INRAE

Annual report
2020

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Cover photo

Close-up of a test tube rack in a water bath (PPCA team, TOXALIM Joint Research Unit) .

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INRAE

science for people, life & earth

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INRAE

Annual report
2020

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AN INTERVIEW WITH

Philippe MAUGUIN

INRAE Chair and Chief Executive Officer

On January 1, 2020, the National Research Institute for Agriculture, Food, and Environment, INRAE, came into being. You have served as its head from the beginning. What have you learned over the past year?

This year has been unique for our institute in many ways. First and foremost, INRAE was born after two years of intense preparation. The foundation for the new institute was collaboratively laid by INRA's and IRSTEA's teams, who have now merged. We should collectively celebrate having navigated this organisational challenge, the first of its kind in the French research landscape. We can be equally proud of INRAE's launch, which was a great success from both a scientific and a social perspective. This accomplishment was made possible by our dedication to active listening and dynamic exchanges, our participatory approach, our teams' deep-seated commitment, and our unflagging pursuit of transparent internal communication.

INRAE is a global leader in research on agriculture, food, and the environment. As part of the creation process, we engaged in an institutional campaign to shine a light on our new identity and scientific strategies. We underscored the expansion of our research themes and the new synergies that arose from the merger of two well-established and well-respected research institutions. INRAE is committed to promoting scientific excellence and developing innovative solutions for major global challenges, which include feeding human populations while sustainably managing essential natural resources; mitigating and adapting to climate change; and, more generally, guiding regional stakeholders in France as they navigate crucial transitions in agricultural and food systems.

How did INRAE's teams manage to juggle the merger and their normal research responsibilities?

INRAE's 12,000 researchers, engineers, technicians, and administrators faced a multifaceted challenge: they needed to draw up the new institute's roadmap, INRAE 2030, while continuing to produce world-class research as they simultaneously adapted to an unprecedented, unpredictable public health situation. They passed this test with flying colours. I warmly thank every single one of INRAE's employees for their exceptional commitment to the institute during the COVID-19 crisis. I congratulate them for all they have accomplished.

Over the course of 2020, around 2,600 INRAE staff and more than 100 French and international partners contributed to the development of INRAE 2030. Informed by the objectives of INRAE's two supervisory ministries, our management team started work on this open, modern, and participatory project in late 2019. It is open because it fosters collaboration and innovation, expertise and support for public policies. It is modern because it promotes interdisciplinary research, the data sciences, and the global health sciences, whose importance has been highlighted by the pandemic. It is participatory because it was built hand in

hand with all our stakeholder partners to account for the full range of research players and beneficiaries, the increasingly complex systems we study, and society's growing demands.

While this work was occurring, INRAE also needed to meet its responsibilities as a public research organisation: to produce knowledge and innovations that serve the public. Cementing their reputation for excellence, our teams published high-impact articles on a number of subjects: environmental challenges and risks (e.g., biodiversity, genetic selection, and mitigation of/adaptation to climate change); transitions in agroecological and food systems (e.g., shifts in livestock farming and the movement towards pesticide-free agriculture); the bioeconomy (e.g., improvements in cycle management, wastewater treatment, and biomass usage); data science and digital technologies (e.g., complex systems, sensors, and data acquisition systems); and global health (e.g., pollution, preventive nutrition, and the transmission of emergent infectious diseases within and among environmental, agricultural, and food systems).

During this time, INRAE also continued to nurture international collaborations. For example, it organised an event at the Paris International Agricultural Show at which 24 research institutions from 16 European countries became signatories of a joint declaration of intent for the European Green Deal. Simultaneously, our teams promoted partnerships and innovation transfer. Notably, INRAE began leading the AgriO Consortium, which benefits from the French Tech Seed funds attributed by Bpifrance. The consortium provides support to agricultural and agrifood start-ups. At the request of the French government for public policy support, the institute produced a national research and innovation plan for developing alternatives to neonicotinoids as well as a report in which potential alternatives to glyphosates in field crops were economically evaluated.

In 2020, the world faced a global crisis with enduring impacts. How did INRAE deal with this situation?

COVID-19 has drastically changed every aspect of our lives. Throughout the pandemic, our institute has continually adapted its structure, functioning, and research. We are proud of the steadfast efforts made by our scientists and support personnel. Without their dedication, it would have been impossible to identify and maintain our essential research activities or to bolster the country's collective actions to support health care workers and establishments.

Through their tireless labour, the INRAE management board and research support departments adapted our research activities while simultaneously ensuring the safety of our personnel. This work was accomplished thanks to close collaborations with health and safety staff as well as with the heads of the research centres, scientific divisions, and research units. For example, over the last year, our national crisis unit held 45 meetings; we reinforced our degree of internal communication; we made psychological assistance available to all employees; and we rapidly adopted new forms of working. At the pandemic's peak, up to 80% of employees were telecommuting. Our support teams displayed great skill, dedication, and availability. Their work paid off: 82% of INRAE personnel had a positive opinion of their quality of life at work in our 2020 survey.

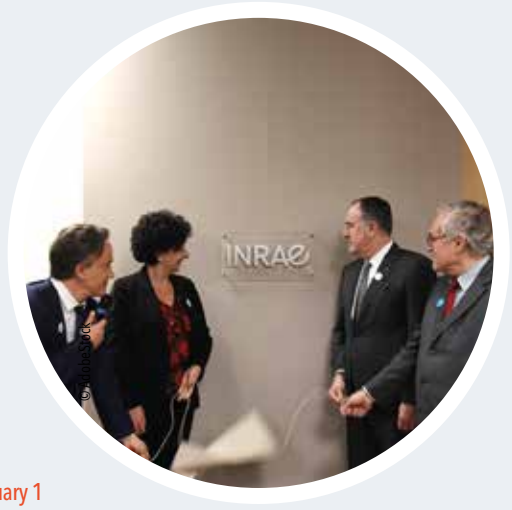
I warmly thank every single one of INRAE's employees for their exceptional commitment to the institute during the COVID-19 crisis. I congratulate them for all they have accomplished.

How does INRAE's research intersect with the current global pandemic?

As a major research establishment, INRAE has a responsibility to contribute its scientific expertise in any way possible. The current crisis is underscoring the importance of the links between environmental protection; biodiversity; and plant, animal, and human health. We have long highlighted how crucial these interactions are, and we have acquired significant expertise on animal coronaviruses. In 2020, we launched around 40 research projects focused on SARS-CoV-2, carried out by our specialists in virology, vaccinology, epidemiology, and mathematics. We are dedicated to this domain of investigation. Indeed, the One Health concept is central among INRAE 2030's five scientific priorities.

This unprecedented period has once again demonstrated the commitment of INRAE employees, who work every single day to meet the global challenges of tomorrow. We each had to greatly step up our efforts as we confronted the need to rethink our traditional ways of working. Yet, every member of INRAE has remained energised by a passion for science and has demonstrated the resilience that makes our institute strong. The resolve we showed in our first year of operations, despite the unparalleled challenges we confronted, is a strong indicator of the successes to come!

2020 in brief
The year's highlights



Ceremony to launch INRAE.
The institute's new name plate is unveiled at Paris headquarters.
© INRAE, B.Nicolas

2020

January 1

INRAE is born

On January 1, 2020, the French National Research Institute for Agriculture, Food, and Environment (INRAE) came into being, arising from the merger of INRA and IRSTEA. Its objective? To pursue high-quality research that provides societal solutions, promotes innovation, generates expertise, and informs public policy. INRAE became the first research institute in the world specialising in all three domains.

January 20

INRAE is recognised for its commitment to equality and diversity

AFNOR granted its Equality and Diversity at Work certification to INRAE, the first public research institute to receive this honour. The organisation was recognising INRAE's commitment to diversity, professional equality, and the fight against discrimination.

February 22–March 1

INRAE successfully participates in its first major convention

At its very first Paris International Agricultural Show, INRAE was honoured by visits from the French president, the heads of the institute's two supervisory ministries, tens of thousands of visitors, and a design award. At its stand, the institute showcased research in its three central domains: agriculture, food, and the environment.

President Emmanuel Macron with INRAE research teams at the Paris International Agricultural Show.
© INRAE, C. Maitre

March 12

COVID-19 puts global health at risk

In March, INRAE joined REACTing, a consortium created by the Aviesan alliance, to help select 20 scientific initiatives seeking to holistically address various battles in the war against the virus. Since then, the institute has participated in interdisciplinary research to better understand, prevent, and deal with epidemics.

May 12

AgriO consortium is created to support agricultural and agrifood start-ups

INRAE became head of a new consortium, AgriO, that has brought together a range of scientific, institutional, and economic stakeholders. AgriO is a recipient of French Tech Seed funds. Its purpose is to support start-ups in the agricultural and agrifood industries, fostering their development until they are ready to recruit investors.

ARC representatives at the remote signing of a trilateral partnership agreement with CIRAD and INRAE.
© J-P Torreton

July 24

France and South Africa commit to a research collaboration

A trilateral partnership agreement was signed by INRAE, CIRAD, and the Agricultural Research Council (ARC), South Africa's leading organisation for agricultural research and development. The three establishments have joined forces for a five-year period. This agreement signals the partners' combined dedication to tackling the challenges that South Africa is facing, particularly by sharing knowledge related to the management of animal health and the adaptation of family farms to climate change.

May 28–29

The French Minister of Higher Education, Research, and Innovation visits an experimental site in northern France

During her visit to INRAE's Estrées-Mons site, Minister Frédérique Vidal discussed the consequences of the COVID-19 crisis with researchers. The conversation notably explored the impacts on the experimental unit, whose work focuses on field crops. Scientists in the new Franco-Belgian EcoBioAgro Joint Research Unit presented their work, which aims to support sustainable and efficient agriculture through biocontrol, biopreservation, environmental remediation, and the bioeconomy.

Vineyard in Napa Valley (California, USA).
© INRAE, M. Meuret

July 1

An international collaboration is established to promote vineyard health

INRAE and the University of California, Davis (USA) signed an initial framework agreement focused on subjects of shared strategic interest. It resulted in the launch of a two-year research project exploring how grapevine health can be improved using plant genetics.

2020 in brief
The year's highlights

October 12

Agreement is signed to improve conditions for civil servants in higher education and research

Minister Frédérique Vidal signed an agreement with French trade unions as the French Parliament voted on legislation affecting civil servants working in higher education and research (*la loi de Programmation de la recherche pour la revalorisation des rémunérations et carrières*). In 2021, permanent staff at INRAE will receive a pay raise via upward adjustments to the various bonuses specific to their employment corps (i.e., AT, TR, AI, IE, IR, CR, and DR). These gains will be retroactively applied, with a start date of January 1, 2021. Through 2027, the size of bonuses will be incrementally re-evaluated for employees in certain corps (i.e., TR, AI, IE, IR, CR, and DR).

September 22

INRAE and French sugar beet stakeholders present a plan for identifying neonicotinoid alternatives

INRAE and the French Sugar Beet Technical Institute (ITB) presented a national research plan to the Minister of Agriculture and Food, Julien Denormandie, in which they described four areas of study that will help build knowledge and generate innovative solutions in the quest to discover alternatives to neonicotinoids and fight the beet yellows virus. The two institutes were then entrusted with carrying out this work.

Minister Julien Denormandie listening to a description of the research plan "Alternatives to Neonicotinoids"
© Cheick Saidou/agriculture.gouv.fr

September 18

INRAE strengthens its ties to the French Ministry for the Ecological Transition

A partnership agreement was signed by Philippe Mauguin, Chair and CEO of INRAE, and Barbara Pompili, Minister for the Ecological Transition, with a view to bolstering research, expertise, and public policy support on environmental issues.

October 13

INRAE holds an international conference to discuss Sustainable Development Goals

INRAE organised a remote conference for its international partners to discuss how the research world can contribute to the United Nation's Sustainable Development Goals (SDGs) targeting land use and food systems. The reflections of researchers at a range of international institutions (e.g., Wageningen University, Oxford University, the University of Washington, Imperial College London, and the International Science Council) contributed to the construction of INRAE 2030.

2021

© INRAE, B. Nicolas

October 22

INRAE head Philippe Mauguin begins another four-year term

Philippe Mauguin was reappointed Chair and CEO of INRAE by the French Council of Ministers following a nearly unanimous vote of both parliamentary chambers. Mauguin has thus embarked on a new four-year term. He made the case for his reappointment by presenting an assessment of his leadership to date, which included coordinating the merger between INRA and IRSTEA and establishing the new institute's research priorities given the major global changes underway.

October 23–28

Trees appear on the big screen

The film *Le Génie des arbres* [The Genius of Trees] received the Biodiversity Award at the Pariscience International Science Film Festival. Co-produced by INRAE, the documentary explores INRAE research looking at the here-to unsuspected abilities of trees and the roles they may play as climate change advances. Broadcast in May on France 5, *Le Génie des arbres* was one of the channel's most popular films to date, with 1.3 million viewers tuning in.

December 14

Recovery Plan funds 55 renovation projects

INRAE was awarded nearly €13 million to update the thermal performance of its buildings. The 55 projects that were financed will allow INRAE to reduce its greenhouse gas (GHG) emissions by approximately 475 tons of CO_2 equivalents by 2023.

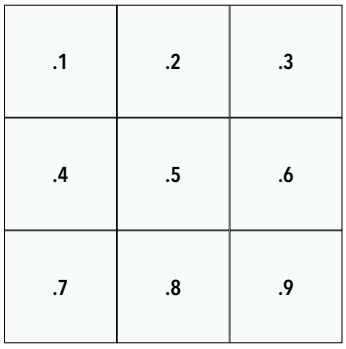
December 17

INRAE 2030 is formally adopted

Having received a stamp of approval from the Scientific Advisory Board, the Board of Directors formally adopted INRAE 2030, the new institute's 10-year strategic roadmap. INRAE 2030 focuses on five scientific priorities and three policy priorities that will guide solutions to major research challenges in the domains of agriculture, food, and the environment.

INRAE is born: a new institute driving research and innovation centred on agriculture, food, and the environment

On January 1, 2020, France's National Research Institute for Agriculture, Food, and Environment (INRAE) arose from the merger of INRA, the National Institute for Agricultural Research, and IRSTEA, the National Research Institute of Science and Technology for the Environment and Agriculture. This achievement was the result of a process initiated in 2018. INRAE's opening ceremony was attended by the institute's supervisory ministries: Frédérique Vidal, Minister of Higher Education, Research, and Innovation, and Didier Guillaume, Minister of Agriculture and Food. By their sides were INRAE Chair and CEO Philippe Mauguin and former IRSTEA CEO Marc Michel. INRAE is the world's leading research organisation specialising in questions related to agriculture, food, and the environment.
Drawing on the synergies created among its 12,000 employees, INRAE will carry out high-quality research that will serve to produce knowledge and innovations; further higher education; and support public policies. Its objective is to play a key role in the transitions we must navigate to confront major global challenges. Success relies on working with partners to promote the efficacy of multiperformance agricultural systems, access to high-quality food, and the sustainable management of resources and ecosystems.



1. Several agroecological projects focused on viticulture (e.g., VITAE, VitiREV) being presented to Minister Frédérique Vidal at INRAE's La Grande Ferrade site in southwestern France
© INRAE - G.Lambert

2. INRAE launch and presentation of scientific projects to Chair and CEO Philippe Mauguin at the Gazinet site in southwestern France
© INRAE - G.Lambert

3. Launch of INRAE and presentation of scientific projects to Philippe Mauguin, INRAE Chair and CEO, at INRAE's Gazinet site in southwestern France
© INRAE - G.Lambert

4. INRAE 2030 workshop at the Estrées-Mons site in northern France
© INRAE - A.Waquet

5. INRAE 2030 workshop in western France (Pays de la Loire)
© INRAE - N.Mansion

6. INRAE 2030 workshop in western France (Pays de la Loire)
© INRAE - N.Mansion

7. Activities marking INRAE launch at the Lyon-Grenoble-Auvergne-Rhône-Alpes Research Centre
© INRAE - A.Dubost

8. Research directors from the Angers Research Centre presenting INRAE at SIVAL, the annual horticultural show

9. Introducing INRAE to the regional press as well as to regional and academic stakeholders partnered with the Burgundy-Franche-Comté Research Centre
© INRAE, L.Piquemal


INRAE

Spotlight on COVID-19

INRAE research increases understanding of COVID-19

ORGANISATION

Trust, understanding, pragmatism: the three pillars of INRAE crisis management

INRAE was put to the test in 2020. Straight out of the gate from the merger between INRA and IRSTEA, the new institute was forced to navigate the COVID-19 health crisis. Surmounting the year's challenges required tremendous collective dedication.

INRAE's teams ensured research continuity in 2020. They completed all their planned projects, including those related to the merger. "Everyone remained extremely committed," notes Fabrice Marty, Deputy Director General of Resources. "Each one of INRAE's employees reflected on the work that needed to be prioritised during the lockdown. Business continuity plans were quickly established, and staff rapidly adapted to the new mode of functioning. We also saw strong adherence to the new health and safety rules."

INRAE set up its own national crisis unit in late February 2020, prior to the first lockdown. From the beginning, the unit held ad hoc meetings between the INRAE management board, the heads of the 18 research centres, and risk prevention personnel. As many as three meetings took place per week. These exchanges allowed for an optimal degree of collaboration between national and local decision-makers. "We trusted the centre presidents and local administrators to appropriately implement the health measures at their sites," adds Marty. These individuals were on the front lines, making sure necessary actions were taken and providing support to telecommuting employees. During this period, human resources (HR), information technology (IT), and risk prevention teams showed great dedication, as did the communications team. The latter carried out complementary actions, working closely with national-level administrators and local communications staff to provide guidance to INRAE employees and managers in handling the crisis. Via the intranet and the internet, the communications team shared a variety of information: risk prevention guides, IT manuals, graphical HR information, and institutional current events. Materials were made available in both French and English with a view to reaching all INRAE employees.

Aiming for improvement

INRAE's communities buckled down during these difficult times but still faced some bumps in the road. Two measures helped transform the lessons learned during the crisis into real-time improvements. First, feedback was collected regarding INRAE's management of the crisis between January and July 2020. A total of 42 individual interviews were conducted with management and supervisory staff; an online survey was sent out to unit leaders, resulting in more than 200 responses; and eight thematic roundtable discussions were held. The institute's strengths and weaknesses were noted. This work defined the course for future improvements: the national crisis unit was in need of better training and resources; the crisis management strategy could benefit from a stronger framework (business continuity plans); the functional relationships with INRAE's partners could be better defined; and team leaders needed to be identified and given proper recognition.

Second, in 2021, INRAE will perform a study of how its employees experienced both the crisis period and the merger. This work will be carried out by the Committee for Health, Safety, and Working Conditions (CHSCT) with the aim of getting ahead of any psychological and/or social issues.

The information gathered via these two measures will yield a broader perspective on how to improve INRAE's crisis management strategies and will help ensure employee well-being.

INRAE confronts the health crisis

First lockdown

All INRAE research centres were closed for eight weeks

Research experiments were suspended and facilities closed, except in special cases (e.g., carrying out COVID-19 research, safeguarding historical scientific resources crucial to the institute's fundamental work, caring for livestock and experimental animals, monitoring crops to avoid jeopardising annual production)

Continuity in INRAE's research services and activities was ensured via an across-the-board switch to telecommuting; employees unable to work remotely were granted a special leave of absence

Second lockdown

Research services and activities were continued

Telecommuting was strongly encouraged, and on-site work was limited

Customised procedures were developed for on-site work to ensure teams functioned effectively

ORGANISATION

Focus

Information technology teams work overtime behind the scenes

It required tremendous organisation and efficiency to switch all INRAE's employees to a telecommuting model overnight. Coming on-site when necessary, INRAE IT teams rapidly guaranteed that every staff member was equipped with a remote workstation. They also helped with set-up when needed. A hotline was put in place: employees could contact IT specialists for help and even ask for their computers to be remotely configured.

In tandem, institute-level IT services were boosted by increasing the number of phone licenses available for Skype connections, and associated technical hosting capacities were doubled. As a result, the system was able to handle up to 7,000 simultaneous connections, and IT teams ensured service continuity from the very start of the crisis.

Versailles-Grignon prepares for COVID-19

INRAE's research centres were tasked with applying national recommendations to local realities. The Île-de-France-Versailles-Grignon Research Centre boasts 1,200 employees spread across eight sites, which are either part of INRAE or partner institutions (i.e., AgroParisTech, ENS Paris, the University of Paris-Dauphine, the University of Gustave-Eiffel). Camille Michon, the centre's president, explains that during the first lockdown, INRAE closed all its centres for eight weeks. She describes how the first crucial steps were quickly and efficiently taken: "Once senior management communicated what was happening, we coordinated the actions to take both internally and externally. We set up a crisis unit. Then, working with our unit directors, we designed and implemented INRAE's business continuity plan, closing our sites within 48 hours. Our objective was to retain a solid foundation to come back to. We kept a select few experiments going after conducting a detailed analysis and consulting with the scientific directorates. Measures for limiting virus transmission were always respected, and trips to the centre were minimised. For example, we had a doctoral student whose experiments on plant and animal biodiversity in farmland had been underway for two years. She was able to carry out 25–30% of the observations she had initially planned. Had she not been able to collect these data, she would have had to extend her PhD by two or three years."

© INRAE, B. Nicolas

"In March, medical personnel lacked masks, glasses, gloves, and gowns. We donated everything we could. For example, one of our units donated 80% of its annual stock of gloves"
Camille Michon

Solidarity as a central tenet

Until the centre reopened on May 11, 70 staff members volunteered to perform essential on-site tasks to ensure any fundamental work. "Their work schedule was organised so that they spent the least amount of time possible at the centre," comments Michon. "They carried out tasks that were very different from their usual work, such as feeding the earthworms, watering the greenhouse crops, and verifying that the -80°C freezers were working properly, so that we did not lose our plant samples. They did the work of three people working full-time."

INRAE also extended this spirit of solidarity to hospitals in western Paris. In March, medical personnel lacked masks, glasses, gloves, and gowns," recalls Michon. "We donated everything we could. For example, one of our units donated 80% of its annual stock of gloves."

INRAE researchers in action on many fronts

INRAE has long promoted the One Health approach. However, the general public has also come to recognise its importance in the face of the COVID-19 pandemic. It is crucial to understand that, worldwide, human health is intimately tied to environmental health and animal health. From the first moment of the crisis, INRAE put its interdisciplinary research units to work understanding, preventing, and managing infectious disease risks.

One Health is an essential part of INRAE 2030's scientific priorities, and its utility has become clear since the beginning of the COVID-19 pandemic. Overall, 75%[1] of emerging infectious diseases in humans are transmitted by animals or via animal-based products. "These diseases regularly appear in equatorial regions, where the density of different mammal species is high," explains Muriel Vayssier-Taussat, head of INRAE's Animal Health Division. "This situation leads to frequent interactions among humans, domestic animals, and wildlife. Also involved are the microbes that these animals carry." In our globalised society, epidemics can now spread easily instead of remaining locally constrained, as they were before.

Prezode: tomorrow's research

INRAE's research clearly illustrates the One Health approach. Prezode is an international initiative that was developed over the course of 2020. Launched by the French president in early 2021, it aims to get ahead of emerging zoonotic diseases and pandemics. As part of a collaboration with a dozen research establishments in France, Germany, and the Netherlands, INRAE is coordinating Prezode alongside the French Agricultural Research Centre for International Development (CIRAD) and the French National Research Institute for Sustainable Development (IRD). The initiative is backed by four French ministries: the Ministry of Higher Education, Research, and Innovation; the Ministry for the Ecological Transition; the Ministry for Europe and Foreign Affairs; and the Ministry for Solidarity and Health. Prezode is bringing together more than 1,000 researchers from 50 countries across 5 continents. "We must expand disease monitoring research to develop more efficient epidemiological surveillance systems at national and international levels. We need to detect the smallest signs of potential epidemics and deal with them immediately," comments Vayssier-Taussat. "We also need to understand the conditions that promote disease emergence so that we can act preventively."

Informing public health decisions

Vayssier-Taussat represents INRAE within CARE, a committee of 12 researchers and medical doctors with different specialties that provides expertise to the French government. "We helped officials define the research priorities needed to respond quickly to the epidemic," indicates Vayssier-Taussat. "We advised the government as it set up a national body for coordinating French research on infectious diseases." As a result, a new agency was born on January 1, 2021: ANRS | Emerging Infectious Diseases. Its objective is to think beyond the COVID-19 crisis and to better prepare us for the future epidemics. To this end, the agency will work with INRAE to set up major interdisciplinary research projects that are guided by the One Health approach.

1. https://pubmed.ncbi.nlm.nih.gov/11516376/

→

SCIENCE/RESEARCH

Focus

Modelling clarifies epidemic dynamics

In the early summer of 2020, the Biostatistics and Spatial Processes Team developed a model to identify the factors explaining the geographical distribution of COVID-19. It was discovered that levels of travel and measures aimed at limiting transmission (i.e., masks, physical distancing, and closing schools) most influenced epidemic dynamics.
The team also developed tools for visualising the effects of national strategies, which were made available to the public.

More information can be found here:
https://url.inrae.fr/3akVB6c

The pandemic affects our diets

On March 15, 2020, just before the first lockdown, INRAE conducted a survey to determine how the food industry was adapting to the crisis. Around 780 responses were collected. They revealed that both long and short supply chains generally fared well, despite some disruptions. Consumers seemed to rely more on short supply chains because they were viewed as safer. Furthermore, consumers wanted to support local producers. Many people also had more time to cook at home and reflect on what they were eating. Producers changed tack and began selling directly to consumers, who, in turn, formed informal buying groups, notably with their neighbours.
Discover all the results of this study, conducted by INRAE researchers and related stakeholders, in the book *Manger au temps du coronavirus* [Diets in the time of coronavirus], published in November 2020 by Apogée.
https://url.inrae.fr/34mKK83

Loss of smell: SARS-CoV-2 does not infect olfactory nerves

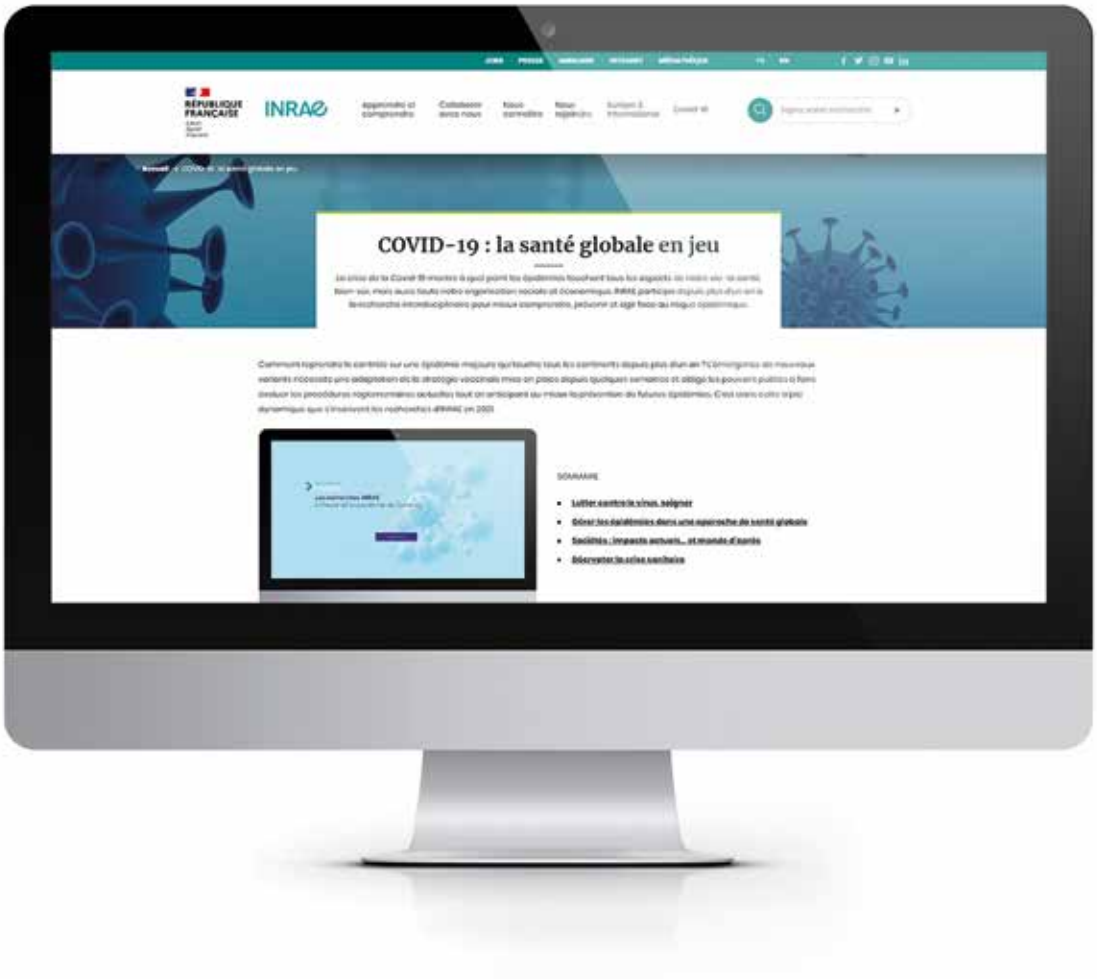
COVID-19 frequently causes anosmia, or the loss of smell. This symptom results when respiratory viruses infect the nasal cavity and, sometimes, olfactory neurons. Both tissues are exposed to the environment and connected to the central nervous system. In collaboration with researchers at the French Agency for Food, Environmental and Occupational Health & Safety (ANSES), INRAE scientists showed that SARS-CoV-2 can infect some nasal mucosa cells but not those making up the olfactory nerves. This work employed a hamster model.

The virus can cause massive infection in the supporting cells around olfactory neurons but does not infect the neurons themselves. Furthermore, nasal mucosa cells may undergo sloughing, which could help explain the loss of smell.

Understanding how SARS-CoV-2 interacts with olfactory neurons is important given that many of those infected develop neurological disorders, especially in cases of severe disease.
https://url.inrae.fr/32hx4dI

See the press report

Find out more about INRAE's COVID-19 research



https://www.inrae.fr/en/covid-19

INRAE 2030

We have entered an era of new research expectations as society faces daunting global challenges: mitigating and adapting to climate change; undertaking agricultural transitions; increasing food and nutrition security; promoting human and planetary health; preserving natural resources; restoring biodiversity; and predicting and managing risks. INRAE is one of the world's top ten public research institutions in sustainable development and leads the way on work related to agriculture, food, and the environment. Thus equipped to respond to these challenges, the new institute defined its strategic priorities using a collective, participatory approach.

This innovative process of co-construction began in 2019. Throughout 2020, input was solicited from numerous individuals in-house as well as from around a hundred national and international collaborators. An online platform, open to all, was created to collect individual and joint submissions. Contributions were further encouraged via in-person workshops at INRAE's research centres. Over 1,600 employee responses were obtained. Even as the pandemic continued, external input was sought out. Feedback was submitted by French collaborators and stakeholders, building upon the internal work performed above. The findings were shared with the Scientific Advisory Board in September.

Finally, in October, an online scientific workshop was attended by approximately thirty high-level researchers from around the world, who explored how international research is contributing to SDGs related to land use and food systems. This input was part of the final document, INRAE 2030, formally approved by INRAE's Board of Directors in December.

INRAE 2030 lays out the scientific and policy priorities that will guide the institute's work in the coming years. The roadmap covers a 10-year period and describes actions that can be taken immediately or that are already underway. The objective is to propose solutions that can be gradually implemented based on customisable trajectories.

This work is rooted in targeted research, which will be carried out by effectively combining the basic and applied sciences and creating value from disciplinary excellence through interdisciplinary approaches. The resulting research will be parlayed into knowledge and solutions that will feed expertise, innovation, and public policy support. INRAE 2030 provides a framework for the specific strategies adopted by the institute's research divisions, centres, units, and support services. It also provides a foundation for the institute to develop collaborations with scientific partners, public officials, socioeconomic stakeholders, and any other interested parties at regional, national, European, and international levels. INRAE is open to working with anyone interested in confronting the global challenges listed above.

The operational version of INRAE 2030, detailing the objectives, procedures, and indicators associated with each priority, will be included in the institute's next agreement on targets.

Our priorities

Scientific priorities

SP1 Responding to environmental challenges and their associated risks

SP2 Accelerating agroecological and food transitions while answering socioeconomic challenges

SP3 Building bioeconomies based on the efficient circular use of resources

SP4 Promoting a holistic approach to health

SP5 Facilitating transitions by mobilising data sciences and digital technologies

Policy priorities

PP1 Placing science, innovation, and expertise at the centre of society-policy dialogue

PP2 Reinforcing our engagement with academic, European, and international partners

PP3 Establishing social and environmental responsibility as a common objective

Foresight studies and metaprogrammes: using interdisciplinarity to confront global challenges

Six interdisciplinary foresight studies were carried out between 2017 and 2020. They focused on themes of major current relevance, highlighting the challenges and scientific priorities that will drive INRAE's research through 2030. Four of the studies were made available to the public in 2020. They focused on 1) agroecology; 2) the health "nexus" (i.e., health as a driver of agricultural, food, and environmental transitions); 3) the bioeconomy; and 4) science for tomorrow's livestock farming. Their results were shared *via* an online collection of reports. The foresight study on agroecology served as the basis for a book published by Quae. The results of these six studies, INRA's first generation of metaprogrammes (2010–2018), and IRSTEA's strategic priorities were used to define INRAE's ten new metaprogrammes. These programmes drive scientific activities and projects centred on a select number of subjects for which systemic and interdisciplinary approaches are needed if we wish to effectively address scientific and societal challenges. Five to eight years of funding have been provided by INRAE.

Three metaprogrammes were launched in 2019: Holobionts and microbial flux within agrifood systems (Holoflux); Farm animal health and welfare (Sanba); and Scaling up organic agriculture (Metabio). Two others saw the light of day in 2020: Sustainable management of crop health (SuMCrop) and Bioeconomy for urban territories (Better).
https://url.inrae.fr/3zWKzPc

Scientific Advances in **2020**

Philippe Lemanceau, 2020 Recipient of INRAE's Lifetime Achievement Award. Director of the Joint Research Unit for Agroecology at INRAE's Dijon Research Centre. © INRAE, C. Maitre

Scientific priorities

Responding to environmental challenges and their associated risks

To successfully navigate current ecological transitions, we need to develop and test strategies for rendering agricultural, food, and environmental systems less vulnerable and more resilient to the impacts of global changes. It is crucial to analyse the adaptive mechanisms used by organisms at different scales. We can thus develop management strategies that better capitalise on the capacities of individuals and populations to deal with change. We must also conduct more research into the dynamics and functions of biodiversity to halt its erosion. Indeed, it is essential to conserve, sustainably employ, and even potentially restore biodiversity. Finally, we need to further study natural and climatic risks to better understand them, including how they may exacerbate certain related challenges.

Climate change: mitigation and adaption strategies

Drought conditions in Europe reduce carbon uptake and crop yields

Thanks to the work of the Integrated Carbon Observation System (ICOS), a European data-collection network, a series of 17 studies was able to examine how natural systems and crops in Europe respond to major droughts, such as the one experienced over the last three summers (2018–2020). The results indicate that carbon sink capacity declined by 18% in 2018, for example. The drought has even resulted in some ecosystems acting as carbon sources instead of carbon sinks. These findings were based on the long-term, high-quality data collected by ICOS, which continuously measures important climate variables at 140 stations across Europe, including 6 run by INRAE. This work has provided knowledge essential to efforts seeking to limit the negative impacts of climate disruption. It also showed that reactions of vegetation to very dry summers will depend greatly on climatic conditions during the previous spring or even winter. Being able to predict the occurrence and consequences of droughts several months ahead of time will enhance adaptation to climate change.

Philosophical Transactions of the Royal Society B, https://royalsocietypublishing.org/toc/rstb/375/1810

Drought on Mont Ventoux INRAE, B. Nicolas

Tropical forests can adapt to climate change...up to a point

Tropical forests store the equivalent of 25 years of global carbon emissions from fossil fuel combustion. Global warming could reduce this storage capacity. An international research team performed a study tracking the growth of half a million trees across the world; all were subject to the effects of climate change. Initial results suggest that increased temperature is the climate change disruption with the greatest influence on carbon storage. Even as the world gets warmer, tropical forests should continue to act as carbon sinks for emissions, but only up to a point. The research team identified the maximum mean daily temperature, 32 °C, that tropical forests should be able to withstand while still functioning normally.

Science, doi.org/10.1126/science.aaw7578

Read more about INRAE's work looking at the vulnerability and adaptive capacities of forest systems:
https://url.inrae.fr/2OV2IqR
https://url.inrae.fr/38b50vr
https://url.inrae.fr/3kjlaHo

A conversation with...

Denis LOUSTAU

Joint Research Unit for Atmosphere-Plant-Soil Interactions (ISPA)

Your work in ecophysiology focuses on the carbon cycle and hydrological dynamics in forests. What led you to change the scale of your research?
I am interested in the interactions between forests and their surrounding environments. I explore organ-level processes, whose impacts on the individual tree or stand of trees can only be grasped at higher levels, such as in the radiation and convective heat exchanges taking place in tree canopies, mineral nutrition, growth, and biotic interactions (e.g., competition, herbivory, symbiosis).
Moreover, the ways in which forests interact with the atmosphere do not respect arbitrarily defined boundaries. If you work with forests, you need to understand their trans-scalar nature, which extends across space and time. Depending on the temporal scale examined, trees and tree stands may display different responses to environmental changes. A good example is that increased temperature can boost soil respiration over the very short term, but declines may result over the longer term. We must use this type of framework to predict how climate change will affect forests and/or carbon sequestration[1].

What challenges do you face when observing ecosystems?
Observation remains our primary source of knowledge about complex natural systems like forests. This approach is necessary if we wish to detect, analyse, and understand how forests function. The same is true if we want to characterise the biotic and abiotic interactions driving tree life cycles. By observing forests, we can quantify their balances of energy, water, or greenhouse gases (GHGs) as well as their level of biodiversity. We can also understand how they respond to heat waves, storms, droughts, pathogens, and/or pollution[2].
We have access to rich, first-rate data displaying unparalleled geographical coverage thanks to the high-resolution, real-time monitoring of forests *via* next-generation observation networks, such as the *in situ* ICOS infrastructure[3] or the *ex situ* Copernicus Programme missions. INRAE's research, service, and experimental units play an important role in all this.

Observation remains our primary source of knowledge about complex natural systems like forests

How do such observations inform predictions about impacts on forests?
A major challenge is predicting how future environmental changes will affect forest behaviour, namely in terms of production, carbon and GHG sequestration, and both water and element cycling. We do not know the spatial areas and time periods over which soil carbon sinks and forest biomass can be maintained.
To deal with this challenge, models of forest functioning are being developed as part of programmes run by France's National Research Agency (ANR), Ministry for Agriculture and Food[4], and the Agency for Ecological Transition (ADEME). Observations play a key role in this work. They provide real data against which model predictions can be compared, to explore whether the models yield plausible results and to understand the sources of uncertainty. Observations also allow us to better characterise complex interactions as well as feedback or amplification effects[5]. ●

1. https://hal.inrae.fr/hal-02900349
2. https://hal.inrae.fr/hal-01757184
3. https://www.icos-cp.eu/
4. https://forets21.inra.fr/pelican3.1/
5. https://doi.org/10.5194/gmd-13-5973-2020

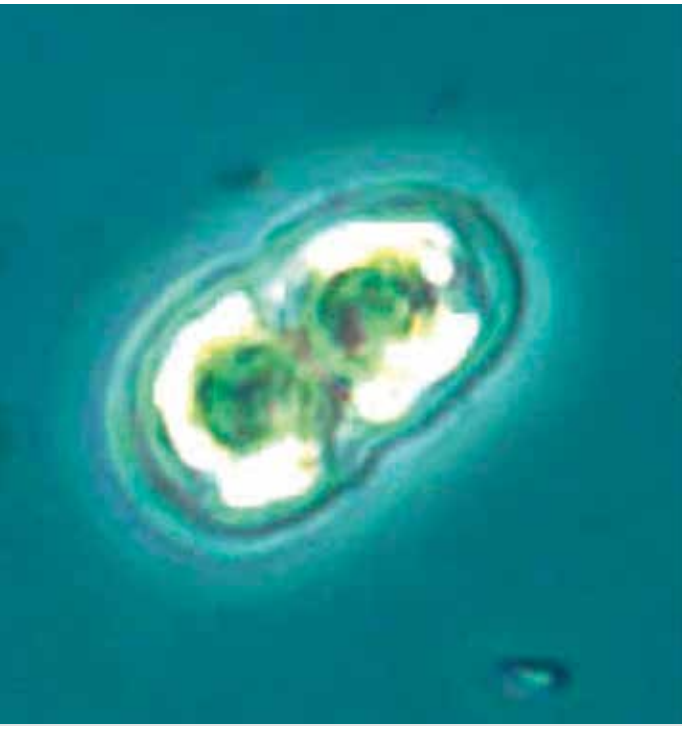
Biodiversity: a powerful tool and a valuable inheritance

Lake microorganisms have experienced a century of impacts

Aquatic microorganisms are important contributors to lake ecosystems and biodiversity. However, we are still largely in the dark when it comes to understanding how they are affected by climatic changes and anthropogenic pressures. Using DNA preserved in the sediments of 48 lakes, INRAE researchers compared present microorganism diversity with that in the late 19th century, before ecosystems were more severely affected by human activities. They found that biodiversity had drastically changed and become more homogenised among lakes. This work sheds light on the shifts in microbial diversity that have taken place over long periods of time, highlighting patterns in a group that is frequently ignored in major discussions about biodiversity.

Nature Communications, doi.org/10.1038/s41467-020-17682-8

Actinotaenium cruciferum
© INRAE, J-C. Druart



Cropping systems incorporate grassland ecosystem services

Diversification is a key tool for increasing the sustainability of arable crop systems. However, until recently, researchers had given little consideration to the possibility of boosting diversification via the addition of temporary grasslands. INRAE researchers wrote a literature review to clarify the role played by temporary grasslands in such systems. It was found that temporary grasslands provide a wide range of "input services" for agricultural systems, such as soil conservation, nutrient supply and recycling, soil water retention, and organic pest and weed control. They also provide societal benefits in the form of water purification, climate regulation, forage production, and biodiversity-promoting habitats. However, these advantages can only be gleaned if the spatial and temporal inclusion of grasslands is well managed. The researchers proposed multiple ways to optimise these ecosystem-level practices.

Agronomy for Sustainable Development, doi.org/10.1007/s13593-020-00620-9

Combining cropping system diversification strategies can improve production and environmental health

There are numerous strategies for diversifying cropping systems, a process that can help maintain or enhance agricultural sustainability. Over the past five decades, thousands of experiments have been conducted around the world to compare and contrast the performance of different diversification methods across a broad range of agroecosystems and climatic conditions. INRAE researchers performed a systematic analysis of these data, employing 99 meta-analyses and the results of more than 3,700 agricultural experiments encompassing 7 crop diversification strategies. They found that rotating and combining crops often boosted yields. The use of agroforestry, which combines tree farming with crop or livestock farming, almost systematically increased biodiversity and soil quality. Notably, it enhanced soil organic carbon content. In this context, it appears that combining several diversification strategies is more effective than utilising any single strategy. However, the analysis also revealed that we still understand little about water usage, economic profitability, product quality, and production consistency. Finally, few meta-analyses have examined the effects of landscape and system heterogeneity on crop species other than grains and legumes. ●

Environmental Research Letters, doi.org/10.1088/1748-9326/ab4449

Spontaneous forests promote species management and preservation

INRAE is leading a European project, SPONFOREST, that is conducting research at five representative study sites in Mediterranean and temperate habitats in southwestern Europe. Researchers are exploring the characteristics and effects of spontaneously established secondary forests as well as the ways in which such forests can help preserve and manage European landscapes. For example, spontaneous secondary forests promote biodiversity and are more resilient when faced with drought. ●

SPONFOREST's results to date have been published in a series of six papers in *Annals of Forest Science, doi.org/10.1007/s13595-020-00993-7*

High-throughput phenotyping platform at the Joint Research Unit for the Ecophysiology of Plants under Environmental Stress (LEPSE) in Montpellier. The laboratory analyses and models the genetic variability underlying plant responses to extreme environmental conditions, notably drought and high temperatures.
© INRAE, C. Maître

Organismal adaptations: tools for guiding genetic selection and preserving biodiversity

Researchers uncover plant mechanisms for coping with biotic and abiotic stresses

To breed crops that perform better in shifting environments, it is essential to have a detailed understanding of the different molecular mechanisms at work.

Using multi-omics approaches, INRAE scientists explored how chronic nitrogen and sulphur deficiencies provoked by different environmental stresses could affect metabolic and cellular responses in the model plant species *Arabidopsis thaliana.* All the biotic and abiotic stresses examined had negative effects on resource allocation at the whole plant level. The results provided a holistic perspective on how plants change their physiological processes and resource allocation in response to different stresses. They also revealed that molecular mechanisms can interact when plants are dealing with nutrient limitations.

Journal of Experimental Botany, doi.org/10.1093/jxb/eraa011 ; doi.org/10.1093/jxb/eraa337
Cells, doi.org/10.3390/cells9020332

Even under water stress, plants can modulate their physiology and development. Prior to any developmental changes, the roots must perceive and transmit an osmotic signal. Little is known about how plants perceive this signal. Using high-resolution *in vivo* microscopy, INRAE researchers showed a key part of the signal involves a GTPase forming nanodomains within the plasma membranes of plant cells. These fine-scale changes in protein structure convey specific signals at the cellular level, thus determining the response seen within organs and the entire plant.

Current Biology, doi.org/10.1016/j.cub.2020.09.013

In plants, resistance to vascular infections largely rests on the host's ability to successfully isolate pathogens within the xylem. There is increasing evidence that this ability is influenced by the structural properties of the vascular system. INRAE researchers experimentally demonstrated that a relationship exists between xylem anatomy and a plant's ability to restrict the movement of a fungal pathogen, *Phaeomoniella chlamydospor*a. This work was performed in a range of grapevine genotypes. These findings have implications in the fight against grapevine decline and, more broadly, in efforts to deal with vascular diseases in perennial plants.

Plant, Cell & Environment, doi.org/10.1111/pce.13848

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Metamorphosis is the start of a new life for grain weevils and their endosymbiotic bacteria

It is important to understand host-microbiota interactions because they influence the physiology and general responses of host organisms. Grain weevils live in symbiosis with intracellular mutualistic bacteria that supplement the weevils' diet with vitamins and amino acids. INRAE scientists performed novel research showing that holometabolous insects (i.e., insects that undergo complete metamorphosis) retain their symbiotic bacteria when developing from larvae to adults. Not only do the bacteria stick around during the tissue reorganisation that occurs during metamorphosis, but the insects also take advantage of this period to relocate the bacteria, such that they are more optimally placed during adulthood. Thus, in the grain weevil, bacteria shape the morphological and spatial changes in symbiotic organs that take place during metamorphosis. The above results can help inform strategies for controlling these major pests of grain crops. ●

Proceedings of the National Academy of Sciences of the USA, doi.org/10.1073/pnas.2007151117

Cabbage shoot weevil
© INRAE, S. Carre

BreedWheat: breeding new wheat varieties for sustainable agriculture

The INRAE-coordinated BreedWheat project has been running for nine years, thanks to funding from the Investments for the Future Programme. The results of its research, produced by 28 public- and private-sector partners, were presented via videoconference on Thursday, December 3, 2020.

As part of the *International Wheat Genome Sequencing Consortium* (IWGSC), BreedWheat helped characterise a reference sequence for common wheat. This work represents a significant technological feat, given that wheat possesses one of the largest, most complex genomes in the plant kingdom. Furthermore, the reference sequence is an excellent tool for expanding understanding of how this grain crop functions.

Genetic variability provides the foundation for breeding programmes. A total of 4,600 common wheat accessions (from modern and ancient modern varieties/lines) were chosen from among the 12,000 accessions available at the Centre for Biological Resources (CRB) for Small-Grain Crops in Clermont-Ferrand. Disease resistance, drought tolerance, and response to nitrogen deficiency had been evaluated in the field for at least 450 varieties.

BreedWheat has vastly improved our knowledge in a variety of domains: researchers have collected substantial multidisciplinary findings; breeders can better exploit genetic diversity, including improving crop tolerance of biotic and abiotic stresses; and farmers have acquired new information and tools to guide their selection and management of new varieties across various agroclimatic conditions in the face of global changes.

https://breedwheat.fr/?lang=en

Assessment and management of natural and climatic risks

Landslides can be better modelled and predicted across space and time

In many parts of the world, landslides represent a danger for local populations, buildings, and infrastructure. At present, high-spatial resolution landslide models utilise remote-sensing data to build inventories and map risk factors (e.g., geomorphic features). Prediction and mapping approaches currently focus on the probability of landslide occurrence and are based on pre-selected spatial units of study; temporal dynamics are rarely examined. As part of an international collaboration, INRAE scientists carried out methodological work in which broad, innovative extensions to traditional approaches were developed and combined. Using a century's worth of inventories for a region of Italy, these new models highlighted how the spatiotemporal dynamics of the landslides were structured. By better understanding the factors at play, it will be possible to improve predictions of these often-catastrophic events.

Earth-Science Reviews, doi.org/10.1016/j.earscirev.2020.103318

Water will play an important role in tomorrow's forests

Trees are a crucial part of terrestrial biodiversity. Acting as carbon "skeletons", tree trunks link the leaves, responsible for photosynthesis, with the roots, which acquire nutrients and water. This critical arrangement arises from the complex vascular system of trees.

However, are trees the only organisms able to transport water in this way? INRAE scientists recently compared water management in trees and mosses. The latter are also iconic denizens of forests. They found that the two types of organisms display great similarities in their water transport systems. One major difference is that moss leaves are more sensitive to relative humidity. In contrast, tree leaves are part of an efficient system for controlling water loss. Trees can thus survive in much drier environments than can mosses. That said, trees still face issues when conditions become abnormally dry. Based on their findings, the scientists developed a model for predicting how climate change will affect the susceptibility of forests to future droughts. The model takes into account both functional and hydraulic mechanisms within trees and the optimal regulation of water loss at the leaf level. The results confirm that, while the trees in our forests have adapted to withstand the droughts they have faced over millennia, they are not equipped to survive major climatic changes.

Nature Plants, doi.org/10.1038/s41477-020-0602-x
Science, doi.org/10.1126/science.aat7631

Highly visible example of tree dieback and mortality in the Romagnat forest near Clermont-Ferrand
© INRAE, B. Nicolas

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Peypin-d'Aigues, a town in southwestern France (Vaucluse). Experimental fire set by the Mediterranean Forest Ecology Team, based out of Avignon. Staff from the French National Forests Office (ONF) verify an edge of the fire.
© INRAE, C. Slagmulder

Storms and fires are two major risks for forests

The ability to resist uprooting is key in allowing forest trees to confront potential wind damage during storms. How well trees are anchored in the soil varies considerably depending on terrain, tree species, and tree age. However, the influence of soil properties has remained largely unexamined until now. Climate change is affecting the hydrological conditions of European soils by increasing precipitation in the winter, the season during which storms are most frequent. Using a decade's worth of data, INRAE researchers modelled the impact of soil moisture content on wind resistance in the maritime pine. They discovered that when the soil is completely saturated with water, tree uprooting becomes much more probable. These findings can inform the management of risks related to inclement weather and its negative impacts on forests.

Forest Ecology and Management, doi.org/10.1016/j.foreco.2020.118614

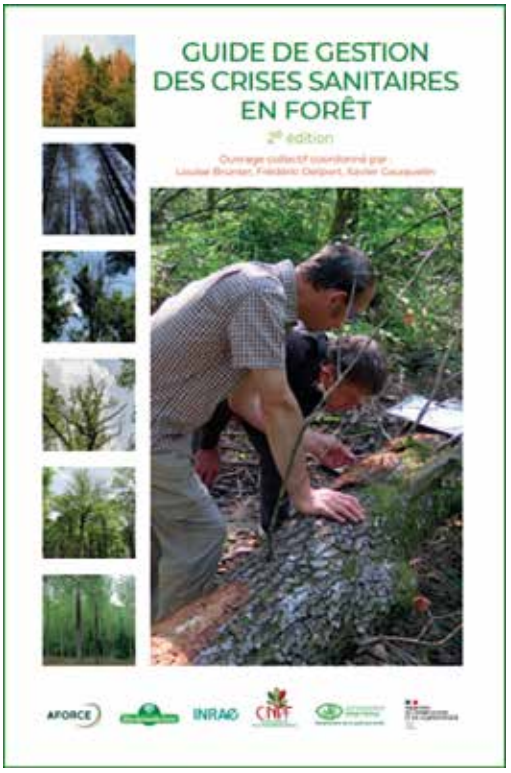
Difficult-to-fight, high-intensity forest fires are a growing threat to ecosystems and societies, especially in the Mediterranean. To increase regional resilience, it is crucial to identify the climatic conditions promoting fire likelihood and to predict how forest fire trends will be affected by climate change. INRAE scientists analysed data from over 10,000 fires that occurred between 1985 and 2015 in the Mediterranean. They discovered that high-intensity fires primarily occurred when dry soils coincided with high temperatures, typically during summer heat waves. Using climate models, they then showed that the frequency of such fires could increase throughout the Mediterranean in coming decades. ●

Scientific Reports, doi.org/10.1038/s41598-020-70069-z

Guide ●●●

Managing forest health crises

Bark beetles, garden chafers, ash and other forms of dieback... Since 2010, forests have been dealing with an array of health crises as local pest populations have exploded. **In most cases, such events have been caused by multiple biotic and climatic variables as well as specific risk factors.** Each crisis has been unique, with its own magnitude, challenges, dynamics, and optimal management strategies. However, every single one of the crises has all disrupted forest management regimes for multiple years. A new edition of a guide for managing forest health crises has been published **by the Joint Technological Network for the Adaptation of Forests to Climate Change (RMT Aforce)**, which has brought together 16 public and private stakeholders interested in forest management, health, and research, including INRAE and the French National Forest Ownership Centre (CNPF-IDF). The guide adopts a generalised risk analysis framework and provides practical recommendations via technical sheets describing twelve health crises in France and Europe. Six occurred in the past; six are more recent and/or ongoing. It details methodological guidelines for dealing with the various components of health crises from both an organisational and a technical perspective.



Scientific priorities

Accelerating agroecological and food transitions while answering socioeconomic challenges

To ensure the success of agroecological and food transitions, we must complete a range of tasks. We need to better understand how biotic and abiotic constraints affect the regulation of biological systems; characterise the genetic diversity found in plants and animals; explore different types of production and production systems; and analyse what encourages and prevents various stakeholders from adopting new production methods. Furthermore, if we want to produce healthy and sustainable food for all, we need more research looking at how industries are organised, how markets function, and how public policies operate.

An exploration of transitions and obstacles to autonomy

Agricultural systems can be transformed via farmers' innovations

We need to transform agricultural practices completely and systemically if we wish the agroecological transition to be successful. Among the suite of promising farming innovations is the strategy of combining crops, which can reduce agriculture's environmental impacts while maintaining or even increasing yields. Although this strategy is not yet widely used, the few farmers employing it are satisfied with the results. This approach may yet become a source of inspiration for others. INRAE researchers explored the temporal organisation of and prospective markets for 77 different combinations of 29 species in total. This study collected and synthesised information about why farmers have adopted certain approaches. This knowledge can be parlayed into concrete resources that other farmers can employ to design customised crop combinations.

European Journal of Agronomy, doi.org/10.1016/j.eja.2020.126018

Understanding and managing "ecosystem disservices" can help promote the agroecological transition

In recent years, much research has been devoted to the services provided by ecosystems to human societies. Underlying this work is the idea that ecosystem functions can serve as the basis for production systems that balance production needs and environmental concerns, namely protecting biodiversity. Consequently, little attention has been paid to the potential downsides of this approach. The ACTAFORSE project examined how farmers perceive rural forests and found that some held highly negative views of wooded areas. This result suggests it is essential to better understand "ecosystem disservices": their emergence, their expression, and their consequences. If farmers' concerns were to be better addressed, particularly in public policies such as the Common Agricultural Policy (CAP), it seems likely that more would commit to the agroecological transition.

Ecosystem Services, doi.org/10.1016/j.ecoser.2020.101066

Combine harvester in an experimental agroforestry plot near the town of Restinclières; the field contains a grain crop (barley) and a plantation of hybrid walnut trees
© INRAE, B. Nicolas

How can organic and conventional farming be more effectively compared?

A common source of debate is how to best assess the environmental effects of agricultural and food systems. At present, the most common method is life cycle analysis (LCA). However, LCA rarely yields favourable assessments of organic farming. As part of an international collaboration, INRAE researchers discovered that the method often fails to account for certain criteria, including biodiversity, soil quality, the effects of pesticides, and/or societal changes. Indeed, it generally evaluates environmental impacts per kilogram of product, which favours conventional, intensive farming systems. The latter can have lower impacts per kilogram of product but have higher impacts per hectare of land. These findings suggest that LCA should be improved and that other environmental assessment methods should be implemented to obtain more balanced evaluations and better inform both stakeholder decisions and public policies.

Nature Sustainability, doi.org/10.1038/s41893-020-0489-6

Agricultural systems free from synthetic pesticides

Monilia laxa *sporulating on "mummified" cherries* © INRAE, I. Végh

Natural compounds in *Prunus* flowers and fruits can help fight fungal diseases

Fleshy stone fruits are susceptible to fungal infections. One of the most damaging is brown rot, caused by *Monilinia laxa*. This disease's development is very much influenced by weather conditions, which affects both the host plant's phenology and the fungal pathogen's life cycle. INRAE scientists performed experiments using different plant genotypes. They found that high levels of certain compounds in apricot tree branches and in peaches were correlated with a reduced susceptibility to the pathogen. Then, *in vitro* tests confirmed that some of the compounds displayed antifungal activity, reducing *Monilinia laxa* growth and sporulation. These results can help guide programmes seeking to create new varieties.

European Journal of Agronomy, https://doi.org/10.1016/j.eja.2019.125960
Journal of Experimental Botany, https://doi.org/10.1093/jxb/eraa284
Scientia Horticulturae, https://doi.org/10.1016/j.scienta.2020.109707

Advances are made in understanding the plant immune system

In plants, quantitative immunity (disease reduction) is the most common form of immune defence. However, little is known about this response because it is highly complex. A joint INRAE-CNRS research team collaborated with the private company iMEAN to analyse the molecular network responsible for quantitative immunity in *Arabidopsis thaliana*. More specifically, they looked at the response to bacterial infection. They were thus able to describe key quantitative immunity functions. They also highlighted that the system's complexity makes it robust. This work enhances understanding of the mechanisms used by plants to defend themselves against pathogens. Such knowledge is essential in the movement towards lower-pesticide agricultural systems.

Proceedings of the National Academy of Sciences of the USA, doi.org/10.1073/pnas.2000078117

Gene conservation among plant families does not equal conservation of pathogen resistance mechanisms

The fungus *Sclerotinia sclerotiorum* causes white rot in a wide range of plant families. Among those affected are the common bean, castor bean, rockcress, tomato, sunflower, and beet. INRAE researchers explored how these very different plants molecularly responded to the fungus. They found that most of the genes involved in defence were conserved across the different plant families but were not necessarily expressed with the same intensity. This study revealed the diverse mechanisms used by different plant species to deal with infection, generating hypotheses for future research. The results have improved understanding of how plant responses to pathogens have been shaped over evolutionary time.

The Plant Cell, doi.org/10.1105/tpc.19.00806

Stem canker caused by Sclerotinia sclerotiorum, *a fungal plant pathogen. Brown lesions partially covered by white fuzz* © INRAE, D. Blancard

A conversation with...

Julie SUBERVIE

Project Coordinator of FAST (Facilitate Public Action to Exit from Pesticides), part of the priority research programme Growing and Protecting Crops Differently

You are leading a research project that addresses largely unexplored questions regarding pesticide-free agriculture. What are the concerns and goals of this work?
Everyone agrees we must act quickly to boost the transition towards pesticide-free agriculture. However, we face numerous obstacles. Some have been clearly identified, namely the socioeconomic barriers. Certain types of public policies and organisational innovations can be used to dismantle these barriers, but their effectiveness has yet to be shown. Indeed, such effectiveness is rarely evaluated.
FAST aims to gather theoretical and empirical evidence to determine how well different public actions could promote the large-scale transition to pesticide-free agriculture.
Our work is original because it explores the transition at different scales: individual, collective, territorial, industrial, national, and international. One axis of the project is focused on the relationships among the different stakeholders involved in the process. More particularly, it is looking at the link between individual and collective decisions when it comes to engaging in the transition.

What is your approach to the experimental part of the project? Have you identified any specific targets?
Our experimental work allows us to determine how well our theoretical understanding of the transition stands up to the reality of the field. To this end, we combine a range of scientific approaches: laboratory experiments for testing certain socioeconomic mechanisms out of context; field experiments involving the transition's main stakeholders; research-in-action where the stakeholders help co-construct concrete solutions; and simulations exploring how potential broad-scale public policies could affect the market.
To come up with new means of public action, we will interact with the following key stakeholders: farmers, input suppliers, consumers, and public administrators responsible for locally implementing programmes with national or European funding. For example, we will implement pilot support programmes dedicated to supporting cooperatives, and/or we will test consumer willingness to pay for new products that carry a pesticide-free label.

> Our work is original because it explores the transition at different scales: individual, collective, territorial, industrial, national, and international

Your project will last six years. Will you obtain results as you go along?
The expectation is that our project will yield concrete tools for designing and evaluating new public actions. Although it is ambitious, we can achieve this overall goal during the six-year span of our project. However, even within the first few years, we will have our first deliverables concerning the socioeconomic mechanisms at the heart of our work.
It is also important to specify that this project has brought together 75 researchers, including economists, specialists in management science, legal scholars, and sociologists. Its objective is to transcend the issue of pesticides and generate discoveries that can be applied to other fields where public action is equally necessary.

Growing and Protecting Crops Differently—the priority research programme's 10 projects

On September 23, 2020, a meeting was held to launch the projects making up the priority research programme (PPR) "Growing and protecting crops differently". The PPR benefits from €30 million in funding, granted by the French Ministry of Higher Education, Research, and Innovation and the General Secretariat for Investment. INRAE has been entrusted with the programme's scientific management. An international committee selected ten projects that bring together research teams from universities and scientific establishments. INRAE teams are involved in each of the ten projects.

Acronyms	Name	Lead research unit
MoBiDiv	Mobilising and breeding intra- and interspecific crop diversity for a systemic change towards pesticide-free agriculture	Joint Research Unit for Quantitative Genetics and Evolution (GQE) – University of Paris-Saclay – INRAE – CNRS – AgroParisTech
SPECIFICS	Sustainable pest control in Fabaceae-rich innovative cropping systems	Joint Research Unit for Agroecology – INRAE – AgroSupDijon – University of Burgundy-Franche-Comté – CNRS
BE-CREATIVE	Building pesticide-free agroecosystems at the territory level	Joint Research Unit for Agronomy – University of Paris-Saclay – AgroParisTech – INRAE
SUCSEED	Stop the use of pesticides on seeds by proposing alternatives	Joint Research Unit for Horticulture and Seeds (IRHS) – INRAE – Institut Agro-Agrocampus Ouest – University of Angers
VITAE	Cultivating the grapevine without pesticides: towards agroecological wine-producing socio-ecosystems	Joint Research Unit for the Health and Agroecology of Vineyards (SAVE) – INRAE – Bordeaux Sciences Agro
CAP ZERO PHYTO	Adapting the concept of ecological immunity to crop protection: ***Rosaceae*** and ***Solanaceae***, two case studies	Research Unit for Plants and Cropping Systems in Horticulture (PSH) – INRAE
FAST	Facilitate public action to exit from pesticides	Joint Research Unit-Centre for Environmental Economics Montpellier (CEEM) – INRAE – CNRS – University of Montpellier – Montpellier SupAgro
BEYOND	Building epidemiological surveillance and prophylaxis with observations both near and distant	Joint Research Unit for Plant Pathology – INRAE – University of Avignon
PHEROSENSOR	Early detection of pest insects using pheromone receptor-based olfactory sensors	Joint Research Unit-Institute of Ecology and Environmental Sciences of Paris (IEES) – CNRS – IRD – INRAE – University of Paris-Est Créteil – Sorbonne University
DEEP IMPACT	Deciphering plant-microbiota interactions to enhance crop defences against pests	Institute for Genetics, Environment, and Plant Protection (IGEPP) – INRAE – Institut Agro-Agrocampus Ouest – University of Rennes 1

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Research and Innovation Transfer Unit accelerates the agroecological transition by passing along discoveries to stakeholders

On February 27, 2020, a presentation was given at the Paris International Agricultural Show by the Agricultural Technical Institutes (ACTA) Association, the French Chambers of Agriculture (APCA), and INRAE. It laid out the activity report for the Research and Innovation Transfer (RIT) Unit and its strategic priorities for the coming years.

Launched in October 2018 by ACTA, APCA, and INRAE, the unit aims to help disseminate and transfer solutions that will aid farmers, better guiding them through the agroecological transition. Since its creation, the unit has received dedicated funding from CASDAR, a special account for agricultural and rural development managed by the French Ministry of Agriculture and Food.

The unit first tackled the topic of identifying alternatives to glyphosate, as extensively documented at the Glyphosate/Herbicide Resource Centre (www.ecophytopic.fr/centre-de-ressources-glyphosate).

In 2020, four new projects were added; details were made available in easy-to-access reports.

- The objectives of developing **alternatives to herbicides** and **alternatives to copper** in viticulture fits squarely with a fundamental research priority–tackling the significant challenge of reducing pesticide use. It is essential to come up with alternatives to herbicides as weeds are developing resistance. Furthermore, concerns are growing over the effects of authorised active substances on human and environmental health. The same applies to alternatives for copper. Organic agriculture would struggle if the use of copper sulphate, a major weapon against fungi, were to be disallowed.
- Another project explores how **plants can serve the needs of agricultural systems**. Certain species can help manage weeds, promote carbon sequestration in the soil, boost levels of soil organic matter, and/or increase food resources for pollinators. More broadly, they can bolster biodiversity.
- Finally, agricultural technical institutes focused on livestock are dedicated to **producing and better exploiting vegetable proteins in animal feed**. This work contributes to France's national plan for protein autonomy and is exploring strategies for reducing nitrogen losses. The results could help improve farm profitability, enhance water quality by limiting nitrate leaching, and limit GHG emissions.

The resulting applied knowledge is put to work via GECO, a collaborative web tool (*https://geco.ecophytopic.fr/*), and EcophytoPIC, a platform for integrated crop protection (*https://ecophytopic.fr/*). ●

Book ●●●

Biocontrol

INRAE researchers wrote and edited a book that summarises current research on biocontrol and crop protection methods based on biological regulatory mechanisms. The text also includes contributions from research partners at other scientific institutes. It presents a critical review of current and hypothetical solutions. The authors present both the conceptual groundwork for understanding and exploiting biological interactions in crop systems and the potential applications that are already in use or in the works.

https://www.quae.com/produit/1605/9782759230761/biocontrole

Farming transitions

Diversity in livestock systems: an asset, not a constraint

Long absent from the debate on livestock farming, the principles of agroecology are now being applied in livestock farming systems that vary in terms of production types, levels of intensification and environmental conditions. This application jointly improves their technical, economic and environmental performance. Following a literature review, researchers reported on how the diversity of feed resources, animals (individuals, breeds, species) and interactions between livestock and/or crop production can increase the productivity, efficiency and resilience of livestock systems, including aquaculture. Diversity within livestock systems offers many keys to adaptation. However, these systems are more difficult to manage, and require new skills and even major investments, which are obstacles to the development of less specialised breeding systems than the current majority of systems.

Frontiers in Sustainable Food Systems, doi.org/10.3389/fsufs.2020.00109

Chickens in an outdoor run
© INRAE, G. Vasseur Delaitre

Studying the cognitive abilities of farm animals to understand their behaviour

In a free-range broiler chicken farm, some animals explore the outdoor run a lot, while others explore it very little. Researchers from INRAE and ISA Lille - Yncréa Hauts-de-France demonstrated that this difference in behaviour is associated with distinct cognitive abilities. For the first time, they showed that – counter-intuitively – chickens that explore the run the least process information from their environment with more attention, resulting in stronger behavioural inhibition. Investigating the cognitive abilities of farm animals is advancing our knowledge of their biological characteristics. In the case of free-range chicken farming, this knowledge is essential for designing farms that are better adapted to the expression of the animals' behaviour and thus more respectful of their welfare. These studies are being conducted in individual breeding facilities at INRAE's experimental Alternative Livestock Farming and Health of Monogastrics unit, at its Le Magneraud site.

Biology Letters, doi.org/10.1098/rsbl.2019.0721

© INRAE, S. Toillon

Possible ways to control Johne's disease in cattle

Johne's disease, or paratuberculosis, is a contagious and incurable disease affecting ruminants caused by the *Mycobacterium avium paratuberculosis* bacterium. Infection often occurs in the first few weeks of life, but the disease develops late, after several years of latency, making it difficult to detect infected animals. The selection of less susceptible animals could help reduce the spread of the disease. Conducted in the framework of a multidisciplinary, multi-partner research project, analysis of the relationship between genetic characteristics and infectious status has revealed three regions on the genome that are strongly connected to resistance to the disease. These results led to the development of a genomic assessment that will make it possible to breed animals most resistant to Johne's disease.

Genetics Selection Evolution, doi.org/10.1186/s12711-020-00535-9

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Combining genetics and nutrition to reduce the environmental impact of pig production

Livestock farming mobilises arable land for the production of animal feed. Improving feed use efficiency is an imperative to reducing the environmental impact of these farms, thanks to research with pigs based on an approach combining genetics (breeding practices) and nutrition (adjustment of feed rations). On the basis of these initial results, it is possible to orientate breeding and management choices in the interest of more sustainable pig production methods, and thus reduce impacts which contribute to climate change, soil acidification, water eutrophication and land use. ●

Animal, doi.org/10.1017/S175173112000138X

Journal of Animal Science, doi.org/10.1093/jas/skab051

Experimental facility ●●●

Porganic: a new INRAE experimental facility for research in organic pig production

Created with the financial support of the European Union and the Nouvelle-Aquitaine region in France, this scheme aims to accelerate research into organic pig production and support the development of this sector. The project was developed by a think tank led by INRAE researchers from different disciplines and representatives from technical institutes and pig farming professionals. Porganic promotes the use of digital tools to improve production conditions by searching for the most suitable animals and adjusting breeding practices to each individual (customised breeding).

Healthy, sustainable, accessible, and satisfying food for all

The FAO, INRAE and local innovators join forces to build sustainable food systems

This manual was written for "innovators in sustainable food systems" by a group of innovators from every corner of the world (Asia, Africa, the Americas and Europe) at the head of initiatives to produce, share, sell and consume more sustainable food. It reviews initiatives with the potential to change the organisational structures of local food systems and the habits of actors in the field in order to bring about greater sustainability. These initiatives were developed collectively, tested in India and Senegal, and then refined and consolidated in a document accessible to different types of readers.

https://www.inrae.fr/en/news/fao-inrae-and-local-innovators-partner-build-sustainable-food-systems

Read the press report (in French)

"Towards healthy and sustainable food systems: when research accompanies the transition"

https://url.inrae.fr/3eHJAlp

A conversation with...

Alban THOMAS

Director, Economics and Social Sciences Division – INRAE (Ecosocio)

The issues involved in transitions for global food security are very much present in the INRAE2030 strategy. In 2020, INRAE and CIRAD presented the results of the interdisciplinary metaprogramme to shed light on this topic. What was the goal of this initiative?
The GloFoodS metaprogramme was an original initiative involving the dual management of a metaprogramme by INRA (now INRAE) and CIRAD, with scientific co-leadership and the pooling of financial and organisational resources. Initiated in 2014, GloFoodS aimed to structure and lead a research community on global food security, renewing the questions it raises and contributing to the international visibility of INRA and CIRAD on the topic. The GloFoodS metaprogramme has achieved its objective of promoting interdisciplinarity, hybrid approaches and cross-disciplinary insight through a wide range of fields of investigation (North and South). More than 70 scientific articles were produced by some 40 interdisciplinary projects, as well as more than 100 scientific papers, 120 Master's level internships and 35 supervised PhDs. The metaprogramme has had a real leverage effect: several ambitious projects have been subsequently funded by European Union programmes (H2020 and DeSIRA), the ANR, and the Agropolis Fondation.

How has the GloFoodS metaprogramme succeeded in articulating the many themes related to global food security?
The scope of food security is very broad, ranging from the analysis of global balances between agricultural availability and food needs, to food technology processes that reduce losses in food systems, to modelling land use change and food security governance, to dietary transitions. GloFoodS has chosen to work on cross-cutting issues, generally less explored in the scientific literature, rather than analyse the pillars of food security one by one (availability, access, use, stability). This has led to incentive funding being directed towards projects that address questions about the role of governance in how food transitions lead to changes and modifications in the balance of availability; agricultural practices and land use; identification of pathways to reduce losses and waste in agricultural and food systems, and others.

Could you give some concrete examples of what the GloFoodS metaprogramme has achieved?
Many of the achievements of GloFoodS are related to the issues of the INRAE 2030 OS 2.5 strategic priority: "Healthy, sustainable, accessible, and satisfying food for all". The work of GloFoodS has contributed to a better understanding of variations in crop and livestock yields, to the global assessment of the potential of land that can be used for food, energy and bio-industrial purposes, to

(...) GloFoodS research has contributed to a better understanding of variations in crop and livestock yields

the identification of processes and organisations that limit losses and waste, and to the understanding of the links between household access to food and the dimensions of poverty and trends in social inequalities in developed and developing countries. These different concrete results are available to field and public actors. ●

Press release on GloFoodS
https://url.inrae.fr/3qXgyKL

Scientific priorities

Building bioeconomies based on the efficient circular use of resources

Ensuring the sustainability of bioeconomies implies in particular the development of sectors (food, energy, chemicals and materials) which substitute renewable carbon for fossil carbon and which encourage the efficient management of water, carbon and nutrients (nitrogen, phosphorus), in order to reduce the environmental impacts.
The role of microbial communities in the nitrogen cycle, the development of tools for water management in agriculture, the optimisation of plastics recycling, the valorisation of plant by-products, and the improvement of waste-to-energy processes are all examples of fields of research for INRAE.

Carbon, nitrogen and phosphorus cycles in terrestrial ecosystems

The impact of durum wheat domestication on the nitrogen cycle

The advent of agricultural practices that reconcile economic and environmental issues in a sustainable manner requires limiting inputs and seeking more efficient plant cover in the use of water, mineral and light resources. In this context, plant-microbiome interactions are set to play a key role in the development of a more sustainable agriculture. A multi-partner team characterised bacterial and fungal communities and the abundance of microbial guilds involved in the nitrogen cycle of 39 accessions representing the four main stages of the evolutionary history of durum wheat. Variability in the relative abundance of fungal and bacterial communities could be related to the domestication process and especially to the genetic variability present within each of these four stages. For example, the emergence of input-rich agriculture has reduced the representation of nitrifying and mycorrhizal fungi involved in mineral resource mobilisation. The presence of a genetic component in these plant-microbiome interactions suggests that breeding would be possible to target beneficial microbial associations. ●

Scientific Reports, doi.org/10.1038/s41598-020-69175-9

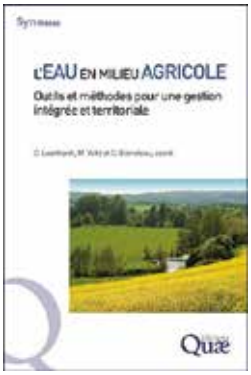
Innovative and sustainable farming systems: view of "La Cage", an experimental, innovative and fungicide-resistant cropping system © INRAE, P. Saulas

ERC Grant ●●●

Carbon neutrality target for Europe

The European Union has set the ambitious goal of achieving carbon neutrality in Europe by 2050. The COSMYCA project, funded by a €2.7 million European Research Council (ERC) Consolidator grant awarded to Lisa Wingate (INRAE), aims to improve current CO_2 monitoring models by studying a similar gas: carbonyl sulphide (COS). This gas is structurally similar to CO_2, making it a reliable tracer gas. This project will allow us to better understand the carbon cycle, to simulate future developments on long time scales in a very reliable way, and thus adapt our ecosystems to cope with climate change.

Book



The water cycle: large and small cycle interaction

Water in agriculture. Tools and methods for integrated and regional management

Water is a major issue in many parts of the world because of rapidly growing needs, but also due to the scarcity and degradation of available resources. As agriculture is the primary source of consumption of water resources, the sustainability of water management in rural areas is crucial. This publication, coordinated by three INRAE researchers, looks at rural water management objectives and approaches, and reviews a broad panel of currently available tools, methods and data. The report also describes examples of implementation in different case studies.

Scientific Reports, doi.org/10.1038/s41598-020-69175-9

Treatment and usage of biomass, by-products, wastewater, and organic residues

How can we turn our plastic waste into resources?

Because of the diversity of their applications, plastics have quickly invaded our daily lives. Polyethylene terephthalate (PET), which is used to make bottles, textile fibres and packaging, is one of the most widely produced polyesters in the world (70 Mt/year). However, thermomechanical recycling, the current main route for PET, only processes a fraction of the waste and diminishes its properties. As a result, this plastic remains a waste product. In collaboration with a company called Carbios, INRAE researchers developed an enzyme with improved depolymerisation results for PET waste. Industrial partners succeeded in producing new bottles using the purified monomers, thus demonstrating the circularity of the process. This is a major step forward in the end-of-life management of plastics and their closed-loop recovery, which makes it possible to meet this environmental and societal challenge.

Nature, doi.org/10.1038/s41586-020-2149-4

Plastic bottles © Pixabay

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A new step in valorising plant by-products

Representing 12.1 million tonnes of dry matter (2016 figure), the food by-products generated each year in France represent a high potential source of renewable raw materials. To support the transition to more sustainable agrifood chains while meeting consumer expectations for more natural products, an assessment was made of the potential of plant by-products as emulsion stabilisers. By-products from the primary processing of plants in the food industry could be used as a new source of ingredients without fractionation, purification or chemical modification. A first proof of concept was established with pomace from apple juice production and oat bran. Subsequently, the study was supported by predictive models of texture and stability. The generality of this approach will be tested using other plant by-products. The sensorial properties obtained by these processes are different from "classic" emulsions and will be compared with consumer perceptions.

Journal of Food Engineering, doi.org/10.1016/j.jfoodeng.2020.110115
Journal of Colloid and Interface Science, doi.org/10.1016/j.jcis.2020.07.078

Compost © Pixabay

Pollution control, fluidised bed anaerobic digester. INRA-Degremont collaboration © INRAE, R. Moletta

Improving the performance of anaerobic digestion

Anaerobic digestion is a microbial bioprocess used increasingly on an industrial scale to convert organic waste into methane-rich biogas, including on farms. However, the microbial interactions that govern it remain sensitive to many inhibitors that can lead to significant functional problems. A major challenge for operators is to anticipate these malfunctions in order to limit their economic and environmental impacts. To this end, significant research efforts were made to characterise the composition of microbial ecosystems in anaerobic digesters under different inhibition conditions by sequencing. An innovative statistical method of data integration was used to study these results and identify a robust microbial signature of anaerobic digester inhibition. Its potential for use in predictive models for early diagnosis of the proper functioning of bioprocesses was then validated with a success rate of over 90%.

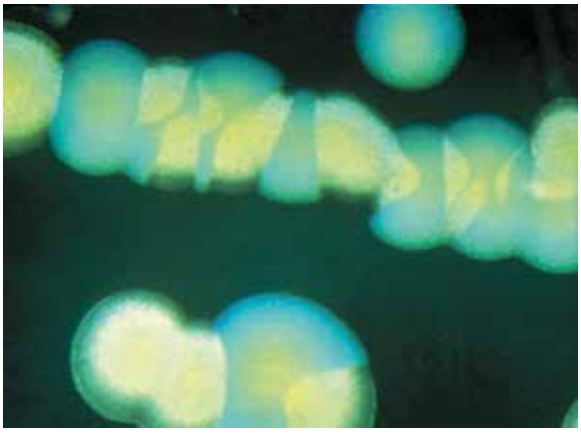
Bioresource Technology, doi.org/10.1016/j.biortech.2020.123952

Exploring without limits the functional potential of microbial ecosystems

Microbial communities play a role in human and animal health, in food quality and in the bioremediation of polluted environments. Researchers from the Toulouse Biotechnology Institute (TBI) and the University of Cambridge developed an ultra-high-throughput screening method that allows the functional diversity of the equivalent of thousands of bacterial genomes to be explored in just one hour of work. The microfluidic technology implemented is now available to the scientific community *via* the PICT-ICEO platform of the Toulouse Biotechnology Institute (European IBISBA infrastructure). ●

Microbiome, doi.org/10.1186/s40168-020-00911-z

Access to PICT-ICEO



Colonies of smooth (blue) and rough (yellow) Brucella bacteria
© INRAE, G. Bezard

Conference ●●●

First World Agrivoltaic Conference organised by INRAE

This conference, organised by INRAE and initially to be held in Perpignan, took place 14-16 October online due to the pandemic. It brought together over 350 participants from 38 countries. Scientific discussions focused on practices and techniques compatible with agricultural production and in line with soil quality, its production potential and the full reversibility of the facilities.

Conference website

Scientific priorities

Promoting a holistic approach to health

In 2020, the public health crisis related to the SARS-CoV-2 pandemic highlighted the importance of the interactions between human health, animal health and environmental health. INRAE scientists are committed to the "One Health" concept of animal, plant and human health awareness. The assimilation of these three dimensions is still difficult, however. Research conducted at INRAE, for example, focuses on the modelling of animal or plant epidemics in order to identify possible areas of emergence and better control them; the treatment of infectious diseases and possible therapeutic roadblocks; and the risks associated with environmental pollution. Nutrition – a major intermediary between human health and the environment – is explored in INRAE research, particularly *via* studies on preventive nutrition

Emerging and re-emerging infectious diseases that move within and among environments, agricultural systems, and food production systems

Epidemiological modelling for animal disease control

Endemic disease is a constant presence in livestock farming that can lead to heavy medium- and long-term losses. Controlling these diseases is essential for sustainable agriculture. A joint interdisciplinary scientific study involving biologists, economists and modelling specialists highlighted the way in which mathematical modelling in epidemiology contributes to a better understanding and prediction of the circulation of these diseases, and can also contribute to controlling them at all levels, from the animal to regions and production sectors. Scientists identified the scientific and methodological difficulties which remain when proposing targeted control options and assessing their impact. For example, the strategic decision-making of farmers needs to be included to better understand the trade-off between individual and collective management, and thus to better direct incentives.

Epidemics, doi.org/10.1016/j.epidem.2020.100398

One week-old lambs born at the Brouëssy experimental farm © INRAE

New drug targets for the prevention and treatment of parasitic diseases

The prevention and treatment of parasitic diseases caused by worms, especially roundworms, in animals and humans is a public health issue. The emergence of drug resistance in parasites compromises the success of treatments. Understanding the mechanisms of parasite development makes it possible to find novel targets for effective drugs. Using a combination of *in vitro* and *in vivo* approaches in parasites together with *in silico* modelling, researchers identified a control point for the development of the infective stage of *Dirofilaria immitis*, which causes cardiopulmonary heartworm disease in cats and dogs. These results offer innovative perspectives for the development of therapies to combat these infections.

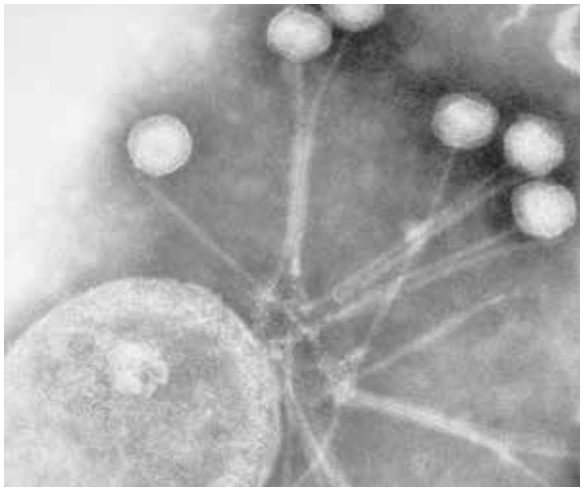
Scientific Reports, doi.org/10.1038/s41598-020-67466-9

The risk of a Rift Valley fever epidemic in Senegal

Rift Valley fever (RVF), transmitted by mosquitoes, mainly to cattle, causes widespread abortion and high mortality in younger animals. It is a zoonosis, the severe form of which can be fatal to humans. RVF is on the WHO list of the most important emerging infectious diseases. The locations most at risk of an outbreak vary from year to year. The authors of this study propose a modelling approach to map this risk on time and space scales that can only be achieved through the use of satellite data. Further work will seek to test climate scenarios in relation to epidemic risk and to anticipate this risk.

Epidemics, doi.org/10.1016/j.epidem.2020.100409

Mosquito © AdobeStock



Bacteriophages of lactic acid bacteria attached to non-pathogenic organic debris
© INRAE, M. Rousseau

Uncovering hidden bacterial viruses in the microbiota to fight antibiotic-resistant bacteria

The composition of the gut microbiota and the role of each of the microorganisms involved are still poorly understood. It is known that the microbiota is composed of hundreds of different species of bacteria, each of which plays a role in the proper functioning of the digestive tract and in our health. Other microbial instigators such as fungi or human and bacterial viruses (bacteriophages) are also found there, but are less well known. This is why researchers are interested in the interactions between each of these elements, particularly between bacteria and bacteriophages. A large-scale international study identified that within the gut microbiota, two classes of bacteriophages emerge, which are distinguished by their strongly contrasting abilities to infect bacteria. The most infectious ones could prove useful in phage therapy, an alternative to antibiotic treatment. ●

Nature Communications, doi.org/10.1038/s41467-019-14042-z

Book ●●●

Zoonoses: diseases that link us to animals

This book, written by researchers from INRAE, CNRS and ANSES, sheds light on zoonoses, the diseases transmitted between animals and humans. After defining what these diseases are, how they are transmitted and presenting the major zoonoses, the authors focus on understanding what supports their emergence. They explain the various ways in which we can protect ourselves from them on an individual and collective scale and question our collective global responsibility.

Pollution, contaminants and the exposome

What are the impacts of water pollution on human health and aquatic environments? What methods should be used to monitor this pollution?

Waste water can contain a large number of organic and inorganic micropollutants that are not fully removed by treatment processes. Certain pollutants remain in the water discharged to the environment after processing. Researchers from INRAE, in collaboration with the *Syndicat national des entreprises de traitement de l'eau* (Synteau), have assessed, for the first time on a country-wide scale, the potential impact of a hundred or so of these micropollutants on human health and the aquatic environment. The substances of greatest concern are polycyclic aromatic hydrocarbons, pesticides, drug residues, and various elements such as trace metals. The presence and persistence of these substances in the environment highlight the importance of developing innovative, specific treatment methods and of taking action to reduce the problem at the source.

Identifying ways to monitor chemical pollution is a crucial issue for preserving aquatic ecosystems and water quality. Researchers from INRAE and the French Office for Biodiversity (OFB) developed and tested an approach using gammarus, a type of crustacean, to predict the contamination of fish by perfluorooctanesulphonic acid (PFOS), a surfactant. The feasibility study shows that measuring the concentration of PFOS in caged gammarus predicts the exceedance of limits imposed by environmental quality standards for this substance in the aquatic environment.

Water Research, doi.org/10.1016/j.watres.2020.116524

Environmental Sciences Europe, doi.org/10.1186/s12302-020-00416-4

Contamination of cereal-based foods: a new risk factor for inflammatory bowel disease

The number of people suffering from chronic inflammatory bowel disease has increased steadily over several decades in both developed and developing countries. These diseases can be caused by multiple factors including exposure to certain food contaminants. A team of researchers from INRAE and Purpan engineering school demonstrated for the first time that low-level exposure to deoxynivalenol, one of the most common mycotoxins found in cereals and cereal-based foods, increases the risk of chronic inflammatory bowel disease and exacerbates its symptoms. ●

Archives of Toxicology, doi.org/10.1007/s00204-020-02817-z

Preventive nutrition for improved public and environmental health

A better understanding of the origin of satiety

With a view to adjusting eating habits to improve health or in relation to particular living conditions, researchers explored the mechanisms that govern the sensations of hunger and fullness in our brain. Carried out in mice, their work showed that this involves a cascade of reactions triggered by a rise in blood glucose levels. This leads to a change in a type of nerve cell (astrocytes) involved in the activity of neurons previously identified as playing a role in food intake. Surprisingly, a high-fat meal does not induce this remodelling. Does this mean that fats are less effective in reducing hunger? Scientists are trying to determine whether they trigger satiety through another circuit. It also remains to be seen whether sweeteners have the same effects or whether they are a decoy for the brain, providing only the addictive sweet sensation without staving hunger.

Cell Reports, doi.org/10.1016/j.celrep.2020.02.029

Monitoring nutritional recommendations: a confirmed positive impact on the environment

Western diets are characterised by high sugar, salt, saturated fat and meat intake, as well as a high consumption of processed foods. In addition to health consequences, current food systems are responsible for almost a third of GHG emissions and contribute significantly to water and soil pollution and biodiversity loss. In this context, changing food production and consumption habits is a necessity. France's national dietary guidelines were updated in 2017 and for the first time incorporated environmental preservation. Scientists from INRAE, Inserm, Sorbonne Paris Nord University and Solagro conducted a multi-criteria evaluation of these guidelines based on data from 28,340 participants in the NutriNet-Santé cohort study. Their results show that adhering to these new dietary guidelines has a positive impact on both health and the environment.

Nature Sustainability, doi.org/10.1038/s41893-020-0495-8

New perspectives in the prevention and treatment of chronic inflammatory diseases

Celiac disease is an immune disease of the intestine that affects more than 1% of the world's population. It is characterised by gluten intolerance, which causes inflammation of the intestine, abdominal pain, diarrhoea and can lead to weight loss and deficiencies in patients. The vast majority of these chronic

conditions are linked to a loss of richness in the intestinal microbiota and its alteration. A balanced dialogue between the human host and its gut microbiota is essential to maintaining health. Using an animal model, the researchers provided evidence for the first time that intestinal inflammation and the accompanying alteration of the microbiota can maintain one another and generate a stable pre-disease state.

They also showed that dietary intake of tryptophan and supplementation with probiotics capable of metabolising this amino acid reduces intestinal lesions caused by celiac disease in animals and opens up new therapeutic prospects for humans – the only existing treatment at present being a strict and restrictive gluten-free diet. These results, obtained within the framework of the European Research Council (ERC) supported Homo.symbiosus project coordinated by INRAE, open up new avenues for diagnosis, preventive nutrition and therapy in human medicine. ●

Science Translational Medicine, doi.org/10.1126/scitranslmed.aba0624

Guide ●●●

Nutritional guide for the elderly

Undernutrition, which affects more than two million people in France, is a pathological condition that threatens the health, independence and life expectancy of the elderly. The risk of mortality is four times greater in an undernourished person. The result of several years of joint effort, an informative and practical guide for the elderly, their families and professional carers, was produced by researchers from INRAE and the Dijon University Hospital.

Access to the guide [in French]: ***https://url.inrae.fr/3nrjLRo***

© AdobeStock

Scientific priorities

Facilitating transitions by mobilising data sciences and digital technologies

The challenges of multiple transitions make it necessary to evaluate agricultural, food, environmental and regional systems in their totality and in terms of their diversity. Scientific, technological and methodological progress made possible by digital sciences and technologies creates new ways to explore this complexity. The modelling and simulation of complex dynamic systems is a growing field of research. Information sensors implanted in the environment or on board drones and satellites have become essential for exploring new scales – spatial, temporal or organisational – of understanding and action.

Complex and evolving systems

A novel statistical method to identify regulatory networks for gene expression in bacteria

Genomic sequences and (transcriptomic) gene expression data are becoming increasingly easy to obtain. In contrast, the integration of these sources of information to improve knowledge of genetic regulatory networks remains difficult and largely manual, even for the integration of organisms as simple as bacteria. To address this challenge, researchers developed a new approach to identify regulatory motifs in DNA sequences. This is based on an original statistical model that uses simultaneously DNA compositional properties and gene expression profile data. To demonstrate its relevance, the method was applied to a large public dataset aggregating the results of numerous studies on *Listeria monocytogenes* bacteria. The results shed light on the regulatory networks of this bacterium, which is both a model pathogen and the pathogen responsible for a major anthropozoonosis: listeriosis. Coupled with the acquisition of transcriptomic data, the method can be applied to any bacterium. ●

Journal of the Royal Society Interface, doi.org/10.1098/rsif.2020.0600 ;
Free software: *forgemia.inra.fr/pierre.nicolas/multiple*

The mapping of cereal crop yields using image processing. Basic satellite image provided by the Spotimage company © INRAE, P. Boissard

Sensors and information acquisition systems

Remote sensors: a necessary change of scale for monitoring the impact of agricultural practices or the state of vegetation

Proxy-detection and sensor-based remote sensing technologies are only one aspect of precision – and, more broadly digital – agriculture. Nevertheless, they play a key role in crop information and the modulation of practices.

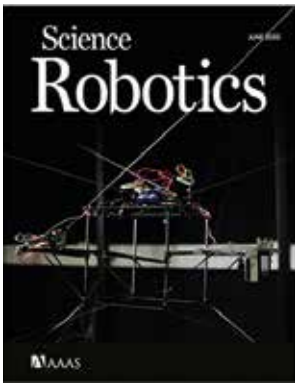
Progress is needed to better quantify the carbon budget of farmed ecosystems and explore the benefits of practices that promote storage across large areas. A new approach was developed to estimate carbon budgets at the plot level using a combination of high-resolution remote sensing and agronomic modelling. The agro-meteorological model was downscaled to accurately illustrate the development of vegetation as "seen" by the satellite, making it possible to implicitly account for the effect of abiotic stresses and practices on biomass production and the components of the carbon budget (CO_2 flows, carbon export at harvest, etc.). This approach is particularly well suited to quantifying the effect of intermediate crops – one of the main mitigation levers in agriculture – on carbon storage in agricultural soils.

Monitoring the condition, functioning and composition of vegetation in response to different stress factors is also necessary to understand adaptation mechanisms. The estimation of leaf chemistry using remote sensing plays a central role, and the monitoring of leaf nitrogen content is particularly important.

Recent work combined modelling and machine learning to measure and monitor the nitrogen content of vegetation.
Geoderma, doi.org/10.1016/j.geoderma.2020.114428
Remote Sensing, doi.org/10.3390/rs12182967
Remote Sensing of Environment, doi.org/10.1016/j.rse.2020.112173

A robot to track and film insect flight

Flying insects have developed efficient strategies for moving around in natural environments. However, the experimental study of these strategies is still difficult because of their small size and the high speed at which they move. Today, only studies of tethered insects (flight simulators) or hovering insects are possible. Scientists taking part in a joint INRAE – CNRS – University of Lorraine collaboration developed the first cable-guided robot capable of following and interacting with an insect in completely free flight. This work is a step toward tracking various insects, such as drosophila or mosquitoes, and will allow us to better understand their orientation strategies in response to olfactory stimuli. In insects, the location of odour sources plays a major role in the expression of sexual and feeding behaviour. ●



Science Robotics, doi.org/10.1126/scirobotics.abb2890
(robot on cover of *Science Robotics*)

CIAg Crossroads for Agricultural Innovation conference: spatial technology applied to ecological transitions

Managers and farmers need agri-environmental indicators and tools to monitor the environmental impact of agricultural activities at various spatial scales. The 2020 edition of the CIAg Environment conference was an opportunity to share new developments in solutions based on high-resolution imagery, new possibilities for characterising agroecosystems, and landscapes that can inform the decisions of stakeholders engaged in agroecological transitions.
This conference was of particular interest to potential users of the results of spatial research: start-ups (in particular companies seeking opportunities with researchers to identify outlets in the agricultural and/or environmental sphere), intermediary actors in these two spheres (cooperatives, consultants, etc.), along with local authorities and land management bodies, associations, teachers and students in these fields.
https://url.inrae.fr/3oV0R6c (in French)

In brief ●●●

The Dinamis portal: simplified access to spatial imagery

This national system for shared satellite imagery facilitates access to very high-resolution spatial images and offers a link to a selection of free images with complementary resolutions for many users. The user-friendliness of data from satellite systems makes it possible to develop its use in research, regional development and planning, environmental monitoring and management, innovation and the creation of added value (in the earth sciences, the environment, agronomy, social sciences, etc.). The scheme was created under the impetus of six founding organisations: CNES, CNRS, IGN, INRAE, IRD and CIRAD.
dinamis.data-terra.org

A book for smart farming

The increasing use of new technologies in agriculture, or smart farming, has led to new approaches in decision support. Agricultural Internet of Things and Decision Support for Precision Smart Farming, a book to which several INRAE researchers contributed, deals with the issues and opportunities related to IoT applications in agricultural production. It answers a need for knowledge and resources to support their development.
doi.org/10.1016/C2018-0-00051-1

Partnerships and impacts

Partnerships and impacts

Placing science, innovation, and expertise at the centre of science-policy dialogue

INRAE's research revolves around major, increasingly complex societal challenges involving a wide range of stakeholders. These relationships drive innovation and have far-reaching impacts. INRAE draws on knowledge, know-how and expertise within its specialty areas and tailored systems to accelerate the design and implementation of public policies and solutions that truly work for economic and societal stakeholders. It promotes open science, knowledge transfer and scientific debate with society.

Collaborative research that fosters innovation

Partnerships are essential to the Institute's activity. INRAE works alongside academic institutions, civil society organisations, public and private economic stakeholders, technical institutes and more. This innovation-focused partnership approach has been strengthened over the past few years through the INRAE-led Carnot institutes and an offer structured around 14 fields of innovation. These efforts have begun to pay off, **with the renewed certification in 2020 of four Carnot institutes and the new certification of the Carnot Eau et environnement** institute, along with backing for projects to increase their level of technological maturity (from level three to five, i.e. the industrial biotechnology catalyst phase), the development of more collaborative partnerships in shared laboratories (called LabComs), and the implementation of a new partnership system with shared resources, known as the Associated Partner Laboratory.

Additionally, support for the creation of new companies and start-up collaborations saw a boost with the INRAE-IRSTEA merger. **A Business Creation Unit** was created within the INRAE Transfert subsidiary with a new manager and several employees (+2.5 FTEs). Scientists who wish to embark on this path can get training and advice, support for creating a new business, help in preparing their pitch, as well as contacts with investors.

For start-ups outside INRAE, the Institute is committed to co-funding research, facilitating access to the results and providing support, which may include hosting these fledgling companies. As proof of this success, more than ten companies were created within two years (2019 and 2020), compared to just two or three per year previously.

In addition to traditional licensing, INRAE is also exploring new ways of transferring its 2020 research results **by developing serious games**. A platform providing access to tools to support and disseminate serious games is being designed to promote dialogue between researchers with experience in this field and those who are new to it. A working group was formed to consider new collaborations, especially with agricultural high schools, ministries, technical institutes and consultancies.

Discussion in the field between a farmer practising soil conservation agriculture and a researcher in the Joint Research Unit for Agroecology
© INRAE, B. Nicolas

INRAE adds a fifth Carnot institute

INRAE heads up four Carnot institutes that were all recertified in 2020: France Futur Elevage, Qualiment, 3BCAR and Plant2Pro. This certification is awarded to public research organisations with an active strategy to develop contractual and collaborative research with socio-economic players (mainly companies). The Carnot institutes are thematic initiatives for private stakeholders designed to encourage stakeholders to get involved in setting up and co-designing research, development and innovation projects. The fifth Eau et environnement Carnot institute (focused on water and environmental issues), centred around the activities of IRSTEA and INRA, has received a probationary certification for 18 months.

LPA: a new form of partnership at INRAE

As a result of the work carried out in 2020, INRAE's first Associated Partnership Laboratory (known by the acronym LPA) was created with the company Excilone. INRAE and Excilone drew up a five-year roadmap to pool their facilities and staff for a research and technology programme in the field of microgenomics. The initiative is covered by a special agreement that can be easily dissolved or renewed and which provides additional flexibility for the terms of creation and evaluation. This new type of collaboration will be extended to other research areas within INRAE.

AlgaHealth awarded LabCom certification

AlgaHealth received LabCom certification from the French National Research Agency (ANR), making it INRAE's tenth shared laboratory. Scientists from INRAE and a partner company, Olmix, are working together at AlgaHealth to assess the potential of algae to ward off infectious diseases in farm animals. This assessment of algae extracts has already shown that they can be used to stimulate animals' immune response, protect mucous membranes against pathogens and reduce the use of veterinary medicines on farms. INRAE and Olmix signed a framework agreement to continue their collaboration.

INRAE supports start-ups via AgriO

In February 2020, the French Tech Seed fund named the AgriO consortium a business contributor for a period of two years. INRAE, through its subsidiary INRAE Transfert, leads this consortium, which brings together AgroParisTech, the Institute Agro via its internal Montpellier SupAgro school, AgrOnov, IAR, Vitagora and Agri Sud-Ouest innovation. Its purpose is to support start-ups in the agriculture, food, agro-industry and environment sectors as soon as projects are identified in laboratories, and to facilitate initial financing from investors through their certification. A total of 21 start-ups applied to AgriO, and three obtained the AgriO French Tech Seed certification and applied for convertible bonds from Bpifrance to complete their seed funding. ●

Key figures

Companies created in 2020

3
companies created based on INRAE results

19
business creation projects based on INRAE research results

20
scientists and project leaders supported (through coaching sessions) by Vianeo

Joint Technology Units and Networks

INRAE is working to consolidate its scientific and technical partnership with teams from technical institutes on topics with major socio-economic and environmental implications. **Six new Joint Technology Units** and **20 Joint Technology Networks** were certified by the French Ministry of Agriculture and Food in 2020.

Joint Technology Units	Partners
Géno-Vigne	IFV
PrADE – Protection of bees in the environment	ACTA-ITSAP
Ruminant health monitoring	IDELE
SANIVOL – Health and well-being	ITAVI
FIORIMED – Multi-performance of protected horticultural crops	ASTREDHOR
PASTO – Resources and transformation of pastoral livestock in the Mediterranean region	Institut de l'élevage

Bee foraging on a flower in the Loubert rose garden, near Angers, France. (Photo) © INRAE, B. Nicolas

Joint Technology Networks involving the ACTA, APCA and ACTIA networks	Lead organisation
FILARMONI – Economics of animal sectors	IFIP
AL-CHIMIE – Chemical contamination of food chains	ACTA
Fields & Territories	Burgundy-Franche-Comté Chamber of Agriculture
Cheese industries promoting their terroir	CNAOL
MAELE – Macro-livestock environment	IFIP
SDDMA – Data science and modelling for agriculture and agri-food	ACTA
Work in agriculture	IDELE
SPICEE – Structuring and producing innovation in mixed crop-livestock farming systems	IDELE
Soils and territories	Chambre d'agriculture Grand Est
BOUCLAGE – Recycling, fertilisation and environmental impacts	ACTA
BIOREG – Biodiversity for natural pest control	ASTREDHOR
CACP – Short food chains for sustainable food	FR – CIVAM Bretagne
AFORCE– Helping forests adapt to climate change	CNPPF
TRANSFOBIO – Maintaining organic product quality	CRITT PACA
ECOVAL – Eco-design and evaluation	ITERG
QUADIFERM – Quality of fermented and distilled products	IFV
PROPACK-FOOD – Sustainable packing, circular economy and food waste	LNE
QUALIMA – Control of the microbiological quality of food	AERIAL
PROT&IN – Development of protein ingredients and feed sources	ADIV – ITERG
ECOFLUIDS – New efficient water and energy solutions (processes, transformation)	CRITT Agro-alimentaire PACA
CHLEAN – Hygienic design of lines and equipment and improved cleanability	CTCPA
FLOREPRO – Role of conservation crops in sector sustainability	ADIV

Scientific expertise as a tool for confronting major challenges, encouraging societal debates, and informing public policies

Because science and society are inextricably linked, INRAE aims to use its scientific expertise to better understand current and future challenges and inform public policy decisions. When INRA and IRSTEA merged in 2020 to form INRAE, the roles and missions of Expertise and Support for Public Policies were firmly established with the creation of a dedicated Directorate General.

With its two directorates – the Directorate for Expertise, Foresight and Advanced Studies and the Directorate for Support for Public Policies – the new Directorate General manages interactions with French ministries, agencies and local authorities. Its staff work with INRAE scientists to develop expertise and support for public policies at the regional, national and international levels, including collective expertise, foresight studies, and tools and indicators for evaluating public policies.

INRAE is working to consolidate its activities through stronger dialogue between researchers, engineers and public decision-makers. For example, these activities are integrated into the principles of individual evaluations that INRAE researchers and engineers undergo.

In 2020, INRAE strengthened its ties with three ministries:

- The Ministry of Agriculture and Food: discussions on major issues and long-term public policy support initiatives, such as three epidemiological surveillance platforms (animal, plant and food chain), the InfoSol research unit, or the GIP GEVES (French Group for the Study and Control of Varieties and Seeds).
- The Ministry for the Ecological Transition: framework agreement signed in September 2020 to structure the priority themes and collaboration conditions for the next five years.
- The Ministry for Solidarity and Health: presentation of expertise to promote discussions on complex subjects involving food and health, agriculture and health, and the environment and health.

P. Mauguin and P. Flammarion present INRAE's work on natural risks and hydraulic structures to French Minister E. Borne at the Paris International Agricultural Show
©INRAE, B.Nicolas

Meetings were held throughout 2020 with public partners to renew over half the Institute's framework agreements (French Biodiversity Agency – OFB; Water authority for the Rhône-Méditerranée-Corse region; French agency for Ecological Transition (ADEME); Météo France; Centre for studies and expertise on risks, the environment, mobility and development – CEREMA; French agency for radioactive waste management – ANDRA). European-level gatherings were also held, such as a seminar with the PEER network of European environmental research institutes and the Directors-General of the European Commission on the challenges of environmental research and the needs for European public policies.

Supporting efforts to phase out glyphosate

Following reports on viticulture and arboriculture, INRAE scientists assessed alternatives to glyphosate in field crops and the related economic impacts at the request of the French Prime Minister and the Ministers for Agriculture and the Ecological Transition, as part of France's plan to phase out glyphosate. This study puts forward an estimate of the additional cost to farmers of no longer using glyphosate based on their cultivation practices.
The study is available online (in French only): https://url.inrae.fr/3dVLYNe

An ambitious CAP that aligns with the Green Deal

The European Green Deal is ambitious, but will the future CAP be able to achieve its objectives? To ensure it can, the European Parliament commissioned a study from experts at INRAE and AgroParisTech. The report makes a series of recommendations, including the strengthening of minimum requirements to benefit from the first CAP pillar, ambitious eco-schemes to reduce greenhouse gas emissions and protect biodiversity, and the safeguarding of budgets allocated to climate and environmental measures in both pillars. This report was used to produce a book published by Quae: What common agricultural policy for the future? This book sketches out an ambitious CAP in terms of objectives and instruments that would facilitate the necessary agroecological transition of European agricultural and agri-food systems.
https://url.inrae.fr/37YlzdF
https://url.inrae.fr/3i0qXRf

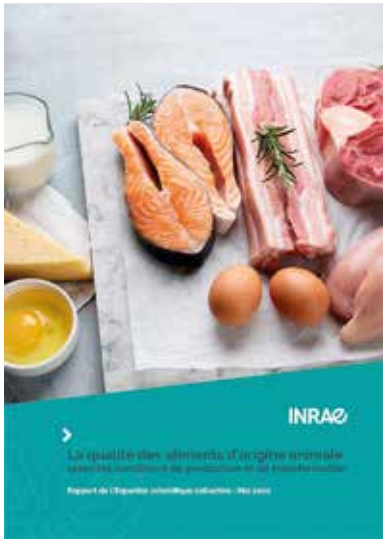
Promoting a holistic approach to the quality of animal products

INRAE coordinates scientific expertise on the quality of animal products at the request of the Ministry of Agriculture and Food and FranceAgriMer. Beef, sheep, pork, poultry, fish, milk and processed foods are described according to their organoleptic, nutritional, health, technological, commercial, use and image properties, and the rearing and processing conditions that enhance or degrade product quality are explained. This study comes at a time when livestock industry professionals are being asked to take better account of societal and environmental issues and to promote a move upmarket in their products.
The summary can be found online:
https://url.inrae.fr/2AlcV64

European agriculture in 2050

In what ways will agricultural land, production and global trade change by 2050? To answer this question submitted by the Pluriagri association, INRAE studied different components of the agricultural and food system in 21 regions of the world, including eight in Europe. The report highlights significant land tensions, particularly in Africa and India. It also suggests that Eastern Europe, Poland and Germany could see their land requirements decrease from their current levels. Several strategies for alleviating land tensions are explored, with each one looking at Europe's contribution to this objective.
Find out more:
https://url.inrae.fr/2HQjy6h

Summary of the expert report on food quality
© INRAE



A plan to replace neonicotinoids in sugar beet cultivation

INRAE and the Applied Agricultural Research Organization for sugar beet (ITB) submitted a proposal for a national research and innovation plan of more than €20 m to the Minister of Agriculture and Food in September. This plan, which is supported by €7 m in funding from the French agricultural and rural development (CASDAR) fund and the economic stimulus plan, aims to identify alternatives to neonicotinoids to combat beet yellow virus, which caused significant yield losses in some regions in 2020.
The plan has four parts:

- improved understanding of the crop health situation;
- identification and demonstration of crop-wide solutions;
- identification and demonstration of control solutions at the plant, crop and landscape environment scale;
- transition to a sustainable economic model. ●

Open science and shared knowledge

Society's expectations of science are growing, particularly in the Institute's areas of expertise, namely agriculture, food and the environment. They reflect societal issues that extend beyond national borders and require a joint, partnership-based response. Digital tools have also transformed the way scientific findings are being shared.

Open science has developed in response to these phenomena, with the aim of opening up the research process to all and making the resulting products such as scientific publications, data and software both accessible and reusable. The intention is to align science with society's expectations as closely as possible, and to enhance society's understanding of the scientific process, its constraints and its rigour.

INRAE has made open science a key component of its 2030 strategic plan. This strategy provides researchers with an ethical frame of reference to guide them towards new and more widely shared practices. The goal is to move forward together towards more knowledge and better integrate it into innovation and public policy.

A new Directorate for Open Science

INRAE was the first French research institute to set up a Directorate for Open Science (DipSO) in early 2020 to support innovation and the transformation of scientific practices linked to digital technology. Its 57 staff members in 16 centres are responsible for supporting open access to research and its findings, data governance and the development of digital infrastructures. This includes the management of the Institute's portals for publications (https://hal.inrae.fr) and data (https://data.inrae.fr). The Directorate is also involved in European projects (EOSC-Pillar) and international working groups (Research Data Alliance) to make scientific data accessible and reusable via efficient digital infrastructure.

Hadi Quesneville: INRAE's new chief data officer

Research director and former unit director Hadi Quesneville took over as INRAE's chief data officer in May 2020. Alongside the DipSO, he oversees data governance, which refers to good data management and sharing practices, and the promotion of data to the various users. Bringing the Institute's employees up to speed on these good practices is crucial. Through his daily contact with researchers, Quesneville coordinates actions to support them and answer their questions, such as "Can we provide open access to this data, and how?" He relies on a dedicated unit to deal with complex governance issues.

Open access to knowledge

Access to research findings is an essential part of open science. Since March 2020, the HAL INRAE portal (hal.inrae.fr) provides access to INRAE's entire body of scientific productions, including the INRA and IRSTEA archives.

→ Four INRAE researchers received the Liber Innovation Award from the Association of European Research Libraries for their Peer Community In (PCI) initiative, which promotes open, transparent and free peer review practices. PCI is an alternative to traditional scientific publishing, which imposes costly subscription and publication fees. It is based on the review of articles at the pre-print stage by 11 specialised PCI communities.

Improving the quality of shared data

Data is an asset that must be managed throughout the research project life cycle and beyond to address issues of proof or reproducibility of findings.

→ Eight engineers from six INRAE laboratories published an article on reproducible research. It outlines three simple principles: organising project steps, writing understandable software programs and automating operations through to the document presenting the findings. These principles are illustrated by good practices, from the simplest to the most sophisticated, with a focus on the functionalities of the most common software used in the field of economics (Stata, R, SAS, MATLAB, Mathematica, GAMS).

Science in society: new commitments

Given the undercurrent of ambivalence in society's relationship with science, a rapprochement between the two is critical. Citizens have many questions, doubts and sometimes high expectations, while also being sceptical and even critical. The fake news phenomenon has further exacerbated these issues.

→ By renewing its signature of the charter on institutional openness towards society (signatories include seven other public institutions), INRAE confirmed its commitment to transparency and openness in its research, expertise and health and environmental risk assessment activities. The Institute is striving to provide a better understanding of these risks and the means of preventing and reducing them, with a view to assisting decision-making and contributing to public debate.

The collaborative platform Pl@ntNet identifies plants based on photos.
©https://plantnet.org/

➔ INRAE and the ALLISS association, which have been partners since 2015, renewed their agreement for the 2021–2025 period. Their goal is to structure partnerships and cooperation between third-sector research stakeholders (associations, local authorities, cooperatives, etc.) and the French research and innovation system.

➔ A consortium is working to continue the Pl@ntNet collaborative plant identification platform, which celebrated its tenth anniversary in 2020. It brings together the four founding members – INRAE, IRD, CIRAD and Inria – and is open to new members. ●
https://plantnet.org/en/

Platform ●●●

RECOLTE: a collaborative platform to preserve agricultural land

Agricultural land management is vital to adapting agriculture to society's expectations for the environment and food. A key challenge involves equipping local stakeholders and developing public policies to manage land in a way that can better support the agricultural and food transition.
INRAE and the citizen movement Terre de Liens are launching RECOLTE, a citizen science project based on a web platform that aims to:

- study and raise awareness on solutions for taking action on agricultural land issues;
- promote community actions to preserve agricultural land;
- enable the sharing of experiences among agricultural land management stakeholders: elected officials and technicians from local authorities, government agencies, consultancy firms, professional agricultural organisations, national agricultural and rural organisations, researchers, farmers, agricultural project leaders and citizens.

This project is helping to create a network of French stakeholders committed to the sustainable management of agricultural land.
https://ressources.terredeliens.org/recolte

Partnerships and impacts

Reinforcing our engagement with academic, European and international partners

To tackle the challenges of global change and the necessary transitions within food and environmental systems, INRAE has a robust policy of cooperation with research and higher education institutions. Its activities include creating regional divisions of major national university partnerships and working on projects with a European and international scope.

The fourth World Agroforestry Congress organised by CIRAD and INRAE, in partnership with World Agroforestry, Agropolis International and Montpellier University of Excellence. 1,200 participants from over 100 countries
© INRAE, C. Maître

Regional academic ecosystems with national coordination networks

INRAE signs its first objectives and resources agreement with a university

Philippe Mauguin, Chair and CEO of INRAE, and Jeanick Brisswalter, President of the University of Côte d'Azur (UCA), signed an objectives and resources agreement on 15 October 2020. This agreement marks the institutions' shared desire to implement a strategic academic partnership policy in terms of research and innovation. Both INRAE and UCA work on scientific issues involving crop protection, including biocontrol, integrated pest management and digital technology applied to plant protection. By strengthening their collaboration and partnerships, this agreement aims to promote research and training activities at the national and international levels and increase coordination between the institutions for their activities in the Côte d'Azur.

Stronger cooperation with ENS Paris-Saclay

Pierre-Paul Zalio, President of ENS Paris-Saclay, and Philippe Mauguin, Chair and CEO of INRAE, signed a five-year partnership agreement on 17 July 2020. This agreement lays out the conditions for INRAE researchers to work as visiting lecturers to share their expertise with students at ENS Paris-Saclay. The visiting lecturers from INRAE will join the school's teaching staff to add their knowledge and know-how in a particular field (economics, life sciences, ecology, process engineering, etc.) or a thematic area (agriculture, environment, food) in a way that complements the disciplines already covered by the school's teacher-researchers.

INRAE and AgroParisTech sign a new partnership agreement

As the world grapples with global food security challenges and natural resource depletion, INRAE and AgroParisTech have joined forces to tackle various issues through excellent science. They have already collaborated for several years to respond to calls for projects, namely those for the French Investments for the Future Programme (PIA). The two institutions are also shoring up their efforts to work together to develop ambitious regional training and research programmes. They are deeply involved in the development of regional academic programmes for Paris-Saclay, Clermont-Ferrand, Nancy, Reims, Montpellier and French Guiana. AgroParisTech recently named a tenth INRAE researcher as a "consulting professor", which illustrates INRAE's supporting role in deploying high-level training on the research themes shared by the institutions.

The new Agreenium Alliance: an organisation to support renewed ambition

INRAE and most of its agronomic and veterinary partners that were members of France's Agricultural, Veterinary and Forestry Institute – IAVFF (dissolved at the end of 2020 following the French law on research programming) have decided to continue their collaboration. This is part of a regional coordination agreement, known as the Agreenium Alliance. This new entity is backed by the French Ministry of Agriculture and Food and the Ministry of Higher Education and Research. A coordination unit hosted by INRAE provides support services so the alliance can pursue its work in a more agile and efficient manner. ●

https://en.agreenium.fr/

As part of the core activities supported by the Investments for the Future programme (PIA3), INRAE is strengthening its participation in strategic regional dynamics.

INRAE supported:

- Seven winning projects for the "Integration and development of IDEx and I-Sites (IDéES)" call for projects;
- 11 winning projects for the "Structuring training through research in initiatives for excellence (SFRI)".

Greater visibility and stronger collaborations within Europe

Signing of a memorandum of understanding by 24 research organisations representing 16 European countries during the 2020 Paris International Agricultural Show © INRAE, C. Maître

Alternatives to synthetic pesticides: 24 European research organisations adopt an ambitious roadmap

In 2020, INRAE pushed ahead with one of its scientific priorities, "Towards a chemical pesticide-free agriculture". Previously, in 2018, INRA had led a European research initiative on this priority in collaboration with its German counterparts from the Leibniz Centre for Agricultural Landscape Research (ZALF) and the Federal Research Centre for Cultivated Plants (Julius Kühn-Institut – JKI). A memorandum of understanding, signed by 24 research organisations representing 16 European countries during the 2020 Paris International Agricultural Show, formalised the initiative and officially marked the creation of the European Research Alliance (ERA) Pesticide Free. The Alliance has been very active ever since and now boasts 34 members from 20 European countries. In 2020, Alliance members responded to three European calls for projects, including one under the European Green Deal call.
https://www.era-pesticidefree.eu/

INRAE's participation in the Horizon 2020 programme

INRAE is the fourth French institute to benefit from the European Horizon 2020 research and innovation programme (all scientific sectors combined), and the leading European beneficiary of the "Societal Challenge 2 – Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy".
INRAE has had a total success rate of 22% on Societal Challenge 2 during the programme, and a 39% success rate for its coordination proposals for 2020. The overall H2020 success rate for Challenge 2 is 13%.

INRAE scientists recognised by the European Research Council for their excellent and original research

- **Julie Reveillaud**, recipient of a Starting Grant for the RosaLind project on interactions between bacterial communities and viral pathogens in mosquitoes, from a public health perspective (Joint Research Unit for Diversity, Genomes and Microbe/Insect Interactions).
- **Olivier Hamant**, recipient of an Advanced Grant for his MUSIX project on the role of mechanical signals in plants (Joint Research Unit for Plant Reproduction and Development).
- **Lisa Wingate** coordinator of the COSMYCA project, which is supported by a Consolidator Grant. This project aims to better understand the carbon cycle to adapt our ecosystems and cope with climate change (Joint Research Unit for Soil-Plant-Atmosphere Interactions).
- **Olivier Berteau** recipient of a Proof of Concept grant which will enable him to develop new applications based on his team's research on the biochemistry of gut microbiota (Joint Research Unit for Food and Gut Microbiology for Human Health). ●

Leadership in international scientific cooperation

Despite the COVID-19 pandemic, INRAE continued to deploy international cooperation strategies in 2020.

Eight major framework agreements were signed with renowned academic partners. They highlight themes of strong common interest, call for strengthening promising or existing scientific collaborations and encourage the development of joint projects with high added value.

- University of California, Davis, USA.
- University of California, Berkeley, USA.
- University of Florida, USA.
- Science New Zealand, New Zealand.
- Agricultural Research Council, South Africa (joint with CIRAD).
- Agriculture and Agri-Food Canada (AAFC), Canada.
- Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia.
- International Food Policy Research Institute (IFPRI, CGIAR).

Five new international associated laboratories (LIAs) will round out the existing LIAs launched in 2014

- **AAGD:** Agriculture, agroecology and green development. Partner: China Agricultural University.
- **C2Fruits:** Impact of climate change on freshwater ecosystems. Partner: Embrapa, Brazil.
- **IFCWS:** Water science. Partner: Indian Institute of Science. Led by CNRS.
- **DROUGHT:** Drought response, climate change and climate unpredictability. Partners: University of the Witwatersrand, Succulent Karoo Research Station and National Museum Bloemfontein, South Africa. Led by CNRS.
- **LMI IESOL:** Ecological intensification of cultivated soils in West Africa. Partners: Cheikh Anta Diop University, Dakar; University of Thiès and Institute of the environment and agricultural research, Senegal; University of Ouaga, Burkina Faso. Led by the IRD.

Two new joint linkage calls (JLCs)

- With AAFC, Canada, on two key themes: soil and plant microbiome, and open innovation (living labs).
- With the University of California, Davis, USA, on the theme of vine health.

← full map of current cooperative schemes (opposite)

A conversation with...

Sophie LAYE

Director of the OptiNutriBrain international associated laboratory

INRAE has launched several international associated laboratories (LIAs) since 2014. As the director of the NutriNeuro Joint Research Unit, you initiated the first LIA at INRAE. Can you explain what drove this collaborative initiative forward?

We had already been collaborating for many years with several teams from the Institute of Nutrition and Functional Foods (INAF) at the University of Laval in Quebec City (specifically with the teams of Frédéric Calon and Yves Desjardin). We wanted a way to facilitate scientific dialogue and support the implementation of other joint actions. We felt this would enable us to better put our complementary skills to use in the field of nutrition and brain health and gain an international reputation in this innovative field of research.

The OptiNutriBrain LIA, which I oversee jointly with Fréderic Calon, has set itself the objective of conducting research into the benefits of optimised nutrition on brain function and well-being and its protective effects on the development of neuropsychiatric and neurodegenerative pathologies throughout life. We also wanted to promote knowledge transfer to users and train young researchers in nutrition and its effects on the brain.

> We want to promote knowledge transfer to users and train young researchers in nutrition and its effects on the brain

After six years, what is your assessment of the initiative?

It's been a very positive experience. I witnessed first-hand the highly productive visits and discussions among scientists from our two teams, the excellent scientific productions and their visibility, as well as the ease with which we were able to obtain substantial funding with an international scope, such as for the Neurophenol project. Our transdisciplinary research is associated with clinical trials, and we have been able to easily access bicentric trials, which increases the robustness of the results.

In terms of training, we created a joint Master's degree in Nutrition and Food Science/Human Nutrition and Health with the University of Bordeaux and the Bordeaux Polytechnic Institute (Bordeaux INP), partners in our joint research unit. With our colleagues at the University of Laval, we developed a joint Master's degree in Nutrition and Food Science/Human Nutrition and Health. This double degree gives students who wish to continue their studies in research more opportunities to do so. We also learned a lot by comparing two academic research systems, especially with regard to the transfer of knowledge to socio-economic stakeholders. In the Canadian model, these stakeholders work very closely with researchers at the sites and so we were able to measure the effectiveness of this model. We set up a transfer unit with the University of Bordeaux to work directly with industry stakeholders and develop partnership projects that could be rolled out internationally.

In short, our respective teams were able to build an excellent foundation of trust, which helps not only develop the attractiveness of the units but also support good team dynamics.

What developments are in the works for the NutriBrain LIA and its research topics?

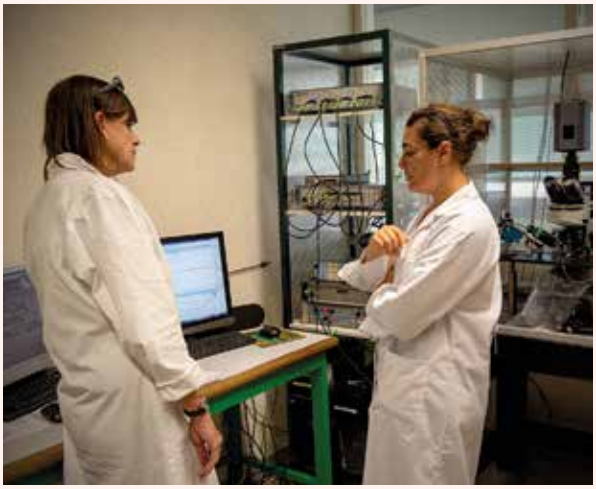
An LIA can be renewed after a first five-year cycle, and we plan to do that. The pandemic has delayed the process somewhat, but the LIA's activities are monitored and evaluated very regularly (annually) by an institutional and scientific committee.

More recently, with our Canadian colleagues, we wanted to expand the scientific cooperation we had initiated with the LIA beyond our two laboratories to create a sustainable network of leading brain nutrition scientists in France and Canada. The development of these networks ties in with efforts to strengthen INRAE's international policy.

The ambition of our network – Nutrition for brain health, from predictive biology to disease prevention and treatment (Food4BrainHealth, @food4_brain on Twitter) – is to foster new multidisciplinary projects and promote joint research programmes in addition to discussions, outreach and training for young researchers. We have added new topics (sensory perception, eating behaviours, the role of the microbiota in brain function, metabolism, signalling effect of nutrients in the brain) and expanded research in the field of neuropsychiatric and neurodegenerative pathologies.

With this network, we have intensified our activities and fields of research, such as by integrating new teams of excellence in the field. We have established our international reputation in the field and applied for major international calls for projects. We will organise scientific short programmes in France and Canada in the summer, and enhance co-supervision of theses and scientist exchanges as soon as the health context allows. ●

INRAE NutriNeuro laboratory (nutrition and neurobiology) integrated into the University of Bordeaux
© INRAE, C. Maître



LIA
https://www.optinutribrain.ulaval.ca/

Joint Master's degree
https://bit.ly/2OwNsDI

NutriBrain transfer cell
http://www.nutribrain.fr/en/

Life and work in the units

INRAE – Year 1

While the health crisis added an extra layer of difficulty in getting the new institute up and running, INRAE was able to move forward with all its planned projects in 2020. The information systems and internal and external operating tools remained stable and continued operating without any major issues. Commitment on the part of all staff, careful human resources management and sustained social dialogue were all instrumental in making this happen.

There were substantial social commitments to take into account for the merger, and they were all upheld. Systems convergences between the two institutions have been achieved. Those for the IS system, remote working and internal communication helped provide the best possible support to staff during the health crisis. The new organisational structure was implemented under remote working conditions. All these projects were carried out with the support of renewed governance bodies. A total of 86 professional elections and the general renewal of the staff representatives of the Board of Directors, the Scientific Advisory Board, the Technical Committee, the centre consultation bodies, the research divisions, the Specialised Scientific Commissions and the National Council of Research Support Services took place during the year.

The Central Committee for Health, Safety and Working Conditions (CCHSWC) is tasked with handling oversight of the merger in conjunction with the psychosocial risk steering group. This merger steering committee actively monitors the effects of the merger, with a specific action plan for certain management services shared by the units. Analyses and HR actions have also been leveraged, such as career guidance, analysis of the second workplace quality of life survey, analysis of staff feedback post-merger and during lockdown in conjunction with the CCHSWT, as well as training of new unit directors, offering mobility to relevant staff without any seniority conditions, etc.

Of the 64 planned support actions, 44 actions have been fully carried out and 16 are ongoing.

Additionally, the INRAE 2030 strategic plan was developed with internal and external input before the plan was adopted by the Board of Directors in December.

What's new in the organisation

- 14 scientific divisions, with seven having been reorganised.
- A Directorate General of Expertise and Support for Public Policy (DGDEAPP).
- Two new directorates: Directorate for Open Science (DipSO) and Directorate for Support for Public Policies (DAPP).
- The INRAE name with its dedicated communication tools: the new website www.inrae.fr/en and Twitter, Facebook, LinkedIn and YouTube social media accounts.

© AdobeStock

Social commitments fulfilled

- No change in unit scope.
- No site closures; no functional or geographical mobility imposed.
- Paris-Antony dual head office and the creation of a new Lyon-Grenoble-Auvergne-Rhône-Alpes centre.
- Convergence of salary scales and bonuses to the more favorable of the two; harmonised working hours, working cycles and leave; harmonised remote working arrangements open to all; complementary offers in terms of social policy, etc.
- Harmonisation of the units' overall budgets.

A generally positive perception of workplace quality of life and the effects of the merger

In mid-October 2020, a second workplace quality of life survey regarding the merger was conducted. The results indicated:

- final participation was 41.4%, compared to 48% in 2019;
- 82% of employees expressed a positive workplace quality of life within the new Institute (stable compared to 2019);
- there was no deterioration in the expressed level of work-related stress, despite the overall context of the merger and the COVID-19 health crisis;
- of the 26 strictly comparable work areas in the 2019 survey, four remained at the same level and 22 improved.

An information system to cope with the crisis

The Information Systems Directorate and its 170 staff were heavily involved in the merger processes. They worked hard to ensure service continuity during the health crisis period starting from the first lockdown. Despite widespread remote working conditions, they were able to carry out the expected work. The merger required a complete reconfiguration of the Institute's information systems, with everything from human resources management to financial management and even the communication system (messaging and collaborative tools) affected. All of this was achieved seamlessly, with payroll ensured in late January for the first month of the new institute, as well as in March during the first month of lockdown. All staff can now work remotely with appropriate collaborative tools and a reinforced support system. A storage system integrating Nextcloud and Stratus, tailored to the new institute and the wide range of equipment used, was also set up. This was a huge success for the central management team, who had taken advantage of the merger for a complete overhaul.

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Social and Environmental Responsibility (SER) strategy: a collective priority

Research support services underpin all the work that happens at INRAE. The Institute's scientific strategy department helps provide a sense of purpose by guiding the use and preservation of available resources, organising decision-making processes, working with supervisory bodies and managing the regulatory, legal and budgetary considerations that govern public actions.
Our SER strategy applies to every employee, regardless of their job, and every unit, regardless of its mission.

SER: a collective priority

A dedicated action plan has been created to see through a new ambitious Sustainable Development and Social and Environmental Responsibility strategy, which is directly supervised by the central management team and supported by the Human Resources and Sustainable Development Directorate. As a major player in research, we have a duty to preserve resources though actions focused on three areas: environmental protection, employer responsibility, and openness and transparency. To this end, the INRAE Management Board will monitor the progress of the action plan. To connect knowledge, research practices and SER, a steering and monitoring committee comprising internal and external stakeholders has been set up.

First greenhouse gas emissions audit

INRAE's first greenhouse gas emissions audit was conducted in 2020, based on a set of data collected at the local and national scales (emissions from livestock, the manufacture of scientific equipment, commuting, etc.). The scope of the audit was the largest ever taken into account by a French public research organisation of the same size. It provides a starting point to identify areas for improvement in terms of carbon impact, across all INRAE activities. On the basis of this exhaustive assessment, which will be repeated every three years, an action plan will be drawn up in 2021 to reduce and offset GHG emissions, activity by activity, in both research and support areas.

Shifting research practices

A network of sustainable development policy officers was created in 2020 to help units make the shift towards a low-carbon approach in their internal operations and research practices. The Environmental Management System, a joint approach aimed at achieving exemplary objectives in terms of environmental protection, has already led to voluntary actions by units to further reduce their carbon impacts (energy performance of facilities, farming and breeding practices, waste recovery, etc.). A total of 40 units and experimental facilities, 20 of which are already ISO 14001 certified, can benefit from these initiatives.

Sustainable mobility policy across France

INRAE's SER strategy includes the implementation of a mobility plan at each centre, in consultation with the staff and stakeholders in the local area. Seven centres are actively working on creating such plans, while others have had one in place for several years. Actions include encouraging staff to leave their cars at home and take up alternative modes of transport such as commuting by train, bus or coach; carpooling; cycling; and walking. Mobility plans are also supporting new mobility infrastructure (bus stops, bike paths, bike shelters) developed in conjunction with regional authorities.

Seminar to welcome new staff members
© INRAE, C. Maître

Improving workplace quality of life

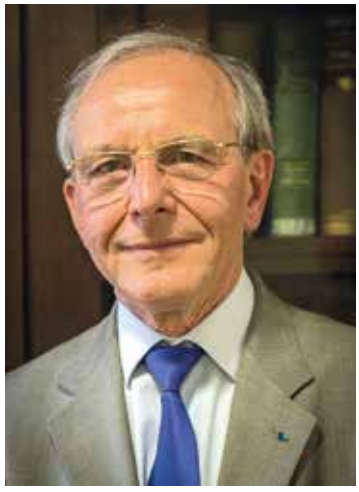
Based on the idea that collective success depends on a set of factors that influence optimal quality of life in the workplace for all employees, a survey covering staff from both institutes was conducted when the merger was launched in 2019. The second survey, sent out in October 2020, included questions related to the health crisis. To address the 2019/20 gaps and areas for improvement that were identified, a workplace quality of life action plan will be included in the various HR actions to be undertaken. Following the results of the first survey, INRAE implemented several initiatives in 2020 with the merger support action plan, the INRAE 2030 participatory internal consultation, and a new AlloDiscrim hotline for discrimination complaints.

Green investments through France Relance

Thanks to €13 million in funding obtained through the France Relance economic stimulus plan, INRAE will reduce its GHG emissions by approximately 475 tonnes of equivalent CO_2 by 2023. For example, 14% of its oil boilers will be replaced with gas boilers and air-to-water heat pumps. Switching from oil to natural gas reduces GHG emissions from combustion by 30%.

Ethics, Scientific Integrity and Code of Conduct for Research Projects

INRAE produces, disseminates and applies knowledge to tackle societal challenges in the areas of agriculture, food and the environment. All these activities require clear rules to be followed at all times, with a rigorous scientific approach and consideration of the ethical stakes of each project. In 2020, INRAE formed a delegation on Ethics, Scientific Integrity and Code of Conduct for Research Projects, with dedicated experts in each of these areas. Françoise Simon-Plas serves as the delegate and reports to INRAE's CEO. She explains the organisation of the delegation, noting that "These three concepts are linked; the stakes overlap in terms of protecting the public interest and a well-functioning democracy. If we try to deal with them separately, we run the risk of introducing inconsistency in thought and action."
She continues, "The values of probity, integrity and dignity, mentioned in the 2016 law on the ethics of public officials, aim to ensure an equal quality of service for all citizens. Ethics in research deals with the consequences of the strategies and objectives of science, with the aim of protecting and guaranteeing the interests of the citizens who are called upon to benefit or contribute to science. Finally, the concept of scientific integrity is gaining ground because transparency is more necessary than ever to maintain citizens' trust in research.
The delegation's activities are also supported by a committee on ethics and scientific integrity, comprising around a dozen INRAE employees tasked with considering these topics in depth and proposing actions to promote their dissemination within the institution.
https://url.inrae.fr/2NS7HuH



Axel Kahn © INRAE, C. Maître

Renewal of the Joint INRAE-CIRAD-IFREMER-IRD Ethics Advisory Committee, and Axel Kahn's new mandate as President

This committee examines the ethical issues that may arise from the research strategies and programmes conducted by these organisations in France and abroad. It operates on the basis of referral, either by an outside institution or one of the committee's own institutions. Its opinions are made public to inform the governance of the institution and to provide food for thought on research topics for the research units of the committee's four organisations. Fifteen external members sit on the committee. It is chaired by geneticist Axel Kahn, who was re-elected in 2020 to a new four-year term.
During a March 2021 interview by AEF, Kahn said, "whether or not one agrees with the recommendations made in these opinions, we are committed to ensuring that they are high-quality opinions based on philosophical considerations to encourage reflection". In 2020, the committee took up the theme of human needs, natural resources and biosphere preservation. "I am convinced that the controversies and contradictions arising from these three areas cannot be overcome except through a philosophical approach and dialectics," said Kahn.
https://url.inrae.fr/38HJ5vv

PRIZES & AWARDS

INRAE's first Awards Ceremony

The first INRAE Awards Ceremony showcased the diversity of our research units and the inspiring and society-focused research they conduct. The virtual awards ceremony was held on 8 December 2020, with the participation of the French Ministers for Research and Agriculture. More than 1,000 people attended, making it a real highlight for our community.

Philippe Lemanceau, winner of the Lifetime Achievement Award, studies an invisible world: the microbial life of soil and its interactions with plants. He develops new methodologies to study these organisms, formulates new research and organisational questions, creates new working groups, and even proposes open innovation on a regional scale to work hand in hand with civil society. His career illustrates how nourishing soil can be! He was director of the Joint Research Unit for Agroecology at the Burgundy-Franche-Comté centre until retiring in June 2021.

Hervé Cochard, winner of the Scientific Breakthrough Award, explores the distress of trees under water stress. He helped create a new discipline – tree hydraulics – and co-founded an open-access journal to share this knowledge. His research on the behaviour of trees and forests under drought conditions provides new knowledge for dealing with climate change. He is an internationally recognised expert in his field, and is a research director at the Joint Research Unit for the Integrative Physics and Physiology of the Tree in Fluctuating Environments at the INRAE Clermont-Ferrand-Auvergne-Rhône-Alpes centre.

Charlotte Sinding and **Thomas Opitz** both received Promising Researcher Awards. Charlotte Sinding is a research scientist at the Center for Taste and Feeding Behavior (CSGA) at the Burgundy-Franche-Comté centre, and Thomas Opitz is a research scientist at the Biostatistics and Spatial Processes Research unit at the Provence-Alpes-Côte d'Azur centre. Sinding's work explores the role of the brain in smell and taste, senses that are often considered minor, but which are absolutely essential. In a society preoccupied with the notion of risk, Opitz's research is focused on extreme, rare and devastating risks, and looks at how they could be amplified by ongoing global change.

The apple, a symbolic fruit with a long history, is the most widely eaten fruit in France and one that requires the most phytosanitary treatments. **François Laurens** has devoted his career to creating new varieties with improved quality in terms of taste, immunity, and practicality for consumers and farmers. He is a true visionary in his work, not only in terms of the science but also his methods. He combined these two aspects very early on after understanding the key role that professionals play in variety recognition. Laurens, a senior research engineer from the Research Institute for Horticulture and Seeds (IRHS) at the INRAE Pays de la Loire centre, received the Innovation Award.

The Science with an Impact Award went to the **"Prevention and Promotion of Carcinogenesis by Food" team** at the Food Toxicology unit (Occitanie-Toulouse centre) for its work on the link between the consumption of red and processed meat and colon cancer. This team, recognised for its expertise, produces scientific data and develops preventive strategies to inform the debate on these issues and public policies. The team's work directly benefits consumers' health as well as the future economic foundation of the meat and processed meat industry.

After 20 years as an environmental researcher, **Dominique Chèneby** has turned her focus towards prevention. She has been the Health and Safety Coordinator at the Burgundy-Franche-Comté Centre for ten years and received this year's Research Support Award. Whether she's dealing with crisis situations, hazards, health or environmental issues, she is always at the ready to handle whatever comes her way. She combines professionalism and rigour with a huge dollop of humanity.
https://url.inrae.fr/3mmPmlP

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PRIZES & AWARDS

Our distinguished scientists

Forests take top honours

The GenTree project, coordinated by Bruno Fady, research director at the Mediterranean Forest Ecology unit at the INRAE Provence-Alpes-Côte d'Azur centre, received a special prize from the "2020 Stars of Europe Trophy" held by the French Ministry of Research. GenTree, which is funded by the Horizon 2020 framework programme, is an experimental and modelling project that combine genomics, ecology and forest sciences.

This large-scale research project is seeking to optimise the management, conservation and sustainable use of forest resources against the backdrop of climate change.

Bruno Fady also received the 2020 Publication Prize (€5,000) from the Botanical Society of France (SBF) for an article published in *Botany Letters*, resulting from work carried out with the French Foundation for Biodiversity Research (FRB). The article sheds light on the history and particularities of the Mediterranean tree flora, a model for studying the adaptation of forests to climate change.

https://url.inrae.fr/2WtDa7P

French Academy of Agriculture

Eighteen INRAE researchers received awards in 2020 from the French Academy of Agriculture. Among the winners, Denis Loustau received **a gold lifetime achievement award.** Loustau is a research director at the Soil-Plant-Atmosphere Interactions Unit at the INRAE Nouvelle-Aquitaine-Bordeaux centre. His work investigates the carbon and water balance of forests, and his substantial contribution to the development of joint research centres in Aquitaine, France and Europe has helped clarify and inform forest management choices that take climate change into account.

The Researcher Award from the Xavier Bernard Foundation research director at the Joint Research Unit for Agroecology at the INRAE Burgundy-Franche-Comté centre. He was recognised for his research on soil microbial communities and his knowledge transfer activities. For example, he was a co-author for the book *Atlas français des bactéries du sol* (French Atlas of soil bacteria) and has developed several agricultural soil quality bioindicators.

The Academy granted four silver-gilt awards in recognition of high-impact research by INRAE engineers and research scientists: **Mélisande Blein-Nicolas** (Quantitative Genetics and Evolution unit) for genetics; **Pascal Denoroy** (Soil-Plant-Atmosphere Interactions unit) and **Folkert van Oort** (Functional Ecology and Ecotoxicology of Agroecosystems unit) for fertilisation and the impact of fertilisers; and **Jean-Luc Le Quéré** (Center for Taste and Feeding Behavior) for the chemistry of odour compounds in food.

Four Dufrenoy silver awards were granted for thesis work defended the previous year: **Candy Abboud** (Biostatistics and Spatial Processes unit) for applied mathematics; **Élise Bordet** (Molecular Virology and Immunology unit) for pig immunity; **Anne-Sophie Lissy** (Mediterranean Environment and Modelling of Agroecosystems unit) for quantitative imaging of soil macropores; and **Mariem Omrani** (Fruit and Vegetable Genetics and Breeding unit) for sustainable resistance in apricot trees.

https://url.inrae.fr/3iXavS6

Foundation for Biodiversity Research Award

The FRB recognised three young researchers with awards.

Philippe Jansen conducted his thesis at the Mountain Ecosystems and Societies Laboratory, Lyon-Grenoble-Auvergne-Rhône-Alpes centre. He demonstrated that forest management that promotes greater availability of old and dead trees in stands improves biodiversity conservation.

Battle Karimi, from the Joint Research Unit for Agroecology at the Burgundy-Franche-Comté centre, contributed to the first soil microbial biodiversity study conducted on a country-wide scale in France by characterising the microbial social networks and the different bacterial habitats. The first French atlas of soil bacteria (*Atlas français des bactéries du sol*) makes this knowledge accessible to a wide audience.

During her PhD research at the Sophia-Agrobiotech Institute, Provence-Alpes-Côte d'Azur Centre, **Flora Aubree** worked on the imbalances in ecosystems caused by rapid, human-induced changes. Species diversity plays an important role in minimising the impact of these disturbances.

https://url.inrae.fr/33YsfqC

Enhanced communication despite the crisis

Through a new institute, INRAE has deepened its commitment to disseminating research results and conducting outreach activities, especially towards citizens. It has established itself as the leading research institution on agriculture, food and the environment. INRAE's intense activity, which was undeterred by the COVID-19 crisis, led to the launch of the new website and social media accounts along with efforts to strengthen press relations. Throughout the year, the website was enhanced with new functionalities so users could browse articles on topics such as COVID-19 research, taste, water, drought and ticks. It attracted up to 60,000 unique visitors in the last month of the year. The Institute and its research were mentioned in the press more than 19,000 times in 2020, with eight in ten mentions properly citing the new INRAE name. After the Paris International Agricultural Show in February, INRAE saw many events cancelled throughout the year. However, some events were able to go ahead through new formats, such as digital sessions, web conferences, webinars and web documentaries, where INRAE could continue to showcase its research. The documentary *Le Génie des arbres* (The genius of trees), co-produced by Hauteville Productions and INRAE, was also a great success, both on the television channel France 5 and at the Pariscience International Science Film Festival in October. With 1.3 million viewers tuning in to watch in May, the documentary brought in one of the highest viewerships at France 5. It also received extra visibility thanks to the Prix Buffon competition at the Pariscience Festival, which was held entirely online.

Four press reports released on themes ranging from biocontrol to the One Health concept

With around 40 topics per theme, several press reports gave a broad overview of the Institute's research on a given subject. After a press report on biocontrol in February and another on ticks in May, two more reports were produced on the concept of One Health. One presented research guided by the principle that environmental protection and human and animal health are closely intertwined. The other focused on INRAE's work to support the design and adoption of healthy and sustainable food systems. Designed with the Institute's researchers, these press reports, which include computer graphics and links to online articles, are made public at press conferences, sparking numerous discussions between researchers and journalists for better dissemination of knowledge.

Biocontrol press pack (in French only) https://url.inrae.fr/38p8Z5H
Ticks press pack (in French only) https://url.inrae.fr/2Ti8BjY
One Health press pack (in French only) https://url.inrae.fr/3fbI68Q
Food systems press pack (in French only) https://url.inrae.fr/3eHJAIp

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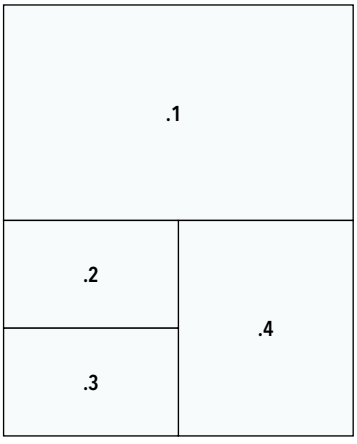
INRAE's first Paris International Agricultural Show

For INRAE's first appearance at the Paris International Agricultural Show, French President Emmanuel Macron visited the stand along with ministers Frédérique Vidal and Didier Guillaume, in honour of the trade show's inauguration. The newly formed institute was chosen to present research solutions to support transitions within its three pillars of agriculture, food and environment.
More than 350 scientists from 21 research units led workshops on solutions to limit the use of synthetic pesticides, including biocontrol, mildew- and powdery mildew and blight-resistant grapevine varieties and improved water resource management. The public was also able to discover INRAE's latest innovations, explore citizen science research projects, attend conferences and debates,and enjoy a "taste of science" in the company of Michelin-starred chef Pierre Gagnaire. At the same time, an "Agricultures 2030" conference and around a dozen meetings provided an opportunity to exchange views with the many professional visitors.
The design award was the cherry on the cake for this successful first appearance!

Stand design award, 2020 International Agricultural Show
© INRAE, B. Nicolas

An intense year that strengthened internal communication

Exceptional situations call for exceptional internal communication. In conjunction with the national crisis unit, the Institute's Communications Department worked hard to maintain contact among staff from the very first lockdown. A special lockdown newsletter was sent out to INRAE's 12,000 staff every week with the latest news on occupational health and safety, the Institute and science along with some entertaining information, in addition to the national and local news and FAQ available on the Intranet sites. Meanwhile, the communication network is being strengthened to reach every INRAE link in the chain (directorates, centres, divisions, units). These strong ties were maintained throughout 2020.



1. Meeting between the public and researchers at INRAE's stand at the Paris International Agricultural Show, 2020
© INRAE, B. Nicolas

2. During a conference
© INRAE, B. Nicolas

3. Visit by French President Emmanuel Macron to the INRAE stand
© INRAE, B. Nicolas

4. INRAE logo decorated with Corsican citrus fruit
© INRAE, B. Nicolas


INRAE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Governance and key figures

Board of Directors

Composition as of 31 December 2020

President

Philippe MAUGUIN, Chair and CEO of INRAE

State Representatives

- Isabelle CHMITELIN, Director General for Higher Education and Research, Ministry of Agriculture and Food
- Bénédicte HERBINET, Deputy Director of Research, Innovation and International Cooperation, Directorate-General for Education and Research, Ministry of Agriculture and Food (alternate)
- Marie-Hélène TUSSEAU-VUILLEMIN, Head of Environment and Universe Sciences, Agronomy, Ecology and Earth System Science, Ministry of Higher Education, Research and Innovation
- Lise FECHNER, Research and Innovation Strategy Department, Deputy Scientific Director for the Environment and Universe Sciences, Agronomy, Ecology and Earth System Science – Directorate-General for Research and Innovation – Ministry of Higher Education, Research and Innovation (alternate)
- Diane SIMIU, Deputy Director to the General Commissioner for Sustainable Development, General Commission for Sustainable Development
- Thierry COURTINE, Deputy Director for Research and Innovation – Ministry for the Ecological Transition (alternate)
- Colin THOMAS, Head of the Office of Research and Higher Education, Ministry of Public Action and Accounts

Representatives of public higher education or research institutions

- Élisabeth CLAVERIE DE SAINT-MARTIN, Deputy Director General for Research and Strategy, CIRAD
- Gilles TRYSTRAM, Director General, AgroParisTech

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

- Paul-Joël DERIAN, Director General Innovation, Research and Sustainable Development
- François ENGUEHARD, Director of Research Centres, Véolia
- Anne-Claire VIAL, President of ACTA, Agricultural Technical Institutes

Labour and Economic Sector Representatives

- Dominique CHARGE, President, Coopération agricole
- Betty HERVE, National Secretary, FGTA-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
- Élisabeth TABONE, CFDT
- Pascale MAILLARD, CGT
- Éric LATRILLE, CGT
- Baptiste HAUTDIDIER, SUD Recherche EPST

Alternate Members

- Anne DE LA FOYE, CFDT
- Jean-Marc BONNEFOND, CFDT
- Michel BERTRAND, CGT
- Laurence ARTIGE, CGT
- Fanny GUYOMARC'H, SUD Recherche EPST

Scientific Advisory Board

Composition as of 31 December 2020

President

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

INRAE members

- Philippe MAUGUIN, Chair and CEO of INRAE
- Christine CHERBUT, Deputy Director General of Science and Innovation

Ex-Officio Members

- Ministry of Higher Education, Research and Innovation
- Ministry of Agriculture: Bénédicte HERBINET, Deputy Director for Research, Innovation and International Cooperation, or Marion BARDY, alternate
- Ministry for the Environment: Gwenaelle HELLO, Deputy Director for Research, 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-Etienne;
- Patrick CARON, Vice President in charge 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;
- Sophie DUBUISSON-QUELLIER, CNRS Research Director, Deputy Director of the Centre for the Sociology of Organisations (CSO);
- Teresa FERREIRA, Professor at the Department of Natural Resources of the University of Lisbon, Portugal;
- Élisabeth 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;
- Éveline 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, French Group for the Study and Control of Varieties and Seeds
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 (alternate)

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
- 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
Éric MALEZIEUX (CIRAD)
CSS 2 – Biology of Host-Pest Interactions, Symbionts and Commensals
Daniel BARTHELEMY (CIRAD)
CSS 3 – Integrative Plant Biology
Emmanuel GUIDERDONI (CIRAD)
CSS 4 – Ecology, Population Biology and Ecosystem Dynamics
Philippe USSEGLIO-POLATERA (University of Lorraine)
CSS 5 – Plant and Animal Genetics
Pierre BOUDRY (IFREMER)
CSS 6 – Mathematics, Informatics, Digital Science and Technology, Artificial Intelligence and Robotics
Étienne BIRMELÉ (University of Paris)
CSS 7 – Microbiology, Microbial Ecosystems, Agri-Food Systems, Biotechnologies
Christophe JUNOT (CEA)
CSS 8 – Nutrition and Toxicology
Christophe MAGNAN (University of Paris)
CSS 9 – Animal Biology
Claude DUCHAMP (Claude Bernard Lyon 1 University)
CSS 10 – Environmental Sciences: Earth, Water and Atmosphere
Anne-Catherine FAVRE (University of Grenoble-Alpes)
CSS 11 – Food Science and Engineering, Materials Science, Biobased Products and Waste-to-Resource
Étienne PAUL (INSA)
CSS 12 – Economic, Social and Management Sciences
Jean-Philippe TROPEANO (University of Paris 1 Pantheon-Sorbonne)
CSS 13 – Research Support and Steering
Philippe MAUGUIN (INRAE)

Joint INRAE-CIRAD-IFREMER-IRD Ethics Advisory Committee

Joint Ethics Advisory Committee Members

Axel KAHN, President of the Committee.
Doctor of Medicine and Doctor of Science, Research Director at INSERM. Currently President of the *Ligue nationale contre le cancer*.

Michel BADRÉ, Vice President of the Ethics Committee.
Graduate engineer of Ecole Polytechnique – Ecole nationale du Génie rural, des Eaux et des Forêts. Member of the Economic, Social and Environmental Council, in the group of environmental associations

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

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

Jean-Louis BRESSON, Nutritionist-Physician, University Professor, founder of the centre for clinical investigation Necker-Cochin

Catherine BOYEN, CNRS research director, PhD 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)

Céline BOUDET, Ineris, scientific coordinator, risk assessment specialist in health and environment (epidemiology, toxicology, biostatistics)

Mireille DOSSO, Director of the Pasteur Institute of the Ivory Coast, Professor of Microbiology

Françoise GAILL, Director of research at the French National Centre for Scientific Research (CNRS), executive officer at the CNRS. Biologist, specialist in deep-water oceanic ecosystems

Stéphanie LACOUR, Director of research at French National Centre for Scientific Research (CNRS), Doctor of Private Law. Deputy Director of the Institute For Social Sciences of Politics, ENS Paris-Saclay. Associate Director of the Standards, Sciences & Techniques Research Group of the CNRS

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

Louis-Étienne PIGEON, Philosopher specializing in environmental ethics, Doctor of Philosophy from Laval University (Quebec, Canada), Assistant Professor at Laval University

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

Michel SAUQUET, graduate of the Institute of Political Studies in Paris, Doctor in Applied Economics. Teacher specialized in intercultural issues

Hervé THÉRY, Geographer, Associate Professor at the University of Sao Paulo (Brazil), Research Director emeritus at the CNRS

Joint Administrative Staff

INRAE: Christine CHARLOT, General Secretary, with the support of Nathalie HERMET
CIRAD: Philippe FELDMANN, Marie DE LATTRE-GASQUET
IFREMER: Philippe GOULLETQUER, Marianne ALUNNO-BRUSCIA
IRD: Chloé DESMOTS

Staff numbers

8,281
permanent staff
(FTE)*

with
4,162
women

51%

4,119
men

49%

with

1,997
researchers

3,188
engineers and assistant engineers

3,096
technicians

2,749
staff with contracts
(FTE)*

with

718
PhD candidates
(195 of whom are foreign nationals)

71
post-doctoral fellows
(45 of whom are foreign nationals)

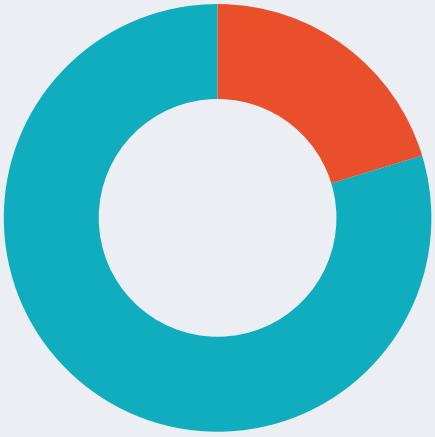
2,029
trainees
(335 of whom are foreign nationals)

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

Budget

2020 resources

€999.1m



79.42%
Subsidy for
public service expenses

20.48%
INRAE resources

Subsidy for
public service expenses
€794.5m

INRAE resources
€204.6m

Detailed breakdown
INRAE resources
(from research contracts)
€137.4m

ANR	34.1
PIA	15.3
Other public institutions	10.4
Local and regional authorities	18.9
Europe	20.5
Ministries	9.0
Research & higher education institutions.	5.3
Socio-economic partners	23.9

INRAE resources
(non-contractual)
€67.2m

Allocated grants	4.4
Donations and bequests	0.1
Royalties for patents, licences	7.1
Services rendered	15.5
Product sales	16.7
Other subsidies	2.6
Other operating income	6.0
Financial and exceptional income	14.8

Partnerships and innovation

Socio-economic Partnerships

New partnership contracts signed with socio-economic partners	380
Revenue from research contracts with socio-economic partners	€24m
Number of partnership arrangements with socio-economic partners	**28** Joint Technology Units, **5** Carnot Institutes, **5** Labcom

Intellectual Property

Declarations of inventions & exploitable research results	116
Patents submitted	45
Patent families held	420
Applications for plant variety rights	10
Plant varieties listed in an official catalogue and/or held	413

Creating Value

New exploitation agreements (licences, options, etc.) on patents, know-how, software, trademarks, models	41
Licences held	640
New plant variety rights licences	28
Plant variety rights licences held	829

Creating New Companies

New companies set up based on INRAE results	3

Subsidiaries

Agri Obtentions, created in 1983, seeks to create and exploit varietal innovations. It espouses the values of sustainable agriculture and innovation.

Key figures for Agri Obtentions include:

- 55 permanent staff;
- €15m in turnover generated in France and in Europe;
- 30% of turnover invested in Research & Development;
- > 400 licensed products;
- 10 species groups and more than 450 varieties distributed by Agri Obtentions;
- research programmes.

The Éditions Quæ publishing house was founded in 2006 by four French research institutes: CIRAD, IFREMER, INRA and IRSTEA (the latter two merged in 2020 as INRAE). With more than 1,500 digital and hard copy publications to its name, Quæ seeks to foster interaction among scientists, promote the transfer of knowledge and expertise, inform policy decisions and encourage public debate. Quæ is a major player in scientific and technical publishing in France. It covers themes that run the gamut from agriculture and the environment to biodiversity, climate change, marine and aquatic resources, food and health. Currently, 170 books are available in open access (quae-open.com). Quæ is working to meet French and European directives on open science requiring free distribution of documents published from activities financed by French public research or EU funds.

INRAE Transfert is a project engineering and technology transfer company for innovation in food, agriculture and the environment. Its missions are to:

- transfer research results to companies by exploiting and managing the portfolio of INRAE technologies via operating agreements with industry players;
- promote the creation of innovative companies by supporting their development;
- support the setting up, negotiation and management of European or national collaborative research projects by lending its expertise in project engineering management;
- set up, lead and manage research and development programmes;
- make resources available for the eco-technologies sector by creating a permeable interface between public research laboratories and the business world.

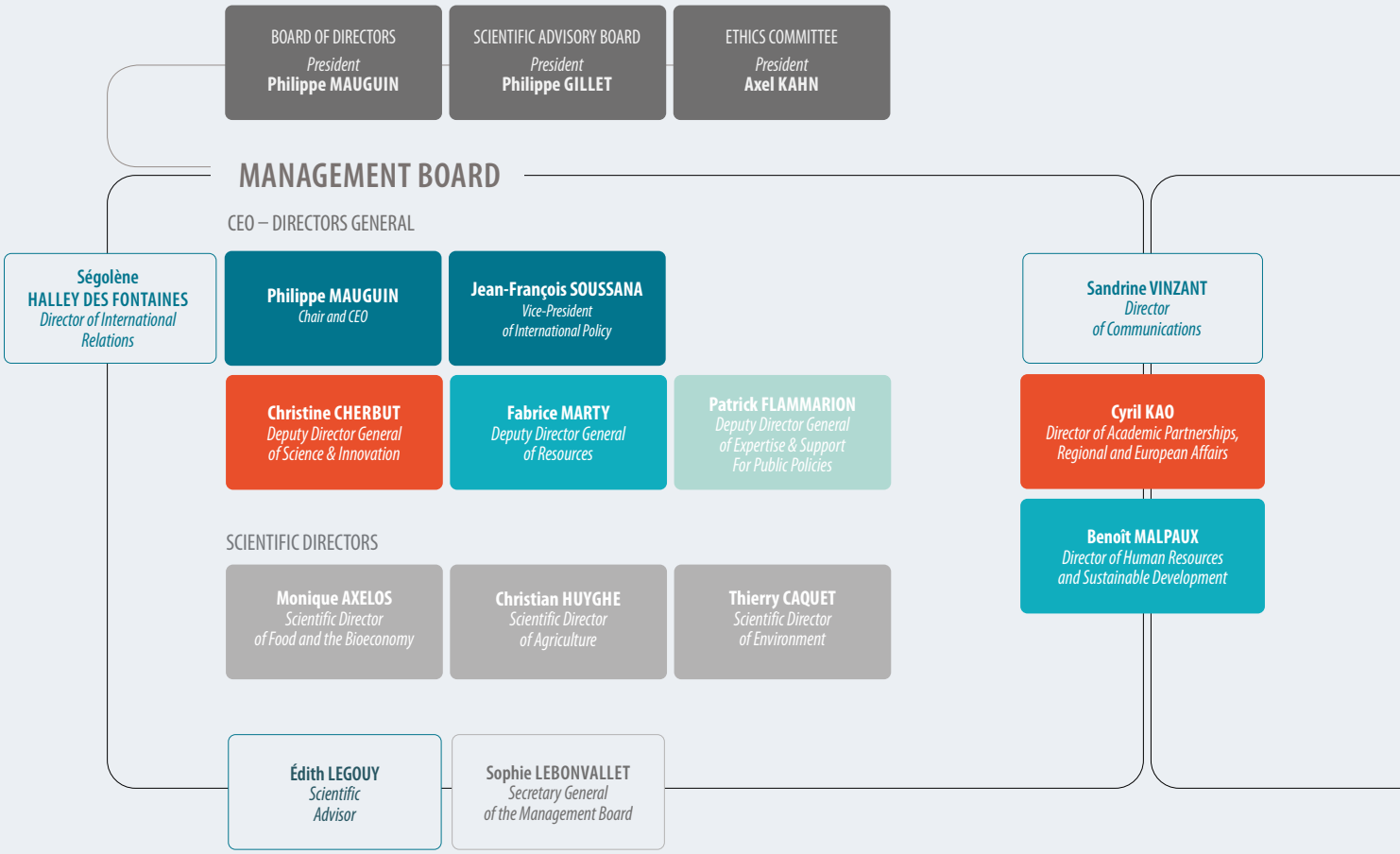
SAS Château Couhins was created in 2018 in honour of the 50th anniversary of this Cru Classé in the Classification of Graves wine produced under the INRAE umbrella. The simplified joint stock company (société par actions simplifiée) is fully integrated into the Graves Crus Classés professional collective while also enjoying the support of INRAE's research resources. The 25-hectare vineyard in Pessac Léognan, with 19 ha dedicated to red wine and six ha to white, includes a demonstration project based on two major ambitions:

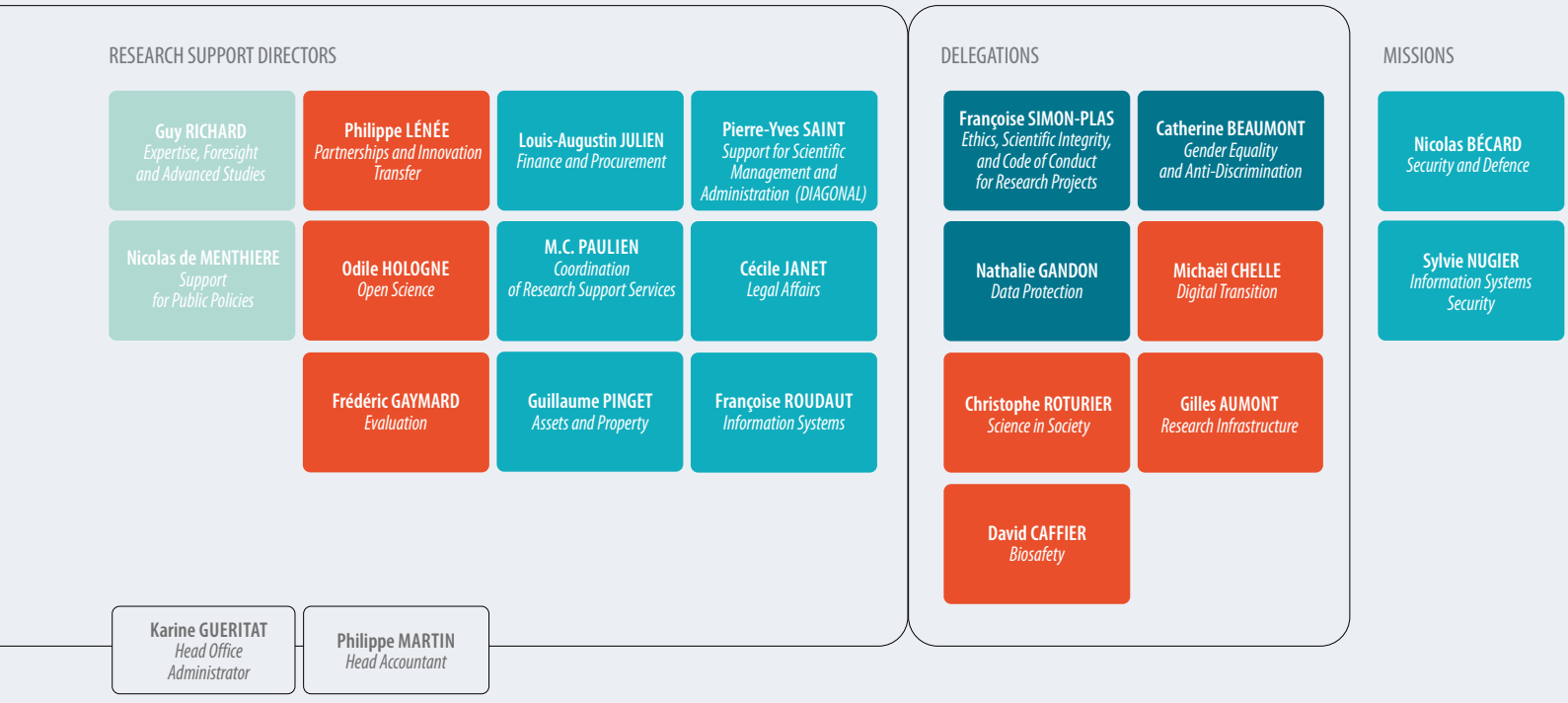
- deploy, *in situ* and at farm scale, the results of INRAE research to produce wine that is more environmentally friendly;
- develop the most promising strategies to reduce inputs, implement biocontrol practices, use agroecological practices namely agroforestry, and innovate in winemaking.

INRAE Organisation

Organisation chart

(As of 31 December 2020)



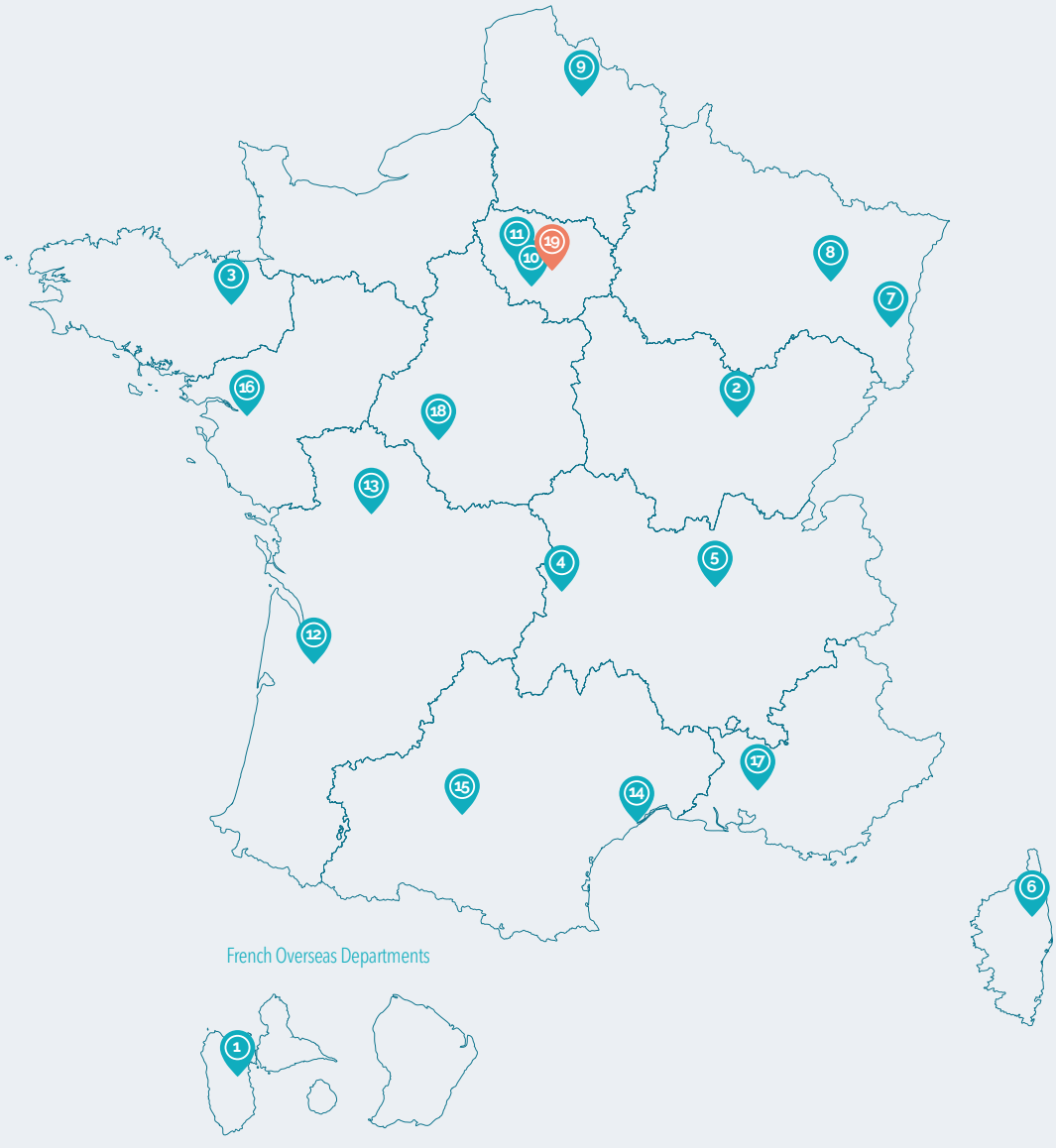

RESEARCH SUPPORT DIRECTORS
Guy RICHARD
Expertise, Foresight and Advanced Studies
Philippe LÉNÉE
Partnerships and Innovation Transfer
Louis-Augustin JULIEN
Finance and Procurement
Pierre-Yves SAINT
Support for Scientific Management and Administration (DIAGONAL)
Nicolas de MENTHIERE
Support for Public Policies
Odile HOLOGNE
Open Science
M.C. PAULIEN
Coordination of Research Support Services
Cécile JANET
Legal Affairs
Frédéric GAYMARD
Evaluation
Guillaume PINGET
Assets and Property
Françoise ROUDAUT
Information Systems
Karine GUERITAT
Head Office Administrator
Philippe MARTIN
Head Accountant
DELEGATIONS
Françoise SIMON-PLAS
Ethics, Scientific Integrity, and Code of Conduct for Research Projects
Catherine BEAUMONT
Gender Equality and Anti-Discrimination
Nathalie GANDON
Data Protection
Michaël CHELLE
Digital Transition
Christophe ROTURIER
Science in Society
Gilles AUMONT
Research Infrastructure
David CAFFIER
Biosafety
MISSIONS
Nicolas BÉCARD
Security and Defence
Sylvie NUGIER
Information Systems Security

INRAE Organisation

INRAE's 18 centres

(As of 31 December 2020)

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



1. French West Indies and Guiana
   President: Harry Ozier-Lafontaine
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: François Casabianca
7. Grand Est-Colmar
   President: Serge Kauffmann
8. Grand Est-Nancy
   President: Meriem Fournier
9. Hauts-de-France
   President: Jean Tayeb
10. Île-de-France-Jouy-en-Josas-Antony
    President: Thierry Pineau
11. Île-de-France-Versailles-Grignon
    President: Camille Michon
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: Jean-Philippe Nabot
18. Val de Loire
    Présidente : Catherine Beaumont
19. **Paris-Antony Head Office**
    Administrator: Karine Gueritat

INRAE'S 14 research divisions

(As of 31 December 2020)

- Action and Transitions
  Christophe SOULARD
- Agroecosystems
  Philippe HINSINGER
- Human Nutrition and Food Safety
  Lionel BRETILLON
- Aquatic Ecosystems, Water Resources and Risks
  Mohamed NAAIM
- Plant Biology and Breeding
  Isabelle LITRICO-CHIARELLI
- Ecology and Biodiversity
  Catherine BASTIEN
- Economics and Social Sciences
  Alban THOMAS
- Animal Genetics
  Edwige QUILLET
- Mathematics and Digital Technologies
  Hervé MONOD
- Microbiology and the Food Chain
  Sylvie DEQUIN
- Animal Physiology and Livestock Systems
  Françoise MEDALE
- Animal Health
  Muriel VAYSSIER-TAUSSAT
- Plant Health and Environment
  Christian LANNOU
- Food, Bioproducts and Waste
  Michael O'DONOHUE

INRAE Units

202 research units

43 experimental units

22 service units

INRAE

science for people, life & earth

Annual report

2020

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www.inrae.fr/en

French national research institute for agriculture, food and environment

RÉPUBLIQUE FRANÇAISE
Liberté
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Fraternité

INRAE

PEFC FSC