODUCTIVE MATERIAL (FRM)

Public policy on reforestation relies primarily on the solution of planting to create or replenish a forest. This consists of planting nursery-raised hardwood or softwood seedlings in a bare or already wooded area. Seedlings, seeds, as well as cuttings, grafts and layers are collectively known as forest reproductive material, or FRM. Most of this material comes from seeds produced in seed orchards or collected from seed stands located in forests. Their selection, with assistance

from INRAE, ensures the genetic quality of this forest material. INRAE is active in both these approaches to seed production, which are inseparable in the effort to maintain softwood and hardwood diversity.

### INRAE's contribution to publicly run seed orchards

Seed orchards are stands of trees created specifically to produce seeds. Between 200 and 500 trees of the same hardwood or softwood species are planted per hectare; these are usually genotypes selected in the framework of forest improvement programs.

Seed orchards are designed to produce frequent and abundant harvests of quality seeds to be used in reforestation. They can be either private or public. Public orchards are funded through public policy and co-managed with the French government. INRAE contributes to the operation of all seed orchards. It also provides targeted support and expertise for public seed orchards. This support is specified in the 'State Seed Orchard' framework agreement signed by INRAE, the ONF (France's national forestry service), the Ministry of Agriculture and the economic interest group Semences Forestières Améliorées. This agreement was up for renewal in 2022. Initially planted with softwood species only, public seed orchards expanded to include hardwood species. Today, 59 orchards grow 15 different species (4 hardwoods and 11 softwoods). It takes 10 to 20 years (depending on the tree species) for a seed orchard to yield sufficient amounts of quality seeds.

### INRAE's investment in dedicated seed stands

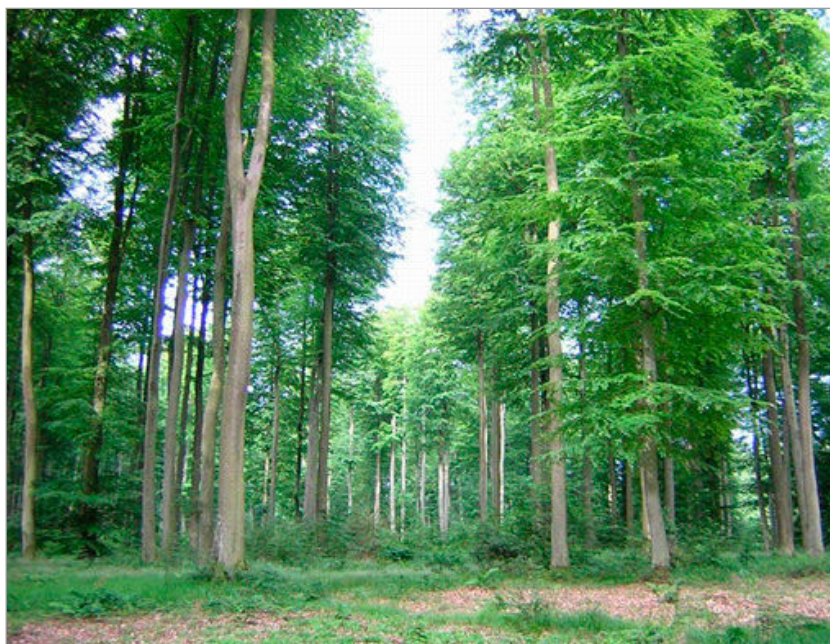
In addition to seed orchards, certain natural stands are used exclusively to produce seeds. These dedicated stands are located in forests in ecologically similar regions and based

#### Public policy for reforestation

- 2013 : European Union Forest Strategy (EUFS) for sustainable forest management
- Octobre 2014 : Law on the Future of Agriculture, Food and Forestry (LAAAF) for the development of sustainable and multifunctional forest management; the creation of a forest and wood strategic fund for reforestation and the promotion of the wood industry
- Janvier 2017 : National Forest and Wood Programme (PNFB) for 2016-2026 to replenish and rebuild damaged forests and planted stands
- Septembre 2020 : measures for forestry in the France Relance recovery plan
  - €150 million for reforestation and the planting of 50 million trees by 2024
  - €5.5 million for the seed and seedling industry
  - €1 million for the replenishment of public seed orchards
- Décembre 2020 : roadmap for the adaptation of forests to climate change prepared by forestry and wood stakeholders
- Octobre 2021 :
  - France 2030: €500 million for French forests and the planting of tens of millions of trees
  - The Assises du bois et de la forêt forum confirms France Relance objectives. Institutions, elected officials, landowners, researchers, entrepreneurs, non-profits and other forest and wood sector stakeholders met to develop a necessary shared vision and operational solutions to meet forest-related challenges

on specific purity and phenotype. Harvesting in these stands yields seeds from 24 species (9 hardwood and 15 softwood). There is a total of 16,400 hectares of seed stands in France. Currently, INRAE's role in selecting and managing seed stands is ensured

by one to two full-time equivalent employees at the Institute's forest ecosystem unit (EFNO). These employees coordinate work carried out in collaboration with staff at regional food, agriculture and forest offices (DRAAF) and representatives from the ONF.



Les peuplements porte-graines sont une des sources de production de graines. La sélection et l'homologation de ces peuplements, basées sur de solides compétences scientifiques et techniques, garantissent la qualité de leurs graines.



**Joël Conche**

National seed and seedling expert at the Sècherie de la Joux (ONF)



I've worked in the seeds and seedling sector since 1981 and was the manager of drying operations at Sècherie de la Joux. In 2010, I joined the ONF as their national seeds and seedling expert. INRAE provides support for FRM production cycles, from varietal creation, research in adaptive genetics, selection of stands for seed harvesting, scientific and technical support in managing production in seed orchards, to the review and analysis of statistical surveys on FRM and managing provenance tests. This technical and scientific support is useful both for the management of FRM resources and their use in the assisted migration of species and origins. Adapting tree species to environmental change is a major challenge for foresters. Dieback is a problem for many species, including common spruce, beech and ash, and raises the issue of how to regenerate these forests. We are open to any approach to forest regeneration, but need scientists close to the field to help us design them.

## ➤ The role of INRAE expertise in material (FRM) certification

Seed orchards and seed stands must be certified to sell the selected, qualified or tested seeds and seedlings produced in them. Certification is based on tests conducted to confirm the outcomes and genetic quality of the material. Certified orchards and selected stands appear on a national register of basic material for forest species which is managed by the forest ecosystems unit (EFNO) on behalf of the Ministry of Agriculture and Food. The unit updates the basic material list every six months and submits changes at meetings of the forestry unit of the permanent



### Forest reproductive material: regulation

The harvesting and sale of seeds and seedlings has been governed by a European Directive since 1966 to ensure that foresters can base their purchases of seedlings on accurate information. The Directive covers 67 species and hybrids planted in France and divides FRM into four categories:

- Source-identified: the tree that produces the FRM is situated in a specific geographical location (region of origin);
- Selected: the tree that produces the FRM is part of a seed stand selected for its phenotypic qualities;
- Qualified: the tree that produces the FRM is from a seed orchard and was individually selected;
- Tested: the tree that produces the FRM is from a seed orchard or seed stand, and the superior quality of its seeds have been validated by tests.

Most 'qualified' and 'tested' reproductive material comes from seed orchards but can also come from a 'tested' category seed stand. These seed sources are also known as 'improved forest varieties' and are considered to be selection-based FRM.



## Three questions for Élisabeth Van de Maele

Head of the sustainable forest and wood management department (BGED) of the Directorate General of Economic and Environmental Performance of Enterprises (DGPE) at the Ministry of Agriculture and Food



**You head the  
sustainable**

**forest and wood management  
department (BGED). What are its roles?**

I trained as an agronomist before holding several roles in various areas of agriculture at the Ministry. My focus has been on forestry for over a decade, and I have been with the BGED for the last six years. We have a ten-person team working on a wide range of issues. The department implements national and European public forestry policy. Biodiversity is an important component of this policy, so we work closely with the Ministry of Ecological Transition in a cross-cutting approach to forest-related issues such as sustainable management, forest expertise and conservation, natural risks, environmental services, as well as the relationship between forest and society and adapting to climate change, a subject that is the focus of significant research and development. Forest genetic resources (FGR) and forest reproductive material (FRM) are two major areas within the remit of the department.

**What are the forest-related challenges  
facing the Ministry of Agriculture today?**

Both now and in the future, forest management will necessarily be a balancing act between production and conservation. Considerations involved in reforestation include the economic need to produce quality wood for a range of uses, but also the resilience of forests and their conservation in the face of natural and man-made risks such as fires and emerging diseases. New developments in science have changed how tree species are selected: emphasis used to be on site adaptation, growth potential and wood quality, whereas now, species must be highly adaptable to global change.

The biggest challenge facing tomorrow's forests is climate change. It affects every forest compartment and complicates management. Stakeholders across the forestry sector agree. For a forest to perform its many functions, including acting as a carbon sink, it must be healthy.

An uncertain future adds to the complexity of selecting species and forest reproductive material for reforestation: a balance must be struck between resilience and competitive wood production, through a process of regional consultation.

### How do science and public policy work together in forestry?

The selection of forest reproductive material is driven by rapidly evolving needs, even though forests grow over a long period of time. Producing seeds and seedlings for tomorrow's forests is increasingly complex and requires significant investment and time. As an example, it takes more than ten years on average for a forest seed orchard to enter into production. We tend to forget that an additional 5-10 years are needed from the decision to plant the seed orchard to its actual plantation, which requires an improved population that itself depends on continuous genetic improvement—genetic recombination, assessment, genetic selection— by INRAE researchers. Planning in advance is essential in the design and implementation of forestry policy. Such planning made it possible in 2021 to quickly support the France Relance recovery plan by allocating €1 million to the creation of seed orchards for future species including Atlas cedar, Douglas fir and downy oak. This task falls to the French government, which in turn relies on its ONF and INRAE operators.

An enormous amount of science is needed for this endeavor and support from INRAE scientists to the French Ministry of Agriculture is longstanding. Expertise in

designing and managing seed orchards and assessing available FRM is therefore essential. An additional €500,000 towards research and development for climate-adapted forest reproductive material was approved at the

Assises de la forêt et du bois forum. INRAE scientists work with the genetic resources commission (CRGF), the forestry unit of the permanent technical committee for selection (CTPS) and the technical coordination committee (CTC) of public seed orchards, not only to conserve FGR, select stands and develop seed orchards, but also to advise us on the use of forest reproductive material to replenish our forests. The advice we receive from INRAE experts is an invaluable form of support based on multiple analyses of single tree species. In addition to support for seed orchards, INRAE contributes expertise for the testing of reforestation solutions with the RENFOR unit and the monitoring of several long-term testing and observation networks such as In-Sylva, ICOS, AnaEE-France and TreeDivnet.

These long-term challenges call for public forestry policies that are sustainable over time and based on scientific findings. Ongoing research is critical in a highly complex field and an uncertain climate context, to ensure that the French government can plan for the future.



technical committee for selection (CTPS)<sup>1</sup>. As a member of this unit, IINRAE also reviews proposals for new seed stands and registers them with the CTPS. The Institute also takes part

<sup>1</sup> The CTPS provides consulting services and technical support to the Ministry of Agriculture for the preparation and implementation of policy on varieties, seeds and seedlings.

in assessing registration and certification applications for basic materials. In November 2021 the national register listed:

- 55 'qualified' category seed orchards for 15 species (4 hardwood and 11 softwood) (536 hectares in total)

- 1,455 'selected' category stand for 24 tree species (9 hardwood and 15 softwood) (61,398 hectares in total).

In May 2019, the following 'tested' category sites were listed on the register:

- Four seed orchards for three tree species: a hybrid larch, Corsican pine and Douglas fir (97 hectares in total)
- Three stands for one tree species: Atlas cedar (146 hectares in total).

The Forestry Unit also classified 12 cherrywood cultivars as 'tested', along with 60 poplar cultivars and 3 eucalyptus.

In addition to their work on the national register, INRAE scientists also advise the Ministry of Agriculture on 1) new additions to the list of regulated species, 2) the approval and modification of technical regulations for 'tested' category approval.

Installation procedures, flowering techniques, fruiting and hybridization: public seed orchards are the outcome of years of research and testing, financed by the French government. Thanks to these orchards, 30,000 hectares of forest are re-planted each year.

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## ➤ Variety assessments: Douglas seed orchards

### AN IMPROVEMENT PROGRAM WITH MEASURABLE IMPACT

A Douglas varietal was created in response to a growing need for softwood for the construction and wood panel industry: two fields in which the technological advantages of Douglas wood are highly valued. Also known for its vigor and resilience to disease and insects, Douglas is the second-most frequently used softwood species in reforestation after maritime pine. In the early 1960s, INRAE joined a program for the genetic improvement of Douglas fir, to 1) develop varieties compatible with low- and mid-altitude

productive forest stands, and 2) establish seed orchards to ensure seed production.

This research contributed to several societal outcomes:

- Economic: over 100,000 hectares replanted using improved seeds produced by INRAE research, generating additional production for French Douglas fir forests.
- Political: France has not needed to import Douglas fir seeds since 2011 and even exports seeds in Europe.
- Environmental: Douglas fir is gradually replacing common spruce, which is subject to dieback due to climate change. With its minimal

impact on soil compared to other softwoods, Douglas is the most efficient species in mainland France for carbon sequestration.

- Social: Douglas fir has helped make the forest-wood sector more competitive and dynamic in several French regions. Annual wood production is expected to reach six million cubic meters in 2035, with Douglas fir trees accounting for a third of national sawn softwood production. In certain regions where reforestation has not been carried out in the framework of land planning, the planting of Douglas fir trees is a controversial issue for civil groups.

## THE QUALITY OF VARIETIES: A CHALLENGE FOR FORESTERS AND FOREST RESILIENCE

Tree varieties are evaluated in experimental stands to compare the outcomes of trees sourced from seed orchards or stands with those of control trees from a natural environment. This process makes it possible to measure tree performance in different soil and climate conditions and ensure quality. Scientists compare the variety with trees in one or more control stands that are known references for the species. If the tested variety is deemed superior, it can be identified as an 'improved forest variety' and be added as a 'tested'-category variety of forest reproductive material. This approach is of particular interest to reforestation professionals using species that were well-adapted to their environment before but are now vulnerable to climate change.

Testing was set up in the 1950s to compare outcomes, but only 20 years later has it been possible to collect and identify all origins of naturally growing Douglas fir in France using a network of comparative resources, thanks to INRAE, the ONF and the FCBA technological institute -- a project largely driven by the International Union of Forest Research Organizations (IUFRO, <https://www.iufro.org/>).

Provenance/progeny tests have also served as the basic material from which



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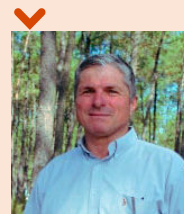
A network of 76 testing programs was established to assess the outcomes of forest reproductive material. The photo shows an experimental ash stand.

INRAE selected plus trees for the creation of the eight seed orchards in operation today. Outcomes at the eight publicly run Douglas fir<sup>1</sup> seed orchards are monitored through a network of 82 hectares of experimental sites created by INRAE, the ONF and French national Forest Ownership Centre (CNPF) and financed by the forestry ministry.

<sup>1</sup> The eight Douglas seed orchards: Darrington, Luzette, Washington, Washington 2, France 1, France 2, France 3 and Californie.

### The Douglas Avenir program: seed orchard replenishment using improved populations

Since 2010, France's eight public seed orchards supply 99% of national demand for Douglas fir seed. The country's annual requirements for Douglas fir seed, stable at around 500 kilograms, have been on the rise since 2015 and in 2020 reached 700 kg. Approximately 11 million seedlings were produced. In 2015, given the advanced age of certain seed orchards and uncertainty caused by climate change, the Ministry of Agriculture launched a research and development program for the replenishment of Douglas fir orchards. Douglas Avenir, a six-plus five-year program (2015-2020 and 2021-2025) entrusted to three research organizations -- INRAE, the FCBA and the ONF -- allows scientists to select, safeguard and test an improvement population for use in a long-term Douglas fir improvement program. The program has also established a basis for orchard strategy that evolves in line with industry needs. Every five years, 20 hectares of seed orchards will be created as part of a strategy to develop Douglas fir seed production sites. The Douglas Avenir project has already created basic material for the creation of 25 hectares of new seed orchards.



**Richard Hébras**  
Director of Tree Seeds at Vilmorin-Mikado and President of the Semences Forestières Améliorées (SFA) economic interest group

Through the SFA, Vilmorin plays a role in the management of seed orchards, harvesting and the sale of orchard products. We also have a role on the technical coordination committee (CTC) of public orchards and the permanent technical committee for selection (CTPS), where we relay industry needs to scientists. In the framework of France Relance 2024 and France 2030, for example, which finance the creation of public orchards for the purpose of replenishing declining forests and making them climate adaptable, demand from the wood industry is centred on softwood and hardwood for construction. Seed orchard programs enable the production of enough high-quality seeds every of sufficient intra- and inter-species diversity to ensure the resilience of forests. The first improvement programs were launched by INRAE. This cutting-edge public research is recognized at the European level. We now need to mobilize scientific and technical expertise to plant new orchards and meet long-term needs.

This network has three functions: scientists 1) can produce data on the plasticity and performance of varieties and submit recommendations, 2) have access to information for the 'tested' category certification of orchards, and 3) can share information with managers via on-site visits.

The VFA network (a part of IN-SYLVA research infrastructure) primarily assesses five tree species: Douglas fir, hybrid larch, European larch, Atlas cedar and Corsican pine. Across the 76 sites planted between 1995 and 2016, 38 are planted with Douglas fir and allow scientists to evaluate multiple criteria including adaptation to

the environment and tree shape. They were planted between 2009 and 2016 in a range of different soil and climate conditions to study their adaptability. As an example, five years of growth in experimental planting conditions demonstrated that foresters dealing with early frost should opt for Douglas fir trees produced in the La Luzette, Washington or Washington 2 orchards. Californian trees, to the contrary, exhibited early bud development. At sites subject to frost in the spring, forest owners should avoid planting the Californian variety.

Notably, for Douglas fir and the other most commonly used reforestation

species, seed orchard evaluation tests are established at a much higher number of sites than is required by regulation for 'tested' category certification. This investment is what generates extensive knowledge of each variety and provides reforestation professionals with the best guarantees and advice on how to use these varieties. For example, scientists used these tests to help draft [8 information sheets](#), one for each seed orchard operating in France, to show reforestation professionals how to use the varieties. A ninth sheet offers a simplified chart of recommended origins depending on the site.

## ➤ Expertise for national and international trade

### HARVEST MONITORING AND SALE OF FOREST REPRODUCTIVE MATERIAL

France's two seed suppliers, Vilmorin and the ONF, together with nurseries, need to monitor the harvesting and sale of seeds in order to manage their own stocks.

They obtain this information from two annual statistical surveys commissioned by the forestry ministry: one on the production and sale of forest seedlings, and another on the quantities of harvested forest seed stocked,

sold and used in France. Data collected by regional forest offices (DRAAF) for these surveys is compiled and analyzed by the forest ecosystems unit (EFNO). This work is part of an agreement with the Directorate General of Economic and Environmental Performance of Enterprises (DGPE) of the Ministry of Agriculture.

According to 2019-2020 survey results, 55 million seedlings were sold in France, a 19% decrease from the previous year, due to a drop in sales of maritime pine following the

end of the post Klaus-storm recovery plan (12 million fewer seedlings were sold). Sales are comparable to levels recorded in the 2000s and early 2010s and remained high despite the COVID-19 pandemic.

Sales of softwood seedlings (46.3 million) fell sharply by 22% while sales of hardwood seedlings (8 million) increased by 4%. Poplar whip sales (930,000 in total) also increased by 2%. The preponderance of maritime pine in the reforestation industry has a direct impact on statistics. Excluding



maritime pine, sales of forest seedlings in France only fell by 3% compared to the previous year. At the international level, 2.7 million seedlings were exported in 2019-2020, the equivalent of the average over the last ten years (2.6 million). Douglas fir and maritime pine accounted for 43% of the exports. Over the period, one million seedlings were imported. Most of these were softwoods (72% of the total).

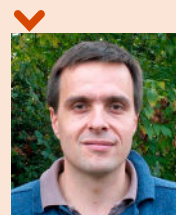
The survey on harvesting and seed transactions for the same year highlights very good harvests and a continued supply of more than one billion available seeds for the third consecutive year. Results show an increase in available seeds for softwood and hardwood species. Seed use levels increased from the previous year, with nearly 520 million seeds used in France or exported. Since supply has increased more than use, stocks were on the rise at the end of the period.

### WHICH SPECIES WILL BE NEEDED TOMORROW? FUTURE OUTLOOKS

In 2020, INRAE used this harvest and seed transaction monitoring to conduct an assessment for the Ministry of Agriculture on the risk of a seed and seedling shortage in relation to expected industry needs, and how to avoid it. The study was led by a working group of the CTPS forestry unit together with seed suppliers, nursery

professionals, construction companies, forestry cooperatives, public and private forest managers, researchers and ministry representatives. They found that shortages could arise in the supply of seeds and seedlings for softwood species, including Douglas fir, European larch, hybrid larch and Atlas cedar, and for hardwood species, including sessile oak, common oak, downy oak and eucalyptus.

In addition to these results, the working group published a 'FRM ten-year roadmap for adaptation and reforestation'. The first phase of the plan, approved by the ministry, involves planting new seed orchards over the next five years. The Douglas fir, black locust, Atlas cedar, European larch and pubescent oak orchards will be funded by the France Relance recovery plan, the forestry industry and the forest and wood strategic fund. The replenishment of several Corsican pine and Scots pine seed orchards was also examined. Another possibility is the creation of small hardwood orchards to alleviate harvesting issues encountered by suppliers of seeds for limes, field maples and apple trees ■



**Frédéric Gosselin**  
Engineer  
specialized in forest  
biodiversity and  
Deputy Head of  
INRAE's Ecology  
and Biodiversity  
(ECODIV) Division

For over 30 years, our EFNO forestry unit has studied lowland forest ecosystems and both their intra-species and global biodiversity. Our objective is to develop forest management systems that simultaneously ensure wood production and protect biodiversity in a context of climate change. Nearly 13% of all forests in France today are planted. The France Relance recovery plan includes the reforestation of 50 million trees between now and 2024 to meet tomorrow's forestry challenges. Can genetic diversity help forests adapt to climate change? If so, to what degree? How do we develop this diversity? Is it best to naturally adapt forests, or ensure genetic diversity through planting? What impact will these choices have on other biodiversity in the ecosystem as a whole? The types of forest reproductive material used is key in meeting these challenges. Management strategies have and hopefully will continue to foster more diversity in both species and forest systems. It is an exciting challenge that requires research.



Tomorrow's forests will reflect forestry management strategies that support wood production and protect forest biodiversity.

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