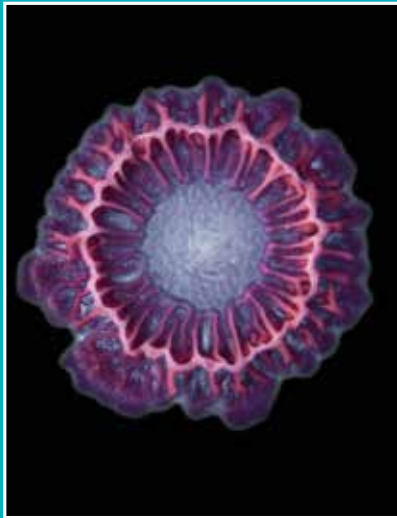




INRAE

Annual report
2022

AE



Cover image
Bacillus subtilis growing on agar.
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Researchers sampling plants from Lake
Hourtin-Carcans (Gironde).
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^
Solar panels casting shade on plum trees in a field near the town of Apt (Vaucluse); researchers are exploring how photovoltaic modules affect tree production.
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>
Charolaise cow grazing in an INRAE-managed grassland near the town of Pin-au-Haras (Orne).
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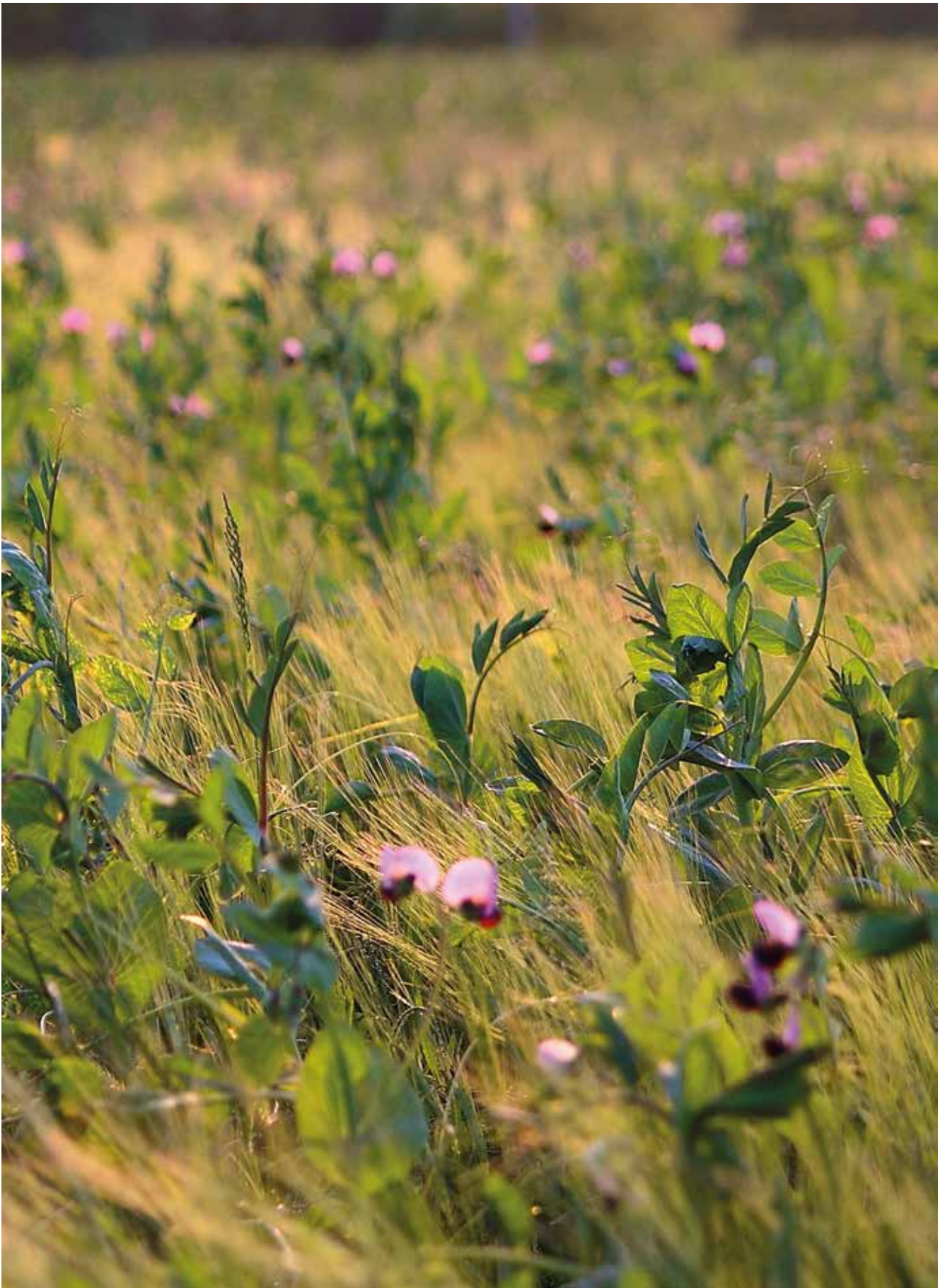




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Young visitor examining a magnified tick atop a blade of grass
at the Paris International Agricultural Show.
©INRAE - B. Nicolas

>
Person adjusting the console of a row cultivator used for organic farming;
INRAE Research Centre of Val de Loire (Bourges site).
©INRAE - C. Maître





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An association of grains and legumes (peas) in a field near the town of Sourcieux-les-Mines (Rhône).
©INRAE - M.C. Lhopital



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Highlights

February 22

INRAE embraces CSR

The institute adopted an ambitious action plan to improve corporate social responsibility (CSR) by transforming its operations and business practices.

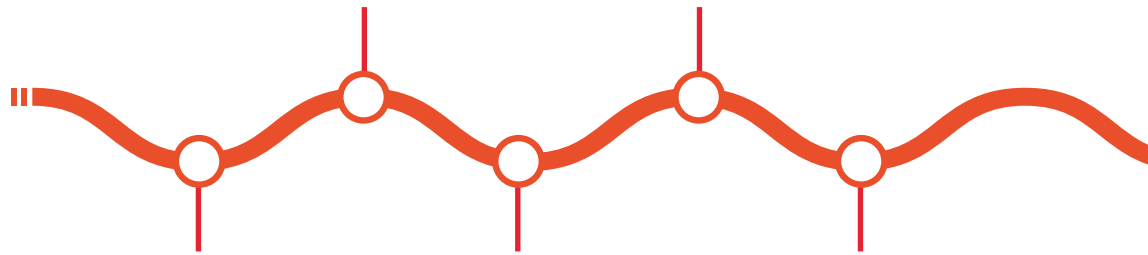


RESPONSABILITÉ
SOCIÉTALE ET
ENVIRONNEMENTALE

March 1

INRAE's 1st Contract of Objectives, Means, and Performance

INRAE put together a COMP, which describes the institute's priorities, objectives, and supplemental resources for the period between 2022 and 2026. Such contracts are associated with France's Research Programming Law and France 2030.



February 28

1st framework agreement between INRAE and Agence BIO

INRAE and Agence BIO have partnered up to promote knowledge and data sharing in the pursuit of an EU goal: implementing organic farming on at least 25% of agricultural lands by 2030.



February 8

EU representatives visit Colmar

While France held the presidency of the EU Council, Europe's ministers of agriculture and an EU commissioner toured the ResDur programme site at the INRAE Research Centre of Colmar. The programme's goal is to reduce pesticide usage in vineyards by breeding resistant grape varieties.



March 3

INRAE grants first-ever award for participatory research

INRAE now formally recognises work by non-scientist stakeholders. In 2022, the institute gave its new participatory research award to members of the Agreenium community. Starting in 2023, the programme will consider candidates who contribute to discoveries in all scientific domains.

March 16

OneWater: a wellspring of water research

Jointly led by CNRS, BRGM, and INRAE, OneWater has received priority research programme and infrastructure (PEPR) funding. Its main objective is to centre research on water resources as France's regions transition towards sustainability.



July 8

Recherche Data Gov is launched

At the request of the French Ministry of Higher Education and Research, INRAE developed a platform for storing and cataloguing validated scientific data. It can be used by all of France's higher education and research establishments to deposit and share results.

June 20

New partnership agreement with INRIA

INRAE and INRIA will combine forces to advance digital innovations in the agricultural, food, and environmental sciences.



April 11

FairCarboN-France pursues zero carbon goals

Led in tandem by CNRS and INRAE, the FairCarboN programme is developing strategies that will allow continental ecosystems to mitigate the effects of climate change and achieve carbon neutrality by 2050.



June 3

INRAE signs 5th Contract of Agreed Objectives and Means with French universities

INRAE signed an agreement with UBFC, the Université de Bourgogne, and the Institut Agro to formalise their scientific collaborations focused on shared objectives.



July 1

400 European researchers seek to reduce pesticide use

As part of France's EU Council presidency, INRAE organised a scientific conference in Dijon to address the following question: "What research is needed to bolster the European Green Deal and its goal of reducing agricultural pesticide usage?"

FERMENTS DU FUTUR >

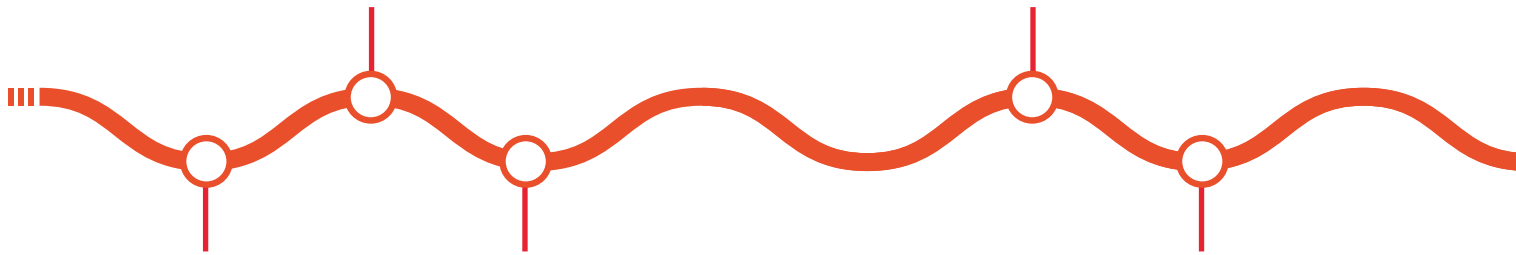
September 12 Ferments of the Future begins

Jointly led by INRAE and ANIA with France 2030 funding, the Ferments of the Future Grand Challenge will explore how fermenting agents and fermented foods can help create the diets of the future.



September 27 INRAE start-ups in the spotlight

INRAE organised a new event called Start-up for Planet to help transform agricultural and food systems. INRAE steps up its efforts to support scientists in their projects to set up businesses.



August 31 Transfer of the Vassal vine collection

It will take until 2032 to transfer the Vassal vine collection to INRAE's Pech Rouge experimental vineyard and winery facilities. This effort seeks to protect a one-of-a-kind collection of plant material and to preserve its research value via experiments conducted along the spectrum "from genes to wine bottles".



15 September Le French Gut

This participatory science project is a call for contributions to map and understand French intestinal microbiota. Led by MetaGenoPolis/INRAE and the Paris Hospital Authority (AP-HP), it is part of a worldwide initiative.



October 18 Transformational work with the FAO

The FAO signed a partnership agreement with INRAE, CIRAD, and IRD, which will fuel collaborative work to transform agricultural and food systems.



December 12

Building ties with the Institut Agro

INRAE and the Institut Agro signed their first framework agreement. The two establishments wish to combine their skills and expertise to accelerate the sustainable transformation of agricultural and food systems.



December 6

TSARA-a Franco-African initiative for research, training, and innovation

The INRAE-CIRAD initiative Transforming Food and Agricultural Systems through Research in Partnership with Africa held its first general meeting with all 19 collaborators on December 5 in Cape Town, South Africa.





Research that fuels transitions

BY

Philippe Mauguin

INRAE Chair and
Chief Executive Officer

On display in our 2022 annual report is the wealth of scientific advances made by the entire INRAE community over the last year, which beautifully illustrate the robustness, assiduity, and quality of the institute's work.

In 2022, we signed our first Contract of Objectives, Means, and Performance (COMP) with the French government. Its purpose is to establish our priorities and shared commitments over the next 5 years. The COMP contains ambitious objectives that align with the strategic priorities set out in INRAE2030, which will be accomplished thanks to a wealth of new resources.

It incorporates the steps taken by France's Research Programming Law (LPR) and France 2030 investment plan. 2023 began with the French government allocating additional sources of support to boost research development. These include innovative means for boosting research impacts and thereby cementing French excellence in

strategic sectors that benefit society as a whole.

In 2022, at the request of the French government, INRAE began participating in several projects with priority research programme and equipment funding (PEPRs). More specifically, the institute has been tasked with designing, launching, and individually or jointly steering 9 PEPRs focused on acceleration strategies in the agricultural sciences, food sciences, bioeconomics, and emerging infectious diseases, in addition to exploratory strategies in the environmental sciences. 2022 was INRAE's first year of involvement, during which it launched the FairCarboN and OneWater programmes. This work will help the institute and France's entire scientific community to fast-track efforts to understand and limit the effects of climate change. The world has been witnessing the consequences of climate change—drought, wildfire, and resource scarcity. 2022 was also the year that we launched the Ferments of the Future Grand Challenge,

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The institute is researching climate change mitigation strategies. This work sets the stage for INRAE to reduce its environmental footprint and reinforce its resilience.

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which will produce innovative solutions for facilitating food system transitions. INRAE is tackling these challenges head-on both nationally and internationally. The institute is working to expand its global influence and strengthen its projects by adopting a dynamic approach to international scientific cooperation. It is also increasing its contributions to international organisations and initiatives. Consequently, INRAE

has been taking multilateral action, becoming significantly involved in the FAO and playing a major scientific role at important international meetings, such as the 2022 UN Climate Change Conference (COP27) and Biodiversity Conference (COP15).

In this same vein, the TSARA initiative was launched at the 2022 International Agricultural Show in Paris. Nine months later, in December, the initiative's first general assembly was held in South Africa, bringing together representatives from INRAE, CIRAD, and 17 partner establishments in 11 African countries. Finally, INRAE has been developing and supporting PREZODE, an international priority programme (PPI) focused on preventing zoonotic diseases. This work has enabled INRAE to plan ahead in its contributions to the initiative, help establish its overall governance structure, and design a strategic research agenda.

With its focus on targeted research, INRAE is inherently prepared to forge the agricultural systems of tomorrow, a task that includes identifying, training, and supporting the next

generation of agricultural producers. These individuals will be on the front lines—confronting the challenges associated with climate change, preserving natural resources, and promoting food sovereignty. Over the next 10 years, around one-third of today's farmers (~166,000 individuals) will be retiring. It is for this reason that President Macron emphasised the importance of preparing for the future and training the next generation of farmers on September 9 at the agricultural festival Les Terres de Jim. INRAE is partnering with France's agricultural technical institutes to help draft future policies that will provide research-based support to these future farmers, who will be facing the above challenges.

The institute is researching climate change mitigation strategies. This work sets the stage for INRAE to reduce its environmental footprint and reinforce its resilience. The institute is making significant strides in research that will help advance the UN's Sustainable Development Goals (SDGs). INRAE is committed to corporate social responsibility (CSR) in its operations and business

practices. This commitment should allow the SDGs to be reached by 2030. To attain its CSR objectives, INRAE is implementing an ambitious action plan, which notably includes voluntary steps for reducing energy consumption. Thanks to the efforts made by each and every member of the INRAE community, we achieved the government's target of 10% energy savings in 2 years by the end of 2022. Our successes have arisen from the dedication, creativity, and scientific expertise of our research units and laboratories, which are both a source of pride and of hope.

While 2022 was shaped by worldwide uncertainty and tensions, there were also many triumphs and newly launched initiatives.

All this together has highlighted the imperative need for science, research, and knowledge, as well as for the daily dedication of the INRAE community, whose members continually strive to tackle the major challenges faced by humanity and the planet. ●



OUR RESEARCH

Sperm cryopreservation is a foundational tool in many biodiversity conservation programmes.
©INRAE / A. Vitorino-Carvalho





INRAE: a major contributor to France 2030



INTERVIEW WITH

Carole Caranta

Deputy Director General
of Science and Innovation

INRAE is heavily involved in France 2030. What are the benefits for the institute?

France 2030 and its acceleration strategies are fuelling innovation by uniting major players and creating communities around important themes within key sectors. Some of the PEPRs are directly tied to the Grand Challenges, which focus on research that drives innovation. As a result, this work will help us progress faster. For example, INRAE is collaborating with the French National Association of Food and Drink Industries (ANIA) on the Ferments of the Future Grand Challenge, which has brought together 36 partners from the public and private sectors. The aim is to develop new products to streamline the transition to safer, healthier, and more sustainable foods. This work will notably draw upon the data sciences and an innovation-centred platform that is unparalleled in Europe. The latter will be located on the Saclay Plateau and will be operational by late 2024. As part of France 2030, our subsidiary INRAE Transfert is running two consortiums dedicated to gestation and maturation, whose goal is to translate the PEPR results into

economic, environmental, and health impacts. These consortiums unite technology transfer acceleration companies (SATTs) with universities and national research establishments and will fund gestation projects, help bridge the gap toward existing maturation grant programmes, promote start-up creation, and facilitate technology transfer to companies.

- ASTRAGAL is a consortium that supports projects associated with two acceleration strategies: "Sustainable agricultural systems and farm equipment contributing to the ecological transition" and "Sustainable food for health".
- BIOSCALE is a consortium that supports projects associated with one acceleration strategy: "Biobased products and industrial biotechnologies, sustainable fuel".

How do these strategies mesh with INRAE site policy?

INRAE is present at 34 institutions of higher education and has contributed to France 2030's new tools for encouraging action at these sites. Indeed, INRAE is involved in 11

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Some of the PEPRs are directly tied to the Grand Challenges, which focus on research that drives innovation.

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ExcellencES projects for transforming universities. In accordance with our national strategy, we have espoused a proactive approach in which we consult with pilot institutions within university innovation clusters (PUIS) to co-construct the innovation landscape, operating on such dimensions as expertise, access to technology platforms, research partnerships, intellectual property, and start-up

creation. At present, INRAE is a partner in 3 pilot PUIs and 16 of the 21 PUIs selected during phase 2.

These tools strengthen our collaborations with site partners as well as our collective capacity to detect concerns and take action. We can already see the structuring effects.

How have you made space for PEPR leadership among your current responsibilities?

We have taken on both the strategic leadership and management of these PEPRs. To ensure the strongest possible ties among these PEPRs, our strategic priorities, and INRAE's other work, the PEPRs are led and managed by individuals positioned at the highest levels of the institute: members of the management board who are under my supervision and who receive guidance from our three scientific directors, Christian Huyghe (Agriculture), Monique Axelos (Food), and Thierry Caquet (Environment). PEPR operations are handled by an administrative unit created specifically to provide the support needed by the programmes' scientific leaders. The unit also takes care of certain tasks that are shared

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INRAE is present at 34 institutions of higher education and has contributed to France 2030's new tools for encouraging action at these sites.

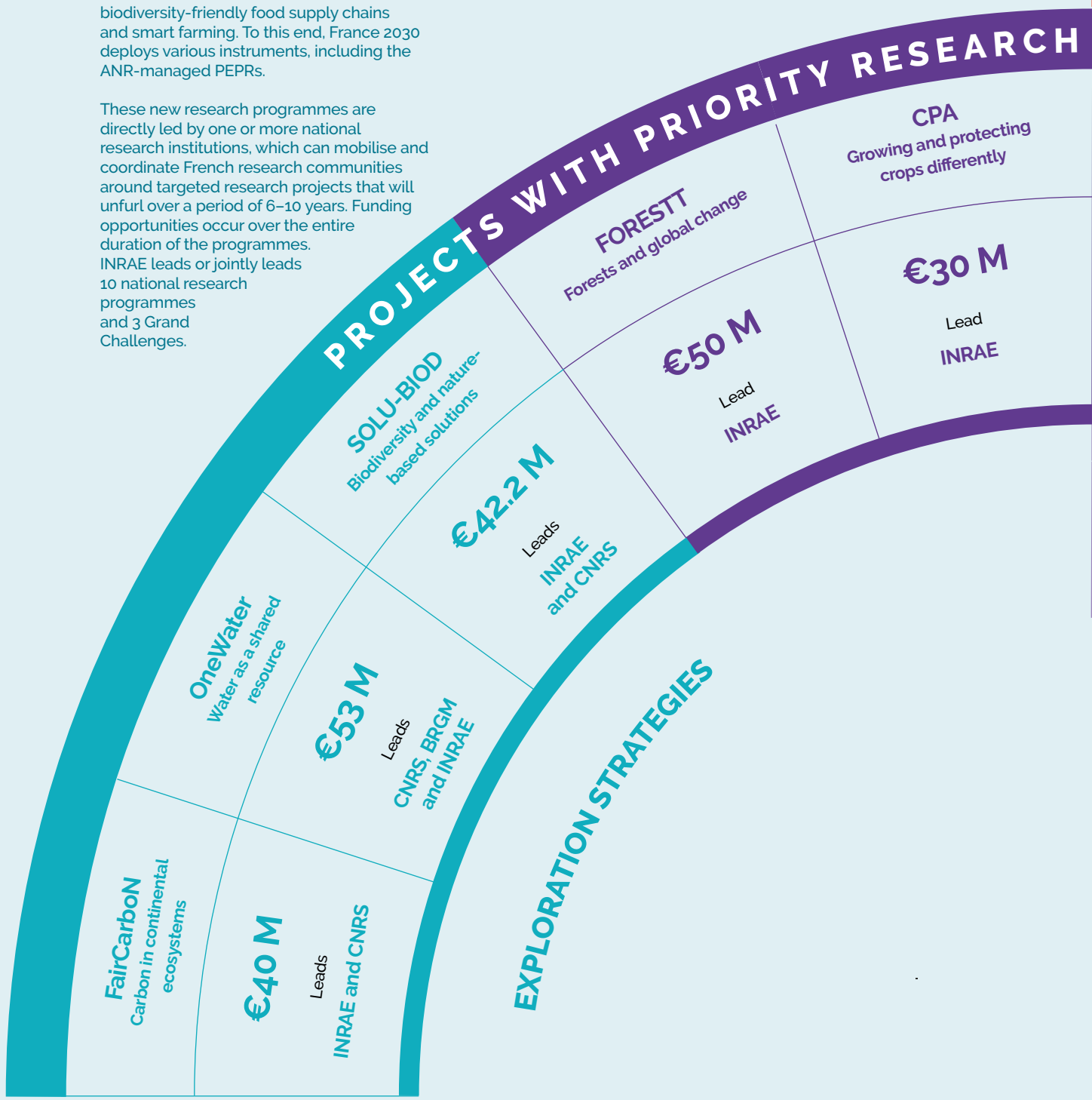
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by all the PEPRs: administrative and financial management; interactions with various programme partners, such as the French National Research Agency (ANR), who runs the PEPRs; assessments and progress towards benchmarks; and communication, which involves engaging with various groups, from related scientific communities to the general public, with the help of the Communications Department. ●

INRAE and France 2030

Under the aegis of the General Secretariat for Investment, France 2030 is allocating €54 billion to spur research and innovation in a vast range of fields as well as to establish and/or cement French competitiveness in tomorrow's industries in a way that aligns with the plan's 10 primary objectives. Objective 6 is to launch the third agricultural revolution, which should be based on biodiversity-friendly food supply chains and smart farming. To this end, France 2030 deploys various instruments, including the ANR-managed PEPRs.

These new research programmes are directly led by one or more national research institutions, which can mobilise and coordinate French research communities around targeted research projects that will unfurl over a period of 6–10 years. Funding opportunities occur over the entire duration of the programmes. INRAE leads or jointly leads 10 national research programmes and 3 Grand Challenges.



Grand challenges

Biocontrol and biostimulation
 Accelerating the design and deployment of solutions based on prevention and natural pest control

Amount
€42 M
 Leads
 INRAE and ITA

Agricultural robotics
 Development of robotics for agriculture and the agroecological transition

Amount
€21 M
 Leads
 INRAE and Robagri

Ferments of the Future
 Accelerating research and innovation on ferments and fermented foods

Amount
€48.5 M
 Leads
 INRAE and ANIA

PROGRAMME AND EQUIPMENT FUNDING (PEPRS)

AE&N
 Agroecology and digital technology

€65 M
 Leads
 INRAE and Inria

SVA
 Advanced plant selection

€30 M
 Lead
 INRAE

SAMS
 Food systems, microbiome and health

€60 M
 Leads
 INRAE and Inserm

B-BEST
 Biomass, biotechnology and sustainable environmental technologies

€70 M
 Leads
 INRAE and IFPEN

Sustainable agricultural systems and farm equipment contributing to the ecological transition

Strategies

Sustainable food for health

Biobased products and industrial biotechnologies, sustainable fuels

Emerging infectious diseases - CBRN threats

PREZODE
 Preventing the emergence of zoonotic diseases

€30 M
 Leads
 IRD, Cirad and INRAE

ACCELERATION STRATEGIES

Our scientific priorities

Responding to environmental challenges and their associated risks



The impacts of global changes cannot be ignored. To deal with current and future consequences, we must develop and, especially, test strategies for strengthening agricultural, food, and environmental systems. There are many tools for promoting system resilience, such as exploiting the adaptation mechanisms of living species as well as preserving and sustainably utilising biodiversity. It is essential to simultaneously conduct research that better characterises the variability and sensitivity of certain issues to improve risk assessment and management.



Climate change: combining mitigation and adaptation strategies

What types of forest should be planted to boost carbon storage?

Forests play a crucial role in the fight against climate change because they are ecosystems with the ability to store carbon as above- and below-ground biomass. A key challenge is to find ways to boost this ability. While much is known about above-ground carbon storage, which notably occurs in the form of trees, little is known about below-ground carbon storage. Research analysing data from 136 experimental sites and 454 forests worldwide has found that forest managers can utilise several factors to enhance the carbon storage capacities of forest soils. This work has underscored that it is crucial to employ high levels of tree biomass, as well as species mixtures that are appropriate to regional climatic conditions and soil composition.

Nature Communications

doi.org/10.1038/s41467-022-28748-0

Selecting seeds to help sessile oaks adapt to future climatic conditions

In 1976, France and part of Europe experienced a drought that killed off a number of forest trees, particularly sessile oaks. These die-offs prompted research into how oaks, and especially sessile oaks, are adapting to global changes in general. The sessile oak is the most widely planted deciduous species in France. Working collaboratively, INRAE and the French National Forests Office (ONF) established 110 sessile oak populations at 4 experimental sites. They used trees from France and other European countries. For 30 years, scientists have been studying how certain oak characteristics and their underlying genetic variability have changed over time. The broader aim is to identify the sessile oak populations that could provide useful seeds because they produce offspring better adapted to future climatic conditions. The results have shown that trees from regional populations long subject to tree farming display the best combination of ecological and silvicultural traits (i.e., survival, growth, shape, and the ability to cope with climatic variation). Drawing upon these findings,



scientists have developed recommendations to increase the success of future plantations.

Annals of Forest Science

doi.org/10.1186/s13595-022-01140-0

doi.org/10.1186/s13595-022-01141-z



Sampling soil in the Orléans forest; INRAE's Research Unit for Forest Ecosystems is exploring how silvicultural management practices can increase wood production and preserve forest biodiversity. ©INRAE - B. Nicolas





CLIMAE metaprogramme

INTERVIEW WITH

Éric Sauquet

Metaprogramme director and member of the RiverLy Research Unit

INRAE2030 clearly expressed that the institute is prioritising research that will help us confront environmental challenges, particularly climate change. What are the goals of the CLIMAE metaprogramme?

The year 2022 left its climatic mark on mainland France. These climatic conditions could well become the norm by 2050, and it is unclear how well agricultural and forestry systems will be able to cope with and mitigate the effects of climate change. Founded in 2021, the CLIMAE metaprogramme follows in the footsteps of the ACCAF metaprogramme (Adaptation to Climate Change in Agriculture and Forestry) and exemplifies how INRAE research can be exploited to tackle these two issues simultaneously. CLIMAE seeks to generate the scientific knowledge needed to dramatically and comprehensively transform agrifood and forestry value chains, from resource production to consumption. They must become adapted to and help mitigate climate change. While recent, repeated extreme weather events make us feel like time is fleeting, research is long-term in nature and requires that we anticipate the challenges and questions that will arise in the decades to come.

What contributions are INRAE researchers making?

This research is inherently interdisciplinary for a number of reasons: system complexity; the need to evaluate solutions based on multiple criteria, including socioeconomic issues; and the variety of tools available (e.g., shifts in diets; product processing and distribution; waste recycling and reuse;

animal feed; crop fertilisation regimes; crop cycles, varieties, and types; water resource management; and land use). The CLIMAE research community is growing as a result of the projects funded in 2021 and 2022, quarterly webinars that are open to all, and communication efforts (e.g., newsletters, Fête de la science). The metaprogramme is fostering exchanges between researchers that focus on adaptation versus mitigation. CLIMAE has funded 7 projects to date. They are generally examining methods for designing and assessing sustainable agrifood and forestry systems by combining adaptation and mitigation objectives, all with a view to promoting agroecological transitions. These projects are exploratory in nature and aim to lay the foundation for more ambitious research to come.

Are there any themes you would like the programme to prioritise?

In 2023, we would like to launch a broad-level research project on livestock farming where the aim is to assess the vulnerability of certain livestock industries to climate change. Integrating both adaptation and mitigation, this work will help build and examine contrasting scenarios for the future development of these and related industries through 2050. We also wish to determine which obstacles are hindering the development of local production systems and the tools that can promote progress. It is important to understand that people have high expectations that regional or national strategies will incorporate productive solutions. For

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These climatic conditions could well become the norm by 2050, and it is unclear how well agricultural and forestry systems will be able to cope with and mitigate the effects of climate change.

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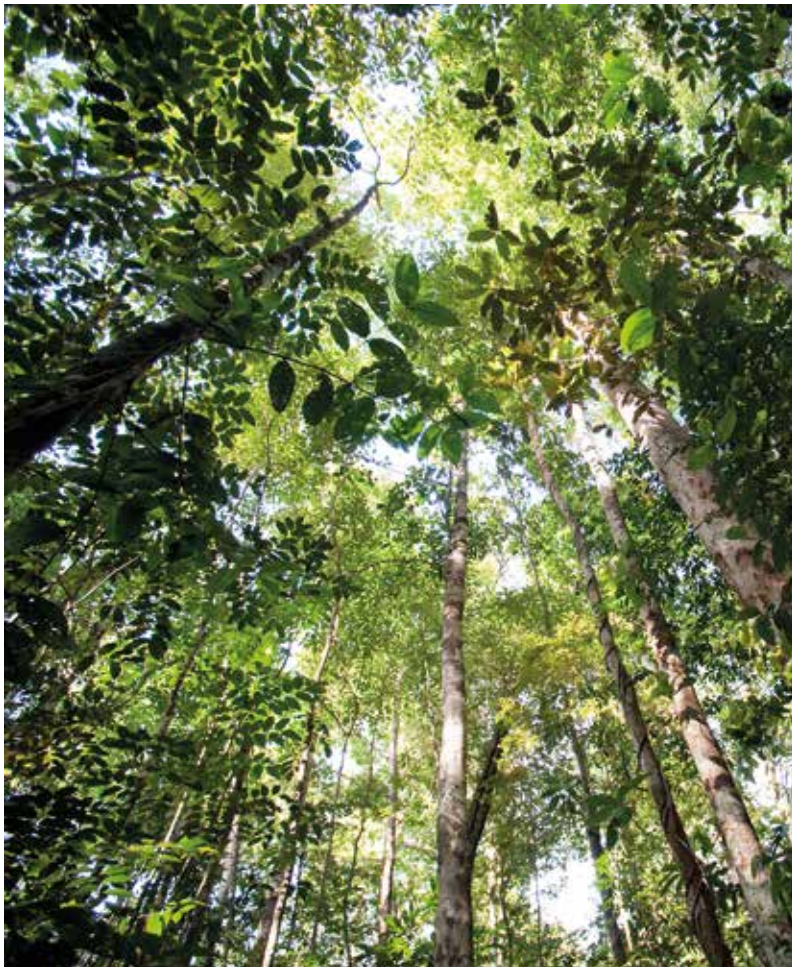
example, France's National Low-Carbon Strategy (SNBC) will require the agricultural and forestry industries to make greater efforts to reduce greenhouse gas emissions and to double levels of carbon storage. Moreover, through its draft covenant and law on agricultural trajectories, the French Ministry of Agriculture and Food Sovereignty has prioritised adapting to climate change and facilitating the resulting transition.

Leaf microbiota influence tree drought tolerance

Trees have variable responses to drought, which are shaped by many factors, including microbial interactions (e.g., with fungi, bacteria). Best known are the interactions that occur in the soil, such as those involving mycorrhizal fungi. Less well characterised are leaf-level interactions. Research to date suggests that leaf microorganisms can alter water transport, thus modulating how forest trees experience drought. This hypothesis has now been tested using the Amazon rainforest canopy as a study system. Genetic

analyses identified 15,000 microbial species and, for around 20 fungal species, there was a positive or negative correlation between microorganism abundance and tree drought tolerance. These preliminary results will inform future experimental research to further investigate the role of these microorganisms.

[Phytobiomes Journal
doi.org/10.1094/PBIOMES-04-22-0023-R](https://doi.org/10.1094/PBIOMES-04-22-0023-R)



IN BRIEF

Observing shifting climatic conditions in mountain pastures

As part of the Alpages Sentinelles programme, INRAE scientists partnered with Météo-France to develop a new tool: a web interface that displays the climatic profiles of more than 2,700 pastures in the French Alps and how they have changed over the last 60 years. This tool will make it easier for all stakeholders to understand and identify the adaptation practices and strategies that should be implemented based on the specific characteristics of each pasture.

[Agronomy for Sustainable Development
doi.org/10.1007/s13593-022-00776-6](https://doi.org/10.1007/s13593-022-00776-6)



Tropical forest in French Guiana; Joint Research Unit for the Ecology of the Forests of French Guiana. ©INRAE - C. Maître



Biodiversity: a powerful tool and a valuable inheritance



A new approach to monitoring biodiversity in aquatic environments

In aquatic environments, there is limited biodiversity monitoring because sampling methods are often invasive and taxonomic expertise is lacking. However, these challenges could be surmounted by utilising trace amounts of organismal DNA present in the environment, also known as environmental DNA (eDNA). To help refine this approach, researchers assessed whether the natural biofilms found in all aquatic environments could act as eDNA sensors. Using DNA extracted from these biofilms, researchers have successfully produced inventories of macroinvertebrate diversity in rivers and fish diversity in lakes. Beyond serving as a proof of concept, this technique has a demonstrated ability to reveal spatial and temporal variation in the occurrence of fish species as a function of habitat and phenology. This method could prove particularly useful to conduct monitoring at sites undergoing restoration.

[Molecular Ecology Resources
doi.org/10.1111/1755-0998.13568](https://doi.org/10.1111/1755-0998.13568)



Experiment exploring the impacts of high concentrations of plant protection products on biofilms; Research Unit for Aquatic Ecosystems and Global Change (EABX).
©INRAE - B.Nicolas

Agricultural biodiversity yields benefits

Using plots of grain cash crops, researchers examined how agricultural practices and landscapes affect biodiversity, ecological functions, and crop yields. This work was carried out at a site dedicated to long-term experimentation. Its results show that farming practices that reduce agricultural biodiversity also reduce potential crop yields. Additionally, heterogeneous agricultural landscapes are a powerful tool for maintaining crop yields in the face of increasingly frequent adverse climatic events. These results underscore the importance of conducting further research that looks at how agricultural biodiversity and ecological functions can help promote cash crop yields.

[Agriculture, Ecosystems & Environment
doi.org/10.1016/j.agee.2021.107810](https://doi.org/10.1016/j.agee.2021.107810)

Intercropping bolsters productivity

As the world population grows, so does the need for food security. Thus, we must ensure levels of agricultural production while reducing the resulting environmental footprint. Crop diversification is an agroecological technique that could sustainably accomplish this task. To objectively assess the utility of crop associations in modern agricultural systems, French, Dutch, and Chinese researchers collaboratively performed an in-depth analysis of crop association productivity, drawing on a vast global database containing the results of 226 agricultural experiments. They found that growing multiple species on a single plot of land in tandem produced mean quantities of protein that were equal to or, often, greater than those produced by the most productive plant species when grown alone. These results should encourage us to espouse a practice traditionally used across the Global South, which is being abandoned because of urbanisation and the exodus of labourers to the cities. In general, it remains a little-used practice in Western countries.

PNAS

doi.org/10.1073/pnas.2201886120

Characterising yeast diversity in French breads

Given global changes, it is crucial to develop sustainable food industries that create value from biodiversity. Researchers recently examined microbial diversity along the production chain for French non-industrial sourdough—, from wheat and yeasts to bakeries and bread. Their analysis of microbial flows suggests that the yeast species found in sourdough breads originate within bakeries. In addition to baker's yeast, *Saccharomyces cerevisiae*, there is an abundance of yeasts in the genus *Kazachstania*. Specific yeast distribution patterns depend on the bakers' practices. Some *Kazachstania* species perform better as leavening agents than do others, notably those from non-bakery environments, suggesting that the former have been "domesticated" over time by baking practices. These findings arose from several years of participatory research conducted in collaboration with numerous bakery professionals. Work is underway to characterise the evolution of these species and their contributions to the nutritional and organoleptic properties of bread.

Peer Community Journal

[10.24072/pcjournal.237](https://doi.org/10.24072/pcjournal.237)

Genome Biology and Evolution

[10.1093/gbe/evac007](https://doi.org/10.1093/gbe/evac007)

Molecular Ecology

[10.1111/mec.16630](https://doi.org/10.1111/mec.16630)

Experimental plot containing alternating rows of vetch and grain crops;
INRAE Research Centre of Ile-de-France - Versailles-Saclay.
©INRAE - M. Gosselin





Organismal adaptations: tools for guiding genetic selection and preserving biodiversity

Bee; INRAE Division of Plant Health and Environment
©INRAE - N. Morison



Plants adapt to extreme environments using a common strategy

The Atacama Desert in South America is one of the most inhospitable regions on the planet. Stressors occur along an elevational gradient: thermal stress followed by water stress and high levels of salinity, then nitrogen-poor soils and very high light intensities. Scientists have been studying the adaptive mechanisms used by plants to cope with these extreme conditions using metabolomics, an approach that characterises all the metabolic compounds found in a given living organism. They have been able to identify molecular markers that are shared by 24 study species and that can be used to predict the environmental conditions of a plant's habitat (e.g., elevation, variation in temperature, water stress). These compounds are also present in plant species found in other climatic zones, such as members of Poaceae (e.g., maize), Fabaceae (e.g., peas), Solanaceae (e.g., tomatoes), and Asteraceae (e.g., sunflowers). These results could accelerate efforts to breed plant species better equipped to handle certain environmental stressors.

[New Phytologist
doi.org/10.1111/nph.18095](https://doi.org/10.1111/nph.18095)

How many mates should honey bee queens have?

With honey bee colonies under threat, beekeepers are seeking to increase colony hardiness and productivity via genetic improvements. These colony characteristics are partially determined by the genetic heritage of the bee populations represented. However, compared to other domesticated



species, it is harder to breed honey bees because they display certain biological specificities. For example, honey bees are polyandrous, meaning that queens mate with several males. Furthermore, beekeepers are most interested in complex traits that arise from the combined behaviour of thousands of worker bees. To obtain highly homogeneous colonies, some beekeepers artificially inseminate their virgin queens with sperm from a single male rather than

from the 10 to 20 males usually used. Researchers looked at the long-term genetic consequences of this breeding method and found that it has negative impacts. Indeed, the mean degree of inbreeding for queens was 50% higher than when polyandrous breeding was used, and colony performance did not significantly improve.

[Genetics Selection Evolution
doi.org/10.1186/s12711-021-00665-8](https://doi.org/10.1186/s12711-021-00665-8)

Corn breeding strategies must adapt to climate change

Over the past 60 years, targeted breeding has led to a sharp climb in maize yields. This progress has been made by acting on simple plant characteristics, such as the duration of different life cycle phases or plant architecture. However, improvements have not been seen in adaptive traits, such as drought sensitivity or water efficiency, despite the fact that a marked degree of genetic variability exists among natural maize varieties. A study compared the performance of 66 corn varieties grown in 30 experimental plots in Europe that experience different climatic conditions. These varieties had been on the market between 1950 and 2015. The results showed that yields increased rapidly, at the same speed, regardless of climatic conditions. Breeding programmes focus on general characteristics and have aimed to maintain the same mean yield, whatever is occurring climatically. In the context of climate change, achieving this goal of steady yields will require future breeding programmes to focus on traits that allow for adaptation to hot, dry conditions, traits that have not contributed to genetic progress to date.

Nature Communications
doi.org/10.1038/s41467-022-30872-w

Plant virus has a complex strategy for maintaining genomic integrity

Multipartite viruses place different segments of their genomes in separate capsids. They thus take a tremendous risk because all of their genetic information must be present simultaneously for infection or transmission to be successful. These viruses account for 35–40% of all plant virus genera and families, but their biology remains poorly understood. A study of faba bean necrotic stunt virus (FBNSV) has shown that infections involving complete FBNSV genomes can follow one of two trajectories.

IN BRIEF

An effective tool for fighting bovine paratuberculosis

Bovine paratuberculosis is caused by the bacterium *Mycobacterium avium subsp. paratuberculosis*. This disease is contagious, incurable, and difficult to control. By combining health monitoring data from cattle farms with the genotyping data routinely gathered during genomic selection, researchers were able to identify certain genetic factors underlying disease resistance. They have also shown that disease resistance can be both predicted and selected for based on an animal's genomic information.

Genetic Selection Evolution
doi.org/10.1186/s12711-022-00757-z



Jean-Christophe Simon, Research Director at the Institute for Genetics, Environment, and Plant Protection (IGEPP), INRAE Research Centre of Brittany-Normandy, and recipient of a European Research Council Advanced Grant

Simon's ALTEREVO project seeks to understand phenotypic plasticity in insects, and, more specifically, polyphenism, which is the ability to produce very different morphological forms depending on environmental conditions. ALTEREVO explores nutritional polyphenism in aphids, including its regulatory mechanisms and evolutionary trajectory.



First, different genomic segments may arrive within the same plant via different aphid hosts. Second, a single aphid may "collect" different genomic segments from different host plants and then transmit the entire genome to a new host plant. These unique pathways could help ensure that virus genomic integrity is maintained over the course of transmission. More generally, this work is the first description of a biological entity that is capable of separately transmitting genes across generations, a phenomenon that greatly amplifies the potential for genetic exchanges.

[PNAS
doi.org/10.1073/pnas.2201453119](https://doi.org/10.1073/pnas.2201453119)

Detecting genetic abnormalities that cause mortality or defects during ruminant development

Genetic mutations are hereditary and can affect the morphology, health, and viability of the individuals who carry them. Genomics offers a powerful tool for identifying, describing, and managing such abnormalities. Traditionally, researchers have identified mutations by comparing DNA between healthy animals and animals with abnormalities. However, when these mutations result in death, particularly during embryonic development, it is not feasible to acquire the DNA samples needed. Consequently, researchers have adopted a "reverse" genomics approach, which exploits the multitude of genotypes obtained during genomic selection efforts. For a given population, tailored statistical analyses can reveal genomic regions from which certain expected genetic combinations are absent, indirect evidence that the individuals carrying these combinations died during early development. Researchers have thus been able to identify the genetic mutations that, during early development, cause mortality or heart defects in Holstein cattle or cleft palates in Limousin cattle. A similar

approach in sheep has identified a mutation that predisposes young lambs (>1 month) to severe infectious pneumonia.

[Genes
doi.org/10.3390/genes13010045](https://doi.org/10.3390/genes13010045)
[Journal of Dairy Science
doi.org/10.3168/jds.2022-22365](https://doi.org/10.3168/jds.2022-22365)
[Genetics Selection Evolution
doi.org/10.1186/s12711-022-00762-2](https://doi.org/10.1186/s12711-022-00762-2)

The Domaine de la Sapinière in Osmoy (Cher), an experimental unit exploring genetic improvements and breeding programmes using multiple species.
©INRAE - G. Cattiau





Assessment and management of natural and climatic risks



A preventive method, prescribed burning protects trees while eliminating the brush and leaf litter that fuel fires.
©INRAE - C. Maître



Better predicting fire risks

At present, fire management efforts use climatic and meteorological indices to predict risks. The functional ecology of vegetation is not taken into account. Indeed, the relationship between fire risks and the response of vegetation to drought has been little studied to date, even if the water content of tree leaves is known to play a key role in the spread of fire. Researchers specialising in plant hydrological functions and forest fires have developed a model that can predict the water content of vegetative cover. The first of its kind, the model integrates how trees mechanistically respond to low levels of moisture in soils and the atmosphere. This model will help

predict fire risks by specifically incorporating the functional attributes of vegetation.

[New Phytologist
doi.org/10.1111/nph.18614](https://doi.org/10.1111/nph.18614)

A model can help evaluate the hydrological and agricultural impacts of reservoirs

Storing water in reservoirs is one solution that would allow agricultural systems to better cope with climate change and drought. At the same time, this proposal has elicited debate. There are concerns, in part, because knowledge and methods are lacking for better understanding and quantifying the cumulative environmental impacts of reservoirs. Indeed, impact

causes and intensities are poorly described, particularly those of a hydrological nature. It also remains unclear how much reservoirs actually help stabilise crop yields. An agrohydrological model, Mhydas-small-reservoirs, has been developed to address this shortcoming. Novel in its approach, it can simulate, at the plot level, the local cumulative impacts of reservoirs on hydrological regimes across river networks and on crop yields. The model is also a tool for exploring regional scenarios in which reservoir density and water management techniques vary.

[Environmental Modelling & Software
doi.org/10.1016/j.envsoft.2022.105409](https://doi.org/10.1016/j.envsoft.2022.105409)

Our scientific priorities

Accelerating agroecological and food transitions while answering socioeconomic challenges



It is essential to completely redesign agricultural and food production systems if we are to meet the qualitative and quantitative needs of human populations while simultaneously reducing the negative impacts of production practices. INRAE is exploring the usefulness of various individual and combined tools. Focus has been placed on biological regulation, genetic diversity, production system diversity (e.g., plant and animal systems), and dietary shifts.

Furthermore, transitions are not exclusively technical challenges. They also involve major socioeconomic issues, some of which are also being addressed by institute research.



Agricultural systems free from synthetic pesticides



Adult two-spotted stink bug (*Perillus bioculatus*) consuming eggs produced by the Colorado potato beetle (*Leptinotarsa decemlineata*).

©INRAE - J. Daumal

Stimulating plants' natural defences to fight disease

Natural plant immunity is a powerful and sustainable tool for protecting crops. However, an ongoing challenge is that pathogens can evolve to escape recognition by the plant immune system. Recent studies have shown that plant immune receptors may bear unique structures that resemble plant compounds but that are actually decoys. Targeted by pathogens, they sound the alarm, triggering a strong defensive response by the plant. Researchers have refined the properties of one of these decoys in rice, "teaching" it to recognize new signals from a pathogenic fungus. Their pioneering research has yielded promising results that can inform the development of new immune receptors in crop species.

Nature Communications

doi.org/10.1038/s41467-022-29196-6

Clarifying interactions between plants and their insect pests

The silverleaf whitefly is one of the major insect pests found on tropical and subtropical crops. Extensive research has explored the complex ways in which this species bypasses plant defence mechanisms. After studying the silverleaf whitefly genome, researchers have noted the presence of 49 plant genes. This is the first time that such large numbers of transferred genes have been observed for plants and insects. Most of the proteins encoded by these genes are known to be involved in plant-parasite relationships. If these plant genes occur in the silverleaf whitefly genome, it is the result of long-term selective pressure, which has ultimately allowed these insects to adapt to a wide range of plant species. The study's findings give rise to new research questions regarding the relationships between plants and their insect pests, as

well as encouraging further exploration of pest control methods.

Genome Biology and Evolution

doi.org/10.1093/gbe/evac141

Embracing allelopathy to facilitate the agroecological transition

Agriculture is experiencing an agroecological transition, which entails a progressive reduction in herbicide usage. In this context, an interesting strategy could be to exploit allelopathy to biologically control weeds. Allelopathy is phenomenon in which organisms, such as plants, release chemical compounds into the local environment. One consequence is that the growth of neighbouring plants may be affected. To date, limited information is available about the identity of allelopathic compounds and the underlying molecular mechanisms. Recent work has highlighted candidate genes that could encode proteins involved in the biosynthesis of allelopathic compounds (e.g., glucosinolates in *Arabidopsis*). Studies are underway to confirm the herbicidal action of the glucosinolates released by rapeseed roots. The broader objective is to utilise allelopathic plant varieties in weed biocontrol.

Trends in Plant Sciences

doi.org/10.1016/j.tplants.2022.08.014

French viticulture can further reduce the usage of plant protection products without affecting yields

Society has increasing concerns about the impacts of pesticides on environmental and public health. The consequence is that the grape-growing industry must reduce its dependence on plant protection products. The DEPHY network was created in 2010



Experimental plants (rapeseed) in greenhouses at INRAE Versailles. ©INRAE - B. Nicolas

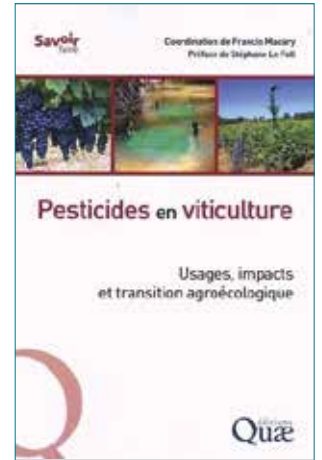
with a view to promoting the general agroecological transition, a necessary step if France is to meet the ambitious goals set out in the Ecophyto Plan. More than 10 years of data have been collected by the DEPHY network. They are stored in a database that can serve as an important resource for researchers focused on strategies for reducing the usage of plant protection products. Analysis of these data has highlighted that the French grape-growing industry could effectively reduce pesticide usage, mainly by adjusting doses during certain periods of the grape life cycle or by replacing synthetic pesticides with biocontrol products. However, among vineyards, pesticide use has varied dramatically within and across years. A range of pesticide-reduction trajectories have been observed, which have been shaped by the specific measures implemented and the

FURTHER READING

Pesticides in grape-growing systems

Researchers from a variety of disciplines, notably the agricultural sciences, agroecology, agroecconomics, environmental chemistry, hydrobiology, ecology, and ecotoxicology, have co-authored a book to address the scientific issues related to the use and impacts of pesticides. To drive home their points, they draw upon their own work. The book's contributors explore strategies for changing grape-growing systems so that pesticide usage can be reduced, relieving the current pressure on ecosystems. They also examine public policies for supporting these strategies.

Francis Macary,
INRAE (editorial coordination)
Stéphane Le Foll (preface)
Éditions Quæ, 2023, 232 p.



IN BRIEF

DeciControl: a biocontrol app

It can be a challenge to properly deploy biocontrol products, whose efficacy often depends on natural regulatory mechanisms. Such is especially the case when microorganisms are involved. DeciControl is an application designed to help farmers successfully use biocontrol products against plant diseases and pests. Available for download on smartphones, this tool recommends the biocontrol solutions that are best suited to the different situations that may be encountered. The app is constantly being improved thanks to various partnerships and funding sources (Consortium Biocontrôle, FranceAgriMer, European Union).

 url.inrae.fr/3GStvz5

producer's initial level of pesticide usage upon joining the DEPHY network. Based on these results, it appears possible that the entire industry could reduce pesticide use by at least 35%.

European Journal of Agronomy
doi.org/10.1016/j.eja.2022.126503



Using olfactory receptors in insect biocontrol methods

INTERVIEW WITH

Emmanuelle Jacquin-Joly

Institute of Ecology and Environmental Sciences (iEES)-Paris

As an INRAE researcher, your expertise is in insect olfaction. What spurred your interest in this field?

Olfactory signals comprise a language of their own that is shared by insects and humans alike. However, unlike sight or hearing, olfaction is a sense whose underpinnings long remained poorly understood. This gap in knowledge changed when olfactory receptors were discovered, first in rodents (leading to the Nobel Prize in Medicine in 2004) and then in *Drosophila*, biology's model insect *par excellence*. Olfactory receptors are proteins located in the membranes of olfactory neurons. They take part in the very first stage of olfaction—they detect smells as they circulate. Surprisingly, while insect and mammalian olfactory receptors share this same role, they are nothing alike in terms of their underlying genetic sequences, their structure, or their function. Indeed, insects have "invented" a new type of receptor that they use in communication. I am fascinated by the evolutionary implications. I also like the multidisciplinary approach required to study olfaction. We must draw upon a wealth of expertise to conduct research in this field, from the chemical analysis of odorant molecules to the molecular and structural characterisation of receptors to describing the electrical responses of neurons and exploring induced behaviours.

Have methodological innovations been key to studying how these receptors work?

Yes! A unique technique we currently use is to artificially express olfactory receptors in an "empty" *Drosophila* neuron (i.e., in vivo). We employ mutant *Drosophila* bred in the US, which have some olfactory neurons that have been stripped of their receptors. These neurons cannot perceive anything, until we introduce the receptors we want to study. Furthermore, the responses obtained from olfactory stimulation come solely from the receptors introduced! This research trick has allowed us to identify key receptors involved in the aggregation of palm weevils, sexual attraction in noctuid moths, and the food choices of caterpillars, to name a few examples.

How could your research be applied in the field of insect pest control?

Our work on receptors has two major applications in crop protection. The first application is that we can directly control insect pests by manipulating their behaviour via odours. In this case, olfactory receptors can serve as screening tools to select new odours in active use. The screening process can take the form of experiments, using *Drosophila* with empty neurons, or simulations, using artificial intelligence and modelling.

“

Insect and mammalian olfactory receptors... are nothing alike in terms of their underlying genetic sequences, their structure, or their function.

”

We have already demonstrated that this type of screening is effective in the cotton moth. We are now working on expanding its general applicability. For example, we are involved in a pesticide phase-out plan, *Sortie du phosmet*. Phosmet is an insecticide that has long been used to eliminate rapeseed pests. The second application is related to pest monitoring. Our receptors can help develop the next generation of biosensors, which will use odours to detect insect arrival or presence. What could be more sensitive and effective for detecting an insect than an insect receptor! This second application is the aim of our Pherosensor project, which has been funded by the PEPR Growing and Protecting Crops Differently.

Cellular and Molecular Life Sciences
hal.inrae.fr/hal-03635144



Farms in flux



A farmer with a hen reared on an organic grassland.
©INRAE - S. Toillon

Animal welfare: an assessment of poultry cognition

Animal welfare encompasses the psychological well-being of animals, including farm animals. It presupposes that we have a good grasp of an animal's cognition. However, while we possess such knowledge for corvid and primate species, it is lacking or extremely limited for farm animals. Yet, this information is essential if we want to correctly evaluate their state of welfare or recommend cognition-customised improvements to their living conditions. Researchers explored whether hens could complete a relatively complex task: solving the delayed recognition test. This task can be challenging because a different symbol is presented during each trial. Hens were able to successfully navigate the test, illustrating that their cognitive abilities are greater than previously imagined. Hens rely on these abilities to psychologically adapt to their environments, making them crucial to well-being.

Animal
doi.org/10.1016/j.animal.2022.100607

Replacing exogenous hormones in livestock farming

When breeding small ruminant livestock, farmers mainly control reproductive cycles via the use of exogenous hormones, most often extracted from mare serum. This practice is increasingly raising societal concerns and is experiencing more intense regulation by the EU. There is a real and pressing need for alternative solutions that have strict usage specifications. Researchers found that analogues of an endogenous neuropeptide, kisspeptin, can be used to elicit ovulation in ewes during out-of-season breeding; such was achieved without any hormonal pre-treatment. Kisspeptin plays a key role in reproductive control. Further studies will look at how this analogue can be deployed to control reproduction in other farm animals, as well as in wild species facing extinction.

Journal of Neuroendocrinology
doi.org/10.1111/jne.13121

Combining tools to promote sustainable aquaculture

While fishing has reached its limits, demand for fish continues to grow every year. Aquaculture represents an alternative supply source, but it is essential to adopt sustainable practices that yield high-quality products. INRAE, the Aqualande company, Aqualande's trout breeding and reproduction subsidiary *Les Sources de l'Avance*, and the French Union of Poultry and Aquaculture Breeders (SYSAF) collaboratively assessed the results of a 20-year rainbow trout breeding programme that the company has been running. They compared growth and feed requirements for programme trout with those of non-programme trout. The results indicated that programme trout required 17–20% less feed to generate the same level of growth, which would translate into reduced environmental impacts during farming. Furthermore, fish from both groups were given a locally and sustainably produced feed, which contained no fish oils, fish meal, or soy. Gains in growth and nutritional quality were preserved with this new feed. Work is continually underway to develop innovative foods that strike a balance between costs and environmental impacts. A recent study led to the development of a new feed that achieved this objective. Trout given the novel feed displayed similar growth to trout given commercial feed. These findings underscore that genetic improvements can be combined with innovative dietary regimes to boost aquaculture sustainability.

Aquaculture Reports

doi.org/10.1016/j.aqrep.2022.101363

Aquaculture

doi.org/10.1016/j.aquaculture.2022.738826



IN BRIEF

Rabbit breeding—there's an app for that

A simple new digital management tool has emerged to help rabbit farmers: GAELA. This application arose from a collaboration between the French Association for Organic Rabbit Farming (AELBF), the French Institute for Organic Agriculture and Food (ITAB), and the University of Perpignan. GAELA also provides technical advice to farmers seeking to adopt alternative rabbit rearing systems, such as those based on organic practices. This tool could be expanded for use with other breeding systems. It was awarded an Innov'Space star at Space 2022, an international livestock farming show.



Rainbow trout:
INRAE Division of Animal Physiology and Livestock Systems.
©INRAE - G. Choubert



Customising dietary qualities



> Bread wheat
(Barok variety).
©INRAE - J. Weber

Designing wheat varieties with more digestible gluten

Bread wheat is a key part of the human diet and is consumed in processed forms (e.g., bread, cookies). Gluten is a set of structural proteins found in wheat grains. It is responsible for the elastic texture of dough, which makes the above food products possible. However, many people have a strong immune reaction to gluten, either as a result of coeliac disease or because of a non-coeliac sensitivity to gluten. The underlying cause is gluten's resistance to being hydrolysed by digestive enzymes. Thus, society could benefit from bread wheat varieties containing more digestible proteins, which have become a crop breeding target. Researchers baked bread using a standardised procedure and 17 bread wheat varieties that were older versus more modern (i.e., registered before versus after 1960). They found that there was genetically determined variability among breads with regards to in vitro protein

digestibility. At the same time, there was no difference in digestibility between older and more modern varieties. In summary, wheat grain or flour characteristics should allow for the indirect selection of more digestible crop varieties during breeding efforts.

[Journal of Cereal Science](#)
doi.org/10.1016/j.jcs.2022.103533

Why some aromas remain on the palate longer than others

The pleasure of eating is shaped by aroma persistence in mouth, regardless of whether a sensory note is agreeable or not. Recently, researchers analysed the molecular mechanisms at work. They used a unique oral mucosa model, which reconstitutes the thin layer of salivary proteins anchored to the surface of our oral cells, known as the mucosal pellicle. The results showed that aromas interact with and are retained by the mucosal pellicle. Other aroma compounds may or may not be metabolised—depending

on their chemical structure—by salivary enzymes or oral mucosa cells. In a later stage of the study, the nasal cavities of 54 volunteers were linked via helmets to a mass spectrometer, which allowed the release of aroma compounds to be characterised. It was found that the unmetabolised aroma compounds persisted longer than did the metabolised aroma compounds, with the latter giving rise to new compounds. A subset of these volunteers then participated in an experiment where they assessed the aromatic intensity of a metabolised and unmetabolised compound over time. The results revealed that the aromatic intensity of the metabolised compound declined more rapidly. This multifaceted research showed, for the first time, that the oral mucosa plays a role in aroma persistence.

[Food Chemistry](#)
doi.org/10.1016/j.foodchem.2021.131467



Healthy, sustainable, accessible, and satisfying food for all

Europe's agroclimatic conditions could support soybean self-sufficiency

Over the past 20 years, Europe has been dedicating an increasing amount of farmland to soybean cultivation, but the vast majority of continental demand is still met via imports. Indeed, Europe currently imports nearly 90% of the soybeans it uses, largely for animal feed. The source is mainly the US and Brazil. Researchers have developed a modelling approach

that combines global agricultural and climatic databases with machine-learning algorithms. Currently available data were used to generate continent-scale projections of soybean yields for different crop-surface-area scenarios and present versus future climatic conditions. Self-sufficiency could be achieved if Europe dedicated 11% of its farmland to soybean crops.

Nature Food
doi.org/10.1038/s43016-022-00481-3



IN BRIEF

Cooperation grows between INRAE and the French Network of Technical Agrifood Institutes (ACTIA)

Given the long-term challenges faced by the agrifood sector, INRAE and ACTIA want to strengthen their synergies and boost their efficiency via a five-year framework agreement. These two organisations are complementary in their approaches and are committed to collaborating on cross-cutting issues with strong societal impacts that span industries and disciplines. They will focus their work on food safety, nutritional quality, taste, environmental impacts, and agrifood economic performance.



Researcher examining plants in a soybean plot on the Époisses Experimental Domain, part of the INRAE Research Centre of Dijon.
 ©INRAE - B. Nicolas

Analysing the environmental impacts of food

Food production has dramatic environmental impacts that must be studied if we are to identify solutions. Furthermore, there are substantial differences in the impacts of different products. However, very little is known about variation within food categories. Researchers used life cycle analysis to explore the environmental impacts of 80 industrial pizzas representative of those available on the French market as well as those of 44 French artisanal PDO cheeses. They found that there was pronounced variability within categories, which meant that substituting one product for another could have large environmental benefits. In addition, they discovered that modifying ingredient choice and quantity can generate more environmentally friendly foods. However, there may be conflict with nutritional objectives. These results highlight that ecodesign must take place at the level of food products. It is essential to adopt a

multicriteria approach that combines, at the very least, environmental and nutritional considerations.

[Journal of Cleaner Production](https://doi.org/10.1016/j.jclepro.2021.130128)
doi.org/10.1016/j.jclepro.2021.130128
 Sustainability
doi.org/10.3390/su14159484

Adopting a new food labelling scheme in France

Consumers are increasingly interested in knowing about the environmental impacts of their food. In response, the French government has launched a nationwide experiment to lay the groundwork for an environmental labelling scheme for all food products. This work is part of current legislation—Reducing Waste for a Circular Economy (AGEC) as well as Climate and Resilience. The intention of this scheme is to give consumers information about the greenhouse gas emissions, water pollution, resource use, and biodiversity loss

associated with food production, processing, and distribution, starting at the farm and ending with the consumer. Officials then set up a scientific advisory council, which included several INRAE researchers, to assess the scheme’s feasibility, particularly given the current state of scientific knowledge. Six key questions were addressed through this work: What environmental issues must be taken into account? What objectives should be established? What data are needed? What methods should be used to assess environmental impacts? Which environmental scores should be employed? What label type should be utilised? Given the answers to these questions, the scientific advisory council felt that an environmental labelling system for food products was feasible and useful, provided that recommended improvements were made to current databases and methods.

[The International Journal of Life Cycle Assessment](https://doi.org/10.1007/s11367-022-02071-8)
doi.org/10.1007/s11367-022-02071-8



◀
 Pizza.
 ©AdobeStock



Socioeconomic research for transitions



Genome modification techniques raise socioeconomic questions

Genome-editing technologies are seen as tools that can dramatically increase the likelihood of producing genetic innovations. Nevertheless, their use is much debated, particularly in light of the European Court of Justice's decision to classify organisms with edited genomes as genetically modified organisms (GMOs). INRAE scientists have carried out preliminary economics research and have found that many French consumers are less willing to pay for products resulting from genome editing than for conventional products. However, they were more willing to pay for the former than for products

^
 Variety of Agri-Obtentions seeds; INRAE Research Centre of Île-de-France - Versailles-Grignon. ©INRAE - J. Weber

made from GMOs. In addition, a literature review showed that research on the economic consequences of these technologies has generally focused exclusively on risk analysis, without considering the socioeconomic repercussions. In addition, there are few economic analyses looking at the effects of the different intellectual property strategies associated with these technologies, or analyses that explore the economic effects of these innovations on the agricultural industry as a whole.

[Applied Economic Perspectives and Policy
 doi.org/10.1002/aep.13208](https://doi.org/10.1002/aep.13208)

[Trends in Food Science and Technology
 doi.org/10.1016/j.tifs.2022.07.013](https://doi.org/10.1016/j.tifs.2022.07.013)



AWARDS

The 2022 prize for the best article in the European Review of Agricultural Economics was given to two INRAE scientists: Laurent Piet (SMART Joint Research Unit) and Yann Desjeux (Bordeaux Unit for the Economic Sciences)

Their work explored the factors underlying income inequalities among farmers. Indeed, while farmer income is a major criterion when evaluating agricultural public policies, such as the EU's Common Agricultural Policy (CAP), the average figures obscure the diverse realities experienced by different individuals. The researchers applied a method that breaks down longitudinal changes in farm income distributions, to examine what is attributable to the interactions between structural modifications on farms and

shifts in product and input prices. Their results indicate that income inequality among French farmers largely remained unchanged between 2000 and 2017. Furthermore, because economic dynamics over this period were relatively more favourable to the lowest-income farmers, inequalities could have even decreased if farm characteristics had not changed. They also found that CAP subsidies have led to a "progressive" redistribution of wealth: the lowest-income farmers had a larger share of the total income post- than pre-subsidy. This award recognises the achievements of the Agr'income research project, which was funded by the French Ministry of Agriculture and Food Sovereignty and carried out by several INRAE units under the leadership of SMART.



Laurent Piet
SMART
Joint Research Unit



Yann Desjeux
Bordeaux
Unit for the Economic
Sciences

FURTHER READING

Agricultural and agrifood trade in the 21st century

The last literature review examining the economics of agricultural trade was published 20 years ago. Researchers recently wrote a book chapter exploring the changes in agricultural trade that have occurred over the intervening years, influenced by shifts in international relations, the growing availability of data, and the emergence of new trade theories. They also discussed the emergence of new political issues, such as climate change, food quality standards, food security, market volatility, and food transitions. Finally, the researchers identified likely future developments in this active field of research, emphasising the importance of consumer preferences, production technologies, market structures, and the hidden costs of trade. Gaigné C., Gouel C. (2022). Trade in agricultural and food products. Handbook of Agricultural Economics. Elsevier, vol. 6, pages 4845-4931



Agricultural policies affect land use

The expansion of agricultural land surfaces is the number-one cause of tropical deforestation and biodiversity losses. In the Équateur Province of the Democratic Republic of the Congo, this trend is largely the result of smallholders who have adopted slash-and-burn practices to carry out subsistence farming. These individuals are struggling to meet their basic needs. To intensify agriculture in the province, the government has sought to create a market for improved seeds. However, local farmers lack access to chemical inputs. Overall, the introduction of improved seeds has not led to more deforestation by smallholders. That said, the pattern of deforestation has changed: losses now more often concern primary than secondary forest. Indeed, it is only by clearing primary forest that smallholders can access soils that are sufficiently rich in nitrogen. While policies that promote improved seeds can augment food security, there is a significant cost to be paid in terms of biodiversity loss, if no action is taken to maintain soil fertility.

Nature Communication

doi.org/10.1038/s41467-023-37278-2



>
Deforestation in Uganda.
©AdobeStock

Our scientific priorities

Building bioeconomies based on the efficient circular use of resources



©INRAE - S. Compoint

Diversifying bioresources and finding multiple new uses for them is necessary to sustainably meet food needs and for the production of materials, molecules and energy. We can do so by exploring the structures of living organisms in greater depth and developing new ways of promoting plant and animal co-products and improving processes for converting waste into energy. INRAE teams also study the conditions for the development of a sustainable circular bioeconomy.



The phosphorus cycle

A more balanced and sustainable management of phosphate rock

The use of phosphate mineral fertilisers in agriculture has significantly increased the phosphorus content and fertility of agricultural soils and crop yields. However, such fertilisers are made from phosphate rock, a non-renewable resource that is distributed unevenly across the planet. A research team has developed a model to calculate, country by country, the fraction of available phosphorus in agricultural soils that comes from mineral fertilisers, and how levels have evolved since the mid-20th century. Their work reveals that, on average, nearly half of the available phosphorus in agricultural soils worldwide comes from mineral fertilisers, with notable disparities between regions. Experts strongly recommend that countries where highly intensified agriculture is practised should protect and enhance acquired fertility through improved recycling and agroecological transition measures. At the same time, a more equitable management is needed of remaining phosphate rock resources to direct them to the countries that need them most.

Nature Geoscience
[10.1038/s41561-022-01092-0](https://doi.org/10.1038/s41561-022-01092-0)

▼
 Wastewater treatment
 (illustration).
 ©AdobeStock



Processing and re-use of wastewater and organic residues

Lime pre-treatment to boost biogas production

Agricultural anaerobic digestion is developing as part of a necessary transition to renewable energies. INRAE and GRDF are driving an innovative process that combines storage and lime pre-treatment for intermediate crops used in anaerobic digestion. Initial findings show that pre-treatment with lime can boost biogas production from crops containing high levels of dry matter by 15%. Easy to use for farmers, this promising alternative process optimises the storage of intermediate crops prior to anaerobic digestion, especially if they are harvested at a late stage.

Bioresource Technology
doi.org/10.1016/j.biortech.2022.126722

Assistance in public decision-making on the management of micropollutants in wastewater

Priority chemicals (such as those found in industrial and cleaning products) and emerging chemicals (personal care and hygiene products, endocrine disruptors) are often poorly removed by conventional processes in wastewater treatment plants. A special additional treatment using oxidation (ozonation) or adsorption (using granular or powdered activated carbon) is necessary. Such treatments require considerable investment, however, along with the consumption of energy and reagents, which have an effect on the environment and incur clean-up costs. Researchers studied different scenarios for the treatment of micropollutants based on financial cost, energy consumption, and the ultimate overall environmental benefit derived from the implementation of these processes at the European level. Their findings show that the direct benefit of improving water quality through the use of the most complex treatments could be offset by the significantly higher indirect effects that result from increased demand for energy and reagents. They propose a mid-way scenario that balances benefits and costs based on treatment plant size and the characteristics of the receiving environment.

Science of the Total Environment
[10.1016/j.scitotenv.2022.157593](https://doi.org/10.1016/j.scitotenv.2022.157593); [10.1016/j.scitotenv.2021.150300](https://doi.org/10.1016/j.scitotenv.2021.150300)



Biobased products



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Development potential of non-food uses of miscanthus and sorghum

A special issue of BioEnergy Research reported on studies carried out for 'Biomass for the Future', a 2012-2020 French Investments for the Future programme. The programme looked at two high-yielding crop species: sorghum, an annual drought-tolerant grass adapted to southern Europe, and miscanthus, a perennial grass adapted to more temperate climates with a lower demand for synthetic chemical inputs than annual species. The articles in this special issue highlight various aspects of the production and use of miscanthus biomass. Given its close taxonomic proximity to maize and sorghum, miscanthus is compared to sorghum in half of the articles. Together, these findings pave the way for interesting prospects to accompany the expansion of this crop in France.

[BioEnergy Research](#)

[Biomass for the Future, vol. 15, June 2022](#)



Experimental plots of miscanthus; INRAE Centre, Versailles.
©INRAE - B. Nicolas

Oligosaccharides to improve health

Oligosaccharides are molecules made up of a combination of 2 to 20 simple sugars. Essential to life, these molecules play a variety of roles inside organisms, including humans. The importance of oligosaccharides in food and human health, and the complexity involved in producing them using chemicals, make biological synthesis a key challenge. Scientists are seeking ways to synthesise oligosaccharides in a laboratory using biocatalysts of bacterial origin, known as glycoside phosphorylases. These enzymes are not well characterised, however. Using an approach involving the screening of large sequence spaces derived from human gut microbiota, combined with methods for glycoside phosphorylase activity detection, the team was able to accelerate the study of these interesting enzymes. This research creates new possibilities for the production of a wide panel of oligosaccharides of interest to human health.

[Journal of Molecular Sciences](#)
doi.org/10.3390/ijms23063043



BETTER Metaprogramme

INTERVIEW WITH

Sophie Thoyer
Programme Director

What does the BETTER metaprogramme set out to do? It covers 'territory' that is unusual for INRAE.

The BETTER —bioeconomy for urban territories— metaprogramme was launched to mobilise INRAE research in efforts to make cities more sustainable and resilient. Many research institutes are exploring what tomorrow's cities should look like. INRAE probes the challenges of connecting geochemical cycles between urban and rural areas and the consequences of increased use of bioresources and nature-based solutions in cities (for construction, energy, services). The bioeconomy will likely play a growing role in urban areas with the commitment made by cities to reduce their environmental footprint and improve their autonomy. Success in these transitions requires understanding what drives changes in habits and policy, developing innovative technology adapted to urban environments, and rethinking urban planning. To meet these challenges, INRAE is mobilising interdisciplinary efforts in three areas: (i) improving circularity and the connection of geochemical cycles in cities and between urban and rural areas; (ii) designing resilient and sustainable urban bioeconomy systems; and (iii) evaluating and assisting in transitions.

What are some examples of projects that are emblematic of this metaprogramme?

A wide variety of projects is underway, from the recovery of unsold bread and scraps, the development of urban biorefineries and recycling urine, to the re-use of processed wastewater and use of the cold chain as a bridge between collective catering and food aid.

Insect4city is a consortium working on urban entomoconversion, which involves growing insect larvae in city environments from urban organic waste. These larvae can then be potentially transformed into protein-rich flours for animal feed and biofuels. The consortium, led by scientists from 6 different scientific divisions, has helped establish a new interdisciplinary community that is very active in this field. The latter has created Fly4Waste, a project to conduct solid benefit-risk analyses of urban entomoconversion and provide the scientific input needed for regulatory reform in this area.

Is an urban bioeconomy always a good idea?

The central aim of BETTER is to strengthen the circular bioeconomy in cities to improve the environmental performance of urban areas and

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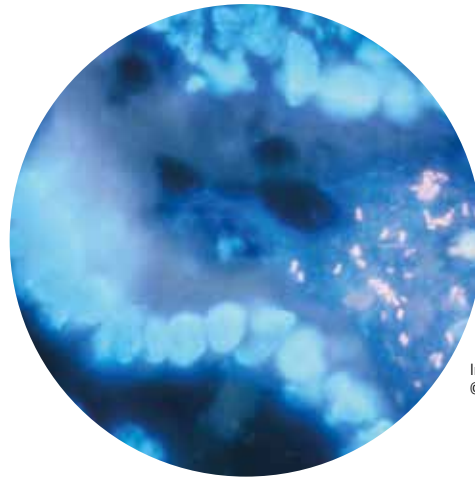
The bioeconomy will likely play a growing role given the commitment made by cities to reduce their environmental footprint and improve their autonomy.

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the well-being of those who live there. But this is contingent upon the technological choices made, the logistical changes needed, and the region surrounding the city. Tools are necessary to evaluate proposed solutions and the routes taken to achieve them. Similarly, a collective effort is needed to adopt more sober lifestyles and avoid the pitfall of a system that requires more bio-waste to be viable. The adaptability and modularity of bioeconomic solutions for cities therefore represent new research challenges at INRAE.

Our scientific priorities

Promoting a global approach to health



Intestinal epithelium and flora.
©INRAE - V. Rochet

Global warming and human activity in all its forms pose numerous risks to plant, animal and human health and the environment. The emergence of pathogens, chemical contaminants in the environment and food, and the impact of diets on health are just some of the challenges explored in INRAE research. Understanding the relationship between food, environment and health, for example, is key to enabling positive change in food systems and environmental protection.



Emergence and re-emergence of communicable diseases



Percentage of human biting ticks carrying pathogens in 2021.
©J.Durand - CITIQUE

Ticks under close supervision

As the primary vectors for pathogens that target humans and animals in Europe, ticks represent a serious public and veterinary health problem. In France, some 40 species have been identified to date. As part of the French government's national strategy to combat lyme disease, INRAE, VetAgro Sup, the pharmaceutical group Boehringer Ingelheim and CIRAD analysed the risk associated with the *Ixodes ricinus* tick, the main vector of pathogens in France. Researchers based the study on datasets collected from 7 laboratories with different microclimates in mainland France, along with weather data. Their findings were used to develop a map to better assess human exposure to bites and better target prevention campaigns.

Monitoring extends to new species of ticks in France and includes research on the identification of the infectious agents they can transmit.

[Geospatial Health](#)

doi.org/10.4081/gh.2022.1058

[Scientific Reports,](#)

doi.org/10.1038/s41598-022-11479-z

[Ticks and Tick-borne Diseases](#)

doi.org/10.1016/j.ttbdis.2022.101934

Improve the early detection of avian influenza virus

France has faced several outbreaks of highly pathogenic avian influenza viruses (HPAI) since 2016. These viruses pose a major threat to poultry farms and a potential zoonotic risk to public health. Each outbreak results in the death of millions of domestic and wild birds. To better understand and control the spread of HPAI viruses, the role of the environment

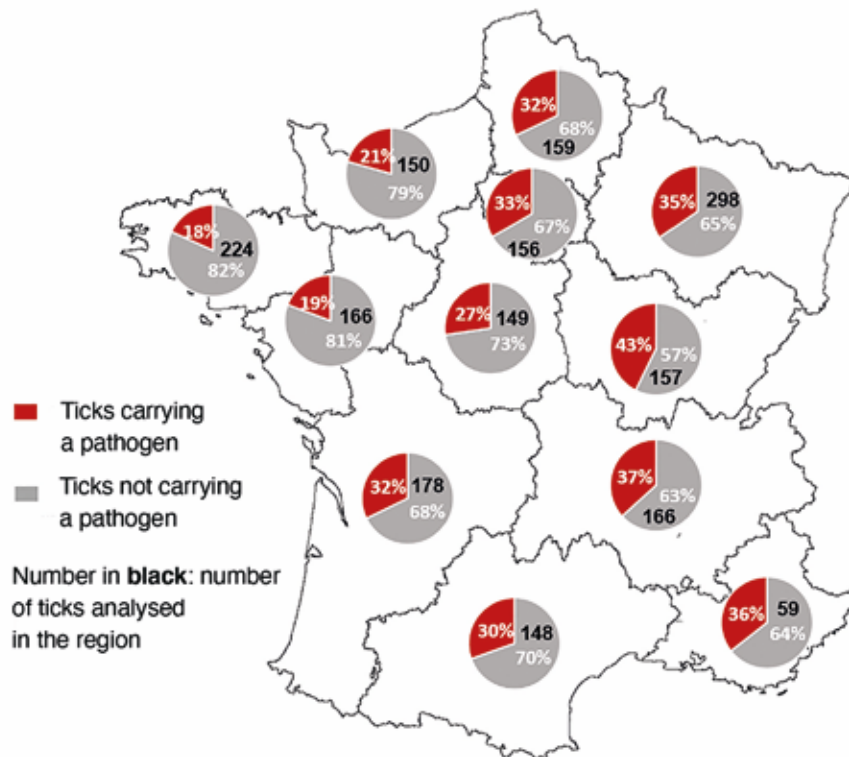
as a vector and detection matrix was studied during the highly infectious H5N8 outbreak of 2020-2021.

In addition to government monitoring based on tracheal swabbing, dust wipe and aerosol samples were taken from 63 infected and suspected poultry houses. Molecular analysis of the environmental samples revealed high viral RNA loads, particularly during the early stages of infection, before clinical signs appeared. The results suggest that this type of environmental sample

is an effective monitoring tool that could detect the virus more rapidly and facilitate the implementation of measures to stop its spread.

[Emerging Infectious Diseases](#)

doi.org/10.3201/eid2807.212247





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Culex pipiens, Female mosquito.
 ©INRAE - R. Coutin

The role of host species in the spread of Rift Valley fever virus

Rift Valley fever (RVF) is a zoonotic viral disease transmitted by mosquitoes, mainly to livestock, that causes widespread abortion and high mortality in young animals. In humans, the severe form of the virus can be fatal. RVF is on the WHO list of the most important emerging infectious diseases. Little is known, however, about the potential of different host species to transmit the RVF virus over the course of their infection. As part of an international study, scientists developed a mathematical model to reproduce the total viral and infection dynamics observed in 3 host species: lambs, calves and goats. Lambs are 3 to 4 times more infectious than goats and calves, and animals that succumb to the virus are twice as infectious as survivors. Research is ongoing to determine the impact of this heterogeneity in individual infectiousness on the relative contributions of host species to RVF transmission in an animal population.

[Plos Computational Biology](https://doi.org/10.1371/journal.pcbi.1010314)
doi.org/10.1371/journal.pcbi.1010314

Wild boars: a reservoir of highly virulent

pathogenic bacteria for pigs

A recent study focused on the causes of excess mortality in wild boars in several regions of mainland France. Preliminary work shows that these wild boars died of a bacterial infection from a particular strain of *Escherichia coli*. Though common in pig farming, this bacterium had never been observed in the pig's close cousin, the wild boar, until now. The new strain, a hybrid of two different kinds of *E. coli*, is currently thought only to circulate in wild animals, given a lack of any antibiotic resistance gene, a frequent feature of bacteria found on farms. This is the first time an hypervirulent *E.coli* strain of this kind has appeared in a wild reservoir (it can be passed on to domestic pigs). The research sheds light on the plasticity of bacterial genomes and the importance of monitoring the health of wildlife, a potential reservoir of new pathogens.

[Emerging Infectious Diseases](https://doi.org/10.3201/eid2802.211491)
doi.org/10.3201/eid2802.211491

An effective new biotechnology to block SARS-CoV-2 virus multiplication

A SARS-CoV-2 infection begins in the nasal cavity. It multiplies abundantly before spreading in the surrounding environment. It can also spread to the lungs, where it causes the most severe pathologies. Obstructing multiplication in the nasal cavity could therefore curb the infection early, and potentially stop the spread of the virus. A consortium of scientists coordinated by INRAE developed antivirals based on biosynthetic proteins called α Reps. Similar to how antibodies work, these biosynthetic proteins can recognise the virus's Spike binding protein. In addition to their strong antiviral activity, these α Reps are highly stable and inexpensive to produce: two key advantages for their development. These results are promising for the development

IN BRIEF

Creation of a research and innovation partnership with the Syndicat de l'industrie du médicament et diagnostic vétérinaires (SIMV)

On 25 January 2022, INRAE and SIMV signed an agreement to establish a partnership alliance on animal health research and innovation. With 25 years' experience working together, the two organisations have created the alliance to enhance cooperation between INRAE and the healthcare industry union. In a One Health approach, joint research programmes will focus on drug prescription, vaccination, diagnostic and livestock disease prevention practices that value animal health and welfare.



of antivirals to reduce the pathology and the spread of Covid-19.

[Plos Pathogens](https://doi.org/10.1371/journal.ppat.1010799)
doi.org/10.1371/journal.ppat.1010799



Predicting the emergence of zoonoses

INTERVIEW WITH

Christine Citti

WiLiMan-ID Project Coordinator

What challenges exist for research in the field of monitoring the emergence of zoonotic diseases?

In an increasingly connected and changing world, preventing and responding to infectious diseases of animal origin are major challenges for animal, human and environmental health in general and for the socio-economic stability of society. The (re)emergence and spread of these diseases are the result of two complex processes. The first is related to pathogen-host interaction and closely linked to the biological properties of the pathogen — its ability to multiply, produce variants, and dodge immune responses from the host, for example. The second is related to the dynamics of pathogens found in complex

socio-ecosystems that interconnect wildlife, livestock, pets, vectors such as mosquitos and ticks, the environment and human beings. Our ability to predict where infectious animal diseases could emerge and minimise their spread depends on our understanding of interactions between these different actors and the impact of human activities (agricultural practices, climate change, etc.). Knowledge remains spotty in this field.

What an immense task. You address a certain number of these issues in a new project: **Ecology of Wildlife, Livestock, huMan and Infectious Diseases in changing environments (WiLiMan-ID)**.

This Horizon Europe project is aimed at improving (i) risk-based monitoring by identifying sources, paths of emergence and spread; and (ii) the prevention of infectious animal diseases in order to preserve animal and human health. It also seeks to better understand the impact of human activity on the ecology and dynamics of animal pathogens so as to forecast and prepare the necessary countermeasures. These issues are also at the heart of the Preventing Zoonotic Disease Emergence (PREZODE) initiative. PREZODE looks at these issues through the study of 5 infectious diseases, each of which is both a study model and a threat to livestock or humans (zoonosis): avian influenza, African horse sickness, West Nile fever, African swine fever

and chronic wasting disease. Host communities include humans, domestic animals (poultry, horses and pigs) and wildlife (wild birds, boars and deer).

What are some unique features of the project?

Two innovative features of WiLiMan-ID are (i) the integration of several scales: the exact properties of pathogens in the region and the different compartments of the ecosystem for an integrated view of their (re)emergence, persistence and spread; and (ii) the parallel study of several contrasting pathoecosystems to highlight their similarities and specificities. This knowledge will help us better prepare for and cope with future infectious health threats, most of which are unknown. To meet this challenge, 14 academic and private-sector partners (11 countries, including ten in Europe) with expertise in virology, immunology, public health, pathology, epidemiology, economics, sociology and modelling are carrying out the project using cross-disciplinary approaches.

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The WiLiMan-ID project brings together experts in virology, immunology, public health, pathology, epidemiology, economics, sociology and modelling.

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Pollution, contaminants and the exposome

Pharmaceutical contamination of the world's rivers

Pharmaceutical pollution is a well-documented phenomenon in regions of the world like North America, western Europe and China, but global data to assess the situation worldwide was unavailable. A large-scale international study led by the University of York (United Kingdom) with INRAE and over 80 research institutes analysed pollution in 258 rivers in over a hundred countries across five continents. The study examined 61 pharmaceutical substances found in major rivers such as the Amazon, the Mississippi and Mekong, with samples taken both in areas where modern drugs are not used (i.e. a Yanomamai village in Venezuela), and in some of the most populated cities on the planet, like New York and New Delhi. Results indicate that the level of pollution in waterways is correlated with the socio-economic conditions of

the country: the most contaminated sites are in low- and middle-income countries where pharmaceutical manufacturers are located or where wastewater and waste management infrastructure is inadequate.

PNAS

doi.org/10.1073/pnas.2113947119

The impact of ingested microplastics on the human digestive tract

Simple and inexpensive to produce, polyethylene is the most commonly found plastic in the world. On average, 100 million tonnes are produced each year, half of which are used to make packaging such as shopping bags. This petroleum-based product, which breaks down into smaller particles called microplastics, can remain in natural environments for between 100 and 400 years. Scientists from INRAE and the Université Clermont-Auvergne conducted

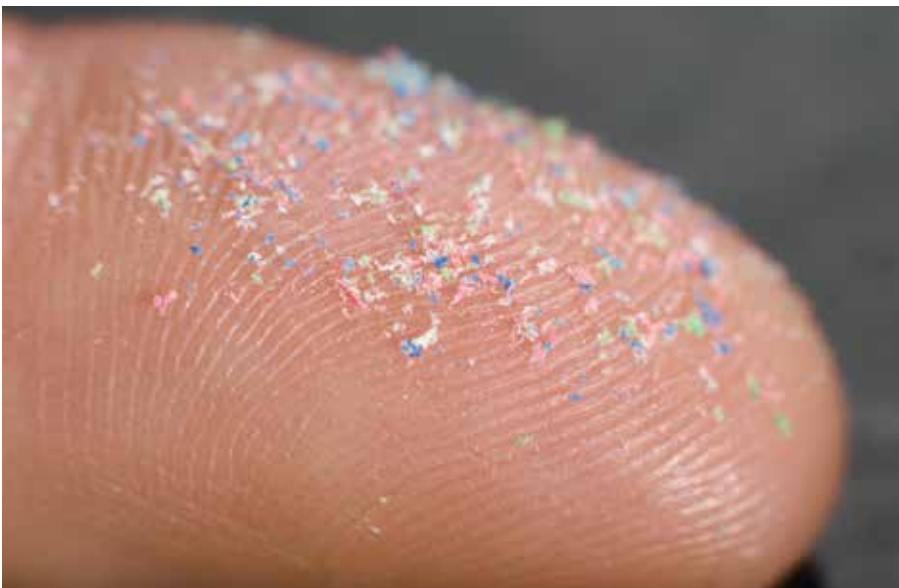
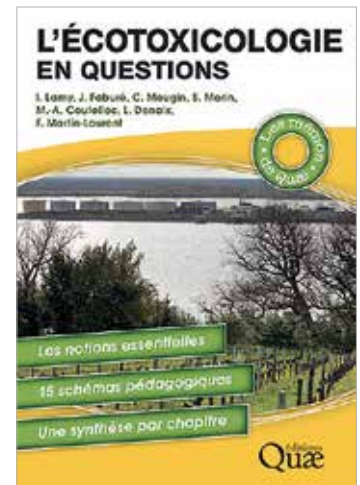
FURTHER READING

A few questions about ecotoxicology

This book discusses current major approaches to ecotoxicology through open-ended questions for readers curious to learn more about this discipline or, more generally, concerned about environmental issues. Answers to these questions offer an overview of major concepts in ecotoxicology and its main associated concepts and explain the breakthroughs that have transformed traditional approaches to this science to a more holistic approach that accounts for the complexity of real environmental conditions.

Editions Quæ

url.inrae.fr/3orQomz



Microplastics (illustration).
©AdobeStock

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Staphylococcus aureus
 (illustration).
 ©AdobeStock

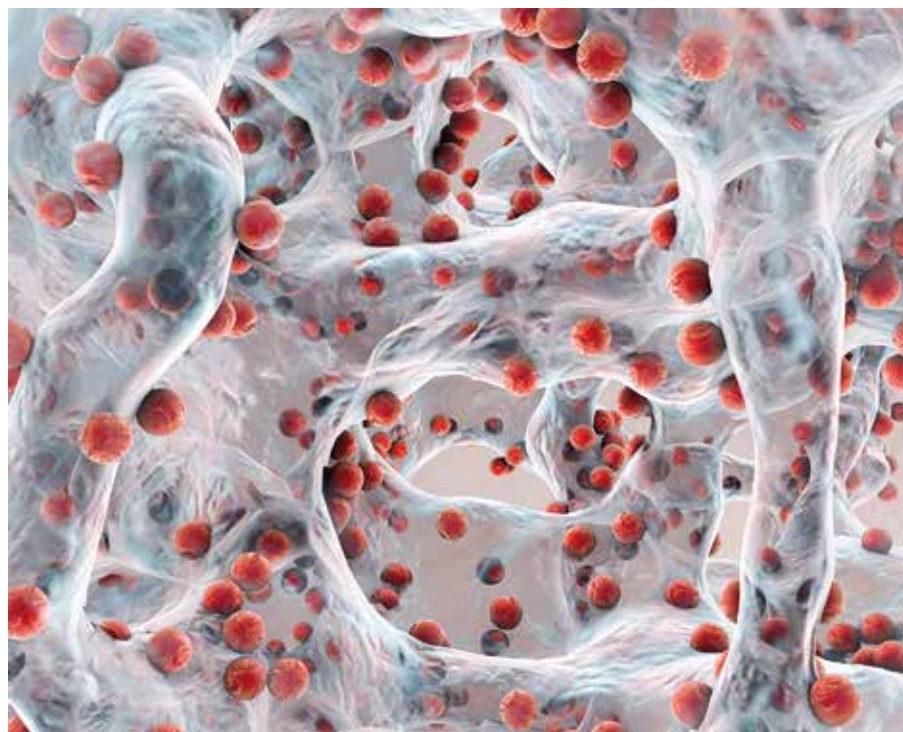
a groundbreaking study to assess the impact of microplastics on gut microbiota. They used an original in vitro model that reproduces the environment of the human colon, the final part of the digestive tract. Results indicated an increase in potentially harmful bacteria and a reduction in beneficial bacteria. However, these changes did not affect gut barrier integrity, which maintained its protective function and showed no inflammation.

[Journal of Hazardous Materials](#)
doi.org/10.1016/j.jhazmat.2022.130010
doi.org/10.1016/j.jhazmat.2022.130010

Discovery of the cocktail effects of foodborne toxins

Food safety is a global issue. Animals and humans are exposed to hundreds of potentially toxic molecules, both natural and synthetic. Given the infinite ways in which these molecules combine, predicting their combined, or 'cocktail' effects is an ongoing scientific challenge. About 80% of individuals are exposed to deoxynivalenol, a toxin of the trichothecene family produced by certain moulds. Scientists wonder whether a cocktail effect is possible with other foodborne contaminants, such as genotoxins, toxins capable of causing DNA damage and to which we are exposed daily. Research led by INRAE in partnership with INSERM, Université Toulouse III-Paul Sabatier and the National Veterinary School of Toulouse shows that mycotoxins of the trichothecene family, frequently found in food, interact with a wide range of other toxins and can increase their genotoxic effects.

[Environmental Pollution](#)
doi.org/10.1016/j.envpol.2022.120625



The fox in the hen house: how *Staphylococcus aureus* bacteria enters host cells and deregulates them to its benefit

Staphylococcus aureus is an opportunistic pathogen that causes multiple illnesses, from mild skin infections to life-threatening severe food poisoning. Long considered an extracellular pathogen, *S. aureus* has now been detected inside different types of cells. Identifying the biological processes involved in the cell response to *S. aureus* is necessary to understand the mechanisms of chronic infection. Researchers developed an in vitro model of long-term infection by only and specifically isolating the cells with internalised bacteria. Their findings suggest that intracellular *S. aureus* infection has a long-term impact on the genome and epigenome of host cells, leading to

pathophysiological dysfunction in addition to the immune response that follows infection. Results improve the understanding of the biological processes involved in chronic infections and identify potential candidates for therapeutic approaches to these infections.

[Front. Cell. Infect. Microbiol.](#)
doi.org/10.3389/fcimb.2022.854242



Preventive nutrition for public and environmental health



Meat-rich meal (illustration).
©AdobeStock

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Tracking down antigenicity in wheat

Allergic reactions involve interactions between the immune system and allergens, which are most often proteins. Lipid transfer proteins (LTPs), including those in wheat, are known to cause food and respiratory allergies mediated by IgE antibodies. Knowledge of areas of interaction, or 'epitopes', between allergens and antibodies in allergic patients is essential, in particular to prevent cross-reactions to several foods and/or pollens. A combination of approaches based on immunochemistry, molecular biology and structural biology revealed the key role played by a group of 5 amino acids in interaction between wheat LTP1 and antibodies, and in triggering symptoms. Amino acids are also important in maintaining a protein's local or global structural characteristics. These residues are conserved in the LTP sequences of other

plant species. This study paves the way for diagnosis and research in allergy treatments.

[Scientific Reports](#)

doi.org/10.1038/s41598-022-15811-5

The impact of maternal consumption of meat products on offspring

The adverse effects of eating too much meat are well documented in adults. Nutritional guidelines for the general public take this body of knowledge into account. Few studies, however, have assessed the consequences of a maternal meat-rich diet on offspring. A study on mice was conducted to evaluate the impact of maternal exposure on gut homeostasis and glucose metabolism. It was found that in adulthood, male offspring, never directly exposed to the heme iron in meat products, but exposed early through the maternal diet, presented signs of oxidative and inflammatory stress

IN BRIEF

Probiotics to limit muscle wasting

With ageing comes a decrease in muscle mass and strength called sarcopenia, explained in part by smaller food intake and/or a low-intensity inflammatory state and/or insulin resistance. Scientists have identified two bacterial strains that target the microbiota and limit muscle loss in preclinical models.

[Frontiers in Nutrition](#)

[10.3389/fnut.2022.928798](https://doi.org/10.3389/fnut.2022.928798), [10.3389/fnut.2022.986542](https://doi.org/10.3389/fnut.2022.986542)

associated with gut barrier disruption and impaired insulin secretion in response to an oral glucose tolerance test. This new data may be useful to inform nutritional guidelines for pregnant or breastfeeding women, for whom iron intake is essential during these periods.

[Redox Biology](#)

doi.org/10.1016/j.redox.2022.102333



French microbiota **Le French Gut**

Le French Gut Getting to know French microbiota better

Recent research on the millions of microorganisms that live in our digestive system illustrates the importance of microbiota to an individual's health.

The national French Gut project is a call for contributions to map and understand French intestinal microbiota. The objective? Collect 100,000 faecal samples by 2027, along with related nutritional and clinical information. Part of a worldwide initiative, this unprecedented participatory science project creates promising prospects for the development of innovative diagnostic tests and treatments to combat chronic diseases, as well as for the development of tailored preventive nutrition. Launched and supported by INRAE's MetaGenoPolis unit, French Gut is co-led with AP-HP, France's public hospital system, and carried out in partnership with four public institutions and 11 private stakeholders in the field of microbiota.

The ambitious project, estimated at €32 million over 5 years, is a One Health initiative and contributes to the INRAE 2030 strategic priority of favouring a global approach to health. The goal is to understand heterogeneity in healthy gut microbiota and identify influential factors and changes that can lead to chronic diseases.

The 3 scientific targets of French Gut:

- **map** the gut microbiota in France;
- **model and predict** changes in the gut microbiota associated with chronic diseases (diabetes, obesity, cancer, chronic inflammatory diseases of the intestine), neurodevelopmental disorders (autism, bipolar disease, etc.) and neurodegenerative diseases (Parkinson's disease, etc.);
- **describe** the variations of the intestinal microbiota associated with the presence and development of the diseases and functional disorders mentioned above.

To take part:

Visit the Le French Gut website

lefrenchgut.fr/the-french-gut-project

Our scientific priorities

Facilitating transitions by mobilising data sciences and digital technologies



Scientific, technological and methodological progress made possible by digital science and technology are creating new ways of exploring complex biological systems and ecosystems at different scales and of predicting the behaviour of living organisms. The growing intersection of experimental science and artificial intelligence offers numerous opportunities for new applications, for example in the assessment of climate impact, crop protection and animal welfare.



Agriculture and Digital Technology: a white paper to build the foundations of responsible digital agriculture

With the challenges that currently face us in the realms of food security, climate and the environment, digital technology is viewed as an opportunity to enhance agricultural practice for the benefit of farmers, consumers and society in general. How can research help to make this vision of responsible digital agriculture a reality? Research must focus on finding ways to seize opportunities while limiting risks. This white paper, jointly produced by INRAE and INRIA, focuses on this question, seeking out the synergies that can be strengthened between digital transformation and both agroecology and food systems.



Analysing complexity

Better predicting the evolution of glaciers using artificial intelligence

Glaciers are rapidly losing mass as a consequence of human-induced climate change. It is of paramount importance to properly understand the physical processes behind these regional and global changes, in order to anticipate the different possible future glacier scenarios and their impacts on sea level rise, water resources and ecosystems. For the first time, an interdisciplinary team of glaciologists, climatologists and mathematicians has used deep learning (a type of artificial intelligence) to simulate the future evolution of glaciers at a regional scale. The approach is particularly well suited to capturing the non-linear effects that are characteristic of many physical processes in nature. This study heralds a new generation of more powerful scientific models better equipped to predict the fate of glaciers in the face of climate change.

Nature Communications
doi.org/10.1038/s41467-022-28033-0



Mountain glacier tongue.
 ©INRAE - C. Slagmulder

IN BRIEF

When artificial intelligence translates pig vocalisations

Using a library of 7,400 vocalisations collected in different contexts throughout the life of farm-reared pigs, a multidisciplinary European team of researchers established a system to automatically classify pig vocalisations according to their emotional valence (indicating a positive or negative emotion) and the situation in which the vocalisations were emitted. Results show that artificial intelligence is very effective at recognising not only the emotional valence of the vocalisations (91.5% accuracy), but also the situation in which they were emitted (82% accuracy). These results can be used to develop a tool to help livestock farmers in their decision-making.

Scientific Reports
doi.org/10.1038/s41598-022-07174-8

The effect of landscape on pest-predator interaction

By combining statistical and theoretical models in population dynamics, researchers were able to simulate the effects of (virtual) landscapes on species dynamics. Statistical analysis based on several spatial scales made it possible to quantitatively assess how landscape variations affect the biological control of pests, sometimes in an ambivalent manner. The network formed by hedges, a source of beneficial insects, for example, could help reduce the use of insecticides, but could also encourage the presence of pests. Landscape structure also influences how species develop and depends on a reciprocal adaptation between beneficial insects and pests. Fragmented habitats, for example, promote a high dispersal capacity at the expense of local growth. And if pests quickly colonise the entire landscape, beneficial insects that use traps to capture their prey will be favoured, while in the opposite case, highly mobile beneficial insects are predominant. These results shed light on the links between landscape structure and the effectiveness of biocontrol in agroecology.

[Ecography](#)

doi.org/10.1111/ecog.05956

A mathematical model for the study of host-microbiota interactions

Human health is strongly influenced by interactions between host cells and gut microbiota. In the colon, crosstalk between the two is mainly mediated by regulations at the intestinal crypt level. The microbiota, which produces metabolites as a result of fibre fermentation, influences cell division and differentiation into specialised cells, thus also influencing the physiology of its host. Conversely, metabolites produced by a host affect microbiota composition. Researchers developed an individual-based, crypt-level stochastic mathematical model that simulates cells interacting with metabolites produced by the microbiota. A case study on the effects of butyrate supplementation after the establishment of a dysbiotic state could thus be represented using a simple representation of the microbiota.

[Journal of Mathematical Biology](#)

doi.org/10.1007/s00285-022-01766-8



Sensors and information acquisition systems

The automatic characterisation of vegetation

Grapevine downy mildew (*Plasmopara viticola*) is a major grapevine disease. Strategies to combat this fungus rely on the remedial use of systemic chemical fungicides that are toxic for non-target organisms and persist in the environment. Several alternatives to fungicides are under development. Accurately detecting and locating pests and disease in time and space is a crucial step in enabling early targeted treatments. Researchers used a hyperspectral image database following the development from 0 to 9 days post-inoculation of three strains of *Plasmopara viticola* inoculated on grapevine leaves and developed a detection tool based on a machine learning method. The tool detected the fungus attack two days before the onset of visual symptoms and enabled a better evaluation of spatial distribution. These results are promising for limiting anti-fungal treatments.

[International Journal of Molecular Sciences](#)

doi.org/10.3390/ijms231710012



Downy mildew on a grape cluster, caused by *Plasmopara viticola*. ©INRAE - Y. Bugaret





AgroTechnoPole: working for the agroecological transition

INTERVIEW WITH

Jean-Pierre Chanet

Research Director at the Technologies and Information Systems for Agro-systems unit (TSCF)

The experimental site of AgroTechnoPole, located in Montoldre in the Allier region, is a new open innovation platform under development for the last few years and launched in 2022. What is the goal of this platform?

The AgroTechnoPole platform is designed to develop technologies that assist in the agroecological transition. This public-private platform is geared towards stakeholders across the agricultural sector and is international in scope. It relies on unique innovative infrastructure that accelerates the development processes and testing of new equipment. The offer is based on the dimensions of research, engineering, testing and training.

What partners are working with AgroTechnoPole?

The platform brings together a diverse range of skills, from academic partners taking part in the CAP 20-25 I-SITE Clermont Auvergne Project and from the French Alternative Energies and Atomic Energy Commission (CEA), as well as from innovative companies that contribute advanced software and technology.

Lead companies play a role in developing infrastructure and in governance and contribute human and financial resources.

A group of professional representatives — RobAgri, AXEMA, SEMAE and competitiveness clusters — provides an outside perspective on the expectations of the agriculture sector.

What are some examples of equipment development that are the priority in the short term?

Short-term priorities focus on agricultural robot safety issues. Safety is a major focus for the development of this sector. For this reason, we are working with RobAgri to develop safety protocols, which we represent for France at the international level (OECD, ISO). Co-built with manufacturers, these protocols make it possible to test solutions before they are sold on the market.

The second example is the issue of weed control. With a view to restricting the use of herbicides, alternative solutions are indispensable. This is why a benchmark for new weed control solutions to facilitate their development is an infrastructure priority. It is a major challenge in agroecology.

Sowing is the third biggest issue. Agroecology aims to promote multi-variety and/or multi-species sowing. Seed drills need to be modelled to enable these new uses.

To do, we are working with lead companies Kuhn and Burel Production to design and develop benchmarks and tests in order to produce new seed drills.

Longer-term objectives involve using robotics in highly targeted and differentiated operations in new farming systems and methods. Also important to consider are factors at play in the reduction of the carbon footprint of mobility in agriculture, so as to promote more environmentally friendly agricultural practices.

Lastly, the use of artificial intelligence

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AgroTechnoPole brings together a diverse range of skills, from academic partners and innovative companies that contribute advanced software and technology.

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is a major issue, addressed by AgroTechnoPole as a participant in the European AgriFood TEF project, an umbrella structure for AI research bodies.



Open Science

INRAE established a bold and ambitious open science policy in 2021. In 2022, the Institute re-affirmed its commitment to opening science in all its forms to a large audience by effectively implementing its action plan. Read on to discover six key measures.



Collecting, storing, analysing and improving the accessibility of scientific data



On the ground: D. Desclaux with organic farmer G. Chirat. ©INRAE - C. Maître

The "Data for science" action plan

The management and sharing of scientific data is a colossal challenge. Fast-paced change in digital technology and the ever-accelerating pace of data production are raising issues for our communities regarding how to transform practices for the collection, storage, analysis and accessibility of research data produced at this new scale. To make these changes, INRAE adopted a "Data for Science" plan in 2022 to develop data science skills and establish data governance measures to promote the sharing, reuse and transfer of data in accordance with certain principles of ethics and integrity.

The plan also includes the development of high-performance and interconnected digital infrastructure to store, process and analyse data.

The Recherche Data Gouv platform

The French Ministry of Higher Education and Research entrusted INRAE with the technical development of Recherche Data Gouv, a national platform aimed at making French research data accessible. INRAE developed the repository, data catalogue and data and services access portal for the platform. Since it launched in July 2022,



10 spaces for higher education institutions have opened in addition to the INRAE space. The repository currently holds over 1,800 datasets and over 28,000 files, which have been downloaded about 253,000 times.

Printemps de la donnée event

INRAE invited its work communities and joint research unit partners to the first Printemps de la donnée event throughout May 2022 to exchange information and share updates on the initiative. The

objective was to highlight local data management and sharing initiatives: training, development of tools, feedback, etc. Some 40 events were held, including: 17 webinars, 10 open classes (on a data management plan, data papers, INRAE data, etc.) and 14 face-to-face events at INRAE centres. In total, more than 700 people took part in the local initiatives. Off to a great start, the event will be held again in 2023 and include a larger focus on higher education.



Science that includes society

NOV'AE: a special issue on science and participatory research

As part of INRAE's global approach to including society in science, the Institute develops a range of research projects involving non-specialists. The first special issue of NOV'AE, published in January 2022, illustrates this diversity of scientific production and the fields covered in a close-up look at several projects. It also provides an overview of the history, stakeholders, tools and challenges involved in participatory science.



OSCAR training

Implementing the principles of open science involves a major overhaul of practices in the scientific community and in research support. A key initiative of the Open Science action plan, the online OSCAR training programme is aimed at supporting this change and making the transition a success. Adapted to each person's needs and skills, the course is composed of 9 subject modules covering the entire scope of open science. Designed for a perfect fit with the needs of different audiences, this engaging, interactive and progressive course can be completed as participants wish, at their pace and according to their interests. OSCAR is a component of the national skills development plan led by the Human Resources division to ensure coordination with other INRAE training programmes.

The Participatory Research award

The first Participatory Research competition, organised by INRAE at the request of the Ministry of Higher Education and Research, was reserved for Agreenium members. Winners included two projects co-sponsored by INRAE and its partners: CITIQUE and From seed to plate: 20 years of participatory cross-disciplinary research. The second competition, held in 2022, was open to all stakeholders in French higher education, in all fields. The Participatory Research award now recognises all areas of scientific study and will be presented at a ceremony at the Ministry in the presence of the Minister and the scientific and community stakeholders involved.





Partnerships and impact



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INRAE station in Mirecourt in the Vosges region.
©INRAE - F. Gaujour





European and international events: key drivers of INRAE partnerships



INTERVIEW WITH

Jean-François Soussana

Vice President of International Policy

What were INRAE's contributions to major international events in 2022?

In 2022, we led action in European and international initiatives to promote the voice of science and research. One example is the Science & Innovation Forum organised by the Food and Agriculture Organization (FAO) in October. We took part in several events that were particularly relevant to our international agenda, on subjects such as collective scientific expertise on the microbiome, and sustainable digital agriculture. In November at the 27th United Nations Conference of the Parties to the Climate Change Convention (COP27), we organised an international event with CIRAD and IRD on the land sector as a strategic lever to meet the challenges of climate, biodiversity and food security. In December, INRAE was a first-time observer organization at the 15th Conference of the Parties (COP15) to the United Nations Convention on Biological Diversity (CBD) held in Montreal. More recently, INRAE contributed to the French partnership

on water at the World Water Forum held in Dakar, Senegal in March. Together with CIRAD, IRD and FAO, we co-organised a scientific event on the positive role of agroecology in irrigated agriculture. These events, along with the dissemination of joint position papers at these international gatherings, successfully boosted the visibility of our scientific messages.

Why is it important to spread our key messages?

Scientific events linked to European and international political agendas are a wonderful opportunity to assist in facing major challenges and do so in more visible and effective ways. They also provide leverage to drive and lead research initiatives and partnerships at this scale. Such events also have a snowball effect on the structuring of our bilateral and multilateral partnerships with international organizations such as FAO. At the Science & Innovation Forum, for example, we signed a

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This is the first time that INRAE, CIRAD and IRD have signed a quadripartite agreement with the FAO.

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new cooperation agreement with FAO, CIRAD and IRD to support the transformation of agrifood systems for the period 2022-2025. This is the first time we have signed a quadripartite agreement with three research organisations that reflects the coherence, quality and complementary nature of French research in our fields. Increased interaction during 2021 and 2022 with the International Fund for Agricultural Development (IFAD) and the World Food Programme (WFP)

has led to new avenues of cooperation currently under study on topics such as agroecology, food system resilience, school meals and digital agriculture.


What is the next step, scientifically speaking?

INRAE's scientific community is heavily involved in the research component of two global coalitions launched at the first UN Food Systems Summit in September 2021. Our scientists are members of the research and innovation working group of the Global Coalition for Food Systems Transformation through Agroecology and the research consortium of the School Meals Coalition. I myself joined the Scientific Committee of the FAO-hosted United Nations Food Systems Coordination Hub, led in the framework of the 2030 Agenda. Together with African organisations and universities, we ensure the coordination of the TSARA initiative for the transformation of food systems, alongside these coalitions and with the countries concerned.

Such events and working groups allow us to expand our scope of action to new partners and form new partnerships through the international associated laboratories (LIA), 2R1 international research networks, Joint Linkage Calls (JLC) and joint research projects.

This ongoing commitment to ensuring that cooperation instruments developed by INRAE and its partners are aligned with the world's scientific agendas also enhances our appeal and scientific reputation abroad, as does our strategy to strengthen international mobility. ●

International



2022 saw the consolidation of INRAE's multiple international arrangements, with the renewal or launch of joint endeavours, efforts to promote mobility and extensive involvement in the international PREZODE and TSARA initiatives.

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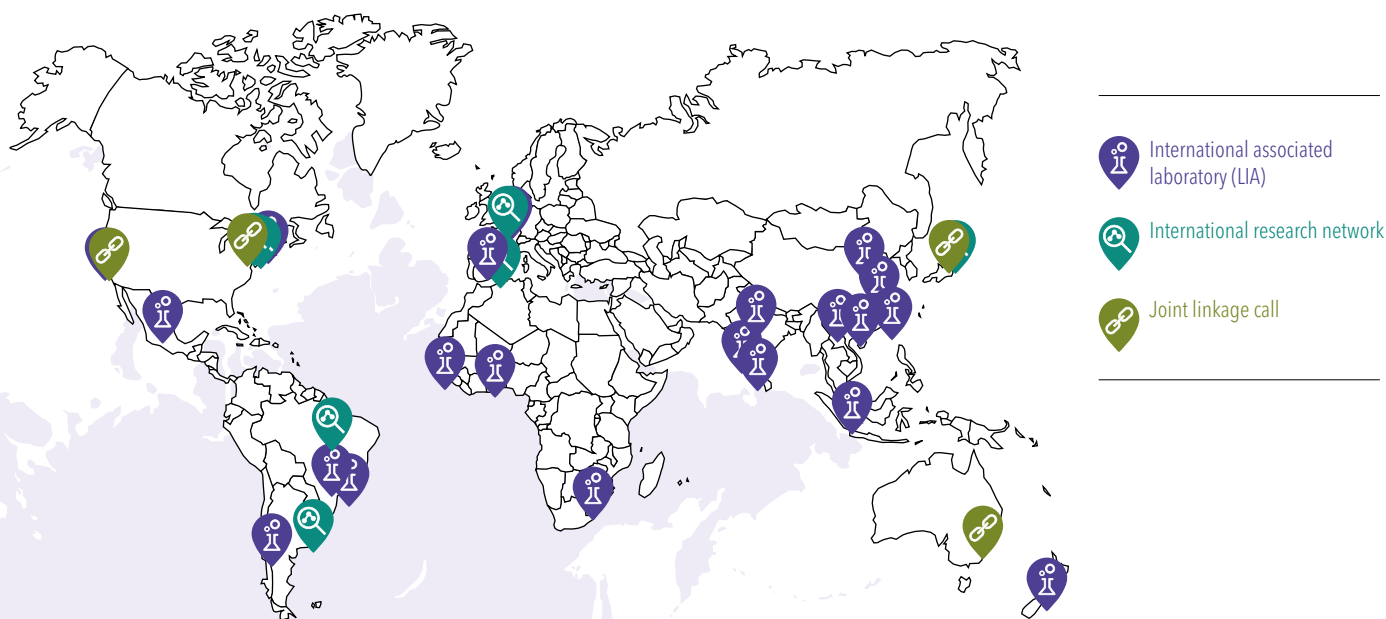
International cooperation instruments: a driving force of action

In terms of international cooperation instruments, INRAE consolidated its international associated laboratories (LIA), international research networks (2RI) and Joint Linkage Call (JLC) programmes on staff mobility. These 25 instruments cover the 5 scientific priorities of the INRAE2030 strategy. They bring together over 35 international partners, from 11 countries, and 17 French partners in higher education and research. A mid-term review of achievements thus far noted an extensive output in co-publications and exchanges between students and scientists, increased visibility for efforts to secure additional funding, and the consolidation of key

partnerships for the potential development of joint programming. In 2022, certain instruments such as the OptiNutriBrain LIA on nutrition and brain health with Laval University in Canada were renewed following positive results. New instruments have also been established. INRAE launched NutriMod, a new LIA on animal nutrition with Laval University; the 2RI FORWARD, on forest, woods, market and society in the context of climate change, with seven partners in Canada and France; as well as the 2RI PisiNet, an international research network on plant and insect interaction with the Japanese National Agriculture and Food Research Organization

(NARO). Two JLC programmes, with AAF Canada and the University of Florida, were launched in June with young scientists to develop cooperation on a jointly selected range of subjects.

Map of international cooperation instruments



Stepped-up support for international mobility

The DRH/International relations (DRI) unit for international mobility and intercultural awareness (M2i) implemented its action plan for the internationalization of the INRAE Formation learning lab. It also released support tools that allowed local teams to build skills and optimise the onboarding of newly recruited staff. A new practical Guide to international mobility, available in French and English, contributes to the appeal of the Institute. DIMI, the mobility funding scheme offered by the divisions and metaprogrammes, provided €260,000 for 40 mobility projects as part of two back-to-back calls for candidates, including for the international initiatives and instruments mentioned above, such as TSARA for Africa.



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Guide for international scientists
guide-for-international-scientists.inrae.fr

Focus

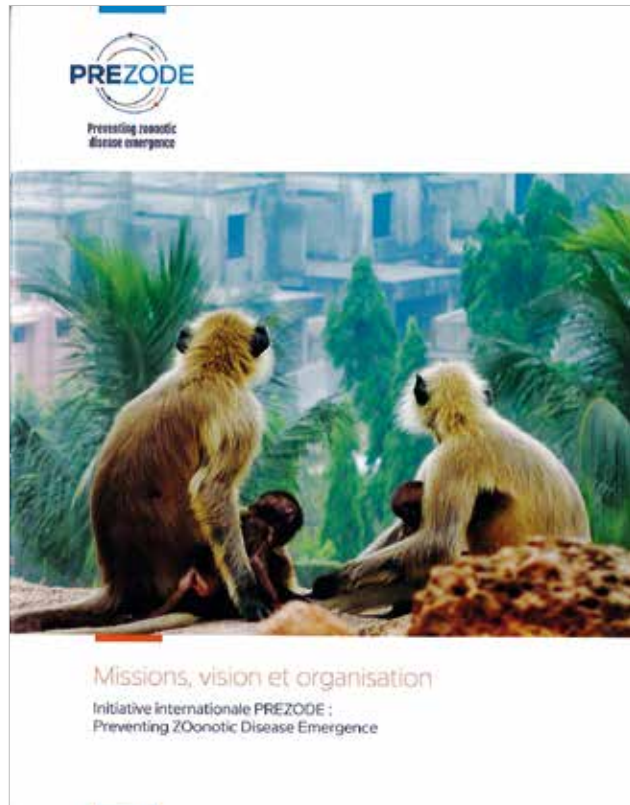
The TSARA Initiative for agriculture and with Africa

The TSARA initiative (Transforming Food and Agricultural Systems through Research in Partnership with Africa), launched at the Paris International Agricultural Show in March 2022, is currently composed of 17 African organizations that signed a letter of intent with CIRAD and INRAE. The initiative remains open to other African, French and European scientific partners. TSARA will develop portfolios for research, training and innovation accompanied by financial support. The initiative will also involve the strengthening of partnership and cooperation schemes; structural instruments such as those developed by CIRAD and IRD; incoming and outgoing international mobility, and the creation of international laboratories and research infrastructure.

The first general assembly, held on 5 December 2022 in South Africa, provided the opportunity to validate the initiative's governance and review the scientific summaries of the thematic groups, with a view to consolidating a common scientific agenda and three-year action plan.

A strategic agenda for the international PREZODE initiative

Initiated in France and led by INRAE with IRD and CIRAD, the international initiative to prevent zoonotic disease emergence (PREZODE), launched in 2021 at the One Planet Summit, now has nearly 200



members from scientific, academic and community and government spheres and 20 signatory countries. At the first general assembly of the initiative, held on 11 October 2022, members adopted the terms of reference of its governance, submitted the strategic agenda (approved in January 2023), and established a roadmap of

where to go from there. PREZODE was selected along with nine other projects as a Scale-Up project for its innovative character and impact at the 2022 Paris Peace Forum on 12 November 2022. The initiative will receive support from the Forum for one year.

Europe



Deeply committed in Europe with 189 projects submitted for the Horizon Europe programme and a new Star of Europe prize awarded in France, INRAE also played an active role during the French Presidency of the Council of the European Union, driving the organisation of events with institutional stakeholders and civil society, primarily about 'One Health' issues and the use of pesticides.



Scientific conference: Towards Pesticide Free Agriculture

What research is needed to meet the objectives of the European Green Deal to reduce the use of pesticides?

Organised by INRAE in Dijon on 2 and 3 June 2022, this scientific conference brought together 400 people for scientific presentations, workshops, a citizens' forum and a visit to the CA-SYS experimental platform. The goal of these encounters was to review the state of science on pesticide reduction and the impact of research on these issues, and bring together the 34 European academic members of the "Towards a chemical pesticide free agriculture" European Research Alliance to exchange perspectives.

The conference was an opportunity to make this issue a more visible part of Horizon Europe and to structure the European Alliance. Building on this event, an INRAE-coordinated project was selected as a European COST action and a documentary series ([#FieldTrip_EU](#)), coproduced by INRAE and independent journalist Pierre Girard, provides further visibility for this topic.



Focus



Horizon Europe

INRAE has been highly mobilised in the Horizon Europe programme since its launch in 2021. That year, the Institute submitted 189 projects and 61 were selected. It has coordinated 16, including Cluster 6 joint projects on food, bioeconomy, natural resources, agriculture and environment, with a success rate of 58% for the coordination of this cluster. In 2022, 189 projects were submitted, including 59 with a coordination role (23 for joint projects, the rest for individual ERC and MSCA grants).

The outcome of these submissions will be announced mid-2023.

Initiatives for the French Presidency of the Council of the European Union

The French Presidency of the Council of the European Union was an opportunity for INRAE to promote its research activity on strategic subjects (One Health, the reduction of pesticides) among institutional stakeholders at the European and national levels as well as the general public. In addition to taking part in a seminar on epidemiological surveillance platforms and a ministerial event on the theme "One Health – Rethink tomorrow's livestock farming", INRAE notably led two official French presidency events: a conference to review the first year of the international PREZODE initiative and a scientific conference on the reduction of pesticides.



IPMWORKS

Based on the French DEPHY farm model, the IPMWORKS project (H2020; 2020-2024) brings together 31 partners from 16 countries in a Europe-wide network of farmers to demonstrate integrated pest management strategies, which rely on small quantities of pesticides, and to promote the adoption of such strategies via knowledge exchange and peer-to-peer learning.

In February 2022, the project prepared an exhibition at the European Parliament in Strasbourg to raise awareness among Parliament members.

Étoile de l'Europe 2022

The SmartCow consortium for an integrated infrastructure to boost research capability and innovation in the European cattle industry, led by INRAE Research Director René Baumont, received the Étoiles de l'Europe Innovation award in December. The project, which received €5 million in funding, brought together 13 European partners from 2018 to 2022 to increase feed efficiency in cattle and reduce methane and nitrogen emissions.
www.smartcow.eu



Higher education and site policy



INRAE is strengthening its collaboration with universities and schools by signing framework agreements and contracts on objectives and means. It also continues to roll out its action plan for higher education and training at all sites where INRAE has existing partnerships.



New framework agreements and contracts on objectives and means

By signing 4 contracts on objectives and means, INRAE is consolidating its collaboration with the universities of Angers, Bordeaux, Pau and Pays de l'Adour, and at its Bourgogne-Franche-Comté site with the Communauté d'universités et établissements (COMUE UBFC), the Université de Bourgogne and the Institut Agro, on clearly identified themes and a number of strategic programmes. Like its partners, INRAE has committed resources for a period of 4 or 5 years.

In the case of Université de Bordeaux, the Institute is strengthening already solid ties in the areas of plant sciences, grapevine and wine, forestry and wood, nutrition and health, in joint and contract-based research units, via a role in the governance of each entity, joint policies for the hosting of PhD students and scientists, the promotion of



international partnership schemes such as LIAs, and concerted action on sustainable development, social responsibility, open science, participatory science, codes of practice, scientific integrity and research ethics.

By signing the framework agreements, INRAE is reinforcing and clarifying the thematic and strategic scope of its cooperation on science and training with key partners and major stakeholders in

research and higher education, including the Institut Agro, INRIA and the Institut Pasteur. The agreement signed in December with the Institut Agro aims to take to the next level the design and promotion of sustainable agricultural and food systems to support all animal and plant sectors, including vine and wine, horticulture, fishing resources, and landscapes, from production to consumption. Building on initiatives carried out at 30 joint research units in the regions of Brittany, Pays de la



General view of the Agro Paris-Saclay campus (opened to students in September 2022). ©INRAE - B. Nicolas



- Loire, Burgundy Franche-Comté and Occitanie, the two institutes have signed this agreement as a commitment to promote their joint training and research initiatives for these transitions at the national, European and international levels. "INRAE is our largest research partner, and this agreement truly takes us to the next level in terms of scale and ambition, in France and abroad", said Anne-Lucie Wack, Director General of Institut Agro. ●

Partners	Subjects
Université d'Angers	Plant immunity for adaptation to environmental change and sustainable protection – Managing microbiota to improve plant robustness and protection
Université de Bordeaux	Plant sciences – Vine and wine – Forestry and wood – Nutrition and health
Université de Pau et des Pays de l'Adour	Impact of climate change and extreme disruptions on freshwater ecosystems - Sustainability of fish farming systems
COMUE Bourgogne-Franche-Comté, Université de Bourgogne and Institut Agro	Agroecological and food transition – Microbial ecology

Focus

Agreenium

INRAE actively contributes to Agreenium initiatives as a member of the alliance. The Institute notably managed the handover to the alliance of the organisation of Crossroads for Agricultural Innovation (CIAG) events and assisted with the new programming, design and hosting of the three events held that year. The CIAG events focused on animal welfare, soil quality indicators and levers for healthy and sustainable food.

INRAE also contributed to Agreenium's application for the award of an Erasmus Charter for Higher Education (ECHE). ECHE approval for European and international cooperation allows Agreenium to take part in Erasmus+ 2022-2027 programmes for the incoming and outgoing mobility of higher education students and staff in the framework of initiatives like AgreenMob,

Agreenium's international research school (EIR-A) and other schemes.



ExcellencES programme

INRAE is a partner in 6 projects selected in the second call for proposals of the ExcellencES France 2030 programme. The Institute is involved in transformational projects at the universities of Rennes, Orléans, Corse Pasquale-Paoli, Reims Champagne-Ardenne, Claude-Bernard Lyon 1 and the COMUE of Toulouse.

Junior Professor Chairs

The first Junior Professor Chair positions were filled in 2022. These positions were created as part of the French law on research programming (LPR). Five researchers were recruited. Positions left unfilled in 2021 and 2022 will be open to recruitment in 2023 with 8 new projects. INRAE assigns these positions to actionable research programmes in highly competitive scientific fields and/or to understaffed disciplines. The Junior Professor Chair positions include an extensive teaching component: the equivalent of 42 hours of supervised teaching, around a quarter of the hours required of a teacher-researcher. These positions are an important part of our contribution to site policy.



Biopolymers Interactions Assemblies (BIA) Research Unit.
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Using our expertise to tackle societal challenges



INTERVIEW WITH

Patrick Flammarion

Deputy Director General of Expertise
and Support for Public Policies

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Two years after its launch, what has the new general directorate achieved?

We strengthened our role in guiding public policy design with the publication of two collective scientific assessments this year. We also reinforced our support role in implementing public policy, by developing facilities, centres and teams that provide a continuum of support for public policies (DPAPP) for the French ministries of agriculture and the ecological transition. The diversity of our public policy expertise and support activities, and their consistency with INRAE research activities, is an asset. As a result of efforts to promote these activities and raise awareness in scientific communities, the General Directorate for Expertise and Support for Public Policies (DGDEAPP) has rapidly become a key entry point on these issues in France and abroad. We also take part in addressing the links between science, society and public policy with the Joint Research Centre (JRC) of the Directorate-General for Research and Innovation (RTD): we co-organised a seminar for stakeholders. INRAE also took part in a course

for EAPP instructors. One instructor and two participants attended and were then tasked with teaching the course internally and in the French scientific community. INRAE is the main facilitator of a network of experience sharing launched in early 2022 by the directorate of support for public policies and composed of a dozen EAPP leaders at scientific and technical organisations and the Université Gustave Eiffel.

Our in-depth knowledge of stakeholders affords us an excellent position in terms of best practices and the credibility required to share them. Every year and in 2022, for example, we provided training to some 20 PhD students. We also organised a research school on collective scientific assessments (see box) and co-organised EAPP training with Aarhus University, the first of its kind at the European level. The recognition of this expertise has enabled us to build our relationship with the European Environment Agency (EEA), the European Food Safety Authority (EFSA), and FAO.

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Our in-depth knowledge of public policy issues and stakeholders affords us an excellent position in terms of best practices.

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What are the most important requests made by public authorities at the national level?

At the national level, we continue to develop a consistent relationship with national ministries and agencies. We took part in two forums on forestry and wood to address the need to adapt forests to climate change, and are involved in one third of the initiatives that resulted from these forums (see box).

Three framework agreements were signed: with the Agence de l'eau Adour-Garonne, to develop suitable policies for sustainable and equitable water management; with Andra, for the long-term monitoring of ecosystems and support for regional transition; and with Agence Bio, to address the issue of scaling up organic agriculture.

Is this role only national and international in scope?

At the heart of transitions, regions are 'fertile ground' in which to deal with topics such as water, soil, and agroecology. They also inspire our activities at every level. Regional mapping of these activities carried out by our directorate of support for public policies with INRAE research centres is an essential tool in building effective partnerships with regional public stakeholders and in relation to those in research and higher education. We are working to support INRAE teams in this process. ●

A forestry and wood forum: the Assises de la forêt et du bois

Launched by the French prime minister from October 2021 to March 2022, this forum brought together elected officials, stakeholders, scientists and non-governmental organisations to build tomorrow's forests. In a support role to the ministries of agriculture and the ecological transition, INRAE contributed significantly to discussions held on this occasion. It is a leader or partner in one third of the initiatives developed during the forum, the operational implementation of which is underway.

- Biodiversity: Vieux bois Plan and old-growth forests
- Adapting to climate change: mapping of areas subject to fire risk, choice of species for the future, forest reproductive material production, soil preservation, promotion of R&D initiatives, forest-game balance
- Low carbon certification: increase in the number of certified forestry projects
- Creation of French Wood Tech in conjunction with the French Agri Tech initiative supported by the Ministry of Agriculture
- Forest observation and monitoring: creation of an observatory (led by the Institut national de l'information géographique et forestière) (IGN)
- Strengthening research: the FORESTT priority research programme and infrastructure (PEPR) on forests and global change: socio-ecological systems in transition, led by INRAE

A Research School on collective scientific assessments

The INRAE Directorate of Expertise, Foresight and Advanced Studies teamed up with INSERM and IRD to host a researcher school on collective scientific assessments, which the three organisations have conducted for more than 20 years. Held in Lyon in June 2022, the event addressed the role played by scientific assessments in science and decision-making, and was an opportunity to share experiences, methods and insight with the goal of better meeting the different needs of decision-makers, civil society and scientists. At the heart of this course were the principles underpinning these activities and how they meet expectations. The event was appreciated by participants from a variety of institutional, disciplinary and geographical backgrounds. A comparison of procedures of the IPCC, ARC, IPBES, ANSES and for INRAE-INSERM-IRD collective scientific assessments demonstrated how each entity ensures the quality of its expertise and incorporates it in public action. This training event will be held again and is expected to expand.

Expertise and support for public policies



Crop protection and the impact of pesticides: insights from two collective scientific expert reports

As part of the French Ecophyto II+ programme, the French Ministries for the Ecological Transition, Agriculture and Research asked INRAE and IFREMER to produce a collective scientific expert report on the impacts of pesticides on biodiversity and ecosystem services from the point of application to marine environments in both mainland and overseas France. The report, published on 5 May 2022, is based on an analysis of over 4,000 publications in the international scientific literature by a committee of 46 experts and scientists from 19 public research organisations. The ministries also entrusted INRAE with a second report entitled "Protecting crops by increasing plant diversity in agricultural areas", published on 20 October 2022. For this report, 31 scientific experts analysed 1,900 scientific references, including 225 literature reviews.

is an important technique for reducing pesticide use. Varietal mixtures, species associations, crop sequences, agroforestry practices, hedges and other semi-natural landscape features help protect crops by supporting the natural regulation of pests and diseases, all without any major yield losses. Research is needed to better understand the combined effects of different practices to regulate several crop pests simultaneously. Modelling tools could be used for this purpose, along with remote sensing to improve monitoring of diversification practices. The report also noted several obstacles both upstream and downstream of agricultural sectors that hinder the implementation of these crop protection strategies, which could be more strongly incentivised by public policies. Such policies need to be both better designed and assessed.

Mitigating the environmental impacts of pesticides through plant diversification

The first report showed that pesticides are everywhere: in the air, soil, water and living organisms, with the most persistent substances found even in the deep seabed and polar regions. Agricultural areas near application points are the most contaminated. Pesticide use is one of the main causes of declining terrestrial and aquatic invertebrate and bird populations, and it is suspected of playing a major role in the decline in amphibians and bats. The impact of pesticides on micro-organisms disrupts the degradation of organic matter in soils and rivers. The ecosystem services of pollination and natural pest control are also inhibited. Further research is needed to better quantify the impact of these products and their combined use on the environment. Regulations, product-use practices and landscape structure (grass strips, hedges, landscape mosaics, etc.) are the typical levers that are pulled to reduce pesticide contamination and its impacts. But these measures will never fully protect biodiversity and should be considered in combination with other approaches.

The findings of the second report indicated that plant diversification

Food for thought and action for society

We announced the findings of the first expert report so that we could quickly raise awareness among European public authorities. The findings were presented on 11 and 12 May 2022 at a conference organised by the Ministry of the Ecological Transition as part of the French Presidency of the European Union, the aim of which was to map out a way forward to better account for biodiversity in the chemical-product risk assessments. ANSES, the French Agency for Food, Environmental and Occupational Health & Safety, also presented the European Partnership for the Assessment of Risks from Chemicals (PARC), which it coordinates. According to Sophie Leenhardt, project manager for the report on the environmental impacts of pesticides, the PARC was created to design "a next-generation assessment that is more protective". Anaïs Tibi, project manager for the report on plant diversity, noted that "the findings on the benefits of plant diversification, as well as those from the foresight study published in 2023 on the feasibility of pesticide-free European agriculture by 2050, aligned well with the timetable for negotiations on the European sustainable use of pesticides regulation (known as SUR), which will attempt to set binding targets for Member States in terms of reducing pesticide

Experimental agroforestry plot on the Restinclières estate, where a cereal crop (barley) is grown alongside a plantation of hybrid walnut trees.
©INRAE - B. Nicolas



use. The targets could then also be used during the annual review of the new CAP programme, which entered into force at the beginning of 2023."

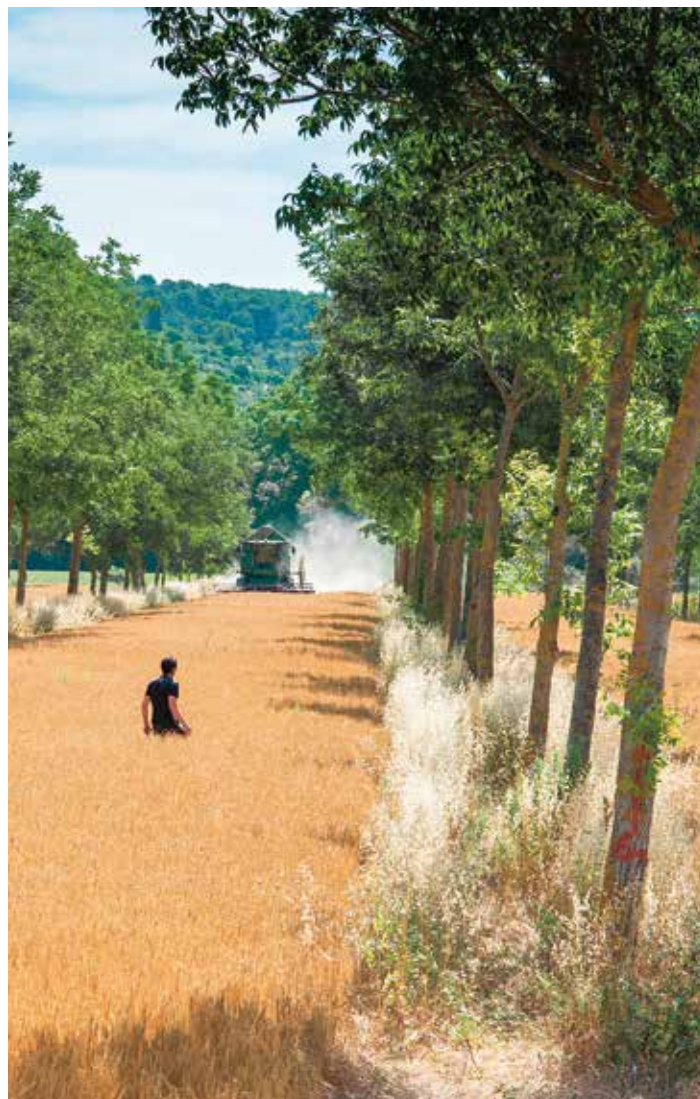
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Clarifying the state of knowledge available to French and European public authorities.

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Discussions with stakeholders and the 25 presentations given to date in response to requests from a wide range of associations, professionals and politicians are helping to disseminate the knowledge to society. The initial presentation of the INRAE-IFREMER report, which followed a press conference, led to over 300 mentions in the traditional media and more than 2,000 mentions on social media. The findings of the report on plant diversity were presented at a symposium attended by nearly a thousand people. This second event attracted media coverage mainly in the agricultural press. "Together, these topics are among the most widely covered in the media for INRAE in 2022," said Sandrine Vinzant, INRAE's Director of Communications.

"Such work also revitalises our research questions. Although the impact of these reports on public policy can only be seen with the benefit of a few years' hindsight, they have been unanimously praised by French and European public authorities for their ability to inform current decision-making," concluded Guy Richard, Director of Expertise, Foresight and Advanced Studies.



Partnerships and innovation



Following on from the Innovation Roadmap (2021–2024), an action plan was drawn up and implemented in 2022. The plan revolves around four priorities: to develop a culture of innovation within INRAE, to bolster partnership research, to optimise the use of research results (especially through our five Carnot networks), and to expand and promote business creation and ties with start-ups.

This has led to the consolidation of the 5th Carnot Institute, Water and Environment, run by INRAE, the strengthening of our collaboration with large companies (Lesaffre, Tereos), the continued development of associated partner laboratories with socioeconomic partners, and support in creating businesses.



More shared laboratories with our partners

Four new associated partner laboratories

Efforts to prioritise the creation of associated partner laboratories, which began in 2021, have resulted in a total of 9 such labs being established, with 4 new agreements signed this year. The goal is to have 30 of these labs by 2026. This new form of partnership has benefits for both sides. The partner can leverage the scientific excellence of INRAE's teams and state-of-the-art equipment to support its development, while INRAE is able to work with the partner on R&D and market access issues to produce new scientific questions. The results of their work are governed by a contract and may give rise to individual or joint publications and joint practical applications. The 4 new labs are tackling the integrated pest management of rapeseed and legumes, wastewater treatment, viruses in vines and the recovery of lignocellulosic fibres (e.g. flax and hemp).

The 4FM laboratory for biomaterials development

One way of developing the bioeconomy is to use plant fibres (flax, hemp, miscanthus, etc.) for new materials (e.g. insulation, concrete and textiles). But several scientific and technical hurdles must still be cleared when it comes to using such plant fibres. To overcome these issues, INRAE and the University of Reims Champagne-Ardenne (URCA), via the Fractionation of AgroResources and Environment joint research unit (UMR FARE), have joined forces with the Fibres Research and Development Research Centre (FRD) to create an associated partner laboratory called 4FM. The lab's key focus is to improve the quality of hemp fibres to standardise the processes involved in textile and composite processing.

Four new LabComs with SMEs

Funded by the French National Research Agency (ANR), LabComs bring together public-sector laboratories and SMEs. They structure the partnership around shared visions and strategies to produce and innovate sustainably. In 2022, 4 new LabComs involving INRAE were created, in the fields of agroecology, probiotics, gut microbiota and health, and digital transformations linked to the environment.



Supporting business creation

START And GROw encourages and supports start-up development

INRAE is stepping up its efforts to encourage the creation of companies to leverage its research results. The START And GROw programme seeks to increase the number of new start-ups by identifying and supporting entrepreneurs from ideation through to creation. The goal is to encourage innovation by creating or offering R&D support to 100 start-ups by 2026. START And GROw offers tailored support, with a twice-yearly call for applications: scientists wishing to take part attend group work sessions (on topics such as positioning, business models, pitches and action plans) before presenting their project to the START And GROw jury comprising experts in start-up support, funders, start-up studios and coaches.



A successful first Startup for Planet event

A brand new event designed to promote the innovations produced by start-ups linked to INRAE, AgroParisTech and the Institut Agro Montpellier was held in Paris on 27 September 2022. The event was attended by 320 innovation players (with 200 online), including development specialists, business angels and public investors,

who were able to discover the innovations of 17 agritech, foodtech and greentech start-ups. A round table with Bpifrance, Demeter, La Ferme Digitale and INRAE also provided an overview of agritech-greentech-foodtech investment trends. The next event will be held in 2024.



Philippe Mauguin,
Chair & CEO of INRAE
at the Startup for Planet event.
©INRAE

The AgriO consortium takes flight

AgriO – the French Tech Seed fund consortium founded two years ago and led by INRAE – is gaining traction. Nine new start-ups were accredited in 2022, bringing the total number of supported accredited start-ups since its creation to 32. The programme enables start-ups to receive public funding and increase their attractiveness to private investors. The consortium has also taken on two new partners, Shakeup Factory and Vegepolys Valley, and four certification experts. Progress on the action plan is monitored through regular meetings with a group of mentors. Seven start-up projects are being supported in the first year of START And GROw.



Public and private players work together on pre-industrial demonstrators to speed up innovation

Launch of the Ferments of the Future Grand Challenge

Fermentation offers exceptional potential for innovation as the world moves towards safer, healthier and more sustainable food. This is why the French government decided to invest €48.3 million in the Ferments of the Future–France 2030 Grand Challenge, coordinated by INRAE and ANIA. Ferments of the Future is a public-private ecosystem of 34 members linked by a consortium agreement. It includes a network of 7 research units and their facilities, as well as a project for an innovation platform at Saclay – the only of its kind in Europe – scheduled for the end of 2024. This challenge, which also receives private funding, was developed to support ambitious research projects. It will finance new research and innovation projects every year.



AgroTechnoPôle: an open innovation platform for agricultural equipment

The AgroTechnoPôle is a pre-industrial demonstrator designed to develop technological solutions to address agricultural challenges and speed up the agroecological transition. The aim is to lift scientific and technological barriers in 6 areas, including agricultural robotics, information systems and decision support. In particular, it will contribute to the “Agricultural Robotics” Grand Challenge led by the RobAgri association.

The AgroTechnoPôle consortium, which was formalised at the end of 2021, was officially launched by the platform’s 15 partners in June 2022 at the first meeting of its Steering Committee at the INRAE site in Montoldre (central France).



Evaluation of new technologies in controlled environments at the AgroTechnoPôle in Montoldre (Allier). ©INRAE / TSCF – P. Héritier



Joint Technology Units

In 2022, INRAE shored up its scientific and technical partnerships with 12 joint technology units (UMTs) that were newly certified or had their certifications renewed (valid for 5 years).

The UMT system works by having technical institutes and research and development organisations team up to cooperate on a joint R&D project.

For a list of INRAE joint technology units, see <https://www.gis-reliance-agronomique.fr/GIS-UMT-RMT/Les-UMT>

Four new joint technology units were approved in 2022 by the Ministry of Agriculture and Food Sovereignty.

UMT Become

Improving the welfare of small animals (rabbits, poultry, fish) by responding to public demands while supporting markets, sector competitiveness and the environment.

Partners

The French Technical Institute for Aviculture, Fish Farming and Rabbit Farming (ITAVI) and the French Poultry and Aquaculture Breeders Technical Center (SYSAAF), with the INRAE Avian Biology & Poultry (BOA) Research Unit.

UMT Ecotech

Identifying, validating and promoting ways to reduce the amounts of crop protection products used in viticulture by improving spraying techniques and practices, adapting doses to the needs of the plants to be protected and leveraging the potential offered by information and communication technologies to make applications safer.

Partners

The French Wine and Vine Institute (IFV) with the Technologies and Methods for the Agriculture of Tomorrow Unit (ITAP, INRAE and the Institut Agro Montpellier).

UMT FUP

Working on the sustainability of professional urban farms to “analyse the economic, technical and landscape challenges of these new forms of agriculture and anticipate their impact on the renaturation of urban areas to ensure their ecological transition”.

Partners

ASTREDHOR, ITAVI, ENSPV and AgroParisTech with the Science for Action and Sustainable Development: Activities, Products, Territories Joint Research Unit (SADAPT-INRAE, AgroParisTech, Paris-Saclay University).

UMT STAR

Focusing on the issues raised by the climate challenge for livestock farming in the three small-ruminant sectors (goats, suckler ewes and dairy sheep), and especially the water stress suffered by animals and the availability and variability of feed resources.

Partners

The French Livestock Institute (IDELE) with the INRAE Genetics, Physiology and Livestock Systems Unit (GenPhySE).



Life at the institute

GrapeVine Resistance team, Joint Research
Unit for Grapevine Health and Wine Quality
in Colmar.
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A commitment to corporate social responsibility



INTERVIEW WITH

Fabrice Marty

Deputy Director General of Resources*

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INRAE launched a corporate social responsibility strategy in 2020. Given the many challenges society faces, what concrete steps has INRAE taken to bring this ambition to life?

The Institute is working to reduce its ecological footprint and increase the positive impact of its activities on the environment and society. This is one of the major policy directions set out in the INRAE2030 Strategic Plan. This policy direction has become a core objective for the entire Institute. INRAE has set up a robust governance and organisational structure, at both national and local levels, to be able to integrate its full range of activities and launch initiatives that can address the needs of its sites as quickly as possible.

By 2021, the foundations had been laid with the creation of a dedicated department (the CSR office) and a network of local CSR managers in the centres. The momentum grew in 2022, with the roll-out of the CSR Action Plan in February following its approval by the Management Board. The plan includes objectives, proposals for action and a method (known as "INRAE low carbon") for developing the Institute's carbon trajectory to achieve

carbon neutrality by 2050.

The Management Board, which represents the interests of both policy support and science, is fully committed to the approach. The board's efforts to ensure that decisions are made on a concerted basis have been strengthened by the creation of a CSR Steering and Monitoring Committee of 18 members, a third of whom are partners and experts in their fields. The CSR committee tackles emerging topics within the Institute and issues opinions on key projects, such as the low-carbon trajectory, challenges on the use of plastics and long-distance mobility requiring air travel. The committee began its work in January 2022 and has since assessed the various CSR incubator projects, which are a powerful way to get staff involved and produce innovative projects to drive this approach forward.

How do you plan to roll out the system across the Institute?

In March 2022, the CSR office began visiting France's centres to discuss CSR issues and garner support by speaking with the local management teams and support staff, with other staff during centre-wide meetings

“

Beyond a rigorous method, success depends on getting everyone to be actively involved in a shared culture.

”

and, finally, with the main academic partners. The CSR strategy has been fully integrated into the 2022–2026 centre plans.

In addition to the essential awareness-raising and advocacy activities, indicators for monitoring INRAE's CSR plan had to be developed so it could be adjusted as necessary and keep things on track.

The experimental units have done groundbreaking work to ensure that their activities and facilities comply with environmental regulations so

* Until May 2023

as to reduce their negative impact and increase their positive impact, in particular through the environmental management approach. Building on this experience, other types of pilot units will be joining the efforts. INRAE researchers have special expertise in biodiversity protection, in food and, of course, in the area of low-carbon trajectories, which is a boon to developing the Institute's ambitious plans.

What is the key factor of success when implementing a CSR strategy?

Beyond a rigorous method, success depends on getting everyone to be actively involved in a shared culture. This requires regular communication, outreach and training for everyone, both within and outside the Institute. INRAE's efforts and progress in the area of CSR must be constantly made visible. Openness and transparency make up the third pillar of our plan, alongside consistency and commitment. Throughout 2022, there were regular communication campaigns (a biodiversity festival, a week-long event on quality of life at work, a disability week, start-up incubator

projects, etc.), awareness-raising campaigns (energy savings, digital housekeeping, etc.) and training initiatives. For example, the CSR office, together with the HR Department and its continuous learning team, have identified and included CSR issues in the Institute's skills development plan, both through job-related training and specific training, such as supporting greater energy efficiency, especially for the directors of experimental units who are responsible for energy-intensive facilities.

How can energy-related uncertainties be taken into account?

With the situation that arose in autumn 2022, it was crucial for each and every one of us to do our part, hence the importance of focusing on awareness-raising initiatives and sharing experiences to ensure the widespread adoption of good practices. In line with the government's guidelines, INRAE launched a national energy efficiency plan, backed up by energy management plans drawn up by each centre, to enable the Institute to trim its energy consumption by 10% by 2023 over 2021 levels.

Thanks to the work of the ad hoc "energy" teams and coordination meetings with the various involved networks, the results are already encouraging in terms of the Institute's overall consumption, which is proof that the efforts are paying off and that we are on the right path. These efforts are contributing to the INRAE low-carbon trajectory, in line with the targets set by the French Ministry of Higher Education and Research in its Climate-Biodiversity and Ecological Transition Plan to reduce greenhouse gas emissions.

Work on creating the low-carbon trajectory began in late 2022 and will continue throughout 2023, buoyed by the participatory process to ensure widespread involvement and support. ●



Promoting CSR

The Institute's CSR strategy applies to all its activities and is centred around a participatory process, strong involvement and tangible results.



An energy efficiency plan shows encouraging initial results

In early 2022, INRAE conducted energy mapping of all its buildings (more than one million square metres spread over 2,200 buildings). This initial inventory identified the most energy-intensive buildings and experimental facilities.

The energy mapping served as the backbone for INRAE's energy efficiency plan, which was drawn up in response to the government's request to achieve a 10% reduction in energy consumption by 2023. Three pillars underpin this plan: optimising technical operations, streamlining the use of premises and equipment while maintaining activities, and raising occupants' awareness of energy use.

At the end of the year, each of INRAE's 19 centres submitted its energy management plan, a local version of the national plan adapted to each centre's geographical and environmental context and activities. As a result of everyone's efforts, certain

research practices have been revised to limit their energy impact (reorganisation of ultra-cold sample storage methods, rescheduling of autoclaving cycles, shared use of scientific equipment).

The initial results are encouraging, with a 10% reduction achieved in 2022 compared with 2021 consumption levels (-15% before correcting for winter severity), even though the measures were only implemented in the last quarter.

In addition to the energy efficiency plan, an investment programme was launched in 2021 with 54 projects receiving €14 million in funding as part of the French stimulus plan. Another €1 million will be added to the budget for 19 new projects.

These investments are earmarked for insulating buildings, improving heat distribution and control systems, replacing boilers and installing photovoltaic panels.



IN BRIEF

A Sustainable Procurement Plan for 2022–2025

The 2022–2025 Sustainable Procurement Plan follows all the guidelines of the Institute's CSR policy. More specifically, it:

- Introduces a set of environmental and social clauses (including the Alliance certification) in tender documents, which apply to extended warranties (for computers and telephones), short supply chains for institutional food services, and calculations of the CO₂ equivalent of services and deliveries.
- Includes sustainable development criteria in the tender analysis tables, which could cover, for example, the energy consumption of scientific equipment.

The Sustainable Procurement Plan will be monitored using specific indicators. In 2022, INRAE will appoint an EGalim consultant to oversee the implementation of the provisions of the French EGalim law in institutional food services contracts. The EGalim law aims to balance trade relations in the agricultural sectors but also to allow healthier and more sustainable food.

An ambitious carbon policy: from an initial assessment to a low-carbon institute

Following an **initial greenhouse gas (GHG) emissions assessment** (known as BEGES) carried out in 2020, the CSR office developed and launched a decision-making tool in 2022 called "**StopGES**" (referring to the French acronym for GHGs). The aim is to enable INRAE units to identify the GHG emissions linked to their activities and the actions to be implemented in three stages: a self-assessment approach, reduction options and possible actions.

The StopGES tool offers a module for assessing the impact of the planned reductions with a view to raising awareness about the relevance of actions, prioritising them and even balancing between different possible strategies. StopGES has been successfully tested in pilot units and is now being offered to the units, with support from CSR managers at each centre on awareness-raising, diagnostics and the operational phase. Moreover, in order to create an ambitious, realistic and shared low-carbon trajectory, preliminary efforts were deemed necessary to identify the obstacles to be removed, ways to balance the costs and benefits, and the consequences for the research activity as well as to assess the Institute's operations, drawing on the driving force of this meaningful approach.

The Assessing low-Carbon Transition® (ACT) method, offered by the French Agency for Ecological Transition (ADEME), was chosen as the basis for this work. It will provide a framework for study based on an approach that has been tried and tested on an international scale. Meanwhile, a participative process will be established to consider INRAE's future by first identifying long-term goals (2050) before then developing medium-term (2030) and short-term (2025) actions. ADEME

is working with INRAE, as a pilot organisation, to adapt this method to a public research organisation.

Mobility plan

INRAE has taken steps to meet its obligations to draw up a **mobility plan** and report annually on indicators showing its investment in this area via the Eco-responsible Public Services scheme. The Institute must also have a mobility coordinator. Each centre has received a national guide on sustainable mobility so they can draw up their own sustainable mobility plan.

Additionally, a new **sustainable mobility package** for staff to encourage soft mobility, efforts to **pool INRAE's vehicle fleets** and recommendations governing certain modes of energy-intensive transport are all tools to help lower the carbon impact of our activities and the pollution associated with them.





An in-house project incubator

A **CSR project incubator** was launched in February 2022. The first call for projects was a resounding success, with 46 projects submitted from 17 centres.

Projects were assessed by the CSR Steering and Monitoring Committee, which prioritised innovative concepts, risk-taking and potential for dissemination, rather than the project size. The Assets and Property Directorate and the Human Resources Directorate were consulted on some of them. The opinions of the CSR committee were submitted to central management for final approval. Once the projects have all been evaluated, 24 projects will be funded with a total budget of around €280,000.

➤ The CADI project: a participatory approach to institutional food services issues

Healthy food that contributes to environmental protection is a key priority for INRAE and the CADI project. Spearheaded by the Centre for Taste and Feeding Behavior (CSGA) at the Burgundy-Franche-Comté centre, the project is attempting to identify research findings that can support the centre's needs in institutional food services. On the basis of the existing regulatory framework in France (EGalim and Climate and Resilience laws), CADI worked with customers to identify 4 priority areas on which to focus improvement efforts: offering quality products, diversifying protein sources, combating waste and eliminating the use of plastic. The project is therefore organised around 4 thematic working groups, responsible for collaboratively determining experiments, implementing them with the catering industry and evaluating the results using sets of indicators.

➤ The SUNFRISE project: using the sun for cold production

One of the challenges the SUNFRISE project is grappling with is achieving greater efficiency by lowering the energy consumption of experimental equipment. The project is headed up by the FRISE unit (Île-de-France - Jouy-en-Josas-Antony Centre), which specialises in refrigeration engineering. The unit's focus is on reducing the environmental impact of cold production systems, and specifically a cold room with autonomous energy requirements. The project is working to equip a cold room with a regulated cooling system that draws on solar energy from photovoltaic panels or solar thermal panels.

These new technologies could have many positive impacts, such as reducing energy consumption costs, implementing environmentally friendly cold production that could be extended at INRAE, and developing an area of research within the unit on the integration of renewable energies.







Dedication to a high quality of life at work

In line with the Institute's social ambition, INRAE's drawing power and quality of life at work are key priorities in the Human Resources roadmap for 2021–2025. New measures have been put in place to improve the way work is organised, ensure cohesion between teams, provide robust risk prevention measures and support our employees as they build their career paths through attentive management and formal processes.





For INRAE, drawing power involves not only attracting new skills but also building loyalty

As such, in 2022 the HR Department and the Communications Department began working on the Institute's employer brand to enhance its drawing power. The aim is to highlight what makes a career at INRAE meaningful, both with regard to the Institute's research activities and its teams. Today, ensuring that the available professional opportunities and HR services (career development, social support, health protection, etc.) are more visible is essential to building employee loyalty and raising our profile. These efforts were well reflected in the 2023 recruitment campaigns.



INRAE seals its reputation with a dual diversity and equality certification

The Institute's diversity and equality in the workplace policy aims not only to combat discrimination and stereotypes, but also to harness diversity as a driver of innovation, creativity and organisational performance. As a result, the dual diversity and equality in the workplace certification awarded to several INRAE pilot centres from 2020 has now been extended to all centres. INRAE is pursuing its existing initiatives while continuing to be inspired by external networks with its counterparts in other research organisations and associations such as the AFMD (French association of diversity managers) and Femmes et Sciences (Women in Science).

At the end of 2023, the Institute will undergo an audit to renew its certification.



Clara Tremberth, INRAE 2022 Research Support Award.
Clara works in the Directorate of Partnerships and Innovation Transfer (DPTI), which is involved in setting and implementing the Institute's innovation policy.
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IN BRIEF

INRAE renews its partnership with the French National Agency for the Improvement of Working Conditions (ANACT) to prevent psychosocial risks and promote quality of life at work

INRAE is receiving support to create an action plan for psychosocial risk prevention. This partnership, which relies on a revised and simplified method, will increase the professionalism of local resource persons within INRAE's research centres while promoting improved quality of life at work.

INRAE Management Charter: clarifying our organisational structure

Following numerous discussions initiated in the spring of 2021 and extensive work between centre presidents and division heads, INRAE's first management charter was finalised in 2022. The charter reaffirms the central position of the units as the foundation of the Institute's scientific, technical and administrative organisational structure and recognises them as key contributors to INRAE's strategy and its implementation. Among other things, this charter acknowledges the place and role of the line managers and confirms the stability of our organisation – which is driven by shared values and a management team that upholds them at the highest level – within a constantly changing environment.





ETHICS AND SECULARISM

INRAE's unwavering attention to ethics and rights continued in 2022 with its reorganisation efforts, communication initiatives and awareness-raising activities on these issues.



Building momentum around ethics, professional conduct and scientific integrity

The joint INRAE-CIRAD-IFREMER-IRD ethics advisory committee, now known as the Ethics in Common Committee, enjoyed a swell of fresh momentum in 2022, which enhanced its visibility and led to increased acceptance of its work. Its new website offers researchers a way to better connect with the committee.

www.ethique-en-commun.org

- The committee also issued two opinions under the common heading of "Human needs, natural resources and preservation of the biosphere": one on "**Pollution and competing uses of water**"
url.inrae.fr/43IV50T
- and a second on "**Agricultural practices and soil quality**".
url.inrae.fr/3KshgKz

In 2022, key steps were taken to apply ethical thinking at the research project scale to support teams in being able to fully address ethics issues and assess any projects with such needs. First, a self-assessment process for project leaders was implemented, and second, a new ethics committee for agriculture, food and environment projects met for the first time in October 2022.

ec éthique
en commun





Secular advisor

On 1 July 2022, Clara Bacchetta became the Institute's first secular advisor. Her role is to advise department heads and employees on implementing the principle of secularism, namely by analysing and responding to requests regarding individual situations or general issues. She will also work to raise awareness of the principle of secularism among INRAE staff and disseminate information about this principle. Finally, she will contribute to INRAE's participation in the national secularism day on 9 December each year.

LES LAURIERS INRAE



Six awards were handed out on 29 November 2022 at a ceremony attended by Marc Fesneau, the French Minister for Agriculture and Food Sovereignty. The international jury honoured five outstanding researchers and one team for the excellence of their work and its impact on society.



Thierry
Candresse

Lifetime Achievement Award

Thierry, one of the world's leading specialists in fruit-tree viruses, took an early interest in virus sequencing and plant metagenomics. His work is paving the way to promising alternatives to pesticides. "Viral diversity is without parallel in the rest of the natural world. Viruses have no common denominators," says Thierry.

Research Director, Virology Team, Joint Research Unit for Fruit Biology and Pathology, Nouvelle-Aquitaine-Bordeaux Centre



Grapevine Resistance Team

Science with an Impact Award

How can we produce grapevines that are naturally resistant to disease without chemical treatments but still produce quality wines?

The members of the Grapevine Resistance team have been working on genetic improvement for 20 years to develop sustainable viticulture. They have created and registered nine new grapevine varieties that are resistant to downy and powdery mildew, resulting in significantly fewer fungicide treatments.

The Grapevine Resistance team includes agronomists, geneticists, pathologists and oenologists working together from several units at the Grand Est-Colmar, Nouvelle-Aquitaine-Bordeaux and Occitanie-Montpellier centres.



Clara Tremberth

Research Support Award

Clara works to strike the best possible balance between protecting inventions and disseminating them. She also deals with transferring knowledge to support research and innovation.

Head of the Common Department for Contract Engineering, Head Office, Paris-Antony



Didier Azam

Innovation Award

Didier's research on wild and farmed fish informs new management measures for aquatic species and their environments.

Director of the Aquatic Ecology and Ecotoxicology experimental unit (U3E), Brittany-Normandy Centre



Sophie Nicklaus

Scientific Breakthrough Award

Sophie's research into eating habits aims to promote healthy, sustainable eating and contribute to food sovereignty in the Dijon area.

Research Director, Centre for Taste and Feeding Behavior, Burgundy-Franche-Comté Centre



Claire Berton-Carabin

Promising Researcher Award

Claire draws on the potential of plant proteins to stabilise food emulsions and develop processing methods with low environmental impact.

Research Director, Biopolymers, Interactions and Assemblies (BIA) Unit, Pays de la Loire Centre





Our distinguished scientists



French Academy of Agriculture Awards

Fourteen INRAE researchers received awards in 2022 from the French Academy of Agriculture.

Three INRAE scientists were honoured with a gold lifetime achievement award.

Abdelhafid Bendahmane, Research Director at the Institute for Plant Sciences, is an international expert in plant genomics and breeding. **Nicole Darmon**, Research Director at the Montpellier Interdisciplinary Center on Sustainable Agri-Food Systems (MoISA), has spent her career conducting research aimed at combating social inequalities in health by promoting sustainable food and nutritional security. **Michèle Tixier-Boichard**, coordinator of the RARE research infrastructure and the platforms team for the Animal Genetics and Integrative Biology unit, works to collect, characterise, conserve and distribute biological resources that are useful for agronomic research.

Four silver-gilt awards recognised emerging research with the potential to have a major impact: **Christian Le Lay**, from the Soil Science Research unit, whose work in soil observation, mapping and micromorphology has led to knowledge transfer to farmers; **Philippe Pinton**, from the Food Toxicology unit, who is developing tools to analyse the effects of food contaminants; **Véronique Souchère**, an agronomist from the SADAPT unit,

whose research deals with methods for organising activities at the regional scale and on participatory research approaches that combine agricultural production and environmental protection; and **Marie-Christine Daunay**, from the Fruit and Vegetable Genetics and Breeding unit, who focuses on the genetic resources of vegetable species.

Seven Dufrenoy silver awards were awarded for these defended the previous year:

Aurore Beral completed her PhD on the genetic and ecophysiological determinism of the variability of individual grain weight in common wheat. **Étienne David** uses digital technology in plant breeding.

Ronan Griot was honoured for his thesis on genomic selection and the genetic determinism of susceptibility to infectious diseases in sea bass and sea bream.

Juliana Melendrez Ruiz was recognised for her work on the mechanisms underlying the choice of foods rich in plant proteins.

Muhammad Tanveer Munir's research centres on the convergence of the fields of wood science and microbiology. **Alexis Porcher's** thesis shows the importance of taking into account the oxidative metabolism of the axillary bud in the adaptation of plants to climate change.

Simon Vonthron's thesis analyses food practices in the Montpellier metropolitan area and looks at issues of food insecurity and food justice.



Chevreul Award

Marie-Caroline Michalski, Research Director at the CarMeN laboratory, received the 2022 Chevreul Award from the French Society for the Study of Lipids for her excellent scientific work in the field of human nutrition and lipids.

Étoiles de l'Europe Trophy

René Baumont received the Étoiles de l'Europe (Stars of Europe) trophy – Innovation category for the SmartCow project (see page 68).

Carnot Prize

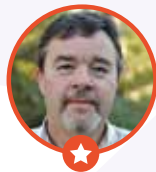
Christian Jay-Allemand (University of Montpellier) and **Luc Bidel** (INRAE), researchers at the Agropolymer Engineering and Emerging Technologies (IATE) unit (part of the Carnot 3BCAR network), won the first Carnot Grand Prize for Partnership Research for their project on selective ecoextraction of active biomolecules (ESBAC).

Ecoantibio Prize

Jing Jing Liu, a doctoral student at the Therapeutic Innovations and Resistance (InTheRes) laboratory, was awarded the Ecoantibio 2022 research prize for her work on the destruction of staphylococcal biofilms.



Abdelhafid
Bendahmane



Christian
Le Lay



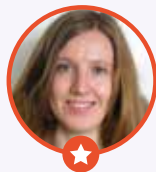
Philippe
Pinton



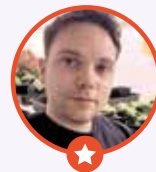
Véronique
Souchère



Nicole
Darmon



Aurore
Beral



Alexis
Porcher



Simon
Vonthron



Marie-Caroline
Michalski



René
Baumont



Luc
Bidel



Michèle
Tixier-Boichard



Jing Jing
Liu



More efficient and responsible communication

This year marked a return to normal for the Institute's various in-person events, with the 2022 Paris International Agricultural Show at the top of the list. Thematic, informal gatherings were tried out to allow for more open scientific mediation between INRAE and its audiences. This format proved quite popular and will be continued for future events. The past year was also an opportunity to get back to basics as well as to develop and improve communications to support the Institute's scientific and general policy priorities.



Methods, tools and approaches for communications engineering

The **professionalisation** objective set for the Communications Department (as well as for INRAE more broadly) has been a focus of work with the national continuing training team, which is planning a training scheme for 2023 as part of the skills development plan. The goal is to make the various communication positions and communicators more professional, whether communication is their full-time job or an occasional task they must handle. The scheme will be rolled out across the entire Institute for the first time in 2023.

In 2022, the Communications Department worked to **improve the digital accessibility of the inrae.fr and jobs.inrae.fr websites** following an audit conducted in November 2022. This improvement initiative was launched following the diagnostic phase of an external audit. The initiative has enabled the necessary upgrades to be made (e.g. a more accessible navigation menu, a naming convention for PDF downloads, the optimisation of information

associated with links and alternative text for images). Although changes are still being made, both sites now have a certificate of compliance, with an average compliance rate of 87.7%, whereas the jobs.inrae.fr site, which had never been audited, was deemed non-compliant at the time of the audit.



Consolidating and building loyalty among our target audiences by offering new formats and approaches

One of the challenges the Communications Department must contend with is staying current and using new formats to bring the knowledge produced by INRAE to the public. In 2022, a new format, known as "Decoding", was launched to share new findings with the press. Designed as a summary report released alongside a press conference (available as a replay), it offered useful insights into the subjects of fires (June) and floods (November). In addition to dedicated special events (11 press conferences and field/lab visits), INRAE launched a monthly newsletter for the press in January 2022, called "Le fil d'INRAE", which saw a strong response. Efforts to bolster INRAE's reputation is paying off, as more than 85% of people now recognise the organisation's name.

To build on the positive trend in the number of visits to our website, which is up by more than 10% compared with 2021 for pages in French, additional measures are being taken to improve our referencing and diversify our formats to enhance the visibility of our regularly updated topics and dossiers. The digital version of Ressources magazine, which was successfully launched in 2021, has proved to be an excellent means for promoting our thematic dossiers among the general public. These dossiers, produced largely by our in-house editorial team, are among the most popular on social media and our website.





Rolling out our international communications strategy

In March 2022, the Communications Department adopted a new communications strategy for Europe and the rest of the world, in line with the Institute's overall strategy. This communication plan, which is designed to support structured communication with the international scientific community, has taken shape through communication initiatives at major international events. These types of events, which have increased INRAE's international visibility, included the World Water Forum in Dakar, the French Presidency of the Council of the European Union, and the United Nations Biodiversity and Climate Change conferences held in the autumn. One of INRAE's top priorities has been to raise its profile with regard to its involvement in major global issues. One way it has done so is to explain its activities in a web documentary that provides a chronological account of major events and INRAE's contributions at each stage of efforts to establish global environmental governance, from 1972 to 2022. The digital version of the *Ressources* magazine in English has been promoted to our community through a new monthly newsletter since October 2022 that covers a single dossier.



Raising awareness of our CSR commitments: an internal communication priority

In line with its corporate social responsibility (CSR) strategy and action plan, INRAE offered various initiatives and events in 2022, both nationally and in the centres, and attracted the interest and support of its employees. For example, the national intranet news item published to mark the Energy Week was the most-read news item since the intranet site was created in 2019 (3,750 visits). Awareness-raising and communication campaigns (serious games, webinars, local events) have been carried out in various areas, such as the European Week for Waste Reduction (focusing on electronic waste) and equality and diversity (feature portraits, videos). Campaigns have also sought to promote INRAE's social actions (promotion of the ADAS policy, social assistance in conjunction with the HR department, etc.). Additionally, the network of communicators held a meeting on 10 May 2022 to learn about the keys to responsible communication.



Increasing communication on innovation

INRAE bolstered its innovation policy in 2017. To make innovation at the Institute more visible and clearer to our partners, and especially our socio-economic partners, INRAE developed a specific communication campaign based on the "Innovate with INRAE" brand. Our innovation community is particularly active on social media. A first event was held in September 2022 to showcase our current and future businesses and connect scientists, investors and public sector stakeholders. Given its success, it will be repeated every two years going forward.





GOVERNANCE

and key figures





Governance



Board of Directors

Composition as of 31 December 2022

President

Philippe MAUGUIN, Chair and CEO of INRAE

State Representatives

- Benoit BONAIME, Director General for Higher Education and Research, Ministry of Agriculture and Food Sovereignty
- Marion BARDY, Deputy Director of Research, Innovation and International Cooperation, Directorate-General for Education and Research, Ministry of Agriculture and Food Sovereignty (alternate)
- Cyril MOULIN, Deputy Director of the Research and Innovation Strategy Department, Ministry of Higher Education and Research
- Anne PUECH, Ministry of Higher Education and Research (alternate)
- Diane SIMIU, Deputy Director to the General Commissioner for Sustainable Development, General Commission for Sustainable Development
- Thierry COURTINE, Head of Research and Innovation, Ministry for the Ecological Transition (alternate)
- Agathe ROLLAND, Head of the Office of Research and Higher Education at the Directorate of the Budget, Ministry of Public Action and Accounts
- Edouard LE METAYER, Third Subdirector of the Directorate of the Budget, Ministry of Finance (alternate)

Representatives of public higher education or research institutions

- Elisabeth CLAVERIE DE SAINT-MARTIN, CEO of CIRAD
- François ROCHE-BRUYN, Director General of AgroSup Dijon

Members chosen for their knowledge in the agriculture, environment and food sectors

- Paul-Joël DERIAN, Director General Innovation, Research and Sustainable Development, Avril Group
- François ENGUEHARD, Time for the Planet
- Anne-Claire VIAL, President of ATCA, Agricultural Technical Institutes

Labour and Economic Sector Representatives

- Dominique CHARGE, President, Coopération agricole
- Annabel FOURY, National Secretary, FGA-CFDT

Members representing approved consumer protection associations and approved environmental protection associations

- Marie-Claude FOURRIER, Head of the Consumer Affairs Office, French National Association for Consumer and User Rights
- François LETOURNEUX, Honorary President, French Committee of the International Union for the Conservation of Nature

Elected Staff Representatives

Full Members

Dominique DESBOIS, CFDT
 Elisabeth TABONE, CFDT
 Pascale MAILLARD, CGT
 Eric LATRILLE, CGT
 Baptiste HAUTDIDIER,
 SUD Recherche EPST

Alternate Members

Anne DE LA FOYE, CFDT
 Jean-Marc BONNEFOND, CFDT
 Michel BERTRAND, CGT
 Laurence ARTIGE, CGT
 Fabrice GUIZIOU,
 SUD Recherche EPST



Scientific Advisory Board

Composition as of 31 December 2022

President

Philippe GILLET, Professor at the École polytechnique fédérale in Lausanne (EPFL), Switzerland

INRAE Members

- Philippe MAUGUIN, Chair and CEO of INRAE
- Carole CARANTA, Deputy Director General of Science and Innovation

Ex-Officio Members

- Ministry of Higher Education and Research: Lise FECHNER, full member, or Alain LAGRANGE, alternate
- Ministry of Agriculture and Food Sovereignty: Marion BARDY, Deputy Director for Research, Innovation and International Cooperation, full member, or Sofia MLALA, alternate
- Ministry for the Ecological Transition: Gwenaëlle HELLO, Deputy Director for Research, full member, or Céline COUDERC-OBERT, alternate

Nominated members

By ministerial order of 9 November 2020, the Ministers for Agriculture and Research appointed the following persons:

- Philippe GILLET, Professor at EPFL (Switzerland), President of the Scientific Advisory Board
- Valérie ARCHAMBAULT, Deputy Director for Research in charge of industrial partnerships, MINES ParisTech – PSL
- Sylvie BAUDINO-CAISSARD, Director of the Plant Biotechnologies Laboratory, University of Saint-Étienne
- Antoine BAULE, CEO of Lesaffre
- Patrick CARON, Vice President of International Relations at the University of Montpellier
- Jérôme CHAVE, Deputy Director of the Evolution and Biodiversity Joint Research Unit at CNRS/Paul Sabatier University
- Cécile CLAVEIROLE, Policy Officer for agricultural issues at France Nature Environnement
- Anne-Charlotte DOCKES, Head of the Livestock Trades and Society Department at the French Livestock Institute (IDELE)
- Thierry DORE, Head of research policy at Paris-Saclay University
- Teresa FERREIRA, Professor at the Department of Natural Resources of the University of Lisbon, Portugal
- Elisabeth GRAF-PANNATIER, Member of the management staff of the Swiss Federal Institute for Forest Snow and Landscape Research WSL in Birmensdorf, Switzerland
- Sophien KAMOUN, Professor at The Sainsbury Laboratory, Norwich University, UK

- Thierry LEFRANCOIS, Director of the Biological Systems Department (BIOS), CIRAD
- Xavier LITRICO, Research and Scientific Director, SUEZ Group
- Eveline VOLCKE, Professor of process engineering at Ghent University, Belgium

Elected INRAE Members

Sector 1: Agroecosystems, Mathematics and Digital Technologies

Wolfram LIEBERMEISTER (full member)

Marie-Anne LAUNAY (alternate)

Sector 2: Ecology and Biodiversity, Aquatic Ecosystems, Water Resources and Risks

Philippe ROZENBERG (full member)

Christelle GRAMAGLIA (alternate)

Sector 3: Plant Biology and Breeding, Variety and Seed Study and Control Group (GEVES)

Juliette SALVAING (full member)

Denis LECLERCQ (alternate)

Sector 4: Plant Health and Environment

Benoit FACON (full member)

Louise VAN OUDENHOVE (alternate)

Sector 5: Food, Bioproducts and Waste

Nathalie GONTARD (full member)

Thierry BENEZECH (alternate)

Sector 6: Animal Physiology and Livestock Systems

Denise AUBERT (full member)

Christophe GAUTHIER (alternate)

Sector 7: Animal Genetics, Animal Health

Claude CHARVET (full member)

Sandrine TRUCHET (alternate)

Sector 8: Human Nutrition and Food Safety; Microbiology and the Food Chain

Jean-Paul LALLES (full member)

Emmanuelle MAGUIN (suppléante)

Sector 9: Economics and Social Sciences, Action and Transitions

Marie THIOLLET-SCHOLTUS (full member)

Vincent MARTINET (alternate)

Sector 10: Research Support Services

Christine CHARLOT (full member)

Bruno COTTE (alternate)



Union Observers

Each union organisation represented on the Institute's technical committee can designate a representative to attend Scientific Advisory Board meetings as an observer.

CFDT: Dominique DESBOIS

CFTC: Bruno PONTOIRE

CGT: Jean-Louis DURAND

SUD: Cyril DUTECH



Specialised Scientific Commissions (CSS) and their presidents

CSS 1: Agronomy, Livestock, Forestry
Eric MALEZIEUX

CSS 2: Biology of Host-Pest Interactions, Symbionts and Commensals
Daniel BARTHELEMY

CSS 3: Integrative Plant Biology
Emmanuel GUIDERDONI

CSS 4: Ecology, Population Biology and Ecosystem Dynamics
Philippe USSEGLIO-POLATERA

CSS 5: Plant and Animal Genetics
Pierre BOUDRY

CSS 6: Mathematics, Informatics, Digital Science and Technology,
Artificial Intelligence and Robotics
Etienne BIRMELE

CSS7: Microbiology, Microbial Ecosystems, Agri-Food Systems,
Biotechnologies
Christophe JUNOT

CSS 8: Nutrition and Toxicology
Christophe MAGNAN

CSS 9: Animal Biology
Claude DUCHAMP

CSS N°10: Environmental Sciences: Earth, Water and Atmosphere
Anne-Catherine FAVRE

CSS 11: Food Science and Engineering, Materials Science, Biobased
Products and Waste-to-Resource
Etienne PAUL

CSS 12: Economic, Social and Management Sciences
Jean-Philippe TROPEANO

CSS 13: Research Support and Steering
Philippe MAUGUIN



INRAE-CIRAD-IFREMER-IRD Ethics in Common Committee

Ethics in Common Committee Members

Michel BADRÉ, President of the Committee

Graduate engineer from the École Polytechnique – École nationale du Génie rural, des Eaux et des Forêts. Member of the Economic, Social and Environmental Council, in the group of environmental associations.

Bernadette BENSAUDE-VINCENT, Vice President of the Committee
Professor emeritus at the University of Paris 1 Pantheon-Sorbonne, Professor of Philosophy and Doctor of Arts and Humanities.

Madeleine AKRICH, Research director and graduate engineer at MINES ParisTech (Center for the Sociology of Innovation – CSI), and Doctor of Socioeconomics of Innovation.

Bernard BRET, Specialist in Latin America with a particular focus on Brazil. Former professor at Lyon 3 University.

Catherine BOYEN, CNRS research director, Doctor in Plant Biology, Director of the Roscoff Marine Station – research and training centre in marine biology and ecology, Sorbonne University-CNRS (marine biology, algae, genomics, evolution, microbiomes, marine biodiversity, and marine biotechnology).

Denis COUVET, Professor at the Muséum National d'Histoire Naturelle (MNHN), president of the French Foundation for Biodiversity Research (FRB), associate professor at the University of Lausanne and at SciencesPo Paris, graduate engineer in agricultural sciences, Doctor in evolutionary science and ecology.

Mireille DOSSO, Director of the Pasteur Institute of the Ivory Coast, professor of Microbiology.

Mark HUNYADI, Professor of Social Philosophy and Politics at the Catholic University of Louvain, associate professor at the Institut Mines-Télécom Business School and at EHESS-School for Advanced Studies in the Social Sciences, member of the Ethics Committee at Orange, member of the strategy committee and of the steering committee of the Forum Vies Mobiles.

Youba SOKONA, Professor, 40 years of experience in the field of water, energy, environment and sustainable development in Africa. Has participated in the IPCC's work since 1990 and was elected Vice-Chair of the IPCC in October 2015. Has since been the co-founder of the

ENDA-TM energy programme, executive secretary of the Sahara and Sahel Observatory (OSS) and coordinator of the African Climate Policy Centre (ACPC). Until 2020, was the principal advisor for sustainable development at the South Centre. Member of the African Academy of Sciences.

Marie-Geneviève PINSART, Philosopher, professor in Applied Ethics at the Université Libre de Bruxelles. Member of the Ethics Advisory Committee for research in partnership (CCERP) of the IRD.

Paula MARTINHO DA SILVA, lawyer specialising in intellectual property and life sciences. Member of the International Bioethics Committee (UNESCO), member of the Ethics Committee of the Champalimaud Foundation and the Central Lisbon University Hospital Centre.

Pere PUIGDOMENECH, Research professor at the Spanish National Research Council (CSIC) at the Molecular Biology Institute of Barcelona, specialist in the molecular biology of plants, Doctor in Biological Sciences.

Laurent THÉVENOT, Director of Studies at EHESS – School for Advanced Studies in the Social Sciences (Chair in Pragmatic Sociology of Politics and Ethics), member of the Georg-Simmel Centre, and member of the French Academy of Agriculture.
Graduate engineer from the École polytechnique and ENSAE.

Joint Administrative Staff

INRAE: Christine CHARLOT, Secretary General, with the support of Claire LURIN

CIRAD: Marie DE LATTRE-GASQUET

IFREMER: Marianne ALUNNO-BRUSCIA

IRD: Chloé DESMOTS



Staff and budget

8,092
permanent staff
(FTE)*

51%
4,098 women

49%
3,954 men

2,019 researchers
3,168 engineers
2,904 technicians

2,433
permanent staff
(FTE)

*FTE: full-time equivalent.
Takes into account the percentage of time
(part-time or not) and the working period
(one year or less).

Subsidy for public service
expenses

€825.1m

INRAE resources

€246.2m

INRAE resources (from research
contracts)
€176.9m

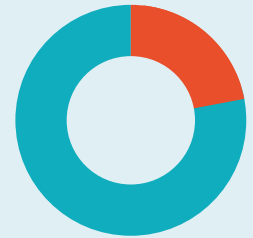
ANR	43.7
PIA	17.9
Other public institutions	15.2
Local and regional authorities	24.3
Europe	37.2
Ministries	7.2
Research & higher education institutions	6.0
Socio-economic partners	25.4

INRAE resources (non-contractual)
€69.3m

Allocated grants	6.7
Donations and bequests	0.1
Royalties for patents, licences	4.4
Services rendered	18.5
Product sales	19.6
Other subsidies	8.2
Other operating income	8.6
Financial and exceptional income	3.2

2022 resources

€1,071.3m



77.02%

Subsidy for public service
expenses

22.98%

INRAE resources



Partnerships and innovation

Socio-economic partnerships

New partnership contracts signed with socio-economic partners **440**

Number of partnership arrangements with socio-economic partners

- 28** Joint Technology Units
- 5** Carnot Institutes
- 8** Labcom
- 9** Associated Partner Labs
- 3** Pre-industrial demonstrators
- 25** start-ups created between 2017–2022
- 80** CIFRE doctoral students

Intellectual property

Declarations of inventions and exploitable research results **150**

Patents submitted **38**

Applications for plant variety rights **8**

Creating value

New exploitation agreements (licences, options, etc.) on patents, know-how, software, trademarks, models **48**

New plant variety rights licences **31**

Pre-maturation

Funding **€970k**

Creating new companies

New companies set up based on INRAE results **4**

AgriO Consortium

Certified companies **9**

Revenues

Research contracts signed with socio-economic partners **€25.4m**

Licences for plant variety rights **€2.9k**

Licences for patents, know-how and software **€1.9k**



Subsidiaries



The Éditions Quæ publishing house was founded in 2006 by four French research institutes: INRA and IRSTEA (which later merged to form INRAE), CIRAD, and IFREMER. It is now the leading French public scientific publisher. It boasts a catalogue of more than 1,000 titles in French and other languages aimed at scientists and industry professionals as well as readers interested in science and societal issues. Éditions Quæ has been expanding its open-access offerings since 2018 to reach an international community with titles available at no cost as well as books for purchase in print and digital formats. Some options combine these two models, with print books available for purchase and digital formats through open access. The books can be purchased directly on the quae.com website or in bookshops, while open-access options can be found on quae-open.com and on national and international platforms.



Working together to transform innovations for the well-being of the planet and people

As a subsidiary, INRAE Transfert develops activities to support INRAE in implementing its technology transfer policy and European projects.

It is specialised in managing complex project engineering and technology transfers in the fields of agriculture, food and the environment in the following areas:

- transferring research results to companies;
- supporting the creation of innovative businesses;
- managing the Carnot Institutes;
- setting up, negotiating and managing European projects;
- handling RDI activities for demonstrators and platforms;
- providing technological and business intelligence services for third parties.



Château Couhins, located in the Bordeaux winegrowing region and owned by INRAE, has been committed to producing high-quality grapes and wine in an environmentally friendly way for more than 20 years. This approach is reflected in its decision to convert its operations to organic production in 1999. The winery's first 100% organic vintage will be available this autumn, with the Château Couhins Blanc 2022 (Grand Cru Classé) and the Dame de Couhins Blanc 2022. The first organic reds (Château Couhins and Dame de Couhins) will be out in spring 2024. The estate is also still working towards its ambitious development objective to deploy INRAE agroecology research results in situ at the full vineyard scale.



Agri Obtentions, a subsidiary of INRAE founded in 1983, is a French multi-species seed producer whose core business is varietal innovation. Agri Obtentions is strongly committed to the agroecological transition and strives to develop new solutions for farmers that work with their practices. As a pioneer in offering varieties adapted to organic farming, Agri Obtentions produces a wide range of seeds for cereals, protein crops, buckwheat, lentils and forage crops. It also has a range of varieties adapted to crop associations and intercropping mixtures and is involved in developing vegetable crop innovations.

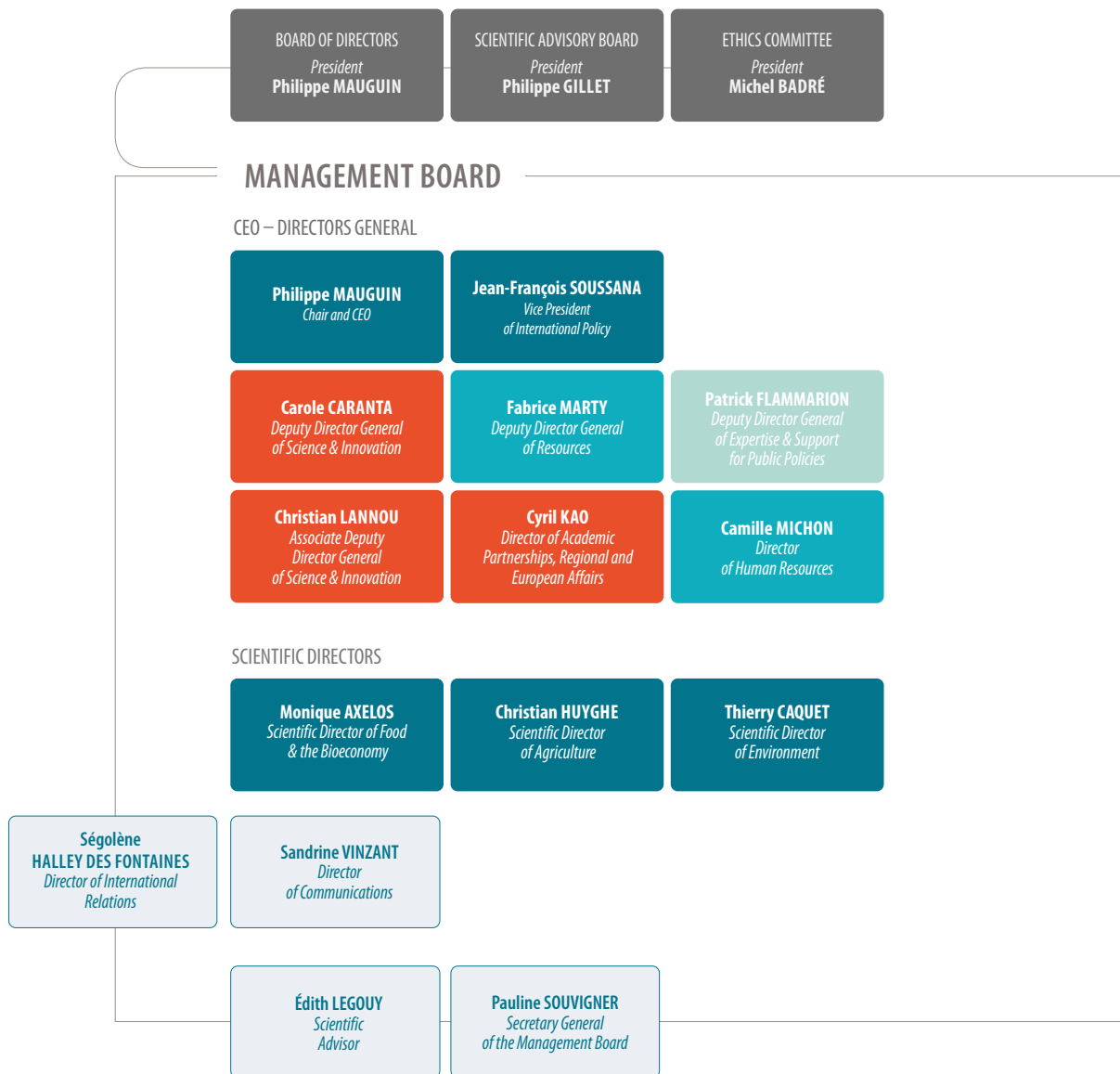
Key figures:

- Sales of €16.22m generated in France and Europe
- 31% of sales invested in research and development
- More than 400 licences
- 10 species groups and more than 450 varieties distributed



INRAE Organisation

(As of 31 December 2022)



RESEARCH SUPPORT DIRECTORS

Armelle CARNET <i>Corporate Social Responsibility</i>	Guy RICHARD <i>Expertise, Foresight and Advanced Studies</i>	Nicolas de MENTHÈRE <i>Support for Public Policies</i>
Philippe LÉNÉE <i>Partnerships and Innovation Transfer</i>	Odile HOLOGNE <i>Open Science</i>	Frédéric GAYMARD <i>Evaluation</i>
Louis-Augustin JULIEN <i>Finance and Procurement</i>	Guillaume PINGET <i>Assets and Property</i>	Françoise ROUDAUT <i>Information Systems</i>
Pierre-Yves SAINT <i>Support for Scientific Management and Administration (DIAGONAL)</i>	Cécile JANET <i>Legal Affairs</i>	Marie-Claude PAULIEN <i>Coordination of Research Support Services</i>

DELEGATIONS

Françoise SIMON-PLAS <i>Professional Conduct, Scientific Integrity, and Research Project Ethics</i>	Catherine BEAUMONT <i>Gender Equality and Anti-Discrimination</i>
Nathalie GANDON <i>Data Protection</i>	Stéphane AYMERICH <i>Research Infrastructure</i>
Jean-Baptiste MERILHOU-GOUDARD <i>Science in Society</i>	David CAFFIER <i>Biosafety</i>

MISSIONS

Nicolas BÉCARD <i>Security and Defence</i>
Sylvie NUGIER <i>Information Systems Security</i>
Michaël CHELLE <i>Digital Transition</i>
Hadi QUESNEVILLE <i>Chief Data Officer</i>

Karine GUERITAT
Head Office Administrator

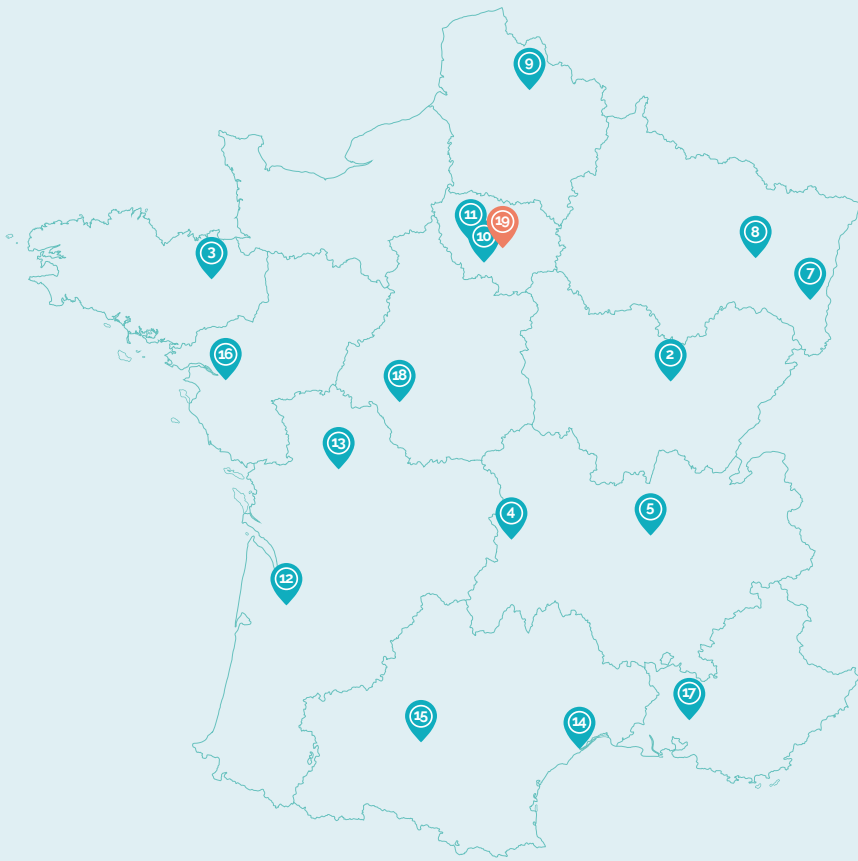
Philippe MARTIN
Head Accountant



INRAE's 18 centres

(As of 31 December 2022)

18 research centres reflect INRAE's involvement in key regional dynamics. The Head Office is in Paris and Antony.



French Overseas Departments

- ① French West Indies and Guiana
President: Harry Archimède
- ② Burgundy-Franche-Comté
President: Nathalie Munier-Jolain
- ③ Brittany-Normandy
President: Hélène Lucas
- ④ Clermont-Auvergne-Rhône-Alpes
President: Emmanuel Hugo
- ⑤ Lyon-Grenoble-Auvergne-Rhône-Alpes
President: Pascal Boistard
- ⑥ Corsica
President: André Torre
- ⑦ Grand Est-Colmar
President: Serge Kauffmann
- ⑧ Grand Est-Nancy
President: Meriem Fournier
- ⑨ Hauts-de-France
President: Julien Fosse
- ⑩ Île-de-France-Jouy-en-Josas-Antony
President: Nathalie Touze
- ⑪ Île-de-France-Versailles-Saclay
President: Egizio Valceschini
- ⑫ Nouvelle-Aquitaine-Bordeaux
President: Olivier Lavialle
- ⑬ Nouvelle-Aquitaine-Poitiers
President: Abraham Escobar-Gutierrez
- ⑭ Occitanie-Montpellier
President: Sylvain Labbé
- ⑮ Occitanie-Toulouse
President: Pierre-Benoit Joly
- ⑯ Pays de la Loire
President: Emmanuelle Chevassus-Lozza
- ⑰ Provence-Alpes-Côte d'Azur
President: Alain Sommervogel (par intérim)
- ⑱ Val de Loire
President: Marc Guérin
- ⑲ **Paris-Antony Head Office**
Administrator: Karine Gueritat



INRAE'S 14 research divisions

(As of 31 December 2022)



Action and Transitions
Christophe SOULARD



Animal Genetics
Edwige QUILLET



Agroecosystems
Thomas NESME



Mathematics and Digital Technologies
Hervé MONOD



Human Nutrition and Food Safety
Lionel BRETILLON



Microbiology and the Food Chain
Sylvie DEQUIN



Aquatic ecosystems, water resources and risks
Mohamed NAAIM



Animal Physiology and Livestock Systems
Xavier FERNANDEZ



Plant Biology and Breeding
Isabelle LITRICO-CHIARELLI



Animal Health
Muriel VAYSSIER-TAUSSAT



Ecology and Biodiversity
Catherine BASTIEN



Plant Health and Environment
Marie-Hélène OGLIASTRO



Economics and Social Sciences
Pierre DUPRAZ



Food, Bioproducts and Waste
Michael O'DONOHUE

INRAE'S units



207
research
units



43
experimental
units



23
support
service units

INRAE

Annual report
2022



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Join us on:



www.inrae.fr/en

**French national research institute for
agriculture, food and environment**



**RÉPUBLIQUE
FRANÇAISE**

*Liberté
Égalité
Fraternité*

INRAE

